PLAINTIFF'S EXHIBIT

UC-4024

UNION CARBIDE

AUDIT REPORT NO. WV-0233

FILE NO. 24

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UCC 020835

UC 149-2

UNION CARBIDE **INTERNAL CORRESPONDENCE**

CHEMICALS AND PLASTICS • SOUTH CHARLESTON PLANT P. O. BOX 8004, SOUTH CHARLESTON, W. VA. 25303

To (Name) Mr. V. H. Johnkoski, Jr.

Date August 14, 1978

Originating Dept. Safety

Answering letter date

Copy to See Distribution List

Subject Process and Equipment
Safety - Plant Operation

Mr. Johnkoski:

The Chemicals and Plastics Task Force project to provide a training document for plant operation is attached. All previous work has been reedited and organized in a text book format for the use of technical and non-technical plant supervision.

The purpose of this manual was to provide enough technology to plant operating people to permit operation, maintenance and minor engineering efforts to be done in the safest manner. The use of accident examples throughout the text should develop and motivate key personnel to put more emphasis on loss prevention and improve the quality of Standard Operating Procedures and training efforts.

The manual has been distributed to key personnel in the South Charleston Plant for immediate use in its present form. You may wish to prepare and distribute additional copies for the C&P safety effort.

Very truly yours,

N. W. Clauss

N. W. Clauss
Chemical Process and Equipment
Safety Consultant

NWC:jjv
Attachment

UCC 020836

COPY TO:

South Charleston

J. W. Allison
T. H. Austin
R. N. Bates
J. E. Beckman
L. E. Carlson
J. C. Carvajal
D. C. Eckermann
T. D. Epps
C. E. Fry
H. S. Hill
G. E. Lewis
R. J. Murphy
L. W. Phair
G. M. Robertson
J. J. Scharf
G. L. Sprague
G. W. Stocking
Shift Superintendent (5)
T. G. Swanson
W. B. Troutman
P. D. Wegrzynowicz
H. L. Wise
J. L. Worstell
D. D. Wragg

Tech Center

R. E. Graebert
U. R. Miller
C. C. Neely
M. E. Sutherland
D. T. Watters

Institute

W. E. Ballard
R. G. Hull
G. F. Morriss

New York Office

J. M. Fallon
A. G. Voress
D. L. Wiley
R. G. Mitchell

Brownsville

R. C. Glock
H. E. Peterson
T. B. Tiffany

Seadrift

R. J. Cottle
H. F. Keag
Ralph Howard

Texas City

W. P. Reeves
R. J. Taylor
W. P. Nichols
F. S. Provenzano

South Charleston Maintenance

W. A. Garrett
J. E. Kidd
J. R. Sanders
G. A. Snyder

UCC 020837

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PROCESS AND EQUIPMENT OPERATING SAFETY

FOR PRODUCTION ENGINEERS AND SUPERVISORS

I. INTRODUCTION (N. W. Clauss and J. J. Walker)

The purpose of this process and equipment safety manual is to provide new field production engineers, day production supervisors, and other personnel associated with day-to-day operations of a chemical unit some knowledge of the type of hazards they may encounter in making even minor additions, alterations or changes in the unit or the process.

Our object is to provide sufficient safety engineering technology to assure a critical and analytical approach to facility changes and hopefully to motivate a personal feeling of responsibility for safety in all aspects of plant work.

Process and equipment safety knowledge should aid in the reduction of plant explosions, fires, equipment failures and attendant personnel injuries and production losses. The operating technical staff and supervisors, in particular, should develop an awareness of hidden hazards and loss prevention in order to safeguard people, material, and equipment. They should also develop an understanding of emergency situations and how to cope with them.

The corporate emphasis on safety is also important from a career standpoint. Responsibility for a few relatively major accidents resulting in serious injury, major equipment, material and production loss, can have a serious affect on another wise promising future.

Another important motivation for assuring safe operations is the responsibility for safety of yourself as well as your fellow employees. The problem of living with guilt resulting from a decision made without adequate safety consideration may be incalcuable if it results in serious injury to a fellow employee.

The general reduction in operating unit technical "know-how" due to the rapid personnel rotation, transfers, and retirements has emphasized the need for such a manual. Also, it became apparent during plant process safety

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audits that reliance must be placed upon persons initiating and specifying small field shop order work to avoid introduction of process safety problems.

The total property damage losses resulting from fires and explosions in the Chemicals and Plastics Division is approximately one half million to eight million dollars per year.

Approximately six million dollars of the total of seven million dollars property damage loss in 1976 to C&P locations, can be attributed to process or equipment safety mistakes or mishaps.

The manual is directed to providing sufficient knowledge about the engineering disciplines which relate to process and equipment safety and loss prevention and of safety problems that operating personnel can encounter along with many examples. It is not intended that the personnel using this manual be educated as process safety design engineers. However, they should be able to recognize problem areas as they are encountered in the field.

Obviously many other employees may benefit from exposure to this training manual.

Process and equipment safety embraces an extremely wide area of technologies. Thus, the subject matter included in this educational manual is extremely broad.

The course will cover in the following order:

1. Introduction
2. Safety Organizations and Functions
3. Chemical Processing
4. Control Systems
5. Flammability, Ignition, Inerting
6. Equipment Safety
7. Electrical Safety
8. Fire Protection
9. Resources and References

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The course will not cover such areas as:

1. Personnel safety
2. All government regulating agencies
3. Energy conservation
4. Insurance regulations
5. Environmental protection
6. Industrial hygiene (occupational health)

The following task group developed the manual:

N. W. Clauss
H. F. Keag
H. E. Peterson
W. P. Reeves
J. J. Walker (Chairman)
D. T. Watters

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2. SAFETY ORGANIZATIONS AND FUNCTIONS (J. J. Walker)

The total safety organization of Union Carbide, including Corporate, Divisional, and Plant locations is quite complex. It is not necessary that the personnel to whom this manual is directed understand this entire structure. However, it is important to know that the first or primary resource for safety related information and assistance for new field production engineers and day production supervisors is the plant Safety Department. Each C&P plant location has some one person designated as being responsible for plant safety. (See attached "SHARE" Contact List). Such person should be able to either answer questions or direct you to sources that can.

Also in each major plant there is an Engineering Safety representative in the Plant Engineering Department who can either answer safety related questions or direct the question to those who can.

Chemicals and Plastics has a Safety Department which is part of the SHARE Department, with related safety functional support as described on the attached organization charts. The Process Safety and Fire Protection Engineering Group, under the leadership of the Safety Engineering Manager, and the Safety Research Laboratory Group, under the leadership of the Safety Technology Manager, provide an "in-depth" resource for complex process safety problems of many types.

These resources are available to aid you in assessing safety problems and to develop solutions for said problems.

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CHEMICALS & PLASTICS SHARE ORGANIZATION

MAY 1976

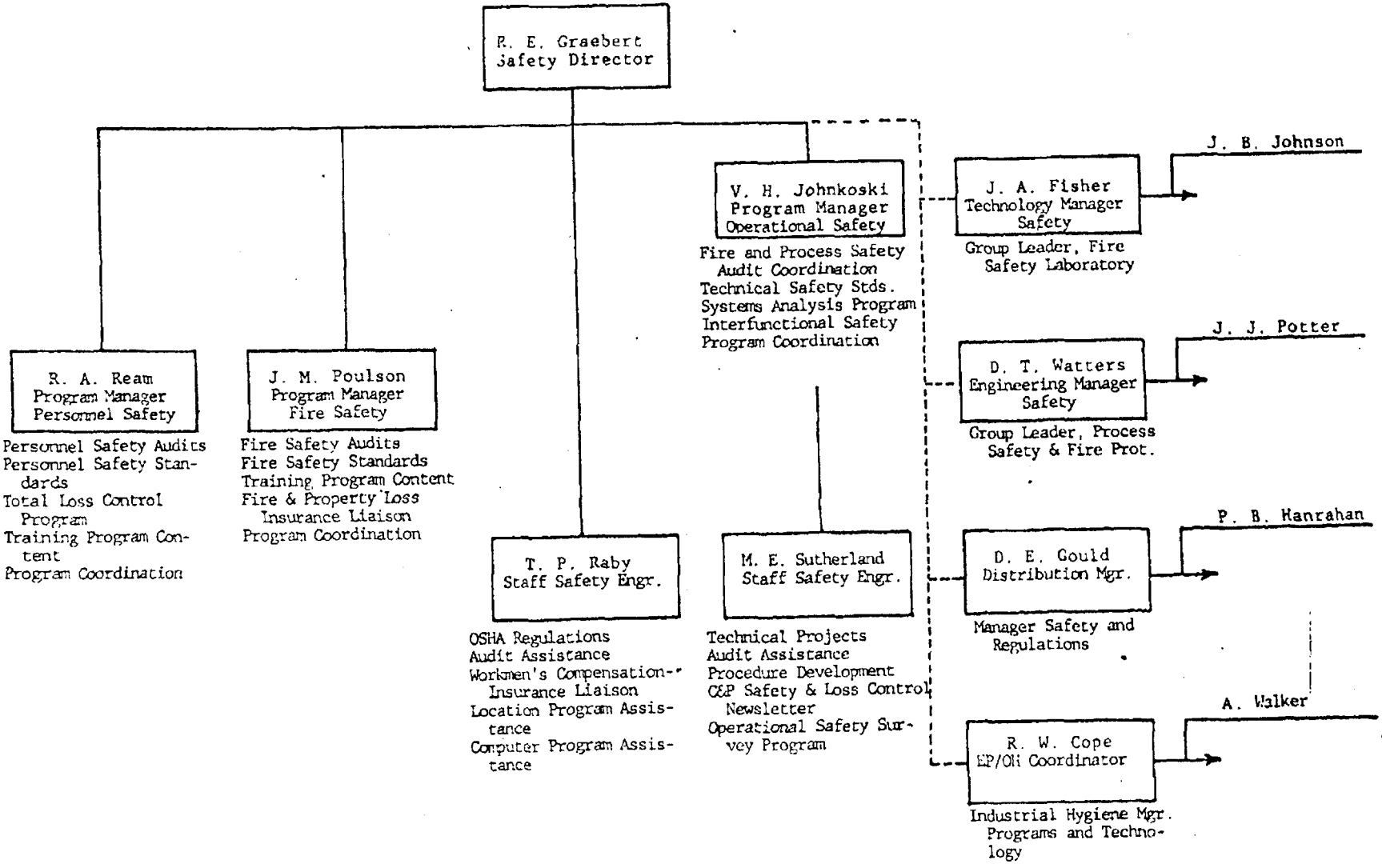
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CHEMICALS AND PLASTICS SAFETY TEAM



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"SHARE" CONTACT LIST

Plant (Mgr.)	APM Safety Contact	Personnel Safety	Fire Safety	Oper. (Process) Safety - Test & Inspection	Specific Process Technology or Design	Distribution Safety	Occ. Health Management	Industrial Health Technology	Medical	Environmental Protection	"Evergreen" EIA Coordinator
Bound Brook (RAD)	E.B.Sharp	W.M.King	S.T.Eberhardt	S.T.Eberhardt	APM resp.	DH respec.	R.F.Kelley/ G.Stringer	W.D.Neal	Dr.P.P.Konyha	G.R.Stringer	R. Burstein
Brownsville (WFM)	R.C.Glock	B.F.Brown	T.B.Tiffany	T.B.Tiffany	APM resp.	J.L.Wyatt	L.T.Windel	K.G.Townsend	L.T.Windel	L.T.Windel	J.L.Garcia
Elk Grove (JOZ)	None	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmer-man	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmerman	J.O.Zimmerman
Institute (HJK)	W.E.Ballard	R.G.Hull	C.G.Roberts/ C. T. Brannon	G.[illegible]Morris	DH resp.	J.L.Strouse/ D.E.Peterson	R.G.Hull	F.Williams	Dr.R.J.Sexton	R.L.Foster	C.D.Quinsey
Latex Plts. (AFS)	A.E.Stafford	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock	K.G.Morlock
Marietta		C.B.Harper	C.B.Harper	C.B.Harper	DH resp.						
St.Falls (GCM)	G.C.Merz (Plt.Mgr.)	R.E.Lindmark	R.E.Lindmark	R.E.Lindmark	J.A.Rothrock	R.E.Lindmark	J.A.Rothrock	J.A.Rothrock	J.A.Rothrock	J.A.Rothrock	J.A.Rothrock
Ponce (WES)	C.R.Kline	F.E.Hand/ J.P.Cordero	F.E.Hand/ C.Tirado	P.J.Costas	DH resp.	J.R.Rodriguez	C.R.Kline	F.J.Garcia-Sharp	Dr.A.A.Lang	V.Vega	W.H.Davies
Seadrift (DLG)	R.J.Cottle	J.H.Sledge	Tom Brooks	Ralph Howard	DH resp.	D.P.Heath	R.J.Cottle	J.N.Dermit	Dr.F.M.Logsdon	V.D.Dutcher	J.L.High
Sistersville (AWB)	R.G.Link	A.G.Olde/ W.F.Long	A.G.Olde/ W.F.Long	A.G.Olde/ D.K.Schoonover	W.F.Long/ D.J.Taylor	A.G.Olde/ W.F.Long	A.G.Olde	A.G.Olde/ D.S.Carroll	A.G.Olde	C.F.Schubert	Tom Jones
So. Chas. (JEB)	T.D.Epps	W.B.Troutman/ A.Wood,Jr.	W.B.Troutman/ G.H.Simpson	N.W.Clauss	DH resp.	J.J.Scharf/ H.L.Wise	J.L.Worstell	W.C.Young	Dr.R.W.Holland	L.E.Carlson/ J.L.Worstell	E.B.Gilbert
Taft (TLR)	J.L.Goodson	J.D.White/ J.Kinchen	R.Bourke	B.A.Mallory	DH resp.	P.G.Harvey	J.L.Goodson	J.C.Schonberg	J.D.White	A.W.Carlson	T.T.Covin
Tech Center (HLR)	None	C.W.Carman,Jr.	R.H.Baxter	C.L.Roy	-	C.W.Carman	-	G.F.Hurley	Dr.T.N.Spencer	G.F.Hurley	S.J.Herzog
Texas City (DLE)	W.P.Nickles(S) F.S.Proven-zano (HARE)	R.J.Taylor	R.J.Taylor/ J.L.Brantley	R.J.Taylor	APM resp.	R.J.Taylor	J.B.Leverton	D.E.Deese	Dr.D.H.Glenn	J.B.Leverton	J.F.Erdman
Torrance (CAG)	J.A.Grady (Plt.Mgr.)	R.H.Thomas	R.H.Thomas	J.M.Stogdon	J.A.Grady	A.M.Paton	J.P.Alexander	J.L.Davidson	F.Eulberg,R.N.	J.P.Alexander	J.P.Alexander

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UNION CARBIDE CORPORATION

Chemicals and Plastics Safety Directory

Name	Title	Location	Phone
R. E. Graebert	Safety Director	So. Chas. Tech Center	4264
V. H. Johnkoski	Program Mgr.-Operational Safety	So. Chas. Tech Center	4204
J. M. Poulson	Program Mgr.-Fire Safety	So. Chas. Tech Center	5284
R. A. Ream	Program Mgr.-Personnel Safety	So. Chas. Tech Center	4818
T. P. Raby	Staff Safety Engineer	Bound Brook Plant	342
M. E. Sutherland	Staff Safety Engineer	So. Chas. Tech Center	4484
J. A. Fisher	Technology Manager	So. Chas. Tech Center	4984
D. T. Watters	Engineering Manager	So. Chas. Tech Center	4766
Construction Safety			
C. W. Carman, Jr.	Safety Coordinator	So. Chas. Tech Center	4335
Corporate Safety			
R. G. Mitchell	Safety Director	New York Office	2191
J. D. Baker		New York Office	2893
Distribution (Chemical Shipping and Storage)			
P. B. Hanrahan		New York Office	3867
D. E. Gould	Mgr. Safety & Regulations	Somerville, N.J.	645
L. W. Lusher	Mgr. Distribution Safety	So.Chas.City Center East	7545
HELP (Hazardous Emergency Leaks Procedure)			304-744-3487
Dust Hazards (Fire & Explosion)			
I. Swift	Combustion Spec./Explosion Venting	So. Chas. Tech Center	4653
J. M. Ondyak		So. Chas. Tech Center	4894
Engineering Department			
Process Safety & Fire Protection			
D. T. Watters	Engineering Manager	So. Chas. Tech Center	4766
Safety Valves, Rupture Discs, Tank Vent Design, Ball Valves, Sight Glasses			
O. J. Cox		So. Chas. Tech Center	5884
Systems Safety Analysis			
D. T. Watters	Engineering Manager	So. Chas. Tech Center	4766
D. C. Wobser		So. Chas. Tech Center	4822
P. W. Pontius		So. Chas. Tech Center	4575
Pumps, Steam/Air/Water Curtains, Dust Explosions			
J. M. Ondyak		So. Chas. Tech Center	4894

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Name	Title	Location	Phone
Engineering Dept. (Cont'd)			
	Flammable Gas Detectors, Unclassified Electrical Devices		
D. Wechsler		So. Chas. Tech Center	4894
	Fire Alarm Systems, Fire Water Systems, Peroxide Facilities		
J. L. DeRoo		So. Chas. Tech Center	4242
	Unit and Field Storage, Storage Tank Safety, Railcar and Truck Loading Rack Design		
P. W. Pontius		So. Chas. Tech Center	4575
	Fire Hose, Sprinkler Systems, Water Spray Systems		
J. A. Lazear		So. Chas. Tech Center	5154
	Bldgs. in Operating Units, Analyzer Bldgs., Flame Arresters		
H. W. Wegert		So. Chas. Tech Center	5194
	Non-Destructive Testing		
B. H. Clark		So. Chas. Tech Center	4080
Fire Research (Research & Development)			
J. A. Fisher	Group Leader	So. Chas. Tech Center	4894
B. Pesetsky	Flammability Studies	So. Chas. Tech Center	4940
G. E. Snyder	Chemical Stability/Fire Research	So. Chas. Tech Center	4940
D. J. Allen	Process Risk Analysis	So. Chas. Tech Center	5917
W. T. Vyn	Explosion Specialist/ Dist. Risk Analysis	So. Chas. Tech Center	4653
Ian Swift	Combustion Specialist/ Explosion Venting	So. Chas. Tech Center	4653
G. J. Preece	Product Safety & Flamm.	So. Chas. Tech Center	4391
Hazardous & Reactive Chemicals (Physical & Chemical Properties)			
M. E. Sutherland	Staff Safety Engineer	So. Chas. Tech Center	4484
E. R. Osborne, Jr.	Reactive & Hazardous Chem. Data Coordinator	So. Chas. Tech Center	4584
J. A. Fisher	Technology Manager	So. Chas. Tech Center	4984

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Name	Title	Location	Phone
HELP (Hazardous Emergency Leaks Procedure)			
FOR "HELP" WITH A UCC CHEMICAL OR PLASTIC INVOLVING A SPILL, LEAK, FIRE OR EXPOSURE, CALL COLLECT DAY OR NIGHT:			
HELP 304-744-3487			
Laboratory Safety			
D. R. Shearer	R/D Safety Coordinator	So. Chas. Tech Center	4260
W. J. Ziemba	Mgr. Safety & Security	Tarrytown	2138
G. G. Himmler	Dept. Safety Coordinator	Bound Brook R/D	775
Location Safety Personnel			
Brownsville Plant			
L. T. Windel	SHARE Dept. Head	Brownsville	335
B. F. Brown	Safety Director	Brownsville	324
T. B. Tiffany	Fire Protection/Process Safety	Brownsville	204
Bound Brook Plant			
W. M. King	Safety Director	Bound Brook	2820
S. T. Eberhardt	Process Safety/Fire Protection	Bound Brook	673
Customer Service Contact			
R. J. Tuefel		Dallas, Texas	340
Elk Grove Plant			
J. O. Zimmerman	Plant Manager	P.O.Box 416, Elk Grove, Calif. 95624	916-685-39
G. Luck		P.O. Box 416, Elk Grove, Calif. 95624	916-685-39
Institute Plant			
R. G. Hull	Safety Director	Institute Plant	6618
H. C. McGinnis	Safety Administrator	Institute Plant	6136
E. L. Adkins	Safety Supervisor	Institute Plant	6415
G. Arbaugh	Safety Supervisor	Institute Plant	6239
R. F. McCullough	Process Safety	Institute Plant	6282
C. T. Brannon	Fire Protection	Institute Plant	6555
C. G. Roberts		Institute Plant	6653

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Name	Title	Location	Phone
Latex Plants			
K. G. Morlock	SHARE Manager	Alsip, Ill.	312-785-3745
G. E. Duran	Safety Coordinator	Torrance, Calif.	213-772-6435
Bill Thomas	Safety Coordinator	Garland, Texas	Dallas, 352
F. C. Burns	Safety Coordinator	Tucker, Ga.	404-939-9356
J. P. Ward	Safety Coordinator	Alsip, Ill.	312-928-4100
R. W. McCord	Safety Coordinator	Somerset, N.J.	Bound Brk. 501
Marietta Plant			
C. B. Harper	Safety Director	Marietta	7207
Niagara Falls Plant			
G. C. Merz	Plant Manager	Niagara Falls	3390
Roy Lindmark	Safety Director	Niagara Falls	3641
Seadrift Plant			
R. J. Cottle	Asst. Plant Manager	Seadrift	2350
J. H. Sledge	Safety Director	Seadrift	2224
T. M. Brooks	Fire Protection	Seadrift	2225
Sistersville Plant			
A. G. Olds	SHARE Manager	Sistersville	233
W. F. Long	Safety Director	Sistersville	349
Sales			
H. R. McNair		New York Office	2222
South Charleston Plant			
W. B. Troutman	Safety Director	So. Chas. Plant	2209
B. E. Nutter	Personnel Safety Tech.	So. Chas. Plant	3419
Anthony Wood, Jr.	Compliance Auditor - Trainer	So. Chas. Plant	2564
G. H. Simpson	Fire Protection	So. Chas. Plant	3348
N. W. Clauss	Process Safety	So. Chas. Plant	2545
Tarrytown			
W. J. Ziemba	Mgr. Safety & Security	Tarrytown	2138
Texas City Plant			
R. J. Taylor	Safety & Fire Director	Texas City Plant	1335
N. Lund	Safety Admin.	Texas City Plant	450
N. Kralj	Safety Specialist	Texas City Plant	447
R. Temple	Safety Specialist	Texas City Plant	603
J. L. Brantley	Fire Protection	Texas City Plant	680
H. Schulz	Safety Engineer	Texas City Plant	1484
H. Milward	Safety Coordinator	Texas City Plant	1301

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Name	Title	Location	Phone
Taft Plant			
J. D. White	Safety & Health Director	Taft Plant	223
J. Kinchen	Personnel Safety Coordinator	Taft Plant	336
R. L. Ward	Resp. Equipment Insp.	Taft Plant	1187
R. Bourke	Fire Protection	Taft Plant	1360
T. P. LaRousse	Safety Technician	Taft Plant	1451
D. L. White	Construction Safety	Taft Plant	364
Torrance Plant			
Ms. J. Pickus	Safety Manager	Torrance Plant	200
R. H. Thomas	Personnel Safety	Torrance Plant	207
J. P. Alexander	Fire Protection	Torrance Plant	208
Technical Center & Construction			
C. W. Carman, Jr.	Safety Director	Tech Center, So. Chas.	4335
H. Dick	Safety Specialist	Tech Center, So. Chas.	4778
Chas. Maxwell	Safety Assoc.	Tech Center, So. Chas.	5147
E. J. Tawney	Const. Safety Insp.	Institute Plant	6455
D. R. Shearer	R/D Safety Coordinator	Tech Center, So. Chas.	4260
R. H. Baxter	Fire Protection	Tech Center, So. Chas.	5135
Ray Neal	Const. Safety Insp.	So. Chas. Plant	2126
Union Carbide Caribe (Ponce)			
C. R. Kline	Asst. Plt. Manager	Ponce, P.R.	261
F. E. Hand	Safety Director	Ponce, P.R.	253
J. P. Cordero	Personnel Safety	Ponce, P.R.	253
C. Tirado	Fire Protection	Ponce, P.R.	253
Mutual Aid Programs			
C. T. Brannon	Fire Safety Coord.	Institute Plant	6555
R. H. Baxter	Fire Safety Coord.	So. Chas. Tech Center	5135
Lee Maes	Dept. Hd. Polystyrene	Bound Brook Plant	
W. F. Long	Safety Supervisor	Sistersville Plant	349
J. H. Sledge	Safety Director	Seadrift Plant	224
H. C. McGinnis	Personnel Safety Admin.	Institute Plant	6136
C. B. Harper	Safety Coordinator	Marietta Plant	207
Occupational Safety & Health (OSHA)			
OSHA (In-Company)			
General			
T. P. Raby	Safety Engineer	Bound Brook Plant	342
Engineering			
C. R. Carder		So. Chas. Tech Center	5222
D. T. Watters	Engineering Manager	So. Chas. Tech Center	4766

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Name	Title	Location	Phone
Fire Protection			
J. M. Poulson	Program Mgr.-Fire Safety	So. Chas. Tech Center	5284
D. T. Watters	Engineering Manager	So. Chas. Tech Center	4766
J. L. DeRoo		So. Chas. Tech Center	4242
Distribution			
D. E. Gould		Somervil[illegible], N.J.	645
Hazardous Materials			
M. E. Sutherland	Staff Safety Engineer	So. Chas. Tech Center	4484
J. A. Fisher	Technology Manager	So. Chas. Tech Center	4984
Legal			
J. W. Whittlesey		New York Office	6797
J. V. Murray		New York Office	5514
Medical			
E. Q. Hull, M.D.		So. Chas. Tech Center	4714
C. U. Dernehl, M.D.		New York Office	4785
Ventilation			
Paul Barna		So. Chas. Tech Center	4619
Noise			
T. E. Gallagher		So. Chas. Tech Center	5318
Respiratory Equipment			
R. E. Peele		So. Chas. Tech Center	4513
Specific Standards Subparts			
C. K. Wood	Walking-Working Surfaces; Means of Egress	So. Chas. Tech Center	4547
B. W. Whittington	Electrical; Electrical Related coverage in any other subpart	So. Chas. Tech Center	5534
A. B. Morgan	Any portion pertaining to process instrumentation	So. Chas. Tech Center	4406
E. C. Powell	Any portion pertaining to insulation for heat or refrigeration	So. Chas. Tech Center	4419

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Name	Title	Location	Phone
Specific Standards Subparts (Cont'd)			
Peter Barna	Any portion pertaining to painting & coating stds.	Institute Plant	6206
D. W. Moody, Jr.	Any portion pertaining to piping	So. Chas. Tech Center	4850
C. C. Neely	Any portion pertaining to tanks, pressure vessels, heat exchangers, and similar pressure-containing enclosures	So. Chas. Tech Center	5224
OSHA (Non-Company)			
U S. Government - OSHA Offices			
Region II - New York, New Jersey, P.R.			
Alfred Barden	Regional Administrator	1515 Broadway, N.Y. N.Y. 10036	(212) 399-57
Chas. Meister	Area Director	970 Broad St., Newark, N.J. 07102	(201) 645-59
Chester Whiteside	Area Director	100 So. Clinton St., Syracuse, N.Y.13202	(315) 423-51
Francisco Encarnacion-Rosa	Area Director	U.S.Court House & FOB Carlos Chardon,Rm.555 Hato Rey,P.R. 00918	(809) 753-44
Region III - West Virginia			
D. H. Rhone	Regional Administrator	Gateway Bldg., 3535 Mkt. Street, Phila., Pa. 19104	(215) 596-12
Thomas V. Martin	Area Director	Charleston Natl. Plaza 700 Va. Street, Chas., W.Va. 25301	(304) 343-61 Ext. 420
Region V - Indiana, Ohio			
Barry J. White	Regional Adminstrator	230 So. Dearborn St., Chicago, Ill. 60604	(312) 353-44
J. Fred Keppler	Area Director	46 E. Ohio St., Indianapolis, Ind. 46204	(317) 269-7
Peter Schmitt	Area Director	200 N. High St., Columbus, Ohio 43215	(614) 469-5
W. E. Funcheon,Jr.	Area Director	Calmuet City, Ill. 60409	(312) 891-38

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Name	Title	Location	Phone
Region VI - Louisiana, Texas			
Robert Tice	Regional Administrator	555 Griffin Sq. Bldg., Dallas, Tx. 75202	(214) 749-2477
Robt. A. Griffin	Area Director	2320 LaBranch Street, Houston, Tx. 77004	(713) 226-5431
J. E. Powell	Area Director	2156 Wooddale Blvd., Baton Rouge, La. 70806	(504) 387-0181
H. M. Kurtz	Area Director	221 W. 6th Street, Austin, Tx. 78701	(512) 397-5783
		San Antonio, Tx. Field Station	(512) 229-5410
Henry J. Ahlf	District Director	Corpus Christi, Tx. 78473	(512) 888-3257
T. T. Curry	Area Director	So. 77 Sunshine Strip, Harlingan, Tx. 78550	(512) 425-6811
Marvin Schierman	Area Director	546 Carondelet St., New Orleans, La. 70130	(504) 589-2451
Region IX - California			
Gabriel Gillotti	Regional Administrator	450 Golden Gate Avenue, San Francisco, Calif. 94102	(415) 556-0586
	Area Office	211 Main Street, San Francisco, CA. 94105	(415) 556-7260
B. L. Tibbetts	Area Director	400 Oceangate, Long Beach, Calif. 90802	(213) 432-3434
Washington, D.C.			
John Leslie	Office of Information, Publications & Reports	Washington, D.C.	(202) 523-2420
Daniel Boyd	Director, Office of Standards Development	Washington, D.C.	(202) 523-2420
National Organizations			
American Society of Safety Engineers			
R. H. Baxter	Member	So. Chas. Tech Center	5135
*J. L. DeRoo	Member	So. Chas. Tech Center	4242
C. H. Dick	Member	So. Chas. Tech Center	4778
*J. M. Poulson	Member	So. Chas. Tech Center	5284
*H. W. Wegert	Member	So. Chas. Tech Center	5194
W. [illegible] Long	Member	Sistersville Plant	349
*H. C. McGinnis	Member	Institute Plant	6139
*T. P. Raby	Member	Bound Brook Plant	342
International Association of Fire Chiefs			
R. H. Baxter	Member	So. Chas. Tech Center	5135

*Certified Safety Professional

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Name	Title	Location	Phone
National Fire Protection Association			
J. L. DeRoo	Member Automatic Sprinkler Code Committee	So. Chas. Tech Center	4242
J. P. McLaughlin	Member Foam Sys. Committee	Houston	224
B. Pesetsky	Member Expl. Vent. Comm.	So. Chas. Tech Center	4940
J. M. Poulson	Member	So. Chas. Tech Center	5284
H. W. Wegert	Member	So. Chas. Tech Center	5194
National Safety Council			
H. C. McGinnis	Member Chemicals Committee	Institute Plant	6136
R. E. Peele	Member Rubber & Plastics Committee	So. Chas. Tech Center	4513
T. P. Raby	Member Rubber & Plastics Committee	Bound Brook Plant	342
National Safety Management Society			
T. P. Raby	Member	Bound Brook Plant	342
Organization Resource Conselors			
T. P. Raby	Member	Bound Brook Plant	342
Society of Fire Protection Engineers			
J. L. DeRoo	Member	So. Chas. Tech Center	4242
J. P. McLaughlin	Member	Houston	224
Society of the Plastics Industry			
M. E. Sutherland	Member of Safety Loss Prev. Committee	So. Chas. Tech Center	4484
Standards Team (Safety)			
R. E. Graelert		So. Chas. Tech Center	4264
W. L. Burgett		Taft Plant	1360
J. D. White		Taft Plant	223
D. T. Watters		So. Chas. Tech Center	4766
S. M. Burton		So. Chas. Plant	2246
V. H. Johnkoski		So. Chas. Tech Center	4204
B. R. Hannigan		Somerville, N. J.	2127
Training (Fire and Rescue Squads)			
C. T. Brannon		Institute Plant	6369
W. L. Burgett		Taft Plant	1360
W. F. Long		Sistersville Plant	349
J. H. Sledge		Seadrift Plant	224

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Name	Title	Location	Phone
Training (Fire and Rescue Squads) - Cont'd			
J. L. Brantley		Texas City Plant	680
Adam Unger		Taft Plant	1324
G. H. Simpson		So. Charleston Plant	3348
Training (In-Company - General)			
Brian Knapp		New York Office	2666
Clyde Watson		So. Chas. Tech Center	5104
R. J. Murphy		So. Chas., Bldg. 3002	3229
E. C. Scherer		Bound Brook Plant	2895
S. Blakeslee		So. Chas. Tech Center	4659
Safety Standards Specialists			
B. F. Brown		Brownsville Plant	335
R. G. Hull		Institute Plant	6618
C. B. Harper		Marietta Plant	7207
Adriel Rodriques		U. C. Caribe Plant	297
J. H. Sledge		Seadrift Plant	2224
D. J. Taylor/W. F. Long		Sistersville Plant	394
W. B. Troutman		South Charleston Plant	2209
W. L. Burgett		Taft Plant	1360
E. N. Lund		Texas City Plant	450

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PROCESS AND EQUIPMENT OPERATING SAFETY

3. CHEMICAL PROCESSING (N. W. Clauss)

I. INTRODUCTION

II. KNOWLEDGE OF CHEMICALS

III. CRITICAL OPERATING VARIABLES

IV. MATERIALS AND ENERGY BALANCES

V. REACTION CONTROL

VI. CONTAMINATION

VII. COMPATIBILITY

VIII. STARTUP

IX. SHUTDOWN

X. EMERGENCY OPERATION

XI. SUMMARY

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PROCESS AND EQUIPMENT OPERATING SAFETY

3. CHEMICAL PROCESSING (Prepared by N. W. Clauss)

I. INTRODUCTION

The Corporate emphasis on safety is important from a career standpoint. You can visualize the effect a reputation developed from a few relatively major accidents resulting in serious injury, major equipment, material and production loss would have on an otherwise promising future. In this era of training by job rotation, you would be well advised to evaluate the risks in any newly assigned facility for accident potential of the processes and equipment you are accountable for.

The chemical industry seems concerned about its safety programs as never before. Inflation is taking away the "ho-hum" attitude of management regarding safety. All kinds of higher costs from accidents are bringing new attention to the importance of safety as it affects the cost of doing business.

The rising costs from accidents are more than the usual workers' compensation payments. Other increasingly costly results are losses from repairing equipment damage and from losing sales because of production downtime. Accident costs seem to be rising faster than accident frequency or severity can be reduced.

It is therefore, essential that effective improvement be made in reducing the cost of accidents by concentrating on the reduction of major disasters. We cannot continue to emphasize employee procedural protection efforts and not emphasize the potential of fatalities, material and production losses resulting from inadequate process knowledge, design or operation. We will discuss this concept later in discussing the risk potential of chemical process operation.

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A. C&P Development, Design and Installation Effort

The Chemicals and Plastics Division continually strives to improve and apply the latest technology in the research, development and engineering of processes and facilities. One section of this manual is devoted to the resource and reference material utilized and available for implementing the latest safety engineering technology in all engineering disciplines for all major projects. Safety technology for most major engineering disciplines as well as safety design engineering is covered in the Safety Technology Manual and will be covered later in some detail.

The seven (7) pages of safety-related check lists contained in the Guidelines For Major Capital Projects issued by our Company Officers are well followed in the Project Procedures and the Process Engineering Methods with detailed emphasis on all aspects of safety.

The processing systems you operate were developed, designed, installed and commissioned according to the best available knowledge at the time of installation.

B. Check Points For the Review of Safety in Design

Major project work is subjected to review for safety by means of Safety Review Board Analysis and deficiencies are corrected as the design work progresses. Major projects are reviewed in the completed stage usually by a separate group of skilled engineering personnel and the results are reported in a Safety Considerations Report; which incidentally is a valuable aid in the preparation of Standard Operating Procedure and Emergency Manuals.

Small projects, some handled by Plant Engineering Groups, are reviewed at various stages of completion and if significant also have a non-project related safety review and resulting Safety Considerations Report.

The local management of a plant in which new facilities are installed initiates an additional safety review by means of the Prestartup Safety Review Procedure -- a final review to uncover and correct safety deficiencies prior to commissioning.

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C. Confidence Level

After commissioning, a new facility will have the maximum level of confidence as far as the safety of operations. It is at this time that the latest safety technology was used, the personnel are the most knowledgeable and the best trained, and the Standard Operating Procedures are most applicable to the operation.

Unfortunately, experience indicates that the confidence level may decrease and operational risks may increase throughout the life of an operating facility. Job rotation and attrition may decrease the knowledge of personnel and the desire for improvement will dictate that raw materials, catalysts, diluents, entraining agents will be changed; operating time, temperature, pressure limits will be changed; and equipment will be altered to match the capacity of the limiting item in a facility or to circumvent production outages.

The major thrust of this manual will be the maintenance of the safety confidence level and the avoidence of unnecessary hazards introduced by change.

D. Safety and Economics

It was mentioned that you should expect the maximum confidence level in the safety of a new facility right after startup. However, you also might wonder why the Prestartup Safety Review Teams usually find hazards that require correction before startup. A recent safety review by a PSSR Team of a new polyols facility came up with 50 potential safety hazards of which 8 were serious situations requiring action prior to startup.

In spite of the concentrated effort to develop, design and install facilities with the latest safety precautions, we still continue to have accidents because of incomplete research and development data, oversights in design, lack of knowledge of operating personnel, human errors or the balance of cost versus "no risk" facilities.

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No chemical processing industry could compete or afford to erect "no risk" facilities. We tend toward compact facilities and larger units for purposes of economy. The result is obviously an increase in the risk of disaster potential. The subject of risk will be discussed further, but the point to realize is that all new processing facilities are, because of a balanced consideration of facility cost, designed and constructed with an element of risk. Risk, per se, does not mean accidents or disaster. It means that risks must be rocognized and dealt with in a safe manner.

E. Process and Equipment Improvements

Although all operating personnel constantly emphasize safety in the performance of their jobs, probably the greatest satisfaction comes from making inovative process improvements and equipment design changes to increase productivity. Changes in raw material, catalyst used, or the use of an inert diluent can increase productivity or efficiency and result in significant cost reduction and higher profits. The same result is frequently achieved by altering the design of equipment.

We are all interested in increasing profitability but it also is obvious that the changes made can introduce potential hazards. Increases in productivity in existing facilities usually mean that the energy release will require additional cooling capacity and safety relief valve capacity. The potential for runaway reactions may be increased. Changing the service of existing facilities can involve materials of construction concerns, or changes in pressure relief requirements.

Inovative changes that increase profits are to be encouraged and commended but must be done without introducing operational hazards. It is for this reason that mandatory standard SF-108 (Facility and Operation Change Review) has been issued to ensure that skilled personnel are involved in checking for hidden hazards introduced by process or equipment changes.

Our hope in preparing this manual is that we can provide the awareness of the hidden hazards that can result from change and recognition of

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the need for reference to the special skills required for safely dealing with the risks. The manual will provide the references and resources available for your use.

F. Hazard Potential and Risk

We need to differentiate between the probability of an accident (hazard potential) and risk. The risks involved in operating a given new facility are at a minimum in the early stage of its life as we explained previously. We do not mean that there is no risk, but that as long as the facility design is not altered and the same chemical process is maintained, the risk of accident stays essentially the same.

The hazard potential, or probability of accidents, may increase however throughout the life of a facility. Complacency creeps in, the knowledge level decreases, residues and polymers form, welded seams deteriorate, there is metal loss, critical moving parts stick, design is changed to improve capacity-quality-efficiency or reduce maintenance costs, operating parameters are changed, etc. It is clear that operating personnel and their ability to prevent the increasing potential for hazards is the real key to reducing the losses by major accident of people, property, products and precursers.

Probably the safest operation is that of the steady state condition of chemical processing, be it continuous or batch. A facility that is running smoothly, operating as it was designed to operate gives us the least concern. The investment in well-designed control systems to maintain steady state operation certainly reduces the probability of upsets and major accidents.

No chemical processing facility can be operated under steady state conditions at all times. There will be process upsets resulting from malfunctions of control systems, loss of utilities, equipment failures, operating errors, etc. There will be changes made in processes and equipment which will sometime cause an abnormal situation resulting in a major accident. You must give thorough attention to the SOP's, training and emergency procedures for batch operations, start up and shutdown procedures since it is

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logical to assume that these non-steady state situations will have a higher probability of accident.

A further consideration relating to potential hazards of operations involves a comparison of extremely complex chemical processes in exotic equipment with the routine type of process in conventional equipment. The experience in recent years where processing is to a significant degree in the Specialty Chemical Area, shows that the accidents may occur in the routine conventional type operation rather than in the highly hazardous processes. This is because the effort expended to recognize and safety deal with the hazards, provides the knowledge, training and utilization of the special skills and resources needed.

The manual will provide the capability to recognize and deal with hazards resulting from changes, all of which are (by intent) improvements, and the awareness to utilize the available special skills required to avoid unsafe situations. You can undo a lot of past efforts by illadvised change.

As an interesting sidelight, the following risk evaluation procedure and hazard factor table was taken from the Manufacturing Chemists Assoc. (1970) "Guidelines for Risk Evaluation and Loss Prevention in Chemical Plants." It is interesting to note that for the average type operation in the Chemicals and Plastics Division, we would expect to lose 60 to 71 per cent of the investment involved in a major explosion or fire.

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* RISK EVALUATION WORK SHEET

The estimation of maximum probable loss or losses utilizes the Western Actuarial Bureau Rating Schedule which establishes explosion-fire (E/F) factors used in calculating the property damage loss (Item 4). The E/F factors used in this work sheet are those applying to Petrochemical Plants. (See Page 8 for details.)

FIRE AND EXPLOSION	ELECTRICAL or MECHANICAL BREAKDOWN
1. Estimate Installed Property Value in Fire Area.	1. Assume Maximum Property Damage (PD) Case.
2. Estimate Annual Business Interruption (BI) Value.	2. Estimate Cost to Repair or Replace Equipment (PD).
3. Assume Maximum Property Damage (PD) Incident.	3. Estimate Days to Repair or Replace Equipment (Outage).
4. PD = Exposed × E/F Property Factor Value	4. Estimate Daily Business Interruption (BI) Value.
5. Estimate Days to Repair or Replace Damage. (Outage)	5. PD = Item 2 Above =
6. BI = Estimated Daily BI Value × Outage	6. BI = Estimated Daily BI Value × Outage
7. Maximum Probable Loss = PD + BI	7. Maximum Probable Loss = PD + BI

NOTES:

* The risk evaluation work sheet and the explosion/fire hazard factor data are from "Guidelines for Risk Evaluation and Loss Prevention in Chemical Plants" issued by the Manufacturing Chemists Assoc. (1970).

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Inherent Explosion Hazard: Inherent explosion hazard of each rating division shall be classified into one of the following five classes according to the susceptibility to explosion of the most hazardous operation in the division.

Class E-1. Minimum: This class contemplates processes or occupancies in which there is *no known explosion hazard* or only slight explosion hazard, such that in the overall analysis of hazard the element of explosion can be considered negligible and disregarded.

Class E-2. Moderate: This class contemplates occupancies having *only limited explosion hazard*, or where explosion hazard is limited to a small part of a unit or where loss potential is moderate and operations are subject to prompt restoration.

Class E-3. Intermediate: This class contemplates occupancies or processes where *an appreciable explosion hazard prevails*, with possibility of substantial damage in major equipment units.

Class E-4. High: This class contemplates processes where there is *considerable explosion potential* or probability with susceptibility to considerable damage or serious delays in restoration.

Class E-5. Extreme: This class contemplates processes involving *severe explosion hazard*, employing extreme pressures, or which are unpredictable and not susceptible to design which will limit or restrict the extent of the damage or interruption to minor proportions. These occupancies while not susceptible to exact description can generally be recognized by engineering analysis. The use of very high pressures in equipment properly designed for the purpose and in connection with processes of predictable hazard, shall not of itself require classification as Extreme under this Section.

Fire Hazard Classification: Each separate rating division shall be classified according to the nature of its fire hazard into one of the following six classes, to be determined primarily on the basis of the area or portion of the occupancy or process unit having the highest hazard, as follows:

a. **Class F-1. Inert:** This class shall apply to *non-chemical occupancies* such as control houses (control equipment only), foam chemical tank houses, machine shops, hospitals, and first-aid stations, power houses and boiler houses, pump houses (water or foam) or warehouses for storage of inert or incombustible materials, or other incombustible contents not packed in combustible containers.

Note: When occupancies described under this class contain more than negligible quantities of combustible contents such as materials or supplies packed in combustible containers, or contents having a moderate degree of combustibility, the occupancy shall be classified in Class F-2 or Class F-3 according to conditions.

b. **Class F-2. Light Hazard:** This class shall apply to:

1. Any process, unit operation, or procedure known by analysis or observational experience to have *little or slight fire hazard*.

2. Unit operations or processes involving use of most *inorganic materials or organic materials in aqueous solution or of non-flammable solvents*.

3. *Storage or compression of gases* generally considered to have limited fire hazard, provided proper precautions are taken to prevent intermingling in combinations within the normal combustibility range. These occupancies may include compression of ammonia synthesis gases, ammonia, carbon monoxide, etc.

c. **Class F-3. Moderate Hazard:** This class shall apply to:

1. Unit operations or processes known by analysis or observational experience to have *only a moderate fire hazard*.

2. The ordinary use or storage of *common combustible solids* such as wood, paper, cloth, sawdust from fresh wood, and crushed (but not pulverized) coal.

3. The *use of combustible liquids or semi-liquids with flash points over 200°F.*, at moderate pressures and temperatures (not over 400°F., and *at least 50°F. below the flash point.)*

d. **Class F-4. Considerable Hazard:** This class shall apply to:

1. Processes, unit operations, and procedures known by analysis or observational experience to have *a marked degree of fire hazard*.

2. Use or storage of ordinary combustible materials in a subdivided (but not finely divided or pulverized) state (excelsior, shredded paper, lint, etc.).

3. Storage of materials having a strong tendency to heat spontaneously.

4. Operations using or producing flammable gases in quantity (excluding the use of gases as fuel).

5. Pumping, mixing, distilling, reacting, or otherwise using flammable liquids, having a *flash point of 110°F. or more* but without processes involving conditions referred to under Class F-5 or Class F-6.

e. **Class F-5. Heavy Hazard:** This class shall apply to:

1. Processes, unit operations, and procedures known by analysis or observational experience to have a *high degree of fire hazard*.

2. Storage or use of highly combustible solids such as nitrocellulose, metallic sodium, etc.

3. Pumping, mixing, distilling, and similar operations utilizing flammable liquids with *flash points below 110°F.*, except that such operations when in totally closed systems with suitable safeguards against release of liquids or vapors may be classed as Class F-4.

4. *Highly exothermic* reactions.

5. Use of low flash flammable liquids in highly reactive processes (nitration, oxidation, etc.).

6. Reactions involving strong oxidizing materials in contact with organic materials.

7. Processing or handling combustible solids in a finely divided state.

f. **Class F-6. Severe Hazard:** This class shall apply to:

1. Production or use of *commercial or military explosives* (not to apply to process stages where product is only in preliminary or intermediate non-explosive forms or in less than critical quantities).

2. Violent chemical reactions presenting difficult control problems.

3. Production or use of chemicals having unusually unstable and dangerous compositions.

E/F FACTOR TABLE

	Not Sprinklered	Sprinklered		Not Sprinklered	Sprinklered		Not Sprinklered	Sprinklered
E1/F1	0.125	0.111	E2/F5	0.390	0.176	E4/F3	0.542	0.515
2	0.167	0.133	6	0.459	0.184	4	0.675	0.563
3	0.221	0.133	E3/F1	0.292	0.277	5	0.709	0.683
4	0.278	0.139	2	0.333	0.316	6	0.800	0.646
5	0.334	0.150	3	0.389	0.340			
6	0.390	0.156	4	0.443	0.365	E5/F1	0.526	0.513
			5	0.500	0.365	2	0.584	0.569
E2/F1	0.180	0.166	6	0.583	0.408	3	0.680	0.646
2	0.221	0.166	E4/F1	0.416	0.403	4	0.805	0.725
3	0.278	0.167	2	0.471	0.457	5	0.971	0.825
4	0.334	0.167				6	1.000	1.000

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G. Knowledge Requirements

The Chemical Processing Section of the Process and Equipment Safety Operating Manual will deal with safety considerations involved in more or less normal chemical process operation. The knowledge required will include the importance of physical property data, chemical reactions and refining processes, material and energy balance utilization, critical operating variables, limiting energy considerations, compatibility hazards and emergency situations to be prepared for.

The manual will cover the Control System Technology from the standpoint of maintaining steady state operation as much as possible, with the safety related concerns in maintaining reliable controls and with emergency control systems.

Abnormal or unsteady state operation introduces the need for knowledge of flammability, ignition sources, inerting, equipment limitations, overpressure relief, and other equipment related concerns all of which will be covered in the section on Equipment.

The special nature of the electrical considerations relating to operating personnel are to be covered as well as fire protection and fire fighting from an operating personnel standpoint. References and resources for all technologies will be provided.

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II. KNOWLEDGE OF CHEMICALS HANDLED (N. W. Clauss)

A. Introduction

Knowledge of chemical processing begins with a thorough study of the physical properties of each of the chemical compounds used or produced including byproducts resulting from side reactions. The readily accessible sources for physical property data include:

1. Laboratory Manual No. 40
2. Laboratory Manual No. 41
3. Material Safety Data Sheets
4. Reactive and Hazardous Chemical Manuals

Data not available in the above references can be obtained from the South Charleston Technical Center Research and Development Department (Physical Properties Group), Process Safety Department and Materials Engineering Department.

B. Laboratory Manual 40 - Tables of Physical Properties

The data available in the Physical Property Manual is listed below. As fundamental and obvious as it may seem, the number of accidents that happen because of the apparent lack of attention to basic physical property data is alarming. A few examples will illustrate this point.

Tables of Physical Properties - Lab Manual 40

Properties of Compounds Available:

1. Molecular Weight
2. Specific Gravity - Density
3. Freezing Point
4. Surface Tension
5. Viscosity

UCC 020865

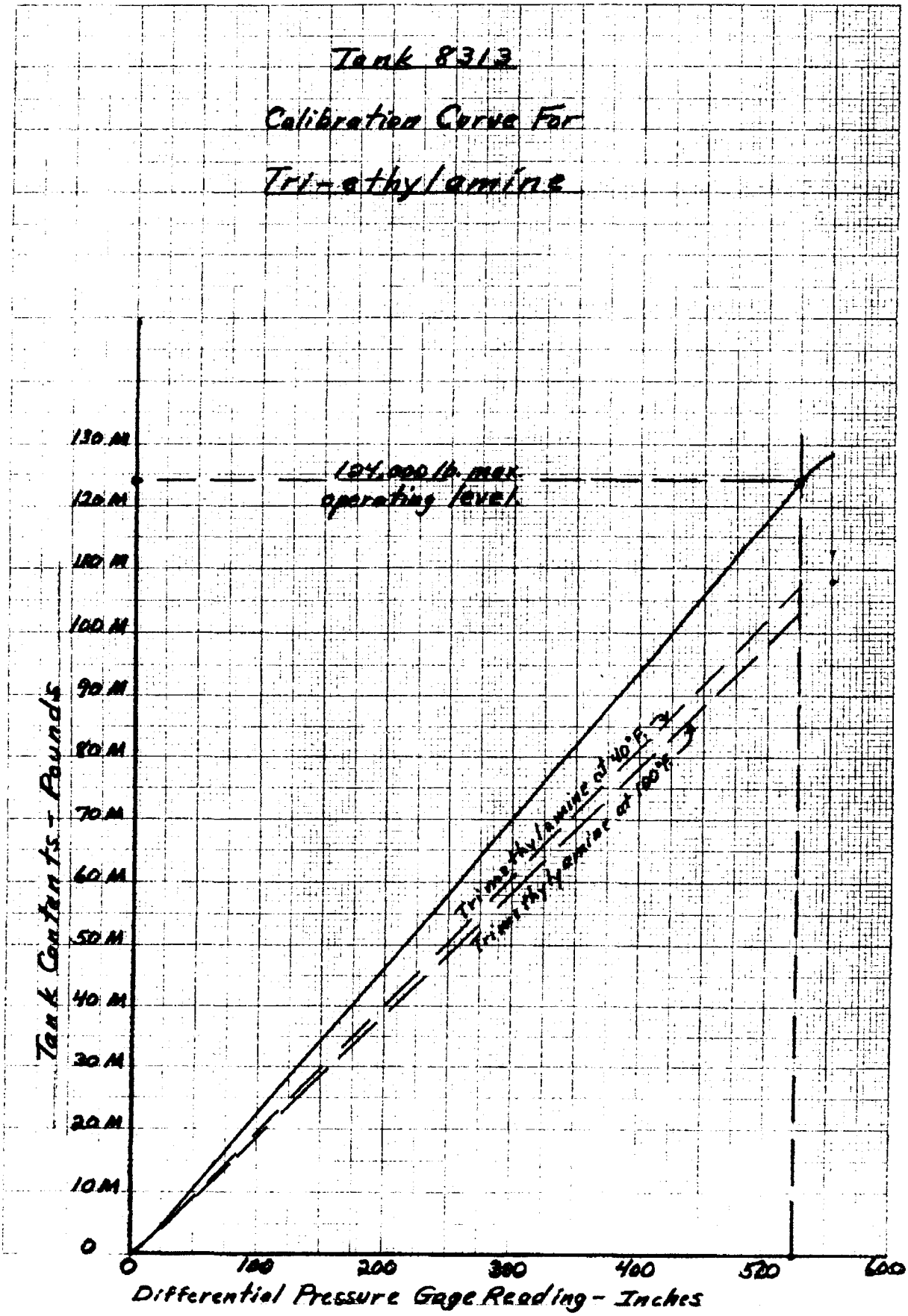
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6. Refractive Index
7. Boiling Point (Vapor Pressure Data)
8. Solubility Data
9. Heat of Vaporization
10. Antoine Constants
11. Specific Heat
12. Thermal Expansion (Coefficient)
13. Flash Point Data
14. Flammable Limits in Air (Upper-Lower)
15. Autoignition Temperature
16. Heat of Combustion
17. Hazard Classification
    a. Health (Toxicity)
    b. Flammability
    c. Stability (Reactivity)
18. Non-Flammable Oxygen Limit
19. Critical Constants
    a. Temperature
    b. Pressure
    c. Volume
    d. Compressability Factor
20. Spontaneous Heating
21. Decomposition
22. Chemical Formulae

The calibration curve shown is for a 9 feet O.D. by 46 feet high tank normally used for triethylamine storage. The service was changed to store trimethylamine. The tank was rated at a MAWP of 21 psi and was equipped with one 10-inch rupture disc set at 21 psi and two 2J3 safety relief valves set at 15 psi.

The tank was filled to 124,000 pounds early one morning with the temperature at 60°F. In the afternoon of the second day, the rupture disc blew and 36,000 pounds of TMA were released to the atmosphere with the remainder salvaged by pumping to another TMA tank.

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Three physical properties were ignored in this change of service. Specific gravity, vapor pressure and thermal expansion. The specific gravity difference required a revised calibration curve and because it was not prepared, the tank was overfilled with no allowance for expansion by the 40°F increase in ambient temperature which occurred over the two-day period. The vapor pressure at 20°C of TMA is 1430 mm Hg. and consequently the material vaporized rapidly with considerable loss of material. Fortunately, the vapor cloud was far enough away from an ignition source to avoid a deflagration.

Rupture discs are not designed to resist hydraulic pressure and thermal expansion of noncompressible fluids.

A reported case in the MCA Bulletin tells of a doctorate in chemistry with ten years experience collecting used mercury in a 2-liter glass flask for recovery. When full, the flask was lifted and the bottom dropped out. With the specific gravity of mercury at 13.6 grams per cc, the weight of mercury was 60 pounds. His neglect of this simple physical property caused the failure of the drains and trap in his lab.

Another reported case involved the eruption of 1000 pounds of hot material from the open manhead of a 5000-gallon polyester wash tank. The operator was adding hot water to material well above the boiling point of water. He ignored the boiling point and vapor pressure physical property data.

Boiling point data is especially important when handling liquified gases since low temperatures can create hazard from freezing water. The low boiling points at atmospheric pressure of propane (-43.8°F) and butane (31.1°F) create hazards in depressuring equipment in which there may be water or heavy hydrocarbons. A cracking unit was severely damaged by a fire and explosion, and one fatality resulted, because it was not recognized that vaporizing butane could lower the surrounding temperature below that required to freeze water. In this accident, a stabilizer tower and reflux drum were being pumped out, depressured and purged of hydrocarbons in preparation for a shutdown. Residual light hydrocarbons vaporized, cooling the drum and freezing water in a drain connection. Since nothing could flow from the drain, the

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operators assumed all liquid was out of the drum and left the drain valve open by mistake. Later the drain thawed and a large amount of liquid escaped and vaporized. The gas flowed along the ground blanketing a large area before it flashed at a furnace.

Had the operators recognized that the drain could be blocked with ice, they would have made sure it was open, found that the drum was not empty, closed the drain valve and proceeded to empty the drum.

The freezing point, an easily available physical property, of acetic acid is 16.7°C (62°F) and yet we still have accidents because the breathing vent with flame arrestor are closed off by frozen acetic acid and the tank pulled in or ruptured when transfers are made at temperatures below 62°F.

A potential for vapor cloud or fires hazards exists for the low pressure equipment protected by seal pots. The seal liquid is usually water and the critical seal pressure needed to prevent overpressure of a vessel is maintained by an instrumented water flow-liquid level control system. If the effect of specific gravity of seal liquid is not recognized, the process vapor lines to the seal pot can condense low gravity organic vapor and lower the seal liquid gravity which has frequently caused unnecessary releases of flammable vapor to the atmosphere.

Failure to consider the spontaneous ignition of flammable liquids has caused many fires in our plants usually due to the significant decrease in autoignition temperature by some types of insulation.

C. Other Important Physical Properties

Physical properties of chemical compounds not quite as readily available, but of equal importance in Chemical Processing, are listed below with the most probable source of reference. Any needed properties that can't be found in the usual C&P Manuals, handbooks, etc., can be obtained by request to Physical Properties Group, Building 740, Room 3103, Extension 4172 at the South Charleston, West Virginia Technical Center.

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List of Other Physical Properties:

1. Fire Point
2. Self-Actuating Decomposition Temperature
3. Corrosion of Materials of Construction (Mat. Eng. Dept.)
4. Toxicity
5. Reactivity (Reactive Chem. Manual)
6. Heat of Reaction (R/D Physical Properties Group)
8. Heat of Solution (Dilution)
9. Heat of Adsorption
10. Heat of Fusion
11. Heat of Hydration
12. Heat of Neutralization
13. Heat of Mixing
14. Heat of Dissociation
15. Rate of Reaction (R/D Physical Prop. Grp)

An example case of lack of knowledge of one of the listed items we can discuss Self-Actuating Decomposition Temperature. This property is of greatest importance for those handling organic peroxides. Five men were bruned from an ignition in an organic peroxide storage room because the critical storage temperature limit was exceeded and molecular decomposition was initiated. Once one molecule of an organic peroxide decomposes, which begins at the SAD temperature, the propogation of decomposition continues at ever increasing rate. The accident was described as follows:

An employee received second and third degree burns during an explosion and fire in the Peroxide Catalyst Storage Room. Four other employees received nondisabling injuries. When the incident occurred, an alarm was sounded and the emergency squad responded. The initial blast destroyed two tile walls approximately 10 to 15 feet long. Shortly after the explosion, a crew cleaned up the debris and placed dry ice around the stored catalyst. As they were leaving the room, the second explosion occurred causing the injuries.

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One accident resulted from grinding (sparks) at the open end of a supposedly clean sulfuric acid line because the potential for a hydrogen generation by corrosion was ignored. A case description follows:

Description: While a workman was grinding at the open end of a 93 percent sulfuric acid line, a flash occurred which resulted in slight burns to his face. He was wearing a face shield. The line had been drained the day before. A flange had been welded on just prior to the grinding operation.

The line could have been purged with nitrogen had the potential hazard been recognized.

Another case follows which illustrates the need for enforcement of procedures to protect personnel from toxicity hazards.

On the evening shift, a chemical operator absorbed sufficient aniline from a drum spill to be hospitalized due to a critical level of methemoglobin in his blood. The operator was righting some aniline drums that had fallen from a pallet. One of the drums leaked onto his trousers. He wiped the affected area with hot water and a soapy towel and changed clothes after the incident but did not shower. Within three hours of the exposure, he reported to his foreman in a weakened condition and with symptoms of methemoglobinemia.

Upon recovery, the operator related the dangers of aniline and the safety practices he had been schooled in, but indicated that at the time of exposure he felt the lesser procedure he followed was enough.

Cause: The prime cause of the disabling injury was the failure of personnel to follow prescribed safety procedures even though they had been thoroughly covered in safety meetings.

D. Azeotropes (Constant Boiling Mixtures)

Involvement in separation processes such as distillation, extraction, etc., will require a knowledge of azeotropes. This knowledge is

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LABORATORY MANUAL
TABLE OF AZEOTROPES

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NO.	COMPONENTS: COMPOUND	SPECIFIC GRAVITY at 20/20°C	BOILING POINT, °C at 760 mm	AZEOTROPE: BOILING POINT, °C at 760 mm	COMPOSITION, % by WT. in AZEOTROPE	in UPPER LAYER	in LOWER LAYER	RELATIVE VOLUME of LAYERS at 20°C	SP. GR 20/20 C of AZEOTROPE or LAYERS
736	Hexane (commercial) Methyl acetate Methanol	0.6600 0.9353 0.7924	68.7 56.3 64.5	45	59 27 14				
752	Hexane (commercial) Methyl ethyl ketone	0.6600 0.8061	68.7 79.6	64.3	71.7 28.3				0.698
755	Hexane Methyl ethyl ketone Water	0.6600 0.8061 1.0000	68.7 79.6 100.0	55	77 22 1	[illegible] 12.5 0.2	0.1 10.0 89.9	U 99 L 1	[illegible] L 0.99[illegible]
353	Hexane 2-Methyl-2-propanol	0.6600 0.790	68.7 82.6	63.7	75 25				0.691
354	Hexane 2-Methyl-2-propanol Water	0.6600 0.790 1.0000	68.7 82.6 100.0	58.9					Heter.
355	Hexane Pentanol	0.6600 0.8240	68.7 138.0	NONE					
356	Hexane Propanol	0.6600 0.8049	68.7 97.2	65.7	96 4				0.67
359	Hexane Water	0.6600 1.0000	68.7 100.0	61.6	94.4 5.6			U 96.2 L 3.8	U 0.660 L 1.000
360	Hexanoic acid Water	0.9295 1.0000	205 100.0	99.8	7.9 92.1	94.6 5.4	1.1 98.9	U 8.5 L 91.5	U 0.934 L 0.999
302	Hexanol 2-Ethylbutyl acetate	0.8203 0.8803	157.1 162.3	154.4	72.5 27.5				0.838
1981	Hexanol Ethylene glycol	0.8203 1.1155	157.1 197.5	NONE					
361	Hexanol Water	0.8203 1.0000	157.1 100.0	97.8	32.8 67.2	92.8 7.2	0.58 99.42	U 39.0 L 61.0	U 0.835 L 0.999
362	2-Hexenal Water	0.847 1.0000	149 100.0	95.1	51.4 48.6	98.3 1.7	0.2 99.8	U 56.3 L 43.7	U 0.848 L 0.999
863	Hexyl acetate Water	0.8739 1.0000	171.0 100.0	97.4	39 61	99.44 0.56	0.05 99.95	U 42.3 L 57.7	U 0.873 L 1.000
2166	Hexylamine Isopropanol	0.7653 0.7862	131.2 82.3	NONE					
2157	Hexylamine Water	0.7653 1.0000	131.2 100.0	95.5	51 49				0.881
2242	Hexyl CARBITOL Water	0.9346 1.0000	259.1 100.0	100.0	1.9 98.1	43.7 56.3	1.7 98.3	U 0.5 L 99.5	U 0.982 L 1.000
2234	Hexyl CELLOSOLVE Water	0.8894 1.0000	208.1 100.0	99.7	9 91	81.2 18.8	0.99 99.01	U 11 L 89	U 0.915 L 1.000
864	Hexyl chloride Water	0.8734 1.0000	133.9 100.0	91.8	70.3 29.7	99.83 0.17	0.01 99.99	U 73 L 27	U 0.873 L 1.000
229	Hexyl ether (50 mm) Diethylene glycol	0.7942 1.1184	137[z] 163[z]	129.9[z]	84.5 15.5	99.8 0.2	0.4 99.6	U 88.6 L 11.4	U 0.795 L 1.117

a Distillation barrier present; see 41-4-1, Section 6
b At 25/20°C
c At 30/20°C
d At 40/20°C
e At 45/20°C
f At 50/20°C
g At 60/20°C
h At 0°C
i At 26°C
j At 27°C
k At 30°C
l At 100 mm
m At 750.6 mm
n Hydrocarbon mixture; composition varies
o Homogeneous at 35°C; sp gr at 26/20°C
p Reference: Air = 1 at 60°F
q % by weight
r % by volume

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MATERIAL SAFETY DATA SHEET

(Approved by U.S. Department of Labor "Essentially Similar" to Form LSB-OOS-4)

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CHEMICAL NAME: METHYL CHLORIDE

SYNONYMS: --

CHEMICAL FAMILY: Alkyl Chlorides

FORMULA: CH_3Cl

MOLECULAR WEIGHT: 50.49

TRADE NAME AND SYNONYMS: Methyl Chloride

I. PHYSICAL DATA

BOILING POINT, 760 mm. Hg	-23.73 °C. (-10.7 °F.)	FREEZING POINT	-97.7 °C.
SPECIFIC GRAVITY (H_2O = 1)	0.920 at 20/20 °C.	VAPOR PRESSURE AT 20°C.	3,723 mm. Hg
VAPOR DENSITY (air = 1)	1.74	SOLUBILITY IN WATER, % by wt. at 20 °C.	0.6
PER CENT VOLATILES BY VOLUME	100	EVAPORATION RATE (Butyl Acetate = 1)	217
APPEARANCE AND ODOR	Colorless gas with ethereal, nonirritant odor.		

II. HAZARDOUS INGREDIENTS

MATERIAL	%	TLV (Units)
Methyl Chloride	~100	100 ppm. ACGIH OSHA
(See Sections III through VIII)		

III. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (test method)	Flammable compressed gas	AUTOIGNITION TEMPERATURE	1170 °F.
FLAMMABLE LIMITS IN AIR, % by volume	LOWER 10.7	UPPER	17.4

EXTINGUISHING MEDIA	Stop flow of gas (see below). Use carbon dioxide or dry chemical for small fires. Use water spray on large fires.
SPECIAL FIRE FIGHTING PROCEDURES	Keep people away; keep upwind. Self-contained breathing apparatus and protective clothing should be available to fire fighters.
UNUSUAL FIRE AND EXPLOSION HAZARDS	Do not put out fire until leak has been shut off. (See MCA Chem-Card CC-67).

EMERGENCY PHONE NUMBER

304/744-3487

This number is available days, nights, weekends, and holidays.

While Union Carbide Corporation believes that the data contained herein are factual and the opinions expressed are those of qualified experts regarding the results of the tests conducted, the data are not to be taken as a warranty or representation for which Union Carbide Corporation assumes legal responsibility. They are offered solely for your consideration, investigation, and verification. Any use of this data and information must be determined by the user to be in accordance with applicable federal, state and local laws and regulations.

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IV. HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE	100 ppm. – ACGIH (1976) and OSHA CFR 29 § 1000 Table G 1.
EFFECTS OF OVEREXPOSURE	May without warning cause headache, dizziness, and loss of consciousness. Continued exposure causes coma, respiratory failure, and death. Chronic exposure causes loss of appetite, nervous symptoms, and weakness.
EMERGENCY AND FIRST AID PROCEDURES	If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. Call a physician. Symptoms may appear at gas concentrations that cannot be smelled.

V. REACTIVITY DATA

STABILITY			
UNSTABLE	STABLE	CONDITIONS TO AVOID	Presence of water and alkalies.
--	√		

INCOMPATIBILITY (materials to avoid)	Alkali and alkaline earth metals, magnesium, zinc, and especially aluminum. Methyl chloride may react explosively with aluminum.
HAZARDOUS DECOMPOSITION PRODUCTS	Decomposition or burning may produce hydrogen chloride, carbon monoxide and/or carbon dioxide.

HAZARDOUS POLYMERIZATION			
May Occur	Will not Occur	CONDITIONS TO AVOID	None
--	√		

VI. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Stop source of leak. Eliminate all sources of ignition. Keep upwind; keep people away. See MCA Chem-Card CC-67.
WASTE DISPOSAL METHOD	Incinerate where permitted under appropriate Federal, State, and local regulations.

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VII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (specify type)		Self-contained breathing apparatus.		
VENTILATION	LOCAL EXHAUST	√	SPECIAL	—
	MECHANICAL (general)	√	OTHER	—
PROTECTIVE GLOVES		Rubber	EYE PROTECTION	Monogoggles
OTHER PROTECTIVE EQUIPMENT		Eye bath, safety shower, and rubber suit.		

VIII. SPECIAL PRECAUTIONS

PRECAUTIONARY LABELING

METHYL CHLORIDE

WARNING! HARMFUL IF INHALED.
FLAMMABLE.

Avoid breathing vapor.
Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.

FIRST AID: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen.
Call a physician.

FOR INDUSTRY USE ONLY

OTHER HANDLING AND STORAGE CONDITIONS

—

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available in UC Laboratory Manual 41 and includes data on the gravity, composition of layers, boiling points, etc. The theory of constant boiling mixtures, both homogeneous and heterogeneous, is included to enable the prediction of CBM's in separation processes. An example page from the Tables of Azeotropes is shown.

E. Material Safety Data Sheets

The Material Safety Data Sheet Manual is issued by UCC Communications Department. Material safety data sheets are printed for all C&P products according to the requirements of the U. S. Department of Labor and mainly as a means of providing useful information to our C&P customers. You should be aware of our obligations to provide customers with accurate end use information.

An example sheet is shown for methyl chloride with key data highlighted which is not readily available in other C&P manuals. The useful data provided in most MSD sheets is listed as follows:

1. Vapor Density (Air = 1.0)
2. Evaporation Rate (Butyl Acetate = 1.0)
3. Threshhold Limit Value
4. Fire Hazard Information
5. Health Hazard Information
6. Reactivity Information (MeCl and Aluminum)
7. Spill/Waste Disposal Information
8. Breathing/Ventilation Information

F. Reactive and Hazardous Chemical Manuals (Refer to Appendix A)

On June 4, 1954, there was a memorable explosion of a tank car of acrolein at our Institute, West Virginia Plant. The Reactive and Hazardous Chemicals Program was initiated as a result. The program was updated in 1965 and today consists of one volume called "Reactive Chemicals Manual": one volume entitled "Bibliography of Reactive and Hazardous Chemicals - References" and three volumes containing "Reactive and Hazardous Chemicals Data Sheets."

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All five of these manuals should be available for reference and basic information to all operating personnel. Extensive training sessions have been held on the use of the contained information including testing. The Reactive Chemicals Program is one of the most important tools ever provided by Chemicals and Plastics for acquiring chemical processing knowledge and for safely designing and operating new processes.

1. Reactive Chemicals Manual (One Volume)

Section 1 of the Reactive Chemicals Manual is reproduced in part in Appendix A and gives the basic definitions of the degree and extent of reactivity by chemical groupings such as vinyl, carbonyl, conjugated, unsaturated, etc. Included are catalyzed polymerizations, reactions with water, spontaneous decompositions.

Section V is reproduced from the Reactive Chemical Manual to acquaint you with the procedure, objectives and responsibilities for the maintenance of the program. The manual Table of Contents and an example page from Appendix A showing the formula and type of reactivity of some reactive chemicals is included.

Reactive chemicals reports or requests for data sheets should be directed to your local Safety Director or to:

C&P Safety Department
South Charleston Technical Center
Building 701 - Room 237
Phone Extension - 4584

2. Reactive and Hazardous Chemicals - Bibliobraphy and References

The description of the content of this volume is taken from Section I-E and is as follows:

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"Additional information is included in the "Bibliography of Reactive and Hazardous Chemicals References", a copy of which has been assigned to each person who has this manual. The original Bibliography was the result of an extended search through the libraries of the various plants, laboratories, and departments of the Division. It is up-dated every three months."

Reactive Chemicals Reference Files, each including all the publications referred to in the Bibliography, have been established and are kept up-to-date at the location previously mentioned.

3. Reactive and Hazardous Chemicals - Data Sheets

The three volumes of basic information on reactive and hazardous chemicals provides the starting point for those involved in designing new processes or making changes in the utilization of existing systems for new product development.

The Manual contains information about 575 different chemicals that are handled in Chemicals and Plastic's locations. Because of the confidential nature of the material, the information should not be reproduced or given to persons not employed by Union Carbide Corporation.

The data sheets in the Manual are classified into two categories:

a. A reactive chemical is defined as a material which will vigorously polymerize, decompose, condense or otherwise react with itself or in the presence of a catalytic amount of some other material or which will react violently with water or spontaneously with air.

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b. A hazardous chemical is defined as one which does not qualify as a reactive chemical but which is hazardous from the standpoint of health, flammability or reactivity with other materials.

These two categories are identified in the Manual by a color code to differentiate them. The reactive data sheets are coded orange, and the hazardous sheets are coded yellow.

One set of reactive chemical data sheets is shown. The particular chemical involved is acetaldehyde. Notice the chemical information given and the physical property data tabulated. In addition to this information, a typical data sheet will include reactivity with various common components, such as water, mineral acids, alkalies, ammonia and amines, chlorine, esterification, oxidizers, or other chemical reactions that may be hazardous. In Section C, health hazards are discussed; such information as responses to eye contact, breathing, skin contact, and swallowing. Protective equipment which should be used in handling the material is discussed in Section C. Section D contains information concerning fire control as to the use of water spray, foam, and the extinguishment of small fires. Section E deals with waste disposal, the hazards involved in incineration, biological treatment and chemical landfill. Section F deals with handling and storage of the chemical and Section G with materials of construction. Section H gives the references from which the information in the date sheet has been gathered.

Depending upon the chemical and its classification, the volume of information in each of these sections will vary.

Note the triangle arrangement in the upper right hand side of the data sheet. This information is part of the Union

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Carbide Chemicals & Plastics Hazards Signal System. For acetaldehyde you will note that the health block is 4, the fire 4, and stability 3.

C&P Safety Standards FP-210, -211, -211A, -211B, and -212 contain information about this hazard signal system. The basis for the signal system are the physical properties and characteristics of the materials being processed. These standards specify the location, size and dimensions applicable to the Hazard Signal System.

The health hazard will always be in the left hand block and these signals or numbers indicate the nature of the particular hazard. The color coding used for this block will be blue. The number 4 is the highest hazard rating and is defined as major residual injury may result in spite of prompt treatment The upper block in the triangle will always be the fire hazard, color coded with red. Signals range from a circular signal indicating noncombustible, to a numeral 4 in red which indicates the material has a flash point below 73°F. The right hand square of the triangle will be color coded in yellow and identifies the degree of chemical stability. The numerals 1 through 4 again are used, 4 being the highest and this indicates that the material can be detonated by shock or will detonate or explode by self reaction under conditions of abnormal pressure temperature or concentration. A "W" in the lower block indicates that the materials are reactive with water and fire fighting squads should be cautious in using water around such materials. A "C" would mean a carcinogen and an "A" would signal an asphyxiant.

The numbers and letters to be used in the hazard signal system come from the Reactive and Hazardous Chemicals Manual Data Sheet. If you are handling a chemical in your unit for which this information is not available, you

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should contact the C&P Safety Department to obtain the correct hazard signal system information. The Reactive and Hazardous Chemical Manual is maintained by the C&P Safety Department with support of the R&D Department.

G. Other Data Requirements

Remember that there may be other significant chemical properties which can only be obtained by special request to the applicable skills area. You may for example need heat sensitivity data available only by special laboratory work.

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REACTIVE AND HAZARDOUS CHEMICALS MANUAL

ACETALDEHYDE

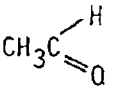
BUSINESS CONFIDENTIAL

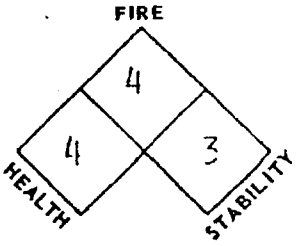
REACTIVE CHEMICAL

CHEMICAL NAME: Acetaldehyde

SYNONYMS: Ethanal

CHEMICAL FORMULA: C_2H_4O

CHEMICAL STRUCTURE: 



A PHYSICAL PROPERTIES (1)

Appearance	Colorless liquid below 69°F
Molecular weight	44.05
Flammability limits, vol %, upper	55.0
lower	4.1
Flash point, open cup, °C (Tag)	<-18 (<0°F)(22)
closed cup, °C	--
Autoignition temperature in air, °C	175 (347°F)(24)
Boiling point at 760 mm Hg, °C	20.4
at 10 mm Hg, °C	-59.0
Freezing point, °C	-123
Vapor pressure, mm Hg at 20°C	750
Solubility, wt % in water	Complete
(20°C) water in	Complete
Specific gravity at 20/20°C	0.7791
Heat of vaporization at 1 atm, Btu/lb	253
Heat of combustion at 25°C, Btu/lb	11,462
Coefficient of expansion at 55°C, vol/°C	0.00184 (22)
Viscosity at 20°C, cps	0.24

Revised 3/1/74

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B. REACTIVITY (3,4,5)

Acetaldehyde is a colorless liquid having a pungent odor; it volatilizes to a gas at 69°F. Acetaldehyde is highly reactive exhibiting the general reactivity of aldehydes. It is miscible in all proportions with water and most common organic solvents.

Some reactions of acetaldehyde, such as polymerization, condensation, oxidation, reduction, acetal formation, acetylation, and chlorination are exothermic and capable of rapidly releasing much heat. Because acetaldehyde is reactive with itself and with many common chemicals, a stability rating of 3 in the UCC hazard signal system is assigned.

Stability

In standard dynamic thermal stability tests, acetaldehyde showed no exotherm or decomposition when heated to 400°C (16). However, acetaldehyde decomposes at temperatures above 400°C, forming principally methane and carbon monoxide (3,7). It should never be allowed to accidentally overheat above this temperature in the plant or laboratory.

There is no evidence that acetaldehyde is sensitive to mechanical shock or decomposes under impact.

Polymerization (3,4)

Acetaldehyde polymerizes to a trimer (paraldehyde) quite readily and exothermally in the presence of a small amount of mineral acids as catalyst. Paraldehyde can be easily decomposed by raising the temperature in the presence of a small amount of sulfuric acid and removing the acetaldehyde immediately as formed. In the presence of excess concentrated sulfuric acid, tarry condensation products are formed. At very low temperatures, polymeric metaldehyde, the tetramer, may be formed as a solid. Acetaldehyde may be deliberately polymerized under special conditions of temperature, pressure, and catalyst to give elastic and crystalline polyacetaldehyde resins.

The polymerization of acetaldehyde is generally not dangerous in the plant. Paraldehyde has been manufactured for many years under controlled conditions by UCC without difficulty. However, any accidental, uncontrolled, rapid polymerization of acetaldehyde can be hazardous and must be prevented.

Reactions

(a) With Water (3) - Acetaldehyde releases heat when dissolved in water. The exothermal heat of solution is: ΔH, 25°C = -1.63 kcal per gram-mole. In aqueous solutions, acetaldehyde exists in equilibrium with its

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B. REACTIVITY (Continued)

unstable hydrate, $CH_3CH(OH)_2$. The exothermal heat of hydration is about -5.1 kcal per gram-mole

Therefore, even though acetaldehyde does not react chemically with water, the heat released upon solution or hydration may create a hazardous condition if acetaldehyde is rapidly added to water. Addition of acetaldehyde to water should be very carefully controlled.

(b) Aldol Condensation (4,5) - Acetaldehyde undergoes the conventional aldol condensation in which one molecule adds to the carbonyl group of another molecule as follows:

$$2CH_3CHO \rightleftharpoons CH_3\overset{H}{\underset{CH_2CHO}{C}}-OH$$

Acetaldehyde Acetaldol

Catalysts for the above reaction are the soluble metal salts of carboxylic acids (especially in the presence of organic acids), alkalies, or amine salts. Specifically, iron or cobalt salts of carboxylic acids will catalyze the aldol condensation of acetaldehyde (19). Historically within UCC, dilute aqueous caustic soda has been used as catalyst when conducting a controlled aldol reaction in the plant. Temperatures of -5 to +40°C are adequate to sustain this exothermic reaction. The heat released by aldolization of acetaldehyde in a plant system has been estimated to be H_R, 25°C = -8.3 ± 5.1 kcal/gram-mole of acetaldehyde reacting (6). Therefore, an unwanted condensation of acetaldehyde can be hazardous and must be prevented by keeping catalytic materials from accidentally contaminating this aldehyde.

(c) Oxidation (3,5) - Acetaldehyde is readily oxidized by many materials. Air (oxygen) oxidizes acetaldehyde to acetic acid, peracetic acid, or peroxides which are unstable and may explode spontaneously (8). Acetaldehyde combines with oxygen in both the liquid and gas phases. It can be oxidized by peracetic acid to form acetic acid and at low temperature can be oxidized to acetaldehyde monoperacetate, which is an intermediate in the production of peracetic acid. Acetaldehyde under controlled conditions can be oxidized by nitric and nitrous acids to glyoxal.

Oxygen or air in the presence of acetaldehyde can be hazardous at temperatures below 20°C because of formation of peracids and peroxides. Peracid formation above 20°C occurs to a measurable degree but usually does not reach dangerous concentrations because peracetic acid reacts rapidly (exothermally) with acetaldehyde at these temperatures to form acetic acid. However, caution must be observed in handling acetaldehyde which has been stored in the presence of air because it may contain some peracetic acid. (See Section F for discussion of stability during storage.)

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B. REACTIVITY (Continued)

(d) Reduction (3,5) - Acetaldehyde can be reduced by hydrogen and a suitable metal catalyst at room temperature to ethanol. This reaction is exothermic. It has been operated commercially and is not considered hazardous when properly controlled.

(e) Addition of Ammonia (3,4,5) - Acetaldehyde combines with ammonia to give a product called acetaldehyde-ammonia. Acetaldehyde also reacts with derivatives of ammonia to form compounds such as oximes, hydrazones, and semicarbazones.

The reaction of acetaldehyde with ammonia (and its derivatives) is not considered hazardous when carefully controlled. However, the unwanted exothermic aldolization of acetaldehyde, which is catalyzed by alkaline materials or amine salts, must be prevented from accidentally occurring whenever ammonia is present with acetaldehyde.

(f) Halogenation (3,5) - Chlorine reacts with acetaldehyde to replace one or more hydrogen atoms on the active alpha-carbon atom to form chloroacetaldehydes. Acetaldehyde also reacts with other halogen-containing compounds such as phosphorus pentachloride. These exothermic reactions may be hazardous if not carefully controlled.

(g) Acetal Formation (3,4,5) - Acetaldehyde reacts with alcohols to form acetals and hemiacetals. Acetal formation, particularly with the lower alcohols, is hazardous and can rapidly release heat. The first step in acetal formation (formation of a hemiacetal) proceeds in the absence of a catalyst and liberates more heat than the second step which converts the hemiacetal to the acetal (18). Accidental contact of alcohols with acetaldehyde must be prevented to avoid hazardous acetal-type reactions.

(h) Miscellaneous Reactions (3,4,5) - Acetaldehyde undergoes other reactions characteristic of aldehydes. It condenses in the presence of an alcoholate (alkoxide) to form ethyl acetate by the Tishchenko reaction. Acetaldehyde also reacts with the following compounds: sodium bisulfite, Grignard reagents, hydrogen cyanide, and aliphatic anhydrides. These reactions are generally very carefully controlled in the plant or laboratory. However, acids (such as sulfuric) catalyze the reaction of acetaldehyde with anhydrides at room temperature (21), and this exothermic reaction can be dangerous under certain circumstances.

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C. HEALTH HAZARDS (9,10,11)

Acetaldehyde, particularly as a vapor, is irritating to the eyes, nose, throat, and respiratory tract of humans. Acetaldehyde may cause severe injury to the eyes, and sensitization may result from exposure to the skin or by breathing. The limit allowed (Threshold Limit Value) by the Occupational Safety and Health Act of 1970 for an employee's eight-hour average exposure to acetaldehyde is 200 ppm by volume in air (12), but 100 ppm has been officially adopted by ACGIH (20).

Acetaldehyde is assigned the maximum health rating of 4 in the UCC hazard signal system. The ratings given in the Manual of Hazards to Health from Chemicals are shown below.

HEALTH MANUAL RATINGS (11)

Swallowing	Skin Penetration	Skin Irritation	Breathing	Eye Contact
2	2	2	5	3

Eye Contact - Acetaldehyde is a serious eye injurant with both concentrated vapor and liquid capable of producing irritation and damage to the human eye. Minor residual injury may result from accidental eye exposure in spite of prompt treatment. If accidental contact does occur with concentrated vapors or liquid acetaldehyde, flush the eyes for 15 minutes with water and report to the medical department as soon as possible.

Breathing - Acetaldehyde is very harmful when breathed and major residual injury is likely in spite of prompt treatment. Possible sensitivity may result from repeated exposure to acetaldehyde. Eye or nose irritation can be readily detected by most people well below 50 ppm (10).

Avoid breathing the vapors of acetaldehyde because it may produce respiratory irritation or residual injury. Air-supplied protective breathing equipment should be used whenever necessary to work in high concentrations of acetaldehyde vapors. For emergency first aid treatment, remove the patient to fresh air, administer artificial respiration if not breathing, and notify the medical department at once.

Skin Contact - Acetaldehyde is only moderately irritating to the skin. It is moderately toxic by penetration of the skin. Possible sensitivity may result from exposure to the skin.

In case of skin contact, flush contaminated area thoroughly with water, remove contaminated clothing, then wash exposed skin areas with soap and water, and report the incident to local supervision.

Swallowing - Minor residual injury may result from swallowing acetaldehyde if not treated promptly. It is unlikely that significant quantities will be ingested incidental to normal industrial handling where acetaldehyde might be accidentally splashed on the face. Harmful effects may result if large quantities are swallowed. If acetaldehyde is accidentally swallowed, report to the medical department.

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C. HEALTH HAZARDS (Continued)

Protective Equipment - Use vapor-proof goggles and approved protective clothing, such as rubber gloves, aprons, face shields, etc., when handling liquid acetaldehyde. Have canister masks or self-contained breathing apparatus available for use in case high concentrations of acetaldehyde vapors are likely to be encountered. Safety showers and eye baths must be available also

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D. WASTE DISPOSAL

Acetaldehyde is toxic to most forms of life and must be considered a potential environmental pollutant. It is toxic to fish in a critical concentration of 53 mg/liter (23). Disposal of acetaldehyde waste streams, or accidental spillages and leakages must be contained and handled carefully to avoid pollution of the environment. This can be done by consultation with the authorized environmental protection department. Indiscriminate dumping of aldehydes into sewers, streams, or waterways must be avoided. Incineration is the preferred method of disposal.

Incineration - Acetaldehyde can be disposed of by incineration under carefully controlled and supervised conditions. Proper precautions must be observed to avoid exposure of personnel to both the liquid and vapor. The products of combustion are carbon oxides and water.

Biological Treatment (15) - Acetaldehyde is amenable to biological degradation and can be disposed of in liquid waste treatment facilities under supervised and controlled conditions. Aqueous solutions of acetaldehyde have been 73 per cent degraded after 10 days in non-acclimated laboratory biological systems.

Caution should be observed in operating waste treatment facilities so that volatile acetaldehyde is not released accidentally as an environmental pollutant during air stripping.

Chemical Landfill - Direct disposal of large quantities of acetaldehyde in a chemical landfill should be avoided because of its reactivity and volatility. Small quantities can be disposed of when treated carefully with sodium hydroxide as a means of decontamination. Personnel should be aware of the toxic effects of breathing acetaldehyde vapors and of contact with skin and eyes. Pollution of the surrounding environment by vapors must be avoided.

Disposal of Leaks and Spills - Spilled material should be contained in an area away from both personnel and sources of ignition. Avoid contact of humans with both the liquid and vapor. Any confined liquid should be vacuumed into a tank truck (or other suitable containers) for subsequent reuse or transfer to an incinerator for ultimate disposal. Decontamination can be done by careful application of sodium hydroxide and water as outlined for acrolein (14) or by use of a water-saturated solution of sodium bisulfite.

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E. FIRE CONTROL (13)

Acetaldehyde is a toxic, volatile, water-soluble, flammable liquid which boils at 69°F and has a flash point below 0°F. It is, therefore, assigned a fire rating of 4 in the UCC hazard signal system.

Methods of extinguishing fires involving acetaldehyde must take into consideration its volatility and toxicity, and the face that it reacts with itself and many chemicals normally found in laboratories and plants, especially at the temperatures likely to be encountered in a fire. Effective fire extinguishing agents are: water spray, "alcohol"-type foams, and carbon dioxide. Normal practice is to use water spray protection for tanks and equipment handling acetaldehyde.

Fire fighting personnel should be very cautious of the unburned toxic vapors and liquids evolved from acetaldehyde fires and should be protected by self-contained breathing apparatus and protective clothing. Acetaldehyde vapors are heavier than air and may travel a considerable distance to source of ignition with subsequent flashback.

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F. HANDLING AND STORAGE

Acetaldehyde must be handled and stored under careful control and supervision. Normally, stainless steel and baked phenolic-lined steel are recommended for pipes, tanks, and other equipment in contact with acetaldehyde (see Section G).

Exclude all materials including oxygen from process equipment, piping, and tanks which might react with or catalyze the polymerization and condensation of acetaldehyde (see Section B). Avoid using common lines or pumps, available for handling other products, unless thoroughly cleaned before being placed in acetaldehyde service.

Acetaldehyde boils at about 69°F. It can be stored as a liquid under inert gas pressure (about 30 psi) at ambient temperatures (less than 100°F). It can be maintained as a liquid by suitable refrigeration at lower pressures.

Storage - Acetaldehyde may be stored safely at ambient temperatures for reasonable periods of time without danger from hazardous decomposition, polymerization, or condensation. Polymerization inhibitors are not generally used nor necessary to protect this aldehyde. No alkalies, oxidizing materials, or strong acids should ever be allowed to accidentally mix with acetaldehyde in storage.

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F. HANDLING AND STORAGE (Continued)

Because acetaldehyde reacts with oxygen (air), storage under an atmosphere of inert gas is recommended. Acetaldehyde, when stored under an atmosphere of air above 20°C, will form some acetic acid and a smaller amount of peracetic acid. The quantity of peracetic acid resulting at atmospheric temperatures or higher should create no hazard. Storage under an atmosphere of air at temperatures below 20°C, however, may result in the formation of hazardous concentrations of peracetic acid since lower temperatures favor its formation. The peracid could decompose violently or detonate under certain circumstances, especially if this cold stored acetaldehyde-peracetic acid mixture were to be heated rapidly, subjected to severe shock, or rapidly fractionated resulting in accidental concentration of the contained peracetic acid. For details on the stability of peracetic acid, see "Peracetic Acid" in the Reactive and Hazardous Chemicals Manual.

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G. MATERIALS OF CONSTRUCTION (17)

The materials listed below have been reported in the Materials of Construction Manual with recommendations for use in storage and shipment of acetaldehyde. Materials marked OK are satisfactory for use in chemical storage and shipment from the standpoint of both general corrosion resistance and protection of product quality. Those marked NG are not approved for such use.

Material	Recommendation
Stainless steel 300 series	OK
Aluminum	OK
Nickel	OK
Zinc	OK
Tinned iron	OK
Baked phenolic	OK
UCC Nos. 2 and 3 coatings	OK
Steel	NG*
Copper	NG
Polyethylene	NG
Plasite 7122	NG
Amercoat 75	NG
Phenoline 368	NG

*Steel has been used to handle acetaldehyde for short periods of exposure; however, it is not satisfactory for storage and shipment of meticulously pure material.

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G. MATERIALS OF CONSTRUCTION (Continued)

Glass, Teflon, and ceramics are acceptable materials in acetaldehyde service. For packing materials, Neoprene 7797, butyl K-53, Thiokol 3060, black and red rubbers, Buna S, and compressed asbestos should be satisfactory elastomeric materials in acetaldehyde service.

For more detailed comments and advice on corrosion problems attending acetaldehyde, consult the Materials Technology Group in the Chemicals and Plastics Engineering Department at South Charleston. For specific shipping recommendations, refer to the "Chemicals and Plastics Shipping Data-Container Manual" (22).

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III. CRITICAL OPERATING VARIABLES (N. W. Clauss)

A. Assume that you are considering a new process in an existing system and that all known physical property data has been obtained and reviewed. The chemical process being considered has been developed by Research or Development personnel who are not familiar with plant operation or your equipment system. Or the process may be a scale-up from a previous pilot scale production.

In considering the application of the process to your facilities the next step in the thought process, after all physical property and process knowledge has been assimilated, is to evaluate the limits of the basic and critical operating variables. We will consider these variables from the viewpoint of hazard recognition.

B. Temperature

Process safety considerations put more emphasis on abnormal situations or on the limiting concept of temperature as a variable.

The temperature effect on the chemicals used or produced can set maximum or minimum limits. Steam as an energy resource will have a maximum temperature related to the supply header pressure. A process using 180 psig steam at 193°C could exceed the flash point of many chemicals or the autoignition temperature of several materials encountered in C&P. For example:

Material	Lowest Recorded AIT-°C
Acetaldehyde	175
Various ethers	160
Tert-butylcatechol	168
Carbon disulfide	90
Copper Acetylide	93
Nickel Carbonyl	60

The storage of organic peroxides usually requires low temperature refrigerated rooms based on the self actuating decomposition temperature. Ethylene oxide has a maximum safe storage temperature of 35°C to avoid polymerization. The limit is the key!

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Do the chemicals you are considering decompose? Can mixtures be formed that decompose? If so, what is the temperature limit? A major explosion occurred when the exotherm temperature limit of a glycolate residue was exceeded. Three operators were hospitalized and the property damage and production loss was extensive. Operating procedures called for allowing the residues from the dipropylene glycol monomethyl ether refining process to build in the kettle. After refining six batches of product a tails cut was taken from the residues. The kettle temperature reached 195°C with all the sodium methylate catalyst from the six runs concentrated in the residues. The temperature limit for initiation of the exotherm was 175°C and should have been specified in the SOP Manual. There have been several major explosions in C&P of alcoholic residues containing alkiline catalysts when the exotherm temperature limit was exceeded. And don't ignore the maximum skin temperature of heat transfer equipment and the potentially undesirable run away reactions.

Consider the maximum temperature limit for every reaction process beyond which you dare not go without losing control. Is there a minimum temperature limit to initiate a reaction? Production urgency has caused the charging of reactants at temperatures below the reaction "kickoff" temperature and resulted in major accidents from the delayed uncontrollable energy release. As an example the urgency to startup a process producing acetic anhydride and acetic acid by the air oxidation of acetaldehyde resulted in the reaction heat removal exchanger being put in service too early. Even though the catalized reaction mixture was only slightly below the "kickoff temperature" the reaction would not go until the cooling water was cut off the heat exchanger. The energy release from the fully charged reactor resulted in venting acetaldehyde to the atmosphere through the safety relieve valves at 100 psi. Again the limit is the key!

What about the upper and lower maximums of air temperature? In your area can the vents from acetic acid storage tank freeze off (F.P.-62°F)? Can processes containing water cause plugged drains or vents? Many accidents have been caused by the presumed lack of knowledge of temperature limits.

Heat removal media has maximum and minimum temperature limits. You must think of the effect of cooling water temperatures, winter and summer,

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on the ability to condense or remove heat. Acetaldehyde cannot be condensed from overhead vapor safely using normal cooling water unless it is refrigerated or the system is operated under pressure. A brine cooled condenser may plug if the freezing temperature limits are not considered.

The materials of construction of your system may have temperature limits such as copper and Everdur which cannot exceed 177°C. Will gasket material stand the maximum temperature, or the safety valve spring? Glass lining? The concept of analyzing your process and system in terms of maximum and minimum limits of the critical operating variables will frequently reveal otherwise overlooked hazards.

C. Pressure

Pressure as a critical operating variable should also be looked at for each chemical involved and the system used. Vapor pressure-temperature curves should be made for each material and should be extended to the maximum and minimum possible limits. By thinking in terms of limits, hazards requiring special treatment can be found such as dealing with the sudden loss of vacuum in a vacuum process or the sudden loss of pressure in a pressure operation with the subsequent rapid release of volatile material.

The pressure ratings for the equipment that make up a processing system will also define pressure limits that must be related to the process pressure extremes or to the pressure limits of the steam supply, inerting gas, instrument blowback, etc. For example can your equipment stand the pressure increase from a calandria tube rupture that is using 600 psig steam? Or can your system pressure exceed the lower limit pressure of instrument blowback and cause loss of control by filling instrument leads with liquid. Does the system pressure exceed the pressure rating of a pump casing?

The knowledge of the lowest and highest possible pressure for fuel, steam, feed streams, or water supply is necessary to evaluate the need for special treatment to avoid hazards. Cooling water pressure reduction can cause runaway reactions or overpressured equipment.

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D. Flows and Flow Rates

The upper and lower limits of flow and flow rates should also be determined. An understanding of these limits will result in a system designed to operate without surprises. The lower limit of flow can be assumed to be zero so your thinking can analyze the consequences of zero flow. For example, inerting gas to keep out of flammable ranges, coolant to reactors or condensers, chemical feeds to reactors or processing systems, catalysts, inhibitors, entraining agents, diluents, heating media, etc. Failure of utility supply systems, pumps or controllers occur often enough to require protection against zero flow hazards.

If a process requires ratioing the feed of two reactants, and maybe a catalyst, to control a reaction the limits of the reactant flows must be determined. Can you get into trouble if one reactant flow drops below some minimum limit? Most chemical process reactions will utilize an excess in the range of 20 percent of one reactant. In some cases it is vital that such a reactant be maintained in excess. Can you always control the critical concentration? What happens if the flow of either reactant goes to its maximum or minimum rate and the critical excess no longer exists?

A major "near miss" occurred in an alkanolamines reaction system when the amines pump failed in a process requiring a feed ratio of 8 to 1 of amine to ethylene oxide (mole ratio). The process was cyclic and the loss of amine feed was not readily apparent. Twelve hours was spent trying to solve the high temperature in the reactor by concentrating on steam supply pressure and temperature and checking the validity of the thermocouple readings. The lack of amine was discovered when an overhead sample rapidly expelled excess ethylene oxide. The zero flow concept would have provided the procedures and training required to avoid such a major potential accident.

What about maximum flow limits? Consider the result of a controller failing wide open - do you know the limit of the steam supply and the possible effect a wide open steam flow can have. A near disaster occurred in a still column used to remove butanol from an Oxide Adducts mixture. The steam supply was reduced from 180 psig to 45 psig, and the 45 psig steam control valve stuck wide open. The operator ignored the temperature alarm

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thinking it was related to a change in the reaction mix. The kettle contents were stripped and 1300 pounds of butanol lost out the vent before the cause was found. The alcoholic alkaline catalyst mixture in the kettle had been concentrated to a KOH content of 14.8 percent with a final temperature of 144°C. If the 180 psig steam had been on the coils the system could have been destroyed by the exotherm energy release.

You must consider the maximum flow generated by pumps or compressors feeding processing systems or transferring material to tanks. Is there enough head to overpressure equipment if a controller fails to open? Is the maximum capacity to remove material from a system less than the maximum capacity to feed or charge a system? What does the resulting accumulation do and how will you deal with the problem should it occur? In the reverse case of outgoing capacity being greater than incoming capacity have you prepared to deal with the depletion problems? Let me remind you again - the limits are the key in the thought process.

E. Concentrations

The upper and lower limits of concentrations of critical material in chemical processes is vital to safe operation. Maximum and minimum limits for catalysts in reaction processes must be determined. The same for processes using inhibitors. For those reactions requiring a specified excess of one reactant the variance limits must be available for safe, controlled chemical reactions. In all such situations the problems resulting from operation above or below the concentration limits must be resolved by proper design.

Several glycol type alcohol-alkaline catalyst systems have blown up in Carbide because the concentration of the catalyst in residues has not be monitored and the concentration exceeded the maxium limit for exotherm initiation.

The assumption that a still system on total reflux is in a steady state equilibrium condition led to a massive property loss of a butadiene column and surrounding facilities. The make valve (motor controlled) leaked and eventually concentrated vinyl acetylene in the column base to the

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detonation point. The concentration was not monitored because concentrations don't change in a total reflux mode. Know the limits of concentrations of all materials!

F. Volume

The idea of concerning yourself with maximum or minimum limits of volume would appear somewhat irrelevant since the limits are usually well defined for equipment and processing systems. However, it is pretty alarming to realize from the number of tanks and other containers that are overfilled that there are those who don't recognize such limits. There are some other volume limit considerations which if applied can avoid hazardous situations. For example if a tank is being cleaned using steam at atmospheric pressure the specific volume ratio of water vapor to water is 26.8/.01672. The volume decrease if a rain storm arrives and the steam is suddenly condensed is 1603 to 1 and the tank will collapse unless the vent was sized to handle the volume depletion.

A major fire occurred in a direct fired heat exchange when the process side coils were valved in because of a leak and the radiant heat from the furnace lining expanded the non-compressible fluid until the coil ruptured. So you do need to consider situations where the coefficient of volumetric expansion or rapid condensations can occur.

G. Liquid Level and Density

Density is included in this discussion on liquid level limits since we are interested in the actual level in a vessel rather than the differential gage readings in inches of water. Beyond the consideration of providing liquid level data for vessels that is corrected for density change - both material and temperature - we will skip the obvious inattention to maximum limits that result in overflowing tanks, etc. There are more subtle reasons for losing control of a process or overpressuring equipment that require consideration of maximum and minimum liquid levels.

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An atmospheric pressure still system can be overpressured in cases where the still feed is from a pressure tank handling highly volatile material. If the feed tank empties, the pressure blow-through can (a) rupture an atmospheric system or (b) can cause a release of easily ignitable material from the relief devices. The minimum liquid level of the feed tank is obviously critical and requires the proper safeguards against too low a level.

Static charge generation is an ignition source in tanks equipped with mixing eductors. A minimum liquid level limit is a must to avoid the risk of a fire.

The upper and lower limit of liquid level must be determined and controlled for vessels depending on agitation to carry out reaction processes. You must evaluate the action required if the level drops below the agitator blades or exceeds the upper limit where mixing efficiency drops rapidly.

Still kettle liquid levels cannot be charged above the maximum limit without effectively blocking the vapor flow to the column and causing unsteady state overpressure or column slugging problems. Neither can the level drop below the minimum critical limit without exposing the hot tubes with potential tube failure or detonation of dried residue in some cases. Are you prepared to handle the operation if the level limits are exceeded? Calandrias are also effected by violating the maximum and minimum liquid level limits.

Gas scrubbers and packed columns are subject to violent upsets if the seal liquid level limits are exceeded. Do you know the maximum and minimum allowable liquid levels and do you have procedures to deal with any overpressure situation or liquid entrainment if these limits are violated.

Seal pots used for overpressure relief can cause fire situations when the minimum seal level is not known and suitable design implemented to avoid an unnecessary flammable vapor release. So here again the emphasis on limits of critical operating variables may reveal to you hidden hazard

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situations that would otherwise be ignored. Condensing organic vapor entering a sealpot from the process side can lower the seal liquid density and cause the loss of seal and escape of flammable vapor.

H. Time

From reviews of many accident reports the relationship of time limits related to pumping rates, resistance to flow and vessel capacity is the prevalent excuse for overfilling tanks, tank cars, etc. Such explanations as "I didn't know the pump would put out so fast", or "I thought there was plenty of room until my next hourly check", or "I thought there would be plenty of time to do the other jobs" tell us that the time limit concept should be emphasized in operator training.

Probably reaction processes are the most time critical since energy release and control is effected by catalyst concentration, excessive temperature or induction time requirements.

A vinyl resins polymerization autoclave was overpressured with great damage when an operator did not recognize the reaction induction time period and added additional catalyst to get things going. The polymerization energy release with the double charge of catalyst was uncontrollable. For each of these situations you should have predetermined the maximum and minimum time limits that can be tolerated and retain control of reactions. Defining these limits should ensure that the proper controls and procedures are available to keep you out of trouble.

When a system purge is required after a maintenance outage the minimum time limit must be defined by the volume requirement and the purge gas capacity. An explosion occurred in a batch still system because the pressure for production resulted in incomplete replacement of air. The minimum time limit was not known.

The time available to maintain an inert atmosphere in another still system (which in the process of shutdown rapidly condensed the vapor phase while pumping out the kettle) was not enough for the inerting system

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rebuilding of the column intervals. It is a C&P design policy to break vacuum with nitrogen where flammables are involved.

I. Conclusion

All Accidents Are Avoidable! IF - every possible mode of creating an unsteady state is recognized. Experience and use of the "limit" concept will help to recognize these situations.

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IV. MATERIAL AND ENERGY BALANCES (N. W. Clauss)

A. Introduction

The effective analysis of chemical processes or proposed process changes has to this point stressed the importance of physical property data and critical operating variable limits. This approach logically leads us to the use of material and energy balances which is the most useful and necessary method of recognizing process safety hazards and the risks involved.

The capacity and limit requirements of piping, control valves, pumps, cooling water, steam supply and relief devices are based on process material and energy balances. In the simplest terms - "what goes in must come out" - or accumulate or deplete in a system. Any system once filled, and the feed or heat continued, is either going to run over, have an abnormal venting, or cause an increase in pressure. As an example, a quantity of cellosolve was lost when a tank was receiving material from another unit while, at the same time, feeding a still system. The tank overfilled because the pumping and feed rate difference was not recognized.

Changes you make in a process which affect the material or heat balance of a system can be major or minor, obvious or subtle, and can involve the critical operating variables, reactivity, heat transfer, relief capacity, etc. At the end of a series of batch runs producing a high molecular weight ester the collected excess acid strips (2 ethylhexanoic) were charged back to the reaction kettle for recovery. The kettle contained 40,000 gallons of 240°C material. The system overpressured, opened the relief valves and $5,100 of product was lost. The strips contained water which immediately flashed when added to the kettle. No analysis of the strips was made even though in an esterification reaction water would be expected.

It is logical to assume that normal, steady state operation will have minimal risk. The unsteady state situations are the major concern from a process safety viewpoint and you should develop the desire and skill to utilize material and energy balance to:

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1. Recognize and deal with all process hazards, and

2. Know when skilled specialist should be called on for assistance in analyzing and providing safeguards to avoid unsteady abnormal situations.

Dangerous conditions may arise in converting a system from one service to another because of unforeseen equipment limitations. Equipment may be inadequate for the following reasons:

1. Heat removal capacity, which was adequate for the last operation, may not be for the new one. Heats of reaction, reaction rates, and heat removal capacity should be calculated carefully before an existing system is used for a new operation.

2. Materials of construction may cause reactions in storage systems and uncontrollable rates in the reaction system. For example, copper and iron salts resulting from equipment corrosion have often been the cause of "wild" reactions in the emulsion "Vinylite" process.

3. The venting requirements for control of a "run-away" reaction may be higher for the new chemical. Rupture disk sizes, safety valve settings, and vent line sizes should be checked carefully for every new operation.

Tank 9484 was a 15,000 gallon stainless vessel used to store A99 Catalyst Mixture. After transferring 3800 gallons to a process charging tank the tank pulled in with extensive damage. The pressure rating was determined for this tank in December, 1971 as part of a system safety review. The ratings was as follows:

Internal Pressure: MAWP = 15 psig from 0°C to 230°C
External Pressure: 710 mm Hg abs. from 0°C to 230°C

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When the relief requirement for this tank was checked by process engineers as part of the safety review completed in mid 1973 the capacity of one 6" and one 10" BS & B pressure-vacuum relief was found to be adequate.

What happened? In 1972 an operating engineer designed and installed a new vent system without benefit of a safety check and without notifying the T & I Department or the Plant Engineering Department. He removed the BS&B devices and substituted a safety valve set at 15 psig for internal pressure protection and a "Check All" check valve for vacuum relief between a shutoff valve and an old "goose neck" vent on the top of the tank.

At the time of the transfer the shutoff valve below the Check All was shut - because someone decided the foul smelling amines should not vent to the air through the "goose neck" vent. After the collapse of the tank it was found that the nitrogen makeup DMV had stuck in the closed position. The removal of 3800 gallons (50 $ft.^3$) lowered the pressure to 507 mm Hg. abs. at the time of collapse. ($P_2 = 14.7 \times \frac{100\ ft^3}{150\ ft^3} \times 2.036\ ^{in.Hg}/_{lb.} \times 25.4\ ^{mm}/_{in.} = 507$).

The deficiencies in this accident case are:

1. Operating Engineer

   a. Insufficient Training
   b. Insufficient records communication.
   c. Improper installation of Check All - No identification and not recommended for vacuum relief.
   d. No safety check by skilled specialist.

2. Operations

   a. Shutoff valve not sealed open per std.
   b. Did not know Check All was there (not visible)
   c. No scheduled test and inspection of critical control valve.

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3. Process Engineering

a. Did a safety review based on records rather than a physical examination of the facility.

B. Material Balances - General

Making a material balance for any system using any process, existing or proposed, requires an accurate schematic diagram showing the relative process location of each equipment item, how the equipment is hooked up, the piping and control valves, tankage, etc. Accuracy is a must to avoid overlooking potential hazards. The process diagram should include piping tie-ins of any and all systems, blanked or not. It should show common suction and discharge tank piping of neighboring systems, common vent systems, venting connections including relief devices, double valve and vent stations, all shutoff valves, pump locations, switch banks, charge pots, seal oil systems, etc. An accurate process diagram will help you analyze for transfer error and contamination potential as well as for material less potential.

For example, a tank of methyl acetate and a tank of propionic acid had a common suction line. Operator was told to charge the No. 21 still with methyl acetate. The propionic acid tank valve was open and the transfer resulted in equalizing methyl acetate into the propionic acid and feeding an unwanted mixture to the still.

In another case a PSS Review discovered a vent line common to an aldehyde and an amines system. Process revisions were made to separate two hydrogenation systems but one common vent line was not removed. An overfill of either system would have caused a reactive runaway reaction.

C. Review of Other "Material Balance" Accident Examples

1. Analysis of Material

A tank truck load of "mineral spirits" was ordered by one department, delivered on a weekend, and sent to another

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department who normally uses "mineral oil". The load was emptied into the mineral oil tank by the weekend crew even though that department had not ordered the material. Using the 150°C boiling point "spirits" in the service intended for 360°C + boiling point mineral oil would cause a fire situation.

2. Loss of Inhibitor

Inhibitors are used to insure the safe transportation and storage at normal temperatures of monomers such as vinyl chloride, styrene, vinylidene chloride, acrylonitrile, and others. Some of the more common inhibitors are alkyl amines, and alkylated and nonalkylated dihydroxybenzenes. Inhibitors are effective in most cases, because they react with active centers as soon as they form, and destroy traces of catalyst that enter the system. "Active centers" are the energized fragments or starting points for chain growth in polymerization. They may be generated by exposure to natural light. Traces of peroxide catalyst may result from the absorption of oxygen and subsequent combination with the monomer. In functioning, the inhibitor is gradually consumed.

To insure against inhibitor loss, such precautions as exclusion of light and elimination of traces of oxygen* (from inert gas systems) should be considered. Laboratory tests should be made if necessary to determine the maximum temperature at which the inhibitor is still effective, and also the minimum effective concentration.

Note: *Oxygen is sometimes an inhibitor. For example, inhibited acrylate monomers must contain some oxygen as well as some conventional inhibitor such as hydroquinone. In sufficient concentration, and particularly at low temperature,

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oxygen will combine with monomers (including acrylates) to form catalytic peroxides, however.

An excellent recent example of how hazardous situations can occur involved a product tank full of hydrogen cyanide. This material can be stored safely at atmospheric pressure for many months if it is kept acid and if the temperature is kept low. In this particular case, acidity was maintained by the continuous addition of sulfuric acid to the refined product; the temperature was controlled by circulating the product through a small brine cooler with a vertical pump submerged in the tank. One day the temperature in the storage tank was observed to be higher than normal. There was indication that polymerization was occurring due to loss of acidity. Trouble had been experienced with the acid addition system, so emergency equipment for injecting acid into the product tank was employed to stop the reaction. This procedure was effective, but the product had turned dark brown because of polymer formation. The tank was pumped out and washed with water to clean it. It was then put back in service. Two days later the same thing happened again. But this time nothing much could be done because the circulating pump plugged up with polymer. The external cooler could not be used, and the acid injection system was ineffective because circulation was impossible. Provisions had been made for emptying the tank by pressuring the contents out through the pump, but this was also impossible because the pump was plugged. A safety valve set at 55 psi finally operated, and almost the entire contents of the tank were eventually discharged through it to a flare tower. Just before the tank was empty, the flexible discharge connection on the safety valve failed and hydrogen cyanide was discharged to the atmosphere. If the safety valve had also been plugged, or if the flexible connection had failed sooner, a catastrophe might have occurred. As it was, only the tankful of hydrogen cyanide was lost.

This "near miss" emphasizes the importance of a few basic principles:

a. When inhibitor is vital to the stability of a reactive chemical, frequent routine checks should be made to determine whether the material is properly inhibited. (If the

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loss of acidity of the product had been detected soon enough, the entire situation could have been avoided.)

b. When cooling is important to maintain reactive chemicals at safe temperatures, frequent routine checks of the cooling apparatus should be scheduled. (If the pump had not been fouled up, the uncontrolled polymerization of hydrogen cyanide could have been checked.)

c. When something unusual happens, find out why it happened and determine all the consequences, taking into consideration any known peculiarities of the material involved. (The plugging of the pump probably occurred as the result of the first reaction since hydrogen cyanide polymer catalyzes further polymerization.)

d. In the design of equipment to handle reactive chemicals, anticipate the failure of critical items and provide for such an emergency. (If some means of emptying the tank had been provided which did not involve the pump, the contents could have been safely removed.)

The actual experience related above occurred because of loss of inhibitor and poor temperature control, due in this case to fouling of equipment, together with equipment limitations.

3. Transfer Error Situations and Hazards

a. Identification of Chemicals

Identical abbreviations for chemical names used in many plants can and has resulted in mixing chemicals. DEA can for example mean diethylacetal or diethylamine.

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b. Inventory Errors

9100 pounds of a mixture containing 85 percent butyl-acetate and 15 percent vinyl acetate was pumped to a vinyl ethyl ether system feed tank because the inventory was not logged properly. Vinyl ethyl ether is a reactive chemical making this error potentially serious. The sending unit tanks were numbered but not labeled as to contents. The receiving unit did not check the transfer and started a run. Stopping the run to remove the contaminant resulted in several days production loss and the loss of 10,000 pounds of material.

c. Switch Banks

It would be impractical to list the accidents occurring because hoses are hooked to the wrong line. The least you can do is to clearly label with legible tags and color code all switch bank hose connections.

d. Pressure Venting Connections

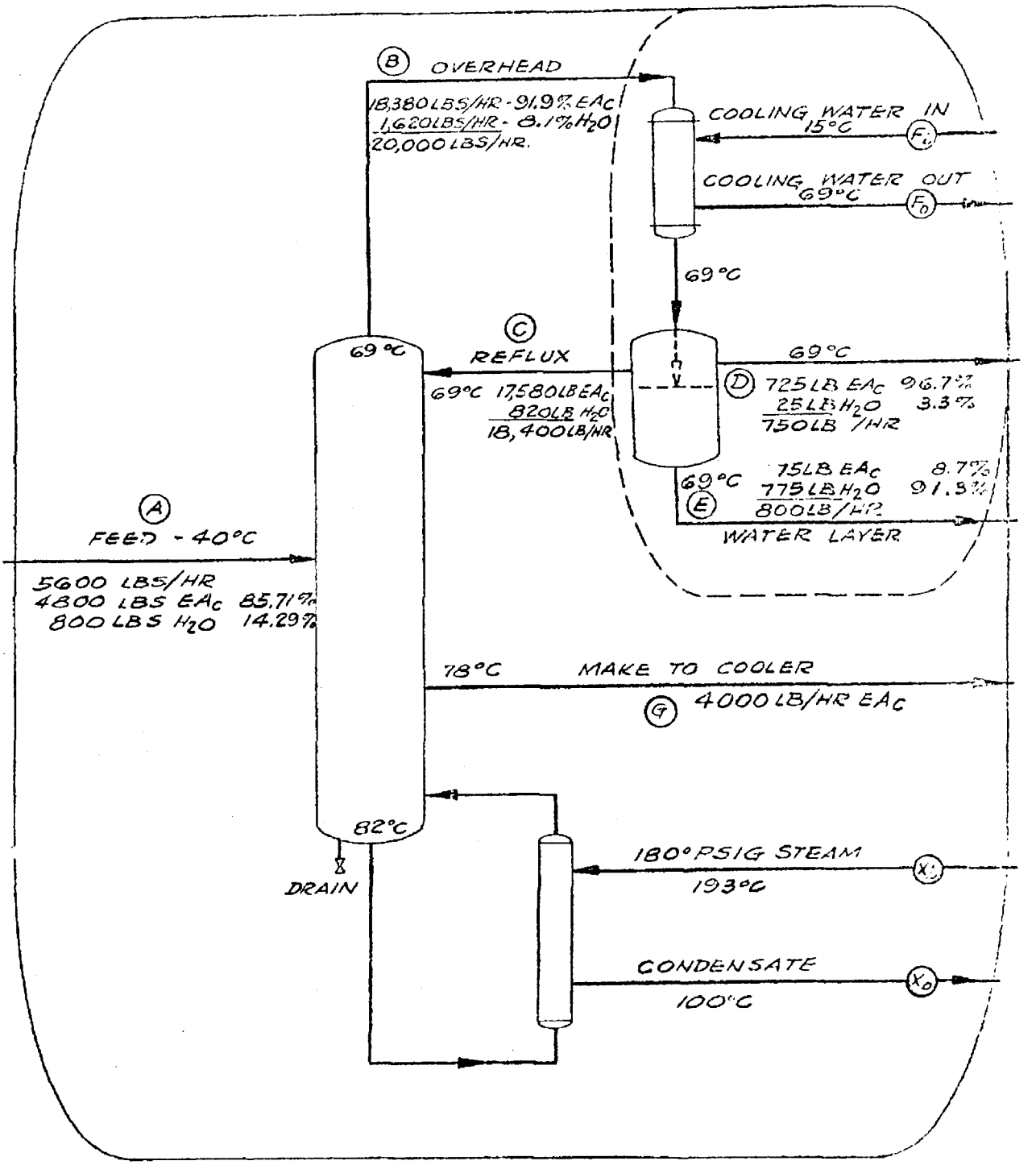
A pressure venting connection in a pump header was left open. The valve change was not logged in the LO/TO card. 1,800 gallons of Polyol E-388 was lost to the sewer on the next transfer.

D. Material Balance Preparation and Procedures

Utilizing all information available relating to the proposed process or process change such as R/D reports, equipment files, unit experience, etc., along with the schematic diagram, you will prepare the process material balance. Physical properties of each chemical compound are to be listed and other data as listed below is to be arranged in an organized manner.

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FLOW DIAGRAM
ETHYL ACETATE REFINING STILL



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PHYSICAL PROPERTY DATA SHEET

	Ethyl Acetate (Liquid)
Name of Compound	
Structural Formula	$C_4H_8O_2$
Molecular Weight	88.11
Normal Boiling Point, °C.	76.7
Freezing Point, °C.	-83.5
Apparent Specific Gravity 20/20°C.	0.9018
Latent Heat, Normal B.P., Btu/lb	158
Surface Tension, Dynes/cm at 20 °C.	23.9
Critical Temperature, °K.	523.3
Critical Pressure, atm abs	37.83
Critical Volume, ft^3/lb	0.0521
Antoine Constant, A	7.09808
Antoine Constant, B	1238.71
Antoine Constant, C	217.00
Total Pressure, atm.	1

Temperature °C.	Specific Gravity	Specific Heat Btu/lb°F.	Viscosity cp	Latent Heat Btu/lb	Vapor Pressure mm Hg
0	0.927	0.428	0.56	182.9	24.53
40	0.875	0.494	0.36	169.3	189.76
80	0.815	0.584	0.19	155.7	845.94
120	0.746	0.725	0.10	139.5	2644.74
160	0.660	0.916	0.06	118.6	6491.98
200	0.543	1.183	0.03	90.5	13413.82
240	0.319	1.567	0.01	46.1	24409.28
280		2.142			40337.21
320					61852.53
360					89385.90
400					123153.37

Calculated By H. M. Jones Date June 28, 1962

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1. Flow rates contemplated - lbs./hr. or gpm:

   a. Feed, make, reflux, tails, etc.
   b. Feed ratios
   c. Diluents or entraining agents
   d. Catalysts or Inhibitors

2. Flow rate capacity:

   a. pumping
   b. control valves

3. Analysis of process mixtures.

4. Temperature and density data.

The following example of data preparation and procedures will illustrate the material balance process. Process safety hazard potential will be pointed out.

DATA PREPARATION

Problem: Refine ethylacetate-water mixture in the atmospheric pressure Esters Still.

Feed: 85.71% Ethylacetate 14.29% Water Rate - 5600 lbs/hr.

Physical Properties

100% Ethylacetate

Mol. Wt. - 88.11
Sp. Gr. - 0.918 @ 20/20°C (7.50 lbs/gal)
Sol. in water - 8.7% @ 20°C (check azeotrope data)

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Boiling Pt. - 760 mm - 77.2°C
300 mm - 51.0°C
10 mm - 15.0°C

Hv @ B.pt. - 155 Btu/lb.

Cp = $0.44869 + 14.09\ t + 3.13\ t^3$

Flash Pt. - 56°F. (open); 24°F (closed)

H-F-S - (3-4-1)

U.E.L. - 2.5% in air

L.E.L. - 9.0% in air

Azeotrope data - Ethylacetate/water

Boiling Pt. - 70.4°C. @ 760 mm

Relative Volume of layers - Upper 95%, Lower 5.0%

Sp. Gr. - Upper layer 0.907; Lower layer 0.999

Composition of azeotrope - 91.9% EtAc; 8.1% water

Composition of Upper layer - 96.7% EtAc; 3.3% water

Composition of Lower layer - 8.7% EtAc; 91.3% water

ETHYL ACETATE - WATER DISTILLATION MATERIAL BALANCES

(1) Process Material Balance - Total System (All in pounds per hour)

process material in = process material out

$A = D + E + G$

$5,600 = 750 + 850 + 4,000$

$5,600 = 5,600$

(a) Ethyl acetate

EAc in = EAc out

$A_{EAc} = {}^{D}EAc + {}^{E}EAc + {}^{G}EAc$

$4,800 = 725 + 75 + 4,000$

$4,800 = 4,800$

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(b) Water (process)

H_2O in = H_2O out

$A_{H_2O} = D_{H_2O} + E_{H_2O} + G_{H_2O}$

800 = 25 + 775 + 0

800 = 800

(2) Process Material Balance - Condenser and Decanter (process material in = process material out)

B = C + D + E

20,000 = 18,400 + 750 + 850

20,000 = 20,000

(a) ethyl acetate

EAc in = EAc out

$B_{EAc} = C_{EAc} + D_{EAc} + E_{EAc}$

18,380 = 17,580 + 725 + 75

18,380 = 18,380

(b) Water (process)

H_2O in = H_2O out

$B_{H_2O} = C_{H_2O} + D_{H_2O} + E_{H_2O}$

1,620 = 820 + 25 + 775

1,620 = 1,620

Process hazard potential:

1- Flash point of 25°F

2- Health hazard - 3

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3- Fire hazard - 4

4- Flammable limits in air

5- Feed pump discharge pressure can overpressure the atmospheric pressure equipment if closed in.

6- Calandria tube rupture can overpressure the system.

7- Steam supply control valve can overpressure the system if it sticks wide open.

8- Loss of cooling water.

9- Malfunction of feed control can overfeed the system, cause steam valve to open wide and overpressure the system.

10- Loss of steam with cooling water on condenser can cause sudden vacuum in system. Equipment is not good for full vacuum so requires vacuum relief using nitrogen.

E. Energy Balances

Energy balance procedures are somewhat more complex but the simple fundamental of "what goes in must come out" still holds. The schematic process diagram along with the material balance is used to make the energy balance. Major accidents are obviously related to uncontrollable energy releases and the energy balance is the key to the recognition of process system hazards. Potential for energy accumulation or depletion must be identified to avoid disaster and the best tool is the energy balance approach for the recognition of unsteady state situations.

Energy balances are more complex because the energy considerations may involve:

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1. Physical property related energy such as:

   a. Heat capacity
   b. Heat transfer - in and out
   c. Heat of vaporization
   d. Heat of Fusion
   e. Heat of Disassociation
   f. Thermal conductivity
   g. Viscosity
   h. Temperature
   i. Pressure
   j. Volume

2. Chemical related energy such as:

   a. Heat of reaction
   b. Reaction rates
   c. Reactant feed ratios
   d. Polymerization
   e. Condensation
   f. Decomposition
   g. Catalytic effects (inhibtor effects)
   h. Heat of Formation
   i. Heat of Absorption
   j. Heat of Solution (Dilution)
   k. Heat of Neutralization
   l. Heat of combustion

3. Mechancial related energy such as:

   a. Mixing
   b. Agitation
   c. Circulation
   d. Compression

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4. Combinations of the above:

   a. Enthalpy
   b. Entropy

The material balance data and the process diagram previously used will now be expanded to illustrate the energy balance procedure.

ETHYL ACETATE - WATER DISTILLATION ENERGY BALANCES

Assume at reference temperature of 0°C.

(1) Heat Balance - Total System

Heat in = Heat out

$$A + X_i + F_i = D + E + G + X_o + F_o$$

Reboiler heat added = $(X_i - X_o)$

Condenser heat removed = $(F_o - F_i)$

$$A + (X_i - X_o) = D + E + G + (F_o - F_i)$$

$$(X_i - X_o) = F_o - F_i) + D + E + G - A$$

(2) Heat balance - Condenser and Decanter

Heat in = Heat out

$$B + F_i = C + D + E + F_o$$

$$(F_o - F_i) = B - C - D - E$$

(3) Combined heat balances to determine steam load in reboiler

$$(X_i - X_o) = (F_o - F_i) + D + E + G - A$$

$$(F_o - F_i) = B - C - D - E$$

(Combined) $(X_i - X_o) = B-C-D-E+D+E+G+A$

$$(X_i - X_o) = B - C + G - A$$

$$(X_i - X_o) = B + G - A - C$$

(4) Enthalpies (0°C base level)

$$Cp_{EAc_{(1)}} = 0.44869 + 0.001409t + 0.00000313t^2$$

At 0°C C_p = 0.449 Cal/gm/°C or Btu/lb/°F

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At 40°C Cp = 0.4487 + 0.0564 + 0.0050 = 0.510

At 69°C Cp = 0.4487 + 0.0972 + 0.0149 = 0.561

At 78°C Cp = 0.4487 + 0.1099 + 0.0190 = 0.578

(a) Stream A (liquid) 40°C

0°C to 40°C (32°F to 104°F)

$C_{pav} = \frac{0.449 + 0.510}{2} = 0.480$

(4800)(0.480)(72) = 166,000
(800)(1.0)(72) = 58,000
224,000 Btu/hr

(b) Stream B (vapor) 69°C

0°C to 69°C (32°F to 156°F)

$Cpav = \frac{0.449 + 0.561}{2} = 0.505$

(18,380)(-.505)(124) = 1,151,000
(1,620)(1.0)(124) = 201,000
1,352,000 Btu/hr

ΔH_v (EAc) = 158 Btu/lb

ΔH_v (H_2O) = 1128 - 124 = 104 Btu/hr

(18,380)(158) = 2,904,000
(1,620)(1004) = 1,626,000
4,530,000 Btu/hr

Stream B enthalpy = 1,352,000
4,530,000
5,882,000 Btu/hr

(c) Stream C (liquid) 69°C

Cpav = 0.505

(17,580)(0.505)(124) = 1,101,000
(820)(1.0)(124) = 102,000
1,203,000 Btu/hr

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(d) Stream G (liquid) 78°C
0°C to 78°C (32°F to 172°F)

Cpav = 0.449 + 0.578 = 0.514

(4,000)(0.514)(140) = 288,000 Btu/hr

(5) Steam Load in Reboiler

$(X_i - X_o) = B + G = A - C$

= 5,882 + 288 - 224 - 1,203

= 4,743 M Btu/hr

Use 180 - psig steam

ΔH_v = 1198 - 343 = 845 Btu/lb

$\frac{4,743,000}{845} \frac{Btu}{hr} \times \frac{lb}{Btu}$ = 5,610 lb/hr steam

F. Energy Capacity Limits

The usefulness of the limit concept as discussed for critical operating variables is also applicable to energy capacity limits. We have covered most of the usual energy limit considerations in the review of the Energy Balance example and in previous discussion. Maximum and minimum, upper and lower limits of temperature, pressure, volume, flow rates, liquid level, concentration and time have been covered. Obviously we would not be in the chemical business without the utilization and control of energy in some form. For this reason we should not leave out other energy limit considerations such as:

1. Heat transfer surface available for heating or cooling may be the controlling limit of a process if the energy source limit exceeds the ability to transfer heat or cool process streams.

2. Process material characteristics may require the definition of the limits that can be tolerated by fouling of heat transfer surfaces by carbonization, polymerization, etc.

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3. Many chemicals handled in C&P are heat sensitive and as a result require carefully controlled limits of energy supply to prevent exceeding the maximum allowable limit of temperature.

4. Our references up to now have covered heating media in terms of steam as the energy source. Other heating media such as Dowtherm or molten metals may be more hazardous and require special design criteria but they will in any event require consideration of the upper and lower limit concept.

The following accident illustrates one of these concerns:

Glacial Acrylic Acid Tankwagon Explosion

Description: About 3600 gallons of glacial acrylic acid (GAA) polymerized explosively in a tankwagon, causing considerable damage to adjacent structures.

The tankwagon was being warmed using manually controlled mixture of steam and water to keep it from freezing. Shortly before the explosion, white fumes were noticed issuing from the tanker, to the extent that the tanker was obscured. Minutes later, the tanker ruptured with considerable damage to adjacent structures and with the ejection of large clumps of ignited polymer which yielded secondary damage.

Based on the design of the tankwagon, it would be expected to rupture in the neighborhood of 300 psi under the anticipated conditions. The rate of energy release from the polymerization of bulk GAA is extremely rapid. Pressures of 400 psi can be experienced under these conditions and enough energy exists in the polymerization reaction to bring the material well above its auto-ignition temperature in air.

The application of excessive heat via the manually controlled steam/water service tee resulted in the uncontrolled polymerization. The inadvertent application of heat triggered the polymerization.

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Only a controlled low temperature heat source such as tempered water should be used to keep GAA from freezing or to thaw out frozen material. A warm room can be used for drum quantities. Manually controlled steam/water systems should not be used for heat sensitive chemicals.

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V. CHEMICAL REACTION CONSIDERATIONS (N. W. Clauss)

The hazards of chemical processing should never be minimized regardless of the function being performed but it is logical to assign the highest risk potential to reaction processes. These are some key approaches to avoiding reaction problems which we will cover briefly.

A. Temperature Control

The old "rule of thumb" that chemical reaction rates will double with a 10°C increase in temperature is worth your consideration. When you couple this with induction time delays you may do a better job of recognizing runaway reaction situations.

Any reaction dependent on a certain minimum kick-off temperature will require extreme care to avoid a mass accumulation of unreacted material which, when it goes, will produce an energy release beyond the control of instrumentation, cooling capacity or pressure relief devices. If the reaction is not going the reactant feed should be stopped until the problem can be corrected.

A reaction that is completely dependent on temperature should be carried out with redundant control systems to provide safe operation. The loss of cooling for such a system will require emergency procedures to cover the potential overpressure situation and should not be overlooked. If reaction temperature is getting out of control you might consider additional cooling by putting cooling water on all heat transfer equipment including steam coils and calandrias.

A reaction process, normally run at 60°C., was changed to double productivity by increasing the reaction temperature 10°C. The feed temperature was increased by increasing the preheater steam pressure. Cooling coils controlled the reaction temperature and were found to have adequate heat transfer surface for the new conditions and did not require revision. Shortly after startup the reactor overpressured and the relief devices were activated.

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The cooling water from the coils was found to be 70°C. A consideration of the temperature limits of the cooling system and a heat balance would have revealed that the cooling water supply rate was inadequate.

B. *Induction Period*

Those reactions that involve an induction period frequently result in accident situations. The more common reactions of this type are in polyols reactors, vinyl monomer polymerizations, latex reactions, etc. Acetic anhydride and water reactions involve an induction period. One accident resulted when acetic anhydride was used to dry wet acetone. The reaction proceeded so slowly that the reactor was fully charged before the energy release took place. 7,000 pounds of acetone were released to the atmosphere through the pressure relief devices.

When an induction period is involved procedures must cover the need for good agitation, the avoidance of an excessive mass of unreacted material and operator training on the time factors involved. An impatient operator may decide to double a catalyst charge or add more promoter if he is not aware of the induction time requirements.

C. Concentrations

Safe operation of most reaction processes will be dependent on the ability to maintain the desired concentration of

1. reactants
2. product
3. catalyst
4. inhibitor
5. promoter
6. acid acceptor
7. pH
8. etc.

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Sampling, analysis, control systems, thorough operator training and good judgement are a must in reaction processes.

Vapor phase reactions can usually be provided with reliable analyzers and control systems such as in C&P ethylene oxide facilities. However, the hazards of operating with an ever present solid catalyst ignition source requires the knowledge and capability of staying out of explosive vapor concentrations. Emergency procedures and training must cover the action requirements to deal with excursions from safe concentration limits. Liquid phase reactions are of many types and include such processes as condensation, esterification, polymerization, oxidation, etc. Some will require careful control of the feed streams to ensure the desired reactant concentrations to produce a desired product. Recycle streams may complicate the problem of control. Deviations from acceptable concentration range limits must be evaluated in order to safely handle excess energy releases. Will shutting off the feed be sufficient? If not you may need overdesign of heat removal equipment or at a minimum enough pressure relief capacity to avoid vessel rupture.

A technique which has been used to minimize the problem of reaction control in the event of an emergency is one in which the total amount of reacting material at any particular instant is held to such a low level that loss of control would result in only a minor pressure surge. This may be accomplished by operating at a high conversion during the run by controlled addition of reactants, or by using a tubular reactor.

Those reactions dependent on continuous feed of catalyst usually can be stopped by discontinuing the catalyst addition and consequently are not of major concern. Reactions dependent on the maintenance of an acid or base condition also can be easily stopped by providing an addition system to reverse the acid or base concentration. Agitation may be a requirement, however.

Highly reactive processes sometimes require the use of inhibitors to slow the energy release to a rate which is consistent with the capacity to remove heat. Obviously great care must be exercised in designing the control systems and a deviation below the minimum inhibitor concentration

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must be covered by adequate pressure relief capacity, emergency procedures and high quality operator training.

Polymerization or addition reactions using a catalyst or promoter to increase reaction rate require careful evaluation of the controlling catalyst or promoter concentration. As previously mentioned the induction periods involved can cause excess reactivity if the maximum concentration limit is exceeded by some impatient operator. Be prepared for uncontrollable energy release! When polymerization or addtion reactions require the addition of a "terminator" to control the product molecular weight the consequences of the loss of the controlling material must be expected and unless provisions are made to quickly react to the situation the reactor may contain essentially solid carbon when the energy release is completed. You might have to provide an emergency dumping facility.

D. Summary of Reaction Considerations

Since our purpose is to understand and deal with deviations from normal steady state operation you might ask yourself How can I stop this reaction? and How can I start the reaction? What are the upper and lower limits of feed rates, concentration and hold up? Will my system have a continued energy release even if the flows are stopped? Is the relief capacity adequate? Do I let it blow or dump it?

Above all a complete knowledge of the reaction process, including side reactions, is a must!

A complaint from an operating unit on an unwanted intermittent release from a BS&B pressure/vacuum relief valve revealed the following:

1. Whenever 5 gallons of sulfuric acid catalyst (98% H_2SO_4) was added to an esterification reaction still the relief valve vented flammable butanol.

2. The reaction required 0.1 percent sulfuric acid catalyst but it was expedient to add every 24 hours rather than feed continuously.

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3. When the acid addition was made the reaction had slowed down and the water concentration was at its peak (water is a product of the reaction).

It doesn't take much thought to realize that the heat of solution of sulfuric acid and water along with the sudden increase in reaction rate was the cause of the venting problem.

A major accident example involving to all appearances a rather insignificant change in a reaction process follows. You should note also the effect of materials of construction and the products of corrosion.

Description: A chemical reaction of an aromatic amine with a chloro nitro compound went out of control due to ferric chloride catalyzed side reactions when the reaction mass became acidic. Natural soda ash used as an acid acceptor in the non-aqueous system was ineffective. The exothermic side reactions developed pressures above those normally encountered in the process. The cover blew off despite operation of a 60 lb. relief valve on the 100 psi designed reactor. Thrust of gases from the open manhole propelled the vessel downward, releasing gases to the building where a combustion explosion took place. Confinement tests indicate the side reactions could develop pressure of 400 to 600 psi.

Six employees were burned in varying degree, one later died. Venting through large window areas of the building limited the amount of structural damage. Damage included non-production areas separated from the process section by a wall not sufficiently strong to withstand explosion forces. Many sprinklers operated and fires were quickly brought under control.

Cause: Natural soda ash was used in this batch as an acid acceptor instead of synthetic material which had been used successfully for over 20 years. In the non-aqueous medium the difference in crystalinity made the natural soda ash less effective than the synthetic type normally used; hence it acted like an undercharge of soda ash. This permitted an acid build up which formed ferric chloride as the reactor was steel. Iron oxides were

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also present. Laboratory work verified the plant experience. However, regardless of soda ash type no significant side reactions could be demonstrated if iron was absent.

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VI. CONTAMINATION POTENTIAL (N. W. Clauss)

Chemical processing and contamination are as inseparable as two sides of a coin. No chemical producer can afford the luxury of dedicated supply lines to and from each and every element of a processing facility. Multiproduct units will inevitably be equipped with versatile switch bank stations to minimize piping investment. Cross ties of process piping are always with us. Plant wide common utility distribution loops are common. A unit inerting or purging supply system will be connected to varying types of chemical processes.

The C&P suggested standards for unit process operations contains the following:

> "Safeguards - such as double valves and vents, automatic interlocks, disconnection of lines, avoidance of fixed piping cross-connections, slip blanking, and other devices - are provided where appropriate to prevent contamination of reactive materials with other materials which may be incompatible or catalytic. A formal procedure exists for assuring that these safeguards are in use prior to startup and that they are periodically checked during operation."

The concept of limit extremes has been repeatedly emphasized. But what about the limits of your though process? Does the analysis for potential process hazards, no matter how thoroughly done, include thinking beyond the boundary limits of system you are to operate? Upsets and operating errors in neighboring or far removed facilities may cause you contamination problems. We will go over some of the more common contamination problems.

A. Inadequate Cleanup

Inadequate cleaning of equipment and process lines is one of the more commonplace occurrences which can lead to serious trouble in systems handling reactive chemicals. This is true for at least two reasons: (a) vital equipment may become inoperative because of fouling (such as the pump on the hydrogen cyanide tanks mentioned before), (b) catalytic quantities of material allowed to remain in equipment or piping may be hazardous in subsequent operations.

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Even though equipment is used continuously in only one service, a regular inspection and cleaning schedule should be set up if fouling occurs, or if it is likely to occur as the result of operating upsets of short duration. This is particularly important if the polymers formed are catalysts for further polymerization. This is true, for example, in the case of hydrogen cyanide. And also for equipment which can accumulate acetylides.

When equipment is to be used interchangeably for various processes, the importance of careful cleaning and inspection cannot be overemphasized. Consider the case of a "near miss" which occurred recently. A quantity of wet, crude hexadienal was transferred by tank truck to the unit for redistillation. When the first 200 gallons had been charged to the kettle an unusually high kettle temperature was noticed. This material was dumped to the sewer, as the operators thought some caustic had been left in the still. The still was boiled with acetic acid and water and drained. The remaining hexadienal was charged to the still and distillation proceeded smoothly for 22 hours. At this time, however, the make stopped, and a kettle temperature much higher than the usual boiling point of hexadienal, would produce no overhead. The kettle was cooled and opened. The residue, containing almost all of the hexadienal charged, had solidified to a coke. The coke was analyzed and found to contain nitrogen. The still had previously been used for the distillation of aniline, and an associated storage tank had been used for monoisopropanolamine. Both items had been cleaned before the hexadienal distillation was started. The transfer line between the tank and the still had apparently been overlooked. Laboratory tests showed that a reaction of explosive violence results from mixing two percent of monoisopropanolamine in hexadienal; a slightly lower concentration causes formation of coke such as that found in the kettle. It was concluded that only the quick action of the operator who dumped the first part of the charge (which contained most of the amine contaminant) to the sewer prevented an uncontrolled reaction and perhaps a serious explosion.

When a system is changed from one service to another, it is important to consider the last operation and determine how serious the consequences of a poor cleaning job would be in the next operation. If, as in the "near miss" cited above, the previous material is a dangerous contaminant, very special precautions should be taken.

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In cases where pumps and pipe lines are used interchangeably for materials which are dangerous when mixed, the only safe procedure is to disassemble the piping or pump to make sure that no residual material remains in trapped sections, valve bonnets, behind orifice plates, or behind undersized gaskets. Tanks, kettles, reactors, and heat exchangers should be examined upon change of service to eliminate contaminating materials in dead-ended nozzles and behind valves leading to the vessel. Heat transfer surfaces should be checked for fouling. Plugged heat exchanger tubes can collect dangerous contaminating liquids and solids. Still columns equipped with bubble caps can retain large quantities of contaminant if drain holes are plugged. Solids which often build up on the trays resist cleaning and remain as potentially dangerous contamination in the succeeding operation. Tray-by-tray inspection is in order if the change-over involves a particularly dangerous reactive chemical. Special precautions may be necessary for cleaning facilities which must be absolutely devoid of water prior to startup to avoid serious uncontrollable reactions.

No matter what procedures are used for cleanup every operating man is obligated to prevent contaminating instrument air and blowback systems, common vent and inerting systems, common process piping, and anything else that will cause others an unsafe situation.

B. Transfer Errors

What can you say! As long as there are humans making transfers there will be errors made. The only sure assumption you can make is that sooner or later some process will be out of control because of a transfer error. We don't help much in these days of abbreviated letter coding when DEA can mean diethylacetal and also diethanolamine. Be sure your procedures and training keep operating people aware of the inevitable emergency situation.

A glycol ether reaction was in progress for one day when it was discovered that the hexanol and hexyl-cellosolve feed tank was contaminated with butanol. They don't know how (?) but obviously the feed tank contained butanol when it was charged. It cost $15,000 to correct this error.

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C. Venting and Inerting Systems

Most chemical processing equipment will include vapor space vent systems and inerting systems. The requirements imposed on operation by environmental concerns is resulting in more and more system vents and relief device discharge piping systems being tied together in order to remove toxic or odorous material from gases discharged to the atmosphere. The chance of contaminating reactive chemical processes through common vent systems is increasing.

Check valves are a necessity for reducing material back up into vent systems but it must be realized that leakage is always a possibility. If reactive and hazardous chemicals are involved reliable protective liquid separation systems may be required. You must be aware of the potential of overpressure of any facility (regardless of where it is located with respect to your unit) if vent gases are tied to some common header such as to an incinerator, flare stack or scrubbing system. Processing systems may be more susceptible to entry of unwanted material during the depressurization of facilities during shutdown and startup. Your procedures and check lists must cover all possibilities. Contamination problems through common vent piping tie-ins are easy to miss as in the case of an accident described as follows:

Explosion in a steam main - A branch line had to be welded onto a steam main. The main was therefore isolated from the steam supply, the pressure blown down, and a welding permit issued. However, when the welder burned through the main there was an explosion.

At first, the operators could not see how this could have occurred. The steam main served only a storage and filling area of the plant, therefore it was impossible for flammable materials to enter the main through leaking heat exchangers or live steam injection points. However, a branch from the steam main served a small vent stack which was used to vent the hoses used to fill propylene tank wagons, after filling was complete. When the steam main cooled, propylene vapor had been drawn back into it due to the pressure change.

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It is a well-established principle that before maintenance work is carried out on plant equipment it should be isolated from other equipment by slip-blanks or physical disconnection. The supervisor in charge accepted this principle, but had looked on the vent stack as a connection to the atmosphere. In fact, it should have been treated as an item of process equipment. It would not have been sufficient to close the valve leading to the vent stack because it might have leaked.

Inerting gas is very useful in a unit where reactive chemicals are processed. Vapors such as ethylene oxide can be rendered non-explosive by dilution with many inert and even some non-inert gases.

Inert gas systems can also be a serious source of contamination. The "other fellow" very frequently lets some of his chemicals-in-process back up into a inert gas header serving the entire plant. Every possible effort should be made when a plant or unit is designed to eliminate the possibility of foreigh materials entering any plant distribution system. When the consequences of contamination are particularly severe, special equipment should be added to assure the purity of inerting gas which will come in direct contact with a reactive chemical.

Backing liquids into inert gas systems used for instrument blow back or controlled inerting stations can spell disaster for highly hazardous processes and, at a minimum, the loss of control of processing operations.

An example involves the use of the plant nitrogen supply for pressure testing a batch still coil for leaks. The nitrogen was hooked up to the steam chest condenstate drain connection for the test. After a successful test the manhead was replaced the still was started with 180 psig steam in the coil. The plant nitrogen header was filled with condensate and the only units in the plant that weren't forced to shut down were those with adequate liquid collecting traps.

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D. Cross Ties of Process Piping

Chemical plants with multiproduct facilities will always have process piping cross ties for the reason of practical economics.

Processes in which alkaline, acidic, or peroxidic materials must be used near or in conjunction with reactive chemicals presents the constant threat that uncontrolled mixing may occur. Although careful instruction may be given to prevent such an occurrence, the only sure way to prevent inadvertent mixing is to keep all transfer lines separated and to make the common tie-in point (such as a reactor) a make-and-break type of connection for one or all chemicals involved.

Where it is not practical to keep the materials separated by disconnecting a line, in such cases as feeding an oxidizing agent to a polymerization or feeding caustic to an aldol condensation, control of the concentration of oxidizing agent or caustic together with a safe rate of pumping at maximum pump capacity has proved effective.

Excessive water leakage into anhydrides, concentrated sulfuric acid, caustic, alkali metals, etc., via heating or cooling systems has occurred and caused considerable trouble. A rigorous inspection program should be set up and followed to guard against such eventualities.

Although not a direct tie-in, water hoses have been hooked up and frequently used to keep pump packing gland and seal leakage washed away. This can spell trouble if water is sucked into a process handling water reactive material.

Probably one of the most destructive accidents resulting from cross tied piping contamination was the explosion of an acrolein tank car.

The situation and events leading up to the explosion have been reported as follows:

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Acrolein was made on a small scale at the Institute Plant in equipment originally designed to perform other operations. Certain derivatives of acrolein were made in a neighboring unit. Another product made in this neighboring unit is methyl ethyl pyridine. A portion of the line used for interunit transfers was also used to load refined acrolein to tank cars. This line was always cleaned and dried prior to loading refined acrolein. A blank was inserted in the branch to the neighboring unit.

Before the fateful car was loaded, instructions were issued to clean the line, to dry it, and insert the customary blank. The line was cleaned and dried, but the blank was not immediately inserted. Meanwhile, the neighboring unit, proceeding on the assumption that the blank had been installed, made a transfer of alpha-picoline within the unit, using a line on the same pump header as the line used for inter-unit transfer of acrolein and acrolein derivatives. The cleaned and dried line was contaminated with alpha-picoline. The blank was installed after the line was contaminated.

The transfer of refined acrolein was started at 2:30 p.m. June 3 and completed at 3:15 a.m. June 4, a period of nearly 13 hours. There was some evidence that the line was partially plugged. The long transfer time prevented shipment of the car as scheduled, and as a result, the time bomb set to explode at 7:30 the evening of that day was at the loading spot instead of in-transit. Over 16 hours passed after the car was loaded before it exploded.

The amine-catalyzed reaction of acrolein with itself is characterized by a long induction period, followed by an accelerating reaction which cannot be stopped before it reaches nearly explosive violence. The accelerating nature of the reaction is indicated by the fact that nearly 16 hours were required for the tank car to reach a temperature of 55 to 60°C (at which time the safety valve opened due to hydraulic pressure), and only a few minutes more to increase to well over 200°C.

The safety valve on the tank car was set for 225 psi; the design pressure of the tank was 500 psi. Rough calculations have been made to determine the number of safety valves which would have prevented the rupture of the tank car. At least thirty-nine 6 in., high-capacity safety valves would have been required!

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The conclusion that can be drawn from this unfortunate experience is that reactive materials such as acrolein must be kept free from dangerous contamination. Furthermore, if contamination occurs, it may be difficult or impossible to prevent damage to equipment and jeopardy to life by the operation of safety devices.

Acrolein is by no means the only material of the most likely material to react violently when alkali is added. Acetaldehyde would react just as violently.

The need for the C&P performance standard for process operations as related to contamination hazard is obvious.

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VII. COMPATABILITY (N. W. Clauss)

Chemical compatibility, or degree of reactivity, is of major concern in the distribution and transportation industry. Multi-compartment containers such as tankers, barges, tank cars and tank trucks are subject to leakage between compartments and it is vital that only compatible materials be loaded in adjacent compartments. The same risk exists in multi-compartment storage tanks and tubular process equipment handling different chemicals or materials.

Will there be a problem of reactivity if a tube leak in a calandria results in contaminating your process with the heating media (steam, Dowtherm, etc.) or the cooling media (water, sea water, brine or refrigerant)? If so do you have procedures for handling the emergency? The reverse situation of contaminating heating and cooling media with process material is also possible.

The Research and Development Department prepared a useful guidance chart on chemical compatibility based on a classification of chemicals into four groups by functional reactivity. These chemical groups are arranged in the approximate order of hazard with Group I being the least hazardous and Group IV the most hazardous. The chart shows the groups which should not be mixed by the symbol X.

A publication in the National Safety Council Newsletter gives a more comprehensive chemical listing which, although published for cargo loadings, is applicable to process compatibility concerns.

About 350 binary combinations were tested and about 160 new chemicals were evaluated. Several hundred experiments by other investigators were worked into the compatability chart with 25 groups of chemicals.

This chart should be a useful reference in the chemical industry. A more detailed explanation of the derivation of the chart can be found in Norwegian Maritime Research, November 1974.

The compatability chart should be used as follows: Look up the compound in Table I and determine in which of the 25 chemical groups it is included.

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Look up that particular chemical group on the compatability graph (Table 2 last page) and determine which other chemicals may form a potentially dangerous combination.

These charts may be useful in arranging warehousing of mixed chemicals, also.

Those who handle reactive chemicals must be continually on the alert to recognize situations which are potentially hazardous. An operator at the South Charleston barge dock reported an episode which illustrates very well how hazardous situations can arise when people are not reactive-chemical-conscious. This man was obtaining the temperature of materials in a multi-compartment barge, using a thermometer in a small sample bottle fastened on a stick. After obtaining the temperature in one compartment, he went on to the next. The bottle contained a small amount of the first material when it was immersed in the second compartment. The operator was surprised to note that the temperature in the second compartment was apparently 40°F higher than the first. Investigation of this strange behavior revealed that the first material was aminoethylethanolamine; the adjacent compartment contained croton oil. The alkaline amine had caused immediate violent reaction when it came in contact with the croton oil. A large imagination is not required for one to picture the consequences of a leak in the bulkhead separating the two adjacent barge compartments.

One processing unit had a tank truck spotted as a precaution to contain any excess sodium methylate from a transfer being made to their storage tank. The tank truck had contained valeric acid according to the Terminal Manager had been cleaned. The reaction that took place when the sodium methylate entered the truck proved that the cleaning was inadequate. So be sure that your procedures cover all potential incompatibility problems.

An explosion occurred in a 55 gallon steel drum, causing the bottom to be blown off and rocketing the drum up 18 feet, penetrating through a 5/8 inch plasterboard ceiling and a 1/2 inch plywood roof and damaging a 2" x 10" joist on the way through. The drum had contained 2.5 gallons of 50% caustic and 10 gallons of methanol. Two gallons of chloroform had just been added to the drum to deactivate any possible traces of a toxic material in the chloro-

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form. A hissing noise was heard and the funnel in the open bung hole was blown out. The technicians quickly backed away and were not injured as the drum "rocketed up".

NFPA's Manual of Hazardous Chemical Reactions, 491M-15, checked after the explosion, clearly states that when chloroform is added to methanolic sodium hydroxide, a vigorous exothermic reaction occurs. This reaction is well documented in MCA Case History No. 498 when the same reaction caused a drum to explode. The incident emphasizes that when new procedures are being established, the literature should be checked prior to start-up, not after an accident. In this case, the decontamination procedure was agreed upon at a committee meeting with people having many years of diversified chemical experience and only points out that in untried areas, nothing can be taken for granted.

There are other more subtle compatibility problems frequently encountered. The use of the conventional Garlock gasketing material in column and pipe line flanges has been the polymerization initiator in glyoxal, acrylic acid and ethylene oxide processing systems. Hurry up maintenance repairs can cause the use of the wrong materials in your systems.

Valve and pump packing must be replaced if a process change introduces material that is not suitable. A still system normally used for refining glycol products was subjected to fire exposure when a vinyl ethyl ether distillation was made and the decanter sight glass packing dissolved.

Lubricating oil used on compressors and seal oil systems must be considered as possible contaminants to process material.

The compatibility of material used for flushing equipment between process change overs must be considered in case the cleanup is really not complete. Diluents used to lower viscosity for ease of handling or dehydrating agents used for water decantation must be compatible with the process you are running. But what about the next process to be scheduled into the system?

The following compatibility charts may be of help in avoiding the mixing of reactive chemicals.

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CHEMICAL COMPATIBILITY GROUP CLASSIFICATION (Mr. D. F. Marples - R/D Dept.)

GROUP I

Bisphenol A
Butanol
Carbon monoxide
Diethoxytetraglycol
Diethyl CARBITOL
Diethylene glycol
Diethyl succinate
Diisobutylcarbinol
Dipropylene glycol
Ethanol
Ethane
Ethyl acetate
Ethylene
Ethylhexanediol
Ethylhexanol
Heptadecanol
Hexane
Hexanetriol
Hexylene glycol
Hydrogen
Isopropanol
Methane
Methyl amyl alcohol
Nitrogen
Octylene glycol
Pentane
Pentanediol
Pentenes
Pentyl formate
Water

GROUP II

Ammonia
Bis(aminopropyl) methylamine
Bis(cyanoethyl) methylamine
Dibutylamine
Dibutylaminopropionitrile
Diethanolamine
Diethylamine
Diethylaminopropionitrile
Diisopropanolamine
Diisopropylethanolamine
Diisopropylethylamine
Dimethylamine
3- Dimethylamino-N, N-dimethylpropionamide
Dimethylaminopropylamine
Dimethylethanolamine
Hardener ZZL-0822
Hydroxyethyl piperazine
Lubricant 032
Methyl piperazine
Monomethylamine
Monomethylaminopropionitrile
NIAX Catalyst A-1
NIAX Catalyst A-2
NIAX Catalyst A-4
NIAX Catalyst A-99
NIAX Catalyst A-376
NIAX Catalyst A-397
Piperazine
Polyglycoldiamine H-221
Polyglycolamine H-163
Tetramethylbutanediamine
Triethylamine
Trimethylamine

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GROUP III

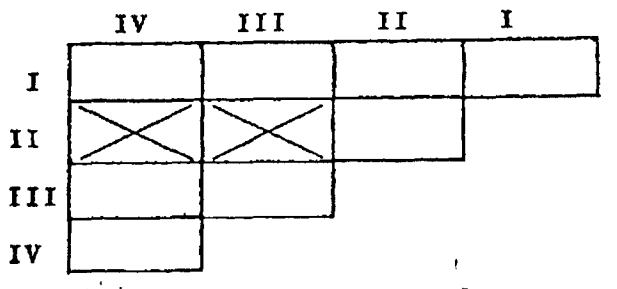
Acetone
Acetaldehyde
Butyraldol
Carbon dioxide
Diacetone alcohol
Diethyl ketone
Diisobutyl ketone
Dimethyl pentaldehyde
Ethylbutyraldehyde
2-Ethylbutyric acid
Ethylcrotonaldehyde
2-Ethylhexanoic acid
Formalin
Glutaraldehyde
Hexaldehyde
Isobutylheptyl ketone
Isoheptyl ketone
Isopentanoic acid
Methyl pentaldehyde
Methyl pentenal
Methylpropyl ketone
Propionaldehyde
Propionic acid
Tetradecanone
Valeric acid

GROUP IV

Acrolein dimer
Acrylonitrile
Crotonaldehyde
Diethyl maleate
Trimethylolpropane diallylether

COMPATIBILITY CHART

Those Groups which should not be mixed are indicated by the symbol X.



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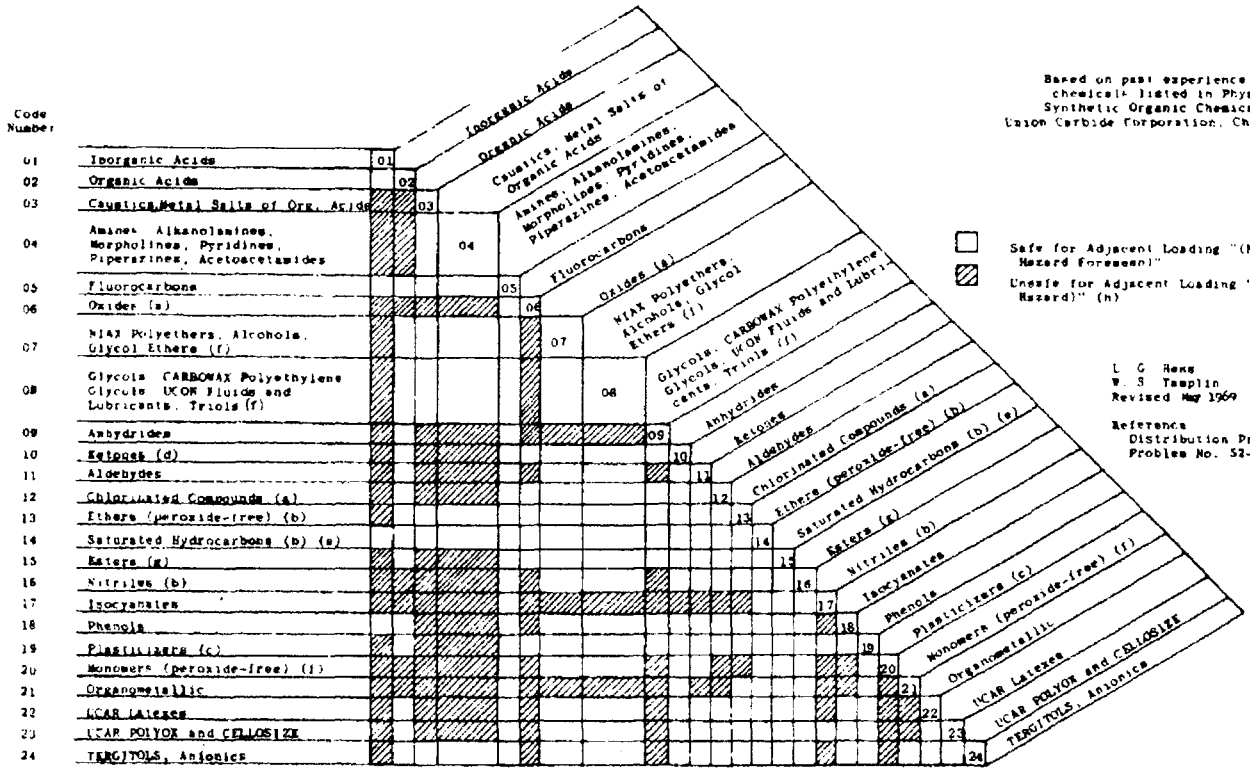
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GENERAL CLASSIFICATION OF CHEMICALS
FOR ADJACENT COMPARTMENT LOADING
AND HOSES USED DURING LOADING

"FOR UNION CARBIDE USE ONLY. USE BY OTHERS IS AT THEIR OWN RISK"

Based on past experience and judgment for chemicals listed in Physical Properties Synthetic Organic Chemicals 1969 Edition Union Carbide Corporation, Chemicals and Plastics



Safe for Adjacent Loading "(No Substantial Hazard Foreseen)"

Unsafe for Adjacent Loading "(Substantial Hazard)" (h)

L. G. Hess
W. S. Tamplin
Revised May 1969

Reference
Distribution Program
Problem No. 52-1961

(a) Except epichlorohydrin which may be safely loaded next to only the following: alcohols, esters, oxides, ketones, aldehydes, chlorinated compounds, ethers, and hydrocarbons.
(b) Acrylonitrile, unsaturated hydrocarbons and unsaturated ethers such as vinyl ethyl ether are included as monomers.
(c) Epoxy plasticizers are considered oxides.
(d) Methyl isoamyl ketone and diisobutyl ketone may be safely loaded adjacent to ethanolamines.
(e) Except strong oxidizing acids such as chromic or nitric.
(f) In the absence of acidic or basic materials, class 07 and 08 compounds, if free of peroxides, may be safely loaded next to monomers, with the exception of maleic anhydride.
(g) Allylidene diacetate, methallylidene diacetate and methyl vinyl acetate should be considered monomers.

TERGITOL Surfactants

Non-Ionics - Handle as alcohols
Anionics - Should not be loaded next to oxides, inorganic acids, anhydrides, monomers, or isocyanates

Aryls, Alicyclics, UCON propellants and UCON refrigerants

Classify for adjacent compartment loading according to functional group.

Example	Functional Group
UCAR Bisphenol A	Phenol
Styrene, monomeric	Monomer
UCON vinyl chloride	Monomer
Acetophenone	Ketone

(h) When double bulkhead containers are used and it is operationally or economically advantageous to deviate from the guide chart, it is permissible to do so.

GENERAL SAFETY AND FIRE PROTECTION
UNION CARBIDE CORPORATION, CHEMICALS AND PLASTICS
SOUTH CHARLESTON, W. VA.

ISSUED 6-23-69 PWZ A-15

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UCC 020940

TABLE 1 - GROUPS OF CHEMICALS

For use with compatibility chart (Table 2)

1. INORGANIC ACIDS

hydrochloric acid
hydrofluoric acid
* phosphoric acid
* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
phosphoric acid	sulphuric acid (1e)	
>	vinyl acetate (14c)	

Notes:
Hydrochloric acid is to be carried in independent tanks according to the IMCO rules.

1a CHLOROSULPHONIC ACID

Notes:
Although laboratory tests indicate no dangerous reactivity towards certain chemicals, the greatest care should be taken to avoid mixing of chlorosulphonic acid with any organic material.

1b NITRIC ACID, above 70%

1c NITRIC ACID, below 70%

1d OLEUM

Notes:
Although laboratory tests, indicate no dangerous reactivity towards certain chemicals, the greatest care should be taken to avoid mixing of oleum (fuming sulphuric acid) with any organic material.

1e SULPHURIC ACID

2. ORGANIC ACIDS

acetic acid
butyric acid, n-, iso-
fatty acid
fatty acid of tall oil (TOFA)
formic acid
heptanoic acid
isononanic acid
lactic acid
naphthenic acid
propionic acid
rosin oil
tall oil

3. CAUSTICS, ALKALIES

caustic potash solution
caustic soda solution

4. PRIMARY AMINES, ALKANOL-AMINES, AMMONIA AQ

aminoethyl ethanolamine
amylamine
aqua ammonia (ammonia dissolved in water)
diethylene triamine
ethylamine
ethylene diamine
hexamethylene diamine
monoethanolamine
monoisopropanolamine
triethylene tetramine
urea ammonia solution

4a SEK., TERT. AMINES, ANILINE, ETHYLENE IMINE

* aniline
dibutylamine
diethanolamine
diethylamine
diisobutylamine
diisopropanolamine
dimethylamine
dimethyl ethanolamine
* ethylene imine
morpholine
triethanolamine
* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
aniline	glyoxal (7)	
>	acrylic acid (14a)	
>	epichlorohydrin (16)	
ethylene imine		unsat. halogenated compounds (5a)
>		vinyl acetate (14c)

5. HALOGENATED COMPOUNDS

butyl chloride, (n)-
carbon tetrachloride
chloroform
* chlorobenzene
dibromoethane (1.1 or 1.2)
* dichlorobenzene
dichlorodifluoromethane
dichloroethane (1.1 or 1.2)
dichloropropane (1.1 or 1.2)
ethyl chloride
ethylene dibromide
ethylene dichloride
methyl bromide
methyl chloride
methylene chloride
monochlorodifluoromethane
* pentachloroethane
perchlorotoluene
propylene dichloride
1, 1, 2, 2, - tetrachloroethane
* 1, 2, 4- trichlorobenzene
trichloroethane (1.1.1 or 1.1.2)

* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
chlorobenzene		chlorosulphonic acid (1a)
dichlorobenzene		
1, 2, 4- trichlorobenzene		
pentachloroethane	>	caustics, alkalies (3)

5a UNSATURATED HALOGENATED COMPOUNDS

allyl chloride
1, 2 - dichloroethylene
dichloroethylene
dichloropropene
1, 1, 2, 2 - tetrachloroethylene
trichloroethylene

6. ALCOHOLS, GLYCOLS

* allyl alcohol
amyl alcohols (n-, p-, iso-, sec-n, tert-)
butyl alcohols (n-, iso-, sec-, tert-)
butylene glycols (1.2, 1.3, 1.4, or 2.3)
butyl glycol
cetyl alcohol
cyclohexyl alcohol
decyl alcohol
diacetone alcohol
diethylene glycol
dipropylene glycol
"dobanol" Shell
dodecyl alcohol
2-ethyl methanol
ethylene glycol
2-ethyl-1-hexanol
* furfuryl alcohol
glycerol
heptyl alcohol
hexylene glycol
isodecanol
isooctanol
methanol
methyl amyl alcohol
methyl glycol
niax polyol
nonyl alcohol
octyl alcohol
polyalcohols
propyl alcohols (n-, iso-)
propylene glycol
stearyl alcohol
tridecanol
* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
allyl alcohol		nitric acid 70% (1c)
furfuryl alcohol		inorganic acids (1c)
>		nitric acid 70% (1c)
>		organic acids (2)

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TABLE I - GROUPS OF CHEMICALS (Cont.)

7. ALDEHYDES

* acetaldehyde
benzaldehyde
* butyraldehyde, n-, iso-
decaldehyde, n-, iso-
* formaldehyde solution (50%)
* furfural
* glyoxal solution (40%)
octaldehyde, n-, iso-
methyl formal
propionaldehyde
* valeraldehyde, n-, iso-

^ Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
acetaldehyde		polymethylene polyphenyl diisocyanate (19)
formaldehyde solut.	sulphuric acid (1e)	
glyoxal solut.	sulphuric acid (1e)	
>	nitric acid 70% (1c)	
n-butyraldehyde	sodium hydroxide, 50% (3)	

7a ACROLEIN, CROTONALDEHYDE, ETC.

acrolein inhibited
crotonaldehyde
2-ethyl-3-propyl acrolein

8. KETONES

acetone
camphor oil
cyclohexanone
diethyl ketone
diisobutylketone
methyl ethyl ketone (MEK)
methyl isobutyl ketone (MIBK)
methyl propyl ketone, iso-, n-

8a MESITYLOXIDE, ISOPHORONE

isophorone
mesityloxide

9. SATURATED HYDROCARBONS, WAX PETROLEUM OILS, ETC.

alkanes
asphalt
butane, n-, iso- (commercial)
casinghead (natural) gasoline
cycloheptane
cyclohexane
decane, n-, iso-
gasoline, commercial
heptane, n-, iso-
hexane, n-, iso-
isoparaffins
jet fuels (JP-3, JP-4, JP-5)
kerosene
methane
mineral spirits
naphtha (non aromatic)
nonane
normal paraffins
octane, n-, iso-
oils
absorption oil
crude oil
diesel oil
fuel oil
lubricating oil
mineral oil
motor oil
penetrating oil
range oil
spray oil
spindle oil
turbine oil
pentane, n-, iso-
petroleum ether
* petroleum sulphonate
propane (commercial)
wax (from petroleum)
white spirits

* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
petroleum sulphonate		oleum (1d)

10. AROMATIC HYDROCARBONS

amyl toluene
benzene
coal tar solvent naphtha
coal tar oil
cumene
p-cymene
diethylbenzene
dodecylbenzene
ethylbenzene
naphtha (aromatic)
naphtha heavy solvent
naphthalene, molten
phenyl cyclohexane
tetrahydronaphthalene
toluene
triethylbenzene
xylenes (n-, o-, p-, and mixed)

11. OLEFINS, UNSATURATED HYDROCARBONS

dicyclopentadiene
diisobutylene
dipentene
heptene
hexadiene
hexene
isoprene
myrcene
nonene (isomers)
pinene, -alpha,-beta
pine oil
polybutene
propylene (trimer, tetramer)
turpentine

12. PYRIDINE AND SOME HETEROCYCLIC COMPOUNDS

2-methyl-5-ethyl pyridine
pyridine
* sulpholane

* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
sulpholane	nitric acid 70% (1c)	
>	sulphuric acid (1e)	
>	β-propiolactone (14)	

13. ESTERS, VEGETABLE AND ANIMAL OILS

amyl acetate, n-, iso-, sec-
amyl tallate
butyl acetate, n-, iso-, sec-
butyl benzoate
butyl benzyl phthalate
butyl butyrate
butyl diglycol acetate
butyl lactate
castor oil
"cellosolve" acetate
coconut oil
cod liver oil
corn oil
cotton seed oil
croton oil
cyclohexyl acetate
dibutyl-o-phthalate
diisononyl phthalate
diisooctyl phthalate
dioctyl phthalate
ethyl acetate
ethyl benzoate
ethyl diacetate
ethylene glycol diacetate
ethylene glycol monobutyl ether acetate
ethyl formate
ethyl glycol acetate
ethyl hexyl tallate
ethyl lactate
fish oil crude
isobutyl acetate
isopropyl acetate
methyl acetate
methyl amyl acetate
neatsfoot oil
olive oil
palm kernel oil
palm oil
peanut oil
propyl acetates, n-, iso-
rape seed oil
resin oil
soyabean oil
sperm oil
tall oil
tallow
tanners oil
vegetable oils
wax, caranuba

14. MONOMERS AND POLYMERIZABLE COMPOUNDS

butyl acrylate, n-, iso-
butyl methacrylate
ethyl acrylate (inhibited)
2-ethylhexyl acrylate (inhibited)
isodecyl acrylate
methyl acrylate (inhibited)
methyl methacrylate (inhibited)
methyl styrene (inhibited)
* β-propiolactone
styrene (monomer, inhibited)
vinyl toluene (meta and para, inhibited)

* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
β-propiolactone		inorganic acids (1)
>		organic acids (2)
>		caustic, alkalies (3)
	sulpholane (12)	pyridines (12)

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TABLE I - GROUPS OF CHEMICALS (Cont.)

14a ACRYLIC ACID
- acrylic acid

14b ACRYLONITRILE
- acrylonitrile

14c VINYLACETATE
- vinylacetate (monomer, VAM stabilized)

14d VINYL - AND VINYLIDENE CHLORIDE
- vinylchloride
- vinylidene chloride (inhibited)

15. PHENOLS AND CREOSOTE
- carbolic acid (phenol)
- carbolic oil (phenol)
- cashew nut oil
- cresols (meta-, ortho-, para-, mixed)
- * creosote
- * creosote oil
- nonyl phenol
- phenol

* Exceptions:

Chemical	Not dangerously reactive with	Dangerously reactive with
creosote	oleum	
creosote oil	oleum	

16. ALKYLENE OXIDES
- ethylene oxide
- propylene oxide
- epichlorohydrin

17. CYANOHYDRINS
- acetone cyanohydrin
- ethylene cyanohydrin
- * ethylene chlorohydrin

* Exceptions:

Chemicals	Not dangerously reactive with	Dangerously reactive with
ethylene chlorohydrin	sulphuric acid (1e)	

18. NITRILES
- acetonitrile
- adiponitrile

19. ISOCYANATES
- diphenylmethane diisocyanate
- polymethylenepolyphenyl diisocyanate
- toluene diisocyanate

20. AMIDES
- dimethyl acetamide
- dimethyl formamide

21. ETHERS AND GLYCOLETHERS
- amyl ether
- butoxy polypropylene glycol
- butyl ether
- dichloroethyl ether
- diethylene glycol monobutyl ether
- diethylene glycol monoethyl ether
- diethylene glycol monomethyl ether
- diphenyloxide
- ethoxytriglycol
- ethylene glycol monobutyl ether
- ethylene glycol monoethyl ether
- ethylene glycol monomethyl ether
- * ethyl ether
- * isopropyl ether
- polyethylene glycol
- polypropylene glycol
- polypropylene glycol methyl ether
- tetraethylene glycol
- tetraethylene glycol dimethyl ether
- tetrahydrofuran
- triethylene glycol
- triethylene glycol monobutyl ether
- triethylene glycol monoethyl ether
- triethylene glycol monomethyl ether

* Exceptions:

Chemicals	Not dangerously reactive with	Dangerously reactive with
ethyl ether		sulphuric acid (1e)
isopropyl ether		sulphuric acid (1e)

Notes:
Ethyl ether is to be carried in independent tanks according to the IMCO rules.

22. WATER SOLUTIONS AND DISPERSION
- ballast water
- * caprolactam solution
- corn syrup
- dextrose solution
- latex
- * molasses
- salt solution
- sea water
- * sorbitol solution
- urea-formaldehyde glue
- wine, red-, white-

* Exceptions.

Chemical	Not dangerously reactive with	Dangerously reactive with
molasses		nitric acid< 70% (1c)
sorbitol solution		sulphuric acid (1e)
sorbitol solution	isocyanates (19)	
molasses	> >	
caprolactam solution		*sodium hydroxide* (50%) (3)
sea water	> >	

23. NITRO COMPOUNDS
- nitrobenzene, mono-, di-, (ortho-, meta- or para)
- nitroethane
- nitromethane
- nitropropane

24. ACID ANHYDRIDES
- acetic anhydride
- butyric anhydride
- propionic anhydride

25. HYDROGEN PEROXIDE <52%
- hydrogen peroxide solution in water of concentration less than 52 per cent by weight.

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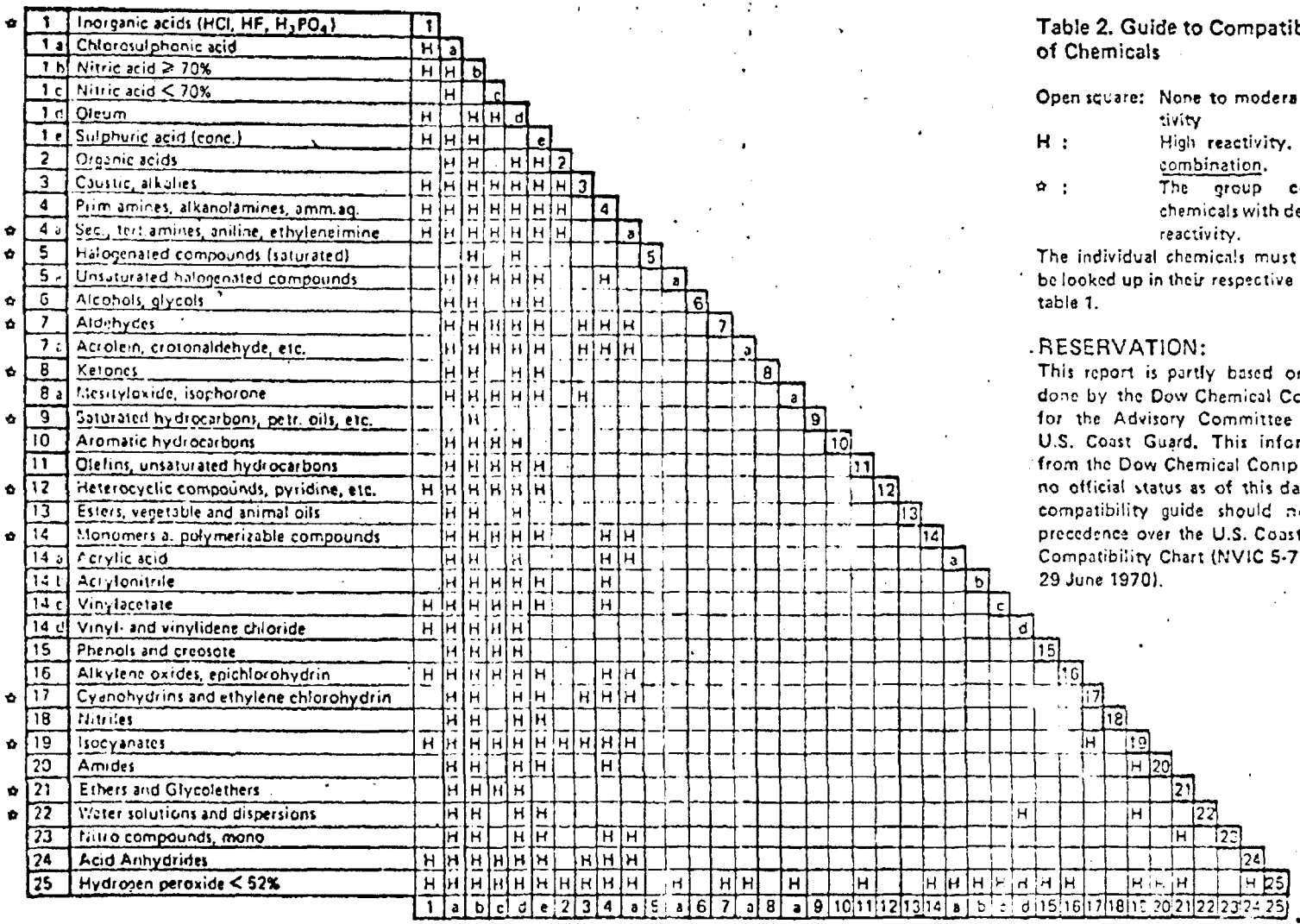
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Table 2. Guide to Compatibility of Chemicals

	1	Inorganic acids (HCl, HF, H_3PO_4)
	1 a	Chlorosulphonic acid
	1 b	Nitric acid ≥ 70%
	1 c	Nitric acid < 70%
	1 d	Oleum
	1 e	Sulphuric acid (conc.)
	2	Organic acids
	3	Caustic, alkalies
	4	Prim amines, alkanolamines, amm.aq.
✪	4 a	Sec., tert amines, aniline, ethyleneimine
✪	5	Halogenated compounds (saturated)
	5 a	Unsaturated halogenated compounds
✪	6	Alcohols, glycols
✪	7	Aldehydes
	7 a	Acrolein, crotonaldehyde, etc.
✪	8	Ketones
	8 a	Mesityloxide, isophorone
✪	9	Saturated hydrocarbons, petr. oils, etc.
	10	Aromatic hydrocarbons
	11	Olefins, unsaturated hydrocarbons
✪	12	Heterocyclic compounds, pyridine, etc.
	13	Esters, vegetable and animal oils
✪	14	Monomers a. polymerizable compounds
	14 a	Acrylic acid
	14 b	Acrylonitrile
	14 c	Vinylacetate
	14 d	Vinyl- and vinylidene chloride
	15	Phenols and creosote
	16	Alkylene oxides, epichlorohydrin
✪	17	Cyanohydrins and ethylene chlorohydrin
	18	Nitriles
✪	19	Isocyanates
	20	Amides
✪	21	Ethers and Glycolethers
✪	22	Water solutions and dispersions
	23	Nitro compounds, mono
	24	Acid Anhydrides
	25	Hydrogen peroxide < 52%



Open square: None to moderate reactivity

H : High reactivity. Unsafe combination.

✪ : The group contains chemicals with deviating reactivity.

The individual chemicals must always be looked up in their respective groups, table 1.

RESERVATION:

This report is partly based on work done by the Dow Chemical Company for the Advisory Committee to the U.S. Coast Guard. This information from the Dow Chemical Company has no official status as of this date. The compatibility guide should not take precedence over the U.S. Coast Guard Compatibility Chart (NVIC 5-70 dated 29 June 1970).

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VIII. STARTUP HAZARD POTENTIAL (N. W. Clauss)

The unsteady state involved in starting up existing or new chemical processing systems increases the potential for unexpected situations. Throughout this manual we are hoping to develope the capability for preparing high quality standard operating and emergency procedures and the ability to train operating personnel in the recognition of hazards and how to avoid accidents.

If you have good procedures and well trained people to cover isolation requirements, clean up, venting requirements, purging requirements, control system reliability, etc. the risks of startups are usually minimal. The use of check lists are advisable but be aware of the fact that there will probably never be an all inclusive procedures manual or check list. A look at some startup accidents may drive home the point.

A- A fire occurred inside the second stage heater of the No. 7 dryer system at the Texas City Plant Supension Vinyls Unit. The empty dryer was being placed in service after a routine resin change. It is thought that 200 psi steam was introduced without initiating air flow resulting in decomposition of residual resin--smoldering, heat, and HCL. There were no injuries. $8,000 property damage.

B- An explosion occurred in the No. 14 Boiler in the South Charleston Plant resulting in $1,500,000 property damage and one disabling injury. The explosion occurred during "light off" after 19 days downtime for overhaul.

C- The following vapor cloud incident occurred in one of our plants and illustrates the value of good maintenance and emergency procedures.

The unit intensifiers were started up after poppet valve replacement. All three intensifiers were running and reactor pressures were up to 28,000 psi. The control room operator could not get the pressure higher which alerted him that something was wrong. He then looked across to the pump building and saw a large vapor cloud. The cloud covered both the No. 5 and 6 Units. Both units were shut down promptly and the pressure was blown down.

UCC 020945

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Sixty percent LEL readings were visually indicated on the control room intake monitors, but audible alarms did not come on due to malfunction. Ethylene was not drawn into the control room due to proper operation of the safeguards on the ventilation system. One new operator started into the vapor cloud but was called back by his supervisor and another operator. The vapor cloud cleared in about 10 minutes because of a brisk south wind and ignition did not occur. It was estimated that 500 pounds of ethylene were released.

The immediate cause of the release was the improper installation of the poppet valve. The normal experience level was not used on the repair and a standard formal procedure for this job was not available. Also, an operator was not present at the pump house as the intensifiers were brought on the line after maintenance, as is normally the practice.

D- An employee received chemical burns to leg, chest, arm and face as the result of being sprayed while removing rubber air hose from phenol scrubber. The previous night the scrubber stopped circulating. Operator blew the circulating line with air, pumped out scrubber, added a fresh load of phenol and started up operation. He neglected to remove air hose when job was done. The employee, without bleeding down system, uncoupled the "loaded" hose.

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IX. SHUTDOWN HAZARD POTENTIAL (N. W. Clauss)

Again the unsteady state hazards exist while shutting down process systems. While temperatures are being lowered and material is being pumped from a system you must have procedures and proper design to avoid sucking air into a flammable vapor or pulling vacuum in equipment to the degree of failure. If acetylides are present the equipment must be kept wet during the outage period. When the process involves polymers, slurrys, heavy residues, high freezers, etc., you may have to overcome the hazards created by plugged drains, lines or pumps.

Cleaning procedures and agents used must be established for each process system to safely cover the equipment geometry problems and the nature of the process chemicals involved. A 15,000-gallon stainless tank was being cleaned by steaming with the normal and emergency vents open. A rain storm condensed the water vapor and the tank was pulled in. Relief design for the tank was undersized because the steam cleaning operation was not part of the original design criteria. You have a responsibility to define all modes of operation during the project design phase of any facility.

Shutdown checklists are a valuable aid in avoiding surprises and accident prevention, but again be reminded that there will never be an all inclusive checklist. Two accidents described below illustrate shutdown deficiencies.

A fire occurred in the No. 1 oxide blowoff oxidation system. The system had been shut down via the ESD and the catalyzed combustion continued in the downstream piping resulting in damage to the piping and gas turbines. The property damage amounted to $30,000.

The pelletizer operator in the plastics department detected an oil leak during a screen change cycle. The leak was at the nipple in the piping that joins the hydraulic accumulator to the screen changer through schedule 80 1" piping. The pelletizer is extruding polystyrene using the screen changer to replace the screens as they become plugged. The hydraulic system is only used when a screen change becomes necessary.

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The operator reported the leak and a work order was written and given to the shift maintenance man as a "repair at your convenience" type work request. The first class maintenance man replaced the nipple without incident and had the operator start up the system to check the repair. Upon starting the pump, another leak was detected at the nipple assembly to the union. The operator was instructed by the maintenance man to stop the pump. (Approximately two seconds had elapsed.)

The hydraulic system normally operates at the 1200 to 1300 psi range. When the hydraulic pump is started the pressure builds up to 500 psi instantaneously and requires only three to four minutes to reach design pressures. The normal screen operating sequence releases the pressure to 800 psi for two-three minutes then the pressure will bleed down to zero within six-seven minutes total.

With the pump shut down, the maintenance man proceeded for the second time to repair the leak and began to uncouple the union. When the union was within a couple of threads of being uncoupled, the pressure vented itself (500-800 psi). The force exerted against the pipe swung the piping around, striking the maintenance man's left leg midway between the ankle and the knee. This impact resulted in a compound fracture and knocked the employee back about 6 feet. Good documented procedures and a shutdown checklist would have avoided the injury.

Residue disposal can lead to accidents to personnel or cause fires. The disposal of pyrophoric material such as spent Raney Nickle or easily ignited containers of organic peroxides can be real problems if preparations are not adequate. A chemical residue line to a boiler used for incineration was opened at inspection connections to check for line pressure. The flammable liquid released was ignited by the burners and the operator suffered flash burns. The residue line procedures were deficient in that the pressure test connection was located at an ignition point.

The Operating Department and all its personnel are responsible for the proper preparation for maintenance work during production outages. Hazardous Work Permit, Vessel Entry and Tag Out-Lock Out Procedures are designed to

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ensure the safety of maintenance workers. If your process involves toxic chemicals you are required to establish adequate decontamination procedures.

Specifications for removing acetylides and cleaning equipment are included at the end of this section for reference.

A fractionator at the Tenneco Oil Company plant in Chalmetta, Louisiana, was being rebuilt by contracted personnel. The repairs involved welding. After eight days of work on the project one of the workers hooked up a Coppus Blower on a hot day to cool the inside of the column while the crew went to lunch. Ten contract workers and three Tenneco employees were in the column when work resumed and the column blew up. All thirteen people were killed. The Coppus Blower had been hooked up to a fuel gas connection rather than air and was set up to blow into the column rather than to exhaust to the atmosphere. Your lesson from this is to avoid complacency in safety watch and vessel entry procedures on maintenance jobs of long duration. We have had several serious accidents in C&P caused by the missuse of Copper Blowers.

Deficient TO/LO procedures are illustrated by two comparable accidents report in a MCA Bulletin.

Company "A" 1967

A pump had to be dismantled. When a fitter removed a cover, hot oil came out and caught fire. Three men were killed, and the plant was destroyed.

The suction valve had been left open.

The supervisor checked that the suction valve was closed but a short time elapsed before work started. He issued a clearnace for work on the bearings but later in the day it was decided to dismantle the pump.

The fitter did not notice that the suction valve was open although he hung something on the projecting spindle of the open valve.

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Company "B" 1974

A pump had to be dismantled. When a fitter removed a cover, hot condensate came out and sprayed him. He received second degree burns to his neck, shoulders and feet.

The suction valve had been left open.

The operator thought the fitter was going to work on the coupling only. Therefore he locked-out the pump motor but did not close the suction valve.

The fitter did not notice that the suction valve was open although it was only one foot from the pump

Another accident in one of our plants was described as follows:

Two shift mechanics were assigned the job of changing a valve on the bottom of a still. The still had been emptied and drained on day shift in preparation for the valve change. Because of having to do day shift maintenance work on higher priority jobs, the valve change had been left to be done on the 4-12 shift. Apparnetly during the time interval between draining of the still and the beginning of the valve change work, the discharge line beneath the valve had plugged with resin, and some distillate from the condenser had dripped back and collected in the bottom of the still. This condition had not been detected. As the mechanics were removing the valve, liquid (phenol distillate) sprayed out of the disconnection with some of it striking the men on various areas of their bodies. One man sustained phenol burns of the left eye, face, neck, chest, and arms while the other received minor burns of the arm. The former's injuries were disabling. Twenty-eight days estimated lost time.

Another near miss in one of our plants was explained in a review board report as follows:

On Monday, April 12, 1971, the No. 2 Isopropanol main column was removed from service and prepared for opening and entry. The overhead vent

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line, top head, ten trays and top two sections were removed. The trays were sent to the shop for revisions, expected to be returned to the unit by Wednesday.

On Tuesday the calandria was removed from the base of the column, tested, repaired, retested and reinstalled. The riggers also replaced one of the sections on the column, nothing unusual was noticed.

On Wednesday, April 14, 1971, at about 10:00 a.m., a very hazardous condition was found by the maintenance personnel assigned to reinstalling the trays. An alert employee noticed a different "smell" in the work area and notified his co-workers and supervisor. Personnel were removed from the scaffold and the "cause" investigated. A utility hose was found connected to the base section of the column and to the unit plant nitrogen header with the valve partly opened.

The hose was disconnected, column filled with water and preparation made for entry. Job was resumed and completed without incident.

It is not known, when and who connected the nitrogen hose to the column. Indications are that it was done on evening or midnight Tuesday.

This incident was caused by a breakdown in our own check and double checking communication between the initiator of the permit and the person he delegated to check conditions prior to release to maintenance. Personnel commenced work without checking or doublechecking job conditions such as:

1. Failure to apply established standard plant and unit procedures.

2. Permit not properly made out by originator.

3. Operations released the permit and equipment to maintenance without proper checking.

4. Maintenance supervisor and personnel accepted an improperly completed permit and commenced work with it.

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5. Violation of Plant Procedure for Preparation of Equipment for repair, opening or entry.

From such accident examples you can see the subtle traps and seriousness of the lack of safe procedures in shutdown situations and how they can spell havoc for maintenance personnel. An accident reported by MCA emphasize this point.

A maintenance man who entered a reactor to assist in aligning the agitator fell, apparently due to partial asphyxia, and suffered a compression fracture of a vertebra. Two co-workers, with assistance from the plant emergency crew, removed the injured employee from the reactor.

The reactor had been meticulously prepared for entry:

1. The unit had been cleaned.

2. Except for the vapor line to the unit condenser, all lines into the unit had been tagged and isolated by removing, blanking or by using a double-closed valve arrangement. The vapor line to the unit condenser was glass and could not be blanked.

3. The unit was purged with air by using a pneumatic air-mover.

4. The tank atmosphere was checked with a combination combustible gas and oxygen indicator and found to be safe.

5. The confined space permit was then signed by all parties involved (operating, maintenance, and safety personnel) in accordance with the rigid procedure.

A nitrogen line to the unit condenser was not disconnected during the checkout. It had not been tagged by operating personnel and was overlooked by maintenance and safety personnel. An automatic valve in this line prevented the flow of nitrogen to the system.

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When the top of the reactor was removed a pressure transmitter was disengaged, which allowed the automatic valve in the nitrogen line to the vent system to open. Nitrogen was free to go through the condenser, back through the vapor line into the reactor. When the top of the reactor was replaced, the nitrogen concentration in the unit increased. After the reactor top was replaced, the unit was not rechecked for sufficient oxygen prior to the employee reentering the reactor to algin the agitator.

Failure to identify, tag and isolate all lines to the system in preparing it for entry was the basic deficiency.

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PROCEDURE FOR REMOVAL OF COPPER ACETYLIDES

1.0 Scope

These procedures are recommended for chemical cleaning of process equipment to destroy copper acetylides or other metal acetylides.

2.0 General

2.1 The chemistry of acetylide formation and a discussion of the known characteristics is presented in Design & Analysis 5.15, "Copper Acetylides" (13.2.1.1).

2.2 Acetylides may be formed by contact of acetylene with copper, silver, gold or mercury. Regardless of source, acetylides are extremely dangerous ignition sources.

2.3 Acetylene is the sole source of acetylide formation. However, small amounts of acetylene may be present in other gas streams. Ethylene, propylene and, to a lesser extent, hydrogen-methane are suspect streams. Streams containing substituted acetylenes, such as vinyl acetylene, definitely will cause acetylide formation.

2.4 Copper acetylides may be carried into various parts of the plant when products are transferred, and be deposited in equipment remote from the source. This can create a potential hazard when least expected.

3.0 Criteria for Safe Handling

3.1 Where the presence of copper acetylide is suspected, the equipment should be:

a. Freed of explosive mixtures.
b. Kept wet.
c. Kept below 50°C.

3.2 The suspected copper acetylides should be considered a potent ignition source.

3.3 A sample of the wet deposit, or some small item of the same material as other internal parts of the equipment (e.g. a bubble cap or bolt) should be tested by the Laboratory. The standard "Ilosvay" test is used to identify acetylides.

3.4 Alternatively, if no laboratory facilities are available, the small item may be dried with acetone and tested for "sparking" (by scratching or scraping) in a location free of explosive mixtures.

4.0 Removal of Copper Acetylide

4.1 In general it is more economical to have this service performed by outside contractors. Treat the affected parts or completely fill the equipment with a solution prepared in proportions for each 100 gal. required as follows:

25 gal. 20° Baume commercial hydrochloric acid (muriatic acid).

2 pints Rodine 50 inhibitor.

9 lb. Thiourea

9 lb. sodium nitrate

75 gal. water

13.5.1.1

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Note: To prepare the cleaning solution, mix the hydrochloric acid slowly into about 50 gal. of water. Dissolve acid slowly into about 50 gal. of water. Dissolve the 2 pt. of Rodine 50 inhibitor in it. Add the thiourea and sodium nitrate to the acid solution. Add sufficient water (about 25 gal.) to make 100 gal. of the cleaning solution. Larger or smaller quantities may be prepared by the same procedure and by using the same proportions of ingredients.

This method must not be used on tinned equipment, except as modified in 4.3 below.

4.2 When the affected parts are being treated, the solution shall be heated to a temperature of 75°C and circulated through the affected equipment by means of a pump, or agitated vigorously with live steam for a period of at least 30 minutes.

Note: Air must not be used to agitate the hot acid as the use of air will result in severe corrosion of metal surfaces. Worthite or CN7M pumps must be used - NOT steel or cast iron.

4.3 This method is to be modified for certain metals as noted below:

At 75°C and below the corrosion rates of the inhibited hydrochloric acid preparations do not appear to be prohibitive on such metals as tin, soft solder, lead, and steel for the short exposure encountered in cleaning operations. Cast iron is rapdily corroded by these solutions at 75°C but not too rapidly attacked at room temperature. It therefore appears likely that when equipment containing the above metals is to be decontaminated, the inhibited hydrochloric acid solution may be safely used at temperatures no higher than 75°C and preferably as low as is consistent with proper scale removal.

4.4 Where greasy or gummy deposits cover the surface of the metal to be treated, the addition of .2 of one percent by volume of Tergitol Nonionic NP-35 or NP-40 in solution with the acid will remove some of these greasy residues.

4.5 For those greasy deposits that are not readily approved by the above acid solution, a degreasing solution should be used before the acid solution. Some degreasing solutions commonly used are: alkaline solutions, perchloroethylene, trichloroethylene, Stoddard solvent, Varsol, and kerosene. Each of these degreasing solutions has certain advantages in specific situations, and the choice of solution should be made according to the particular equipment to be treated and the health and fire hazard involved. (See Table G-2, OSHA Standards 29CFR1910 and 1910.252 (f) (2) (II) for hazards of chlorinated solvents). A common alkaline solution is made as follows: to each 120 gallons of water in the total solution, add 100 pounds of sodium hydroxide, 1 pound of sodium metasilicate or trisodium phosphate, and 1 pint of Tergitol Anionic 08 or 7. This solution should be used at 100°C for a maximum of 2 hours. (Proper protective clothing should be worn throughout this treatment). If at the end of this time there are indications of large remaining greasy deposits in the equipment, the alkaline treatment should be repeated. After degreasing, the equipment should be treated for acetylides unless the equipment is clean. The liquid hydrocarbon degreasing solutions should be used straight and at temperatures well below their flash point. After degreasing with a liquid hydrocarbon, the surface should be treated for acetylides unless the conditions of Paragraph 4.6 apply.

4.6 The equipment shall then be drained, flushed thoroughly with water, and examined. If the metal surfaces are bright and clean, free of scale and oxides, and no residues or deposits remain, it may be assumed that the acetylide has been destroyed and removed. However, if any deposits or discolorations remain, the above procedure should be repeated and continued until the desired condition is attained and copper acetylide tests are negative.

4.7 After use, the solution should be disposed of, since re-use of the cleaning solution may result in severe corrosive attack to the vessel. Disposal is to be as prescribed by the plant environmental engineer.

13.5.1.1

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4.8 Copper heating coils that have (or are suspected of having) deposits of copper acetylide on them must be kept wet when they are removed from equipment. After removal to a safe area, this deposit can be burned off with a torch. Use of a torch may ignite a large area of copper acetylide which is capable of flashing with emission of fire. Copper acetylide covered with gummy deposits is often difficult to decompose and the decomposition, when finally initiated, may propagate throughout the mass under the surface of the gummy deposit. The use of a torch with a long extension on the handle is recommended for burning off copper acetylide deposits.

4.9 Formations of copper acetylide can also be removed by a hot oil process. Laboratory tests prove that 600 W oil, when heated to 300°C will disintegrate any copper acetylide formations in ten minutes. This method may be satisfactory in some cases, but because of the use of oil and the temperature involved, it is not generally considered practical.

5.0 Supervision

It is important that the department head or foreman be consulted in all doubtful situations. The utmost caution is required in order to cope with copper acetylides. Of particular importance is the elimination of hazardous atmospheres within equipment where copper acetylide formations may exist. Vapor-air concentrations within the explosive range can be ignited by the decomposition of copper acetylide. When copper acetylide is dry it will ignite at the slightest friction or impact, or will ignite automatically at temperatures above 50°C. Copper acetylide should be considered as an ignition source and should be treated as such.

13.5.1.1

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RECOMMENDED PRACTICES FOR PRE-SERVICE CLEANING PROCEDURES FOR PROCESS EQUIPMENT

1 SCOPE

1.1 These recommended practices cover the pre-service cleaning procedures for process vessels and ancillary piping and equipment. The procedures are intended to remove dirt, metal chips, rust, scale, debris, grease and other foreign material from the equipment. Stand-by practices to maintain cleanliness after specific preparations are also included.

1.2 The recommended practices cover the general cleaning procedures recommended but do not give specifics as to how to fill and drain or vent equipment being cleaned. The specific, detailed plans must be prepared by the Operating Department, Field Construction personnel or the Cleaning Contractor and approved in writing by the Start-Up Team.

2 GENERAL

2.1 These recommended practices cover specific procedures for mechanical cleaning, solvent cleaning, alkaline cleaning or passivation. Also covered are the procedures suitable for maintaining clean conditions in the equipment after treatment.

2.2 Specific items or parts which are of a different material or group of materials, and which might be corroded or otherwise damaged by the procedures selected for the major system, are to be removed or effectively isolated during the cleaning procedure.

2.3 Adequate consideration shall be given to draining and flushing of low points, blind legs, etc., where acid, solvent, sand or other materials might accumulate and not be removed.

2.4 The inspection and acceptance of equipment cleaned by these procedures is prescribed in the Criteria section of the Materials of Construction Manual (13.1.1.1).

3 METHODS

3.1 MECHANICAL

3.1.1 Air Cleaning/Steam Cleaning of Piping

3.1.1.1 Check piping grid and be sure all manifolds, main headers, branch lines and drops are properly installed and connected.

3.1.1.2 Blow piping free of all loose material with air or steam. While blowing is in progress, strike or hammer the exterior of piping at all joints to jolt loose any material clinging to the interior of piping so that it may be carried out of the lines.

3.1.1.3 An alternative procedure consists of installing a suitable rupture disk and pressurizing with steam until the disk blows.

3.1.2 "Pigging" of Piping

3.1.2.1 Install a "pig catcher" or other arresting barrier to prevent entry of the "pig" into unwanted areas or equipment.

3.1.2.2 Insert stiff-bristled nylon or polypropylene radioactive "pig" of suitable size and blow thru line with compressed air to remove loose rust and particulate matter.

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3.1.3 Water Blasting

3.1.3.1 Dirt, rust, grease or oil, scale (other than mill-scale) and other loosely adhering contaminants can be removed by water-blasting.

3.1.3.2 Equipment and Operating/Safety Procedures, as well as parameters for pressure, velocity and time per unit area are described in NACE Standard RP-01-72, "Recommended Practice - Surface Preparation of Steel and Other Hard Materials by Water Blasting ---".

3.1.4 Abrasive Blasting

3.1.4.1 Blasting of steel with specific abrasives (e.g., corn cobs, nut shells, fly ash, glass beads, sand) is effective in the removal of adhesive contaminants (e.g., rust and mill-scale).

3.1.4.2 Abrasive blasting shall be conducted to obtain a commercial finish in accordance with NACE Standard TM-01-70 No. 3 Commercial Blast Cleaned Surface Finish or Steel Structures Painting Council Specifications SSPC-SP-6.

3.2 SOLVENT CLEANING

3.2.1 Water Washing - All materials of construction are amenable to flushing with a good quality water (i.e., city or potable water, steam condensate, demineralized water) to remove loose contaminants. Addition of 0.01% non-ionic wetting agent in hot water is permissible, as required, followed by flushing with cool, clean water.

3.2.2 Inert Solvents - Discrete particulate contaminants may be flushed from oil-lubricated systems by rinsing with trichlorethylene or varsol, which must be drained before filling with oil.

3.2.3 Oil Flushing

3.2.3.1 Lube oil systems may be flushed with hot (180°F) oil, using steam/water on the water-side of an oil cooler to maintain the heat. Screen or strainers of 100 to 200 mesh should be provided between the bypasses and the common return header.

3.2.3.2 Remove heat source and add cold water to cooler to lower temperature to 70°F as fast as possible. During the cooling cycle, hammer welded connections, flanges and elbows to break loose material from the pipe wall and keep it moving in the oil stream.

3.2.3.3 Flush on a 24-hour basis with hot and cold oil alternately until no foreign material is found on the temporary strainers. (Note: "Tattle-tails" cut from the fingers of clean white cotton gloves may be wired in the oil supply tubing as a measure of cleanliness).

3.2.3.4 Once the flushed oil is clean, stop the oil flow and drain the system. Replace with new or thoroughly filtered oil. (Note: The temporary strainer may be left in place the first time a compressor train is run up to speed but MUST BE REMOVED before operating any compressors or other equipment serviced by the system).

3.3 DEGREASING

3.3.1 Oil and grease may be removed from carbon steel or stainless steel equipment by circulating a degreasing solution thru the pipe for approximately 4 hours at 180°F. The degreasing solution shall be one of the following compositions:

3.3.1.1 Three percent by weight sodium hydroxide: 3 percent by weight sodium metasilicate: 0.01 percent by weight wetting agent.

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3.3.1.2 Six percent by weight trisodium phosphate plus 0.01 percent by weight wetting agent.

3.3.1.3 One percent by weight non-ionic detergent such as Tergitol NPX or Tergitol NP-35.

3.3.2 Flush with clean water until degreasing solution has been completely removed, verifying removal with a pH meter or "Universal" pH paper. (Note: A soft, distilled, or dimineralized water should be employed. DO NOT use a hard water which could precipitate calcareous deposits on the hot metal surfaces).

3.3.3 For the special case of degreasing prior to Vapor Phase Acid Cleaning per Dow Industrial Patent No. 3084076, equipment shall be preheated by saturated steam at atmospheric pressure. The degreasing solution of 5 percent by weight sodium hydroxide, 5 percent by weight trisodium phosphate and 0.1 percent by weight wetting agent shall be injected in the ratio of one part per four parts of saturated steam for one hour, or as required to effect complete degreasing.

3.4 ACID CLEANING

3.4.1 Inhibited Hydrochloric Acid Cleaning Procedure (used for steel or copper alloy equipment only).

3.4.1.1 Remove or isolate from the system any items such as valve trim, pump internals, etc., made of cast iron, twelve percent chromium steel, austenitic stainless steel, aluminum or other materials that are attacked by dilute inhibited hydrochloric acid at the temperatures and concentrations stated below.

3.4.1.2 Pickle the system to bare metal by circulating one of the following solutions: 15 percent by weight inhibited hydrochloric acid for four to six hours at ambient temperature (i.e., 60-90°F); 5 percent by weight inhibited hydrochloric acid for two to four hours at 160°F.

In all cases, the pickling process should be stopped as soon as bare metal has been obtained. (Note: This is conventionally determined by a cessation of significant dissolved iron pick-up in the spent acid).

3.4.1.3 The effectiveness of the inhibitor shall be verified by a corrosion monitor. A clean steel sample immersed in the selected acid at the proposed temperature for 30 minutes shall lose not more than one milligram per square centimeter of surface (0.02 inches per year average penetration). This is to be further verified by a clean steel specimen, weighted to the nearest 0.001 gram exposed to the cleaning operation and reweighed after the cleaning.

3.4.1.4 Rinse with 0.01 percent by weight citric acid and drain system under an inert atmosphere (e.g., nitrogen). Rinse with water containing passivating agents such as sodium phosphate or sodium nitrite until a neutral pH is obtained.

3.4.2 Ammoniated Citric Acid Cleaning

3.4.2.1 The ammoniated citric acid technique will remove light rusting, loose mill scale and copper deposits. It is not harmful to stainless steel trim or other ferrous components. It shall not be allowed to contact copper or copper alloy equipment.

3.4.2.2 Fill system with a solution of inhibited 3% citric acid made with condensate and ammoniated to 3.5 pH.

3.4.2.3 Circulate at 200°F and titrate for dissolved iron. Cleaning is complete when iron titre is essentially constant for 2-4 hours.

3.4.2.4 When cleaning is complete as indicated by iron analysis, raise pH to 9-10 by addition of anhydrous ammonia.

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3.4.2.5 Place on stand-by by one of the following procedures: Passivated - Add 1000 ppm sodium nitrite as a 10% solution, aerate with plant air, drain and flush with condensate. Deaerated - Drain under nitrogen blanket. Flush with condensate until effluent is within 100 micromhos of the influent; add 200 ppm ammonia and 50 ppm catalyzed hydrazine.

3.4.3 Phosphoric Acid Cleaning

3.4.3.1 Phosphoric acid cleaning is used only to remove light rusting on steel surfaces. Mill scale or heavy rust deposits should be removed by other means (see 3.4.1).

3.4.3.2 Remove all loose rust and dirt by impingement of a heavy water stream onto the surface as supplied by a high pressure water jet, fire hose, or rotating spray head for a vessel.

3.4.3.3 Prepare adequate amount of 5% by weight of phosphoric acid (1 part by volume of 85% phosphoric acid to 30 parts water) to fill the equipment or to provide continuous circulation through rotating spray equipment installed on the vessel.

3.4.3.4 If possible, heat the phosphoric acid to a temperature of 50°C (120°F) during circulation. [Note: During winter use, the freezing point of the mixture is -1°C (30°F).]

3.4.3.5 Circulate or agitate the acid in the equipment for 30 minutes or until adequate cleaning has been achieved visually.

3.4.3.6 Remove all excess acid from the equipment. Assure that blind legs, low areas in bottom tank plates and similar areas are free of stagnant cleaning solution.

3.4.3.7 Either

(a) Wash the surface lightly with fresh water to remove excess acid and salts

and/or

(b) Circulate hot air (60-90°C; 140-200°F) through the system until dry.

3.4.3.8 Close the system and place in service as quickly as practical. If a considerable period of time is to elapse before the equipment is used, the internal air should be replaced with dry air (less than 30% relative humidity at the lowest temperature expected) or with nitrogen or other inert gas.

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PROCEDURE FOR CLEANING LUBE OIL SYSTEMS

1 SCOPE

These procedures are recommended for preservice cleaning to remove dirt, metal chips, rust, scale, debris, grease and other foreign material from the equipment.

2 PREPARATION

2.1 Disconnect the lines from the main or package equipment and provide necessary jumper lines.

2.2 Disconnect control valves, remove filter elements, pressure gauges and switches.

2.3 Blank off accumulator.

2.4 Open pressure control stations.

2.5 Blank off pumps and install auxiliary circulating pumps if required (see 3.2.2 below).

3 CLEANING

3.1 Stainless steel components.

Clean with trisodium phosphate and detergent per Paragraph 3.3 of MOC-501 (Materials Engineering Technology Manual No. 13). Dry by blowing with dry air or nitrogen.

3.2 Carbon Steel Components (Class 1 per MOC-C5)

3.2.1 Degrease per Paragraph 3.3 of MOC-501.

3.2.2 If not "pre-pickled", acid-clean (using auxiliary circulating pumps) and neutralize per Paragraph 3.4 of MOC-501, neutralize, rinse and dry.

NOTE: Ammoniated citric acid cleaning per Paragraph 3.4.2 may be used to clean steel and stainless equipment simultaneously.

3.2.3 Oil reservoirs should have been sandblasted or pickled to remove mill-scale. If not so prepared, they should also be degreased and acid-cleaned.

4 OIL FLUSHING

4.1 Reconnect all piping and provide temporary by-passes as required. Provide a by-pass around the speed increaser (if used), the bearings and/or seals to prevent accumulation of debris in the fine clearances of bearings and seals.

4.2 Provide a 100 to 200 mesh screen or strainers for inspection of the flushed oil beyond the by-passes and in the common return header connection at the reservoir. Clean or replace frequently during early stages of flushing.

4.3 Fill reservoir with oil to approximately 2" above the designated normal operating level.

4.4 Oil viscosity is to be as recommended for normal operation.

4.5 Energize oil pump to start oil flow through the system.

4.6 Once the flush is started, continue on a 24 hour basis until the system is clean, using the following procedure:

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4.6.1 Heat oil to 180°F by introducing hot water or combinnation of steam and water to water side of oil cooler. Hold this temperature long enough to raise piping system temperature to oil temperature.

Caution: Be especially careful if oil coolers are of the "two-pass" type, since uneven heating of the tubes may cause them to pull excessively on the tubesheet.

4.6.2 Remove heat source and, using cold water, lower oil temperature to 70°F as fast as possible Hold low oil temperature long enough to cool the piping system. During the cooling process, hammer the entire piping system, along the pipes, with a steel hammer, concentrating on the welded connections, flanges, and elbows, to break loose material from the pipe wall and keep it moving in the oil stream. Air can also be injected in the drain system for agitation to help sweep out particles hiding in stagnant areas.

4.6.3 Repeat steps 4.6.1 and 4.6.2 around the clock until little or no foreign material is found on the temporary strainer at the lube tank drain connection after a 24-hour cycle.

4.6.4 One method of determining system cleanliness is to install "tattle tails" on the bearing by-pass tubing. These may be made by cutting the fingers from clean white cotton gloves and wiring them to the bearing oil supply tubing. By frequently inspecting these "tattle tails", the cleanliness of the system may be readily ascertained.

Important: If flushing indicates a continual recurrence of abrasive residue, which would be injurious to the system, repeat the cleaning and continue flushing until system indicates a satisfactory pipe condition.

4.7 Once the flushed oil is clean as described above, proceed as follows:

4.7.1 Stop the oil flow through the system.

4.7.2 Drain all oil from reservoir and system.

4.7.3 Clean reservoir thoroughly and replace oil with new or thoroughly filtered oil.

NOTE: Use only lint-free materials for cleaning oil system.

4.7.4 Drain and clean filter element housing.

4.7.5 Clean or replace filter elements.

4.7.6 Remove and clean bearings and brushings.

4.7.7 Clean bearing housing casing passages.

4.7.8 Remove by-pass.

4.7.9 Reconnect piping, oil supply and oil return to bearings and/or seals.

4.7.10 Reinstall the temporary strainer at the drain header connection at the lube tank to catch dust, lint or any other foreign material that has accidentally entered the lube system during the clean-up inspection.

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4.7.11 After lube piping is re-assembled and the reservoir refilled with oil, circulate oil for a short period of time to collect remaining foreign materials in temporary drain header strainer. Stop the lube pump and clean the strainer as required.

4.7.12 Leave the temporary drain header strainer in place the first time the compressor train is run up to speed. This is usually a run only long enough to get the driver up to speed. After the train coasts to a stop, shut down the lube system and remove the header strainer. If no foreign material has collected, discard the strainers at this point. If an appreciable amount of foreign material has collected on the strainer, repeat above until the system cleans up.

4.8 Temporary flushing screens that have been installed at any connection point in the oil piping to protect the equipment against damage by any dirt, welding beads or other foreign material that might be in the inter-connecting piping are to be removed when system has been determined clean. SCREENS MUST BE REMOVED BEFORE OPERATING ANY COMPRESSORS OR OTHER EQUIPMENT SERVICED BY THE SYSTEM.

4.9 Leave the system filled with oil.

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X. EMERGENCY OPERATION (N. W. Clauss)

Chemical processing requires that all risks be recognized, evaluated and procedures, design and training provided to cope with these risks.

The thrust and purpose of reviewing the fundamental concepts of chemical processing from the viewpoint of safety is that hazards will be better recognized and action plans completed to make your facility a safer place in which to work. The end result of this effort is the preparation of Standard Operating Procedures that cover all the hidden and subtle situations that cause accidents. Remember that "all accidents are avoidable" - but only if every potential hazard is recognized in the design, installation and operation of facilities, new or old.

The quality of operator training is dependent on the quality and the thoroughness of the SOP's used for training. There is no other way to get the message to an operator of a fully automated process who ignored an alarm on the critical steam supply control valve when a DP cell failure caused the steam valve to go wide open. No other alarms were actuated, the kettle temperature remained normal, but the increase boil-up spewed 1,300 lbs. of butanol out the vent. By the time the situation was corrected the boil-up was rapidly dropping off and the kettle was at 144°C with 14.8 percent alkaline catalyst concentration in a glycol mixture. If the temperature had reached 175°C there would have been an uncontrollable exotherm.

A very recent incident in the same unit during a startup resulted in losing 1,000 gallons of n-hexanol through the jet system when the high level alarm on the condenser accumulator pot was ignored at shift change time. The operator forgot to put the overhead make pump in service.

The SOP's did not cover these possibilities and the operators were not, as a result, adequately trained. There probably is no way to eliminate all emergency situations but good thorough SOP's covering known potential problems will go a long way toward avoiding losses from emergency situations.

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The need for complete coverage of potential hazards in SOP's can best be illustrated by an analysis of a major accident. Following is an accident description, an investigation report and a published interpretation. After going over this information we will further analyze deficiencies to show the need to include all potential hazards in operating procedures.

A. Description

A major fire loss resulted from the failure of an 18" diameter process liquid stream outlet manifold on a gas fired stripper heater. The plant investigation of this incident indicated that the manifold failure resulted from thermal expansion of process liquid contained between closed inlet and outlet valves on one of the two sets of tube banks in the heater. In accordance with normal shutdown procedure this tube bank had been closed in preparation for maintenance only a short time before the failure occurred. The confined liquid apparently became heated by burning liquid from a leak in the other tube bank. A fire resulted from the release of a large quantity of flashing liquid from the ruptured pipe.

B. Investigation Team Report

The team reviewed the sequence of events in detail and outlined action plans so as to improve the safety of the unit and prevent recurrence as follows:

On the evening of August 2, 1976, the UDEX portion of the Benzene Unit was in normal operation. Plans had been made to shut down the unit about 2:00 a.m. on August 3 to repair a small drip-type leak at the base of the Stripper Column. At about 10:30 p.m. on August 2, a leak was discovered inside the 'A' Stripper Reboiler Heater, so the unit was shut down early. This heater along with the 'B' Stripper Reboiler Heater supplies the source of heat for the Stripper Column to remove the Aromatics from the Tetraethylene Glycol (TEG) Solvent in the extractive distillation UDEX Process.

When the unit was shutdown, the 'B' Heater was utilized to strip the Aromatics out of the solvent for the shutdown. The 'A' Heater was

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taken out of service at 11:00 p.m. when the feed flow was stopped to the unit. The main burners were extinguished and the heater inspected with the pilots in-service. Solvent was detected in the heater when it began leaking out of the heater meaning there was a tube leak inside. The pilots were then extinguished and the process lines blocked in. This heater has 10 parallel passes. There are two inlet and outlet headers, each with five parallel heater passes. Nitrogen was connected to the inlet header for the north side passes and valves set up to blow the solvent from the heater into the plant solvent tank.

When nitrogen was injected into the heater to clear the tubes a loud noise was heard and suddenly there was a fire inside the heater. Solvent poured out of the heater and ignited. Through the use of foam, four fire monitors and three fire hoses, the fire was brought under control within 15 minutes. The fire was almost extinguished when the 18" heater outlet line on the South side of the heater ruptured. This released another large quantity of hydrocarbons that ignited almost immediately. Flames extended approximately 200 feet to the Southeast for an estimated three to four seconds. The fire was completely extinguished within 15 minutes from the time the line ruptured. Four monitors were used for quite some time afterward to cool the equipment. Equipment damage to piping, electrical cables, instrumentation, insulation, heat tubing, etc., amounted to $200,000.

The investigation team reported there were three items that were contributing factors to this incident. The first item could possibly have avoided the entire fire. Either of the latter two items could have prevented the 18" line rupture.

1. Procedures were inadequate to clear the heater of solvent in the safest manner.

2. The South header and five passes were blocked in while full of solvent. The liquid was heated by the fire, expanded and had no place to go.

3. There were no relief devices provided to protect the system when the heater is blocked in.

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4. TEAM ACTION PLANS TO PREVENT RECURRENCE

	ACTION PLAN	COMPLETION DATE
a.	Develop adequate procedures	8/17/76
b.	Determine the need for Pressure Relief Devices.	8/17/76
c.	Resolve system erosion problem.	1/1/77
d.	Determine if snuffing steam should have a 5-minute timer or be continuous.	8/10/76
e.	Issue letter emphasizing plant policy on leaving Actylene Welding equipment in units.	8/6/76
f.	Issue letter to plant to identify equipment that does not have relief devices.	8/6/76

C. The C&P Engineering Report of the Accident

This article is intended to provide design feedback to the Engineering Department gained from a recent, major fire that occurred in the UDEX portion of a Benzene Unit. The fire originated in a gas-fired stripper reboiler heater which has ten parallel passes, five each on two inlet and outlet headers. The sequence of events began when solvent was detected leaking from the tubes into the heater. The burners and pilots were extinguished and the process lines were blocked in. Three hours later, nitrogen was injected into one inlet to clear the tubes on one header while the second header remained valved in. Immediately a loud noise was heard and suddenly there was a fire inside the heater. Solvent poured outside the heater and ignited. The

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fire was almost extinguished when the second header, which was still full of solvent, ruptured outside the heater. This second release of a large amount of solvent ignited almost immediately. Flames rose approximately 200 feet for an estimated three to four seconds. This fireball caused the greatest amount of damage. The fire was completely extinguished within 15 minutes from the time the line ruptured. Fortunately, nobody was seriously injured.

The investigation team pointed out that the procedures were inadequate to clear the heater in the safest manner. They also felt that the pipe rupture could have been avoided if relief devices had been provided to protect the system when the heater tubes were valved in.

The follow-up design feedback is noted:

1. It is the Engineering Department's practice to provide relief devices to protect liquid-filled fired heater tubes that can be valved in. In fact, in the original mechanical flow diagram for this heater, proper relief was included in the design.

   A revision made late in the design stage added shut-off valves which introduced the capability of blocking in the heater tubes without relief protection. The Engineering Department's practice regarding the subject of providing relief devices for fired gas heaters, including Olefins Furnaces is presently under review.

2. This incident clearly indicates that revisions to a design should be reviewed for safety as thoroughly as the original design. It is the accountability of the process design group leader to insure that original safety provisions are not violated or compromised by a process design change and that all necessary additional provisions are made.

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D. An Analysis Of Deficiencies Not Mentioned In The Above Reports

The team investigation report of this accident did not include or adequately cover the following:

1. The danger of design change without the usual review for safety requirements.

2. The action plan states a need to determine the necessity of pressure relief devices. How can there be a question when the operating procedures call for blocking in the process material in a furnace radiating heat? Thermal expansion would be inevitable.

3. Only by inference from the action plan do we find that the direct fired tubes were subject to erosion problems. The leak for which the shutdown was made was probably caused by the erosion problem.

4. The solvent used with the tetraethyleneglycol was benzene with a flash point of 20°F and easily ignited by the hot refractory lining or by static discharge when blown through a small leak under nitrogen pressure. The possibility of a spray or mist of benzene also would provide an easily ignitable mixture.

5. Furnace or direct fired heater linings should be recognized as a heat sink and also as an ignition source for low flash point chemicals.

6. If relief devices had been available the discharge when actuated could add fuel to fire unless directed to a safe location or collection system.

7. The procedure of pressuring material from the tubes in a leak situation should have been recognized as a hazard. The nitrogen pressure could have ruptured eroded tubes

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without the thermal expansion. The material should have been drained by gravity to a process sewer or a portable tank.

8. The time lapse from the time of the leak discovery until the system was pressured with nitrogen was two hours and fifty-five minutes. Any delay in taking proper action must be avoided in an emergency situation.

Hindsight may be better than foresight but it is nevertheless true that IF the foresight is good enough the SOP's and proper training would have prevented this $200,000 loss.

Let's take a look at an accident that caused disabling injuries and burned five people. A new organic peroxide catalyst was purchased for a solvent vinyl resins operation. The new catalyst, dicyclohexyl peroxydicarbonate, was to be used in a trial run and if successful would replace a shock sensitive peroxide, diacetylperoxide. 525 pounds of DCHP was delivered in 25 pound drums and transferred and stored in the unit cold room by Receiving Department personnel as has been normal practice for other less reactive catalysts.

Four days after the delivery a fire alarm was activated because of smoke from the exhaust vent of the cold room. Fire hose was directed to the east door and upon entry into the room small fires were extinguished with water and it was found that two walls of the cold room had blown out. It was assumed that a drum of some catalyst had exploded and with over 7,000 pounds of catalyst in the room something should be done to keep this material cool. Nine men completed the job of packing the catalyst with dry ice and covering with plastic sheeting and tarps. As they were leaving a second drum of DCHP popped, vaporized and within two seconds they were engulfed by a fire ball.

The following list of deficiencies are divided in two groups. The first includes the items that should have been covered by good procedures and training and would normally appear in the Standard Operating Procedures. The purpose being to prevent an emergency. The second list would be expected in a good Emergency Procedures Manual in order to cope with the emergency.

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1. Standard Operating Procedures Coverage

a. Knowledge of the new catalyst was inadequate. The known maximum allowable storage temperature was not communicated from the vendor or the R&D Technology Group to the departmental management. The cold room temperature was 11°F higher than the recommended storage temperature.

b. Failure to communicate to the responsible shift supervision that a new catalyst had been received or that the new catalyst had different reactivity characteristics and required closely controlled handling.

c. The cold room design was inadequate for the more hazardous catalyst. A 3" hot steam line ran within 3 inches of the wall where the DCHP was stacked. The storage room is not in compliance with Standard SF-7 for organic peroxide storage.

Had the above situations been properly covered no emergency would have occurred but since it did let's cover the inadequacies of the emergency procedure as follows:

2. Emergency Procedure Deficiencies

a. The sprinkler system was valved off to repair HAD's after the first drum exploded and was still off when the second drum exploded about an hour and half later.

b. A section of the fire water line ruptured between the first and second explosion reducing fire water pressure to 10 psig.

c. The fire and emergency squad had no training for handling organic peroxide fire as specified in Standard SF-7.

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d. Personnel assisting during the emergency (there were too many) did not wear proper protective clothing.

e. The fire squad and emergency squad did not wear Bunker Gear for this emergency according to plant safety practice.

f. Synthetic fibre clothing is less effective than cotton or wool in a fire situation.

g. A deficiency exists in handling multiple injury situations (backup ambulance, truck driver, etc.)

h. Not enough ice in the Dispensary for multiple burn situations.

i. Too many phone calls and spectator interference.

Reviewing the above list of nine deficiencies you might feel that, other than having your people wear the proper protective clothing, there is nothing directly related to your responsibility. The Operating Department does, however, have a responsibility to provide adequate emergency procedures and training for their own people and also to see that all service functions have prepared their emergency procedures and training programs to ensure the safety of their own people and the provision of quality service to your Department.

In the above list it is apparent that the fire and emergency squads were not informed of the need for special training in handling organic peroxide emergencies. The Operating Department is also responsible for eliminating the spectator interference problem. Operating management has a responsibility to see that medical emergency procedures are adequate.

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From your unit view point do your emergency procedures cover the recommended action when a sprinkler system is inoperable or when the fire water supply is non-existent?

Experience has proved that advance planning of emergency procedures can materially reduce the severity and duration of the hazardous period following a plant power failure. A plant suffered six power disturbances of varying magnitude. The first failure created so much confusion that about an hour was required to regain control of potentially hazardous reaction systems on one plant area. Similar difficulties were experienced during each of the subsequent failures, but by the time the sixth had occurred, only 15 minutes was required to regain complete control of the reaction systems. Lessons learned by experience during the first few occasions had been put to good use. Emergency procedures which had been worked out were responsible for the improved performance.

Procedures and operator training must be prepared for both unit and external emergencies to minimize losses of people, material, equipment and production capability. In addition to the items mentioned above your procedures must cover all aspects of emergencies resulting from:

1. Loss of electric power for electric drives, computer operation, lighting, etc.

2. Loss of steam or heating media used for energy input or the prevention of freezing.

3. Loss of cooling media such as water, brine, refrigerents, etc.

4. Loss of plant instrument air supply by failure or contamination.

5. Loss of inerting gas supply by failure or contamination.

6. Loss of instrument blowback by failure or contamination.

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7. Loss of vacuum by equipment failure.

8. Loss of pressure by equipment failure.

9. Loss of agitation or circulation from the loss of power or by coupling failure.

10. Loss of material transfer capability by failure of power supply, pipelines, pumps or by plugging. Including such losses that may occur external to your facility.

11. Loss of control capability such as critical control valves stuck wide open or stuck shut both in and outside the operating facility battery limits.

12. Rupture of calandria or heat exchange tubes.

13. Runaway reactions of any type.

14. Fire exposure and potential damage. Emergencies external to your operation should be included. As an example a line rupture fire in one plant caused a deflagration and detonation in an acetylene line that affected the producing unit 11 miles away.

15. Vapor cloud emergencies both in and external to your facility.

16. Rapid decompositions, exotherms, etc. Emergency procedures should have been available in on accident involving the buildup of detonatable vinyl acetylene in a butadiene refining column that resulted in a tremendous loss. The fact that the make valve could leak and cause a concentration increase when the still was on total reflux should have been covered in the procedures.

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17. Loss of all firefighting and emergency service capability, including communications, in a major catastrophy.

Again, we will repeat that no check list of emergency possibilities is all inclusive! It is hoped that this manual will result, however, in much better coverage than there has been in the past.

A power failure, loss of cooling water, or loss of any service results in hazardous situations when reactive chemicals are involved. Considerable thought should be given to the consequences. In anticipation of failure of services, procedures should be developed that will prevent not only build-up of excessive pressures, but also dangerous accumulation of hazardous gases or liquids in process equipment or in the surrounding areas due to dumping or venting.

Some of the usual methods for emergency control of reactions are:

1. Dilution or flooding of reaction mixture with an inert, cold medium.

2. Addition of inhibitor or neutralizing agent. The addition of inhibitor to a reacting mixture should be investigated thoroughly before use. There are instances in which addition of an inhibitor which is a reducing agent to emulsion-type polymerization has resulted in an increased reaction rate due to the generation of excess active centers (leading to initiation of new polymer chains) caused by a reduction-oxidation reaction involving the reducing agent and the polymerization catalyst (oxidizing agent)

3. Emergency blowdown venting to atmosphere to cool charge by evaporation.

4. Dumping the charge out of the reactor into a prepared control area.

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Attention should also be given to the design of process equipment to reduce fouling and plugging in the event services fail. Polymers form and slurried materials settle.

Other emergency control methods include:

1. Emergency blowdown devices and controls to reduce system pressure to its lowest level prior to an explosion, thereby decreasing damage.

2. Well designed energy shutdown systems.

3. Remote controlled isolation valves to reduce fire propagation to other facilities and to reduce the fuel source to a fire. The use of flame traps to prevent the movement of burning liquids to other areas.

4. The use of excess flow check valves to minimize losses from large tanks if highly flammable materials are involved.

Emergency control systems must be designed by professional specialists in C&P Engineering Department. Operating personnel are accountable for assisting in the definition of emergency control methods in the design stage and also for being completely knowledgeable about the operation and limits of the emergency control systems. You cannot permit operators for example to use emergency blowdown devices as a control method to depressurize equipment to keep safety relief devices from actuating.

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XI. CHEMICAL PROCESSING SUMMARY

Safety in chemical processing was approached by citing the importance of maintaining a high safety confidence level throughout the life of a facility. Because of economic constraints some level of risk is always present even in new installations. If risks are recognized the potential hazards can be safely handled by designing proper safeguards and maintaining a high level of competence in operation.

The importance of complete knowledge has been stressed in relation to physical properties, reaction data, the process chemistry and the need to utilize available resources in C&P so that no question goes unanswered.

Thorough knowledge of process operation can be achieved by utilization of the extreme limit concept analysis of critical operating variables, material and energy balances and reaction control considerations.

Accident cases and experience have been used throughout this section of the manual to increase your ability to recognize the hidden hazards resulting from process change, transfer errors, contamination, compatibility of chemicals and the materials they contact. Unsteady state operations such as startups, shutdowns and loss of process control have been stressed as high hazard situations.

Hopefully the ultimate benefit of this course will be a high quality and complete Standard Operations Procedures Manual and Emergency Procedures Manual for each operating system which is broad enough to include the safety needs of external service groups. The completeness and quality of these procedures manuals should improve but one thing you can count on is that the competence of the operators will be dependent on them as a training base.

The OIP effort along with the satisfaction of introducing innovative process improvements is encouraged and commended. However, the accident cases presented prove the need to utilize skilled professional resources to avoid creating unwanted hazards. Safety reviews of all process changes must be made and approved by technology and engineering managers, departmental and plant management and the related safety functions.

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As a final cliche - "All Accidents Are Caused By People - All Accidents Are Avoidable."

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PROCESS AND EQUIPMENT OPERATING SAFETY
FOR PRODUCTION ENGINEERS
AND SUPERVISORS

4. CONTROL SYSTEMS SAFETY (Prepared by H. F. Keag)

I. FORWORD AND INTRODUCTION

In this section we will cover the safety aspects of control systems applications and problems. This will be from a Production Engineer viewpoint. This section is not designed to make an Instrument Engineer out of anyone, but to help you in observing, evaluating and communicating. In most of our locations, in C&P, we have highly qualified, trained and skilled Instrument Engineers, Instrument Technicians and Instrument Repair Route Men. These people have become very proficient in their trade and are able to discuss our problems with most of us non-instrument type people. The use of the written resources that are available will be covered later on.

The safety aspects to be covered are: Proper design, degree of realiability (where needed) and in particular, the fail-safe condition for shutdown devices - so that we have everything we've asked for and can expect.

In all of the Plant Engineering Departments there is a copy of the technology manuals that cover different subjects. There are two volumes of a Control Systems Applications Technology Manual and one volume of Measurement and control Technology Manual. You will also find references to control systems safety in the Safety Technology Manual.

Some of our worse loss experiences have been related to instrumentation. As an example, there was explosion in one of the C&P Plants in the 1940's in which six persons were killed that was attributed to a faulty instrument. Another example in a C&P Plant around 1969 concerns the glyoxal explosion. In this case, excess nitric acid feed resulted in the condition that set off the explosion. More sophisticated instrumentation with more and/or better interlocks could have prevented the explosion. The Peracetic Acid Derivatives explosion at the Taft Plant in 1968 was the result of a

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series of errors of which one was the installation of the wrong type of regulator or one installed improperly. The epichlorhydrin explosion in another C&P plant the same year was attributed, at least in part, to the fact that some of the instruments were not operating. In one of the largest losses moneywise, the butadiene explosion in another C&P plant in 1969, a non-working analyzer was a strong contributing factor.

There are on record many other incidents related to inadequate instrumentation application, maintenance or use that have caused accidents throughout C&P and the industry in general.

I have broken down this presentation into several major portions. One, hardware, dominates our considerations, but we'll talk first about location within a facility, then about the climate effect of the area where the plant may be, then about reliability and accuracy, and then finally, about hardware. Under hardware we'll talk about flow measurement, level, pressure, temperature, differential pressure, interface level, boiler protection devices, analyzers, steam desuperheaters, control valves, computers, instrument air and electric power, and maintenance capabilities.

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II. LOCATIONS

The hazard classification of control rooms, the governmental codes and industry standards, and the company and plant standards are followed by C&P down to the smallest detail. Various specific guidelines exist for the electrical area classification of control rooms and analyzers buildings which are related to our topic. Most of the old control rooms were "classified" as having material that was either potentially explosive or toxic and was solved by having everything in them explosion proof, from telephones to light fixtures and switches and instruments, and even at that time, some of them had to have purged cases. Today, with our modern units, we meet this problem in a slightly different fashion. Either the control rooms are located adequately remote to the process or the control rooms and the portion of an analyzer building which houses the electronic equipment can be pressurized and purged. Most of the regulations regarding this concern are covered, in C&P locations, by an electric area classification team. We must meet all of the C&P's standards as well as the OSHA, National Electrical Code and the NFPA 496 Requirements.

When a control room is pressurized because of it being within a certain distance of potential release of toxic or flammable materials, the criteria stipulates that there will be a certain number of changes of air through these buildings, plus having a pressure on the buildings of 1/10" of water which must be maintained with a certain number of doors or openings letting the air out. OSHA additionally requires that there be a certain velocity of exhaust air through all openings when wide open. Where the buildings are pressurized by air from an external source and purged, it is proper to have an alarm on air flow failure. Also, a flammable gas detection device should sound an alarm and/or shutdown the air intake system at the point of about 25% of the lower explosive limits. Depending upon the potential for hazardous or toxic gases, we normally supply, at a minimum, six changes of air per hour. If the conditions for flammable gas potential are greater, this can be up to as high as 12 changes of air per hour. Where toxic materials are included, Industrial Hygiene may require additional changes.

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In the case of analyzer buildings, we sometimes use two rooms that are sealed one from the other. In the sample room, we treat the building as the same requirements as previously mentioned for pressure and purge rate. The analyzer detection room will frequently have electronic equipment that is very difficult to keep from being in a non-hazardous category and therefore we have two options: either to pressurize and purge the building; or to seal, pressurize and purge each of the individual electronic component cases or parts. In this case, according to NFPA 496, we are required to keep a 1/10" of water pressure from a clean source and have an audible and/or visual alarm to indicate loss of clean purge air flow.

In some of our older facilities where the instrumentation is all pneumatic and the control room is classified as a hazardous area, we always have to watch for two items that tend to slip by and that is, pressure switches and chart drives that have to be purged or we must use pneumatic chart drives. In our more modern installations, electronic instruments, analyzers, computers, are virtually impossible to purge and pressurize individually making it necessary to purge and pressurize control rooms or locating them remote to the process. In the older existing units, you continuously have to be alert to the type of instruments that are added by way of revisions so that they do not violate the original classification. The affect of distance on response time must be considered where it is important to the control of the process. This is more frequently the case in the sample supply to on-stream analyzers.

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III. CLIMATE

I would next like to cover briefly the section of our discussion on "climate". Climate affects us from a standpoint normally of cold northern areas where we have process fluids and steam and water measurements freezing in the signal leads to the transmitters. In these northern climates we also have considerable problem with freezing in the instrument air supply lines. This is to the extent that in some places driers have to be used and in other cases, we have to steam trace and insulate the low spots in the instrument supply. Ironically, in some of our more southern located areas, this can be even a bigger problem because the condition of low temperature is so seldom reached that these provisions are not included in the construction of the facilities and the people are not accustomed to fighting this battle all the time, so that freezing leads are handled by the northern plants sometimes better than in southern plants. In most areas the steam traced leads are only required in the winter or cold months, however, you also have another area that needs to be considered and that is where the steam tracing may potentially boil the material out of liquid filled instrument leads giving erroneous read-out.

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IV. REALIABILITY, ACCURACY

Instrument systems are only as good as the design data input was. In the original design certain assumptions must be made and the degree of accuracy considered in every instrument installation. As the process changes and/or is revised, this input data must be kept up and considered as to its effect on each item. We must consider the range of acceptable control, not only in the original installation, but as process conditions change or are revised. Very narrow range of control must be available in some instances and this will then give the handicap of not being able to use the same instrument for a broad change. For example: in the control of a high temperature reaction system, we may want to use two transmitters and a 3-way valve on the signal to the controller; the one transmitter would be a narrow range, say, if this was for high temperature, to control at 630°C $\pm$ 2°, we would use something that would have a temperature range from about 600 to 670°. However, there is usually a need to bring this temperature up from ambient to the normal operating range, and a second transmitter, with a range of 0 to 700°C, would be used to put a signal in from ambient temperature up to the start of the control range of 600 to 630°C.

The choice of materials of construction are usually dictated by the corrosive nature of the part of the system where they will be installed, the strength or pressure requirements of the place where they will be installed and the temperature tolerance to process or ambient conditions. When looking at temperature tolerance, one must not only consider the atmospheric temperatures encountered, but, in the case of vapors and liquids that may be superheated, their effect on the elastomers used in the O-rings and gaskets. Probably one of the biggest potentials for getting into trouble on this, is when we either replace, repair or revise a part of the instrument that is in contact with the process. We have a potential here for substitution of a non-compatable material. I'm thinking particularly here for example of a valve of a Hastelloy type material for a halogen acid process stream, where the repair must be made in the repair shops without complete knowledge of the process; it is replaced with stainless steel which would be absolutely unsuitable. In another section of this manual, you'll be told about things that effect the relief sizing on equipment. One of the areas here that can reach

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out and bite you for example: if the trim is changed in a steam valve, supplying steam to a re-boiler on a distillation column, this negates the original calculations for the sizing of the relief devices on that column. All plants should have a policy requirement that any trim size changes in valves must be cleared through an engineering consideration and safety check procedure.

For real critical items of measurement or control, one of the best ways to improve reliability is through redundance. This may be just on control, on an alarm or shutdown device or on a complete shutdown system. In some areas it may be needed for the detection devices used in the monitoring of % LEL or toxic gases on the supply of the air purge of a control room or for vibration monitoring. To have redundance of indication or control, does not just mean parallel devices at the end of the line where one would back up the other or both put off a signal together. True redundancy means to have two separate process taps, separate lines to and from separate transmitters or other sending device and separate receivers, controllers, alarms and shutdown devices. Obviously, if two will do a lot of good, the use of more than two devices may be desired for getting even greater reliability. In some cases you may want to have two or more completely different types of devices to put out signals that you're wanting to monitor that closely.

Alarms and shutdown equipment, emergency shutdown systems must be separated into critical and the non-critical. The non-critical are frequently used just for the monitoring of something that normally happens, and you want to have a signal show up that you reached this point in the filling of a reactor or something of that nature. The reliability and accuracy might be sacrified to some degree. In the critical services, you must get the best possible devices, not only from a standpoint of reliability, but accuracy. Then another area that we have seen that violates good practice, is alarms that are coming in either so frequently, or staying on so long, that they become ignored. This is one of the areas that a decision should be made, if it is a critical device, administrative controls will have to be taken to see that they are no longer ignored. If they're critical devices, you may want to go to a less annoying type of alarm. If they're the non-critical type, you may want to consider doing away with the alarm or solving the problem producing the alarm. Now, alarms and shutdown devices and emergency shutdown

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systems should be tested on a prescribed schedule and with a set procedure covered in the SOP manual. Each type of device, the service that it's in, or the degree of criticality will dictate the frequency of the testing required. This should always be set up in writing as a specified procedure that is to carry on from one genertion to the next. Not to meet this schedule would be a deficiency. Also, the testing of the shutdown devices should be from a point of origin, for example: in the case of a detection device in the inlet air duct pressurizing a control room, the actual analyzer probe should be removed and exposed to the calibrating gas that it is trying to detect; it is not sufficient to merely test the electronic output of the system. An acceptable bypass switch or other means for testing shutdown systems must be provided during design. Transmitters are sometimes installed in a process with no means for checking accuracy or performing normal maintenance without shutting down the unit. The process may be too hazardous to allow bypasses, however, some compromises may be needed or parallel set-ups required.

A couple of other items that fall into this discussion on reliability and accuracy are devices for measuring the running condition of critical driven equipment. The simplest thing is running lights. This can also be done off of a shaft on the driven equipment with a sensing device such as, a reluctance pick up (toothed wheel), or worm gear to a tachometer generator. In some cases, electrical driven equipment can be checked with a measure of the ampere rate to the motor of something like an agitator or a pump where, if the mass and viscosity are assumed constant, a drop in amperes would indicate a shaft breakage or an impeller or propeller coming off. Another one that we frequently run into now is vibration monitoring on the large, high speed rotating compressors and on fin-fan blades.

So far, we have just talked about reliability and accuracy of the individual instruments or alarms or systems, another point that needs to be brought up is the reliability or the redundance of the supplies that operate the devices in our areas of concern. By this, I mean the electrical instrument power should have an emergency back-up system. When you have this, you would normally want to take one source off of the process electrical supply and another one off of the lighting electrical or utility supply. In the case of instrument air, you would want to have parallel filters or strainers which can be monitored for pressure drop and disposal of the build up of materials

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accumulated. In addition to this, you may even want to have a separate original source of the instrument air or instrument gas (which could be nitrogen or other by-product gas) that may be characteristic of the individual plant. You must be careful that the back-up does not contain flammable gases; such as methane, hydrogen or propane since it would be impossible to assure that every place the instrument air is used, is safe to the electrical spark generation potential. In all cases where instrument air is used in closed control rooms, the switching to a backup gas must be alarmed to prevent breathing air problems. Certain electrical sources use battery back-up power. In the cases where this is done, a formal schedule should be put out for testing and monitoring the condition of the battery back-up power. Analyzers and computers also need emergency back-up power for operations. The "Fail Safe" action of all instrument loops should be considered in the original installations and in all revisions for every segment of the loop.

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V. HARDWARE

Hardware is the heart of instrumentation. We will be talking about flow measurement, level measurement, pressure control, temperature, differential pressure, interface, analyzers, control valves, computers, boiler protection, etc.

Flow Measurement

The example at the start of our discussion of this section, will give you an indication of why it is frequently important to have reliable, accurate flow measurements. This part of the system is relatively simple. Most of us understand orifice runs and orifice plates. The type of accuracy put into and the precision used in fabrication of orifice runs and plates, makes them acceptable for places where you can tolerate the differential pressure and you do not have other problems; such as having pulsating, two phase, or dirty material. In the case of liquids you need to have a vent hole at the top of the plate for the gas to keep from getting trapped in the back of a liquid orifice plate and for gases you need to have drain holes at the bottom to keep from trapping liquid in the bottom of the gas orifice run. Liquid leads should be tailored, or of the type, to suit their needs. You can have sealed liquid filled leads, normal process fluid filled leads, vapor filled leads, self draining leads, gas blow-back or a combination gas blowback and liquid drip, or liquid blow-back. The choice of which of these to use would depend upon the type of service or conditions encountered, such as: are there solids or dirt to contend with, characteristics of plugging, polymerization of the material in the leads, depositing out solids or salts. In each case you should make sure again that you have the ability to blow the leads, to flush the leads with liquids, or in some cases you may even have tees in them so that they can be drilled out through a packing gland. The leads should be capable of withstanding both the process side corrosion as well as the external corrosion problems. Care should be taken in the installation of the leads to consider vibration, mashing, freezing, support, fire exposure, thermal expansion. Orifice differential receivers in their simplest form can be U-tube or manometers. What is used most of the time is differential pressure cells. The limitations in the use of DP cells is extreme temperature and

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pulsating flows. Pulsating flows can be frequently compensated for by using a pulsating damper, but this at the same time does leave some problems with decreasing the accuracy and response of the signal from the orifice run. A few of the rare cases where pressure drop is of great concern, pitot tubes or venturies can be used; the same is true with them and their loads and receivers as with orifice runs. For pitot tubes to be reasonably accurate, you have to be very precise in the position they're located and the direction. The most primitive of measuring devices are overflow weirs, used mostly in sewers and trenches.

Very frequently you find rotameters being used today and they are basically two kinds; glass tube and magnetic tube. The hazards of using glass tube, of course, is breakage of the glass tubing through vibration, strain, and impact. Glass rotameters should never be used for flammable and highly toxic materials. The magnetic rotameters do have a problem with dirt and other materials getting into the narrow clearance between float and tube wall. There's also another danger and that is if the flow changes too fast, the float can leave the magnetic indicator and it can actually be at the opposite end of what it's indicating. Flows have to be put on very gradually. A last problem with the magnetic rotameters is that they do not stand up well under pulsating flows and the results that they give are just a wild guess when it's bouncing up and down.

Positive displacement meters have several major problems. One is flashing which can cause trouble anywhere from getting gas readings, to rapid mechanical wear, to physical breakage, and to damage of the elements inside the meter. Another is dirt or solid which can cause all these others plus erosion. Another is correcting for changes in physical properties. In good clean nonflashing liquid service, positive displacement meters are considered to be sometimes far more accurate than even our best orifice runs. They're used in a variety of blending and loading installations.

A few other of the flow measuring types of devices that are seldom used, would be rate of fall of liquid level in tanks, rate of fall of weight scales, sight glasses with flappers (these can also be non-glass using magnetic for position of the flapper); these are rather crude. Some of the newer types of devices are turbines and using radio frequency devices.

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I'd just like to discuss rate of fall of liquid level in a tank. These can be used in tanks such as inhibitor feed tanks that are tall and small in diameter and are recharged and fed out over a fairly long period of time with batch charging, either by having two tanks, one of which is charged while the other one is being used, or where one only takes 30 minutes to charge it and runs 24-48 hours on the feed cycle. This rate of fall can be recorded and in many cases with a little more complicated instrumentation can be used for control. It's an excellent use of a completely independent redundant system for use in duplication of flow measurements. Weigh scales could be used the same way.

Levels

Level, as we have indicated in one of our examples at the start of this section, is frequently the cause of accidents. The oldest means of level and level measurement in tanks, of course, is to take a rod and stick it down in a tank or vat like they do in a gas station and see how far the rod is wetted. The simpler type that has been used by Carbide in a lot of tanks for many years has been floats that are suspended in the tanks reading out on an external tape, gage board or sight glass. The major problem with floats is corrosion of the float and cable and the hang up of the float on the anti-swirl cables that are frequently installed, or the pulling of the float around if it is not anchored for keeping it in one line, or the liquid seals to hold pressure out. Turbulence is definitely a problem unless the floats are suspended with guidewires. As long as they don't get holes in them, and don't hang up, there's just not much else that can go wrong with them. To operate one properly, it should be checked and should be moved from the outside some distance up and then see if it comes back to rest at the same location.

A sight glass is another device that has been used for many, many years. The old glass tubular sight glass is pretty hard to beat if the material is anywhere near clean and if it isn't clean, you can flush it from top or bottom. This type of device, due to breakage, has caused many accidents to personnel and release of materials resulting in incidents or fires. The tubular sight glass for flammable or toxic materials is forbidden in C&P

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plants. The more acceptable type of sight glass is the high pressure reinforced glass sight glasses or the magnetic type. The former example being the so called Jergensen sight glasses. These are the type that were developed primarily for high pressure boilers. These have excess flow ball checks in each tee valve. They are used on hazardous and flammable chemicals when there's no other means of doing it, or as a redundant system to be put in service to check the other measuring devices. The major concern here, of course, is the materials of construction, and very important, the compatibility of the elastomer gasketing with the process material.

DP cells that we discussed in a use with orifice runs or pitot tubes or venturies are also used for liquid level indication and/or control. Again, the same problem exists for this service as would be for flow measurement, and that is the integrity of the leads for internal and external corrosion, the type of leads, and the problems with vibration, freezing, support and fire exposure.

There are two other types of floats that work somewhat the same way. They're not suspended from cables, as we discussed in the first part of level measurement, but rather these are suspended either as a ball on the end of a rod transmitting a torsion to a device something like a DP cell or transmitter and those in which the liquid actually comes out of the vessel into a float chamber mounted close to and on the side of the vessel you're measuring it in. There is usually a long cylindrical cylinder that hardly moves at all. It does transmit a torsion strain to the transmitter which then can be transmitted in to a control instrument. Problems concerning these would be corrosion, the strength of materials, if the material can freeze at ambient temperatures, the difficulty of steam tracing the float chamber. The fact that these are not used in Carbide plants to any extent, you would not have the expertise in your Maintenance Departments for repairmen coming in from other areas and being able to set these properly. There is another problem involved in cleaning them.

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Mass Measurement

Weigh scales as they have been developed to date are much improved over what they were 15-20 years ago. The weigh scales now are solid state electronic measurement from a completely safe external pillow underneath the legs. The only concern with weigh scales is that they be properly installed and they have to be in a relatively clean atmosphere. In painting or re-painting of weigh scales as part of maintenance, you have to guard against people blocking up the slides that guide the vessel being weighed and also the weigh pillows themselves. Weigh scales as I mentioned before also can be coupled into a recording device which can control the flow of material by loss of weight rate and are pretty reliable type of devices. I think possibly one of the areas of concern over weigh scales is again the knowledge level within most of the plants for maintenance of the weigh scales. The last of the level or mass measuring devices that I'd like to talk about are the radioactive devices. These are, in my opinion, a case of last resort where the disadvantages are that a Radiation Protection Officer has to be available within the plant to sign for exposure around the area, to monitor the area and to survey the maintenance on it. It would have to be a controlled area. Incidentally, these are also used for density measuring devices.

Pressure

First of the pressure measuring devices for either vacuum or very low positive pressures are u-tube, straight or inclined type of u-tube manometers. These are referred to quite frequently around boiler installations as draft gauges when inclined. These have a very sensitive but limited range of use. In cold areas you have to be concerned to use a non-freezing liquid in them. Most references are made to something of a gravity of 1.0. There just isn't too much that can get you in trouble with a plain old bent piece of glass tubing other than breakage. With regards to the commonly used pressure gauges, that is, Bourdon tube types, the things that we are concerned with relating to safety here, is of course, corrosion of the material under the pressure gauge, the pulsation, also overpressure limit. Pressure gauge that have been designed to measure 0-100 psi have been known to blow-up, with serious consequences, when suddenly exposed to pressure 1-1/2 to 2 times their

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top rating. Pressure gauges have been known to eat out also the with corrosion products and as a result of this, if you need to use a pressure gauge around corrosive service, you need to put in a diaphragm, oil filled, pressure gauge. The biggest problem with these are they eventually leak out some of the liquid sealed between the diaphragm and the gauge. Or someone doesn't recognize the installation of the diaphragm and it will therefore be abused and mistreated. Then you've got the same problems you had when you didn't have the diaphragm in to begin with.

Pressure Measurement and Control

Pressure transmitters are essentially the same as differential pressure transmitters. Again, you can have liquid filled, vapor filled, self draining, gas blow back, etc., type of leads. The integrity of these pressure transmitters is pretty high and the reliability is pretty good and there is a very little limitations to the use of these. All the comments I made on the differential pressure transmitters would apply right here to the pressure transmitters.

Pressure regulators and back pressure regulators are used extensively throughout C&P Plants for various services and various ranges of pressure that they're controlling. Most of the pressure regulators have a weakness in that they need relief for their diaphragms. The common "Big Joe" regulator used in blanketing tanks that have very low pressure, frequently has to have a step down from whatever the source of blanketing gas is because sometimes you can't handle this all in one step. For quicker, more ensitive and more accurate use in this low pressure service, it is not unusual to also use a pilot regulator in connection with the two pressure regulators in series. Reliability of these is very good. With pressure regulators up to the high pressure range, you're primarily concerned with the materials of construction that are available for the needed strength. Two words of caution here, 1) the downstream pressure rating may not be the same as the upstream pressure rating, hence, if a valve were closed downstream, and if the pressure regulator did not shut-off 100% tight, it could exceed the downstream pressure rating of the regulator body, and 2) involved in sizing relief devices, full flow to the vendor means maximum flow at some specified drop in downstream pressure and

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they will put out much more as the downstream pressure goes below that specified level. Pressure switches are another category in which the old standby is gradually fading out. It was primarily the one that had the little oblong glass capsule filled with mercury that tilted from one end to the other to make or break contacts. This entire enclosure must be kept inside an explosion proof case. These were susceptible to vibration damage more than the new type that is now coming out which is basically a solid state type of pressure switch.

Temperature

Thermometer wells, as they have been used in C&P, have been pretty good but many times with contract construction and outside engineering design people we have found places where they do not live up to the Carbide standards. There is a tremendous requirement of strength in cases where the thermowells have to be put in perpendicular to the flow in a pipe or piece of equipment. The vibration due to velocity and the weaknesses that are brought about by this have caused quite a few serious accidents, mostly to equipment. There is a specific new standard under piping in the STM. There have been known incidences where a temperature measuring device which went inside of a thermowell started giving bad readings and the instrument man would remove the temperature measuring device from a thermowell to find out to his shock and surprise, and sometimes to his regret, that the thermowell was no longer any protection between him and some high pressure, flammable or toxic material. The best way to avoid this velocity effect on thermowells is to put them in at elbows parallel to the flow inside the line.

The cheap plain old fashioned dial thermometers just do not stand up very well for long periods of time when you have the normal vibration that you get around a chemical manufacturing unit. This is a case where the more expensive ones are the best bargains. Other temperature measuring devices are: filled capilary instruments with the expansion going through a transmitter and being transmitted into the control device. This is best with pneumatic instruments. With thermocouples, there is not very much in the way of anything that could happen to them, except they do have a limited life in high temperatures up in ranges of 600-700°C, the thermocouples themselves

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probably should be changed somewhere around annually. Their accuracy can be as low as ± 1/2%. One of our newer devices is the resistance temperature detector. This one can get down to ± .10%. The limitations on this does not go up to very high temperatures such as the thermocouples are capable of doing. In all cases in this category it is just about violating the Ten Commandments to install any one of the temperature measuring devices that I have mentioned, into process piping or equipment without the use of an approved thermowell.

Differential Pressure

Differential pressure is a measurement just about the same as for liquid level and interface levels. The leads again, can be liquid filled or vapor filled, gas blow-back same as with the other ones and one of the unique things about differential pressure is that it is a very sensitive sure-fire way of putting in a redundant system to check valve. I have seen check valves that had varying degrees of reliability. In the case of an extremely critical condition, a differential pressure instrument can be used, measuring across a restriction (such as from one side of a shut-off valve and a check valve with their normal pressure drop) and used to close a conventional type of motor valve. Anytime the pressure downstream gets equal to, or higher than the pressure on the upstream side, it closes the motor valve as the check valve was supposed to do.

Interface Level

The simplest of the interface level devices is a gauge glass, where you can see the two layers in the sight glass. Sometimes the dirtier materials makes it very difficult to see and sometimes the tendancy will be for the materials, if they have a very low differential specific gravity, to hang up over the slightest of obstructions. Corrosion is a concern in this area and, of course, glass is no longer acceptable.

Our good old friend, the DP cell, is probably the most universally used interface level indicator or controller in C&P. The leads are normally filled with the process liquid. You again run into the problem of one layer,

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normally water, in the cold climates. You'll have to protect it from freezing with steam tracing and other things. And again, the danger of steam tracing is having too much where it influences the boiling or turbulence inside the process leads. The other companion to this is the internal float device that's used by a lot of other people, not so much by C&P. The problem here is in the fact that the differential specific gravity is all that's being noted between the bottom layer and top layer, and therefore, it's normally a very low range of differential pressure actual measurement. Same thing is true with regards to integrity of the leads, corrosion, etc. The biggest problem with external float device is that it now works on a very small range of actual measurement and the specific gravity change of water with regards to temperature is rarely the same as the specific gravity change of the organic layer with regard to temperature. You'll get this type of thing where the level could stay constant and the difference between cold nights and hot days will in effect really make the level go up and down inside the vessel while you're getting a constant reading on the read-out from the float device. There is a newer type of device which is sometimes more expensive, and not as well known except by the better informed instrument people, and that is where either capacitance or conductivity is used to measure the interface position in a vessel. These are a little hard to maintain and sometimes difficult to check in service. I guess one of the other big problems, again, is that it takes a sort of special knowledge of this particular type of device which can be acquired by the instrument repairman, but his backup brought in from a different area may have troubles with it.

Boiler Protection Devices

The people who design and operate steam generation boilers or similar devices have, as far as we production C&P people are concerned, their own type of thing, as far as the way they instrument equipment. The State usually has very rigid laws as far as the safety devices and protection. Boilers are usually shutdown on high level or low level in the water drums and they have protection relief devices that are unique to their segment of our business, that have to be reset each time to bring a boiler backup. The one thing in particular I'd like to point out is that the liquid level controllers or shutdown devices are to be exercised on a routine schedule; not just by

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imposing a signal on it, but by the actual raising or lowering of the liquid level in the drum to see that the response is obtained. Of course, you do this a step short of shutting down the boilers. As the last thing on boiler protection, most C&P Plants Steam Generators use mostly Bailey controllers. The controllers usually require an instrument man who is specialized in Bailey controllers. There are a lot of differences between the conventional Foxboro, Taylor, Honeywell types that we use and Baileys. Most states steam boiler codes, as well as C&P, now require Flame Failure Safeguards.

Analyzers

Analyzers are starting to be used more and more in the process industry, not only as an on-stream indicator, but now as on-stream controllers or feed into computers which in turn do the controlling based on the analyses. The design of these analyzers is a specialty field all of its own. Some of the critical things to be considered are: is the time lag from the sample point to the analyzer fast enough, do you get a fast enough cycle time, and do you have the overpressure protection that's required? You need to be specifically concerned with the location, as we discussed under the general category of location. It's usually in a hazardous area and it's an ignition source. Again, we find the problem that analyzer mechanics are usually pretty good instrument mechanics who then must specialize in analyzers. The problem of keeping analyzers properly maintained and calibrated is pretty important. The capabilities of back up people to the regular repairmen is again a serious consideration. Analyzers, as we told you in the opening introductory paragraph, was considered to be at least in great part responsible for the butadiene explosion and fire.

Steam De-Superheaters

Steam de-superheaters are frequently required in the total complex of the chemical plant where the steam is used at different levels and expanded down for use at some lower level which ends up with sometimes more superheat than the lower level user can tolerate. In most of the places we use pretty much of a compact, locally mounted control device. The feed of the de-superheating material into the main stream sometimes may come from a very high

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source of pressure and you'll have to take that into consideration when you specify for a steam de-superheating station. The downstream valves might get closed. When this occurs, you have to be sure all parts are capable of handling the maximum pressure of all materials coming from the upstream source. Another problem is when the temperature source is too high for the downstream equipment when you have a loss of the de-superheating material. Speed of response is again an important factor in this installation.

Control Valves

I probably should've talked about control valves a lot earlier in this discussion, but there is some merit to getting together all of the different devices that do the controlling of a valve first. The signal of temperature pressure, etc., is the input to the controller and then the controller sends a signal out to the control valve which is the end result. Here design is very important. The type of valve that you would specify is influenced by the flow characteristics that you have to live with or that are desired. The materials of construction of control valves are a matter of concern as usual. The maximum flows are usually the thing that dictate the size of not only the valve, but the size and type of the trim inside the valve. Most of these places we are talking about are the conventional parabolic, or needle or other types of plugs. Bellows versus standard packing is purely a question of the need to go to bellows packing for extremely high temperatures or extremely toxic material. Packing glands will sometimes stick if a valve stays in a single position for long periods of time. The use of "Grafoil" packing has solved many of the incidents of valve sticking in high temperature service in the past. All of these valves usually have air on one side of the diaphragm versus a spring on the other side to give the control action.

You have to study what is the safest condition or position for this valve to be in during emergency or shutdown. The normal procedure for important control in cases of loss of instrument air supply or in ESD service is to put an intercepter valve in the air signal to the controlled valve. The newer type of intercepter valves have built in bypasses that allow for testing of the ESD loop without shutting the system down or wiring up latches. You must be sure in your study of fail-safe condition that both the air supply and

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its action and the electric supply and its action are studied so that both components fail in a safe direction. The consequence of using stem limit stops to prevent valves from closing or opening in normal service, or of using hand bypass valves to augment capacities, must be carefully analyzed as a potential source of hazard under abnormal condition. Minimum flows are also of importance in talking about control valves.

There are two things that I'd like you to keep in mind. One is that the flow can be too low and if the plug is just barely off the seat you will quite frequently get the chattering which leads to rapid wear, and this chattering may be as a result of cavitation going through a real tiny opening, if a valve is too big. Today we are using some of these control valves without bypass and shut off valves. In cases such as this, we have to use hand wheel jacks for overpowering the air signal in one or the other or both directions of the stroke of the valve. You can get special valves that will give positive shut-off, if that is what is required, however, the best control valves normally will not give positive shut-off, so that you must take into consideration if you use it in part of a ESD system, that the motor valve is not going to completely stop all flow. One of the better types of an ESD system valve is to use a piston operated ball valve. The materials to be handled or real high temperatures may limit you from using something like this. The fail-safe considerations on the piston operated ball valve are, again, that the electrical action intercepting the air to the piston be a fail-safe type of action and that the air supply to the piston also be a fail-safe direction. The shutoff that use pistons have one of two things; they either put air out in only one direction of the piston against a spring in the opposite direction, or they can have air move it in either direction. In other words, to open or close, you reverse the side that has positive pressure air and bleed the other side off. This last device is not fail-safe because it does require air to change the position. Where you have the air opposing the spring action, this will be fail-safe if it is set up in such a way that the loss of air pressure gives you fail-safe condition.

Butterfly valves are another type of valve that can be used, and again, if you're in high temperatures, it's pretty hard to get a butterfly that will completely close off the flow without having the problem of having

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it stick. This is due to the difference of temperature between inside and outside or the different alloys and the thermal expansion of the flapper itself. There are newer types of valves which are the wafer type of construction that will give close to positive seal and still not have the sticking problem when closed.

Computers

Computers are getting to be the primary thing in new installations, and in modernizing older existing facilities, to give not only better control but usually with less manpower. Computers are very sophisticated instruments and the training required to maintain computers is extensive. Training is also required over and above the normal training in older plants of the people who are going to operate the computers to know their limitations and to know how they can be fully utilized. This includes the ability to monitor many points for alarm conditions and to energize emergency shutdown devices. Safety limits set into some computers must have strong Administrative Controls to assure that the wrong action is not called for. You do have an improvement in what you can get in the way of control and shutdown by the use of computers. However, you must also recognize that programmable computers can be messed with and conditions changed without giving you the protection you want. So training is the big word in the use of computers. Computers can be used for any critical service for specific action including control, alarm and shutdown. Production Engineers need to be cautioned about changing ESD systems in programmable controllers and in relay devices without thinking through the problem; the first assumption may be wrong. Keep in mind that they are subject to as many, or more, failures as the standard old fashioned type instrumentation and you should have a redundant backup to the computer critical action and the operating force needs to be informed and trained on how to operate without the computer when it is lost.

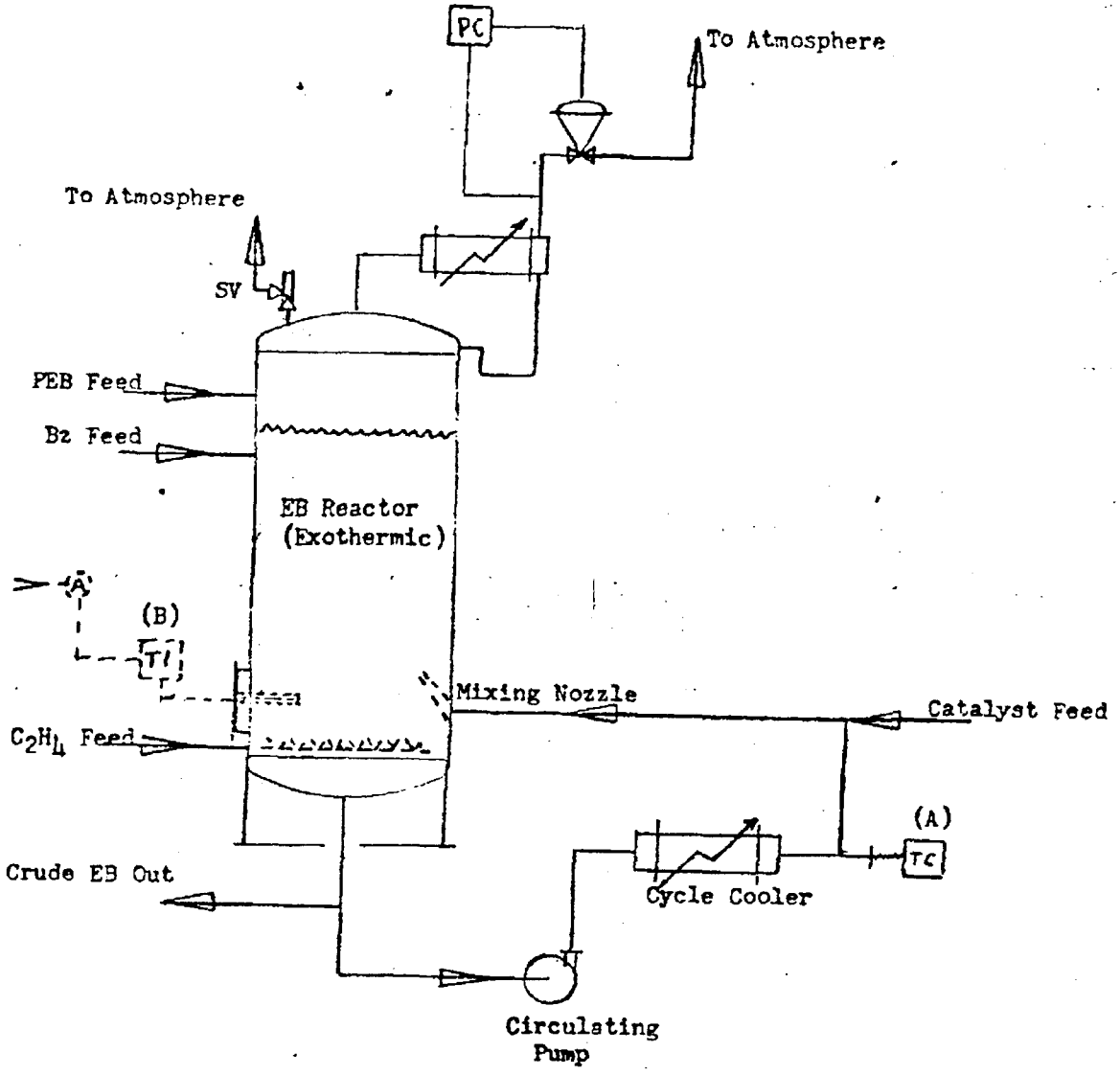
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VI. SUMMARY

I'd like to summarize the material that we've covered, and again, reemphasize the high points. The importance of getting a control system to work is in the quality of the input data for the design and that the production people need to have some basic knowledge of instrumentation and control systems in order to communicate with the instrument trained people. One of the more critical periods in a production facility is during the first startup. Instruments and control valves are sized for normal conditions and frequently during the first startup, few things are normal. The first tendancy is to start changing shutdown systems, control valve sizes, or control loop configurations. Think before you change. A lot of thought was given to safety during the design. Review any proposed changes with the original designer or, at least, with another skilled person if at all possible. These resource people not only should be used, but in making changes it is an absolute necessity to work through these people. The individual production type can always increase and broaden his knowledge by the use of reference books and manuals that are available in all of our plants. There are many good courses in basic instrumentation. Years ago control systems course were not taught in the colleges in getting most types of degrees. Today instrumentation is taught as one of the courses. Extensive computer courses are mandatory for most technical degrees and most of you have better knowledge of computers, programming, and so forth, than the graduate of 8 to 10 years ago. The next phase of importance that I'd like to reemphasize is that fail-safe conditions be considered not only in design but any time a change is made in the process or the instrumentation. The reliability of instrument air for pneumatic instruments and electrical power supply and instrument air for electronic instruments, analyzers and computers should always have a back-up supply and not be limited to one source. The quality of the supply is also important. If you have any additional questions concerning control systems safety you're best source, your main resource, is the instrument trained people in your plant or Engineering Department.

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I.



EXAMPLE FOR NEED OF REDUNDANCY:

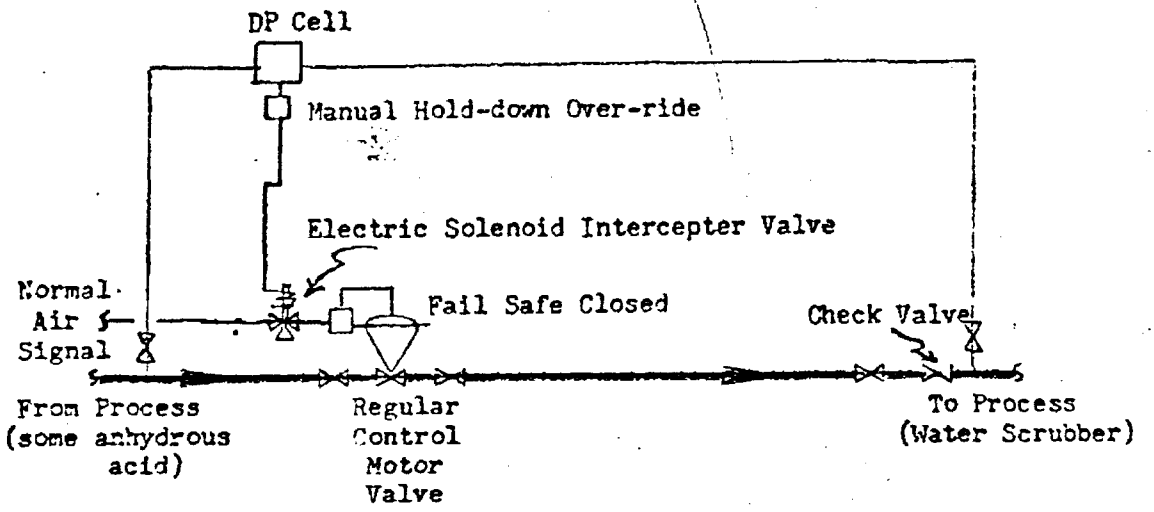
1. Reaction is Exothermic; reaction is very dependent on agitation; all heat is removed in cycle cooler; agitation is mostly from mixing nozzle off circulating line; reaction temperature is just a few pounds over vapor pressure of benzene at reactor temperature; vent condenser is small; cycle cooler is also hooked up for steam heating for startup.
2. Circulating pump kicked off but this fact was not discovered.
3. Reactor pressure started going up and venting pretty hard.
4. Reactor temperature per controler (A) sarted dropping.
5. Steam was put on Cycle Cooler to turn temperature around.
6. Safety valve eventualy started to relieve; hazardous vapors started to become a potential of greater degree.
7. Ethylene feeds, which were being reduced gradually, were finally cut drastically.
8. Pump was then found to be off, was started and true temperature was found to be considerabv higher than normal, was brought into control and all beccme normal
9. Redundant TI would have shown this; was eventually installed.as (B)

HFK, 3/31/77

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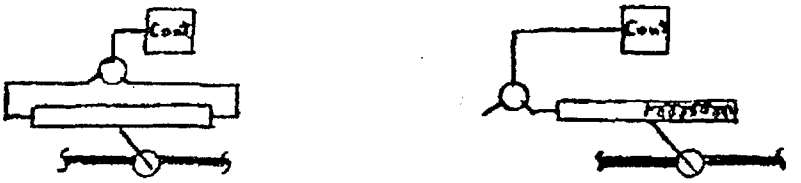
II,



EXAMPLE OF USE OF A DP CELL USED AS A REDUNDANT DEVICE FOR A CHECK VALVE

With positive pressure drop signal received to DP Cell, the normal signal, is received to the Motor Valve.

With zero or negative signal received to DP Cell, the electric power to the holding coil is interupted which in turn interupts the normal air signal to the motor valve, bleeds off the air signal pressure, closing the valve.



NOT Fail-ssfe Ball Valve

Fail-safe Ball Valve

EXAMPLE OF A TRULY FAIL-SAFE AND A NOT FAIL-SAFE SHUTDOWN DEVICE

HFK, 3/30/77

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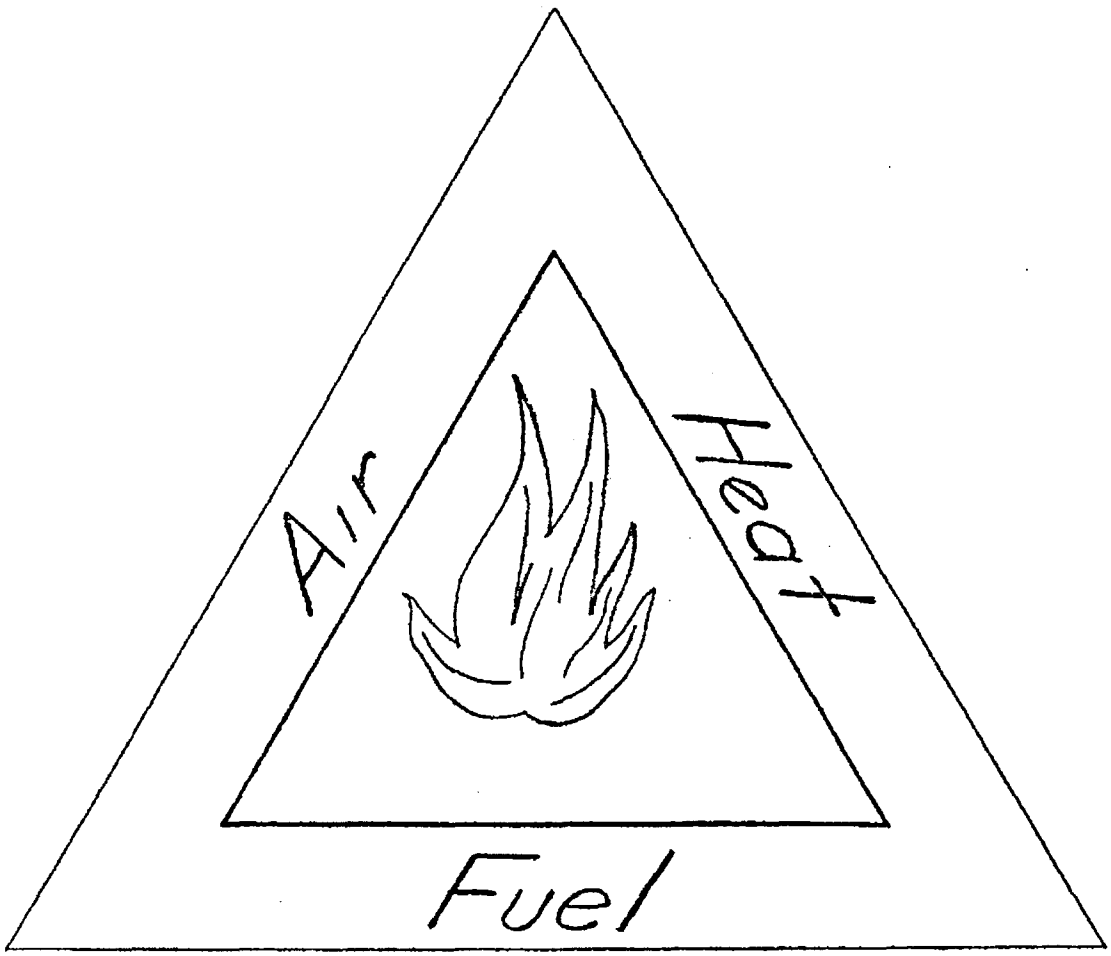
I. FLAMMABILITY (H. E. Peterson)

A. Introduction

The purpose of this presentation is to emphasize the importance for recognizing the various sources of ignition which cause fires and explosions when flammable materials and oxygen are present and to recognize the presence of flammable mixtures. Our daily tasks within the processing plants expose us to a broad range of fire hazards because of the presence of flammable solids, liquids and gases. Protecting our working areas from threats of fire brings into perspective those programs that seek to control the use of open flame or other potential sources which ignite flammable mixtures. For example, the Hazardous Work Permits in wide use throughout the Chemicals and Plastics Division is a mandatory procedure formally adopted for this purpose. Other company programs committed to the practice include: Vehicle Entry Permits, Welding Permits, etc. It is obvious that recognition of ignition sources is all important if elimination of unwanted fire is to succeed.

The role of ignition in the fire process can clearly be shown in terms of the fire triangle. For simple demonstrational purposes the three sides of the triangle represent fuel, oxygen and heat, all which must be present for fire to occur. However, any two of the elements shown on the triangle can combine without risk from fire as long as the third component is excluded. If either fuel or oxygen is absent no fire will occur. Obviously without some heat to start combustion there can be no fire. The heat or energy side of the triangle is initiated by the ignition source. Because most plantwide operations are surrounded by atmospheric oxygen (air), protection of flammable materials from contact with all ignition sources is a necessary precaution for eliminating unwanted fires.

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Fire Triangle

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B. Combustion Of Flammables

Burning of flammables is sometimes more complicated than is explained by the fire triangle. For example, in addition to air, the oxidizing substances shown on the fire triangle can include a variety of agents such as pure oxygen, peroxides and halogens. However, most plant situations involving common fire hazards occur in the presence of normal air. It is the vapor or gases of a flammable liquid that are capable of entering into combustion rather than the liquids which must be vaporized and mixed with air before they can burn. Based on these considerations combustion for our purposes is an exothermic reaction involving a flammable vapor generally in contact (but not necessarily) with air.

Although it is vapor of a flammable liquid rather than the liquid itself that burns, several properties of a flammable liquid influence the degree of the fire hazard. The flash point, ignition temperature and explosive limits are of particular importance. These properties vary for each flammable liquid. The flash point of a liquid is the temperature at which it gives off vapor sufficient to form a flammable-air mixture. At the flash point, the liquid will not continue to burn unless it is further heated to a higher temperature. The fire point is the higher temperature at which the liquid flashes and continues to burn. The ignition temperature (auto-ignition temperature) of a vapor is the minimum temperature required to initiate or cause self-sustained combustion independently of the heating or heated element. The explosive or flammable limits are the minimum and maximum concentrations of vapor in air that will support flame. Because environmental conditions can also influence flammability characteristics, the overall behavior of combustibles burning in air can conveniently be shown on schematic fammability diagrams.

In developing these diagrams the relationship between the physical properties of the combustible and the flammable limits are experimentally determined at varying concentrations of the combustible while changing temperatures but holding pressure constant. A plot of these values establishes the boundaries of the flammable region. Among the physical properties of a liquid is the vapor pressure. The vapor pressure of a substance

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is related to its volatility (a measure for change of liquid to its vapor) and is a primary factor in setting conditions under which an ignitible mixture can occur. Highly volatile liquids are more hazardous because they extend the flammable region toward lower temperature.

The stoichiometric mixture of a combustible and air represents the theoretical composition for burning and the maximum energy release. Concentrations of vapor reduced below this mixture are termed lean and a low concentration can be reached which will not support ignition. The lowest concentration of vapor which will support combustion is called the lower flammable limits (LFL) or the lower explosive limit (LFL).

However, if the vapor concentration is increased above the stoichiometric composition, the mixture can become so rich that combustion will not occur because of insufficient oxygen. The highest concentration of vapor which will support combustion is the upper flammable limit (UFL) or the upper explosive limit (UEL).

For example, the lower and upper explosive limits for ethane respectively occur at 3.0 per cent and 12.5 per cent by volume in air. In oxygen the values are different and the range of the explosive limits are extended. For mixtures of two or more flammable materials the properties will differ from their components. In the case of mixtures it is common practice to base precautions on the properties of the more hazardous component. The flammable range, which can change with temperature, becomes greater at higher temperatures.

In examining a finished plot, Figure 1 illustrates how the UFL concentration increases slightly with temperature, and the LFL line descends as temperature increases. All mixtures between the two limits are capable of burning. Plot of the vapor pressure of each combustible with temperatures establishes the partial pressure line (ratio of oxygen to combustible) and is a clear borderline between mixtures which are just capable of ignition at specified temperature and pressure, and those that are not. The intersection of the pressure line with LFL at A is where air above a liquid contains just enough vapor to allow a flame to propagate. This is the flash point. At mixtures too lean or rich, concentrations are reached at which a mixture will not sustain combustion.

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Flammable limits can also be influenced by other factors. For example, the threshold of ignition generally varies with the square of the pressure of the mixture. Lowering the pressure below atmospheric pressure (vacuum) generally has little effect for the first few hundred millimeters; beyond that the upper limits descend to intersect the combustible vapor pressure curve and then converge with the lower limit so that ultimately no mixture is capable of propagating flame. This effect of absolute pressure on limits of flammability is shown in Figure 2.

A more generalized flammability diagram of a particular combustible-oxidant system can be presented in a three dimensional plot of temperature, pressure and combustible content - as illustrated in Figure 3. Here, composition is given as the ratio of partial pressure of the combustible vapor $P_{vapor,}$ to the total pressure P. For any value of P, the limits of flammability are given as a function of temperature. The behavior of the flammability of methane-air mixtures is interesting when temperature and pressure are increased simultaneously. The flammability range is extended from 5-14% at S.T.P. to 2-75% under sudden compression of the order of 100 atm.

Because the limits of a combustible gas are much closer in air than in oxygen, so the limits of air with inert diluents such as carbon dioxide are closer than in pure air. This is shown in Figure 4 where it is apparent that the increase in the amount of the CO_2 diluent causes the lower and higher limits of methane to approach and finally coincide. In general the addition of a diluent lowers the value of the upper explosive limit, but usually does not have a significant influence on the lower explosive limit. Inerting a flammable mixture is an effective method for reducing the degree of the explosive hazard.

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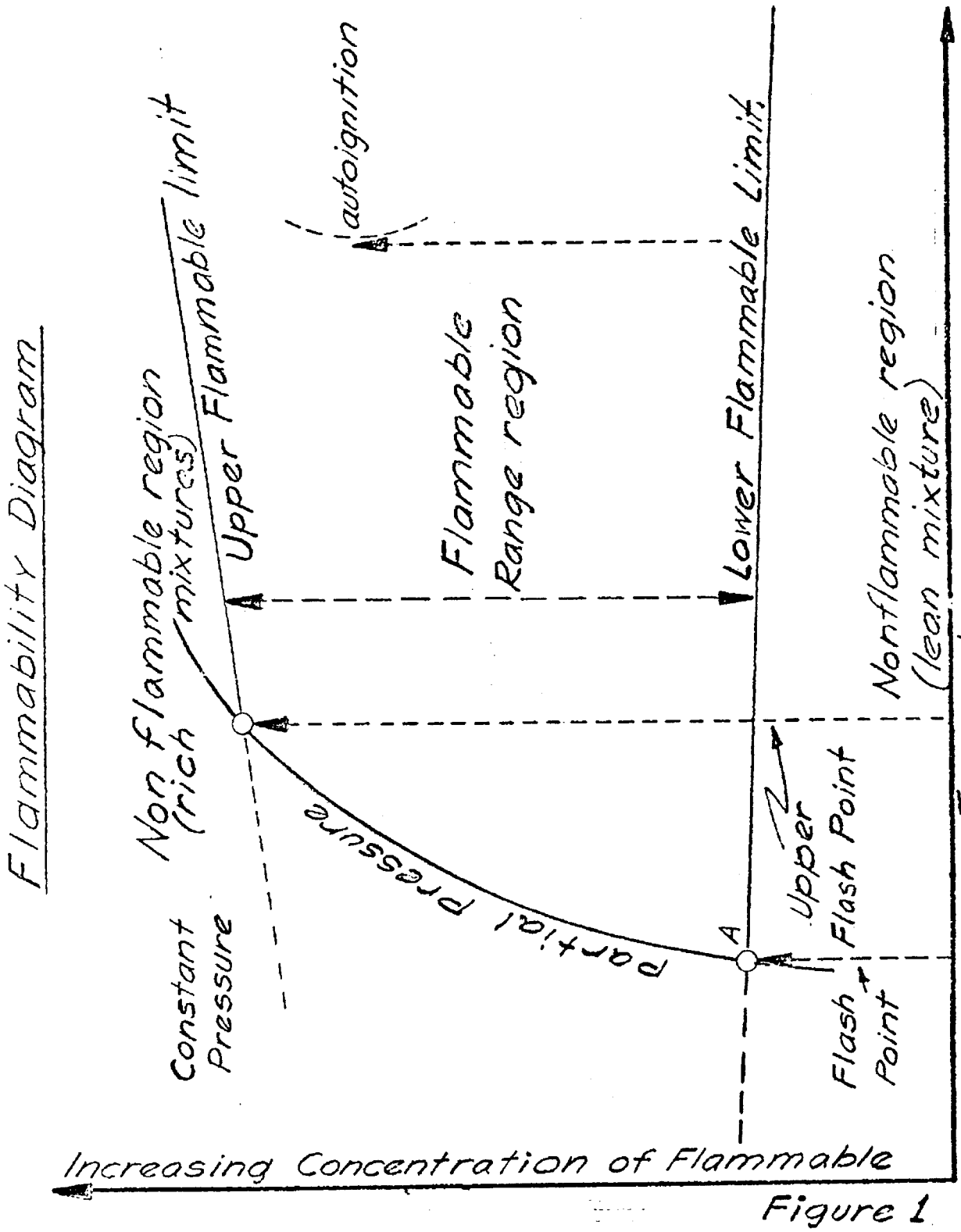


Figure 1

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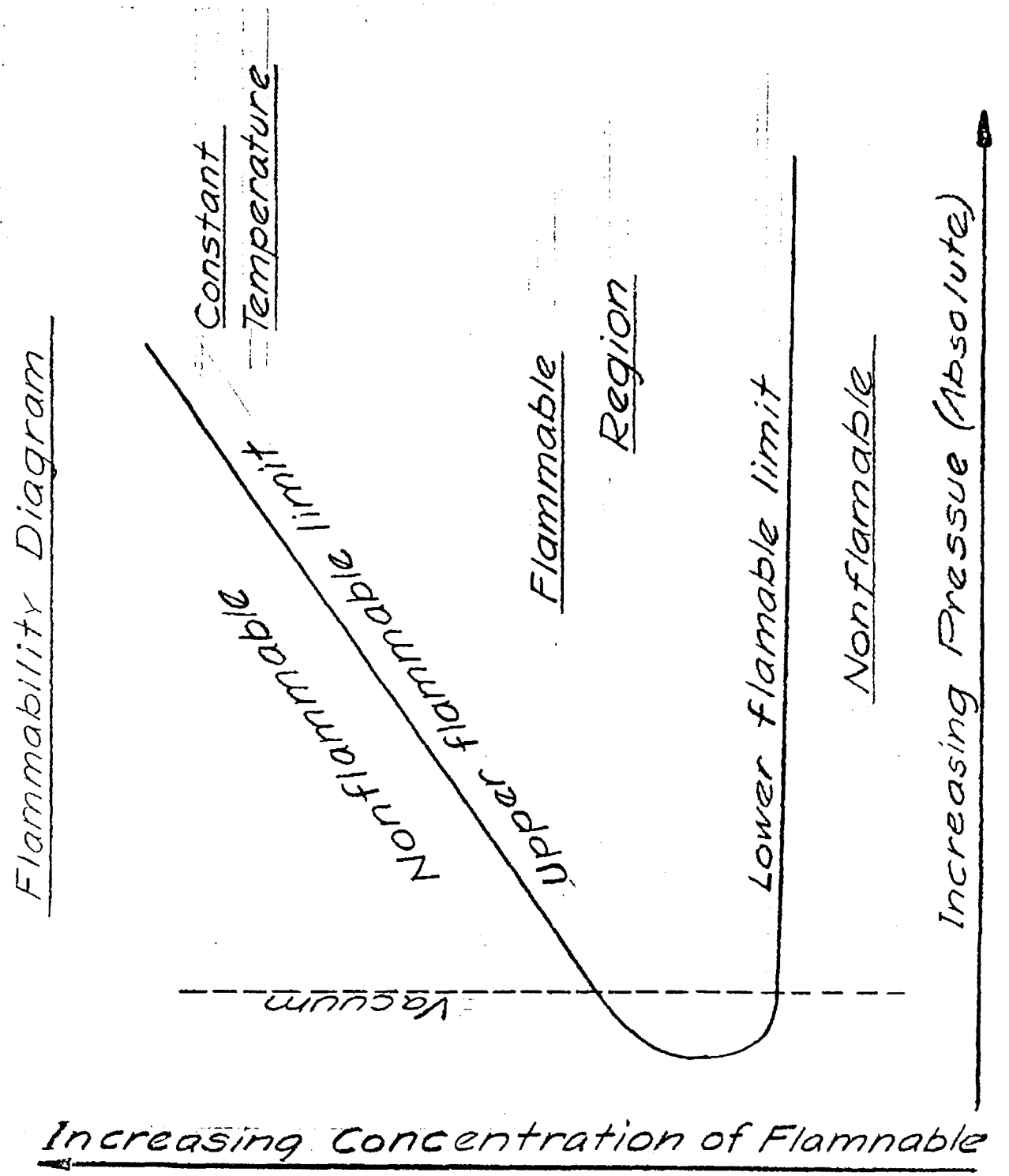
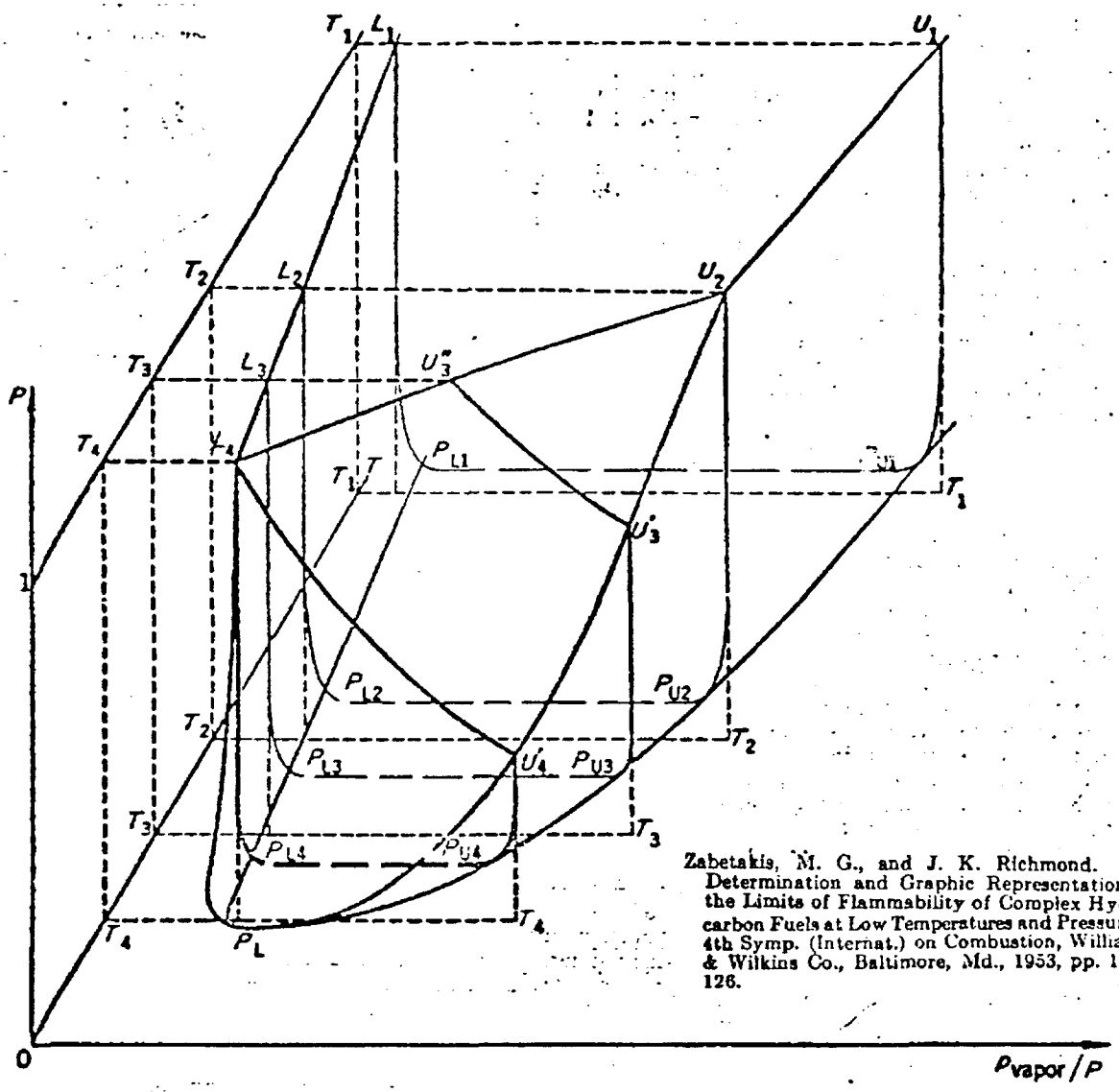


Figure 2

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Zabetakis, M. G., and J. K. Richmond. The Determination and Graphic Representation of the Limits of Flammability of Complex Hydrocarbon Fuels at Low Temperatures and Pressures. 4th Symp. (Internat.) on Combustion, Williams & Wilkins Co., Baltimore, Md., 1953, pp. 121–126.

FIGURE 13.—Effect of Temperature and Pressure on Limits of Flammability of a Combustible Vapor in a Specified Oxidant.

Here, composition is given as the ratio of partial pressure of the combustible vapor, p vapor, to the total pressure, P. For any value of P, the limits of flammability are given as a function of the temperature. For example, at 1 atmosphere (P = 1), the flammable range is bounded by the lower limit curve $L_1L_2L_3L_4$, and the upper limit curve U_1U_2; all mixtures along the vapor pressure curve $L_4U_3''U_2$ are flammable. At constant temperature (for example, T_1), the flammable range is bounded by the lower limit curve L_1P_{L1} and the upper limit curve U_1P_{U1} ; the broken curve P_{L1} P_{U1} represents the low pressure (quenched) limit. A similar range is defined at temperatures T_2, T_3, and T_4 which are less than T_1. However, at T_3 and T_4 the upper limit curves intersect the vapor pressure curves, so that no upper limits are found above U_3' and U_4'. In other words, all compositions along $U_3'U_3''$ and $U_4'L_4$ are flammable. The curve $L_4P_LU_4U_3U_2$ defines the range of limit mixtures which are saturated with fuel vapor. Further, since L_4 is the saturated lower limit mixture at one atmosphere, T_4 is the flash point.

Figure 3

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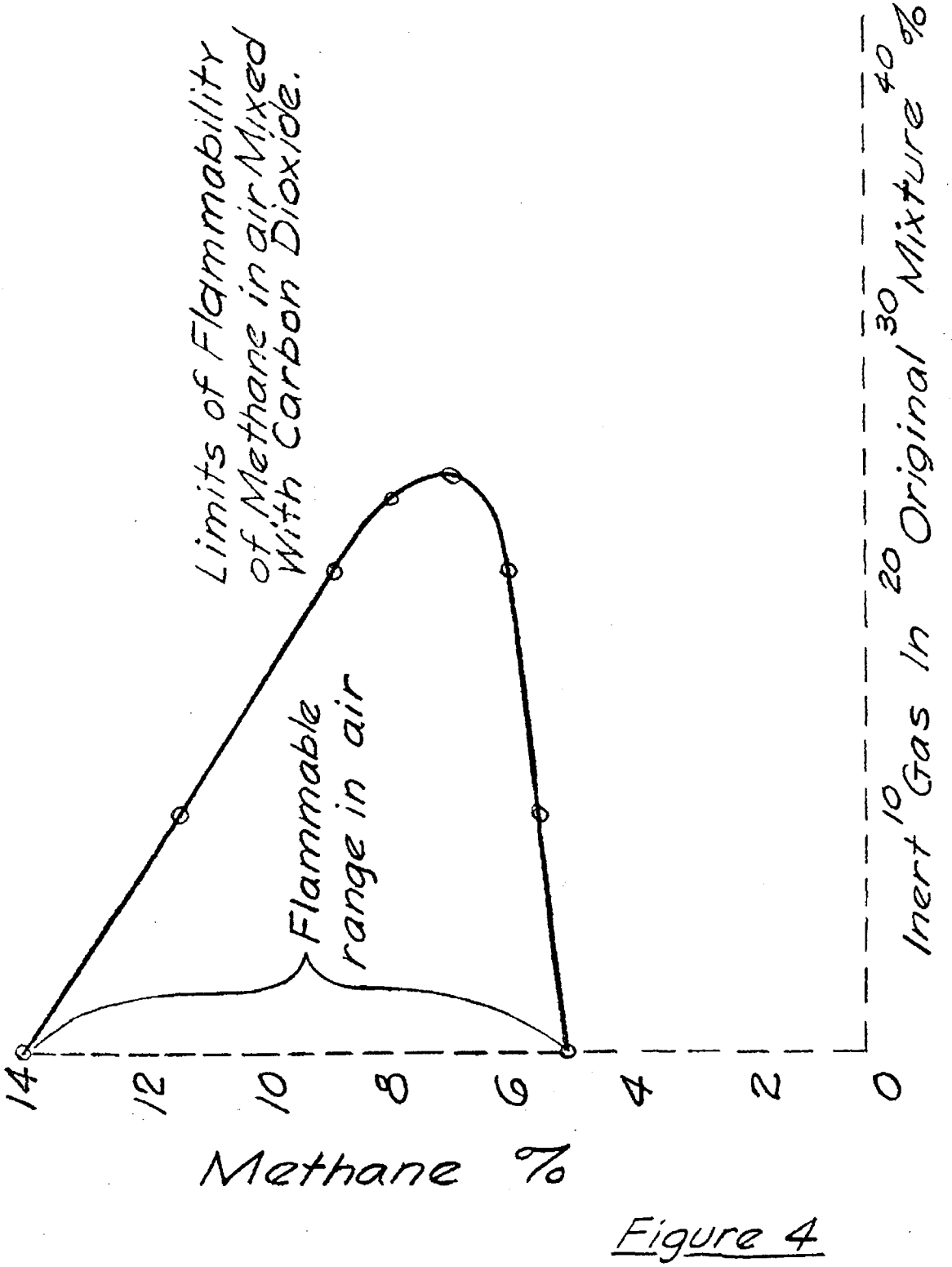


Figure 4

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Information on the flammable properties of chemicals is essential for the prevention of fire or explosion and to those confronted with emergencies involving them. A common source of information available to departments of the Chemicals and Plastics Division of the Corporation is the Laboratory Manual, Volume 40; 17th Edition, Tables of Physical Properties. The Bureau of Mines Bulletin No. 627 is a basic reference on flammability. A comprehensive manual is the National Fire Protection Guide on Hazardous Materials. This guide is arranged in five texts as follows:

1. 325A - Flashpoint Index of Trade Name Liquids.

2. 325M - Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids.

3. 49 - Hazardous Chemicals Data.

4. 491M - Manual of Hazardous Chemical Reactions.

5. 704M - Recommended System for the Identification of the Fire Hazard of Materials.

Accurate, reliable detection of flammable gases or flammable liquid vapors is vital to the prevention of fire or explosion. A knowledge of where and when a mixture within the flammable range can occur is important too is the measurement of oxygen as a means for evaluating:

1. Effectiveness of inerting procedures.

2. Procedure for protecting personnel from the effects of oxygen deficiency.

Instruments designed for these purposes are available in all plant operating departments. All operate by sensing some characteristic of a sample drawn into the instrument and relating this to hazardous or physical property data.

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The "hot wire" type of meter is the most commonly used. This instrument responds to all combustible gases or mixtures of combustible gases regardless of chemical composition. This is an advantage since it is not necessary to know the exact identity of a gas or vapor to evaluate the risk of fire or explosion. Propane is generally used to calibrate this instrument to read the percentage of the lower flammable limit. Specialists are available in the plants to perform this calibration.

C. Mists, Sprays and Dusts

As is true for gases and vapors; mists, sprays and dusts can cause explosions. Of special concern is the fact that mists of flammable liquids at temperatures well below their flash point can propagate flame. In plant operation, dispersion of liquid droplets in air to form mists can occur by atomizing fluids or by flashing hot liquids and then quenching the resulting vapor in a colder atmosphere. For example a break in a hot chemical line could result in considerable mist formation by flashing of hot liquid into the surrounding cooler atmosphere.

Droplet size appears to be a factor in mist explosion. Size of the particles influences the rate of heat transferred to individual liquid particles for vaporization to proceed prior to ignition. As a result mists can be made nonflammable by additives which can rapidly remove enough heat from the burning zone to prevent significant vaporization. Nonflammable additives such as nitrogen, carbon dioxide and water can sufficiently dilute the mist to quench the flame. as a consequence heat of vaporization is much more significant than flash point for evaluating the hazardous nature of mists.

When combustible dusts suspended in air are ignited, they can cause severe explosions. Factors influencing the explosibility of dust include particle size, concentration, other impurities, oxygen concentration and source of ignition. The presence of moisture in dust particles tends to range the ignition temperature and as a result compress the explosion range. This occurs because heat is absorbed for vaporizing the moisture subsequent to ignition. As is characteristic of vapors the addition of inerts reduces the combustibility of dusts.

UCC 021016

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D. Flammable Vapor Clouds

Large flammable vapor or gas releases are of very serious concern and are receiving much attention throughout the world because of a few catastrophic explosions such as Flixborough, Antwerp, etc. Small vapor or gas releases in confined spaces can, of course, ignite and explode with disastorous affect. However, in an unconfined area, a much larger release is generally necessary for major damage if an explosion occurs. Usually, more than one to two tons must be released in an unconfined area to result in major damage if ignited and if an explosion occurs.

Many, many vapor and gas releases occur throughout the Chemical Industry each year. Very few of such releases are ignited. Of the releases that are ignited, most are manifest by a slow burning phenomena (no explosion) which, of course, is dangerous to personnel. In all C&P locations, we have elaborate vapor cloud emergency procedures. All persons should be aware of such procedures. In very few instances, the ignitions of large vapor cloud releases result in a high level-energy-explosion. Such explosions are sometimes termed detonations. Whereas detonations have occurred (reference FAE bomb) to date, no true detonations have been obtained in tests with ignition of unconfined gases unless the ignition is a result of a detonator. Whether detonations occur or not, the high level of energy that occurs is adequate to cause extensive damage to equipment, structures, and buildings and, of course, to personnel. If any of you are interested in learning more about this phenomena, please contact the Fire Safety Programs Manager, the Safety Technology Manager or the Safety Engineering Manager.

E. Explosions

Although the terms explosion, detonation and deflagration are frequently used interchangeably a basic difference between the processes does exist. In contrast to the relative slow chemical changes that characterize the usual burning or combustion process, exceedingly rapid chemical reactions may be initiated with pressure effects exerted on surroundings. Detonation is such a process in which an exothermic reaction takes place in a high pressure wave that advances with supersonic velocity into the unreacted medium. However, a deflagration is similarly an exothermic reaction but which propagates

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from the burning gas to the unreacted material by conduction, convection, and radiation. A distinctive characteristic is that the deflagration wave travels at a rate less than the velocity of sound in the unreacted material. The term explosion, when restricted to chemical change, is a happening resulting from the combustion, deflagration or the detonation process with a rapid release of energy accompanied by a pressure increase and noise.

UCC 021018

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II. IGNITION (H. E. Peterson)

It has been shown that flammability is a function of composition, temperature, and pressure, however it is independent of the means of ignition. The combustion process can be initiated by any source of energy that can heat the combustible material to its ignition temperature.

There are three types of energy that can generate sufficient heat to achieve ignition temperature. These include (1) Chemical, (2) Mechanical, (3) Electrical.

A. Chemical Heat Energy

Energy from this source is produced from oxidation reactions. This is the source of energy which is of primary concern in the fire prevention effort since most sources of ignition causing fires occur in this area. The oxidation reactions are classified as follows:

1. Combustion or open flame and burning

The heat of combustion is the amount of heat released during complete oxidation of the substance. Intense oxidation can result in open flame or produce sufficient heat to exceed the ignition temperature. Common examples are:

a. Careless use of matches and smoking material.

b. Improper use of portable torches, boilers, driers, ovens and furnaces.

These ignition sources are controlled by safe design, safe maintenance practice and proper operating procedures.

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2. Spontaneous heating

Almost all organic substances are capable of combining with oxygen with evolution of some heat. This process can increase the temperature of a material without drawing heat from the surrounding. If this does occur the process is termed spontaneous heating. Dangerous heating can develop if the heat evolving from the process exceeds the rate of heat dissipated to the surroundings. The conditions which influence the accumulation of heat and can cause temperatures to rise above spontaneous ignition are:

a. Rate of oxidation (heat generation).

b. Air supply (oxygen source).

c. Insulation properties (rate of heat transfer to surroundings).

Spontaneous heating in insulation is frequently encountered in plant operation. Most flammable liquids that have soaked into hot insulation can be expected to smoke and glow if enough air (oxygen) is present and the heat of reaction is not dissipated. Such situations cause a hot spot and constitute a potential ignition source. Ethylene oxide, Dowtherm, aldehydes and oils have caused many fires. Asbestos catalyzes some reactions and magnesia is one of the worst offenders. Isolation of organic chemicals from insulation is the only effective solution for preventing this hazard.

Pyrophoric materials are those which ignite spontaneously. Organic aldehydes rapidly oxidize when exposed to the atmosphere and can ignite from the accumulated heat of reaction.

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There are numerous other examples of spontaneous ignition, however the many substances subject to this phenomena may be conveniently classified into three groups as follows:

Group 1 -- Substances not themselves combustible, but which may cause ignition such as unslaked lime in the presence of water.

Group 2 -- Substances having ignition points below ordinary temperatures such as sodium or potassium in the presence of water or ammonia in the presence of chlorine.

Group 3 -- Substances which may undergo sufficient oxidation at ordinary temperature to reach their ignition points. This includes finely divided metals, such as iron dust, Raney Nickel, aluminum in point. Accumulation of oily industrial wastes and certain fats can also oxidize to the ignition point.

These ignition sources are controlled by good housekeeping practices, open ventilation for dissipating heat and limiting air supply to control oxidation rates.

3. Heat of solution

Heat of solution is the heat released when a substance is dissolved in a liquid. In some cases sufficient heat may be released to be dangerous and ignite nearly combustible material. An example is the dilution of concentrated acid with water. The resulting heat of solution could ignite highly volatile ether compounds.

4. Catalytic reaction

Catalyst are substances which by their mere presence evoke chemical reaction which would not otherwise take place. A

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catalyst influences (generally speeds up) the rate of chemical reaction and the accompanying release of heat. A common example is the use of catalytic converters.

B. Mechanical Heat Energy

Classification of potential sources of ignition due to mechanical heat energy include:

1. Frictional heat

Hot bearings, misaligned or broken machine parts and poorly adjusted power drives are examples of mechanical energy transferred to heat. The hazard depends on the amount of mechanical energy converted. Prevention of this source of ignition is through a regular schedule of inspection, maintenance and lubrication.

2. Friction sparks

Friction sparks include fires caused by the sparks which result from the impact of two surfaces at least one of which is a metal. Some examples of sparks often reported as responsible for fires are:

a. Sparks from dropping steel tools on concrete floors.

b. Sparks from tramp metal in grinding machine.

c. Sparks from tearing and failure of metals.

C. Electrical Heat Energy

Electrical energy produces heat when electrical current flows through a conductor, or when a spark jumps an air gap.

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1. Current flow

Heat from current flow can stem from resistive, inductive or dielectric effects. Ignition from these sources are the leading cause of industrial fires. Most start in electrical wiring and motors. Most are prevented by proper maintenance. When flammable vapors may be present special electrical equipment may be required (See ELC-88) in Section VI on Electrical Safety. These requirements may include vapor-proof lighting fixtures, totally enclosed motors, oil immersed or properly enclosed switches, and complete absence of open sparking devices.

2. Arcing and Sparking

Heat from arcing includes those sources that arise from electric circuit interruption, static electricity and lightning. Grounding, bonding and special attention to equipment as required by NFPH 70 are preventive measures.

D. Special Considerations

Special considerations include combination of energy effects that can cause sufficient heat to reach ignition temperature. Among these are:

1. Unstable Materials

These are materials which spontaneously react with themselves to evolve heat, flammable gases or explosive gases. The reaction may be catalyzed. Examples of such materials are:

a. Acetylides of copper or its alloys which form in combination between the metal with acetylene or acetylene-bearing gases. The solids detonate upon contact at ordinary conditions if not kept wet.
(Procedure for removal of copper acetylides - pages 117-119)

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b. Aluminum paint when used on hot ferrous surfaces is hazardous. Contact of aluminum with a rusted surface can initiate a thermal reaction. The principle hazard of the reaction is the considerable amount of heat generated when the aluminum and rust react to form iron and aluminum oxide.

c. Peroxides - Peroxides and compounds which form peroxides are insidious. Under normal storage conditions they can form and accumulate peroxide which may explode violently when subjected to thermal or mechanical shock. Ethers and acetals are common peroxide-forming compounds. To prevent accidents from peroxidizable compounds users of these substances should develop a program for their recognition and safe handling. Refer to Safety Standard SF-7 for organic peroxides.

d. Ethylene Oxide - Ethylene oxide spontaneously polymerizes in the presence of inorganic substances. The materials which catalyze the polymerization include aluminum, aluminum oxide, rust, inorganic bases and chlorides of iron and aluminum. Shock and heat can likewise initiate polymerization reaction. Garlock asbestos gaskets can initiate polymerization reaction of ethylene oxide with alcohols, amines and acids and can liberate sufficient heat to cause polymerization.

e. Aldehydes - Aldehydes can undergo dangerous reactions with either acids or caustic. With caustic the aldol condensation occurs with explosive violence.

2. Water and Air Reactive Materials

These are materials which react with water, steam or air to evolve heat which can ignite flammable or explosive gases. Examples of such materials are:

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a. Aluminum Trialkyls - These are pyrophoric compounds which ignite spontaneously on exposure to air, and react violently with water.

b. Anhydrides - Anhydrides are compounds formed from organic acids from which water has been removed. Upon reacting with water they regenerate the acid with liberation of heat. Violent reactions can occur.

c. Activated Carbon - Under certain conditions, activated carbon reacts with air at a sufficient rate to heat spontaneously and ignite. Particularly susceptible to ignition is activated carbon exposed to oil-laden air. The oil upon depositing on active sites catalytically oxidizes to flame both the carbon and oil. Compressor after cooler fires are caused by this mechanism.

3. Hot Surfaces

Hot surfaces are introduced by steam lines, heating mediums and hot repair operations. Temperatures on these surfaces may exceed 700°F. Many organic chemicals and miscellaneous hydrocarbons ignite at temperatures below the temperature of 200 psi steam. Isolation of the hot surfaces from low igniters is the only effective preventive.

4. Hot-Exhaust Hazards

A Task Force has examined information and data from General Motors Corporation, National Fire Protection Association, trade organizations, other petrochemical companies, and "in-house" tests. The effort was a result of our concern for potential hazards introduced by the new catalytic converters being installed on 1975 cars and trucks.

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It was concluded that all internal combustion engine-driven vehicles (those with and without catalytic converter exhaust systems, regardless of year) constitute a serious fire ignition hazard. The Task Force recommendations to the Manufacturing Department are directed toward control of hazards of all such vehicles.

The data indicate operating temperatures higher than those necessary for ignition of most chemicals handled in C&P facilities. (966°F for manifolds and 875°F for catalytic converters.) Merely turning off the engine does not remove fire ignition potential until the exhaust system has cooled.

The following guidelines were recommended for incorporation in the development of safe vehicle operating procedures:

a. Vehicles should not be permitted in "classified" areas without vehicle entry authorization. This requires all C&P facilities to be properly "classified" and identified.

b. Formalized entry and operation controls are necessary with adequate monitoring and assigned responsibility.

c. Experience indicates that not only hazardous operating unit areas should be given special attention with regard to safe vehicle entry procedures but also such areas as:

   (1) Chemical loading and unloading areas
   (2) Pipe racks
   (3) Drainage ditches (open drainage manholes, etc.)
   (4) Tall dry grass areas (which should be cut).

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d. An alarm system is needed to control vehicular traffic during emergencies.

e. Other internal combustion engine-driven equipment should have similar in-plant regulation. Such equipment includes:

Diesel locomotives
Portable generators and compressors
Welding machines
Lawn mowers, etc.

f. Plant revisions, alterations, and additions should include arrangement and layout to facilitate safe movement and operation of automotive vehicles.

5. Static Electricity

Static electricity is a serious ignition potential in chemical operations. Field engineers should be aware of the many ways in which they may introduce static problems or nullify systems that are designed to preclude static hazards.

There is much confusion and lack of understanding in regard to static electricity. We want to establish (and to reiterate for those of you who are already aware of it) our policy with respect to the treatment of static electrical hazards.

Static problems exist in the handling and processing of many solids and fluids, particularly those which have low electrical conductivity. Liquids when being transferred between storage tanks and/or processing equipment often build up extremely high electrical charges. Under suitable conditions these charges may rise to massive elec-

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trical fields that may discharge sparks of sufficient energy to ignite flammable mixtures.

Under unusual conditions as little as 0.2 millijoules can ignite an explosion. At 1300 volts hydrogen has been ignited with as little as 0.02 millijouls. Hydrogen explosions can be ignited by corona discharge or "St. Elmo's" fire.

Required spark energy for an explosion is related to the combustible material. The lower and upper explosive limits for flammable vapors in the air are roughly 50 and 400 percent of the stoichiometric proportion for combustion. At the high and low limits 5 to 10 millijoules is needed. At near the stoichiometric proportions the spark energy required is about 0.2 millijoule. For determination of hazards, minimum ignition energies at ambient temperatures and pressure should be considered to be: 0.1 millijoule for vapor in air, 1 millijoule for mist in air, 10 millijoules for dust in air.

Practical experience indicates that it takes from 2 to 10 times more energy, than the experimentally determined minimum, to ignite flammable mixtures under normal field conditions. This probably accounts for many situations where sparks have been observed but ignition has not occurred. Furthermore, some people believe that static potentials of less than 1500 volts are not likely to cause ignition because of the quenching effect of electrodes when the gapped distance is smaller than that required for a 1500 volt sparkover.

The production and accumulation of static electricity by hydrocarbons seems to depend upon the presence of trace components which increase the conductivity of the liquid, although there is no predictable relationship between a charging tendency and conductivity.

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We note for example that ordinary water can be shown to generate static electricity. Many of you have witnessed the Bureau of Mines experiment in this regard. Ordinary water generates more static than does distilled water.

Furthermore, we have examples (some of them recorded in motion pictures) of gasoline containing water droplets generating much more static electricity than would be generated by plain gasoline, even as much as 50 times more.

Pure gases generate little, if any, static electricity when escaping from pipes. If, however, the gas is contaminated with foreign particulate matter, a charge may be generated. This may be only trace amounts. We have experienced many examples of this type of static generation. Hydrogen is especially susceptable to ignition.

We know for example that ethylene can generate static electricity and we have had many unfortunate incidents of fires and explosions from this very source.

A pipe stream of flowing liquid or gas can become charged by flowing through the pumps, filters, and long lengths of piping. additional charges can be generated within the tank by the action of the entering liquid. Splashing or spraying of the incoming stream can generate very high static charges. The disturbance of water, the contaminants in the bottoms of tanks, also produce static electricity. Air or other gases bubbling through liquids or jet and propeller blending are additional causes of static generation. In all cases, any condition which increases the contact and separation of droplets or particles of liquid would generate static electricity.

Air hoses, steam hoses, sand blasting hoses, chemical mixing nozzles, and paint spray nozzles are examples of high static generation sources.

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You must bear in mind that static generation in hoses and pipe lines can be an internal ignition hazard where explosive mixtures are present inside of the hose or piping and also an external ignition hazard in any hazardous area.

Filling vessels by dropping liquid through the vapor space is of course condusive to static generation. Downpipes to discharge liquid below the liquid level should be used. Also sub-surface filling can be likewise hazardous if violent agitation occurs with extensive breaking of the liquid surface. All of the foregoing discussion leads to several general conclusions:

a. Static electricity is generated in chemical processes by the movement of the fluids in the process, as well as by personnel or mechanical devices or vehicles that are in motion in the process area.

b. It is established that the level of static generation, the potential capacitance of equipment, etc., and the potential release of static charges are more than enough to ignite flammable vapor and gas air mixtures.

Now some organizations feel that when flammable liquids or gases have conductivities or resistivities of such nature that preclude the generation of static or ensure the rapid dissipation of any static charges that are created, there is no danger and no bonding or grounding or other precautions need be taken.

We cannot accept this philosophy. first of all, we know and have had experience to prove that materials which have resistivities of less than 10^{10} ohm-centimeters have caused fires -- such as acetone.

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Acetone has a resistivity of 1.6×10^7 ohm-centimeters and a dielectric constant of 21 which is quite high.

c. Therefore, our third general conclusion is that wherever hazardous materials are processed or handled, care must be exercised with respect to the potential static electrical problem.

d. Low velocities are of value but by themselves will not preclude the danger of static ignition, bonding and grounding by themselves do not necessarily preclude all the dangers of static ignition. (Refer to Electrical Safety Section for reference to grounding and bonding standards). Avoiding of top-filling or agitation do not in themselves avoid all the dangers of static ignition. The entire problem must be examined step-by-step to determine the reasonable application of engineering principles in order to reduce the hazard to an acceptable level.

e. Inerting of tanks and vessels is the only 100 percent guarantee against ignition by static in a vessel (providing that the inert gas supply is reliable). This does not mean that inerting is necessary in all instances. The other precautions already mentioned, applied as indicated, will suffice in many cases. Ionization, humidifcation, relaxation time, and increasing electrical conductivity are other measures which may be looked at in special circumstances. Relaxation time is particularly practical in certain instances.

f. We would like to emphasize that the academic value of detailed technical treatment of static electrical problems is recognized. However, it is our position that practical applications of electrical safety principles provide the reasonable answers.

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For those of you who are interested in pursuing the academic approach to static generation problems we have a section in the Appendix B which contains some rather basic formulas and discussion on static electricity.

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III. INERTING AND PURGING (N. W. Clauss)

A. Basic Needs

Flammability and Ignition has been covered because the knowledge requirement, protective design considerations and procedures are needed to prevent equipment failure and is a logical precedent to the subject of inerting.

Many of the chemicals handled in C&P processing plants have flammability limits in air ranging from 2% (L.E.L.) to 8% (U.E.L.) with some noteable exceptions such as acetylene (2 to 80%), hydrogen (4 to 75%) and ethylene oxide which burns or decomposes from 3 to 100%. Since the presence of oxygen is required for combustion, deflagration, or detonation it is necessary to provide some means to keep the oxidizing agent (oxygen) concentration at levels that remain outside of the limit boundaries of the flammability envelope. Maximum oxygen concentration must usually be kept below 8 to 10%. This is done by inerting vapor phase systems by dilution with some inerting gas.

Inerting is essential for prevention of explosive mixtures in chemical systems because such mixtures occasionally are ignited by unforeseen and often unknown sources. Inerting is usually accomplished by maintaining a closed system under vent gas pressure with the necessary pressure reducing and back pressure regulators. Vent gas systems are designed by the Control System engineers, and the required vent rates may be calculated by the methods given in Appendix C on Inerting and Purging.

Vent gases are those which, when mixed with process gases containing air, reduce the oxygen concentration in a process system below the flammable limit, thereby eliminating the possibility of a fire or explosion. Typical example of inert gas usage are:

1. To prevent the formation of flammable mixtures, or oxidation, or other hazardous chemical reactions in process equipment and storage tanks. To maintain product quality.

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2. To break or prevent vacuum in process equipment.

3. To empty flammable liquid storage tanks by pressure.

4. To prevent dust explosions. To protect against spray or mist explosions.

5. To protect operations conducted at or above the ignition temperature of contained materials.

6. To purge equipment prior to repair.

7. To control system pressure (still columns, etc.).

Vent gas is usually provided for all atmospheric tanks with contents of 125°F flash point or less, all tanks containing flammables which have heating systems, and all tanks which contain flammable gases and vapors in addition to the stored contents.

A similar system is used to dilute unstable vapors and gases that do not require oxygen for exothermic decomposition. Some such compounds are ethylene oxide and acetylene. The proportion of vent gas necessary for stability varies with temperature and pressure. For ethylene oxide vapor, the necessary inert dilution for safe handling at various temperatures and pressures is presented graphically in the UCC Product Bulletin on Ethylene Oxide. Pure acetylene can be handled safely up to a maximum pressure of 15 psig except when it is being flared. In that case, fifty percent dilution with a compatible gas is essential to prevent explosion in the flare system. At higher pressures, acetylene must be diluted with acetone or other compounds for safe handling.

Special inerting requirements for handling oxygen bearing materials such as chlorates, nitrates, peroxides, etc., should be designed by skilled process safety engineering specialists.

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B. Air Leakage Problems

Operating process systems, even though provided with properly designed inerting or purging facilities, require procedures and training to prepare for the unexpected introduction of air in the following situations:

1. Processing systems operating under vacumm can pull in air from vessel defects, leaking flange gaskets, valve packing, etc. Scheduled inspections and maintenance procedures should be rigidly followed to keep a tight system.

2. Vacuum systems, during shutdown periods, require good inerting system controls when breaking vacuum.

3. Insufficient purging of processing systems when opening up for maintenance work can admit air in the presence of flammable vapors. Procedures must be adequate to ensure a safe atmosphere in preparing systems for maintenance and equally so for removing air from systems prior to the addition of flammable material.

4. Startup periods for systems handling hazardous flammable material are times when extra precautions are in order to avoid creating explosive atmospheres. A system may consist of several equipment items which must all be properly purged. The pressure of getting a process on the line may result in the ignition of an explosive mixture if one item was valved out of the system during purging. A long transfer line open to the air for repairs can contain enough air to cause trouble when a system is charged. Startup checking procedures must cover such possibilities.

5. Unit emergency procedures must cover the possibility of sudden rupture or failure of equipment pipe connections, expansion joints, excessive corrosion failures, etc. which could introduce air and cause an explosion.

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6. A generally ignored source of oxygen is dissolved oxygen in the feed streams to process systems. The following example explains the nature of this hazard.

Three propane tanks were ruptured and an extensive fire occurred because of the unrecognized introduction of oxygen. In this case, oxygen was carried in solution with the propane stream. Laboratory research has shown that oxygen may be absorbed by oils and later released - somewhat like bubbles in soda water. This may cause a non-flammable vapor space to become flammable by the process of oxygen concentration or enrichment. Let's see how this is possible.

Assume the propane stream contains a small amount of oxygen dissolved in the liquid. When the propane is pumped into storage, some propane vaporizes into the space above the liquid. Also, along with the propane vapor, oxygen leaves the liquid and an equilibrium vapor phase is built up containing a much higher concentration of oxygen than was present in the liquid. Now suppose that the liquid level is raised in the vessel and the vapor space is not vented. Much of the propane vapor under pressure condenses back to a liquid, but the gaseous oxygen, because it redissolves very slowly in the liquid, becomes more concentrated in the vapor because of compression. The percentage of oxygen in the vapor thus has increased many times what it was in the liquid entering the storage vessel.

Lighter hydrocarbons, such as propane and butane, are particularly hazardous. They can carry with them more oxygen than heavier hydrocarbons, and frequently are stored under conditions which can lead to the oxygen concentrating effect described. When there is a possibility of air accumulation anywhere in a process unit, the vapor spaces of the equipment involved should be sampled routinely and routine checks for oxygen in the feed should be considered.

C. Selection of Inerting Gas

Many gases may be used for fire and explosion prevention, but considerations of availability, cost, corrosiveness, and compatibility

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with chemicals being processed results in our using fuel gas and nitrogen extensively. Nitrogen is preferred because it is nonflammable and is generally supplied as one of the plant utilities, and it is normally a clean, pure, oxygen deficient inert gas. Other inert gases being used in plants include:

1. Flue Gas

Flue gas from power plant stacks has been used as an inert gas. However, in actual power plant practice, it is impossible to have a flue gas with zero oxygen content. The oxygen content of flue gas may reach 15 or 16 percent if the dampers are not properly adjusted. However, the average flue gas has a carbon dioxide content of 9 to 14 percent while carbon monoxide content varies from about 0.1 percent to several percent. Sulphur dioxide in the flue gases may cause corrosion as will the oxides of nitrogen. In general, flue gas should not be used for vent gas because of these objectionable constituents.

2. Process Blow-Off Gases

Process blow-off gases, such as the gas from an oxide blow-off converter, are frequently used. The ethylene oxide content of these gases may be in the range of 0 to 500 ppm; oxygen range is normally 2 to 3%, and ethylene content may be 1 to 2%. Operational upsets can result in higher ethylene and oxygen contents.

3. Steam

Steam is often used for purging prior to maintenance work. However, steam must be used with care and only in vacuum vented vessels. Numerous vessels have been collapsed from internal vacuum by steaming and the subsequent condensation due to rapid cooling. Also steam can cause ignition by static discharge and should not be used when flammable vapor air mixtures are present.

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4. Carbon Dioxide

Carbon dioxide is a good inert gas but is ordinarily used only for small plants or where the spaces to be protected are remote, or small, and the demand is low.

The butane oxidation units at Brownsville use carbon dioxide as an inerting material in the reaction area for controlling upset conditions and for purging equipment upon shutdown or startup. At other locations, large low pressure tanks installed for fire extinguishment are also used for inert gas supply.

Use of liquid carbon dioxide for inerting can present a potential static problem. Static charges accumulate on the solid particles formed from expansion of the liquid. Static discharge from the particles can ignite flammable mixtures.

5. Methane/Fuel Gas

Methane has been used for inerting flammable vapor-air mixtures. The method is covered in the handout on Inerting. Using combustible gases for inerting requires special design considerations by skilled specialists and is usually considered only if nitrogen is not available.

Fuel gas contains mercaptans for odor detection which can cause an acidic condition in some process fluids and corrode condenser tubes. Flue gas absorbed in process material can when released in storage vessels result in enrichment of the vapor space.

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D. Inerting Gas Quality

1. Contamination

Unless a dedicated inert gas supply is used for each process the precautions against contamination must be thoroughly reviewed and suitable means provided to deal with the problem. Inert gas taken from a plant wide supply header will sometime be contaminated with unwanted and perhaps reactive material. Catch pots and alarms are advisable. Special considerations for pure inerting gas are required for ethylene oxide inerting service.

Each connection to the main distribution system shall be provided with a check valve or other suitable device to prevent contamination of the system through reversal of flow. This can occur either through loss of inert gas pressure or by excessive pressure in an inerted unit.

2. Quality

Process blow-off gases that are used in inert gas systems are subject to variations in composition that may create hazardous conditions under certain circumstances, e.g., the total hydrocarbon content of ethylene oxide reaction system blow-off gas may go as high as three percent under "normal" operating conditions and much higher under reaction "up-sets". The oxygen concentration normally runs from 2.5 to 3.5 percent but may go as high as 6 percent or more under "upset" conditions. "Fuel Gas" composition can, through improper damper operation, etc., vary a great deal in oxygen and carbon monoxide content. The units which "generate" these purge gas streams will tend to operate at conditions which favor the process rather than at conditions that will give the most desirable purge gas composition. When such blow-off streams are used as

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"inerting gas", where variations in composition are critical, analyzers should be provided to monitor and alarm the components.

Suitable analyzing (indicating or recording) equipment should be provided to indicate the quantity and quality of the inert gas available. Some of the factors which may require measurement are: pressure, temperature, rate of flow, dew point, oxygen content, and purity. Purity is determined by measuring such undesired contaminants as may be present.

When a dangerous increase in the oxygen content occurs, the equipment creating the hazard shall be shut down (unless the operator is able to reduce the oxygen to a safe level promptly) by the ESD system.

E. Inerting Techniques

There are three ways of applying inert gas to a process system to ensure the formation of a non-combustible atmosphere within an enclosed tank or space. These are: (1) the fixed volume requirement method, (2) the fixed rate control method, and (3) the variable rate control method. The fixed rate method requires setting inert gas flow to a vessel at a sufficiently high rate to satisfy the peak requirement. As such, it generally requires excessive vapor losses. Since this method is rarely used, only the fixed volume and variable rate methods are described:

1. Fixed Volume Method

This method is most usually used as the initial step in preparing equipment for maintenance. In this method, the system to be protected is purged and the atmosphere rendered inert by first bringing the pressure to atmospheric and then introducing inert gas. Inert gas under pressure is then introduced into the system and, after mixing has

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taken place, the pressure is reduced to atmospheric. Several pressurizing cycles may be necessary to reduce the vapor content sufficiently. In all cases the design limitations of the equipment must be observed. Enclosures may be purged by displacing or diluting the flammable vapors at essentially atmospheric pressure. One or more vents discharging to a safe location are opened and the inert gas added until the flammable content, as shown by test, has been reduced to the required safe limit.

2. Variable Rate Methods

In the variable rate method the inert gas is admitted on a demand basis. The variable rate method is recommended for maintaining an inert atmosphere in systems subject to a wide variation in inert gas demand. Two methods are used, one for low pressures and one for high pressures (pressures above the range of standard vent units). These are explained below:

a. Method for Low Pressures (1 to 2 oz./sq. in.) - This is used where the supply of inert gas is to a vessel equipped with a vent unit. The vent unit is set at a higher pressure than a pressure regulator in the inert gas line. If the tank is being filled, vapors exhaust from the tank at the set pressure of the vent unit. If the tank is being emptied, or if a sudden rainstorm, etc., occurs, the pressure drops to the set pressure of the regulator and inert gas flows in. Special design requirements are needed where the inert gas supply is inadequate for the most severe case.

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b. Method for Higher Pressures (Above 2 oz./sq. in.) - This method is used on vessels operating above standard vent unit settings. The control system is arranged to supply inert gas as required, and relieve higher than desired operating pressures to the atmosphere or vent gas collection systems.

F. Limitation of Inerting Systems

Since it is practically impossible to eliminate ignition sources such as static electricity, friction sparks, reactive residues, etc., the only practical way to prevent ignition is to use inerting. However, inerting has limitations. These involve:

1. The reliability of the source and adequacy of supply of inert gas under normal and emergency conditions. A major blast damage accident could rupture an inert gas supply system. Emergency procedures should cover this possibility.

2. Purity of inert gases. These should be free from moisture or other constituents which might contaminate the material protected. Contamination by absorption may occur in long term storage. Certain inert gases may be excessively soluble at application pressure and temperature or may be reactive with certain materials.

3. Dependability of instrumentation and venting devices.

4. Difficulty of design for supply systems of adequate application rates at points of use based on peak demand.

5. Adequacy of operation and maintenance controls.

Limitations as listed above can be best illustrated by use of the following accident cases:

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1. The gases entering a flare stack are scrubbed with water to cool the gases and wash out any water-soluble components. There is a continuous make-up of water, and a continuous overflow into an underground concrete sump (10 ft. by 5 ft. by 7 ft. deep), from which it is pumped to drain by a submerged pump.

One day an explosion occurred in the sump, throwing the steel man-hole cover a distance of 60 ft. The fuel was oil, which had either gotten past the knock-out pot or condensed in the bottom of the stack and settled out on top of the water in the sump. Air was present because the sump was not airtight.

The source of ignition may have been overheating of the submerged pump. The impeller was found to be damaged, and due to a fault in the level controller the level was unusually low and the impeller casing was barely covered.

This incident shows once again that mixtures of flammable gas or vapor and air are likely to explode even though no obvious source of ignition is present. The designer had overlooked this principle.

It would have been difficult to blanket the sump with nitrogen, because it was not gas-tight and no nitrogen was available in the area. It was therefore decided to accept the risk of another explosion but to replace the metal man-hole cover (4 sq. ft.) with a light plastic one which would blow off without causing harm. Calculations showed that if the weight of the cover was less than 3 lb./sq. ft., the sump would stand the maximum pressure that could be developed. The man-hole cover was, of course, fenced to prevent anyone walking on it.

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2. A still system refining Cellosolve Acetate was being prepared for cleanup. An inerting system existed and was operable but not adequate to prevent an explosive mixture when the kettle boilup ceased (with the cooling water on the condenser) and the kettle contents were being pumped out. With an inadequate inert gas supply and the admission of air the ignition and explosion damaged the column internals. The approximate damage amount to $25,000 not including the less of production capacity.

G. Inerting To Prevent Dust Explosions

The discussion thus far has been mostly concerned with flammable vapors; however, inerting is just as important in dust-air mixtures.

In the transfer of combustible dusts in pneumatic conveyors, consideration should be given to using an inert gas. The cost of doing this must be weighed against the hazard of the particular dust involved and the cost of providing sufficient explosion venting panels or suppression systems.

A continuous flow of inert gas may be used to protect grinding, mixing, pulverizing, conveying, and other enclosed equipment, including bins. Inert gas atmospheres are specifically recommended for crushing and grinding systems and over storage and handling of pyrophoric metal powders and dusts.

Sufficient inert gas must be introduced to reduce the oxygen content of the atmosphere in the enclosure to a point that will prevent ignition of the dust. This point is the "limiting oxygen percent" (13% for most carbonaceous dusts).

Some metal powders, notably titanium, magnesium, zirconium, and thorium, will ignite in air. These materials require the use of nitrogen, argon, or helium as the inerting gas and the reduction of oxygen to very low levels.

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Another way of inerting dusts is to add solid inerts to hazardous dust to produce a mixture that is not explosive or at least prevents serious pressure build-up in case an explosion does occur.

H. Design Methods

The design of inerting systems is covered in the Safety Technology Manual in Sections 2.8 and 8.0 (Criteria Section). This information along with methods from other sources is included in Appendix C-Inerting for informational purposes only.

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EXAMPLE CALCULATION - INERTING

I. THE PROBLEM

A. Storage of wet acetone in a 300,000-gallon tank.

B. Data from Operating Department:

1. Transfer to and from tank a mixture of the following composition:
   Acetone - 10% by weight
   Water - 90% by weight

2. Temperature - ambient

3. Pressure - atmospheric (open vent to air)

C. Problem:
Is inerting required?

II. DATA REQUIREMENTS

A. Tank Condition:

1. Inspection made and found satisfactory.
2. Tank Rating based on inspection as follows:

MAWP Internal - 8 oz per square inch - 0 to 40°C
MAWP External - 4 oz per square inch - 0 to 40°C
Specific Gravity Used - 1.000

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B. Physical Property Data

	Acetone	Water
Molecular Weight	58.08	18.015
Boiling Point - ^{o}C @ 760 mm.	56.29	100
300 mm	31.0	
50 mm	-6.41	38
10 mm	-32.30	11
Vapor Pressure @ 20^{o}C	184	17
Flammable Limit - L.E.L. - Vol. %	2.6 (in air)	-
" " - U.E.L. - "	12.8 (in air)	-
Max. Oxygen Concentration- "	13.5 (in air)	-

III. CALCULATIONS

1. Mol Fraction in liquid

	Ratio	Mol Fraction
Acetone (X_a) = 10 ÷ 58.08 =	0.172	0.0333
Water (X_w) = 90 ÷ 18.015 =	4.996	0.9667
	5.168	1.0000

2. Assume Temperatures of
   a. 30^{o}C b. 40^{o}C c. 50^{o}C

3. Read vapor pressure curve for each component:

	Acetone (V_{pa})	Water (V_{pw})
Vapor Pressure at 30^{o}C	282 mm	32 mm
" 40^{o}C	425 "	56 "
" 50^{o}C	610 "	92 "

4. Using Dalton's and Raoult's Law
   a. At 30^{o}C

$$X_a \times V_p @ 30^{o}C = P_a$$

$$P_a \div P_T = \text{mod percent}$$

$$P_T = 745 \text{ mm}$$

$$\frac{.0333 \times 282}{745} = .0126 \quad \text{or} \quad 1.26\% \text{ acetone vapor}$$

(48.5% of L.E.L.)

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4, Using Dalton's and Raoult's Law (Continued)

b. At 40°C

$$\frac{.0333 \times 425}{745} = .0190 \quad \text{or} \quad 1.90\% \text{ acetone vapor}$$

(73.1% of L.E.L.)

c. At 50°C

$$\frac{.0333 \times 610}{745} = .0273 \quad \text{or} \quad 2.73\% \text{ acetone vapor}$$

(Exceeds L.E.L.)

d. At L.E.L. Temperature (Lower flammability limit for acetone in air)

$$\frac{.0333 \times V_p}{745} = .0260$$

$V_p = 581.7$ mm

Temp. of 49°C (from curve)

∴ Fire exposure would put vapor phase in explosive range.

5. Assume ± change in acetone concentration

a. 15% acetone - 85% water

15	÷	58.08	=	.2583	.0519
85	÷	18.015	=	4.7183	.9481
				4.9766	1.0000

At 30°C

$$\frac{.0519 \times 282}{745} = .0196 \quad \text{or} \quad 1.96\%$$

At 40°C

$$\frac{.0519 \times 425}{745} = .0296 \quad \text{or} \quad 2.96\% \text{ (Exceeds L.E.L.)}$$

At Max. Temperature for 15% Acetone Mixture

$$\frac{.0519 \times V_p}{745} = .0260$$

$V_p = 373.2$ mm

Temp. at 36°C (from curve)

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b. At 30°C, find the max. acetone concentration for L.E.L.

$$\frac{X_a \times 285}{745} = .026 \text{ (L.E.L.)}$$

$$X_a = .0680$$

$$X_w = \frac{.9320}{1.0000}$$

$$\frac{\frac{C_a}{58.08}}{\frac{C_a}{58.08} + \frac{100-C_a}{18.015}} = .068$$

C_a = Concentrations of acetone in liquid

C_a = 19.0% acetone

C_w = 81.0% water

The results of these calculations tell us that at a reasonable maximum storage temperature of 30°C, the acetone in the vapor phase would be about 48.5 percent of the lower explosive limit and nitrogen would not be required. Furthermore, the temperature could go to 49°C before the L.E.L. is reached and the acetone could go to 19 percent in the liquid.

So you might conclude that inerting is not required -- but that conclusion is wrong!

Acetone-water solutions are not ideal and vapor pressure data must be corrected for non-ideality. Van Larr's equation of state can be used if the constants are known. From Perry's Chemical Engineering Handbook, the VanLarr constants are given for acetone-water mixtures and the activity coefficient correction is as follows:

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$$\log \gamma_A = \frac{A_{1-2}}{\left[1 + \frac{A_{1-2} \times X_A}{A_{2-1} \times X_W}\right]^2}$$

$A_{1-2} = 0.83$

$A_{2-1} = 0.71$

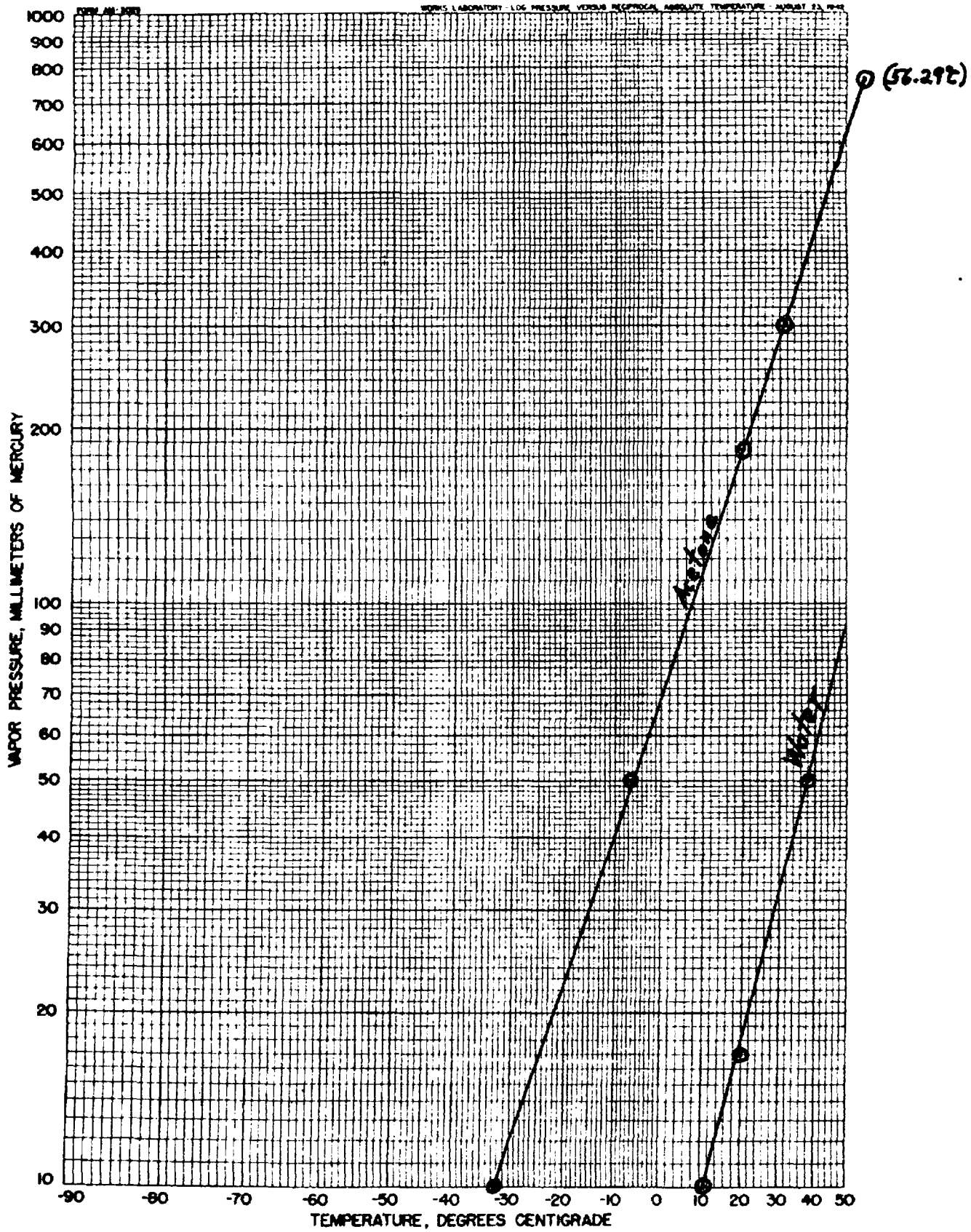
$$\log \gamma_A = \frac{0.83}{\left[1 + \frac{0.83 \times .0333}{0.71 \times .9667}\right]^2} = 0.7634$$

$\gamma_A = 5.8$

This means that for a 10 percent solution of acetone in water at atmospheric pressure and 30°C, the acetone in the vapor phase will not be 1.26 percent but 5.8 times that or 7.3 percent. So we are well above the L.E.L, and must inert.

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6. EQUIPMENT SAFETY

	Prepared By
I. INTRODUCTION	N. W. Clauss
II. LAYOUT AND CONGESTION	N. W. Clauss
III. PROCESS VESSELS	N. W. Clauss
IV. PRESSURE RELIEF	N. W. Clauss
V. TEST AND INSPECTION	N. W. Clauss
VI. MATERIALS OF CONSTRUCTION	H. E. Peterson
VII. PIPING	W. P. Reeves
VIII. MACHINERY	W. P. Reeves
IX. DISTRIBUTION SYSTEMS	W. P. Reeves
X. INSULATION	N. W. Clauss
XI. SAMPLING	N. W. Clauss
XII. SUMMARY	N. W. Clauss

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6. EQUIPMENT SAFETY

I. INTRODUCTION (N. W. Clauss)

Unlike mechanical processes where the accident rate is related to the number of machines, in the Chemical Process Industry the rate and severity of accidents is related to both number and size of the machines (equipment) and has a more serious design problem in dealing with risk.

Previous introductory sections have covered the purpose and objectives of this manual with emphasis on the efforts of all C&P functions to provide facilities which are designed to protect people, processes and equipment with a proper balance of risk with economic constraints. C&P capital project guidelines, engineering technology manuals and design criteria, safety check points including the Safety Considerations Report for project work along with prestartup safety reviews are all geared to providing facilities in which chemical processing can be done safely if operated properly.

Operation of facilities was covered in the section on Chemical Processing with the emphasis on chemical and process knowledge requirements, critical operating variables, reaction control and the avoidance of operating hazards leading to emergency situations. All effort to this point has been concentrated on the importance of maintaining steady state conditions to reduce the hazard and risk potential of operation.

Control systems and instrumentation were then studied as the next logical step in maintaining steady state operation with minimal risk. You may have participated in the development, design and installation of the facilities for which you are presently accountable. If not, you will at some time be accepting responsibility for input to expansions, additions or changes in present facilities, or improvements to gain benefits in capacity and efficiency increases, cost reduction, etc.

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The importance of caution and thorough reviews has been stressed many times since change, whether process or equipment, has the potential of introducing safety hazards and increasing operating risks of any facility. Your input to all design changes involving your facilities is extremely important not only to meet the design change objective but also to define all the possible limits of operating conditions that effect the design and safety considerations.

Take for example a Plant Engineering project initiated by the Operating Department to increase the capacity of a still system by 50 percent and at the same time provide a cleaning system to reduce production outage time. The column internals were completely redesigned using valve trays. The washing system consisted a water pressure spray system with a full cone spray nozzle located between each tray. What is disturbing, to say the least, is that no check was made on the effect of increased throughput or liquid hold up on the relief capacity requirements for exposure to fire or for increased energy requirements. Furthermore the spraying of water into an acetone vapor phase was not reviewed for the ignition hazard from static electricity. Fortunately the relief sizing was adequate (but borderline) and the operating procedures were revised to require complete purging of acetone from the column prior to washing.

Periods of production outage are often a time when many modifications are made and also a time of intense pressure. It is, therefore, not surprising that some modifications introduced during outages have resulted in serious unforeseen consequences.

One incident started when a temporary filter was put in a compressor suction line. Unfortunately, it was placed between the compressor and the low suction pressure trip. The filter plugged, the compressor sucked some air in, causing a decomposition reaction to occur further on in the process where the pressure was higher. This caused two pipe joints to fail and when the escaping gas ignited the fire caused over $250,000 damage and many months delay.

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On another plant, a repeat relief and blow-down review was carried out one year after startup. The review brought to light 12 instances in which the assumptions of the original review were no longer true, and additional or larger relief valves, or changes in the position of a relief valve, were necessary.

This section of the course is on Equipment Safety and is directed toward the care and protection of equipment against operating deficiencies and the inevitable energy releases that can potentially overpressure and rupture equipment. Layout considerations, although usually defined in original capital project work, will cover the tendency to concentrate risk level and introduce congestion.

Your ability to recognize the consequences of change from a safety viewpoint will be dependent on having enough knowledge of the technologies utilized to design and protect equipment systems. The objective of the Equipment Safety section is to (a) provide the limiting considerations of process vessel design, over-pressure relief and the procedures to maintain equipment integrity; (b) review the common pitfalls relating to materials of construction, piping, machinery, distribution installations, insulation and sampling. Example cases will be used to point out the problems caused by the omission of thought relating to the consequences of change and safety of your facilities.

The emphasis will be on the modifications of equipment and battling the thought process that keeps our minds so firmly fixed on the problems we are trying to overcome that we fail to see the consequences of our solutions. We may feel so pleased that we have managed a solution to our problem that we do not search diligently for the consequences.

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II. LAYOUT AND CONGESTION (N. W. Clauss)

Balancing reasonable investment cost with an acceptable level of risk is a complex problem and requires a great deal of experience and good judgement. The complexity involved in site layout is well described for control rooms by V. C. Marshall in an article taken from Chemical Engineering, dated Dec. 22, 1975. Excerpts are presented below.

CONTROL-ROOM SITING AND CONSTRUCTION

Control rooms must also be capable of dealing with disaster. There are, however, a number of incompatibilities between control-room routine-plant operation and disaster planning. One of the most important ones of these is negative feedback. For example, during a loss of containment, there must be positive feedback to stop material flow.

The ideal design for a control room for routine functioning would be to structure it like an airport control tower, i.e., elevated with total picture windows commanding an overall view of the plant. Yet, such a control room would be exceedingly dangerous for a person to be in, in the event of disaster. The windows would shatter and there would also be the serious risk fires.

On the other hand, a control room designed solely for disaster would have no windows, be sited as far away from the plant as possible, and would be of massive construction. Such a control room would have many disadvantages from the point of view of routine operation. A control room represents only a part of the overall control function. Another part is played by the presence of operators who receive information directly through their sight, hearing and smelling senses.

Operations are not all push-button; even heavily automated plants require on-the-spot operations. There are samples to be taken, and maintenance needs must be carried out in close communications with controls. All of these functions are favored by an open-access control building situated close to the plant.

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Certain points should be emphasized, which at first may seem obvious. Yet, these same points did not appear obvious to the designers of plants that have suffered severe damage in recent disasters.

The first concerns materials of construction. There is much evidence that when an explosion strikes, the brick panels of concrete-framed buildings cave in. Even worse, the bricks themselves can become missiles. Reinforced concrete buildings have shown remarkable resistance.

The second point is that a building should preferably have only one floor. If it must have two or more, on no account should the top floors have heavy equipment on them.

The third point concerns control-room siting. This room should have an open line of retreat, because the personnel within should be the last ones to leave a disaster area. A central situation will not allow this.

Fourth, a control room should be so sited that other structures will not fall on it, as occurred at Flixborough, where the main pipe bridge collapsed on top of the control room.

Fifth, a control room must have forced ventilation and emergency supplies, as well as small safety-glass windows. Provisions must also be made so that control rooms have disaster-proof data storage to permit an investigation, should disaster strike. It is also a good idea for plant operators to practice with mock-up disaster drills.

All of the above considerations can only be handled by safety policies established by top management (End of article).

The significant criteria for plant facilities layout of concern to operations personnel is taken from the C&P Safety Technology Manual and presented below. We will discuss the deficiencies of these criteria since operating decisions can and do sometimes increase the risk level.

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From Section 2 on Layout (STM Criteria):

A chemical process plant consists of processing units and various supporting facilities such as utilities, distribution, storage, waste treatment, and administrative and personnel services. Each of these possesses different potential exposures, different degrees of hazard, and requires different safety considerations in its location. Plant layouts are planned to segregate hazards and isolate equipment accidents. Based on the degree of hazard, the process unit represents the high hazard extreme while the administrative or personnel facilities represent the low hazard extreme. A fundamental premis regarding the location of personnel facilities is that all personnel not absolutely essential to direct operation of the plant or unit should be located in nonhazardous peripheral areas. Refer to safety standard SF-10.

Maintenance facilities should be located in areas separated from other installations. Maintenance activities usually involve ignition sources and ignition sources are incompatible with all flammables and exposure to them should be avoided. Maintenance people should not be stationed in hazardous plant process areas.

For plant drainage ditches, twenty feet horizontal clearance is required to all aboveground installations (pipe racks, cable trays, electric power distribution lines, etc.) excluding roads. Culverts should be used if the twenty foot clearance cannot be obtained.

Building, structure, and equipment are generally arranged in line with process flows using proper separation. Equipment in process structures should be separated at least 35 feet from surrounding groups of equipment in the same unit. This provides a maintenance access way and fire lane. Unit storage tanks should have a separation of 75 feet from processing areas. Lesser spacing increases fire protection costs and emergency manpower needs. Control buildings must be located a minimum of 50 feet from all flammables to an outside position from protection of personnel and instruments and to permit a nonhazardous electrical classification inside the buildings. Every unit undergoes revisions and additions, and space must be allowed to maintain the minimum separations. All direct fired equipment should be located upwind or sidewind from process equipment.

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Surface temperatures above 95% of the auto-ignition temperature (AIT) in °C of the materials handled in the unit should be treated as continuous ignition sources and a separation of 100-125 feet from any flammables source should be provided, unless other protective measures such as purged enclosures can be provided.

Large process areas in buildings need separation in the form of fire and/or explosion walls. Also, very hazardous process steps should be confined in reinforced concrete cells. Vapor barriers should be provided to shield sources of flammables from ignition sources that must, for process reasons, be located near processing areas.

All units handling flammables require adequate, clear operating and access aisles with travel distance to exits not more than 50 feet from any point within the structure. There must be two directions of unobstructed travel from every location. All valves, instruments, and controls must be safely accessible.

New layouts may become crowded by late appearing auxiliary facilities which should be anticipated prior to final design. These include instrument houses, switch racks, motor control centers, substations, catalyst facilities, in-unit loading and unloading stations, operator's shelters, shop and material houses, deluge valve shelters, cable trays, etc.

There are other layout considerations that should concern the Operating Departments. These are:

A. Venting or emergency release of flammable vapors within your departmental battery limits as it requires conducting these vapors away from hazardous operations.

B. Emergency releases and vapor clouds of flammable materials emitted from units adjacent to your facility which may cause series damage.

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The explosion of an ethylene oxide redistillation column illustrates this point. One of the theories advanced to explain the explosion was that acetaldehyde discharged by a safety valve on a neighboring column was ignited, perhaps by a hot steam line, and exposed the oxide column to intense heat. Whether this is actually what caused the explosion is not important. *This could have been the cause.* The oxide redistillation system was rebuilt in a new location, remote from equipment handling such potentially dangerous materials as acetaldehyde.

C. Changes in existing facilities must be done with consideration for safety of maintenance. Revisions have resulted in unsafe work situations when vessel openings are obstructed, spacing congested and accessability for maintenance made hazardous.

The Vice-presidents responsible to the Chemicals and Plastics Manufacturing, Engineering and SHARE functions have issued the following statement:

"Layout of new plants, location of new units in existing plants, and expansions of existing units shall include the best means to ensure prevention of personnel injury and property loss, and the protection of employee health in the work place. In developing a layout for a new facility, full consideration will be given to our community obligations.

Layout safety considerations shall include the following:

1. Plan consistently for the development of each location in a manner which recognizes obligations to employees and the community.

2. Provide sufficient space to permit effective isolation of hazards and do not violate the space in future expansions.

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3. Maintain sufficient buffer zones to avoid exposure of the community to toxic chemicals and undesirable elements of sight, sound, and odor.

4. Give proper consideration for compatibility of adjacent units with regard to potential hazards and reactive or toxic chemicals.

5. Lay out equipment and facilities to minimize concentration of investment and possible property loss.

6. Where new technology is introduced, or significant increase in size of unit is planned, an evaluation should be made to determine effects on storage and distribution needs, maintenance, and general plant layout.

A Long-Range Planning Committee at each location will provide guidance for the layout of new facilities to ensure proper consideration is given to safety and health standards in the plant and community.

T. W. Carmody

R. G. Chenoweth, Jr.

D. L. Wiley

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The original design spacing in one Company's facility was used to increase the number of reaction systems by 150 percent (two to five). The concentration of investment and blast damage potential was increased and a major disaster caused the loss of many lives and a total property loss approaching $80,000,000. The results of this disaster would have been greatly minimized by adherence to the original safety spacing criteria.

A new vinyl ethyl ether still system was installed inside a building already congested with processing equipment. The materials to be handled had flash points ranging from -60°C. to a high of 21°C. and four chemicals had auto ignition tempperatures below 202°C. with nearby hot surface equipment with temperatures of 250°C. and above. The decision to install this system inside a building surely increases the potential for high property and personnel damage. Would you resist having the hazards increased in your work area?

Capital project expansions or additions, as well as unit change order modifications, that add equipment, material and energy within existing boundry limits of any facility will increase the risk and the potential for larger losses and more fatalities. So remember that knowingly increasing the risks of plant operation will also require the application of greater safety design skills to deal with the added problems.

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III. PROCESS VESSELS AND PRESSURE RATING (N.W. Clauss)

A. Introduction

The design pressure of process vessels for chemicals should be chosen on the basis of operating pressure, maximum operating pressure during a likely operating upset, and maximum explosion pressure. Sometimes it is possible to design a vessel to withstand explosion pressures - particularly if the initial pressure is low or if some material such as Raschig rings is used to fill the vapor space.

When material is heat-sensitive, some provision must be made for protecting the vessel in case of exposure to fire. Barricades around equipment containing particularly dangerous materials can be used to protect personnel and nearby equipment and piping. Operators should not be expected to enter the barricaded area during operations involving dangerous materials.

The size of process vessels which will contain reactive chemicals must be chosen with care. The choice will be influenced by several factors. The capacity of relief devices should be adequate to relieve excessive pressure caused by uncontrolled reaction of the contents of the vessel. The arrangement of process vessels should be such that damage will be localized in case an accident should occur. The amount of reactive material contained in a vessel should be minimized to lessen explosion damage.

The design and fabrication of process vessels used in the chemical industry is regulated by such codes as:

1. ASME - Boiler and Pressure Vessel Code.
2. API - Standards 620 and 650.
3. ANSI - Standard B96.1.
4. National Board Inspection Code.
5. TEMA Standards for Heat Exchangers

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Chemicals and Plastics adheres to the following policy statement:

The ASME Code is the only engineering document in the pressure vessel field which is sponsored by the interested Professional Society, ASME; written by pressure vessel manufacturing, using, insuring, and inspecting representatives; and given stature by law in many jurisdictions. As such, it constitutes the "standard". Therefore, regardless of whether or not a vessel is stamped, complies with Code rules, or is within Code jurisdiction, the Code influences not only the price and quality of equipment we purchase, but also becomes the "standard against which our safety decisions will be judged in the event of legal action. Accordingly, whether we like it or not, the design of new and existing tanks and pressure vessels will be compared with the requirements of the ASME Code in the event of failure. Likewise, alterations and repairs will be judged by comparison with the requirements of the National Board Inspection Code (NBIC).

B. ASME Code - (Exerpts For Operations)

Appendix D has been prepared by taking exerpts from the ASME Code on Pressure Vessels - Section VIII - Division I. Included are code definitions of terms of interest to operating personnel. The scope of Section VIII covers the definition of pressure vessels from 15 to 3000 psi. Division I has three subsections covering (a) general requirements applicable to all pressure vessels, (b) methods of fabrication, and (c) the class of materials used. Vessels that are not within the scope of the code are defined and the termination of the vessel boundry limits are spelled out with respect to connecting parts.

Of particular interest to plant personnel are the subsections covering the following:

UG-20	Design Temperature
UG-21	Design Pressure

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UG-22	Loadings
UG-24	Castings
UG-25	Corrosion
UG-26	Linings
UG-45	Nozzle Neck Thickness
UG-78	Repair of Defects in Materials
UG-98	Maximum Allowable Working Pressure
UG-99	Standard Hydrostatic Test - General
UCI-99	Standard Hydrostatic Test - Cast Iron
UCD-99	Standard Hydrostatic Test - Ductile Iron

At any time you are involved in providing data to process vessel design engineers it is imperative that the maximum operating pressure and temperature conditions be provided. This includes upsets, runaway reactions, etc., so that the extremes can be designed for. Other design problems that you should consider include hydrostatic head, superimposed loading (agitators, piping), corrosion allowances, packing bed weight, materials of construction (fragile, soft), and number and size of openings. The operating integrity of process equipment will be only as good as the input design data used.

C. Chemicals - Olefins - Plastics (COP) Specifications

1. Introduction

You are all familiar with the Standards Program which was initiated in August of 1970 and which established the concept of an essentially mandatory standards program. This program made provisions for the establishment of Teams which were to document the minimum requirements in their technology area that should be included in the mandatory standards. One of these Teams was the Process Vessel Engineering/Operations Standards Development Team which had the responsibility for the COP Series Standard Specifications that cover process vessels and components. The general coverage of the eight COP Standard Specifications, all of which have now achieved mandatory status,

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will be found in Appendix E, the titles of which are as follows:

Interim Spec. 93859-200 January 1976	Process Vessels Exempt from COP Pressure Vessel Specifications.
COP-1-72	General Requirements for Materials, Design, Fabrication, Inspection, Testing and Certification of Welded Pressure Vessels.
COP-B1-72	Material Specifications for Threaded Alloy-Steel Fasteners.
COP-2 September 1977	Supplementary Requirements for Materials, Design, Fabrication, Impact Testing, and Inspection of Welded Pressure Vessels of Ferrous Materials for Low-Temperature Service.
COP-21 December 1977	General Requirements for Repair, Major Repair and Alteration of Welded Pressure Vessels.
COP-31-70	Requirements for Welded, Low-Pressure, Shop-Fabricated Tanks.
COP-61-72	Specification for Field Erected Storage Tanks.
COP-65 September 1977	General Requirements for Design and Construction of Shop-Fabricated Glass-Fiber Reinforced Plastic Tanks.

Of particular interest to Production Supervision is COP-21.

2. Why Are COP Standard Specifications Needed?

The answer is relatively simple. One of the most basic ingredients for obtaining a process vessel that is safe for the intended service, is a thorough and complete set of specifications that define the materials, design, fabrication, inspection,

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testing and certification requirements. However, simply specifying that a pressure vessel be furnished in accordance with the ASME Code(1) is not an adequate specification. The use of the Code as a purchase document in this manner suggests that the rules in the Code can somehow magically make the proper allowance for the hazards that may be associated with every conceivable process fluid, every possible range of process. Accordingly the Code is not nor is it intended to be, a purchase document. It is very important that we all understand this point since a lack of this understanding will lead to difficulty if you are involved in the purchase or repair of vessels for our chemical process units.

D. Process Vessel or Pipe?

The fabrication of small vessels can be based on process vessel criteria or on piping specifications. These small vessels would include surge pots, seal oil pots, addition pots for acids, bases, catalysts, inhibitors, entrainment pots, etc.

From an engineering viewpoint, economy can be realized by utilizing pipe specifications. The Engineering Department will usually use pipe specs if all of the following apply:

1. The nominal diameter is 24" NPS or less.

2. It can be fully described by a valve and piping specification and a piping sketch.

3. Additional design calculations are not required (all parts are covered y the valve and piping specifications).

4. It is for service other than "Lethal."

(1) Unless otherwise specified, all references to the "Code" are to be 1977 ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

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From the viewpoint of operations and equipment safety there are risks involved in the above approach. The RM-1 program will not include items without a Property Number for identification and may therefore not be included in scheduled test and inspection procedures. These have been serious failures of small vessels because of inattention.

Regardless of the design method used for small vessels it is recommended that each one used as a process vessel be identified with a property number and included in the usual RM-1 scheduling program.

E. Alterations and Repairs

Repairs and alterations to equipment systems have resulted in reducing the system MAWP. This can happen when fittings with lower pressure ratings are substituted to expedite repairs, or when the materials of construction are changed.

Replacing nozzles with larger sizes or without reinstalling reinforcing pads can lower the pressure limit. Installation of expansion joints require special design skills to avoid failures.

Flange, bolting and gasketting change can create weakness in a piping or equipment system. Substitution of gasketting material to reduce leakage problems is a frequent source of trouble because the use of harder gaskets in a flange will result in overstressing the bolts and deforming or cracking the flanges.

Our experience during mechanical equipment evaluations has brought to our attention the malpractice of interchanging flange gasket material in pressure vessel main flange joints with no regard to the effect of the replacement gasket on the flange bolts nor the effect on the flange itself. In several cases, this practice has caused flange leakage and subsequent shutdown to alleviate leakage failures.

To supply the reader with some basic insight to flange design, flanges and flange bolting must be designed to sustain the greater of the following:

UCC 021068

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1. The gasket seating "bolt-up" condition under which sufficient bolt load must be maintained to seat the gasket, as well as sufficient flange thickness, must be maintained to support the required bolt load. Each and every gasket material possesses different seating requirements; consequently, the flange joint must be evaluated for the particular gasket material used.

2. The MAWP which must include the static operating and/or hydrostatic test loads.

We have a large number of flanges which were designed for and are currently operating in low pressure applications. Hence the gasket seating condition is the controlling factor when designing or evaluating these flanges thus making the joint stresses strictly a function of the hardness of gasket material employed.

For example compare the relative hardness of three gasket materials which are commonly used in our plant, the asbestos composition encased in a teflon envelope requires approximately 5.5 times more bolting than that of 1/8" plain asbestos composition, the solid flat dead soft copper material requires approximately 8.1 times more bolting than that of 1/8" plain asbestos, and the solid flat stainless steel material requires 16.1 times more bolting than that of 1/8" plain asbestos. Replacing a gasket of a harder material can induce extremely high bolt stress and induce 5 to 16 times more bolt load on the flange.

Another factor which can cause leakage failures and unsafe flange joint stress levels is plant external corrosion. Several of our Process Safety inspections have revealed that some current flanges are as much as one-half that of the original thickness. This detorioration alone, even with the gasket material remaining unchanged, increases flange stress 4 times over that of the original calculated design.

In conclusion, no gasket should be replaced with a material other than that originally specified for the joint without the approval of Engineering.

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F. Excessive Temperature

1. Introduction

The maximum allowable working pressure (MAWP) of any vessel can be drastically lowered by exposure of the material of construction to high temperatures. For this reason process changes involving new chemicals, changes in heating media or operating pressures which increase temperature must be reviewed for possible loss of strength. The rapid decrease of ultimate tensil strength of copper with increasing temperature is an example.

Temperature increases will increase metal loss by corrosion by a factor of about 2 for every 10°C rise in temperature.

Exposure to fire can raise metal temperature of pressure vessels to the point of rupture as the following case illustrates.

In 1956 at a Texas refinery, 19 firefighters died when vapors from about 500,000 gallons of a mixture of pentane and hexane excaped as a huge ball of fire from a ruptured spheroid tank. Flame from burning vapors issuing from a nearby vent impinged on the spheroid, weakened the metal on the top plate above the vapor space and caused the rupture.

2. Example Cases

a. The following accident caused by over-temperature provides some valuable lessons on the need for temperature limit control. The case study is taken from Chemical Engineering Progress - April, 1974.

An electric heater heated a stream of circulating nitrogen which was used, for a few days every two months, to regenerate a catalyst bed. The instrumentation and control were simple because the unit

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was not used very often. The heater was a shell-and-tube type, with electric heating elements in the tubes.

One day, the heater shell burst. Subsequent investigation disclosed the following:

(1) The cooler was plugged with catalyst dust, stopping gas circulation.

(2) The flow indicator was not working, because it was also plugged with dust. It had never worked since the plant start-up, and the operators had learned to manage without it, controlling the plant by watching the temperature inlet to the catalyst bed. If the temperature was low, they switched on more heating elements; if high, they switched some off.

(3) The temperature recorder on the inlet to the catalyst bed was stuck at its normal reading. Even if it had been working it would not have prevented the incident but would have shown a fall in temperature when the circulation stopped and the operator would then have switched on more heating elements.

(4) As a result of the loss of circulation the high temperature trip on the elements operated, at 740°C, and isolated the electricity supply.

(5) The operator, not noticing anything unusual in his other readings, assumed the trip to be faulty, and after a few minutes switched the power back on. The elements, which had a low-heat capacity, had cooled a little, and it was another ten minutes before the trip isolated the electricity again.

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(6) Altogether, the trip operated and the electricity was restored three times in one hour. There was a shift change during this hour. Finally, the heater shell burst.

The action of the plant staff after the incident was as instructive as the incident itself. Because the shell had burst, they assumed that the relief valve was faulty and sent it to the shop for test. The test showed that it was lifting at the set pressure. It was only then that the staff realized that the heater had burst because it had become too hot.

The principal change made after the incident was to install a high temperature trip onto the heater shell. Many lessons can be learned from this simple incident, for example:

(1) Plant staff do not always understand that a relief valve will provide no protection for a vessel if it gets too hot. If the metal is weakened by heat, it will burst at or below the relief valve setting.

(2) Wherever possible there should be a direct measurement of the property in which there is interest; the value should not be inferred from some other property which has been measured. In the present case, it might be inferred that when the heating elements reach 740°C, the shell had not reached a dangerously high temperature.

(3) There is a great difference between the standards adopted for protection of equipment against over-pressure and against over-temperature.

For protection against over-pressure, vessels are fitted with relief valves or rupture discs.

UCC 021072

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Over-temperature can be just as hazardous as over-pressure, but the precautions taken against it are not comparable. In many cases, such as furnace tubes, protection against over-temperature is much more difficult to achieve than protection against over-pressure. Long experience has developed this high degree of concern about protection against over-pressure, but there remains a blind spot towards protection against over-temperature.

Much needs to be learned before high-temperature trips (or other trips) are treated with the same respect as relief valves, and before operators accept the fact that disarming a trip is the equivalent to isolating a relief valve. It is unlikely that an operator would ignore the repeated lifting of a relief valve without investigation.

b. A very versatile specialty chemicals reaction still system was set up to use a calandria with process material on the tube side and with the shell side capable of using 600 psig steam, 180 psig steam, 30 psig steam, 30 psig cooling water and - 10°C brine. The process pressure ranged from full vacuum to 40 psig. In checking the MAWP for the most severe case (600 psig steam and full vacuum) it was found that primary bending, tube shear load, and tube sheet stresses exceeded the maximum allowable. It was necessary to restrict the shell side temperature to the equivalent of 450 psig steam in order to operate safely.

G. Testing Requirements COP-21

1. Hydrostatic Test

Repaired or altered vessels shall be hydrostatically tested in accordance with the following requirements:

a. Major Repair or Alteration - Any major repair or alteration shall be followed by a hydrostatic test in

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accordance with Article 43 of UCC Standard Specification COP-1.

b. Repair - Hydrostatic test of repairs need be performed only when required by governing jurisdictional laws or regulations, when deemed necessary by a National Board commissioned inspector, or where required by the responsible UCC plant representative.

c. Vessel Temperature - The temperature of the water shall be sufficient to ensure that the vessel metal temperature (for the entire duration of the test) is not lower than the following:

Carbon Steel - For vessels constructed of carbon steels, the metal temperature shall not be lower than the highest value obtained from Figure 1 of UCC Standard Specification COP-1 for all material grades and thicknesses in the shell and formed heads plus 17°C (°F + 30); and except for materials with enhanced brittle fracture resistance, never lower than 16°C (60°F). For plate thicknesses greater than 3 inches (76.2 mm) the following paragraph applys:

Materials Other Than Carbon Steel - For vessels constructed of materials or thicknesses not covered above the minimum metal temperature during test shall be determined in collaboration with a UCC Process Vessel Design Group.

d. Holding Time - The hydrostatic test shall be maintained for one hour per inch (25.4 mm) of maximum shell or formed head thickness with a one hour minimum and a five hour maximum.

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2. Pneumatic Test

For some vessels it may not be feasible to conduct a hydrostatic test, and hence it may be necessary to substitute either a combined hydrostatic and pneumatic test (vessel is only partly filled with liquid) or a pneumatic test. Because of the increased amount of stored energy inherent in compressed gases, additional precautionary measures are required if a pneumatic or combined hydrostatic-pneumatic test is substituted for the hydrostatic test. When either of these substitute tests are to be used, the following requirements shall apply:

a. Use of Compressed Air - Compressed air tests shall be made only when equipment is known to be completely free of hydrocarbons or organic residues. Vapors from deposits in bubble caps, baffles, tube bundles, and other entrapments can cause an explosive mixture with oxygen-rich compressed air. When possible, nitrogen or a process-acceptable gas should be used. The vessel safety relief device should never be closed off.

b. Nondestructive Examination - Compliance with the provisions of Code Par. UW-50 (Nondestructive Examination of Welds on Pneumatically Tested Vessels) is required as a minimum additional inspection requirement over those normally provided prior to a hydrostatic test.

c. Vessel Temperature - Arrangements shall be made to provide vessel metal temperature during the test in accordance with the requirements for hydrostatic test.

d. Test Pressure - The pneumatic test shall be conducted in accordance with Code Par. UG-100 (Pneumatic Test).

e. Prior Approval - Either of these substitute tests shall be conducted only with prior approval of UCC plant management or UCC construction management, whichever is responsible for the repair or alteration under consideration.

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H. Change In Vessel Rating

Under no circumstances shall the rated maximum allowable working pressure be increased or the rated operating temperature be changed without prior approval of a UCC Process Vessel Design Group.

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I. Miscellaneous Equipment and Hardware

1. Air Coolers

Fin-tube equipment is easily damaged and requires pressure relief and spray protection (STM-D&A 3.3).

2. Boilers and Fire Heaters

Guidelines are covered in the Energy Systems Manual - Criteria 109 pages 1 through 10.

3. Ceramic Packing

Thermal shock can cause severe breakage of ceramic packing and the resulting rapid increase in pressure drop may create hazards that should be covered in SOP and Emergency Manuals.

4. Drainers

The casing MAWP must be at least as high as the processing system MAWP.

5. Filters

Various types of filters are used many different services in most chemical processing plants. The semi-permanent or temporary portable filters frequently cause problems because pressure relief is ignored.

One accident resulted from the use of a 12 cartridge Ful-Flo filter installed in a temporary system without relief devices and operating instructions cautioning against high pressure generated by a 10 x 7 x 3 Cameron reciprocating pump. A bypass was to be adjusted to keep the pressure down but no gage was available to read the pressure. The pump was capable of generating 400 psig and the 150 psi MAWP filter ruptured. The

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system was set up in an unsafe manner and the need for pressure relief was ignored.

Again pressure relief is being stressed for filters used in any service as follows:

(a) Systems handling flammable liquids having low flash points.

(b) Systems operating at sub-ambient temperatures, i.e., say below 5°C.

(c) Systems operating at pressure near the design working pressure of the filter vessel.

(d) Systems which may be subjected to pressures in excess of design working pressure through inadvertent closing or opening of certain valves in or around the system.

Most of the filter vessels which are larger than 6 inches I.D. have a spare connection (1 inch or 1-1/2 inches) on which a relief valve may be installed. For those that do not have such a connection, the relief device can be installed on the inlet or outlet piping between the filter vessel and any block valve which may be present.

Recently three transparent bowls on air line filters/ lubricators failed catastrophically, scattering fragments over a wide area. Investigation reveals that the bowls are of Polycarbonate construction. Polycarbonate cannot be exposed to an atmosphere containing vapors or fluids of acetone, benzene, ethylene dichloride, gasoline, toluene, etc., or to air systems which use synthetic fire resistant lubricants in the compressors. By using metal bowls only on air line filters/lubricators this type of failure can be eliminated.

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6. Glass, Glass Linings

Glass is subject to mechanical shock damage and should never be used for hazardous chemical service. Glass lined autoclaves are limited to definite maximum temperatures as specified by the vendor to prevent cracking.

The use of alkaline material in glass lined vessels must be avoided. Any damage to the lining can expose steel to the process material sometimes with disasterous results.

7. Heat Exchangers

Safety considerations relating to heat exchangers involve two separate systems, the shell side and the tube side. The pressure rating of both sides must be known along with the temperature limitations. The lowest pressure rated side must be protected in case of a tube rupture with adequate pressure relief.

Thermal expansion relief must be provided for both shell and tube side of any heat exchanger if valving is provided and the possibility exists for closing in either side.

8. Instrument Hardware

Instrument bodies, such as for DP cells, when exposed to process pressure must have pressure ratings equal to the system relief set pressure.

9. Karbate Equipment

Karbate is not subject to thermal shock but has a maximum temperature limit depending on the binder used and is subject to mechanical shock. Steam or hydraulic hammer must be avoided.

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10. Plastic

The use of plastic equipment is not to be used for hazardous service without review by skilled specialists. Such equipment is relatively fragile and weakens quickly when exposed to heat.

11. Pressure Gages

Chemical releases have occurred because gages were exposed to pressures greater than their maximum limit. Corrosion of gage pipe connections must be checked at scheduled intervals to maintain integrity.

12. Sumps

Covered sumps for collecting assorted chemicals are subject to explosions, especially those in which vertically mounted sump pumps are used. If there is no way to inert the vapor space a light weight cover should be used (approximately 3 lbs. per square foot) or other means of venting should be provided. The sump area would have to be fenced and warning signs provided.

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IV. PRESSURE RELIEF (N. W. Clauss)

A. Introduction

Under the subject of Chemical Processing the importance of chemical and process knowledge, operating variables, material and energy balances, reactivity, reaction control, and emergency operation was stressed with emphasis on the hazards that can be introduced by change. Efforts to operate processes under steady state conditions with well designed, operated and maintained control systems were reviewed.

In addition the considerations for safe layout of equipment spacing, the provision of inerting systems to stay out of explosive vapor situations, the pressure and temperature rating limits of process vessels and the problems of maintaining process vessel integrity have been covered.

With all the preparation, knowledge, procedures and training covered thus far could you give a positive answer to the question - "Can you operate your process and equipment safety?" The Chemical Industry believes not, as evidenced by the regulatory Codes required to protect equipment. Human errors of omission or commission are inevitable in all disciplines of design, installation, operation and maintenance. It is for this reason that all chemical processing equipment must be protected against overpressure from unexpected energy releases. We must, therefore, become knowledgeable in the design requirements and limitations of pressure relieving systems and in the actions of operating personnel that negate the effectiveness of these systems.

A recent C&P effort to inform engineering and operating personnel revealed the following problems:

1. The need for more complex venting systems to meet air pollution regulations and to reduce product losses.

2. The proper definition and use of the maximum allowable operating pressure:

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a. To provide a suitable margin between maximum operating pressure and MAWP.

b. To provide the most suitable venting devices.

3. Long inlet lines to safety valves can cause safety valve chatter and can require additional bracing.

4. Lack of pressure indication or vent between rupture disk and safety valve. Possibly more common is the lack of attention by the Operating Department to pressure indicators; the indicators must be checked and maintained.

5. Seals missing on safety valve block valves or block valves closed - Incidence is rapidly decreasing but must be eliminated.

6. Relief device opening pressure above equipment MAWP.

7. Rupture disks - Two problems, both of which are being corrected, are as follows:

   a. Installation by untrained personnel, and

   b. Failure to realize that rupture disks have a limited life. See Safety Standard SF-2.

8. All pressure vent checking and maintenance should be placed on RM-1 at all Plants.

9. Discharge line drain holes - These are occasionally found clogged. Somtimes they are not provided.

10. Safety reviews for Plant changes - The possible effects of change on pressure relieving requirements should be checked by the Plant Engineering Group Safety Representative.

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11. Inert gas supply - Contamination of these systems is not uncommon. Clean-up and the possible addition of filters in strategic locations should be considered to eliminate product contamination and reaction hazards.

12. Spare parts delivery and availability.

13. Shop testing and repair facilities - Shop facilities vary from Plant to Plant; some are not adequate.

14. Misdirected venting discharge - This applies to all types of venting equipment and includes discharges into walkways, impingement on equipment and piping, near the top of ladders, etc.

15. Orientation of shutoff valve handwheels relative to safety valve outlets - Orientation should be such that personnel will not be exposed to safety valve discharge when operating block valves.

16. Lack of support for venting equipment components - Not common but sometimes overlooked.

17. Check valves and reduced port shutoff valves must not be used in safety valve installations. Check valves downstream of safety valves that are tied into common discharge headers and reduced area valves are not permitted by the ASME Code between safety valves and the equipment they are protecting or between safety valves and their point of discharge. Such installations are not only in violation of the Code, they can reduce the capacity of safety valves by causing excessive inlet and/or outlet pressure drop that reduces the safety valve capacity. It should be remembered that safety valves are flow tested under ideal installation conditions and that any piping or components we add can only reduce the capacity below the rated capacity.

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18. Inert gas blankets for low pressure storage tanks - Inadequate pressure regulators causing excessive venting of inert gas and product. Some installations are not self draining into tanks.

19. Use of unapproved venting equipment - The most potentially hazardous example of this category is the use of Consolidated Model 1811 safety valves.

20. Misapplication of venting equipment - Specification of BS & P vents in ap[illegible] or other pu[illegible]

[illegible]

To [illegible]

definitions are a[illegible]

DEFINITIONS

SAFETY VALVE - An [illegible]
pressure upstream [illegible]
action. It is us[illegible]

RELIEF VALVE - An [illegible]
pressure upstream [illegible]
pressure over the[illegible]

SAFETY RELIEF VAL[illegible]
for use as either[illegible]

PRESSURE RELIEF V[illegible]
valves, or safety[illegible]

SET PRESSURE

1. Liquid Servic[illegible]
set pressure,[illegible]
inlet pressur[illegible]
tions.

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2. Gas, Vapor or Steam Service - a safety or safety relief valve in gas, vapor or steam service, the set pressure, in pounds per square inch gage, is to be considered the inlet pressure at which the valve pops under service conditions.

DIFFERENTIAL SET PRESSURE - The pressure differential in pounds per square inch between the set pressure and the constant superimposed back pressure. It is applicable only when a conventional type safety relief valve is being used in service against constant superimposed back pressure.

COLD DIFFERENTIAL TEST PRESSURE - The pressure, in pounds per square inch gage, at which the valve is adjusted to open on the test stand. This cold differential test pressure includes the corrections for service conditions of back pressure and/or temperature.

OPERATING PRESSURE - The operating pressure of a vessel is the pressure, in pounds per square inch gage, to which the vessel is usually subjected in service. A vessel is usually designed for a maximum allowable working pressure, in pounds per square inch gage, which will provide a suitable margin above the operating pressure in order to prevent any undesirable operation of the relief device. (It is suggested that this margin be as great as possible consistent with economical vessel and other equipment design, system operation and the performance characteristics of the pressure relieving device.

MAXIMUM ALLOWABLE WORKING PRESSURE - The maximum allowable working pressure depends on the type of material, its thickness, and the service conditions set as the basis for design. The vessel may not be operated above this pressure or its equivalent at any metal temperature other than that used its design; consequently, for that metal temperature, it is the highest pressure at which the primary pressure relief valve is set to open.

OVERPRESSURE - Pressure increase over the set pressure of the primary relieving device is overpressure. It is the same as accumulation only when the relieving device is set at the maximum allowable working pressure of the vessel.

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ACCUMULATION - Pressure increase over the maximum allowable working pressure of the vessel during discharge through the pressure relief valve, expressed as a per cent of that pressure, or pounds per square inch, is called accumulation.

BLOWDOWN - Blowdown is the difference between the set pressure and the reseating pressure of a pressure relief valve, expressed as per cent of the set pressure, or pounds per square inch.

LIFT - The rise of the valve disc in a pressure relief valve is called lift.

BACK PRESSURE - Pressure on the discharge side of a pressure relief valve.

1. Constant Back Pressure - Back pressure which does not change appreciably under any condition of operation whether the pressure relief valve is closed or open.

2. Variable Back Pressure - Back pressure which develops as a result of the conditions outlined below.

   a. Built-up Back Pressure - The pressure in the discharge header which develops as a result of flow after the pressure relief valve opens.

   b. Superimposed Back Pressure - The pressure in the discharge header before the pressure relief valve opens.

SIZING PRESSURE - Used in calculating pressure relief requirements and can be no higher than the allowable accumulation.

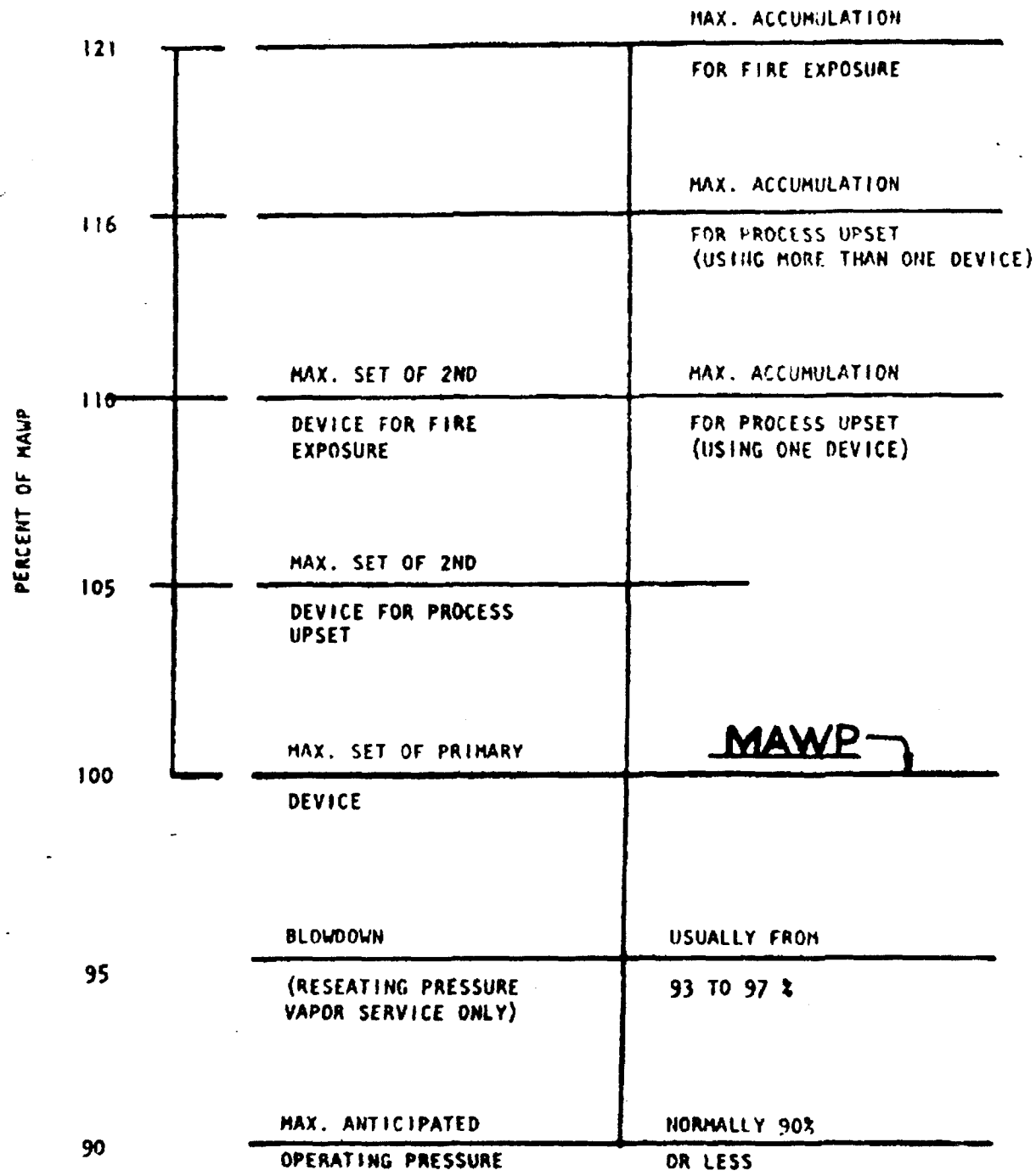
The relationship of operating pressure, MAWP, set pressure, accumulation and blowdown as defined is shown in the following Pressure Terminology Chart.

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CHART

PRESSURE TERMINOLOGY

SECTION VIII, ASME CODE



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Designing venting systems for chemical process equipment is quite complex and requires the use of engineering personnel skilled in the field of explosion and overpressure relief technology. The performance of well engineered pressure relief systems is easily nullified by changing service, operating conditions, inadequate procedures, equipment changes, etc.

Process changes made in the chemicals used on the operating conditions can effect the designed capacity of relief devices. We will be covering relief design later but you should know that relief capacity is effected by:

Specific gravity/density, Molecular weight, Relief device back pressure, Relief device inlet pressure drop, Temperature, Latent heat, Gas flow constants, Compressibility factor, Specific heat, Viscosity.

Any process change effecting any of these design variables should be a signal to you to recheck the relief capacity effects using the resource skills available.

B. REGULATORY CODES

1. ASME Code

The chemical process industry bases the requirements for pressure relief in the ASME Pressure Vessel Code - Section VIII-Division I for pressure vessels. Relief requirements for steam generators (boilers) is covered in Section I. The pressure relief requirements are covered in paragraphs UG-125 through UG-136 and Appendix F has been updated to December 1976 and includes paragraph UA-358 (Pressure Differentials), Appendix XI (Conversion Calculations and Appendix M (Installation and Operations).

The significant requirements include:

a. All pressure vessels require one or more relief devices.

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b. The pressure in a vessel equipped with one relief device shall not be allowed to increase more than 10% of the MAWP.

c. When there are multiple relief devices on a vessel the vessel pressure shall not increase more than 16% of the MAWP. In case of fire exposure the vessel pressure shall not increase more than 21% of the MAWP.

d. Safety, safety relief and relief valves shall be of the direct spring loaded type.

e. Spring resetting and set pressure tolerances are defined.

f. Rupture disc specifications and requirements are detailed.

g. When a rupture disc is installed between a safety valve and the vessel the safety valve capacity will be 80 percent of the original valve rated capacity.

h. The space between a rupture disc and a safety or safety relief valve must be provided with pressure gage, try cock, free vent or suitable telltale indicator such as a pressure alarm.

i. Relief device set pressures are specified based on percent allowable above MAWP:

1) One relief device in vessel:
Set pressure = MAWP.

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2) Multiple devices on vessel:
One device must be set at the MAWP.
Other devices can be set above the MAWP but in no case higher than 105%.
Devices added for fire exposure protection can be set at no more than 110% of MAWP.

j. The opening through all pipe and fittings between a pressure vessel and its relief device shall have at least as much area as the pressure relieving device inlet.

k. Means must be provided to drain liquid from the discharge side of a relieving device.

l. Pressure differential considerations are spelled out including recommended tolerances with respect to leakage.

2. API (American Petroleum Institute) Standards

The ASME pressure vessel code does not cover vessel with pressure ratings below 15 psig. The API Recommend Practice Bulletin No. RP-520 is usually used by chemical industries for vessels with pressure ratings from 2 ounces per square inch to 15 psig.

Pressure relief requirements, guidelines and design methods in C&P are however, covered in the Safety Technology Manual for all vessels regardless of rating.

The API Standard 2000 is the industry standard for venting of atmospheric tanks which are constructed in a manner that the head to shell seam will rupture and thus provide relief.

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C. Pressure Relief Criteria - Equipment Protection

1. Introduction

The importance of pressure relief devices cannot be realized unless the hazards of overpressure are recognized and understood. Without pressure relief any upset, equipment failure, operating error or other abnormal condition could destroy an entire chemical complex. Operating a chemical facility without safety or relief valves would be impossible for any acceptable length of time. All closed vessels, piping, tanks, etc., could be potential "bombs" causing a chain of explosions during a fire if not properly protected. A pressure relieving system is like a good insurance policy - "difficult to keep up and you may never need it, but if you do, you are glad you had it."

The criteria for pressure relief requirements and design are thoroughly covered in the C&P Safety Technology Manual and is the basic resource for safety engineering and operation. Criteria highlights are to be covered briefly which relate to operating personnel.

2. Causes of Overpressure

The more common emergency situations involved in the need for pressure relief include:

a. Fire Exposure - All process vessels, piping, pumps or other facilities exposed to fire or heat from a fire are subject to overpressure. Thermal expansion of liquid in a single vessel or in systems which can be valved in require devices to relieve pressure in preference to uncontrolled rupture. Heat from fire can vaporize material in closed systems increasing pressure; and depending on the physical properties, temperature and composition may result in rapid combustion or explosion.

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b. Equipment Failure - Pressure relief is required to prevent flammable liquid, vapor or dust explosions from rupturing closed systems. Heat exchanger tube rupture overpressures many shells because of inadequate relief capacity. The Dow Chemical Plant in Louisiana had a major disaster resulting from a heat exchanger tube failure which ruptured the shell side and the escaping Humbletherm ignited. The 300 psi shell of a Carbide exchanger was not protected against a 1600 psi process tube side rupture but fortunately the steam trap blew apart and released enough pressure to avoid the shell failure.

Equipment overpressure can result from hydraulic hammer, accumulation from pumps or compressors with greater head and capacity than the available discharge system capacity. Failure of mechanical drives of pumps, compressors, agitators, etc., cause situations creating overpressure and the need for protection.

c. Utility Failures - The loss of one or all of the main supply sources for steam, cooling water, electric power, etc. will create abnormal overpressure in many situations.

d. Thermal Expansion - Failure of equipment, pipe lines, etc., frequently occurs when liquid can be valved in and expansion results by heat transfer from the hot side of heat exchangers, from direct fired heaters, steam traced lines, the sun or fire exposure.

e. Controllers and Control Systems - Serious pressure problems result from the failure of instrument air or electric power to one or all critical controls of a processing system. The failure of pressure control systems, regulators, etc., can cause dangerous over-

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pressure accidents. The sudden break of an instrument lead could be responsible for excess heat input, loss of cooling or runaway reactions. A steam controller stuck in the wide open position or a nitrogen controller stuck in a closed position has caused overpressure accidents.

f. Changed Services and Other Operating Problems - Overpressure hazards are created by changes in service usually with the intent of processes improvement. Examples include changing the trim on control valves to increase heat input, heat removal rates or material flow rates without a review of pressure relief capacity. Changing the process to make a new product using different raw materials introduces possible corrosion problems, new flammability ranges and different relieving capacity requirements. Equipment alterations or piping changes can create pressure rating hazards and remove relief devices from providing the pverpressure relief for which they were originally installed.

Closed outlets create overpressure of still systems when the overhead or make lines are blocked. Overpressure is a serious hazard when the outlet or exhaust side of pumps, compressors or turbines are closed, especially when the exhaust side has a lower pressure rating than the inlet side.

Any equipment not rated for full vacuum service is subject to failure and the introduction of air. Vacuum relief must be provided for protection against plugged vents, sudden cooling plus pump out rate, loss of steam on columns, siphoning, steaming and rapid condensation, malfunction of controls or erroneous valve settings.

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Probably the most serious operating situations result from runaway reactions caused by loss of control, process contamination, excess useage of catalyst or promoter, lack of operator knowledge and training, etc. The energy release producing overpressure is usually greater in runaway reaction situations than for fire exposure.

3. Specific Equipment Overpressure Problems

Special considerations for overpressure protection requirements for specific types of equipment are highlighted below and in most cases are well covered in the Safety Technology Manual.

a. Still Systems - Distillation systems are used extensively in chemical processing, have a history of involvement in many major disasters and therefore incorporate virtually all relief considerations discussed previously. If chemical reactions are integrated with still systems overpressure can occur from improper feed rates, failure of temperature controls, contamination, loss of vacuum, etc. Stills handling material that polymerizes require special treatment in the event of plugging.

Relief requirements for still systems are generally based on the worst contingency plus the second worst contingency when they can occur simultaneously. For example if the cooling water is lost to a condenser the decrease in column differential may open the steam supply wide open. Relief capacity may be reduced by installing a temperature or pressure activated steam shut off system.

Distillation systems are susceptible to the creation of vacuum hazards from loss of heat input or sudden

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cooling and require well designed protective vacuum relief systems to prevent the entrance of air into flammable atmospheres. Low pressure columns are especially vulnerable since they are rarely good for full vacuum service. The Pressure Vessel Design Group should determine the minimum pressure limit and also can frequently specify design improvements which will improve vacuum ratings and thus greatly reduce the relief capacity required. Reinforcing pads and stiffening rings are not expensive and can improve the safe operating pressure range.

Operating procedures must include the method for cutting steam off without creating a vacuum by rapid condensation.

b. Vapor Phase Reactors - Most vapor phase reactions depend on complex and reliable control systems to prevent rapid combustion and overpressure. Pressure relief will usually be in the form of rupture discs. Good inspection, testing and maintenance procedures are needed to maintain reliability.

c. Liquid Phase Reactors - Safety devices for exothermic liquid reactions must handle the vapor generated by runaway reactions caused by loss of control, contamination, erroneous catalyst concentrations, loss of agitation, loss of circulation and loss of cooling. The response time of safety relief valves is too slow for many explosive combustions and rupture discs must be used. The design of pressure relief for reaction systems is quite complex and depends on knowledge of reaction kinetics, rate of pressure and rise, time interval from operating to release pressure, liquid entrainment. Relief capacity for fire exposure will usually be much less than that generated by runaway reactions.

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d. Heat Exchangers - Relief requirements for tubular heat exchangers are based on the maximum allowable low side pressure plus 10 percent (1.1 x MAWP). Inertial effects resulting from tube rupture, liquid entrainment and liquid filled relief device piping can cause high peak pressure. Good inspection and testing programs are required to minimize tube rupture hazards caused by corrosion or errosion.

Direct fired heaters are provided with pressure relief from fire exposure and resulting thermal expansion.

Air cooled condenser relief capacity is based on fire exposure during normal operation. This relief requirement is additive to the total requirement of still column relief when cooling water is lost. If a condenser can be valved in thermal expansion relief is required in every case.

Air cooled exchangers used for liquid cooling must be protected against pressure increases by vaporization when exposed to fire and for thermal expansion when closed in full of liquid.

e. Dust Handling Equipment - Organic plastic dusts and other purticulate matter with particle sizes in the range of 0.003 inches and in concentrations of about 0.03 ounces per cubic foot of air can generate explosion pressures up to 100 psi with a pressure rise rate of 5000 psi per second in closed unvented equipment. Small explosions in areas contaminated with settled dust can create a dust cloud which could, and has, produced very serious secondary explosion damage. Housekeeping is extremely important to minimize such a possibility.

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Dust handling equipment must either be designed to safely contain full explosion pressure or be provided with continuity of grounding and inerted to prevent ignition. Buildings containing dust handling equipment must be designed with explosion venting panels.

f. Turbine and Pump Casings - Sentinel valves on turbine casings are warning devices not pressure relief devices. Turbine casings require relief to prevent the exhaust side pressure from exceeding the MAWP rating. Pump casings are occasionally ruptured by exposure to process pressures exceeding the MAWP unless pressure relief is not provided.

g. Filters - Pressure limitations of filters require protection against excess process pressure or fire exposure regardless of size.

h. Multiple Compartment Tanks - The extension of vents from multiple compartmented tanks will introduce a hydraulic head which may exceed the MAWP of one or more of the compartments. Pressure relief design engineers must recognize this potential problem.

i. Safety Relief Devices - Relief devices must be protected from plugging by polymers or from "high freezers" by proper purging or steam tracing.

D. Types Of Relief Devices

1. General

The primary function of a safety valve is to protect equipment or piping by automatically opening to prevent the internal pressure generated by an emergency condition from rising above a predetermined safe value. The secondary function is to close after the emergency condition has been corrected.

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The term safety valve generally refers to a direct spring loaded device in a suitable body, usually an angle type, having an inlet connection capable of withstanding the inlet pressure-temperature conditions. The body and outlet connection are usually designed for a lower pressure than the inlet connection.

The inlet incorporates a valve seat or nozzle which is matched with a disc for full closure of the inlet port. The disc is spring loaded with the spring force applied directly on the disc by means of a stem.

The valve outlet is usually larger than the inlet; this is necessary for expanding fluids such as gases, vapors, etc. Safety valves must always relieve to a lower pressure. For expanding fluids, this lower outlet pressure may require an increase in discharge piping size.

The spring housing on safety valves in steam service can be yoke type (exposed spring) or bonnet type (enclosed spring). Safety valves in all other services should be the bonnet type. A lifting lever is used for safety valves in steam service on boilers — to allow manual operation of the safety valve to determine that the working parts are operable.

A comparison of safety and relief valve types given in the Safety Technology Manual shows the differences in operating and physical characteristics between conventional and bellows type full nozzle safety valves, pilot-operated safety valves, and relief valves. The table will help the user make the best choice of safety valve type for specific applications. Additional guidance can be obtained by using the specification form, instructions and capacities given in Appendices G and H.

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There are four general types of equipment used to relieve pressure and vacuum: (1) safety valves, (2) safety heads, (3) vent units, and (4) pilot-operated units.

There are four general types of safety valves: (1) full nozzle, conventional, (2) full nozzle with bellows, (3) pilot-operated, and (4) relief.

Three types of safety heads are used: (1) reverse buckling, (2) conventional, and (3) graphite.

There are three general classifications of vent units: (1) breather vents, (2) special purpose vents, and (3) emergency vents.

The typical relief valves used in the process industries are classified as safety relief valves, functioning as safety valves on gases or vapors and as relief valves on liquids.

Safety-relief valves do not close at the same pressure they are set to open. Blowdown helps to prevent valve chatter when it trys to seat. Blowdown can be adjusted to protect vessels or lines that contain products that might react in any way to cause rapid pressure build up. For example, if we are protecting a storage tank which normally operated at 25 lbs., the relief valve would be set to lift at the maximum working pressure of the vessel (50 lbs.)

If the product stored started to polymerize and a fast rate of pressure build up occured, we would not want the valve to seat until a substantial amount of the pressure had been removed from the vessel. For this case we might allow a 50 percent blowdown (maximum) so that the valve would not close until tank pressure had dropped to 25 lbs. again. This will amount in greater loss of product, but

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cost alone would not be worth taking a chance of rupturing the vessel, and endangering personnel.

Blowdown can be expressed as percent of set pressure, or in pounds. For example, if a pilot operated safety valve has a set pressure of 100 lbs., the average blowdown would be 2% of set pressure, or .02 x 100 lbs. = 2 lbs. What this means is that the valve will lift at 100 lbs., and close at 100 lbs. -2 lbs. or 98 lbs, allowing a 2% or 2 lb. blowdown. Blowdown is adjusted by changing position of the blowdown ring located within each valve. See Figure 1.

FULL NOZZLE VALVES - The term full nozzle refers to the orifice size of the valve. Full nozzle indicates that a valve has the largest possible orifice available for that size valve. See Figure 1.

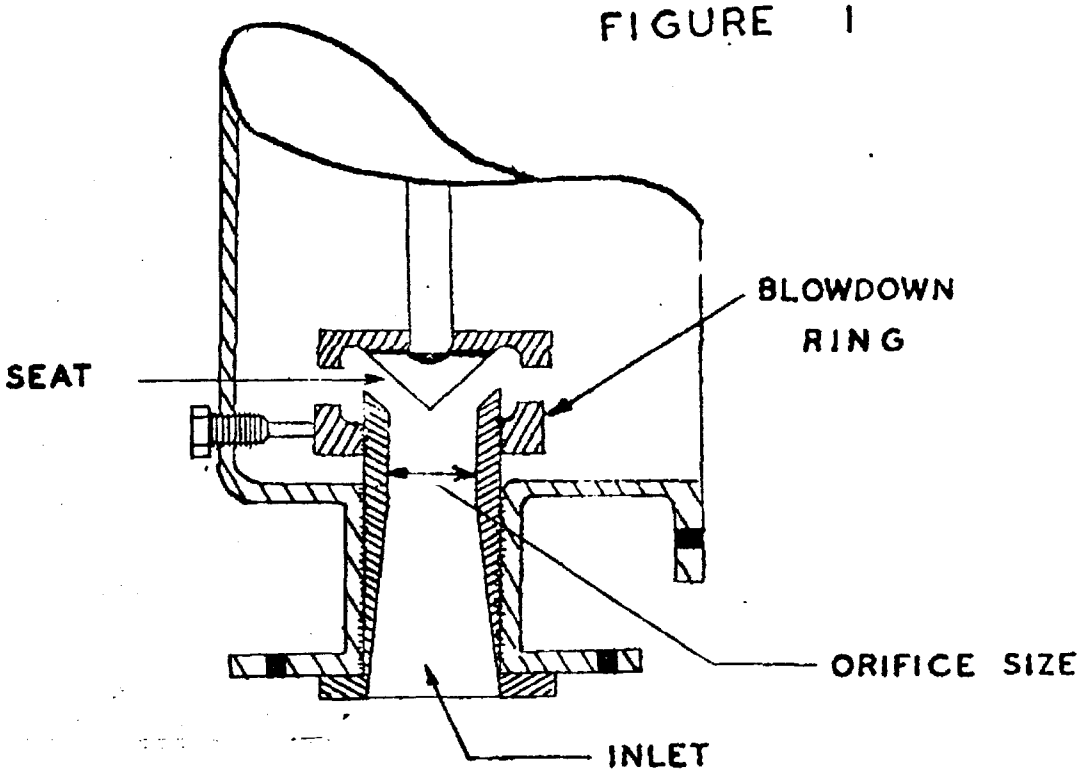
a. Process Considerations

Corrosive Services - All UCC approved full nozzle safety valves are supplied with 18-8 stainless steel nozzles and discs as standard. When these safety valves are in the closed position, the process fluid is in contact with the nozzle and disc only. Other standard components (body, bonnet, and spring) are steel. When the valve discharges, the process fluid comes in contact with these other components. If the valve is tied into a discharge header, all components will be in contact with the contents of the header.

Because any deviation from standard materials of construction adds to the cost, it can be advantageous in some applications to use a bellows-type safety valve. Standard bellows material is Type 316-L stainless steel; other materials are available. The bellows will prevent the process fluid from contact-

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FIGURE 1



The type of safety or relief valve should be determined from the service in which it is used. Valves designed for vapor service pop open at the set pressure and snap shut at slightly below the set pressure; valves designed for liquid service open and close with a slower action. Valves recommended for vapor service will function to some degree if they are used in liquid service and vice-versa; but, the manufacturers recommendations should always be followed.

Figure 1

UCC 021101

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ing the bonnet and spring under all conditions but does not protect the safety valve body. Depending on the application, it may be necessary to specify material other than carbon steel for the body.

In addition to providing corrosion protection for the spring and bonnet, the bellows protects the stem and guide from corrosion and from deposition of solids on the moving parts. Solids buildup on these parts can render a safety valve inoperable. Safety valves used for process service usually have cast steel bodies with stainless steel trim. To meet special requirements valves are also available with bodies of alloy steel, stainless steel, Monel or Hastelloy with suitable trim for the operating conditions. Springs are generally carbon steel for inlet temperatures of 450°F and less and tungsten steel for higher temperatures. They may be nickel-plated or aluminized for protection against corrosion. Springs of stainless steel, Inconel, or Hastelloy also are available. For low-temperature operations, valves with 3 1/2 percent nickel steel or stainless steel bodies are used with full stainless steel trim including springs.

Plugging - Safety valves in contact with a polymerizing or highly corrosive liquid should be provided with gas or liquid purging on either or both the inlet and outlet side. Purging may be specified by a note added to the safety valve specification; a sketch to indicate the installation should be provided.

Freezing - When the process fluid can freeze in the piping system or in the safety valve body before draining, protection against freezing must be provided. The use of steam or hot liquid tracer lines is recommended.

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Soft Seats and Low Melting Point Materials - Materials that do not resist fire and should not be used in petrochemical plants for safety valves are brass, bronze, aluminum, lead, tin, plastic, and elastomeric compositions. Metal-to-metal seats backed with composition material are acceptable.

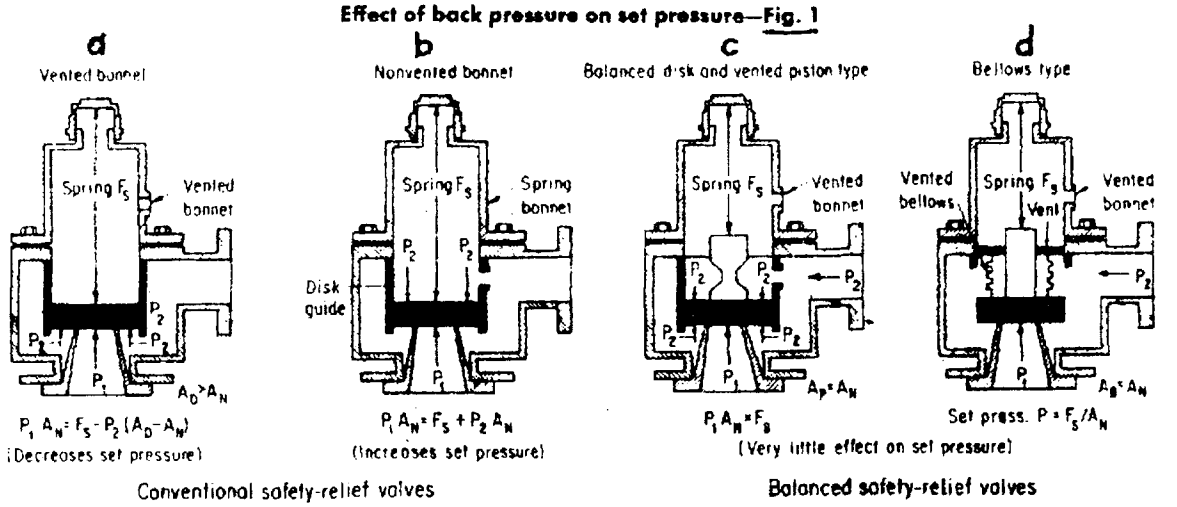
b. Effect of Back Pressure - The set pressure of this type valve is affected by back pressure. If the space above the disc is vented to the discharge line, the set pressure will be increased by an increase in back pressure. If the space is vented to the atmosphere, the set pressure will be decreased. If back pressure is constant, no serious problem will arise because the spring setting can be adjusted to compensate. For varying back pressures, such as may occur when the valve discharges into a header, the spring adjustment solution cannot be used. To overcome this problem, the balanced bellows safety relief valve has been developed. The bellows is so proportioned that the area open to the atmosphere is exactly equal to the area of the disc exposed to the process pressure thus, theoretically, eliminating any effect of back pressure on the set point. Actually, because of practical limitations, this is only approximately true - but the variation can generally be tolerated if the back pressure does not exceed 40 percent of the set pressure. With conventional valves the customary limit of variable back pressure is 10 percent of the set pressure.

Figure 1 illustrates the unbalanced forces across the disc of a conventional valve. The illustration on the left depicts a conventional type of valve with the disc guide plugged and the bonnet vented to atmosphere. Next we see the same valve except that the disc guide is not plugged and the bonnet is

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plugged at the vent to atmosphere. Figure 1c and 1d illustrates the forces across the disc of a balanced-bellows valve within the recommended differential pressure range.

Effect of back pressure on set pressure—Fig. 1



A_B = bellows area; A_D = disk area; A_N = nozzle area; A_P = piston area; F_S = spring force; P_1 = inlet pressure; P_2 = back pressure.

c. Effect of Temperature

An increase in temperature causes a reduction of valve set pressure as a result of the direct effect of temperature on the spring and expansion of body and bonnet which reduces spring loading. Since Safety-Relief Valves are invariably tested at atmospheric temperature, it is customary to adjust the set pressure at ambient conditions to compensate for higher operating temperatures as follows:

Operating Temperatures	% Increase in Set Pressure at Atmospheric Temperature
450°F to 200°F	None
201°F to 450°F	2%
451°F to 900°F	3%
901°F to 1200°F	4%

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d. Differential Between Operating and Set Pressures - For optimum performance in process work Safety-Relief Valves are generally set to open at 10% above the operating pressure.

It is recommended to provide a suitable margin above the operating pressure in order to prevent any unsuitable operation of the Safety-Relief Valve. The margin should be 10% higher or 25 psi whichever is greater.

A greater differential is recommended for pump and compressor discharge lines if possible since pulsations within the system can result in faulty operation. Consequently the Safety-Relief Valve should be set as high above the discharge line pressure as possible.

2. Safety Valves

All approved full nozzle safety valves are automatic pressure relieving devices actuated by the static pressure upstream of the valve and characterized by rapid full opening or pop action.

"Overpressure" (pressure increase over the initial set pressure) will hold the valve in its full lift position for maximum capacity. This pressure corresponds to the accumulated pressure of the vessel when the valve is set at the maximum allowable working pressure of the vessel.

The safety valve will continue to discharge and not reseat until the inlet pressure drops 4 to 7% below the set point.

Safety valves should not be used: 1, in corrosive chemical services; 2, in any back-pressure service; 3, where

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the discharge must be piped to a remote location; 4, where the escape of the lading fluid around the blowing valve is not desirable; 5, in liquid service; or, 6, as pressure-control or bypass valves.

3. Relief Valves

The operating action of a relief valve differs from a full nozzle valve in that a relief valve opens in proportion to the increase in pressure rather than the pop action of a full nozzle valve. Relief valves are designed primarily for liquid service and should not be used in gas or vapor service. In general, they incorporate similar components and appearance to full nozzle valves, but are usually smaller. Standard connections are screwed instead of flanged. To lift the disc to full discharge capacity, 25% overpressure is required.

Relief valves are usually pressure-tight on the downstream side of the valve and are not furnished with a lifting lever to operate the valve manually. The set pressure of this device is the pressure at which the valve starts to open, and can be checked by pressuring with air and determining the point at which the valve starts to open audibly.

Relief valves should not be used generally in: 1, steam, air, gas, or vapor service; 2, variable back-pressure service; or, 3, as pressure-control or bypass valves.

4. Safety Relief Valves

Safety-relief valves are characterized by rapid full opening or pop action on gas or vapors and are suitable for use as either a safety or relief valve, depending upon the application. There are two types of safety-relief valves: conventional and balanced.

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Safety-relief valves were designed for use by process industries where the material discharged by the valve may be flammable or toxic and may have to be discharged at a remote safe point through a closed discharge system.

Safety-relief valves should not be used: 1, on steam-boiler drums or superheaters; or, 2, as pressure-control or bypass valves.

a. Conventional Safety-Relief Valves

Conventional safety-relief valves are constructed in such a manner that the back pressure on the downstream side of the valve affects the action of the valve. A variable back pressure will cause erratic action of the valve. Conventional safety-relief valves are normally pressure-tight on the downstream side of the valve, and can be furnished with a lifting lever to open the valve manually.

Conventional safety-relief valves are normally used in all of the services where the superimposed back pressure is constant, not variable.

Conventional safety-relief valves should not be used: 1, on steam-boiler drums or superheaters; 2, in cases of variable back pressure; or, 3, as pressure-control or bypass valves.

b. Balanced Safety-Relief Valves

Balanced safety-relief valves are balanced by the addition of a pressure balancing mechanism (bellows, piston, or both) to decrease the valve's sensitivity to change in back pressure. They may or may not be pressure-tight on the downstream side of the valve, depending on the specific design. A lifting lever

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can be furnished optionally to open the valve manually. Balanced safety-relief valves may be used in all of the services where the back pressure is either constant or variable, in high-viscosity lading-fluid service, and in pump discharge service. The balanced-bellows type of safety-relief valve is especially effective in corrosive service because it seals the corrosive lading fluid from contact with the guiding surfaces of the valve, thus preventing sticking as a result of corrosion at this contact point.

Balanced-type safety-relief valves should not be used on: 1, steam-boiler drums or superheaters; and, 2, as pressure-control or bypass valves.

Because balanced-type valves must have their bonnets vented to the atmosphere, the need for piping the vent to a safe location must be determined. The balanced-piston type will always discharge small amounts of liquid from the bonnet vent because of leakage past the guiding surfaces. The balanced-bellows type will only discharge fluid from the bonnet vent in case of failure of the bellows.

5. "O" Ring Sealed Valves

Description: Some relief and safety-relief valves are being manufactured with resilient O-rings or other types of soft seals to supplement or replace the conventional metal-to-metal valve seating surfaces. Usually the valves are similar in all respects to the basic valves previously described, with the exception that the discs are designed to accommodate some type of seal ring to promote a degree of tightness exceeding the usual commercial tightness of conventional metal seats.

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This type of valve seat is used to advantage on valves which must, of necessity, operate close to the set pressure, resulting in a relatively small differential pressure on the disk.

Resilient materials are available which will resist attack by most fluids in a refinery but may be used only at low temperatures.

The use of O ring valves would probably eliminate the need for rupture disc protection of safety relief valves if the EPA would approve and furthermore it would be cheaper than the usual safety relief valve - rupture disc installation.

Farris Engineering produces the best "O" Ring Seal Valves since they can be easily converted to bellows type valves with little cost.

6. Pilot Operated Safety Relief Valves

Pilot-operated safety valves consist of a main valve and a small pilot valve to operate the main valve. The only working part in the main valve is a piston. The top of the piston is loaded by the process pressure through a sensing line that can be connected near the main valve inlet or directly on the equipment being protected. The bottom of the piston houses the disc which seats against the inlet nozzle to close the valve. The area at the top of the piston is greater than the area of the inlet nozzle. Because the top of the piston and the inlet nozzle both "feel" the same pressure, the larger area on top of the piston causes the main valve to remain tightly closed until the pressure on top of the piston is unloaded by actuation of the pilot valve. This type valve should be used where both automatic and remote manual relief are desired.

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A flowing pilot (one that continuously discharges fluid during periods of system overpressure) or a non-flowing pilot (one that discharges only the fluid on top of the main valve piston) can be used. The latter is preferable. Pilot-operated safety valves with non-flowing pilots are available from both the Anderson-Greenwood and Farris Companies. Both are approved by the Engineering Department.

Pilot-operated safety valves, unlike other safety valves, are bubble tight at 98 percent of set pressure. They can be successfully used on equipment operating up to 95 percent of set pressure.

Pilot-operated valves are used primarily in services which require a large pressure-relief area and low differential between the normal vessel-operating pressure and the set pressure of the valve. Since the net downward force on the piston of the main valve holding it closed is equal to the difference in area times the process pressure, the force actually increases as the set point is approached, rather than decreases to zero, which occurs with a spring-loaded valve.

These valves are not generally used in: 1, general refinery process service; 2, back-pressure service; 3, liquid service; or, 4, service where the temperature exceeds the safe limits of the flexible diaphragms.

They should be used only in clean vapor or gas service.

7. Rupture Discs

A rupture disc and safety head assembly consists of a rupture disc which is an intentionally designed weak spot in a pressure system and a safety head which consists of a hold-down flange and a base flange. The safety head is a

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holder for the rupture disc. The assembly fits between a pair of ANSI flanges.

Safety heads can be used as primary or secondary relieving devices and in parallel or in series with safety valves. The ASME rules quoted in Appendix F should be followed.

Minimum and maximum pressures and temperatures for which safety heads can be used depend upon the type, size, and material of construction.

Effect of superimposed back pressure on burst pressure is directly proportional pound for pound, i.e., one pound of back pressure raises the burst pressure one pound. Effect of built-up back pressure is a function of the length and diameter of the discharge piping. In no case should the discharge piping be smaller than the rupture disc and in some cases should be larger.

Location of rupture discs upstream of relief valves guards against valve leakage in systems containing very toxic or extremely valuable materials. Such an application also provides added protection in a system handling materials that are likely to cause fouling or corrosion of the relief valve to the extent of making it inoperative. A vent, usually provided with an excess-flow valve, is required between the relief valve and rupture disc to prevent pressure buildup. Normally, a pressure gage is also included with the excess-flow valve to show when the disc has blown.

In some cases, the rupture disc is used downstream of the relief valve when conditions are such that upstream installation is not practical or where the mechanisms of valves connected to a header are to be protected against corrosion. With this arrangement, it is necessary to use a valve whose set point is not affected by backpressure, or

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a vent must be included between the relief valve and rupture disc.

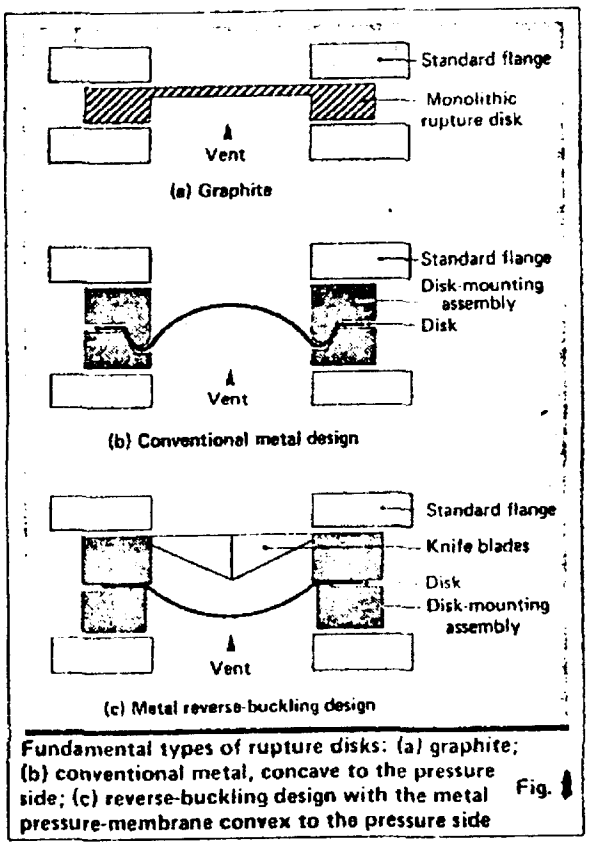
In addition to better corrosion resistance, rupture discs have the following advantages over pressure-relief valves: no leakage until failure, suitable for liquid slurry service, better handling of slow explosions and detonations; affected less by high viscosities.

Limitation: For a normal service life from rupture discs, the operating pressure of the protected system is usually limited to 66 percent of the disc rupture pressure. The service life of a rupture disc under normal operating conditions is usually one year.

Rupture discs are subject to relatively rapid creep-stress failure and, if not replaced periodically, are liable to fail without warning at the normal operating pressure.

There are three different basic types of safety heads: (1) reverse buckling, (3) prebulged (conventional), and (3) flat (graphite) as shown in Figure 1.

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Fundamental types of rupture disks: (a) graphite; (b) conventional metal, concave to the pressure side; (c) reverse-buckling design with the metal pressure-membrane convex to the pressure side

Fig.

Figure 1

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a. Graphite Rupture Discs - This type has the most limitations and is normally specified for noncritical or for very corrosive services.

b. Conventional Design - This is the type that has been in use for many years and in practically every conceivable service. It operates well in non-cycling pressure services on vapor, gas and liquid at pressures up to 70 percent of specified bursting pressures.

c. Reverse Buckling Design - This is the newest design available. Its operating characteristics make it the best choice for the majority of our vapor and gas relieving requirements. It is not recommended for use in liquid service as accumulated pressure may be high. It is the most expensive of the three types, but it has advantages given below.

(1) Suitability for operation at 90% of burst pressure.

(2) Pressure cycles from full vacuum to 90% of burst have little or no effect on burst pressure.

(3) Vacuum supports are not required.

(4) The metal is 3 to 5 times thicker than metal in a conventional design rupture disc and is therefore less susceptible to corrosion.

(5) Fragmentation is not a problem.

(6) It is the best choice for use beneath a safety valve because there is no fragmentation and because the safety valve can be tested in place without causing damage to the disc.

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A reverse buckling rupture disc supplied by one manufacturer must not be used in a safety head supplied by another manufacturer. Such interchanging can severely alter the operating characteristics of the disc.

With a conventional disc, the system pressure should not be more than about 70 percent of the rated bursting pressure. In other words, the RB-90 discs are more accurate and/or reliable. To the designer this means that for a system designed to run at 100 psig, the design pressure using RB-90 disks will be 100/0.90, or 111 psig; the design pressure using the conventional discs would be 100/0.70, or 143 psig. The lower design pressure saves investment dollars.

All rupture disc failures should be investigated to determine the cause and should be examined to determine its possible contribution to failure.

The RB-90 disc should fail fairly cleanly into four quadrants. If only one or two quadrants are cut, a reduced pressure reversal should be suspected. The most likely cause for reversal at a reduced pressure is slippage of the RB-90 disc in the safety head flanges. The base flange has a small nubbin on the surface--about 0.005 inch high by 0.050 inch wide. If sufficient torque was applied in making up the flange bolts during installation, this nubbin will leave a sharply defined groove on the bottom side of the rupture disc edge. The absence of a sharply defined groove means that the bolting torque was insufficient.

Careful examination of the nubbin groove on the failed disc may disclose evidence of slippage. The slippage occurs in an outward direction due to the

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pressure thrust against the convex disc. The nubbin groove will appear to be slightly wider at a point of slippage. Clean the surface carefully and look closely.

d. Fatigue, Creep and O/B Ratio - Fatigue and creep eventually affect the metals' rupture-disc burst-rating by lowering the original tensile strength of the materials. Very thin membranes used at low pressures, as well as at elevated temperatures, aggravate fatigue and creep effects. A wider margin (lower O/B ratio) is therefore recommended between the operating pressure and the burst rating. Because of metal fatigue and creep, a strict metal-disc replacement schedule is normally followed, especially when the discs are used at low pressures.

e. Rupture-disc Materials - Materials used for low-pressure rupture discs can be divided into two main categories: graphite and metals, either one of which can be plastic coated or lined.

The most common construction materials are: aluminum, Monel, Inconel, and austenitic stainless steel. However, discs are sometimes made of copper, silver, gold, platinum, tantalum and titanium.

Rupture discs are readily but not exclusively available in sizes from 1/2 to 24 in. dia. Some manufacturers list a size range from 1/8 to 44 in.

A 1/2-in. disc may have a minimum rupture pressure ranging from 65 to 850 psig., depending on the metal from which it is manufactured. A 24-in. disc may rupture at as low as 3 to 35 psig. Rupture pressures of 6,000 psig are readily available on smaller sizes

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but rupture pressures higher than 700 psig are rare on larger sizes.

f. Temperature Limits - The upper and lower operating-temperature limits of the disc material must be considered, because it is the temperature of the disc material itself that governs its suitability, and not the process temperature. Low limits are seldom a concern. At high limits, where discs are located some distance away from the heat source, dead space in the vent line will act as an insulator.

Metal discs accommodate high temperatures without protection. For example, Monel can be used up to 540°C. Graphite discs are used with a standard insulating assembly for temperatures above 200°C, up to 340°C. High operating temperatures increase the tendency of the metal to creep, depending upon the metal used. As a result, metal discs must be rated for a precise operating temperature. Graphite does not creep, and is insensitive to temperature up to its operating limit.

A second consideration in the case of metal discs occurs when significant variations in operating temperatures might occur at low pressure. Metal disc-burst ratings vary inversely with temperature. As a result, increased temperature alone can conceivably rupture a low-pressure metal disc, even though the process pressure has not reached the burst rating of the disk. For instance, a 4-in aluminum disk rated to burst at 10 psig at 22°C, will burst at 8.1 psig at 120°C, according to published temperature-burst curves. In some temperature-sensitive service, this may be desirable.

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g. Minimum Ratings and Tolerances by Diameter - Minimum burst ratings are a function of diameter in all materials. Should the vent line diameter be too small for a desired low-burst rating, either an alternate material can be selected in that diameter, or a larger-diameter disc can be used in the preferred material.

h. Other Considerations - When rupture discs are used upstream of a safety relief valve the valve must be of the high lift type if located under the valve. A RD cannot be used under a low lift safety relief valve.

The ASME Code has recently been revised and now requires that the capacity of a safety relief valve be rated at 80 percent of normal capacity if a rupture disc is used with the valve.

The EPA wants an excess flow check valve installed at the test connection between a rupture disc and safety valve to prevent losses to the atmosphere. C&P is using for hazardous service a pressure lead, pressure switch alarm or horn when necessary.

BS & B is producing a newer shop-torqued safety head with an S-90 disc which may be an improvement over the RB-90 disc in that there is no knife edge to corrode.

Caution: a pin hole leak in a rupture disc will result in equallized pressure and the disc will not rupture.

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8. Low Pressure Relief Devices

A vent unit is a device which reduces evaporation losses while protecting a low pressure vessel from the possible damaging effects of overpressure or over-vacuum. When the vapor space pressure within the vessel exceeds the pressure set point, the vent unit opens to release vapor from the vessel unti the pressure is reduced below its set point. When a vacuum is formed within the vessel and exceeds the vacuum set point, the vent unit opens to admit air or inert gas into the vessel until the vacuum is reduced below its set point.

Pressure and/or vacuum vents are usually pallet type, hinged type, or pilot-operated type relieving devices actuated by the pressure or vacuum in the equipment being protected. Pallet and hinged types can be either weight loaded or spring loaded on both the pressure and vacuum side and are normally used on equipment with a MAWP of less than 15 psig. Although pressure and vacuum vents are available as separate units, they are normally used as combination units in one body. Flame arresters may be used between the vent unit or free vent and the equipment to prevent travel of a flame from an outside source into the equipment.

Since it is not possible to obtain any capacity without some overpressure or overvacuum, these vents must be selected to provide the necessary capacity without exceeding the maximum allowable conditions for which the equipment to be relieved was designed. Standard size vents for venting equipment for atmospheric storage tanks are tabulated in Appendix G. Pilot-operated valves can be used as pressure-vacuum or pressure-only vents. Each application for pilot-operated valves being considered for vacuum relief requires review by the manufacturer to determine capacity and overvacuum requirements. These

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valves provide positive opening and closing action and are bubble tight at 98 percent of set pressure. It is likely that air pollution regulations will necessitate the use of more of these valves even though they are more complicated and more expensive than breather vents of the ordinary types.

Regardless of the type of venting equipment used, it is extremely important when utilizing a vent gas blanket to provide a gas pressure regulator that will maintain good control at a pressure of 75 percent of the vent set pressure.

a. Vent Pressure and Location of Vent Unit - The recommended set pressure for an emergency vent is 1.5 oz/sq.in. when used in combination with a breather vent. The breather vent should be set for 1 oz/sq.in. pressure and 0.5 oz/sq.in. vacuum.

The normal breather vent for an atmospheric tank should be located at the highest point of the roof to assure free venting. Emergency vents may be conveniently located near the side with other fittings where a guard rail should be provided. Consideration should be given to the location of any overfilling discharge.

b. Breather Vents

Varec Series 2000-81 or Equal - This is the most common type. It consists of two pallets built into one body, one to relieve pressure and one to relieve vacuum. It is weight loaded and is limited to approximately 8 oz/sq.in. set pressure on either pallet.
BS&B Model 76-13 - This is also a common type vent unit, but has less capacity for comparable size than the Varec or equal type. It will provide a reasonably tight seal when supplied with an elastomeric

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seating surface such as Buna-N. This unit has a hinged cover and relieves pressure by the cover raising to the required angle. Vacuum relief is accomplished by an upward movement of the diaphragm or seating surface resulting from atmospheric pressure being higher than the internal pressure of the equipment being protected.

c. Special Purpose Vents

Pressure Only - These units, usually specified as Varec, are single pallet type either weight loaded or spring loaded. When weight loaded, they are limited to a set pressure of 12 oz/sq.in. Normally spring loaded units with a set pressure in excess of 13.5 psig are not specified.

Vacuum Only - These units are similar to the pressure only units described above except they are designed to relieve over-vacuum conditions in equipment. The spring loaded units are limited to a set pressure (external differential relative to equipment internal pressure) of 10 psi.

Pressure and Vacuum - These units, usually specified as Varec, are double pallet type with either weight loaded or spring loaded pressure pallets.

Pilot-operated Low Pressure Vents - The only UCC approved pilot-operated valves for low pressure venting applications are manufactured by Anderson-Greenwood Company. These items permit us to operate equipment closer to MAWP than other available venting equipment, but they are subject to the operational limitations. Discharge from these units can be collected.

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d. Emergency Vents - Any of the venting equipment previously described could be used as an emergency vent provided it will supply the required relieving capacity for the application. Although it is possible to use emergency vents for normal breathing, it is good practice to provide a separate vent for normal breathing and to maintain a reasonable margin between the set pressures of the two units. Discharge from emergency vents cannot be collected, no outlet connections are provided.

Varec or Equal - Pressure Only - This is a hinged type unit that is usually either 20" or 24" nominal diameter and flanged to fit standard API Type tank connections (they will not fit ANSI Standard 125 or 150 lb. connections). Pressure settings are available from 0.75 oz/sq.in. to 2.0 oz/sq.in.

Varec or Equal - Pressure and Vacuum - These are similar to the pressure only type except they are provided with a spring loaded vacuum relief pallet. They should not be used on equipment that requires a flame arrester (use a breather vent with flame arrester and a pressure only emergency vent).

BS&S - Pressure and Vacuum - This unit has a hinged cover and relieves pressure by the cover raising to the required angle. It will provide a reasonably tight seal when supplied with an elastomeric seating surface such as Buna-N. Like the Varec or equal pressure and vacuum emergency vent, it should not be used as an emergency vent where a flame arrester is required.

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9. Seal Pots and Loops

Seal pots and pipe loops are frequently ignored as pressure relieving devices. For example a power plant maintenance procedure resulting in closing a block valve in a seal loop on a deaerater. The block valve was never opened and shortly after startup over-pressure blew a 4 foot diameter cast iron end off the vessel. The seal loop was the only pressure relief device.

Precaution against freezing in cold climates must be taken to prevent closing off seal pots used on low pressure still columns as pressure relief devices.

10. Shear Pins

Processes handling highly viscous polymeric materials, such as in fibers production, cannot be protected with conventional relief devices. Shear pins in prime mover shafts are used to prevent pressuring equipment above its MAWP.

E. Design Of Pressure and Vacuum Relief

The proper design of a vapor relief system is one of the most serious aspects of good plant design because upon this rests the safety of personnel and also the protection of equipment and product. The consequences of poor design can become disastrous, aside from being expensive.

In this section we will cover the highlights of pressure relieving system design and will in Appendices G, H and I cover the calculation methods along with sample problems and forms.

1. Establishing a Basis

An evaluation of all abnormal, hazardous and emergency possibilities must be made. From this evaluation the

UCC 021123

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worst, credible, single condition will be selected for the basis of the relief requirements design. If the selected "worst condition" introduces or actuates additional relief requirements the control system (such as high temperature or pressure actuated shut down systems) must override it or additional capacity for relief must be provided.

The use of a restricting orifice in the steam supply line is sometimes used to keep the relief system requirements at a practical level. For systems or equipment containing both liquid and vapor the relief capacity will be determined on the basis of (a) venting all vapor and (b) all liquid and the worst case used for the relief device selection.

2. Relief Valve Characteristics

The size of the relief valve depends chiefly on the quantity of fluid to be relieved per unit time and the differential pressure across the valve.

When dealing with gas, vapor, or steam, the general practice in the industry is to select relief valves that start relieving at the maximum allowable working pressure of the vessel and reach full capacity at 3 to 10 percent above this pressure. This overpressure is generally termed "accumulation," and is based on the per cent pressure rise from the time the valve begins to open to when it is fully open.

Back pressure in the downstream piping affects the standard type of valve. In the disk type, if the guide is vented and the bonnet plugged, the relieving pressure of the valve increases linearly with increase in back pressure. Take, for example, a relief valve that is designed to open initially at 100 psig differential and 10 percent accumulation. If the back pressure is 10 psig, the valve

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will begin to open at 110 psig and relieve its maximum design capacity at 120 psig. If the vessel is designed for 100 psig, the ASME Code will have been violated by permitting the internal vessel pressure to rise 20 psig, or 20 percent above the vessel design pressure, even though the valve was originally set to open at the vessel design pressure.

On the other hand, if the guide is plugged and the bonnet vented, the relieving pressure of the valve will decrease with increase in back pressure. This arrangement causes the valve to relieve in all cases at or below initial set pressure.

Back pressure built up in the relief header theoretically should not affect the relieving pressure of a balanced-type valve. However, because of manufacturing imperfections and practical design limitations, the balanced valves available today will vary in relieving pressure when the back pressure reaches approximately 40 percent of the set pressure.

3. MAWP, Design, Sizing and Set Pressure Limits

The ASME Code is expected to be adhered to in setting the criteria for design and operation of process vessel pressure relieving systems and devices. ASME Code sections UG-21 and UG-98 are as follows:

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UG-21 Design Pressure[1]

Vessels covered by this Division of Section VIII shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation. For this condition, the maximum difference in pressure between the inside and outside of a vessel, or between any two chambers of a combination unit, shall be considered (see UG-98 and UA-60 (b)).

UG-98 Maximum Allowable Working Pressure

a. The maximum allowable working pressure for a vessel is the maximum pressure permissible at the top of the vessel in its normal operating position at the operating temperature specified for that pressure. It is the least of the values found for maximum allowable working pressure for any of the essential parts of the vessel by the principles given in (b), and adjusted for any difference in static head that may exist between the part considered and the top of the vessel. (See UA-60(a)).

b. The maximum allowable working pressure for a vessel part is the maximum internal or external pressure, including the static head thereon, as determined by the rules and formulas in this Division, together with the effect of any combination of loadings listed in UG-22 which are likely to occur, for the designated coincident operating temperature, excluding any metal thickness specified as corrosion allowance. (See UG-25).

[1] It is recommended that a suitable margin be provided above the pressure at which the vessel will be normally operated to allow for probable pressure surges in the vessel up to the seating of the pressure relieving devices (see UG-133).

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c. Maximum allowable working pressure may be determined for more than one designated operating temperature, using for each temperature the applicable allowable stress value.

It is apparent that design pressure and maximum allowable working pressure are not necessarily the same as some seem to think. When MAWP ratings are not available the design pressure, if known, can be used in place of the MAWP. At any rate the MAWP is the basic pressure level upon which relief devices are sized and opening pressures are set. The relationships between MAWP, sizing pressure and set pressure as defined by the ASME Code are shown in the following chart.

4. Basic Design Data

a. Fire Exposure Heat Transfer Rates - The heat transfer rate through vessel walls during fire exposure has been established by fundamental research to be as follows:

Unprotected, bare metal.
20,000 Btu/hr/ft^2

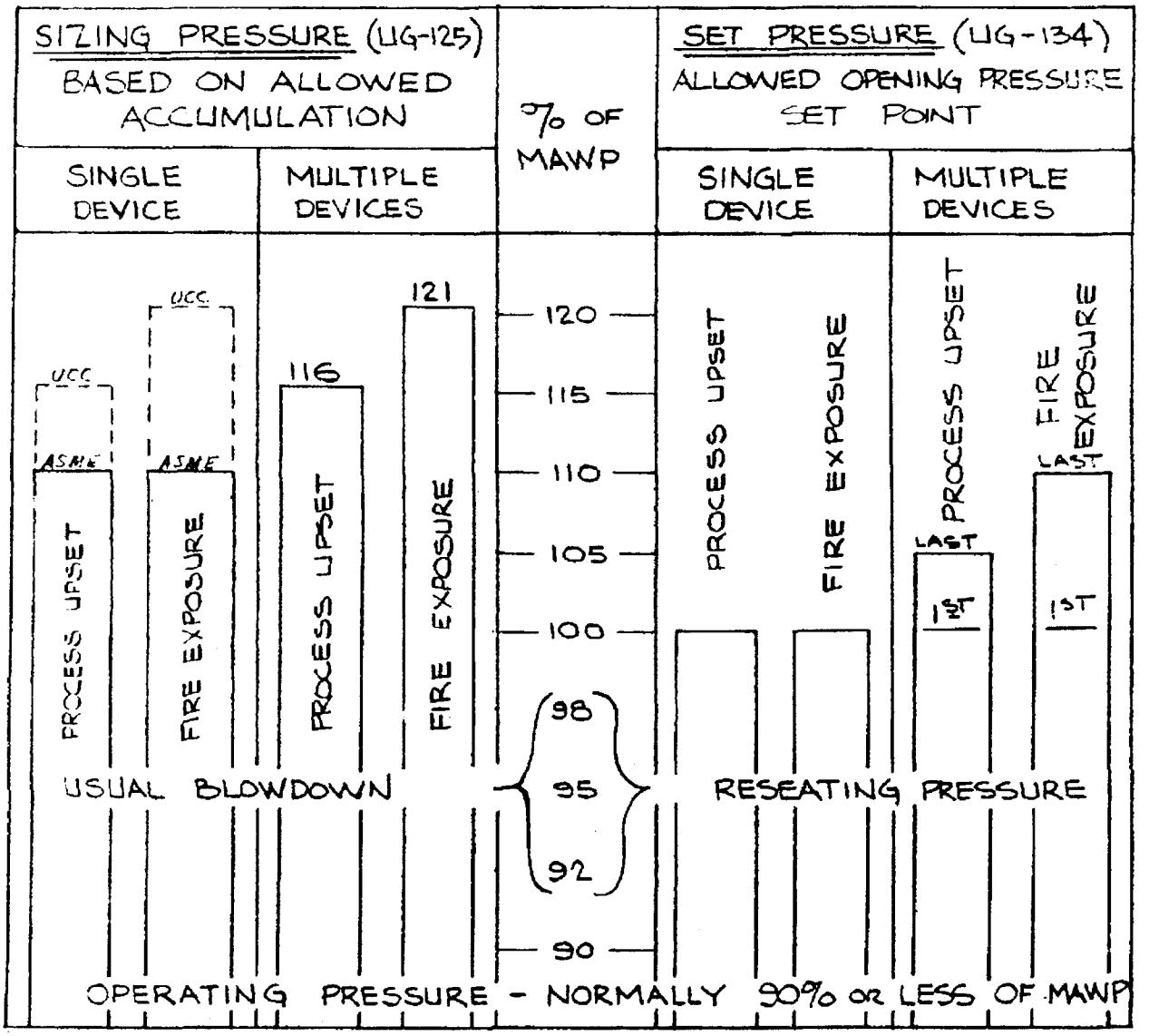
Insulated vessels or Water Sprayed but not insulated
6,000 Btu/hr/ft^2

(This rate would be used for uninsulated brick lined equipment. Polyurethane insulation cannot be considered and the 20,000 Btu/hr/ft2 heat transfer rate would be used.)

Insulated and Water Sprayed.
3000 Btu/hr/ft^2

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ASME CODE ALLOWABLE PRESSURE LIMITS FOR RELIEF DEVICES



ACCUMULATION = ALLOWED PRESSURE ABOVE MAWP.

OVERPRESSURE = PRESSURE ABOVE SET PRESSURE.

OPERATING PRESSURE SHOULD BE SUFFICIENTLY BELOW THE BLOWDOWN SEATING PRESSURE TO PREVENT LEAKAGE.

(N.W. Clauss - 1977)

UCC 021128

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This rate for insulation that is in good condition with full protective cover and well sealed. Inspection and judgement as to heat transfer rate will be required for deteriorated insulation.

The heat transfer and the resulting vapor formation in large low pressure storage tanks is also a function of volume, distance and time. The heat transfer rate used by UCC decreases from 20,000 Btu/hr/ft2 for tanks up to 15 feet in diameter down to 2500 Btu/hr/ft2 for a tank 80 feet in diameter. A curve in Appendix G gives the tank diameter - heat transfer relationship.

b. Vessel Contents

Liquid Only - Capacity is based on removing vapor generated to restrict vessel pressure to 16 percent above the MAWP for process upsets and 21 percent above the MAWP for fire exposure. Relief capacity is based on the wetted surface area, heat transfer rate, latent heat, molecular weight and the temperature at set pressure.

Gas and Vapor Only - Valve sizing is based on the critical flow through an orfice and depends on heat transfer, orfice area, pressure and temperature at the set pressure and temperature at the set pressure and molecular weight. Heat transfer is based on the total vessel surface area and the heat transfer rate.

Both Vapor and Liquids - Unless accurate liquid entrainment rates can be calculated the usual approach is to size for (a) the liquid case and (b) the vapor case and take the worst case for valve selection. The liquid case assumes the vessel full of

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liquid to the maximum operating level. The vapor case assumes the total surface area of the vessel is involved.

For liquid mixtures the single component that gives the highest capacity requirement is used as the base for valve selection.

c. Rupture Disc Sizing - Graphical or calculated methods for sizing rupture discs are provided for determining the resistance to flow for vessels containing either gases or liquids. The ASME Code requires the use of multipliers to the official size determination as follows:

Type of Disc	Multiplier
Conventional	0.62
RB-90	0.95
Combined Safety Valve and Rupture Disc	0.80

d. Still Columns - Heat transfer to still columns from fire exposure is based on the assumption of wetted surface being one half of the total column surface up to an elevation of 100 feet.

Tray holdup is assumed to be 2 inches unless accurate tray level is known.

Determination of the position or location of pressure relief devices must be made to prevent overpressure damage to the column or the column internals.

Low pressure columns relief capacity tends to be excessive and can be greatly reduced if the vacuum rating can be increased. Upgrading by the addition of reinforcing pads, stiffening rings, etc., should be investigated prior to sizing relief devices.

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Inert gas pressure control systems are not acceptable as the sole vacuum relief protection. A vacuum relief device must be used as backup.

e. Thermal Expansion (Section 2.4.2.5 in STM) - Relief valves for this purpose need only be of nominal capacity; generally, the smaller commercially available orifice is many times larger than required. When calculations are desired, the required capacity may be determined by the following formula:

$$Q = \frac{\beta H}{7.2Sc}$$

Where: Q = Required capacity, gpm
H = Heat input, Btu/hr.
β = Coefficient of volumetric expansion per °F.
= 0.0001 for water
= 0.0010 for light hydrocarbons
= 0.0008 for gasoline
= 0.0006 for distillates
= 0.0004 for residual fuel oil
S = Specific gravity
c = Specific heat, Btu/lb./°F

f. Explosion Venting - Generally, explosion venting is needed where an internal explosion hazard can exist due to the possible accumulation in explosive concentrations of flammable gases, vapors, mists, and combustible dusts. Explosion relief for combustible dusts is described in Appendix G.

NFPA No. 68 Explosion Venting Guide provides a composite list of explosion characteristics for common vapors, gases, and dusts.

g. Calculation Methods - The basic design methods for relief capacity requirements are covered in Appendix G. Calculation methods cover the following:

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(1) Fire Exposure Sizing
(2) Rupture Disc Sizing
(3) Distillation Columns
(4) Liquid Phase Reactors
(5) Tube Rupture
(6) Air Cooled Heat Exchangers
(7) Vacuum Relief Sizing
(8) Low Pressure Vent Sizing
(9) API 650 Tank Venting
(10) Dust Explosion Relief
(11) Vessel Explosion Relief

F. Back-Pressure, Line Pressure Drop, Reaction Forces

A vapor relief system may consist of piping with only one relief valve or rupture disk on a single vessel, or it may be one of the more complex piping systems in a plant involving many relief valves manifolded into a common header. Such systems are indispensable to any plant having processes in closed vessels of either high or low pressure. Adequate relief valves manifolded into inadequate piping produce a poor system because pressure drop in the lines can prevent satisfactory relief of the pressure in the vessel. Thus, it is not enough to select a valve suited for the job; one must also size the common header to permit the flow of the full vapor or gas load from wide-open relief valves without excessive pressure drop.

Furthermore, the size of the outlet pipe shall be such that any pressure that may exist or develop in the discharge line will not reduce the relieving capacity of the safety devices below the amount required to protect against over-pressure.

1. Line Sizing

Maximum design capacity is generally based on the valve or group of valves that may simultaneously vent the maximum amount of vapor. This condition, as mentioned before, could be attributed to abnormal process situation or fire, whichever governs in establishing maximum flow.

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Fire selection is generally based on the number of vessels in an area that could be subjected to the same fire. Radius of the fire zone may vary from 30 to 60 feet depending on plant policy, experience, or both.

2. Inlet Pressure Drop

Excessive pressure loss at the inlet of a safety valve in gas, vapor, or flashing-liquid service will cause extremely rapid opening and closing of the valve. This is known as "chattering." Chattering will result in reduced capacity, damage to the seating surfaces, and possible destruction of the safety valve.

For gas, vapor, or flashing-liquid service, the inlet piping between the protected equipment and the inlet flange of the safety valve must be (1) at least as large as the safety valve inlet connection, and (2) designed so that the total pressure loss does not exceed 3 percent of the set pressure of the valve in pounds per square inch gage.

It is poor practice to mount the safety valve at the end of a long, horizontal piping run through which there is normally no flow. Foreign matter may accumulate, or liquid may be trapped, which may interfere with the operation of the valve or be the cause of more frequent valve maintenance.

3. Back Pressure Effects in Relief Capacity

Often valves must operate with a back pressure. For example a valve on a gear pump discharge, which pops into the suction of the pump. Here we have a constant pressure on the discharge side of the relief valve. This type operation requires that the valve be calibrated to allow for this, since it will lift at the set pressure plus the back pressure.

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One method for handling increase in back pressure (when standard relief valves are used) is to lower the setting of the valve below the vessel design pressure. For example: Assume the vessel design pressure is 50 psig and the normal operating pressure is in the range of 5 psig. The relief valve may be set to open, in this case, at 30 psig but may be designed for full rated capacity at 55 psig - (50 psi + 10%). The arrangement will now tolerate a back pressure of 20 psig, as against 5 psig with the valve set at 50 psig, with 10 percent accumulation. Consequently, one may design the relief header for a smaller diameter pipe and still use the same size valve as the one set for 50 psig.

Another method is the procedure mentioned earlier - plug the guide and vent the bonnet. An increase in back pressure will lower the relieving pressure and will not overpressure the vessel. This arrangement, however, can increase venting if the valve setting is too close to the operating pressure.

One can also use balanced relief valves. The cost of the valves may be slightly more than for the standard type, but the savings in pipe cost plus the operating advantages and flexibility in design gained will more than compensate for this.

Capacity reduction takes place in the discharge of conventional safety valves (those usually used) when pressure builds up in the downstream piping.

Bellows type valves require no compensation in setting because the back pressure effect is eliminated by the bellows. Valves equipped with bellows also prevent the process fluid from coming in contact with the working parts of the valve.

Comparative sizing factors for variable back pressure are given in Figure 1.

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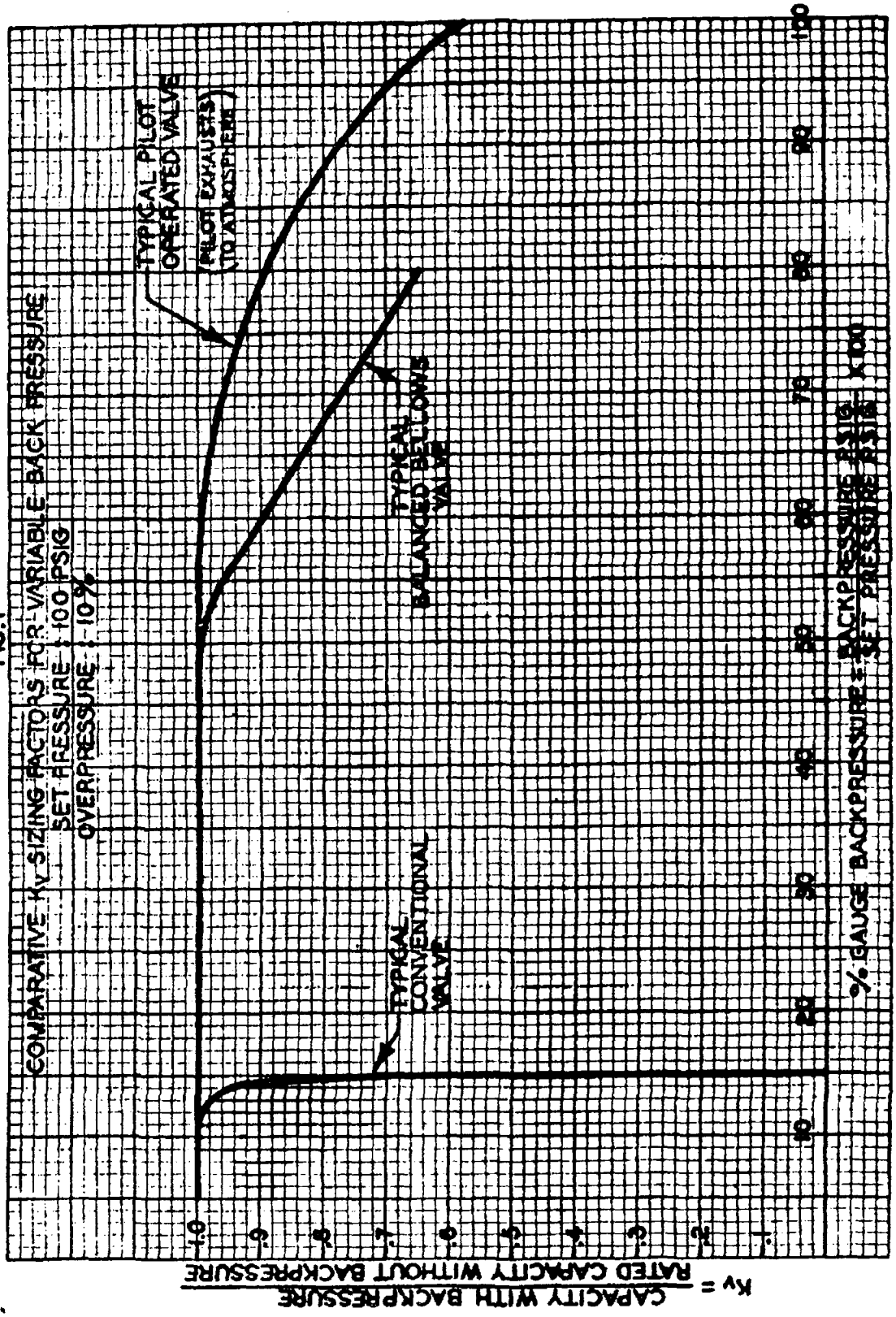


FIG. 1

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4. Pressure Drop in Discharge Piping

Since the pressure drop in the discharge piping is reflected in back pressure at the relief valve, and developed back pressure greater than about 10 percent of the set point for conventional valves or 40 percent for balanced bellows valves is undesirable, the pressure drop from each valve to the atmosphere must be checked for the maximum anticipated load. Where other valves also discharge into the same line, their loads must also be considered. Actual calculations for valves discharging directly to the atmosphere are seldom required, since it is usually apparent by inspection that the allowable back pressure will not be exceeded.

A closed pressure relieving system must be designed with great care to ensure that it will accomplish its intended purpose. Unlike many plant components, there is generally no way of testing the system in service.

The final header system design, then, is simply a matter of calculating back along each of the branches to the individual valves.

Discharge piping from a single safety valve shall be at least as large as the safety valve outlet with consideration given to line pressure drop. The area of any section of a common discharge header downstream from each of two or more safety valves that may reasonably be expected to discharge simultaneously shall be at least the sum of their outlet areas. This size must be checked to ensure that back pressure under any expected condition will not adversely affect set pressure or capacity of any safety valve discharging into the header system.

As EPA regulations become increasingly restrictive existing chemical processing equipment will require more com-

UCC 021136

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plex safety relief device collection headers, flares, etc. The important message is that changes in relief device systems must be analyzed and approved by the related engineering skills to avoid decreasing the pressure relief capacity needed to protect equipment.

A computer program (LSSVPN) is available for sizing of safety valve discharge headers.

5. Reaction Forces

The discharge at high velocity from safety relief valves and rupture discs result in reaction forces. All relief device piping and vessel connections must be analyzed by process vessel engineers to determine and provide the necessary bracing and support. This subject is covered in Section 5 of the Design and Analysis Section of the Safety Technology Manual.

G. Installation, Location, Mainteance

Reference: Standards SF-1 and SF-16

1. Safety Relief Valves

Safety and relief valves are very delicate pieces of equipment, and should be handled with care. The seating surface of a valve is usually machined, then polished to a flatness of about three millionths of an inch. This smooth finish is necessary in order for the valve to seat off. Any rust, dust, dirt, or foreign matter must be kept out, because it will damage the seats. A small jolt or impact to the valve could scratch the seats bad enough that the valve could not seal. Too often valves are dropped or hit, which can not only damage the seat, but also misalign its moving parts. Misalignment usually causes leakage, but could cause a valve not to operate at set pressure, or not at all.

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The physical location of safety-relief valves can vary, but usually they are mounted in a vertical position, and at the highest point in the vapor space of the vessel. The reason for this is simple. The fastest way to relieve pressure on a vessel is to remove the vapor.

When a column requires more than one safety valve, it is most desirable that one safety valve be installed at the top of the column and a second at the base of the column in the space above the liquid level. This is to reduce the possibility of distorting and damaging the internal trays when the column is venting as well as to release most of the vapors well overhead. If the trays and supports are of adequate strength so as not to be damaged when the maximum designed emergency flow is discharging through relief area at the top of the column only, and if there is no danger of the trays becoming plugged, it is satisfactory to provide the relief area at the top of the column only. This is not, however, the most effective relief for the kettle section.

The following accident resulted from poor judgement in the location of a safety relief valve:

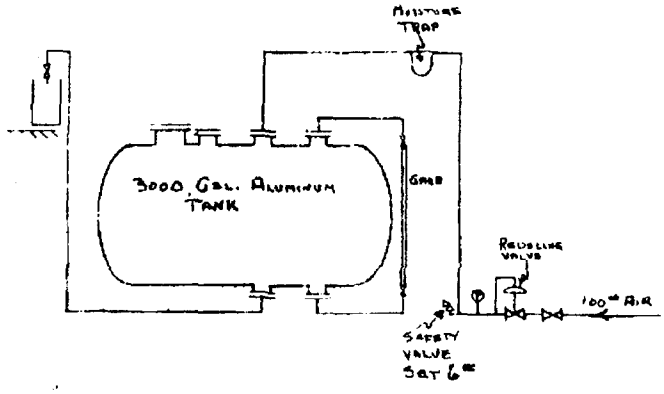
Description: A 3000 gallon aluminum tank was being used for 56 percent Acetic Acid service. It was pressurized with 6 pounds of air to force it through overhead lines to the dispensing locations inside the building. The Safety Valve was located on an elbow right next to pipe tee with a vertical riser of about 6 feet. The moisture trap was on the horizontal line.

The scale, dirt, and moisture from the vertical pipe and the horizontal run was driven into the elbow and the Safety Valve opening each time the system was pressurized. Finally the elbow and valve became plugged so that when the Reducing Valve leaked, the Safety Valve could not

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function. One head was blown out of the tank with enough force to remove 1000 square feet of window, a portion of the roof, and the brick chimney of the adjacent building. Fortunately the injuries were minor but the property damage was extensive.

Preventive Measure: A Safety Valve should be located to minimize the amount of foreign material that can accumulate in its fitting or entrance. In this case it could have been off a tee in the vertical riser, or at the top of the riser.



A full-port shutoff valve is normally installed on the inlet side of all full-nozzle safety-relief valves. The shutoff valve will permit the safety valve to be removed from service for repairs or replacement without shuting down the system. Also, it will permit testing, in place, of large safety valves. The shutoff valve should be sealed open with a car seal or other device by the Operating Department or Safety Department personnel.

None of the Carbide standard plug or ball valves is full-port; they should not be used with full nozzle type safety valves. To determine if a Carbide standard valve is full-port, refer to PPF-5 in the Valve and Piping Specifications Manual; reduced port valves are so designated.

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Safety valves in contact with a polymerizing or highly corrosive chemical should be provided with gas or liquid purging on either or both the inlet and outlet side. A Teflon split gasket is normally used on the inlet side to reduce the amount of purge gas (or liquid) required, with the purge gas introduced between the safety valve and the split gasket.

Because of large size and weight, safety valves with 3-inch and larger inlet connections should be installed with test connections to permit testing in place. The use of test connections should also be considered for safety valves smaller than 3 inches that will be in very hazardous or toxic fluid service. A 1/2 inch shutoff valve should be provided for the test connection. (See UCC Standard PPM-17A, PPM-17B, and PPM-17C.) A filler flange is usually used for this purpose.

Concerning safety value installation, for further details, refer to Engineering Standard SF-1.

Soft seats and low melting point materials do not resist fire and should not be used in petrochemical plants for safety valves. This includes brass, bronze, aluminum, lead, tin, plastic, and elastomeric compositions. Metal-to-metal seats backed with composition material are acceptable.

When two or more safety valves handling corrosive or toxic material are connected to a common vent collection header, a full-port shutoff valve should be installed in the discharge line of each safety valve. Gate or ball valves can be used for this purpose but never a globe valve, because of its flow restrictions. A shutoff valve on the vent header will prevent the hazardous material from escaping in the unit in case one of the safety valves opens when another valve is removed.

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Vapor discharge lines located outdoors should have a Tee or 45 degree bend connection provided at the top of the discharge line to keep out the weather. A 3/8 in. drain hole should be provided at the low point in the line to drain any liquid that condenses in the line; for inside locations, or where it would be bothersome for liquid to drain down the unit, a 1/2 in. drain line and valve should be installed from the low point in the vent line.

When safety valves discharge a very hot fluid such as Dowtherm, the discharge line should run to the side of the structure. A vertical rising line should be provided for the vapor and a liquid line should run to the ground.

When testing discharge piping, pressure must not be applied on the downstream side of bellows type safety valves. This will damage or destroy the bellows.

Flexible Connections in the Discharge Lines of Safety Valves

Flexible connections should be avoided whenever possible, but may be needed on the discharge of safety valves, subject to stress analysis, when any of the following conditions prevail:

a. Where vibration is prevalent.

b. Where there are high temperature differences between the safety valve and the discharge piping.

c. Where excessive loads may be imposed on the safety valve by piping.

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Servicing Provisions

All safety valves must be installed so that they are easily accessible for testing in place and/or removal for shop maintenance. Ladders, platforms, and handrails should be provided as needed for safety of personnel and for low maintenance expense. To reduce personnel hazards, the installation of davits should be considered for 3 inch and larger flanged safety valves in some locations.

2. Rupture Discs

a. Disc Installation - Care should be used in locating safety heads. They must be installed so that personnel will not be endangered or equipment damaged when the disc ruptures. Shutoff valves can be used under safety heads provided they are sealed open.

Reverse buckling type safety heads are the only ones recommended for installation beneath safety valves. When used beneath safety valves, they should be installed according to Section VIII of the ASME Code. Rupture discs are used under safety valves to prevent any leakage, to prevent valve corrosion, to exclude compounds which interfere with valve operation, and in the case of reverse buckling type, to permit testing of a safety valve in place. They are not to be used in liquid filled systems.

Refer to Safety Standard SF-2 for further details.

A serious deficiency reported by MCA illustrates one possible hazard that can only be avoided by proper training.

Description: A metal rupture disc was installed in the flange assembly of a pressure vessel with the

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rupture disc still enclosed in its metal shipping protector. (Installed in this manner, the rupture disc would be unable to function.) The problem was discovered by a pressure vessel inspector during a routine inspection.

Cause: Maintenance Department personnel failed to recognize and discard the metal shipping protector before installing the rupture disc.

b. Purge - In special cases, either a liquid or vapor purge may be used to prevent plugging of the inlet components. The purge is usually controlled by a restrictive orifice and supplemented by a flat gasket with a cross-slit in the center. The gasket should be located between the purge connection and the protected equipment. The purge should be introduced through a drilled and tapped hole in the safety head base flange where possible.

c. Protection - Provide a means to prevent liquid build-up on the disc and to protect the disc from atmospheric corrosion. A thin plastic cover can be used for this purpose.

Intermittent checks should be made to ensure that the plastic cover on the outlet side is intact.

d. Accessibility - All safety head assemblies and ruptures discs must be installed so that they are accessible for inspection and replacement.

If inlet shut-off valves are used they must be so located that personnel operating the valve will not be endangered by the rupture disc discharge.

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e. Maintenance - Rupture discs do not have an infinite life. They should be changed-out and the safety heads inspected on a routine basis (normally during a shutdown). The time period between change-outs will vary with the application but should rarely exceed two years.

f. Installation and Torquing - The installation of any rupture disc and safety head is a critical operation. The rupture disc is a precision device designed to protect equipment and life. These instructions pertain to RB-90 discs specifically, although some of the same precautions and steps can be applied to conventional discs. Never re-install a disc that has been in service. When stresses are relieved by unbolting, the proper seal may not be re-obtained.

(1) Be sure the safety head flange surfaces are clean and free of foreign matter.

(2) Do not clean the base flange with emery cloth or other abrasives in such a fashion that will damage the nubbin. The use of a solvent to clean deposits is recommended.

(3) Inspect the knife blades in the hold-down f lange. They must be clean and sharp.

(4) Place the disc between the safety head flanges squarely and evenly. Make up the disc in the safety head flanges with the tabs or Allen screws provided. Use no gasket or sealant compound above or below the rupture disc.

(5) A spiral-wound gasket is installed under the base flange at the pipe or vessel flange. Free-vented discs, discharging directly to the

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air, do not require a gasket on the top side of the assembly.

(6) The condition of the bolt and nut threads is critical to the bolting operation. The values obtained with the torque wrench are supposed to relate to bolting force--not to friction on rusty, dirty, or scarred bolt or nut threads. Use a thread die to clean the threads on both ends of each bolt. Inspect the thread condition; discard damaged bolts or nuts. Lubricate threads with a good thread dope.

(7) Install the assembled safety head assembly between the pipe flanges. Tighten all bolts evenly, hand tight.

(8) Release the top bolt on the assembly holder tab (if any). Let the tab fall free, held by the bottom bolt. Leave the top tab bolt in the hold-down flange.

(9) Tighten the flange bolts with a dial-indicating torque wrench in good condition.

(10) The bolting procedure, depending on the number of bolts, is:

Step 1. Tighten all bolts evenly, hand tight.
Step 2. Torque four bolts at 0°, 90°, 180°, and 270° around the flange to 25% of max torque shown on chart.
Step 3. Torque four bolts at 45°, 135°, 225°, and 315° around the flange to 25% of max torque shown on chart.

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Step 4. Torque the remaining bolts to 25% of max torque shown on chart.

Step 5. Repeat Steps 2, 3, and 4 to 50% of max torque shown on chart.

Step 6. Repeat Steps 2, 3, and 4 to 75% of max torque shown on chart.

Step 7. Repeat Steps 2, 3, and 4 to 100% of max torque shown on chart. Repeat this step three times.

Step 8. Provide a loose fitting, light weight plastic cover to protect the downstream side of the disk from atmospheric corrosion.

3. Low Pressure Vents (Refer to Standard SF-3)

Vent systems for storage tanks should normally operate only when the vessel is being filled, emptied, or breathing. The pressure setting of the normal and emergency vents on standard EQ tanks should be the maximum setting available for the size vent used, but it must not exceed the MAWP of the vessel. Setting the vent at its maximum pressure will help conserve the inert gas and the process vapors.

A pressure reducing regulator is used to reduce the gas from line pressure to one that the tank and vent unit can handle. The regulator should normally be set for a downstream pressure of approximately 2 ounces for the standard EQ tanks.

Flame arrestors can normally be omitted when an adequate oxygen-free gas is used for inerting. A jacketed-type flame arrestor is available (in some sizes) when the process vapors are high freezers.

A jacketed-spool piece with steam facilities can be installed under the normal vent unit when it is possible for the vented process vapors to freeze. Also, an inert or

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RECOMMENDED TORQUE
for RB-90 Safety Heads only

Size	ASA Rating	TORQUE (FT. LBS.) NOTE 1.				
		Al. Plain or Plastic Lined		Nickel, Monel, Inconel, SST		
		Min.	Max.	Min.	Plain Max.	Plastic Lined Max.
1"	150	15	20	20	30	25
	300-600	30	40	40	60	50
1½"	150	15	20	20	30	25
	300-600	60	80	80	120	100
2"	150	30	40	40	60	50
	300-600	30	40	40	60	50
3"	150	30	40	40	60	50
	300-600	60	80	80	120	100
4"	150	30	40	40	60	50
	300	60	80	80	120	100
	600	90	120	120	180	150
6"	150	60	80	80	120	100
	300	60	80	80	120	100
	600	135	180	180	270	225
8"	150	60	80	80	120	100
	300	90	120	120	180	150
	600	200	270	270	405	340
10"	150	90	120	120	180	150
	300	135	180	180	270	225
	600	290	390	390	585	490
12"	150	90	120	120	180	150
	300	200	270	270	405	340
	600	290	390	390	585	490
14"	150	135	180	180	270	225
	300	200	270	270	405	340
	600	290	390	390	585	490
16"	150	135	180	180	270	225
	300	290	390	390	585	490
	600	525	700	700	1,050	875
18"	150	200	270	270	405	340
	300	290	390	390	585	490
20"	150	200	270	270	405	340
	300	290	390	390	585	490
24"	150	290	390	390	585	490
	300	525	700	700	1,050	875
30"	150	290	390	390	585	490
	300	860	1,150	1,150	1,725	1,440
36"	150	525	700	700	1,050	875
	300	1,320	1,760	1,760	2,600	2,200

notes:

1. 12 inch pounds = 1 foot pound.
2. Torque values are based on free running and lightly oiled threads.
3. Torque values are for use with companion flanges that have minimum yield strength of 25,000 psi. Consult BS&B when using other flange materials such as glass lined, where suppliers recommend maximum torque.

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oxygen-free gas can be introduced in the vapor space of the tank to help reduce the formation of crystals and freezing of the vent unit. The vent gas will be discharged instead of the process vapors when the tank is venting.

H. Safe Disposal Of Vented Material

1. Introduction

A vital concern to operating personnel in a chemical producing or handling facility is the disposal of liquids or vapors from pressure relieving devices or systems. Risks are always present, and dealing with them to ensure the greatest protection to unit and surrounding area personnel is an obligation of the people operating the units as well as the safety engineer designing the systems.

Environmental restrictions are becoming more and more complex as are the systems required to prevent exposure to personnel of toxic material. Regardless of the flammability of liquids and vapors released through relieving devices the relatively high pressure release at sonic velocities provides vapor cloud and fire hazards to those working in chemical units.

A disabling injury occurred in one of our plants because a faulty low pressure venting device overexposed an employee sensitive to ethylenediamine. The exposure hazard was not recognized and the normal action to correct the faulty vent device was not taken.

Sections 2.6 and 2.7 in the Criteria Section of the Safety Technology Manual, along with the references, thoroughly covers the safety aspects of the disposal of fluids from relieving systems. The highlights of this material are covered below as they relate to performance requirements and safety of operating personnel.

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2. Discharge From Relief Devices

In general, gases and vapors should be discharged upward well overhead and liquids downward to proper receivers or nearby trapped drains which lead to waste collection facilities. Frequently, liquids will be discharged with vapors, and this requires a proper separation pot or enlarged section of line.

All vent pipes must drain to minimize back pressures and to prevent freeze-ups due to atmospheric condensate, rain, or process fluid condensate. Vent outlets should be designed to exclude ice and snow. All gas and vapor must be projected above equipment, piping, structures, and persons or to large open areas for rapid dissipation in the atmosphere.

All atmospheric tanks for nonflammable corrosives (acid, caustic, etc.), hot water, hot oil, and similar fluids dangerous to persons must also be provided with adequate overflow pipes as well as vents. These overflows must lead to safe points of disposal and be sized to prevent overpressure.

a. Liquids - Fluids discharged from relief devices as liquids should be handled as follows:

(1) Flammable liquids with atmosphere boiling points above 20°C should be directed downward within 4 to 8 inches of grade and shielded to prevent splashing of liquid and debris. The discharge should be in or near a trapped drain or some other safe location.

(2) Flammable liquids with atmospheric boiling points below 20°C should be routed to a liquid knockout pot to separate vapor and liquid. The

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vapors should be disposed of as in the following section on Gases and Vapors.

b. Gases and Vapors - Fluids discharged from relief devices as gases or vapors should be handled as follows:

(1) Flammable gases and vapors should be directed upward such that adjacent piping or equipment is not exposed to flame impingement or excessive heat radiation should the discharge ignite. The discharge should be at least 10 feet above grade, operating levels, or buildings and shelters. Discharge lines from safety valves 2-inch and larger should discharge 10 feet above operating equipment. If there are known spark producing or air intake areas within a 100-foot radius of the relief device, all discharge lines should extend 10 feet above the operating equipment in the area.

Acetylene represents a special case in this category, because of its ease of ignition and wide flammable limit. Acetylene should not be discharged to headers with other material and special precautions should be taken to prevent any back pressure from developing in the discharge header. Acetylene discharges should be expected to ignite, so the discharge should be located such that personnel and equipment will not be exposed.

(2) Nonflammable gases and vapors that are not hazardous to personnel should be discharged a minimum of 10 feet above grade or nearby operating levels.

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(3) Nonflammable gases and vapors that are hazardous to personnel must be discharged at a height sufficient to remove hazard to personnel.

3. Vent Collection Headers

Although generally not desirable it is often economical and advantageous to collect relieved fluids from a number of devices for release at a safe point via a vent stack. Such stacks should terminate above all surroundings. Vent headers and stacks are usually filled with air until a discharge occurs, resulting in a flammable mixture. Certain prone to ignite or high energy fluids such as acetylene, hydrogen, or ethylene oxide may introduce unusual explosion hazards in large or extensive vent systems necessitating gas purging to exclude air. Adequate attention must be given to the radiant heat evolved in case a vented fluid is ignited.

For inert gas conservation and effective purging, the top of a vent stack should be covered with a normally closed, automatically closing, soft composition, flapper valve. These are simple, locally fabricated covers which effectively conserve the gas and exclude the elements. They must not be used on the discharge stacks of rupture disks where a thin plastic film fastened over the end will serve well.

a. Flammable Materials - When flammable materials are discharged into a collection header the following requirements should be met:

(1) A one-half inch drain valve is to be installed at any spot in vent headers where liquid might collect. A drain line should be routed to allow personnel access to the drain valve and shutoff valves under relief devices. A trap or liquid

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seal should not be used in place of a valve in the drain line. The screwed nipple connecting the drain valve to the header should be Sch. 80 304 SS.

(2) A weekly or more frequent draining schedule will be required to keep liquid from collecting in harmful quantities.

(3) Wet gases or liquids should not dischrage into the same header as cold (below freezing) gases or liquids. A separate wet header or individual vent stack is required.

(4) A full-port shutoff valve is (usually) required when discharging into any collection header. No check valves are to be used.

(5) Weep holes (3/8 inch) will be permitted only on individual vapor vent stacks. In cold (below freezing) temperature headers, the design should prevent water entry, utilizing a dry gas purge if necessary. If the weekly drain check indicates liquids are present the source must be located and either corrected or removed from the header system.

(6) The discharge line is to be sized such that no safety valve sees more than 10 percent of the absolute set pressure to pass its discharge to the atmosphere. Collection header piping must be sized to handle all simultaneous discharges at full rates.

b. Vent Header Knockout Pots - Vent header knockout pots should be constructed of mild steel with a MAWP of 75 psig, and should be sized to hold the unflashed

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liquid portion of safety valve discharges that are expected to occur during utility failures. A drain valve should be provided on the bottom of the tank to allow operating personnel to check for water and to pump accumulated liquids to a recovery or safe disposal location. An inert purge sufficient to maintain a slight positive pressure on the pot should also be provided.

c. Steam Snuffing of Vent Fires - Fires often occur at the discharge end of vent pipes and stacks used for disposal of organic vapors. Since, in most cases, such fires are inaccessible by conventional fire extinguishing techniques, it has been common practice to attach a small steam line to the stack with a manually or remotely operated valve, for steam snuffing of a vent fire. A drain line with a seal loop or drain valve must be provided at the low point in the vent line to drain off the condensed steam.

With relatively small amounts of vented vapor in small stacks, it is possible to dilute the vented vapor to the point where combustion ceases. It requires on the order of 1 pound of steam per cubic foot of vented vapor to dilute a flammable vapor to this point. As the vented vapor rate and stack size increase, the steam rate for dilution to the extinguishment ratio becomes excessive, and it becomes necessary to depend on a "blowout" phenomena for achieving extinguishment. Blowout results from the combined effects of dilution with steam and outside air at high velocities and cooling resulting from the dilution.

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4. Blowdown Systems

The term blowdown refers to the intentional release of material from a system, either by local or remote control. The blowdown system consists of the valves, piping, separator drums, holdup or treatment tanks, stacks, flares, and other associated equipment. It also includes the connection to the equipment concerned, a valve which may sometimes be operable from a remote location, and adequate piping for conducting the released materials to appropriate disposal facilities or other safe locations.

Blowdown facilities are ususally manually operated. When acutated, they release quantities of vapor or liquid by depressurizing the system they serve. Blowdown systems are used to reduce pressure or to remove system contents under emergency conditions. The blowdown facilities supplement but do not replace automatic relief valves.

a. Safety Considerations - Safety aspects to be considered in the design of blowdown systems are as follows:

(1) The blowdown connection on the vessel should be located and properly sized to obtain the desired rate of pressure reduction and/or vapor removal. This requires a thorough analysis of the process, the physical state of the materials, and the exit flow characteristics during all emergency conditions.

(2) The blowdown connection in the vessel should be placed or designed so that it cannot be choked off by an accumulation of material.

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(3) The blowdown valve itself should incorporate a high degree of reliability, desirable flow characteristics, and adaptability to power drives or other means to facilitate quick operation.

(4) The blowdown valve should be operable from a nonhazardous location which will always be accessible to operators or be automatic.

(5) The blowdown valve, including the drive mechanism, should be insulated or otherwise protected if it may be exposed to fire.

(6) Any remote operating mechanism must be highly reliable. If distance requires a power mechanism, an air motor is preferred over an electric motor by virtue of its better resistance to fire and other mishaps.

(7) The blowdown rate must be in line with the capacity of any downstream facility. For example, a flare system handling the blowdown must have the proper gas handling capacity, the proper vapor-liquid separating capacity, and the proper burning capacity without overheating adjacent, exposed objects.

(8) A blowdown stack which may discharge flammable vapors must be located sufficiently far from or above operating and other pieces of equipment to prevent envelopment of the equipment in flammable vapors.

(9) A particular concern in locating a blowdown stack is to ensure that the location and the prevailing winds do not cause flammable vapors to be drawn into air intake systems.

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(10) Environmental pollution control requirements must met. Dispersion calculations should be used to predict concentrations of contaminants at various locations. One frequently used method is that of Pasquill-Gifford found in the "Workbook of Atmospheric Dispersion Estimates" by D. Bruce Turner. The Environmental Protection Engineering Group should be contacted for help in using this method.

5. Dumping Systems

A dumping system is a a blowdown system, for liquids. The term as used in the chemical industry refers to a system which permits rapid removal of contents in an emergency (generally resulting from fire or chemical reactions). In the petrochemical industry, polymerization reactions are one area where dumping systems are used. Dumping systems are most common in batch processing where large volumes offer potential for serious runaway conditions.

Virtually all of the characteristics of the blowdown valve should be present in a dump vlave. Quick opening characteristics, speed of response, blowdown rate, and unobstructed flow requirement are even more critical for the dump valve. Needless to say, reliability is of utmost importance.

Any quench system must provide sufficient volume for the coolant and the process liquid. Frothing and vapor generation as well as safe handling of the vapor must be considered in the design. Hot flammables must not be dumped into air filled systems. Inerting should be provided.

Auxiliary facilities to neutralize any discharge or a means of rendering toxic materials safe must be provided.

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Environmental pollution control criteria and requirements must be met for the specific location.

6. Flare Systems

Refer to Section 2.7.4.2 in the Criteria Section of the Safety Technology Manual for details on the safety consideraitons relating to location, design, auxiliaries and environmental concerns.

I. Miscellaneous Equipment Considerations

1. Flame Arresters

Flame arresters are designed to prevent the ignition of a storage tank vapor space from an external source. They utilize spirally wound tube banks of alternate flat and corrugated sheets around a solid core of like material. Tubes thus formed for the passage of gases run parallel with the line of flow. The tube bank in its housing is retained between two end sections of the same material as the tube bank housing.

Flame arresters can be installed with either vent valves or as free vents. Flame arresters larger than eight inches should not be used as larger ones are not always effective.

Unless nonflammable gas atmosphere is dependably maintained in the vapor space of an atmospheric storage tank, flame arresters are required for any of the following conditions:

a. When a liquid with a flash point below 52°C (125°F) is stored in a tank aboveground outdoors.

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b. When a liquid with a flash point below 32°C (90°F) is stored in a mounded or buried tank.

c. When accidental heating of a liquid above its flash point is possible (by heating coil or other means).

d. When liquids with flash points below 66°C (150°F) are stored in substandard or congested tank areas outdoors.

e. When a flammable gas or vapor-air mixture may be present in a vented tank or vessel for any cause such as from absorbed gas.

Flame arresters are subject to clogging by such things as dust, pollen or other foreign material that may be breathed in. Often the element has a film of oil or chemicals clinging to its surface to which these particles adhere and eventually build up an appreciable deposit.

Because of their ability to dissipate heat, flame arresters can act as condensers when their temperature is lower than that of the mixture passing through. Therefore flame arresters may have their flow capacity reduced by the formation of liquid droplets in the elements and in the winter months may become dangerously clogged with ice. Heating with steam or hot fluid tracing is required to prevent freezing when arresters are used with "high freezers" such as benzene.

Putting a flame arrester under a vent unit reduces the flow capacity for pressure relief. The reduction in flow capacity for a combination Varec installation is apparent by comparing the two flow capacity curves shown.

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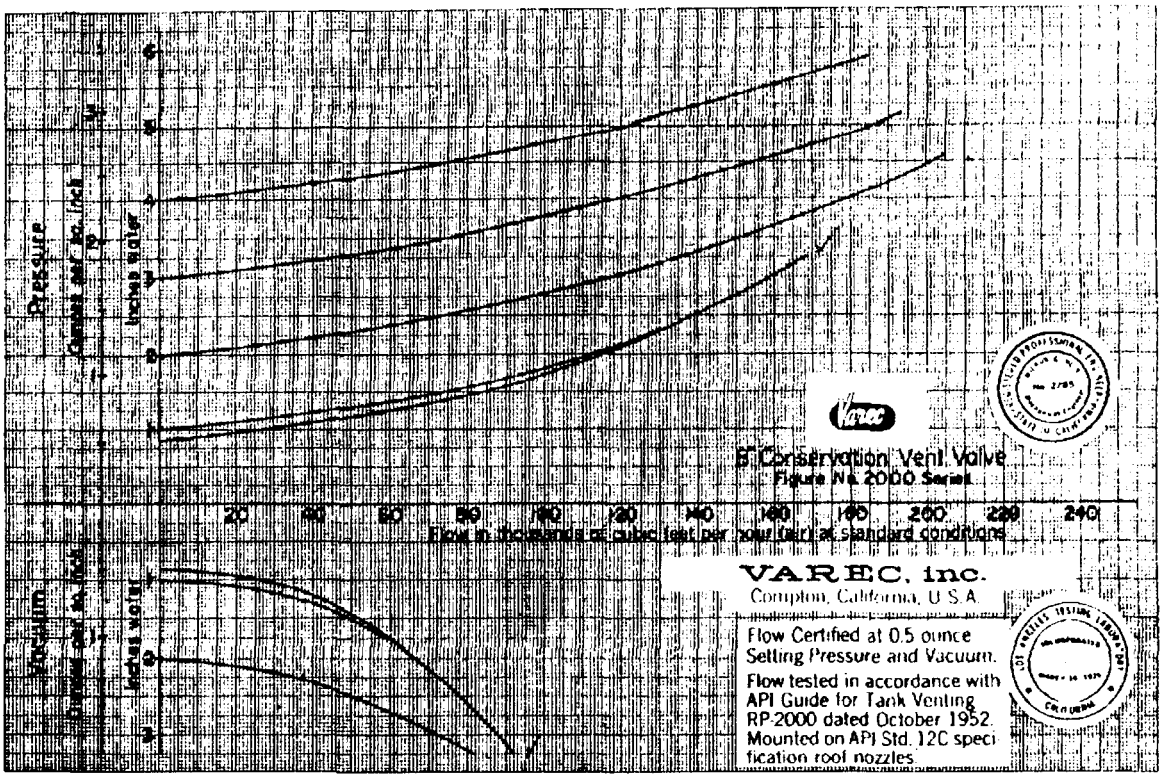
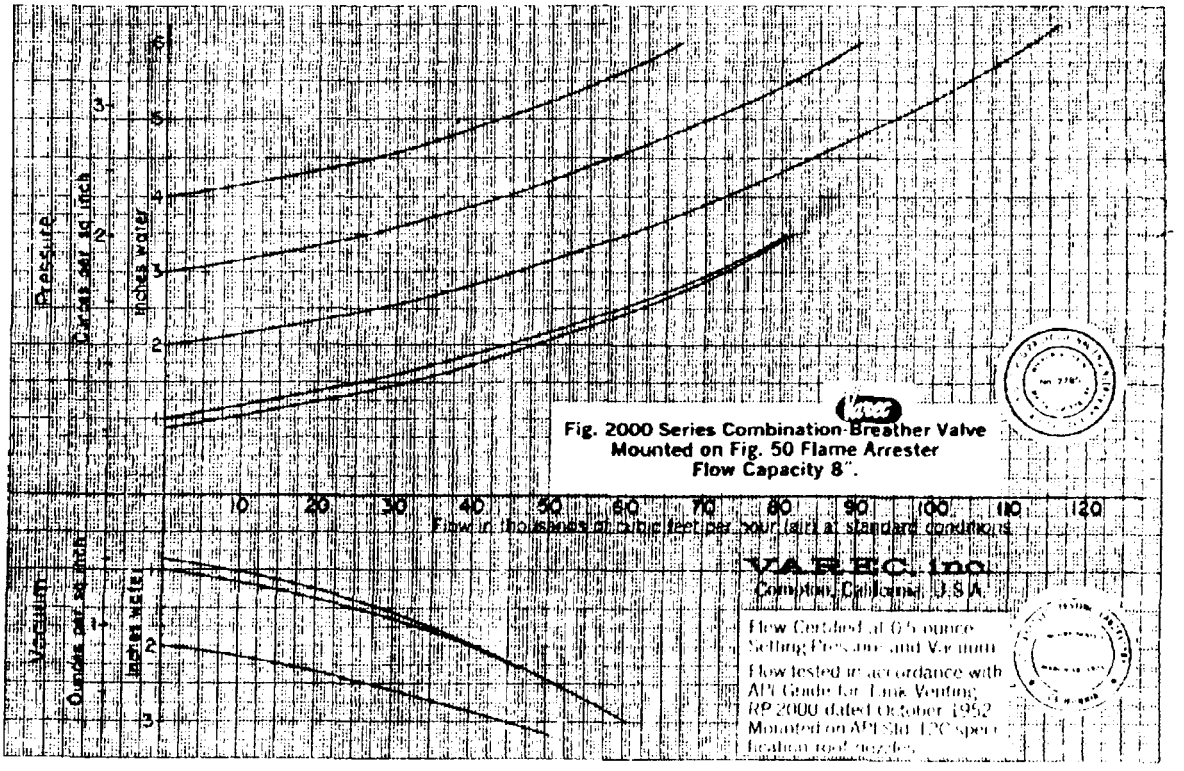


FIG. NO. 2000 SERIES – 8" FLOW CAPACITY CURVES



8" FLOW CAPACITY CURVE (VENT WITH FLAME ARRESTER)

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2. Pipeline Flash Arresters

Pipeline or piping system flame arresters are needed particularly in acetylene and ethylene oxide systems to localize exothermic decompositions and limit major destruction. The object is to safely isolate the larger volume production and consuming facilities from the connecting transfer lines. The best type is the Linde Hydraulic Back Pressure Valve, but it is limited to 8-inch size with relatively low capacity (20 MCFH) in order to maintain the essential liquid seal. Some acetylene manufacturers use packed beds, both wet and dry, as arresters; they are effective under many conditions. Valve and Pipe Specification 1C4 specifies the use of 1/2 inch tube bundles for ethylene oxide gas through 6-inch pipe size.

3. Cold Boxes

A cold box is a container housing the low temperature equipment used for liquefaction and separation of gases by distillation.

The equipment is placed in such containers and then completely filled with cryogenic insulation. With the exception of controls and means for sampling, the equipment is not accessible. All cold boxes should have these safety features:

a. Valved openings at three well separated elevations of the tank shell for insertion of 1/4-inch gas sample hose.

b. A cross type (from wall to wall) bottom-perforated, purge gas sparger in the bottom of the box.

c. Clean, dry nitrogen or dry oxygen-deficient (not more than 3 percent O_2) purge gas.

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d. Valves, gages, and controls for a high rate purge before and during cooling down (without blowing the insulation) and an adjustable continuous purge during operation.

e. A 10-inch water manometer on the cold box shell to show purge pressure.

f. A 20-inch, 1-1/2 ounce per square inch pressure vent and a 1/2 ounce per square inch vacuum vent valve on top of the cold box enclosure.

g. All openings in the tank shell shall be sealed with compound as required to maintain 1 to 2 inches of water purge-gas pressure in the cold box.

4. Check and Excess Flow Check Valves

One of the Standards for unit process operations states - "Large tanks containing high vapor pressure flammables are equipped with check valves in inlet liquid lines and excess flow check valves in the liquid outlet lines".

To minimize escapes, check and excess flow check valves should be used with all large containers of dangerous, liquefied gases. All flammable liquefied petroleum gases, ethylene oxide, ammonia, butadiene, methyl and ethyl chloride, methyl and ethyl ethers, chlorine, phosgene, hydrogen chloride, hydrogen fluoride, hydrogen cyanide, oxygen, and many others should be so treated. Excess flow check valves are required for these materials by Federal Shipping Regulations and many insurance companies.

Excess flow valves have a long history of misuse and abuse form erratic operation, which has caused hydraulic shock from closure of the valves. These valves can be selected

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and adjusted for all normal transfer operation where pipe sizes do not exceed 8-inch. Above that size, Process Control Engineers may provide fire safe differnetial pressure valves or remote, manually controlled valves. Large size is not justification for omission of these emergency control devices; in fact, the larger the size, the greater the need. Lack of excess flow valves in the 10-inch outlet of two isobutane spheres contributed to the largest refinery loss in this country.

5. Air Coolers

There is an increasing use of fin tube-air fan coolers in chemical manufacture. The fins are usually aluminum, very thin, fragile, and subject to immediate fire damage. The fire exposure relief requirements for fin tube coolers necessitate a thorough and careful analysis.

K. Equipment Changes and Pressure Relief

1. Changing Service

Operating engineers, supervisors, and operators must recognize the hazards created when changes are made in service, equipment and controls which result in inadequate pressure relief capacity. The relief capacity of any equipment or processing system which undergoes a change in service or capacity must be re-evaluated for adequacy in its new condition or service.

Major changes generally present little problem. Small changes or changes of a relatively subtle nature are frequently overlooked. Some such changes are enlarging the trim in a control valve, increasing heat transfer capacity, changing heat transfer media, modifying controls from temperature control to differential pressure, and increasing throughput in a stepwise manner. Another

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common change which can result in the necessity of additional relief capacity is the addition of shutoff valves which isolate equipment from relief formerly provided by devices on lines or other equipment.

All the incidents described here have much in common; they all indicate a departure from established design procedures. The problems did not arise from untried technology, but from a failure to recognize what should have been obvious, or to apply well established design or operating procedures.

A still system service was changed from the usual high flashpoint material service to refine a mixture containing vinyl ethyl ether. Relief capacity and materials of construction were not checked. A fire resulted because the gasket material failed in the new service. Fortunately the fire was extinguished before the fire exposure caused a serious overpressure situation.

A temporary filter was set up to remove dirt from a highly viscous oxide adduct. A reciprocating pump capable of generating a 400 psig discharge pressure was used to feed the 150 psi MAWP filter. The filter head ruptured.

Inadequate cleaning of the storage tank following a change of service caused a reaction in an Amines Unit Storage Tank due to the inadvertent mixing of approximately 21,000 pounds of mixed crude amines and 3,000-9,000 pounds of ethylene dichloride. In spite of heavy venting through its BS and B vent, the tank's roof and bottom were severely deformed due to overpressure.

The more common hazard situations created by equipment and process changes which effect overpressure relief requirements will be reviewed as a summary of the Equipment Safety Section.

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2. Process Changes and Equipment Overpressure

Some of the equipment modifications made to increase productivity or change an energy balance include:

a. Higher capacity pumps
b. Higher capacity control valves or changing valve trim to increase throughput or steam supply rate.
c. Piping changes
d. Larger calandrias
e. Larger condensers
f. Equipment alterations to reduce pressure drop
g. Heat source header pressure
h. Temperature changes
i. Change in heat transfer media

All such changes will require a review of the process system relief capacity needed to prevent overpressure of equipment.

When a system is operated to use and produce the chemicals for which it is designed the relief capacity is usually assumed to be adequate. However, any chemical changes that effect temperature, molecular weight, latent heat of vaporization, specific heat, specific gravity, or density will effect the relief capacity and the degree of protection for equipment. The following procedure can be used to determine the need for evaluation.

Physical Property Factors

The capacity requirements for relief devices are related to the physical properties of the chemicals handled in the process vessels which are being protected. If you analyze the calculation methods used for relief valve capacity the common properties in every case are related to:

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a. the temperature [Ts(°R)] at the sizing pressure which, for fire exposure, is 21% above the MAWP (1.21 x MAWP)

b. the molecular weight (M) c. the latent heat of vaporization at the temperature of the set pressure (ΔHvs)

When a new process is contemplated for an existing system with known adequate pressure relief protection, it is possible to quickly check the new chemicals physical property factors and thus determine the need for a re-design of relieving capacity. The relationships are expressed by this equation:

$$PPF = \frac{1}{\Delta Hvs} \times \sqrt{\frac{Ts}{M}}$$

3. Control System Changes

Relief requirements are effected by the removal of cascade controls on steam heated still columns when the control system is put on manual control. Any mode of operation or change that would cut out an emergency steam shutdown system could be disasterous if it were designed to be part of the overpressure protection.

The reliability of inerting, purging, pressure control and control valve system can change if regularly scheduled inspection, testing and maintenance programs are not adequate.

4. Equipment Changes

An operating engineer redesigned a relief system in a 15,000 gallon stainless steel tank to use a nitrogen inerting pressure control system and a spring operated check vavle for backup vacuum relief. The check valve was

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installed between two flanges in a goose-neck vent without the required marking. An operator had closed what he thought was an open vent to the air to prevent pollution by amines. When the nitrogen make up supply valve stuck in the closed position the tank was pulled in when a transfer was made. This equipment change resulted in junking the tank.

A still system was changed by replacing an old kettle with a calandria. One large safety relief valve left the unit with the kettle and the lost relief capacity was not installed until the deficiency was discovered by a process safety engineer.

These are serious violations of good engineering practice. We have mentioned before how unsafe situations develop by substituting the wrong materials of construction during production outages.

A more subtle equipment change is that of metal loss due to corrosion. Good inspection scheduling and testing programs along with keeping running records of equipment corrosion are absolutely necessary. Equipment MAWP must be downgraded as metal thickness decreases and the corresponding relief valve sizing must be increased.

Changes in equipment nozzles or other alterations if not done properly can result in lower MAWP ratings and increased safety valve sizes.

Equipment alterations to decrease pressure drop and increase capacity will require an evaluation of the pressure relief capacity.

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5. Pressure Relief Devices

Changing relief valve trim can cause problems as evidenced by a safety valve release on the Dowtherm side of an ethylene oxide converter. The high temperature removed the spring tension and the valve would not reseat. A tungston spring should have been used.

Process chemical changes that result in plugging of safety relief valves with polymer, or high freezers can cause a serious accident. Introducing corrosion materials for which the relief device is not designed can result in its failure to operate when needed.

All emergency relief devices should be protected from any conditions which might make them inoperative. Piping downstream of safety valves should be viewed with suspicion if the material likely to be discharged tends to foul or freeze. This occurrence is an example of what can happen: A relief valve discharge was piped away from the operating area. One day a spontaneous reaction of the residues occurred. The safety valve operated, and a foam of residues and gas was discharged. This foam solidified in the cold discharge piping, sealing it off. The tank exploded and did considerable damage to nearby equipment.

Protection of safety devices themselves from fouling or freezing is of utmost importance.

6. Piping Changes

Modifications or additions of process piping can lead to hidden hazards such as installing shut off valve which can block out the exisitng relief devices from performing their designed function.

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Using surplus pipe and fittings that do not meet minimim standards, even for temporary installations, has been the cause of several accidents throughout C&P. Using screwed threaded piping for installations in corrosive service has also been a problem.

Piping changes or inadequate maintenance that aggravate hydraulic hammer problems must be avoided. A disabling injury occurred when an operator was forced to use a 125 psi, cast iron, 10-inch valve to regulate the hydraulic hammer while putting a steam header in service. The normal condensate draining system had frozen in cold weather, was shut off and not repaired.

7. Maintenance Changes

Even when systems for controlling modifications have been set up, alterations often slip in unchecked during maintenance. Someone decides, for what he thinks is a good reason, to put the plant back together in a slightly different way.

In one particular plant years ago a special network of air lines was installed in a plant for use with breathing apparatus only. A special branch was taken off the top of the compressed air main as it entered the works. For 30 years this system was used without any complaint. Then, one day a man got a faceful of water while wearing a face mask inside a vessel. Fortunately, he was able to signal that something was wrong, and was rescued before he suffered any harm.

An investigation showed that the compressed air main had been renewed, and that the branch to the breathing apparatus network had been moved to the bottom of the main. Unfortunately, everyone had forgotten why the branch came off the top of the main, and nobody realized that this was important.

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A tank car was returned to service after a complete overhaul for handling a resin solution containing vinyl chloride. A near miss occurred when the car was sampled because pressure had built up on the car. No one checked or noticed that the two safety relief valves had been left off the car.

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Six chemicals with a wide range of properties will be used to illustrate the procedure. We will assume a miscellaneous still system with an MAWP rating of full vacuum to 30 psi. The sizing pressure for fire exposure would be:

(30 psi x 1.21 + 14.7) x .06804 atm/psi x 760 mmHg/atm = 2637 mm

The following chemicals will be considered:

	M	Boiling Point -°C 760	300	50	10	Tc °C	ΔHv kcal/ g.mol	ΔHv Btu/lb.
Acetaldehyde	44.053	20.3	-2.2	-36.3	-59.3	202.35	6.145	251.1
Butyl Carbitol Acetate	204.266	246.7	211	156	119	407.0	12.029	106.0
Cellosolve Acetate	132.159	156.3	126	80	49	334.5	9.765	133.0
Glycenyl Triacetate	218.205	258.0	225	175	140	435.0	13.820	114.0
Propionaldehyde	58.08	48	29	-13	-38	223.0	6.811	211.1
Propionic Anhdride	130.144	169	137	90	57	346.0	9.980	138.0

Using the boiling point data, the temperature at the sizing pressure is obtained by plotting the Cox line vapor press-temperature curves to get the corresponding sizing pressure temperature.

The latent heat of vaporization at 760 mm and the normal boiling point is corrected for the sizing pressure and temperature using the Watson equation:

$$\Delta Hvs = \Delta Hv \left[\frac{Tc - Ts}{Tc - Ti}\right]^{0.38}$$

For acetaldehyde:

$$\Delta Hvs \text{ at } 56°C. = 251.1 \left[\frac{202.35 - 56}{202.35 - 20.3}\right]^{0.38} = 231.1 \text{ Btu/lb}$$

Again for acetaldehyde the physical property factor would be:

$$PPF = \frac{1}{231.1} \times \sqrt{\frac{(56 + 273) \times 1.8}{44.053}}$$

$$PPF = 0.0159$$

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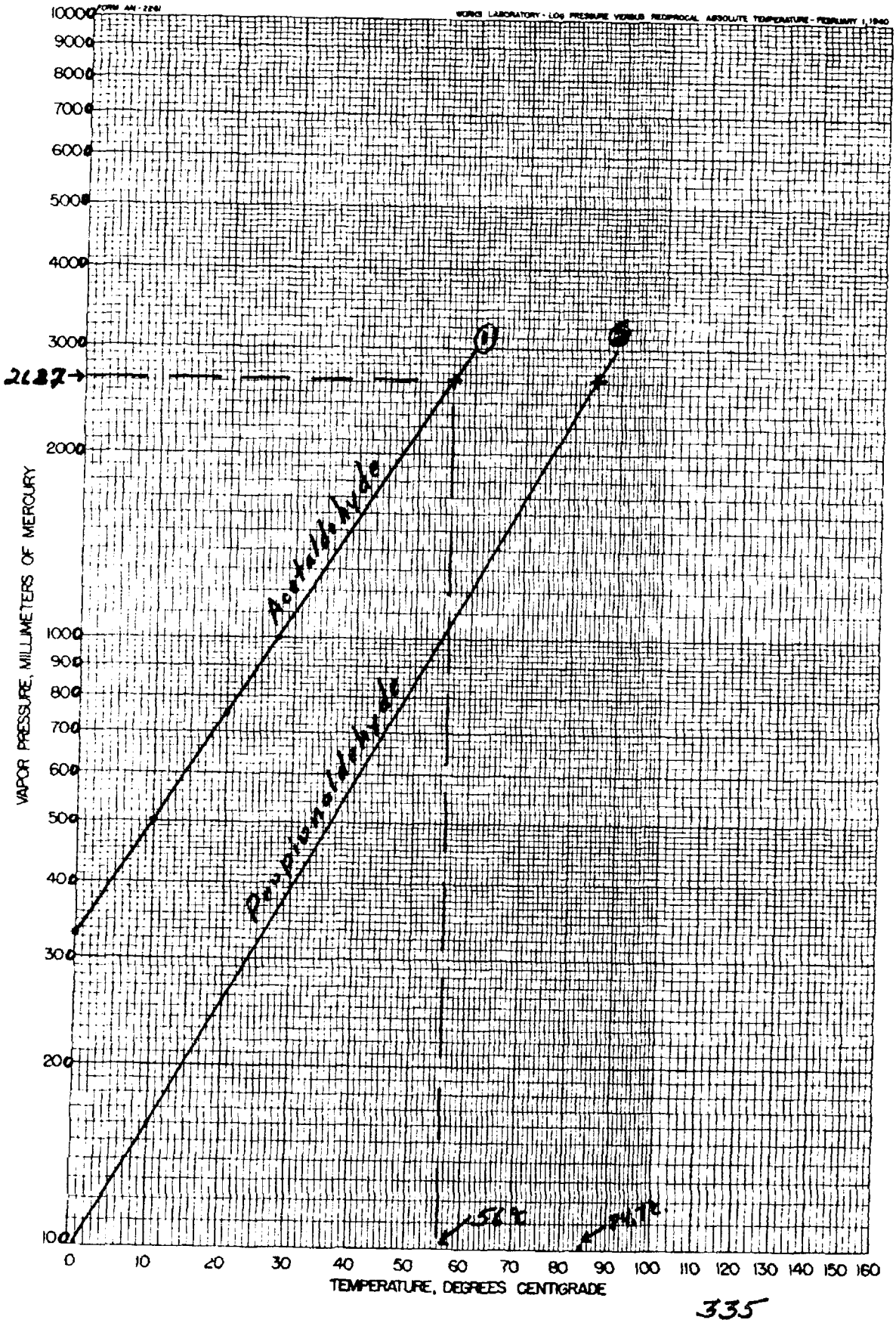
A tabular summary for the six chemicals gives the physical property factor data:

	Ts °C	Ts °R	ΔHvs @Ts	PPF
Acetaldehyde	56.0	592.2	231.1	0.0159
Butyl Carbitol Acetate	306.6	1043.3	88.7	0.0255
Cellosolve Acetate	206.0	862.2	117.5	0.0217
Glycenyl Triacetate	311.9	1052.8	99.3	0.0221
Propionaldehyde	84.7	643.9	193.0	0.0173
Propionic Anhydride	218.5	884.7	121.8	0.0214

The relief capacity requirement is the product of the physical property factor, the heat transfer surface in square feet, the heat transfer rate in Btu's per square foot and the applicable conversion constant. It is therefore apparent that the greatest capacity will be for the chemical with the largest PPF which in the above table would be Butyl Carbitol Acetate.

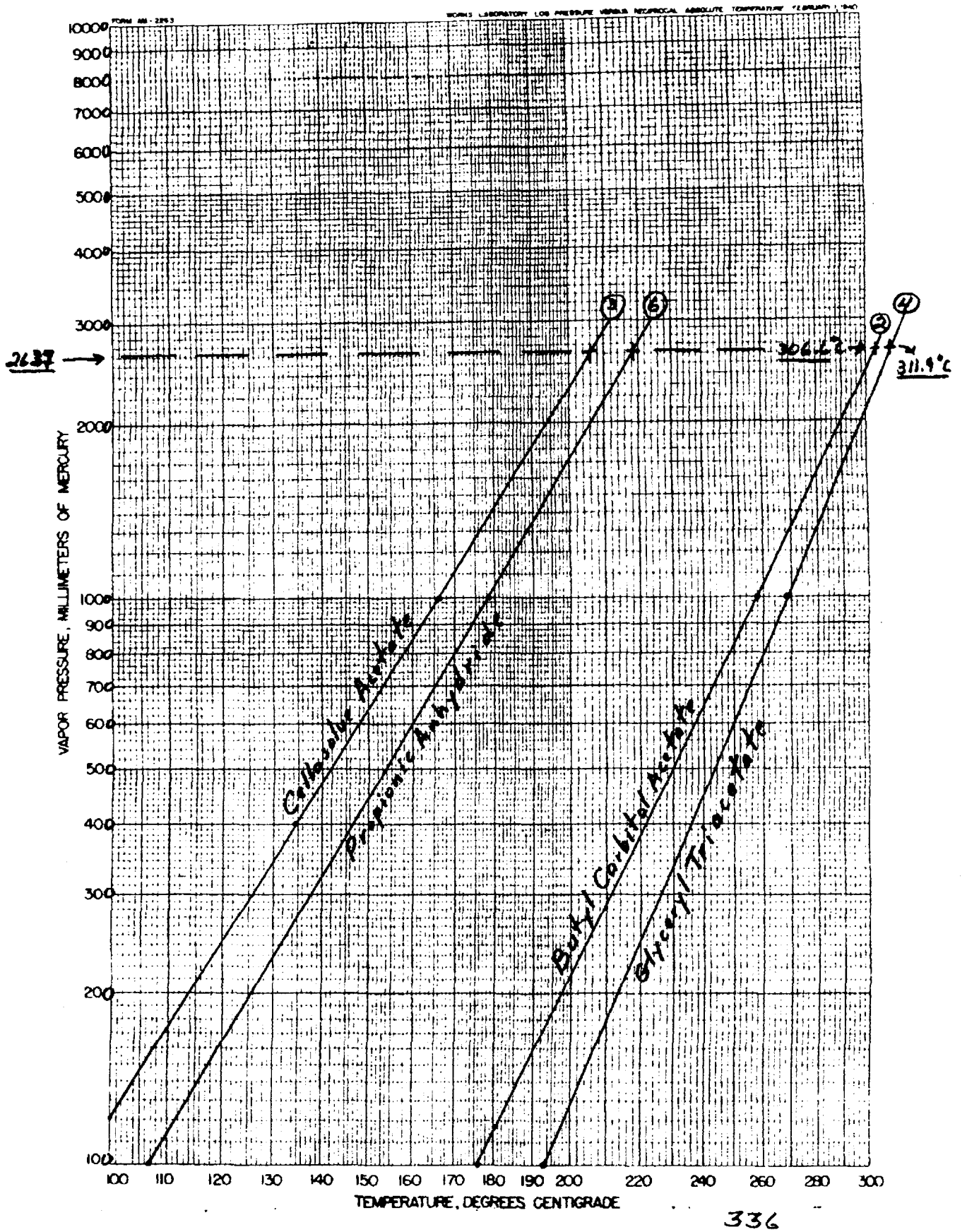
The calculation procedure for physical property factor (PPF) can be used when new chemical processes are being considered for an existing system to determine the need for a re-evaluation of the system relief design. In the particular system we have used for this example any chemical with a PPF lower than that for Butyl Carbitol acetate (0.0255) could be safely processed. Since the relief capacity design work would have been done on the basis of a 0.0255 PPF any chemical with a higher PPF will require a re-check of the design.

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V. TEST AND INSPECTION (N. W. CLAUSS)

A. Introduction

The maintenance of chemical processing equipment in a condition which can ensure continued safe operation is dependent on the quality and performance of the Test and Inspection Department. The ability of the T&I Departments to do a quality job is completely dependent on the cooperation of production personnel in allowing T&I inspectors to perform this function on schedule.

B. Regulatory Codes

The criteria for testing and inspection are spelled out in the following Codes and Guidelines:

1. National Board Inspection Code.

2. ASME Pressure Vessel Code - Sections V and VIII.

3. American Petroleum Institute Guidelines for Inspection of Refinery Equipment.

Using the above as reference the Process Veseel Technology Manual (C&P) sections on COP Specifications give the testing requirements in COP Spec. No's 1, 2 and 21 for process vessels.

The requirements for servicing relief devices are given in the Safety Standards SF-1, SF-2, SF-3 and SF-16.

C. C&P Test and Inspection Procedures

The C&P Safety Department has assembled guidelines for the test and inspection of tanks and pressure vessels which are reproduced here in its entirety. It is strongly recommended that these guidelines be made mandatory standards.

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TEST AND INSPECTION PROCEDURE
UNION CARBIDE CORP. CHEMICALS & PLASTICS

1. SUBJECT: Periodic Examination of Tanks and Pressure Vessels

2. PURPOSE:

The establishment of examination requirements and intervals to assure safe operation and predict serviceability of process tanks and pressure vessels as required by UCC Specifications, with reference to the ASME Pressure Vessel Code, Sections V and VIII, the National Board Inspection Code, and the American Petroleum Institute Specifications.

3. RESPONSIBILITIES:

3.1 The operating unit department head or his designated representative shall be responsible to:

3.1.1. Establish the intervals of examination of process tanks and vessels under his control according to this procedure with joint U/A of the operating department head and T & I Group.

3.1.2. Obtain needed guidance for establishing such intervals from the plant Materials and Corrosion Group, the Vessel Design Group, and the Test and Inspection Group.

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3. RESPONSIBILITIES: (Cont'd)

3.1.3. Report any major change in operating conditions or service, new equipment installation, and relocation to the official records maintained by the Test and Inspection Group, and repeat item 3.1.2. as necessary.

3.1.4. Submit copies of all final design and acceptance documents and/or construction drawings in his possession to the official records maintained by the T & I Group prior to unit startup.

3.1.5. Request that required examinations be performed during any period in which the tank or vessel is normally prepared for access according to intervals established in this procedure.

3.1.6 Secure the participation of the Vessel Design Engineering Group where major deficiencies are discovered and in repairs and alterations as required in UCC Standard Specification COP-21-75.

3.2 The T & I supervisor will be responsible to:

3.2.1. Perform required examinations requested by the operating department head or his designated representative.

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3. RESPONSIBILITIES: (Cont'd)

3.2.2 Issue reports of examinations made on individual tanks and pressure vessels. This report is to outline the examination and differences between current and original condition.

3.2.3. Update computer and/or manual records dealing with intervals and schedules of examination.

3.2.4. Maintain the manual or hard copy files required to support the computer records and provide necessary data for analysis of the condition of tanks and pressure vessels.

3.2.5. Be prepared to advise the operating department head or his designated representative on methods of examination and support requirements for each NDT method.

3.2.6. Review reports of examination and report any detrimental or suspect conditions to the unit and appropriate engineering group.

4. DEFINITIONS:

4.1 Pressure Vessel - An enclosure used for storage, accumulation, or processing of any gas or liquid having MAWP equal to or exceeding 15 psig or those in vacuum service.

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4. DEFINITIONS: (Cont'd)

4.2 Tanks - An enclosure which has a MAWP less than 15 psig not including vacuum service.

4.3 External Visual Examination - A visual examination of the exterior surfaces, structures, foundations, and insulation of a tank or pressure vessel to determine its readily apparent condition according to UCC form (see attachment).

4.4 Internal Visual Examination - A visual examination of the interior surfaces and structures of a pressure vessel or tank to determine its condition according to UCC form (see attachment).

4.5 Reports - A written record of an examination of a pressure vessel or tank performed according to UCC form (see attachment).

4.6 Non-Corrosive Service - Shall be determined as a result of at least five years of comparable service experience with the fluid contained revealing no corrosive effects attributable to trace components, the contents, or external sources.

4.7 Corrosive Service - All except as defined above in paragraph 4.6.

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4. DEFINITIONS: (Cont'd)

4.8 Test - Defined as final test such as a hydraulic or pneumatic test to determine structural strength of a tank or vessel.

4.9 Inspection - Defined as the formal report from an examination such as X-ray, Probolog, UT, etc.

4.10 Examination - Defined as the actual examination as in 4.9.

4.11 Pneumatic Test - Defined as a test where air, compressed air, N_2, or other gas is used to pressurize vessels or tanks.

```
* * * * * * * * * * CAUTION * * * * * * * * * *
*                                               *
* Pneumatic testing of vessels and tanks can be *
* an extremely hazardous operation. Minimum re- *
* quirements before testing pneumatically will  *
* be a meeting of the operating department head  *
* or his designated representative, T & I super- *
* visor, Corrosion/Materials representative and *
* Engineering representative. The purpose of     *
* the meeting will be to make sure all require-  *
* ments are made to insure a safe test.          *
*                                               *
* * * * * * * * * * * * * * * * * * * * * * * * *
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4.12 Hydrostatic Test - Defined as a test where liquid is used to fill a system and an applied hydraulic pressure is used to test structural strength of a vessel or tank.

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4. DEFINITIONS: (Cont'd)

```
* * * * * * * * * * CAUTION * * * * * * * * * * *
*                                                 *
*  Hydrostatic testing of vessels and tanks may   *
*  put stresses on the vessels, tanks and con-    *
*  necting piping that will never be encountered  *
*  in operation.                                  *
*                                                 *
* * * * * * * * * * * * * * * * * * * * * * * * * *
```

NOTE: Tests and inspections required for repairs, major repairs, alterations and modifications to pressure vessels are outlined in UCC Standard Specification COP-21-75.

5. PROCEDURE:

5.1 Pressure Vessels or Tanks in Non-Corrosive Service

When contents of an enclosure as designated by the operating department head or his designated representative are known to be non-corrosive, the enclosure is exempt from internal visual examination and subject to the following examination.

5.1.1 Types of examinations for non-corrosive service.

5.1.1.1 External visual examination.

5.1.1.2 Various NDT methods as deemed necessary by operations and/or T & I Group.

5.1.2 Intervals of examination for non-corrosive service. The only exam required is an external visual examination. It shall be conducted at a

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5. PROCEDURE: (Cont'd)

5.1.2 (Cont'd)

frequency determined by the operating department head or his designated representative not to exceed five years. This examination may be made by trained operating unit personnel provided the prescribed report form is completed and submitted to the T & I Group for the permanent record.

5.2 Pressure Vessels or Tanks in Corrosive Service

When the contents of an enclosure as determined by the operating department head or his designated representative are known to be corrosive, the enclosure shall be subject to the following examinations:

5.2.1 Examinations of pressure vessels or tanks in corrosive service.

5.1.1.1 External visual examination.

5.2.1.2 Internal visual examination.

5.2.1.3 Thickness determinations.

5.2.1.4 Various NDT methods as required.

5.2.2 Intervals of examination of pressure vessels or tanks in corrosive service.

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5. PROCEDURE: (Cont'd)

5.2.2.1 External visual examination will be at an interval determined by the operating department head not to exceed one year.

5.2.2.2 Internal visual examination will be at an interval determined by the operating department head in conjunction with the Materials/Corrosion Group not to exceed one half the safe remaining operating life or a maximum of five years, unless in extreme circumstances, plant management waives this to a given date.

5.2.2.3 Thickness determinations will be at an interval determined by the operating department head not to exceed one year.

5.3 Required Reports

5.3.1 Inspection Reports - Original reports of examinations and tests shall be prepared by the T & I Group for distribution to the operating department, Materials/Corrosion Group, the T & I official record files using UCC forms (see attachment). This report shall include any sketches necessary to clarify the above report.

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5. PROCEDURE: (Cont'd)

5.3 Required Reports: (Cont'd)

5.3.2 Changes of service, addition of new pressure vessels or tanks, or replacement of existing vessels or tanks shall be reported by the operating unit to the T & I Group.

5.3.3 Re-rating Reports - Results of pressure vessel re-rating by Vessel Design Engineer will be submitted to the operating unit and the T & I official record files.

5.3.4 *
* Deficiency Report - A summary report shall be made regularly by the T & I supervisor listing those pressure vessels and tanks examined which have, in the opinion of the T & I supervisor, major deficiencies in safe operation. The minimum distribution for this report shall be the operating department head and the appropriate assistant plant manager. *
* *

5.3.5 Reports to state and federal agencies as required.

5.4 Required Records

Design data necessary to establish original purchase condition and materials of construction of pressure vessels and tanks shall be supplied to the T & I Group for the permanent files by the operating department and/or UCC Vendor Inspection Group.

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5. PROCEDURE: (Cont'd)

5.4 Required Records (Cont'd)

5.4.1 RM Computer Files - Intervals of examination established by the operating department head shall be entered in the RM computer program. Update of these records by the T & I Group shall be accomplished as work is completed on each item of equipment.

5.4.2 Manual File System - Manual or hard copy files shall be maintained by the T & I Group or the plant as the official record files for pressure vessels and tanks to support the computerized records.

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D. Clarifying Misconceptions

The ASME code specifies the standards for materials, design and methods of construction of pressure vessels, and since 1951 is based on a factor of safety of four (4) with respect to allowable metal stress values. The Code also sets the procedures for calculating the Maximum Allowable Working Pressure (MAWP) for pressure vessels as an alternative to determining the MAWP by pressuring equipment to failure or destruction. The calculated MAWP is a function of the design process and is not a function of hydrostatic test pressure determinations. You cannot establish MAWP by hydrostatic testing.

In 1951 the factor of safety for design was lowered from 5 to 4 because the quality of materials and methods of fabrication had improved sufficiently to warrant the change. at this time the hydrostatic test pressure was lowered from 2 to 1.5 times the calculated MAWP for most metals. The rules of the Code in effect at the time (date) a vessel was fabricated must be used for establishing MAWP and the related hydrostatic test pressure.

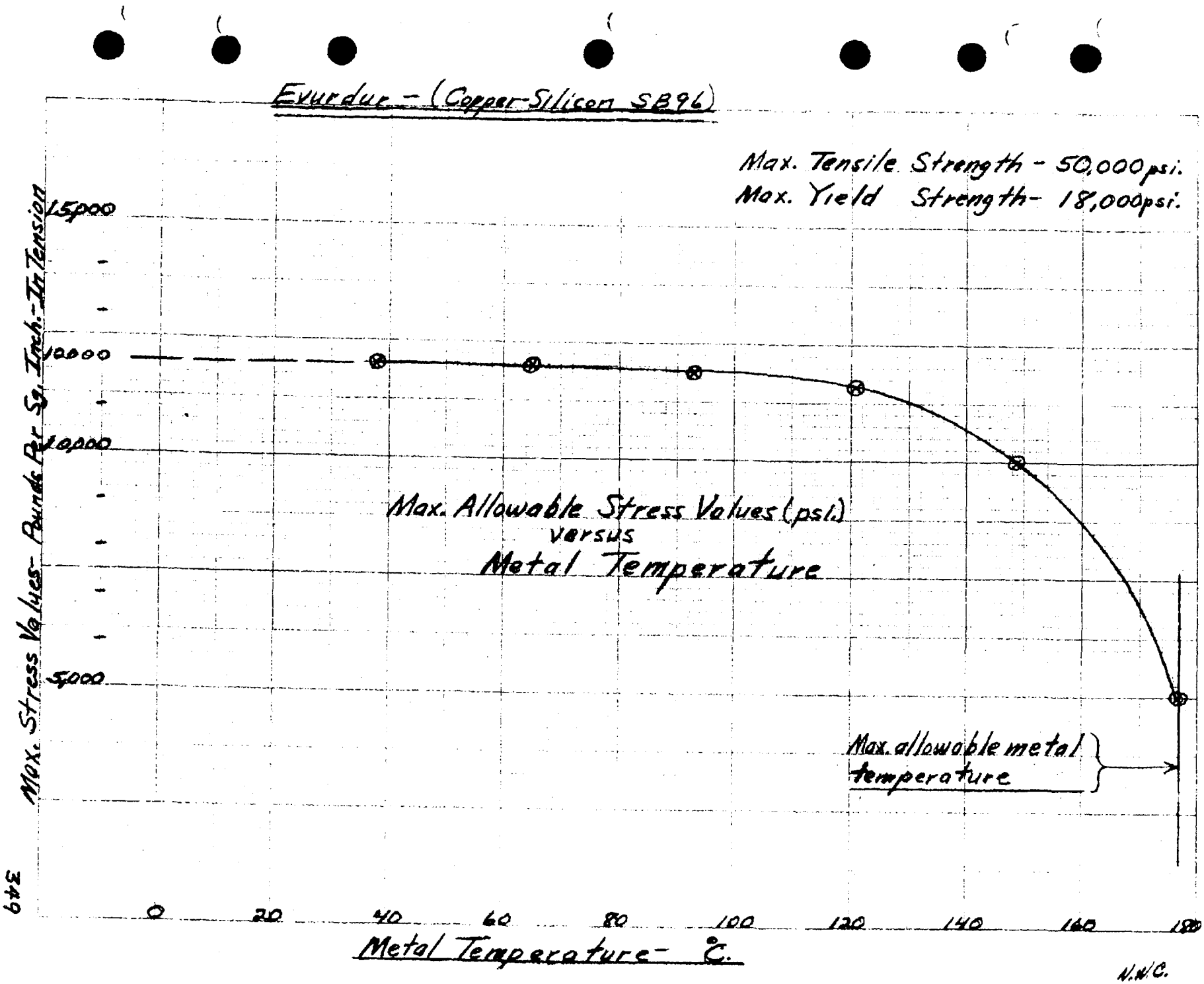
The purpose of hydrostatic testing of pressure vessels is to ensure the integrity of the materials of construction, vessel fabricating methods, and assembly of parts. The ASME code specifies the hydrostatic pressure limits required to check vessel integrity in a manner that the maximum yield strength of a given material of construction is not exceeded. The design of a vessel and its calculated MAWP, is based on meeting code requirements for metal thickness at given maximum limits of operating pressure and temperature. Hydrostatic testing is done, however, using water at 15.6°C (60°F) and must therefore be regulated to take into account the maximum operating temperature of the vessel, and hydrostatic head corrections. The maximum allowable metal stress decreases with increasing temperatues. Therefore, a stress-temperature correction must be made to establish the hydrostatic test pressure at 15.6°C.

A curve showing the maximum allowable stress values for Everdur (SB-96) versus metal temperature is used to illustrate the code test pressure determination. Ignoring corrections for hydrostatic head, the test pressure used for testing a vessel at 15.6°C using water would normally be 1.5 times the design calculated MAWP. From the curve, the allowable stress value of

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Everdur drops from 12,000 psi at 15.6°C to 5,000 psi at 177°C metal temperature would be tested at 1.5 x 2.4 or 3.6 times the MAWP using water at 15.6°C in order to provide the equivalent stresses necessary to establish the integrity of the vessel. An "old code" Everdur vessel operating at 177°C with a calculated MAWP of 15 psig would, for example, be tested at 2 x 2.4 x 15 or 72 psig using 15.6°C water.

The temperature stress ratio correction for most materials of construction would be fairly small but must, never-the-less, be made to correct for the difference in the test water temperature and the maximum operating temperature.

Every design stress limit is determined for all elements of a vessel and the MAWP is established by the weakest item of the assembly. The same approach must be used in testing processing systems containing several items of equipment.

Ideally, a system would be tested in its entirety but the permissible hydrostatic test pressure for each component of a system must be considered prior to a system test. The limit of a system test pressure would have to be based on the component with the lowest MAWP and consequently the code requirements for testing the integrity of other components would not be met. In such cases, blanking may be required to properly test each component of a system. At times, it may be necessary to test a column in a horizontal position so that stress limits are not exceeded at the column base because of hydrostatic head.

Vessels requiring a corrosion allowance are always tested on the basis of the actual metal thickness requirement, whereas the MAWP is based on the design thickness.

Vessel linings, column trays, etc. are not considered to add any strength to a vessel for design or calculation of MAWP.

In cases where the integrity of the metal of construction is questionable, such as stress-corrosion cracked Everdur, there may be reason for concern in applying test pressures required by ASME code. In such cases,

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the MAWP can be calculated assuming the defects do not exist, but the hydrostatic pressure test must then be passed to obtain the rating. If the test pressure can not be achieved without leakage or failure, the vessel must be properly repaired to meet the test conditions, or be replaced. Equipment which does not pass the specified pressure test must be stamped "Approved With Reservations" until repairs or replacement are completed.

There are two alternative considerations to minimize the chance of damage when pressure testing equipment of questionable integrity. These are:

1. Limitation of the maximum operating temperature. By arbitrarily limiting the maximum operating temperature, the temperature-metal stress ratio can be reduced thus reducing the code pressure required for the hydrostatic test. In the case of Everdur, the stress ratio correction for a reduction in temperature from 177°C to 160°C would drop from 2.4 to 1.37.

2. Arbitrarily lower the MAWP nameplate pressure from its calculated maximum rating. When the calculated MAWP rating of all components of a system exceed the predicted maximum operating pressure, it would be possible to arbitrarily lower the rating to within 5 psi of the operating pressure. The lower MAWP used would also lower the required test pressure. This approach would require a reassessment of the capacity of relief devices.

Hydrostatic pressure testing using some fluid heated to the maximum predicted operating temperature, in order to eliminate the temperature-stress correction ratio, is not acceptable because of the hazard to personnel. Pneumatic pressure testing is also hazardous because of the energy of gas released in the event of failure, and the only gain would be the elimination of static head considerations.

Acceptable repairs to pressure vessels usually require welding or riveting. repairs utilizing cement filled liners, cement filled nozzles,

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epoxy-glass patches, rubber bands, etc., are not acceptable. Since there is no way to determine the mechanical strength of substandard repairs, no rating is possible by definition. Equipment with substandard repairs must be stamped "Approved With Reservations." We may assume the repairs will be made and therefore evaluate relief requirements on the basis of the MAWP ratings in the repaired state if we specify that the vessel remains "stamped" until the repairs are complete.

E. Variables Effecting Pressure Ratings

The MAWP (pressure rating) of process vessels is calculated based on stress analysis of many elements of mechanical design. Included would be shell thickness, unsupported shell length, flanges, bolting, gasketing, operating pressure limits (both internal and external), head design and type, low temperature requirements, nozzles, reinforcing, stiffening rings, support saddle stresses, expansion stresses, tube sheet stresses, etc.

Responsible operating personnel are accountable for maintaining the integrity of their process systems with quality inspection, testing, repair and scheduling programs to avoid increasing the hazards of operations. The relieving capacity of pressure relief devices is directly proportional to pressure rating and is precisely sized for the original MAWP of process vessels. It can be readily seen that relief capacity will be undersized if any change (known or unknown) decreases the MAWP. We will now examine ways in which MAWP ratings are decreased.

1. Metal Loss

a. External Corrosion - Equipment located in corrosive atmospheres or covered with insulating material require scheduled inspection to be cognizant of metal loss.

A two year old propylene oxide column located inside a building with amines in the atmosphere lost one half of its shell thickness just above the flanges of the insulated column.

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Four insulated storage tanks in a vinyl chloride resins area corroded under insulation. The insulation was removed, the tanks cleaned and painted. A decision made to leave the tanks uninsulated had to be countermanded because the relief capacity would have been inadequate for fire exposure.

External corrosion of flange bolting is a serious problem. Flat bottom tanks designed with anchor bolting for support can for example be seriously distorted on hydrostatic test if the anchor bolting has been corroded to the point of failure.

b. Internal Corrosion/Errosion - Materials engineers select materials for a given service in the design stage which will give acceptable corrosion rates. However, the quality of data upon which material selections are based is not always accurate. Furthermore the effect of unknown side reactions, gaseous decomposition products, air leakage, changing raw materials or catalysts used, may increase the corrosion rates above the design plan.

The C&P Test and Inspection Procedures, if followed, will reveal the actual process corrosion rates. Periodic internal inspections are required to determine the point in time when the vessel pressure rating must be lowered or the vessel replaced. Loss of weld metal in shell seams or nozzles can only be found by internal inspection.

A kettle used for 30 years as part of an acetic acid/acetic anhydride refining system decreased from 0.501" to 0.216" in thickness over that period. The corrosion rate was 0.0095 inches per year (1936 to 1966). The service was changed to methylacetate and operated four years with additional metal loss from

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0.216" to 0.184". The pressure rating of the kettle had been reduced and the last inspection resulted in condemning the kettle for continued service since the minimum possible metal thickness at the saddles supports had been reached.

A surplus tank was inspected and evaluated for butyl chloride service. The pressure rating was reduced from it's original 18 psi to 8 psi based on the metal thickness obtained in July 1970. An inspection made in February 1975 revealed further metal loss and nozzle deterioration and the MAWP was again lowered to 4 psi. The pressure was still adequate for atmospheric pressure service but the relief capacity had to be recalculated and increased.

Errosion or impingement metal losses frequently occur, and where applicable must be monitored by scheduled inspections. Examples would be the metal loss of calandria tubes opposite steam inlet nozzles, the erosion of metal above steam chest nozzles on equipment using U-Bend coils, or metal surfaces erroded by impingement of corrosive material such as acid catalysts. Regardless of the cause for metal loss a point will be reached where a decrease in pressure rating will be required. As a rule of thumb a 20 percent metal loss requires evaluation for possible pressure rating loss by the C&P Process Vessel Technology Group.

c. Stress Corrosion - Stress corrosion problems cause strength losses which are not readily evaluated. The best approach is to avoid the problem by using proper materials of construction. Organic chlorides should not be processed in the usual stainless equipment. Everdur equipment should not be exposed to atmospheres containing ammonia or amines. If you are

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contemplating a process change be certain that the Materials Engineering Specialist reviews and approves. Reference to the horrible disaster at the Flixborough Works in England has stressed the cause as being due to a jumper made to continue operation while one of six reactors was removed for repair of the leaking shell. More than two months prior to the disaster an inspection revealed a 6 foot long crack in the reactor shell. The cause of the failure was determined to be nitrate stress corrosion cracking. It was a practice of this plant to use nitrate treated water to dilute and disperse small process leaks. If the vessel had not been stress cracked the temporary jumper would not have been made and the disaster would never have happened.

d. Test Water Temperature and Brittle Fracture - Of all the metals and alloys used in chemical processing equipment only the ferritic steels exhibit low temperature brittleness. Brittle fracture can occur at temperatures between minus 40°F and plus 40°F (occasionally higher). This temperature range is called the "transition temperature." Brittle fractures sometimes occur with disasterous results during hydrostatic testing if tests are not conducted above the transition temperature. It is for this reason that the water temperature for testing is specified to be 60°F.

e. Testing Repairs and Alterations - Vessels being repaired or altered in a shop should have test pressures applied until all work is completed. For example a test for nozzle replacement should not be made until after reinforcing pads are installed.

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F. Test and Inspection Problems

1. System Testing

Multi component systems introduce testing problems in that a test can not be made above the MAWP of the weakest item. It may be necessary to blank in an item for testing if its MAWP is higher than other parts of the system.

Systems containing expansion joints or spring hangers require special preparation to prevent distortion.

Responsibility for the results of system testing must be shared by the Operating Department Head and the T & I Department.

2. Surplus Equipment

Using surplus equipment requires inspection and testing prior to installation. Do not make assumptions as to the integrity of surplus items.

3. Changed Service

The T & I Department inspections occasionally find that equipment system service has been changed from the time of the last inspection. When this happens the inspector should report such changes and recommend a recheck of relief capacity to the Operating Department.

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4. Cast Iron Equipment

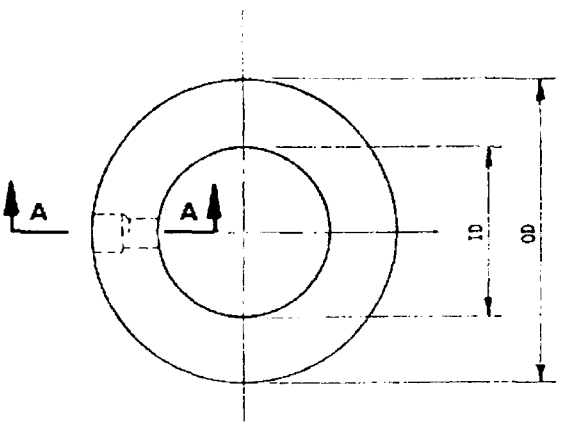
Thickness measurements are not reliable for cast iron and for this reason the Process Vessel Design Group can not rerate the MAWP. The original design MAWP must be used and hydro tested as follows:

MAWP Rating	Test Pressure
0 to 24 psi	2.5 times MAWP
24 to 30 psi	Test at 60 psig
30 and above	2.0 times MAWP

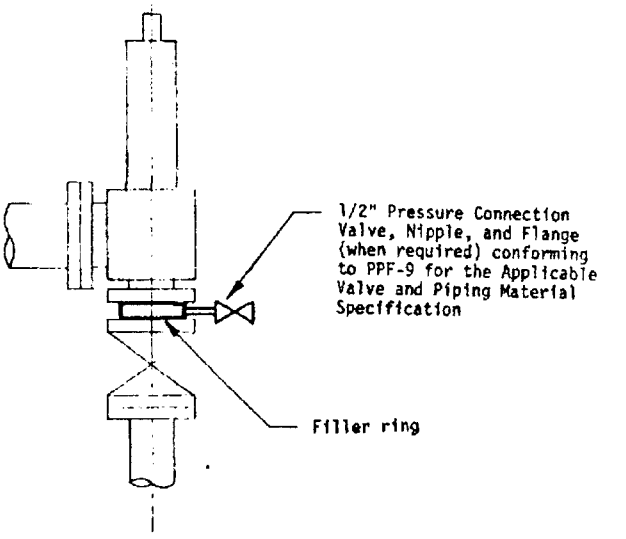
Ductile iron vessels are tested at 2.0 times the MAWP.

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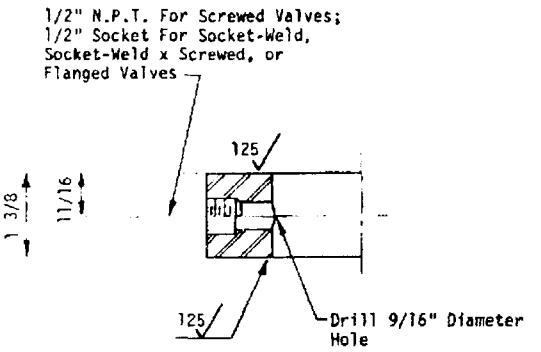
TEST CONNECTION FOR INSTALLED SAFETY VALVE
FILLER RING FOR RAISED FACE FLANGES



FILLER RING DETAIL



ASSEMBLY



SECTION A-A

NOM PIPE SIZE	RING OD 150 LB	RING OD 300 LB	RING OD 600 LB	RING ID ALL
1 1/2	3 1/4	3 5/8	3 5/8	1 1/2
2	4	4 1/4	4 1/4	2
2 1/2	4 3/4	5	5	2 1/2
3	5 1/4	5 3/4	5 3/4	3
4	6 3/4	7	7 1/2	4
6	8 5/8	9 3/4	10 3/8	6
8	10 7/8	12	12 1/2	8

NOTES:

[1] The suffix (TH) designates a threaded connection for the nipple. The suffix (SW) designates a socket connection for the nipple. The material for Filler Rings shall be as specified in the bill of material, and generally, shall be equivalent to the pipe line material. The Filler Rings may be made from high pressure tubing. Other materials shall be in accordance with the governing Valve and Piping Specification.

The bore of Filler Rings shall be machine faced. The outside edge shall be smooth and regular. The faces shall be flat and true.

Each Filler Ring shall be marked on the outside edge with figures 1/4-in. high indicating the material, size, and pressure rating. For example: 304L-3" - 300 lb.

✓ = surface roughness in accordance with ANSI B46.1.

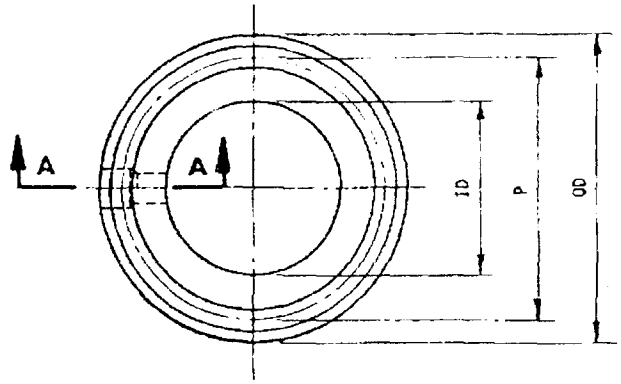
The bill of material shall specify the filler rings by quantity, size, pressure rating, material, OD x ID, socket-weld or screwed, and shall refer to this Standard.

Unless otherwise indicated, all dimensions given in inches

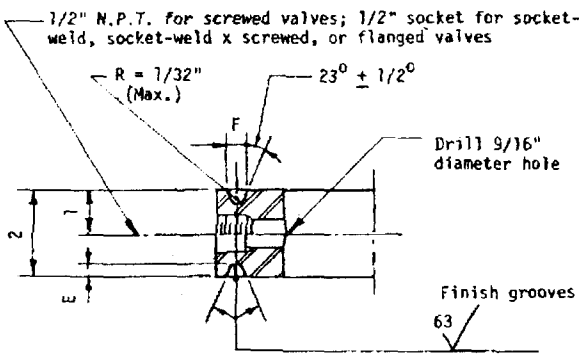
16.6.10.1

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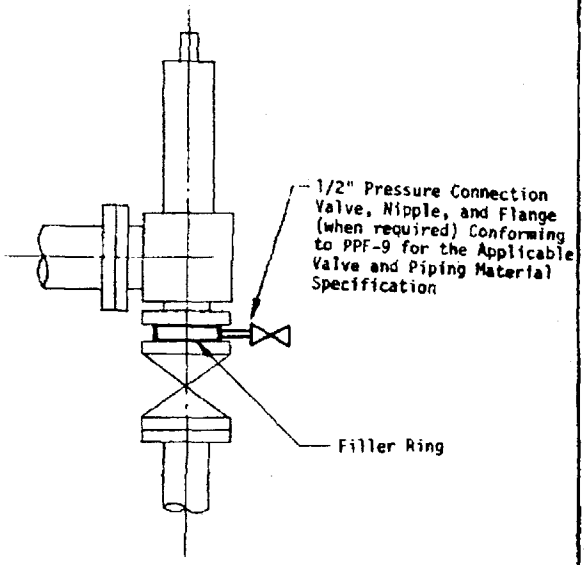
TEST CONNECTION FOR INSTALLED SAFETY VALVE
FILLER RING FOR RING JOINT FLANGES



FILLER RING DETAIL



SECTION A-A



ASSEMBLY

NOM PIPE SIZE	RING OD 150 LB	RING OD 300 LB	RING OD 600 LB	RING ID ALL	E, ± 0 1/64 150 LB	E, ± 0 1/64 300 LB	E, ± 0 1/64 600 LB	F, ± .008 150 LB	F, ± .008 300 LB	F, ± .008 600 LB	P, ± .005 150 LB	P, ± .005 300 LB	P, ± .005 600 LB
1 1/2	3 1/4	3 5/8	3 5/8	1 1/2	1/4	1/4	1/4	11/32	11/32	11/32	2 9/16	2 11/16	2 11/16
2	4	4 1/4	4 1/4	2	1/4	5/16	5/16	11/32	15/32	15/32	3 1/4	3 1/4	3 1/4
2 1/2	4 3/4	5	5	2 1/2	1/4	5/16	5/16	11/32	15/32	15/32	4	4	4
3	5 1/4	5 3/4	5 3/4	3	1/4	5/16	5/16	11/32	15/32	15/32	4 1/2	4 7/8	4 7/8
4	6 3/4	7	7 1/2	4	1/4	5/16	5/16	11/32	15/32	15/32	5 7/8	5 7/8	5 7/8
6	8 5/8	9 3/4	10 3/8	6	1/4	5/16	5/16	11/32	15/32	15/32	7 5/8	8 5/16	8 5/16
8	10 7/8	12	12 1/2	8	1/4	5/16	5/16	11/32	15/32	15/32	9 3/4	10 5/8	10 5/8

NOTES:

[1] The suffix (TH) designates a threaded connection for the nipple. The suffix (SW) designates a socket connection for the nipple. The material for Filler Rings shall be as specified in the bill of material, and generally, shall be equivalent to pipe line material. The Filler Rings may be made from high pressure tubing. Other material shall be in accordance with the governing Valve and Piping Specification.

The bore of Filler Rings shall be machined faced. The outside edge shall be smooth and regular. The faces shall be flat and true.

Each Filler Ring shall be marked on the outside edge with figures 1/4-in. high indicating the material, size, and pressure rating. For example: 304L-3" - 300 lb.

√ = surface roughness in accordance with ANSI B46.1.

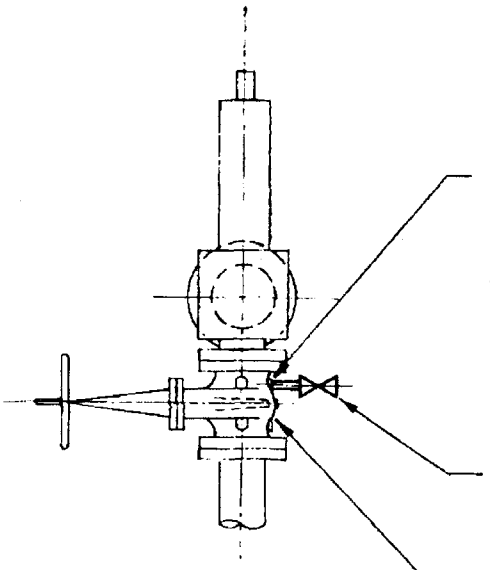
The bill of material shall specify the filler rings by quantity, size, pressure rating, material, OD x ID, socket-weld or screwed, and shall refer to this Standard.

Unless otherwise indicated, all dimensions given in inches

16.6.10.1

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TEST CONNECTION FOR INSTALLED SAFETY VALVE INSTALLED IN CAST STEEL GATE VALVE BODY



Before installing the valve, field drill 9/16" diameter hole through boss above valve disc and opposite valve stem. Provide 1/2" N.P.T. for screwed valves. Provide 1/2" socket for socket-weld, socket-weld x screwed, or flanged valves. Throughly clean all metal particles from the valve.

1/2" pressure connection valve, nipple and flange (when required) conforming to PPF-9 for the applicable valve and piping material specification.

Use only for cast steel gate valves with intergral bosses. (Examples: V-59, V-23, V-79)

ASSEMBLY

NOTES:

[1]The suffix (TH) designates a threaded connection for the nipple. The suffix (SW) designates a socket connection for the nipple.

16.6.10.1

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HALOGEN LEAK TESTING OF SHELL AND TUBE HEAT EXCHANGER

1.0 SCOPE

This recommended practice describes a method for halogen leak testing shell and tube heat exchangers in which the tubes are welded to the tubesheet. The practice follows the requirements of Article 10, and the requirements of Paragraphs 1040-1043 of Section V of the ASME Code with provisions adapting the technique to shell and tube heat exchangers. The assumption is made that the exchanger has been air tested previously to locate tubes and tube-to-tubesheet welds which contain gross leaks and that the gross leaks have been repaired.

2.0 EQUIPMENT PREPARATION

2.1 The vessel must be placed in such a location that the test will not be influenced by the presence of halogen containing materials in the atmosphere. Smoke, paint fumes or similar atmospheric contaminants must be avoided.

2.2 The vessel must be thoroughly cleaned to be free of oil, grease, paint and other contaminants which will falsely influence the accuracy of the test. If liquids are used to clean the vessel, the vessel must be thoroughly dried before testing.

2.3 The shell side of the heat exchanger shall be prepared using plugs, blind flanges, etc. to withstand the test pressure. Materials used must be halogen-free.

2.4 It is recommended that the vessel and the air/gas mixture be not colder than 60F (where practicable) at the time of test.

3.0 LEAK DETECTION INSTRUMENT

3.1 The leak detection instrument shall be of the Halogen Diode Detector type as described in Paragraph 1041.1 of Article 10, Section V, ASME Code.

3.2 The instrument shall be calibrated against a capillary type halogen leakage standard whose leakage rate shall have a range of from 0 to 9×10^{-5} standard cc/sec of halogenated refrigerant/air mixtures (see Paragraph 4.1) and shall be capable of detecting the leak rate within the range of the standard.

3.3 The detection instrument shall be allowed to warm up for a minimum of 30 minutes before calibration with the leak standard.

4.0 TESTING GAS

4.1 The following tracer gases may be used in the halogen leak test:

Trichloromonofluoromethane (Refrigerant 11)
Dichloromonofluoromethane (Refrigerant 21)
Chlorodifluoromethane (Refrigerant 22)
Dichlorotetrafluoromethane (Refrigerant 114)
Dichloromethane (Methylene Chloride)

4.2 Ten percent concentration of the tracer gas (by volume) in clean, dry air shall be used to pressurize the shell side of the vessel.

4.3 The shell side of the vessel shall be pressurized to the lesser of 15% of the maximum allowable working pressure or 60 PSI with the clean, dry refrigerant/air mixture.

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5.0 TESTING PROCEDURE

5.1 The shell of the vessel shall be maintained at the test pressure and the test instrument warmed for a minimum of 30 minutes before testing is started.

5.2 One end of the vessel shall be lifted a minimum of two feet above the floor to provide a tilt to the heat exchanger tubes.

5.3 Both ends of the heat exchanger tubes shall be plugged with halogen-free stoppers. The tube-to-tubesheet welds shall be probed with the instrument with the stoppers in place to determine the leak tightness of the tube-to-tubesheet joint. Welds having a leak rate greater than 1×10^{-4} standard cc/second are to be repaired and retested in the same manner as above.

5.4 After completing the testing of the tube-to-tubesheet welds, the stoppers shall be removed one at a time, from the tubes at the lower tubesheet and the probe inserted in the tube and held for 10 seconds. Tubes found to be leaking shall be marked and replugged. Leaking tubes may be permanently plugged or replaced. Replaced tubes must be subjected to the same testing procedure as described above.

6.0 PERSONNEL QUALIFICATION

6.1 Personnel qualified and certified in accordance with standard SNT-TC-1A, Level II or equivalent shall perform the examination.

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VI. MATERIALS OF CONSTRUCTION (H. E. Peterson)

The necessity of handling plant process streams at varying conditions require that special consideration by given to equipment design and selection of materials of construction for chemical plants. What makes this of even more concern is that the size and complexity of operation within recent years is increasing and, as they do, so do the potential hazards. It is on such a premise that a general understanding of the proper choice and use of material of construction demand the attention of the operating engineer.

The selection of materials of construction is a major problem of the chemical industry. The choice is usually based on many considerations. Factors to be taken into account include not only resistance to corrosion and wear but also the moral responsibility to operate a plant that will not endanger those that work in it. Accordingly, this implies an awareness on the part of the operating engineer to appreciate both the mechanical and process risks that do exist when using a material of construction to withstand the rigors of service encountered in the chemical industry.

A. Mechanical Consideration

Mechanical considerations are frequently the controlling factor in selecting a material for process use. In addition to fabricability and ease of maintenance, mechanical properties include the capability of a material to safely handle the mechanical stresses developed under load to process temperatures and pressures. Because at higher temperature materials begin to lose their tensile and yield strengths, overpressure protection is required by relief valves or other means to offset this tendency and fix the range of pressure a system can safely accommodate. For pressure applications, material selection and design are based on maximum allowable working stresses established by the ASME Boiler and Pressure Vessel Code Section VIII.

A general understanding of the codes and regulations embodied in the ASME Boiler and Pressure Vessel Code provides the guidelines for recognizing the minimum standards required for safe process pressure design. This generally recognized standard included in the C&P COP (Chemicals, Olefins, Plastics) Pressure Vessel Specifications established the mandatory Standards

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Policy for design, alteration, repair and testing for all C&P plant pressure vessels. General requirements for valves and piping used in plant design are described in the Chemicals & Plastics General Piping Specifications and Valve and Piping Material Specification.

In light of the high premium placed by UCC management on the design of process hardware conforming to well established procedures, no change in design, repair or alteration of equipment or pipe should be attempted in the field without consultation or approval of C&P experts in these specialties. So often only slight change of process or equipment in conflict to these standards has resulted in serious unforeseen consequences.

B. Corrosion

Like everything else in the world, even the most inert materials start to age or corrode from the moment of initial service. Fortunately a regular and on-going program of maintenance and control can safely slow or nearly stop the corroding process to give a longer and more useful equipment life. With field and in-service testing, the operating engineer can assist the specialist in overcoming corrosion problems resulting in contamination of products, shutdown of production, loss of efficiency, equipment accident or damage.

The severe effects on plant operation of corrosion failure to plant equipment make corrosion control one of the most important aspects of safe operating practice. The presence of some contaminant or additional substance, a change in construction, temperature or pressure, or the successive use of the same material under different corrosive conditions can have a profound effect on the extent of the corrosive attack. Control of the various corrodent variables can be accomplished with an understanding of corrosion fundamentals, proper engineering practice, testing procedures and protective measures.

Among some of the more important service conditions or factors which must be periodically taken into account in order to minimize corrosive problems are:

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1. Material Application

Corrosion can occur so that a metal corrodes at the same rate over its entire surface or it is localized with only some of the areas affected. Uniform corrosion usually causes the greatest amount of equipment damage, but it is the easist type to measure and unexpected failures can usually be avoided by regular inspection. For example, appreciable corrosion can be permitted if anticipated and allowed for in design thickness. In practice a corrosion allowance may be added to the shell thickness as calculated by C&P specification for the process temperature -- pressure loadings involved. The C&P specification, with reference to the ASME Pressure Vessel Code fixes the maximum allowable working pressure (MAWP) which the vessel can safely withstand. If later when complying with C&P Plant Test and Inspection Procedures, measurements reveal metal loss beyond the corrosion allowance, repair of the vessel or down-rating of the MAWP is required prior to returning the vessel safely to service.

Despite careful selection of materials of construction, unexpected failure from corrosion does arise. It is important to emphasize the early recognition of such problems through regular inspections and following programs of preventive maintenance. For example, corrosion of equipment, flanges and bolts frequently result from poor insulating practices. Aside from uncovering the affected surface, use of protective coating may be considered as an alternate procedure. Use of coatings are particularly recommended for the protection of equipment exposed to the outdoor environment. In addition to organic paints which protect the metal from its environment by relatively impervious films, films based on chemical treatment of the metal surface are frequently applied. Protection by this means include anodizing procedures which increase the thickness of the protective oxide film.

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A common example is anodized aluminum. The treatment of iron to form iron phosphate is an example of yet another type. Films of this type are used as base coats prior to painting. Many proprietary coatings include zinc for anodic protection of the more noble painted metal.

2. Environmental Contamination

The presence of comtaminants such as soluble salts, chlorides, air, water vapor, etc., form environments that accelerate corrosion. Common examples are:

a. Copper which is fully resistant to acetic acid attack in the absence of oxidizing agents, rapidly fails in the presence of both air (oxygen) and acid.

b. Steel tanks are used for storage and transportation of all strengths of sulfuric acid 80 per cent by weight and above. Because corrosion is materially higher on 80 per cent acid than at higher strengths and becaue sulfuric acid readily takes up and retains moisture, dilution of the acid by exposure to humid air rapidly accelrates corrosion. Use of dry inert gas or a desiccant to absorb the atmospheric moisture would prevent the condition causing this problem.

3. Process Variables

Temperature control is one of the major methods for reducing corrosion. As a rule of thumb an increase of 10°C in temperature will usually double the corrosion rate. Many corrosion problems related to high operating temperature stem from heat-transfer conditions where localized areas of high temperature occur. In contrast temperature induced brittleness results with decreasing temperature. For example carbon steels are subject to this hazard and are most sensitive at ambient conditions of about 20°F.

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Other process variables which can materially affect corrosion rates include pH, velocity, pressure, startup and shutdown procedures.

4. Engineering Design

The most insidious forms of corrosion are localized types which are difficult to detect, predict and control. Among these forms are crevice, erosion corrosion cracking. A crevice either internal or external can intensify corrosion and become more severe than on a nearby open surface. Accelerated corrosion can result in liquid system where movement of the corrodent over the metal surfaces causes mechanical wear. Erosion is generally attributed to the removal of protective oxide surface films or coherent corrosive products. For example, iron in sulfuric acid is largely unattacked not because the reaction does not proceed spontaneously but because initial formation of an insolvable coherent corrosion film prevents further reaction by imposing a barrier of ferric sulfate. High velocity conditions can cause turbulence to remove protective barriers and cause erosion corrosion.

Cracking results from the continued effects of applied stress and a corrodent. Stress can be averted by several means to avoid cracking. High residual stresses stemming from welding repairs, etc., may be reduced by stress - reliefing heat treatments at temperature lower than the recrystallization temperatures. Another approach is simply to avoid mechanical designs that produce high residual stresses. The environment condition is extremely specific for each metal affected. typical examples include the cracking of brass which occurs in atmospheres containing ammonia or amines. Mild-steel boiler plate is subject to caustic embrittlement; stainless steels are cracked in acid chloride solutions.

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All these localized forms of corrosion are most amenable to control by proper design of process equipment.

Another form of localized corrosion is galvanic attack. Galvanic corrosion results when two dissimilar metals in contact are exposed to a conductive solution to form a galvanic cell. Because of the electro-chemical nature of the cell, a flowing current is produced proportional to the rate of corrosive attack. If galvanics corrosion is a problem, cathodic or anodic protection can reduce it to a very low rate. Of the types of protection available, cathodic imposes an impressed counter current while anodic protection provides a sacrifical anode to supply the current required to control corrosion. The plating or cladding of metals with other more active or sacrificial metals constitutes on example of anodic protection. Galvanized iron depends on the sacrificial coating of zinc to protect the underlying iron.

Cathodic protection is widely used to control seawater corrosion in plant heat exchangers. Galvanics attack between dissimilar metals of the exchangers occurs in seawater service. The galvanic series for seawater shown in Table I indicates which of any two or more metals coupled in seawater will fail as the anode. As shown by the galvanic series, zinc installed as the anode will sacrificially corrode to protect a steel and copper alloy constructed exchanger.

C. Special Considerations

Disastrous effects can result from neglecting the peculiar physical and chemical properties of materials. Acids, anhydries and alkalies can react with metals to form dangerous materials. These include both toxic and explosive compounds. This is best illustrated by considering some common cases.

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Acetylides frequently are formed in copper or copper alloy equipment. Acetylides are very sensitive to shock, friction and heat. They explode readily. Because of this hazardous nature, special procedures to decontaminate the system is required prior to handling equipment. Various reactions between metals and liquids can generate toxic fumes. Metals in contact with mineral acids can form explosive gases such as hydrogen. Equipment handling hydrogen is subject to embrittlement.

These examples illustrate the need to recognize the special properties of material since potentially serious consequences can arise from neglecting them.

Often causes of poor materials performance stem from human factors reflecting poor judgment, neglect or error. Common among these occurrences is the indiscriminate substitution of less corrosion resistant metals for those of proper choice. For example, the use of type 304 stainless steels for fully resistant type 316 stainless steel has frequently occurred. Other common errors include the use of improper welding rods or procedures, corrosion cracking of stainless equipment with chloride laden water during hydraulic testing, or simple arithmetical errors while adjusting chemical concentrations.

Plastics, glass or cast iron should not be used in process plants for storage or processing flammable materials. Likewise, corrosives, poisons, lethal, and other dangerous, nonflammable compounds should not be handled in these materials where other suitable and more substantial materials are available. Using cast iron, glass, or plastic linings, or coatings on metal, or glass and plastic systems enclosed in metal, or use of plastics alone is permissible where other materials or combinations are not satisfactory, provided that adequate safeguards are incorporated as required for fragile construction, and adequate fire protection is provided.

Actual Carbide plant experiences illustrating corrosion problems resulting from both design and operating factors are reported as follows.

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Case Studies of Corrosion Problems

The following case studies are taken from actual Carbide Plant experiences, which we believe will demonstrate the more common corrosion problems which result from a mix-up in Operations, due to error, lack of understanding, or communications gap.

1. We have a number of products which will solidify when the ambient temperature start to get chilly. To prevent this freezing, lines are often heat traced and insulated. Corrosion problems have occurred many, many time when heat tracing is improp..y used, resulting in overheating of the metalic pipe material. There are two very common examples of this. First is the piping of 50% sodium hydroxide. If the temperature of the caustic and of the pipe is kept low enough, steel is suitable for use in 50% caustic. However, if the steel is overheated, for instance by using 200# steam instead of 25# or 50# steam, or if the heat tracing is left on all summer, allowing heat to build-up in the line, wide spread stress corrosion cracking at the steel welds will occur. Another troublesome problem with heat tracing is in acetic acid piping. The concentrated acid freezes when the weather starts to get cold. Tracing of either aluminum or 304 stainless steel is perfectly safe and adequate under controlled conditions of low heat input. However, if an attempt is made to add more heat because if a little bit of heat is a good thing, a lot more heat is better", the corrosion rate will sky-rocket. The same thing happens when the heat tracing is left on in the summertime. A general rule here is that you can do as much damage by leaving the heat tracing on in the summer as you can benefit by using it in the winter.

2. The lowly decimal point has been responsible for more than one serious corrosion loss. A common situation is the esters reaction, which reacts an organic alcohol and organic acid to make an actate. To catalyze this reaction, we normally use a small quantity of sulfuric acid. For example, the formula might call for 0.20% H_2SO_4. If however through typrographical error or incorrect reading of the number, 2.0% sulphuric acid is added, then drastic and dramatic

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corrosion of expensive stainless steel equipment will take place. Check your numbers.

3. A carbon steel product tank was lost due to caustic stress corrosion cracking, due to foaming which occurred in a NaOH scrubber preceding the tank. In order to build economically competative plants, materials of construction are selected based on the engineering design of what the vessel is susposed to be doing. If however, as in this case, operations is "having trouble" with the caustic scrubber they should realize the potential of carrying contaminants downstream, which might destroy other equipment.

4. A common design problem in vertical heat exchangers is the vapor space underneath the top tubesheet on the shell side water system. This is caused by non-condensible gases, such as air or carbon dioxide collecting there. In this vapor space, water salts will collect and rapid corrosion and failure of the tube will occur. In order to prevent this, a hole is drilled through the side of the tubesheet, into the vapor space to vent the gases. A valve is usually attached to the vent hole so that operations can vent it periodically or a small line is dropped to the nearest trench and a continuous stream of water is passed through to prevent this vapor space formation. In the presence of our current need to conserve materials and energy, this constant venting of water is difficult to justify. Therefore, it is important that operations pay particular care to routine venting, because it really does have an effect on the life of the equipment.

5. Some heat exchangers are designed to cool extremely hot gases. The only way that they can survive is through the cooling mechanism of the water on the other side of tubes. An outstanding example of this is the Schmitzde, thousand pound steam generators on the outlet of Olefin Furnaces. The red hot gas comes into these steel exchangers and is immediately cooled down by the cold metal of the tubes. If however, as has happened more than once, the cooling water is not turned on when the furnace is started up, we will burn up the heat exchanger in a very short order.

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6. Many of our products are transferred by a temporary conduit such as a chemical hose or corrugated metal hose. When using these hoses, it is important that they always be rinsed out, shook out, and hung up to dry. Leaving residual chemicals in the hoses is most undesirable as illustrated by the 347 corrugated metal hose which was destroyed when ethylene dichloride was left in the convolutions as the hose was laying on the ground. When the summer sun heated up the metal and the humid Gulf Coast atmosphere came in contact with the hot EDC, hydrochloric acid was generated which ate thousands of holes in the hose.

7. The problem of over-filling tanks can generate more than one problem. Not only is the spill a problem, but the overflow will probably wipe out the fairly expensive protective coating on the outside of the tank. But even more important may be the consequences of the contamination of the air with the chemical being carried into adjacent equipment. A fairly common case and a most severe example are ammonia tanks. If ammonia is allowed to escape into the air, any brass equipment exposed to it may fail in a matter of minutes by stress corrosion cracking.

8. There are probably many cases where a few drops are noticed to be leaking from a packing or gasket joint; each drop in itself is not a problem. Over a long period of time, not only are our materials wasted, but serious corrosion damage can result. In one case, a boiler had to be shut down because over the years a very small leak of boiler feedwater from the packing of a large feedwater valve ate away the valve bonnet to where a hole the size of your fist occurred underneath the insulation. Only through an alert operators curiousity as to the "buldge" in the insulation around the valve was the corrosion discovered before the high pressure water blew into the boiler house. In another case, boiler feed water resulted in a serious problem when a gasket in a boiler feedwater pump did not seal tight. The boiler feedwater leaked out of the pump in very small amounts over many months time, the pump became incrusted with feedwater salts which are predominately caustic. Eventually the caustic cracked the bolts on the thousand pound pump volute which

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allowed it to blow apart, spraying hot water over a large area. Be alert to small leaks and have them repaired as quickly as possible.

9. A number of our processes handling organic chlorides and HCl are done in a dry environment. This is conducive to proper reaction chemistry and also allows us the use of carbon steel since dry HCl does not attack steel. In these operations, the dew point of the process gases is frequently measured and is extremely critical in maintaining the conditions free from corrosion. If you have such a low dew point controlled process steam, you may be assured that if moisture gets into the equipment, serious corrosion problems and loss of production will result.

10. Some process streams which are corrosive to inexpensive materials of construction maybe inhibited against corrosion by the additive of small quantities of relatively inexpensive chemicals. This corrosion inhibition may seem like a rather insignificant operating detail, however adding a pound or two of chemicals to the process each day, make a very large difference in the corrosion rate. In one polyethylene plant, where the cooling water on the jacket is inhibited with a mixture of caustic and borax, the inhibitor supply ran out and no one bothered to replinish it or to order more materials. Within a months time, piping was spraying water in all directions and a great deal of work and money had to be spent for repairs, because a few dollars worth of chemicals were not used.

11. Sometimes the best of intentions lead to problems. In one operation a product was being neutralized with caustic and then shipped by truck to another location. An enterprising operator decided to add the caustic and the product to the truck and let them mix during the 150 mile trip to the other location. This was a good time saving idea, however, corrosion conditions were not carefully considered. It turned out the truck which hauled the neutralized product had an aluminum tank and when the caustic was added, the truck dissolved -- the bottom ate out of the truck before it even got halfway down the road. Therefore, before making any changes in the way of doing

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things, be sure to check them out with supervisors or other specialists regarding materials of construction and possible corrosion effects.

The previous case studies were examples of operating problems causing corrosion failures. The Maintenance Department and its work with materials and equipment can also influence corrosion problems and needs to be particularly alert and aware of what is going on with relation to materials of construction. The following several case studies will illustrate.

1. Back to the steel piping handling strong sodium hydroxide. The piping specs clearly describe that the pipe welds must be stress relieved. That is, heated to 1150°F and slowly cooled. This must be done to prevent stress corrosion cracking. Many times however, revisions to caustic piping have been made in the field without proper attention to the specification and without stress relieving. Another notable problem in this area was a failure of an entire line when it was found that the T-Bars, used to support the line so that it could be insulated, were welded on the outside without stress relief: this caused cracking of the pipe at each the T-Bar location.

2. Sometimes pipe specs aren't available or don't cover the situation. An example was the steel pipe nipple which was screwed into the bronze river water pump for the attachment of the vent valve. This unfortunate mixture of steel and bronze in river water results in a galvanic corrosion cell with rapid corrosion of steel part. The basic rule for the maintenance man is to put similar materials together and if you don't have what you think are the right materials, check with your supervisor or the corrosion engineer. By the way, this same problem occurs in most of our homes if we have ganvalized piping and bronze valves at the water heater.

3. A few years ago, a major step forward in corrosion protection of steel equipment occurred with the development of the inorganic zinc spray coatings. With the introduction of this material, zinc was

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being sprayed all over everything. This is not all bad, but particular care should be taken to keep the zinc spay off of stainless steel. While there is no immediate danger or reaction, anytime in the future that it becomes necessary to make a weld in the stainless steel, serious and damaging cracking will result if zinc is present. This warning also applies to the welding of galvanized or zinc coated steel to stainless steel. DO NOT DO IT. The result will be cracking of the stainless steel.

4. Be alert at all times when handling materials of construction. Look for differences and if you find them ask "WHY?". A resent failure of stainless steel tubing occurred when a valve was shut in against a Manzel lubricater. The extreme pressure burst one piece of tubing among six or eight, all in the same system. It was discovered that the failed piece of tubing was ordinary heavy walled stainless and not super pressure stainless tubing which is extra strong and extra heavy. Even a cursory examination of the outside of the tubing showed that they were not alike, an alert mechanic or supervisor could have asked why and possibly saved what was nearly a very bad situation.

There are some situations which occur where both operations and maintenance may be involved and need to support each other to keep out of trouble.

1. When hydrotesting stainless steel equipment, particularly in the Gulf Coast area where the hydrotest water contains chlorides, it is imperative that the water not remain in the equipment for any significant length of time and that after the test, the equipment be drained and if necessary flushed with condensate to remove all chlorides. Recent pitting failures of two pipe lines and several stainless steel tanks have occurred when the hydro test water was left in the pipes or in the tanks for several days.

2. Because of the presence of reciprocating machines or pulsating pressures, many of our pipelines vibrate and jump around. Within limits, this is not a problem. However, if the normal vibration changes and becomes more severe or changes frequency, contact your supervisor and bring this to his attention. For example, pipe

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clamps may come loose or corrode allowing the lines to assume a greater vibration load. This may lead then to cracking due to fatigue failure. Another situation to be particularly alert for are the small branch connections on vibrating or pulsating pipe lines. The branch if it is a threaded pipe nipple, may be in danger of cracking in the threaded area. One of these nipple failures in an ethylene line caused a major ethylene release and explosion with a serious loss of equipment and production.

3. There are a considerable number of Carbide processes for which type 316 or 316L stainless steel are specified. In a good many of these, the molybdenum in the 316 alloy is critical. Substitution with the straight (18-8) 304 stainless will not work. Such areas as the organic acids in Brownsville, Texas City, Charleston and Taft; and Ethyleneamines Units at Taft and Texas City, as well as a number of locations in the Institute Plant are well documented as requiring the 316 alloy. Unfortunately, the parts are not always what they seem and is necessary to spot test and check out the piping and associated equipment to be sure it is 316. For example, during the first month of the start-up at Taft Ethyleneamines Unit, there were seven individual unit shut-downs caused by 304 used in place of 316. The Plant Corrosion Engineers and most plant shops and inspectors have means of rapid identification of the alloys. When you know tat a material selection is critical to combat corrosion, it may be wise to consider checking to prevent later corrosion failure, product loss, environmental pollution and potential personel equipment safety hazards.

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VII. PIPING (W. P. Reeves)

The purpose in discussing piping is not to make a design engineer out of you, nor to make you a piping expert in the fields of materials of construction, pressure and temperature ratings, and piping stress analysis. The purpose is to acquaint you with the fact that piping can and does affect the safety of your unit.

I hope that this discussion of piping will have the following effects -

a) That it will give you some knowledge of the piping problems that you could run into at your unit,

b) That it will help you to prepare your equipment and your operations to avoid incidents, and

c) That it will better prepare you to react to the accidents once they happen.

We will be heavy in examples, in relating case histories of past accidents, in some do's and dont's that affect safety. We won't be heavily theoretical, we want to emphasize the practical.

A. Valve and Piping Specifications

Perhaps the best place to start talking about piping is to say a bit about the C&P pipe specifications. C&P has an Engineering Manual called Valve and Piping Specifications. This is an accumulation of all of C&P experience over many years in the field of piping - and it is an excellent work. Properly used, it can solve all of your pipe and valve specification problems in an instant, and insure that you will spend the minimum amount of money on any given piping installation. Improperly used, it can crucify you and your unit - it can be a source of misinformation that could cause most anything from a minor hinderance to a major catastrophe. Refer to the four figures of Spec. 1C2 - probably the most commonly used 150 psi steel pipe spec at the end of this Section. These figures show pressure rating - temperature rating -

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what chemicals handled - adjusted pressure and temperature rating - various pipe for various sizes - valves - gaskets - elbows - flanges etc.

The minimum and maximum fluid temperature limits permissible for a given piping system are indicated in the block entitled "Primary Rating - Temperature Rating." When selecting a V&P Specification for a new installation or changing service conditions in installed piping, be careful that these limits are not exceeded.

The lower fluid temperature limit for normal construction carbon steel is 0°C (32°F). Recently, during a discussion with plant personnel regarding an unrelated problem with a carbon steel system in hazardous service, it was indicated that the operating fluid temperature for part of the system was appreciably below 0°C (32°F). This is a dangerous condition since carbon steel can be brittle at low temperatures.

Whenever service conditions appear to be outside the limits of the applicable Valve and Piping Specification, consult the Piping Technology Group. They will confirm the suitability of the specification, suggest alternates, or prepare new specifications as required.

There is a C&P standard for piping testing. It is PPM-570, and is a part of a manual called Piping Technology-Pressure Piping. Figure 5 will give you an idea of the items covered by this standard.

You need to know what piping specifications are used in your unit - every single specification that is used - and where - and why. Know what the correct materials of construction are. Know the pressures involved in the piping installations. Don't permit any substitutions or changes of material or of pressure rating without sound decisions based on complete knowledge of the situation. Don't permit any modifications without knowing what you are doing.

The valve and piping spec covers gasket material and types of valve packing as we have seen. It is important that you know what types of gaskets and packing can be used in your unit. Substitution of a wrong type of

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gasket could be hazardous if it failed in service. Do not use asbestos bearing gaskets in ethylene oxide service - the asbestos is a polymerization initiator source. Teflon gaskets are widely used - but remember that Teflon cold flows at all temperatures - indicating perhaps a need for spiral wound Teflon gaskets - and remember also that Teflon has an upper temperature limitation of about 540°F. If your unit is called upon to process a new chemical, check out the gasket and packing requirements, just as you check out the equipment requirements of temperature, pressure and material of construction.

Another section of this process safety manual deals with materials of construction in some detail, but one frequently occurring problem dealing directly with piping needs to be mentioned here. If you weld a dimetcoted or zinc coated piece of steel to a piece of stainless steel, you can expect that the stainless will be "zinc cracked". An example of this comes from a C&P plant very recently. Zinc coated steel pipe supports were welded to a stainless line. Extensive "zinc cracking" of the stainless line occurred. The affected areas had to be cut out and patched.

Even when you have the correct materials of construction, it is possible to get in trouble. Glacial acetic acid can be handled easily in 304 SS piping. But the acetic acid freezes at 62°F, and acetic acid lines are more often than not traced and insulated. By simply forgetting to shut the steam off the steam tracings during the summer time, and allowing the acid to heat up to about 80°C (176°F), the corrosion rate of acetic acid on 304 SS is accelerated to a point that will destroy the line in a short time.

B. Strainers

In past years, we have had problems with strainers in condensate service. Our records show that "semi-steel 1/2" screwed Sarco strainers have failed in 600 and in 200# psi condensate service. Investigatin of the incidents revealed that a) semi-steel is another name for cast iron; b) C&P engineering practice limits the use of CI pipe and fittings in condensate service to 125 psi max. All C&P plants have been requested to check for the presence of cast iron strainers in condensate service above the 125 psi limit. Condensate at low pressure is covered by Spec. 1B2 or 1C1-1C2, with strainers covered by Spec. PPF-8. Page 3 of PPF-8 shows that strainers under the 1B2

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spec. for steam service, and therefore for condensate service, are CS-600 lb. type STR 361 strainers. Cast steel - not semi-steel or cast iron strainers are to be used in condensate service. C&P good practice recommend you check your condensate system for any of the "semi-steel - 250 lb" strainers and get them out of there! Refer to Figure 6.

C. Leaks

Leaks are an immediate indication of something that needs to be done, and a long range indication of possible serious consequences. An example - there was a gasket leak between a valve body and bonnet in an insulated line carrying boiler feed water at 750 psi. Corrosion had proceeded for a long time - because the valve was insulated. The leak was discovered because corrosion products had built up and bulged the insulation. Similar valves in the same service were stripped of insulation and examined. Obviously - leaks also represent a product loss, and therefore an energy loss - the leak is a source of pollution - it represents a hazard. Be alert for leaks - and what they tell you.

D. Ball Valves

C&P plants have had a considerable number of problems with ball valves. In February 1973, a C&P plant experienced its first disabling injury in approximately 450 days when an employee was burned by hot condensate as he accidentally opened a ball valve by brushing against the handle. The problem is that the wrench (or lever) handles are non-locking, moved only 90° from closed to open, and are susceptible to being either opened or closed easily. Example - catching on peoples clothes, being stepped on - hit by any object. Safety standars SF-4 deals with the use of hand operated ball valves. It sets the guidelines - do not use ball valves in open-end service when handling fluids that are above 60°C (140°F) -- or at any temperature where the fluid has a rating of 3 or greater in the UCC Hazard Signal Classification Data (either health, fire or stability). Do not use in in-line service if there is a possibility that a serious operational upset or hazard would occur through accidental operation of the valve, or if the fluid handled can polymerize or react if it is trapped with the cavity of the valve. Use another type valve in accordance with the governing valve and piping specifications.

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Soft-seated (usually Teflon) ball valves are susceptible to damage and leakage when exposed to fire. Therefore, do not use Teflon seated vall valves where leakage would create an additional hazard during a fire.

Ball valves with non-conducting soft seats can build up a static electrical charge on the ball and stem. This built-up static electricity can discharge causing an ignition source for flammable fluids in the piping. Ball valves listed in the Valve and Piping Specifications will be provided with bonding of the body to the stem to ensure electrical continuity. Please consult the Valve and Piping Specifications for ball valve usage.

A distribution specialist received chemical burns to the eyes following the unloading of a tank car of acetaldehyde. The incident occurred after the tank car was emptied and the employee proceeded to disconnect the liquid filling and vapor vent lines. There was about 65 psig nitrogen pressure on the empty car. The car was equipped with a Jamesbury 2A ball valve on the liquid inlet line. This particular model valve has a packing nut bushing which screws into the discharge port of the valve holding the ball mechanism in place. A nipple on the plant piping was screwed into this bushing. When the specialist attempted to disassemble the plant piping, the bushing unscrewed from the valve, rather than the piping from the bushing, and the ball was ejected from the valve body allowing the pressure on the car to vent through this opening. The employee was knocked backwards with considerable force, his coverall goggles were knocked off, and he was sprayed with acetaldehyde. Some of the chemical got into his eyes causing burns. Three days lost time.

E. *Piping Vibrations*

Be aware of the problems that can be the result of cyclic stresses caused by piping vibtations or pressre pulsations. A C&P plant recently experienced failure of a Sch. 80 steel threaded pipe nipple due to fatigue cracking in the threads. In this case, the service environment of the nipple was unimportant, it was the vibrations of the ground and associated piping that put a cyclic stress on the threaded joint. In high pressure piping systems (1000 psi and above), threaded branch connectins are prohibited, and a welded joint is required, but in lower pressure systems, the threaded nipple is standard piping design.

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In a similar incident, not one but two SS pipe nipples failed in service on a vinyl resins autoclave. Both SS Sch. 40 nipples failed from fatigue cracking caused by cyclic stresses from piping vibrations or pressure pulsations. The assembly weighed only 7 pounds. The first nipple broke after several months of service. The cracked nipple was replaced with an identical nipple, and it broke in the same location after only 14 hours in service. The operating conditions were 60°C and 65 psig. The material in the process was not corrosive to stainless steel and a metallurgical examination of the failed parts showed no evidence of stress corrosion cracking or metallurgical defects. The process was pressured by stream-driven reciprocal pumps which generated both mechanical cyclic vibration and pulsating pressure. Either one or both were sufficient to cause piping vibration resulting in cyclic stresses acting on the pipe fitting.

In discussing this incident with the Operating Department, it was recommended that the threaded nipple connection at the main pipe header be back-welded and the branch assembly be braced to the main piping.

Let me point out that all threaded pipe nipples are not in danger of failing by fatigue. There are many thousands of pipe nipples in service throughout all of industry, which have not and never will fail by this mechanism. Therefore, a blanket action to backweld and brace all threaded pipe nipples would be unwarranted. What is necessary and justifiable is an engineering approach to the evaluation of the problem when cyclic or pulsating pressures or mechanical vibrations from reciprocating machines are inducing vibration.

Figure 7 shows the best brace points for existing connections which require bracing. Figure 8 shows a bracing arrangement for vents, drains, pressure gauges.

The Belgium explosion resulted in an immediate check of the high pressure piping in Carbide's Polyethylene Units around the world. At one plant this thorough investigation required a 24-day down time. Vibration measurements were taken on suction headers and on hyper compressor discharge headers. The vibration data was analyzed, and resulted in some additional pipe line anchors being installed. All lines were checked to make certain the

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material was the correct steel alloy. Several unacceptable steel lines and valves were found and replaced. All "tees" and branch connection welds were dye checked for fatigue cracking. No fatigue cracks were found, but eleven welds were found to have cracks defined as "incipient hot-short cracking" - due to original weld procedure or contamination. These welds were ground out and rewelded. All pipe was checked for compliance with piping specs. Spot ultrasonic thickness measurements were made. No major deviations from pipe specs were found.

F. Flexible Hose

C&P uses a great deal of flexible hose, of many varying materials and sizes. Caution is the word for using hose. Hose are used for loading/unloading of tank cars, trucks, barges, ships - etc. - and must constantly be on guard against hose failure. Recently, a 2-inch chemical hose in acetone service burst between the pipe rack and the chemical tank truck being loaded. Examination of the hose by the Materials of Construction group revealed that the hose was tested to 200 psi on 6/76 (because the stainless steel test tag was still on the hose) but shortly after the June test, the hose was run over and pinched and small crack or split developed on the inner liner. Further use of the hose opened up the split in the liner, allowing acetone or water, or humid air to get to the steel reinforcing braid. The braid had corroded and disintegrated, allowing the hose liner to further become unsupported. Finally, the hose burst as would be expected. The report concludes that the stainless test bands should be placed on hose to provide a hose history, and that a 5-year life limit be placed on chemical hose. Further, the report says that there is no way to determine the total life of a hose.

Hose Failures Fall Into Five Major Categories

1. Improper application - pay particular attention to operating temperature and pressure of the hose, including hose for vacuum service, and pay attention to the compatbility of the hose with the fluid.

2. Improper assembly - pay attention to fittings and their installation.

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3. External damage - abrasion - corrosion - crushing.

4. Faulty equipment - or malfuncting equipment leads to premature hose failure.

5. Some times the hose itself is faulty.

One final word on hoses. Very recently at a C&P plant, a hose fitting broke during transfer and 6000 gallons of product was lost. Investigation of the incident revealed that a cast aluminum fitting had failed, and that this very design of cast aluminum hose fitting had been giving the plant problems for over 13 years. The plant is now considering a blanket recommendation to replace all of its aluminum fittings with either bronze or stainless steel - whichever is applicable.

G. Thermowells

An incident occured recently at a C&P plant where a thermowell in a high pressure process piping system broke, and blew out. The failure of the thermowell was due to vibration caused by high fluid velocity in the piping. The plant was faced with checking a large number of other thermowells throughout the process, and devised the following method of checking the thermowells without having to remove them from the line.

H. Hydraulic Hammer

Consider the term HYDRAULIC HAMMER - What does it mean -what causes it, what kind of pressures can be built up, when it may be expected. Hydraulic hammer is the series of shocks, like hammer blows, that are produced by suddenly checking the flow of water (or other fluids) in a pipe. When a valve is suddenly closed, the kinetic energy of the moving column of water is expended in compressing the water and stretching pipe walls - assuming no relief devices are provided. The physical phenomena of water hammer are a matter of concern for those working with liquid systems in which the velocity of flow is more than 2 or 3 feet/sec. This applies to us every day - we normally design for liquid flow rates at 5 to 7 ft/sec - we load tankers and barges at up to 10-12 ft/sec. When the valve is suddenly closed, a wave of

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THERMOWELL - FLUID VELOCITY CHECK PROCEDURE

1. Check thermowell head.
The maximum fluid velocity in the tables below applies only to UCC standard thermowells. UCC standard thermowells have either a 1 3/8" hex head (screwed) or 1 1/2" hex head (welded).

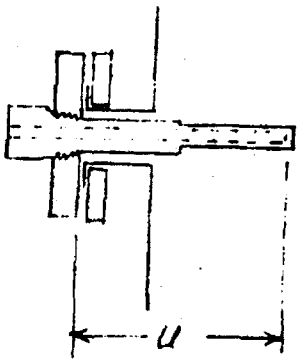
2. Check thermowell I.D.
It is suggested that a 24" long 3/8" O.D. stainless tubing be used. If the tubing will not go in the well, it is Type 1; if a snug fit it is Type 2; and if a loose fit it is Type 3.

3. Check thermowell length (U dimension). See below.
Measure total length of the thermowell inside the line. Stick a wire in the thermowell bore and deduct the length not actually in the pipe (to the process side of the flange or coupling).

4. Determine maximum fluid velocity in ft/sec from table below.

Type	U Dimension (inches)			
	7.5	10.5	13.5	16.5
1	78	59	39	25
2	83	64	43	28
3	121	79	50	33

Should the thermowell not be a UCC standard, it will be necessary to pull the well to determine the O.D. Contact Mr. L. R. Zinck of Control Systems Engineering at ext. 1139 for maximum velocity for non-standard thermowells.



THERMOWELL DATA -
SEE PPF-10

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increased pressure is transmitted back thru the pipe at constant velocity and pressure. The shock pressure is the same on the valve as it is on the pipe, but if a bursting pressure is developed, it may show its effects near the valve simply because it acts there first. If the pipe were perfectly rigid, the pressure wave velocity would be that of sound thru water or 4700 ft/sec. Actually, depending on the pipe material, the pressure wave velocity is about 4200 ft/sec for up to 6" pipe, and about 3300 ft/sec for 24-inch pipe. The intensity of the pressure in the hammer wave depends on the amount of reduction in stream velocity. As a rough guide, it could be said that the pressure increase would amount to about 60 psig for each foot per second of extinguished velocity for 2-6 inch pipes, and about 45 psig for each foot per second in a 24-inch pipe.

What actually happens when a valve is closed instantly?

First - a high pressure wave travels back up the pipe line to the reservoir.

Second - the flow reverses, and a normal pressure wave travels down the pipe to the valve tending to create a vacuum at the valve.

Third - the reversed flow is checked, and a wave of subnormal pressure moves back up the line to the reservoir.

Fourth - the greater normal pressure in the reservoir starts flow into the pipe (thus the flow reverses again), and a wave of normal pressure and forward flow travels downstream toward the valve.

Refer to the following diagram.

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WATER HAMMER



ASSUME - NORMAL FLOW IN THE NORMAL DIRECTION.

THEN ASSUME VALVE  CLOSES INSTANTLY.

STEP	LIQUID FLOW	WAVE FLOW
I	STOP (INST.)	HIGH PRESS. WAVE BEGINS AT VALVE, MOVES UPSTREAM TO SOURCE.
II	FLOW REVERSES (TENDS TO CREATE VAC AT VAL)	NORMAL PRESS. WAVE BEGINS AT SOURCE, MOVES DOWNSTREAM TO VALVE.
III	STOP	SUBNORMAL PRESS. WAVE BEGINS AT VALVE, MOVES UPSTREAM TO SOURCE.
IV	FLOW STARTS	NORMAL PRESS. WAVE BEGINS AT SOURCE, MOVES DOWNSTREAM TO VALVE.
I(REPEAT)	STOP (INST.)	HIGH PRESS. WAVE BEGINS AT VALVE. REPEAT PROCESS UNTIL DAMPENED OUT BY FRICTION.

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We are full cycle - back where we started the instant before the valve closed. The completed cycle of pressure waves and reversals of flow is accomplished in the time required for two round trips. The time period we are talking about is short - less than 30 seconds normally. Automatic controls should be set to close the valve over a calculated time period longer than the time required for completion of the pressure cycles that we talked about.

The possibility of hydraulic hammer is real whenever a steam line that has been down is placed back in service. The line must be vented and drained - all condensate traps must be in working order - care must be taken to prevent a buildup of condensate in the line. Recently, in a C&P plant, a 12" - 125 psi rated cast iron valve in a 30 psi steam line failed as the line was being placed back in service. One operator was injured as he jumped off the rack to avoid the escaping steam and condensate. An investigation revealed that the line had been vented downstream of the valve, but the condensate drains upstream of the valve had been closed off. Differential thermal stress and hydraulic hammer were found to have caused the valve failure.

A second lesson should be learned from the case of the 12" cast iron valve, and that is that the use of cast iron pipe - fittings - valves - proves to be an economical material of construction if properly installed and maintained but - there is a risk involved in the use of a frangible material which has little or no ductility. Another example of the safety problems involved with the use of cast iron pipe fittings occurred at Texas City in 1948. Two breaks in a propane-propylene transfer line operating at under 250 psi caused a flash fire at a road crossing - seven people were killed. It was postulated that excessive stresses in the line caused the two cast iron fittings to break.

I. Hydraulic Pressure Relief

Hydraulic relief or over pressure relief for liquid filled pipe lines - is a potential problem that faces us all the time. Long liquid filled pipe lines that can be valved in require protection against thermal liquid expansion. Generally a 1/2" or a 3/4" safety relief valve is used - never anything smaller than 1/2" from a mechanical safety point of view. Take

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care where the safety valve discharges - do not create another safety or maintenance problem. Frequently it is necessary to protect a line against hydraulic accumulation - that is more fluid going in than out. The capacity of the safety valve must equal the capacity of the pump. Watch out for any change that will increase the pump capacity by increasing the suction pressure to the pump. If you change the pump for one with higher capacity - change the safety valve also. Some times a long line is protected by a safety valve which is down stream of the flow control motor valve. Be sure and re-size the safety valve when you re-size the motor valve for higher flows. On all direct fired heaters, if the tubes can be valved in, a safety valve is required. Long liquid filled lines containing fluids which will not condense at ambient temperature and pressure can be protected by expansion chambers on top of the line. Example - chlorine. Do not use expansion chambers for materials which will condense at ambient pressure and temperatures - because no vapor space will be left for liquid expansion upon increased temperature. Example - phosgene which condenses at atmospheric pressure and 47°F. A section of frozen condensate line was being thawed by attaching an electric welder to either end. No one thought about over pressure relief. The line pressurized and ruptured - neither end had been cleared to vent.

J. Pipe Lines and Reactive Chemicals

Pipe lines handling reactive chemicals should be as short and as direct as possible; equipment layouts should be prepared with this thought in mind. Cross-ties between lines, even though they are closed-off with blind flanges or line blanks, should be avoided, and there should be no provision for their addition in the future. Insofar as possible such lines should be for one purpose only.

The lines should be designed, fabricated, and installed so as to be self-draining, and where pockets are unavoidable, drain valves should be provided. If drain valves are used, consideration should be given to the collection and disposal of the materials drained from the lines. Pipe lines which will be in potentially fouling service should be constructed and installed in such a way that they can be removed easily at regular intervals for inspection and cleaning. Trenches or pits in which reactive chemicals may collect and react with other chemicals should be avoided.

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Important valves and control stations should be located in such a way that operation is simplified and chances of confusion are minimized. Apply these test questions: If an operator confuses two control stations, side-by-side, and operates the wrong valve, will a hazardous situation arise? If he operates two valves in the wrong order what will happen? What happens if a valve leaks? If it appears that potentially hazardous situations can occur very easily, consider installing interlocked valves, double-valve-and-vents, or other appropriate safeguards.

Here is an example of poor thinking that resulted in an improper line installation. A versatile piping system was designed for the use of three different pressure ranges of steam to the calandria shell. The steam supplies were to be automatically controlled at 30,180, and 600 psi. An existing 600 psi header was utilized, and the 30 and 180 psi steam lines were tied to the 600 psi header. Only one thing was omitted - there were no provisions made to protect either the 30 or the 180 psi systems from over pressure by the 600 psi system.

K. Reverse Flow

Be aware that accidents can be caused by reverse flow. By reverse flow, I mean flow in a direction thru a pipe line or system that is backwards to the normal flow. The possibility that a gas or liquid might travel thru a line in the opposite direction than the normal flow direction is not always obvious or recognized. Back flow in drains - or back flow from process systems into utility lines, such as water-air-nitrogen - or back flow from one process vessel to another - all of these things can and do happen.

An example of unexpected back flow - a still column had been shut down, all lines broken loose except for one water line, and the column prepared for entry. Unknown and unsuspected, liquid from the column had previously backed into the water line and, while the column was being worked on, the liquid in the water line emptied back into the column.

Another example of an unexpected direction of flow of a fluid - this time a gas - at the Tennaco Refinery in 1976, 14 were killed in a vessel fire. The vessel had been completey blanked off, cleaned, and entered - work

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was proceeding within the vessel. Someone unthinking - but in order to ventilate the vessel better - pointed an air nozzle into the vessel - not out of but into, which is a grave error in itself - and then hooked the air line to a hydrogen-methane header and filled the vessel full of gas.

The Tennaco disaster pointed out several areas where safety could be improved, and one of them was mistaking one utility line for another. The fuel gas line was mistaken for the air line. C&P has adopted standard utility hose stations which we designed to help prevent the unthinking from hooking up to the wrong utility. Standard PPM-13 shows a two-tiered installation for plant air - non potable water - nitrogen and 75# max steam. In Figure 9 note the difference in elevation of the end points, and the special attachment boss required for the steam. Line identification itself is important. Process and utility lines should be identified in the unit, and on the pipe racks. The line identification should be complete and correct, and should be checked periodically on a regular basis. When a line changes service, the line identification should change. Color coding is another method of line identification.

Sometimes the possibility of a back flow is not foreseen. A case in point concerns the revision to a flare system shown in Figure 10. The flare system was serviced with steam to prevent smoking, and the steam main had to be shut down so that a branch connection could be welded into it. The steam valve at the flare stack was closed, and the steam main was then blown down. The steam valve at the stack leaked and this is where the possibility of back flow enters in. As the steam main cooled, propylene from the flare stack was sucked into the pipe. When the welder burned thru the steam pipe, an explosion occurred - fortunately the welder was not injured. This is an excellent example of where a slip-blind installed in the steam line at the flare stack would have prevented the incident. Another method of line preparation would have been to disconnect the steam line from the flare stack.

Figure 11 shows another example of back flow - this time caused by failure of a pump. When the pump tripped out, the check valve in the discharge line failed to close. The pressure and head of liquid in vessel A backed thru the line, and the pump was driven backwards. The impeller of the pump disintegrated, and the motor was damaged. In other cases, the pump shaft

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has been broken. Reverse rotation locks on pumps should be considered. Beyond that, the check valve question should be considered. Whenever the failure of a check valve can have serious consequences, it should become a candidate for a regular inspection. Also, the use of two check valves in series should be considered - preferably two different types of check valves. Never install a check valve in a vertical down flow position.

In another example of unexpected flow, shown in Figure 12, an operator was taking a furnace out of service. The furnace had been operating on steam, not on raw material. All of the standard procedures were being followed. As he was checking the positions of the condensate plug valve and the furnace plug valve, he was burned on the shoulder by hot condensate pouring out of a vent line above him. Hot condensate had leaked thru the closed condensate header valve, and out thru the vent line.

At times, when the consequences of unexpected back flow are serious, extraordinary design features are followed in order to prevent back flow. Figure 13 illustrates the design of such a system. This design followed an incident involving an unexpected back flow of aqueous ammonia into an ethylene oxide storage vessel. In order for the ammonia to back flow thru the system, it had to pass several check valves in series, and a pump. The ammonia got past the pump by flowing thru a leaking relief valve that discharged from the pump discharge line to the pump suction line. There followed a violent rupture of the ethylene oxide tank causing wide spread damage and destruction. Note that the redesign includes two motor valves. The pressure drop and the flow thru the system is measured. One motor valve trips automatically on low pressure drop and low flow; the other controls flow and trips on low pressure drop and low flow. Duplication was deemed necessary to provide high reliability. Care was taken to develop a system that would prevent back flow thru a broken diaphragm on the pressure differential instrument.

An obvious means of preventing back flow in a line is to slip blind the line. But don't use a Muley slip blind in slip blinding lines. A Muley slip blind is one without a handle, and since it doesn't have a handle sticking out, it is practically impossible to locate in a line and is very easily over looked. Use a slip blind per UCC Standard PPM-10 shown in Figure 14 and 15.

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L. Summary

Become thoroughly familiar with C&P's Valve and Piping Specification Manual. Use it. Learn the correct materials of construction for your unit, and see to it that only these materials are used. Be aware of the problems involved with piping vibration - and that something can be done to correct it. Hose is an ever present potential safety problem - know that hose failures stem from five sources - 1) improper hose application, 2) improper hose assembly, 3) external hose damage, 4) faulty equipment, and 5) faulty hose itself. Be aware of the potential problems of hydraulic hammer. For reactive chemicals, keep the piping short - direct - and single purpose. Always consider the possibility of reverse flow through your unit lines - and the safety problems that unexpected reverse flow cause. Prevent reverse flow by breaking lines and installing blind flanges or by installing a slip blind - but don't use a Muley slip blind.

Be sure you comply with C&P Safety Standards:

SF-4 - Ball Valves
SF-17 - Chain Wheel Valves
SF-108 - Facility Change
SF-215 - Identification

Other piping specifications of interest to operating people are attached for reference.

UCC 021230

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Spec. PPF-A

PIPING

UNION CARBIDE STANDARD

1 C 2 ← 2nd Spec at 1C Combination

Material ↑ Pressure Rating ↑

VALVE AND PIPING SPECIFICATION 1C2 / 1C2A / 1C2B

PAGE: 1 of 2

DATE: December 1974

CHEMICALS/PLASTICS

Pipe Testing → PPFA-1

Valved Assembly

Gauges

PRIMARY RATING - TEMPERATURE RANGE	HYDRO TEST	SERVICE
Thru 20": 150 psi 24": 130 psi at 0°C to 260°C (32°F to 500°F)	(Per PPM-570) 425 psi max. 240 psi max.	Chlorine Hydrocarbon Gas and Liquid Vacuum (1C2A (See Note 1)) Steam Distribution
ADJUSTED PRESSURE - TEMPERATURE RATINGS See Table - Page 2	CORROSION ALLOWANCE 0.030"	MANDATORY GENERAL SPECS PPF-1, -9, -9A, -9C and -10

COMPONENTS	NOTES	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	6	8	10	12	14	16	18	20	24
PIPE	6	Steel-40-Smls							PPF-A → Steel-40-ERW										
FITTINGS: THREADED NIPPLES		Steel-80-Smls																	
FITTINGS: COUPLINGS		FS-3000-Scrd																	
FITTINGS: UNIONS		FS-3000-Scrd																	
FITTINGS: BUSHINGS		Steel																	
FITTINGS: PLUGS		Steel																	
FITTINGS: ELBOWS	6	FS-2000-Scrd	FS-3000-SW	Steel-Std-BW															
FITTINGS: CAPS		FS-3000-Scrd	FS-3000-BW	Steel-Std-BW PPF-A															
FITTINGS: REDUCERS		FS-3000-Scrd	FS-3000-SW	Steel-Std-BW															
BRANCHES: FULL SIZE		FS-2000-Scrd	FS-3000-SW	Fabricate from pipe without added															
BRANCHES: REDUCING	1	FS-2000-Scrd	FS-3000-SW	reinforcement of 90° branch connections.															
FLANGES: STRAIGHT	5, 6, 7	FS-150 RF-Scrd	FS-150-SW-RF-60	FS-150-SO-RF															
FLANGES: REDUCING	7	FS-150 RF-Scrd	FS-150-SO-RF																
FLANGES: BLIND		See Notes	FS-150-RF																
VALVES: SHUTOFF	2, 8	Su-800-Scrd GA-1422	Steel-150-Flg GA-1148	Steel 150-Flg GA-59	Steel 150-Flg GA-1174	Steel-150-Flg GA-59													
VALVES: SHUTOFF	8		Steel-800-SW GA-1423	Steel-150-BW GA-1202			Steel-150-BW GA-1202R												
VALVES: CONTROL	8	Su-4000-Scrd GL-115	Steel-150-Flg GL-115	Steel-150-Flg GL-143															
VALVES: CONTROL	8		Steel-800-SW GL-1256	Steel-150-BW GL-1203			GL-1203R												
VALVES: CHECK		Su-800-Scrd CK-1197	Steel-150-Flg CK-1154	Steel-150-Flg CK-203															
VALVES: CHECK			Steel-800-SW CK-1204	Steel-150-BW CK-1205			Steel-150-BW CK-1205R												
VALVES: EXCESS FLOW CHECK	3, 4			Steel-600-Flg GK-1196															
VALVES: EMERGENCY BLOWDOWN	4	Steel-600-Flg GK-1055																	
		1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	6	8	10	12	14	16	18	20	24

PPF-5

BOLTING: (5) 1C2: To 5/8" diameter: ASTM A307 Gr B regular square or heavy hex head bolts; heavy hex nuts.
3/4" diameter up: ASTM A307 Gr B regular square or hex head bolts; standard or heavy hex nuts.
1C2A, 1C2B: ASTM A193, Gr B7 or B16 alloy steel stud bolts; ASTM A194, Gr 2 or 2H heavy hex nuts.

GASKETS: 1C2, 1C2A - Compressed asbestos
1C2B Spiralwound 304 with asbestos — Note the difference

DOPE: GASKET - 1C2, 1C2A - Graphite and oil
1C2B - None
THREAD - Teflon tape (32°F to 500°F)
Crane 425A (500°F to 750°F)

GENERAL: A. In vacuum service, the detail design of 20" and larger systems shall be per Par. 304.1.3 and 304.1.4 of ANSI B31.3. — Abbreviations-PPF-1

NOTES:
(1) Connections welded into lines for vent, drain, or instrument connections shall be in accordance with PPF-9, -9A, -9C, and 10.
(2) GA-1422, GA-1423, GA-1148 and GA-1174 are reduced-port valves. Do not use under a safety valve in vapor relief service or where port reduction is of significance, instead use GA-1198 in place of GA-1422, GA-1423 and GA-1148, and GA-59 in place of GA-1174.
(3) Excess flow check valve shall be installed inverted (stem down) with the flow such that it tends to move the disc towards the seat closing the valve.
(4) Mating flanges shall be 600 lb. flanges with raised face.
(5) When mating ANSI 300 lb. flanges, use alloy stud bolts and weld neck flanges: FS-300-Scrd-RF to 3/4"; FS-300-WN-RF-Std, 2" to 24" except with flare construction use FS-300-LJ.

16.5.60.1

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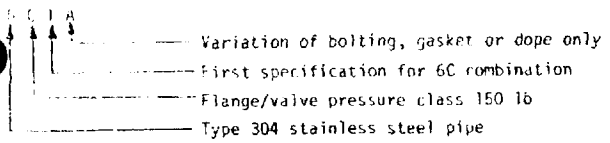
Fig. 1

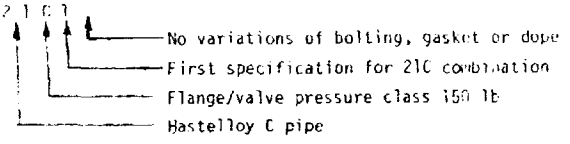
UCC 021231

The number for a standard valve and piping specification consists of four parts: (1) a number indicating the major pipe material, (2) a capital letter indicating the flange/valve pressure class, (3) a number identifying sequentially specific specifications for particular pipe material and flange/valve pressure class combinations, and (4) a capital letter indicating a bolting, gasket, or dope variation. The fourth part is omitted when there is no variation of bolting, gasket or dope. In special cases, a capital letter in the fourth position is used to identify Code jurisdiction other than B31.3.

Number identifications of various pipe materials are given in Table 5. Letter identifications for various flange/valve pressure classes are given in Table 1.

The following examples illustrate the numbering system.





Some specifications have a mixture of pipe materials and/or a mixture of flange/valve pressure classes. For these specifications, the most significant material and pressure class identification are used.

In all cases variations other than bolting, gaskets, and dope are covered by separate specification numbers. This results in a considerable number of specifications, but greatly increases convenience to the user, especially in the field. At the same time, it makes possible precise specification of materials to be used in a particular pipe line.

TABLE 1
FLANGE/VALVE ANSI PRESSURE CLASS IDENTIFICATION

A	Below 125 lb	G	600
B	125 lb	H	900 lb
C	150 lb	K	1500 lb
D	250 lb	L	2500 lb
E	300 lb	M	Over 2500 lb
F	400 lb	W	Specified in Piping Technology - Underground Manual
		X	Specified in Piping Technology - Underground Manual

ABBREVIATIONS

Abbreviations are used in valve and piping specifications (for example, 1B2) to save space. These abbreviations are fully defined in PPF-4 to cover purchase specifications, applicable standards, etc. However, the complete definitions in PPF-4 are not needed to understand the specifications.

Abbreviations in valve and piping specifications are in accordance with the following system:

Pipe			Schedule, or		
	Material	-	Wall Thickness	-	Type
Example 1:	304L	-	10S	-	W
Example 2:	Steel	-	.156"	-	ERW

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TABLE 5
PIPE MATERIAL IDENTIFICATION*
NUMERICAL

0 Not used	50 Glass-lined steel
1 Carbon steel	51 Conical end glass
2 Silicon-Aluminum-killed steel	52 Capped end glass
3 Chrome-copper-nickel-aluminum steel	53 Armored glass
4 Aluminum	54 thru 56 reserved for glass and glass lined steel
5 Copper	57 Polybutylene
6 304 stainless steel	58 ABS
7 304L stainless steel	59 Polyester
8 316 stainless steel	60 Phenolic
9 316L stainless steel	61 Epoxy
10 347 stainless steel	62 Polyethylene
11 Alloy 20	63 Polyvinyl Chloride
12 409 stainless steel	64 Reinforced plastic (mixed resins)
13 405 modified stainless steel	65 Kynar
14 26-1 stainless steel	66 Polypropylene
15 thru 19 reserved for stainless steel	67 Vitrified clay
20 Hastelloy B	68 Concrete
21 Hastelloy C	69 Transite
22 Hastelloy C-276	70 Polypropylene-lined steel
23 thru 29 reserved for Hastelloy	71 FEP Teflon-lined steel
30 1-1/4% Chrome - 1/2% Molybdenum steel	72 TFE Teflon-lined steel
31 Reactor tubing (Polyethylene)	73 Saran-lined steel
32 thru 34 reserved for alloy steel	74 Penton-lined steel
35 Ductile iron	75 Epoxy-lined steel
36 Cast iron	76 Polyethylene-lined aluminum or steel
37 Galvanized steel	77 Kynar-lined steel
38 Brass	78 Phenolic-lined steel
39 Coal tar coated steel	79 Coal Tar Enamel lined steel
40 Monel	80 Copper-lined steel
41 Nickel	81 Coal Tar epoxy-lined steel
42 Inconel	82 Nickel coated steel
43 90-10 Copper-nickel	83 thru 89 Not used
44 Zirconium	90 Culvert pipe
45 Titanium	91 thru 99 not used
46 thru 49 reserved for alloys	

*This list also applies to Piping Technology - Underground Manual. Specifications therein are identified by "W" or "X" in second field of specification number.

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Fig. 3

16.5.60.1

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PRESSURE-TEMPERATURE RATINGS - 1G2, 1G2A, and 1G2D
(Maximum pressure - psi)

										Max.
Maximum temp, °C	0 to 38	66	93	121	149	177	204	232	260	Hydro
Maximum temp, °F	32 to 100	150	200	250	300	350	400	450	500	Test
Thru 14"	275	255	240	225	210	195	180	165	150	425
16"	250	245	235	225	210	195	180	165	150	375
18"	220	215	210	205	200	195	180	165	150	330
20"	195	190	185	180	175	175	170	165	150	290
24"	160	160	155	150	145	145	140	135	130	240

PRESSURE-TEMPERATURE RATINGS - 1G2B ONLY

Maximum temp, °C:	288	316	343	371	399
Maximum temp, °F:	550	600	650	700	750
	130	125	120	110	100

NOTES: (Continued)

(6) When Leonard or equal bending and/or flaring machines are available, they shall be used to fabricate 1", 1-1/2", 2", 3", and 4" sizes. See Table I for components. Piping drawings and/or instructions to the pipe fabricating shop shall specify the construction method to be used.

Table I

Construction	Sizes	Pipe	Elbows	Flanges
Bend (no flaring)	1", 1-1/2"	BF Steel-40-ERW	Bend - 1-1/2R	FS-150-SW-RF-40
	2", 3", 4"	BF Steel-40-ERW	Bend - 1-1/2R	FS-150-SO-RF
*Flare (no bending)	1", 1-1/2"	BF Steel-40-ERW	FS-3000-SW	FS-150-LJ
	2", 3"	BF Steel-40-ERW	Steel-Std-BW	FS-150-LJ
	4"	BF Steel-40-ERW	Steel-.188-BW	FS-150-LJ
*Bend and Flare	1", 1-1/2"	BF Steel-40-ERW	Bend - 1-1/2R	FS-150-LT
	2", 3", 4"			

*With this construction, 4"x3", 3"x2", 2"x1-1/2", 2"x1", and 1-1/2"x1" concentric reducers shall be fabricated by expanding the smaller pipe to the larger size. The apex angle of the flared section shall not exceed 60°.

(7) 2" or smaller flanges welded to elbows shall be weld necks: FS-150-WN-RF-40; see Table 7 in Piping Technology - Dimensions Manual.

(8) For steam service, use valves with GRAFOIL packing: See Table A.

TABLE A

	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	6	8	10	12	14	16	18	20	24
SHUTOFF	GA-1422C		GA-1148B				GA-59D	GA-1174C	GA-59D									
			GA-1423C				GA-1202C						GA-1202CR					
CONTROL	GA-1132C		GL-1151B				GL-143B											
			GL-1206C				GL-1203G						GL-1203 CR					
	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	6	8	10	12	14	16	18	20	24

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Fig 4

UCC 021234

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PIPING TESTING

1 GENERAL

1.1 SCOPE - This Piping Testing specification prescribes general requirements for testing piping systems. These requirements are intended to be used with line lists, flow diagrams, and other process/project design information to prepare detailed project Piping Systems Test Schedules for major projects, and to determine testing requirements for plant work. (Piping Systems Test Schedules are covered in PPM-470.)

1.1.1 Detailed Test Procedures - Specific detailed test procedures, including provisions concerning safety, to be used to accomplish required testing are not within the scope of this specification.

1.2 EXCLUSIONS

1.2.1 Equipment - This specification does not cover the testing of process vessels, heat exchangers, pumps, instruments, and other equipment which are tested in accordance with the Codes and Specifications under which the equipment is built. The testing of such equipment in accordance with provisions of this specification is incidental only.

1.2.2 Gravity Systems - The testing of gravity sewers and drain systems is covered in the UCC manual - Piping Technology-Underground.

1.2.3 Lines Open to Atmosphere - Short lines that are normally open to atmosphere such as vents, drains, and safety device discharge piping shall not be pressure tested. All joints in such lines shall be visually examined for proper installation.

1.3 REQUIREMENTS FOR FLAMMABLE AND TOXIC SERVICE - The Occupational Safety and Health Administration, U.S. Department of Labor (OSHA) requires that all piping systems in flammable liquid service be hydrostatically or pneumatically tested. Generally, although not required by OSHA, piping systems in flammable gas or vapor service, and systems in toxic service shall also be so tested.

1.4 SELECTION OF TEST SYSTEM - The selection of the piping to be tested in any one test system shall be done so as to include the maximum amount of piping consistent with the test fluid and the test pressure.

1.5 ISOLATION FOR TEST - Piping shall be divided into test systems by closing valves when the valves are a part of the piping system and the maximum test pressure does not exceed the 38C (100F) service pressure rating of the valve. Provision shall be made to prevent build-up of pressure outside the test system due to a valve leaking. When valves are not used, piping shall be divided into test systems by using blinds (see PPM-10), blind flanges, caps, or plugs.

1.6 TEST DURATION - When a longer period is not specified in the governing valve and piping materials specification, the test pressure shall be maintained for at least 30 minutes prior to starting examination. The test pressure shall continue to be maintained for sufficient time to permit examination of the system under test, but not less than 10 minutes.

1.7 ACCESSIBILITY FOR EXAMINATION - Piping to be tested shall not be insulated, covered, or enclosed until testing is completed.

1.8 PROCESS VESSELS IN TEST SYSTEM

1.8.1 General - When a process vessel is included in a test system (see 1.2.1), the test pressure shall not exceed the test pressure of the vessel for the test fluid used. When the piping system test pressure exceeds the vessel MAWP, the metal temperature of the vessel during test shall be not less than the minimum design temperature of the vessel plus 16.7C (30F). When the piping system test pressure is equal to or less than the vessel MAWP, the metal temperature of the vessel during test shall be not less than the minimum design temperature of the vessel.

1.8.2 Vessels Not Previously Tested - A vessel not previously tested in accordance with applicable Codes and Specifications to a pressure at least equal to the test pressure for the piping system shall not be included in the piping test system.

1.8.3 Consultation - For major projects, questions regarding the inclusion of process vessels in piping test systems shall be referred to the UCC Process Vessel Design Group. For plant work, such questions shall be referred to the appropriate Plant Engineering Group.

1.9 ROTATING EQUIPMENT IN TEST SYSTEM

1.9.1 Pumps - Pumps may be included in a piping test system provided the pump has been previously tested to a pressure at least equal to the test pressure for the piping system. The metal temperature of the pump during test shall be not less than the minimum design temperature of the pump plus 16.7C(30F). Special care shall be used to avoid overpressuring mechanical seals.

1.9.1.1 Consultation - For major projects, questions regarding the inclusion of pumps in piping test systems shall be referred to the UCC Equipment Engineering Group. For plant work, such questions shall be referred to the appropriate Plant Engineering Group.

1.9.2 Rotating Equipment Other Than Pumps - Rotating equipment other than pumps (e.g., compressors, turbines, blowers) shall not be included in a piping system test.

Fig 5

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TABLE 3

STRAINER SPECIFICATIONS

Valve & Piping Specification	1/2	3/4	1	1-1/4	1-1/2	2
1B2	CI-250-Scrd-SS-1/32 STR-344*					
1B3 1B4	CI-250-Scrd-SS-1/32 STR-344		CI-125-Flg-SS-1/32 STR-342			
1B5	CI-250-Scrd-SS-1/32 STR-344					
1C1	CS-600-Scrd-SS-1/32 STR-361					
1C2	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1C3	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1C4	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1C5	Use conical strainer					
1C6	CS-150-Flg-Alloy 20-1/32					
1C7	CS-600-SW-SS-1/32 STR-366					
1C8	CS-600-Scrd-SS-1/32 STR-361		CS-150-Flg-SS-1/32 STR-351			
1C9	CS-600-SW-SS-1/32 STR-366		CS-600-BW-SS-1/32 STR-370			
1C51	CS-600-SW-SS-1/32 STR-366					
1E1	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1E2	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1E3	CS-600-SW-SS-1/32 STR-366					
1E4	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1E5	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			
1E6	CS-600-Scrd-SS-1/32 STR-361		CS-600-SW-SS-1/32 STR-366			

*For steam service use CS-600-Scrd-SS-1/32:STR-361

Fig. 6

16.5.10.1

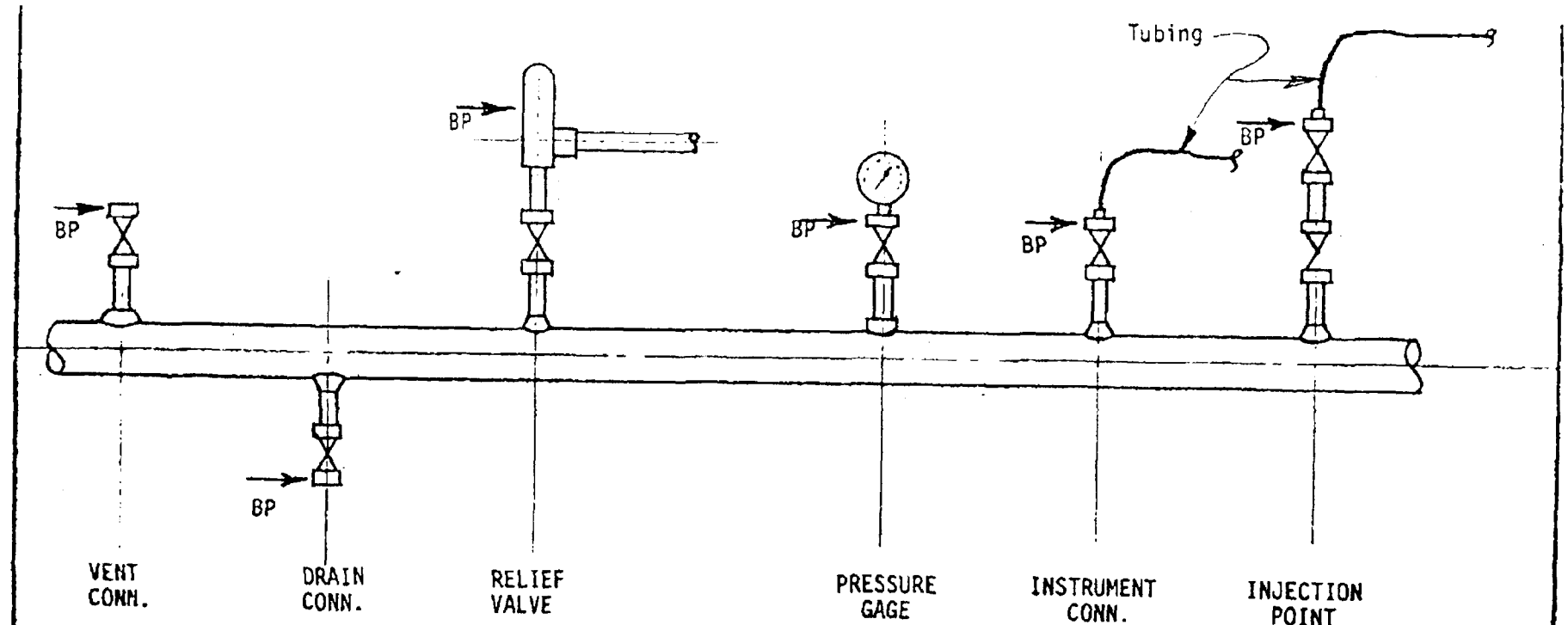
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UCC 021237



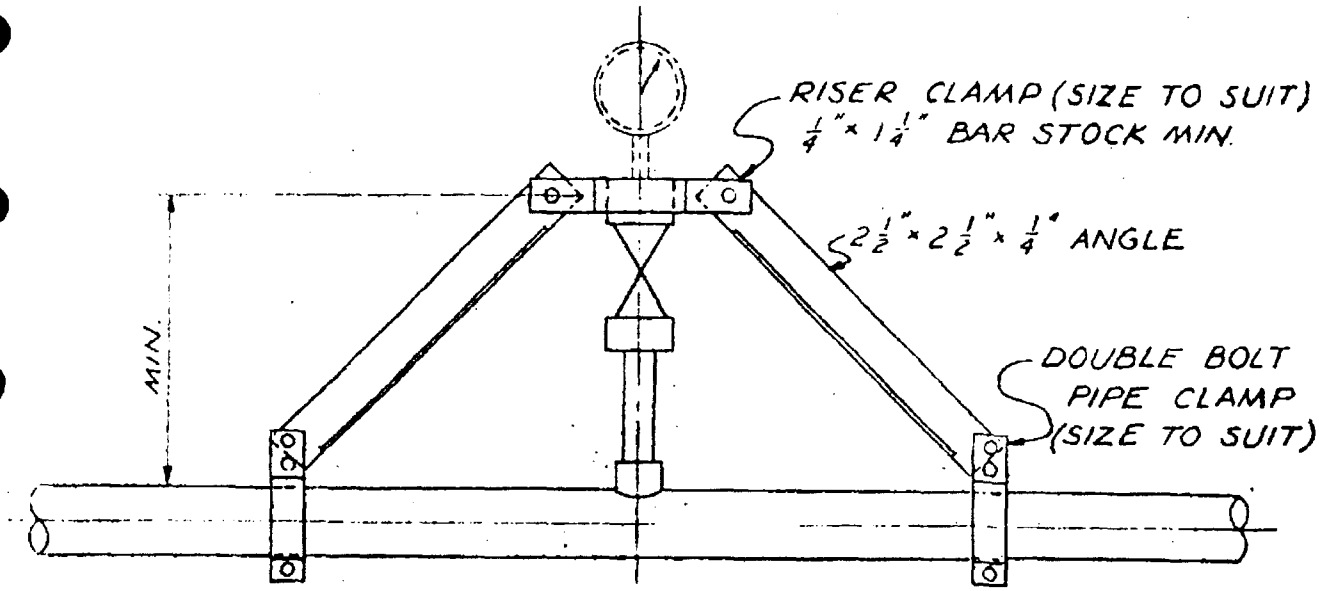
NOTE:
This sketch indicates brace points for typical existing connections, when bracing is required. Brace points are indicated by the symbol (BP→) There is no intent to show type of construction (scrd., welded, etc.) here, as different types exist. See Item 8 of the criteria for types of construction which require bracing. Sketches 2, 3, and 4 show bracing arrangements for the different types of connections. See Sketches 5 and 6 for the location of restriction orifices at pressure gage and instrument connections for the various types of construction.

BRACE POINTS FOR EXISTING CONNS. WHICH REQUIRE BRACING

SK-1

Fig. 7

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NOTES:

(1) ALL BOLTS SHALL BE ASTM A193, GR. B7 WITH ASTM A194, GR. 4 HEAVY NUTS. DOUBLE NUT ALL BOLTS.

(2) THIS SKETCH IS FOR BRACING ARRANGEMENT ONLY, CONNECTION CONSTRUCTION VARIES.

(3) SEE ITEM NO. 8 OF CRITERIA FOR BRACING REQUIREMENTS.

Fig. 8

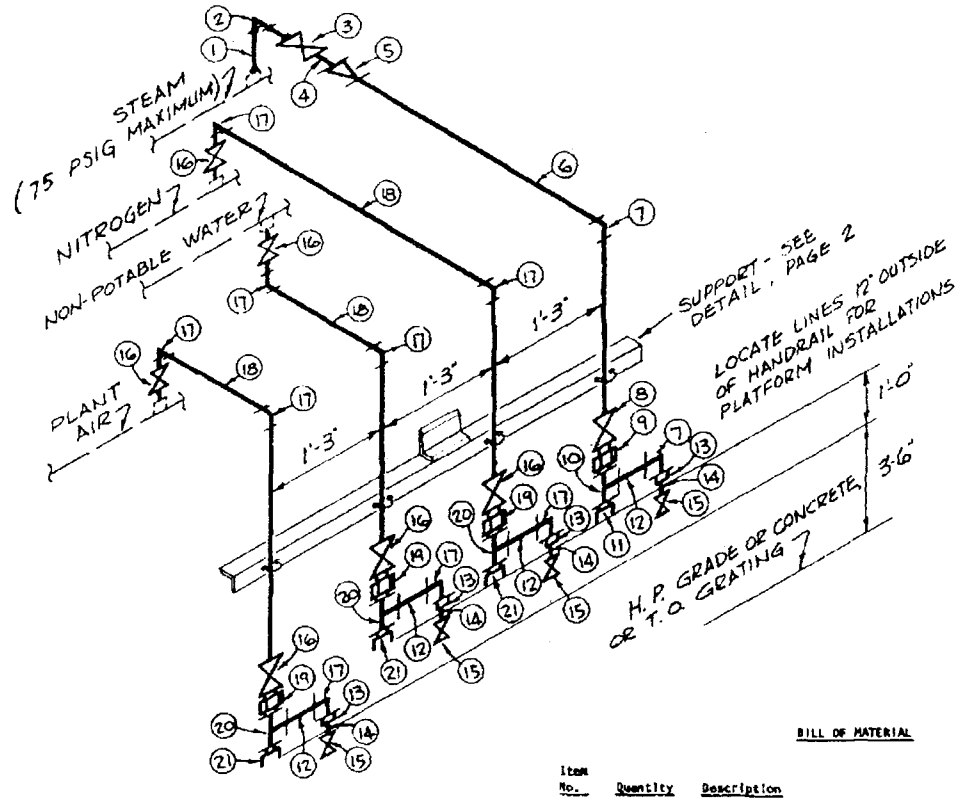
BRACING ARRANGEMENT FOR VENT, DRAIN, PRESSURE GAUGE, AND INSTRUMENT CONNECTIONS WHICH REQUIRE BRACING

SK-2

401

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UTILITY HOSE STATIONS



BILL OF MATERIAL

Item No.	Quantity	Description	Master Material Code Number
1	Varies	1" Pipe, Steel-40-Smls	1611-553-015
2	1 Pc.	1" Elbow, FS-3000-SW	2474-308-106
3	1 Pc.	1" GA-1424	2662-625-224
4	1 Pc.	1" x 3" Nipple, Steel-80-Smls, Black	2511-753-089
5	1 Pc.	1" x 3/4" Reducer, FS-3000-Scrd	2512-510-015
6	Varies	3/4" Pipe, Steel-40-Smls	1611-553-011
7	2 Pc.	3/4" Elbow, FS-2000-Scrd	2512-440-205
8	1 Pc.	3/4" GA-1422	2662-601-183
9	1 Pc.	3/4" Connector check valve, Check-all Mfg. Co. style CDN-075-SS-M-2, or approved equal	2756-808-181
10	1 Pc.	3/4" Tee, FS-2000-Scrd	2512-475-205
11	1 Pc.	3/4" Male spud for Dixon Boss X-34GJ coupling, or approved equal	2551-062-239
12	7 Pc.	3/4" x 3" Nipple, Steel-80-Smls, Blk.	2511-753-073
13	4 Pc.	3/4" x 3/8" Bushing, Steel	2512-722-009
14	4 Pc.	3/8" x Short Nipple, Steel-80-Smls, Blk.	2511-753-035
15	1 Pc.	3/8" GA-1422	(Later)
16	6 Pc.	1/4" BA-1173A	2624-050-182
17	9 Pc.	3/4" 90° Elbow, CI-125-Scrd	2511-313-005
18	Varies	3/4" Pipe, Steel-40-W	1611-502-011
19	3 Pc.	3/4" Connector check valve, Check-all Mfg. Co. Style CDN-075-C-B-2, or approved equal	2758-359-181
20	3 Pc.	3/4" Tee, CI-125-Scrd	2511-332-005
21	3 Pc.	3/4" Bronze male spud, Chicago Pneumatic Part Number C1512IY, or approved equal	2551-205-004

NOTES:

PIPING

Service lines shall follow sequence as shown (from left to right-air, water, nitrogen, steam). Each line shall be marked in accordance with Safety Standard (later) so it can be identified as to content.

The field shall route and adequately support the lines. There shall be no pockets in the steam line.

The lines shall be painted in accordance with the Project Painting Criteria.

The steam line shall be insulated in accordance with the insulation schedule.

The water line may require heat tracing and insulation at locations where there is a possibility of freezing. These requirements shall be covered by appropriate drawings and standards.

If it is necessary to install a trap before the shutoff valve on the steam line to prevent freezing, it shall be noted on the flow diagram and a piping detail drawing shall be made for the entire line.

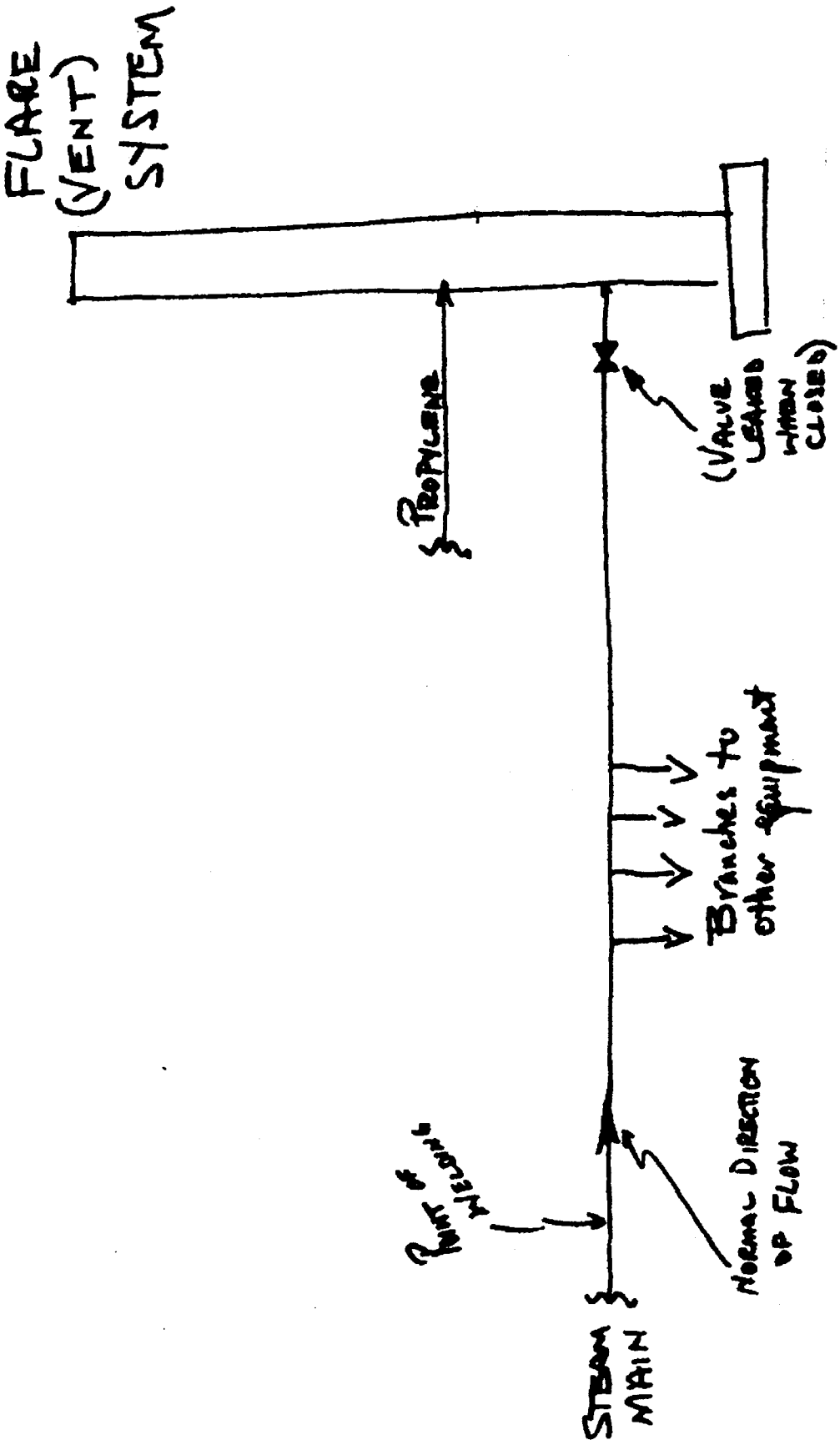
Unless otherwise indicated, all dimensions given in inches.

402

16.6.10.1

Fig. 9

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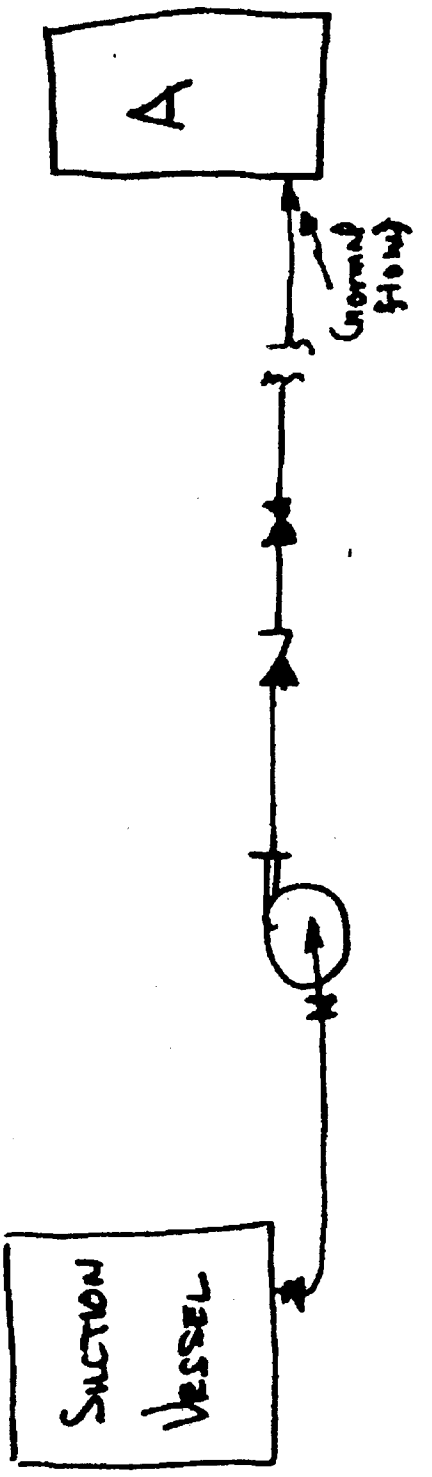


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UCC 021240

Fig. 11



.91 BOMS

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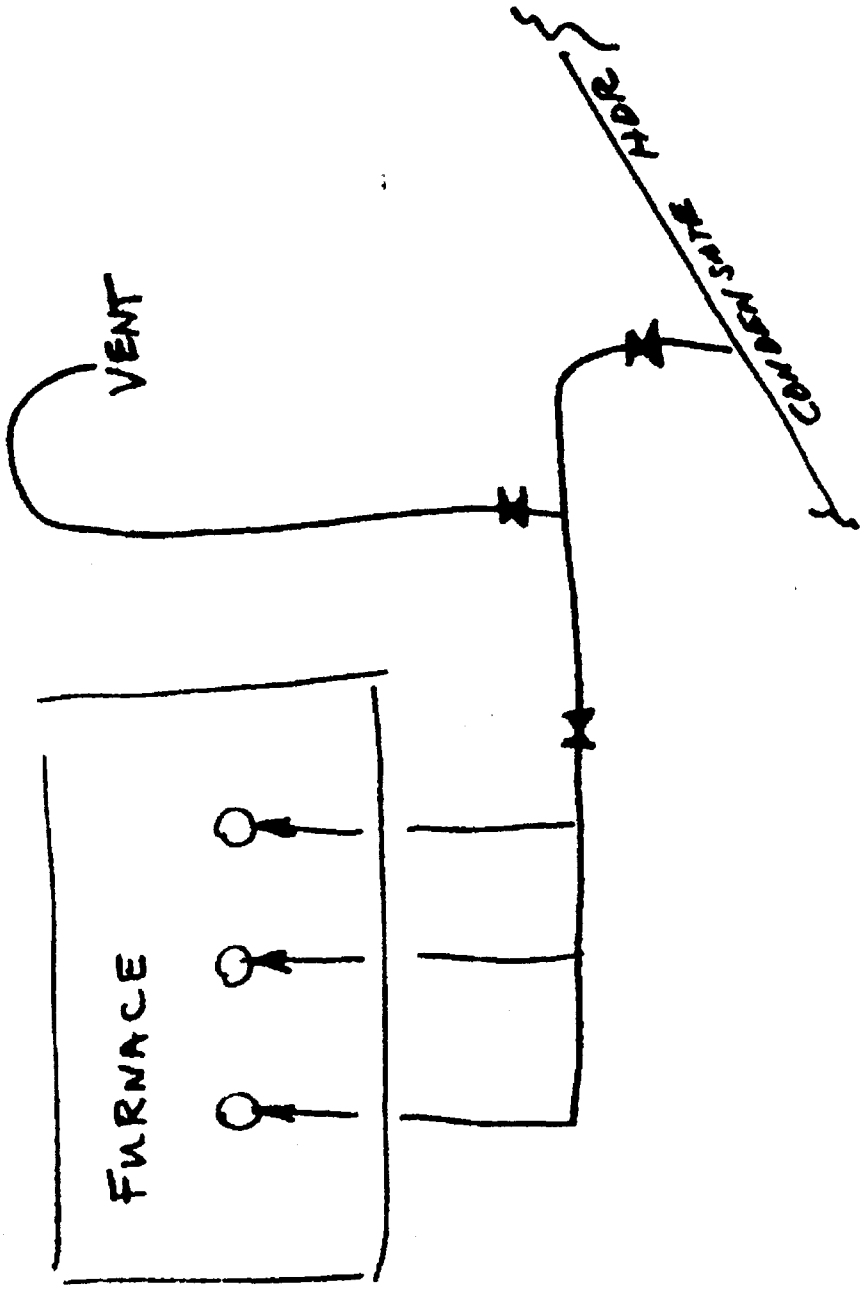


Fig. 12

4-1 70175

405

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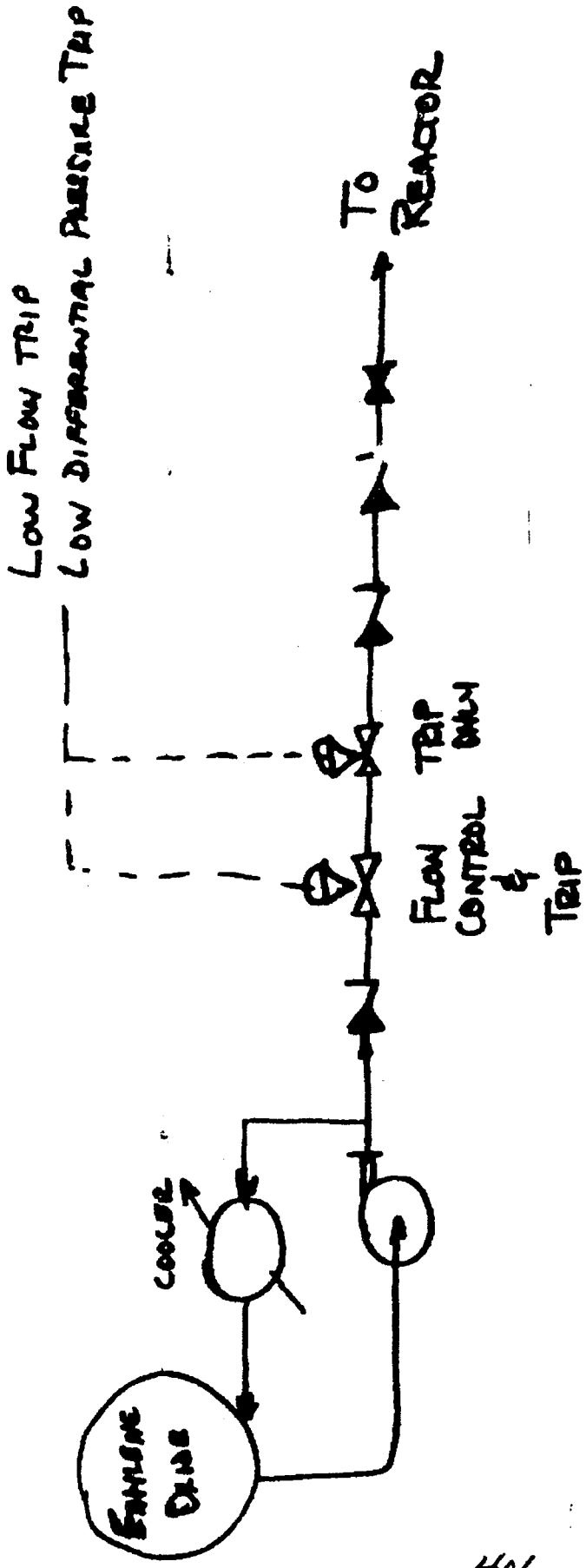


Fig. 13

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STANDARD SPECTACLE BLINDS, BLINDS, AND SPACERS

TABLE 1
BLIND AND SPACER DIMENSIONS

NPS	150-LB E	G	W	A	B	C	D	300-LB A	B	C	D	600-LB A	B	C	D	900-LB A	B	C	D	1500-LB A	B	C
1/2	1/2	7/16	1	1-3/4	3/4	2-3/8	4-1/4	2"	3/4	2-5/8	4-3/8	2"	5/8	2-5/8	4-3/8					2-3/8	1/2	3-1/4
3/4	1/2	7/16	1	2-1/8	7/8	2-3/4	4-1/2	2-1/8	7/8	3-1/4	4-7/8	2-1/2	3/4	3-1/4	4-7/8					2-5/8	5/8	3-1/2
1	1/2	7/16	1	2-1/2	1-1/8	3-1/8	4-5/8	2-3/4	1-1/8	3-1/2	5	2-3/4	1	3-1/2	5					3	1	4
1-1/2	1/2	7/16	1	3-1/4	1-5/8	3-7/8	5	3-5/8	1-5/8	4-1/2	5-5/8	3-5/8	1-1/2	4-1/2	5-5/8		SEE 1500-LB			3-3/4	1-5/8	4-7/8
2	1/2	7/16	1	4	2-1/8	4-3/4	5-1/2	4-1/4	2-1/8	5	6-3/4	4-1/4	2	5	6-3/4					5-1/2	2	6-1/2
2-1/2	1/2	7/16	1	4-3/4	2-5/8	5-1/2	6	5	2-5/8	5-7/8	6-1/4	5	2-1/2	5-7/8	6-1/4					6-3/8	2-3/8	7-1/2
3	1/2	7/16	1	5-1/4	3-1/8	6-1/4	6-1/2	5-3/4	3-1/8	6-5/8	6-5/8	5-3/4	3"	6-5/8	6-5/8	6-1/2	3	7-1/8	7-1/4	6-3/4	3	8
4	3/4	11/16	1-1/2	6-3/4	4-1/4	7-1/2	7	7	4-1/4	7-7/8	7-1/2	7	4	8-1/2	7-7/8	8	4	9-1/4	8-1/4	8-1/8	3-7/8	9-1/2
6	3/4	11/16	1-1/2	8-5/8	6-1/4	9-1/2	8	9-3/4	6-1/4	10-5/8	8-3/4	10-3/8	6	11-1/2	9-1/2	11-1/4	6	12-1/2	10	11	4-7/8	12-1/2
8	3/4	11/16	1-1/2	10-7/8	8-1/4	11-3/4	9-1/4	12	8-1/4	13	10	12-1/2	8	13-3/4	10-3/4	14	8	15-1/2	11-3/4	11-3/4	7-3/4	15-1/2
10	3/4	11/16	1-1/2	13-1/4	10-1/4	14-1/4	10-1/2	14-1/8	10-1/4	15-1/4	13-1/4	15-5/8	10	17	12-1/2	17	10	18-1/2	13-1/4	17	9-5/8	19
12	3/4	11/16	1-1/2	16	12-1/4	17	12	16-1/2	12-1/4	17-3/4	12-3/4	17-7/8	12	19-1/4	13-1/2	19-1/2	12	21	14-1/2	20-3/8	11-1/2	22-1/2
14	3/4	11/16	1-1/2	17-5/8	13-1/2	18-3/4	13	19	13-1/2	20-1/4	14	19-1/4	13-1/2	20-3/4	14-3/8							
16	3/4	11/16	1-1/2	20-1/8	15-1/2	21-1/4	14-1/4	21-1/8	15-1/2	22-1/2	15-1/4	22-1/8	15-1/2	23-5/8	15-1/2	23-3/4	16					
18	3/4	11/16	1-1/2	21-1/2	17-1/2	22-3/4	15	23-3/8	17-1/2	24-3/4	16-1/2	24	17-1/2	25-3/4	17-1/8							
20	3/4	11/16	1-1/2	23-3/4	19-1/2	25	16-1/4	25-5/8	19-1/2	27	17-3/4	26-3/4	19-1/2	28-1/2	18-1/2							
24	3/4	11/16	1-1/2	28-1/8	23-1/2	29-1/2	18-1/2	30-3/8	23-1/2	32	20-1/2	31	23-1/2	33	21							
30	3/4	11/16	1-1/2	34-5/8	29-1/2	36	21-7/8	37-3/8	29-1/2	39-1/4	24											
36	3/4	11/16	1-1/2	41-1/8	35-1/2	42-3/4	25-1/2	43-7/8	35-1/2	46	27-1/2											

NOTES
Blinds are designed in accordance with ANSI B31.3 using the formula
$t = d\sqrt{3/16\,(P/S) + A}$ wherein
t = blank thickness
d = inside dia of gasket (assumed to be OD of pipe)
P = internal design pressure
S = applicable allowable stress
A = allowance (assumed to be 0)

Blind thicknesses were determined on the following bases:
Table 2 - Allowable stress at 38C (100F) = 18,300 psi
Table 3 - Allowable stress at 38C (100F) = 20,000 psi
Table 4 - Allowable stress at 38C (100F) = 27,000 psi (90% of specified minimum yield strength)
Table 5 - Design P/S values for carbon steel blinds are .0150 for 150 lb flgs; .0393 for 300 lb; .0787 for 600 lb; .1181 for 900 lb; .1970 for 1500 lb.
Design P/S values for 304 SS and 316 SS blinds are .0138 for 150 lb flgs; .0360 for 300 lb; .0720 for 600 lb; .1080 for 900 lb; .1800 for 1500 lb.

Carbon steel blind material shall be ASTM A285 Gr C; ASTM A515 any grade, or ASTM A516, any grade.

Stainless steel blind material shall be ASTM A240 Type 304 or Type 316 as applicable.

Stamp all blinds with 1/4" (min) letters to show size, flange rating, material, thickness, and rating reference - for example
6" for 150 FLG
1/4" 316SS
PPM-10

TABLE 2
CARBON STEEL-PRESSURE RATINGS, PSI, AT 38C (100F) FOR PERMANENT INSTALLATION

Pipe Size	DISC THICKNESS, INCHES 1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-5/8	1-3/4	1-7/8	2
1/2	2138	8632														
3/4	1382	5528	12438													
1	881	3526	7923													
1-1/2	422	1689	3800	6755												
2	270	1081	2432	4323	6755											
2-1/2	184	738	1660	2950	4610	6638										
3	124	498	1120	1990	3110	4478	6098									
4	75	301	677	1204	1882	2709	3688	4817	6096							
6	34	139	312	556	868	1250	1701	2222	2812	3472	4201	5000	6868	6805		
8	20	82	184	328	512	738	1004	1311	1660	2049	2479	2951	3463	4016	4610	5245
10	13	53	119	211	329	474	646	844	1068	1318	1595	1898	2227	2583	2966	3374
12	9	37	84	150	234	337	459	600	759	937	1134	1350	1584	1837	2109	2399
14	7	31	70	124	194	279	380	496	628	776	938	1117	1311	1520	1745	1986
16	5	24	54	95	149	214	292	381	482	595	720	857	1006	1167	1339	1524
18	4	19	42	75	118	169	230	301	381	470	569	677	795	922	1058	1204
20	3	15	34	61	95	137	187	244	309	381	461	549	644	747	857	975
24	2	11	24	42	66	95	130	169	214	265	320	381	447	519	595	677
30		1	4	15	27	42	61	83	109	137	169	205	244	286	332	381	433
36		1		10	19	29	42	56	75	95	118	142	169	199	230	265	301

TEMPERATURE CORRECTION FACTORS FOR TABLE 2

Maximum Temperature °F	38	66	93	121	149	177	204	232	260	288	316	343	371	399
Multiplication Factor	1.00	1.00	1.00	1.00	0.99	0.97	0.94	0.91	0.88	0.85	0.81	0.79	0.76	

Multiply pressure rating at 100F in Table 2 by Multiplication Factor to determine pressure rating at elevated temperature.

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Fig. 14

16.6.10.1

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STANDARD
CHEMICALS/PLASTICS

TABLE 3
TYPE 304 & 31655 - PRESSURE RATINGS, PSI, AT 38C (100F) FOR PERMANENT INSTALLATION

Pipe Size	Disc Thickness, Inches 1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 9/16	1 5/8	1 11/16	1 3/4	1 13/16	1 7/8	2
1/2	2160	9440																													
3/4	1332	8240																													
1	853	3854	8572																												
1 1/2	401	1804	4134	7354																											
2	253	1142	2619	4726	7385																										
2 1/2	201	908	1814	3224	5018	7254																									
3	136	644	1224	2172	3400	4896	6664																								
4	82	369	749	1316	2057	2942	4031	5265	6664																						
6	38	172	342	607	940	1360	1860	2429	3075	3796	4593	5466	6415	7440																	
8	22	98	202	358	560	806	1098	1434	1814	2240	2710	3226	3786	4390	5040	5734															
10	14	58	118	210	330	469	644	844	1067	1441	1744	2075	2434	2822	3240	3689															
12	10	41	92	164	259	368	505	662	838	1025	1240	1476	1732	2009	2306	2624															
14	6	34	79	136	213	306	417	544	689	859	1029	1224	1417	1066	1913	2176															
16	6	26	59	104	163	234	319	417	527	651	787	937	1100	1276	1464	1666															
18	5	21	47	82	129	185	252	329	417	514	622	740	869	1008	1157	1316															
20	4	17	37	67	104	150	204	267	337	417	504	600	704	816	937	1066															
24	2	12	26	46	72	104	142	185	234	289	350	416	489	567	651	740															
30	1	7	16	30	46	67	91	118	150	185	224	266	312	363	416	474															
36	1	5	11	21	32	46	63	82	104	129	156	185	217	252	289	329															

TEMPERATURE CORRECTION FACTORS FOR TABLE 3

Maximum	°C	38	66	93	121	149	177	204	232	260	316	371	399																		
Temperature	°F	100	150	200	250	300	350	400	450	500	600	700	750																		
Multiplication Factor	316SS	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.94	0.90	0.87	0.82	0.80	0.78																	
	304SS	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.96	0.92	0.89	0.85	0.83	0.80																	

Multiply pressure rating at 100F (table 3 or 4) by Multiplication Factor to determine pressure rating at elevated temperature.

TABLE 5
THICKNESS FOR FLANGE-RATED BLINDS
BASED ON CARBON STEEL FLANGE RATINGS[1]

Pipe Size	CARBON STEEL BLIND FLANGE RATING, LB 150	300	600	900	1500	2500	304SS AND 316SS BLIND FLANGE RATING, LB 150	300	600	900	1500	2500
1/2	1/8	1/8	1/8	1/8	1/4	1/4	1/8	1/8	1/8	1/8	1/4	1/4
3/4	1/8	1/8	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/4	1/4
1	1/8	1/8	1/4	1/4	3/8	1/4	1/8	1/8	1/8	1/8	1/4	1/4
1-1/2	1/8	1/4	1/4	3/8	3/8	1/2	1/4	1/4	1/4	1/4	3/8	3/8
2	1/4	1/4	3/8	3/8	1/2	5/8	1/4	1/4	1/4	1/4	3/8	1/2
2-1/2	1/4	1/4	3/8	1/2	5/8	3/4	1/4	1/4	1/4	1/4	1/2	5/8
3	1/4	3/8	1/2	5/8	3/4	7/8	1/4	1/4	1/4	1/4	1/2	5/8
4	1/4	1/2	5/8	3/4	7/8	1	1/4	1/4	1/4	1/4	5/8	7/8
6	3/8	5/8	7/8	1	1-1/8	1-3/8	1/2	3/4	5/8	5/8	7/8	1
8	1/2	3/4	1	1-1/8	1-3/8	1-3/4	1/2	3/4	5/8	5/8	1	1-1/4
10	5/8	1	1-1/8	1-3/8	1-5/8	2-1/8	5/8	1	1	1	1-1/4	1-5/8
12	3/4	1-1/8	1-5/8	2	2-1/8	2-5/8	5/8	1	1	1	1-1/4	1-5/8
14	3/4	1-1/4	1-3/4	2-1/8	2-3/4	3-1/8	3/4	1-1/8	1-1/8	1-1/8	1-3/8	2
16	7/8	1-3/8	2	2-1/4	3	3-3/8	3/4	1-1/8	1-1/8	1-1/8	1-3/8	2
18	1	1-5/8	2-1/4	2-3/4	3-1/2	4	1	1-1/4	1-1/4	1-1/4	1-5/8	2-1/8
20	1-1/8	1-3/4	2-1/2	3	3-7/8	4-3/8	1-1/8	1-3/8	1-3/8	1-3/8	1-5/8	2-1/8
24	1-3/8	2-1/8	3	3-5/8	4-1/2	5-3/8	1-1/4	1-5/8	1-5/8	1-5/8	2	2-3/8
30	1-5/8	2-5/8	3-5/8	4-1/2	5-3/8	7	1-5/8	2	2	2	2-1/2	3-1/8
36	2	3-1/8	4-3/8	5-3/8	7		2-1/8	2-1/2	2-1/2	2-1/2	3	4-1/8

[1] Blinds are suitable for use with carbon steel, 30455, 31655, AK Steel, CON Steel, and FII flanges.

TABLE 4
CARBON STEEL, 30455, AND 31655 - PRESSURE RATINGS, PSI, AT 38C (100F) FOR HYDROSTATIC TEST[1]

Pipe Size	Disc Thickness, Inches 1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-5/8	1-3/4	1-7/8	2
1/2	3185	12740														
3/4	2018	8154														
1	1301	5202	11704													
1-1/2	743	2932	6606	9907												
2	397	1595	3588	6379												
2-1/2	272	1088	2448	4352	6800											
3	184	734	1652	2938	4590	6610										
4	111	444	999	1774	2775	3996	5439	7104								
6	51	204	461	820	1281	1844	2510	3279	4150	5123	6199					
8	30	121	272	484	756	1088	1481	1934	2448	3022	3657	4352	5107	5923	6800	
10	19	78	175	311	486	700	953	1245	1575	1945	2355	2801	3287	3812	4376	4979
12	13	55	124	221	346	499	678	885	1120	1383	1675	1992	2337	2710	3112	3540
14	11	46	103	184	287	413	562	734	929	1147	1388	1652	1939	2249	2581	2937
16	8	35	79	141	220	316	430	562	712	878	1063	1265	1484	1722	1976	2249
18	7	28	62	111	174	250	340	444	562	694	840	999	1173	1360	1562	1777
20	5	22	51	90	141	202	275	360	455	562	680	809	950	1102	1265	1439
24	4	15	35	62	98	141	191	250	316	390	472	562	665	765	878	999
30	2	9	22	39	62	90	122	160	202	250	302	360	422	490	562	640
36	1	6	15	27	43	62	85	111	141	174	210	250	293	340	390	444

(1) Do not use Table 4 ratings for pneumatic tests; use Table 2 or 3 ratings.

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Fig. 15

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INDEX - SUMMARY[1]

SERVICE	SPECIFICATIONS
Acetylene	1E12, 3E4
Additives Injection (LDPE)	6K2, 6L1
Air, Plant	1B2, 37B1
Instrument Distribution	6C4, 38C1
Instrument Tubing	See Instrumental Installation Manual
Ammonia, Annydrous	(See Chemicals, steel pipe below)
Boiler Blowoff	1E54, 1G52
Boiler Feed Water	(See Steam Below)
Brine (Calcium Chloride)	1B5
Carbon Dioxide-Oxygen-Water	
Mixture (Ethylene Oxide Process)	6E30
Catalyst Conveying (LPPE)	1C14, 1E23
Caustic Soda	1B3/1B4
Chemicals, general	
Aluminum pipe	4C1, 4C2
Copper pipe	5B3
Hastelloy B pipe	20C1
Hastelloy C pipe	21C1
Hastelloy C-276 pipe	22C1
Monel pipe	40C1, 40E1
Nickel pipe	41C1, 41E1
Steel pipe	1B2, 1C1, 1C2, 1E1, 1E2, 1E3, 1E4, 1E5, 1E6, 1G1, 1H1, 1K1
Titanium pipe	45C1
304 pipe	6C1, 6C2, 6E1. 6E4
304L pipe	7C1, 7C2, 7C3, 7C5, 7E1
316 pipe	8C1, 8C2, 8E1
316L pipe	9C1, 9C2, 9C3, 9C4, 9E1, 9E2
347 pipe	10C1, 10C2, 10E1
Polypropylene Lined Pipe	70C1
TFE Lined Pipe	72C1, 72E1
Chlorine, (dry)	
Gas	1C8
Liquid	1E13
Conveying (LDPE)	4A1, 4C3, 4C4
Cycle Gas (LPPE)	1E22
Dowtherm	1E7, 1E8
Duct	4A2, 6A1, 37A1
Ethylene Oxide	1C4, 1E16, 6C5, 6E2
Ethylene Return Gas (LDPE)	1L1, 8L1, 30L1
Ethylene Suction (LDPE)	2K2, 6K3, 6L2
Feeder Tube (LPPE)	6G3
Hydraulic Oil	1C7, 1E14, 1G2, 1K2, 1K3
Hydrogen, gas	(See Hydrocarbon below)
Hydrogen (LPPE)	1G4, 1K6

[1]See INDEX - SPECIFICATION DESCRIPTION for additional information.

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Hydrocarbon, liquid and gas	
Normal Service:	
0C to 399C (32F to 750F)	1C2, 1E1, 1E2, 1E3, 1G1, 1H1, 1K1
-45C to 204C (-50F to 400F)	1C3, 2C1, 2E1, 2E2, 2E3, 2G1, 2H1, 2K1
-101C to 204C (-150F to 400F)	3C1, 3E1, 3E2, 3E3, 3G1, 3H1, 3K1, 6C51, 6E52, 6E53
Pulsating Service:	
0C to 399C (32F to 750F)	1C11, 1E18, 1G3, 1H2, 1K4, 1L2
-45C to 204C (-50F to 400F)	6K3
-101C to 204C (-150F to 400F)	6L2
Lime	1B3
Low Density Polyethylene	31M1, 31M2
Lube and Seal Oil	1C9, 1E15, 6C6, 6E3
Molten Polymer	1K5, 1L3, 6K4, 6L3
Multiproduct Transfer (pigged)	
Steel	1C10
304L	7C4
Nitrogen	1B2
Nitrogen, High Purity (LPPE)	1C13, 1E21
Oil Mist	37B1
Oxygen	1C5, 1E10
Phosgene	1E13
Potassium Carbonate	1E17
Refrigerant	5B2, 5E1
Sodium Silicate	1B3
Steam and Boiler Feed Water	
In Power House - with ASME Code Stamp	1C51, 1E52, 1E53, 1G51, 1H51, 30H51
- without ASME Code Stamp	1C51A, 1E52A, 1E53A, 1G51A, 1H51A, 30H51A
Other	1B2, 1C1, 1C2, 1C51B, 1E1, 1E2, 1E3, 1E52B, 1E53B, 1G1, 1G51B, 1H51B, 30H51B
Sulphuric Acid	6C3
Water	
Potable - above ground	5B1, 12B1, 37B1
- underground	See Piping Technology - Underground Manual
Non-potable - above ground	1B2, 37B1
- underground	See Piping Technology - Underground Manual

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INDEX - SPECIFICATION DESCRIPTION[1]

SPEC	REMARKS
ACETYLENE	
1E12	Specifically for acetylene service from 0C to 52C
3E4	Specifically for acetylene service from -65C to 0C
ADDITIVES INJECTION (LDPE)	
6K2	Specifically for additive injection service at 3000 psi in LDPE Units
6L1	Specifically for additive injection service at 5000 psi in LDPE Units
AIR	
Plant	
1B2	Basic specification for plant air
37B1	Use for plant air when all-galvanized system is desired
Instrument Distribution	
6C4	Type 304SS
38C1	Screwed red brass
AMMONIA, ANHYDROUS	
(See Chemicals, steel pipe)	
BOILER BLOWOFF	
1E54	Specifically for Boiler Blowoff piping ASME Code stamped. See Note A1, Specifications 1E54
1E54A	Same as 1E54 except piping per ANSI B31.1.0. See Note A2, Specification 1E54
1G52	Similar to 1E54, but higher pressure rating. Piping to be ASME Code stamped. See Note A1, Specification 1G52
1G52A	Same as 1G52 except per ANSI B31.1.0. See Note A2, Specification 1G52.
BOILER FEEDWATER	
(See Steam)	
BRINE (CALCIUM CHLORIDE)	
1B5	Specifically for inhibited calcium chloride brine (from -29C to 179C)
CARBON DIOXIDE-OXYGEN-WATER MIXTURE	
6E30	Specifically for carbon dioxide-oxygen-water mixture in Ethylene Oxide process only
CATALYST CONVEYING (LPPE)	
1C14	Specifically for catalyst conveying service in LPPE units (Class 150 flanges)
1E23	Same as 1C14 except Class 300 flanges
CAUSTIC SODA	
1B3	Carbon steel for caustic soda not requiring stress relief. See Page 2, Specification 1B3/1B4.
1B4	Same as 1B3 except stress relief required. See Page 2, Specification 1B3/1B4
CHEMICALS, GENERAL	
Aluminum Pipe	
4C1	Basic aluminum specification with 150 lb. flanges
4C2	Similar to 4C1, but higher pressure rating
Copper Pipe	
5B3	Basic copper specification with 150 lb flanges

[1] See INDEX - SUMMARY for concise listing of specifications.

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INDEX - SPECIFICATION DESCRIPTION[1]

SPEC	REMARKS
CHEMICALS, GENERAL - Continued	
Hastelloy B Pipe	
20C1	Basic Hastelloy B specification with 150 lb flanges. (Use 20C1A for vacuum service.)
20C1A	Same as 20C1 except alloy steel bolting. For vacuum service.
Hastelloy C Pipe	
21C1	Basic Hastelloy C specification with 150 lb flanges. (Use 21C1A for vacuum service.)
21C1A	Same as 21C1 except alloy steel bolting. For vacuum service.
Hastelloy C-276 Pipe	
22C1	Basic Hastelloy C-276 specification with 150 lb flanges. (Use 22C1A for vacuum service.)
22C1A	Same as 22C1 except alloy steel bolting. For vacuum service.
Monel Pipe	
40C1	Basic Monel specification with 150 lb flanges. Compressed asbestos gasket.
40C1A	Same as 40C1 except alloy steel bolting and spiralwound Monel/Teflon gasket.
40E1	Basic Monel specification with 300 lb flanges. Compressed asbestos gasket.
40E1A	Same as 40E1 except spiralwound Monel//Teflon gasket.
Nickel Pipe	
41C1	Basic specification for nickel with 150 lb flanges. (Use 41C1A for vacuum service.)
41C1A	Same as 41C1 except alloy steel bolting and spiralwound Inconel/Teflon gasket.
41E1	Basic specification for nickel with 300 lb flanges.
41E1A	Same as 41E1 except alloy steel bolting and spiralwound Inconel/Teflon gasket.
Steel Pipe	
1B2	Use only for non-flammable, non-toxic fluids. Cast iron flanges, valves, and fittings. Threaded thru 2-1/2".
1C1	Lowest cost steel specification with 150 lb flanges for chemical service. Threaded thru 2". See 1C2. (Use 1C1A for vacuum service.)
1C1A	Same as 1C1 except alloy steel bolting. For vacuum service.
1C2	Similar to 1C1 except threaded thru 3/4". Basic specification for chemical service for which 1C1 is unsuitable (because of threaded thru 2"). Compressed asbestos gasket. (Use 1C2A for vacuum service.)
1C2A	Same as 1C2 except alloy steel bolting. For vacuum service.
1C2B	Same as 1C2 except alloy steel bolting and spiralwound SS/asbestos gaskets.
1E1	Basic steel specification with 300 lb flanges for chemical and hydrocarbon service. Compressed asbestos gaskets.
1E1A	Same as 1E1 except spiralwound SS/asbestos gaskets.
1E2	Similar to 1E1, but thicker pipe and fittings and higher pressure ratings. Compressed asbestos gaskets.
1E2A	Same as 1E2 except spiralwound SS/asbestos gaskets.
1E3	Similar to 1E1 and 1E2, but thickest pipe and fittings and highest pressure ratings. Spiralwound SS/asbestos gaskets.
1E4	Essentially same as 1E1 except Teflon valve packing and spiralwound SS/Teflon gaskets.
1E5	Similar to 1E4, but thicker pipe and fittings and higher pressure rating.
1E6	Similar to 1E4 and 1E5, but thickest pipe and fittings and highest pressure ratings.
1G1	Basic steel specification with 600 lb flanges.
1G1A	Same as 1G1 except thread dope for high temperature (over 260C).
1H1	Basic steel specification with 1500 lb flanges.
1H1A	Same as 1H1 except thread dope for high temperature (over 260C).
1K1	Basic steel specification with 1500 lb flanges
1K1A	Same as 1K1 except thread dope for high temperature (over 260C).

[1] See INDEX - SUMMARY for concise listing of specifications.

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INDEX - SPECIFICATION DESCRIPTION[1]

SPEC	REMARKS
CHEMICALS, GENERAL - Continued	
Titanium Pipe	
45C1	Basic Titanium specification with 150 lb flanges.
Type 304 SS Pipe	
6C1	Basic 304SS specification with 150 lb flanges. (Use 6C1A for vacuum service.)
6C1A	Same as 6C1 except alloy steel bolting. For vacuum service.
6C2	Essentially same as 6C1 except reinforced branch connections and higher pressure ratings. (Use 6C2A for vacuum service.)
6C2A	Same as 6C2 except alloy steel bolting. For vacuum service.
6E1	Basic 304SS specification with 300 lb flanges.
6E4	Similar to 6E1, but thicker pipe and fittings and higher pressure ratings. Teflon gaskets.
Type 304L SS Pipe	
7C1	Basic 304L SS specification with 150 lb flanges. (Use 7C1A for vacuum service.)
7C1A	Same as 7C1 except alloy steel bolting. For vacuum service.
7C2	Essentially same as 7C1 except reinforced branch connections and higher pressure ratings. (Use 7C2A for vacuum service.)
7C3	Similar to 7C1, but .021" corrosion allowance.
7C3A	Same as 7C3 except alloy steel bolting. For vacuum service.
7C5	Similar to 7C2A except spiralwound 304L with Teflon flange gaskets and Teflon valve bonnet gaskets.
7E1	Basic 304L SS specification with 300 lb flanges.
Type 316 SS Pipe	
8C1	Basic 316SS specification with 150 lb flanges. (Use 8C1A for vacuum service.)
8C1A	Same as 8C1 except alloy steel bolting. For vacuum service.
8C2	Essentially same as 8C1 except reinforced branch connections and higher pressure ratings. (Use 8C2A for vacuum service.)
8C2A	Same as 8C2 except alloy steel bolting. For vacuum service.
8E1	Basic 316SS specification with 300 lb flanges.
Type 316L SS Pipe	
9C1	Basic 316L SS specification with 150 lb flanges. (Use 9C1A for vacuum service.)
9C1A	Same as 9C1 except alloy steel bolting. For vacuum service.
9C2	Essentially same as 9C1 except reinforced branch connections and higher pressure ratings. (Use 9C2A for vacuum service.)
9C2A	Same as 9C2 except alloy steel bolting. For vacuum service.
9C3	Similar to 9C1, but .021" corrosion allowance.
9C3A	Same as 9C3 except alloy steel bolting. For vacuum service.
9C4	Similar to 9C2A except spiralwound 316L with Teflon flange gaskets and Teflon valve bonnet gaskets.
9E1	Basic 316L SS specification with 300 lb flanges.
9E2	Similar to 9E1 except spiralwound 316 with Teflon gaskets, valves with Teflon gaskets.
9E2A	Same as 9E2 except coating bolting.
Type 347 SS Pipe	
10C1	Basic 347SS specification with 150 lb flanges. (Use 10C1A for vacuum service.)
10C1A	Same as 10C1 except alloy steel bolting. For vacuum service.
10C2	Essentially same as 10C1 except reinforced branch connections and higher pressure ratings. (Use 10C2A for vacuum.)
10C2A	Same as 10C2 except alloy steel bolting. For vacuum service.
10E1	Basic 347SS specification with 300 lb flanges.

[1] See INDEX - SUMMARY for concise listing of specifications.

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INDEX - SPECIFICATION DESCRIPTION[1]

SPEC	REMARKS
CHEMICALS, GENERAL - Continued	
Polypropylene Lined Pipe	
70C1	Basic specification for polypropylene lined CS pipe, 150 lb flanges, machine bolts.
70C1A	Same as 70C1 except coated machine bolts.
70C1B	Same as 70C1 except black stud bolts.
70C1C	Same as 70C1 except coated black stud bolts.
TFE Lined Pipe	
72C1	Basic specification for TFE lined CS pipe, 150 lb flanges, black machine bolts.
72C1A	Same as 72C1 except coated black machine bolts.
72C1B	Same as 72C1 except black stud bolts.
72C1C	Same as 72C1 except coated black stud bolts.
72E1	Basic specification for TFE lined CS pipe, 300 lb flanges, alloy stud bolts.
72E1A	Same as 72E1 except coated alloy stud bolts.
CHLORINE (DRY)	
1CB	Specifically for dry chlorine gas.
Liquid	
1E13	Specifically for dry chlorine liquid (and phosgene).
CONVEYING (LDPE)	
4A1	Specifically for conveyor piping - Morris Couplings.
4C3	Specifically for conveyor piping - Victaulic Couplings.
4C4	Similar to 4C3, but heavier elbows to permit scoring.
CYCLE GAS (LPPE)	
1E22	Specifically for cycle gas service in LPPE units.
DOWTHERM	
1E7	Specifically for Dowtherm.
1E8	Specifically for Dowtherm requiring higher pressure ratings than 1E7.
DUCT	
4A2	Basic aluminum specification for low pressure ductwork.
6A1	Basic stainless steel specification for low pressure ductwork.
37A1	Basic galvanized steel specification for low pressure ductwork.
ETHYLENE OXIDE	
1C4	Specifically for ethylene oxide.
1E16	Specifically for ethylene oxide requiring higher pressure rating than 1C4.
6C5	Specifically for ethylene oxide.
6E2	Specifically for ethylene oxide requiring higher pressure rating than 6C5.
ETHYLENE RETURN GAS (LDPE)	
1L1	Carbon steel specifically for ethylene return gas to 750F.
8L1	316SS specifically for ethylene return gas to 800F.
30L1	1-1/4 chrome - 1/2 moly specifically for ethylene return gas to 1000F.
ETHYLENE SUCTION (LDPE)	
2K2	AK steel specifically for ethylene suction; 3000 psi nominal.
6K3	304SS specifically for ethylene suction; 3000 psi nominal.
6L2	304SS specifically for ethylene suction; 5000 psi nominal.

[1]See INDEX - SUMMARY for concise listing of specifications.

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FEEDER TUBE (LPPE)	
6G3	Specifically for feeder tube service in LPPE units.
HYDRAULIC OIL	
1C7	Specifically for hydraulic oil.
1E14	Specifically for hydraulic oil.
1G2	Specifically for hydraulic oil.
1K2	Specifically for hydraulic oil. ANSI 1500 lb. flanged.
1K3	Specifically for hydraulic oil. Grayloc construction.
HYDROGEN, GAS	
(See Hydrocarbon Below)	
HYDROGEN (LPPE)	
1G4	Specifically for hydrogen service in LPPE units (class 600 flanges).
1K6	Same as 1G4 except class 1500 flanges.
HYDROCARBON, LIQUID AND GAS	
0C to 204C (32F to 400F)	
Normal Service	
1C2	Basic specification with 150 lb. flanges for hydrocarbon service. Compressed asbestos gaskets. (Use 1C2A for vacuum service.)
1C2A	Same as 1C2 except alloy steel bolting. For vacuum service.
1C2B	Same as 1C2 except alloy steel bolting and spiralwound SS/asbestos gasket.
Normal Service	
1E1	Basic specification with 300 lb. flanges for hydrocarbon service. Compressed asbestos gasket.
1E1A	Same as 1E1 except spiralwound SS/asbestos gaskets.
1E2	Similar to 1E1, but thicker pipe and fittings and higher pressure ratings. Compressed asbestos gaskets.
1E2A	Same as 1E2 except spiralwound SS/asbestos gaskets.
1E3	Similar to 1E1 and 1E2 but thickest pipe and fittings and highest pressure ratings. Spiralwound SS/asbestos gaskets.
1E3A	Same as 1E3 except thread dope for high temperature (over 260C).
1G1	Basic specification with 600 lb. flanges for hydrocarbon service.
1H1	Basic specification with 900 lb. flanges for hydrocarbon service (1500 lb. flanges thru 2-1/2").
1K1	Basic specification with 1500 lb. flanges for hydrocarbon service.
-45C to 204C (-50F to 400F)	
1C3	Carbon steel specification for Hydrocarbon vapor (not liquid). Special limit on axial stress.
2C1	Basic AK steel specification with 150 lb. flanges.
2E1	Obsolete; do not use (for reference only).
2E2	Basic AK steel specification with 300 lb. flanges.
2E3	Similar to 2E2, but thicker pipe and fittings and higher pressure ratings.
2G1	Basic AK steel specification with 600 lb. flanges.
2H1	Basic AK steel specification with 900 lb. flanges (1500 lb. flanges thru 2-1/2").
2K1	Basic AK steel specification with 1500 lb. flanges.

[1] See INDEX - SUMMARY for concise listing of specifications.

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SPEC	REMARKS
HYDROCARBON, LIQUID AND GAS (Cont'd)	
-101C to 204C (-150F to 400F)	
3C1	Basic CCN steel specification with 150 lb. flanges.
3E1	Obsolete; do not use (for reference only).
3E2	Basic CCN steel specification with 300 lb. flanges.
3E3	Similar to 3E2, but thicker pipe and fittings and higher pressure rating.
3G1	Basic CCN steel specification with 600 lb. flanges.
3H1	Basic CCN steel specification with 900 lb. flanges (1500 lb. flanges thru 2-1/2").
3K1	Basic CCN steel specification with 1500 lb. flanges.
6C51	Basic SS specification with 150 lb. flanges for low temperature. Intended especially for use in plant work where less-than-mill-order quantities make the use of CCN impracticable. Also useful for small new construction projects.
6E52	Basic SS specification with 300 lb. flanges for low temperature. Intended use same as 6C51.
6E53	Similar to 6E52, but thicker pipe and fittings and higher pressure ratings.
0C to 399C (32F to 750F)	
Pulsating Service	
1C11	Basic specification with 150 lb. flanges for hydrocarbon service. Special construction requirements.
1E18	Basic specification with 300 lb. flanges for hydrocarbon service. Special construction requirements.
1G3	Basic specification with 600 lb. flanges for hydrocarbon service. Special construction requirements.
1H2	Basic specification with 900 lb. flanges for hydrocarbon service. Special construction requirements.
1K4	Basic specification with 1500 lb. flanges for hydrocarbon service. Special construction requirements.
1L2	Basic specification with 2500 lb. flanges for hydrocarbon service. Special construction requirements.
6L2	Basic 304SS specification with 2500 lb. flanges. Special construction requirements.
LIME	
1B3	Basic specification for lime.
LOW DENSITY POLYETHYLENE	
31M1	Discharge tubing.
31M2	Reactor tubing.
LUBE AND SEAL OIL	
1C9	Specifically for return piping. Special fabrication and cleaning requirements.
1E15	Specifically for return piping requiring higher pressure rating than 1C9. Special fabrication and cleaning requirements.
6C6	Specifically for supply piping. Special fabrication and cleaning requirements.
6L3	Specifically for supply piping requiring higher pressure rating than 6C6. Special fabrication and cleaning requirements.
MOLTEN POLYMER	
1K5	Basic specification for molten polymer, CS pipe, 1500 lb flanges.
1K5A	Same as 1K5 except coated alloy steel stud bolts.
1L3	Similar to 1K5 except 2500 lb flanges.
1L3A	Same as 1L3 except coated alloy steel stud bolts.
6K4	Basic specification using 304SS piping, 1500 lb flanges.
6K4A	Same as GK4 except coated bolting.
6L3	Similar to 6K4 except 2500 lb flanges.
6L3A	Same as 6L3 except coated bolting.

[1] See INDEX - SUMMARY for concise listing of specifications.

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SPEC	REMARKS
MULTIPRODUCT TRANSFER	
1C10	Basic specification for "pigged" lines. Special construction requirements.
7C4	Basic 304LSS specification for "pigged" lines. Special construction requirements.
NITROGEN	
1B2	Basic specification for nitrogen.
NITROGEN, HIGH-PURITY (LPPE)	
1C13	Specifically for high-purity nitrogen service in LPPE units (class 150 flanges).
1E21	Same as 1C13 except class 300 flanges.
OIL MIST	
37B1	Basic specification for oil mist lubrication lines.
OXYGEN	
1C5	Specifically for oxygen. Special testing and cleaning requirements.
1E10	Specifically for oxygen. Special testing and cleaning requirements.
PHOSGENE	
1E13	Specifically for phosgene (and dry chlorine liquid).
POTASSIUM CARBONATE	
1E17	Specifically for potassium carbonate.
REFRIGERANT	
5B2	Specifically for refrigerant (150 lb. flanges). Complies with ANSI B31.5, Refrigerant Piping Systems.
5E7	Similar to 5B2 except with 300 lb. flanges.
SODIUM SILICATE	
1B3	Basic specification for sodium silicate.
STEAM AND BOILER FEEDWATER	
In Power House with ASME Code Stamp (.065" Corrosion Allowance)	
1C51	Specifically for steam and boiler feedwater. See Note A1, Specification 1C51.
1E52	Specifically for steam and boiler feedwater requiring higher pressure ratings than 1C51. See Note A1, Specification 1E52.
1E53	Specifically for steam and boiler feedwater requiring higher pressure ratings than 1E52. See Note A1, Specification 1E53.
1G51	Specifically for steam and boiler feedwater requiring higher pressure ratings than 1E53. See Note A1, Specification 1G51.
1H51	Specifically for steam and boiler feedwater requiring higher pressure ratings than 1G51. See Note A1, Specification 1H51.
30H51	Specifically for steam and boiler feedwater requiring higher pressure and temperature ratings than 1H51. See Note A1, Specification 30H51.
In Power House Without ASME Code Stamp (.065" Corrosion Allowance)	
1C51A 1E52A 1E53A 1G51A 1H51A 30H51A	Same as same specification without suffix "A" except piping complies with ANSI B31.1.1.0, Power Piping Code. See Note A2 of each specification.

[1] See INDEX - SUMMARY for concise listing of specifications.

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INDEX - SPECIFICATION DESCRIPTION[1]

SPEC	REMARKS
STEAM AND BOILER FEEDWATER (Cont'd)	
Main Distribution Lines Outside Steam Plant (.065" Corrosion Allowance)	
1C51B	
1E52B	Same as same specification without suffix "B" except piping complies with ANSI B31.3, Petroleum Refinery Piping Code.
1E53B	
1G51B	See Note A3 of each specification.
1H51B	
3CH51B	
From Main Distribution Lines to Units, and Inside Units (.030" Corrosion Allowance)	
1B2	Basic specification for low-pressure steam thru 16". CI flanges, valves, and fittings.
1C1A	Basic specification with 150 lb. flanges and alloy steel bolting for steam. Threaded thru 2". Compressed asbestos gaskets.
1C2A	Similar to 1C1A except threaded thru 3/4". Compressed asbestos gasket.
1C2B	Similar to 1C2A except spiralwound SS/asbestos gaskets.
1E1A	Basic specification with 300 lb. flanges and spiralwound SS/asbestos gaskets for steam service.
1E2A	Similar to 1E1A but thicker pipe and fitting and higher pressure ratings.
1E3A	Similar to 1E1A and 1E2A but thickest pipe and fittings and highest pressure ratings.
1G1A	Basic specification with 600 lb. flanges and spiralwound SS/asbestos gaskets for steam service.
SULFURIC ACID	
6C3	Specifically for 92% or greater sulfuric acid.
WATER	
Potable - Above Ground	
5B1	Specifically for potable water above ground. Soldered copper.
12B1	Same as 5B1 except tubing Titanium modified chromium stainless steel.
37B1	Basic galvanized steel specification for potable water above ground.
Potable - Underground	
	See Piping Technology - Underground Manual.
Non-Potable - Above Ground	
1B2	Basic steel specification for non-potable water above ground.
37B1	Basic galvanized steel specification for non-potable water above ground.
Non-Potable - Underground	
	See Piping Technology - Underground Manual.

[1] See INDEX - SUMMARY for concise listing of specification.

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PIPING DESIGN

700 GENERAL

700.1 SCOPE

PPF-7 covers detailed design of all piping except instrument piping, heating and air conditioning piping, plumbing, and sewers. The conceptual design (see 700.2) for the unit contains general concepts to be followed in this detailed design.

700.2 CONCEPTUAL DESIGN

700.2.1 Design Reports - Conceptual design is usually issued in Design Reports prepared by one or more of the following UCC groups:

Process
Utilities
Plant Layout and General Facilities
Process Safety and Fire Protection
Pollution Control Engineering

Design Reports are covered in Section 5 of the Chemical and Plastics Engineering Department's PROJECT PROCEDURES MANUAL. The following articles in Section 5 are of special interest from the standpoint of piping design:

5.1.3 Equipment List
5.1.4 Minor equipment Schedules
5.1.5 Line List
5.1.7 Control System Specifications
5.1.8 Special Valve and Piping Specifications
5.1.10 Flow Diagrams (Preparation)
5.3.1 Flow Diagrams (Naming and Numbering)
5.3.3 Control Systems Loop Diagrams
5.3.5 Piping (Naming and Numbering)

700.2.2 Piping Design Covered - The group(s) responsible for preparing Design Reports for a project provide the following items (see 5.1.10 of the UCC PROJECT PROCEDURES MANUAL for a more complete listing):

(a) Flow diagram showing: major equipment; all piping; all valves; control systems including control valves and orifice runs; pressure and vacuum relieving equipment (see 700.2.5); minor equipment such as indicating thermometers, pressure gages, spray nozzles, steam traps, strainers, filters, suction screens, local flow indicators, etc.

(b) Size of each line.

(c) Valve and piping specification for each line (see 700.2.3).

(d) Line numbers

(e) Origin and destination of each line and direction of flow.

(f) Size of each valve

(g) Specifications, including valve type, for each valve (see 700.2.3). Pressure class is noted, *if different from Valve and Piping Specifications.*

(h) Designation of piping to be underground.

(i) Requirements for heat tracing including whether steam, electric, or hot water.

(j) Piping to be insulated and the temperature for which it is to be insulated (or that it is to be insulated for safety only).

(k) Piping to be bonded and grounded.

(l) Piping to be cathodically protected.

(m) Special information regarding detailed piping design.

(n) Preliminary unit layout and general arrangement drawings. (See 700.2.4)

(o) Minor equipment purchase specifications for: thermometers, pressure gages, spray nozzles, steam traps, strainers, filters, etc.

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700.2.3 Valve and Piping Specifications - UCC General Piping Specifications and UCC Valve and Piping Material Specifications are used. See 100.2 and 100.3 of PPF-1 for a description of these specifications and their use.

700.2.4 Preliminary Layout Drawings - The UCC group responsible for layout for the project prepares preliminary layout and general arrangement drawings as part of the conceptual design. These drawings are prepared by the General Facilities and Layout Group, the Process Group, or Design Engineering. They may be issued in Design Reports or separately. Preliminary drawings show set-back and over-all dimensions, but are conceptual regarding individual equipment location. Minor adjustments in layout may be made, but major changes must have the prior approval of the group responsible for layout.

700.2.5 Pressure and Vacuum Relieving Equipment - Fire exposure and all abnormal process and mechanical conditions are considered when selecting pressure and vacuum relieving equipment. Required capacity for pressure and vacuum relief is determined in accordance with Section 9 of the UCC PROCESS DESIGN MANUAL. Valves in inlet and discharge piping, manifolding, special considerations for safe disposal of discharged fluids, and similar items are covered by the conceptual design. Also see 709.

700.2.6 Conceptual Design Done Outside UCC - Conceptual design performed outside UCC is done in general accordance with 700.2.1, 700.2.2, and 700.2.3 unless specifically designated otherwise. UCC prepares or approves all preliminary layout and general arrangement drawings (see 700.2.4).

701 INFORMATION SOURCES FOR DETAILED DESIGN

The conceptual design (see 700.2) contains basic information needed as the starting point for detailed design. Valve and Piping Material Specifications give pressure-temperature ratings and other information necessary for detailed design. Various UCC Engineering Standards, Standard Specifications, and Manuals also contain information required for detailed design. These are listed in 719, 720, and 721 and are specified at appropriate places in other parts of this specification.

702 DESIGN CONDITIONS

Detailed design, except flexibility analysis, shall be based on the most severe pressure-temperature condition in the pressure-temperature ratings of the governing Valve and Piping Materials Specification. Flexibility analysis shall be based on the maximum operating pressure and temperature.

703 DESIGN CRITERIA

703.1 CODES

The detailed design of a piping system shall be in accordance with the section of the ANSI B31 Code for Pressure Piping governing the system. Unless otherwise specified in the Valve and Piping Material Specification, design shall be in accordance with ANSI B31.3, Petroleum Refinery Piping. Detailed design shall also comply with applicable local codes.

703.2 EXPANSION AND FLEXIBILITY

703.2.1 Analysis - All piping shall be arranged to afford the flexibility necessary to conform to applicable codes and stress limits. When formal analysis of a piping system is required, it shall be done using UCC Computer Program No. 52250 for piping flexibility analysis or another method approved by the UCC engineering office responsible for the project. Flexibility analysis calculations shall be retained in the project file.

703.2.2 Expansion Joints - Expansion joints shall not be used if the necessary flexibility can be provided by other means, unless it can be clearly shown that expansion joints are the best choice for a specific application. If used, expansion joints shall be packless type without circumferential welds in the bellows. Bellows for expansion joints in steam service shall be Inconel. The Materials Engineer and the Process Safety and Fire Protection Engineer for the project should be consulted regarding bellows material for expansion joints in services other than steam.

703.2.3 Reactions on Equipment - Reactions on equipment shall not exceed manufacturer's recommendations. Also see 706.7 and 709.

704 MATERIALS

Materials shall be as called for in the governing Valve and Piping Material Specifications or, for special materials, as noted on the Flow Diagram. An exception to this requirement is that the thickness of piping components may be increased as necessary to satisfy stress analysis for loadings (including thermal expansion) other than from pressure. (See PPF-1 for additional information regarding substitutions.)

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705 GENERAL PIPING LAYOUT

705.1 OBJECTIVE

The objective in piping layout is to produce, within limits imposed by equipment layout, the most economical plant possible consistent with safe, convenient, and economical operation and maintenance.

705.2 FUTURE NEEDS

Except where specifically called for in the conceptual design (see 700.2) and in 705.6.2, provision shall not be made for any future needs.

705.3 FIRE SAFETY SPACING REQUIREMENTS

Minimum fire safety spacing requirements for the basic elements of a plant are established by the UCC Process Safety and Fire Protection Engineer. These spacing requirements are reflected in preliminary layout and general arrangement drawings (see 700.2.4) prepared as part of the conceptual design. Deviations from these spacing requirements must have the prior approval of the UCC Process Safety and Fire Protection Engineer. *Requirements not covered by the preliminary layout* and general arrangement drawings shall be referred to the UCC Process Safety and Fire Protection Engineer for resolution.

705.4 ACCESSIBILITY AND MAINTENANCE CRITERIA

705.4.1 General - Space shall be provided around equipment for convenient operation, and access for maintenance and fire fighting. Unless specified otherwise, overhead clearances shall be as specified in 705.4.2 and horizontal clearances as specified in 705.4.3. (These clearances are taken from the UCC Chemical Plant Layout Manual and repeated here for convenience.)

705.4.2 Overhead Clearances to Bottom of Nearest Obstruction

(a)	Over railroads, top of rail	--	25 ft
(b)	Over main plant roads	--	25 ft*
(c)	Over accessways for mobile equipment	--	25 ft
(d)	At pump row accessway	--	10 to 12 ft
(e)	Over pumps and turbines	--	8 to 10 ft minimum (may need more for large equipment)
(f)	Over walkways, passageways, and platforms	--	6 ft 6 in

* Clearance over secondary peripheral roads may be lower; refer to UCC Plant Layout and General Facilities Group.

705.4.3 Horizontal Clearances to Closest Obstruction

(a)	From center of railroad track	8 ft 6 in (9 ft preferred)
(b)	At driver end of pumps where truck access is required	10 ft
(c)	At driver end of pumps where hand truck access is required	5 ft
(d)	Passageways, one way two way	2 ft minimum 4 ft minimum
(e)	At shall cover end of exchangers at grade	4 ft
(f)	At tube bundle removal end of exchangers	tube bundle length plus 2 ft (or as shown on Vendor drawings)
(g)	Maintenance platforms at end of elevated exchangers	3 ft
(h)	Between extremities, including piping, of adjacent pumps	18 in
(i)	Between extremities including insulation of paired vessels or exchangers	18 in
(j)	In front of manways	3 ft plus longest straight length of material to enter vessel

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705.4.4 Access for Maintenance - (a) Piping arrangement shall permit crane access to large major equipment not provided with built-in maintenance facilities.

(b) Clearance shall be provided to remove removable tube bundles (see 705.4.3), piston rods, and other equipment components that are periodically removed for maintenance.

(c) Hand truck access shall be provided to the driver end of small pumps.

(d) Clearance shall be provided at equipment to be charged with material such as catalyst to permit removing old material and charging new material.

705.5 LINE ROUTING

705.5.1 General - General guides for line routing are given in the UCC CHEMICAL PLANT LAYOUT MANUAL. Piping shall be run in an orderly and maintainable manner. Routing shall be as direct as practicable with piping grouped, wherever possible, in banks or pipeways; however, care shall be taken to avoid intrusions into aisles and other access areas. Routing shall provide for economy in the location of pipe supports. Larger lines shall generally be routed for flexibility and fluid-flow considerations with smaller lines following the routing of larger lines. Rack piping shall be routed without flanges. All service lines should be on the top level under electrical conduits or trays. Steam lines should be on the outside of pipeways if possible. Piping shall be above ground unless underground or trench installation is specified in the conceptual design (see 700.2.2).

705.5.2 Expansion and Flexibility - Routing shall provide for expansion and flexibility; design for these considerations is covered in 703.2. Routing shall insure that expanding lines (including insulation) will not touch adjacent lines, electrical conduits, or structures. Spacing for insulated lines is controlled by flange insulation. Flexibility needed to install slip blinds and remove temporary strainers shall be provided.

705.5.3 Critical Piping - Special attention shall be given to the routing of piping for severe service conditions. Some of these severe conditions are: dynamic loadings (cyclic pressure, cyclic temperature, vibration, pulsating flow, etc.), limited pressure drop, high temperature, low temperature, and erosion. Lines to be pigged shall be given special consideration to insure that the piping layout and interior are satisfactory for passage of the pig. All lines for flow measurement shall be treated as critical.

705.6 PIPEWAYS

705.6.1 Location - Unless otherwise specified, pipeways will be overhead in processing units. Between processing units, pipeways will be overhead or low level as specified in preliminary layout and general arrangement drawing prepared as part of the conceptual design.

705.6.2 Size - In general, pipeways should be sized to provide for 25% increase in capacity, but this must be determined for each project; in addition, space shall be provided for known future expansion. In units where cable trays are used, space shall be provided on the top level between the support columns in overhead pipeways. Space in lower levels of piping shall be provided for water spray headers where they are required.

705.6.3 Piping Arrangement - Where practicable, piping in banks shall be given specific elevations for lines running north-south and different elevations for lines running east-west. Lines shall change elevation when they change direction.

705.7 VALVES

705.7.1 General - The Flow Diagram shows valves to be installed on equipment and in piping. Valving shall be as shown except vents and drains not required for unit operation shall be added as required by 705.10.

705.7.2 Location - Valves required to operate the unit shall be accessible from grade or a platform. Valves 4-inch and smaller not required for unit operation and instrument connection valves may have ladder access only; a portable ladder is satisfactory when these valves are not more than 14 feet above grade. Valves in vertical lines should preferably be about 4 feet above grade or a platform (see 707.2 regarding steam valves). Usually gate and globe valves should not be installed with the stem below horizontal; the upright position is preferred except in pump suction lines (see 706.3.1). As a general rule, valves or flanges shall not be located inside vessel skirts, but equipment and tank shut-off valves shall be located on the equipment or tank nozzle unless there is a strong reason to do otherwise.

705.7.3 Chain and Reach Operation - Except for all screwed valves and other valves smaller than 2-inch, chain wheels or reach operation shall be provided for valves when the bottom of handwheel is over 7 feet above the operating level. Chain operators with a hammer-blow provision should be considered, especially for valves operated frequently or that are normally open. (Provide chain wrenches for wrench-operated valves.) Chains shall reach to about 4 feet above the operating level, shall not be in passageways, and shall be clear of equipment, piping, and structures. Reach rods shall be in accordance with UCC Engineering Standard P-88. Valves operated by chain or reach rod shall be visible from the point at which the chain or reach rod is operated. Where chain or reach operation is not feasible, one of the following should be considered: (1) a pneumatically operated valve with operation of the valve effected by connecting air hose at grade level; (2) hydraulic remote operation; (3) electric remote operation.

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705.7.4 Globe Valves - Unless otherwise indicated on the Flow Diagram, globe valves shall have upstream pressure under the disc.

705.7.5 Check Valves - (a) Swing check valves shall be installed so that normal flow is horizontal or vertical upward; horizontal installation is preferred.

(b) Piston check valves shall be installed so that normal flow is horizontal unless the valve is designed for vertical upward flow. Upstream pressure shall be under the piston (disc).

(c) Ball check valves shall be installed so that normal flow is horizontal unless the valve is designed for vertical upward flow. Upstream pressure shall be under the ball.

(d) Poppet type and other spring loaded check valves may be installed in any position. Horizontal or vertical upward flow is preferred.

705.7.6 Excess Flow Valves - An excess flow valve shall be located on or near the outlet shut-off valves of the vessel it protects. The valve shall be installed in its proper operating position; this varies for different valves.

705.7.7 Blowdown Valves - Steam generators often require continuous and/or intermitten blowdown valves. This service is very severe because the high pressure water flashes as it passes through the valve. Neither the continuous nor the intermitten blowdown valves are included in the Valve and Piping Materials Specifications. Because of their special requirements, these valves shall be specified as major equipment items in the design report.

Continuous blowdown valves must be designed to provide long-term service and to permit accurate control of blowdown flows. They should be purchased with a vernier calibration on the handwheel and stem to permit accurate adjustment. Several valves in parallel are required for large flows. Hancock 5505 or 7105 valves, or equal, are acceptable.

For intermittent blowdown service, special dual valves are required because of the need for tight shutoff. One valve provides the sealing action - it is opened first and closed last. The other valve takes the cutting action of the blowdown. Manufacturer's recommendations should be followed in establishing operating procedures. Edwards 440, 640 or 940 series valves, or equal, are acceptable.

705.8 CONTROL VALVES

Control valves shall be provided as shown on the Flow Diagram. The location of all control valves shall be shown on the model or in design or piping arrangement drawings, and shall be approved by the UCC Control Systems Engineering Group. In general, control valves should be located 2 to 4 feet (4 feet minimum in heavy snow country) above grade or a convenient platform, when this can be done without having to loop piping only for this purpose. Permanent ladders or platforms are not usually required if control valve diaphragms are within 14 feet of grade or from a safe operating level and can be reached by a portable ladder. Where practicable, control valves should be located within sight of instruments showing variables they control. Control valves shall be installed with stems in a vertical up position. Arrangements for control valve manifolds are covered in the UCC INSTRUMENT INSTALLATION MANUAL.

705.9 ORIFICE RUNS

The location and arrangement of all orifice runs should be made an early consideration in layout. Orifice runs shall be shown on the model, or in design or piping arrangement drawings, and shall be approved by the UCC Control Systems Engineering Group. In general, orifice runs should be in horizontal runs not over 12 feet above grade or a platform. They may be located in a conveniently accessible part of a pipeway. Maintenance access by portable ladder shall be provided for these runs. Arrangement of orifice runs shall be in accordance with UCC Standard IN-18.2. Location of connections in orifice flanges shall be in accordance with UCC Standard IN-18.26-1.

705.10 VENTS AND DRAINS

In addition to vents and drains specified on the Flow Diagram, all high points in piping shall have a valved vent plugged or blinded, and all low points shall have a valved drain plugged or blinded. All vents and drains shall be in accordance with the governing Valve and Piping Material Specification. Vents and drains shall be sized as required, but in no case shall be smaller than 1/2" (1" for main steam headers). Vents and drains must be located so they will not be damaged by piping movement.

705.11 PRESSURE TAPS

Pressure taps (except for orifice runs) shall be horizontal for liquid and steam service and vertical for gases and vapors; except that in pipeways where space is critical, (1) taps for direct-mounted pressure gages shall be vertical, and (2) taps for pressure transmitters shall be 45° below horizontal for liquids and vertical for steam, gas, and vapor. Pressure gages shall be installed in accordance with UCC Engineering Standards P-91, P-91A, P-91B, and P-91C. See 705.9 for location of taps in orifice flanges.

705.12 TEMPERATURE CONNECTIONS

705.12.1 Connections for Separable Sockets - Installation of connections for separable sockets shall be in accordance with the governing Valve and Piping Material Specification and UCC INSTRUMENT INSTALLATION MANUAL, Section 24.

705.12.2 Thermometer Test Wells - Thermometer test wells shall be in accordance with UCC INSTRUMENT INSTALLATION MANUAL, Section 24.

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705.13 DRIP LEGS AND DIRT POCKETS

Drip legs and dirt pockets shall be provided at all header low points. Drip legs and dirt pockets shall be in accordance with UCC Engineering Standard (to be issued later).

705.14 HEADER TAKE-OFF POSITIONS

Where possible, steam, air, gas, and vapor branch take-off position from above ground headers should be at the top of the header. For relatively clean liquids branch take-off position from above ground headers should be at the bottom of the header. For relatively dirty liquids, branch take-off position from above ground headers should be at the top of the header.

706 EQUIPMENT PIPING

706.1 VESSEL AND COLUMN PIPING

Generally, valves shall be mounted on nozzles as close to equipment as possible. All valved nozzles, vents, and drains discharging to atmosphere which are not used during unit operation shall be provided with blind flanges or screwed plugs. Valves shall be accessible in accordance with 705.7.2. Adequate room for slip blinding shall be provided at each vessel nozzle.

706.2 EXCHANGER PIPING

Exchanger piping shall be flexible and so arranged that blind flanges or slip blinds can be installed to isolate the exchanger and permit removal of the tube bundle. Removable spools shall be provided where necessary between channel nozzles and valves. (Spools shall not be connected directly to the downstream side of wafer valves.) Impact wrench clearance shall be provided at exchanger flanges. Drains shall be provided on the water side of heat exchangers to permit sufficient draining to avoid freezing. Also see 705.4.3.

706.3 PUMP PIPING

706.3.1 Suction Piping - Suction lines shall be as direct and short as possible and free of trapped sections. Unnecessary pressure drop shall be avoided. Where size change is necessary in horizontal suction lines, eccentric reducers installed with the straight side up should be used to avoid air or vapor pockets. Concentric reducers or reducing elbows may be used if they are in a vertical line or otherwise installed to prevent a pocket. If possible, at least five pipe diameters of straight piping should be provided immediately before the pump suction flange. When strainers are required, provision shall be made for their installation and removal. All elbows, valves, or other fittings except reducers should be ahead of the straight section of piping. Valves in suction lines should be installed so as to avoid a pocket in the bonnet (e.g. a gate valve should be installed with the stem in a horizontal position). Elbows should be long radius. In general the suction piping should be one or two sizes greater than the pump suction connection. Ideally suction piping should slope gently upward toward the pump. Vertical loops in either the suction or discharge piping should be avoided. However, where they are necessary the high point should be provided with a vent or the low point with a drain. Suction piping for end suction pumps shall be arranged so that the suction cover and pump impeller may be removed with the suction valve (where required) in place; except this is not required for the American Voluntary Standard design which embodies the back-pull-out feature (maintenance performed without removing suction or discharge piping). See Fig. 706.3.1 for proper and improper methods of installing suction piping. Also see 706.8.

706.3.2 Valve Accessibility - All valves in pump suction or discharge lines shall be accessible for operation by hand or provided with chain or reach operator in accordance with 705.7.3. For hazardous liquids, consideration should also be given to locating valves at a safe distance so they can be used to isolate and shut down the pump in the event of a seal or packing failure where product may be spewing from the pump.

706.3.3 Pipe Supports - Suction and discharge lines shall be supported independently of the pump. The piping shall be designed to prevent undue strains in the pump casing in accordance with 706.8.1.

706.3.4 Temporary Strainers - Where permanent strainers are not specified in the Flow Diagram, temporary strainers shall be installed in all pump suction lines except when the pump is designed to handle large solids. Temporary screens shall be installed in accordance with 706.8.2. Piping should be designed for easy installation and removal of strainers.

706.3.5 Vibration - Piping subject to vibration from dynamic loading shall be given special consideration. Small branch connections subject to fatigue failure due to vibration shall be specially designed to minimize the chance of such failure. Consideration should be given to using pneumatic accumulators or pulsation dampeners when reciprocating pumps are used. When check valves or fast acting automatic control valves are used in the discharge line of a pump, it may be necessary to provide a means to prevent water hammer.

706.3.6 Vents and Drains - All pumps should be equipped with drain connections. Pumps handling hazardous fluids should be fitted with a valve and drain piping to a sewer or other receiver. All pumps should be supplied with a casing vent connection except AVS or other pumps with a vertical centerline discharge which are self-venting. For hazardous fluids, vent piping should be directed to a vent header or returned to the suction vessel.

706.3.7 Pressure Relief - All positive displacement pumps (reciprocating and rotary) should be provided with pressure relief in the discharge piping ahead of any block valves unless adequate relief is provided as an integral part of the pump.

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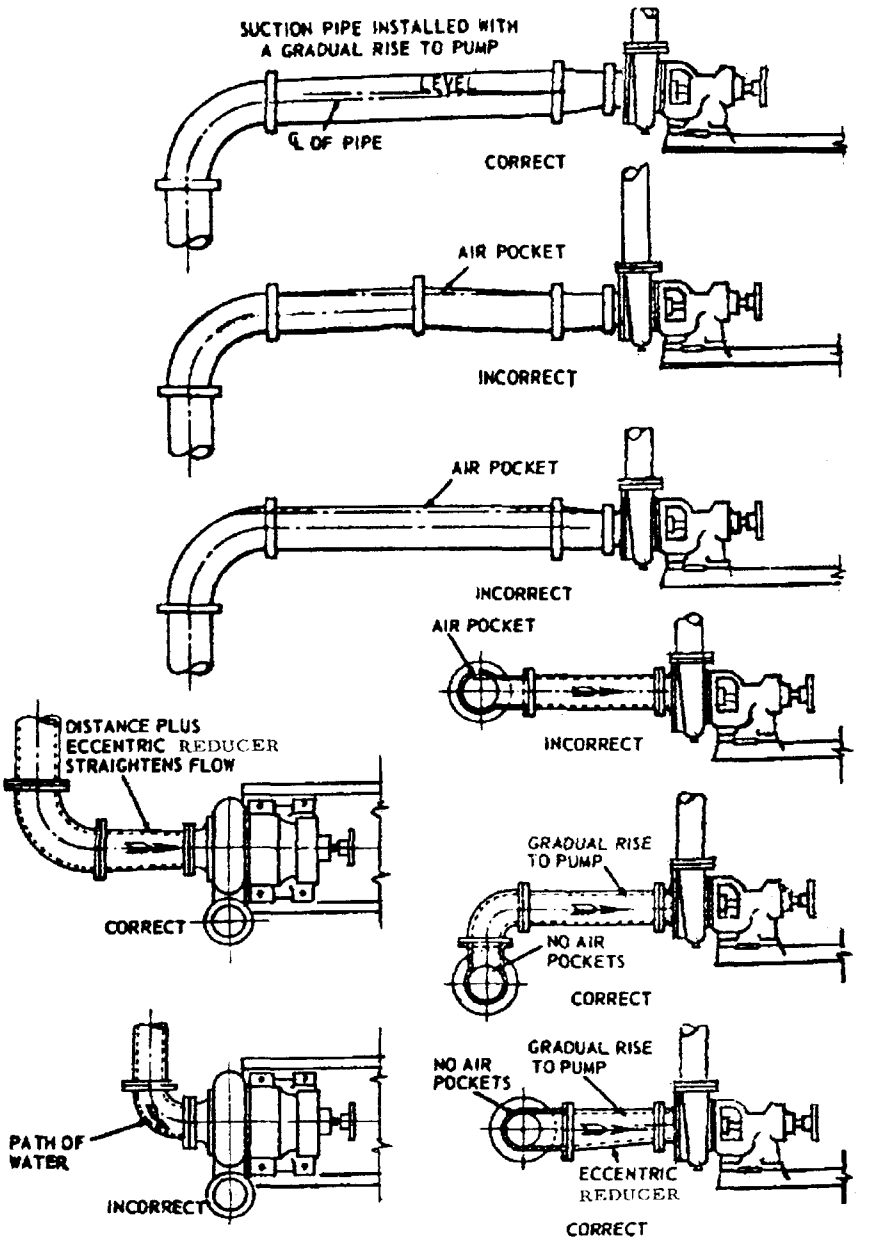


Figure 706.3.1

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706.3.8 Miscellaneous - All piping entering the suction vessel shall discharge below the liquid level and shall be sufficiently removed from the pump suction line entrance to prevent entraining air or vapor in the suction line. When the suction vessel liquid level can get low or suction entrance velocity is high, anti-swirl baffles in accordance with UCC Engineering Standard EQ-185 should be used. Where necessary, protection against reverse rotation shall be provided by installing a check valve in the discharge line. Consideration shall be given to supplying pressure gauges and sample connections.

706.4 TURBINE PIPING

706.4.1 Inlet and Exhaust Piping - Special care shall be taken to prevent reactions on the turbine casing due to thermal expansion of inlet and exhaust piping (see 706.8.1). Piping shall be arranged so the turbine can be removed while block valves are in place. Abrupt line size changes (reducing flanges, etc.) should be avoided as they may adversely affect turbine performance. Piping shall be designed to provide easy access for operation and maintenance. Inlet piping shall be designed for easy cleaning prior to connection to the turbine. (Cleaning methods vary; the design must accommodate the method to be used. Piping should be routed to avoid oil spills on hot lines (steam lines, for example).

706.4.2 Temporary Strainers - Permanent strainers are provided as part of the trip-throttle valve on all turbines. Therefore, temporary strainers are not required.

706.4.3 Water Washing - Connections shall be provided for water washing multi-stage units in accordance with the turbine manufacturer's recommendations. If manufacturer's recommendations are not available, where mixing nozzles are used provide 3/4" connections for the arrangement recommended in NEMA Standard SM20-4.07. For direct spray into the inlet line, provide a 3/4" spray connection not less than 3 diameters upstream of the thermowell and pressure gauge.

706.5 COMPRESSOR PIPING

706.5.1 General - Special consideration shall be given to compressor piping layout. Specific approval of the layout by the Engineering Group that performed the conceptual design is required; this shall be done by reviewing the model and/or piping drawings. The recommendations of the compressor manufacturer should be followed. Maximum velocity should be such as to prevent overheating. A maximum velocity of 125 ft per second shall be used at the suction flange connection unless otherwise specified by the manufacturer. The Noise Abatement Group should be consulted for recommendations regarding noise abatement. Low points in suction piping should be avoided downstream of suction scrubbers. Piping shall be arranged to provide easy access for both operation and maintenance. Piping should be routed to avoid oil spills on hot lines (steam lines, for example).

706.5.2 Vibration - Piping subject to vibration from dynamic loading shall be given special consideration. Small branch connections subject to fatigue failure due to vibration shall be specially designed to minimize the chance of such failures.

706.5.3 Temporary Strainers - For large compressors where it is possible to inspect the assembled suction piping from the inside to make sure it is clean, suction strainers are not recommended. On smaller compressors, when permanent strainers are not specified, a temporary strainer should be installed in accordance with 706.8.2.

706.5.4 Cleaning - Piping requiring special cleaning shall be designed so that cleaning may be conveniently done. Pre-installation cleaning requirements may be a part of the Valve and Piping Material Specifications or may be issued separately. A specific check should be made to determine the cleaning method to be used and piping designed accordingly.

706.5.5 Spool Pieces - Removable spool pieces shall be provided to permit maintaining the compressor without major piping disassembly.

706.6 STEAM-JET EJECTOR PIPING

Convenient access to the steam nozzle in each stage shall be provided. Where practicable, arrange steam piping so that each steam nozzle throat may be inspected by removing an inspection plug. For ejectors with flanged connections to suction stages, sufficient piping flexibility for the installation of blinds at suction stage connections shall be provided. A 1-inch screwed connection shall be provided upstream of the first stage jet, between the jet and isolating valve, for pressure gauge and testing. When test pressure taps have not been provided in the suction chamber of the ejector, provide a 1/2-inch tap with a screwed plug in accordance with governing Valve and Piping Material Specifications. For jets discharging to atmosphere, final jet discharge should be through a flapper-type check valve installed in a horizontal position to prevent inhaling air into hot flammable vapor.

706.7 FIELD STORAGE TANK PIPING

706.7.1 Flexibility - Adequate piping flexibility shall be provided to avoid damage from tank settlement. In earthquake regions, additional flexibility may be needed to compensate for tank movement under earthquake conditions.

706.7.2 Piping Through Dikes - Where piping runs through dikes, positive provision shall be made to insure a liquid seal at the inside of the dike. Seals shall provide for anticipated movement of piping. Piping passing through an earth dike shall be coated to prevent corrosion from the soil. See 717 regarding cathodic protection requirements. Piping passing through a masonry dike shall be installed in a pipe sleeve large enough to allow for passage of any flanges. The piping shall be wrapped with asphalt and felt and the annular space between the pipe and sleeve filled to insure a liquid seal.

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706.8 SPECIAL CONSIDERATIONS RELATING TO ROTATING EQUIPMENT

706.8.1 Loads Due to Piping - The piping should be designed to insure that the allowable flange loadings are the minimum practicable, but never exceed those specified by the manufacturer. Consideration shall be given to the thermal expansion of the connected equipment when calculating the pipe loads. If the manufacturer cannot provide realistic load limits, the piping shall be designed to minimize the loadings as much as practicable and the manufacturer's approval obtained for the loads determined by a piping flexibility analysis. (Not only the design, but the fit-up of the piping in the field must be correct to minimize pipe loads on equipment. Also, care must be used in aligning equipment to see that undue strains are not caused by the equipment shifting on the foundation.) In many cases it is practical to use metal-jacketed flexible hoses to eliminate excessive piping strains. Often the greater flexibility and reduced forces introduced by the jacketed flexible hose will make it preferable to expansion joints.

706.8.2 Temporary Strainers - Strainers should be installed in the suction lines of all equipment which could be damaged by foreign material passing through, unless it is possible to visually inspect the complete suction line. These screens should be in accordance with UCC Engineering Standard (to be issued later). Provision should be made by means of spool pieces or otherwise so the screens can be cleaned or removed without disturbing the alignment of the equipment. Provision shall be made to reassemble piping after removing a strainer without applying undue loads on equipment. A spacer may be required to take up space previously occupied by the strainer flange.

706.8.3 Turning Vanes and/or Flow Straighteners - All turning vanes, flow straighteners, or anti pre-rotation vanes in inlet lines to pumps, compressors, and blowers shall be designed to withstand the forces imposed during normal operation. Such devices shall also be designed to be free of vibration and possess infinite fatigue life. The same design basis shall apply to vanes and flow straighteners in gas turbine inlet air ducting.

707 UTILITIES PIPING

707.1 WATER SYSTEMS

For relatively clean water (i.e. potable water, condensate, clean process water, general service), branch take-off position from an above ground header should be from the bottom of the header. For seawater and silty water, branch take-off position from above ground header should be from the top of the header. In areas subject to freezing, provision shall be made to maintain circulation in lines that cannot be blocked off and drained. Cooling water piping should be designed to prevent draining exchangers if water failure occurs. Provision shall be made to permit flushing cooling water lines to exchangers prior to circulating water through the exchanger. Any connection between a potable water system and any other piping system shall be through an open atmospheric break or, when specifically approved by the local jurisdiction, through a reduced pressure backflow preventer. Questions regarding use of backflow preventers should be referred to the Energy Systems group at the Charleston Engineering Center.

Under ground water lines shall be in accordance with UCC Standard Specification B-143. Branch take-off position should be from the top or side of the header.

Rupture discs for water lines may be in accordance with UCC Engineering Standard P-96.

707.2 STEAM SYSTEMS

Branch take-off position should be from the top or side of the header. Block valves at headers shall be installed in the horizontal run at the high point of the branch so the line will drain both ways from the valve. Normally, valves should not not be installed in vertical steam lines, If no reasonable alternative exists, the vertical valve body should be tapped and a trap connection provided as near the upstream seat as possible. Where condensate can collect upstream of a block valve in a main steam service line when the valve is closed, a drain valve shall be installed in accordance with the governing Valve and Piping Material Specifications to permit draining the condensate prior to opening the valve. Return exhaust steam lines shall connect to the top or the side of the exhaust steam header. Steam piping shall be designed for complete removal of condensate. Drip legs and dirt pockets in accordance with UCC Engineering Standard (to be issued later) and steam traps shall be installed at the low points of the system.

Buried steam lines should be spaced sufficiently far from other buried lines to prevent their overheating. (In very dry conditions, earth is an effective insulation.)

707.3 AIR SYSTEMS

Branch take-off position should be from the top or side of the header. Air piping shall be designed for good drainage. Except for dry instrument air, provide a drip leg and drain valve in accordance with the governing Valve and Piping Material Specifications at the low points of the system.

707.4 FUEL GAS PIPING

Branch take-off position shall be from the top of the header. A drip leg should be provided to remove condensate from the system.

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708 FIRE PROTECTION PIPING

Requirements for all piping systems for fire protection for each job will be specified by the UCC Process Safety and Fire Protection Engineer.

Fixed water spray protection shall be in accordance with UCC Standard Specification B-281.

Sprinkler piping shall be in accordance with UCC Standard Specification B-280. The Process Safety and Fire Protection Engineer should be consulted to determine needs for clips, etc., to support sprinkler piping on equipment.

709 PRESSURE RELIEVING EQUIPMENT PIPING

Valving and general piping arrangement shall be in accordance with the Flow Diagram (prepared as part of the conceptual design) and Section 9 of the UCC PROCESS DESIGN MANUAL.

Discharge of pressure relieving devices shall be directed so that it cannot endanger personnel or damage piping, equipment, or structures. In general, liquid should be directed downward and vapor upward; when both liquid and vapor will be discharged, provision shall be made to properly direct each. (Straight discharge lines minimize reactive forces on equipment and anchors.) Discharge piping shall be not smaller than pressure relieving device outlet. Discharge lines shall be securely anchored against reaction effects; consideration shall be given to reaction effect on equipment and anchor bolts and suitable provision made to avoid damage. Consideration should be given to thermal effects (e.g., cooling across the valve) on discharge piping. Discharge piping shall be provided with drains at low points where fluid may condense or moisture collect. When discharge is not into a header for flammables, the drain may be a 3/8-inch hole for non-hazardous fluids in outdoor locations; for other conditions, a drain line shall be provided. Drain lines shall be either valved or trapped depending upon the fluid drained. The open end of horizontal discharge lines shall be undercut 45°. The open end of vertical discharge lines should be cut on a 45° bevel. An elbow or mitered turn should not be used on the open end unless the line and anchoring components are specifically designed for the reaction effect. Provision shall be made to exclude ice and snow in locations where these can occur.

Test connections to permit in-place testing of safety valves shall be in accordance with UCC Engineering Standards P-89, P-89A, or P-89B. Safe access shall be provided to valves intended to be tested in place.

710 UTILITY HOSE STATIONS

Utility hose stations at grade and for main operation platforms will consist of air, steam, nitrogen, and water as specified on the Flow Diagram (prepared as part of the conceptual design). Hose stations shall be in accordance with UCC Engineering Standard (to be issued later). Hoses will be 50 feet long.

711 SAFETY SHOWERS AND EYE WASH FOUNTAINS

Safety shower and eye wash fountains will be specified by the UCC Process Safety and Fire Protection Engineer. Unless specified otherwise, safety shower installation shall be in accordance with UCC Engineering Standard P-121, and eye wash fountain installation in accordance with UCC Engineering Standard P-123.

712 SUPPORT SYSTEMS

While it is primarily used to support piping, the support system also carries power and control cable trays, fire alarm systems, telephone lines, and electrical conduit. Needs of all systems to be carried shall be considered in designing the support system.

712.1 GENERAL

The design of all pipe supports shall be in accordance with the applicable section of ANSI B31, Code for Pressure Piping, and local codes. Gang-type hangers shall be used wherever possible to minimize the use of individual hangers. Chain, strap, perforated bow, or wire hangers are not permitted. Generally, supporting one line from another line shall be avoided.

712.2 SPACING

Pipe support spacing shall be in accordance with UCC Engineering Standard P-76, adjusted as necessary to support items other than piping (see 712.1). Pipe spacing (between lines) shall be in accordance with UCC Engineering Standard (to be issued later).

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712.3 SLIDE SUPPORTS

712.3.1 Uninsulated Lines - Slide supports in accordance with UCC Engineering Standard P-223 shall be considered for uninsulated steel lines in main and unit pipeways when (a) the line is *not* primed with a zinc-rich paint, and (b) the service life of the piping is expected to be more than 10 years. All other steel lines shall rest directly on their supports. Do not use slide supports in accordance with Engineering Standard P-223 for aluminum lines.

712.3.2 Hot Insulated Lines - Slide supports for hot insulated lines 16-inch and smaller shall be in accordance with UCC Engineering Standard P-226. Slide supports for hot insulated lines over 16-inch shall be in accordance with UCC Engineering Standard P-86C. Guides for all sizes shall be in accordance with UCC Engineering Standard P-224.

712.3.3 Cold Insulated Lines - Slide supports for cold insulated lines shall be in accordance with UCC Engineering Standard P-225; the steel cradle support shall be in accordance with UCC Engineering Standard P-82.

713 THERMAL INSULATION

713.1 General - Piping to be insulated and the temperature for which it is to be insulated is specified in the Line List accompanying the Flow Diagram (prepared as part of the conceptual design). Insulation shall be in accordance with the UCC THERMAL INSULATION MANUAL. VOLUME 1 (SPECIFICATIONS) and VOLUME 2 (DESIGN).

713.2 Leak Detectors - Insulated piping to be fitted with flange leak detectors to protect insulation from the process fluid will be specified on the Flow Diagram, in the Line List accompanying the Flow Diagram, in the Process Safety and Fire Protection Report (prepared as part of the conceptual design), or in the governing Valve and Piping Materials Specifications. Leak detectors shall be in accordance with UCC Engineering Standard P-101.

714 HEAT TRACING

Piping to be heat traced and requirements for heat tracing are specified in the Line List accompanying the Flow Diagram (prepared as part of the conceptual design).

Steam tracing shall be in accordance with UCC Engineering Standards P-140, P-140A, P-141, P-141A, P-141B, P-141C, P-141D, P-141E, P-142, P-142A, P-142B, P-142C, P-142D, and P-142E. For steam tracing temperatures of 400F and less, the tracer may be copper; above 400F the tracer shall be stainless steel. Consideration shall be given to the possibility of the process line heating and overpressuring the tracer line when the tracer is shut off. Pressure relief shall be provided if required by this condition.

Electric tracing shall be in accordance with the UCC ELECTRIC HEAT TRACING MANUAL and UCC Engineering Standards EL-40, EL-41, EL-42, EL-43, EL-44, EL-45, EL-45A, EL-46, EL-46A, EL-47, EL-48A, EL-48B, EL-49, and P-140A when the electric heating system utilizes Mineral Insulated (MI) cable. Other types of electric tracing, such as Therman, may be used when particular design requirements so dictate; these systems shall be in accordance with the general design procedures set forth in the UCC ELECTRIC HEAT TRACING MANUAL.

The surface temperature of a traced line shall be less than the ignition temperature of gases or vapors in the area.

715 BONDING AND GROUNDING

Piping to be bonded and grounded is specified on the Flow Diagram, in the Process Safety and Fire Protection Report (prepared as part of the conceptual design), in the electrical section of Design Reports, or the governing Valve and Piping Material Specifications; no piping is to be bonded or grounded unless so specified. Bonding and grounding of pipelines shall be in accordance with UCC Engineering Standard EL-67; ground rods shall be in accordance with UCC Engineering Standard EL-50 or EL-51. Grounding at tank car, tank truck and barge loading spots is covered by UCC Engineering Standard EL-63.

716 PAINTING

Unless otherwise specified, painting specifications for a project will be prepared by a UCC Painting Engineer. Surface preparation, prime coating, finish coating, and colors will be covered by these specifications.

Surface preparation shall be in accordance with UCC Standard Specification B181.

Application of paint shall be in accordance with UCC Standard Specification B182.

717 CATHODIC PROTECTION

Mr. L. S. VanDelinder (Engineering Department, Technical Center, P. O. Box 8361, South Charleston, West Virginia 25303) shall be consulted regarding requirements for cathodic protection of underground pipelines.

Cathodic protection of underground steel lines shall be in accordance with UCC Standard Specification B-260 and UCC Engineering Standards ELC-51, ELC-52, ELC-75, ELC-76, ELC-77, ELC-78, and ELC-79. Design, testing, and operation shall employ the principles defined in NACE Standard RP-01-69.

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718 COATING AND WRAPPING UNDERGROUND LINES

Underground carbon steel lines shall be coated and/or wrapped in accordance with UCC Standard Specification B-148. Underground lines of materials other than carbon steel shall be coated and wrapped as recommended by the UCC Materials Engineer responsible for the job.

719 ENGINEERING STANDARDS

The following UCC Engineering Standards (from the ENGINEERING STANDARDS MANUAL) are referred to in this specification and are listed here for convenience:

EL-40	EL-46	ELC-51	ELC-77	P-82	P-91A	P-140A	P-142	P-224	
-41	-46A	-52	-78	-86C	-91B	-141	-142A	-225	
-42	-47	-63	-79	-88	-91C	-141A	-142B	-226	
-43	-48A	-64	EQ-185	-89	-96	-141B	-142C	Pipe Spacing	to be issued later
-44	-48B	-67	IN-18.1	-89A	-121	-141C	-142D	Drip Legs	
-45	-49	-75	-18.26-1	-89B	-123	-141D	-142E	Hose Stations	
-45A	-50	-76	P-76	-91	-140	-141E	-223		

720 UCC STANDARD SPECIFICATIONS

The following UCC Standard Specifications (from STANDARD SPECIFICATIONS, VOLUME I) are referred to in this specification and are listed here for convenience:

B-143	B-190
B-148	B-260
B-181	B-280
B-182	B-281

721 UCC MANUALS

The following UCC Manuals are referred to in this specification and are listed here for convenience:

CHEMICAL PLANT LAYOUT
ENGINEERING STANDARDS MANUAL
INSTRUMENT INSTALLATION MANUAL
PROCESS DESIGN MANUAL
PROJECT PROCEDURES MANUAL
STANDARD SPECIFICATIONS, VOL I
THERMAL INSULATION MANUALS, VOLS I AND II
VALVE AND PIPING SPECIFICATIONS MANUAL
ELECTRIC HEAT TRACING MANUAL

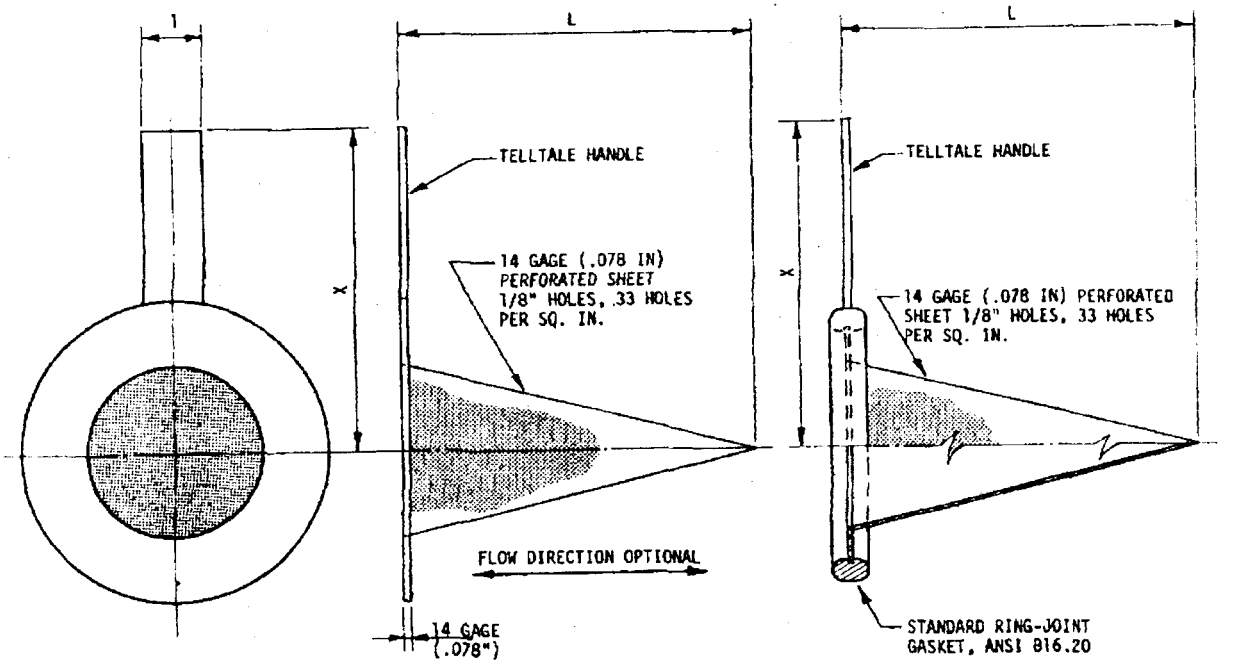
Manuals (and individual Engineering Standards and Standard Specifications) are available from:

W. Griffin Hammar
Union Carbide Corporation
Technical Center
P. O. Box 8361
South Charleston, West Virginia 25303

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TEMPORARY STRAINERS FOR SUCTION LINES NONCRITICAL SERVICES



STRAINER FOR USE WITH RAISED OR PLAIN FACE FLANGES (SUFFIX R/FF ON SERIES DESIGNATION)

STRAINER FOR USE WITH RING - JOINT FLANGES (SUFFIX RJ ON SERIES DESIGNATION)

NOMINAL PIPE SIZE		2	2 1/2	3	4
L	SERIES PCL-*	6	7	9	11 1/2
	SERIES PCS-*	4 1/2	5 1/2	6 1/2	8 1/2
X		5 1/2	6 3/4	6	6 3/4

NOTE:

2", 3", AND 4" STRAINERS OF MORE RUGGED DESIGN AND STRAINERS FOR SIZES ABOVE 4" ARE COVERED BY UCC STD PPM-11B.

TEMPORARY STRAINERS SHOWN ON THIS STANDARD SHALL BE AS MANUFACTURED BY THE MACK IRON WORKS COMPANY, SANDUSKY, OHIO, OR APPROVED EQUAL. THEY ARE AVAILABLE FOR USE WITH RAISED - OR FLAT-FACE FLANGES IN 150-, 300-, AND 600-LB RATINGS, AND FOR USE WITH RING-JOINT FLANGES IN 300- AND 600-LB RATINGS.

THESE TEMPORARY STRAINERS ARE MADE IN LONG (PCL) AND SHORT (PCS) MODELS. IN GENERAL, THE LONG MODEL SHOULD BE SPECIFIED FOR MOST INSTALLATIONS, BECAUSE OF THE GREATER AMOUNT OF OPEN AREA PROVIDED. SHORT MODEL STRAINERS MAY BE SPECIFIED WHEN SPACE FOR INSTALLATION IS LIMITED.

TEMPORARY STRAINERS SHALL BE USED IN SUCTION LINES AND STEAM INLET LINES OF COMPRESSORS, PUMPS, AND OTHER MACHINERY WHEN SO SPECIFIED BY ENGINEERING OR OPERATING DEPARTMENT. USE OF TEMPORARY STRAINERS SHALL NOT REPLACE PROPER CLEANING OF LINES AND EQUIPMENT.

ORIGINAL PIPING DETAILS SHALL PROVIDE FOR EASY INSTALLATION AND REMOVAL OF TEMPORARY STRAINER.

TEMPORARY STRAINER SHALL BE INSTALLED IN LINE PRIOR TO FIRST RUNNING OF THE MACHINE IT IS TO PROTECT. STRAINER SHALL BE REMOVED AND CLEANED PERIODICALLY AFTER MACHINE HAS BEEN PLACED IN SERVICE. CARE SHALL BE TAKEN TO REMOVE ANY DEPOSIT FROM LINE ON UPSTREAM SIDE OF STRAINER. WHEN A REASONABLE NUMBER OF INSPECTIONS INDICATE THERE IS NO MORE FOREIGN MATTER IN THE SYSTEM, STRAINER SHALL BE PERMANENTLY REMOVED AND RETURNED TO STORES DEPARTMENT. DO NOT INSULATE FLANGED JOINTS UNTIL STRAINER IS REMOVED.

MATERIAL SPECIFICATION:

ALL MATERIAL, EXCEPT RING-JOINT GASKET, SHALL BE TYPE 304L OR 316L STAINLESS STEEL. RING JOINT GASKET, IF REQUIRED, SHALL BE SOFT IRON (90 BRINNEL MAXIMUM HARDNESS).

*ADD SUFFIX INDICATING TYPE OF FLANGES WITH WHICH STRAINER IS TO BE USED.

Unless otherwise indicated, all dimensions given in inches.

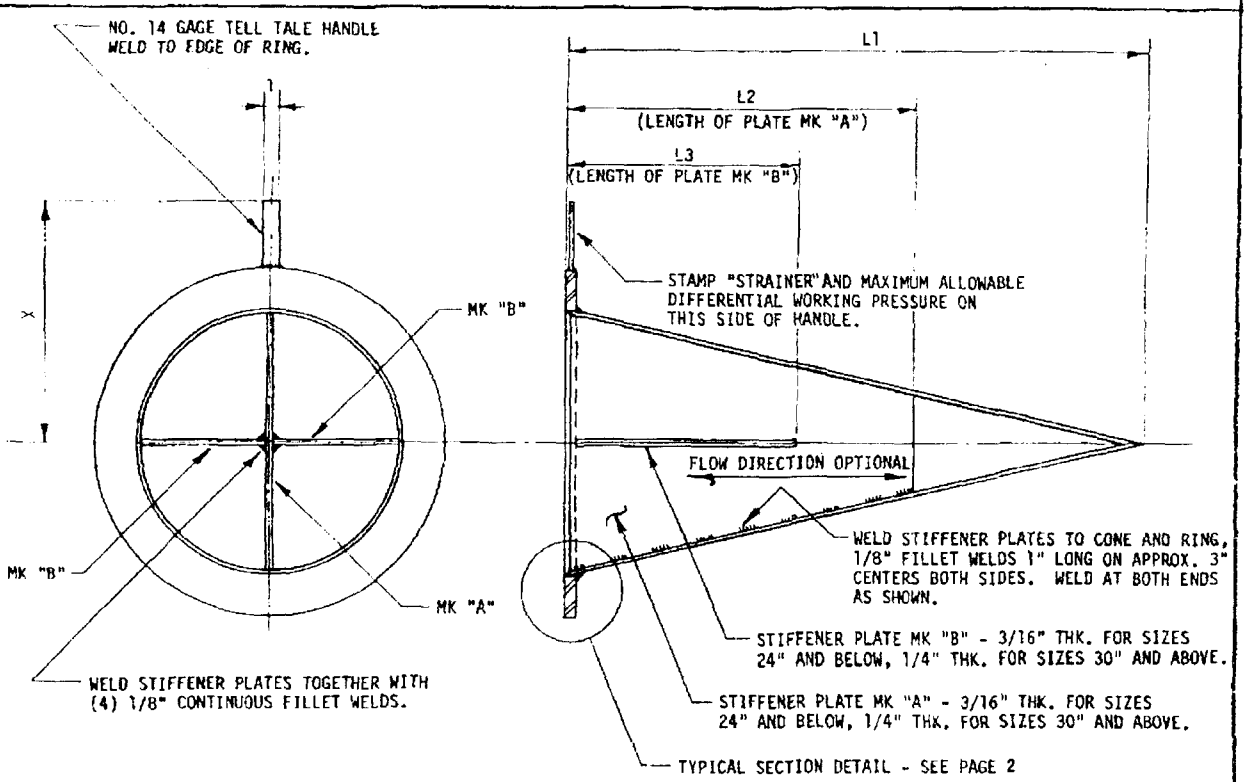
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TEMPORARY STRAINERS FOR SUCTION LINES CRITICAL SERVICES



NOM. SIZE	MAX. DIFF. PRESS. PSI*	D1	D2 150 LB FLG.	D2 300 LB. FLG.	D2 600 LB. FLG.	L1	(1) L2	(1) L3	T	X
48	1	46	SEE PURCHASE ORDER			96	80	72	3/8	31 3/4
42	1.25	40 1/8				84	68	60	3/8	28 1/2
36	1	34				72	56	48	3/8	24 1/2
30	1.5	28 1/8				60	44	36	3/8	21 1/2
24	3	22 1/4	28 1/4	30 1/2	31 1/8	48	32	24	1/4	18 1/2
20	5	18 1/4	23 7/8	25 3/4	26 7/8	40	24	16	1/4	16 3/4
18	6	16 1/4	21 5/8	23 1/2	24 1/8	36	20	12	1/4	15 1/2
16	6	14 1/4	20 1/4	21 1/4	22 1/4	32	16	8	1/4	14 1/4
14	6	12 1/4	17 3/4	19 1/8	19 3/8	28	12	4	1/4	13
12	4	11	16 1/8	16 5/8	18	24	8	--	1/4	11 3/4
10	6	9	13 3/8	14 1/4	15 3/4	20	4	--	1/4	10 1/4
8	6	7	11	12 1/8	12 5/8	16	--	--	1/4	9
6	2	5 1/4	8 3/4	9 7/8	10 1/2	12	--	--	1/4	7 3/4
4(2a)	8(2b)	3 1/4	6 7/8	7 1/8	7 5/8	8	--	--	1/8(2c)	7
3(2a)	4(2b)	2 1/2	5 3/8	5 7/8	5 7/8	6 1/2	--	--	1/8(2c)	5 5/8
2(2a)	4(2b)	1 11/16	4 1/8	4 3/8	4 3/8	4 1/2	--	--	1/8(2c)	4 3/4

*MAXIMUM ALLOWABLE DIFFERENTIAL WORKING PRESSURE AT 300°F, PSI

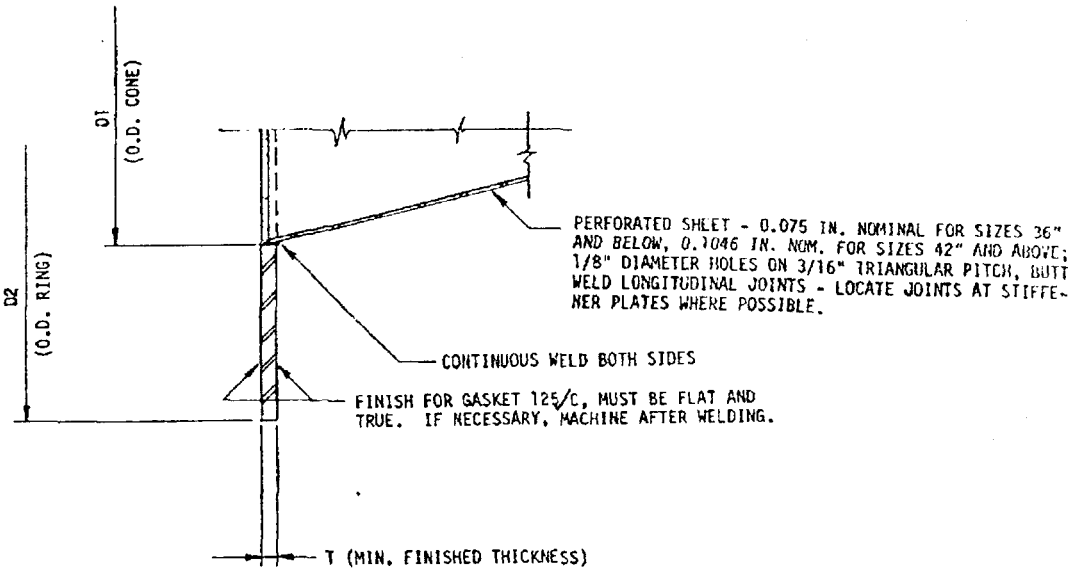
SEE PAGE 2 FOR NOTES.

Unless otherwise indicated, all dimensions given in inches.

16.6.10.1

UCC 021271

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TYPICAL SECTION

NOTES:

Use with caution where subject to vibration.

The purchase order will specify nominal size of strainer, material, and pressure class of flanged joint in which strainer will be installed. For pressure classes higher than 600 lb. ANSI Standard, the purchase order shall also specify O.D. of ring D2 (equal to bolt circle diameter minus one bolt diameter).

Material shall be good weldable quality carbon steel or AISI type 304L or 316L stainless steel as specified by purchaser.

Strainers shall be made with a minimum number of joints. Girth joints are not permitted unless approved by the purchaser. Welding shall be done by the gas-tungsten arc method unless otherwise approved by the purchaser. All welding shall conform to Section IX of the ASME Code.

Strainers shall be accurately made to the form of a right circular cone. Flat spots or oval sections are not acceptable.

1. Stiffener not required where no dimensions are shown.

2a. These sizes may be as manufactured by Mack Iron Works, Sandusky, Ohio, series PCS-RF/FF or equal, except for thicker lap required.

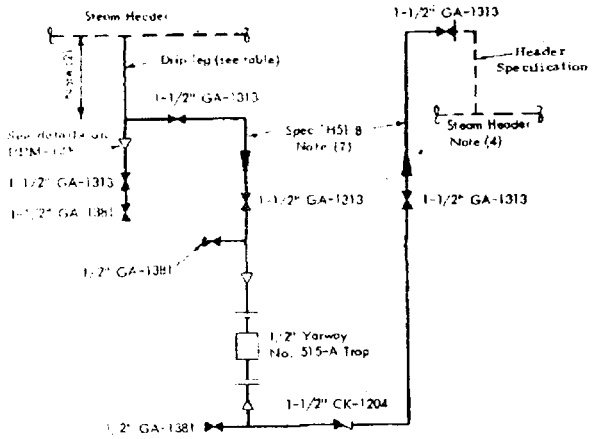
2b. Two inch, 3 inch, and 4 inch sizes will each have roughly 1 psi strainer pressure drop for 10 ft./sec. piping water velocity and 0.4 psi for 6 ft./sec. piping water velocity. Larger sizes will have approximately half these pressure drops.

2c. Laps for these sizes need not be machined provided they are smooth, flat, and true.

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FLOW DIAGRAM ARRANGEMENT FOR STEAM HEADER DRIP AND DIRT POCKET

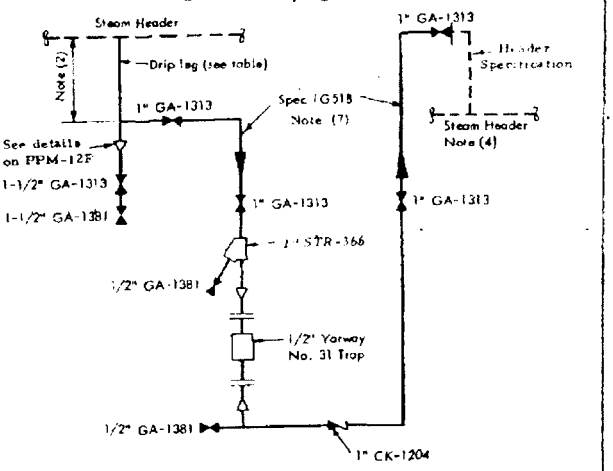
716 to 1100 psig at 750°F



ARRANGEMENT A Note (3)

Ref PPM-12A, F

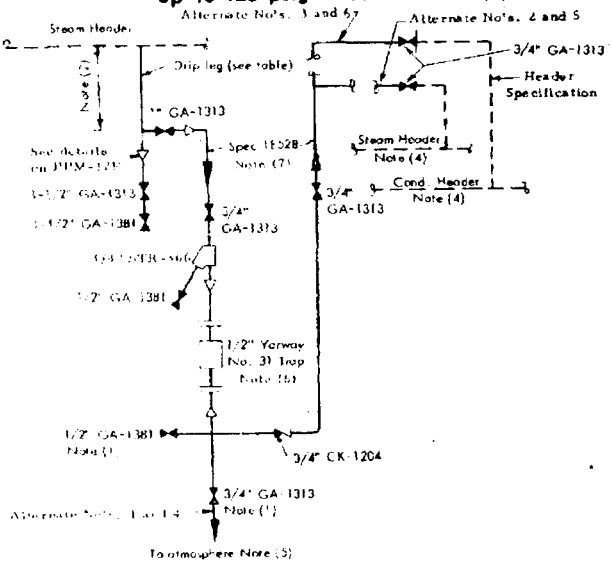
291 to 715 psig at 750°F



ARRANGEMENT B Note (3)

Ref PPM-12A, F

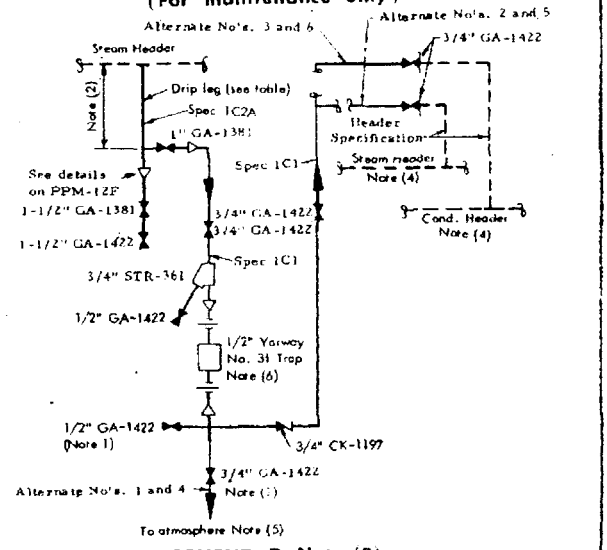
Up to 290 psig at 750°F
Up to 125 psig at 350°F Note (6)



ARRANGEMENT C Note (3)

Ref PPM-12B, C, F
Alternates 1 through 6

Up to 125 psig at 450°F
Up to 125 psig at 350°F Note (6)
(For maintenance only)



ARRANGEMENT D Note (3)

Ref PPM-12D, E, F
Alternates 1 through 6

Header Diameter	Drip Leg Diameter
1-1/2" - 4"	1-1/2"
6" - 8"	3"
10" - 12"	4"
14" - 16"	6"
18" - 30"	8"

Drip Leg Sizing Table

Notes:

(1) Do not provide this valve for Alternate No. 1 and No. 4 when trap discharges independent of other traps.

(2) This dimension should be equal to $\frac{\text{Header OD}}{2} + 12"$ minimum.

(3) Flow diagram should show alternate best suited for each application. Dry wells are not recommended for impervious soils.

(4) Pressure in this header must not exceed 50 percent of trap inlet pressure.

(5) Provide for safe disposal of condensate.

(6) If steam is oily, trap should be 1/2" Sarco T-125 (Up to 125 psig at 350°F).

(7) Assigned line number and pipe specification to be the same from the steam header to the condensate header.

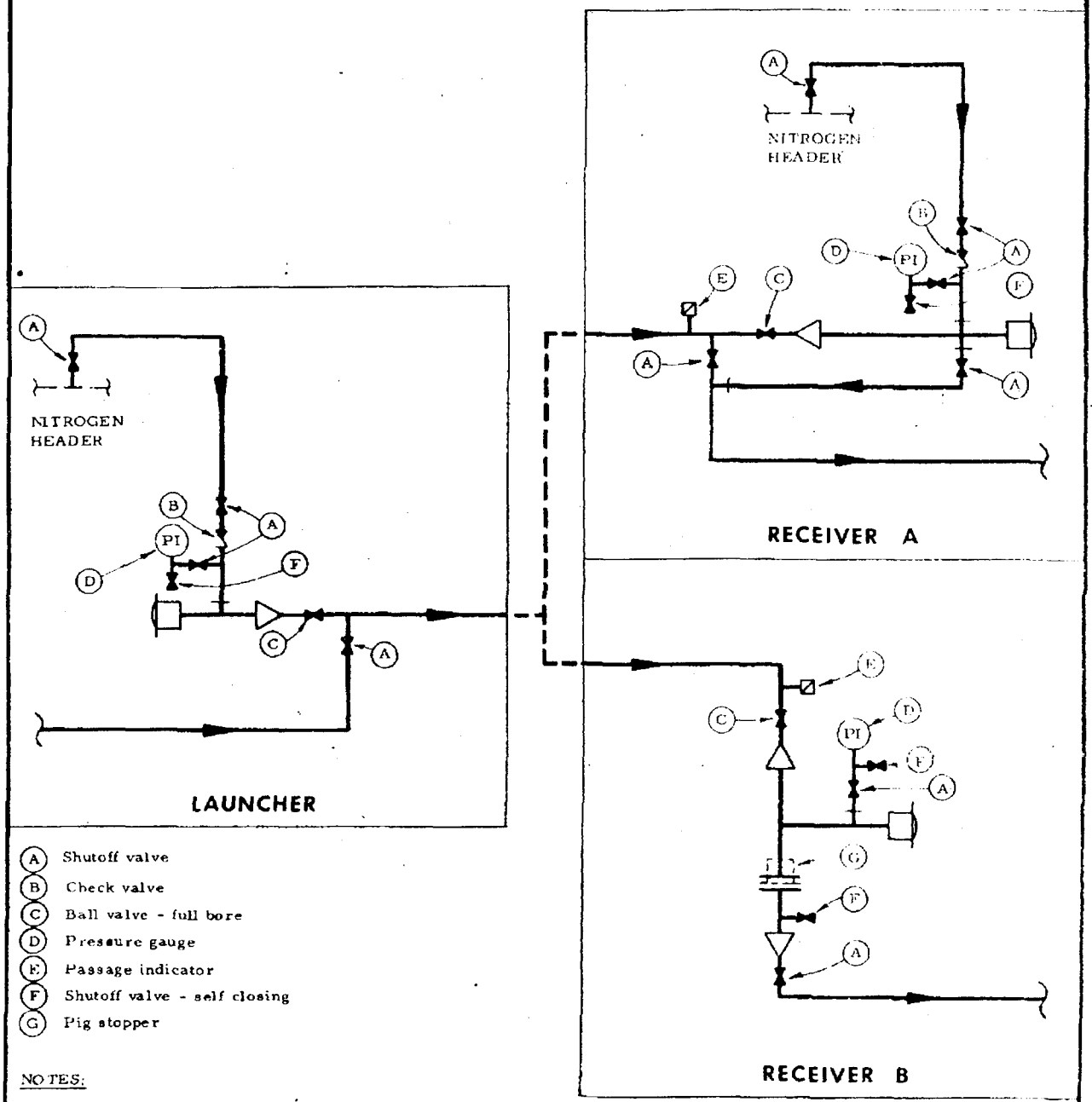
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TYPICAL FLOW DIAGRAM ARRANGEMENT FOR PIG LAUNCHERS AND RECEIVERS



(A) Shutoff valve
(B) Check valve
(C) Ball valve - full bore
(D) Pressure gauge
(E) Passage indicator
(F) Shutoff valve - self closing
(G) Pig stopper

NOTES:

A. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.

B. Receiver A: (a) Capable of handling scrapers, spheres, or urethane pigs; (b) May pig without shutting down line; (c) Control loop may be required to prevent over-pressuring of storage tanks when pigging with nitrogen.

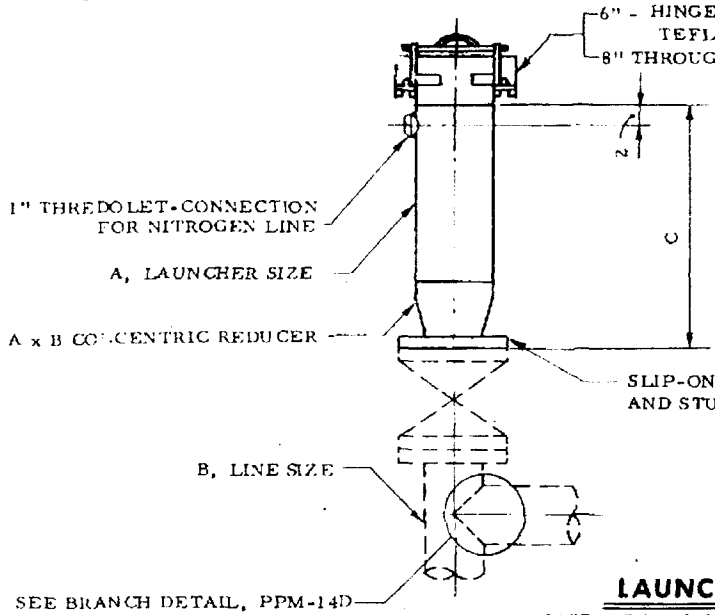
C. Receiver B: (a) Capable of handling spheres or urethane pigs, not scrapers; (b) Must shut down line in order to recover pig; (c) Mechanically prevents over-pressuring of storage tanks.

D. See details on *PPM-14A, PPM-14B, PPM-14C, PPM-14D, and PPM-14E.*

E. This standard is intended to serve as a guide from which individual pigging systems may be designed. The arrangement and components of the system may vary to satisfy the various operating procedures.

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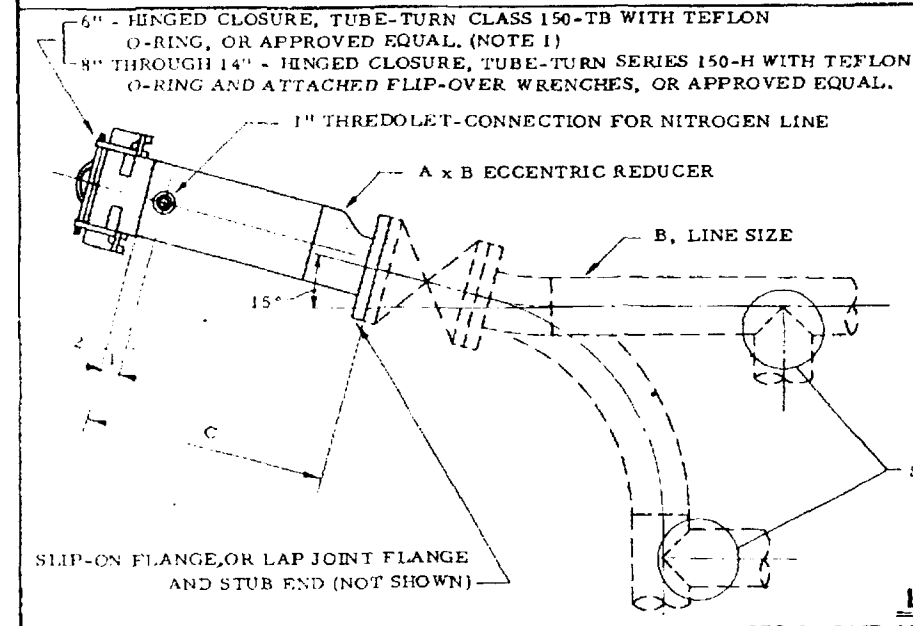
PIG LAUNCHER DETAILS



ELEVATION

LAUNCHER A
VERTICAL INSTALLATION

A	B	C
6	3	16
6	4	16-1/2
8	6	25
10	8	27-1/4
12	10	29-1/4
14	12	30-1/4



ELEVATION

LAUNCHER B
15° ABOVE HORIZONTAL INSTALLATION

NOTES:

A. All dimensions are in inches.
B. See piping drawings for the out-of-function portion of the assembly.
C. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.
D. A blind flange may replace the 6" hinged closure, depending on frequency of operation.

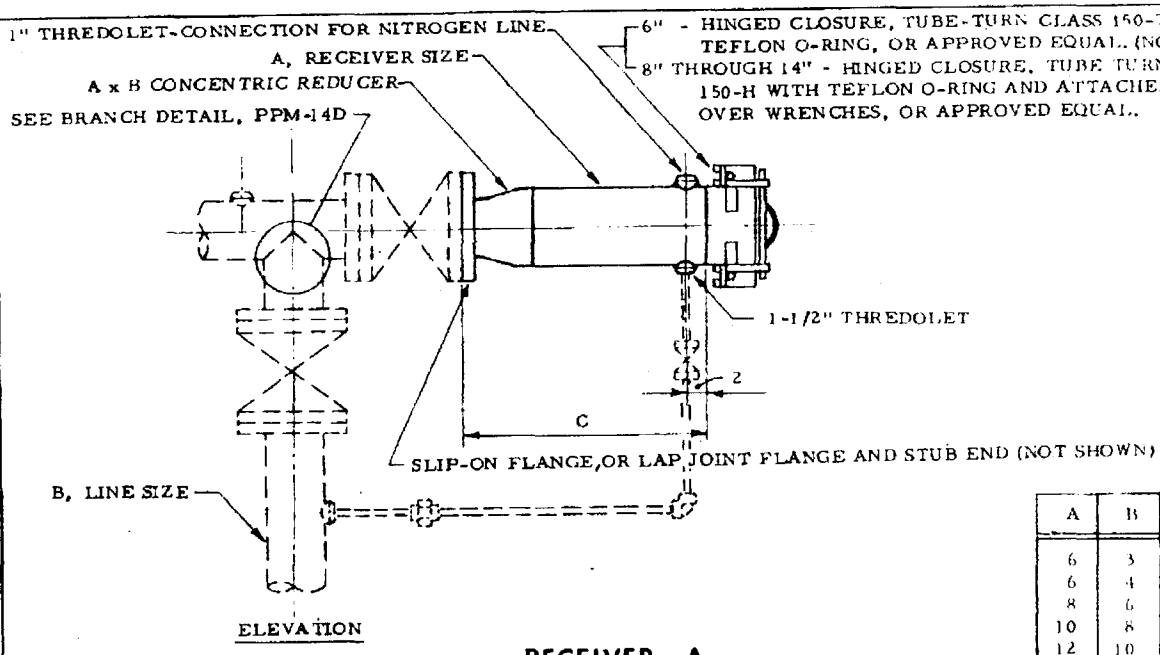
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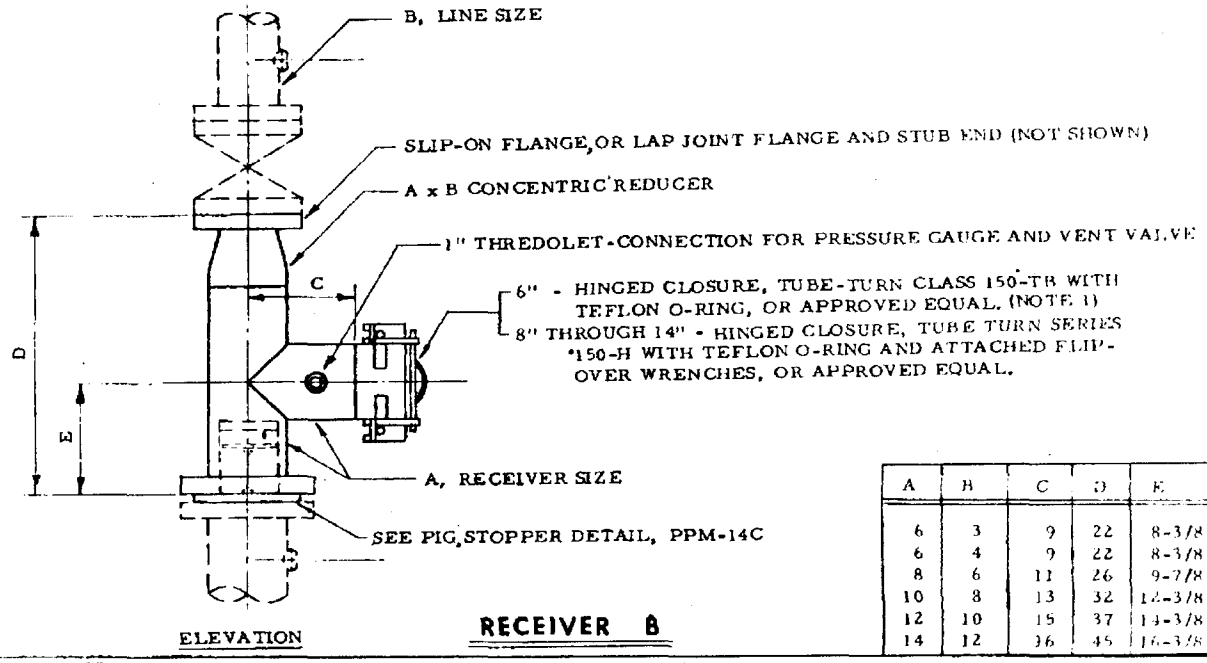
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PIG RECEIVER DETAILS



RECEIVER A

A	B	C
6	3	16
6	4	16-1/2
8	6	25
10	8	27-1/4
12	10	29-1/4
14	12	30-1/4



RECEIVER B

A	B	C	D	E
6	3	9	22	8-3/8
6	4	9	22	8-3/8
8	6	11	26	9-7/8
10	8	13	32	12-3/8
12	10	15	37	14-3/8
14	12	16	45	16-3/8

NOTES:

A. All dimensions are in inches.

B. See piping drawings for the out-of-function portion of the assembly.

C. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.

1. A blind flange may replace the 6" hinged closure, depending on frequency of operation.

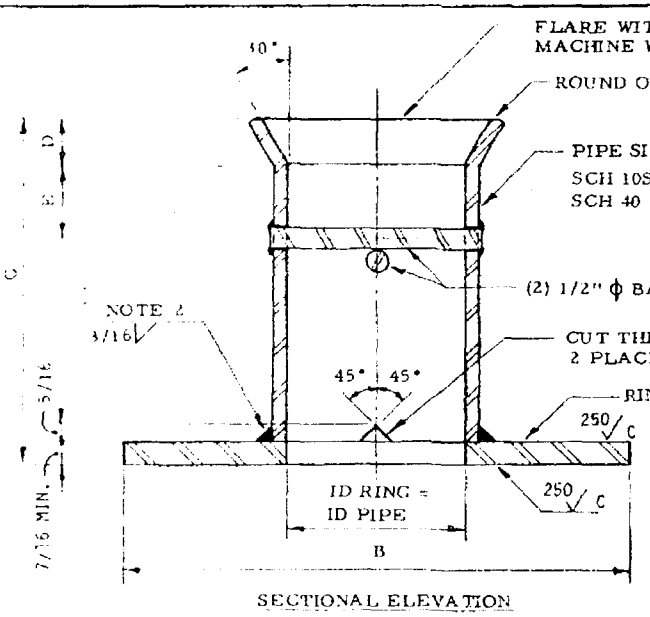
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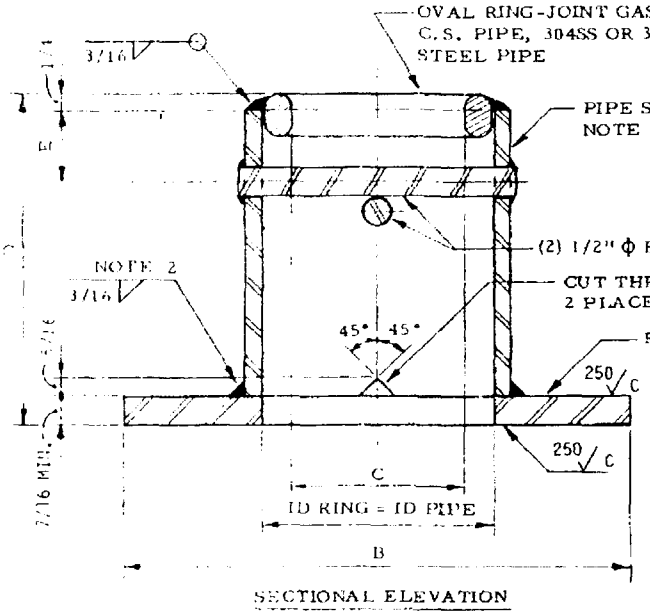
PIG STOPPER DETAILS



Line Size	Rec. Size	A	B	C	D	E
3	6	2	8-5/8	6	1	3/4
4	6	3	8-5/8	6	7/8	1-1/8
6	8	4	10-5/8	6-1/2	1-3/4	1-1/4

STOPPER A

3" THROUGH 6" LINES



PIPE SIZE, A	RING GASKET NO.
6	R35
8	R41
10	R47
12	R51

*AS LISTED IN TABLE 1 OF ANSI B16.20.

Line Size	Rec. Size	A	B	C	D	E
6	8	6	10-7/8	4-15/16	6-1/4	1-3/4
8	10	8	13-1/4	6-11/16	7-3/4	2-1/2
10	12	10	16	8-1/4	8-3/4	3-1/4
12	14	12	17-5/8	10-1/8	10-1/8	3-3/8

STOPPER B

8" THROUGH 12" LINES, ALTERNATE FOR 6" LINES

NOTES:

A. All dimensions are in inches.

B. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.

C. Use wall thickness as given in the applicable Valve and Piping Specification as a minimum.

D. Two welds, 2-1/2" long, spaced 180° apart to miss holes through pipe.

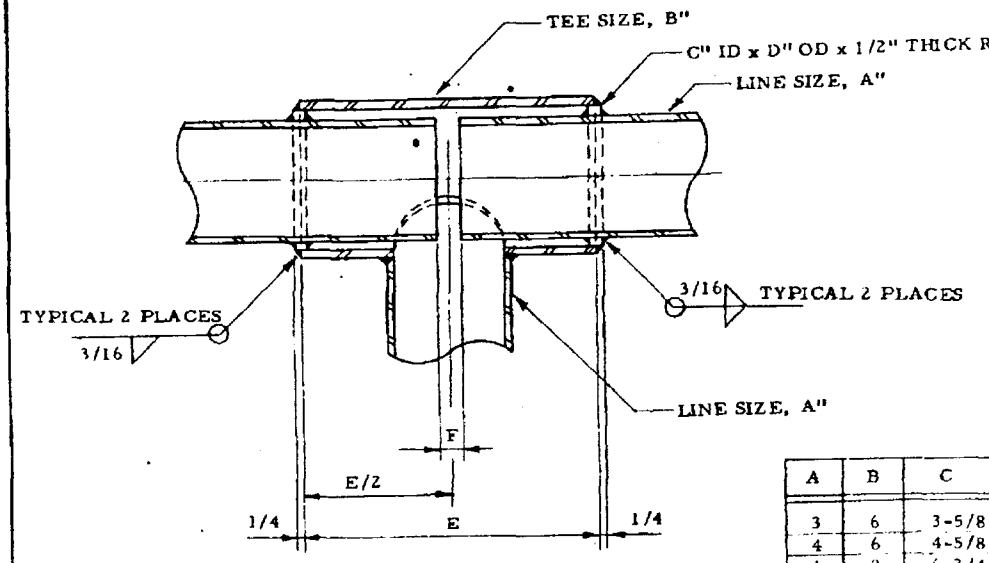
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UCC 021277

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BRANCH DETAILS FOR PIGGED LINES

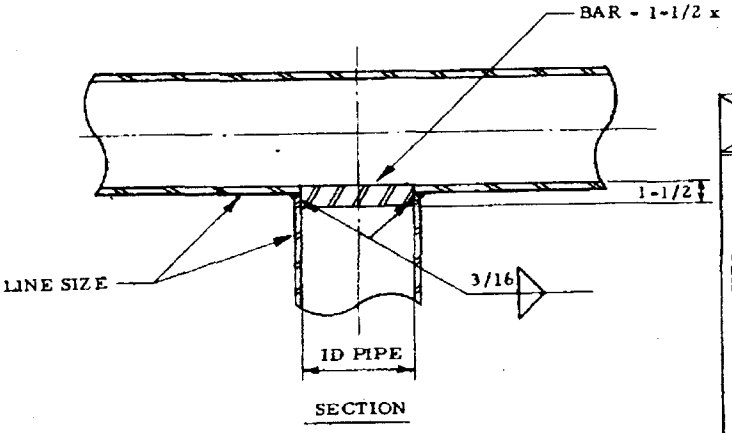


SECTION

A	B	C	D	E	F
3	6	3-5/8	5-7/8	12	11/16
4	6	4-5/8	5-7/8	12	15/16
6	8	6-3/4	7-3/4	16	1-3/8
8	10	8-3/4	10-1/8	20	1-13/16
10	12	10-7/8	12	24	2-5/16
12	14	12-7/8	13-1/4	28	2-13/16

TYPE A

FOR USE AT RECEIVER A, EXCEPT USE BRANCH TYPE B WHEN PIGGING WITH SCRAPERS.



SECTION

TYPE B

FOR USE OTHER THAN AT RECEIVER A AND IN ALL CASES WHEN PIGGING WITH SCRAPERS.

WIDTH A

BRANCH SIZE \ RUN SIZE	3	4	6	8	10	12
1	N	N	N	N	N	N
1-1/2	3/8	N	N	N	N	N
2	3/8	3/8	N	N	N	N
3	3/8	3/8	3/8	N	N	N
4	-	1/2	1/2	1/2	N	N
6	-	-	1/2	1/2	1/2	1/2
8	-	-	-	3/4	3/4	3/4
10	-	-	-	-	3/4	3/4
12	-	-	-	-	-	3/4

N indicates bar is not required.

NOTES:

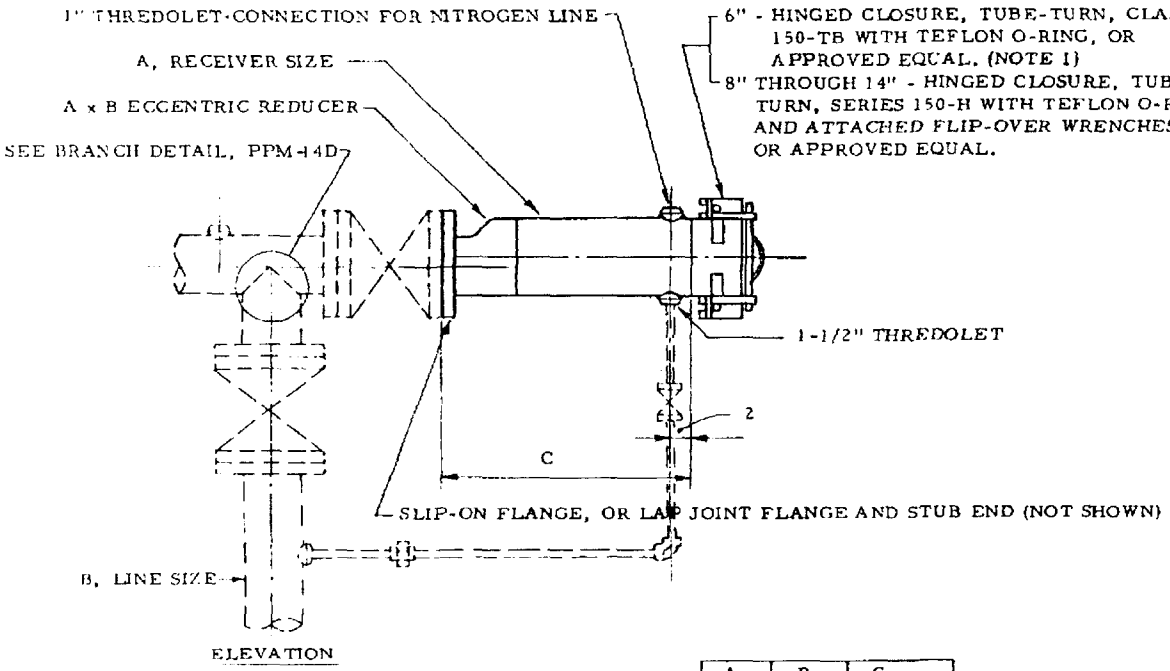
A. All dimensions are in inches.
B. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.

16.6.10.1

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PIG LAUNCHER/RECEIVER DETAIL



A	B	C
6	3	10
6	4	16-1/2
8	6	25
10	8	27-1/4
12	10	29-1/4
14	12	30-1/4

NOTES:

A. All dimensions are in inches.
B. See piping drawings for the out-of-function portion of the assembly.
C. Materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel 150 lb. specifications.
D. This standard is intended for use only when pigging in both directions is desired.
1. A blind flange may replace the 6" hinged closure, depending on frequency of operation.

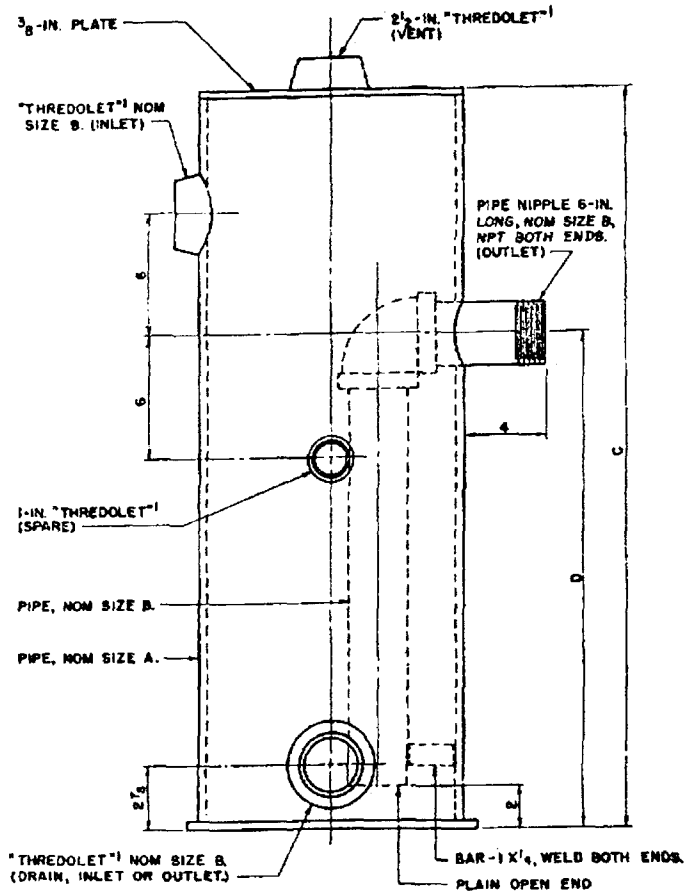
16.6.10.1

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STEAM CONDENSATE FLASH TANK-STEEL (SMALL CAPACITY)



ELEVATION

CAPACITY-LB CONDENSATE PER HOUR	NOMINAL SIZE A	NOMINAL SIZE B	C	D	E
950	6	1 1/2	2'-6	1'-6	9 1/2
1700	8	1 1/2	3'-6	2'-6	11
2600	10	2	3'-6	2'-6	1'-1
3800	12	2 1/2	4'-6	2'-6	1'-3

NOTE :

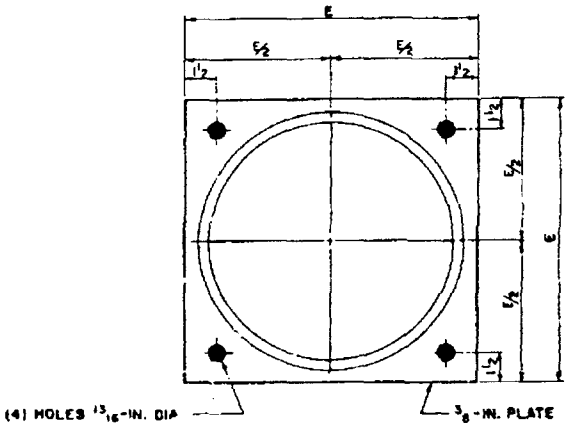
MAXIMUM ALLOWABLE WORKING PRESSURE : 5 PSI@ 450°F (SERVICE)

MATERIAL AND FABRICATION : IN ACCORDANCE WITH VALVE AND PIPING SPECIFICATION 1B2, EXCEPT AS OTHERWISE NOTED (PLATE MATERIAL, ASTM A36, OR EQUIVALENT WELDABLE QUALITY).

TEST : 7-1/2 PSI, HYDROSTATIC.

CONNECTION ORIENTATION SHALL BE AS SHOWN IN ELEVATION, UNLESS OTHERWISE INDICATED.

[1] "THREDOLET", MANUFACTURED BY BONNEY FORGE AND TOOL WORKS.



BASE PLATE DETAIL

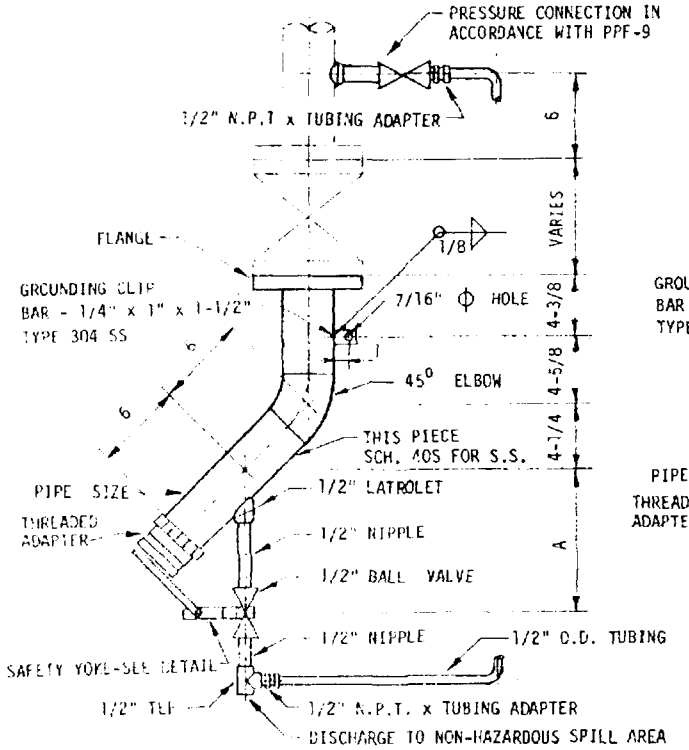
UNLESS OTHERWISE INDICATED, ALL DIMENSIONS GIVEN IN INCHES.

936-130-003

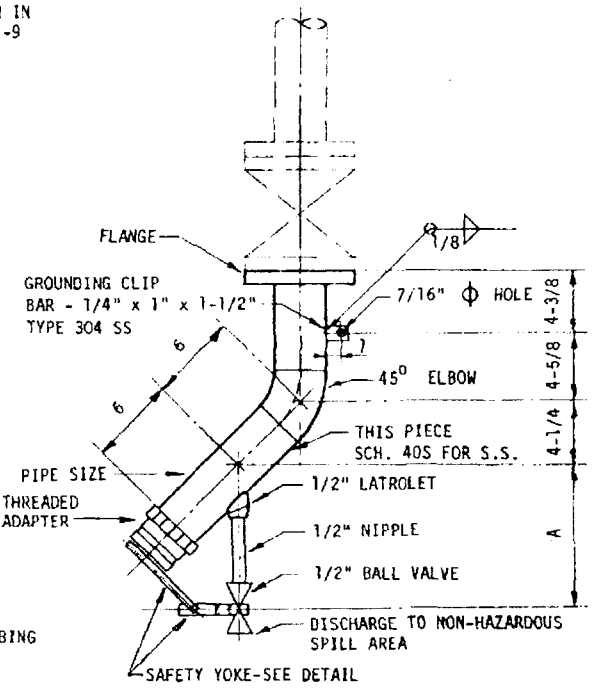
16.6.10.1

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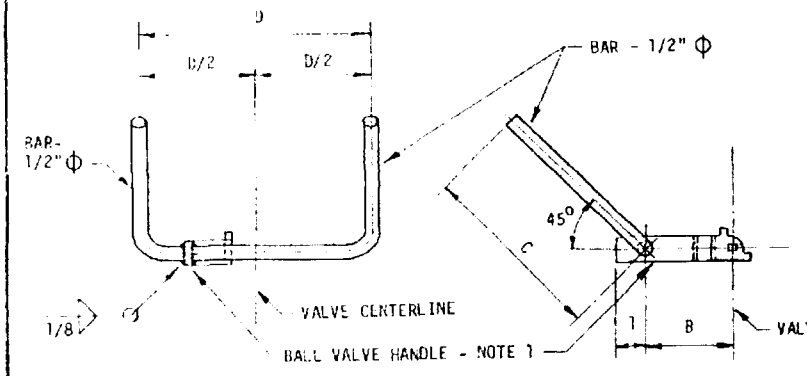
TRANSFER HOSE CONNECTIONS
LIQUID SERVICE



TYPE A (Note 2)



TYPE B



SAFETY YOKE DETAIL

DIM.	PIPE SIZE 1-1/2	2	3	4	6
A	8-7/8	9-1/2	10	10-5/8	11-1/4
B	3-1/2	3-1/4	3	3	2-1/2
C	4-7/8	6-1/2	6-1/2	7-3/8	9-1/8
D	6-1/8	6-1/4	8	9	12-3/4

NOTES:

Except as noted, materials shall be in accordance with the Valve and Piping Specification listed on the flow diagram. Use only for carbon steel and stainless steel specifications. See Note 3 for ball valve.

Verify in field that the safety yoke prevents the female hose coupling cam arms from opening when the ball valve is closed.

1. Cut to noted length.
2. Type A shall be used when backwashing, purging, or sampling is required.
3. Use BA-316 for carbon steel specifications and BA-1191 for stainless steel specifications. Remove hex handle and install special handle. Install valve such that the weight of the safety yoke tends to close the valve.

Unless otherwise indicated, all dimensions given in inches.

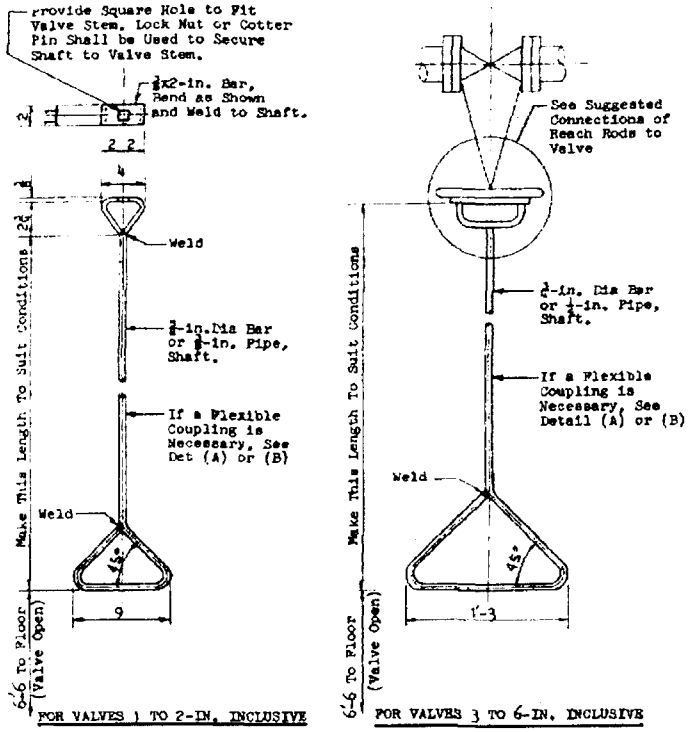
16.6.10.1

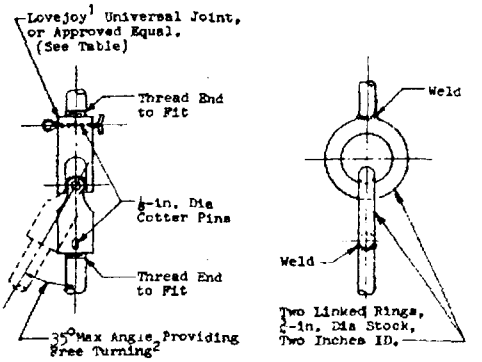
444

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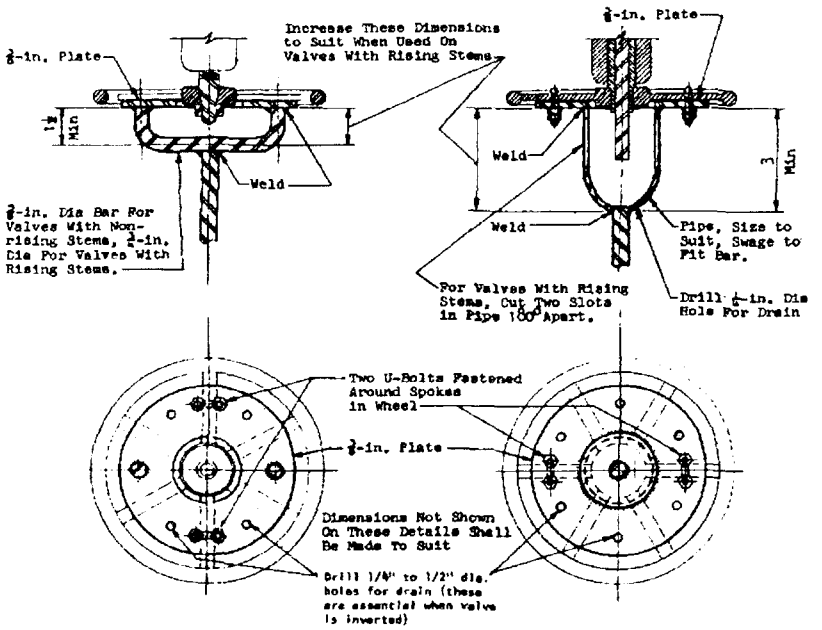
REACH RODS FOR OVERHEAD VALVES





(ALTERNATIVE FLEXIBLE COUPLINGS FOR REACH RODS)

REACH ROD SIZE and DESCRIPTION	LOVEJOY[1] UNIVERSAL JOINTS	
	CATALOG NO.	DRILL and TAP
⅜-in. Dia Bar	D-8	⅜-in. 16NC-2B, ASA B1.1
¾-in. Nom Pipe	D-8	¾-in. 18NPT, ASA B2.1
½-in. Dia Bar	D-10	½-in. 10NC-2B, ASA B1.1
1-in. Nom Pipe	D-10	1-in. 14NPT, ASA B2.1



SUGGESTED CONNECTIONS OF REACH ROD TO VALVE

(These Details are offered as suggestions only and are not intended to Eliminate the use of other Acceptable Connections)

NOTE:

Exact Location of Flexible Coupling on Rod, and any necessary Bracing or Bearings, shall be Detailed and Provided in Field.

Do Not use for Caustic, Acids, or other Hazardous Solutions. Check possibility of Fouling Leakage or Freezing of Fluid if Valve Stem is installed in any but Upright Position.

All Threaded Connections on Reach Rods, and Handwheel to Valve Stem Connections, shall be secured by means of Locknuts or Cotter Pins.

[1]Lovejoy Flexible Coupling Co., Chicago, Ill.

[2]Where Angles Greater than 35° are Required, or for other Special Conditions, Consideration shall be given to the use of CONSECO Bevel Gear Universal Joints as Manufactured by Condenser Service and Engineering Co., Inc.

UNLESS OTHERWISE INDICATED, ALL DIMENSIONS GIVEN IN INCHES.

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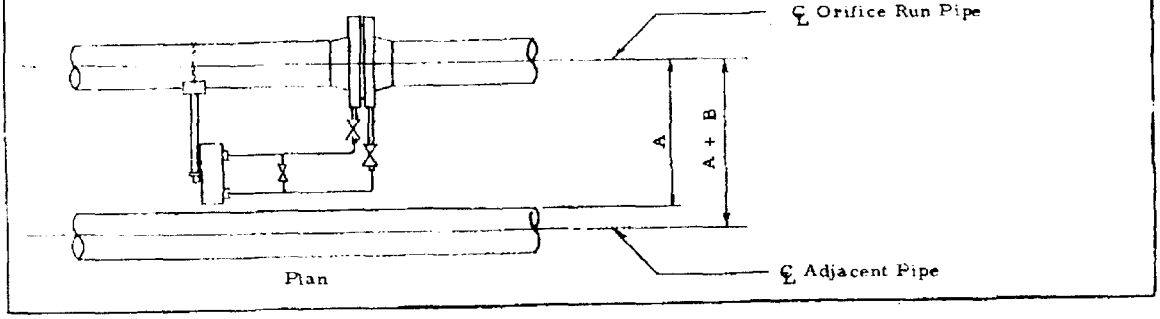
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MINIMUM CLEARANCES FOR MOUNTING ORIFICE RUN INSTRUMENTS CLOSE COUPLED ON SIDE OF LINE

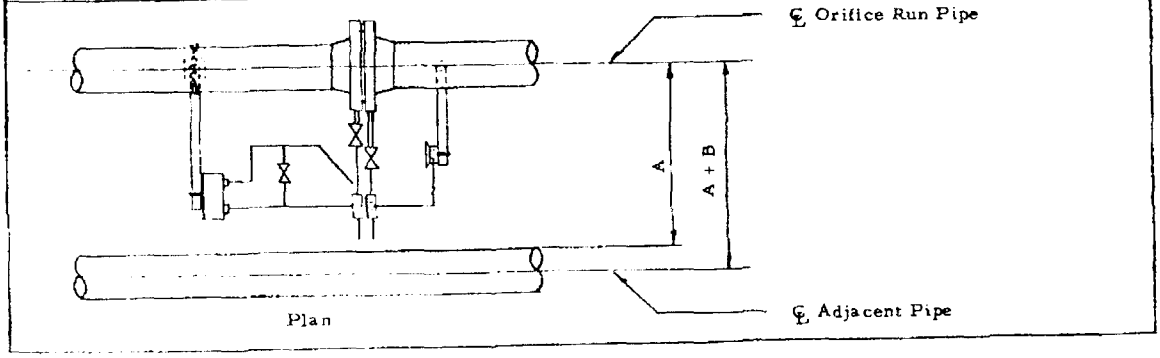
Reference: IN-9.4 and IN-9.76

Orifice Run Pipe Size	1	1½	2	2½	3	4	6	8	10	12	14	16	18	20	24	30
Dimension "A" 150													26	27	29	33
300	16	17	17	17	18	18	20	21	22	24	25	26	27	29	31	35
600	16	17	17	17	18	19	20	22	23	24	25	27	28	29	32	
900					18	19	21	23	24	25	26	27	29	30	34	
1500	16	17	18	18	19	20	21									



Reference: IN-9.6 and IN-9.7

Orifice Run Pipe Size	1	1½	2	2½	3	4	6	8	10	12	14	16	18	20	24	30
Dimension "A" 150													32	33	35	39
300	22	23	23	23	24	24	26	27	28	30	31	32	33	35	37	41
600	22	23	23	23	24	25	26	28	29	30	31	33	34	35	38	
900					24	25	27	29	30	31	32	33	35	36	40	
1500	22	23	24	24	25	26	27									



NOTE: Dimension "B" = Adjacent Pipe Insulation O.D. / 2
or Adjacent Pipe O.D. / 2 if uninsulated

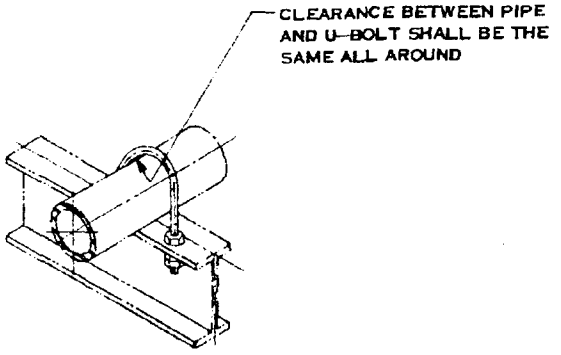
16.6.10.1

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GUIDE AND ANCHOR

GUIDE



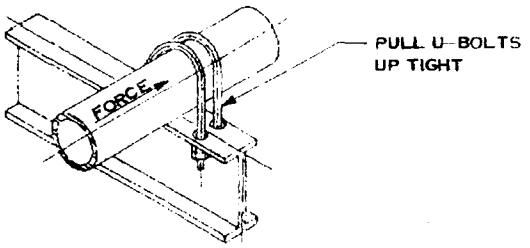
MPS4-A

PIPE SIZE	U-BOLT
1/2	U-39
3/4	U-40
1	U-41
1-1/2	U-42
2	U-43
3	U-44
4	U-45
5	U-46
6	U-47
8	U-48
10	U-49
12	U-50
14	U-51
16	U-52
18	U-53

GUIDE
SYMBOL ILLUSTRATION

MPS4 - A - 6
STD. NO. — PIPE SIZE

ANCHOR



MPS4-B

PIPE SIZE	U-BOLT	FORCE (LBS)*
1/2	U-38	1200
3/4	U-39	1200
1	U-40	1200
1-1/2	U-41	1200
2	U-42	1200
3	U-43	1200
4	U-44	1200
5	U-45	1200
6	U-46	2000
8	U-47	2000
10	U-48	3000
12	U-49	4000
14	U-50	4000
16	U-51	4000
18	U-52	5000
20	U-53	5000

ANCHOR
SYMBOL ILLUSTRATION

MPS4 - B - 6
STD. NO. — PIPE SIZE

* ANCHOR IS GOOD FOR FORCES SHOWN. HOWEVER, THE PIPE MUST BE ANALYZED TO DETERMINE THAT IT IS NOT STRESSED. STRUCTURAL MEMBER OR CONCRETE PIER TO WHICH ANCHOR IS ATTACHED MUST ALSO BE ANALYZED TO MAKE SURE IT IS GOOD FOR THE PIPING REACTION.

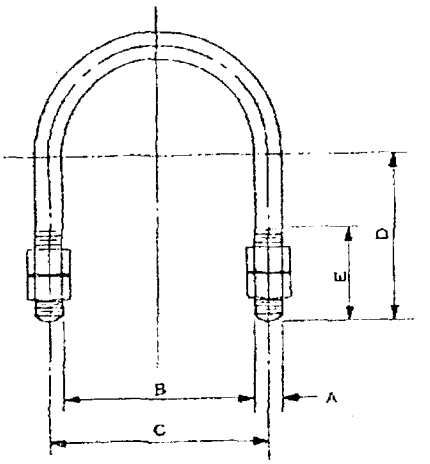
Unless otherwise indicated, all dimensions given in inches

16.6.50.1

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U-BOLT DETAILS



U-BOLT NUMBER	DIMENSIONS				
	ROD "A"	B	C	D	E
U-38	1/4	15/16	1-3/16	2-3/4	2-3/8
U-39	1/4	1-1/8	1-3/8	2-3/4	2-3/8
U-40	1/4	1-3/8	1-5/8	2-3/4	2-3/8
U-41	3/8	2	2-3/8	3	2-1/2
U-42	3/8	2-7/16	2-13/16	3-1/4	2-1/2
U-43	1/2	3-9/16	4-1/16	4	3
U-44	1/2	4-9/16	5-1/16	4-1/2	3
U-45	1/2	5-5/8	6-1/8	5	3
U-46	5/8	6-3/4	7-3/8	6-1/8	3-3/4
U-47	3/4	8-3/4	9-3/8	7-1/8	3-3/4
U-48	3/4	10-7/8	11-5/8	8-3/8	4
U-49	7/8	12-7/8	13-3/4	9-5/8	4-1/4
U-50	7/8	14-1/8	15	10-1/4	4-1/4
U-51	7/8	16-1/8	17	11-1/4	4-1/4
U-52	1	18-1/8	19-1/8	12-5/8	4-3/4
U-53	1	20-1/8	21-1/8	13-5/8	4-3/4

MANUFACTURER: GRINNELL FIG. 137 OR APPROVED EQUAL.

NOTE:

MATERIAL SHALL BE STEEL IN ACCORDANCE WITH ASTM A36, HOT DIP GALVANIZE IN ACCORDANCE WITH ASTM A123 OR A153 AS APPLICABLE.

Unless otherwise indicated, all dimensions given in inches

16.6.50.1

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VIII. MACHINERY (W. P. Reeves)

Let's talk now about some of the problems you may experience with rotating equipment and machinery. We'll talk first about pumps - and then about heavy equipment.

A. Pumps

A pump should be recognized as a high risk piece of equipment and a potential source of maintenance and operating problems. Pumps are of cast construction - sometimes the casting is not too good. They have mechanical seals - which require proper installation and maintenance. They are a potential source of product leakage greater than any other piping arrangement, they have electrical safety problems, they have mechanical safety problems, they have chemical safety problems.

Here are some tips on pump operation. One is simply that if you run pumps dry - or unprimed - you can expect problems.

A second is that pump rotation is important - even critical in some cases. At the very least the efficiency, capacity, and head of the pump is affected if you run the pump backward. In the case of Duriron Mark II and some other pumps, the impeller - which is screwed to the shaft - will back off the shaft and become wedged on the pump volute. Other impellers may actually shear a pin and come off the shaft.

A third tip concerns mechanical seals. About 3 out of 4 pumps are equipped with a mechanical seal. Remember that if a mechanical seal is operated wihout seal cooling - as in dry pump - then seal damage is assured. Ethylene pumps - which are multistage high speed Bingham pumps - have a mechanical seal with a rotating tungsten Carbide seal face that will heat check if the seal is run without cooling, and the face has been known to shatter.

If a pump can be started remotely, warning signs should be provided at the pump location notifying personnel of this possible safety hazard.

UCC 021286

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All pumps require a guard for the shaft coupling. Existing pumps, or new pumps purchased without a guard shall be fitted with a guard in accordance with SF-18. C&P specifications state that guards purchased with a pump will comply with current OSHA regulations.

As you know, a centrifugal pump raises the temperature of the fluid being transferred due to the inefficiency of the pump. The temperature rise which would occur under all possible conditions of flow must be carefully checked to insure that heat sensitive liquids are not overheated, and to insure, for all liquids, that the temperature limitations of the materials of construction are not exceeded.

Always check the length of time a pump may operate at zero flow without overheating using:

$$\text{Temp. Rise, } ^\circ\text{F/Min.} = \frac{(\text{BHP shut-off})\ (42.4)}{(\text{Weight of liquid in pump})\ (C_p)}$$

BHP shut-off is horsepower input at zero flow, as read from pump performance curves. C_p is liquid heat capacity Btu/lb.F°. Weight is in lbs. Estimate the minimum safe flow rate for continuous heat dissipation during extended operation. Temperature rise in a pump during reduced flow is given as:

$$\text{Discharge temp-suction temp.} = \frac{HD(1\text{-Eff.})}{788\ C_p\ \text{Eff.}}$$

Where temperatures are in °F. HD is total head in ft. Eff. is pump efficiency at the reduced flow rate (brake HP/theoretical HP).
C_p is heat capacity (Btu/lb.°F).

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Over pressure relief must be considered on all pump installations. Centrifugal pumps require relief valves if the pump shut-off head exceeds the pressure rating of the system. The relief valve shall be sized to accommodate the full flow of the pump without creating excessive pressure accumulation in the system.

Centrifugal pumps require pressure relief if the pump could be operated with both the suction and discharge valves closed. Any pump operating with both suction and discharge valves closed without pressure relief may rupture due to thermal expansion of the liquid, especially in the case of heat sensitive liquids.

Positive displacement pumps require relief devices in the event the discharge line is shut off or restricted. The relief valve shall be sized to accommodate the full flow of the pump without creating excessive pressure accumulation in the system. When relief valves are required for positive displacement pumps, internal relief valves are not acceptable safeguards. If a pump is manufactured with an internal relief valve, no credit is taken for this relief capability.

For maintenance purposes, all pumps require provisions for safe drainage of the pump casing and the suction and discharge piping. For centrifugal pumps, typically a drain valve on the pump casing will be adequate. For positive displacement pumps, drain valves may be required on both the suction and discharge piping, because the design of the pump may prevent the liquid from draining through it. The discharge from the drain connection should be visible and should be directed so that personnel are not injured in the event the drain valve is inadvertently left open during pump startup.

A pump which is improperly specified can be a source of constant maintenance problems. A good example is the pump that requires an abnormally high discharge pressure at a relatively low flow rate, and sometimes to solve this problem it is expedient to throw in a pump that is capable of very high volumes at the required head, just so the head requirements can be met. In this case, what actually occurs is that the horsepower is put into recirculated liquid in the pump, and the pump heats the fluid. Under these conditions, the mechanical and corrosion problems on the pump are increased. Cases

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have been found where there was evidence of flashing or cavitation in the pump - resulting in continual maintenance problems.

Pump suction and discharge piping should be supported independently of the pump. Expansion joints shall not be used if the necessary flexibility can normally be provided by other means. Pumps have been mounted on sliding, spring supported baseplates to avoid the use of expansion joints. When check valves or fast acting control valves are used in the discharge line of a pump, it may be necessary to provide a means to prevent the effect of hydraulic hammer.

Special criteria have been developed for certain pumping problems - for example - for ethylene oxide pumps. Questions on minimum instrumentation for ethylene oxide pumps should be referred to the Engineering Manager of the Oxide Business Team.

For pumps handling liquified gases, single seals with throttle bushings may be used if the pressure in the cavity between the throttle bushing and the seal face is monitored. For pumping moderately hazardous liquids, a throttle bushing in the seal gland should be used to reduce leakage in case of seal failure. The throttle bushing will not prevent leakage in case of a seal failure, but will restrict it to a small leak and thus minimize fire danger and personnel exposure. Moderately hazardous liquids are defined as flammable liquids that are being pumped at temperatures above their flash point but below their auto-ignition temperature, or liquids that are moderately hazardous with respect to their toxicity or personnel contact. Examples of these types of liquids are hot kerosens, 50% caustic, and oleum (strong sulfuric acid).

When pumping highly hazardous liquids, precautions must be taken to prevent escape of the fluid to the atmosphere. The common method is to provide a double inside mechanical seal or tandem mechanical seals with a buffer liquid (usually a lubricant) between the seals. "Highly hazardous liquids" are those that are: 1) Highly flammable and/or liquified gases, or 2) pumped at temperatures above their auto-ignition temperature, or 3) pyrophoric, or 4) very toxic. Pumps handling moderately or highly hazardous

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liquids should be located in well ventilated, open areas to prevent accumulation of flammable or toxic vapors and to reduce fire exposures. Location of such pumps under pipe racks should be avoided. A trapped drain near the pump will safely carry away the process spills.

Additional precautions must also be taken when pumping liquids that are heat sensitive (such as glyoxal, ethylene oxide, vinyl chloride, vinyl acetate, peroxides, etc., which can be hazardous if allowed to be overheated). These precautions include protection for pumping against a closed discharge, and can take one or more of the following forms: An automatic pump shut off or alarm on low flow, an automatic pump shut off or alarm on high temperature at the pump discharge, a bypass around the control valve to prevent complete shut off, and pressure relief valves.

The use of temporary strainers in the pump suction line should be considered in all new installations or following major maintenance to a unit. There is also a standard which covers the design of permanent strainers if they are required. See Figure 1 and 2 (PPM-11A).

There are some special do nots that you should think about when considering a pump for a given task. First, cast iron pumps should not be used for highly hazardous fluids, flammable liquids, or at pressures above 200 psig or temperatures above 200°C. Use steel or ductile iron. If ductile iron is used however, it must be fully watersprayed, because it will revert to cast iron if overheated. Check the material of construction of your pump - there are too many recorded incidents of cast iron pump failure in caustic service. Second, the use of diaphragm pumps is not recommended in an area where a great variety of cemicals are being handled. The diaphragm material must be resistant to all of the chemicals used - not just some of them. An example of where not to use a diaphragm pump is in a chemical mixing unit where a great many plant mixtures are made. Refer to Safety Standard SF-21. Third, a word of caution to those using a Wilden air-operated sump pump. Several near-miss incidents have been recorded - they all state that when the air supply was turned on a valve cover was blown off the pump. The reason is that the valve cover is held in place by a snap ring. The snap ring groove had been battered by some one using a hammer or other tool to free a sticking valve and the snap ring could not seat properly in the groove.

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B. Compressor and Turbines

For heavy rotating equipment gas turbines, compressors steam turbines - there are some rules that the Machinery Reliability Group insist be followed:

1. Overhauls are to be made at definite, preset intervals. There is a no "waiting until next month" - when the operational interval is up, the machines should be shut down for overhaul.

2. All worn parts are to be replaced during an overhaul. Trying to strength another short time out of a worn part does not pay dividends.

3. Detailed life history records are kept on the socalled consumable parts, and these parts are replaced after their life span has been reached regardless of their condition.

4. The entire machine operates on a predictable life span - and scheduled actions depend on the point in their life span.

Many pieces of operating equipment throughout the C&P plants are equipped with automatic overspeed trip devices. It is extremely important that these devices be kept in service, and in good working condition. Many C&P plants have adopted mandatory periodic inspections of all such devices, as well as testing the devices in any of the following situations: After repairs have been made to the equipment served, or upon replacement of the device, or if there has been a malfunction of the trip device during normal operation. C&P has numerous examples of problems with turbines and compressors.

On a 3500 KV generator that was driven by a steam turbine, the steam turbine overspeeded and the speed governor could not or did not react fast enough to save the generator. The steam turbine itself was not damaged. Another - a steam turbine was driving a Bingham pump. The coupling broke and the steam turbine went to 40M rpm before it blew up. The overspeed governor did not stop the turbine.

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Do you know how to start a turbine - instructions are given at the end of this section.

In one accident there were three air compressors - all steam turbine driven - all three units in parallel. One of the compressors was shut down for maintenance. The discharge valve on the compressor was not closed - an oversight. The check valve on the discharge of the compressor leaked, and the unit began to run backwards, the turbine now being driven by the backwards running compressor. Before anything could be done the compressor/turbine destroyed itself - running backwards.

Cooling water to the low stage of a Fuller Air Compressor at a C&P plant froze bursting the jacket. Water had been valved off the compressor while it was down, and the water was not drained out of the system.

In another case, an Ingersoll Rand compressor auxiliary oil pump turbine disintegrated due to overspeed. It was determined that operator was shutting down the compressor, and had drained the oil from the sump, but was called from the job before he had closed the steam valve to the oil pump turbine. An overspeed trip and fail safe system had not been provided for the turbine.

The Machinery Reliability Group has developed a number of different diagnostic procedures to monitor the performance of large pieces of rotating equipment.

Vibration measurements, temperature measurements, and the axial positions of the shafts are all used to check on the large turbines - compressors, etc. In addition, sound data at all frequencies is taken, analyzed, and used to identify abnormal conditions - even in some cases to identify items that are likely to fatigue. We now are able to use appropriate combinations of vibration, temperature, and axial shaft measurements to automatically shut down machines - or alarm or whatever.

Care and caution need to be constantly preached. An operator opened the filler valve to a turbine oil reservoir, and in due time the reservoir overflowed. This condition in the reservoir prevented the drain lines from 20

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bearings from draining the hot oil back into the reservoir. The fire started first in the gear box and eventually resulted in a total unit shutdown with major damage to the heavy rotating equipment.

A 450 HP vent gas compressor using 200 psi motivating steam and discharging to the unit 20 psi steam header tripped off line at shift change. It was shut down and both the suction and discharge valves were closed by the off-going operator. The on-coming operator normally did not close the discharge valve, so he started opening the inlet vale which put full 200 psi pressure on the casuing which was only good for 70 psi. The casing was equipped with only a Sentinel alarm whistle and no full size safety valve. About the instant the full pressure was reached, the upper half of the casing split in half and a segment weighing about 60-70 pounds flew over the operator's head. The procedures called for having the discharge valve open. Either an interlock system to prevent the inlet valve from being opened until the discharge valve was opened - or a full size safety valve should be located between the casing and the discharge valve.

You might not think of a cooling tower fan as a piece of rotating equipment, but a C&P plant recently discovered that galvanic corrosion between cast aluminum fan blades and the cast iron hub is a potential safety hazard and problem. Several aluminum blades were thrown through the wooden housing on top of a cooling tower - no one was injured. A T&I procedure was developed to quickly determine the ned for hub or crosspiece replacement. Fiberglass fans have proven to be a safer factory replacement for the aluminum blades.

A word about conveyors and grinding mills or hammer mills this type of equipment tends to coast for several seconds - even minutes - after it is shut down.

C. Summary

Always regard a pump as a high risk piece of equipment, a potential source of maintenance, operating and safety problems. Mechanical seals are subject to failure - with loss of product to the outside. Pumps raise the temperature of the fluid being pumped - a good thing to remember especially in the case of heat sensitive liquids. Remember that pump systems

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require overpressure relief even the pump itself if it can be valved it requires overpressure relief due to liquid thermal expansion. Always consider safety showers, eye baths, spray systems, and area drainage around pumps. Consider carefully every use of a cast iron pump - restrict cast iron pumps to those liquids which can safely be handled in such a material of construction. In heavy equipment, make overhauls at definite intervals, and keep a history of the machine performance. Make mandatory the regularly scheduled and all special inspections of over speed trip devices.

LARUE'S COMPRESSOR START-UP

DE RULES FOR MAKE-START DE TUR-BEEN

DE FIRS TING IS FOR COMENCE DE HOIL PUMP. WHEN DE PRESS-SUR HITS HO-K, DEN COMENCE DE TUR-BEEN. HOPEN DE THROTTLE WALVE PRETTY SLOW, SO DO STEAM WHAT HIS TURN TO WATER HAS COME OUT DE LILIE HOLE ON DE BOTTOM. WHEN DE WATER ANIT NO MORE PLUG DE LILLE HOLE, SHUT DE WALVE, HAN HOPPEN DE THROTTLE SOME MORE WHEN DE TURBEEN HAS START FOR TURN OVER (NOT DE HOLO MACHINE, JUST DE ROTOR). DEN SHUT DE THROTTLE WALVE.

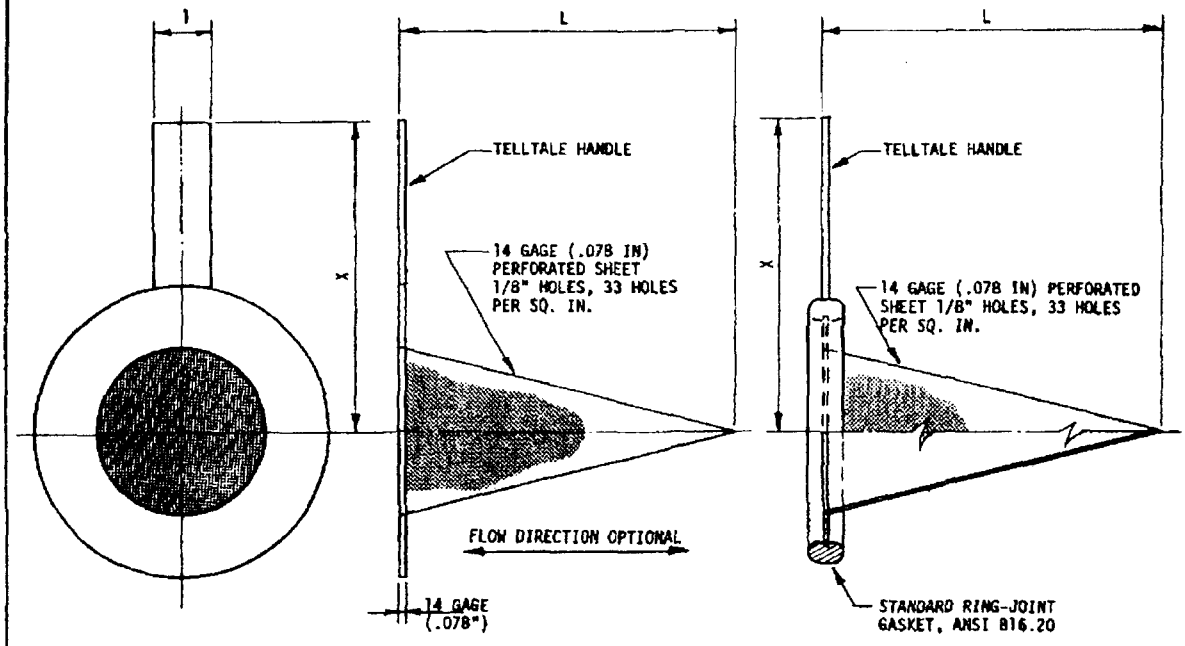
NOW'S DE TIME FOR LOOK TO SEE HIF YOU HEAR SOMETHING: WHEN YOU LOOK GOOD, SHE IS HO-K FOR MAKE GO MORE FAST. LOOK DE HOIL PRESSURE, LOOK DE WATER, LOOK DE STEAM, LOOK HEFRYTHING, AND HIF SHE'S HO-K, TOOK HIM TO DE TOP SPEED. NOW HIF HE HAINT BLOW UP, BY NOW SHE IS HO-K FOR PUT DE LOAD. TRY FIRS DE HEFRYTER TO SEE IF SHE WORK. PUT YOU HAN HON DE WIRE, DE HODDER HAN ON DE TURBEEN. HIF YOU HAN FEEL LIKE YOU FOOTS ASLEEP SHE'S HOK. NOW HEFRYTHING HIS GOOD FOR DE LOAD SO DE SWITCH HAN LET HER GO. HALL DE TIME DE HERGINEER MUST WALK AROUND DE TURBEEN AND LOOK FOR SOMETHING. HIF YOU NO FIND, DATS GOOD. BUT LOOK HANNYWAY SO YOU BOOS TINK YOU GOOD HENGINEER.

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UNION CARBIDE **STANDARD**

CHEMICALS/PLASTICS

TEMPORARY STRAINERS FOR SUCTION LINES
NONCRITICAL SERVICES



STRAINER FOR USE WITH RAISED OR PLAIN FACE FLANGES
(SUFFIX R/FF ON SERIES DESIGNATION)

STRAINER FOR USE WITH RING - JOINT FLANGES
(SUFFIX RJ ON SERIES DESIGNATION)

NOMINAL PIPE SIZE		2	2 1/2	3	4
L	SERIES PCL-*	6	7	9	11 1/2
	SERIES PCS-*	4 1/2	5 1/2	6 1/2	8 1/2
X		5 1/2	5 3/4	6	6 3/4

NOTE:

2", 3", AND 4" STRAINERS OF MORE RUGGED DESIGN AND STRAINERS FOR SIZES ABOVE 4" ARE COVERED BY UCC STD PPM-11B.

TEMPORARY STRAINERS SHOWN ON THIS STANDARD SHALL BE AS MANUFACTURED BY THE MACK IRON WORKS COMPANY, SANDUSKY, OHIO, OR APPROVED EQUAL. THEY ARE AVAILABLE FOR USE WITH RAISED - OR FLAT-FACE FLANGES IN 150-, 300-, AND 600-LB RATINGS, AND FOR USE WITH RING-JOINT FLANGES IN 300- AND 600-LB RATINGS.

THESE TEMPORARY STRAINERS ARE MADE IN LONG (PCL) AND SHORT (PCS) MODELS. IN GENERAL, THE LONG MODEL SHOULD BE SPECIFIED FOR MOST INSTALLATIONS, BECAUSE OF THE GREATER AMOUNT OF OPEN AREA PROVIDED. SHORT MODEL STRAINERS MAY BE SPECIFIED WHEN SPACE FOR INSTALLATION IS LIMITED.

TEMPORARY STRAINERS SHALL BE USED IN SUCTION LINES AND STEAM INLET LINES OF COMPRESSORS, PUMPS, AND OTHER MACHINERY WHEN SO SPECIFIED BY ENGINEERING OR OPERATING DEPARTMENT. USE OF TEMPORARY STRAINERS SHALL NOT REPLACE PROPER CLEANING OF LINES AND EQUIPMENT.

ORIGINAL PIPING DETAILS SHALL PROVIDE FOR EASY INSTALLATION AND REMOVAL OF TEMPORARY STRAINER.

TEMPORARY STRAINER SHALL BE INSTALLED IN LINE PRIOR TO FIRST RUNNING OF THE MACHINE IT IS TO PROTECT. STRAINER SHALL BE REMOVED AND CLEANED PERIODICALLY AFTER MACHINE HAS BEEN PLACED IN SERVICE. CARE SHALL BE TAKEN TO REMOVE ANY DEPOSIT FROM LINE ON UPSTREAM SIDE OF STRAINER. WHEN A REASONABLE NUMBER OF INSPECTIONS INDICATE THERE IS NO MORE FOREIGN MATTER IN THE SYSTEM, STRAINER SHALL BE PERMANENTLY REMOVED AND RETURNED TO STORES DEPARTMENT. DO NOT INSULATE FLANGED JOINTS UNTIL STRAINER IS REMOVED.

MATERIAL SPECIFICATION:

ALL MATERIAL, EXCEPT RING-JOINT GASKET, SHALL BE TYPE 304L OR 316L STAINLESS STEEL. RING JOINT GASKET, IF REQUIRED, SHALL BE SOFT IRON (90 BRINNEL MAXIMUM HARDNESS).

*ADD SUFFIX INDICATING TYPE OF FLANGES WITH WHICH STRAINER IS TO BE USED.

Unless otherwise indicated, all dimensions given in inches.

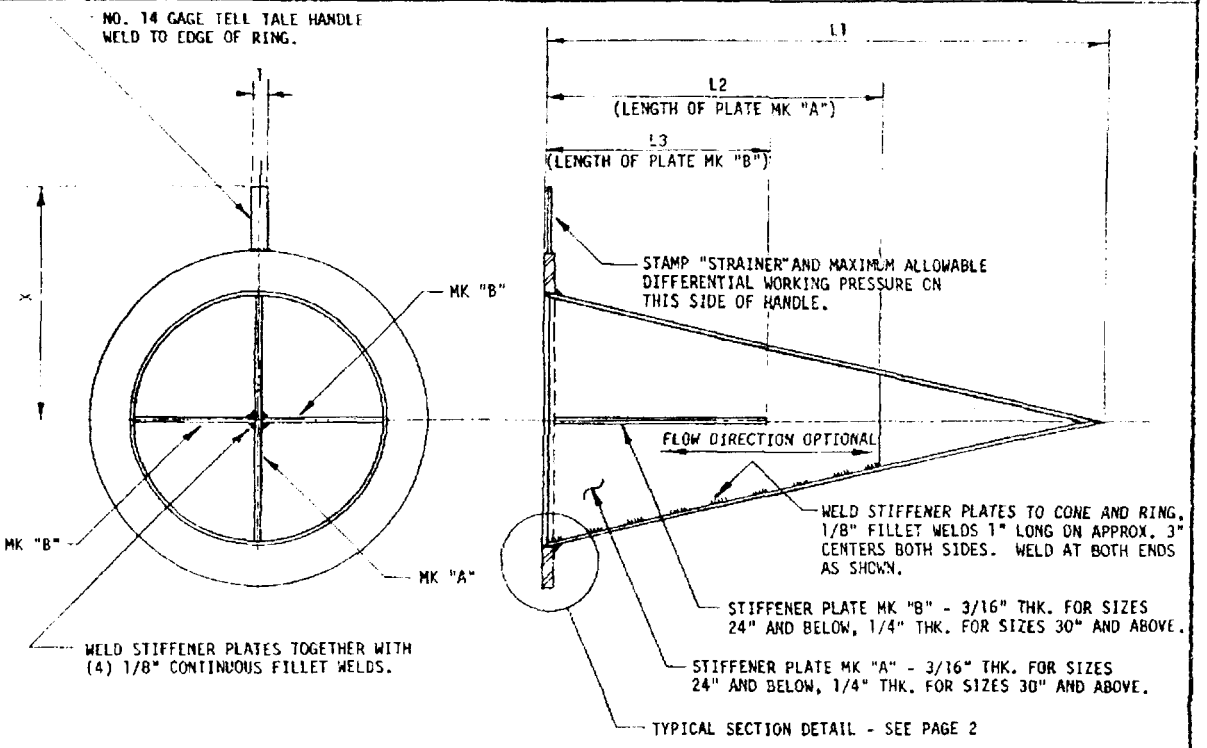
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Fig. 1

16.6.10.1

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TEMPORARY STRAINERS FOR SUCTION LINES CRITICAL SERVICES



NOM. SIZE	MAX. DIFF. PRESS. PSI*	D1	D2 150 LB FLG.	D2 300 LB. FLG.	D2 600 LB. FLG.	L1	(1) L2	(1) L3	T	X
48	1	46	SEE PURCHASE ORDER			96	80	72	3/8	31 3/4
42	1.25	40 1/8				84	68	60	3/8	28 1/2
36	1	34				72	56	48	3/8	24 1/2
30	1.5	28 1/8				60	44	36	3/8	21 1/2
24	3	22 1/4	28 1/4	30 1/2	31 1/8	48	32	24	1/4	18 1/2
20	5	18 1/4	23 7/8	25 3/4	26 7/8	40	24	16	1/4	16 3/4
18	6	16 1/4	21 5/8	23 1/2	24 1/8	36	20	12	1/4	15 1/2
16	6	14 1/4	20 1/4	21 1/4	22 1/4	32	16	8	1/4	14 1/4
14	6	12 1/4	17 3/4	19 1/8	19 3/8	28	12	4	1/4	13
12	4	11	16 1/8	16 5/8	18	24	8	--	1/4	11 3/4
10	6	9	13 3/8	14 1/4	15 3/4	20	4	--	1/4	10 1/4
8	6	7	11	12 1/8	12 5/8	16	--	--	1/4	9
6	2	5 1/4	8 3/4	9 7/8	10 1/2	12	--	--	1/4	7 3/4
4(2a)	8(2b)	3 1/4	6 7/8	7 1/8	7 5/8	8	--	--	1/8(2c)	7
3(2a)	4(2b)	2 1/2	5 3/8	5 7/8	5 7/8	6 1/2	--	--	1/8(2c)	5 5/8
2(2a)	4(2b)	1 11/16	4 1/8	4 3/8	4 3/8	4 1/2	--	--	1/8(2c)	4 3/4

*MAXIMUM ALLOWABLE DIFFERENTIAL WORKING PRESSURE AT 300°F, PSI

SEE PAGE 2 FOR NOTES.

Unless otherwise indicated, all dimensions given in inches.

16.6.10.1

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Fig. 2

UCC 021296

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IX. DISTRIBUTION FACILITIES (W. P. Reeves)

The same careful consideration of details is required for the design and operation of shipping facilities as is required for processing units. The checklists of physical and chemical properties and of potential sources of trouble are as much for the Shipping Department employees as they are for those in production units.

Special arrangements must be made so that the Shipping Department employee will be as fully informed concerning the unusual behaviors, the potential hazards, and the special precautions peculiar to each reactive chemical as are the operators in the production units. It should be the responsibility of each operating unit head to make sure that the Shipping Department employees who handle reactive chemicals from a unit are well enough informed to know about the potential hazards, and the importance of following strictly the prescribed procedures.

A. Design and Layout

Proper design and arrangement of shipping facilities is just as vital to the safe handling of reactive chemicals as is the design of the processing unit itself.

Tank car spots or other shipping facilities for reactive chemicals should be isolated from similar facilities for chemicals which would be dangerous contaminants. For example, it is known that caustic was unloaded at a spot adjacent to the acrolein loading platform at a C&P plant prior to the explosion. It was thought that a hose used for caustic might have inadvertantly been used also to load the acrolein car. This was proven not to be the case, but the point is it could have happened. The best way to avoid such possibilities is to keep the dangerous contaminants away. You should comply with separation spacing standard in the Layout Manual.

All lines used for loading - including liquid lines, vent lines, purge lines, and headers, should be single purpose lines. No cross connections with other chemical service lines should be permitted. Blind flanged branch connections should be eliminated. Lines should be color coded

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or othrwise identified. The use of hoses and other detachable equipment should be carefully controlled to make certain that no hazardous contaminant can be introduced.

Special precautions are needed to insure that the gas used for purging tank cars and other containers cannot introduce harmful contaminants. Ordinary plant nitrogen and fuel gas headers are unacceptable because of the opportunity for materials to back into these headers during operating upsets or errors. A single purpose purge and vent system is needed, with continual tests for harmful contaminants.

Service lines need to be properly labeled. A master file should be kept on the location of all service lines. Storage tanks should be properly labeled. A periodic inspection of all storage facilities is needed to insure proper maintenance and cleanliness.

B. Operations

A Shipping Department Manual of Operations should be prepared under the supervision of the Head of the Shipping Department containing detailed instructions for each cleaning, inspection, storage, mixing, and loading or transferring step in the handling of all chemicals. In this Manual of Operations reactive and hazardous chemicals should be given special consideration. Each set of instructions for a reactive or hazardous chemical should be so labeled in order to assure special attention on the part of shipping personnel. Each set of instructions should be written in such detail that even someone who is not familiar with chemicals could safely follow the procedures.

The instructions should include a section on precautionary measures required, including the reasons for each precaution so that its importance becomes immediately evident to those carrying out the instructions. Critical portions of the instructions should be pointed out and stressed.

The instructions should also include sections which indicate the best procedure to follow in the event of an emergency. This set of emergency instructions may be used to acquaint the personnel with some of the hazards involved in handling a given chemical, but it should also allay fears

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by indicating proper corrective steps. These instructions might well include information which could be used in the immediate surroundings to prevent the emergency from spreading. For example, a means of isolating the hazard might be given.

Each set of instructions should be reviewed periodically and revised when necessary. Any revisions should be reviewed by the Shipping Department Supervisor and by the appropriate production unit head. A periodic check should be made to make sure that the instructions are being followed. This periodic check will aid in revealing any inconsistencies or errors in the instructions.

The manual should include a Distribution chart listing of the chemicals that can be loaded in adjacent compartments - and those that cannot be. Refer to Section 3 - VII on Compatability.

The Distribution Department Head should insure that each supervisor and foreman in the Shipping Department understands fully the sections dealing with the handling and loading of reactive or hazardous chemicals. The supervisors and foremen should in turn see that all Shipping Department employees are thoroughly trained in handling and loading reactive or hazardous chemicals. Instructions should be carefully followed, no substitution or deviation from the instructions should be permitted except in event of an emergency, in which case emergency procedures should be followed in so far as possible.

C. Tank Trucks

C&P distribution standards are being developed to cover the installation of a tank truck loading area to include:

Personnel - shelter/lunch room located elsewhere at grade.

Safety - eye bath - safety showers - masks - breathing equipment.

Handrails on catwalk.

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Electrical equipment grounding.
Clearances - fire lane.
Spill collection system.
Grouping of utility lines.

In spite of the best possible physical installations, an unthinking individual can manage to have an accident - can manage to hurt or endanger himself and others. A case in point involving a tank truck - an LPG transport. An employee was attempting to unload propane from an LPG transport. He did not connect the liquid line hose prior to opening the liquid line valve, which resulted in the employee being sprayed with liquid propane. His knees, thighs, and groin area received first and second degree cryogenic burns. The protective apron being worn had been altered (cut off) so short as not to protect the areas it was designed to, and was unable to deflect the spray.

In another recorded incident, a tank trailer was being loaded, and overturned because the landing gear was not resting on a surface that would bear the cargo weight. The conclusion was that "A" frames or jacks must always be used - as per OSHA - but more importantly, just sound practice and judgement demands that the trailer be securely supported.

D. Drums

A C&P distribution standard on drum storage will be issued soon (FP-15) and will include:

- Hoods and fume disposal are to be provided where product requires it.

- In general, down draft vapor removal is preferable for personnel protection. (Institute has this system.)

- Special venting as required for toxic and flammable materials.

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- Electrical grounding per EL-64.

- Fill lines extend to bottom of drum.

- Provide spill pans - water flush non slip grating - platforms.

A major concern of Distribution is the safety problems involved in the re-use of drums. For reactive chemicals, the non-returnable or single purpose drum is preferred; they provide an extra safeguard against accidental contamination of the reactive chemical. The recycled drum requires cleaning - which means vigorous control and complete removal of the cleaning agent - or the recycled drum could be used for miscellaneous storage. Indiscriminate use of "empty drums" poses a continual safety hazard. One recorded example - a machinist received a severe injury when he used an empty drum to receive spent oil from a turbine during an oil change. When he removed the bung from the drum, vapors venting from the drum caused severe eye burns and intense lung irritation. Could an "empty drum" cause a similar incident in your plant?

Transfering material to and from drums requires compliance with grounding standards to prevent ignition by static electric discharge.

E. Tank Cars

C&P distribution standards are being developed to cover the installation of tank car loading/unloading area to include:

Safety items:

eye-bath/safety showers
breathing cylinders
shelter/lunch room
water cooler (drinking water)

Hand rails on catwalk
Elect grounding of all equipment
Clearances

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Spill collection system
Grouping of utilities

The tank truck and tank car racks are areas where you will find many safety problems - problems caused by defective swivel joints, defective couplings, defective unions, plugged valves, plugged dip tubes, gasket leaks, etc. Hoses are in use continually. When any temporary tie is made from a pipeline to the tank truck or tank car a safety problem exists. A review of several recorded incidents will illustrate some of the problems.

An employee receives facial burns while loading a phenol tank car. Phenol had sprayed from a Wheaton swivel joint on a loading arm. The cause of the accident was the absence of proper gasketing - the details of the swivel joint construction were misunderstood resulting in improper repair. In addition, the employee was not wearing the proper type of safety equipment required by phenol loading procedure.

A tank car was filled brim full of vinyl acetate at a product temperature of 6°F. The tank car was not shipped immediately, and 53 days later it was discovered that about 10 gallons of liquid had leaked out around the dome gasket. The loading procedure was changed to take into account the liquid coefficient of expansions.

A tank car had been filled with 9000 gallons of 63% caustic solution which contained sludge (solids). An attempt was made to unload the car thru the top unloading line by pressurizing the car, but the caustic solution did not flow. It was assumed that the top unloading dip tube was plugged, so the air pressure was bled off the car and the unloading line and fittings removed from the dip tube. A 12-foot long lance was inserted into the dip tube, hooked to an airline, and pressurized. Liquid caustic erupted from the annular space between the lance and the dip tube - the employee was sprayed with liquid caustic.

A tank car containing 50% caustic had been heated with steam on the coils for 48 hours. The employee who put steam on the coils did not vent the car to the air. It was later determined that the air vent valve did not have a handle on it. Another employee was instructed to unload the car. He

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climbed to the top of the car, did not check the vent valve, loosened the two-inch plug on the dip leg unloading valve, and opened the unloading valve. Not hearing any pressure surge, not seeing any liquid emitting from the loosened plug, he continued to loosen the plug until suddenly the plug blew off and caustic flowed out under pressure, splashing him in the face.

At a C&P plant, propylene was being loaded to two tank cars simultaneously. The union connecting the loading arm to one car separated. This allowed the loading arm to retract and swing around with such force that it bent the stem on the loading arm hand valve and jammed the arm against the walkway hand rail and adjacent piping. Propylene was discharging from the open end onto the dome area of a third tank car already loaded with propylene. Ignition of the propylene occurred. It was postulated that ignition could have been caused by 1) sparks due to metal-to-metal contact of the swinging loading arm, or 2) static electricity - the humidity was very low, or 3) sparks from exposed electrical wires - a light fixture was later found on the ground, broken but not burned - it could have been broken by the swinging arm. Why did this happen? The threads on the union on the loading arm were found to have been worn flat and would not hold the union together. Inspection of the union showed that it could be hand tightened, then the ears hit with a hammer for snugging, and it would come apart. So many times the safety of personnel and equipment depends upon the alertness and willingness of the individual to totally commit himself to the safe handling of his job.

F. Barges

C&P distribution standards are being developed to cover the typical barge handling installation.

Safety problems involved with barges are the same type of safety problems that distribution deals with on land - storage of hazardous and reactive chemicals, hoses, loading arms and couplings, unions, gasket leaks - plug the obvious problems involved with mooring and the vertical movements of the barge. Coast Guard regulations govern the handling of cargos on barges. Liscensed cargo handlers are required by the Coast Guard.

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G. Summary

The heart of safe operation in Distribution lies in the Shipping Department Operating Manual. In it you'll find data on physical and chemical properties of the chemicals handled, data on reactive and hazardous chemicals, emergency procedures that deal with handling of all chemicals entering the area. Shipping personnel must be trained just as operational personnel so that they are as familiar with the various chemicals as are the operators. Personnel safety and emergency procedures are an important part of every Distribution training manual. For reactive chemicals remember to keep your lines single purpose - remember to provide a special purging system that is free of contamination, and color code or otherwise identify the lines.

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X. INSULATION (N. W. Clauss)

The value of approved process equipment insulation, its limitations and service requirements are covered in this section. Insulation is primarily used for energy conservation, protection of personnel from hot metal surfaces above 55°C, and for fire protection.

All insulation systems specified by the Engineering Department were subjected to fire tests. The following standard compositions with fire resistive fastenings prevented surface temperatures from exceeding 1000°F. for a period of one hour in complete flame envelopment: calcium silicate, diatomaceous earth, asbestos fibers, asbestos fibers and perlite, cellular silica, and stainless steel sheet reflective type.

Insulation systems that could not pass the one hour test include cellular glass, vegetable cork, foamed polystyrene, aluminum reflective sheets, and glass fibers in standard systems.

Fire protection is provided by standard approved process insulations as specified in the Thermal Insulation Standards Manual.

A. Design Requirements

Insulation engineers must be provided with the expected operating temperature in any vessel, the nature of the process fluid with respect to its heat sensitivity or likelyhood of detonation, whether the flanges are to be left open or covered and provided with leak indicators and the type of tracing to be used. The maximum and minimum ambient temperatures must also be taken into account.

1. Fire Exposure

The heat absorbtion rate of process equipment can be reduced from 20000 Btu/hr/sq.ft. to 6000 Btu/hr/sq.ft. by the normal thickness of approved insulation. Heat absorbtion can be reduced to the same rate by water spray systems and when both insulation and water spray is used the heat absorbtion rate further reduces to 3000 Btu/hr/sq.ft.

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The cost of insulation is somewhat balanced by the decreased cost of pressure relief device size requirements. A decision made by the Operating Department to permanently remove insulation from four tanks to avoid corrosion problems, had to be countermanded because the relief capacity was designed for a heat absorbtion rate of 6000 Btu/hr/sq.ft. The relief capacity was only one third that required for uninsulated tanks.

Although acceptable in certain cases the fiber glass, flexible plastic foam, cork filled mastic and polyurethane foam insulation provides no resistance to fire exposure and equipment so insulated has a heat absorbtion rate of 20,000 Btu/hr/sq.ft. The use of polyurethane foam is described in the Criteria Section of the Safety Technology Manual in section 4.14.4.

2. Special Service

a. Process equipment handling ethylene oxide, acetylene, peracetic acid and dinitrotoluene require mandatory compliance with Insulation Specification 4. This specification also covers reactive chemicals.

b. Fire protective insulation is usually mandatory for materials of construction that do not resist fire such as aluminum, plastic, glass, tile and ceramics.

3. Flanges

When the process flanges are handling non-critical fluids the flanges may be left uninsulated for ease of maintenance. In cases where the flanges must be protected from fire exposure the flanges are provided with leak indicators and then fully insulated. Leak indicator specifications are covered in the Piping Technology Manual Spec. No. PPM-22.

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4. Heat Tracing

Steam tracing specification for process equipment are covered in the Insulation Manual Specs. TIM-205 and 206.

Electrical heat tracing is covered in the Electrical Technology Manual under Spec. No. EL-43.

B. Operating Concerns

1. Spontaneous Heating in Insulation

Most flammable liquids that have soaked into hot insulation can be expected to smoke and glow if enough air (oxygen) is present and the heat is not dissipated. Such situations cause a hot spot and constitute a potential ignition source. (There is also a corollary effect of lowering the ignition temperature of the liquid.) If the oxygen supply is deficient, heating will not start. If the oxidation is too exposed, it will be cooled and not be self-sustaining. If the liquid is too volatile, the mixture may be too rich to oxidize. Hundreds of organic chemicals, oils, resins, and residues have been involved in spontaneous insulation fires. Ethylene oxide, Dowtherm, polyethylene oils, and lubricating oils have caused many fires. Natural fibers are a greater source of difficulty than synthetic fibers; asbestos catalyzes some reactions and magnesia is one of the worst offenders. Iron rust, carbon, alkali, and other residues catalytically increase the rate of oxidation. Cellular glass and expanded silica resist spontaneous heating. The Thermal Insulation Group selects the most suitable kind of insulation for the process conditions, taking into consideration spontaneous heating effects. Reflective metal insulation has been a cure in one critical location. Metal shields have been used successfully at many locations to prevent spills from contacting the insulation,

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and it is probable that foil or film applied with adhesive would be a great improvement where metal cannot be fitted. Leak detectors should be used on flanges for ethylene oxide, Dowtherm, and polyethylene oils. No generally accepted solution has evolved, so flammable liquids must be kept out of the hot insulation. Glowing insulation masses can be extinguished most promptly by saturation with low surface tension, noncombustible fluids such as chlorobromomethane. Wet water is much less effective.

Because of the fact the insulation soaked with organic chemicals is an ignition source the leakage of material into insulation must be minimized by:

a. Adequate maintenance to preserve covering.

b Adequate maintenance to preserve the liquid tight condition at all times.

c. Relocation of frequently used valves which leak on hot insulation.

d. Adequate inspection schedules and corrective action. The field inspection of insulation systems is covered in Spec. No. TIM-705 of the Insulation Manual.

A fire causing $6,000 damage resulted from a flange leak which had soaked the insulation on a still kettle.

2. Electrical Tracing when exposed can be an ignition source. Here again adequate maintenance would have prevented the ignition of soaked insulation on the suction line of a tank of flammable material.

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3. Corrosion of Process Equipment

Improperly sealed or maintained equipment has caused extensive corrosion damage to process equipment. A two year old propylene oxide column was corroded to one half its shell thickness under the insulation just above the column flanges. The importance of keeping insulation sealed against moisture or entry of any unwanted external chemical should be recognized by all operating personnel.

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INSULATION

UNION CARBIDE STANDARD

CHEMICALS/PLASTICS

MATERIAL SPECIFICATION **4M:4M-B 4S:4S-B 4A:4A-B 4SS:4SS-B**

PAGE 1 of 2

DATE JANUARY 1978

SERVICE	TEMP RANGE
This specification covers the insulation material for use on equipment and piping in reactive chemical service, including ethylene oxide and acetylene, electric-traced systems, and for maximum fire protection.	15°C (59°F) to 800°C (1472°F)
LIMITATIONS	**MANDATORY ADD'L. SPECS**
	GS; AP-1, AP-2

PRECAUTIONS When using these materials for fire protection, absolutely no substitutes will be allowed. Do not use treated steel weather barrier in ethylene oxide-rich services. Inhalation of perlite dust may cause minor nose and throat irritations.

SPEC. IDENTIFICATION

4M	Celotemp	with mastic	4M-B	Celotemp	with mastic plus cushioning blanket
4S	Celotemp	with treated steel	4S-B	Celotemp	with treated steel plus cushioning blanket
4A	Celotemp	with aluminum	4A-B	Celotemp	with aluminum plus cushioning blanket
4SS	Celotemp	with stainless steel	4SS-B	Celotemp	with stainless steel plus cushioning blanket

ACCEPTABLE MAJOR MATERIAL COMPONENTS

COMPONENT	MATERIAL	TRADE NAME	MANUFACTURER
PIPE COVERING AND BLOCK	Expanded Perlite	Celotemp 1500	Celotex Corp.
WEATHER BARRIER	Mastic	WC-1 Jaxsan 600 L&L 300 Mastic Sealfas GPM #35-00(1) Vi-Cryl(1)	Vimasco Coatings Corp. Plastic Coatings Corp. L&L Coating Corp. Foster Div. of Amchem Products Co. Childers Products Co.
	Treated Steel (DO NOT USE IN CORROSIVE ATMOSPHERE)	Tuf-Jac Steel-Jac Steel-Cote Steelite	Insul-Coustic Div. of Birma Prod. Corp. Childers Products Co. Premetco International, Inc. (2) Herren Metals, Inc. Quality Service Metals, Inc.
	Aluminum (Smooth or 3/16" Corrugated)	Type 3003 or 5005, H14 alum. roll jacketing with polyethylene coated .010" min. up to 24" dia. .016" min. 24" dia. and above .020" when crimping and goring of jacket is required.	Insul-Coustic Div. of Birma Prod. Corp. Childers Products Co. Premetco International, Inc. (2) Herren Metals, Inc. Quality Service Metals, Inc.
	Stainless Steel	.010" thk. type 301, 302 or 304 S.S. roll jacketing with polyethylene coated Kraft paper vapor barrier	Insul-Coustic Div. of Birma Products Corp. Childers Products Co. Premetco International, Inc. (2) Herren Metals, Inc. Quality Service Metals, Inc.
CUSHIONING BLANKET	Glass Wool (Above 800°F and all SS surfaces)	Temp-Mat Burl-Glas	Pittsburgh-Corning Corp. Burlington Glass Fabrics Co.
	Glass Wool (800°F or below)	Fiberglas TIW Type H Spin Glas No. 1001 Ultralite No. 300 (425°F max)	Owens-Corning Fiberglas Corp. Johns-Manville Corp. Certain-Teed St. Gobain Insulation Co.

NOTES

(1) Approved for use at Ponce, Torrance and Gulf Coast Locations only.
(2) Metal jacketing should be purchased from Premetco International, Inc. as per UCC National Price Agreement thru 12/31/78. Purchases from other suppliers should be made under emergency conditions, only.

Expanded Perlite shall conform to ASTM Standard Specification C610 (latest revision).

24.5.1.1

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ACCEPTABLE ACCESSORY MATERIAL COMPONENTS

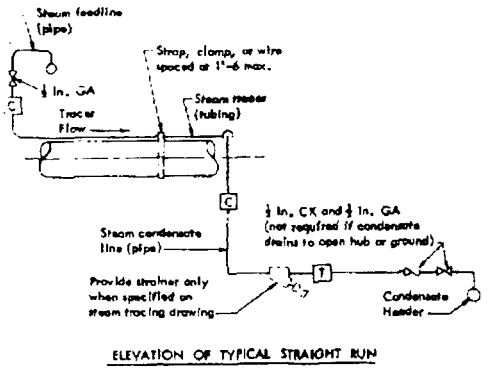
COMPONENT	TRADE NAME	MANUFACTURER
Insulating Cement (Hydraulic Setting)	Quik-Set Super-Powerhouse No. 375 Cement Thermokote 1-MWP	Forty-Eight Insulations, Inc. Keene Corp. Johns-Manville Corp. Ryder Industries, Inc.
Reinforcing Fabric	Elastafab #894 PC Fabric 79 Q	Vimasco Coatings Corp. Pittsburgh-Corning Corp.
Fabricating Cement	Fibrous Adhesive #81-27 Brush Grade 7B High Temp Adhesive	Foster Div. of Amchem Products, Inc. Michael Walter Industries
Heat Resistant Sealer	Silastic 732RTV #30-43	Dow Corning Corp. Foster Div. of Amchem Products, Inc.
Wire Netting	One inch, hexagonal mesh, 20 gage, Type 304 or 430 SS or Monel	(Any building materials supplier)
Insulation Strap Pipe Equipment	3/8" x .015 Type 304 SS 1/2" x .020 Type 304 SS	A. J. Gerrard, Childers Prod. Co. or Techalloy
Strap Clip Pipe Equipment	3/8" x 1/2" double pronged SS 1/2" x 7/8" double pronged SS	A. J. Gerrard, Childers Prod. Co. or Techalloy
Stainless Steel Wire	18 gage dead soft annealed Type 304 or 430 SS	(Any building materials supplier)
Insulating Cement (Air Setting)	Super 48 Cement Super 1900 Thermokote - MW	Forty-Eight Insulations, Inc. Keene Corp. Ryder Industries, Inc.

24.5.1.1

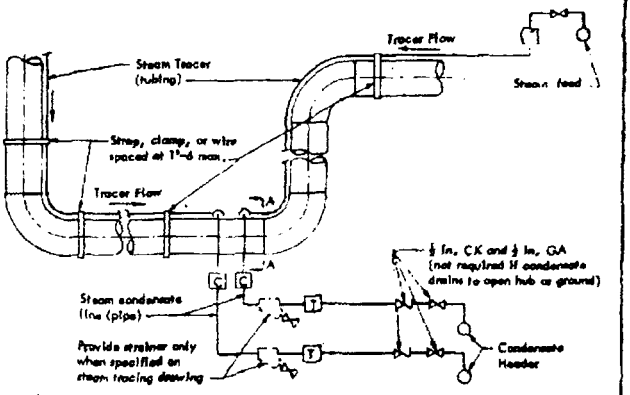
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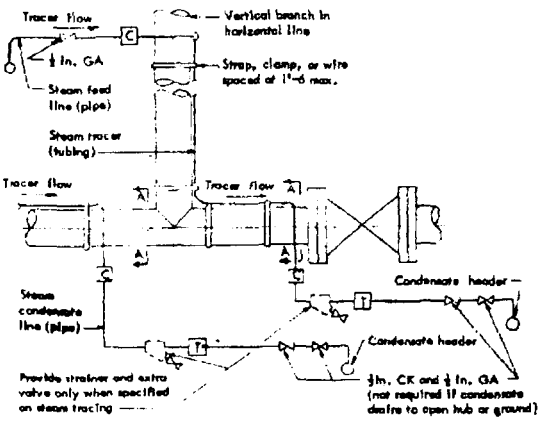
STEAM TRACING SYSTEM DETAILS



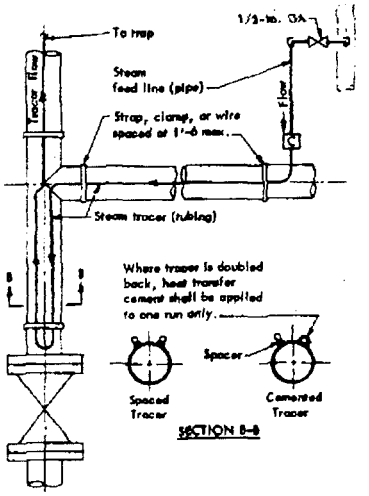
ELEVATION OF TYPICAL STRAIGHT RUN



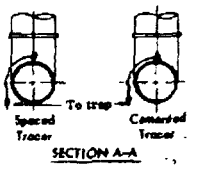
ELEVATION OF POCKET IN VERTICAL RUN



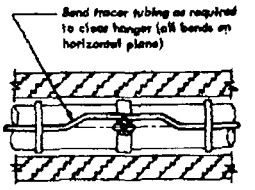
ELEVATION OF VERTICAL BRANCH IN HORIZONTAL LINE



SECTION B-B

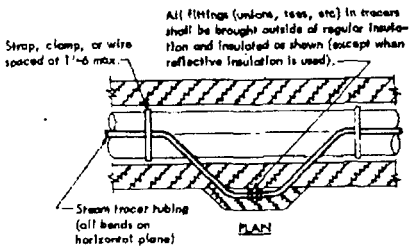


SECTION A-A

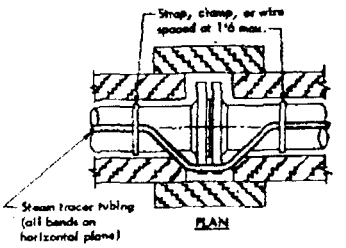


PLAN

PLAN OF HORIZONTAL BRANCH IN HORIZONTAL RUN



PLAN



PLAN

NOTE:

Units containing lines with high freezing points shall be termed Special Requirement. These lines should be given special instruction by the Process engineer for Control. Details for this Control should be shown on the steam tracer design drawings.

Unless otherwise indicated, all dimensions given in inches.

24.6.1.1

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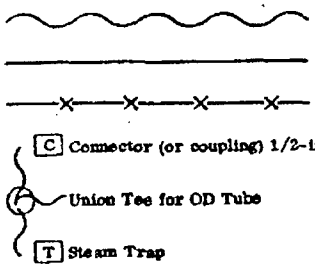
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NOTE:

Size of tracer (3/8-in. OD or 5/8-in. OD), material of tracer (copper, stainless steel, or aluminum), and type of tracing system (spaced or cemented) shall be as specified on the steam tracing drawings. Nominal size, thickness, and specification of insulation for traced line shall be as specified in the insulation schedule. Insulation for steam supply and condensate lines that do not have line numbers shall be as specified on the steam tracing drawings.

All steam tracing is shown diagrammatically on steam tracing drawings with symbols having the following meanings:



Shop-fabricated piping that is to be steam traced shall be supported as shown or specified on the piping drawings. Field-fabricated piping that is to be steam traced, and for which supports are not detailed on the piping drawings, shall be supported in accordance with Standards P-77 or P-81, or as otherwise necessitated by job conditions. Lines less than 3/4-in. OD may be supported by cradles as shown on Standard P-82. Except for lines less than 3/4-in. OD, methods of support that would impose a load on the insulation or tracer shall not be used.

Steam tracer tubing shall extend beyond pipe insulation only far enough to make feed and condensate line connections. Fittings shall be used only at beginning and end of tracer, at branches, and at ends of standard lengths of tubing. Changes in direction shall be made by bending the tubing. Tracer tubing shall be installed parallel to, and along the top of the line being traced.

REFERENCES:

Steam Tracing System —
Insulation Sizes and Assembly
Dimensions . . . . . Std TIM-206
Spaced Tracer Data . . . . . Std TIM-201
Cemented Tracer Data . . . . . Std TIM-202

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INSULATION

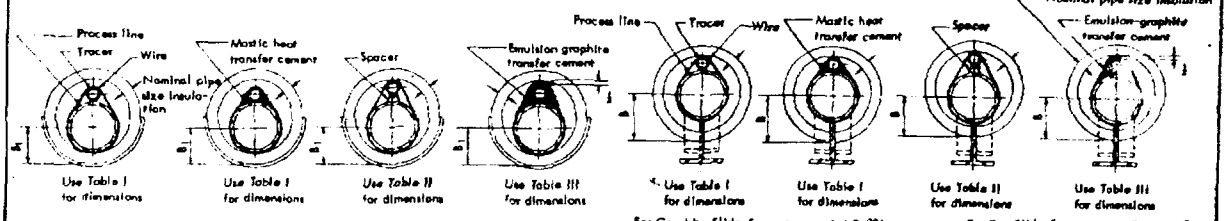
UNION CARBIDE **STANDARD**

CHEMICALS/PLASTICS

TIM-206

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April 1973
(Taken from Standard P-140A
Duplicated for Reference)

INSULATION SIZES FOR HEAT TRACED SYSTEMS



Use Table I for dimensions | Use Table I for dimensions | Use Table II for dimensions | Use Table III for dimensions | *Use Table I for dimensions | Use Table I for dimensions | Use Table II for dimensions | Use Table III for dimensions

For Graphite Slide-Supports, see Std P-226. For Tee Slide-Supports, see Std P-86C.

TABLE I — WITHOUT SPACERS

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	½	1½	1⅝	2⅛	3⅛	3⅝
½ OD	½	½	1½	1⅝	2⅛	3⅛	3⅝
¾	½	½	1⅝	1⅞	2⅜	3⅜	3⅞
	¾	1	1¾	2	2⅜	3⅜	3⅞
¾ OD	½	1	1¾	2⅛	2⅝	3⅛	3⅝
	¾	1	1⅞	2⅛	2⅝	3	3⅝

TABLE II — WITH SPACERS

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1	1½	1⅝	2⅛	3⅛	3⅝
½ OD	½	1	1½	1⅝	2⅛	3⅛	3⅝
¾	½	1½	2⅛	2⅛	3⅛	4	4½
	¾	1½	1⅝	2⅛	3⅛	3⅝	4½
¾ OD	½	1½	1⅞	1⅞	2⅝	3⅛	3⅝
	¾	1½	1⅞	1⅞	2⅝	3⅛	3⅝

TABLE III — WITHOUT SPACERS EMULSION-GRAPHITE HEAT TRANSFER CEMENT

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1	1½	1⅝	2⅛	3⅛	3⅝
½ OD	½	1	1½	1⅝	2⅛	3⅛	3⅝
¾	½	1½	2⅛	2⅛	3⅛	4	4½
	¾	1½	1⅝	2⅛	3⅛	3⅝	4½
¾ OD	½	1½	1⅞	1⅞	2⅝	3⅛	3⅝
	¾	1½	1⅞	1⅞	2⅝	3⅛	3⅝

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	½	1½	1⅝	2⅛	3⅛	3⅝
½ OD	½	½	1½	1⅝	2⅛	3⅛	3⅝
¾	½	½	1⅝	1⅞	2⅜	3⅜	3⅞
	¾	1	1¾	2	2⅜	3⅜	3⅞
¾ OD	½	1	1¾	2⅛	2⅝	3⅛	3⅝
	¾	1	1⅞	2⅛	2⅝	3	3⅝
1	½	1	1⅞	2	2⅝	3⅜	3⅞
	¾	1½	1⅞	2	2⅝	3⅜	3⅞
1 OD	½	1	1⅞	2	2⅝	3⅜	3⅞
	¾	1½	1⅞	2	2⅝	3⅜	3⅞
1	½	1½	2⅛	2⅛	3	3⅜	4
	¾	1½	2⅛	2⅛	3	3⅜	4
1¼ OD	½	1½	2⅛	2⅛	3⅛	3⅝	4
	¾	1½	2⅛	2⅛	3⅛	3⅝	4
1½ OD	½	1½	2⅛	3	3⅛	3⅝	4
	¾	1½	2⅛	3	3⅛	3⅝	4
1½	½	1½	2⅜	2⅜	3⅛	3⅝	4⅛
	¾	2	2⅜	2⅜	3⅛	3⅝	4⅛
1⅝ OD	½	1½	2⅛	3	3⅛	3⅝	4
	¾	1½	2⅛	3	3⅛	3⅝	4
1¾ OD	½	1½	2⅛	3⅛	3⅝	3⅝	4⅛
	¾	2	2⅛	3⅛	3⅝	3⅝	4⅛
1¾	½	2	2	2⅝	3	3⅝	4
	¾	2	2	2⅝	3	3⅝	4
1⅞ OD	½	1½	2⅛	2⅛	3⅛	3⅝	4⅛
	¾	2	2⅛	2⅛	3⅛	3⅝	4⅛
2 OD	½	2	2	2⅝	3⅛	3⅝	4⅛
	¾	2½	2	2⅝	3⅛	3⅝	4⅛
2	½	2½	2⅛	3	3⅛	4	4⅛
	¾	2½	2⅛	3	3⅛	4	4⅛
2⅛ OD	½	2	2⅛	2⅝	3⅛	3⅝	4⅛
	¾	2½	2⅛	2⅝	3⅛	3⅝	4⅛
2½ OD	½	2½	2⅛	3⅛	3⅝	4⅛	4⅛
	¾	2½	2⅛	3⅛	3⅝	4⅛	4⅛
2½	½	3	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	3	2⅜	3	3⅝	4	4⅛
3 OD	½	3½	3⅜	4	4⅛	5	5⅛
	¾	3½	2⅜	3⅛	3⅝	4⅛	5⅛
3 and 3½ OD	½	3½	3⅜	3⅝	4⅛	4⅝	5⅛
	¾	3½	3	3⅝	4	4⅝	5⅛
4 OD	½	4	3⅛	3⅝	4⅝	5⅛	5⅛
	¾	4	3	3⅝	4	4⅝	5⅛

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1					
½ OD	½	1					
¾	½	1½					
	¾	1½					
¾ OD	½	1½					
	¾	1½					
1	½	1½					
	¾	1½ *					
1 OD	½	1½ *					
	¾	1½ *					
1	½	2	2½	2⅝	3⅛	3⅝	4⅛
	¾	2	2	2⅝	3	3⅝	4
1¼ OD	½	2	2⅜	3	3⅛	4	4⅛
	¾	2	2	2⅝	3	3⅝	4
1½ OD	½	2	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	2	2⅜	2⅝	3	3⅝	4
1½	½	2½	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	2½	2	2⅝	3⅛	3⅝	4⅛
1⅝ OD	½	2	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	2	1⅞	2⅝	3⅛	3⅝	4⅛
1¾ OD	½	2	2	2⅝	3⅛	3⅝	4⅛
	¾	2½	2	2⅝	3⅛	3⅝	4⅛
1¾	½	2½	2⅛	3	3⅝	4⅛	4⅛
	¾	2½	2⅛	3	3⅝	4⅛	4⅛
1⅞ OD	½	2½	2⅛	3	3⅝	4⅛	4⅛
	¾	2½	2⅛	3	3⅝	4⅛	4⅛
2 OD	½	2½	2⅛	3	3⅝	4⅛	4⅛
	¾	3	2⅛	3	3⅝	4	4⅛
2	½	3	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	3	2⅜	3	3⅝	4	4⅛
2⅛ OD	½	3	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	3	2⅜	3	3⅝	4	4⅛
2½ OD	½	3	2⅜	3⅛	3⅝	4⅛	4⅛
	¾	3	2⅜	3	3⅝	4	4⅛
2½	½	3½	2½	3⅜	4⅛	4⅝	5⅛
	¾	3½	2⅜	3	3⅝	4	5
3 OD	½	4	3⅛	3⅝	4⅛	4⅝	5⅛
	¾	4	3	3⅝	4	4⅝	5
3 and 3½ OD	½	4	3⅛	3⅝	4⅛	4⅝	5⅛
	¾	4	2⅜	3⅝	4	4⅝	5
4 OD	½	5	3⅝	4⅛	5	5⅛	6
	¾	5	3⅜	4⅛	4⅝	5⅛	5⅝

*Some nominal pipe size insulation as Table I.

All dimensions given in inches

For Steam Tracer System, see Std TDM-205
For Electric Tracer System, see Std EL-43.

24.6.1.1

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UCC 021314

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TABLE I – WITHOUT SPACERS – cont'd

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	4½	3⅛	4⅜	5⅛	5⅜	5⅞
	1/2	5	3⅜	4½	5⅜	5⅝	5⅞
5 OD	3/8	5	3⅜	4½	4⅞	5⅜	5⅞
	1/2	5	3½	4	4½	5	5½
6 OD	3/8	6	4⅛	4⅜	5⅛	5⅜	6⅛
	1/2	6	4	4½	5	5½	6
6	3/8	7		5⅛	6	6½	7⅛
	1/2	7		5⅛	6⅛	7	7⅛
8 OD	3/8	8		5⅜	6⅜	7	7½
	1/2	8		5½	6	6⅝	7⅛
8	3/8	9		6⅜	7⅜	7⅝	8⅜
	1/2	9		6½	7⅛	7⅝	8⅛
10 OD	3/8	10		7	7½	8	8½
	1/2	10		6⅜	7½	7⅞	8⅜
10	3/8	11		7⅜	8⅛	8⅜	9⅜
	1/2	11		7⅜	7⅞	8⅛	8⅜
12 OD	3/8	12		8	8½	9	9½
	1/2	12		7½	8½	8⅞	9⅜
12	3/8	14		8⅜	9½	9⅜	10½
	1/2	14		8½	9	9⅜	10
14	3/8	15		*9⅜	9⅞	10½	10⅝
	1/2	15		9	9½	10	10½
16	3/8	17		10⅜	10⅞	11⅛	11⅝
	1/2	17		9⅞	10⅜	10⅝	11⅛
18	3/8	19		11⅛	11⅝	12⅛	12⅝
	1/2	19		10⅝	11½	11⅞	12⅜
20	3/8	21		12⅛	12⅝	12⅞	13⅜
	1/2	21		11⅜	12⅜	12⅝	13⅛
24	3/8	25		14⅛	14⅝	15⅛	15⅝
	1/2	25		13⅝	14⅜	14⅞	15⅜

TABLE II – WITH SPACERS – cont'd

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	5*	3⅜	4⅛	4⅝	5⅛	5⅝
	1/2	5*	3⅜	4⅛	4⅝	5	5⅛
5 OD	3/8	6	4⅛	4⅛	5⅛	5⅛	6⅛
	1/2	6	4	4⅛	5	5⅛	6
6 OD	3/8	7		5⅛	9⅝	6⅛	7
	1/2	7		5	5⅛	6	6⅛
6	3/8	7*		5	5⅛	6	6⅛
	1/2	7*		4⅞	5⅛	5⅝	6⅛
8 OD	3/8	9		6⅛	6⅛	7⅛	8
	1/2	9		6	6⅛	7⅛	7⅞
8	3/8	9*		6	6⅛	7⅛	7⅛
	1/2	9*		5⅞	6⅛	7	7⅛
10 OD	3/8	11		7⅛	8	8⅛	9
	1/2	11		7⅛	7⅞	8⅛	8⅞
10	3/8	11*		7⅛	7⅞	8⅛	8⅛
	1/2	11*		7	7⅛	8	8⅛
12 OD	3/8	14		8⅛	9⅛	9⅛	10⅛
	1/2	14		8⅛	9	9⅛	10
12	3/8	14*		8⅛	9	9⅛	10
	1/2	14*		8	8⅞	9⅛	9⅞
14	3/8	15*		8⅛	9⅛	9⅛	10⅛
	1/2	15*		8⅛	9	9⅛	10⅛
16	3/8	17*		9⅛	10⅛	10⅛	11⅛
	1/2	17*		9⅛	10	10⅛	11
18	3/8	19*		10⅛	11⅛	11⅛	12⅛
	1/2	19*		10⅛	11	11⅛	12
20	3/8	21*		11⅛	12⅛	12⅛	13⅛
	1/2	21*		11½	12	12⅛	13
24	3/8	25*		13⅛	14⅛	14⅛	15⅛
	1/2	25*		13⅛	14	14⅛	15

TABLE III – WITHOUT SPACERS
EMULSION-GRAPHITE HEAT TRANSFER CEMENT – cont'd

Supports Attached to Process Pipe

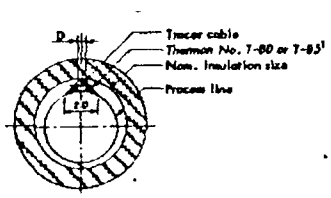
PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	5	3⅜	4⅛	4⅜	5⅛	5⅜
	1/2	5	4⅛	4	4⅛	5	5⅛
5 OD	3/8	6	4⅛	4⅛	5⅛	6	6⅛
	1/2	6	4⅛	4⅛	5⅛	5⅛	6⅛
6 OD	3/8	7		5⅛	5⅛	6⅛	7
	1/2	7		5⅛	5⅛	6⅛	6⅛
6	3/8	7		5⅛	5⅛	6⅛	6⅛
	1/2	7		5	5⅛	6	6⅛
8 OD	3/8	9		6⅛	7	7⅛	8⅛
	1/2	9		6⅛	6⅛	7⅛	7⅛
8	3/8	9		6⅛	6⅛	7⅛	7⅛
	1/2	9		6	6⅛	7⅛	7⅛
10 OD	3/8	11		7⅛	8⅛	8⅛	9⅛
	1/2	11		7⅛	8	8⅛	9
10	3/8	11		7⅛	7⅛	8⅛	8⅛
	1/2	11		7⅛	7⅛	8⅛	8⅛
12 OD	3/8	14		8⅛	9⅛	9⅛	10⅛
	1/2	14		8⅛	9⅛	9⅛	10⅛
12	3/8	14		8⅛	9	9⅛	10
	1/2	14		8⅛	8⅛	9⅛	9⅛
14	3/8	15		8⅛	9⅛	9⅛	10⅛
	1/2	15		8⅛	9⅛	9⅛	10⅛
16	3/8	17		9⅛	10⅛	10⅛	11⅛
	1/2	17		9⅛	10⅛	10⅛	11⅛
18	3/8	19		10⅛	11⅛	11⅛	12⅛
	1/2	19		10⅛	11⅛	11⅛	12⅛
20	3/8	21		11⅛	12⅛	12⅛	13⅛
	1/2	21		11⅛	12⅛	11⅛	13⅛
24	3/8	25		13⅛	14⅛	14⅛	15⅛
	1/2	25		13⅛	14⅛	14⅛	15⅛

*Some nominal pipe size insulation as Table I.

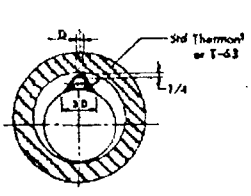
INSULATION SIZE DATA FOR ELECTRICALLY TRACED PIPELINES

TABLE IV – MINERAL INSULATED ELECTRIC TRACING CABLE

Conductors	2 #18	2 #18	3 #18	2 #16	3 #16	2 #14	3 #14	2 #12	3 #12	2 #10	3 #10	2 #8	3 #8
Cable OD-In.	.230	.246	.246	.340	.355	.371	.387	.402	.434	.449	.480	.512	.543
T-80 or T-85	Table I (⅜-In. Tracers)							Table I (½-In. Tracers)					
Std or T-63	Table III (⅜-In. Tracers)							Table III (½-In. Tracers)					

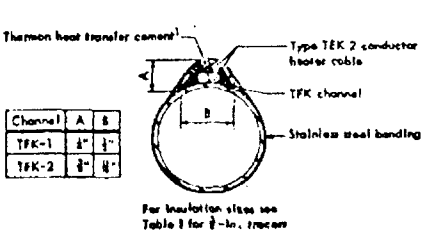


For comparable tracer size see Table IV, then select insulation size from Table I



For comparable tracer size see Table IV, then select insulation size from Table III

ELECTRIC TRACER AT CABLE CEMENTED TO PROCESS LINE



Channel	A	B
TEK-1	½"	½"
TEK-2	¾"	¾"

For insulation sizes see Table I for ½-in. tracers

ELECTRIC TRACER THERMON TYPE "TEK" CABLE CEMENTED WITH STEEL CHANNEL TO PROCESS LINE

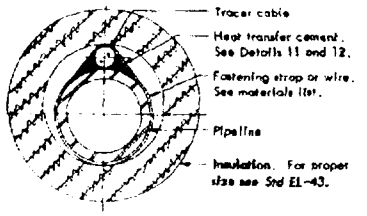
[1]Heat Transfer Cement by Thermon Mfg. Co., or approved equal

24.6.1.1

UCC 021315

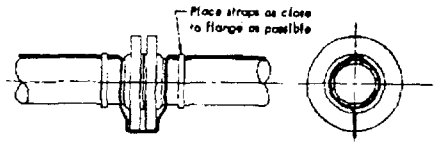
Union Carbide trial exhibit UC-4024: N. W. Clauss to V. H. Johnkoski, Jr., Transmitting the Process and Equipme…
ACL Doc 18647 · Page 481 of 602
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asbestosclaims.law/library/18647/481

ELECTRIC TRACING SYSTEM DETAILS AND MATERIALS



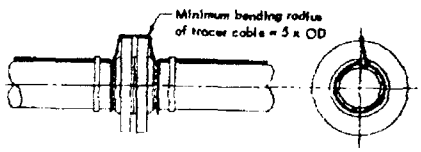
Section A-A

Typical cross section of completely installed tracer cable



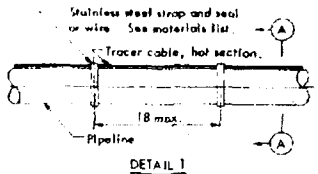
DETAIL 5

Elevation - Tracer cable on pipe flange 2-inches nominal size and smaller



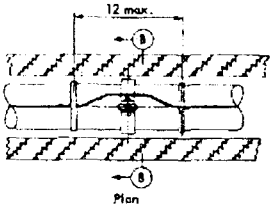
DETAIL 6

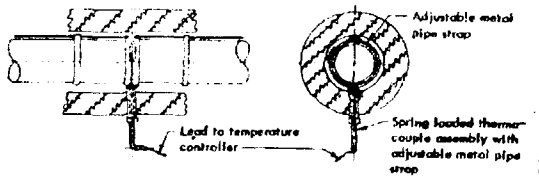
Elevation - Tracer cable on pipe flange larger than 2-inches nominal size



DETAIL 1

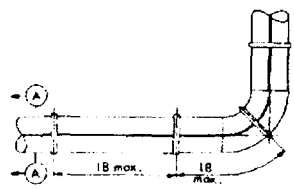
Elevation - Tracer cable on straight pipe run





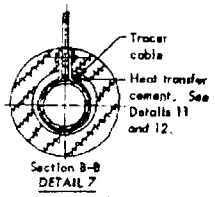
DETAIL 8

Elevation - Thermocouple installation for pipeline temperature control



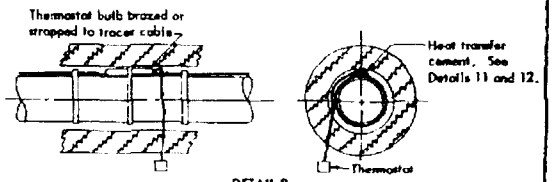
DETAIL 2

Plan - Tracer cable on pipe run with 90° elbow



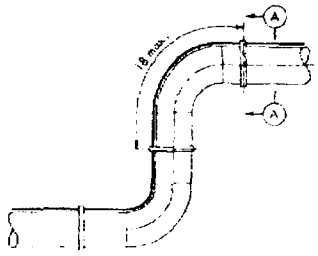
DETAIL 7

Tracer cable at pipe hanger



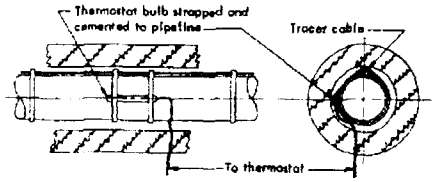
DETAIL 9

Elevation - Thermostat bulb installation for tracer cable sheath temperature control



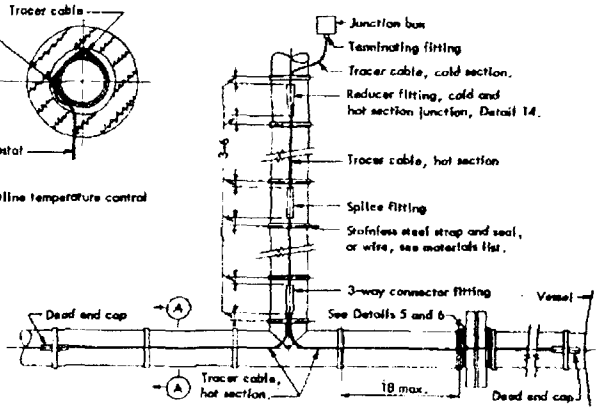
DETAIL 3

Elevation - Tracer cable on vertical pipe run of less than 3-inches nominal size



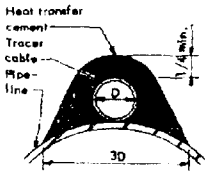
DETAIL 10

Elevation - Thermostat bulb installation for pipeline temperature control



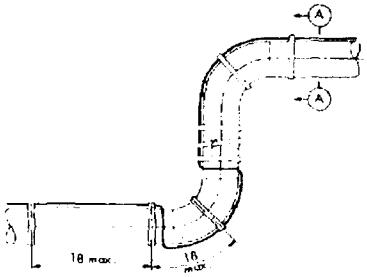
DETAIL 13

Plan - Typical installation of tracer cable fittings (See Stds EL-41, 42, 45 and 46).



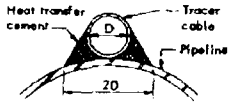
DETAIL 11

Installation of tracer cable with heat transfer cement type T-63 or Std



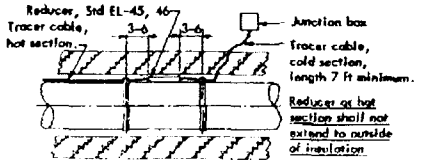
DETAIL 4

Elevation - Tracer cable on vertical pipe run of 3-inches nominal size and larger



DETAIL 12

Installation of tracer cable with heat transfer cement type T-85



DETAIL 14

Elevation - Tracer cable, cold and hot section junction.

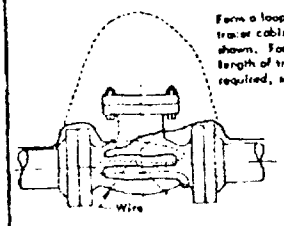
All dimensions given in inches

NOTE: Notes and dimensions not given for various details are the same as for details 1 and 2.

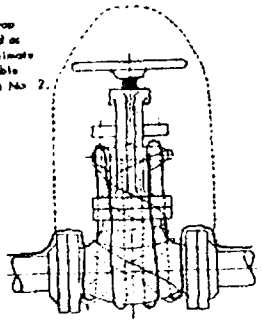
(OVER)

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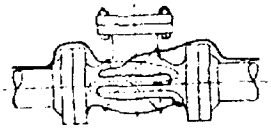
Union Carbide trial exhibit UC-4024: N. W. Clauss to V. H. Johnkoski, Jr., Transmitting the Process and Equipme…
ACL Doc 18647 · Page 482 of 602
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asbestosclaims.law/library/18647/482



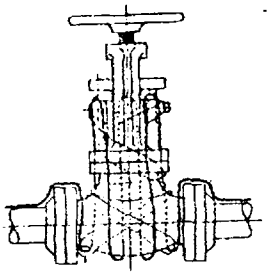
DETAIL 15
Tracer cable applied to check valve



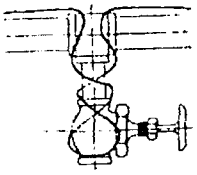
DETAIL 16
Tracer cable applied to globe or gate valve



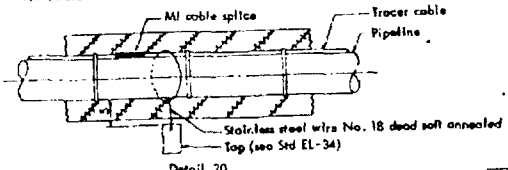
DETAIL 17
Valve electrically traced and heat transfer cement applied



DETAIL 18
Valve electrically traced and heat transfer cement applied



DETAIL 19
Elevation – Tracer cable run on blow-off valve



Detail 20
Installation Detail of Identification Tag for the Location of Tracer Cable Hot Splices on Long Tracer Systems

MINERAL INSULATED CABLE INSTALLATION DETAILS

In order to provide an efficient and dependable electric tracing system, it is mandatory that the *installation instructions* be followed carefully and that good workmanship be applied.

Tracer Cable Installation:

The size of the tracer cable (No. and size of conductors) shall be as specified on the electrical tracer system design drawing.

The tracer cable shall be installed on top of, parallel to, and as much as possible in direct contact with the pipeline; and shall be fastened with stainless steel wire (up to 2-inch diameter lines), or stainless steel straps (over 2-inch diameter lines), at a spacing not to exceed 18-inches. At tracer fittings the fastening wire or strap shall be installed within 3 to 6 inches from the fitting. At pipe flanges or valves, the fasteners shall be as close to these items as possible and in no case shall this distance be more than 3-inches.

The configuration of the tracer cable shall follow the design drawing when special layouts are given for vessels or other equipment.

No allowance for expansion shall be made by forming loops in the tracer cable hot section. A normal installation contains sufficient irregularities to allow for expansion between fastening wires or straps.

The entire hot section of the tracer cable shall be contained under the pipeline insulation; the connecting cold section shall be fastened under the insulation in accordance with Detail 14, and then be continued to the outside of the insulation.

All tracer cable fittings shall be cemented to the pipeline in a manner similar to Details 11 and 12, as shown for tracer cables.

Proper insulation sizes for electrically traced pipelines may be selected from Standard P-140A

Heat Transfer Cement Installation:

Heat transfer cement shall be applied to pipeline surfaces that should be essentially free of loose paint, mill scale, rust or dirt, and of grease, oil or mill varnish. Wire brushing, sandblasting and solvent cleaners for the removing of oil and grease, shall be used to clean pipeline surfaces in order that heat transfer cements may be applied properly.

If heat transfer cement is to be applied to aluminum or galvanized surfaces, Thermon[1] ALP primer should be used. The to be primed surface shall be wiped free of loose scale, dirt or oil. The primer shall be applied with a stiff brush, and then be allowed to set for 24 hours before the heat transfer cement is applied. Only the surface to be covered by cement needs to be primed.

Heat transfer cements types T-63 or Standard by Thermon[1] shall be applied by a hand trowel, a caulking gun or pumping equipment using a special nozzle (see Detail 11). Thermon type T-85 cement shall be applied by a caulking gun covering the tracer and pipeline as shown in Detail 12. For best results, care should be taken to force heat transfer cement thoroughly around and under the tracer cable.

The same general technique as explained above in applying heat transfer cement is applicable to vessels, valves, flanges and other equipment where tracer cable is used.

The curing of heat transfer cement shall be in strict accordance with manufacturers recommendations (see table 1).

[1]As manufactured by Thermon Manufacturing Company, Houston, Texas, or approved equal.

REFERENCES:

List of all Standards on MI Cable and Electric Tracing Data . . . . . STD EL-40

STAINLESS STEEL BANDING DATA

Pipe Size, In.	½	¾	1	1½	2	3	4	6	8
Feet per Band	.46	.52	.593	.746	.870	1.16	1.42	1.98	2.50
Pipe Size, In.	10	12	14	16	18	20	24	30	36
Feet per Band	3.06	3.60	3.91	4.43	4.96	5.48	6.55	8.10	9.66

TABLE 3 - HEAT TRANSFER CEMENT REQUIREMENTS

MI Cable OD In.	Process Line Size In.	Ft of Tracing per Gal. Std or T-63 Hand Trowel Appl.	Ft of Tracing per 1/6 Gal. Cartridge T-85
.246	All	50	40
.340	All	49	30
.543	½ - 1½	30	18
.543	All other	33	16

It is suggested to add 10% to amounts given for estimating and waste.

TABLE 2 - ELECTRICALLY TRACED VALVES
Tracer Cable and Heat Transfer Cement Data

Valve Size In.	Feet of Tracer Cable Required	Gallon per Valve (Std & T-63)[1]	Cartridge per Valve (T-85)[2]
½	1 - 2	0.14	.03- .07
¾	1 - 3	0.21	.03-0.1
1	2 - 3	0.29	.07-0.1
1 1/2	2 1/2 - 4	0.36	.08-0.13
2	3 - 5	0.43	0.20-0.33
3	4 - 7	0.71	0.27-0.47
4	6 - 10	1.00	0.40-0.67
6	9 - 15	1.43	0.60-1.00
8	12 - 20	2.00	0.80-1.34
10	15 - 25	2.50	1.00-1.67
12	18 - 30	3.00	1.20-2.00
14	21 - 35	3.50	1.75-2.82
16	24 - 40	4.00	2.00-3.33
18	27 - 45	4.50	2.25-3.75
20	30 - 50	5.00	2.50-4.16
24	36 - 60	6.00	3.00-5.00
30	45 - 75	7.50	3.75-6.25
36	54 - 90	9.00	4.50-7.50

[1]Hand trowel application completely covering valve surface is recommended.

[2]Hand gun application as fillet on each side of tracing is recommended.

MATERIALS FOR ELECTRIC TRACING SYSTEMS

Item	Description
Tracer Cable	Mineral insulated cable by General Cable Corp., 1, 2, or 3 copper or alloy conductors, bare copper sheath, for use up to 250 C temperatures. For temperatures over 250 C the cable sheath shall consist of stainless steel or other suitable metal.
Fittings	Terminations and seals for cold sections by General Cable Corporation. Splices, reducer, 3-way connectors and dead-end caps for hot sections by Bundy Corporation.
Straps and Clips	For pipeline tracers: 3/8-in. x 0.015-in. thick dead soft annealed stainless steel straps, with double pronged 3/8-in. x 1/2-in. Econ-O-Clips, by Techalloy Company, Rahns, Pennsylvania, or approved equal. For vessels and equipment tracers: Same as above except 1/2-in. x 0.020 in. straps and 1/2-in. x 1/2-in. Econ-O-Clips.
Strapping Tool	No. 111 steelbinder with stainless steel nose, by A. J. Gerrard & Company, Des Plaines, Illinois, or approved equal.
Wire	18 gage (0.047-in. Dia.) dead soft annealed stainless steel wire.
Heat Transfer Cement	Thermon, types T-63, T-80, T-85, or Std., as manufactured by Thermon Manufacturing Company, Houston, Texas, or approved equal.

TABLE 1 - PROPERTIES OF THERMON HEAT TRANSFER CEMENTS

DATA	STANDARD	T-63	T-80[1]	T-85
Maximum Temp F	600 Cont. 750 Int.	1250	325	375
Minimum Temp F	-320	-100	-320	
Shear Bond lb/sq in	150		1000 - 1800	
Start-up Curing Each curing time and temperature indicated must be executed in sequence.	4 Hrs-Air Dry 4-24 Hrs-180-212 F	4 Hrs-Air Dry 4 Hrs-180-212 F 4 Hrs-250 F		
Installation				
Shelf Life	One Year		60-90 Days	
Water Soluble	Yes		No	
Volume Resistivity	0.767 OHM IN.	3.3 OHM IN.	146 OHM IN.	

[1]Ambient Temperature for Application is +10 F or above.

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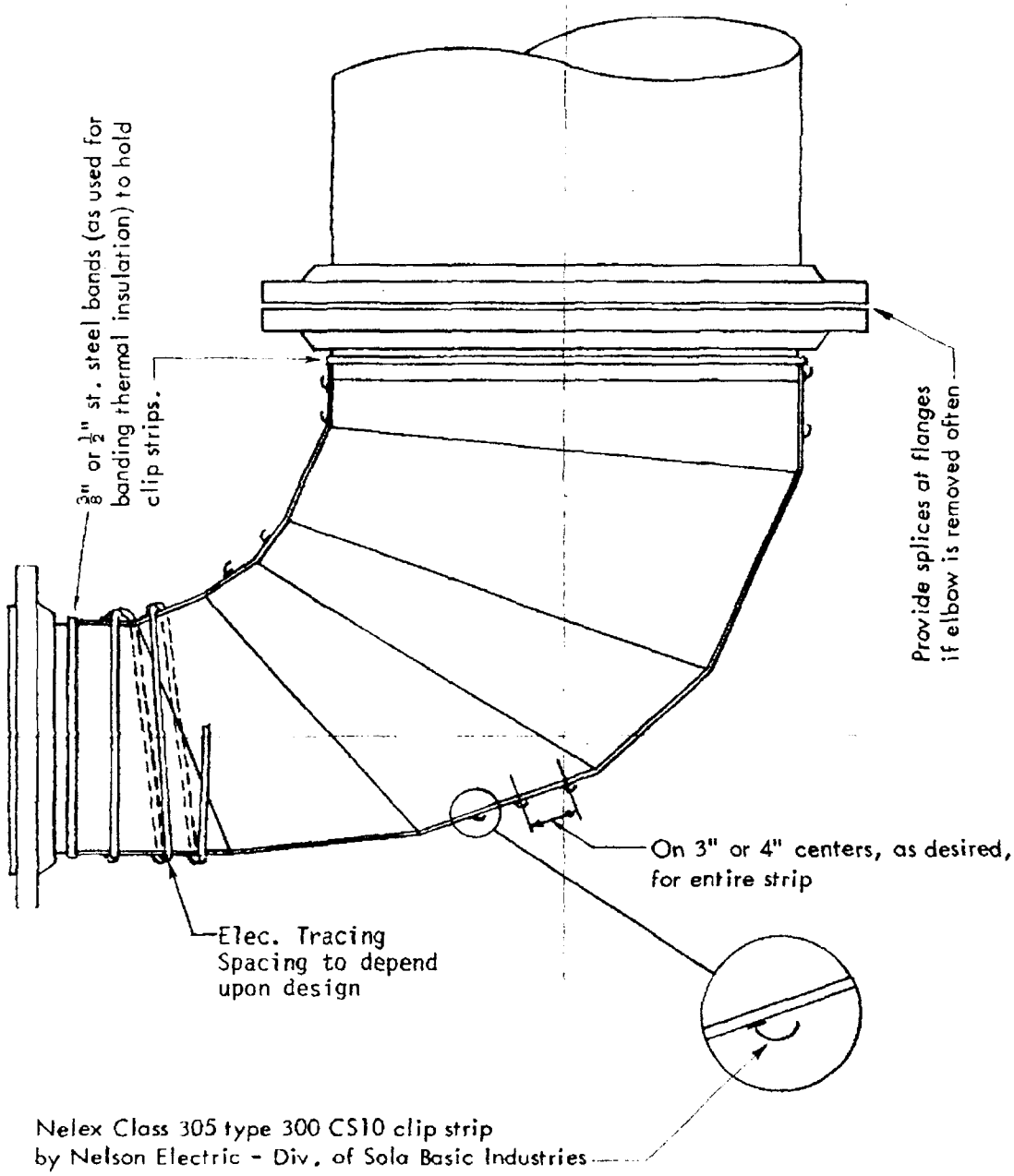
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UNION CARBIDE STANDARD

CONSTRUCTION

ELC 43A
DETAIL
6-1-70

METHOD OF ATTACHING ELECTRIC TRACING
TO CONE SHAPED PIPING



NOTE: This basic method may be used for other odd shaped equipment or tanks, etc.

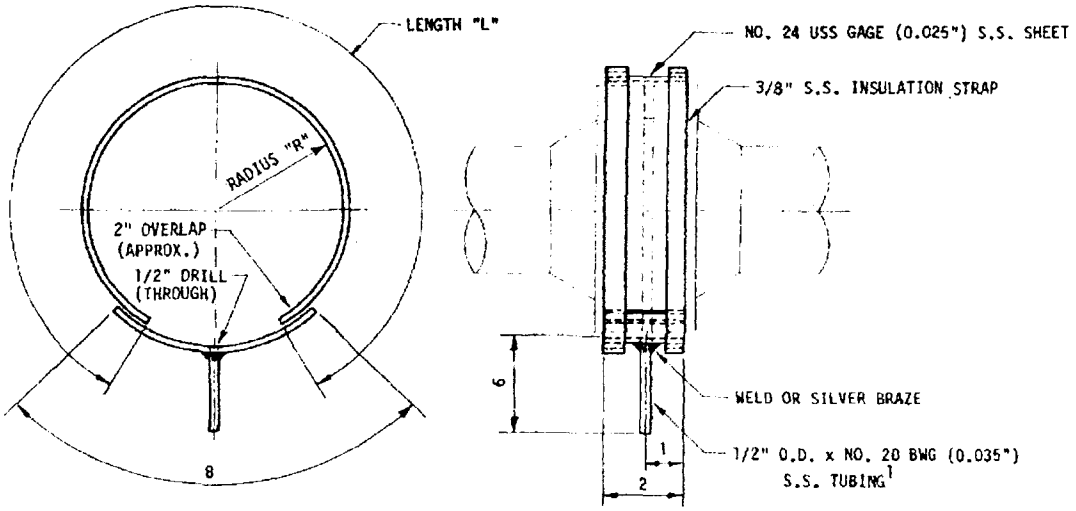
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MULTIPLE DISTRIBUTION

LEAK INDICATOR



NOM. PIPE SIZE	FLANGE RATING 150 LB. L	150 LB. R	300 LB. L	300 LB. R	600 LB. L	600 LB. R	900 LB. L	900 LB. R	1500 LB. L	1500 LB. R
1	9 3/8	2 1/8	11 3/8	2 7/16	11 3/8	2 7/16	14 1/2	2 15/16	14 1/2	2 15/16
1 1/2	11 3/4	2 1/2	15 1/4	3 1/16	15 1/4	3 1/16	18	3 1/2	18	3 1/2
2	14 7/8	3	16 1/2	3 1/4	16 1/2	3 1/4	22 3/4	4 1/4	22 3/4	4 1/4
3	19 5/8	3 3/4	22	4 1/8	22	4 1/8	25 7/8	4 3/4	29	5 1/4
4	24 3/8	4 1/2	27 1/2	5	29 7/8	5 3/8	32 1/4	5 3/4	34 1/2	6 1/8
6	30 5/8	5 1/2	35 3/8	6 1/4	40	7	43 1/8	7 1/2	44 3/4	7 3/4
8	38 1/2	6 3/4	43 1/8	7 1/2	47 7/8	8 1/4	54 1/8	9 1/4	55 3/4	9 1/2
10	46 3/8	8	51	8 3/4	58 7/8	10	63 5/8	10 3/4	68 3/8	11 1/2
12	55 3/4	9 1/2	60 1/2	10 1/4	65 1/8	11	71 1/2	12	79 3/8	13 1/4
14	62	10 1/2	68 1/4	11 1/2	70 5/8	11 7/8	75 3/8	12 5/8	88 3/4	14 3/4
16	69 7/8	11 3/4	76 1/8	12 3/4	80 7/8	13 1/2	83 1/4	13 7/8	98 1/8	16 1/4
18	74 5/8	12 1/2	84	14	88	14 5/8	93 1/2	15 1/2	109 1/8	18
20	82 1/2	13 3/4	91 7/8	15 1/4	96 5/8	16	102 1/8	16 7/8	117 3/4	19 3/8
24	96 5/8	16	109 1/8	18	112 1/4	18 1/2	124 7/8	20 1/2	140 5/8	23

NOTES:

Generally, leak indicators are required for all Dowtherm, Tetralin, and Ethylene Oxide Services. After installing insulation, make sure the tube is open.

[1] 1/2" O.D. x .049" wall S.S. tubing or 1/2" Sch. 40 S.S. pipe may be used when 1/2" O.D. x .035" wall S.S. tubing is unavailable. For horizontal lines, install tubing pointing down in order to minimize accumulation of liquid.

Unless otherwise indicated, all dimensions given in inches

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16.6.10.1
24.6.1.1

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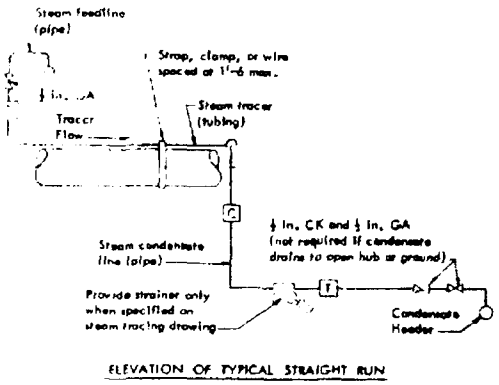
UNION CARBIDE

STANDARD

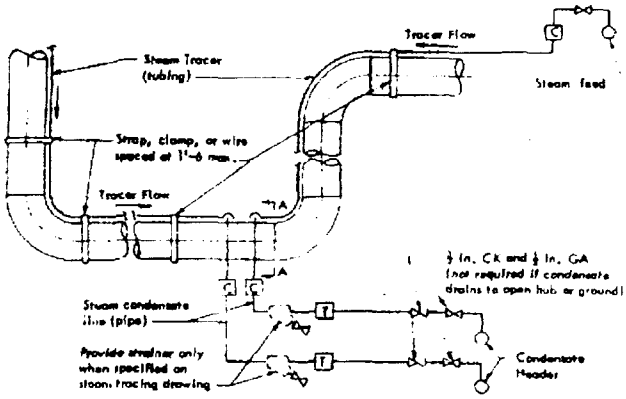
CHEMICALS AND PLASTICS OPERATIONS DIVISION
AND UNION CARBIDE CANADA LIMITED

P-140
PIPING - DETAIL
6-15-67

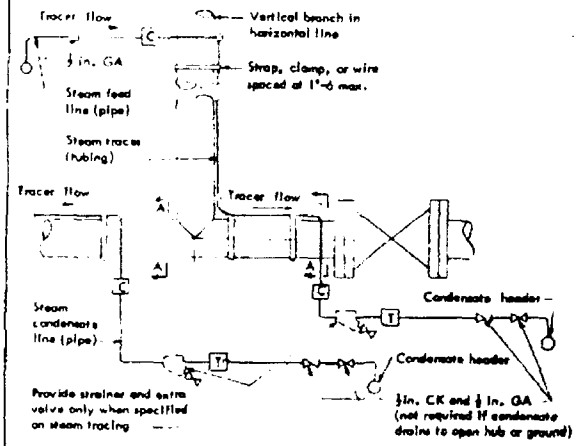
STEAM TRACING SYSTEM DETAILS AND MATERIALS



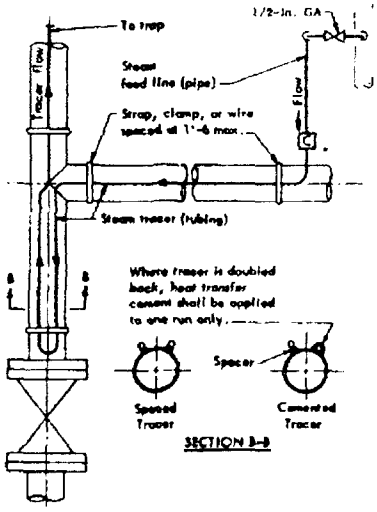
ELEVATION OF TYPICAL STRAIGHT RUN



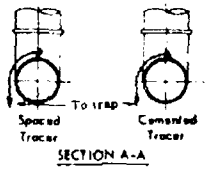
ELEVATION OF POCKET IN VERTICAL RUN



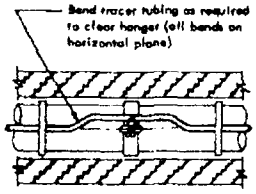
ELEVATION OF VERTICAL BRANCH IN HORIZONTAL LINE



SECTION B-B

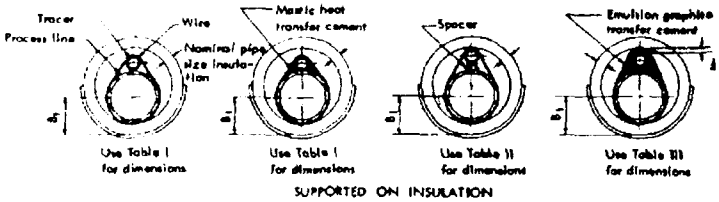


SECTION A-A

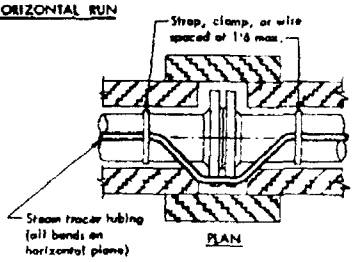


PLAN

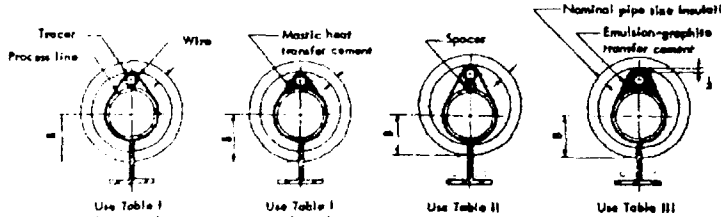
PLAN OF HORIZONTAL BRANCH IN HORIZONTAL RUN



SUPPORTED ON INSULATION

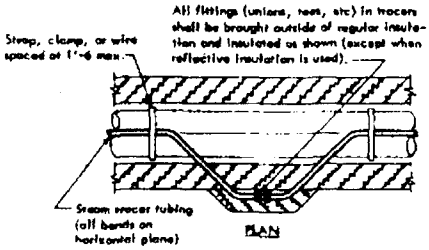


PLAN



SUPPORTS ATTACHED TO PROCESS PIPE

DETAILS OF STEAM TRACER ATTACHMENT



PLAN

NOTE:
Refer to Std P-140A for Tables I, II and III

NOTE:
Units containing lines with high freezing points shall be termed Special Requirement. These lines should be given special instruction by the Process engineer for Control. Details for this Control should be shown on the steam tracer design drawings.

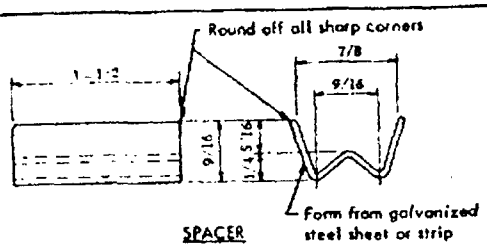
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SPACER

NOTE:

Size of tracer (3/8-in. OD or 5/8-in. OD), material of tracer (copper, stainless steel, or aluminum), and type of tracing system (spaced or cemented) shall be as specified on the steam tracing drawings. Nominal size, thickness, and specification of insulation for traced line shall be as specified in the insulation schedule. Insulation for steam supply and condensate lines that do not have line numbers shall be as specified on the steam tracing drawings.

All steam tracing is shown diagrammatically on steam tracing drawings with symbols having the following meanings:

Steam Tracer

Steam Feed

Steam Condensate

C Connector (or coupling) 1/2-in. IPS to OD Tube

Union Tee for OD Tube

T Steam Trap

All aluminum tubing tracers shall be insulated from system components of other materials by inserting a stainless steel connector at all points where the aluminum tubing connects to components of other materials.

Shop-fabricated piping that is to be steam traced shall be supported as shown or specified on the piping drawings. Field-fabricated piping that is to be steam traced, and for which supports are not detailed on the piping drawings, shall be supported in accordance with Standards P-77 or P-81, or as otherwise necessitated by job conditions. Lines less than 3/4-in. OD may be supported by cradles as shown on Standard P-82. Except for lines less than 3/4-in. OD, methods of support that would impose a load on the insulation or tracer shall not be used.

Steam tracer tubing shall extend beyond pipe insulation only far enough to make feed and condensate line connections. Fittings shall be used only at beginning and end of tracer, at branches, and at ends of standard lengths of tubing. Changes in direction shall be made by bending the tubing. Tracer tubing shall be installed parallel to, and along the top of the line being traced.

REFERENCES:

Steam Tracing System —
Insulation Sizes and Assembly
Dimensions . . . . . Std P-140A
Spaced Tracer Data . . . . . Std P-141
Cemented Tracer Data . . . . . Std P-142

*Do not use aluminum tubing at direction changes of 90 degrees or more. Where such changes occur at intervals of 20 feet or less, use stainless steel throughout. For intervals greater than 20 feet, make the direction change with stainless steel tubing, and use a stainless steel tubing union with an aluminum sleeve at each joint, installed so that aluminum connects to aluminum.

MATERIALS FOR STEAM TRACING SYSTEMS

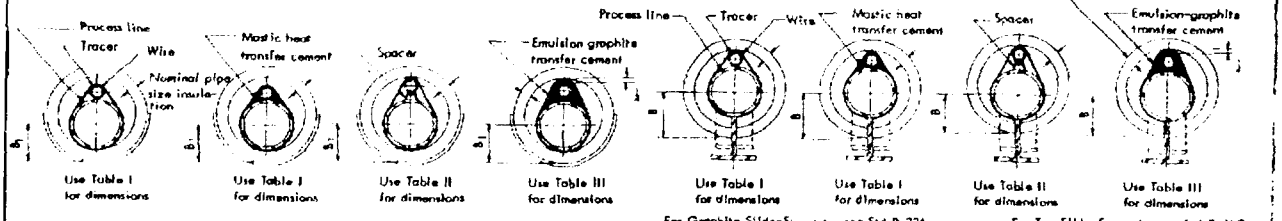
ITEM	COPPER	STAINLESS STEEL	ALUMINUM*
Tracer Tubing	ASTM B88 Type L annealed copper tube in 60-ft coils (3/8-in. OD x .030-in. thk, or 5/8-in. OD x .040-in. thk)	ASTM A269 TP304 Stainless Steel tube for use in steam service. Flaring Test (Section 8) is required and good bending properties are necessary. (3/8-in. or 5/8-in. OD x .035-in. thk)	5050-0 Aluminum Alloy, Alcoa "Utili-tube", or approved equal. (3/8-in. OD x .035-in. thk or 5/8-in. OD x .049-in. thk)
Fittings for Tracer (Connectors, Unions, Tees, etc)	Brass, Ferrule-type with cutting edge. (Imperial Hi-Seal", Crawford "Swage-lok", or approved equal.)	AISI Type 316 Stainless Steel, Ferrule-type with cutting edge. (Imperial "Hi-Seal", Crawford "Swagelok", Parker "Ferrulok", or approved equal)	Ferrule-type with cutting edge (Imperial "Hi-Seal", Crawford "Swage-lok", Parker "Ferrulok", or approved equal). Connectors (IPS to OD) shall be AISI Type 316 stainless steel, all other fittings shall be aluminum alloy
Spacers	Per this Standard	Per this Standard	Per this Standard
Straps	1/2-in. wide x .020-in. thk soft annealed stainless steel (any 18-8 type) straps with double pronged clips.		1/2-in. wide x .034-in. thk aluminum alloy straps with double pronged clips.
Wire	18 gage (.047-in. dia) annealed temper (bright annealed, or annealed and pickled) stainless steel (any 18-8 type) wire.		16 gage (.0508-in. dia) aluminum alloy wire.
Steam Traps	Size, manufacturer and model number as specified on steam tracing drawings.		
Steam Supply Header and Feed Lines, and Steam Condensate Lines	Valve and Piping Specification as called for on steam tracing drawings.		
Heat Transfer Cement	Standard Thermon, manufactured by Thermon Manufacturing Company, Houston, Texas, or approved equal.		

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INSULATION SIZES FOR HEAT TRACED SYSTEMS



For Graphite Slide-Supports, see Std P-226.

For Tee Slide-Supports, see Std P-86C.

TABLE I — WITHOUT SPACERS

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	½	1¼	1⅜	2½	3⅛	3½
½ OD	½	½	1¼	1⅜	2⅝	3⅛	3⅝
¾	¾	½	1⅜	1⅝	2⅝	3⅛	3⅝
		1	1½	2	2½	3⅛	3⅝
¾ OD	¾	1	1⅝	1⅞	2⅝	3⅛	3⅝
	¼	1	1⅝	1⅞	2⅝	3	3¼
1	1	1	1¾	2	2⅝	3⅛	3⅝
1 OD	1	1	1¾	2	2⅝	3⅛	3⅝
	¼	1	1¾	2	2⅝	3	3¼
1¼	1¼	1	1⅞	2	2⅝	3⅛	3⅝
1¼ OD	1¼	1	1⅞	2	2⅝	3⅛	3⅝
	¼	1	1⅞	2	2⅝	3	3¼
1½	1½	1	2	2⅛	2⅝	3⅛	3⅝
1½ OD	1½	1	2	2⅛	2⅝	3⅛	3⅝
	¼	1	2	2⅛	2⅝	3	3¼
2	2	1	2⅛	2⅜	2⅝	3⅛	3⅝
2 OD	2	1	2⅛	2⅜	2⅝	3⅛	3⅝
	¼	1	2⅛	2⅜	2⅝	3	3¼
2½	2½	1	2⅜	2⅝	2⅝	3⅛	3⅝
2½ OD	2½	1	2⅜	2⅝	2⅝	3⅛	3⅝
	¼	1	2⅜	2⅝	2⅝	3	3¼
3	3	1	2⅝	2⅞	2⅝	3⅛	3⅝
3 OD	3	1	2⅝	2⅞	2⅝	3⅛	3⅝
	¼	1	2⅝	2⅞	2⅝	3	3¼
3½	3½	1	2⅞	3⅛	2⅝	3⅛	3⅝
3½ OD	3½	1	2⅞	3⅛	2⅝	3⅛	3⅝
	¼	1	2⅞	3⅛	2⅝	3	3¼
4	4	1	3⅛	3⅜	2⅝	3⅛	3⅝
4 OD	4	1	3⅛	3⅜	2⅝	3⅛	3⅝
	¼	1	3⅛	3⅜	2⅝	3	3¼

TABLE II — WITH SPACERS

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1	1¼	1⅜	2¼	3⅛	3½
½ OD	½	1	1¼	1½	2⅜	3⅛	3⅜
¾	¾	1	1½	2⅛	2⅜	3¼	4
		1½	1½	1⅝	2⅜	3¼	4¼
¾ OD	¾	1½	1⅝	1⅞	2⅝	3⅜	3⅞
	¼	1½	1⅝	1⅞	2⅝	3⅛	3⅝
1	1	1½	1⅞	2	2⅝	3⅜	3⅞
1 OD	1	1½	1⅞	2	2⅝	3⅜	3⅞
	¼	1½	1⅞	2	2⅝	3⅛	3⅝
1¼	1¼	1½	2	2⅛	2⅝	3⅜	3⅞
1¼ OD	1¼	1½	2	2⅛	2⅝	3⅜	3⅞
	¼	1½	2	2⅛	2⅝	3⅛	3⅝
1½	1½	1½	2⅛	2⅜	2⅝	3⅜	3⅞
1½ OD	1½	1½	2⅛	2⅜	2⅝	3⅜	3⅞
	¼	1½	2⅛	2⅜	2⅝	3⅛	3⅝
2	2	1½	2⅜	2⅝	2⅝	3⅜	3⅞
2 OD	2	1½	2⅜	2⅝	2⅝	3⅜	3⅞
	¼	1½	2⅜	2⅝	2⅝	3⅛	3⅝
2½	2½	1½	2⅝	2⅞	2⅝	3⅜	3⅞
2½ OD	2½	1½	2⅝	2⅞	2⅝	3⅜	3⅞
	¼	1½	2⅝	2⅞	2⅝	3⅛	3⅝
3	3	1½	2⅞	3⅛	2⅝	3⅜	3⅞
3 OD	3	1½	2⅞	3⅛	2⅝	3⅜	3⅞
	¼	1½	2⅞	3⅛	2⅝	3⅛	3⅝
3½	3½	1½	3⅛	3⅜	2⅝	3⅜	3⅞
3½ OD	3½	1½	3⅛	3⅜	2⅝	3⅜	3⅞
	¼	1½	3⅛	3⅜	2⅝	3⅛	3⅝
4	4	1½	3⅜	3⅝	2⅝	3⅜	3⅞
4 OD	4	1½	3⅜	3⅝	2⅝	3⅜	3⅞
	¼	1½	3⅜	3⅝	2⅝	3⅛	3⅝

TABLE III — WITHOUT SPACERS
EMULSION-GRAPHITE HEAT TRANSFER CEMENT

Supported on Insulation

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B, FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1	1½	1⅝	2⅜	3⅛	3½
½ OD	½	1	1¼	1⅝	2⅜	3⅛	3⅜
¾	¾	1	1½	1⅞	2⅜	3⅛	3⅜
		1½	2⅛	2⅜	3⅛	4	4½
¾ OD	¾	1½	1⅞	2⅛	2⅝	3⅜	3⅞
	¼	1½	1⅞	2⅛	2⅝	3⅛	3⅝
1	1	1½	2	2⅛	2⅝	3⅜	3⅞
1 OD	1	1½	2	2⅛	2⅝	3⅜	3⅞
	¼	1½	2	2⅛	2⅝	3⅛	3⅝
1¼	1¼	1½	2⅛	2⅜	2⅝	3⅜	3⅞
1¼ OD	1¼	1½	2⅛	2⅜	2⅝	3⅜	3⅞
	¼	1½	2⅛	2⅜	2⅝	3⅛	3⅝
1½	1½	1½	2⅜	2⅝	2⅝	3⅜	3⅞
1½ OD	1½	1½	2⅜	2⅝	2⅝	3⅜	3⅞
	¼	1½	2⅜	2⅝	2⅝	3⅛	3⅝
2	2	1½	2⅝	2⅞	2⅝	3⅜	3⅞
2 OD	2	1½	2⅝	2⅞	2⅝	3⅜	3⅞
	¼	1½	2⅝	2⅞	2⅝	3⅛	3⅝
2½	2½	1½	2⅞	3⅛	2⅝	3⅜	3⅞
2½ OD	2½	1½	2⅞	3⅛	2⅝	3⅜	3⅞
	¼	1½	2⅞	3⅛	2⅝	3⅛	3⅝
3	3	1½	3⅛	3⅜	2⅝	3⅜	3⅞
3 OD	3	1½	3⅛	3⅜	2⅝	3⅜	3⅞
	¼	1½	3⅛	3⅜	2⅝	3⅛	3⅝
3½	3½	1½	3⅜	3⅝	2⅝	3⅜	3⅞
3½ OD	3½	1½	3⅜	3⅝	2⅝	3⅜	3⅞
	¼	1½	3⅜	3⅝	2⅝	3⅛	3⅝
4	4	1½	3⅝	3⅞	2⅝	3⅜	3⅞
4 OD	4	1½	3⅝	3⅞	2⅝	3⅜	3⅞
	¼	1½	3⅝	3⅞	2⅝	3⅛	3⅝

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	½	1¼	1⅜	2½	3⅛	3½
½ OD	½	½	1¼	1⅜	2⅝	3⅛	3⅝
¾	¾	½	1⅜	1⅝	2⅝	3⅛	3⅝
		1	1½	2	2½	3⅛	3⅝
¾ OD	¾	1	1⅝	1⅞	2⅝	3⅛	3⅝
	¼	1	1⅝	1⅞	2⅝	3	3¼
1	1	1	1¾	2	2⅝	3⅛	3⅝
1 OD	1	1	1¾	2	2⅝	3⅛	3⅝
	¼	1	1¾	2	2⅝	3	3¼
1¼	1¼	1	1⅞	2	2⅝	3⅛	3⅝
1¼ OD	1¼	1	1⅞	2	2⅝	3⅛	3⅝
	¼	1	1⅞	2	2⅝	3	3¼
1½	1½	1	2	2⅛	2⅝	3⅛	3⅝
1½ OD	1½	1	2	2⅛	2⅝	3⅛	3⅝
	¼	1	2	2⅛	2⅝	3	3¼
2	2	1	2⅛	2⅜	2⅝	3⅛	3⅝
2 OD	2	1	2⅛	2⅜	2⅝	3⅛	3⅝
	¼	1	2⅛	2⅜	2⅝	3	3¼
2½	2½	1	2⅜	2⅝	2⅝	3⅛	3⅝
2½ OD	2½	1	2⅜	2⅝	2⅝	3⅛	3⅝
	¼	1	2⅜	2⅝	2⅝	3	3¼
3	3	1	2⅝	2⅞	2⅝	3⅛	3⅝
3 OD	3	1	2⅝	2⅞	2⅝	3⅛	3⅝
	¼	1	2⅝	2⅞	2⅝	3	3¼
3½	3½	1	2⅞	3⅛	2⅝	3⅛	3⅝
3½ OD	3½	1	2⅞	3⅛	2⅝	3⅛	3⅝
	¼	1	2⅞	3⅛	2⅝	3	3¼
4	4	1	3⅛	3⅜	2⅝	3⅛	3⅝
4 OD	4	1	3⅛	3⅜	2⅝	3⅛	3⅝
	¼	1	3⅛	3⅜	2⅝	3	3¼

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1					
½ OD	½	1					
¾	¾	1¼					
		1½					
¾ OD	¾	1½					
	¼	1½					
1	1	1½					
1 OD	1	1½					
	¼	1½					
1¼	1¼	1½					
1¼ OD	1¼	1½					
	¼	1½					
1½	1½	1½					
1½ OD	1½	1½					
	¼	1½					
2	2	1½					
2 OD	2	1½					
	¼	1½					
2½	2½	1½					
2½ OD	2½	1½					
	¼	1½					
3	3	1½					
3 OD	3	1½					
	¼	1½					
3½	3½	1½					
3½ OD	3½	1½					
	¼	1½					
4	4	1½					
4 OD	4	1½					
	¼	1½					

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1½	2	2½	3
½	½	1	1½	2	2⅜	3	3⅜
½ OD	½	1	1⅜	2⅛	2⅜	3⅛	3⅝
¾	¾	1½	1⅝	2⅛	2⅜	3⅛	3⅝
		2	2⅛	2⅜	3⅛	3⅝	4
¾ OD	¾	1½	1⅞	2⅛	2⅝	3⅜	3⅞
	¼	1½	1⅞	2⅛	2⅝	3⅛	3⅝
1	1	1½	2	2⅛	2⅝	3⅜	3⅞
1 OD	1	1½	2	2⅛	2⅝	3⅜	3⅞
	¼	1½	2	2⅛	2⅝	3⅛	3⅝
1¼	1¼	1½	2⅛	2⅜	2⅝	3⅜	3⅞
1¼ OD	1¼	1½	2⅛	2⅜	2⅝	3⅜	3⅞
	¼	1½	2⅛	2⅜	2⅝	3⅛	3⅝
1½	1½	1½	2⅜	2⅝	2⅝	3⅜	3⅞
1½ OD	1½	1½	2⅜	2⅝	2⅝	3⅜	3⅞
	¼	1½	2⅜	2⅝	2⅝	3⅛	3⅝
2	2	1½	2⅝	2⅞	2⅝	3⅜	3⅞
2 OD	2	1½	2⅝	2⅞	2⅝	3⅜	3⅞
	¼	1½	2⅝	2⅞	2⅝	3⅛	3⅝
2½	2½	1½	2⅞	3⅛	2⅝	3⅜	3⅞
2½ OD	2½	1½	2⅞	3⅛	2⅝	3⅜	3⅞
	¼	1½	2⅞	3⅛	2⅝	3⅛	3⅝
3	3	1½	3⅛	3⅜	2⅝	3⅜	3⅞
3 OD	3	1½	3⅛	3⅜	2⅝	3⅜	3⅞
	¼	1½	3⅛	3⅜	2⅝	3⅛	3⅝
3½	3½	1½	3⅜	3⅝	2⅝	3⅜	3⅞
3½ OD	3½	1½	3⅜	3⅝	2⅝	3⅜	3⅞
	¼	1½	3⅜	3⅝	2⅝	3⅛	3⅝
4	4	1½	3⅝	3⅞	2⅝	3⅜	3⅞
4 OD	4	1½	3⅝	3⅞	2⅝	3⅜	3⅞
	¼	1½	3⅝	3⅞	2⅝	3⅛	3⅝

* Some nominal pipe size insulation as Table I.

All dimensions given in inches

For Steam Tracer System, see Std P-140.
For Electric Tracer System, see Std EL-43.

(OVER)

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ENGINEERING STANDARD NO. P-140A

TABLE I - WITHOUT SPACERS - cont'd

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	4	3 3/8	4 3/8	3 3/8	5 3/8	5 3/8
	1/2	5	3 3/8	4 1/2	4 1/2	5 3/8	5 3/8
5 OD	3/8	5	3 3/8	4 1/2	4 1/2	5 3/8	5 3/8
	1/2	5	3 1/2	4	4 1/2	5	5 1/2
6 OD	3/8	6	4 1/4	4 3/8	5 3/8	5 3/8	6 3/8
	1/2	6	4	4 1/2	5	5 3/8	6
6	3/8	7		5 3/8	6	6 1/4	7 3/8
	1/2	7		5 3/8	5 3/8	6 1/4	7
8 OD	3/8	8		5 3/8	6 3/8	7	7 3/8
	1/2	8		5 3/8	6	6 3/8	7 3/8
8	3/8	9		6 3/8	7 3/8	7 3/8	8 3/8
	1/2	9		6 1/2	7 3/8	7 3/8	8 3/8
10 OD	3/8	10		7	7 3/8	8	8 3/8
	1/2	10		6 3/8	7 3/8	7 3/8	8 3/8
10	3/8	11		7 3/8	8 3/8	8 3/8	9 3/8
	1/2	11		7 3/8	7 3/8	8 3/8	8 3/8
12 OD	3/8	12		8	8 3/8	9	9 3/8
	1/2	12		7 3/8	8 3/8	8 3/8	9 3/8
12	3/8	14		8 3/8	9 3/8	9 3/8	10 3/8
	1/2	14		8 3/8	9	9 3/8	10
14	3/8	15		9 3/8	9 3/8	10 3/8	10 3/8
	1/2	15		9	9 3/8	10	10 3/8
16	3/8	17		10 3/8	10 3/8	11 3/8	11 3/8
	1/2	17		9 3/8	10 3/8	10 3/8	11 3/8
18	3/8	19		11 3/8	11 3/8	12 3/8	12 3/8
	1/2	19		10 3/8	11 3/8	11 3/8	12 3/8
20	3/8	21		12 3/8	12 3/8	12 3/8	12 3/8
	1/2	21		11 3/8	12 3/8	12 3/8	13 3/8
24	3/8	25		14 3/8	14 3/8	15 3/8	15 3/8
	1/2	25		13 3/8	14 3/8	14 3/8	15 3/8

TABLE II - WITH SPACERS - cont'd

Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	5*	3 3/8	4 3/8	4 3/8	5 3/8	5 3/8
	1/2	5*	3 3/8	4 3/8	5	5 1/2	
5 OD	3/8	6	4 1/2	4 3/8	5 3/8	5 3/8	6 3/8
	1/2	6	4	4 1/2	5	5 3/8	6
6 OD	3/8	7		5 3/8	5 3/8	6 3/8	7
	1/2	7		5	5 3/8	6	6 3/8
6	3/8	7*		5	5 1/2	6	6 3/8
	1/2	7*		4 3/8	5 3/8	5 3/8	6 3/8
8 OD	3/8	9		6 3/8	6 3/8	7 3/8	8
	1/2	9		6	6 3/8	7 3/8	7 3/8
8	3/8	9*		6	6 3/8	7 3/8	7 3/8
	1/2	9*		5 3/8	6 3/8	7	7 3/8
10 OD	3/8	11		7 3/8	8	8 3/8	9
	1/2	11		7 3/8	7 3/8	8 3/8	8 3/8
10	3/8	11*		7 3/8	7 3/8	8 3/8	8 3/8
	1/2	11*		7	7 3/8	8	8 3/8
12 OD	3/8	14		8 3/8	9 3/8	9 3/8	10 3/8
	1/2	14		8 3/8	9	9 3/8	10
12	3/8	14*		8 3/8	9	9 3/8	10
	1/2	14*		8 3/8	8 3/8	9 3/8	9 3/8
14	3/8	15*		8 3/8	9 3/8	9 3/8	10 3/8
	1/2	15*		8 3/8	9	9 3/8	10
16	3/8	17*		9 3/8	10 3/8	10 3/8	11 3/8
	1/2	17*		9 3/8	10	10 3/8	11
18	3/8	19*		10 3/8	11 3/8	11 3/8	12 3/8
	1/2	19*		10 3/8	11	11 3/8	12
20	3/8	21*		11 3/8	12 3/8	12 3/8	13 3/8
	1/2	21*		11 3/8	12	12 3/8	13
24	3/8	25*		13 3/8	14 3/8	14 3/8	15 3/8
	1/2	25*		13 3/8	14	14 3/8	15

*Some nominal pipe size insulation as Table I.

TABLE III - WITHOUT SPACERS
EMULSION-GRAPHITE HEAT TRANSFER CEMENT - cont'd

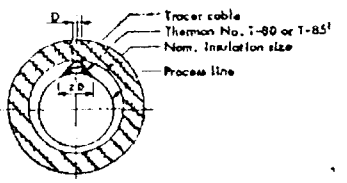
Supports Attached to Process Pipe

PROCESS LINE SIZE	TRACER SIZE OD	NOMINAL PIPE SIZE INSULATION	DIMENSION B FOR NOMINAL INSULATION THICKNESS 1	1	2	2	3
4	3/8	5	3 3/8	4 3/8	4 3/8	5 3/8	5 3/8
	1/2	5	4 3/8	4	4 3/8	5	5 3/8
5 OD	3/8	6	4 3/8	4 3/8	5 3/8	6	6 3/8
	1/2	6	4 3/8	4 3/8	5 3/8	5 3/8	6 3/8
6 OD	3/8	7		5 3/8	5 3/8	6 3/8	7
	1/2	7		5 3/8	5 3/8	6 3/8	6 3/8
6	3/8	7		5 3/8	5 3/8	6 3/8	6 3/8
	1/2	7		5	5 3/8	6	6 3/8
8 OD	3/8	9		6 3/8	7	7 3/8	8 3/8
	1/2	9		6 3/8	6 3/8	7 3/8	7 3/8
8	3/8	9		6 3/8	6 3/8	7 3/8	7 3/8
	1/2	9		6	6 3/8	7 3/8	7 3/8
10 OD	3/8	11		7 3/8	8 3/8	8 3/8	9 3/8
	1/2	11		7 3/8	8	8 3/8	9
10	3/8	11		7 3/8	7 3/8	8 3/8	8 3/8
	1/2	11		7 3/8	7 3/8	8 3/8	8 3/8
12 OD	3/8	14		8 3/8	9 3/8	9 3/8	10 3/8
	1/2	14		8 3/8	9 3/8	9 3/8	10 3/8
12	3/8	14		8 3/8	9	9 3/8	10
	1/2	14		8 3/8	8 3/8	9 3/8	9 3/8
14	3/8	15		8 3/8	9 3/8	9 3/8	10 3/8
	1/2	15		8 3/8	9 3/8	9 3/8	10 3/8
16	3/8	17		9 3/8	10 3/8	10 3/8	11 3/8
	1/2	17		9 3/8	10 3/8	10 3/8	11 3/8
18	3/8	19		10 3/8	11 3/8	11 3/8	12 3/8
	1/2	19		10 3/8	11 3/8	11 3/8	12 3/8
20	3/8	21		11 3/8	12 3/8	12 3/8	13 3/8
	1/2	21		11 3/8	12 3/8	12 3/8	13 3/8
24	3/8	25		13 3/8	14 3/8	14 3/8	15 3/8
	1/2	25		13 3/8	14 3/8	14 3/8	15 3/8

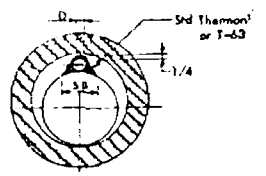
INSULATION SIZE DATA FOR ELECTRICALLY TRACED PIPELINES

TABLE IV - MINERAL INSULATED ELECTRIC TRACING CABLE

Conductors	2 #18	2 #18	3 #18	2 #16	3 #16	2 #14	3 #14	2 #12	3 #12	2 #10	3 #10	2 #8	3 #8
Cable OD-In.	.230	.246	.246	.340	.355	.371	.387	.402	.434	.449	.480	.512	.543
T-80 or T-85	Table I (3/8-In. Tracers)							Table I (1/2-In. Tracers)					
Std or T-65	Table III (3/8-In. Tracers)							Table III (1/2-In. Tracers)					

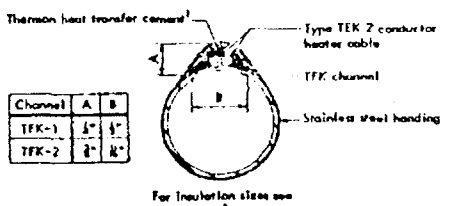


For comparable tracer size see Table IV, then select insulation size from Table I



For comparable tracer size see Table IV, then select insulation size from Table III

ELECTRIC TRACER MI CABLE CEMENTED TO PROCESS LINE



Channel	A	B
TEK-1	1"	1"
TEK-2	2"	2"

For insulation sizes see Table I for 3/8-in. tracers

ELECTRIC TRACER THERMON TYPE "TEK" CABLE CEMENTED WITH STEEL CHANNEL TO PROCESS LINE

[1]Heat Transfer Cement by Thermon Mfg. Co., Houston 19, Texas, or approved equal.

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XI. SAMPLING (N.W. Clauss)

The hazards of sampling process material include breakage of glass containers, thermal bums, static discharge ignition of flammables, inaccessability of sample points, plugged connections, sampling under pressure, identification of material, etc.

Tagging samples to indicate potential hazards in handling is important to protect laboratory personnel. One program is attached giving the definitions, procedures, and coding for tagging samples.

Certain chemicals such as ethylene oxide require fairly elaborate grounding procedures to prevent ignition by static discharge. The Ethylene Oxide - Glycol Production Manager can obtain the procedures if needed in your facility.

Identification of material is of critical concern especially since the symbolism used in C&P is often confusing. For example, the symbol DAA could mean diacetone alcohol, diallylamine or diamyl amine.

The following accidents illustrate some unusual sample hazard situations:

1. Liquid butane was sampled using a 500 psi pressure rated container. The vessel was filled with butane at 220 psi and a temperature of 26°F. The container was not vented to provide some vapor space as procedures stated and the container ruptured in the laboratory at the room temperature of 75°F. The vapor cloud ignited causing considerable damage.

2. Waste samples of acrylates were collected in a 5 gallon drum on a daily basis. One day a sample bottle had begun polymerization and when added to the 5 gallon drum contents all the acrylate material polymerized. The sample that initiated the reaction had not been inhibited as procedures called for.

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3. Laboratory personnel notice fumes emitting from a glass bottle but before any action could be taken the bottle exploded. The bottle was sitting in direct sunlight and next to a bottle of colorless liquid. The "lens effect" of the suns rays beamed into the sample bottle initiated an exothermic reaction.

In summary sampling procedures must be thoroughly analyzed and corrective action taken to safely deal with risk involved.

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MEMORANDUM

RED-TAG SAMPLES

GROUND RULES USED IN SELECTING CHEMICALS FOR RED-TAGGING

It was the consensus of the Laboratory Staff that any scientific approach to selecting chemical samples for "red-tagging" would involve those products already categorized as highly FLAMMABLE, extremely REACTIVE and/or HAZARDOUS to health. It was apparent after a cursory study that a combined listing of all chemicals in the three categories would involve many samples for which safe practices have already been established, thus defeating the purpose of the Red-Tag Program. So, a screening of the three categories for the so-called "bad actors" seemed the only logical approach to a listing for "red-tagging."

From information provided in the Reactive Chemicals Index and the Manual of Hazards to Health from Chemicals, a summary list was prepared of the Plant products which are considered to offer the greatest potential danger in handling. Guidelines for selecting this list are documented below, so that similar ones can be used to reduce the number even to a shorter more meaningful list.

At the heading of the attached list are the three general categories discussed above. Each was reviewed and arbitrary limits were established using definitions set up originally in the existing manuals. The limits are coded in the table as follows:

FLAMMABILITY

A - (1) Chemicals considered highly flammable under ambient conditions. —B. pt. < 32°C and flash point below 80° centigrade.

(2) Chemicals which ignite spontaneously in air or water to produce fire.

(A) - Chemicals borderline with respect to limits in A.

REACTIVE

B - Chemicals which readily polymerize, condense, decompose, ignite in air or detonate.

(B) - Chemicals borderline with respect to conditions in B. Reactive chemicals eliminated from the list are those which require catalysts for polymerization or condensation and those which undergo mild aldol condensation.

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HAZARDOUS TO HEALTH

C - Chemicals hazardous to health as defined by a rating of "5" in one or more of the five conditions listed in the Manual of Hazards to Health from Chemicals and a rating of "4" in two or more or in combination with "5" rating.

(C) - Chemicals judged borderline for red-tagging. These are chemicals which rate a severity of "4" or less in only one of the five conditions discussed in C.

The numerical ratings in the five columns are added to the table to assist further reviews in efforts to shorten the list. The numerical columns from left to right are:

(a) Swallowing

(b) Penetration of skin

(c) Irritation uncovered

(d) Breathing

(e) Eye

Relative hazards defined by the numerals are described as follows:

1. No residual injury is to be expected from accidental exposure even if no treatment is applied.

2. Minor residual injury may result from accidental exposure if no treatment is applied.

3. Minor residual injury may result in spite of prompt treatment.

4. Major residual injury may result in spite of prompt treatment.

5. Major residual injury is likely in spite of prompt treatment.

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SPECIAL HANDLING

S - Chemicals which could be removed from the Red-Tag list if subjected to safe practices already established, such as, special containers, dilution, addition of inhibitors, or refrigeration. THIS GROUP SHOULD BE REVIEWED VERY CAREFULLY BY THOSE WHO ARE EXPERIENCED AND KNOWLEDGEABLE IN MANUFACTURING AND HANDLING PROCEDURES.

No attempt was made to include gaseous products which require special sampling techniques, special containers, and usually special transportation.

No plant mixtures were listed. Each component must be judged according to its contributions and level of concentration in the mixture. In most cases plant mixtures do not require red-tagging.

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
All "hot" samples— mark as "HOT" on tag if this is the only reason for the red tag								C	
Acetaldehyde	A	(B)	2	2	2	5	3	C	
Acetaldol	(A)	B	2	4	2	3	2	(C)	S
Acetic Acid		(B)	2	3	3	3	5	C	
Acetic Anhydride		(B)	2	2	2	4	5	C	
Acetone Cyanohydrin	(A)	B	4	5	1	4	5	C	
Acetyl Chloride		(B)	3	3	4	5	5	C	
Acids, Mineral								C	
Acids, Organic (under name)									
Acrolein		B	4	4	5	4	5	C	S
Acrolein Cyanohydrin		B	4	5	5	5	5	C	
Acrylic Acid		B	2	3	4	1	4	(C)	
Acrylonitrile		B	4	3	1	4	2	(C)	
Acrylic Anhydride		B	2	3	4	5	4	C	
Alkyl Tin Compounds		B						C	
Alkyl Aluminum Compounds	A	B	3	0	5	4	5	C	S
Allyl Acetate		(B)	3	3	1	4	2	(C)	
Allyl Alcohol		B	4	4	1	4	2	C	
Allyl Chloride		B	3	2	1	3	1		
Allylidene Diacetate			3	4	3	5	5	C	
Amyl Amines			3	3	4	3	4	(C)	
Aniline			3	4	2	3	2	(C)	
o-Anisidine			2	4	1	1	4	(C)	
Benzene Sulfonic Acid			3	3	5	1	4	C	
Boron Trifluoride		(B)	0	0	4	5	5	C	
Boron Trifluoride Etherate		(B)	3	3	5	4	5	C	
Brucine Alkaloid			5	5	3	4	4	C	
Butyl Acrylate		B	2	2	1	4	2	(C)	S
Butyl Amine			3	3	4	4	4	C	
Butyl Aniline								C	
Butyl Chloride			1	2	1	5	1	C	
Butyl Magnesium Chloride		(B)	2	2	3	0	3		
Butyl Tin Compounds			3	3	5	3	5	C	
Butyraldehyde		(B)	2	2	1	3	4	(C)	
1,3-Butanediamine			2	3	4	1	4	(C)	
Butyric Anhydride		(B)	2	2	3	3	4	(C)	
t-Butyl Hydroperoxide	A	B							S

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
Calcium Acrylate		B	2	1	2	1	4	(C)	
Calcium Amide	A	B							
Carbon Tetrachloride			2	2	2	5	3	C	
Calcium (Metallic)	A	B							
Catalysts, (Pyrophoric)	A	B							
Calcium Cyanide			4	4	4	4	4	C	
Caustic Sol. (Strong, > 5%)			3	1	5	0	5	C	
Chloroacetic Acid			3	3	4	4	4	C	
Chloroacetophenone			4	4	3	4	2	C	
Chlorosulfonic Acid		B	4	3	5	0	5	C	
Chloroacetamide			4	4	4	4	5	C	
Chlorotrifluoro ethylene		B							
Chromium Oxide			4	2	4	4	5	C	
Cobalt Carbonyl	A	(B)	0	0	0	5	0	C	S
Copper Acetylide	A	B	3	1	2	0	4	(C)	S
Crotonaldehyde		(B)	3	3	4	5	4	C	
Crotonic Acid			2	2	2	1	4	(C)	
Croton Oil		(B)	3	4	4	5	4	C	
',3-Cyclo Pentadiene		B	3	2	1	3	2		
Decyl Acrylate		B	2	2	3	1	1		
Decyl Amine			3	3	4	2	4	C	
Diacetylene	A	B							S
Diacetyl Peroxide	A	B	3	2	4	4	5	C	S
Diamino Propane			3	4	5	1	4	C	
Di Allyl Maleate		B	3	3	2	1	1		
Dibutyl Amine			3	3	3	5	4	C	
Dibenzoyl Peroxide	A	B	3	2	4	4	5	C	S
Dibutyl Tin Dilaurate			2	3	5	0	2	C	
Diethylether Peroxide	A	B	3	4	4	4	5	C	S
Diethyl Amine			3	3	2	4	5	C	
Di-2-Ethyl Hexyl Phosphoric Acid			2	3	5	1	4	C	
Dicyclopentadiene		B	3	2	3	2	1		S
Diethyl Sulfate		(B)	3	3	4	2	3	(C)	
Diisopropyl Amine			3	2	2	5	4	C	
Diisopropylether Peroxide	A	B	3	4	4	4	5	C	S
Diketene		B	3	2	3	5	5	C	S
Dilauroyl Peroxide	A	B						C	S
Dimethyl Acrylic Acid			2	2	2	1	4	(C)	

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
Dimethyl Sulfate		B	3	3	5	5	5	C	
Di-n-propyl Amine			3	3	4	4	4	C	
Dioctyl Tin Dichloride			3	3	4	0	4	C	
Di-t-butyl Peroxide	A	B	3	4	4	4	5	C	S
Divinyl Sulfone			3	4	5	1	4	C	
Dripolene "C"	A	B	2	2	1	3	1		
Epichlorohydrin		(B)	4	3	1	4	2	C	
Ethyl Acrylate		B	3	3	1	3	2		
Ethyl Amine			3	3	4	3	4	C	
Ethylbutyric Acid			2	3	1	1	4	(C)	
Ethylene Chlorohydrin			4	4	1	4	3	C	
Ethylene Cyanohydrin		(B)	4	4	1	4	3	C	
Ethylene Diamine			2	3	4	4	4	C	
Ethylene Dichloride			3	2	1	4	2	(C)	
Ethyleneimine			4	5	4	5	3	C	
Ethylene Oxide	A	B	0	0	5	3	5	C	S
Ethyl Ether	A		2	1	1	4	1	(C)	
Ethyl Propylacrolein			2	2	2	1	2	(C)	
Ethyl Propyl Amine			3	3	4	4	4	C	
Ethyl Propenyl Ether	A	(B)	2	2	1	4	1	(C)	S
Ethyl Hexyl Amine			3	3	4	4	4	C	
Ethyl Hexyl Acrylate		B	2	2	3	1	1		
Ethylidene Diacetate			3	3	3	4	4	C	
Formaldehyde		B	3	4	4	3	4	C	
Formic Acid			2	2	4	4	4	C	
Gases									S
Glutyraldehyde			3	3	3	1	4	(C)	
Glyoxal (40% Solution)		(B)	2	2	1	2	2		
Glycidyl Acrylate			3	3	5	3	5	C	

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
Hexachlorocyclohexane			4	5	3	4	2	C	
Hexadienal		B	3	4	4	3	4	C	
Hexanoic Acid			2	3	4	1	4	C	
Hexaldehyde		(B)	2	2	1	2	1		
Hexyl Amine			3	3	4	3	4	C	
Hydrazine	A	B	3	3	3	4	4	C	S
Hydrochloric Acid			3	3	5	5	4	C	
Hydrocyanic Acid		B	4	4	2	5	4	C	
Hydrofluoric Acid			4	4	5	5	5	C	
Hydrogen Peroxide	A	B	4	4	5	0	5	C	
N-(Hydroxyethyl)ethyleneimine			4	3	4	1	4	C	
Hydroxyadipaldehyde		(B)	1	1	1	1	1		
Imino-bis-(propyl amine)			3	4	5	1	4	C	
Imino dipropionitrile			4	4	1	3	1	C	
Iodine			4	3	4	4	5	C	
Isoamyl Amine (mixed Isomers)			3	3	4	3	4	C	
Isobutyronitrile			3	3	1	4	1	(C)	
Isobutyric Acid			3	3	4	1	4	C	
Isopentanoic Acid			2	3	4	1	4	C	
Isopropyl Amine			3	3	4	3	5	C	
Isopropyl Ether	(A)		2	2	1	4	1	(C)	
Ketene (gas)		B	0	0	0	5	5	C	S
Lactonitrile			4	5	2	5	4	C	
Maleic Acid			2	2	4	2	4	C	
Maleic Anhydride		(B)	2	3	4	1	4	C	
Methacrolein		B	3	3	2	5	4	C	
Methacrylic Acid		B	2	3	4	1	4	C	
Methyl Amine			0	0	4	5	5	C	
Methyl Butyl Amine			3	3	4	4	4	C	
Methyl Isocyanate			4	3	4	5	5	C	
Methyl Iso Thiocyanate			3	3	4	4	4	C	
Methyl Thiocyanate			4	4	4	4	4	C	
Mono Chloro Acetone			4	4	4	5	5	C	
MYLONE Fungicide			3	3	5	4	2	C	
Mono Ethyl Sulfate		(B)	3	3	4	2	4	C	
Methyl Pyridine			2	3	4	3	4	C	

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
Nickel Carbonyl	A	B						C	S
Octyl Phenol			2	2	4	1	5	C	
Paraldehyde		B	2	2	2	2	4	C	
Pentanoic Acid			2	3	4	1	4	C	
Peracetic Acid (40% in HAc)		B	2	3	4	3	5	C	
Perchloric Acid		B	4	2	4	4	5	C	
Peroxides (all types)	A	B						C	
N-Phenyl Piperazine			3	4	4	1	4	C	
Phosphoric Acid			3	2	4		4	C	
Phosphorus	A	B	4	4	5	5	5	C	S
Phosphorus Oxy Chloride		(B)	3	3	4	4	5	C	
Phthalyl Chloride			3	3	4	3	5	C	
Phosphorus Trichloride		(B)	3	3	4	4	5	C	
Polvox Catalyst (1XM & 2XM Type)	A	B							
Potassium (Metal)	A	B						C	
Potassium Hydroxide			2	1	5	0	5	C	
Propionic Acid			2	3	4	1	4	C	
Propylene Imine			4	4	4	4	4	C	
Propylene Oxide	A	B	2	3	1	5	2	C	S
Propionaldehyde		(B)	2	2	1	4	2	(C)	
Pyridinium Compounds			3	3	4	0	4	C	
Silicon Tetrachloride		B	0	0	2	3	5	C	
Silver Acetylide	A	B							S
Silver Nitrate			4	2	4		5	C	
Sodium	A	B	0	0	4	0	5	C	S
Sodium Cyanide			4	3	3	0	4	C	S
Sodium Hydroxide			3	1	5		5	C	
Sodium Di(2-ethylhexyl)phosphate			2	2	4	0	4	C	
Sodium Mernylate		(B)	3	2	3	0	4	C	
Stabilizer D-14			4	4	4	0	4	C	
Stabilizer D-22			2	3	5	0	2	C	
Styrene		B	2	2	2	2	2		
Styrene Oxide		B	2	3	1	2	1		
Sulfuric Acid			4	2	4		4	C	

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RED-TAG SAMPLES

Chemical	Flammability	Reactive	Health (a)	(b)	(c)	(d)	(e)		Special Handling
TEMIK								C	
TEMIK Oxime		B						C	
Tetramethylbutanediamine			3	3	4	1	4	C	
Tetramethyl Silane			2	0	4	3	5	C	
Titanium Tetrachloride		B	2	3	4	5	5	C	
Trialkyl Aluminum Compounds	A	B	3	0	5	4	5	C	S
Tributyl Amine			3	3	3	4	4	C	
Tributyl Phosphine	A	B	3	3	1	4	2	(C)	S
Tridecyl Aldehyde	A	B	2	2	2	0	2		S
Triethylene Tetramine			2	3	4	1	2	(C)	
Trimethylamine			0	0	4	4	4	C	
UCAR Butylene Oxide 12			2	2	1	4	2	(C)	S
UCANE Akylate 12 & 13			2	2	4	0	3	(C)	S
Valeric Acid			2	3	4	1	4	(C)	
Vanadium Pentoxide Cat.		(B)	3	4	2	3	5	C	S
Vinyl Acetate (Monomer)	A	B	2	2	1	3	1		S
Vinyl Acrylate (Monomer)	A	B	2	2	1	2	1		S
Vinyl Allyl Ether (Monomer)	A	B	3	2	1	4	1	(C)	S
Vinyl Butyl Ether (Monomer)	A	B	2	2	2	4	1	(C)	S
Vinyl Butyrate (Monomer)	A	B	2	2	1	3	1		S
Vinyl Ethyl Ether (Monomer)	A	B	2	1	1	2	1		S
Vinyl Chlorethyl Ether (Monomer)	A	(B)	3	2	1	4	1	(C)	S
Vinyl Crotonaldehyde		B	3	4	4	4	5	C	S
Vinyl Crotonate		B	2	2	1	3	1		S
Vinyl Formate	A	B	2	2	1	4	4	C	S
Vinyl Isobutyl Ether	A	B	1	1	1	4	1	(C)	S
Vinyl Isopropyl Ether	A	B	1	2	1	4	1	(C)	S
Vinyl Methyl Ether	A	B	2	2	1	3	1		S
Vinyl Propionate	(A)	B	2	2	1	4	1	(C)	S
Vinyl Trichlorosilane			2	3	4	4	3	C	

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XII. SUMMARY (N. W. Clauss)

The section on Equipment Safety has included the Operations safety-related concerns for layout and congestion; flammability, ignition sources and inerting for the protection of equipment and personnel; code requirements for process vessel and their protection from overpressure; test and inspection needs; materials of construction, piping, machinery and insulation; distribution facilities; and sampling hazards.

The safety of chemical processing systems can be invalidated by changes in service or equipment initiated by Operating supervision when the hazards introduced are not recognized. It is for this reason that the C&P Safety Department has issued Standard SF-108 to cover the review and approval requirement for changes made to chemical systems.

The following exerpts from an article in Chemical Engineering Progress (November 1976) covers the concerns related to plant modifications.

A number of incidents, some serious, have occurred because plant modifications produced results that were not foreseen. The emphasis here is on modifications to the equipment, but the same principles apply to modifications to the process - such as a change in catalyst, raw materials, or operating conditions.

HOW AND WHEN THINGS GO WRONG:

Modifications Made During or Just Before Start-Up. This is often a time when many modifications are made and it's always a time of intense pressure. It is, therefore, not surprising that some modifications introduced during this period have resulted in serious unforeseen consequences.

Minor Modifications. This term is used to describe modifications so cheap that they do not require financial sanction. Often times the only documentation associated with them has been a workshop note.

Temporary Modifications. The most famous of all temporary modifications is the bypass pipe installed at the Nypro Co. plant at Flixborough, England, in

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March 1974. It failed two months later, causing the release of about 50-tons of hot cyclohexane, an unconfined vapor cloud explosion, and the loss of 28 lives. Designing the type of highly-stressed piping required for the by-pass demanded a specialized knowledge that the Flixborough people did not possess. Few engineers do. What is more, they did not realize that such sophisticated engineering was necessary; they did not know what they did not know.

Sactioned Modifications. This term is used to describe modifications for which the money has to be authorized by a senior official, or perhaps by a committee. The modifications cannot therefore, as a rule, be made in a hurry. Justifications have to be written out and people persaude.

Although the systems are, or have been in the past, designed primarily to control cost rather than safety, they usually result in careful consideration of the proposal by experienced technical personnel and unforeseen consequences may come in mind (though not always; sometimes sanction is obtained before detailed design has been carried out and the design may then escape detailed consideration).

HOW TO PREVENT THINGS FROM GOING WRONG:

There must be a rigid procedure for making sure that all modifications are authorized only by competent persons, who, before doing so, try to identify all possible consequences of the modification and then specify the change in detail. (Refer to SF-108 Standard).

There must be some sort of guide sheet or check list to help people identify the consequences.

As a final concluding statement, it is obvious that accidents result from errors of omission or commission on the part of "people" and all accidents can be avoided by "people." Education in the many ways hidden hazards can be introduced may help people in avoiding the hazards that result in accident losses of people, equipment, material and lost production time.

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7. ELECTRICAL SAFETY (J. J. Walker)

I. INTRODUCTION

There are a wide variety of electrical safety problems in all of our plant locations. You will be faced with many of these problems and may even cause some of the problems by virtue of changes and alterations that are made in the field without due consideration for electrical safety.

Whereas fires involving electrical equipment usually account for only about 7 percent of the total fires in the plants the results of fires involving electrical equipment are usually very serious because of production loss. (Also serious production losses occur because of malfunctions of electrical equipment which can result in hazardous situations.) Electrical equipment accounts for a rather large number of ignition sources of fires that are not classified as electrical.

Emergency lighting is another area of electrical service that pertains to safety.

Whereas personnel safety is not specifically considered in this Process Safety Educational Manual it too must be considered as a hazard potential where electrical equipment is concerned.

II. ELECTRICAL HAZARD CLASSIFICATION

Electrical hazard classification should be understood by all field engineers. Changes made in the field can effect the electrical hazard classifications. We have a formal procedure for electrical hazard classification. OSHA requires that we follow the National Electric Code insofar as installation of electrical equipment in classified areas. It does not however indicate how areas are to be classified. In general, we follow the API system for classification of hazardous areas. This is based on API Bulletin RP-500A which has specific steps for classification. Reference is made here to the Safety Manual, Section 2.2.1.

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Step No. 1 states "the need for classification is indicated by an affirmative answer to one of the following questions:"

A. Is the presence of flammable liquids likely?

B. Are liquids having flash points over 140°F likely to be handled, processed, or stored at temperatures above their flash points?

Step No. 2 - Assignment of Classification

Assuming an affirmative answer results from Step 1, the following questions should be used to determine the assignment of classification.

Division 1 locations may be distinguished by an affirmative answer to any one of the following questions:

A. Is a flammable gas or vapor concentration likely to exist in the air under normal operating conditions?

B. Is a flammable atmospheric concentration likely to occur frequently because of maintenance activities or leakage?

C. Would failure of process, storage, or other equipment be likely to cause an electrical system failure simultaneously with the release of flammable gas or liquid?

D. Is the flammable liquid or vapor piping system in an inadequately ventilated area, and is the piping system (containing valves, meters, or screwed or flanged fittings) poorly maintained?

E. Is the area below the surrounding elevation or grade such that the flammable liquids or vapors might accumulate therein?

Note: The important parts of Step No. 2 are parts A and B. As an example, in a analyzer house the gas sample room is usually full of screwed connections. There are likely to be leaks from these myriad connections thus

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a sample room in an analyzer house is usually a Division 1 area. Another example would be a packing gland on a pump. In many cases the area immediately surrounding a packing gland for a distance of two or three feet should be considered a Division 1 area. Still another example of a Division 1 classification would be the area around a switching station where frequent connections and disconnections of portable hoses are made. Below grade pits and trenches where vapors are likely to accomulate are always classified as Division 1 areas.

Division 2 locations may be distinguished by an affirmative answer to any one of the following questions:

A. Is the flammable liquid or vapor piping system in an inadequately ventilated area and is the piping system (containing valves, meters, or screwed or flanged fittings) well maintained? NOTE -A well maintained metering station without adequate ventilation may be a Division 1 area.

B. Is the system handling flammable liquid or vapor in an inadequately ventilated area, and can liquid or vapor escape from that system (exclusive of well-maintained piping system) only during abnormal conditions such as accidental failure of a gasket or rupture of a pipe?

C. Is the location adjacent to a Division 1 location or can vapor be conducted to the location as through trenches, pipe, or ducts?

D. If positive mechanical ventilation is used, could failure or abnormal operation of ventilation equipment permit atmospheric vapor mixtures to build up to flammable concentrations?

Step No. 3 - Extent of Classified Areas

The extent of a classified location may be determined by applying with sound engineering judgement the distances recommended as shown in Figures 1 through 18.

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Whereas in the past some of the people responsible for electrical hazard classification have been inclined to be somewhat conservative in their classification - particularly if there was any question in their mind - it now behoves us to "sharpen our pencil" so to speak. With the advent of the Occupational Safety and Health Act of 1970, it is now mandatory that we adhere to the requirements of the National Electric Code which, can be quite costly. Thus, we should examine very carefully any area that is to be classified electrically and, while we recommend that it be given as accurate definition as possible, we should certainly not be over-conservative in this regard. Reference is made here to Standard ELC-85. This Standard shows an electrical design guide for many hazardous areas. With the use of good judgement and a guide such as this, many of our problems can be eliminated in the careful arrangement and location of electrical devices.

Also Figures 19, 20, and 21 indicate flammable vapor dispersion data. This data indicates that for liquified gases such as ethylene, some of our classifying dimensions may be on the "short side." The dispersion data for ordinary flammables such as acetone, acetaldehyde, etc. indicate that our classification dimensions may be overly conservative or "too long" for areas in which these types of chemicals are used. This type of information should be considered when applying electrical hazard classification dimensions.

In each plant there is an electrical hazard classification team usually composed of an electrical engineer, a representative of the Safety Department, a representative from Instrument Engineering, and the Operating Department. The Operating Department member usually rotates depending upon the area of the Plant that is under consideration. It is responsibility of this team to maintain an up-to-date record of all areas of the plant as to electrical hazard classification with supporting rational for said classifications.

Any questions regarding classification should be directed to this team. However, all field engineers should recognize what the classifications are in the areas in which they are working and (as stated earlier) how these classifications may be affected by changes made in the field. Also they should be aware of what types of electrical equipment as specified by the National Electrical Code, are needed to qualify for the various classifications.

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If all areas of the plant are classified correctly, and all electrical equipment used is the proper type - approved for the specific classification for the area involved - we've gone a long way toward reducing the numbers of fires and the attendant production losses. We've also reduced potential ingition sources and provided a large measure of personnel safety.

III. PURGING

Positive pressure air purge may be used to reduce the classification of an enclosure or room from Division I to Division II or from Division II to unclassified. NFPA Code 496 contains requirements for such purging. Alarms upon loss of air purge and/or automatic electrical disconnects or flammable gas detectors in air inlet may be needed depending upon the type of purging required.

Field engineers should be aware of the purging requirements in installations in their respective areas and how they might nulify the "approval" of such installations by field changes or additions.

One somewhat common problem involves machinery rooms in control buildings where unapproved electrical equipment is used and no purge is provided.

IV. SWITCHGEAR AND BACKUP BATTERY POWER

There are some other things to consider for reducing the size of fire losses and business interruptions (and increasing personnel safety). One of these is back-up switchgear. Back-up switchgear should be available to cut off hazardous service pumps, etc., when the ordinary start-stop switch is involved in the fire. Proper identification of such back-up switchgear is also necessary.

Lock-out capability for switchgear is also mandatory. Sometimes switchgear is installed without the little loops provided for lock-out.

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Backup of battery power for emergency controls, for radio base stations and for critical protective relays is necessary. Such backup battery power must be maintained adequately so as to always be available for emergency service.

V. CONDUIT SEALS

Conduit seals are a never-ending problem in all plant locations. Electrical conduit in classified areas is provided with seals which must be filled with sealing compound and maintained in that condition. Normally filling the seals is the last thing that is done upon completion of a job because of testing out of electrical equipment and the possibility of having to pull additional wiring. Frequently seals are missed. Insurance inspectors usually look at this feature and it is to our own benefit to make sure that these seals are maintained as the classification approval for certain equipment is dependent upon the seals being provided.

The location of electrical conduit seals and the filling of the seals can effect the electrical classification of an area. See EL-12 and ELC-22. Thus changing the seal locations or breaking the seals in order to pull wiring can effect electrical hazard classification.

VI. LIGHTNING

Lightning is also a source of ignition in the plants. Usually this is not by direct stroke but rather induced charges. It is quite common in plants to have vent fires during lightning or thunder storms. This is the result of an induced charge which arcs at the end of the grounded vent to the gas cloud. Normally some sort of snuffing arrangement is provided for vents that have frequent fires caused by this source. Nitrogen or steam are usually used for this purpose. (For extinguishment with steam, see Section 5.2.3.5 of the Safety Engineering Manual.) Vent ignitions are most often due to atmospheric electricity (static bleed-offs or inceptions) rather than lightning strokes. An air terminal or lightning rod can be used to prevent this. If the rod is made several feet long, the electricity concentration is usually located at a point where the gas-air mixture is too lean to burn. A little experimentation will solve the problem if the first trial is not successful.

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Plants containing flammables are ordinarily constructed of metal which is at ground potential and thus are protected from lightning damage. The highest structures in such areas do, however, act as lightning terminals. All should therefore be electrically continuous and be well grounded. This is the case with many columns, towers, stacks, and vent pipes. Difficulties are not encountered until such high points and objects are not metal conductors to ground.

In the cases of high structures being part or all masonry, reinforced concrete, or other nonconductor, special precautions are necessary to provide for interception, collection, and conduction of lightning discharges to ground. When planned into the original design, this is not difficult nor expensive. The "Lightning Protection Code NFPA 78" provides all the necessary details.

VII. GROUNDING

All plant structures and equipment are grounded in accordance with Standards EL-60, 61, and 62. These grounds should be checked periodically to assure that they are still in-tact. If the ground is permanently attached to the equipment or structure a test cannot be made. However, a visual inspection should be made as such grounds are often corroded or torn loose from the structures. Removal of any of these ground connections for field changes or maintenance can be a source of potential hazard. Portable grounds are also provided for transfer of chemicals to and from drums, tank cars, tank trucks, barges, etc. These grounds should be attached as recommended in Standards EL-63 and 64 and should be inspected periodically to insure their integrity. Chemical transfer hose has ground wires embedded in the hose or the hose is of the conductive type which maintains electrical continuity from coupling to coupling. Such hoses should be tested periodically to assure that electrical conductivity is maintained. Refer to Appendix B for electrical standards on grounding.

Generally, no ground loops, fields, or beds are required for process grounding. No water connected process equipment nor process equipment resting on grounded steel needs further grounding.

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Pipe racks are not usually grounded unless they contain certain unstable chemicals, pneumatic dust conveyors, or those used to support piping switching stations. A pipe rack traversing an open unoccupied area and thereby exposed to lightning should be grounded if it contains flammables.

The Fire Protection Layout or the Electrical Design Report for each project should show the following process system grounding:

1. Steel equipment structures, prefabricated metal buildings, and steel frame buildings according to standard drawings EL-60 and EL-61.

2. All processing equipment, tanks, and metal stacks according to standard EL-62.

3. All loading and unloading, filling and emptying equipment for railroad tank cars, tank trucks, barges, ships, drums, cans and containers as shown on standards EL-63, -64, and -65.

4. All pipe switching stations should be ground and this includes make and break transfer points.

5. All piping and pipe racks for ethylene oxide, acetylene, peracetic acid, and dinitrotoluene (detonable compounds) per standard EL-67.

6. All electrical instrument cases and panels.

7. Lightning protection for all masonry buildings and stacks according to the NFPA 78 Code.

8. All hazardous area ventilation systems shall be bonded and grounded where not supported by grounded steel framing.

9. All resin handling equipment, ducts, conveyors, bins, and transfer facilities containing combustible dusts.

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VIII. EVALUATION AND TESTING OF UNLISTED (UNAPPROVED) ELECTRICAL DEVICES

From time to time unlisted or unapproved electrical devices are required for use in hazardous areas. Some of these devices are dictaphones, portable recording devices, calculators, telephones, radios, occupational health monitoring devices, etc. Reference is made to "Safety Guidelines" For Use of Portable Battery-Powered Devices in Hazardous Areas". An on-going program of handling problems of this nature has been established. The Safety Engineering Manager should be contacted with respect to evaluation of unapproved devices. An analysis is made of such a device to find out whether it is incendive (a device that when operated produces enough energy-spark, arc, or heat - to ignite a flammable mixture) or non-incendive (a device that will not cause ignition when operated unless damaged or faulty) and whether it is intrinsically safe. If the device is non-incendive but not intrinsically safe the Safety Department will pass judgement as to what conditions must apply before such a device can be used. Obviously an intrinsically-safe device may be used without qualification and a incendive device must only be used under hazardous work permit.

IX. EMERGENCY LIGHTING

Emergency lighting is required in certain areas of the plant such as Control Rooms and at critical operating areas and sometimes critical access areas or intersections of critical access corridors or roadways. Such emergency lighting may be provided by an approved flashlight and electric hand laterns. (This is short-term protection and is often all that is needed locally for simple operation.)

X. STATIC ELECTRICITY

Static Electricity is primarily an ignition source hazard and is thus included in "Ignition Sources", Section 5-II.

XI. PROTECTING ELECTRICAL EQUIPMENT SYSTEMS

Questions pertaining to protection of, or problems concerning, electrical equipment or distribution systems should properly be addressed to

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your plant electrical engineers. However you should have some basic understanding of the types of protection that are provided for electrical equipment and systems and what kinds of problems can be expected if proper precautions are not observed.

Electrical protection can be defined as the application of protective devices such as protective relays, circuit breakers, and fuses to detect and isolate electrical equipment which may fault in some manner. The term electrical equipment as used here includes all the various elements in the electrical system - cables, motors, transformers, switchgear, etc.

There have been unfortunate incidents where serious injuries to C&P personnel have resulted from electrical faults. We would be shocked if it were possible to know the monetary losses to C&P in equipment and production as a result of electrical faults. We wish to emphasize the importance of minimizing fault propagation.

The main causes of electrical failures are:

1. Contamination of insulating surfaces with dirt and moisture -this promotes leakage current paths to ground and most likely damaging faults will occur.

2. Another primary cause is loose connections. This is a big problem with equipment in all voltage classes. When there is a loose connection in current carrying parts, rapid heating results and this quickly deteriorates into arcing and burning. Ionization takes place and most likely a line to line (phase to phase) or ground fault will occur.

3. Poor quality equipment - many factors are involved in this -the basic insulating levels may be too low for the service; there may be inadequate clearances between phase conductors, and between phase conductors and ground; there may be misalignment of moving parts to stationary parts; these are just a few examples of equipment deficiencies.

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4. Misapplication of equipment - this covers a host of sins, some of which are: the load rating of equipment is not adequate for the duty; the fault interrupting rating is too low for the system fault capacity; and the equipment may be the wrong type for the system configuration and coordination of such.

5. Poor workmanship - here again an exhausting list of problems could be sited: cable splices and terminations improperly made; entrance of water into electrical enclosures; and lack of improper adjustment of equipment components.

6. Lack of or inadequate surge protection - over voltage surges can and do cause equipment failure, and there are many other causes that time does not permit to enumerate.

There are several types of protective relay configurations such as the radial system, the loop system, etc. The Electrical Technology Group periodically evaluates the settings of the protective relay systems. Also it is important that the adequacy of the protective relaying system be evaluated. It is not always clear that this is done on some periodic basis. Perhaps you can help here. Also it is of primary importance that protective relays (not only be properly set) but that they be maintained in a proper fashion, i.e. an acceptable T&I program is operable. There have been a number of cases of total plant power failure with resulting damage and lost production to the plant due to improperly operating protective relays.

The use of dissimilar metals in switchgear, connectors, etc., have also been a source of trouble (reference "Materials of Construction Section").

There are ten be-sures to keep in mind: These ten be-sures are really the responsibility of the plant electrical engineers. They are listed here for your information so that you can assure that they are carried out in your unit.

1. Be-sure to identify and understand the type of faults which can occur in the system. There are several types - single line to ground, double line to ground, single line open, two line open, etc.

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2. Be-sure to calculate the currents for type faults identified at representative locations throughout the system. Make sure that contributions to the fault current from all sources, including induction and synchronous motors have been included. Consider both the assymmetrical and symetrical components of fault current.

3. Be-sure to determine the heat energy release (I^2T) for fault currents based on fault clearing times established in No. 4 which follows.

4. Be-sure to develop a coordinated clearing and isolating scheme for faults from the highest voltage level to the lowest.

5. Be-sure the stability requirements of the system are known -specifically where fault clearing times are required to keep synchronous machines and induction motors from loosing stability and shutting down.

6. Be-sure to give special attention to ground-fault protection and to low magnitude faults of all types identified - quickly clear all ground faults on 13.8 KV systems regardless of magnitude of ground fault current. On 480, 2400, and 4160 volt grounded systems, do likewise unless the allowable system ground fault current is limited to 2 amperes or less.

7. Be-sure all protective relays are of the proper type and range and are compatible with current transformer ratios and burdens.

8. Be-sure all interrupting devices are fully rated for maximum fault current and their cleaning times are compatible with stability times established.

9. Be-sure to protect the tripping integrity of all breakers and switches - this means, for example, that if battery tripping power is used, the battery and associated charging equipment must be secured at all times.

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10. You know at this point someone should ask "so what," we do all of this and problems still occur. Well, it turns out this is a pretty good "so what." I believe the answer is to provide means for the periodic testing of protective devices - testing and checking on some periodic basis is imperative to the continuing good health of electrical safety.

XII. GENERAL CRITERIA RELATING TO ELECTRICAL SAFETY

Listed below are some general, miscellaneous criteria relating to Electrical Safety.

All electrical equipment shall be Factory Mutual's Underwriters', of Bureau of Mines' approved for the specific classification involved unless otherwise authorized by the Process Safety and Fire Protection Department.

Division 2 open, tropical, TEFC or WP-II electrical motors, standard weight conduit and fittings, vapor tight overhead lights with heat resistant globes and oil tight enclosures with alarmed purge or hermetically sealed apparatus are all acceptable in Division 2 areas.

To minimize ignition sources, power operated industrial trucks for use in Division 2 areas shall be of the battery powered type constructed in accordance with the requirements for Type EE of the National Fire Protection Association Pamphlet 505.

Battery charging equipment must be located in a segregated electrical switch room, be of the oil-immersed type, or be suitable for Division 2 locations. Switch rooms containing battery charging equipment shall be given adequate ventilation.

Electrical instruments or equipment (apparatus, controls, panels, switches, breakers, etc.) which may arc, spark, or overheat must be contained in explosion-proof or purged (with alarm) housings when located in Division 1 or 2 areas. Electrical equipment surface temperatures must be known to avoid ignition source hazards.

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Intrinsically safe electrical communications equipment and controls as defined by the ISA or NFPA require no additional safeguards.

Process system grounding is not required for those vessels containing nonflammables but may be desired for lightning protection and dissipation of stray currents and static electricity where there are other flammables.

Power and instrument cable trays are essential to production, but very vulnerable to fire.

Experience has taught that an optimum of protection might be achieved in areas of severe fire hazard by careful consideration of the following guidelines:

1. Install control and critical power cables underground except in those areas of the process served where they should be otherwise protected. Underground portions of the cables must be suitable for the environment, must be protected from mechanical damage, and underground gas pockets must be avoided.

2. Fire proect other power and control cables installed overhead in fire hazardous areas with shields shown on standard drawing FP-58 and automatic fixed water spray protection. Install trays (galvanized steel preferred) within or on top of pipe racks and not on the outside of racks where they are the most vulnerable and expensive to protect.

3. Route all cables overhead where there is no process fire hazard and avoid bringing them all together at one point even at control buildings where all will be subject to a single accident.

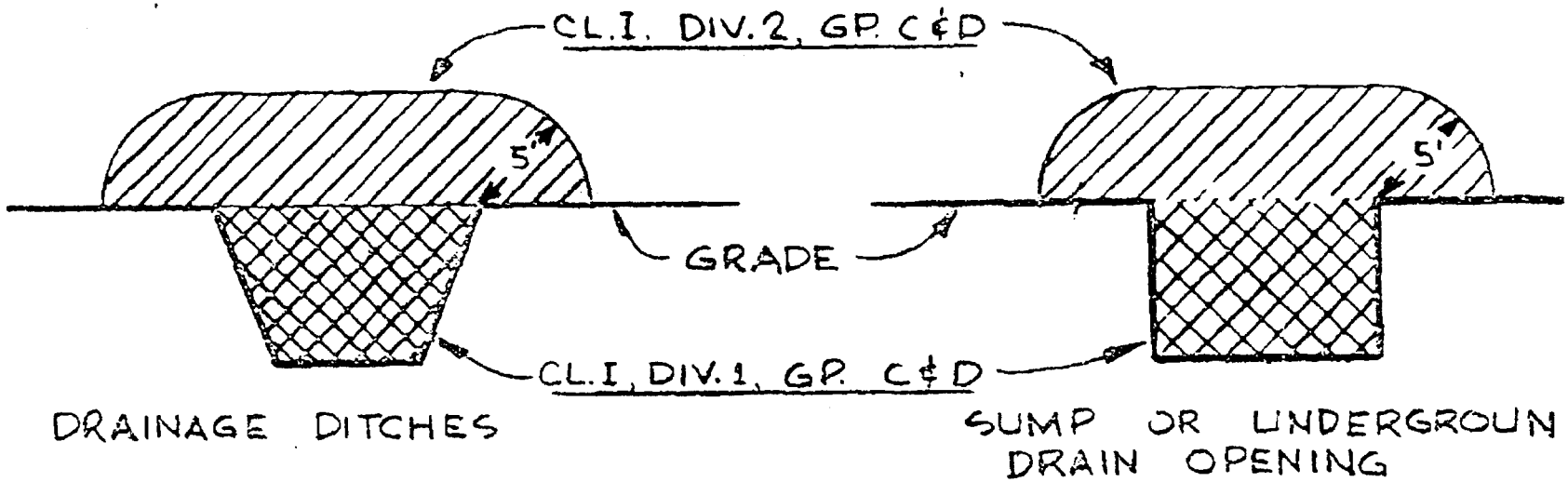
Reference standards on safety covering of cable pits, cable sealing, tracing for safety showers and lighting requirements are included at the end of this section.

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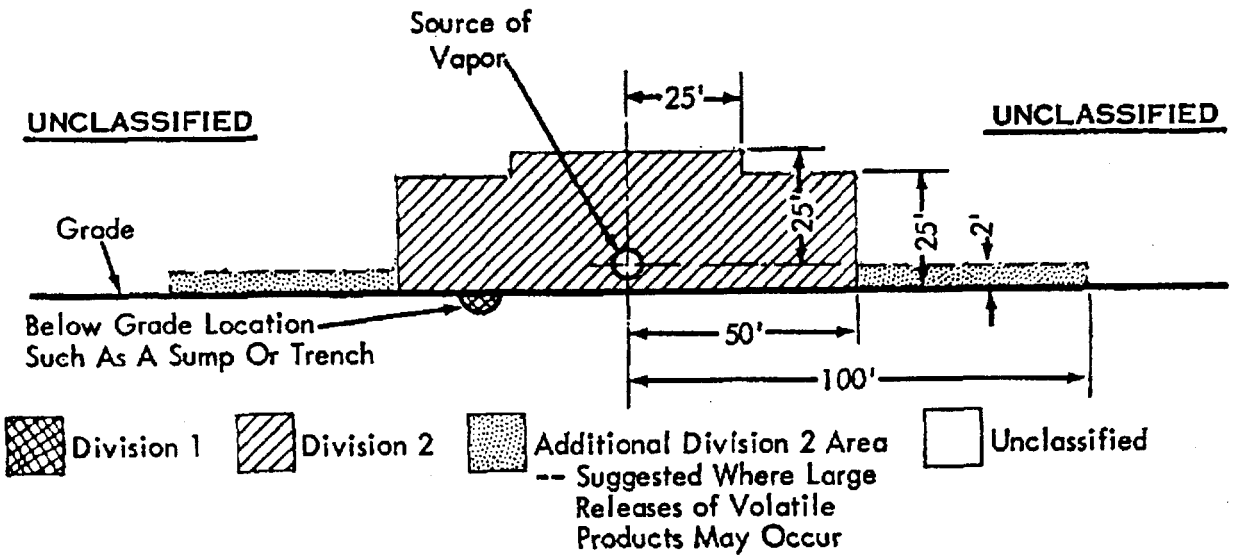
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TYPICAL UNDERGROUND DISTANCES (NOT TO SCAL

Fig. 1

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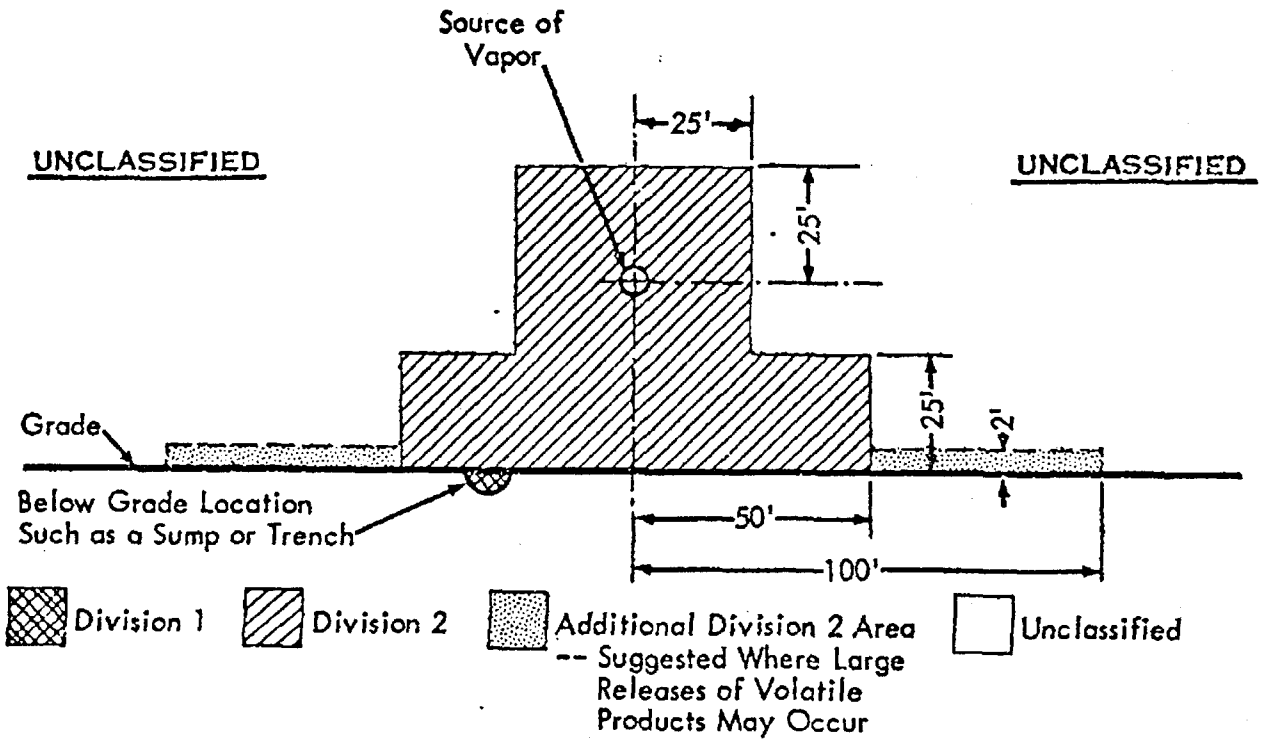
Note: Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

Adequately Ventilated Process Area (Source of Hazard Located Near Grade).

FIGURE 2

22.2.1.1

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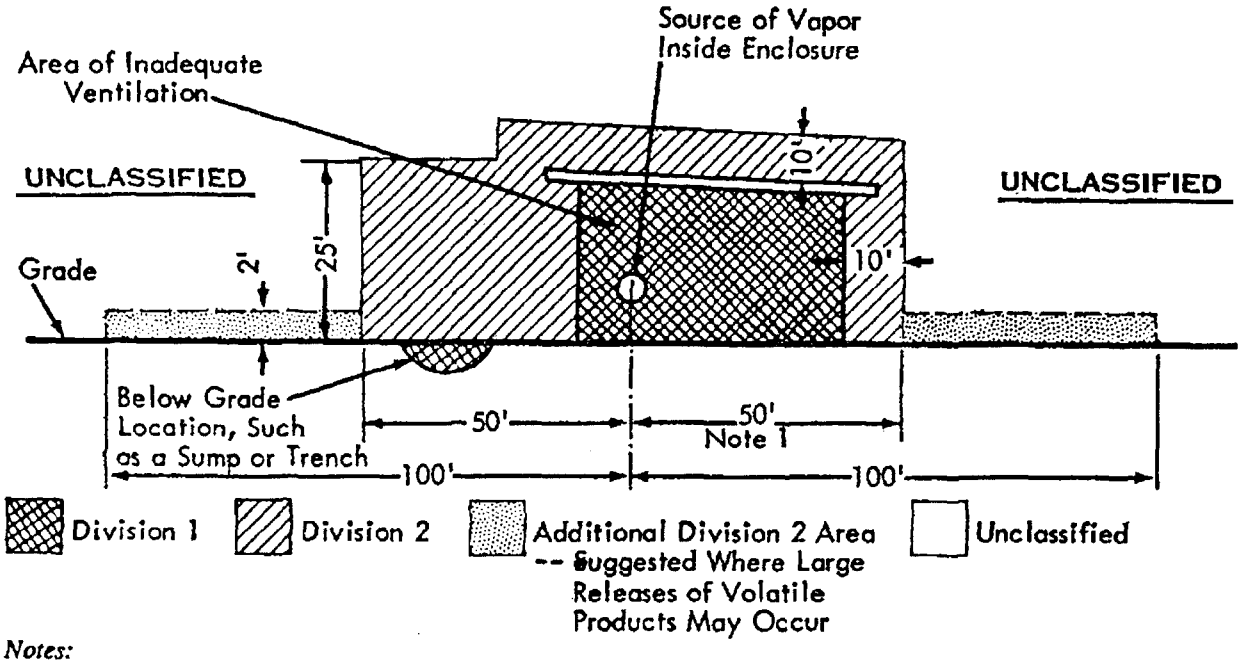
Note: Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

Adequately Ventilated Process Area (Source of Hazard Located Above Grade.)

FIGURE
3

22.2.1.1

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Notes:

1. Apply horizontal clearances of 50 ft from source of vapor or 10 ft beyond perimeter of building, whichever is greater; except beyond unpierced vaportight walls, the area is unclassified.

2. Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

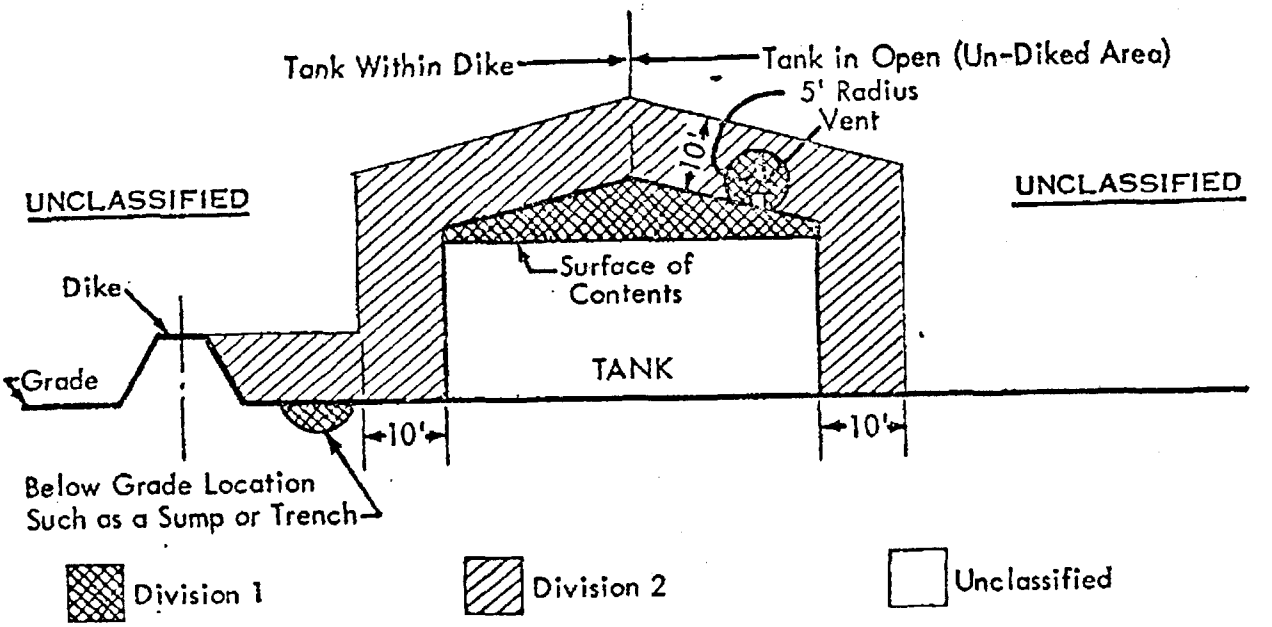
Process Area with Inadequate Ventilation.

FIGURE
4

22.2.1.1

517

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Notes:

1. For floating-roof tanks, the area above the tank roof and within the shell is classified Division 1.

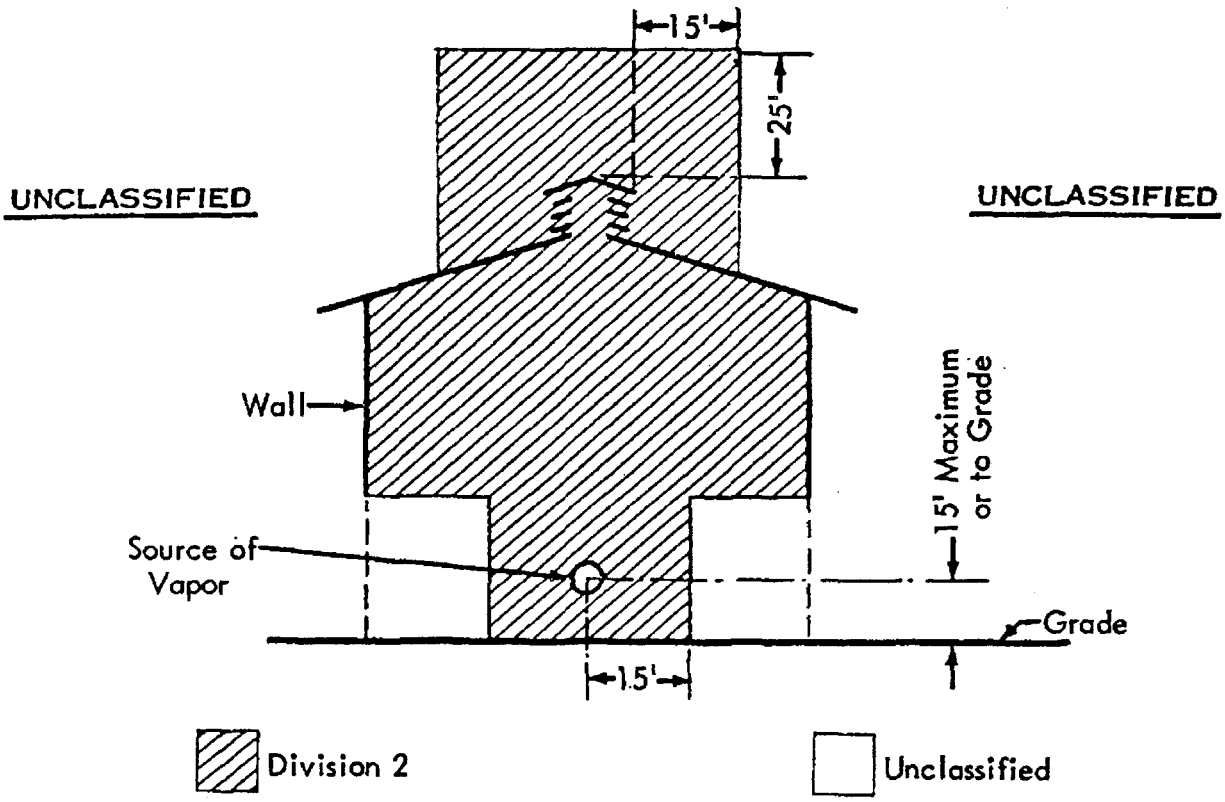
2. High filling rates or blending operations involving Class I liquids may require extending the boundaries of classified areas.

3. Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

Refinery Tank.

FIGURE
5

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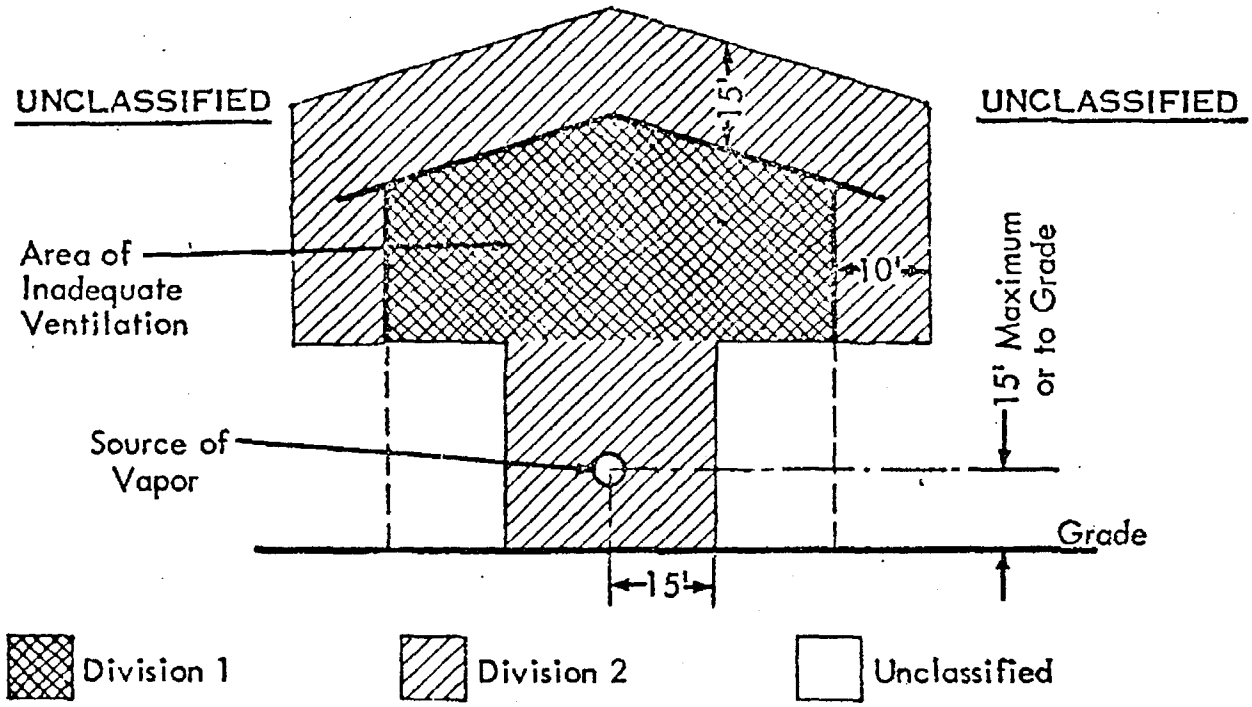


Note: Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

Compressor Shelter with Adequate Ventilation for Lighter-Than-Air Vapor.

FIGURE
6

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Note: Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in RP 500A.

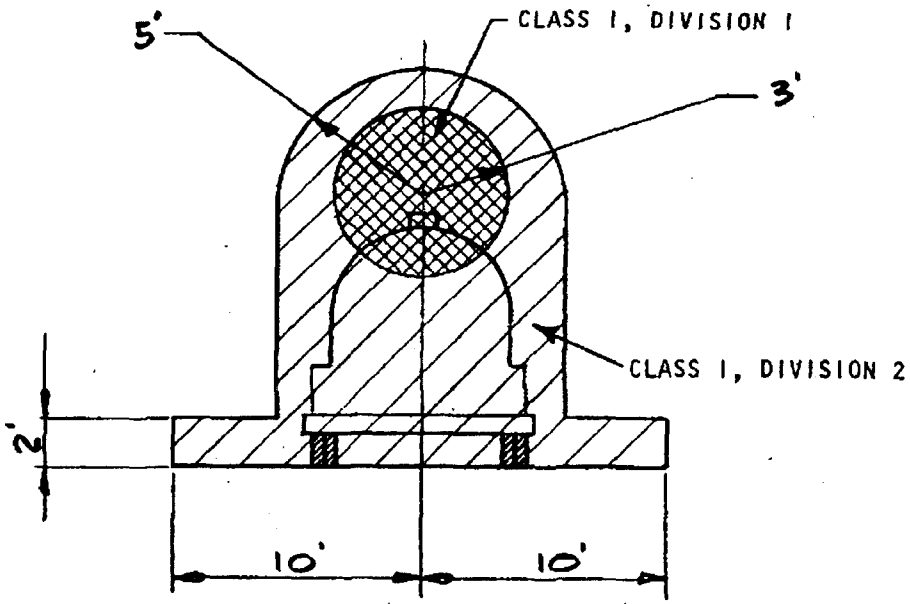
Compressor Shelter with Inadequate Ventilation for Lighter-Than-Air Vapor.

FIGURE
7

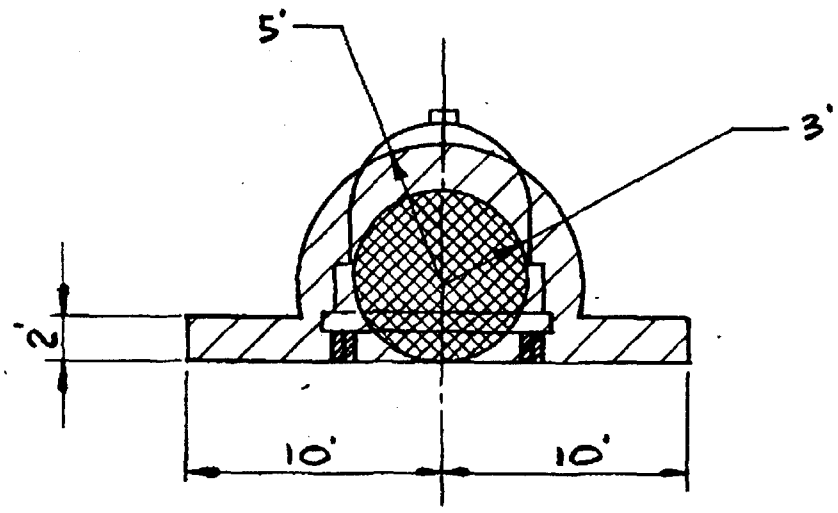
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22.2,1.1

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TOP LOADING



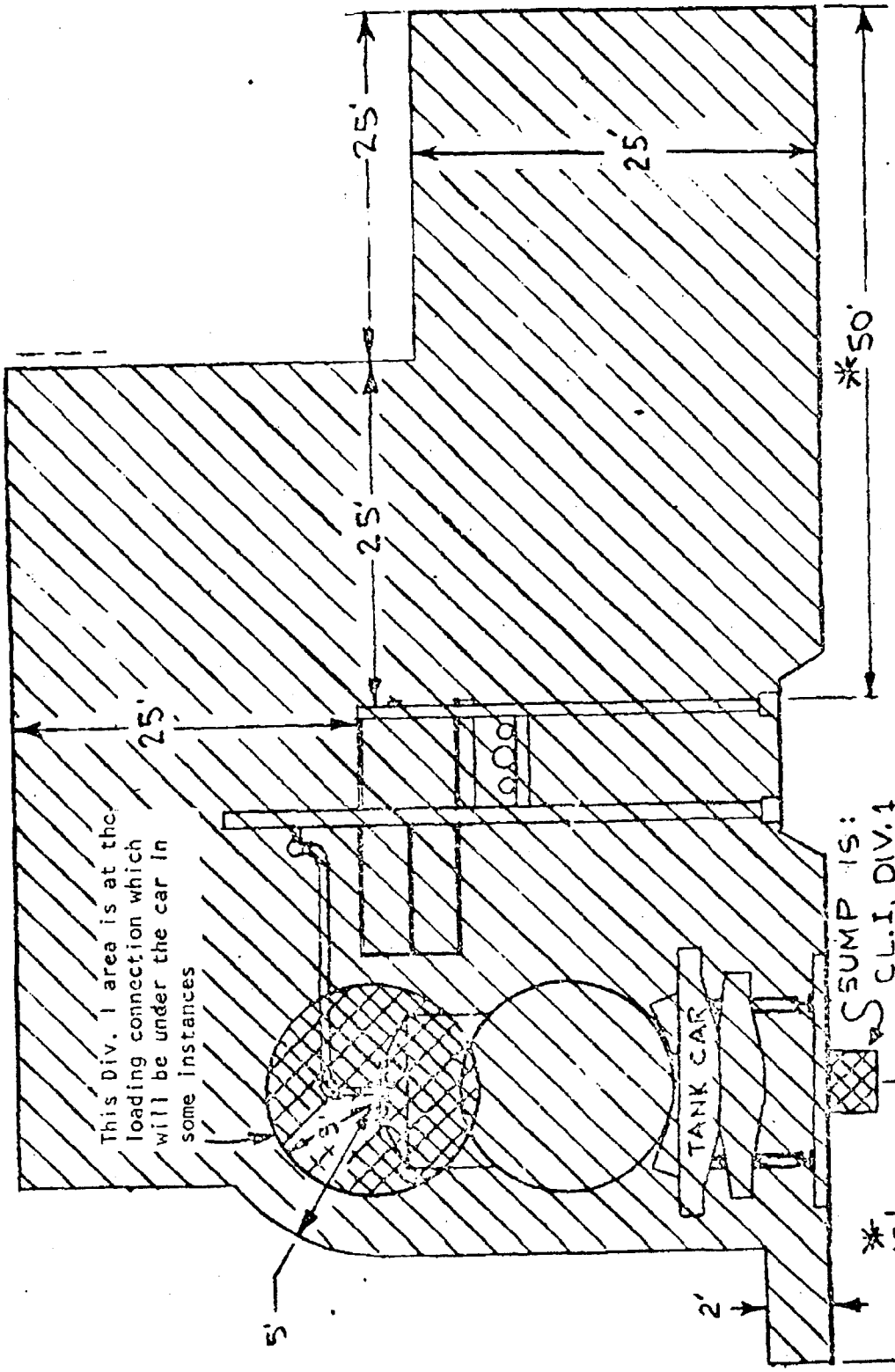
BOTTOM LOADING

TANK TRUCK LOADING SPOTS

FIGURE
8

22.2.1.1

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* The farthest extension of these two distances will be outer limit of the Cl.1, Div. 2 area

FIGURE 9 TANK CAR LOADING RACK (Not to Scale)

22.2.1.1

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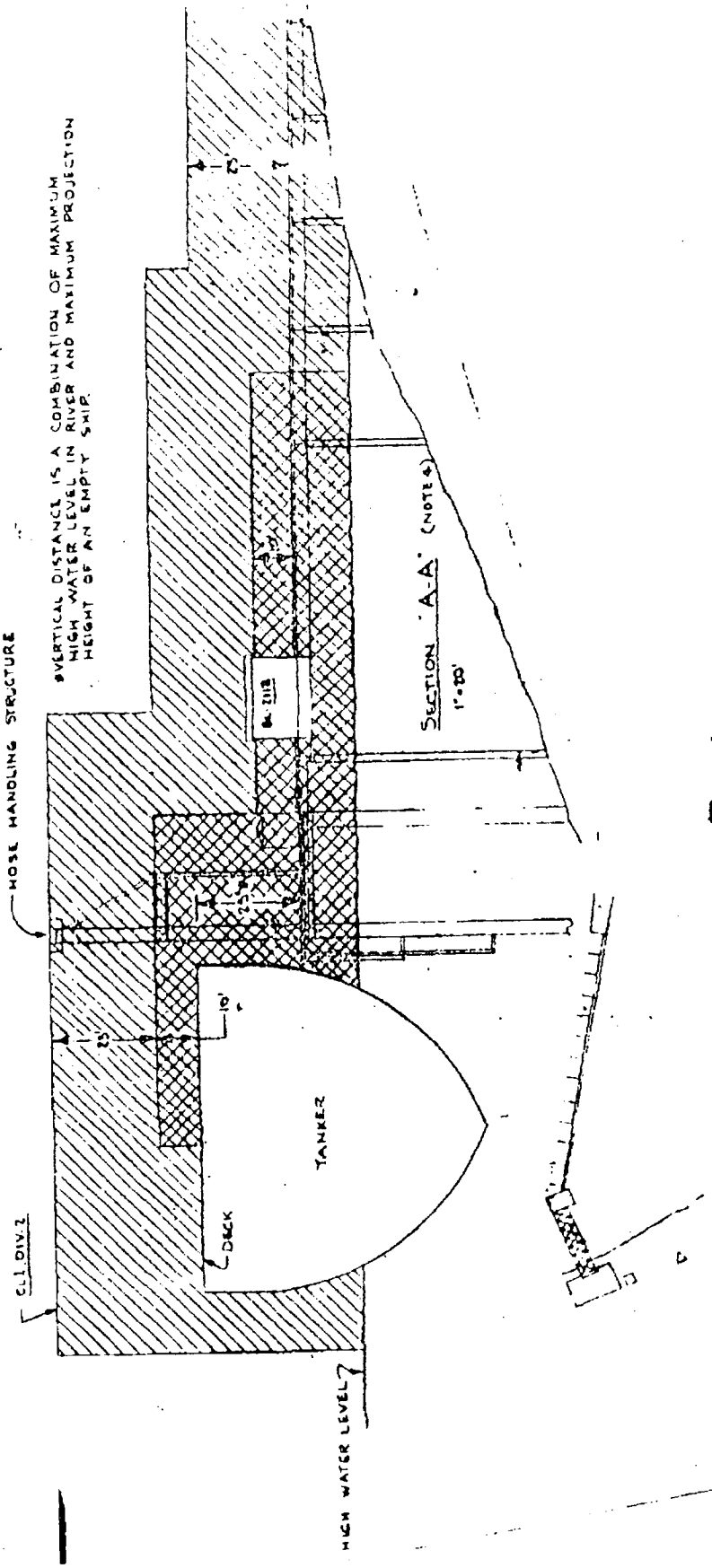
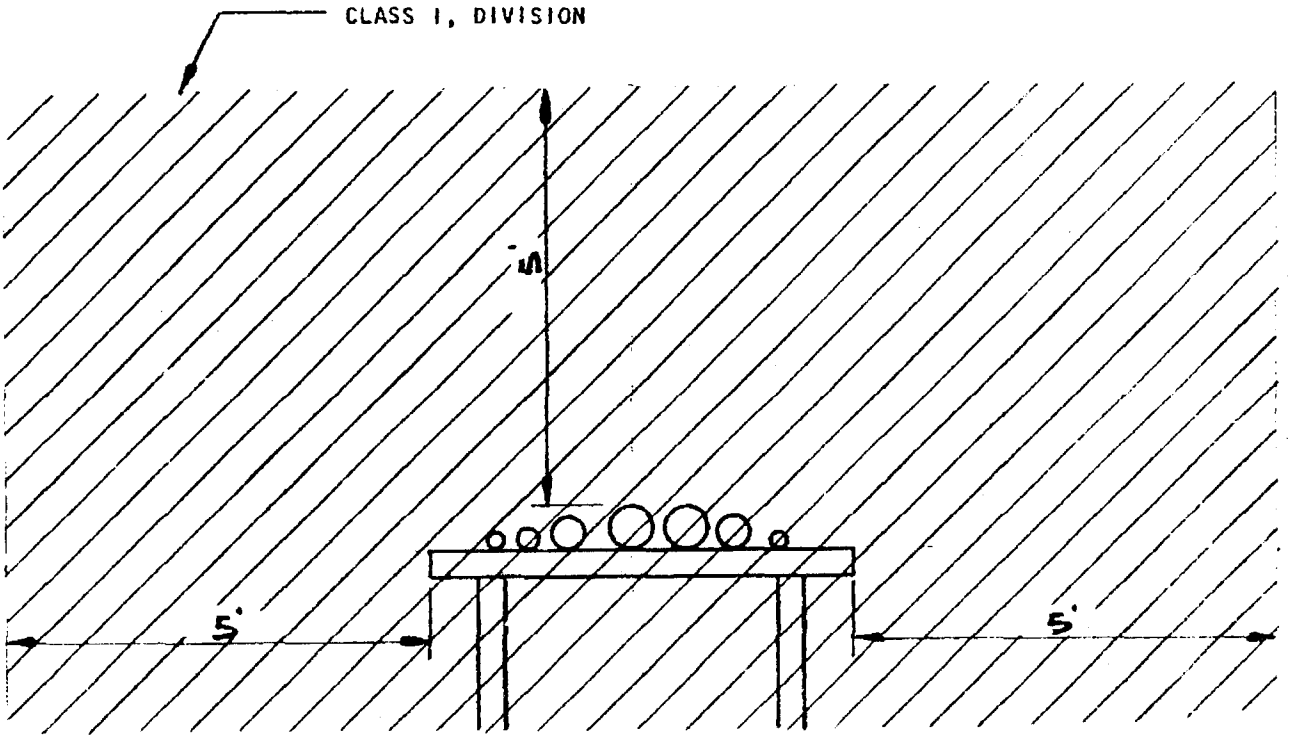


Fig. 10

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TYPICAL PIPERACK DISTANCES

(FOR NORMALLY WELDED PIPING)

FIGURE
11

22.2.1.1

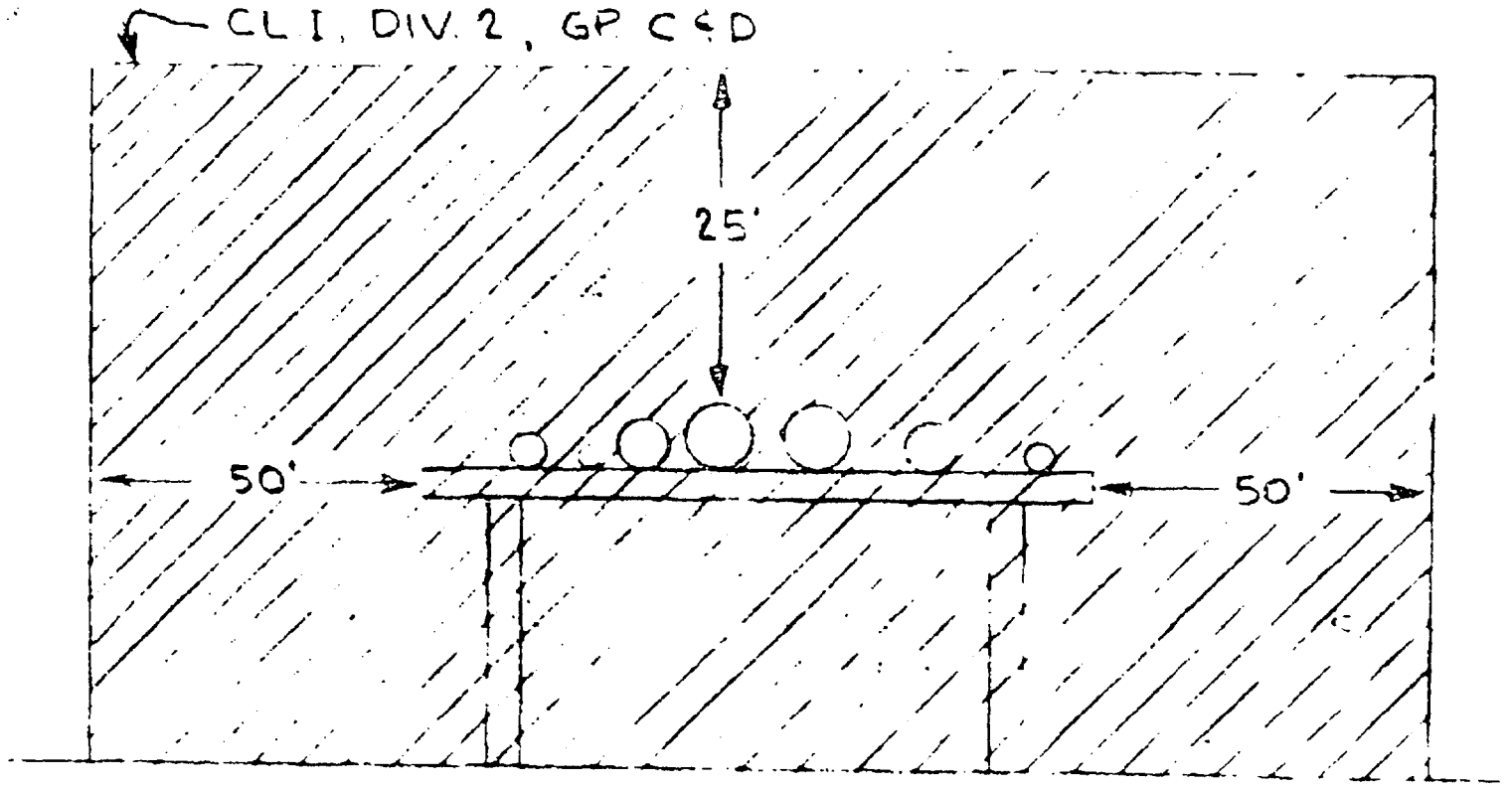
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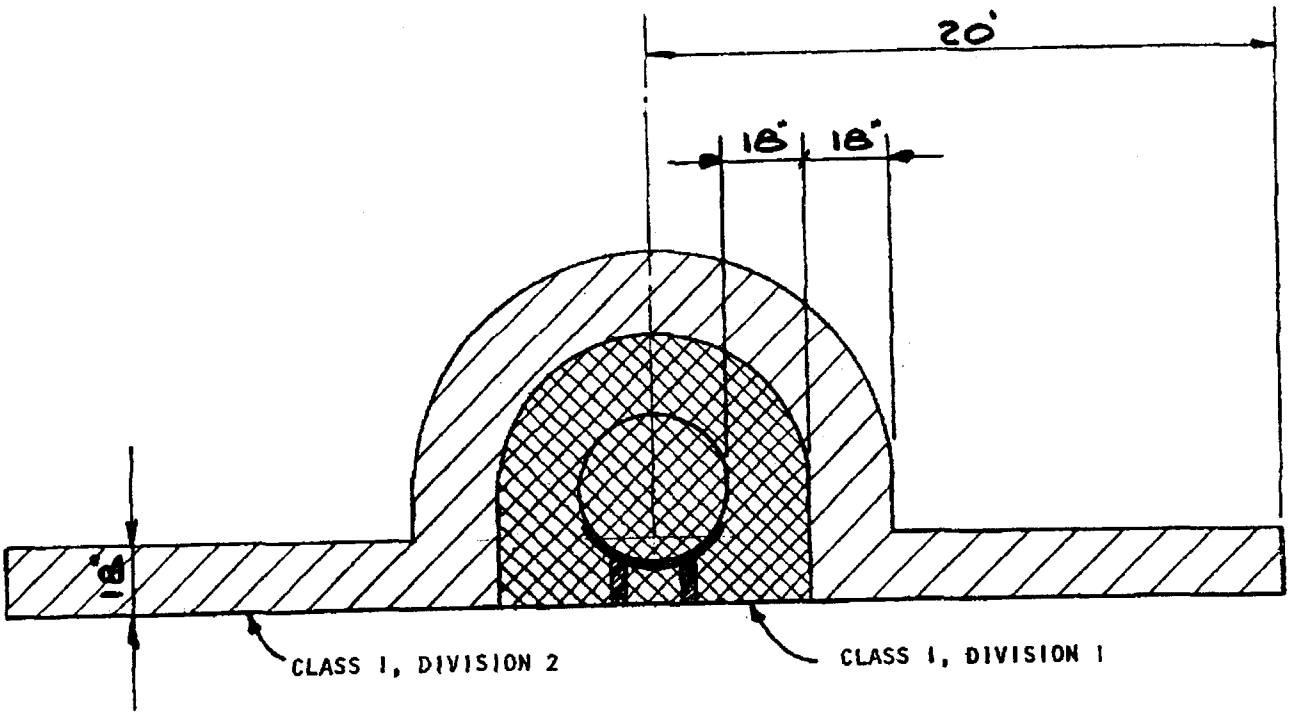
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TYPICAL PIPERACK DISTANCES (NOT TO SCALE
(FOR SECTIONS OF PIPERACK WHERE
ORIFICE FITTINGS EXIST)

Fig. 12

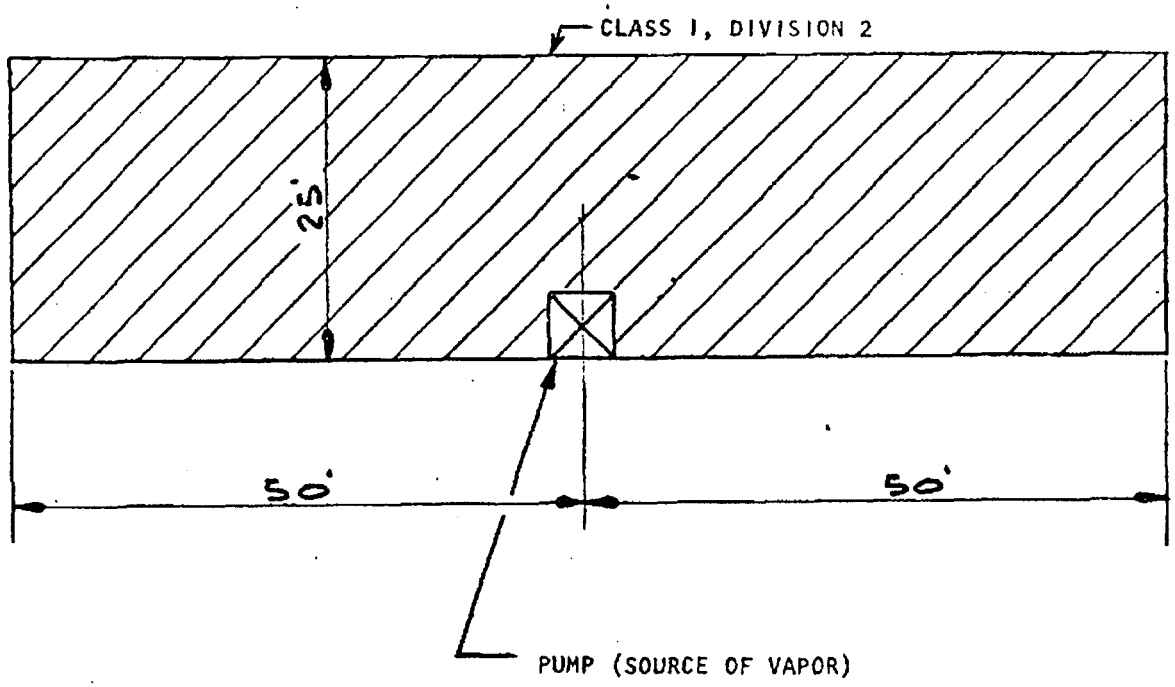
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TYPICAL DRUM DISPENSING INSTALLATION

FIGURE
13

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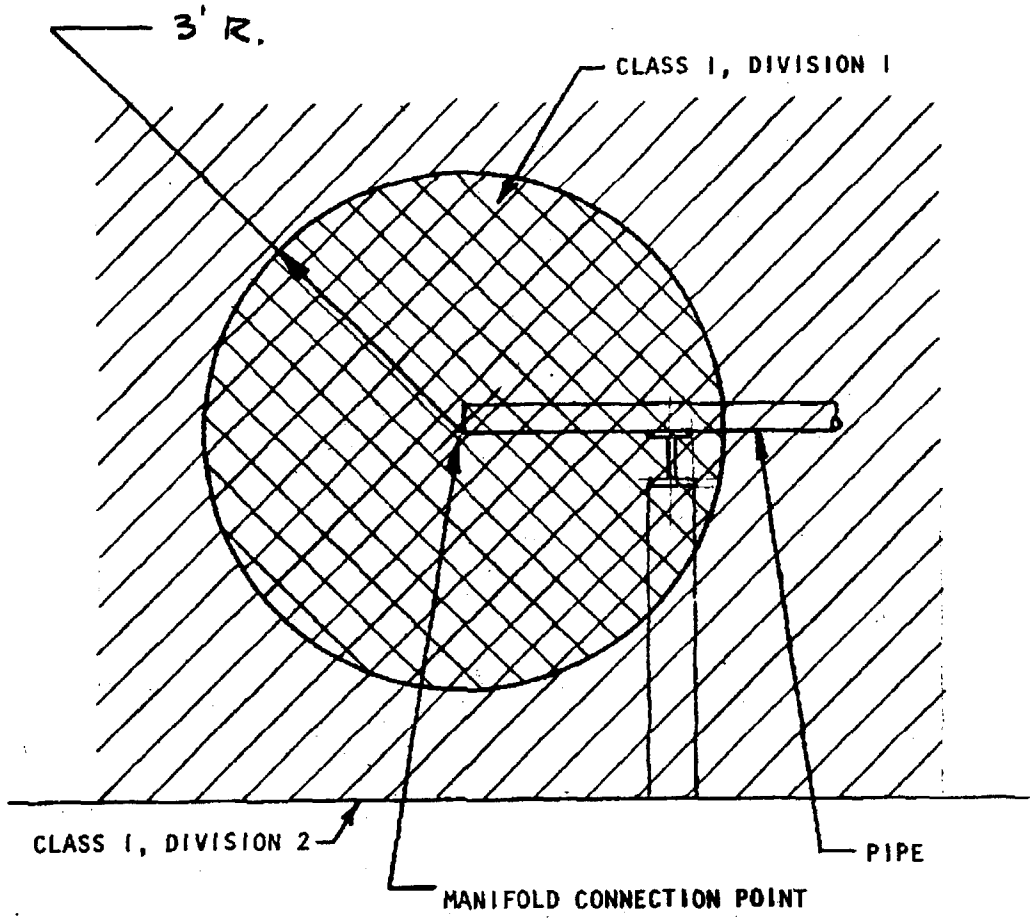


TYPICAL PUMP INSTALLATION

FIGURE
14

22.2.1.1

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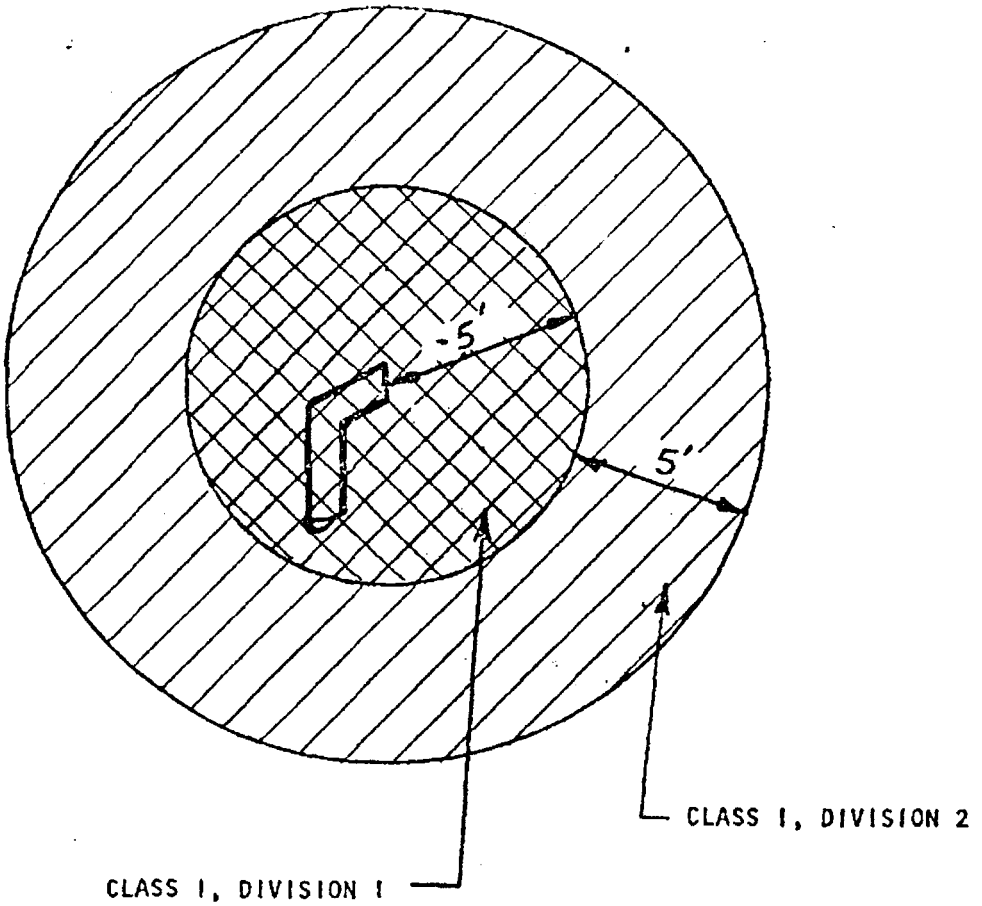
TYPICAL HOSE MANIFOLD INSTALLATION

FIGURE
15

22.2.1.1

UCC 021365

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TYPICAL VENT INSTALLATION

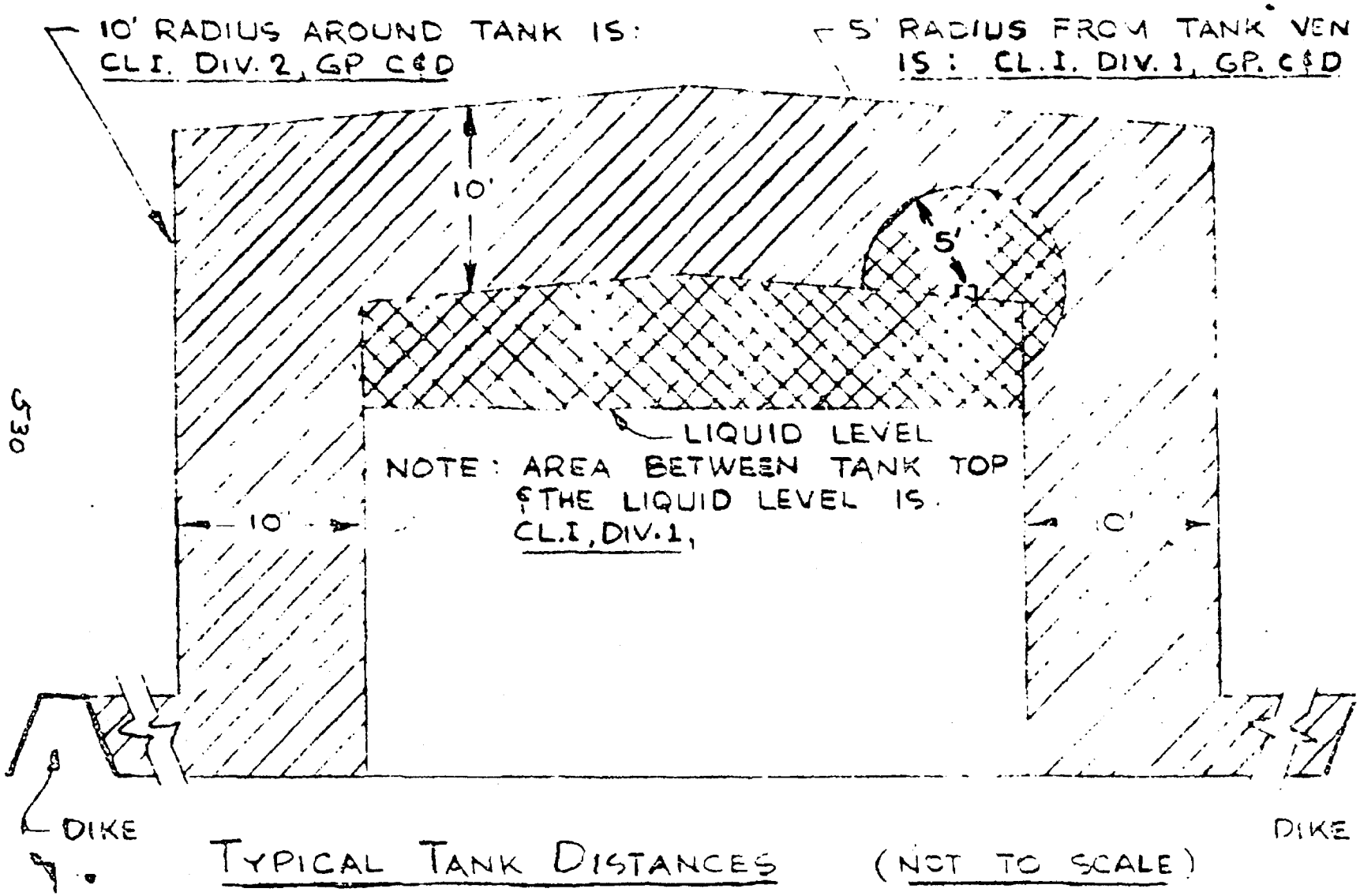
FIGURE
16

22.2.1.1

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UCC 021367



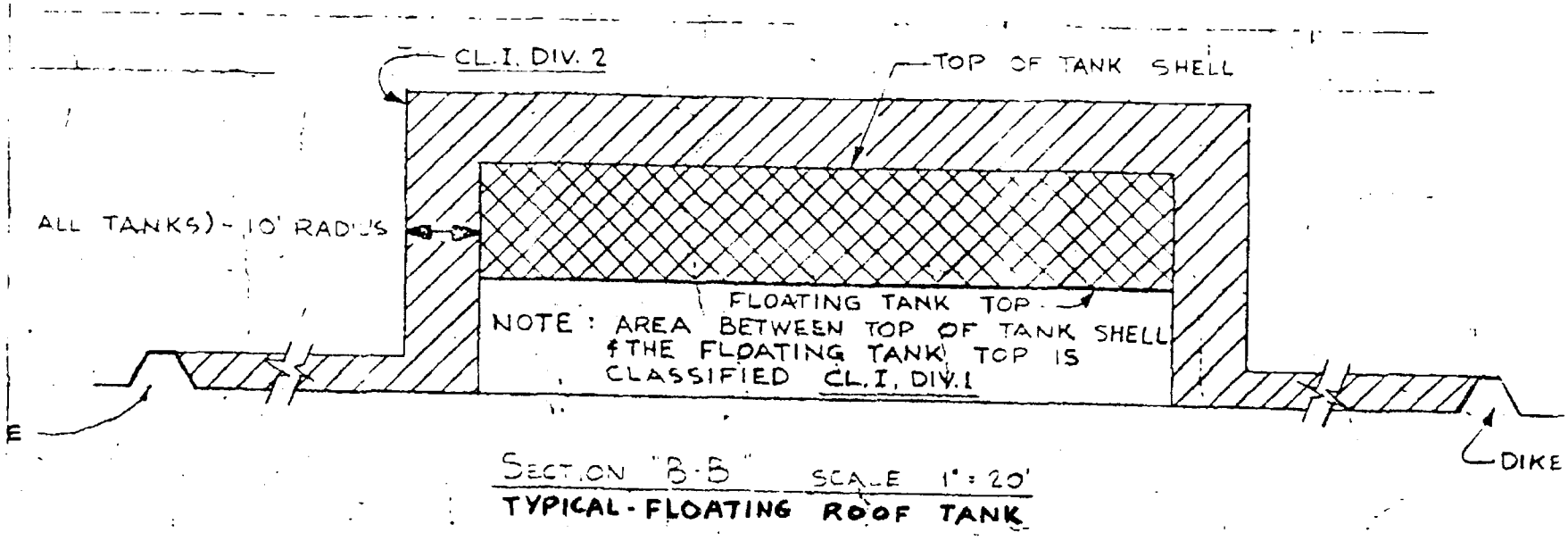
TYPICAL TANK DISTANCES (NOT TO SCALE)

Fig. 17

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Fig. 18

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ETHYLENE (ASSUME LEAK IS IMMEDIATELY VAPORIZED)

0.25 GPM	
ASC = 3	ASC = 5
6.2'	12.5'

ACETALDEHYDE (ASSUME 5'X5' POOL)

0.25 GPM	
ASC = 3	ASC = 5
<5'	<5'

ACETONE (ASSUME 5'X5' POOL)

0.25 GPM	
ASC = 3	ASC = 5
<5'	<5'

ISOPROPANOL (ASSUME 5'X5' POOL)

0.25 GPM	
ASC = 3	ASC = 5
<5'	<5'

Fig. 19

UCC 021369

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ETHYLENE (ASSUME LEAK IS IMMEDIATELY VAPORIZED)

2 GPM	
ASC = 3	ASC = 5
20'	43'

ACETALDEHYDE (ASSUME 5'X5' POOL)

2 GPM	
ASC = 3	ASC = 5
<5'	7.2'

ACETONE (ASSUME 5'X5' POOL)

2 GPM	
ASC = 3	ASC = 5
<5'	8.8'

ISOPROPANOL (ASSUME 5'X5' POOL)

2 GPM	
ASC = 3	ASC = 5
<5'	6.4'

Fig. 20

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ETHYLENE (ASSUME LEAK IS IMMEDIATELY VAPORIZED)

5 GPM	
ASC = 3	ASC = 5
34'	74'

ACETALDEHYDE (ASSUME 5'X5' POOL)

5 GPM	
ASC = 3	ASC = 5
5.6'	11.2'

ACETONE (ASSUME 5'X5' POOL)

5 GPM	
ASC = 3	ASC = 5
6.6'	13.8'

ISOPROPANOL (ASSUME 5'X5' POOL)

5 GPM	
ASC = 3	ASC = 5
<5'	7.2'

Fig. 21

UCC 021371

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ELECTRICAL DESIGN GUIDE FOR HAZARDOUS AREAS

N. E. Code Group Class I Articles 501 and 501

Type of Atmospheres		DIVISION 1		DIVISION 2	
		Sparking Equipment	Nonsparking Equipment	Sparking Equipment	Nonsparking Equipment
A	Acetylene	No suitable equipment available as explosion-proof enclosures. If electrical equipment must be in area, then interlocked ventilation is ideal method.	Same as for Sparking Equipment	No explosion-proof enclosures available. Standard enclosures are acceptable if arc making contacts are under oil, hermetically sealed, or intrinsically safe	External surfaces of lamps, resistors, solenoids, motors, etc. should not exceed 80% of the ignition temperature. [6] Rigid metal conduit, MI, MC, and ALS cable may be used. See Note [7]
B	[1] Butadiene [2] Ethylene Oxide Hydrogen Manufactured Gas [3] Propylene Oxide		Same as for Group A above See Notes [1] and [2]	[4] Adequate ventilation with alarm need with gasketed enclosures and sealed conduit may be used. [5] Rigid metal conduit, MI, MC, and ALS cable may be used.	Same as for Group A above See Notes [4] and [7]
C	Acetaldehyde Cyclopropane Diethyl Ether Ethylene Isoprene Unsymmetrical Dimethyl Hydrazine (UMDH)	[4] Most electrical equipment is available with explosion-proof enclosure. Interlocked ventilation may be used when explosion-proof enclosures are not available. Use of MI cable suggested.	Same as for sparking equipment except conduit fittings, junction boxes, etc. may not be available. Use of MI cable suggested.	Same as for Group A above except explosion-proof enclosures are available.	Same as for Group A above See Notes [4] and [7] Cable trays, rigid metal conduit with fittings, and vaporlight light fixtures to be used generally.
D	Acetone Acrylonitrile Alcohol Ammonia Benzene Benzol Butane Ethylene Dichloride Gasoline Hexane Lacquer Solvent Vapors	Same as for Group C above except junction boxes, conduit fittings, etc. are available.	Same as for Group C above except explosion-proof enclosures are available.	Same as for Group C above except explosion-proof enclosures are available.	Same as for Group C above

Naptha
Natural Gas
Propane
Propylene
Styrene
Vinyl Acetate
Vinyl Chloride
Xylenes

References:

N. E. Code Tentative Interim Amendment No. 146

U. S. Code 50[1]-9 (b)(2) 51[1]-A(a) and (b), etc.

NFPA No. 496

NOTE:

[1] Butadiene is reduced to Group D by conduit seals for sparking equipment. (Paragraph 501-5(a) Division 1)

[2] Ethylene Oxide and Propylene Oxide are reduced to Group C by seals for sparking equipment (as in 1 above).

[3] Maximum efforts should be made to exclude all electrical equipment from Division 1 areas.

[4] Interlocked ventilation (or air purge) should be circuited to cut off all electrical energy. However, should immediate loss of electrical energy present further hazards, an alarm with a small time limit before loss of electrical energy may be required. This should be resolved by the Electrical and Fire Protection Engineers.

[5] Adequate vent ration (or air purge) with alarm may be used if immediate attention can be depended upon. This should be resolved by the Electrical and Fire Protection Engineers.

[6] UCC Insurance Carrier allows cable tray systems without special cable protection such as MC or ALS types.

[7] Electrical equipment above or adjacent to hazardous areas should be enclosed and gasketed to prevent sparks or hot metal from entering the hazardous area. (Light fixtures and control making equipment on fork-lift trucks, etc).

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UCC 021372

TABLE 2.1 - CHEMICALS BY GROUPS

Group A Atmospheres

acetylene

Group B Atmospheres

butadiene[1]
ethylene oxide[2]
hydrogen
manufactured gases containing more than 30% hydrogen (by volume)
propylene oxide[2]

Group C Atmospheres

acetaldehyde
cyclopropane
diethyl ether
ethylene
unsymmetrical dimethyl hydrazine

Group D Atmospheres

acetone
acrylonitrile
ammonia[3]
benzene
butane
1-butanol (butyl alcohol)
2-butanol (secondary butyl alcohol)
n-butyl acetate
isobutyl acetate
ethane

Group D Atmospheres (Continued)

ethanol (ethyl alcohol)
ethyl acetate
ethylene dichloride
gasoline
heptanes
hexanes
isoprene
methane (natural gas)
methanol (methyl alcohol)
3-methyl-1-butanol (isoamyl alcohol)
methyl ethyl ketone
methyl isobutyl ketone
2-methyl-1-propanol (isobutyl alcohol)
2-methyl-2-propanol (tertiary butyl alcohol)
petroleum naphtha[4]
octanes
pentanes
1-pentanol (amyl alcohol)
propane
1-propanol (propyl alcohol)
2-propanol (isopropyl alcohol)
propylene
styrene
toluene
vinyl acetate
vinyl chloride
xylenes

[1]Group D equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit 1/2-inch size or larger.

[2]Group C equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit 1/2-inch size or larger.

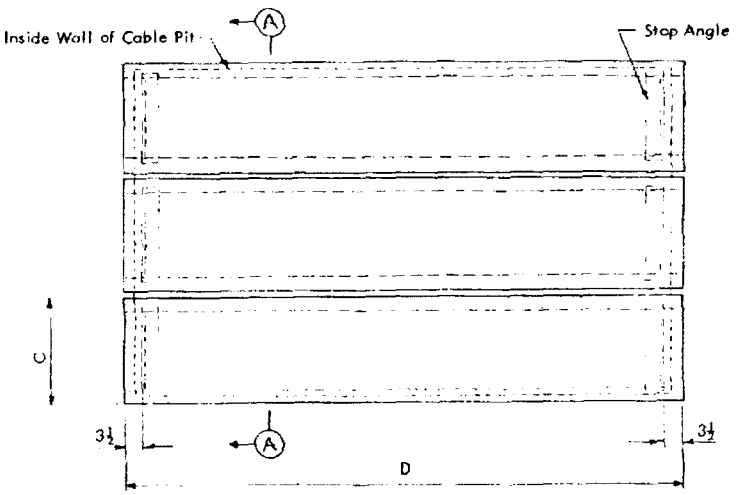
[3]For Classification of areas involving ammonia atmosphere, see Safety Code for Mechanical Refrigeration (ANSI B9.1-1971) and Safety Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1-1972).

[4]A saturated hydrocarbon mixture boiling in the range 20-135°C (68-275°F). Also known by the synonyms benzine, ligroin, petroleum ether, or naphtha.

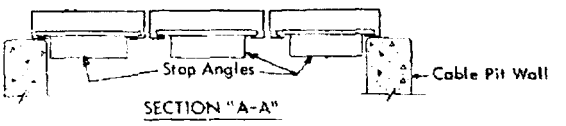
In addition to these chemicals listed in the NEC, the National Academy of Sciences has assigned tentative classifications to 370 chemicals. This information is available from the Process Safety and Fire Protection Group.

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ELECTRICAL CABLE PIT SAFETY GRATING AND SAFETY SURFACE COVER DETAILS

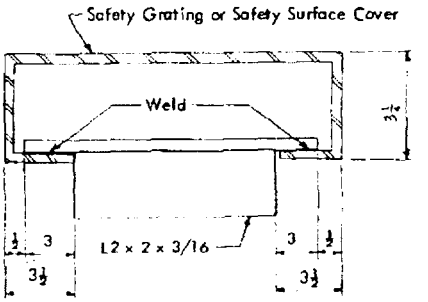


PLAN



SECTION "A-A"

Acceptable alternate stop details may be used such as angles bolted through the floor surface or welded cross section pieces of 12 gage sheet metal.



STOP ANGLE DETAIL

	Mark	For Std. Size Pit: Pit No.	For Std. Size Pit: No. of Panels	C	D	Size of Safety Grating	Stop Angles	Weight of Panel, Lbs
Safety Grating	CP-9	1	3	16	5'-0	16 wide x 5'-0	6Ls - 2 x 2 x 3/16 x 1'-3	45
	CP-10	2	4	18	6'-0	18 wide x 6'-0	8Ls - 2 x 2 x 3/16 x 1'-5	57
	CP-11	3	4	18	7'-0	18 wide x 7'-0	8Ls - 2 x 2 x 3/16 x 1'-5	65
	CP-12	4	6	16	7'-0	16 wide x 7'-0	12Ls - 2 x 2 x 3/16 x 1'-3	60
	CP-13	5	6	16	8'-0	16 wide x 8'-0	12Ls - 2 x 2 x 3/16 x 1'-3	67

	Mark	For Std. Size Pit: Pit No.	For Std. Size Pit: No. of Panels	C	D	Size of Safety Surface	Stop Angles	Total Weight per Cover, Lbs
Safety Surface	CP-14	1	3	16	5'-0	16 wide x 5'-0	6Ls - 2 x 2 x 3/16 x 1'-3	63
	CP-15	2	4	18	6'-0	18 wide x 6'-0	8Ls - 2 x 2 x 3/16 x 1'-5	70
	CP-16	3	4	18	7'-0	18 wide x 7'-0	8Ls - 2 x 2 x 3/16 x 1'-5	80
	CP-17	4	6	16	7'-0	16 wide x 7'-0	12Ls - 2 x 2 x 3/16 x 1'-3	74
	CP-18	5	6	16	8'-0	16 wide x 8'-0	12Ls - 2 x 2 x 3/16 x 1'-3	84

SAFETY GRATING AND SAFETY SURFACE COVER SCHEDULE FOR STANDARD SIZE CABLE PITS

Unless otherwise indicated, all dimensions given in inches.

*Standard number prefix changed from S-82B to CE-82B on Feb. 1, 1974.

2.6.1.1

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STANDARD UNION CARBIDE
CHEMICALS/PLASTICS

ELECTRICAL CABLE PIT SAFETY GRATING AND SAFETY SURFACE COVER DETAILS

NOTES:

1. The detailed dimensions and panel weights shown on this standard are based on the use of 12 gage x 3-1/4 channel height Open-Grip Safety Grating and Tread-Grip Safety Surface as manufactured by the Morton Manufacturing Company and distributed by Joseph T. Ryerson and Son, Inc. Any other similar material which meets the loading and deflection criteria listed and has a minimum 14 gage material thickness may be used. A suggested alternate to the Morton Open-Grip Safety Grating is United Interlock Anti-Skid Grating as manufactured by United McGill Corporation of Columbus, Ohio.

2. The Open-Grip Safety Grating can be an appropriate choice for conditions where it is not necessary to shield the cable pit from rainwater and/or splashing mud, and galvanized carbon steel materials are compatible with atmospheric conditions in the area.

3. The Tread-Grip Safety Surface can be an appropriate choice for using the lightest weight individual panels for conditions which indicate a need for shielding most rainwater and/or splashing mud from the cable pit, and galvanized carbon steel materials are compatible with atmospheric conditions in the area.

4. All Safety Grating and Safety Surface covers and stop angles are to be hot-dip galvanized after fabrication in accordance with ASTM A 123, unless otherwise required by location needs.

5. All references to Codes, Standards, and Specifications are to the current issue in effect at the time of Purchaser's request for quotation.

6. Design criteria for covers is based on a 100 lb. per sq. ft. uniform load with a maximum deflection of 3/8 inch.

REFERENCE:

Electrical Cable Pit - - - - - - - - - - - - - - - - Std. CE-80

Unless otherwise indicated, all dimensions given in inches.

2.6.1.1

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LEAD ACID CALCIUM ALLOY STATION BATTERY

1 SCOPE

1.1 This specification covers the minimum requirements for lead acid, calcium alloy, station batteries. The battery consists of multiple storage cells electrically connected to produce the specified load requirements. Batteries shall conform to this specification unless the Seller secures written approval from the Buyer for any exceptions.

2 APPLICABLE STANDARDS AND CODES

2.1 Applicable sections of the standards and codes by the organizations listed below are a part of this specification unless amended herein. References to codes, standards, and other specifications are to be the latest revisions in effect at the time of Buyer's request for quotation.

The National Electrical Manufacturers Association (NEMA)
The Institute of Electrical and Electronic Engineers (IEEE)
American National Standards Institute (ANSI)
The Instrument Society of America (ISA)
The National Electrical Code (NEC)

3 SERVICE CONDITIONS

3.1 Unless otherwise noted on the order, batteries shall be designed for indoor service mounted in a switchgear house with an ambient temperature between 10°C (50°F) and 40°C (105°F) and at an altitude of 3300 feet or lower.

4 DESIGN AND MATERIAL

4.1 BATTERY CELL

4.1.1 Element - The cell element shall consist of positive and negative groups with separators. Positive plates shall be pure lead in an alloy grid. The size and number of plates shall be designed to supply the rated ampere-hours from a fully charged condition for the normal life of the battery. The plate separators shall prevent short circuiting and permit free flow of electrolyte.

4.1.2 Cell Cover - The cell cover shall be strong enough to carry the weight of the element if suspended from it. The cover shall be secured in such a manner that a permanent leak-proof seal exists between the cover and container. Each cell cover shall have a vent well to allow the escape of gas and the addition of water.

4.1.3 Cell Container - The cell container shall be constructed of a transparent, heat resistant, shock absorbing, thermoplastic. The containers shall be large enough to contain one or more elements with sufficient reservoir space above and below the element. The upper reservoir shall allow the gradual lowering of the electrolyte from water loss without exposing the plates. All sides of the container shall have high and low electrolyte level markings. The lower reservoir shall provide space below the element to collect the sediment for the normal life span of battery without short circuiting the plates. Labels shall be provided to number each cell.

4.1.4 Electrolyte - The electrolyte shall have a specific gravity of 1.210 at 25°C (77°F) when the cell is fully charged unless specified otherwise on the data sheet. Electrolyte shall be supplied to provide full capacity at all ratings.

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4.1.5 Performance - The battery cell shall have a nominal rating of 2.00 volts dc. The fully-charged cell shall operate at the specified discharge rate at 25°C without falling below 1.75 final cell voltage.

4.2 CONNECTION HARDWARE

4.2.1 Connectors - Inter-cell, inter-tier, inter-rack, and inter-row connectors shall be supplied with acid-resistant connection bolts and nuts. Connectors shall be high rate, low loss, lead plated copper. Connectors shall allow a *minimum* 0.5 inch (12.7 millimeters) spacing of containers in each row unless additional spacing is specified. Any special tools required for installation shall be provided. Terminal connectors and cable support clamps shall be supplied for size and number of cables specified on battery *data sheet*.

4.3 BATTERY RACK

4.3.1 Construction - The battery rack shall be constructed of steel rails, frames, and braces completely covered with an acid-resistant vinyl type material. A fiberglass rack is acceptable if indicated on data sheet. The battery rack shall have side and end rails to restrain the battery within the physical design limits.

4.3.2 Configuration - The battery rack shall be single-row two-step unless specified otherwise on the battery data sheet.

4.3.3 Grounding - Provisions shall be made to adequately *ground* a steel battery rack.

4.4 BATTERY ACCESSORIES

4.4.1 Portable Hydrometer - A portable acid-electrolyte hydrometer shall not be supplied.

4.4.2 Vent-Mounted Hydrometer - A vent-plug-mounted acid electrolyte hydrometer syringe shall be supplied to measure the specific gravity of a test cell.

4.4.3 Vent-Mounted Thermometer - A vent-plug-mounted acid electrolyte thermometer shall be supplied to measure the temperature of a test cell.

5 INSPECTION AND TESTS

5.1 PERFORMANCE - The battery shall be capable of meeting the prototype and standard production tests as defined under 2. Applicable Code and Standards.

6.5.1.1

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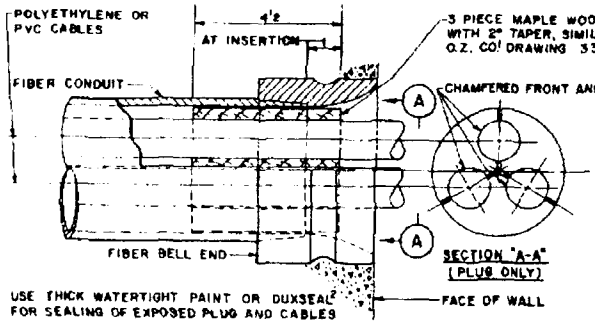
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UNION CARBIDE CHEMICALS COMPANY
DIVISION OF UNION CARBIDE CORPORATION
SOUTH CHARLESTON, WEST VIRGINIA

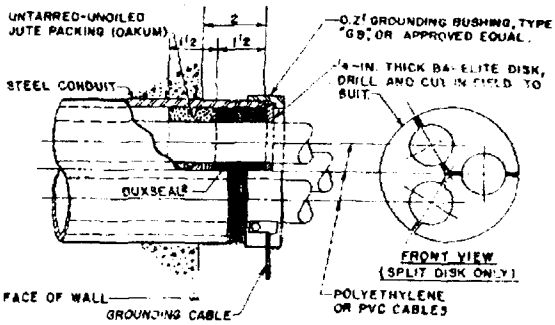
CABLE AND CONDUIT SEALING DETAILS

ENGINEERING STANDARD No. EL-12

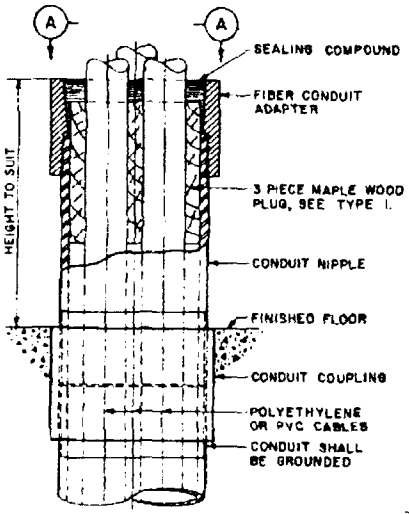
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DETAIL	DEPT 936			8-1-60	



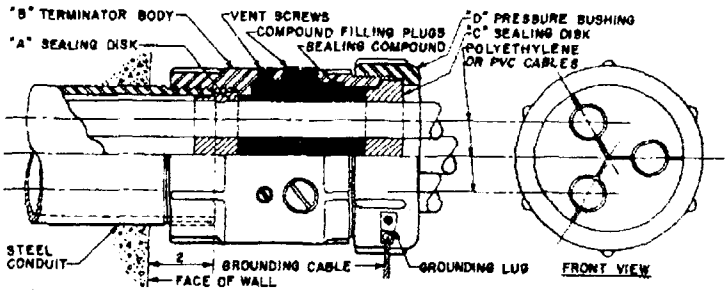
TYPE 1
MAPLE WOOD SEALING PLUG FOR 4-INCH FIBER CONDUIT



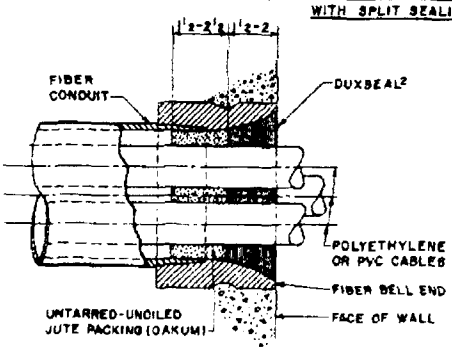
TYPE 4
CABLE AND STEEL CONDUIT SEALING WITH DUXSEAL² JUTE AND GROUNDING BUSHING FOR 3 TO 5-INCH STEEL CONDUIT



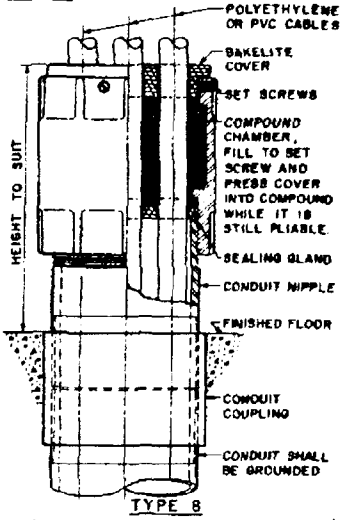
TYPE 2
MAPLE WOOD SEALING PLUG FOR 4-INCH STEEL CONDUIT



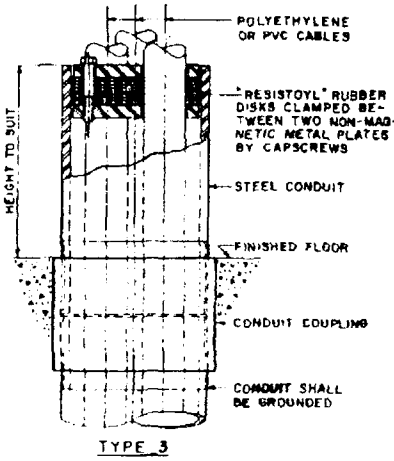
TYPE 5
CABLE AND STEEL CONDUIT SEALING WITH O.Z.¹ TYPE "CRR" HORIZONTAL TERMINATOR WITH SPLIT SEALING DISKS



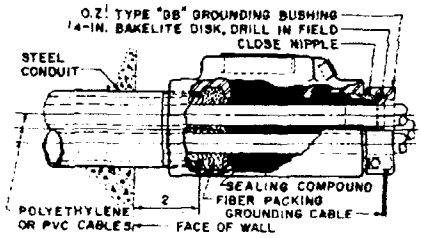
TYPE 6
CABLE AND FIBER CONDUIT SEALING WITH DUXSEAL² AND JUTE FOR 2 TO 5-INCH FIBER CONDUIT



TYPE 8
CABLE AND STEEL CONDUIT SEALING WITH O.Z.¹ TYPE "CRC" VERTICAL TERMINATOR



TYPE 3
CABLE AND STEEL CONDUIT SEALING WITH G&W³ TYPE "CS" CONDUIT CABLE SEAL (FOR VERTICAL OR HORIZONTAL USE)



TYPE 7
CABLE AND STEEL CONDUIT SEALING WITH EYS SEALING FITTING FOR 2-INCH CONDUIT

NOTE:
SEALING COMPOUND FOR CABLES WITH POLYETHYLENE OR PVC INSULATIONS SHALL NOT HAVE A MELTING POINT OF MORE THAN 90 C (194 F). WHERE SEALING COMPOUND HAS TO CONFORM WITH THE NEC, FOR CLASS I, DIVISIONS 1 AND 2 LOCATIONS, CROUSE HINDS CHICO "A" COMPOUND MAY BE USED.

¹O.Z. ELECTRICAL MFG COMPANY, INC., BROOKLYN 17, NEW YORK.
²BY JOHNS-MANVILLE, NEW YORK 16, NEW YORK
³G AND W ELECTRIC SPECIALTY COMPANY CHICAGO 19, ILLINOIS.

ALL DIMENSIONS GIVEN IN INCHES

(OVER)

838 130-004

541

EL-12

UCC 021378

ENGINEERING STANDARD NO. EL – 12

DATA

TABLE 1 – O.Z. ELECTRICAL MFG CO INC, TERMINATORS

CONDUIT SIZE	MAX DIA OF CABLE PERMITTED		TYPE S[1]-HORIZONTAL TERMINATORS				TYPE B[1]-VERTICAL TERMINATORS				APPROX COMPOUND REQ'D. PT
			CATALOG NO.	DIMENSIONS		WEIGHT LB	CATALOG NO.	DIMENSIONS		WEIGHT LB	
	3 WIRE	4 WIRE		MAX DIA	OVERALL LENGTH			MAX DIA	OVERALL LENGTH		
3	1.16	0.97	CRR 300	4 1/2	5 1/8	6	CRC 300	4 1/4	4 3/4	5.1	3/4
4	1.52	1.27	CRR 400	5 7/8	6 3/8	11	CRC 400	5 3/8	5 7/8	9.7	1 1/2
5	1.91	1.60	CRR 500	7	6 7/8	16	CRC 500	6 1/2	6 1/2	13.0	2 3/4

WHEN ORDERING O.Z. TERMINATORS, THE FOLLOWING SHALL BE SPECIFIED:

a) SIZE OF CONDUIT
b) NUMBER OF CONDUCTORS
c) DIAMETER OVER INSULATION OF INDIVIDUAL CONDUCTOR
d) GROUNDING LUG AND SIZE OF GROUNDING CABLE FOR PROPER SIZING OF LUG

TABLE 2 – G & W TYPE CS CONDUIT CABLE SEALS – TYPE 3[1]

CONDUIT SIZE	MAXIMUM DIAMETER OF HOLES FOR CABLES		CATALOG NO.	APPROXIMATE SHIPPING WEIGHT, LB
	3 WIRES	4 WIRES		
3	1 1/8	15/16	CS 30	4
4	1 9/16	1 3/8	CS 40	5
5	2	1 13/16	CS 50	6

WHEN ORDERING G & W CABLE SEALS, SPECIFY AS UNDER a, b, AND c, TABLE 1.

NOTE:

All steel or fiber conduits, that terminate in substations, cable vaults, and similar areas shall be sealed to prevent the entrance of gases, fumes, vapors, or water. The design layout of such sealed conduits shall provide slope for the drainage of condensate to the open end of the conduit.

[1]See other side of this Standard.

001

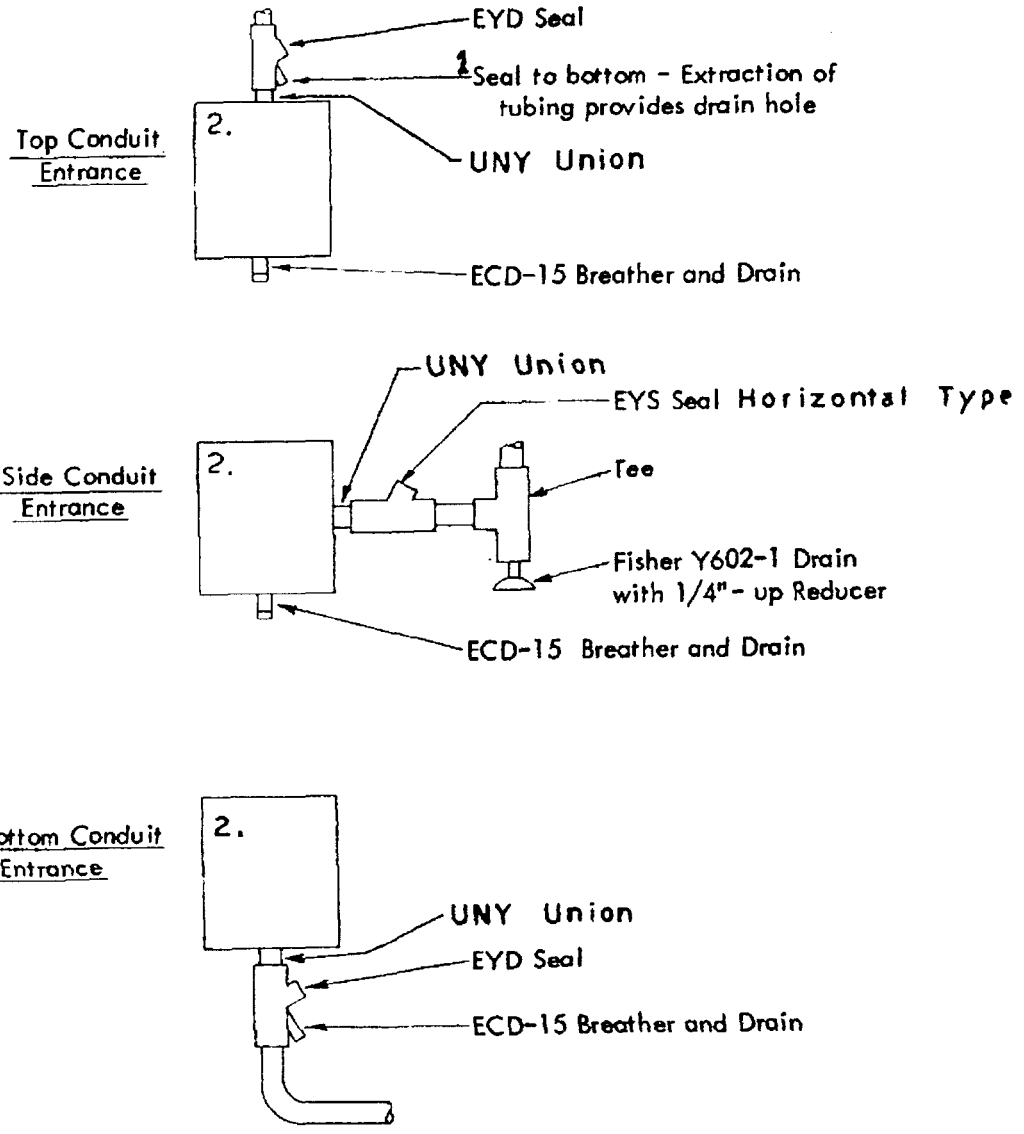
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UNION CARBIDE STANDARD CONSTRUCTION

ELC-22
DETAIL
6-1-70

SEALING AND DRAINING EXP-PRF ENCLOSURES AND CONDUIT



NOTE:
EYD, EYS, UNY and ECD-15 are Crouse-Hinds. Equals by others may be used.

1. In Top Conduit Entrance Sketch, the Fisher Y-602-1 drain may be used with the EYD seal.

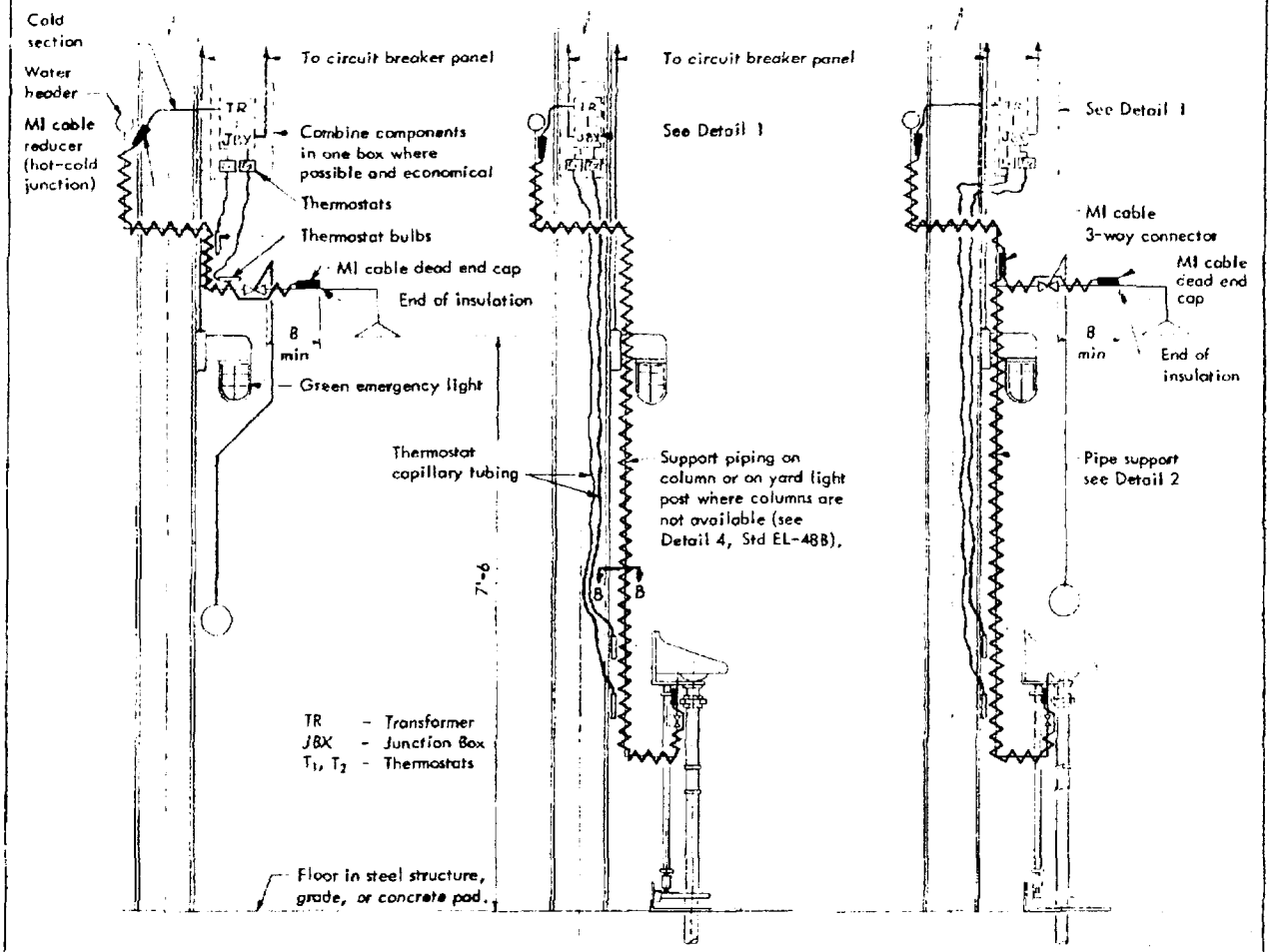
2. Exp-Prf. Enclosures may be Junction Boxes for Wiring Motors, Process Pressure Switches, etc., Div. 1 or 2 Areas.

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ELECTRICAL TRACING DETAILS FOR OUTDOOR SAFETY SHOWERS AND EYEBATHS

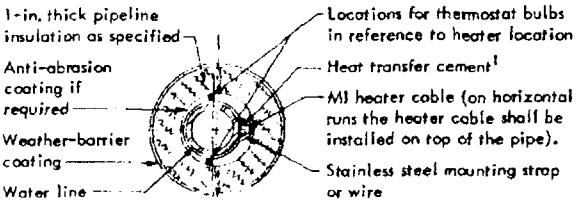


DETAIL 1
Outdoor Safety Shower With Overhead Water Supply Piping

DETAIL 2
Outdoor Safety Eyebath With Overhead Water Supply Piping

DETAIL 3
Outdoor Safety Shower and Eyebath Combination With Overhead Water Supply Piping

Insulation, anti-abrasion coating, and weather-barrier coating shall be in accordance with Union Carbide Corporation Thermal Insulation Specification No. 10-L.



SECTION B-B
Typical Cross-Section of Tracer Cable Installation

NOTE:

Notes not given for various details are the same as for Details 1 and 2.

For tracer routing and configuration see piping detail drawings. For tracer data such as length, cable size, fittings, wiring diagram, etc see "Table of Tracer Data" shown on electrical design drawings.

All tracer cables shall be bonded to pipeline with heat transfer cement.[1] See Section B-B. Installation details for MI tracer cables as shown on Standard EL-43 shall be followed.

Tracer systems for safety showers and eyebaths shall be installed and operated with two (2) thermostats. The first thermostat shall be set to operate on temperature rise by breaking tracer circuit at 55 F. The second thermostat acting as back-up protection should be set at 75 F. Locate thermostat bulbs as indicated in typical cross section and bond to pipe with heat transfer cement.[1]

Before heat transfer cement is applied over installed tracer, the cable shall be meggered and resistance value be checked to insure that installation is in accordance with design drawing requirements.

See Standard EL-48B for additional data and details.

REFERENCES: MI Cable Data . . . . . Std. EL-40

[1]Standard "Thermon" by the Thermon Manufacturing Company, Houston, Texas, or approved equal.

Unless otherwise indicated, all dimensions given in inches

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ENGINEERING STANDARD NO. EL-48A

NOTE:

Safety shower and eyebath tracer systems as shown on Standards EL-48A and EL-48B are to be installed where the outdoor water piping in open structures, yards, etc, may be exposed to freezing temperatures. In cases where safety showers or eyebaths are located on upper levels of open structures it might be necessary to extend the tracing system to include the water supply header.

Electrical design drawings shall show conduit routings and locations of traced pipeline and tracer, give tracer number, and specify that tracer installation shall be in accordance with, or similar to, a specific detail (1 to 6) as shown on this standard without further details on electrical design drawings.

Since shown details on this standard will serve as installation details, no tracer layout drawings will be needed for most tracers for safety showers and eyebaths. In order to specify needed materials as cables, fittings, etc, a table of tracer data must be provided on electrical design drawings for material description and billing, and also for field assembly and installation guides. A sample table is shown below.

Thermostats installed in hazardous areas must be enclosed in explosion-proof housings.

TABLE OF TRACER DATA FOR SAFETY SHOWERS AND EYEBATHS

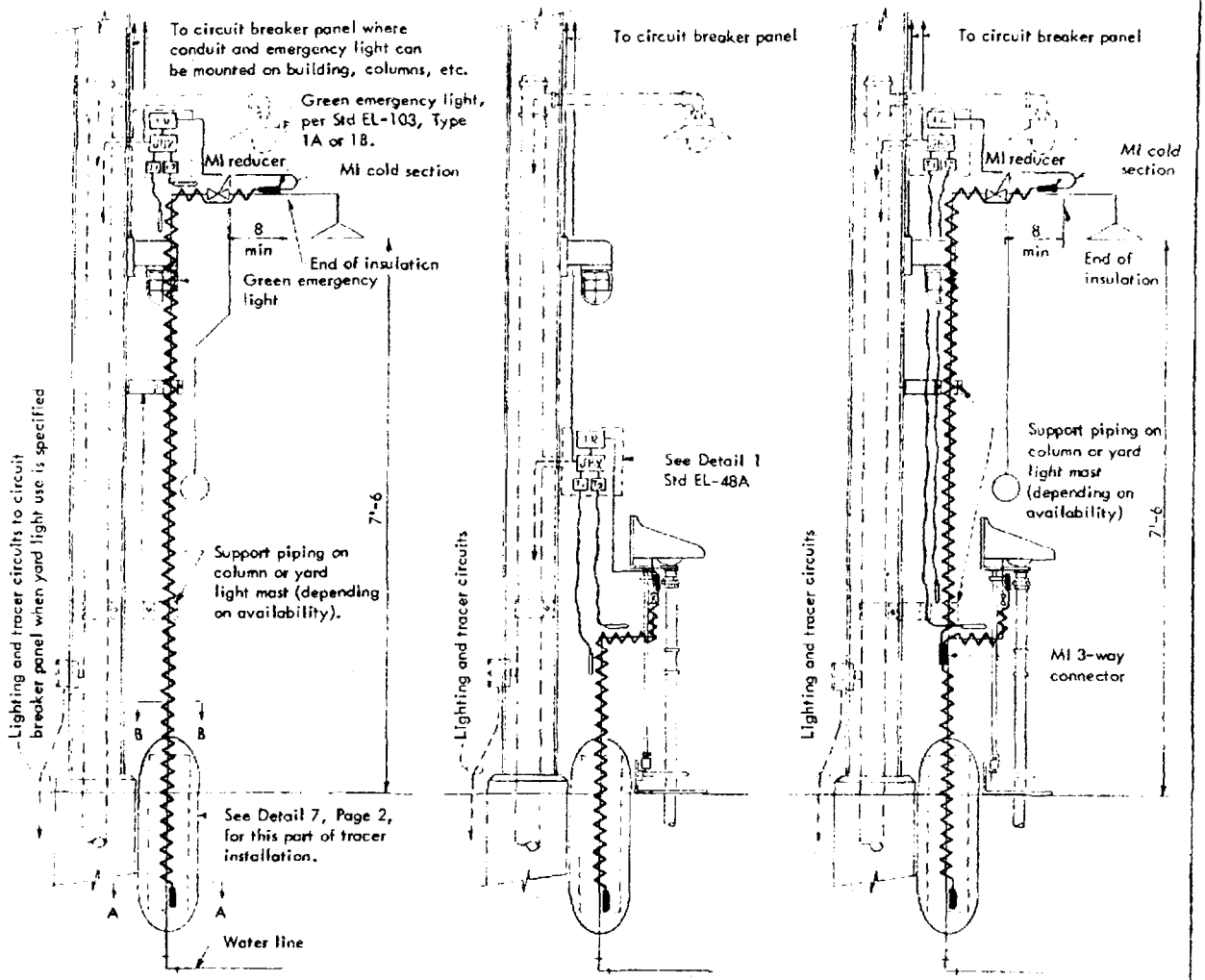
Heater Number	W/Ft	Operating Voltage	Total Watts	Standard EL-48A or B Installation Detail No.	MI Cable												Thermostats		Transformers		Wiring Diagram
					Hot Section									Cold Section							
					Length, ft	Size	Reference Number	Resistance in OHMS at 20°C	Fittings					Length, ft	Size	Reference Number	Fittings				
									Dead End Cap	Splice	Reducer	Three-Way Connector					Gland	Seal	Manufacturer	Catalog Number	Manufacturer	Catalog Number	Per Standard EL-48B Diagram Number
1																							
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							

Reduced copy of fill-in tracer data table as shown on standard design drawing form.

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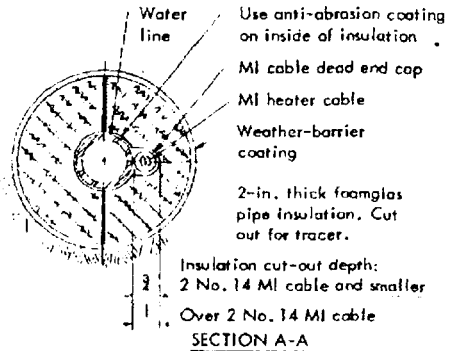
ELECTRICAL TRACING DETAILS FOR OUTDOOR SAFETY SHOWERS AND EYEBATHS



DETAIL 4
Outdoor Safety Shower With Underground Water Supply Piping

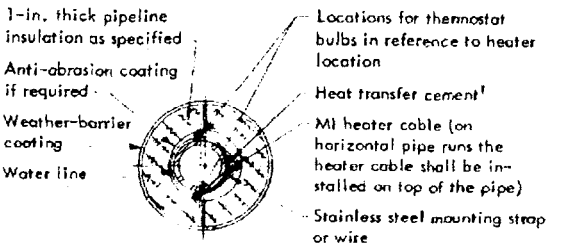
DETAIL 5
Outdoor Safety Eyebath With Underground Water Supply Piping

DETAIL 6
Outdoor Safety Shower and Eyebath Combination With Underground Water Supply Piping



SECTION A-A

Insulation, anti-abrasion coating, and weather-barrier coatings shall be in accordance with Union Carbide Corporation Thermal Insulation Specification No. 10-L.



SECTION B-B

Typical Cross-Section of Tracer Cable Installation

NOTE: See Std EL-48A for notes and additional data and details.

REFERENCES: MI Cable Data . . . . . Std. EL-40

Unless otherwise indicated, all dimensions given in inches

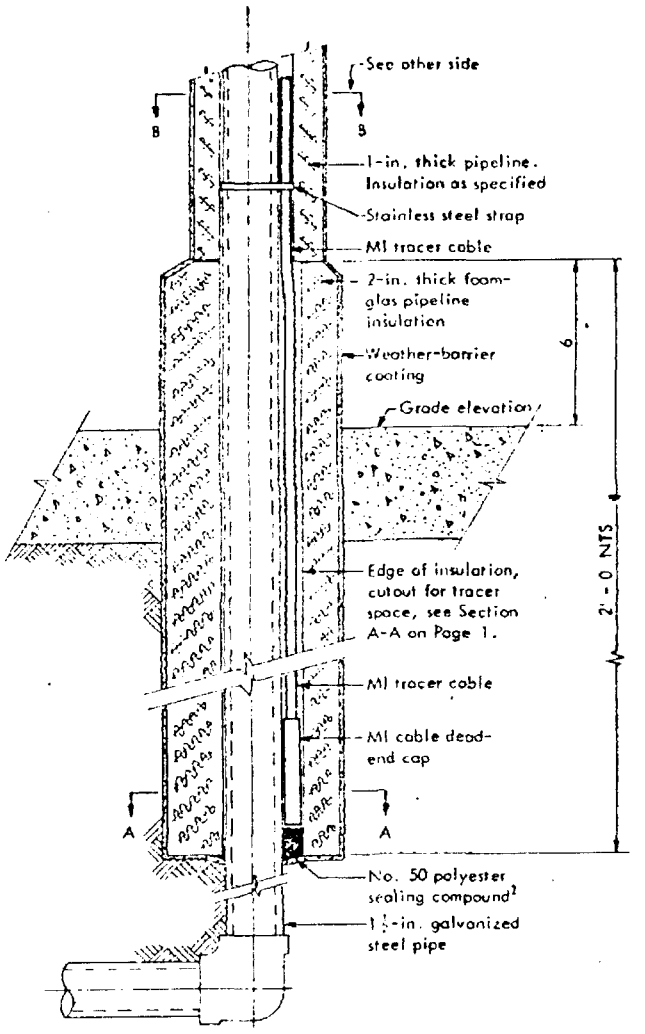
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ENGINEERING STANDARD NO. EL-488



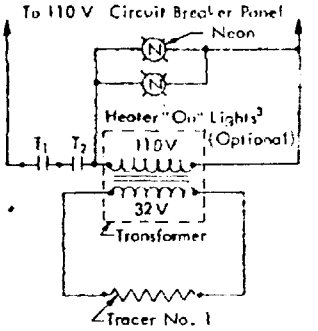
DETAIL 7

Tracer installation procedure: First install 2-in. thick insulation with groove cut out for tracer. Then slip tracer cable with dead end cap into grooved insulation, and fasten heater cable with SS strap just above the 2-in. insulation to the water pipe. In this way cable may be removed or repaired easily in the future. Above the 2-in. insulation the tracer shall be fastened to pipe every 12-18 inches, and bonded to pipe with heat transfer cement.[1] See Sections A-A and B-B.

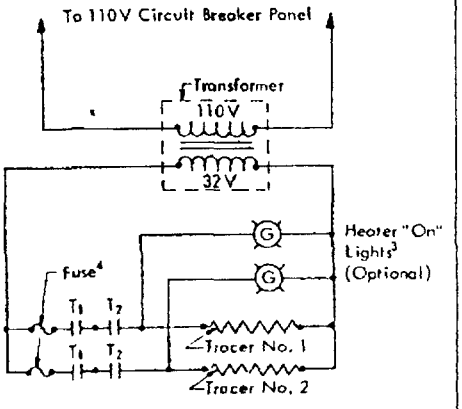
[1]Standard "Thermon", by the Thermon Manufacturing Company, Houston, Texas, or approved equal.

[2]By the American Chemical Company, Cincinnati 32, Ohio, or approved equal.

[3]When Heater-On Lights are used, Bill of Material shall specify voltage, wattage and type of lamp as well as catalog number for lamp holder. Location of heater-on lights shall be shown on power design drawings.



Wiring Diagram No. 1 for Transformers With Only One Heater



Wiring Diagram No. 2 for Transformers With Various Heaters

[4]Any necessary fuses should be installed in box with other control components. Bill of Material shall specify type of fuse (glass tube type preferred), ampere rating and fuse holder. Location of box with control equipment shall be shown on power design drawings.

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ELECTRICAL

UNION CARBIDE **STANDARD**

CHEMICALS/PLASTICS

EL-1311

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DECEMBER 1977

(FORMERLY ELC-149)

MAINTAINED ILLUMINATION INTENSITIES[1]

(FOOTCANDLES)[2]

TYPE OF FACILITY	GENERAL AREA (WALKING) SURFACE	TASK STATION (WORKING) SURFACE	TYPE OF FACILITY	GENERAL AREA (WALKING) SURFACE	TASK STATION (WORKING) SURFACE	TYPE OF FACILITY	GENERAL AREA (WALKING) SURFACE	TASK STATION (WORKING) SURFACE	TYPE OF FACILITY	GENERAL AREA (WALKING) SURFACE	TASK STATION (WORKING) SURFACE
AIR COMPRESSOR PLANTS - INDOORS	7.5	—				PILOT PLANT - PROCESS & SPECIALTY (SEE LABORATORIES)			STORAGE - COUNTER TOPS	—	30
AIR COMPRESSOR PLANTS - OUTDOORS	1.5	—	LABORATORIES						- LARGE BINS - INDOORS	—	7.5*
			- GENERAL - INDOOR	15	50	PROCESS AREA - INDOORS	7.5	—	- PALLETIZED - INDOORS	—	7.5*
ANALYZER ROOMS - INDOORS	10	—	- FUME HOODS	—	30	PROCESS AREA - OUTDOORS			- SHIPPING & RECEIVING - INDOORS	20	—
AUDITORIUMS	10	—	- PILOT PLANT - INDOORS	15	—	- GENERAL	0.5	—	- SMALL BIN INDOORS	—	15*
BARGE DOCK & TANKER FACILITIES	1	4	- PILOT PLANT - OUTDOORS	1.5	—	- COLUMNS ABOVE 20 FT.	0.3	—	- TAGGED - INDOORS	4	—
BOILER PLANTS - OUTDOORS	1.5	—	- STOCK ROOMS	7.5	—	- DUST COLLECTORS	1.5	—	- TAGGED BULK - OUTDOORS	4	—
BOILER PLANTS - INDOORS	7.5	—				- FURNACES	1.5	—	SUBSTATION LIGHTING - OUTDOORS	1.5	2.5*
CAFETERIAS & LUNCH ROOMS	5	40	LIBRARIES			- GAUGE GLASSES	—	2.5*	SUBSTATION LIGHTING - INDOORS	7.5	—
CHANGE HOUSE	3	—	- GENERAL	15	30	- HEAT EXCHANGER	3	—			
CLOCKHOUSE	2.5	10	- STACKS	—	40*	- INSTRUMENTS ON PROCESS UNIT	—	2.5*			
COMPRESSOR HOUSES - OPEN SIDES	2.5	—	LOADING RACKS	3	—	- LADDERS & STAIRS - (ACTIVE & INACTIVE)	1.5	—	TANK FARMS		
COOLING TOWERS - EQUIP. AREA	1.5	—	LOCKER ROOM	5	—	- MAIN OPERATING AREA	3	—	- GENERAL	0.5	—
CONTROL ROOMS & HOUSES	25	30*	LOADING/UNLOADING AREAS	3	—	- MAINTENANCE PLATFORMS	1	—	- GAUGING AREA	—	2
EMERGENCY EXIT LIGHTING - INDOOR	0.1	—				- OPERATING PLATFORMS	1.5	—	- LADDER & STAIRS (ACTIVE & INACTIVE)	1.5	—
EMERGENCY LIGHTING FOR OPERATIONAL PURPOSES)	5	—	OFFICES			- PUMP AREAS	3	—	- MANIFOLD AREA	—	4
ENTRANCE GATE	4	—	- INDIVIDUAL	15	50	SHIPPING & RECEIVING (SEE STORAGE)			TANK CAR - LOADING POINT	—	1
ENTRANCE GATEHOUSES	2.5	—	- CONFERENCE ROOMS	15	50	SHOPS - CARPENTER	30	50	TANK TRUCK - LOADING POINT	—	1
EXR LIGHTING	1	—	- DATA PROCESSING	15	100	- ELECTRICAL	25	50	TANKER & BARGE DOCK FACILITIES	1	4
FIRE-HOUSE	7.5	30	- DRAFTING ROOM	25	150	- INSTRUMENT	25	60	VESSEL INTERIORS - 2FT BELOW	—	5
FIRE VALVE HOUSE - INDOORS	7.5	—				- MACHINE	30	150	WAREHOUSES & STOCK ROOMS (SEE STORAGE)		
FIRST AID ROOMS	30	60	- EQUIPMENT & SERVICE ROOMS	7.5	—	- REPAIR	15	30			
GARAGE	7.5	20	- HALLWAYS	5	—	- SHEET METAL	15	150			
GAUGES (VERTICAL) - INDOORS	—	10*	- LAVATORY	7.5	—	- WELDING	15	150			
INSTRUMENT PANELS IN INDOOR OPERATING AREAS	—	10*	- PROLONGED DIFFICULT TASK	—	150	STREET LIGHTING - HEAVY TRAFFIC	0.4	—			
			- RECEPTION ROOM	7.5	—	STREET LIGHTING - LIGHT TRAFFIC	0.2	—			
			PARKING LOTS	0.1	—						
			PERIMETER SECURITY LIGHTING	0.2	—						

(1) BASED ON NON-UNIFORM LIGHTING LEVELS AND AS REQUIRED BY AMENDMENT D-48, U.S. GOVERNMENT PROPERTY MANAGEMENT REGULATIONS.

(2) A MAINTENANCE FACTOR OF 0.7 SHOULD NORMALLY BE USED. THE INITIAL LEVEL WOULD THEN BE 1.43 TIMES THAT LISTED.

* THESE TASK STATIONS EXTEND IN A VERTICAL PLANE. INTENSITIES NOTED ARE FOR A 60 INCH HEIGHT FROM FLOOR LEVEL.

GENERAL NOTES

1. THE FOOTCANDLE LEVELS LISTED ABOVE SHALL BE USED IN THE LIGHTING DESIGN FOR ALL NEW FACILITIES AND FOR RENOVATION OF EXISTING FACILITIES.
2. PORTABLE OR FIXED SUPPLEMENTARY TASK LIGHTING SHALL BE FURNISHED WHERE REQUIRED.
3. GENERAL AREA LIGHTING MEASUREMENTS SHALL BE MADE ON THE WALKING SURFACE (FLOOR LEVEL). NOTE: THESE LEVELS ARE HIGHER AT WORKING SURFACES. EXAMPLE: AN INDIVIDUAL OFFICE WITH AN ILLUMINATION OF 15 FOOTCANDLES AT FLOOR LEVEL APPROXIMATES 30 FOOTCANDLES AT DESK HEIGHT.
4. TASK STATION LIGHTING MEASUREMENTS SHALL BE TAKEN AT DESK SURFACE, TYPEWRITER SURFACE, WORKING SURFACE, ETC., (GENERALLY 30 INCH LEVEL).

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8. FIRE PROTECTION (O. T. Watters)

I. INTRODUCTION

The objective of this section is to familiarize new production engineers with needed information on fire protection facilities that are used in the C&P plants. During the presentation, we will briefly describe major fire protection facilities - their purpose and their method of operation. Importance of fire protection cannot be understated because it is unlikely that we will ever be able to control these unavoidable fires and totally avoid personnel injury while minimizing loss of property and production.

We will also discuss fire protection considerations which are directly related to the operating personnel involved in the loss reduction efforts of C&P.

The National Fire Protection Association (NFPA) classifies fires as follows:

Class A - Ordinary Combustibles

Class B - Flammable Liquids (NFPA30)

Class	Flash Point	Boiling Point
IA	Below 73°F	Below 100°F
IB	Below 73°F	Above 100°F
IC	Above 73°F, below 100°F	-------
II	Above 100°F, below 140°F	-------
IIIA	Above 140°F, below 200°F	-------
IIIB	Above 200°F	-------

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II. BASIC DESIGN CONSIDERATIONS

There are many factors that affect the nature of the fire protection facilities. The significant factors include:

1. Process conditions. The degree of fire protection facilities will be proportional to the hazard resulting from a combination of high pressures and temperatures, volume of flammable liquids in the process and the presence of any unstable or toxic chemicals.

2. Plant layout and equipment arrangements. A well layed out plant with generous spacing between units and equipment within a unit simplifies fire control and reduces the need for installed fire protection facilities.

3. Degree of automation. In plants where there is a heavy reliance on automated production facilities there often is a shortage of personnel that can be used for fire fighting. This reduction in manual fire fighting capabilities results in an increase in fixed mechanical fire protection systems.

The essential aspect of the fire protection facilities is that they be designed to reflect the degree of hazard and have the correct balance between fixed mechanical systems, mobile apparatus and manual fire fighting.

III. WATER SPRAY SYSTEMS

A. Objectives

1. Fire Exposure

When exposed to fire, the physical components of a processing unit such as structures, process lines, pipe racks, instrumentation, and processing equipment absorb heat rapidly and failure occurs from overpressure and/or overheating. This failure can result in adding additional

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fuel to the existing fire, growth and spread of the fire to other areas, and losses of additional equipment. Water spray protection is provided to stop this chain reaction.

2. Fire Prevention

Water spray systems are used for fire prevention. If there is a process upset, or there is a flammable liquid spill or a flammable vapor or gas release, the water spray may be turned on to dissolve, dilute, flush away, disperse, or cool flammable or hazardous materials.

3. Control of Burning

If a water spray system is specifically designed to control burning, nozzles shall be installed to impinge on the source of fire. The water application rate on the anticipated surface of a fuel spill should be at the rate of not less than 0.50 gpm per square foot or double the rate for exposure protection. However, in multiple level pipe racks and in structures, the discharge rate per level is cumulative at grade, and this rate approaches and sometimes exceeds the rate specified for control of burning.

B. Where Needed

Fixed water spray protection is needed to control fires in "extra hazard" process and storage areas containing flammable liquids, gases and sometimes flammable solids under the following conditions:

1. The fire hazard and/or the value of the installation justifies such an installation. Generally, water spray protection is used for heat sensitive reactive chemicals and for liquified petroleum and hazardous gases. High value can be defined as excessive replacement cost, long delivery for a replacement piece of equipment or the piece of equipment is critical for operation.

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2. The area is congested, or has large volumes of liquids above flash point temperatures, such that personnel or equipment would be seriously jeopardized in the event of fire.

3. Hose streams cannot be brought into play promptly or the area might not be approached safely at the distances required for hose stream application.

Generally, the upper portions of process equipment and the upper levels of process structures are less severely exposed by fire than are the lower elevations. This is true because of the grade level accumulation of fuel resulting from spillage or equipment rupture. Consideration may thus be given to reducing the degree of water spray protection for the upper portions of tall equipment and upper levels of structures, provided a serious accumulation of fuel or torch action from broken process piping or equipment is not likely to occur at these elevations. Examples of this are processing columns above the 40 foot level, and multi-level open structures above the third or fourth level. A notable exception to this is an ethylene oxide refining, exhausting or redistillation column which is protected for its entire height because of the severe hazards presented by the heating of oxide-rich vapors.

C. Design Criteria

1. General

The essential feature of a water spray system is configuration of nozzles that surround the items of process equipment or are directed at structural steel or grouped piping and discharge water onto the equipment in the form of a spray as well as all other surfaces to be protected. The object is to get a uniform film of water onto all parts of the equipment structural steel or piping so that

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the water will absorb the heat and prevent the rupture of a vessel or pipeline or the collapse of a structural column.

2. FP-281

C&P's Specification FP-281 is a basic document for specifying water spray systems. Included in this standard specification are our specific design requirements including spray densities materials, location nozzles, etc.

3. Automatic vs. Manual

Virtually all water spray systems now being installed are automatic in operation; however, there are still many systems in service that can be manually operated only. The automatic operation generally consists of a heat actuated device which de-pressures the release mechanism and trips the deluge valve permitting water to enter the system. The manual operation is virtually the same thing, except it must be initiated by a person opening a ball valve which de-pressures the system.

4. HAD vs. Pilot Sprinklers

Most of our automatic water spray systems are actuated by heat actuated devices which operates on a differential expansion rate of an aluminum rod inside an aluminum tube. With slight temperature changes, both expand at a constant rate. However, with a rapid rise in temperature, the tube expands much quicker than the rod and trips the mechanism that opens the deluge valve. Corroision problems, excess maintenance requirements, and occasional false operation has caused the chemical industry to use pilot sprinklers more extensively. A pilot sprinkler is nothing more than a standard sprinkler head with a fusible element which melts at a fixed temperature and thus releases a pressure

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on the pneumatic system that trips the deluge valve. Water spray systems now being installed in the Chemicals and Plastics Division are using the pilot sprinklers for automatic operation.

5. Water Spray Capacity

The number of water spray systems actuated at any one time is limited to the water supply available. Personnel actuating water spray systems must know how many systems can be put in service.

IV. SPRINKLER PROTECTION

A. Objective

The purpose of the sprinkler system is to control a fire by applying a uniform density of water to the fire area. Often the sprinkler system will extinguish the fire before the emergency squad arrives. If not, it will prevent any growth of the fire until final extinguishment can be affected by the emergency squad.

B. Where Needed

Sprinklers are most useful in plant buildings having flammable contents or combustible construction. In petrochemical plants, it is generally profitable practice to install automatic sprinkler protection in the following occupancies:

1. Buildings where flammable liquids, liquefied gases, or combustible dusts are processed, handled, or stored, such as in chemical processing, drumming packaging, shipping, and storage buildings.

2. Buildings used for storage of plastics and other combustible materials.

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3. Maintenance or storage buildings such as shops, repair garages, or plant stores critical to production or the continuation of business if valued above $500,000.

4. All chemical laboratories, including small auxiliaries.

5. Flammable gas cylinder filling and storage buildings.

6. Basements of office, service, and cafeteria buildings where personnel assemble.

7. Any cooling towers built of combustible materials if the tower is critical to plant operation. As strange as this appears, cooling towers can be involved in a fire because not all combustible materials are consistently wetted and organic materials are sometimes present due to small leaks in heat exchange equipment. The fire hazard is extremely severe when the tower is out of service.

V. FIRE WATER SUPPLY

A. Reservoir

The reservoir can be any large body of water or tank(s), natural or manmade, which are capable of providing a four-hour supply of fire water at maximum demand rates. Supplying the maximum demand for a minimum of four hours is the generally accepted criteria for petro-chemical plants.

The maximum rate of fire water that will be consumed at any one time is applicable on both a plant-wide and unit basis. Considerable judgement is required to arrive at this figure because the fire protection engineer must determine on a probability basis where this "maximum" fire will occur and how large an area it will encompass. For most of the major C&P plants, the demand will be 12,000 to 16,000 gpm which makes the minimum reservoir requirements three to four million gallons.

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B. Pumps

Fire pumps are used to deliver fire water from the reservoir to the distribution system. There are essentially no differences between a fire pump and any other centrifugal pump, except the pump is to be approved for fire service by Underwriters' Laboratories and/or Factory Mutual Engineering Corporation. After installation, the pump is performance tested by the Insurer's representative and UCC for final acceptance. Pumps in our major plants generally have capacities of from 1,500 to 2,500 gpm at 100 or 125 psig with the total capacity for the plant equaling or slightly exceeding the maximum demand. At least one fire pump should be automatic starting with loss of pressure in the fire water system or a fire alarm and at least two-thirds of the pumps should be gasoline or diesel engine driven to insure protection during a power failure.

C. Block Grid Distribution

This is the underground network of piping that carries the fire water to the demand.

Generally, these lines are installed adjacent to plant roadways to form a loop around each occupied plant block.

To the extent possible, these lines should not be routed below roadways, other paved areas, railroads, or crane accessways; the reasons being the potential for physical damage to the pipe and the difficulty and cost in finding the repairing a leak that develops below a paved surface. In no case should a line be routed below a building except to enter the building as a supply for the building's fire protection systems. If it is necessary to run a line under a building, a full length solid sleeve should be used to prevent undermining the building in event of pipe failure.

Most fire water lines in C&P plants are eight, ten, and twelve inch, although fourteen, sixteen inch, and larger lines are sometimes used. To determine the line size, the fire water demand must be estimated for each area of the plant. The lines are then sized to deliver this quantity of water at pressures not less than approximately 75 psi.

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Sectionalizing valves are installed throughout the distribution system (preferably at intersections) to facilitate removing sections of piping from service without totally impairing the fire water system. The guidelines that are applicable for determining the location for these valves are:

1. Fire water must be available to at least 50 percent of any single area or plant block, as well as to provide alternate routes for water to adjacent blocks.

2. Not more than seven items can be out of service at any one time. For this purpose, an item is a water spray system, sprinkler system, hydrant, or hose cabinet branch. In critical plant blocks, the limit may have to be reduced to five items. In no case should the five or seven items include more than four water spray systems.

Sectionalizing valves are also installed in the branches that supply the water spray and sprinkler systems. Some of the worst fire disasters have resulted from the improper use of sectionalizing valves. These valves should only be closed by personnel authorized to do so and then only under the strictest control.

D. Hydrants, Monitors, and Hose Houses

Hydrants are installed in the fire water distribution system at 200 to 300 foot intervals. Obviously, the hydrants are spaced closer together in the process areas where high hazards exist. Larger spacing should be used in tank farms, utility blocks, and areas of similar low hazard.

They are located among plant roads which places them about fifty feet from the unit and in an accessible position clear of all traffic. However, many blocks are large enough that hydrants must be placed in central areas of the block so that all installations are accessible to hose streams. A good rule-of-thumb is to have a minimum of two hydrants within 200 feet of any point where a significant hazard exists.

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Monitors are large capacity fixed nozzles which are usually mounted on posts and supplied from hydrants. Their direction can be varied within an arc of about 125 degree vertically and 360 degrees horizontally. Their advantage is that they can be placed in operation very quickly, locked in position, and be left unattended. Their disadvantages are their maximum range of about 100 feet at hydrant system pressures and the inefficient use of water. Almost all of the monitors installed in C&P plants are provided with tips with rated capacities of 500 gpm.

Hose houses are small enclosures which are located throughout the plant and contain fire hoses, nozzles, and other apparatus necessary for fire fighting operations. The number and location of these houses will vary from one at each hydrant in some hazardous area to one for every other hydrant in areas with a lesser hazard. Hydrants and monitors are specified in Standards FP-2 and FP-4.

VI. DRAINAGE

A. Importance of Emergency Drainage

The most effective means of controlling a flammable liquids spillage or fire is with a closed, underground drainage system which removes the fuel automatically and quickly to a safe location. It is essential that all drain inlets be liquid trapped to prevent transmission and spread of burning liquid. The burning surface in a drain basin does not pass through a trap but the liquid below the surface does, thereby safely removing it from the fire. Should the drain be dry and thus untrapped when burning liquid arrives, the trap or seal will be reestablished, and the fire inside of the drain will subside as soon as the oxygen in the closed portion of the system is consumed. If all other connected surface drains are trapped, the normal condition in most plants, flammable gases and vapors will not be forced out from them, thus confining the fire to the original location.

B. Design Criteria

In general, drains and surfaces should be located and sloped to carry spillage away from equipment, piping, and structures because liquid

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fires concentrate at the drains. Unfortunately, it is not always feasible to do this.

Most spillage drains are six inch, but occasionally larger ones are needed. One six inch drain with a capacity of about 200 gpm for each 20 to 25 foot square bay is usually adequate and prevents excessive spread of spillage and consequent piping and equipment involvement. One drain per bay also lessens problems in sloping of the surfaces, which should be two percent for good or complete drainage. Drains should not be spaced more than 30 feet apart.

The total drainage requirement is based on the outfall or discharge rate of fire water from the process or tank area, based on fire safety requirements. A general guideline is to use one half of the expected water spray discharge rate of up to six systems; that is, one half the spray rate but not more than 6,000 gpm for the total area drainage rate. For larger requirements, a second drainage course should be established and terminated at a separated location. Under emergency conditions, the yard grading, including swales where needed, must carry the excess water and any floating materials to roadside ditches.

Insofar as is possible, pits, trenches, and open collector boxes should be excluded from fire hazard areas, since they act as collection points for heavier than air vapor, and can transmit fire from one area to another. Where trenches must be used, they should have firestops between fire areas and have two-thirds of their open area covered with checker plate to minimize any fire that develops in the trench. This trench protection is illustrated in Standard FP-6.

As previously stated, trapped drainage is provided to prevent and control fires and has built-in provisions for separating pollutants. Any installation of closed valves in the process area drainage system defeats the fire safety features in that the spilled fuel is retained in the equipment environment, endangering the entire installation and personnel. This is contrary to our Insurance carrier directives and should not be permitted unless the spillage is automatically removed by other means.

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VII. DIKING

Dikes are barriers that are designed to contain spillage from field storage tanks. General requirements and construction details are included in Standards FP-48 and CE48 A&C.

A. Operation of Dike Valves

The following rules must be followed by departments having tanks with dikes and dike valves:

1. Dike valves must be kept closed at all times except when draining accumulated water from the diked area.

2. The departments having diked areas valved off from the river, or collection basin, shall be responsible for inspecting the valves on a regular basis (at least 3 times per week) and for keeping a log as to condition and status of valves and inspection dates.

3. The Foreman shall inspect all dike valves once each week and record his findings on the log sheet provided. Send the completed form to the Environmental Protection Office. The Distribution Department Head will also submit a copy of his weekly valve inspection log to the Environmental Protection Department.

4. When a diked area is to be drained the following procedures are to be follows:

   a. Take a sample of the liquid within the dike and send, or hand carry, to the Stream Pollution Laboratory for determinination of total carbon.

   b. If the material to be drained is 5000 ppm carbon or less, and contains no immiscible material, notify the Foreman of the proceeding results and obtain his

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permission to open the dike valve. The person opening the valve must close the valve before the end of the shift. His relief must do likewise.

c. If the material to be drained is over 5000 ppm carbon and/or contains an immiscible material do not drain but notify your Department Head. The Department Head, after conferring with the Environmental Protection Department, will determine the proper method of disposal.

d. The Department Foremen are to record the time each diked area is drained.

Maintenance of the dike valves and compliance with these rules must have top priority to eliminate accidental pollution from this source.

SAFETY CONSIDERATIONS

All persons involved with diked tank farms, with closed valves on the drain lines to the river must be aware of the "HAZARDOUS CLASSIFICATION" health, fire, stability of the material stored in each tank. In case of a catastrophic failure and/or fire in such a diked area material with a high hazardous rating may require special handling in regard to vapor cloud formation, personnel exposure, odor emission, etc. In all cases the Department Head and Shift Superintendent must be informed immediately.

B. Vapor Cloud Potential in Diked Areas

1. Physical Property Difinition of Vapor Cloud Hazards:

Boiling Point	-	Less than 36°C
Vapor Pressure	-	More than 425 mm Hg. (at atm. press.)
Flash Point	-	Less than 0°F.
Toxocity	-	Health rating of 4.

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2. List of Hazards Chemicals Stored at One Plant:

	Boiling Pt.-°C	Vapor Press.-mmHg.	Flash Pt.-°F
Acetaldehyde	20.4	750	0
Ammonia	-33	6247	Gas
Butane	- 0.5	1557	Gas
Ethane	-88.6		Gas
Ethylamine	16.6	873	0
Ethylene Oxide	10.4	1095	0
Ethyl Ether	34.6	439	0
Hydrogen	-252.8		Gas
Hydrogen Chloride	-85.0	28995	
Isopropylamine	32.4	478	0
Ketene	-41.0	699	Gas
Propane	-42.1	6230	Gas
Propylene Oxide	34.3	442	0
Vinyl Chloride	-13.4	2310	0
Vinyl Ethyl Ether	35.6	426	0
Vinyl Methyl Ether	5.0	1175	Gas
Isobutylene	- 6.9	1953	0
Mono Methyl Amine	- 6.3	1396	0
TriMethyl Amine	2.8	1432	0

VIII. EMERGENCY ALARM SYSTEMS

Every major C&P production facilities has an emergency alarm system. The typical system sounds a coded signal on whistles, bells and chimes located throughout the plant. This signal is usually three digits that identify the location of the alarm box that has been activated. This number is derived by dividing the plant into a grid of areas and zones which make up the first two digits. The third number identifies the individual box. It is essential that you know the locations of all the emergency boxes and their numbers in your area and actions you should take when you hear the alarm signal. It is equally important that the alarm system be used without hesitation for any emergency where the assistance of the emergency squad will be beneficial.

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IX. OTHER SYSTEMS

A. CO_2 Systems

Carbon dioxide reduces the oxygen content of air to a level that will no longer support combustion. Atmospheres which do not support combustion do not support life, therefore, CO_2 is applied to personnel occupancies only with adequate safeguards such as pre-actuation alarms or manual only actuation. It can penetrate and spread into congested, hard-to-reach areas such as a mass of electrical cables under a computer room floor if the openings in the floor and below the floor have been packed or sealed.

B. Halon Systems

Halon 1301 has been used in UCC Plants as an extinguishing agent in such places as buildings housing boiler feed oil pumping and heating systems, and computer installations. Its chief advantage over carbon dioxide is that it presents a minimal personnel hazard at extinguishing concentrations, and can therefore be used in personnel occupancies. It is, however, more expensive than CO_2.

C. Dry Chemical Systems

Dry chemical extinguishing systems are combinations of tanks, controls, piping, and nozzles which expel dry powder upon a fire. The application of dry chemical systems is currently limited primarily to flammable liquids. Dry chemical is effective on gas fires or volatile spill fires when backed up with other media to extinguish residual or smoldering ignition sources. Fixed systems are used industrially to protect open containers of flammable liquids such as dip tanks and degreasing tanks, switch gear, transformers, and other hazards described in the standards referred to above.

D. Foam

Foam fire protection is generally needed in our plants to extinguish fire involving liquid spills, storage tanks, pits, trenches, or

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ponds. This protection will normally be in the form of a foam fire truck. Fire fighting foam is an aggregation of small bubbles of lower specific gravity than oil or water that flows freely over a burning liquid surface and forms a tough, air-excluding continuous blanket to seal volatile combustible vapors from access to air.

E. Steam

Several processes require the generation of high temperatures by use of direct-fired Dowtherm or tetralin heaters or furnaces. Fires sometimes occur in these heaters through tube failure, usually caused by overheating at a carbonized hot spot. The released Dowtherm, tetralin, or other medium generally ignites immediately from the high furnace temperature. Steam extinguishing systems are normally installed in these heaters and furnaces to pressurize the interior of the furnace to exclude air, thereby extinguishing the fire; or the steam prevents ignition of any flammable gas cloud that approaches the furnace, by preventing the gas from entering the hot furnace.

F. Fire Extinguishers

Fire extinguishers are designed to handle fires of certain sizes and for use on fires in their early stages.

The most common usage of fire extinguishers is for the 20 and 30-pound dry chemical for liquids and gases in outdoor process units, unit tank areas, field storage and shipping areas, as well as drumming and shipping buildings.

They are provided in outdoor process units and in buildings even though automatic water spray, sprinklers, or other fixed fire extinguishing systems are present. Their use often precludes operation of fixed extinguishing systems. FP-1 is the standard for selecting fire extinguishers.

X. CABLE TRAY PROTECTION

Cable trays are so susceptible to fire exposure that they must be given special attention. Standard FP-58 gives the details of this protection

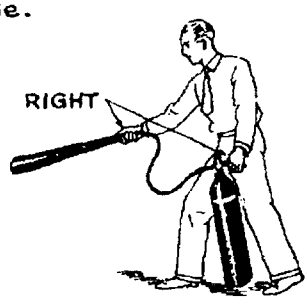
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THE RIGHT WAY

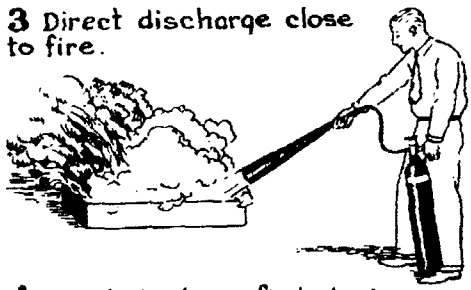
1 Remove extinguisher from rack, (see std. FP-70). Carry to fire by carrying handle with left hand.



2 Loosen discharge nozzle. Pull out locking pin - break seal. Open valve. Hold nozzle at hose end of handle.



3 Direct discharge close to fire.



4 Direct discharge first at edge nearest operator or, if on vertical surface, at bottom of fire.



5 Slowly and deliberately advance discharge as flame is extinguished. Be sure all flame is out in part of fire tackled before advancing.

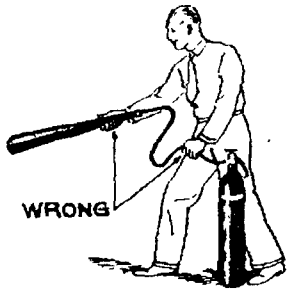
6 Continue discharge after flames are out so as to coat hot material with snow.

7 Notify the Fire Protection Division to have extinguisher recharged as soon as possible. Give reason for use.

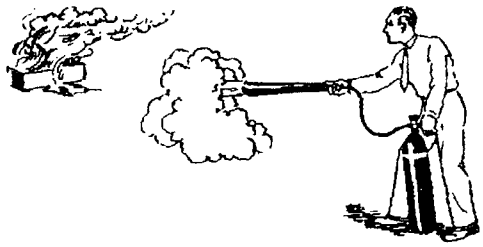
THE WRONG WAY

1 Don't open valve before carrying extinguisher to fire.

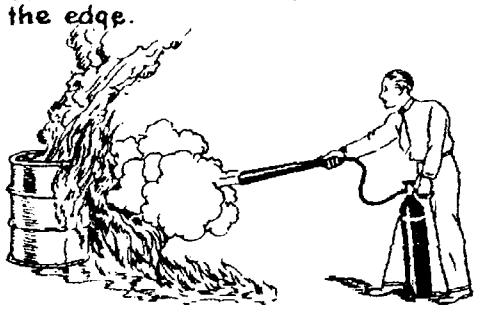
2 Don't hold nozzle near discharge end.



3 Don't direct discharge from a distance exceeding 8 feet.



4 Don't direct discharge at center of fire and then attempt to work to the edge.



5 Don't haphazardly direct discharge over various sections of fire. Put out one portion of fire completely before attacking other parts.

6 Don't shut off extinguisher as soon as flame is put out.

7 Don't put used extinguisher aside and forget about it.

CARBIDE AND CARBON CHEMICALS CORP.
PROCESS SAFETY DEPT. - FIRE PROTECTION DIVISION
SOUTH CHARLESTON, W. VA.

STANDARD HOW TO USE CARBON DIOXIDE EXTINGUISHERS	PSK 368
DRAWN BY: LWH- CHECKED BY:	APP'D DATE 7-24-42

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which consists of a metal shield below the tray and water spray nozzles directed at the tray from above. The shield will protect the tray for at least one minute which is the approximate time required for the water spray system to be actuated and then become effective. After the water spray becomes effective, the system will withstand normal fire exposure for an extended period of time.

XI. FIRE WALLS AND FIRE DOORS

Fire walls are concrete walls that separate individual fire areas. All openings must be protected by fire doors that are specifically designed and approved for use in fire walls and are self-closing when exposed to a fire. They were extensively used when our older plants were constructed. In our newer plants, process equipment is installed outside. Brick or block construction is prohibited; therefore, fire walls are rarely used in new plant construction.

XII. SMALL ADDITIONS AND REVISIONS AND FIRE PROTECTION REQUIREMENTS

A single small addition or revision to a unit probably would have little effect on the overall integrity of the fire protection system. However, several small editions or revisions could create a situation where we would have a domino effect with disastrous results. To avoid this, the production engineer must consult with the Plant Fire Safety Representative who will either provide the appropriate fire protection facilities or initiate action to involve the Engineering Department's Process Safety and Fire Protection Group to provide the necessary fire protection whenever there is a small edition or revision to a unit. Water spray installations removed for maintenance work must be replaced in proper position prior to startup.

XIII. FIRE FIGHTING HAZARDS

There are a number of conditions which have the potential for a severe hazard to fire fighters. The production engineer should be aware of these conditions and should assist in emergency squad training related to these conditions. Examples are:

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1. Water reactive chemicals

2. Acid reactive chemicals

3. Combustible metals

4. Toxic chemicals

5. Chemicals with toxic products of combustion

6. Heat sensitive chemicals such as acetylene or peroxides

7. Consequences if fire fighting systems are inoperative

8. Consequences if emergency shutdown systems is inoperative.

XIV. COMMON ERRORS

It is physically impossible to tabulate all the possible errors that a production engineer can make. However, some of the more common ones are:

1. Not fully evaluating the consequences of adding a new chemical to the unit. These are:

   a. Increase the hazard to personnel due to toxicity, fire or instability.

   b. Cause additional overpressure relief capacity to be required on process equipment.

   c. Cause the electrical classification to be changed.

   d. Increase the fire hazard to the extent that the fire protection facilities are inadequate.

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e. Existing materials of construction may be unsuitable.

2. Make a minor modification that will:

   a. Interfere with the discharge pattern of water spray nozzles. An example is to place a cover on a cable tray to prevent drippage on the cables which also intercepts the water spray.

   b. Interfere with the 12-foot rundown of water on the shell of process equipment.

   c. Block access to an emergency exit.

   d. Block access to a hydrant, fire alarm box, etc.

   e. Interfere with the water stream from monitor.

   f. Increase ignition sources.

3. Removing water spray or sprinkler piping for maintenance or construction activity and not replacing it correctly.

4. Installing a heat source close to a heat actuated device in a water spray system which will cause false actuatuions.

5. Make an opening in a fire wall without a fire door.

6. Permit sewer inlets to become plugged, thus negating emergency drainage.

7. Forgetting the need for flame traps during drainage system repair or alteration.

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XV. NEED TO RESTORE FIRE PROTECTION SERVICES, EQUIPMENT, ETC., AFTER IN-PLANT MAINTENANCE WORK

Many of the most horendus fire disasters have been in properties where the fire protection facilities have been out of service for one reason or another. Normally, this is a valve that was closed for a legitimate reason and then forgotten.

Unfortunately, there are times that fire protection facilities must be out of service for maintenance or repair. During this outage, there must be extra surveillance and precautions taken to avoid a fire emergency and facilities must be restored to service as soon as possible. This is most easily done by scheduling and limiting the fire protection outages to the day shift.

One of the necessary maintenance functions is periodic testing of every fire protection system to insure its operability. The frequency of this testing is as agreed upon by the Production Representative and the Plant Fire Safety Representative.

XVI. RESOURCES OR QUESTIONS, CONSULTATIONS, OR CHANGES

A. Local Fire Protection Personnel

This is the plant fire safety representative who is a member of the Plant Safety Department. He normally has many years of practical experience in fire fighting techniques, fire protection systems, and protable fire fighting equipment.

B. Process Safety and Fire Protection Group

The Process Safety and Fire Protection Group consists of the Group Leader, six to eight engineers, a relief device specialist who functions as consultant to UCC personnel of matters of safety and fire protection. Your plant fire safety representative is in a position to request assistance from this group in any fire protection matter.

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XVII. SUMMARY

From the above discussion, you can see that there are many facets to fire protection and each of these has a special purpose. It is imperative that these systems be maintained, be updated to include all changes and revisions to the unit, and be used properly. To accomplish this, you must be familiar with all the fire protection facilities in each unit and know how they operate. This can best be accomplished through discussions with your Plant Fire Safety Representative.

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9. RESOURCES AND REFERENCES (D. T. Watters)

I. INTRODUCTION

The objective of this section is to familiarize production personnel with the Technical Manuals useful in becoming familiar with, and understanding, the location safety activities.

We will cover a typical Location Safety Manual; the Safety Technology Manual; the Safety Information Manual; the Reactive Chemicals Manual, which is treated in detail in the section entitled "Chemical Processing", other technology manuals that have safety impact; and other miscellaneous information. Some of the manuals discussed are not completely devoted to process safety, but because of their high importance to safety they are mentioned in this discussion. We will list for you resources that you may contact to answer questions or make interpretations concerning the above manuals.

This information is important because we will cover the manuals that contain information pertaining to the safety and operations of your particular unit as well as your particular location. For each of these aforementioned manuals we will cover why the manual is important and review the contents of the manual in highlight fashion.

II. LOCATION SAFETY MANUAL (LSM)

Location Safety Manuals are particular to the environment of the location for which the manual is prepared. The LSM should include actions and reactions of the organization and individual accountabilities for response to a safety related and activities incidents. The objective of the LSM is to achieve uniform understanding and action across the location. It is the accountability of the location to prepare and maintain the Location Safety Manual.

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All plants may not have a manual entitled LSM, but there are equivalent manuals or documents available at each location. Consult with your local safety director for definitions. For purposes of this discussion the term Location Safety Manual (LSM) will be used.

A. Contents of Typical Location Safety Manual

As previously stated, a Location Safety Manual (LSM) will vary depending upon the location because of the various needs and organization of a particular location, geographical location, local mutual aid organization, chemicals and processes being handled, and the particular facilities of the location.

Three Location Safety Manuals have been reviewed and the following information is a composite of representative contents from those three manuals. The typical manual would be expected to contain this basic material.

1. Introduction - Location Safety Philosophy
2. Hazard Control Procedures and Safe Work Practices
3. Emergency Procedres
4. Personnel Safety
5. Accident/Fire Prevention
6. Equipment Safety
7. General Safety Rules

In the Introduction Section, there will normally be a statement by the location manager indicating that manager's commitment to a safety at his location and explicitly stating that the hazard control procedures and safe work practices are to be followed unless management variance is obtained. There will also usually be a list of telephone contacts pertinent to that location so that these telephone contacts will be readily available in case of emergency. The location safety organization will also be described in the introduction.

Hazard control procedures and safe work practices are important categories because these sections are described the safety practices for executing the day-to-day work at the location. Such items as confined space

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entry, hazardous work permit procedures, mastertag lockout procedures, excavating procedures, electrical hot work, the handling of railroad cars when loading and unloading, safety practices concerning radioactive materials, procedures concerning safety valves, the handling of portable ladders, and preparation of equipment for maintenance. These are typical procedures that are executed everyday by many people in the location. It is very important that all of these people understand and practice these safe practices and that you be familiar with them so that you can enforce these practices and procedures in your particular area of accountability.

The Emergency Procedures section applies to the general plant environment, not a particular unit. This section includes such things as emergency alarms procedures and responses to such alarms, actions of the emergency squad, the location's participation or calling out of a mutual aid organization and procedures for flammable vapor cloud entry. These aid organization and procedures for flammable vapor cloud entry. These procedures are important because they must be preplanned and preunderstood in case of an emergency. There is not time to open a book and read a procedure if an emergency develops. Therefore you should be familiar with these procedures so that you may properly respond in an emergency situation.

A typical LSM will include a personnel safety section which will deal with such items as personnel safety equipment (hard hats, safety shoes, eye protection, clothing, noise protection, respiratory equipment), minimum acceptable dress, facial hair, and breathing air standards. These are important items to you because again in your area of accountability, you have responsibility for enforcing these personnel safety standards.

Accident/Fire Prevention activities procedures include such things as investigation (fires, recordable and disabling injuries), control of fire extinguishers, and use of fire hydrants. You may find yourself assigned very quickly to the investigation of incidents. This is not unusual for a new person in the location because he will have an open mind and no preconceived ideas as to past practices.

Equipment Safety standards and procedures apply to equipment used in your area on an everyday basis. Such things as hose standards, test

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meters (explosimeters, oxygen, carbon monoxide), portable lights, equipment, temporary wiring extension cords, compressed gas cylinders, drum containers-the use and handling, test and inspection procedures, facility/process change review, welding or hot tapping on equipment in service are typical standards and procedures that are covered in the equipment safety section. Because of their frequent use you should be familiar with these standards and procedures.

The test and inspection activity is of particular importance to the safety of your unit. Because of its importance the subject is discussed in greater detail in a section dealing with Equipment Test and Inspection.

The general safety rules category in the LSM includes such frequently used standards as visitor safety rules, smoking regulations, and vehicle safety.

As noted previously, the LSM is the document with which you should be most familiar. These LSM's are available from your department head or other location resource personnel and you are encouraged to be completely familiar with these documents. The three documents reviewed in preparation of this particular presentation were up-to-date and current in their contents. The location Safety Department is accountable for preparing and maintaining the LSM.

III. SAFETY TECHNOLOGY MANUAL

Next, let's discuss the Safety Technology Manual, or STM. The STM is one basic document from which the Location Safety Manual is derived. The objective of the STM is to establish uniform safety technology across C&P. The STM contains the safety technology that is currently used in the facility design of your unit. The STM also contains a SF-100 group of standards, which describe minimum mandatory requirements for some critical-few safety activities in the operation of your unit. Section 5 and 6 of the Safety Technology Manual contain C&P mandatory specifications and standards that are used by all locations unless a variance is filed and approved. The Safety Standards Team, a team within the C&P Standards Program, is accountable for maintaining the Safety Technology Manual.

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A. Contents of Safety Technolgoy Manual

The STM is divided into eight sections, the same basic sections as all technology manuals. These sections and their major parts are -

Section 0, Function Description contains information of interest to the Safety Director Group but not new production engineers.

Section 1 contains about 200 pages of criteria which deals with process safety, personnel safety and fire protection.

Process safety topics include plant layout; electrical safety; control system; pressure and vacuum relief devices; venting of relief devices; inerting, purging, sampling and vacuum breaking; safeguarding pumps; drainage, and dust hazards; among many other items.

Personnel safety criteria topics include personnel safety equipment, safety in working areas, guarding, shielding and insulating for safety, industrial hygiene criteria, and plant safety to be observed by visiting personnel.

Fire protection is a very important topic and is covered in another lecture in this course, but the criteria for the lecture is in the STM.

Section 2 describes Design and Analysis Methods, about 75 pages. This gives methods for design and analysis of:

1. Electrical Classification
2. Relief capacity requirements
3. Relief device sizes
4. Discharge pipe reaction forces
5. Steam Snuffing of vent fires
6. Vent header knockout pots
7. Inerting for fire and explosion prevention
8. Fire water systems

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These two sections, some 275 pages, make up Volume 1 of the STM.

Volume II consists of sections 3 through 8. The titles of these sections are:

1. Section 3 Computer Programs
2. Section 4 Drafting
3. Section 5 Mandatory C&P Specifications
4. Section 6 Mandatory C&P Standards
5. Section 7 Field Inspection & Testing Criteria
6. Section 8 Operation & Maintenance

Section 3, 7 and 8 currently contain no information. In the future, material may be added.

Section 5 and 6 contain mandatory safety specifications and standards. These two sections are of particular interest to you.

The Table of Contents for Section 5 and Section 6 is provided at the end of this section. We ask that you read these at your leisure and discuss any questions with your Department Head or one of the location resource personnel. Note especially the SF-100 series which deal with minimum operative practices in a "critical-few" procedures.

Safety Technology Manual information is available from your location safety director or Engineering Group.

IV. SAFETY INFORMATION MANUAL (SIM)

The Safety Information Manual is referred to as the SIM. The purpose of the SIM is to establish uniform administrative safety activities across C&P via the general, non-technical, safety information in the SIM.

The SIM contents include five sections - Administrative, Procedure Criteria and Guidelines, Audits, Training and Programs.

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Information in the SIM will change periodically as new data or experience is gained or as recommended criteria becomes mandatory. Because the contents of the SIM is administrative in nature, the SIM is generally distributed only to Safety Directors or location management personnel. Should you have questions related to administrative safety matters or audits contact your location safety director. The SIM is maintained by the Chemical and Plastics Safety Department.

V. REACTIVE CHEMICALS MANUAL

The Reactive and Hazardous Chemicals Manual is a prime reference for the Manufacturing Department. The Manual contains information about 575 different chemicals that are handled in Chemicals and Plastic's locations. Because of the confidential nature of the material, the information should not be reproduced or given to persons not employed by Union Carbide Corporation.

The Reactive and Hazardous Chemicals Manual is discussed in detail in Appendix A. Mention is made here because of the overall impact of this manual on the safety activities in your unit.

The manual encompasses the C&P Hazards Signal System. The system uses a grouping of numbers, presented in four diamonds, to indicate the health, fire and reactivity hazards of a chemical. Facilities within the units are to be marked with the system symbols.

The numbers and letters to be used in the hazard signal system come from the Reactive and Hazardous Chemicals Manual. If you are handling a chemical in your unit for which this information is not available, you should contact the C&P Safety Department to obtain the correct hazard signal system information. The Reactive and Hazardous Chemical Manual is maintained by the C&P Safety Department with support of the R&D Department.

VI. OTHER TECHNOLOGY MANUALS

The aforementioned manuals are those that are directly related to the safety efforts. However, there are other Technology Manuals which have a major impact on safety.

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Within the Technology Manual Program there are 27 manuals that cover various C&P technologies. The total list of the technology manuals to which you may have reference from time to time is included at the end of this section.

Highlighting some of the manuals that have particular safety interest we note the Layout Manual, the Electrical Manual, the Civil Manual, the Valve and Piping and the Control Systems Manual. Each of the technologies have safety related items that are particular to their technologies and are included within their manuals.

You can see from the above, that the Technology Manual Program actively supports the safety effort and that safety is too large to cover in one technology. Our total C&P safety effort is gained by the mutual support of all the technology manuals rather than the single or few safety manuals.

VII. OTHER MISCELLANEOUS DOCUMENTS

Other manuals and documents that are of interest to production engineers are the Distribution Manuals for your location. These manuals will cover the distribution activities associated with the receiving of raw materials and the shipment of products from your location. While you may not be directly involved in these distribution activities you should be familiar with these manuals because all locations carry out the function of receiving raw materials and making product shipments. Many times these activities offer one of the most hazardous situations within our scope of activities.

Another document that will be of interest to you is the Safety Considerations Report which is prepared for engineering projects which furnish new or revised facilities at your location. The report is to describe the safety features and philosophies that went into that particular project. Because the report is for a particular project, personnel at each unit can collect the safety consideration report for projects executed at their unit, and thus maintain a file of safety consideration reports for the unit. Appropriate accountable personnel at the unit should be completely familiar with the safety consideration reports because these reports highlight the safety of each project design at the unit.

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R&D reports are another source of information having safety impact. The reports may be prepared for chemicals or activities at the particular unit. These reports generally deal with the chemistry and thermodynamic safety implications of the process.

Information involved in safety consideration reports and in the R&D reports should be included in the location operating instructions and emergency procedures.

Some Engineering Department manuals that may be of safety interest to you are - Process Engineering Methods Manual, Project Procedures Manual, and manuals that apply to various product areas such as polyethylene, ethylene oxide, hydrocarbons, etc.

VIII. SUMMARY

From the above presentation, you can see that we have covered a lot of information in a large number of manuals that may have safety impact on operations at your location. We do not expect that you will have grasped all of the information in the manuals, both in regard to data and interpretation of the material. However, there are people in the C&P organization who can assist you in answering questions and interpreting data. Your location Safety Department, the location Industrial Hygienist, and the location Engineering Group--all of these people have an accountability at your location to be familiar with many of the above documents.

If they cannot answer your questions, they can call upon resources outside your location such as the C&P Safety Department, the Process Safety and Fire Protection Grup of the Engineering Department, the Safety Research Laboratory of the R&D Department, standard teams that are accountable for technologies in question, or the engineering manager or technology manager for an involved business team. These outside sources have an interest in seeing that the technologies are uniformly applied and answering questions that you may have. Please do not hesitate to call on your location contacts or these outside resources if you should have questions. Not only will your questions get ansewered, but feedback will be made to accountable parties concerning the use of their particular document.

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In summary, during this presentation, we have discussed the typical Location Safety Manual, the Safety Technology Manual, the Safety Information Manual, the Reactive Chemical Manual, other manuals of the C&P Technology Manual Program, and some miscellaneous manuals and documents that may be of interest to you in safely operating your facilities and your processes.

Remember that each of these manuals are supportive of each other in forming the total safety information and documentation for Chemicals and Plastics activities.

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SECTION 5, C&P STANDARD SPECIFICATIONS

Standard Number	Issue Date	Title
FP-1	JULY 1976	STANDARD FOR SELECTION OF FIRE EXTINGUISHERS
FP-2	JANUARY 1977	STANDARD FOR FIRE HYDRANTS
FP-2A	JANUARY 1977	STANDARD FIRE PROTECTION VALVE DESCRIPTIONS
FP-280	JANUARY 1975	SPECIFICATION FOR SPRINKLER SYSTEMS
FP-281	JANUARY 1975	SPECIFICATIONS FOR WATER SPRAY SYSTEMS
FP-304	JANUARY 1976	HOSE FOR FIRE WATER SERVICE
SF-1	JANUARY 1976	GENERAL GUIDELINES FOR SAFETY VALVE INSTALLATION
SF-2	MARCH 1975	GENERAL GUIDELINES FOR SAFETY HEAD ASSEMBLY AND RUPTURE DISK INSTALLATIONS
SF-3	AUGUST 1975	GENERAL GUIDELINES FOR OPEN VENT, BREATHER VENT, FLAME ARRESTOR, AND EMERGENCY VENT INSTALLATIONS
SF-4	FEBRUARY 1977	GENERAL GUIDELINES FOR APPLICATION OF HAND OPERATED BALL VALVES
SF-6	JANUARY 1976	GUIDELINES FOR AUTOMATIC STARTING FIRE PUMP AS A PRIMARY FIRE WATER SUPPLY
SF-7	JULY 1975	SAFETY GUIDELINE FOR IN-PLANT STORAGE OF ORGANIC PEROXIDES
SF-10	JUNE 1978	SAFETY CONSIDERATIONS FOR OCCUPIED BUILDINGS LOCATED NEAR DEFINED OPERATING AREAS
SF-16	FEBRUARY 1977	USE OF BLOCK VALVES AT RELIEF DEVICE INLET AND/OR OUTLET
SF-19	SEPTEMBER 1976	GUIDELINES FOR SAFETY AND FIRE PROTECTION IN ANALYZER BUILDINGS
SF-20	APRIL 1977	STANDARD SPECIFICATION PLANT EMERGENCY ALARM SYSTEM
SF-21	NOVEMBER 1977	PUMP SAFETY GUIDELINES
SF-22	NOVEMBER 1977	PHENOL SKIN EXPOSURE EMERGENCY TREATMENT AND EQUIPMENT
SF-23	NOVEMBER 1977	SIGHT GLASS SELECTION FOR PROCESS EQUIPMENT

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SAFETY

UNION CARBIDE

CHEMICALS/PLASTICS ENGINEERING

Standard Number	Issue Date	Title
SF-24	NOVEMBER 1977	STANDARD FOR GAS DETECTION SYSTEMS
SF-101	OCTOBER 1975	MASTER TAG PROCEDURE
SF-102	OCTOBER 1975	HAZARDOUS WORK PERMIT PROCEDURE
SF-103	OCTOBER 1975	CONFINED SPACE ENTRY PROCEDURE
SF-104	OCTOBER 1975	PROCEDURE FOR USE OF RESPIRATORY PROTECTIVE EQUIPMENT
SF-105	MAY 1978	PROCEDURE FOR USE OF BREATHING AIR
SF-106	OCTOBER 1975	PROCEDURE FOR REACTING TO A FLAMMABLE VAPOR CLOUD
SF-107	OCTOBER 1975	PROCEDURE FOR ACCIDENT INVESTIGATION
SF-108	APRIL 1977	FACILITY AND OPERATIONS CHANGE REVIEW PROCEDURE
SF-109	APRIL 1977	HOT TAPPING PROCEDURE
SF-110	APRIL 1977	TRENCHING AND EXCAVATION PROCEDURE
SF-111		Radiation Procedures

22.5.1.2

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SECTION 6, C&P STANDARDS

Standard Number	Issue Date	Title
FP-4	JANUARY 1977	FIREWATER MONITORS
FP-L		Fire Grating for Trenches
FP-48	APRIL 1977	SIZING AND SPACING REQUIREMENTS FOR DIKES FOR FLAMMABLE AND HAZARDOUS LIQUIDS
FP-48A	APRIL 1977	LARGE STORAGE TANK - GENERAL LAYOUT
FP-48B	APRIL 1977	STORAGE TANKS (COMPATIBLE PRODUCTS) ACCESSORIES
FP-48C	APRIL 1977	STORAGE SPHERE - FIRE PROTECTION
FP-48D	APRIL 1977	HORIZONTAL PRESSURE TANK - FLAMMABLE STORAGE
FP-48E	APRIL 1977	SAFETY AND FIRE PROTECTION FOR LARGE TANKS
FP-58	MARCH 1978	FIRE PROTECTION FOR CABLE TRAYS
FP-70	FEBRUARY 1977	FIRE EXTINGUISHER RACKS
FP-72	MARCH 1978	INSIDE FIRE HOSE CABINET AND EQUIPMENT
FP-75	MAY 1976	PIKE HOSE TOOL
FP-201	SEPTEMBER 1974	SYMBOLS FOR FIRE PROTECTION LAYOUTS
FP-210	AUGUST 1975	CHEMICAL HAZARD-SIGNAL SYSTEM: CLASSIFICATION DEFINITIONS
FP-211	MARCH 1975	CHEMICAL HAZARD-SIGNAL SYSTEM: APPLICATION DATA
FP-211A	AUGUST 1975	CHEMICAL HAZARD-SIGNAL SYSTEM: ARRANGEMENT
FP-211B	MARCH 1975	CHEMICAL HAZARD-SIGNAL SYSTEM: APPLICATION EXAMPLES
FP-212	MARCH 1975	CHEMICAL HAZARD-SIGNAL SYSTEM: SIGNAL DIMENSION
SF-9		Breathing Air Stations
SF-11	OCTOBER 1974	SAFETY SHOWER AND EYE BATH INSTALLATIONS (FOR COLD CLIMATES)
SF-12	MARCH 1977	SAFETY SHOWER AND EYE BATH INSTALLATIONS (FOR WARM CLIMATES)
SF-13	MARCH 1978	EYE WASH FOUNTAIN
SF-17	MAY 1976	STANDARD FOR CHAIN WHEEL VALVE OPERATORS
SF-18	MARCH 1977	GUARD FOR SHAFT COUPLINGS

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0.3 MANUAL PUBLICATIONS

The Engineering Department sponsors manuals useful in conducting the functions of the Department, in training new or re-assigned personnel, and in documenting the technologies developed and applied by the Department.

A manuals steering committee is the policy-making body governing the development of technology manuals. The functional activity for each of these manuals is managed through the appropriate associate director. Technology manuals currently planned are listed in 0.3.1. The assigned technologist and, in some cases a principal author, is noted for each manual. This section also indicates which sections of each manual have been published at least in part, and, where possible, the sections not applicable to particular manuals.

A brief description of the scope of each manual is given in 0.3.2, and 0.3.3 describes the purpose of each section. This descriptive material is intended to aid a potential user to determine his needs since distribution of individual sections will be possible.

Included as sections 5 and 6 of the technology manuals are the specifications and standards prepared as part of the Chemicals and Plastics Engineering/Operations Standards Program. This joint publication effort grew from the recognition that standards for repetitive activities are the logical outgrowth of technology development.

Other current manuals published by the Engineering Department are listed in 0.3.5, and 0.3.6 lists a number of now outdated manuals to guide past users to replacement sources of information and to warn against use of outdated materials.

0.3.1 Technology considerations in twenty-seven areas of expertise have been identified as requiring presentation in engineering department publications. Those areas, the assigned manager for each manual, and the present status of each manual are shown in Table 0.3.1.1.

0.3.2 Scope of Technology Manuals

1. Bulk Solids Handling

The scope of this manual has not been developed, and no activity is presently scheduled.

2. Civil Engineering

Site development, property improvements, structures, foundations, walking-working surfaces, and related civil-engineering details for chemical plants.

3. Control Systems Applications

Designed to guide the control-systems design engineer in applying the latest proven technology to his project assignments. Sections may be used to offer guidance to contractors on drafting, specifications, documentation, standards, and methods.

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TABLE 0.3.1.1

Manual Number	Technology	Responsibility/ Principal Author	Sections								
			--.0 Function Description	--.1 Criteria	--.2 Design and Analysis Methods	--.3 Computer Programs	--.4 Drafting	--.5 Specifications	--.6 Standards	--.7 Field Inspection and Testing	--.8 Operation and Maintenance
1	Bulk Solids Handling	C. L. Higgins		INACTIVE							
2	Civil Engineering	C. K. Wood		x[3]	x	x	x	x	x		
3	Control Systems Applications	J. C. Nelson						x	x		
4	Measurement and Control Technology	J. C. Nelson									
5	Distribution	R. C. Buxton									
6	Electrical	J. W. Beard		x			x	x	x	x	
7	Environmental Protection	R. A. Payne									
8	Fluid Dynamics	L. L. Simpson									
9	General Facilities	J. M. Redington									
10	Heat Transfer	L. L. Simpson/ P. E. Minton									
11	Heating and Ventilating	Paul Barna									
12	Investment Estimating	W. F. Shawver			x						
13	Materials Engineering	L. S. VanDelinder	x	x	x	x	o	x	o	x	x
14	Mathematics - Applied	G. J. Farris									
15	Painting and Coating	F. P. Helms	x	x	x	o[4]	o	x	o	x	x
16 PIPING	.X.10.Y Pressure Piping	O. W. Moody/ E. N. Dotson		x			o	x	x		
	.X.20.Y Underground Piping	D. W. Moody/ L. A. Peggs	o	x	x			x	x	x	
	.X.30.Y Dimensions	D. W. Moody/ F. X. Schoen	o	o	o	o	o	o	x	o	o
	.X.40.Y Valve Manual	D. W. Moody/ F. X. Schoen	o	o	o	o	o	x	o	o	o
	.X.50.Y Pipe Support	D. W. Moody/ F. X. Schoen	o		x	o	o	x	x		o
	.X.60.Y Valve and Piping Material Specifications	D. W. Moody/ F. X. Schoen	o	o	o	o	o	x	o	o	o
	.X.70.Y Drafting	D. W. Moody/		o	o	o	x	o	o	o	o
17	Planning and Scheduling	J. F. Bell									
18	Plastics Processing	(Not Assigned)		INACTIVE							
19	Process Vessels	C. C. Neely			x	x		x	x	x	
20	Reaction Systems	R. R. Bannister									
21	Rotating Equipment	D. F. Neale	x[5]		x[5]						
22	Safety	D. T. Watters		x[6]	x[6]						
23	Separation Systems	W. J. Simmons									
24	Thermal Insulation	E. C. Powell		x				x	x		
25	Thermodynamics	D. R. Vredeveld									
26	Energy Systems	J. W. Beard									
27	Layout	J. M. Redington		x[7]				x[7]	x[7]		

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FOOTNOTES TO TABLE 0.3.1.1

1. The manual numbers were originally assigned according to alphabetical sequence of titles.

2. Cross-hatching in this column identifies a manual for which no published material presently exists. Contact the technologist concerning such manuals, for draft copy may be in preparation.

3. An "X" indicates a section for which some content has been formally issued although the section may not be complete. (See special-use explanations in 6 and 7.)

4. An "O" indicates a section for which no probable need is presently known.

5. Presently available portions, prepared to document prior facets of UCC&P compressor experience, do not yet match recommended technology manual style and format.

6. The Safety Engineering Manual was prepared during the same period as that during which the technology manual format was being developed, and therefore it does not conform to that format. The "X" 's indicate probable location of present content when the Safety Manual is reformatted as additional material is prepared.

7. The Chemical Plant Layout Manual is a long-existent compilation of material similar to criteria, specifications, and standards but which is not formatted in the manner of newer technology manuals. This manual is presently distributed only as a complete package.

0.3.2 Scope of Technology Manuals (Continued)

4. Measurement and Control Technology

Will be a technology resource manual describing the services available for technical assistance in process measurement and control. General analysis techniques used in process control simulation, process computers, process measurements, final control elements, and the design and application of special instruments are planned for inclusion.

5. Distribution Engineering

Will include methods available to determine the optimum combination of distribution facilities for a given distribution plan, considerations that should be evaluated during the determination of the required facilities, and an outline for a PBD Engineering Data Package. Also to be included will be guidelines for the installation of distribution facilities as well as references to standards developed specifically for these installations.

6. Electrical

The technology of electric-power transmission/distribution and utilization required for UCC&P plants. (Note: While electric-power transmission/distribution is an energy-systems process function, the technology is included in the Electrical rather than the Energy-Systems Technology Manual because of reasons stated in the scope for the Energy-Systems Technology Manual.) The scope of the technology covers methods and techniques, standards and criteria, and operating and maintenance practices and techniques for the design of safe, reliable, and efficient electric-power transmission/distribution and utilization systems.

7. Environmental Protection

Completed manual will contain guidance for EP Engineering. The emphasis has been placed on guidelines and procedures concerning environmental problems rather than presentation of design methods. The manual deals with atmospheric emissions, solid wastes, residues, thermal pollution, noise abatement, and wastewater treatment facilities in a petrochemical plant.

8. Fluid Dynamics

Will contain methods for pipe sizing and for the functional design and evaluation of entrainment separators, flash tanks, decanters, mixers, pumps, spargers, etc.

9. General Facilities

Will ultimately cover a broad spectrum of plant facilities serving more than one production unit. Items will include buildings, main pipe racks, roads, ditches, parking, site preparation, bulk-storage facilities, general fire-protection facilities, maintenance buildings and equipment, communications facilities, etc. Coverage will be generated in cooperation with any functionally responsible business or other group.

10. Heat Transfer

The process technology of heat transfer, application of different techniques, process considerations in the selection of mechanical details, and related matters. (Mechanical-design matters are covered in Manual 7.)

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0.3 MANUAL PUBLICATIONS (Continued)

0.3.2 Scope of Technology Manuals (Continued)

11. Heating, Ventilating, and Air Conditioning

Will cover requirements for laboratories, process control rooms, warehouses, maintenance shops, enclosed processing areas, etc. OSHA requirements, process and personnel safety, atmospheric effects, balancing, and similar parameters will be included.

12. Investment Estimating

Contains guides for estimating the cost of manufacturing and supporting facilities for chemicals & plastics production and distribution.

13. Materials Engineering

Properties and application of engineering materials as affected by exposure to either the process fluids or the industrial atmosphere of chemical plants. Corrosion of metals, cooling-water problems, cathodic protection, and materials used for storage and shipment of UCC&P products are typical subjects.

14. Applied Mathematics and Computing

Will contain conventions and procedures for utilizing available computing and applied mathematics resources; programming and documentation standards; abstracts for mathematical and utility subprograms; cross-reference list of program abstracts contained in other technology manuals; application notes on mathematical methods and subprograms.

15. Painting and Coating

Contains general and specific requirements for selection, application, materials, and testing of 1) paints and painting for atmospheric protection of structures and equipment and 2) of coatings for use internally in tanks, vessels, piping, and equipment. The manual consists of four parts; 1) the list of acceptable paints, 2) evaluation and quality control procedures for paints, 3) painting methods, and 4) coating materials and their application.

16. Piping

Contains general and specific requirements for selection, design, materials, fabrication, and testing of piping components and piping systems for chemical plants. The technology is presently subdivided into two basic parts; (1) above-grade pressure piping and (2) underground piping including gravity sewer and drain systems, and buried pressure piping systems. Separate volumes permit interest-based distribution.

17. Planning & Scheduling

To include the basic concepts of planning and scheduling of major capital projects and will cover the designing, procurement, construction, testing, and startup phases. Intended to serve as a training tool for analysts and project managers and as a reference for functional engineering groups.

18. Plastics Processing

Manual inactive, responsibility not assigned.

19. Process Vessels

Materials, mechanical design, fabrication, inspection, testing, and certification requirements for pressure vessels (including heat exchangers) and tanks subject to some part of the full range of chemical plant pressure, temperature, and media exposures.

20. Reaction Systems

Will catalog and describe reactors currently operating in Chemicals & Plastics plants. Tutorial development of reaction-engineering concepts relevant to Chemicals & Plastics processes. Compendium of analytical and design methods and computer programs.

21. Rotating Equipment

Contains guidelines, criteria, and techniques for selection, application, specification, quality assurance, and system design of rotating machinery for compression and power generation and recovery. Steam and gas turbine, gas expander, gear and electric motor drivers are included in the first phase. Other rotating machinery such as pumps, centrifuges, and extruders will be added.

22. Safety

Contains safety requirements and practices concerning the layout, design, and operation of chemical plants. Covers process-safety, personnel-safety, and fire-protection considerations.

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0.3 MANUAL PUBLICATIONS (Continued)

0.3.2 Scope of Technology Manuals (Continued)

23. Separation Systems

Will cover the technology for conceptual process design and equipment functional design of chemical engineering separations. The technology includes: equilibration processes, such as distillation, extraction, crystallization, and ion exchange; diffusion-rate-governed processes, such as gas permeation, dialysis, and reverse osmosis; and separation processes based on differences in density or size, such as centrifugation and filtration.

24. Thermal Insulation

Materials and application practices for the insulation of chemical-plant piping and process-equipment for heat conservation, fire protection, personnel safety, sound attenuation, etc. Engineering of steam-tracing systems is also included.

25. Thermodynamics

Theory and calculational methods for physical and thermodynamic properties, vapor-liquid equilibria, and high-pressure process behavior. Lists sources of process design data including the computerized DATA BANK, the Engineering Department files, and the literature. Abstracts standard thermodynamic and physical property programs and subroutines.

26. Energy Systems

The technology of energy systems processes - namely, steam generation and distribution, electric-power generation, water (all types), plant and instrument air, industrial gases, and waste and residue incineration - required for UCC&P plants. (Note: The technology of electric power transmission/distribution is covered in the Electrical Technology Manual since a part of that technology is common and requires coordination with in-process electric power utilization systems.) The scope of the technology covers methods and techniques, standards and criteria, and operating-and-maintenance practices and techniques for the design of safe, reliable, and efficient energy systems facilities.

27. Layout

Covers principals and philosophy of equipment layout in process units and those of units and service layout within plants. Applied concepts include safety, operating efficiency, maintainability, etc.

0.3.3 Scope of Technology Manual Sections

X.0 Function Description

This section is the introduction to the technology and will contain information such as:

a. Role of the Functional Group - Covered will be the type of work done, relationships with other functional groups, group organization, and physical facilities such as laboratories or pilot plants.

b. Contents of the Complete Manual - This table should be complete enough to guide infrequent users of the technology to other sections of the manual for further information.

c. Directory of Key Personnel - Offices addresses and phone numbers are necessary. Special expertise may also be listed.

X.1 Criteria

Section 1 is a what-to-do or strategy manual. The content will be those requirements to be imposed upon all designs or analyses whether done in-house or by outside contractors. Criteria applicable only to a specific project are to be prepared as part of the engineering of the project.

X.2 Design and Analysis Methods

This section should comprise the "heart" of most technology manuals. Its contents will be of a "how-to-do" it nature, whether the activity is design or analysis. Recommended calculation methods, design aids, and useful data may be included or the sources referenced. A bibliography of important literature references should be included.

X.3 Computer Programs

This section will include brief descriptions of programs used in the technology function. The description will be sufficient to convey understanding of the nature of the program operation and its application. Section 3 will identify the responsible technologist-custodian for each program described.

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0.3 MANUAL PUBLICATIONS (Continued)

0.3.3 Scope of Technology Manual Sections (Continued)

X.4 Drafting

A general subsection covers drawing coding, drawing-size requirements, drafting conventions, and similar material common to all technologies. A separate sub-section will include drafting requirements unique to the specific discipline.

X.5, X.6 Specifications and Standards

These sections contain specifications and standards prepared under the auspices of the Chemicals & Plastics Engineering/Operations Standards Program. Special specifications and standards and other non-mandatory documents may also be included.

X.7 Field-Inspection and Testing

This section, prepared as a joint effort between technology- and inspection-oriented personnel, provides criteria for the testing and examination of both components and systems.

X.8 Maintenance and Operation

This section will contain engineering department recommendations for specific maintenance and operation procedures for both systems and individual pieces of equipment.

0.3.4 Distribution of Manuals

The matrix form of table 0.3.3.1 represents the distribution potential for most manuals in that the various sections are intended to be separable for individual distribution. Thus only standards and specifications, Sections 6 and 5, need be requested by purchasing, maintenance, and other personnel not involved in design work, and inspection personnel can secure separate copies of Section 7. This versatility will allow one to secure only that information which he needs and to avoid maintaining unneeded sections.

Requests for full manuals or for sections other than 5 and 6 will be screened by the appropriate technology-manual manager. Standards and specifications assignments may also be requested through the Standards Office. Copies of standards and specifications for use in a contractor's office will only be issued to UCC project-management personnel who must maintain control of and repossess volumes at conclusion of a project.

0.3.5 Scope of Other Current Manuals

	Coordinator	Administrative Responsibility
Process Engineering Methods Manual	W. R. Manning	C. E. McConnell
Completed manual will contain guidance for the practice of process engineering. The six sections are to cover design philosophy, functional interfaces, preparation of engineering reports and records, design methods, equipment specifications, and reference material. Only the third and fifth sections were relatively complete in mid-1974. Much of the fourth section will be simplified material abstracted from the detailed information in technology manuals.		
Project Procedures Manual	J. H. Bell	J. H. Howell
Contains guidance for the project manager and the groups with which he must interface. Covers the procedures necessary to augment a project from the time of facilities definition, including project planning, project design criteria, design reports, safety, construction criteria, materials management, equipment design and acquisition, control systems, drawing distribution, control and reporting, project files and records, and preoperational checkout.		
Standard Specifications - Volume III - Non-Destructive Examination	B. H. Clark	M. J. Hughes
Presently contains specifications for the ultrasonic examination of process vessels, mechanical equipment, and structures.		

0.3.6 Obsolete Manuals

The following volumes are obsolete and have been cancelled as noted or will be recommended for cancellation as technology-manual coverage is completed. Distribution of some of these volumes has already been discontinued as stocks of binders and contents were depleted.

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.3 MANUAL PUBLICATIONS (Continued)

Obsolete Manuals (Continued)

	Present Information Source
Standard Specifications - Volume I - Constructional (Cancelled June 1974) Contained contract-oriented specifications related to site-development, architectural requirements, electrical work, fire-protection installations, equipment erection, etc. Updated technical content is being included in appropriate technology manuals. Previous holders were given a list of consultants to provide interim support.	C. R. Carder
Standard Specifications - Volume II - Unfired Pressure Vessels Contains standard specifications covering requirements for materials, mechanical design, fabrication, inspection, testing, and certification of pressure vessels (including heat exchangers) and tanks. Presently these specifications are located in both this volume and in Section 19.5.2.1 of the Process Vessel Technology Manual which will be surviving location. Cancellation of Standard Specifications, Volume II, will occur when the new manuals-distribution system is effected.	C. C. Neely/ J. H. Howell
Engineering Standards Each section is being transferred to the appropriate technology manual. Civil, electrical, and piping (exclusive of plumbing-fixture details) have already been relocated. Process vessels are presently contained in both the Engineering Standards Manual and the Process Vessel Technology Manual. Additional issuance of the manual is discouraged.	C. S. Hines
Cable Tray Systems Manual Contained information related to tray system for the support of electrical cables. Current manual no longer distributed but required content will be placed in the Electrical Technology Manual.	J. W. Beard
Electric-Heat Tracing Manual Contained design procedures for tracing systems used to maintain piping or vessels above some specified minimum temperature. Manual no longer distributed but current requirements will be placed in the Electric Technology Manual.	J. W. Beard
Design Manual (Process Engineering) (Replaced by Process Engineering Methods Manual) - Contained information of aid to the process engineer in the selection and specification of piping, equipment, and other plant components. Basic replacement will be the PEM manual while more detailed information on many subjects will be found in appropriate technology manuals.	W. R. Manning
Drafting Manuals; Mechanical, Electrical, Civil, Control (Cancelled August 1974) Contained drafting procedures, drawing-coding details, filing procedures, microfilming requirements, etc. These volumes were only subdivisions of an earlier single-volume drafting manual. Each subdivided volume contained a general section plus material pertinent to the titled discipline. Current general procedures now contained in Section X.4 of several technology manuals and, where necessary, are supported by the drafting requirements unique to the specific technology.	R. C. Ellis J. E. Dennie P. C. Vickers L. A. Bowen
Thermal Insulation Manual - Volume I - Specifications Cancelled. Replaced by Sections 5 and 6 of the Thermal Insulation Technology Manual.	E. C. Powell
Thermal Insulation Manual - Volume II - Design No longer distributed. Partially transferred to the Thermal Insulation Technology Manual and further transfer will be effected.	E. C. Powell
Coatings Manual (September 1963) (Cancelled September 1974) Was a compilation of coating and preparation-for-coating specifications from other volumes. Equivalent material has been updated and will be issued as Volume 4 (painting) of technology manual 15, Painting and Coating.	F. P. Helms
Paint Manual (Cancelled September 1974) Listed paints standard in 1970. Content has been updated and issued as Volume 1 (SUMP) of the Paints and Coatings Technology Manual.	F. P. Helms

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EQUIPMENT SPECIFICATION, PROCESS DESIGN COMPUTATIONS, AND PROCESS DESIGN DATA TRANSMITTAL

Description	Form No.	No. of Pages	Date	Responsibility
Absorber	(None Available)			G. K. S. Connolly
Adsorption System	(None Available)			D. S. Peterson
Aerator (Waste Water Treatment)	(None Available)			J. C. Boesch, Jr.
Agglomerator	(None Available)			S. H. Melton
Agitator,				
Mechanical	938-301	6	8/67	J. C. Boesch, Jr.
Notes for Form 938-301	-		8/67	J. C. Boesch, Jr.
Portable	938-303	4	8/67	J. C. Boesch, Jr.
Notes for Form 938-303	-		8/67	J. C. Boesch, Jr.
Air-Cooled Heat Exchanger	(See Heat Transfer Equipment)			
Air Dryer	(See Adsorption System)			
Air Flow Rate Table	938-346	1	6/65	O. J. Cox, Jr.
Alarms and Interlocks	(See Schedule of Alarms and Interlocks)			
Analyzer System Design Data	938-416	2	4/72	A. B. Morgan
Arrester, Flame	(See Flame Arrester)			
Autoclaves	(See Pressure Vessel)			
Bag House Filter	(See Dust Collector)			
Bag Packer	(See Packaging System)			
Baler	(None Available)			S. H. Melton
Bin	(None Available)			I. C. Phares
Bin, Activator/Discharger	(None Available)			S. H. Melton
Blender	(None Available)			S. H. Melton
Blower	(See Fan and Blower)			
Boiler, Waste Heat	(See Waste Heat Recovery System)			
• Breather Vent Valve,				
"BS&B"	938-337	1	3/75	O. J. Cox, Jr.
"Varec"	938-341	2	3/75	O. J. Cox, Jr.
Bubble-Cap Trays	(See Distillation Trays)			
Calandria	(See Heat Transfer Equipment)			
• Capacity Calculations for Varec Pressure and Vacuum Relief Valves	938-347	1	2/71	O. J. Cox, Jr.
Centrifuge	(None Available)			C. G. Moyers, Jr.
Clarifier	(None Available)			N. W. Gaines
Coalescer	(None Available)			L. L. Simpson/ J. C. Boesch, Jr.
Coatings	(See Painting Specifications)			
Coil, Removable Pipe Coils for Standard Size Tanks - Heating or Cooling	938-312	1	1/70	I. C. Phares
Column,				
Vessel Design	938-300	3	1/76	C. C. Neely
Instructions for Form 938-300	938-300A	9	1/76	C. C. Neely
Functional Design	(See Distillation Trays and Distillation System)			
Compressor,				
Jet	(See Jet Ejector)			
Mechanical	938-305	2	10/67	R. L. McCoy
Condenser	(See Heat Transfer Equipment)			
Construction Order,	(See Section 15.6, Project Procedures Manual)			
Page 1	938-393-1	1	11/69	E. D. Amick
Page 2 and up	938-393-2	1	11/69	E. D. Amick
Control System Engineering Data	938-415	3	11/74	A. B. Morgan

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Description	Form No.	No. of Pages	Date	Responsibility
Conveying System,				
Mechanical	(See Conveyor)			
Pneumatic	(None Available)			S. H. Melton
Conveyor,				
Belt	(None Available)			S. H. Melton
Gravity, Power Roller	(None Available)			S. H. Melton
"General Specifications for Conveyors Handling 55-Gallon Drums"	(Being Developed)			S. H. Melton
Screw	938-432	3	1/72	S. H. Melton
Vibrating	(See Feeder, Vibrating)			S. H. Melton
Cooling Coil	(See Coil)			
Cooling Tower	(None Available)			F. M. Rhodes
Crystallizer	(None Available)			C. G. Moyers, Jr.
Cyclone	(See Dust Collector)			
Deaerator	(None Available)			F. M. Rhodes
Decanter,				
Electrical Precipitator	(None Available)			C. G. Moyers, Jr./ J. C. Boesch, Jr.
Gravity	(None Available)			L. L. Simpson
Demineralizer	(See Ion Exchange System)			
Demister	(None Available)			L. L. Simpson
Densifier	(See Agglomerator)			
Design Report Change Notice	(See Informal Design Report Change Notice)			
Distillation System,				
Performance Survey (Data Form for Analyzing Performance of Existing Systems)	938-308	5	1/72	P. G. Nygren
Distillation Trays,				
Bubble Cap	(None Available)			G. K. S. Connolly
Sieve	(None Available)			G. K. S. Connolly
Tray Design	938-425	3	6/70	G. K. S. Connolly
Notes for Form 938-425			6/70	G. K. S. Connolly
Valve Trays	938-426	3	6/70	G. K. S. Connolly
Other Types	(None Available)			G. K. S. Connolly
Distributor, Gas or Liquid	(None Available)			L. L. Simpson
DOF, Change From (Refer to Section 15.6, Project Procedures Manual)	938-392	1	4/71	E. D. Amick
Drawing Status	(See Status of Drawings for Review)			
* Drive, Variable-Speed	(See Motor, Variable Speed and Speed Changer)			
Drum-Loading System	(None Available)			S. H. Melton
Dryer,				
Drum	(None Available)			C. G. Moyers, Jr./ S. H. Melton
Flash	(None Available)			C. G. Moyers, Jr./ S. H. Melton
Fluid Bed	(None Available)			C. G. Moyers, Jr.
Fluid (Liquid)	(See Adsorption System)			
Rotary Vacuum	(None Available)			C. G. Moyers, Jr./ S. H. Melton
Spray	(None Available)			C. G. Moyers, Jr./ S. H. Melton
Tray	(None Available)			C. G. Moyers, Jr.
Dust Collector	(None Available)			S. H. Melton
Eductor	(None Available)			J. C. Boesch, Jr.

* Drainer Schedule 938-587 D W Moody, Jr.

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Description	Form No.	No. of Pages	Date	Responsibility
Ejector,				
Gas Jet Compressor	(See Jet Ejector)			
Hogging Jet	(See Jet Ejector)			
Steam Jet	(See Jet Ejector)			
Electrical Precipitator	(See Decanter)			H. F. Bell
Electrostatic Precipitator	(None Available)			
Elevator,				S. H. Melton
Bucket	(None Available)			S. H. Melton
Screw	(None Available)			
Emergency Vent Unit,				
"BS&B"	(See Breather Vent Valve)			
"Varec"	938-342	1	3/75	O. J. Cox, Jr.
Energy Systems Engineering				
PBD & DOF Survey Sheet	938-389	2	5/74	F. M. Rhodes
Engineering Calculations, Process	(See Process Engineering Calculations)			
Entrainment Separator,				
Vane, Centrifugal, or Streamline Strut	938-327-1	2	10/66	C. C. Neely/L. L. Simpson
Small-Line Separator for Air, Gas, or Steam	938-327-2	1	1/61	C. C. Neely/L. L. Simpson
Equipment List	938-370	1	8/68	R. A. Kemmer
Equipment Log	(See Major Equipment Design and Procurement Log)			
Equipment Temperature Data	938-304	1	7/72	R. A. Kemmer
Evaporator	(See Heat Transfer Equipment)			
Exhaust Head	938-310	1	1/72	D. W. Moody, Jr.
Existing Equipment, Use of	938-309	2	1/72	R. A. Kemmer
Expander	(None Available)			R. L. McCoy
Expansion Joint	938-438	3	7/73	E. N. Dotson
Instructions for Form 938-438	938-438-A	6	7/73	E. N. Dotson
Extractor	(None Available)			B. Y. Hill
Fan and Blower, (See Also Compressor)				
Centrifugal	(None Available)			D. S. Peterson
Lobe	(None Available)			D. S. Peterson
Propeller	(None Available)			D. S. Peterson
Rotary	(None Available)			D. S. Peterson
Feeder,				
Belt	(See Conveyor, Belt)			
Rotary Air-Lock	(See Rotary Air-Lock)			
Screw	(See Conveyor, Screw)			
Vibrating	938-433	2	1/72	S. H. Melton
Filter, Process,	938-329	6	1/76	C. G. Moyers, Jr./C. C. Neely/ J. S. Peterson
Instructions for Form 938-329	938-329A	4	1/76	
Cartridge	(See Filter, Process,)			
Centrifugal	(See Centrifuge)			
Disk	(See Filter, Process,)			
Leaf	(See Filter, Process,)			
Plate & Frame	(See Filter, Process,)			
Rotary Vacuum	(See Filter, Process,)			
Tray	(See Filter, Process,)			
Fired Heater	(None Available)			A. C. Skinner/S. H. Melton
Flaker	(None Available)			C. G. Moyers, Jr./ S. H. Melton

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Description	Form No.	No. of Pages	Date	Responsibility
Flame Arrester	938-372	1	3/75	O. J. Cox, Jr.
Flare,				
Ground	(None Available)			A. C. Skinner/S. H. Melton
Tower	(None Available)			C. C. Tanona/S. H. Melton
Flexible Metal Hose Schedule	938-313	3	5/74	D. W. Moody, Jr.
Floation System	(None Available)			N. W. Gaines
Flocculation System	(None Available)			N. W. Gaines
Flow Diagram Notes	938-377	1	9/63	R. A. Kemmer
Furnace	(See Fired Heater)			
Gage Glass Assembly	938-388	2	4/72	A. B. Morgan
Gas Dryer	(See Adsorption System)			
Gaskets	(None Available)			C. P. Dillon
Gear Reducer	(See Speed Changer)			
Glass-Lined Pressure Vessel	(See Pressure Vessel)			
Grinder	(See Pulverizer)			
Heat Transfer Equipment	938-314	1	8/70	P. E. Minton
Notes for Form 938-314		8	8/70	P. E. Minton
Heaters - Process, Fired	(See Fired Heaters)			
Heating Coil	(See Coil)			
Hogging Jet Ejector	(See Jet Ejector)			
Homogenizer	(None Available)			J. C. Boesch, Jr.
Hopper	(See Bin)			
Hose, Metal	(See Flexible Metal Hose)			
Incinerator	(None Available)			A. C. Skinner/S. H. Melton
Indicating Thermometer Schedule	938-316	1	4/72	A. B. Morgan
Informal Design Report Change Notice	938-306	1	8/68	R. A. Kemmer
In-Line Mixer	(See Mixer)			
Instrument System Performance Data	(See Control System Engineering Data)			
Ion Exchange System	(None Available)			J. C. Boesch, Jr.
Item List	938-370	1	8/68	R. A. Kemmer
Jet Ejector,				
Air Operated	(None Available)			J. C. Boesch, Jr./ L. L. Simpson
Gas Jet Compressor	(None Available)			J. C. Boesch, Jr./ L. L. Simpson
Hogging	938-311-H	1	7/73	J. C. Boesch, Jr./ L. L. Simpson
Instructions for Form 938-311-H	938-311-N	2	5/71	J. C. Boesch, Jr./ L. L. Simpson
Liquid Operated or Pumping	(None Available)			J. C. Boesch, Jr./ L. L. Simpson
Process Vapor Operated	(None Available)			J. C. Boesch, Jr./ L. L. Simpson
Steam Jet Ejector	938-311	2	7/73	J. C. Boesch, Jr./ L. L. Simpson
Instructions for Form 938-311	938-311-N	2	5/71	J. C. Boesch, Jr./ L. L. Simpson
Jet Mixer	(See Mixer)			
Jet Scrubber	(See Scrubber)			
Lime Slaker	(None Available)			N. W. Gaines
Line List	938-353	1	3/72	R. A. Kemmer
(See Also Piping Design Summary)				
Line Size Sheet	938-378	1	7/64	L. L. Simpson
Lining, Vessel	(None Available)			C. P. Dillon
Liquid Dryer	(See Adsorption System)			

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Description	Form No.		No. of Pages	Date	Responsibility
Lubrication System	(None Available)				R. L. McCoy
Magnetic Separation	(None Available)				S. H. Melton
Mass Transfer Equipment	(None Available)				G. K. S. Connolly
(Refer to Distillation System and Distillation Trays)					
Major Equipment Design and Procurement Log	938-366		1	7/68	R. A. Kemmer
Mechanical Seal	(See Pumps)				J. A. Reynolds
Mixer,					
In-Line, Motionless	938-371		2	8/72	J. C. Boesch, Jr.
In-Line, Mechanical	938-302		4	8/67	J. C. Boesch, Jr.
Jet	(None Available)				J. C. Boesch, Jr.
Propeller	(See Agitator)				
Portable	(See Agitator)				
Turbine	(See Agitator)				
Mixing Nozzle	(See Mixer, Jet)				
Motor,					
Induction,					
Horizontal, or Vertical up to 460 volts	(See Electrical Standard, ELS-1)				J. W. Beard
Horizontal, 2.3 KV & 4.0 KV	(See Electrical Standard, ELS-4)				J. W. Beard
Vertical, 2.3 KV thru 4.0 KV	(See Electrical Standard, ELS-3)				J. W. Beard
Synchronous, 2.3 KV thru 13.2 KV	(See Electrical Standard, ELS-5)				J. W. Beard
Variable-Speed	(None Available)				J. W. Beard
Operations Improvement Proposal	938-386		1	5/71	C. S. Hines
Packaging System	(None Available)				S. H. Melton
Packing,	(None Available)				C. P. Dillon
Column/Tower	(None Available)				G. K. S. Connolly
Shaft	(None Available)				J. A. Reynolds
Painting Specifications,	(See Painting Manual)				
Pre-Erection Painting Selection Guide	PCM-503				
Pre-Erection Painting Specifications	PCM-200 Series				
Paint Material	PCM-100 Extract				
Palletizer	(None Available)				S. H. Melton
Piping Design Summary	938-307		1	1/72	R. A. Kemmer
Pressure Gage Schedule,					
Grade B - Accuracy 2%	938-321-A		2	4/72	A. B. Morgan
Grade AA - Accuracy 0.5%	938-321-B		1	4/72	A. B. Morgan
Pressure Vessel,					
Glass-Lined	938-399		5	1/76	C. C. Neely
Instructions for Form 938-399	938-399A		9	1/76	C. C. Neely
More Than 15 PSIG and Vacuum, Code	938-398		6	1/76	C. C. Neely
Instructions for Form 938-398	938-398A		9	1/76	C. C. Neely
Process Engineering Calculations,					
Horizontal	938-407		1	3/71	R. A. Kemmer
Vertical	938-406		1	3/71	R. A. Kemmer
Process Safety Review,					
Alarms	938-403-D		1	6/70	H. W. Wegert
Check List	938-375	For Safety	1	1/72	H. W. Wegert
Control Valves	938-403-C	Review Engineer	1	6/70	H. W. Wegert
Equipment Design	938-403-A		1	6/70	H. W. Wegert
Relief Devices	938-403-B		1	6/70	H. W. Wegert
Relief Device Sizing Record	938-401-A, B	For	2	2/71	H. W. Wegert
Vent Unit Sizing Record	938-401-C	Process Engineer	1	2/71	H. W. Wegert
Process Waste Load Summary	(Being Developed)				N. W. Gaines
Pulsation Dampener	(None Available)				T. E. Gallagher

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UNION CARBIDE

PROCESS ENGINEERING METHODS

CHEMICALS AND PLASTICS ENGINEERING DEPARTMENT

Description	Form No.	No. of Pages	Date	Responsibility
Pulverizer	(None Available)			S. H. Melton
Pump,				
Calculation Sheet,				
Centrifugal	93838-323-A	1	5/75	J. A. Reynolds
Positive Displacement	93838-323-B	1	5/75	J. A. Reynolds
Centrifugal	93838-322	1	2/75	J. A. Reynolds
Gear or Sliding Vane	93838-339	1	3/75	J. A. Reynolds
Jet	(See Jet Ejector)			
Metering (Reciprocating)	93838-318	1	2/73	J. A. Reynolds
Piston	93838-324	1	2/63	J. A. Reynolds
Vertical Turbine	93838-369	1	4/75	J. A. Reynolds
Viscosity Correction Worksheet,				
Centrifugal Pump	938-419	2	11/75	J. A. Reynolds
Reboiler	(See Heat Transfer Equipment)			
Refrigeration System	938-320	2	10/67	R. L. McCoy
Relief Capacity Calculations,				
1 - Liquid - 15 PSIG and Over	938-325-1	1	3/75	O. J. Cox, Jr.
2 - Vapor and Gases - 15 PSIG and Over	938-325-2	1	3/75	O. J. Cox, Jr.
3 - Liquid - Below 15 PSIG	938-325-3	1	3/75	O. J. Cox, Jr.
4 - Vapor and Gases - Below 15 PSIG	938-325-4	1	3/75	O. J. Cox, Jr.
5 - Abnormal Operation	938-325-5	1	3/75	O. J. Cox, Jr.
6 - Liquid or Vapor	938-325-6	1	3/75	O. J. Cox, Jr.
Relief Device Sizing Record	(See Process Safety Review)			
Relief Valves,				
Capacity Tables	938-373	4	12/70	O. J. Cox, Jr.
Pressure, "Varec"	938-344	1	3/75	O. J. Cox, Jr.
(Use Air Flow Rates, Form 938-346, and Capacity Calculations, Form 938-347)				
Pressure and Vacuum, "Varec"	938-343	1	3/75	O. J. Cox, Jr.
(Use Air Flow Rates, Form 938-346, and Capacity Calculations, Form 938-347)				
Special	938-348	(Later)		O. J. Cox, Jr.
Vacuum, "Varec"	938-345	1	3/75	O. J. Cox, Jr.
(Use Air Flow Rates, Form 938-346, and Capacity Calculations, Form 938-347)				
Rotary Air-lock	938-431	2	1/72	S. H. Melton
Rupture Disk	(See Safety Head)			
Safety Head,				
Capacity	(See Relief Valve, Capacity Tables)			
Conventional	938-326	3	3/75	O. J. Cox, Jr.
Graphite	938-326-B	1	3/75	O. J. Cox, Jr.
Reverse Buckling	938-326-A	3	3/75	O. J. Cox, Jr.
Safety Review	(See Process Safety Review)			
Safety Valve,				
Capacity	(See Relief Valve, Capacity Tables)			
Safety Valve Schedule	938-335	1	3/75	O. J. Cox, Jr.
Instructions for Form 938-335	-	4	3/75	O. J. Cox, Jr.
Schedule, Alarms and Interlocks	(None Available)			J. J. Walker
Screening System	(None Available)			S. H. Melton
Screw Conveyor	(See Conveyor)			
Scrubber,				
Jet	(None Available)			G. K. S. Connolly
Spray	(None Available)			G. K. S. Connolly
Others	(None Available)			G. K. S. Connolly
Venturi	(None Available)			G. K. S. Connolly

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Description	Form No.	No. of Pages	Date	Responsibility
Seal Oil Systems	(None Available)			J. A. Reynolds
Seals	(See Mechanical Seals)			
Separator, Entrainment	(See Entrainment Separator)			
Sieve Trays	(See Distillation Trays)			
Sifter	(See Screening Systems)			
Sight Glass	938-387	1	3/69	O. J. Cox, Jr.
Speed Changer	(None Available)			R. L. McCoy
Spray Nozzle	(None Available)			L. L. Simpson
Start-Up Screen	(See Strainer)			
Static Mixer	(See Mixer)			
Status of Design Information	938-367	1	-	R. A. Kemmer
Status of Drawings for Review	938-368	1	8/68	R. A. Kemmer
Steam Jet	(See Jet Ejector)			
Steam Trap Schedule	938-328	1	1/60	D. W. Moody, Jr.
Strainer,				
Line	(See PPF-8, Valve and Piping Specification Manual)			
Plant Water	(None Available)			F. M. Rhodes
Schedule, Special	938-330	1	Later	D. W. Moody, Jr.
Self-Cleaning (Edge-Type)	(None Available)			D. W. Moody, Jr.
Special	(Use Schedule, Special Strainer)			
Start-Up/Temporary,				
Conical	(See PPM-11A and PPM-11B, Piping Technology - Pressure Piping Manual)			
Flat	(None Available)			D. W. Moody, Jr.
Suction Line/Permanent	(None Available, Standard Being Developed)			D. W. Moody, Jr.
Stripper	(See Distillation Trays)			
Tank,				
Field-Erected, API	938-397	5	1/76	C. C. Neely
Instructions for Form 938-397	938-397A	11	1/76	C. C. Neely
Glass-Lined	(See Pressure Vessel)			
Low-Pressure, Standard	938-395	4	1/76	C. C. Neely
Instructions for Form 938-395	938-395A	7	1/76	C. C. Neely
Multi-Compartment, Non-Code	938-331	7	1/76	C. C. Neely
Instructions for Form 938-331	938-331A	6	1/76	C. C. Neely
Pressure-Code	(See Pressure Vessel)			
Thermometer Schedule	(See Indicating Thermometer Schedule)			
Transmittal Memorandum,				
Control Systems	(See Section 12, Project Procedures Manual)			
Definition of Facilities Report	(See Section 1, Project Procedures Manual)			
Drawings	(See Section 13, Project Procedures Manual)			
Major Equipment Specification and Purchase Requisition	938-376	2	2/73	R. B. Power
Mechanical Design Data Report	(See Section 5, Project Procedures Manual)			
Miscellaneous Activities	938-374	1	2/73	R. B. Power
Operations Design Data Report	(See Section 7, Project Procedures Manual)			
Tray Column	(See Column)			
Tray Design	(See Distillation Trays)			
Trays	(See Distillation Trays)			
Turbine, Steam and Gas	(None Available)			R. L. McCoy
Utilities Balance Data Sheet	(See Energy Systems Requirements Data Sheet)			
Vacuum Pump,				
Jet	(See Jet Ejector)			
Mechanical	(None Available)			D. S. Peterson
Vacuum Truck	(None Available)			N. W. Gaines
Valve Trays	(See Distillation Trays)			
Variable-Speed Drive	(See Motor, Variable-Speed and Speed Changer)			

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UNION CARBIDE

PROCESS ENGINEERING METHODS

CHEMICALS AND PLASTICS ENGINEERING DEPARTMENT

Description	Form No.	No. of Pages	Date	Responsibility
Vent Unit.				
Normal	(See Breather Vent Valve)			
Emergency	(See Emergency Vent Unit)			
Sizing Record	(See Process Safety Review)			
Venturi Scrubber	(See Scrubber)			
Vertical Sump Pump/Sump Dim.	93837-3228 4 C			SA Reynolds
Waste Heat Recovery System,				
Gas Turbine Exhaust	(None Available)			F. M. Rhodes/S. H. Melton
Process	(See Heat Transfer Equipment)			
Waste Treatment System	(None Available)			N. W. Gaines
Water Treatment System	(None Available)			F. M. Rhodes

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