PLAINTIFF'S EXHIBIT

UC-2312

INSULATION APPLICATOR TRAINING MANUAL

UNION CARBIDE CORPORATION
Chemicals and Plastics

UCC 002600

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INTRODUCTION

In the following chapters the theory of heat transfer is explained, the properties of materials will be discussed, the influence of requirements as affecting materials and their application will be presented. Complete understanding of these are essential to become a proficient insulator. However, additional knowledge and skills are also necessary.

The training program has for its purpose the systematic training of craftsmen through a formal program. In order to develop well-trained craftsmen, related instruction courses and work experience are programmed for each trainee.

One of the instruction courses presented is this course "Insulation Application." Two other courses are required to provide the theory and knowledge necessary for insulation applicator craftsmen. These are "Blueprint Reading and Sketching" and "Basic Mathematics."

Some of the items covered in a course of Blueprint Reading and Sketching are as follows:

I. Blueprint Reading

1. Meaning of standard drafting symbols
2. Types of lines
   (center lines, visible lines, invisible lines, dimension lines, extension lines)
3. Measuring and use of scale, i.e.
   1/4" = 1'0", 3/8" = 1'0" and 1/2" = 1'0"
4. Relation of plan and elevation views
5. Sections
6. Details
7. Reading and interpreting shop sketches

II. Drawing

1. Drawing to scale
2. Drawing plans, elevations, sections, details
3. Making field sketches

III. Interpretations of Drawings and Specifications

1. Read and interpret specification
2. Read and interpret fabrication manual
3. Make material take offs

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Under "Basic Mathematics"

I. Basic arithmetic

II. Conversion of fractions to decimals and reverse

III. Use of simple formulas

IV. Geometric Math

1. Angles, planes
2. Geometric figures
3. Calculation of areas, surfaces, etc.

In addition to the knowledge of these subjects, it is equally important to develop the skill of workmanship. This can only be accomplished by practice, doing a specific job or operation.

To illustrate this point, consider a tight wire acrobat. We all know that an acrobat maintains his balance by the skillful changing of his weight above the wire. In spite of this common knowledge few become skilled enough to accomplish this feat. Basically this is because few take the necessary time to practice to develop such a skill.

In similar manner, to become a skilled craftsman requires practice. To provide the practice needed by a trainee to become efficient in all phases of insulation application, the shop and field training program was developed. The shop and field training program attempts to provide sufficient time in each aspect of the craft so that the trainee has a broad knowledge and a skill for the entire craft. The shop and field training program attempts to provide each trainee with the opportunity to gain experience in all aspects of his trade. A summarization of what this includes follows:

Phases of Field Training of Insulation Craft

I. Use and Maintenance of Tools

A. Hand tools
B. Power tools
C. Riggings

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Phases of Field Training of Insulation Craft – Contd

II. Use of Insulation Specifications, Schedules, Bills of Material and Drawings

A. Thermal Insulation Specifications

1. General Specifications
2. Material Specifications
3. Individual Specifications

B. Bills of Material

1. Insulation
2. Securements
3. Accessories
4. Weather Barrier or Jackets

C. Insulation Schedules for Equipment and Pipe

1. Identification
2. Location
3. Specification
4. Thickness

III. Organization of Work

A. Tools required
B. Materials required
C. Procurement of tools and materials

1. Job Site
2. Storage
3. Point of installation

D. Work

1. Function
2. Time

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INTRODUCTION

Phases of Field Training of Insulation Craft - Contd

The previous is common to all of the insulators craft. However, over the past years some insulators have become shopmen whereas others became the field applicators. As there is considerable difference in the type of work performed, the training for each is different. As the shopmen fabricate the fittings and special shapes prior to its installation, this part of the insulation training program will be presented first.

Training of Insulation Shopmen

IV. Forming

1. Band saw operation
2. Grinding operation

V. Assembly

1. Low temperature service
2. Moderate and high temperature service
3. Traced service

VI. Finishes and jac kets

1. Spray finishing
2. Jacket forming and attachment

VII. Packaging and marketing

III. Safety practices

IX. Field application

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Phases of Field Training of Insulation Craft – Contd

Training of Insulation Applicators

X. Installation of insulation to high temperature surfaces

1. Rigid insulation

a. Cushion blanket (where required)

b. Cutting and fitting

c. Securement and supports

d. Expansion joints

e. Weather barrier

(1) Mastic

(2) Metal jacket

(3) Flashings

f. Coverings

2. Sprayed asbestos insulation

a. Securements and supports

b. Machine operation

c. Spray gun operation

d. Consolidation

e. Finish

f. Weather barrier

(1) Mastic

(2) Metal jacket

(3) Flashings

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INTRODUCTION

Phases of Field Training of Insulation Craft - Contd

Training of Insulation Applicators - Contd

3. Panel insulation (factor jacketed panels)
   a. Cutting and fitting
   b. Securement and support
   c. Joints (weather tight)
4. Heat traced installation
   a. Application of tracer
      (1) Air convection system
      (2) High conduction cement bonded
   b. Application of insulation
      (Same as listed under X-1)

XI. Installation of insulation to moderate temperature surfaces

1. Rigid insulation
   a. Cutting and fitting
   b. Securement
   c. Weather-barrier
      (1) Mastic
      (2) Jacket
2. Flexible insulation
   a. Cutting and fitting
   b. Securement
   c. Weather barrier or covering

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INTRODUCTION

Phases of Field Training of Insulation Craft - Contd

Training of Insulation Applicators - Contd

3. Sprayed urethane insulation
    a. Machine operation
    b. Spray operation
    c. Weather barrier
4. Heat traced installation
    a. Application of tracer
        (1) Air convection system
        (2) High conductive cement system
    b. Application of insulation
        (Same as XI-1)

XII. Installation of insulation to low temperature surfaces

1. Rigid insulation
    a. Cushion blanket
    b. Cutting and fitting
    c. Anti-abrasive coating
    d. Joint sealing
    e. Securement and supports
    f. Contraction joints
    g. Terminations
    h. Weather barriers

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INTRODUCTION

Phases of Field Training of Insulation Craft - Contd

Training of Insulation Applicators - Contd

2. Fill type insulation

   a. Double wall container

   b. Compacting

   c. Purging system

   d. Seal

XIII. Underground insulation

   1. Steel conduit, pre-insulated

   2. PVC conduit, pre-insulated

   3. Bituminous Fill

XIV. Building Insulation

   1. Walls, roofs and floors

   2. Air conditioning ducts

XV. Space Insulation

   1. Coolers and refrigerated spaces

   2. Constant temperature and humidity spaces

XVI. Shop fabrication of Insulation

In all work it is vital that each one learn to perform his work safely and be familiar with the hazards related both to his work and his environment. These safety considerations include:

I. General safety consideration related to construction

II. The safety considerations related to work in a chemical plant

III. Specific hazards related to the insulation craft.

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INTRODUCTION

By the use of this manual to provide information and the field experience to provide practice of skills, it is the sincere desire that the trainees become fine and safe workmen who take justifiable pride in their craft.

W. C. Turner
April 1970

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HISTORY OF THE INSULATION INDUSTRY

Thermal insulation was one of man's earliest inventions. He found that by covering himself with dried animal skins he could retard the heat loss from his body and could stay warmer in cold weather. Later he learned to weave cloth to enclose his body to obtain the comfort he desired. As time passed, the wearing of clothes became so accepted that the fundamental purpose -- as thermal insulation -- became of less significance. Further development by man of his invention of thermal insulation made this true.

At a very early age man discovered he could use fire to his advantage -- to cook food and to provide heat to make him more comfortable. He found that by putting rocks around a fire he could better control the fire and direct heat toward the food he was cooking. These simple rock enclosures he built around his fire were thermal insulation although, of course, he did not have them so named.

Later he found that by building a larger enclosure of sufficient size to house both him and the fire he would stay more comfortable than if the fire was just out in the open. This simple enclosure was the beginning of the building of better enclosures from which has evolved our present day buildings and homes. Again we tend to forget that these buildings are thermal insulation type enclosures by which we isolate ourselves from weather and maintain the temperature inside for our comfort.

As tends to be true of many old basic fundamentals, the importance begins to be lost with passing of time. The use of thermal insulation as clothes and as enclosures (houses, buildings) became universally used and accepted and further development stopped for many years. Not until the invention of the steam engine did the need for additional development of thermal insulation become apparent.

In the early days of the steam engine when temperatures and pressures were low, coal cheap and plentiful, any old thing was used to cover the pipes. In one steamboat installation, for instance, it was found very economical to use old carpet from the saloon, which at that very time was being replaced by a new Brussels rug; thus, the old one, when used for pipe covering, was so much salvage. This was in 1858. Other mixtures were clay and cattle hair or other binding material; fire clay, charcoal and sawdust, ground fine, mixed with water, and cattle hair for a binder. Hair felt was used extensively, and one of the favorite binders was cattails.

For boilers, plastic materials were used as early as 1865, but asbestos was not known in the business. One of the first installations of cement covering consisted of a layer of plaster of paris, covered with chicken wire, then a layer of fire clay held in place with chicken wire, the finishing being done with sand and plaster of paris.

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HISTORY OF THE INSULATION INDUSTRY

The indifference with which pipes were covered or left uncovered was traceable, of course, to the fact that the pressures were too low to prove troublesome, and also because little attention was paid to the conservation of heat or the saving of coal in those early days. In fact, it was considered more important to keep the heat out of the engine room than in the pipes. Appearance was also more important than either the conserving of coal or heat, if we are to believe the story told of the salesman who approached a quite noted engineer in New York and endeavored to sell him covering for the pipes of a fairly large job. "Why should we cover the pipes," said the engineer, they are very nicely painted."

As steam power began to make its importance felt in transportation and industry, it became necessary to control the heat loss from the pipe and equipment. A number of individuals recognized this problem and started to develop thermal insulation first for steam pipes and boilers then for the control of heat transfer in process industries, refrigeration industry, buildings and transportation. As would be expected, development started and continued for long periods in the various forms of insulation materials. To try to give a history of the entire industry based on time would be quite confusing. So this history is presented based on the development of a material or related class of materials.

ASBESTOS AND 80% MAGNESIA

The first insulation containing asbestos was used in 1866, in a material made by Robert F. Toope, and consisted of asbestos fiber and silicate of soda. Curiously enough this same insulation was also the first sectional insulation material to be made. Mr. Toope's place of business was on E. 79th Street, New York City, and he sold his patent rights in the United States to the Johns Company (now Johns-Manville).

The first asbestos cement for use on boilers was tried about 1870, and contained 15% of asbestos fiber. It was made by the Chalmers-Spence Company at the foot of E. 9th Street, New York City. Magnesia Sectional Covering appeared in 1885 while the first asbestos aircell covering was produced in Brooklyn in 1898.

The discovery of the heat insulating properties of magnesia carbonate is credited to Hiram N. Hanmore, who had been in the pipe covering business for many years in a minor way. He was troubled with what the doctors then called a sour stomach and was recommended to carry with him a little piece of carbonate of magnesia and eat a small piece of it when he felt that his stomach was out of order. One night while

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HISTORY OF THE INSULATION INDUSTRY

ASBESTOS AND 80% MAGNESIA - Contd

sitting in a barroom in the coal mining region of Pennsylvania where he had a big job on hand, he took the magnesia from his pocket and while toying with it suddenly realized its lightness, indicating to him that it might make a good non-conductor of heat. He walked over to the stove, which was very hot, and laid the piece of magnesia on the top. At the end of ten minutes he picked it up and finding it was practically cool, remarked, "This is going to revolutionize the pipe covering business." Some tell the story differently, but there is little doubt that Hanmore got the idea of its insulating qualities from the very light weight in proportion to the bulk of magnesia carbonate, and there is no doubt at all that his discovery did revolutionize the insulation business.

Hanmore found that the Keasbey and Mattison Company made carbonate of magnesia, and bought a quantity in order to experiment with it as a substitute for the plaster of paris he was using in his cement. His first patent covered a non-heat-conducting covering made of magnesia and shredded rope. He found it very hard work, however, to chop up the second hand ship's rope, and also a very slow process. At that time he did not use enough of it to warrant putting in a machine to chew up the rope. So he tried out silk noils and found that these gave the mixture more strength than the rope. (Noils -- waste silk produced in the production of spun silk.)

About this time someone told Dr. Mattison of the large orders for carbonate of magnesia coming from Mr. Hanmore. When one of Mr. Hanmore's workmen drove up to the Keasbey and Mattison Company's plant and asked for 1000 pounds of magnesia carbonate, the shipping clerk was astounded as the largest orders previously had been for a keg containing 30 pounds or sometimes a barrel of 60 pounds, but since the man had cash to pay for it, the men in the shipping department got busy and packed up as much as they had on hand which was about 500 pounds. Mr. Hanmore's man said he would call the next day for the balance. When he came back he said he needed five tons. The shipping clerk could hardly believe that he had heard correctly. "Do you know how much a ton of this stuff is?" he demanded. "Why you couldn't begin to get it in your wagon." The man said he did know and would make several trips to get the full amount, which he did, paying cash each time. The clerk finally asked him what in the world he was doing with the stuff, and was told that Mr. Hanmore had patented the idea of using carbonate of magnesia as a pipe covering and was at that time covering the pipes of Uncle Sam's Navy vessels which then lay in the Philadelphia Navy Yard.

This being a new idea it was promptly brought to the attention of Dr. Mattison with the final result that an arrangement was made with Mr. Hanmore for the manufacture of the covering.

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HISTORY OF THE INSULATION INDUSTRY

ASBESTOS AND 80% MAGNESIA - Contd

At that time the magnesia mixed with silk noils was simply put on the pipe in a plastic form but shortly afterwards Dr. Mattison took over the manufacture of the material, he formed the Magnesia Sectional Covering Company then molds were made for forming the mass into sections and blocks. Dr. Mattison, who had long been interested in asbestos as a mineral, suggested the use of the asbestos fiber instead of silk noils because the asbestos was fireproof, but it is not certain just when the change from silk noils to asbestos was made.

The present Johns-Manville Corporation traces its origin to 1858, when H. W. Johns, roofing manufacturer and founder of the asbestos industry, started out as a jobber and manufacturer in a small basement shop at 78 William Street, New York City, under the name of the H. W. Johns Manufacturing Company.

His first business was the production of a roofing made from rag felt and coal tar, together with paints and coatings for roofs and for preserving wood, metals and fabrics.

In 1868, the H. W. Johns Manufacturing Company first made known the results of long and continued research and experiment with asbestos fibers, and began the manufacture of numerous products composed wholly or in part of asbestos fibers, many of which came to be recognized as standard articles for mechanical, structural and electrical uses.

By 1886, there were four departments in the company, Paints, Roofing, Insulations, and Asbestos Fiberizing and Textiles.

While Mr. Johns was carrying on his experiments with asbestos, Charles B. Manville and his three sons were pioneering in other industrial fields and in 1886, they founded the Manville Covering Company in Milwaukee, Wisconsin. The early days of the Manville Company were largely occupied in determining the best materials for covering boilers and steam pipes. Mixtures of paper pulp and blue clay, common in the vicinity of Milwaukee, were tried successfully. Later, wool felt shoddy was used as a binder in the clay, instead of paper pulp, and failure from contraction and expansion of the metal surfaces as well as loss of temperature was considerably lessened. (Shoddy -- reclaimed wool.)

Since production methods in industry were rapidly changing, corresponding demand for higher temperature insulations resulted. This led to an arrangement by which the Manville Covering took over the H. W. Johns Manufacturing Company branch in Chicago, handling the rapidly developing asbestos products for high temperature insulations.

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HISTORY OF THE INSULATION INDUSTRY

ASBESTOS AND 80% MAGNESIA

Mr. Johns died in 1898, and three years later, in 1901, the Manville Covering Company of Milwaukee, in business since 1886, was merged with the H. W. Johns Manufacturing Company of New York, taking the firm name of H. W. Johns Manville Company. From the H. W. Johns-Manville Company the present Johns-Manville Corporation inherited the line of insulating cements, asbestos and asphalt roofings, asbestos paper, high and low temperature insulations and other specialities. When T. F. Manville, President, died in 1925, the company began a transition from limited to widespread public ownership, and in 1927, became known as Johns-Manville Corporation.

MINERAL WOOL

Mineral wool was first produced by nature during an eruption of the volcano of Kilauea, which native Hawaiian legend explained was the goddess, Pele, holding court. After the crater had cooled, natives would venture up the mountain and collect strands of wool-like substance which they reverenced as "Pele's Hair," thought to have been torn out by the goddess in a rage. Geological survey revealed this substance to be lava, blown into soft threads by the gigantic forces of the volcano.

Mineral wool from blast furnace slag is supposed to have been in commercial production in Wales in 1840, and in Germany as early as 1870. Here in the United States production started in 1897. As far as the United States is concerned, experimental work was carried on several years before this commercial production date.

A patent issued August 21, 1877, describes the fabrication of bonded products from bulk mineral wool using a bituminous binder. This patent might be considered the forerunner of current batt and felt production as we know it today. A patent issued August 7, 1883, describes a thermal insulating cement composed of mineral wool, clay to give binding action and the addition of animal hair.

Mineral wool insulation in block form was first described in a patent issued July 10, 1888. These blocks were made from mineral wool fiber that was dispersed in water and formed in a filter mold to remove the water, followed by a drying of the wet block.

Mr. Charles C. Hall, founder of the commercial rock wool industry, moved to Alexandria, Indiana, in 1895 from Belleville, Illinois, to become Superintendent of Construction of a small steel plant then being built in Alexandria. The steel plant was

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HISTORY OF THE INSULATION INDUSTRY

MINERAL WOOL - Contd

completed and ready for operation in the fall of 1896, but never operated because it was merged with other steel interests to form the original Republic Steel Company.

Mr. Hall was a graduate chemical engineer from Worcester Polytechnic in the class of 1882. He had access to the chemistry laboratory of the steel plant and while the steel merger was pending his duties as Superintendent were so light that he utilized his time in making chemical analyses. Among the many things he tested was the peculiar formation of argillaceous limestone which was quarried in large quantities in Alexandria and used as building foundation stone.

Mr. Hall's chemical analysis of this limestone showed that it had a low melting point and possessed a vary stable chemical composition before and after melting. He conceived of melting this rock in a furnace with heat supplied by gas, which was then abundant in Alexandria, and blowing the molten rock into rock wool by means of compressed air. He developed the process successfully then laid it aside. About six months after the merger of the steel interests, it was decided to move the steel plant from Alexandria. Mr. Hall did not care to leave Alexandria, so he turned to the job of making rock wool in commercial quantities.

In the spring of 1897, Mr. Hall borrowed $600 and built the original commercial rock wool plant. About $500 of the capital went toward building the furnace in which the rock had to be melted. The other $100 was spent erecting the make-shift building which housed the furnace. Early in November, 1897, the first run of commercial rock wool came out of the factory. Due to his limited working capital it was quite a struggle for Mr. Hall to keep the plant in operation, but by borrowing additional capital and selling out some interests in his company, managed to keep the plant on a profitable basis.

About the time he had the gas furnace operating effectively, the supply of natural gas at Alexandria gave out and he was faced with the problem of melting rock with a different type of fuel. Mr. Hall then developed the water-jacketed cupola using coke to obtain the necessary temperature. This is the method used in almost all rock wool manufacturing plants.

Since 1897, there were several corporations in which Mr. Hall was interested, that have manufactured rock wool at Alexandria. The last one, before Johns-Manville, was the Banner Rock Products Corporation organized in 1906. This corporation was acquired by Johns-Manville on February 1, 1929.

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HISTORY OF THE INSULATION INDUSTRY

MINERAL WOOL - Contd

About this time, it became known that slags from the refining of non-ferrous metal would result in a suitable product. The resulting mineral wools were dark in color in contrast to the whiteness of the rock wools of the lime, and also the whiteness of the wools made from iron blast furnace slag. The dark wools, however, had the advantage of providing a composition that was more refractory and showed greater chemical stability. Eagle-Picher, due to their past experience in the smelting of lead and zinc ores, looked to these waste materials as a source of income and started investigating the possibility of using their waste products to make mineral wool in 1927. Actual commercial Eagle-Picher production started in December of 1929, and by the end of 1930, had in production almost a full line of mineral wool products in the forms that they are known today.

CORK

The first mention of the use of cork as insulation appears to be by the elder Pliny in the first century of the Christian era, when he called attention to its use by women as winter footgear. Undoubtedly, it was utilized as sandals because of its insulating qualities and its freedom from capillarity. Pliny spoke of cork bark being used as a covering for roofs. John Evelyn, the English writer and diarist (1620-1706), mentions that cork was much used by old people for linings to the soles of their shoes. The poor of Spain laid planks of cork on the floor like tiles, to obviate the need for a floor covering that would be warm to the touch. They also lined the inside of their stone houses with cork bark, to make their homes easier to heat and to correct the precipitation of moisture on the walls. The primitive races of northern Africa used cork mixed with clay for the walls of their crude dwellings, and cork slabs as roof tiles.

About the year 1890, the German firm of Grunzweig and Hartmann acquired patents in Germany and in the United States for a type of insulation known as "impregnated corkboard," and soon became the leaders in their own country in the manufacture of these "impregnated" cork slabs for insulating purposes, particularly for cold storage work. The United States patent rights for this new type of insulation were subsequently acquired by the Armstrong Cork Company of Pittsburgh, about the year 1900, following which a plant for its manufacture was established at Beaver Falls, Pennsylvania. This location was selected principally because the necessary clay for the preparation of the foreign binder to stick the granules of cork together was available there in generous quantity and at a point not far from Pittsburgh.

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HISTORY OF THE INSULATION INDUSTRY

CORK - Contd

The business grew rapidly, especially among the brewers, for the insulation of their cellars; but it was soon discovered that this impregnated corkboard was inferior in insulating quality, and in structural strength in service to a brand of "pure" corkboard being made under the patents of one John T. Smith, an American, and subsequently the manufacture and use of the impregnated, or "composition", corkboard gave way entirely to the pure corkboard insulation. The manufacture of pure cork insulation was begun in 1893, in the United States, under the original John T. Smith patents by Messrs. Stone and Duryee. Cork covering was produced first, and then the manufacture of pure corkboard followed within a very few years.

It is interesting to know that the discovery of the process of baking cork particles under pressure to bind them together, which later made pure cork insulation possible, was purely an accident; the process was not thought of in connection with cork covering and corkboard until Messrs. Stone and Duryee later applied it to that purpose.

In the "Boat Works" of John T. Smith on lower South Street, on the East River, in New York, was a large cast-iron kettle with a fire box under it. The kettle was used to steam oak framing for row boats that Smith manufactured there for many years. He also produced boat fenders, life preservers and ring buoys, in the manner common in those days, by packing granulated cork in canvas jackets. Girls packed the cork in these jackets, using tin forms or cylinders to keep the canvas distended until filled. One of these cylinders became clogged in the hands of one of Smith's employees and was laid aside for the moment, but it inadvertently rolled into the dying embers of the fire box during clean-up late that evening. Early the next morning, Smith, owner and fireman, cleaned out the fire box and found his misplaced utensil. However, the hot ashes had not consumed the cork particles that had clogged it. The heat had been sufficient merely to bind the mass together in the form of a very substantial chocolate-brown cork cylinder.

Smith noted this peculiar fact with much interest, if not with actual astonishment, and put the tin form and cork cylinder aside for future secret study and an investigation. He repeated the original and wholly unintentional experiment enough times to satisfy himself that for some good reason a certain degree of heat applied for a length of time served to glue cork particles together without the addition of a foreign substance or binder of any kind or character, to produce what he later termed "Smith's Consolidated Cork." He thereupon applied for and was granted basic patents in the United States, Germany, France, and England, covering the broad principles involved.

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HISTORY OF THE INSULATION INDUSTRY

CORK - Contd

In 1893, Messrs, Stone and Duryee purchased the Smith patent rights for the United States, France, and England, and began the manufacture, at No. 184 North Eighth Street, Brooklyn, New York, of asbestos-lined cork covering for steam pipes. This suggestion probably came to Junius H. Stone, who had previously been engaged in the steam pipe covering business, from the original Smith cork cylinder, which, incidentally, Smith had failed to utilize to any good purpose whatever. Not long thereafter the patent rights on "85%magnesia" steam pipe covering expired, and the resultant competition so reduced prices as to seriously interfere with the further sale of the cork product.

Then the Engineering Department of the United States Navy became interested in molded cork covering for cold pipes, to replace hair felt and such other fibrous materials as possessed a marked affinity for moisture. It was subsequently tried out as an insulation for brine lines on one of the large battleships being built. From here the material rapidly found favor in other governmental departments. Thus the real field of usefulness of Smith's Consolidated Cork -- as an insulating material for cold surfaces -- was discovered. Soon thereafter, the firm of Stone and Duryee began the manufacture of the very first pure corkboard that was ever produced, sold, or used.

Mr. Harvey H. Duryee, of the firm Stone and Duryee, was of French Hugenot descent, and it please him to designate the products of his firm "Nonpareil," from the French words "non pareil," meaning no parallel, or no equal. The firm of Stone and Duryee subsequently became the Nonpareil Cork Works, and with the construction of a factory at Camden, New Jersy, it became the Nonpareil Cork Manufacturing Company.

In June, 1904, the Armstrong Cork Company purchased the patents, plant and business of the Nonpareil Cork Manufacturing Company. By the time the patents expired, both pure corkboard insulation and cork pipe covering were known wherever the use of refrigeration had been scientifically introduced.

DIATOMACEOUS SILICA

For high temperature service, an insulating material to be of value must not only have a low conductivity, but also a high degree of refractoriness, a quality not ordinarily found in insulating materials. Less than forty-five years ago, there was no material available that possessed sufficient refractoriness to be of use in the high temperature ranges.

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HISTORY OF THE INSULATION INDUSTRY

DIATOMACEOUS SILICA - Contd

At that time, with no suitable insulation available, the loss of valuable heat used in certain processes in manufacturing steel and metal products, glass, portland cement and lime, brick, tile and pottery was tremendous. Attempts were made to curtail this loss by building furnace walls of brick several feet thick. This method was unsatisfactory because construction costs were exceedingly high, and such walls soaked up heat like a sponge, thus robbing the furnace of heat.

In 1912, a new insulation was put on the market by the Celite Company. Composed of diatomaceous silica, it made available an insulation suitable for use at high temperatures. Diatomaceous silica is silica shells or skeletons of "diatoms" -- microscopic plants which lived in the rolling waters that swept over what is now California millions of years ago. Upon its death this minute organism sank to the ocean floor, leaving as its only trace a silica shell built up during its life. Countless billions of other diatoms lived and died in these same waters and their tiny skeletons piled up in layer after layer, during some thirty thousand years, to form huge deposits of almost pure silica more than 1400 feet in thickness.

Brick cut from these deposits contains myriads of tiny voids formed by these minute diatom skeletons. These voids represent as much as 85%of the volume of the brick. Thus loss of heat by conduction is reduced because of the small proportion of solid material present. In the manufacture of insulating brick for use at higher temperatures, this material is ground, pugged, pressed and fired in kilns. Calcined ground grades are used as an insulating conrete aggregate and as insulating fills.

Diatomaceous silica can only be prepared in brick or powder form; therefore, in order to extend its range of usefulness it is necessary to combine it with other materials such as asbestos.

STRUCTURAL INSULATING BOARD

The first structural insulating board was manufactured in 1914, at International Falls, Minnesota, by the Minnesota and Ontario Paper Company. The product called insulite was made from ground wood and sulphite screenings. About the same time, in Penetaguishene, Ontario, a product called Ten-Test was made from coarse brown pulp and is now being produced by International Fiberboard Limited at Gatineau, Quebec. In 1915, the production of structural insulating board was approximately 2,750,000 square feet on a $\frac{1}{2}$ inch thickness basis.

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HISTORY OF THE INSULATION INDUSTRY

STRUCTURAL INSULATING BOARD - Contd

In 1920, the Celotex Corporation at Marrero, Louisiana, started producing structural insulating board from sugar cane fiber called bagasse. The industry grew rapidly thereafter, and in 1955, there were 16 companies with 20 plants in the United States and 4 companies with 4 plants in Canada producing 3,280,000 square feet on a ½ inch thickness basis.

In the early days, structural insulating board was primarily one product being cut to size for various uses. It was first used to form partitions in buildings and in 1916, was used extensively in railroad refrigerator cars. During the First World War, the Army used large quantities to build barracks. In 1918, it was fabricated into insulating lath used in home building. By 1920, insulating board was being used extensively in home building and remodeling. In 1927, the automobile industry began to use it as a means of quieting automobile bodies. The following year it was used as an insulation in mechanical refrigerators. Also in that year it was used in the building of Hollywood sound stages with the development of sound movies.

In 1929, it was used by Admiral Byrd on his Antarctic expedition as part of portable housing. In 1930, the aviation industry used it for sound deadening as did a large railroad in 1934.

Roof insulation was developed as a special product in 1928, and the first ceiling tile was fabricated in the late 20's. In the late 30's, plank, thin board, and sheathing were special ly fabricated. In 1948, the board was fabricated into insulating roof deck slab used in post-and-beam construction. In 1950, shingle backer was developed which is used for undercoursing, wood shake or asbestos cement shingles.

METAL TYPE REFLECTIVE INSULATION

About the year 1800, history tells us that Count Benjamin Thompson Rumford, in England, conducted experiments in calorimeters which were polished metal containers to reduce the heat transfer to the surroundings. Likewise, James Prescott Joule, also in England, used polished metal calorimeters for his experiments. From this information, it is evident that these physicists recognized the effectiveness of a bright metallic surface as a barrier to heat transfer.

In 1878, Jean Claude Peclet, in France, recognized the excellent insulating value of multiple sheets of tin separated by air spaces, and publicized it in his book, "Traite' de la Chaleur."

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HISTORY OF THE INSULATION INDUSTRY

METAL TYPE REFLECTIVE INSULATION - Contd

However, credit for the first invention of reflective insulation having commercial significance must go to Sir James Dewar. In 1885, he conceived the "Dewar Flask," which is now known as the "Thermos" Bottle. Millions of "Thermos" Bottles are in daily use in the United States today. This invention employs two parallel heat reflective surfaces with a vacuum, i.e., a non-conductive space -- between them.

Forty years later, in 1925, Ernst Schmidt and Eduard Dyckerhoff discovered that a number of crumpled tissue-thick aluminum foils separated by air spaces would insulate effectively -- without a vacuum. Furthermore, aluminum was now cheap enough to use for such a purpose. Hence, from this time on, substantial quantities of insulating materials of this type were manufactured and sold in Europe and the United States, principally for insulating houses and buildings. Such a product having substantial commercial use in this country was sold under the trade name "Alfol."

In the second "World War," around 1940, the Germans used layers of tissue-thick aluminum foil insulation on steam lines of the pocket battleship "Deutchland." The U. S. Navy subsequently obtained a piece of this insulation which had been in service for approximately 6 months. This piece was place on exhibit at the U.S. Naval Esperiment Station, Annapolis, Maryland. It had apparently served its purpose as effective insulation, when new. Yet, in its short service life, the foil had become badly corroded away by the sea air, with holes big enough to put a man's hand clear through the insulation. Obviously , its value as insulation had been reduced.

In the United States, during the "forties" a number of cold storage plants were built in which the walls were insulated by a field-fabricated assembly of aluminum sheets separated by wooden spacer strips. This construction was sold under the trade name "Alumiseal."

However, the first significant reflective insulation for power and industrial plants was invented in 1949. In that year, George E. Gronemeyer, a U.S. Consulting Engineer, applied for patents on a new conept of reflective insulation for hot or cold service. This invention employed multiple sheets of reflective metal, such as aluminum separated by confined air spaces, supported by non-metal low-heat-conductor material, and prefabricated into rigid insulation units. This product was manufactured and sold to industry from 1949-1953. However, it was found to be limited in application and temperature range due to the non-metal spacer material. Union Carbide Corporation was the first large industrial concern to use this insulation.

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HISTORY OF THE INSULATION INDUSTRY

METAL TYPE REFLECTIVE INSULATION - Contd

Then, in 1955, George E. Gronemeyer made a major break-through in reflective insulation. He, at that time, placed on the market a more advanced concept of reflective insulation, suitable for heavy duty use in power and industrial plants. This invention employed multiple sheets of reflective metal separated by confined air spaces, supported by metal high-heat-conductor material, and prefabricated into rigid insulation units. Heat loss through the metallic supports was limited by an ingenious construction to the point that the all-metal insulation was more effective than conventional "mass-type" insulation. This sturdy structure overcame the limitations of his earlier invention.

This product is patented, and is sold under the trade name "MIRROR(R) Insulation." It is factory prefabricated into units, or assemblies of units, to fit nuclear reactors, large and small vessels, pipes, ells, tees, valves, etc. However, this insulation is not sold as insulating material but as a system, engineered to fit the piping and equipment involved, with due allowance for expansion and contraction.

This insulation has been and is being installed in most of the large nuclear power plants in the United States and abroad. It is in current usage at temperatures up to 1400°F and is available for higher temperatures. Industrially, again, Union Carbide Corporation has led the way by making extensive use of this development in its plants.

MIRROR has a unique combination of product characteristics which is not available in mass-type insulations. Being of all-metal construction, it is highly fire-resistant, clean, dustless, non-absorbent, chemically neutral, mechanically strong, durable, and maintenance-free. Furthermore, all insulation units are removable and reusable.

This insulation has filled the need for dependable performance in continuous power and process service, year after year. Thus, it has achieved a leading position in the market for thermal insulation in the United States, and is presently expanding into foreign markets.

EXPANDED SILICA INSULATION

The Philip Carey Corporation started in the manufacture of 80% magnesia molded pipe insulation in 1906. In the early 1950's, Carey, in conjunction with the Mellon Institute, developed a formula to produce expanded silica (Perlite) as a base material for rigid high temperature pipe and block insulation. This material was introduced on

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HISTORY OF THE INSULATION INDUSTRY

EXPANDED SILICA INSULATION - Contd

the market under the tradename "Alltemp" in 1954. Improvements were made to the original product, the major improvement being that the material was made water repellent. This new product was named "Careytemp" and was put into production in 1958.

Perlite in loose form has become an extremely useful insulation, as a poured-in-place insulation. It can be used as a high temperature insulation up to service temperatures of 1400F, and it can also be used for low temperature service when installed in vapor-tight container.

CELLULAR GLASS

Basic cellular glass patents date from 1934-1938 by St. Gabain in France. Pittsburgh Plate Glass and Pittsburgh Corning Corporation research in cellular glass started in 1937.

After material had been developed successfully in the laboratory, the question arose as to what to do with it. Market research revealed a need for a material of this type for use in curtain wall construction, refrigerating equipment, railroad and refrigerator cars, insulated truck bodies, marine field, and the cold storage field.

A pilot plant for cellular glass was started in June 1941, using glass cullet from the glass block tank and lampblack. Actual manufacturing at Port Allegany, Pennsylvania, commenced June 29, 1942, using the same batch as the pilot plant used. In June 1943, batch cullet glass from Corning's Wellsboro Plant was used with lampblack until November 1943, then carbon black was used.

During the latter part of 1947, a special field survey was made of some of the FOAMGLAS (R) installations subjected to severe conditions, e.g., pulp mills, tobacco curing rooms, and dry kilns. As a result of this survey, the basic composition of the batch glass was altered from regular soda-lime batch to a modified boro-silicate type to obtain better durability. This change occurred in January 1948, and is still the type batch used today. Modern FOAMGLAS (R) is 8 to 10 times as durable as the original.

The big improvement in thermal conductivity values of FOAMGLAS(R) took place by the first of 1951, at which time the density was changed from an average of about 10 pounds per cubic foot to around 9 pounds. This, coupled with a stabilization of the

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HISTORY OF THE INSULATION INDUSTRY

CELLULAR GLASS - Contd

cell gases, brought the actual thermal conductivity value of FOAMGLAS(R) from about .42 to .38 at a mean temperature of 50°C. Further research and refinements have brought the conductivity value of today's material down to .35 at a mean of 50°F.

POLYSTYRENE INSULATION

STYROFOAM(R), polystyrene expanded by the Dow Chemical Company, was first produced in research laboratories in Midland, Michigan, in the early 1940's. Basically this material is comprised of a system of non-interconnected cells providing numerous, minute air spaces. The extremely light weight of cellular polystyrene plus its sealed cell system immediately suggested it as a buoyance agent. Since at that time World War II was imminent, the material was brought to the attention of the Armed Forces with its suggested use in mind. It proved of value to various branches of the Armed Services and it became necessary, because of this interest, to build production facilities. Paralleling the supply of material for the Armed Services, work toward improving the product and evaluating any other potential markets was being done at Dow.

Research into the insulating ability of this material was conducted. This research resulted in a definite program of improvement looking to the day when the war would end. It was therefore in 1946, that the first commercial application of expanded polystyrene as low temperature insulation was made. Starting in 1946, the markets for STYROFOAM(R) grew rapidly. The florist found the material much more pleasant to handle than wet moss on frames, and STYROFOAM(R) began to be accepted for a basic floral material. Various fabricators for STYROFOAM(R) came into existence and developed a market in the novelty and display fields. The buoyancy market was continued by small boat manufacturers and by the Armed Services, particularly the Navy. The growth in its use as low temperature and comfort insulation was steady into practically all fields requiring this type of insulation.

RIGID POLYURETHANE INSULATION

In 1940, Schlack reacted polyesters with diisocyanates leading to chain extension and increase in viscosity. This led Farenbabriken Bayer into an active research program to develop rigid foams, adhesives and coatings based on this principle. In 1945-1947,

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HISTORY OF THE INSULATION INDUSTRY

RIGID POLYURETHANE INSULATION - Contd

scientific teams studying German developments issued a number of reports describing the uses of polyurethanes. Using chemicals produced by DuPont and Monsanto, Goodyear Aircraft Co. and Lockheed Aircraft Co. developed techniques for rigid polyurethane foam in 1946-1947.

Since that time others, such as Union Carbide, Dow, Upjohn, and Hooker, have entered the field as producers of raw materials. Rigid urethane insulation is produced and sold nationally by Pittsburgh-Corning, Dow, National Gypsum and Unarco, and by numerous other formulators in smaller market areas. The major market for rigid polyurethane foam insulation is for insulating refrigerated railroad cars and truck trailers, and household refrigerators. Inudstrial uses, especially the spray application of the material to moderate temperature vessels, have developed since 1965.

GLASS FIBER INSULATION

In 1931, working independently, the Owens-Illinois Glass Co. and Corning Glass Works began research programs investigating the commercial possibilities of glass in fibrous form. These separate efforts were joined together when these two companies formed the Owens-Corning Fiberglass Corporation in 1938. The first commercial products of this new company were building insulation and furnace filters. In 1939, development of binders and application processes made possible the manufacture of rigid and semi-rigid insulation boards.

Development of superfine light-weight glass fiber in 1949, opened up the use of glass fiber for thermal and acoustical insulation for aircraft and automobiles. In the early 1950's, other companies entered the glass fiber business. These were Johns-Manville, Pittsburgh Plate Glass, Gustin Bacon Manufacturing Co., Ferro Co., and Reichold Chemicals, Inc. Today glass fiber insulation is available in many shapes, densities, and properties to fulfill any individual installation requirements.

CRYOGENIC INSULATION

The thermal performance of cryogenic insulations previously developed and currently in use covers four orders of magnitude, depending upon the performance requirements as a function of cost for a given application.

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HISTORY OF THE INSULATION INDUSTRY

CRYOGENIC INSULATION - Contd

Cryogenic insulations can be roughly divided into two types: gas filled and vaccuum. There are any number of gas filled insulations, including many types of fibers, mineral wool and powders. The most common are Perlite and Vermiculite powders. The use of gas filled insulation dates back to the infacy of the air separation business, but it is still important in many applications such as large storage reservoirs and liquefiers where the large volume does not justify the costs of the more expensive vacuum insulations and where the value of the products stored is low.

Vacuum insulations date back to the original James Dewar work of the late Nineteenth Century. The original Dewar consisted of concentric glass jars with the annular space evacuated. Later, in order to cut down on the heat transport by radiation, these two surfaces were silvered, resulting in the common thermos bottle. Linde work in the 1940 s resulted in a practical means of interjecting a multiplicity of separate radiation shields or additional polished surfaces within this vacuum space, resulting in further improved performance.

While James Dewar and a number of other investigators did do some work with evacuated powder insulations, it was not until the late 1930's and early 1940's that the concept of the evacuated powder insulation was applied to large scale cryogenic fluid storage containers by Dana. This concept is still widely employed, particularly with Perlite powder in large cryogenic tankage. It will be seen that improvement of two orders of magnitude is achieved over non-vacuum insulations (which have the thermal conductivity of the gas involved).

In the early 1950's, development work was conducted in order to achieve another improvement in cryogenic insulations. In these powders, because of their small dimensions, gaseous conduction is essentially negligible and with the heavier powders, such as Perlite, solid conduction contributes about 70% of the heat transport. Thus, it was decided to use powders with lower solid conductivity, but essentially transparent, and to include copper flakes as an opacifying agent. Silica aerojel was chosen for the powder and the resultant formulation consisting of equal parts by weight of copper flakes and silica aerojel powder was designated Linde insulation CS-5, possessing an exceptionally low thermal conductivity. This made possible for the first time the economical distribution of low temperature fluids in small quantities.

Early in the powder development program, it became apparent that an even better insulating material would be necessary for the economical storage and distribution of the lower temperature cryogens, hydrogen and helium. Initially, for this application, the concept of radiation shields and fibrous paper spacers was investigated, resulting in the Linde Super Insulation concept which became the cryogenic insulation of the 1960's.

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HISTORY OF THE INSULATION INDUSTRY

CRYOGENIC INSULATION - Contd

Many variations of the materials have been employed, depending upon the application, including aluminum foil and aluminized plastic radiation shields combined with fiber glass and rayon fiber papers and mats to achieve varying degrees of performance and cost. More recently, the concept has been extended to extreme high temperature insulation systems by the use of copper, nickel and tantalum shields with quartz spacers. Currently, development work is under way for insulations up to 2000F.

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FUNCTION

HEAT TRANSFER

Heat

To understand the function of thermal insulation in controlling the transfer of heat, it is necessary to have an understanding of heat. Everyone knows what heat is, but to properly define it in words is not easy.

To start, heat is a form of energy. What is energy? According to Webster's Seventh New Collegiate Dictionary, the definition of energy is:

> Energy 1: Vitality of expression; 2; the capacity for action; 3: power forcefully exerted; 4: the capacity for doing work.

Energy, as restricted to the field of science, is the capability of, or the causing of a moving force or work. Science further defines various forms of energy. These are:

a. Mechanical Potential Energy is energy stored by virtue of the relative distance of a body above a horizontal reference plane.

b. Mechanical Kinetic Energy is energy stored by the relative motion between parts of a system.

c. Internal Energy is energy stored within a body, such as a quantity of gas, liquid or solid, by relative motion of, and forces between the molecules or atoms composing the body.

d. Work is a transient form of mechanical energy. Transformation of other forms of energy are brought about through the agency of force acting through distance (or work).

The above is the definition of heat. As originally stated, it is one form of energy. It should be noted that it, and the other forms of energy, do conform to the dictionary defintion of energy. Definitions a, b, and c, relate to energy stored and d relates to energy being transferred or in transformation. This is in agreement with the dictionary definition of "the capacity for or doing."

Energy can be measured. However, there are a number of units of measure, each of which is for the convenience of measuring a particular form of energy. The unit commonly used to measure heat energy it the British Thermal Unit. The definition of measurement of heat in terms of BTU's is as follows:

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FUNCTION

HEAT TRANSFER - Contd

Heat - Contd

British thermal unit (Btu) was defined in the early days of science as the quantity of energy (heat) required to raise the temperature of 1 pound of water 1°F, from and at 32°F. As the boundaries of knowledge expanded, the definition was changed to 1/180 of the quantity of energy (heat) required to change 1 pound of water from the ice point to the steam point at standard atmospheric pressure. The difficulty of setting up standards for such a definition, taking into account the now known variations of specific heat with both pressure and temperature, was so great that no standard was ever generally accepted. To relate the measurement of heat with other energies and to arrive at an acceptable standard for a Btu, the International Steam Table Conference in 1926 recommended that that the International Calorie be set at 1/860 of an International Watt-hour. By calculation, this established the Btu as 778.26 ft-lb.

Other units used to measure energy are calorie, horsepower-hour, foot-lb, and kilowatt-hour. Each of these have a fixed relation with the other.

1 Btu = 252 calories

1 Btu = 0.000379 horsepower-hour

1 Btu = 778 foot-lb

1 Btu = 0.000298 kilowatt-hour

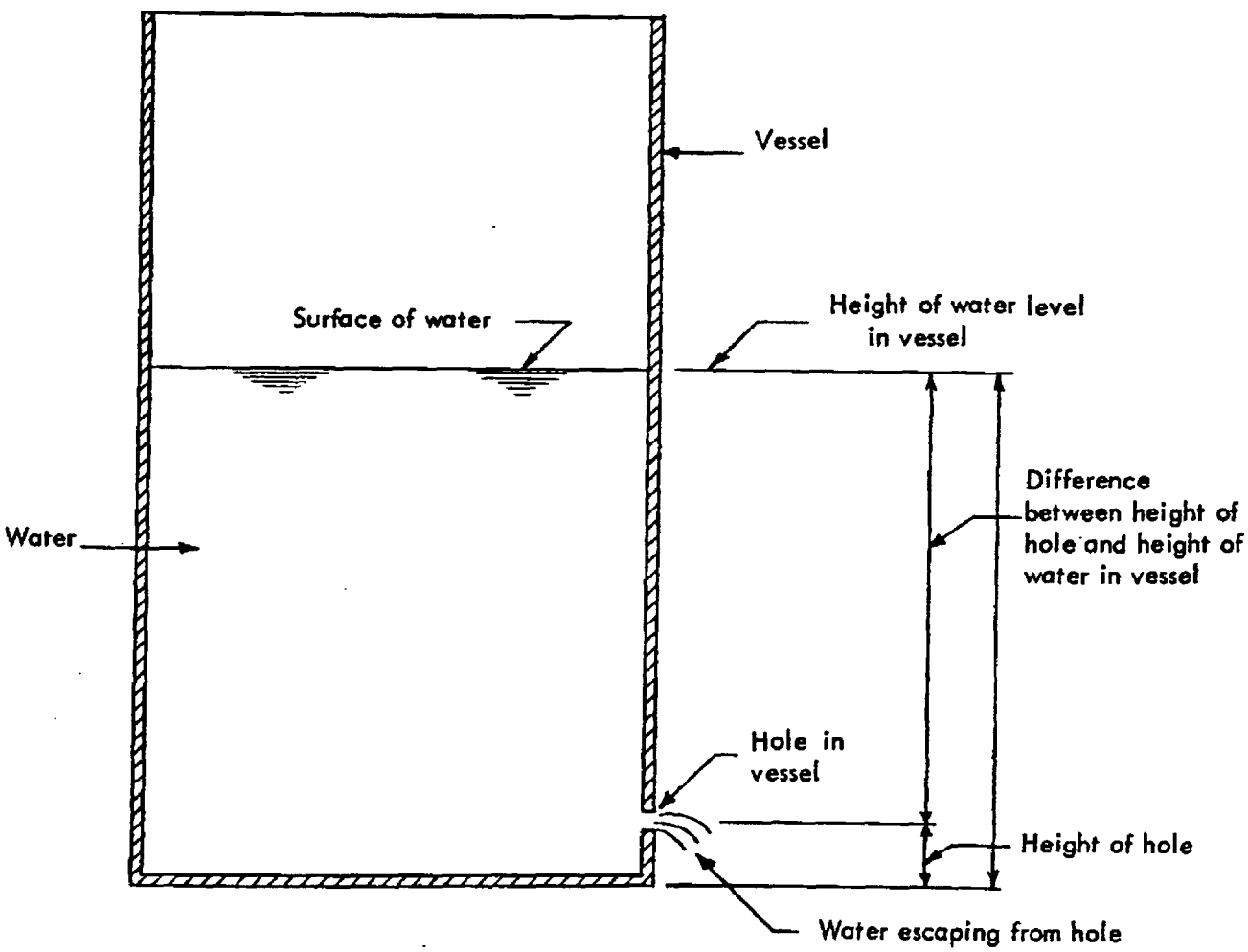
Energy transfer from one body to another is by virtue of the existence of a temperature difference existing between the two bodies. Thus it is necessary to establish the definition of temperature:

> The temperature of a body is its thermal state in relation to communicating heat to other bodies. When two bodies are placed in thermal communication, the one that loses heat to the other is stated to be at the higher temperature.

By definition, temperature is a level of hotness. Temperature, by itself, is not a measure of heat or energy. To illustrate this point, assume that there is a vessel containing water and that there is a hole in the bottom by which water could escape. This is shown in Figure II-1. Consider the water to be heat and the height of the water in vessel to be temperature. Like heat, because of the difference in height between the hole and the top of the water, the water will flow out the hole and escape. However, measurement of this height will not determine the amount of

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FUNCTION



Knowing only the height of water level will not provide information necessary to determine amount of water escapting from hole. Difference in height between hole and water level determines amount of water which will escape from hole.

ILLUSTRATION OF FLOW AS EFFECTED BY WATER LEVEL DIFFERENCE

Figure II-1

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FUNCTION

HEAT TRANSFER - Contd

Heat - Contd

water which will escape. In a similar manner temperature measures the level of hotness, but is no measure of quantity of heat. As shown in the illustration of the water in a vessel, the water flows only if the hole is at a lower level than the surface of the water inside the vessel. A difference of height causes the flow. Similarly, in transfering heat the energy transfer is by virtue of a difference in temperature.

To measure temperature a number of temperature scales have been devised. These scales were devised in view of where certain definite physical phenomena occur. The two phenomen used as fixed points are the ice point and the steam point.

The Fahrenheit temperature scale subdivides the temperature interval between ice point and steam point into 180 parts. Its 0 point was set by the lowest temperature attainable by means of a salt-ice mixture. From this the ice point was set at 32 and the steam point 212.

In the Centigrande scale, which is now called "Celsius", the clean-water ice point was set at 0 and the steam point 100.

Two other scales have been devised based on "absolute zero", the calculated level of complete absence of heat. The Rankine temperature scale was set with 0 being equal to absolute zero and with the same divisions of the Fahrenheit scale. This made the ice point 491.7 and the steam point 671.1 The other is the Kelvin temperature scale using starting point of absolute zero as 0, but using the same divisions as the "Celsius" scale, causing the ice point to be 273.16 and steam point to 373.16.

These temperature scales have a relationship and knowing the temperature by degrees by one scale the degrees of any other can be determined. The relationship of these scales is as follows:

To Get	From °Fahrenheit	From °Kelvin	From °Celsius (Centigrade)	From °Rankine
°F Fahrenheit		$\frac{9}{5}(°K-273.16)+32$	$\frac{9}{5}$ °C + 32	°R - 459.67
°K Kelvin	$\frac{5}{9}(°F-32)+273.16$		°C + 273.16	$\frac{5}{9}$ °R

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FUNCTION

HEAT TRANSFER Contd

Heat - Contd

To Get	From °Fahrenheit	From °Kelvin	From °Celsius (Centigrade)	From °Rankine
°C Celsius (Centigrade)	$\frac{5}{9}$(°F - 32)	°K - 273.16		$\frac{5}{9}$ °R - 273.16
°R Rankine	°F + 459.69	$\frac{9}{5}$ °K	$\frac{9}{5}$ °C + 491.69	

The most commonly used scales are Fahrenheit and Celsius (Centigrade). At the temperature F of -40, Centigrade is also -40. Only at this point does the number of degrees on each of these scales designate the same level of hotness. For this reason, in stating the number of degrees it is essential that the temperature scale be given otherwise the statement has no meaning.

In the definition of heat the term bodies is used. Again, this term is used in its scientific sense. The meaning being as follows:

> Body is a mass of matter distinct from other masses; a sensible object in physical space.

All the previously written matter was an attempt to provide a full understanding of heat. From the definitions of the terms used in the original defintion of heat, substitutions could be made so that the definition might be written as follows:

> Heat is force in transformation or transfer from one mass to another because of a difference in level of hotness existing between the two masses.

Although this definition is not as scientifically correct as the first presented, the act of arriving at it may have clarified many points of question.

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FUNCTION

HEAT TRANSFER - Contd

Effect of Heat on Substances

All substances are made up of molecules in constant motion. Adding heat speeds up the motion of the molecules; removing heat slows them down. At the same time, molecules pull toward each other. This pull tends to restrict their movement and hold them together in a body. Speeding up motion by adding heat tends to overcome the attraction of molecules; so substance expands. The temperature rises in a substance as heat is added unless there is a change in state of the substance.

Substances may be solid, liquid or gas state depending on the attraction of molecules and rate of their rate of motion. The motion in these states are as follows:

SOLID STATE. Energy of moving molecules is small as compared to attraction; so molecules move as if on tethers.

LIQUID STATE. Molecule movement and attraction are close to balance. Molecules will stick close together but can wander in any direction in the (liquid) substance. Surface tension is a result of molecular attraction.

GAS STATE. Molecules are independent in their motion. Travel is limited only by collisions with other molecules or confining walls.

A number of terms are used for particular actions of changes of state of substances. These are: melting, sublimation, evaporation, boiling and condensation.

MELTING. When solid is heated to point where molecules move fast enough to break away from rigid pattern, temperature no longer rises with heat imput until all molecules have broken loose.

SUBLIMATION. In breaking bonds of solid state, some molecules move fast enough to break away from all others to become a gas. To illustrate a typical example of this, carbon dioxide dry ice (solid) sublimes directly to gas.

EVAPORATION. In heating liquid, some molecules speed up sufficiently to break through surface-tension layers, against attraction of other molecules in the liquid state to become a gas. In escaping gas molecules take away energy. This may cool the liquid.

BOILING. Molecules in the liquid state gaining sufficient heat to accelerate and break away from each other to be in gas state.

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FUNCTION

HEAT TRANSFER - Contd

CONDENSATION. Gas molecules losing heat slow down and pull together as a liquid.

Molecules in gas state has relationship in respect to saturation, vapor pressure, and superheat. These relationships of molecules in gas state are as follows:

SATURATION. To stay as gas, molecules must move fast enough to keep apart. Speed depends on temperature. For every temperature there is a maximum number of molecules that can exist as gas in a given volume. Adding more gas to a given volume of maximum density (minimum specific volume) without increasing temperature will increase mutual attraction of molecules to start condensation. This saturation always exist where gas and its liquid touch.

VAPOR PRESSURE. Moving gas molecules exert a force in any confining surface, called vapor pressure. Vapor pressure goes up as the speed and number of molecules, or as temperature and density.

SUPERHEAT. Saturated vapor not in contact with its liquid can be superheated in two ways: (1) increasing its temperature (adding heat) to expand it or (2) decreasing its pressure (throttling) over certain ranges.

A graphic illustration of the relationship of substance changes of state are shown in Figure II-2.

As heat has these effects on substances it becomes clear that its transfer from one substance to another must be carefully controlled in manufacture of chemicals. Control of heat transfer is the function of thermal insulation.

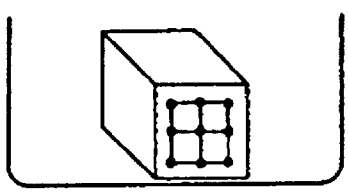
Heat Transfer

Although the function of thermal insulation is to retard heat flow, to accomplish this it is necessary to know how heat is transferred.

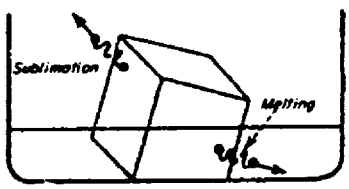
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FUNCTION

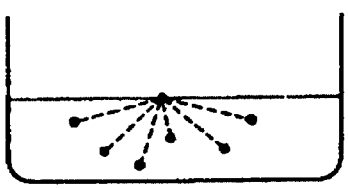
WHEN A SUBSTANCE CHANGES STATE, ITS MOLECULES DO NOT CHANGE, ONLY THEIR RELATION



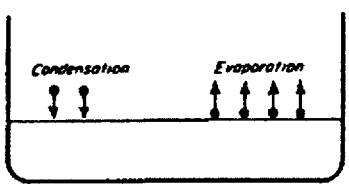
SOLID-STATE molecules are free to move, but are kept in rigid pattern by "tethers" of mutual attraction to form crystals



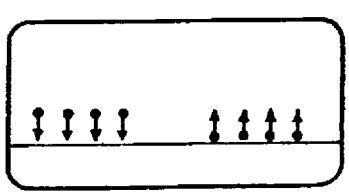
MELTING AND SUBLIMING molecules both need extra dose of energy ("latent heat") to break their attraction tethers



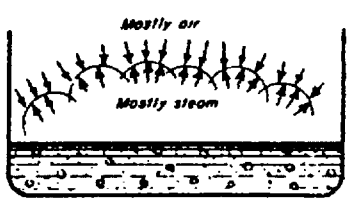
LIQUID SURFACE TENSION caused by unequal pull on molecules at surface by the molecules inside liquid forms a barrier



EVAPORATION, CONDENSATION of individual molecules go on at same time but net effect is usually one or the other



SATURATION IN CLOSED VESSEL. Molecules reentering liquid equal those leaving liquid when temperature is kept constant



BOILING IN OPEN VESSEL takes place when the vapor pressure is equal or greater than external pressure; bubbles form

FIGURE II-2

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FUNCTION

HEAT TRANSFER - Contd

Heat Transfer - Contd

Heat has two methods of transfer named conduction and radiation. Convection, fre uently called a method of heat transfer, is movement of mass from one position to another. However, for ease of discussion and understanding, although incorrect, it will be presented as if it were a method of heat transfer.

As each of the above methods of heat or mass transfer are names for a phenomena, the definition of the terms describe the phenomena.

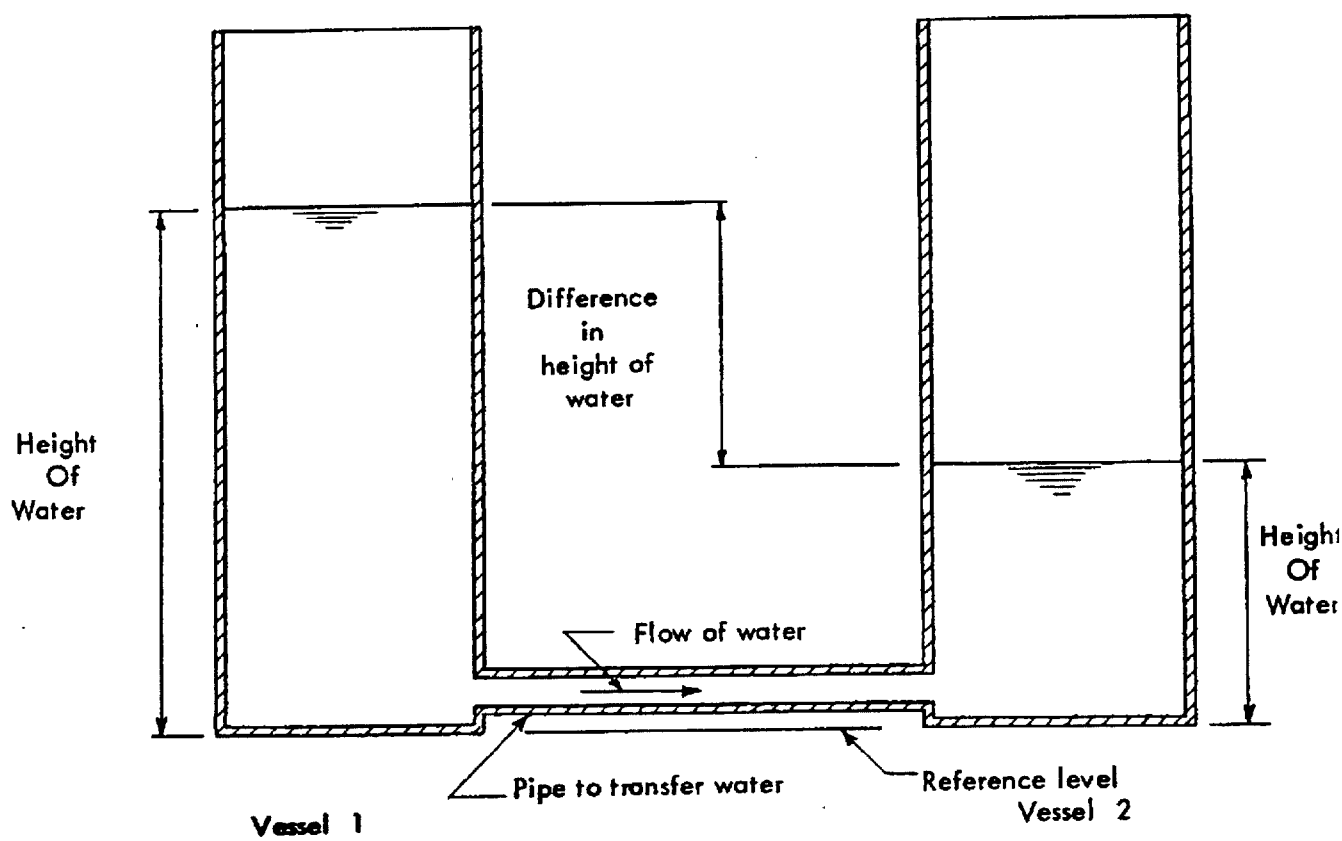
> Conduction, external is energy transferred from one body to another body at a lower temperature by tangible contact.
>
> Conduction, internal is energy transferred from one molecule to another at a lower temperature within a single body.
>
> Radiation is energy transmission through space from a hotter body to a colder body.
>
> Convection is the movement of a body, or bodies, with its, or their associated energy from one position to another without change or energy transformation. By this definition, convection is not a method of heat transfer. A typical example of convection is the movement of air from one part of a room to another.

These are the methods by which heat is transferred or moved. To illustrate these factors again, let us use water to represent heat and two vessels to represent bodies. For the transfer method, the two vessels are connected by a pipe representing radiation and conduction. The height of water in each vessel represents the temperature of a body. The illustration of two vessels is shown in Figure II-3. It is apparent that when the water in vessel (1) is at a higher level than vessel (2), water will flow to vessel (2). This flow will continue as long as a difference exists in the water level between the two vessels. When the water level in both vessels becomes the same, there is no flow of water between the vessels. Heat transfer is similar. A temperature difference must exist before heat flow occurs. When two bodies are at the same temperature, no heat will flow between the two, regardless of level of the temperature.

To illustrate the methods of heat transfer, consider the example of a rod heated at one end. In the diagram shown in Figure II-4, a metal rod is heated by a candle on the left end. The rod is initially at ambient temperature.

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FUNCTION



Water will flow from vessel 1 to vessel 2 as long as vessel 1 has a greater height of water than vessel 2 in respect to common reference level. Water flow is result of existance of difference in height of water

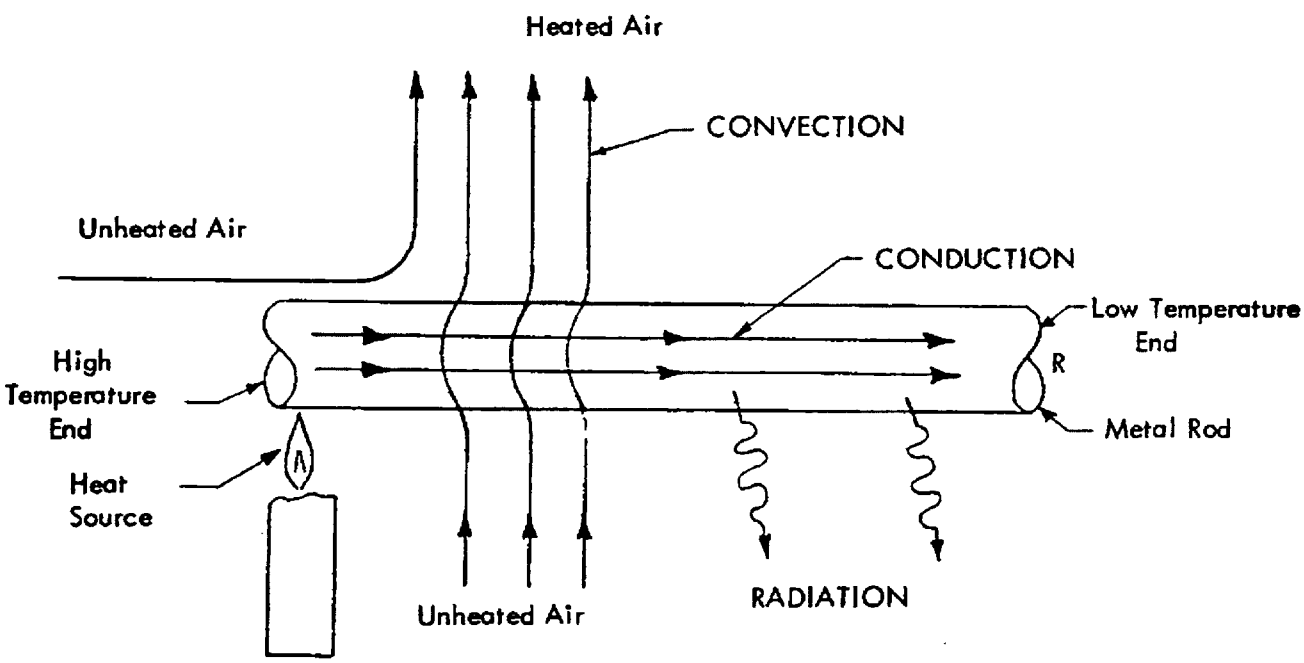
ILLUSTRATION OF WATER FLOW BETWEEN TWO VESSELS DUE TO DIFFERENCE IN WATER LEVEL

Figure II-3

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FUNCTION



HEAT TRANSFER FOR A HEATED ROD

Figure II-4

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FUNCTION

HEAT TRANSFER - Contd

Heat Transfer - Contd

After heating the rod a certain length of time, a rise in temperature can be felt at the right end and all along the rod. This occurs because of heat transfer by conduction along the rod from a region of high temperature at the left to a region of low temperature at the right. The rate of heat transfer depends on the thermal conductivity of the metal. For copper, with a high thermal conductivity, heat transfer will be quite rapid.

However, convection heat transfer complicates the picture. Convection occurs when unheated air sweeps in around the heated rod. The air particles in intimate contact next to the rod are heated up by conduction from the rod to the air. The heated particles become less dense and therefore rise, thus carrying away the heat. More unheated air sweeps in and up to take its place and this process continues. If this happens of its own accord, the process is known as free convection. If air is forced across the rod, say by a fan, it is known as forced convection.

The rod will also emit heat by radiation. The heat energy in the rod will be converted to radiant heat in the form of "batches" of energy called quanta. These will be propagated away from the rod to surroundings at a lower temperature in the form of electromagnetic waves. The transfer of heat in this manner is said to occur between two bodies that are different in temperature; the larger the difference, the more that is radiated.

Electromagnetic waves travel at 186,000 miles per second and are characterized by their wavelength. Visible light, radio waves, radar, cosmic rays, and radiation are all electromagnetic waves; but they differ in wavelength -- the shorter the wavelength, the higher the energy. Electromagnetic waves need no medium, such as air, for their transmission.

Therefore, unlike convection, radiation can occur through a vacuum; for instance, the energy that arrives to earth from the sun is radiant energy only.

Restriction of Heat Transfer

The purpose of thermal insulation is to retard or hinder the transfer of heat between bodies of different temperatures. Thermal insulations are materials or systems that are resistant to the flow of heat.

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FUNCTION

HEAT TRANSFER - Contd

Restriction of Heat Transfer - Contd

To illustrate their function return to the illustration of the water flowing between two vessels. If the pipe between two vessels was large and had little resistance to the flow of water, the flow of water between the two vessels would be large. If the pipe was very small, thus having large resistance to water flow, then the quantity of water flowing between the two vessels would be small. Thus, the higher the pipe resistance the smaller the quantity of water which will pass through the pipe in a given period of time. This is shown in Figure II-3.

In a similar manner, the greater the thermal resistance between two bodies of different temperature the lower the quantity of heat transfer between the bodies for a given period of time. This brings in a new variable which is time.

In the water vessel illustration a valve could be put in the pipe, which would enable one to completely stop the flow of water. However, heat will be transferred through all materials if a temperature difference exists either within or between the surfaces of the material. There is no way to completely stop the flow of heat between bodies of different temperatures. By providing thermal resistance between bodies of different temperatures the quantity of heat transferred in a given period of time can be reduced.

The relationship can be expressed as follows:

$$\text{Quantity of heat per period of time} = \frac{\text{Temperature difference between bodies}}{\text{Thermal resistance}}$$

Note: The thermal resistance must be based on time and area units corresponding to that of quantity of heat.

When Q = heat transfer per hour

Δt = temperature difference

R = thermal resistance

$$Q = \frac{\Delta t}{R} \qquad \text{(Equation 1)}$$

As stated, the relationship does require that units be of proper units of measurement.

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FUNCTION

HEAT TRANSFER - Contd

Restriction of Heat Transfer - Contd

In the English System of measuring heat, the common unit is British thermal unit (Btu) and the common unit of measuring temperature is Fahrenheit (°F). However, there was never a unit named for measuring thermal resistivity. This thermal resistivity is the reciprocal of conductance (C) or $\frac{1}{C}$. The previously expressed relationship of heat flow in respect to time, area, temperature difference and thermal conductivity can be written:

$$\text{Heat transfer in Btu per sq ft, hr} = \frac{\text{Temperature difference in } ^\circ\text{F}}{\frac{1}{\text{Thermal conductivity in Btu per sq ft, hr}}}$$

To state in easily used terms:

When

Heat transfer = Q in Btu/sq ft, hr

Temperature difference between surfaces = $t_1 - t_2$

if t_1 equals °F of higher temperature surface

and t_2 equals °F of lower temperature surface

Thermal conductance of material = C in Btu/sq ft, hr, °F

Then

$$Q = \frac{t_1 - t_2}{\frac{1}{C}} \qquad \text{(Equation 2)}$$

Thus, the basic equation for the calculation of heat transfer, through one material, is established. This equation shows that to obtain a low rate of heat transfer requires a material of high thermal resistance. It also shows that to obtain high thermal resistance requires materials or systems of low thermal conductance.

Classes of Thermal Insulation

Thermal insulation is material, or assemblies of material, having high thermal resistance and low thermal conductance. It is produced in many different forms.

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FUNCTION - Continued

HEAT TRANSFER - Contd

Classes of Thermal Insulation - Contd

Basically there are two general classes. One is mass insulation and the other is reflective insulation. In some instances, the two are used together in a single installation.

Mass Insulation

Mass insulation is made of solids arranged to form finely divided spaces of air or gas. An enlarged section of typical mass insulation is shown in Figure II-5. As shown in the figure, when a temperature difference exists between the two surfaces of the material the heat will use all means to get from the hotter surface to the colder surface. The heat passes through the material by conduction, radiation, and convection. As it is impractical to separate each of the quantities of heat in regard to its mode of transfer, the total amount is stated to pass through the insulation by conduction.

The measurement of the ability of a homogeneous material to transfer heat is conductivity (k). The definition is:

> Conductivity: the heat rate "per unit area per degree per unit length of heat travel."
>
> In English Units: Conductivity k = Btu/sq ft, hr, °F, inch

Notice that in English units the heat transfer is per one inch of thickness. Although the purpose of insulation is to provide thermal resistance, mass materials are tested and evaluated based on the heat that does transfer per inch of thickness. Naturally it is desirable that the conductivity be small. Knowing the conductivity it is easy to obtain the thermal resistance of flat materials, as thermal resistance R equals the thickness divided by the conductivity.

When

R is thermal resistance

k is conductivity in Btu/sq ft, hr, °F, inch

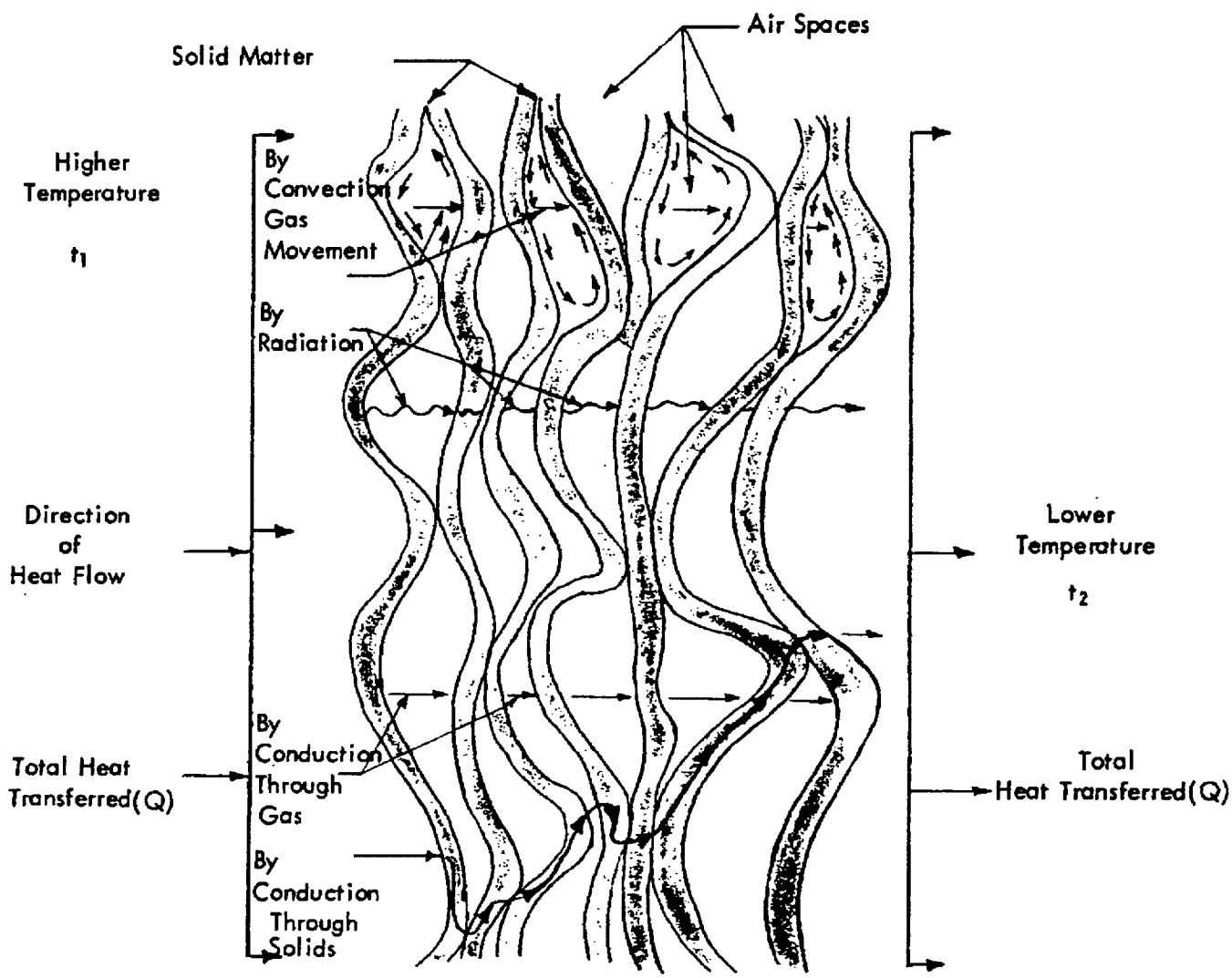
l is thickness of insulation in inches.

Then:

$$R = \frac{l}{k} \qquad \text{(Equation 3)}$$

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FUNCTION



SCHEMATIC ILLUSTRATION OF HEAT TRANSFER THROUGH MASS INSULATION

Figure II-6

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FUNCTION

HEAT TRANSFER - Contd

Classes of Thermal Insulation - Contd

It follows then from Equation (3), the heat transfer per hour (q_a) through a single flat mass insulation, l inches thick with a higher temperature t_1 on one side and a lower temperature t_2 on the other, is:

$$Q_a = \frac{t_1 - t_2}{\frac{l}{k}} \qquad \text{(Equation 4)}$$

Reflective Insulation

Reflective insulation is thermal insulation, depending for its efficacy in large part on reduction of radiant heat transfer across spaces by use of one or more surfaces of high reflectance or low emittance. In most instances reflective insulation is an assembly of materials, and more properly may be called an insulation system. It is not a homogeneous material. For this reason the heat transfer must be measured as the conductance across the system.

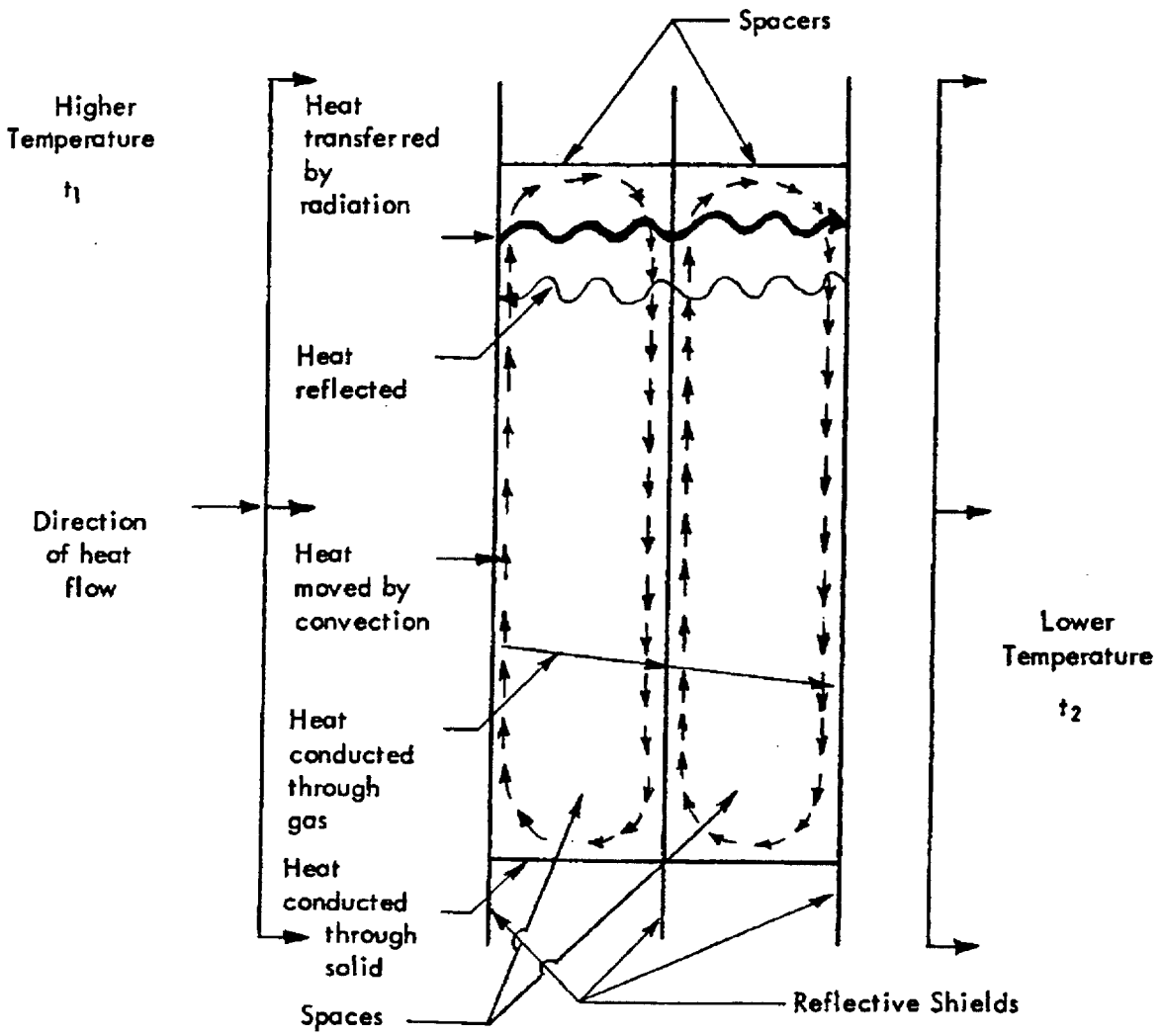
Heat transfer across the system is due to the temperature difference existing between the two sides of the system. Like mass insulation the heat uses all methods to get from the hot side to the cold side. This illustrated in Figure II-6. Again, like mass insulation the means by which heat is transferred from one side to the other are not separated into individual parts and the total of all is measured as conductance across the reflective insulation system. In this case as the entire system must be measured as a single unit, the length of heat flow path is the entire unit. Thus the basic heat transfer equation is Equation (2).

$$Q = \frac{t_1 - t_2}{\frac{1}{C}} \qquad \text{(Equation 5)}$$

Typical illustration of a reflective insulation system is the "thermos" bottle.

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FUNCTION



SCHEMATIC ILLUSTRATION OF HEAT TRANSFER THROUGH REFLECTIVE INSULATION

Figure II-6

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FUNCTION

HEAT TRANSFER - Contd

Surface Air Film Resistance to Heat Transfer

In the use of insulation for conservation of energy in industrial installations, the resistance of the outer air film to the transfer of heat becomes important, as it directly influences the outer surface temperature of insulation.

Under static conditions all heat transferred to, through, and from must be of equal quantity. This is illustrated in Figure II-7.

As shown in Figure II-7, the heat transfer is from hot gas (air) on one side to cold gas (air) on the other. In most installations of insulation on industrial pipe and equipment, the inside surface is the pipe or equipment which is directly in contact with the insulation. Under these conditions, the inner surface temperature is essentially the same as the temperature of the pipe or vessel, and an inner air film resistance does not exist. The vessel or pipe may be hotter or colder than the outside air. These conditions are illustrated in Figure II-8.

The air film has an overall heat transfer conductance f. Or a resistance to heat flow $\frac{1}{f}$. Thus,

$$Q_{a3} = \frac{t_2 - t_a}{\frac{1}{f}}$$

Equation 4 states that:

$$Q_a = \frac{t_1 - t_2}{\frac{1}{k}}$$

as $Q_a = Q_{a1} = Q_{a2} = Q_{a3}$ (As illustrated in Figure II-7)

In the case of one air film

$$Q_{a3} = \frac{t_2 - t_a}{\frac{1}{f}} = Q_a = \frac{t_1 - t_2}{\frac{1}{k}}$$

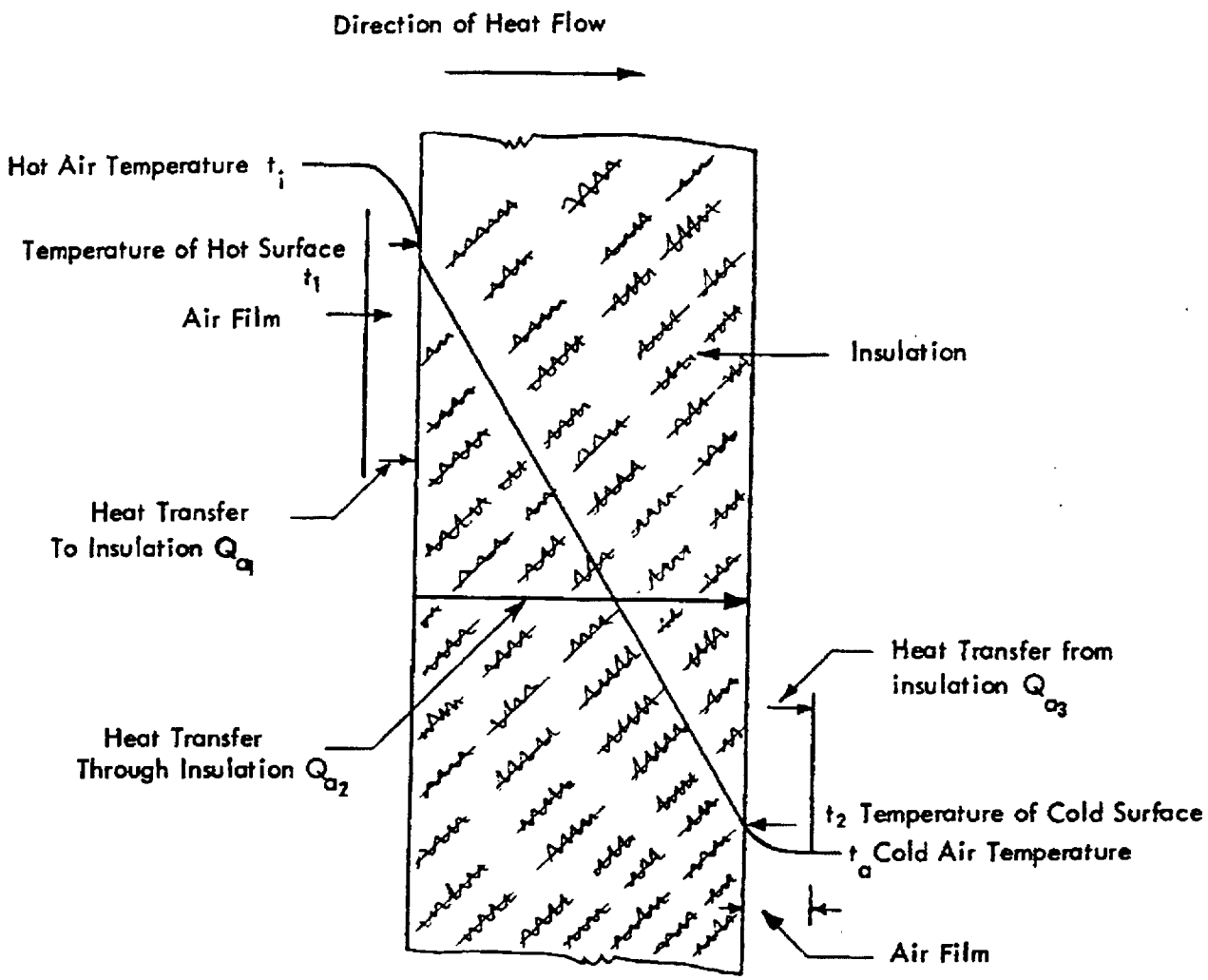
or

$$Q_a = \frac{t_1 - t_a}{\frac{1}{k} + \frac{1}{f}}$$ (Equation 6)

(Illustrated in Figure II-8)

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FUNCTION



All temperatures t_i, t_1, t_2, and t_a are held constant (static)

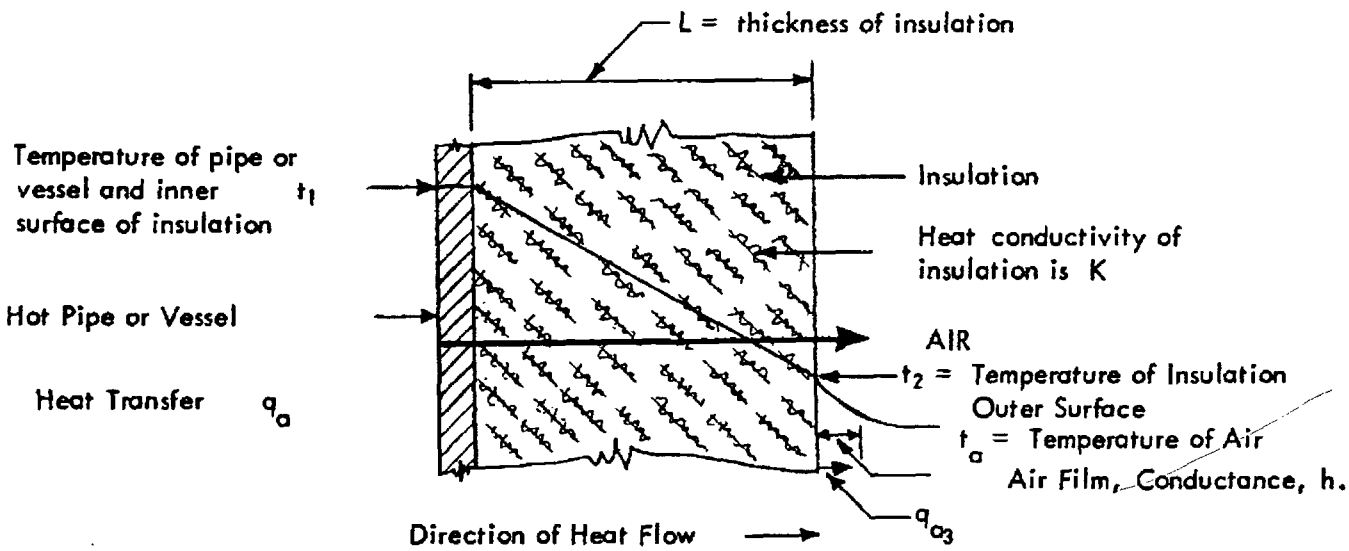
Heat transfer Q_{a_1} equals Q_{a_2} equals Q_{a_3}

HEAT TRANSFER THROUGH INSULATION
UNDER STATIC CONDITIONS

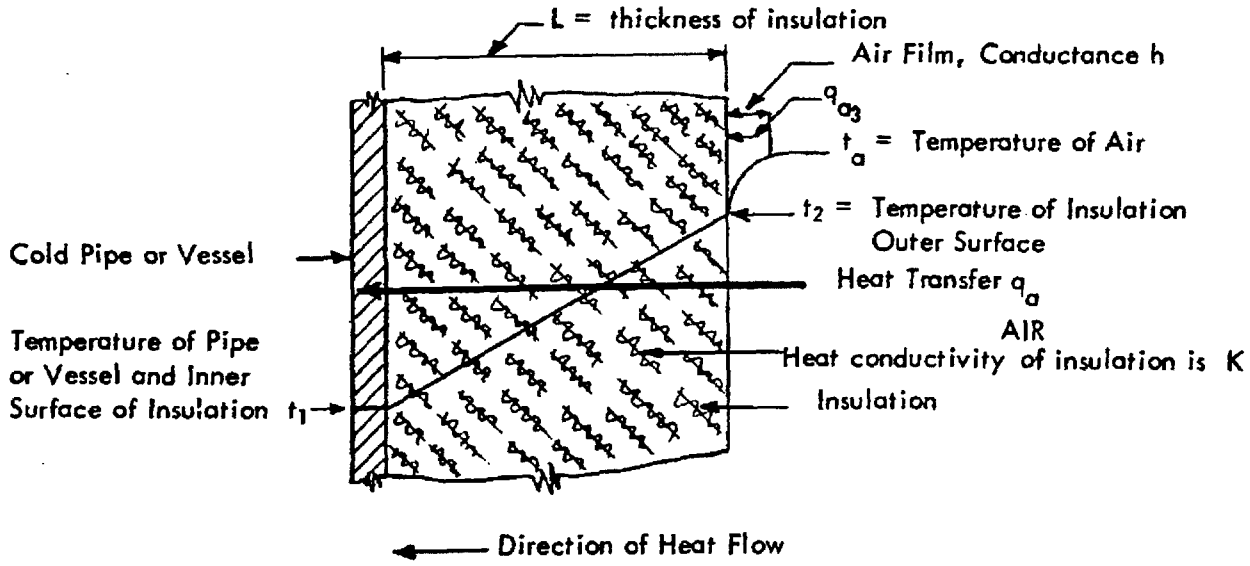
Figure II-7

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FUNCTION



INSULATION ON HOT PIPE OR VESSELL



INSULATION ON COLD PIPE OR VESSEL

SCHEMATIC ILLUSTRATION OF
HEAT TRANSFER THROUGH INSULATION

Figure II-8 UCC 002654

FUNCTION

HEAT TRANSFER - Contd

Surface Air Film Resistance to Heat Transfer - Contd

Which is the basic formula to calculate heat transfer through one flat thickness of insulation.

The following examples will illustrate the use of this equation for the calculation of heat transfer.

Example 1. Three inches of insulation is installed on a large hot vessel. The temperature of the vessel if 400°F. The temperature of the air is 50°F. The conductivity (k) of the insulation is 0.4 Btu/sq ft, hr, °F, in. The conductance of the air film is 2.2 Btu/sq ft, hr, °F. What is the heat loss per square foot per hour?

To find Q_a in Btu/sq ft, hr

Given:

t_1 temperature of inner surface of insulation = 400°F

t_a temperature of air = 50°F

l thickness of insulation = 3 inches

k conductivity of insulation = 0.4 Btu/sq ft, hr, °F, in.

f conductance of air film = 2.2 Btu/sq ft, hr, °F

Equation is

$$Q_a = \frac{t_1 - t_a}{\frac{1}{k} + \frac{1}{f}}$$

Substituting in proper values

$$Q_a = \frac{400 - 50}{\frac{3}{0.4} + \frac{1}{2.2}} = \frac{350}{7.5 + .45} = \frac{350}{7.95}$$

$$= 44 \text{ Btu/sq ft. hr} \quad \text{Answer}$$

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FUNCTION

HEAT TRANSFER - Contd

Surface Air Film Resistance to Heat Transfer - Contd

Example 2. Five inches of insulation is installed on a large diameter vessel, operating at -100°F (t_1). The air temperature is 90° F (t_a). The conductivity (k) of the insulation is 0.33 Btu/sq ft, hr, °F, in. The conductance (f) of the air film is 1.5. What is the heat transfer per square foot per hour?

To find Q_a in Btu/sq ft, hr

Given:

t_1 temperature of inner surface = -100°F

t_a temperature of air = 90°F

l thickness of insulation = 5 inches

k conductivity of insulation = 0.33 Btu/sq ft, hr, °F, in.

f conductance of air film = 1.5 Btu/sq ft, hr, °F

Equation is

$$Q_a = \frac{t_1 - t_a}{\frac{l}{k} + \frac{1}{f}}$$

Substituting proper values

$$Q_a = \frac{-100 - 90}{\frac{5}{0.33} + \frac{1}{1.5}} = \frac{-190}{15.15 + 0.66} = \frac{-190}{15.81}$$

$$Q_a = -12 \text{ Btu/sq ft, hr}$$

Note the minus quantity indicates the heat flow is from the air to the insulation.

The theory of heat transfer and heat transfer through two simple cases of insulation has been established.

Additional equations and data for solving more complex insulation problems are presented in Thermal Insulation Manual, Volume II, Design.

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PURPOSE

GENERAL

All materials transfer heat. Thermal insulations are materials which transfer a small quantity as compared to others. This ability to retard heat flow makes these materials useful many places where control of heat is desirable or essential.

The use of animal fur was one of man's first uses of a material as an insulation to conserve his own body heat. Over the passage of years we tend to forget that clothes are man's personal insulation to control the heat losses from his body. Yet, automatically in winter we use more efficient insulation -- heavier and thicker clothing -- than in summer.

From the first crude lean-tos, today's office buildings, laboratories, industrial buildings and homes have evolved to provide a resistance to heat transfer so that the inside temperature could be maintained at a level necessary for human comfort. The increased use of refrigeration to keep the interior of buildings cool has further increased the importance of insulation and insulation-type material.

In the preservation of food and its preparation, insulation is used in cold storage rooms, refrigerators, and stoves to control heat transfer. Likewise, in transportation insulation is used in automobiles, ships, airplanes, and railroad cars, and, of course, it is highly important in space craft. Thermal insulation is essential in the production of power and the processing of almost all materials. Thus there is hardly any phase of modern life which is not influenced by thermal insulation.

Many craftsmen, who are not called insulators or asbestos workers, use or install insulating-type materials. For example, a man who makes clothes is a tailor. The insulator's craft has developed as installers of materials having the prime function of providing resistance to heat transfer. This craft is closely associated with the construction industry; hence, both material and labor for its installation are supplied by distributor-contractor companies.

In the field of construction there has developed a loosely defined division of types of insulation services. One of these is called commercial and includes the use of insulation in building, such as duct insulation, hot and cold water piping insulation and insulation on low pressure steam piping and equipment. The other is industrial and includes the insulation of power plants, and the piping and equipment of process industries.

COMMERCIAL INSULATION

In general, commercial insulation is used to control heat flow so as to maintain the atmosphere in the enclosed space at the temperature and humidity as required by the occupants or contents of the building. In addition the insulation serves to reduce the

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PURPOSE

COMMERICAL INSULATION - Contd

cost of heating and cooling the structure. Although this is a large portion of the insulation industry these specific uses of insulation will not be further discussed as the major importance to our Company is in the field of industrial insulation.

INDUSTRIAL INSULATION

Insulations are used in the industrial field to control heat to conserve energy, control temperature, protect personnel and as fire protection. In all instances, from an economic view, it is used to save money or make possible the earning of money. The manner in which this is accomplished depends upon the individual installation. Some of the various services requiring insulation are presented to show where insulation is used to save money or make the earning of it possible.

HOT TEMPERATURE SERVICE

Hot service is commonly considered to be when the temperature of the surface on which the insulation is installed is above 212F. The temperature may be obtained from steam or other heating mediums, such as Dowtherm or electric heaters, or from process reaction.

Insulating these hot service lines and equipment may be done for one or more of the following reasons:

1. When the heat in these lines or vessels is of value, they are insulated to conserve this heat. For any particular cost of steam (or other heating medium) and particular cost of installed insulation, it is possible to calculate the correct insulation thickness as determined by good economics. In this case the insulation saves money by saving heat.
2. When insulation is used to control temperature, it is a necessary component of the process system. In this case insulation makes the earning of money possible.
3. When insulation is used to prevent personnel from being burned, it performs a function as a safety device. As such it serves to protect personnel from painful burns and reduces costly lost-time accidents.

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PURPOSE

HOT TEMPERATURE SERVICE - Contd

4. When insulation is used to protect piping and equipment from fire, it again performs a function of increasing plant safety. In this use it also minimizes financial damage in case of fire and also makes it possible to obtain more reasonable insurance rates.

In many instances the same insulation serves more than one of the above given functions on a single installation. Frequently an insulation is used to conserve energy and to control temperature in a process vessel. Also, very often an insulation is used to conserve energy loss from a pipe and act as fire protection for that same pipe. It quite often serves all four functions at the same time.

MODERATE TEMPERATURE SERVICE

Moderate service is most often considered to be in the temperature range of 35F to 212F. This temperature range includes such insulated items as field storage tanks, hot and cold water, moderate temperature vessels indoors, and air conditioning ducts.

The reasons for insulating are the same as the four listed for hot service plus three others. These additional reasons are:

1. When a field storage vessel is insulated to minimize vapor loss caused by solar radiation, it is used to conserve product and by so doing saves money.
2. To control condensation of moisture on the surface. Condensation on outer surfaces causes rusting of steel and causes slippery, unsafe conditions. Preventing it reduces maintenance cost and cost due to accidents.
3. To retard (not prevent) freezing of contents of pipes or vessels in cold weather. Used in this manner the insulation is a necessary part of process control and contributes to the ability to produce a product to earn money.

Again, the insulation may be used to accomplish more than one of these at the same time.

LOW TEMPERATURE SERVICE

Low temperature service is below 35F and extends down to approximately -240F. Although -150 down to -459.7F is low temperature, this range is given the special name of cryogenic. Service in the low temperature range includes insulation on equipment and pipe, and insulation of refrigerated spaces.

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PURPOSE

LOW TEMPERATURE SERVICE - Contd

The reasons for insulating is to conserve energy, control temperature, protect from fire, control vaporization, and prevent condensation on outer surfaces. All of these have been previously mentioned.

CRYOGENIC SERVICE

The temperatures encountered in liquifying gases require special insulation consideration. Below -240F the ordinary mass insulations require such bulk to control the heat transfer and temperature, that the insulation becomes impractical. The ideal cryogenic insulation must possess the ability to minimize heat transfer from radiation, conduction and convection. Vacuum assists in this, because a completely evacuated space has no gas to establish convection currents and no molecular contact to provide conduction paths. Radiant energy transfer can be retarded by the use of reflective surfaces. For this reason most cryogenic insulations are similar in principles to the Dewar flask.

As this is a very special field of insulation, these systems are seldom installed in the field as ordinary insulation, but must be produced in manufacturing plants where it is possible to seal weld and produce vacuum spaces between the two walls containing the insulation. The Linde Division of Union Carbide Corporation has developed a number of cryogenic systems and named them Super Insulation.

TRACING SYSTEMS

The use of pipe or tubing externally attached to process lines or vessels to supply heat or refrigeration to them is called tracing. Tracing is used in high, moderate, and low temperature services. Steam, Dowtherm, hot water or electric tracers are used to supply heat to process lines and equipment. Brine or other refrigerants are used to transfer heat from process lines and equipment. The major amount of tracing is used to supply heat rather than to remove it.

HOT TEMPERATURE TRACING SYSTEMS

In this temperature range, pipe and equipment tracers simply add heat, or supply heat to replace lost heat and so retard heat loss from the process liquids and gases. The heat is generally obtained from (1) steam or (2) electricity.

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PURPOSE

HOT TEMPERATURE TRACING SYSTEMS - Contd

1. Steam heated systems consist of tubing to transmit steam, which is secured to the external surface of the process pipe or vessel, over which is installed insulation. Heat is transferred to the process pipe or equipment either by system (a) air convection, or (b) conduction through heat transfer cement. These two systems are shown in Figure III-1.

2. Electric heated systems consist of electrically heated cable secured to the external surface of pipe or vessel, over which insulation is installed. At high temperatures the electric tracing must always be connected to the process pipe or vessel with heat transfer cement to prevent excessive temperature rise in the electric tracer.

MODERATE TEMPERATURE TRACING SYSTEMS

Within this temperature range steam or electricity may be used to add heat to the process line or equipment, or brine used to remove heat, depending upon the control of temperature required.

When heat is added by steam, the air convection system is most frequently used as the temperature desired can be obtained without the use of heat transfer cement. When electric heating cable is used the transfer may be either by the air convection system or heat transfer cement system, depending upon design requirements.

When heat is removed from the system by brine, in almost all instances, the heat transfer cement system should be used to obtain efficient cooling.

In all cases the insulation over the tracer system is used to control the temperature of the process. In so doing it also conserves energy and provides personnel protection and fire protection. In these cases the insulation saves money and assists in the production process to earn money.

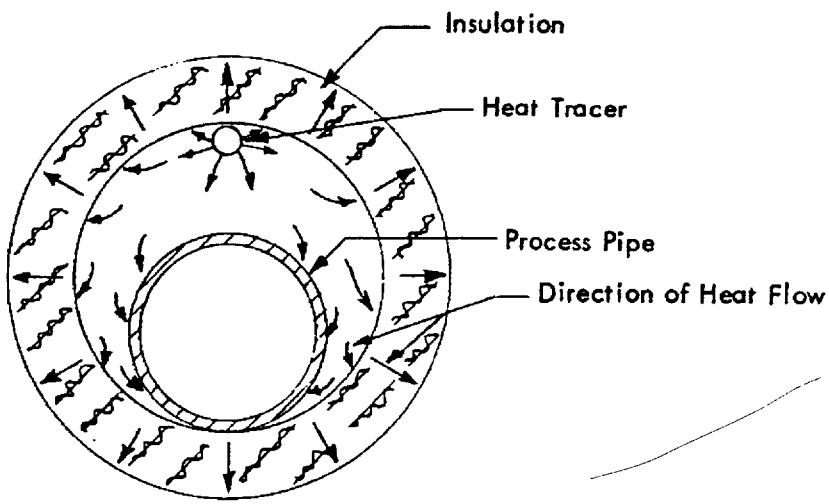
It has been indicated that thermal insulation is used to obtain economical plant operation. Therefore, it is important to understand some of the economics involved.

ECONOMICS

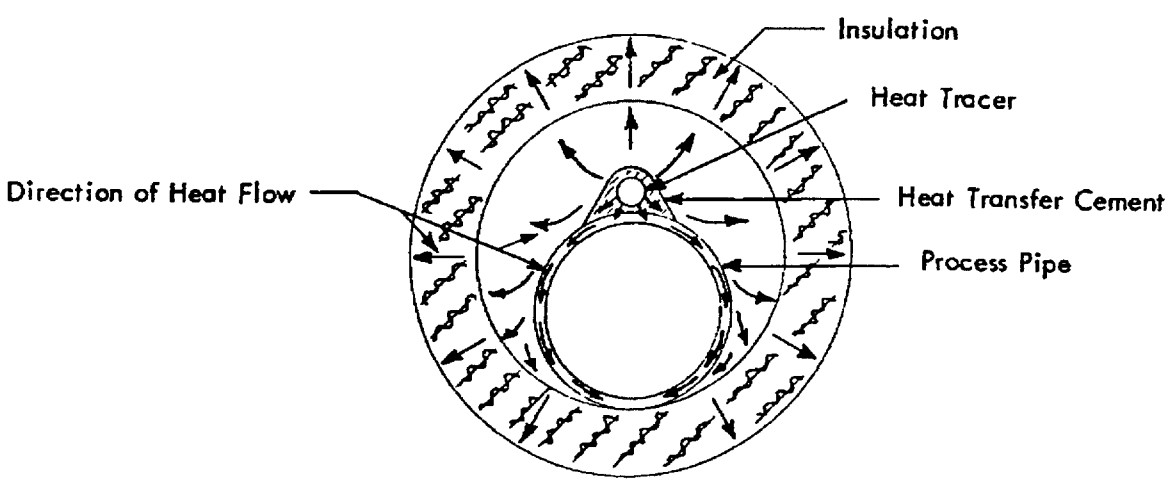
Industrial insulation is used only when the saving, or earnings, justify the expenditure for it and its installation. The first consideration in any particular installation is whether

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PURPOSE



AIR CONVECTION SYSTEM



HEAT TRANSFER CEMENT SYSTEM
DIRECTION OF HEAT TRANSFER FOR THE
TWO SYSTEMS OF HEAT TRACING

Figure III-1 UCC 002662

PURPOSE

ECONOMICS - Contd

or not insulation is justified. The savings, or profit, must provide a sufficiently large return on the investment in insulation to warrant the expenditure. The decision as to when investment in insulation is justified is based on a number of factors such as the amount of heat the insulation will save, the capital investment to produce the heat, the operating cost of producing the heat, the cost of insulation investment, and the maintenance cost of insulation.

At moderate temperatures the temperature difference between service and atmosphere is small; therefore, the heat loss would be small. In such circumstances the amount of money that could be invested in insulation to retard this heat loss would be small. Therefore, in this temperature range low cost insulation must be used, otherwise it could not be justified. To illustrate: low cost sprayed foam insulation is used in these services where higher investment insulations could not provide sufficient return to warrant their use.

At higher temperatures, when there is no question that insulation is a good investment, the question then becomes one of how much (thickness) of insulation should be used to obtain the best economy. Heat energy is valuable in that it has monetary value. However, there is no direct conversion from Btu's into dollars, as the cost of heat depends upon many factors, such as its form, location and use. For example: the Btu's in gasoline are generally more costly than those from coal. Also Btu's obtainable from coal are less expensive at the mine than at some distant point to which coal must be moved to be used. Likewise, the cost of installed insulation varies with the materials used, location, labor rates and other factors. The simple statement that "the greater the thickness of insulation the smaller the loss of heat," may be restated as "the greater the cost of insulation the smaller the cost of heat." Depending upon the cost of installed insulation and the cost of heat, a definite thickness of insulation provides the lowest total cost.

This basic truth has been recognized for years. At a meeting of the American Society of Mechanical Engineers in New York City, on December 6, 1926, Mr. L. B. McMillan presented a paper entitled "The Heat Transfer Through Insulation," in which he presented the formulas for calculating the economic thickness of insulation. For those interested in mathematics, the formula is shown on the following page.

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PURPOSE

ECONOMICS - Contd

Mr. L. B. McMillan's Equation for Determining the Most Economical Thickness of Insulation - Cylindrical Surfaces

When B = cost of insulation per year in dollars; including depreciation of capital investment, cost of money, return of investment and maintenance.

k = conductivity of insulation in Btu/sq ft, hr, in, °F.

r_1 = inside radius of insulation in inches.

r_2 = outside radius of insulation in inches.

t_o = operating temperature of surface to be insulated, in. °F

t_a = temperature of air-mean average, in. °F.

M = value of heat in dollars per 1,000,000 Btu; including depreciation of capital investment of equipment to produce heat, cost of money, return on investment and maintenance.

R_s = sum of thermal resistances, including surface resistance.

Y = hours of operation per year.

Then

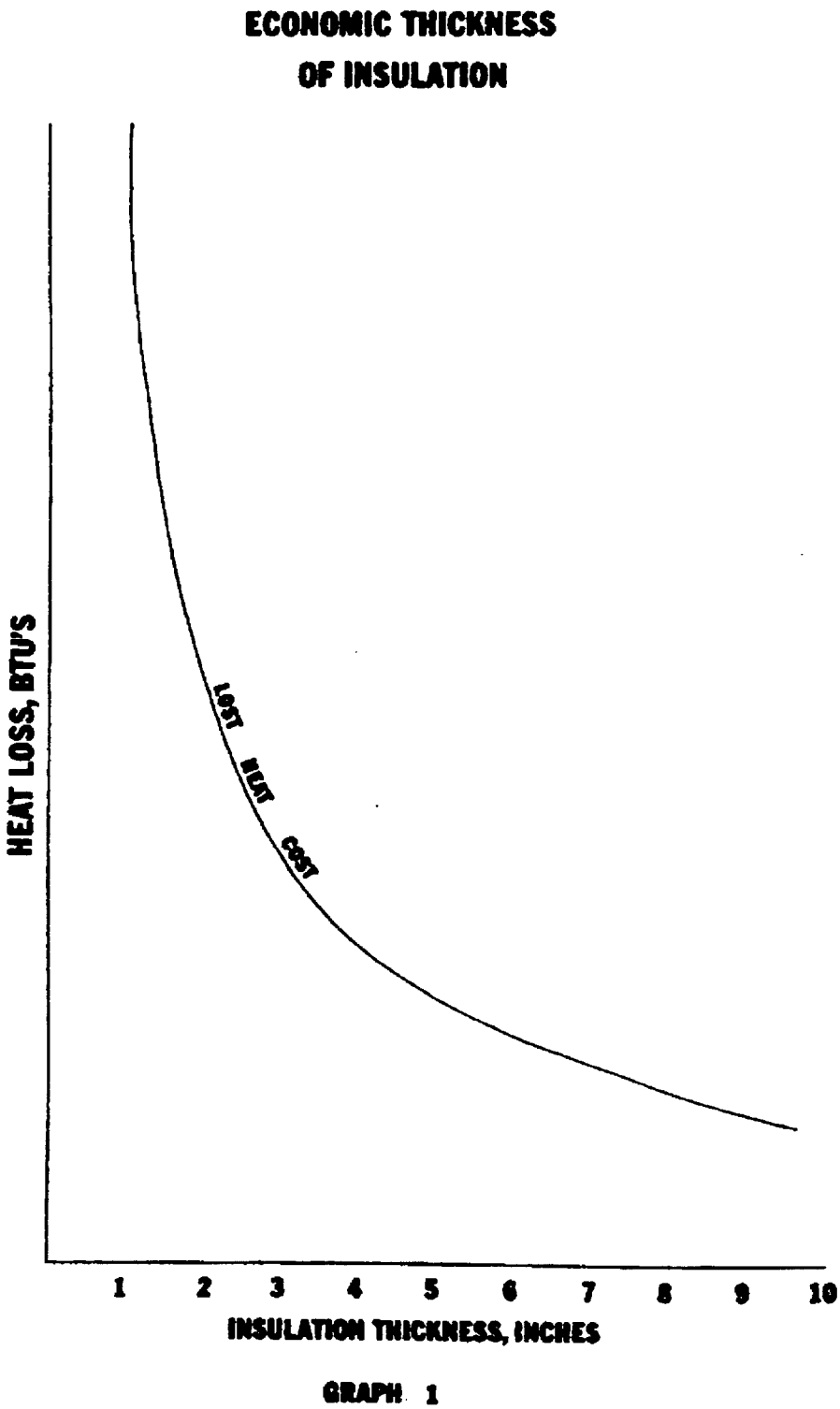
$$\left[(r_2 \log_e \frac{r_2}{r_1} + R_s k)\right] \sqrt{\frac{2r_2 - r_1}{r_2 - R_s k}} = \sqrt{\frac{Y(t_o - t_a)M \times k}{B}}$$

Although the formula is complex, the physical laws upon which it is based are quite simple and can best be understood from graphs.

To illustrate the first statement "the greater the thickness of insulation the lower the heat loss," see Graph No. 1. Notice that on a bare pipe or piece of equipment the heat loss curve runs completely off the chart. Also notice that after insulation is installed it becomes necessary to double the insulation thickness to cut the remaining heat loss in half.

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PURPOSE



GRAPH 1

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PURPOSE

ECONOMICS - Contd

As previously stated, Btu's have monetary value; therefore, the scale showing "Btu's" can be replaced by dollars per year. This in no way affects the curve if the vertical scale is converted to the correct unit value. As shown in Graph 2, the heat loss-cost curve will include the following cost factors: (1) cost of fuel, (2) capital investment of heat producing equipment, (3) cost of moneyfor capital investment, (4) interest on investment, (5) depreciation period, (6) maintenance, (7) number of hours of operation per year. In dollars per year the insulation cost can be plotted. Cost factors included in this curve are: (1) capital investment, (2) cost of money for capital investment, (3) interest on investment, (4) depreciation period, (5) maintenance cost. The sum of these two curves produces total cost curve. As would be expected, the most desirable condition is where the total cost per year is the lowest. The formula given by Mr. McMillan gives the method of determining this low point. As can be seen in Graph 3, each addition of $\frac{1}{2}$ inch of additional insulation saves less heat than the preceding $\frac{1}{2}$ inch. Therefore, it also saves less money.

To illustrate the influence of economical insulation on the capital investment and operating cost of a typical actual installation, consider an 8-inch steam line operating at 425F. The average ambient temperature is 50F. With the following cost factors:

Capital Investment in Steam Production is $12.00 per lb hour.
Production Cost of Steam is $0.40 per 1000 lb.
Capital Investment in Insulation is as follows:

$1\frac{1}{2}$ inch thickness	$3.30/linear foot
2 inch thickness	$4.10/linear foot
$2\frac{1}{2}$ inch thickness	$4.84/linear foot
3 inch thickness	$5.90/linear foot

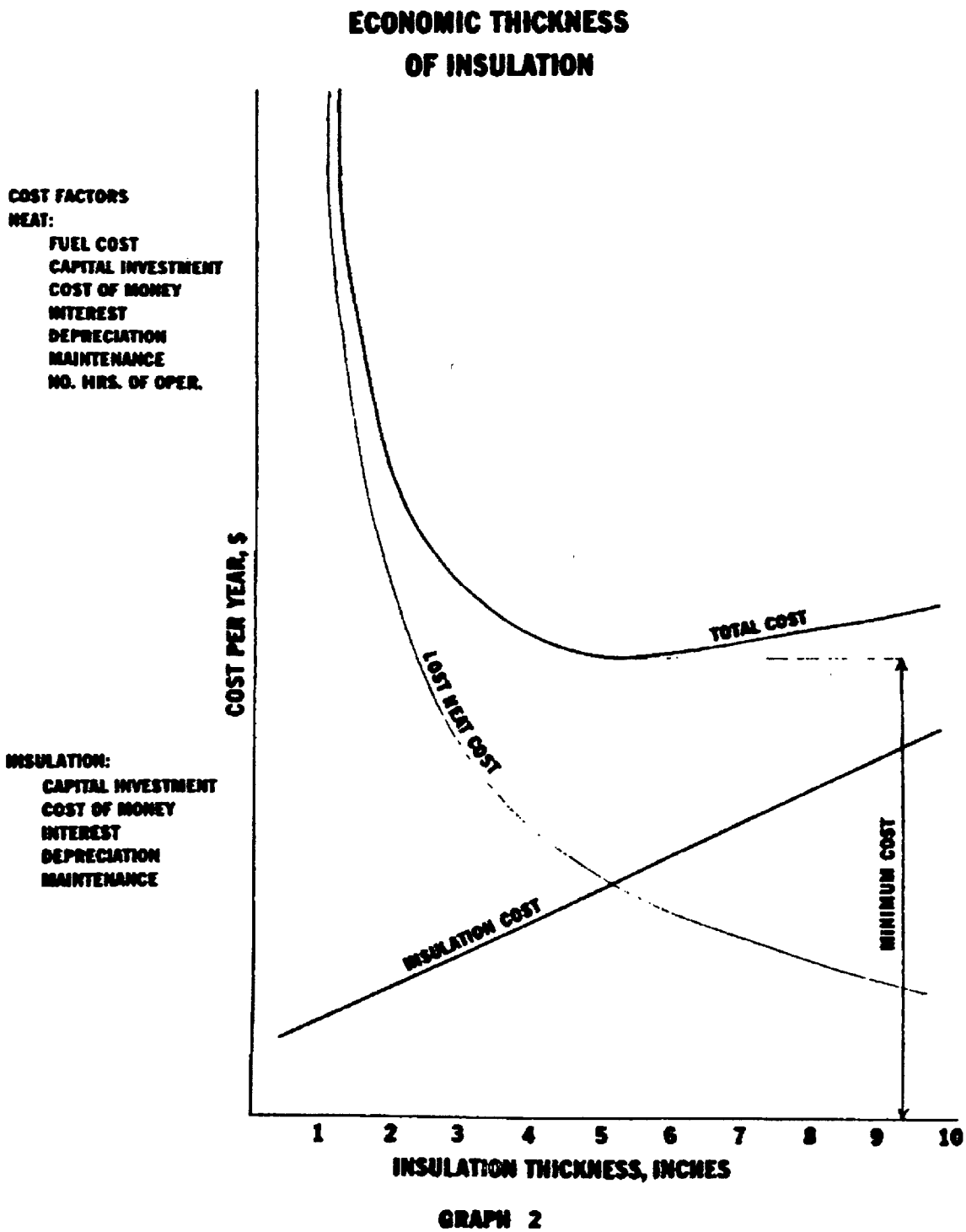
Depreciation period -- 15 years

With no insulation at all, the heat loss would be 2,841 Btu per hour, per linear foot of pipe. (The heat contained is 2.36 lb of steam per hour.) To produce this lost heat, a capital investment for steam production would have been $28.32. The cost to produce this heat would be $6.25 per year.

By calculating costs based on the information given, the following table is obtained.

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PURPOSE

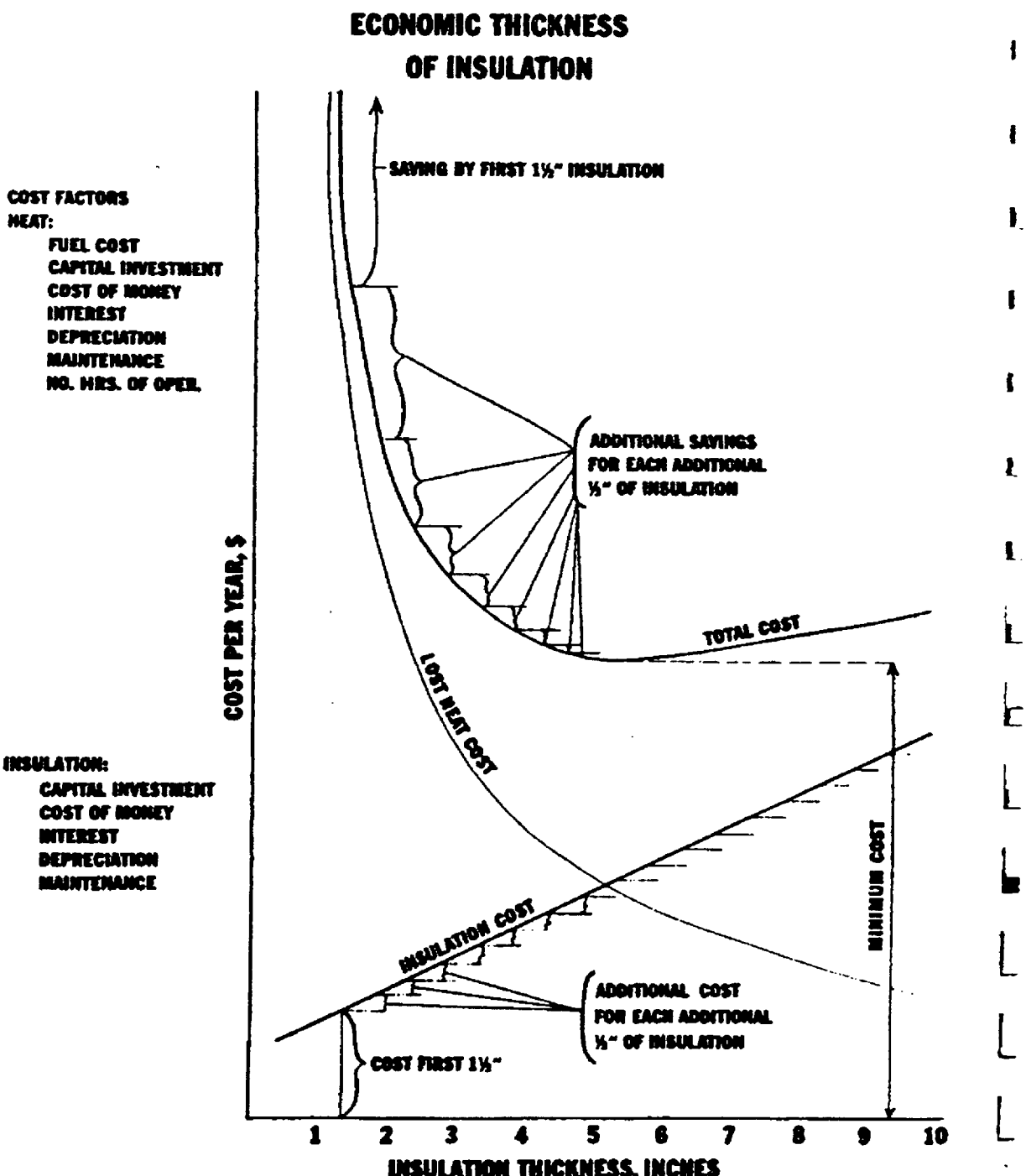


GRAPH 2

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PURPOSE



UCC 002668

GRAPH 3

PURPOSE

ECONOMICS - Contd

Insulation Thickness Inches	Capital Investment to Provide Steam for Heat Loss $	Capital Investment in Insulation $	Total Capital Investment $	Yearly Cost of Heat $	Additional Cost for Each Added ½ inch of Insulation $	Fuel Savings for Each Added ½ inch of Insulation $/Year
Bare	28.32	None	28.32	6.25		
1½	2.57	3.30	5.87	0.58		
2	2.10	4.10	6.20	0.46	0.33	0.12
2½	1.74	4.84	6.50	0.36	0.38	0.10
3	1.52	5.90	7.42	0.30	0.92	0.03

The lowest capital investment would be if only 1½ inch insulation were used. But, with an additional investment of $0.33 to obtain 2-inch thickness, a saving of $0.12 per linear foot is obtained. The increased capital cost to obtain 2½ inch thickness over 2-inch thickness is $0.33 and a saving of $0.10 per linear foot is obtained. This is still a good investment.

When the thickness is increased from 2½ inches to 3 inches, the capital cost increase is $0.92 and the savings if $0.003 per year. This is not considered a good investment. Thus, 2½ inch thickness is the correct thickness.

In the absence of compelling reasons otherwise, the economic thickness determines the insulation thickness. This is not always as easy as one might expect, as even within a single chemical unit the economic thickness may differ from one pipe to another, although all operate at the same temperature. The difference is caused by difference in cost of heat to be conserved. For example: heat caused by chemical reaction may have little value and might even be required to be dissipated. The cost of high pressure steam might be different from low pressure steam. Heat from a Dowtherm boiler is more expensive than steam. Electric heat or electrically heated Dowtherm is very costly energy. Good economy demands that each be insulated the correct thickness.

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PURPOSE

ECONOMICS - Contd

Although the "economic thickness" was given for high temperature service it applies equally well when units of cost are based on cost of refrigeration.

In both instances the calculations to determine economic thickness by McMillan's equation is quite time consuming. To make the determination simple, a manual of "How to Determine Economic Thickness of Insulation" was prepared by Union Carbide Corporation in cooperation with the Engineering Experiment Station, West Virginia University. This manual was later published by the National Insulation Manufacturers Association.

The specification of the correct insulation thickness is properly an engineering function, and may be considered of no particular interest to the field applicators. However, even the most careful engineering design is of no value until the insulation is correctly installed by competent craftsmen. Poor workmanship can completely ruin the economics obtainable by insulation. The knowledge as to the importance of insulation in saving money makes one understand the importance of skilled workmanship.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

The two fundamental types of thermal insulation are mass and reflective. Each of these is produced in a number of forms.

MASS INSULATION

Mass insulation is made of numerous mass structures. These are: fibrous, granular, flake, cellular.

Fibrous insulation is composed of fibers produced of many materials, some of which have similar characteristics and others possessing very different characteristics. Some of the fibers used in producing insulations are:

1. Refractory fibers
2. Lime or slag fibers
3. Glass fibers
4. Asbestos fibers
5. Cattle hair

The various fibers are bonded, felted, or woven together to produce various forms of materials. By variations in manufacturing methods and composition, a wide range of materials having different properties is produced.

Granular insulation consists of small nodules which contain voids or hollow spaces. They are not considered true cells, since gas (air) can be transferred between the individual spaces. The following materials fall within this classification:

1. Calcium-silicate
2. Diatomaceous earth
3. Expanded silica
4. Open cell plastics
5. Vegetable cork

In production of calcium-silicate, diatomaceous earth and expanded silica products, fibers are frequently added to improve the tensile strength of the material. However, the major amount of material resisting heat flow is thegranular material.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

MASS INSULATION - Contd

Cellular insulation consists of small individual cells sealed from each other. Their major difference is that each cell is hermetically sealed from all others. The materials which fall within this classification are:

1. Cellular glass
2. Cellular plastics

The fact that a material is cellular does not mean that no gas can pass from cell to cell. Gas will pass through many plastics; thus, there can be an interchange of gas through the walls of the cells of cellular plastic insulations.

Flake insulation consists of small leaflike pieces. The material, of this description, most commonly used for insulation is vermiculite.

Combination of these basic materials to produce an insulation of specific properties is quite common. Granular material is used as bonding agent for fibrous and flake material. Fibers are added to granular material to increase tensile strength. Therefore, in many instances, a finished product can only be classified by the material which is its major component.

Forms of Mass Insulation

These insulations are produced in many forms. Some of them are:

1. Rigid board, block, and pipe covering.
2. Semi-rigid board, block and pipe covering.
3. Flexible board and preformed pipe covering.
4. Blankets.
5. Felts.
6. Loose.
7. Tape.
8. Rope.
9. Cloth.
10. Paper.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

MASS INSULATION - Contd

Other insulations are produced in one form and after application change into rigid material. These are:

1. Insulating or finishing cement made of fibers, grandules, or flakes with binders, in loose form. When mixed with water to proper consistency, it is applied to surfaces by trowel or palm. Sets to a rigid form after it has dried.

2. Fibers and binders made in bulk form. The fibrous mixture is applied to the surfaces to be insulated by spray gun, which adds water to the mixture. The sprayed plastic mix dries to form a rigid material.

3. Insulation mastics are fibers, flakes, or granules of insulation factory mixed with binders and liquids to a heavy plastic consistency. Application to surface is by trowel, palm, spray or brush. After the material has dried it becomes a firm semi-rigid mass.

4. Sprayed organic foam consists of two (or more) liquids. When the components are mixed together by spray gun or mixer, then applied, the chemical reaction causes a foaming action. After reaction is complete the resultant mass is a cellular, organic, rigid insulation.

5. Bulk bituminous granules, which are poured into cavities, generally in trenches around underground pipe. After heat curing, the granules harden into a rigid mass.

REFLECTIVE INSULATION

Reflective insulation is composed of parallel thin sheets, or foil, of high thermal reflectance, spaced to direct radiant heat back toward the source. The spacing is also designed to provide restricted air (or gas) spaces. This reduces heat transfer by convection and conduction. In most instances, the thin metal sheets, or foil, are made of aluminum or stainless steel.

Forms of Reflective Insulation

Reflective insulation may be installed as part of building construction by the installation of sheets or foil in walls or ceilings. In this case the material comes in rolls or sheets and is field applied with other construction materials to form insulation.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

REFLECTIVE INSULATION - Contd

Reflective insulation is also obtainable in preformed pipe covering and panels to fit vessels and equipment. This is a rigid factory assembly. Because of the fact that these assemblies are factory produced to fit the pipe configuration and individual equipment, most are custom made to fit the piping or equipment to which they are installed.

A third form of reflective insulation is flexible insulation. Although a few years ago one manufacturer devised a reflective lining for overcoats, there has been relatively little development in flexible reflective insulations until very recently. However, the space agency has developed insulation suits using light-weight reflective insulation as the principal thermal resistance. This same development is also being used to make special suits for fire fighters.

Combination of Types of Insulation

Sheets of reflective insulation are used with light density fiber insulation. In such an arrangement the fiber material acts as the spacer for the reflective insulation and also provides resistance to heat flow by its low conductivity and causes resistance to convective air movement. The amount of surface contact between the reflective insulation and the mass insulation must be kept to a minimum to ensure effectiveness of the reflector.

Use of Vacuum in Insulation

Both mass insulation and reflective insulation are much more effective if in a vacuum. This is due to the fact that air, and all other gases, does conduct heat. In the field of cryogenics, insulation in vacuum is commonplace. The use of vacuum to obtain effective insulation is not new. At the early part of this century, Sir James Dewar invented a container with an evacuated space between the two silvered walls. This is called the Dewar flask and is now commonly known as the "Thermos" bottle.

Using this same principle, insulation for low temperature gases is installed in evacuated wall spaces. Sometimes the space is filled with powders and other times with reflective sheets separated by layers of glass mat or cloth. This latter system was devised by Linde and is named "Superinsulation."

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS

From the number of types, forms and varieties of insulation material, it is evident that there must be considerable differences in the properties of these materials. This being so, it becomes important to understand the properties of these materials in order to select the one which will satisfactorily serve for a given installation.

Some of the properties are of a nature which can be tested and numerically evaluated. Others, although no less important, cannot be so evaluated. Some of the latter are:

1. Availability.
2. Price.
3. Shape and sizes available.
4. Straightness and squareness, or trueness.
5. Smoothness of surface.
6. Cutting characteristics.
7. Dust hazard-health.
8. Compatibility with adhesive or cement.
9. Compatibility with coating (weather barrier).
10. Speed and cost of fabrication.
11. Speed and cost of installation.
12. Cost of shipping, handling and storage.
13. Efficiency of packaging.

Some of the items will, in the future, have methods of testing by which they can be evaluated. These are straightness and squareness, trueness, smoothness, cutting characteristics, and compatibility with adhesives, cements or coatings. Other items such as availability, price, size and shape available are related to procurement and are constantly changing, thus requiring periodic reevaluation. In addition, other factors such as cost and speed of fabrication must also be considered.

The workability of material is a property which cannot be evaluated, at present, by technical test methods. Thus, these properties and factors although difficult to measure or evaluate, are important and must be considered.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

The physical, chemical, moisture and thermal properties are:

1. Abrasion resistance.
2. Alkalinity, pH
3. Capillarity.
4. Combustibility
   a. Flash point
   b. Flame point
   c. Self-ignition point
   d. Flame spread index
   e. Smoke index
   f. Fuel contribution
   g. Melting point
5. Corrosion - rusting of carbon steel or other metals.
6. Corrosion - stress corrosion of stainless steel.
7. Cracking - hot surface.
8. Density.
9. Dimensional stability.
10. Dusting.
11. Drop resistance.
12. Elongation.
13. Expansion coefficient.
14. Hardness.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

15. Hydroscopicity.

16. Resistance to acids.

17. Resistance to caustics.

18. Resistance to solvents.

19. Shrinkage - heat.

    a. Linear
    b. Volumetric

20. Solvent absorption.

21. Specific gravity.

    a. Real
    b. Apparent

22. Strength.

    a. Breaking
    b. Compressive
    c. Flexural
    d. Shear
    e. Tensile

23. Temperature limits, minimum and maximum.

    a. Continuous
    b. Short periods
    c. Cyclic

24. Temperature rise - self internal heating.

25. Thermal conductivity.

26. Thermal diffusivity.

27. Thermal shock resistance.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Cont'd

28. Vibration resistance.

29. Warpage - in service.

30. Water absorption.

31. Water vapor transmission.

Materials which are installed in a wet state, such as cements or mastics, have all the above listed properties as dry materials, but in addition have the following:

1. Adhesion

    a. Wet
    b. Dry

2. Shrinkage - wet to dry

    a. Linear
    b. Volumetric

Organic foams applied in wet state have the property of swelling or as follows:

1. Expansion - wet to cured

    a. Linear
    b. Volumetric

All these properties relate to the properties necessary for a material to be purchased, shipped, stored, fabricated, installed and ability to function properly in service.

Because these terms are those which describe materials, it is essential that the meaning of each is clear and the significance of each is understood. In conversation, or written communication, problems related to materials must be discussed in these terms. For this reason the definition of each and the significance follows.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Abrasion resistance, the ability of a material to resist wearing away when rubbed by another material.

Significance: Whenever insulation is installed on a pipe or vessel which vibrates or moves, the insulation must be able to withstand the rubbing of the metal without wearing away. On the other hand, many materials are formed by the use of abrasive materials which rapidly grind the surface to the desired contour. Almost all insulations can be abraded away. The problem is to obtain the degree of abrasion resistance desired. To illustrate: Wood can be abraded away relatively rapidly by sand or garnet paper, but is very satisfactory when used in floors or furniture, particularly when protected with a wear-resistant finish such as varnish.

Alkalinity (pH), A relative value of soluble caustic contained in the material.

Significance: A reference to indicate insulation materials which may be applied to metals without causing corrosion. Insulations slightly alkaline are suitable for carbon steel; whereas, they should be slightly acid when applied to aluminum.

Capillarity, the action by which the surface of a liquid, where it is in contact with a solid, is elevated due to the relative attraction of the molecules of the liquid for each other and for those of the solid.

Significance: This is a measure of liquid transfer through insulation. Should one water leak occur in installed insulation, a high rate of capillarity spreads the water damage.

Combustibility, the capability of burning.

Significance: This property is vital in determining fire hazard. Measurement of degree of combustibility is quite difficult as there are many aspects to fire, fire spread and release of gases and smoke. For this reason these various aspects of fire given below we re separated for tests and evaluation.

Flash point is the temperature at which the vapors from a material at that temperature will flash into flame when ignited from an external fire source.

Flame point is the temperature at which the vapors will flash and continue to burn when the ignition source is removed.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Self ignition point is the temperature at which a material will begin to burn without an external ignition source.

Flame spread index is the rate at which fire will spread from its original burning point.

Smoke index is the measurement of the density of smoke given off when a material burns.

Fuel contribution is the amount of heat given off by a material when it is burned.

Melting point is the temperature at which a material changes from a solid to a liquid state.

Corrosion, rusting of carbon steel, or erosion of other metals by chemical action.

Significance: If the insulation causes rusting or corrosion of metals to which it is applied, failure of the pipe or equipment may occur.

Corrosion - stress, of austenitic stainless steel, is deterioration of austenitic stainless steel due to attack of chloride ions.

Significance: The stress corrosion cracking takes place in the presence of concentrated chloride ions. Moisture absorbed by the insulation from the atmosphere, or from rain, will cause leaching of chloride contained in the insulation. To prevent this type of pipe or equipment failure, either the stainless steel must be protected, or insulation used which does not cause the stress cracking. Insulation, when used on stainless steel, should be tested to determine if it will cause this corrosion.

Cracking - hot surface, is the cracking of the insulation on its face next to a hot surface to which it is applied.

Significance: Excessive hot cracking on the surface reduces the strength of insulation and causes a loss in its efficiency.

Density is the weight per cubic foot.

Significance: Must be known to figure loading of supports, etc.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Dimensional stability, is the ability of a material not to change in dimension in respect to time or temperature.

Significance: This is generally considered to be change beyond ordinary change due to expansion. Excessive shrinkage, swelling or warping, will cause excessive cracks and voids with resultant greater heat transfer.

Dusting, is the release of particles from insulation material as it is handled or cut.

Significance: Dust particles are an annoyance and may be a health hazard.

Drop resistance, is the ability of a material to fall on a hard surface without chipping or cracking.

Significance: In shipment, handling and application, this property affects the amount of rejected broken material.

Elongation, the ability of a material to stretch without fracture.

Significance: Insulation, especially in high temperature service, is applied to metal surfaces that expand and contract. The ability of insulation to elongate under tension reduces its tendency to fracture.

Expansion coefficient is the unit change in dimension due to a unit change in temperature.

Significance: This property of an insulation material establishes the relationship of its change in dimension in reference to other materials of construction. It is necessary to know the value of the coefficient of expansion to calculate problems related to spacing, and expansion joints.

Hardness, the resistance of insulation penetration.

Significance: This physical property is often ignored in the insulation industry because of wide range of surface hardnesses of various insulations. In some services a hard surface is needed, while in others a soft surface is desired.

Hydroscopicity, the amount of moisture a material will absorb when exposed to damp air or gas.

Significance: The amount of moisture contained in insulation affects many of its other properties including its thermal conductivity.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Resistance to acids,
Resistance to caustics,
Resistance to solvents, — The ability to resist the chemical action, or destruction.

Significance: All materials can be destroyed by various acids, caustics, or solvents. Thus when insulation may be subjected to any of these, it should be determined which insulation will resist the particular contaminate involved.

Shrinkage - heat, the amount of dimensional change due to being subjected to maximum temperature for which the insulation is used. This change is both linear and volumetric.

Significance: Shrinkage is the major cause of cracks in high temperature insulation.

Solvent absorption: The amount of solvent, (or acids or caustics) that a material will retain after being wetted and allowed to drain. The amount of these liquids which a material will retain may be quite different, especially as compared to water.

Significance: The amount of liquid a material will take up or hold constitutes a safety hazard or fire hazard.

Specific gravity, the weight of material as compared to water. As most insulations contain many voids of trapped air or gas, the apparent specific gravity is the weight of the insulation, including all voids, as compared to the same volume of water. The real specific gravity is the weight of the solids only as compared to the same volume of water.

Significance: The differences of these indicate the amount of air or gas space contained in the insulation. It should be noted that from the apparent specific gravity given for most insulations, it might be assumed that they would float on water. However, in mass cellular insulation water can replace the air and if the real specific gravity of the solids is greater than 1.0 the mass will sink.

Strength, the ability of material to resist forces. Strength is a combination of abilities to resist many types of forces. These are breaking, compressive, flexural, shear and tensile.

Breaking strength is the ability of a material to resist a transverse load.

Compressive strength is the ability of a material to resist a pressing or squeezing load.

Flexural strength is the ability of a material to resist a bending load. Conversely, flexibility is the property to be able to be bent without fracture.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Shear strength is the ability of a material to resist a slicing load.

Tensile strength is ability of a material to resist a pulling load.

Significance: The particular combination of these various strengths is what makes one material more suitable to fulfill a given set of physical requirements than another.

Temperature limits, the minimum and maximum temperature beyond which the insulation will not give satisfactory service. These temperature limits are affected by the time of subjection to temperature and by the rate of change of temperature; therefore insulation temperature limits are rated as continuous temperature, short period temperature, cyclic temperature.

Significance: When insulations are subjected to temperatures beyond their limit, they fail mechanically, thermally or chemically.

Temperature rise - self internal heating, the characteristic of some materials, which when heated, experience an internal combustion reaction, with a resultant internal temperature rise well above that of the heat to which it was subjected.

Significance: This most often ruins the insulation and might ruin the surface to which it is applied. In some instances it might cause serious accidental fire.

Thermal conductivity, the heat flow rate per unit of area, per degree, unit of length and time.

Significance: The basic measure of heat transfer, used in calculation of heat flow, economics and temperature determinations. The lower the conductivity the more efficient an insulation is in reducing heat flow.

Thermal diffusivity, the temperature flow rate per unit of area per degree unit of time.

Significance: This property is that which determines the rate of "heat-up" or "cool-down". Materials used in cyclic operation most generally require a material of high diffusivity; whereas, materials used for fire protection should be of very low diffusivity.

Thermal shock resistance, the ability of a material to withstand rapid change in temperature without cracking or spalling.

Significance: Very important property for materials subjected to thermal shock or direct fire impingement.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

Vibration resistance, the ability of a material to resist oscillating motion.

Significance: Many applications of industrial insulation are to surfaces that vibrate. If the material breaks down, packs, or settles because of vibration, it becomes ineffective as a thermal insulator.

Warpage resistance, the ability of a material to maintain its trueness of dimension after subjection to the effects of time, and high or low temperature.

Significance: Warpage of insulation in service causes cracks and openings between the fitted insulation blocks or pipe covering. In addition it may cause failure in the weather barriers.

Water absorption, the amount of water that a material will retain after being wetted and allowed to drain.

Significance: The amount of water an insulation will take up and hold directly affects its conductivity.

Water vapor transmission, the rate of water vapor (moisture in gaseous state) movement of a body between two specified parallel surfaces, under steady conditions, through unit area, for a unit time.

Significance: This is the most important factor for insulations used in low temperature service. As vapor penetrates the insulation, it is likely to condense into liquid water and increase the conductivity of the insulation.

In addition to the properties related to insulations installed in the dry state, the properties related to insulating cements that need to be defined are:

Adhesion, the ability of a material to stick to a surface. In water-mixed cements and mastic, this ability to stick may be different when it is wet and plastic than when it is dry and in solid state.

Significance: Good adhesion is necessary in the wet state for ease of application and sufficiently good adhesion is necessary in the dry state to keep the material from falling off or parting from the substrate.

Shrinkage, wet to dry, the difference in volume and dimension from wet to dry state.

Significance: The amount of shrinkage affects the amount of insulation applied to obtain that desired. Excessive shrinkage may cause cracks and loss of adhesion.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF INSULATION MATERIALS - Contd

The preceding items are the terms used to describe insulation materials and their properties. In many, test methods have been devised which are used to establish numerical values for these properties. An engineer must use these numerical values to design and specify insulation materials. However, these properties are frequently described in general terms. To illustrate, assume one rigid insulation was described as having a compressive strength of 50 psi and another of having a compressive strength of 125 psi. For design purposes, the numerical values must be used. For general communication, it could be stated that the first had fair compressive strength whereas the second had excellent compressive strength.

To promote understanding between engineering and field erection, it is essential that both use these terms when describing materials.

TABLES OF PROPERTIES OF VARIOUS INSULATIONS

Each particular insulation has its individual physical and thermal properties. The difference in properties of one material as compared to others is what determines its particular usefulness in particular service requirements. There is no one material which is the best for all service requirements. Thus each set of service requirements must be evaluated and the material (or materials) most suitable should be selected.

In most instances selection of the materials for a particular set of services is a responsibility of the design engineer. However, in some cases, such as emergencies, the insulation applicator may be forced to make a material selection.

In this training course, it is impossible to present all the technical facts concerning all insulation materials but it is certainly desirable for the applicator to have some of the basic facts of the most commonly used insulations. For this reason tables presenting some of the basic physical and thermal properties of insulations commonly used in industrial insulation has been prepared.

These tables have been tabulated in reference to the types and forms of the insulation. Included are Rigid and Semi-Rigid, Flexible, Blanket, Loose and Fill, Cements, Sprayed or Foamed In Place, Reflective, and Cryogenic Vacuum insulation. Such forms as Tape, Rope, Cloth, Paper has not been covered as it was felt that these were very specialized.

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PROPERTIES OF THERMAL INSULATIONS

RIGID AND SEMI-RIGID

TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

GENERIC TYPE	FORM	MAX. TEMP. LIMIT °F	DENSITY LBS/CU. FT.	COMBUSTIBILITY FLAME SPREAD	COMPRES. STRENGTH LBS/SQ. IN.	WATER ABSORP. % VOL.	WATER VAP. TRANS. PERM-IN	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN. TEMP.
Asbestos Fiber	Blk. & P.C.	1200	10 to 16	Non-Comb.	12.5 at 5%	84	Very High	100F, .32:300F, .42:500F, .52
Calcium Silicate	Blk. & P.C.	1200	10 to 13	Non-Comb.	110 at 5%	90	Very High	100F, .33:300F, 41:500F, .51
Calcium Silicate, Hi-Temp.	Blk. & P.C.	1800	10 to 14	Non-Comb.	100 at 5%	90	Very High	100F, .45:500F, .64:800F, .8
Diatomaceous-Silica	Blk. & P.C.	1600	21 to 24	Non-Comb.	65 at 5%	85	Very High	300F, .61:500F, .64:100F, .74
Diatom.-Silica, Hi-Temp.	Blk. & P.C.	1900	24 to 36	Non-Comb.	75 at 5%	83	Very High	300F, .67:500F, .71:100F, 82
Diatom-Silica & Asbestos	Board	1200	23	Non-Comb.	800 at 10%	75	16.0	300F, .59:500F, .61:100F, .67
Diatom-Silica & Asbestos	Board	1200	36	Non-Comb.	1500 at 10%	70	8.0	300F, .78:500F, .80:1000F, .86
Diatom-Silica & Asbestos	Board	1200	65	Non-Comb.	2500 at 10%	55	8.0	300F, 1.80:
Glass-Cellular	Blk. & P.C.	800	7 to 9.5	Non-Comb.	100-Ult.	0	0.0000+	100F, .39:300F, .55
Glass-Fiber-Organic Bind.	Board	450	1 to 12	Fl.SP. 25(1)	0.2 to 4.0	90 to 93	Very High	100F, .22 to .31:300F, .34 to .6
Glass-Fiber-Organic Bind.	P.C.	450	4 to 7.5	Fl.SP. 25(1)	1 to 3 at 10%	90 to 93	Very High	100F, .26 to .3:300F, .33 to .38
Glass-Fiber-Inorganic Bind.	Board	1000	3 to 3.5	Fl.SP. 25(1)	1 to 3 at 10%	93	Very High	100F, .26:300F, .4:500F, .54
Mag. Carbonate-Asb. Fibers	Blk. & P.C.	600	11 to 13	Non-Comb.	50 at 10%	90	Very High	100F, .36:300F, .43
Mineral Fiber-Inorganic Bind.	Blk.	1800	15 to 18	Non-Comb.	2 to 18 at 10%	85	Very High	200F, .36:500F, .42: 700F, .51
Mineral Fiber-Inorganic Bind.	Blk.	850	4 to 12	Non-Comb.	1 to 1.2 at 10%	85 to 93	Very High	200F, .32:500F, .50
Perlite Glass Fibers - Bind.	Blk. & P.C.	1200	9.5 to 11.5	Non-Comb.	80 at 5%	Repellent	18	100F, .34:500F, .52:1000F, .80
Polystyrene-Molded Beads	Blk. BD.P.C.	165	1	Combustible	6 to 8 at 5%	2.5	3	100F, .27
Polystyrene-Cell. Foam	Blk. BD.P.C.	165	1.5 to 3.3	Combustible	10 to 30 at 5%	0.1 to 1.3	0.5 to 2.0	100F, .25
Polyurethane	Blk. BD.P.C.	220	1.4 to 5.0	Combustible	16 to 80 at 5%	1.5 to 3.0	1.5 to 2.0	100F, .19
Refractory-Cell. Foam	Blk. & P.C.	1000	8	Non-Comb.	60	0.1 to 0.3	0.04	40F, .38, 75F, .04
Rubber Resin Foam	Blk. BD. P.C.	220	5 to 8	Combustible	40 at 10%	1.5 to 3.0	0.1 to 0.4	100F, .29
Vinyl Chloride Foam	Blk. BD. P.C.	220	1.5 to 3.0	Combustible	30 to 50 at 5%	1.0 to 1.5	1.1 to 1.0	100F, .19

ABBREVIATIONS

BLK - Block: Bd. - Board: P.C. - Pipe Covering
Fl.SP. - Flame Spread

(1) Flame Spread Index based on White Oak having an idex of 100. An index below 100 has a lesser flame spread, and above 100 a greater flame spread than White Oak. Most building codes will not allow any materials to be used with an index greater than 25.

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF THERMAL INSULATIONS

FLEXIBLE

GENERIC TYPE	FORM	MAX. TEMP. LIMIT °F	DENSITY LBS/CU. FT.	COMBUSTIBILITY FLAME SPREAD	COMPRES. STRENGTH LBS/SQ. IN.	WATER ABSORP. % VOL.	WATER VAP. TRANS. PERM-IN	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN TEMP.
Asbestos Braided Cloth Filled with Glass Fibers	Seamless Tube	500	10 to 14	Non-Comb.		80 to 90	Very High	100F, .57:300F .62
Glass Fiber & Organic Binders in Various Facings	Roll	400	0.6 to 1.5	Flame Spread Less Than 25	0.01 to 0.2 at 10%	95	Very High	100F .32:200 .42
Glass Fiber & Organic Binders in Various Facings	Sheets	400	1.5 to 4.0	Flame Spread Less than 25	.03 to .5 at 10%	93	Very High	100F .26:200F .32
Polystyrene Cellular Foam -	Roll	165	0.9 to 1.2	Combustible	7. at 10%	1	1.0 to 2.4	100F .27
Rubber Resin Cellular Foam	Sheet & P.C.	220	5 to 11	Combustible		.9 to 1.2	0.2 to 0.4	100F .27

BLANKETS, FELTS OR BATTS

GENERIC TYPE	FORM	FACINGS	MAX. TEMP. LIMITS °F	DENSITY LBS/CU.FT.	COMBUSTIBILITY OR FLAME SPREAD	WATER ABSORP. %	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN TEMP.
Alumina-Silica and Binders	Bln. Felt	None	2300	3 to 6	Non-Comb.	90 to 95	500F .36:800F, -.62:1200F .97
Asbestos Fibers	Blanket	None	750	9 to 12	Non-Comb.	90	200F .50:400F .61:800F .78
Asbestos Woven Fibers	Felt	None	750	10	Non-Comb.	90	200F .50:400F .62:800F .72
Glass Fibers	Batts	Foil & Others	200	.62 to 2	Less than 25	90 to 95	100F .31
Glass Fibers - Organic Binder	Blanket	Foil & Craft	200 to 450	.6 to 3	Less than 25	90 to 95	100F .24 to .32:200F .29 to .42
Glass Fibers	Blanket	Nettings	1000	2.4 to 6	Non-Comb.	85 to 95	100F .25:300F .40:500F .61
Glass Fibers - Felted	Felt	None	1100	6 to 8	Non-Comb.	85 to 95	200F .28:500F .41:800F .55
Glass Fibers - Needled	Matt	None	1200	6 to 11	Non-Comb.	85 to 95	300F .36:500F .41:800F .52
Mineral Fibers	Blanket	Nettings	1200	6 to 8	Non-Comb.	85 to 95	100F .25:300F .39:500F .54
Mineral Fibers with Binders	Blanket	None	450 to 600	3 to 9	Less than 25	9.0 to 96	100F .24 to .28:300F .34 to .50

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF THERMAL INSULATIONS

INSULATING AND FINISHING CEMENTS

GENERIC TYPE	USE	SETTING	TEMP. LIMITS °F	COMBUSTIBILITY OR FLAME SPREAD	DENSITY LBS/CU. FT.	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN TEMP.
Alumina-Silica-Semi Refractory	Insulating	Hydraulic	2000	Non-Comb.	48 to 70	600F 1.42:800F 1.52:1200F 1.76
Alumina-Silica, Asbestos and Bind	Insulating	Air Dry	1900	Non-Comb.	54 to 56	200F 1.6
Asbestos and Bonding Clays	Insulating	Air Dry	1000	Non-Comb.	25 to 60	200F 2.1
Asbestos (Long Fibers) and Bind	Finishing	Air Dry	1000	Non-Comb.	40 to 70	200F 1.5
Asbestos (Long Fibers) and Clays	Finishing	Air Dry	1000	Non-Comb.	40 to 55	200F 2.1
Asbestos and Special Binders	Finishing of Water Repel. Insul.	Air Dry	1000	Non-Comb.	50 to 60	200F 1.2:400F 1.4
Calcium Silicate	Insulating & Finishing	Air Dry	1200	Non-Comb.	19 to 22	100F .4:500F .57 800F .74
Diatomaceous Silica and Binders	Insulating	Air Dry	1900	Non-Comb.	18 to 30	200F .75:500F .82 1000F .94
Magnesia Carbonate and Asbestos	Finishing	Air Dry	600	Non-Comb.	15 to 20	100F .48: 300F .54
Mineral Fibers and Binder	Insulating	Air Dry	1500	Non-Comb.	18 to 24	100 F .49:500F .81:800F 1.06
Mineral Fiber and Bind (High Adhesion)	Insulating & Finishing	Hydraulic	1200	Non-Comb.	40 to 45	200F .70:300F .81:500F .92
Mineral Fiber, Asbestos, and Bind	Insulating & Finishing	Hydraulic	1400	Non-Comb.	30 to 42	200F .80:300F .90 500F 1.00
Vermiculite and Binders	Insulating	Air Dry	1800	Non-Comb.	15 to 20	200F .74:500F .88:1000F 1.11

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF THERMAL INSULATIONS

LOOSE AND FILL

GENERIC TYPE	FORM	MAX. TEMP LIMIT °F	DENSITY LBS/CU. FT.	COMBUSTIBILITY OR FLAME SPREAD	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN TEMP.
Alumina-Silica - Short Fibers	Bulk Fibers	2300	3 to 6	Non-Comb.	700F .8:1000F 1.22:1200F 1.55
Alumina-Silica - Long Fibers	Bulk Fibers	2300	3 to 6	Non-Comb.	700F .7:1000F 1.2:1200F 1.6
Asbestos Fibers	Bulk Fibers	1000	20 to 50	Non-Comb.	100F .6 to 1.6
Cork, Vegetable	Granules	200	8 to 12	Comb.	100F .31
Diatomaceous -Silica	Powder	1600	20 to 31	Non-Comb.	500F .55 to .89:1000F .7 to 1.2
Diatomaceous-Silica, Calcined	Powder	2000	22 to 26	Non-Comb.	500F 1.0 to 1.08:1000F 1.37
Diatomaceous-Silica and Asbestos	Loose	1800	16 to 19	Non-Comb.	500 F .63:1000F .71
Gilsonite Granules	Granules	300 to 460	44 to 50	Comb.	100F .65 to .85
Glass Fiber, Unbonded	Shredded	1000	2 to 12	Non-Comb.	100F .24:400F .45 to .51
Glass Fiber and Organic Binder	Wool	250	.5 to 1.5	Flame SPD. 25(1)	100F .30
Glass, Cellular	Pellets	800	6	Non-Comb.	100F .40
Gypsum	Pellets	800	12 to 20	Non-Comb.	100F .44 to 1.0
Lampblack	Powder	1200	5 to 18	Non-Comb.	100F .22 to .26
Mineral Fibers wi th Small Amount of Oil	Loose	1000	4 to 12	Flame SPD 25(1)	100F .28:500F .61
Mineral Fibers (Oil Free)	Loose	1200	6 to 15	Non-Comb.	200F .53:500F .7:800F .91
Mineral Fibers	Nodules	1000	6 to 7	Non-Comb.	100F .28:500F .61
Perlite, Expanded Spheres	Loose	1400	3	Non-Comb.	100F .27:200F .35
Silica	Fibers	1800	6 to 12	Non-Comb.	600F .4 to .66:1000F .75 to 1.25
Silica Aergel	Granules	1300	4 to 5.5	Non-Comb.	0F .17:100F .21
Vermiculite	Flakes	2000	5 to 10	Non-Comb.	100F .44:500F .8:1000F 1.32

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TYPES AND FORMS

PHYSICAL AND THERMAL PROPERTIES

PROPERTIES OF THERMAL INSULATIONS

SPRAYED, FORMED OR FOAMED IN-PLACE

GENERIC TYPE	MAX. TEMP LIMIT °F	DENSITY LBS/CU.FT.	COMBUSTI-BILITY OR FLAME SPREAD	COMPRES. STRENGTH LBS/SQ. IN.	WATER ABSORP. % VOL.	WATER VAP. TRANS. PERMS	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT LISTED MEAN TEMP.
Asbestos Fibers (Amosite) with Binders - Spray Mix	750	8 to 13	Non-Comb.	5 at 5%	85 to 95	Very High	100F, 0.34:500F, 0.52
Asbestos Fibers (Crocidolite) with Binders - Spray Mix	1350	8 to 15	Non-Comb.	1.5 at 5%	85 to 95	Very High	100F, 0.34:500F, 0.52
Bituminous Material with Cork or Mica (Spray or Trowel)	200	40 to 50	Comb.		10 to 20	Moderate	100F, 0.90
Ceramic Fiber and Binder Spray Mix	2200	12 to 13	Non-Comb.	0.6 at 5%	90 to 95	Very High	500F, 0.46:1000F, 0.64
Mineral Fiber-Granuals - Asbestos and Binders	1800	11 to 15	Non-Comb.		90 to 95	Very High	100F, 0.32:500F, 0.51
Polyvinyl Acetate and Cork Granuals (Spray or Trowel)	170	35 to 45	Less than 25		10 to 20	Moderate	100F, 0.69
Polyurethane 2 Part Mix Sprayed as Liquid Foams	220	1.6 to 3	Comb.	15 at Yield	0.1 to 0.5	1.5 to 3.0	100F, 0.18

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PROPERTIES OF THERMAL INSULATIONS

PREFORMED REFLECTIVE

GENERIC TYPE	FORM	MAX LIMITS °F	DENSITY (APPARENT) LBS/CU. FT.	COMBUSTIBILITY OR FLAME SPREAD	WATER ABSORP. % VOL.	THERMAL CONDUCTIVITY Btu/S.F., HR., IN., °F AT MEAN TEMP. LISTED
Stainless Steel Casing and Stainless Steel Reflective Sheets	Factory Fabricated to Fit Dimensions of Equipment or Piping Systems	1500	8 to 10	Non-Comb.	0	(Apparent) Varied to Suit Need
Stainless Steel Casing and Aluminum Reflective Sheets		1000	6 to 8	Non-Comb.	0	(Apparent) 100F .27, 500F .54
Aluminum Casing and Aluminum Reflective Sheets		1000	5 to 7	Non-Comb.	0	(Apparent) 100F .26, 500F .51

VACUUM-CRYOGENIC

GENERIC TYPE	CONSTRUCTION	NUMBER OF LAYERS	RECOMD. VACUUM ABSOLUTE PRESS. MICRONS OF Hg	DENSITY (APPARENT) LBS/CU.FT.	THERMAL CONDUCTIVITY (APPARENT) Btu/S.F., HR., IN., °F AT MEAN TEMP. LISTED
Aluminum Foil and Glass Mat	Mats Separating Foil Sheets	10 to 20	0.1	2.5	-200F 0.0018
Aluminum Foil and Glass Mat	Mats Separating Foil Sheets	15 to 30	0.1	2.0	-200F 0.00078
Aluminum Foil and Glass Mat	Mats Separating Foil Sheets	35 to 70	0.1	4.7	-200F 0.00024
Aluminum Foil and Glass Paper	Paper Separating Foil Sheets	50 to 100	0.1	5.5	-200F 0.00022
Aluminum Foil and Glass Paper	Paper Separating Foil Sheets	75 to 150	0.1	7.5	-200F 0.00012
Carbon-Silica	Mixture		2.0	8.0	-200F 0.0048
Perlite	Perlite Powder		2.0	8.0	-200F 0.00865
Santocel(R)	Santocel Powder		2.0	6.0	-200F 0.01150
Santocel(R) & Aluminum Powder	Santocel and Opacified Powder		2.0	10.0	-200F 0.00264
Santocel(R) & Copper Powder	Santocel and Opacified Powder		2.0	11.0	-200F 0.00270

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

FUNCTION OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS

Weather-barriers are materials which will resist the weather elements such as rain, sleet, snow, wind, solar radiation, and mechanical damage. Such materials are used to protect thermal insulation from these abuses. In addition, these materials may be required to assist in protecting insulation from fire and they also may be used to serve as pipe identification, color identification, or as a decorative surface. A listing of the fundamental functions which weather-barriers serve is:

1. Weather protection
2. Mechanical protection
3. Fire protection
4. Decoration

As explained in Chapter I, thermal insulation (with exception of reflective types) depends upon finely divided air (or gas) spaces to retard the flow of heat. These small spaces are formed by the flakes, fibers, or nodules of solids in the insulation, or they are formed by cells in the material itself. Each space must be sufficiently small to cause considerable resistance to air flow so that little heat can be transferred by air movement in the space itself. These small air spaces are essential to the ability of thermal insulation to effectively retard the flow of heat. When insulation becomes wet, or partly so, all or part of these air spaces become filled with water.

Heat transmission through water-filled spaces will approach the rate of conductivity of water instead of air. The conductivity of water at 70F means temperature is 4.7 Btu per sq ft per inch thickness, per degree temperature difference per hour as compared to 0.17 for air. Thus the increase of heat transmission through the spaces is increased by approximately 27 times. Therefore, from a completely dry to completely wet air, insulation will function at less than 5% of its thermal resistance efficiency.

Besides lowering the effectiveness of the thermal insulation, an additional heat loss occurs in drying out insulation once it becomes wet. As most insulations are quite absorptive, any water which does get into the insulation must be vaporized to drive it out. The heat required to vaporize one pound of water (at 212F) is approximately 1150 Btu. Expressed another way, each pint of water which may leak into insulation will require approximately 1200 Btu of heat to drive that water out of the insulation.

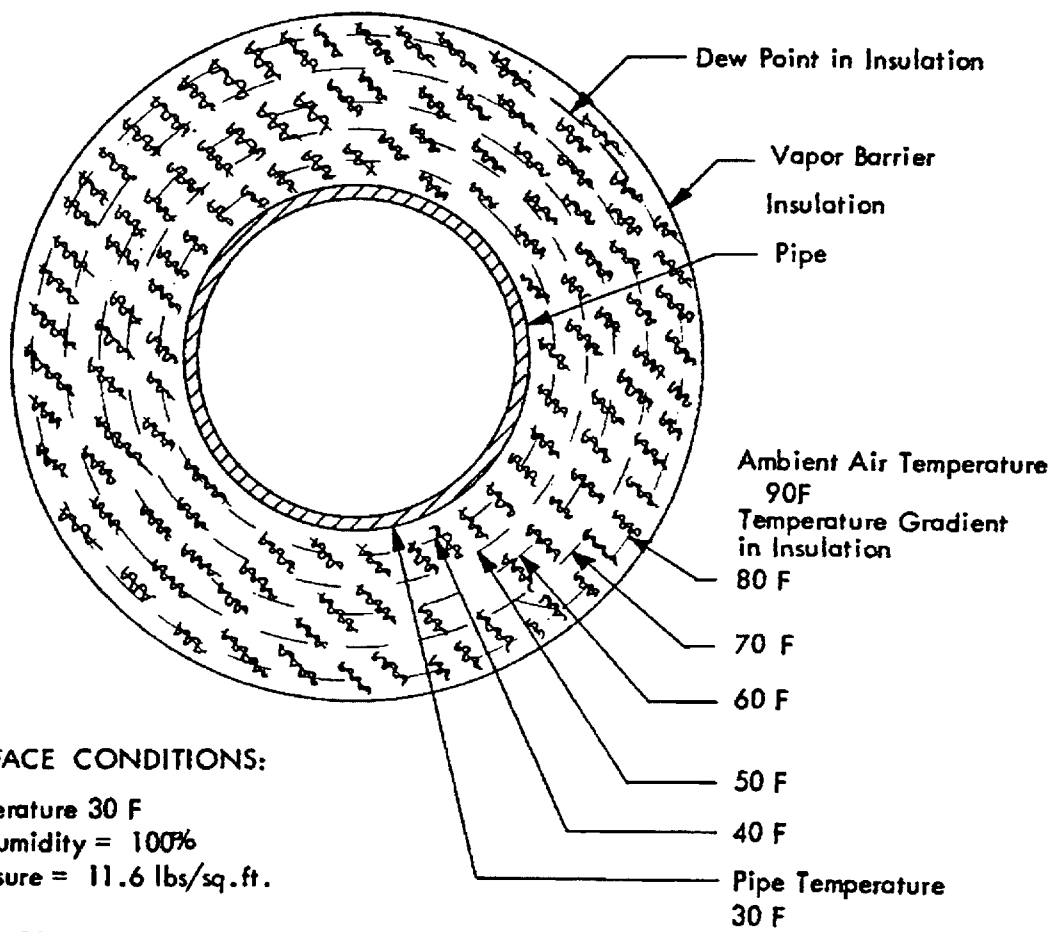
Because water leaks in insulation cause both of these losses of heat, it is necessary to have effective weather-barriers to keep the insulation dry.

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WEATHER-BARRIERS, VAPOR-BARRIER, COVERINGS

AMBIENT CONDITIONS:

Air Temperature = 90 F
Relative Humidity = 80 %
Dew Point Temperature = 83 F
Vapor Pressure = 77.8 lbs/sq. ft.



PIPE SURFACE CONDITIONS:

Pipe Temperature 30 F
Relative Humidity = 100%
Vapor Pressure = 11.6 lbs/sq.ft.

VAPOR PRESSURE DIFFERENCE =
Ambient vapor pressure minus pipe surface vapor pressure is 77.8 lbs/sq.ft minus 11.6 lbs/sq. ft. equals 66.2 lbs/sq. ft.

VAPOR PRESSURE DIAGRAM

Figure V-1

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

VAPOR PRESSURES
at 100%Relative Humidity

TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE	
°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.
-40	-40	.0029	.2758	32	0.0	.1803	12.752	77	25.0	.9352	66.147	134	56.7	5.03	355.77
-35	-37.2	.0052	.3678	33	0.6	.1878	13.283	78	25.6	.9666	68.367	136	57.8	5.30	374.87
-30	-34.4	.0070	.4951	34	1.1	.1955	13.827	79	26.1	.9989	70.652	138	58.9	5.59	395.38
-25	-31.7	.0094	.6648	35	1.7	.2035	14.393	80	26.7	1.032	72.993	140	60.0	5.88	415.89
-20	-28.9	.0126	.8912	36	2.2	.2218	14.981	81	27.2	1.066	75.398	142	61.1	6.19	437.82
-15	-26.1	.0167	1.181	37	2.8	.2403	15.582	82	27.8	1.102	77.944	144	62.2	6.51	460.45
-10	-23.3	.0220	1.556	38	3.3	.2652	16.211	83	28.3	1.138	80.490	146	63.3	6.85	484.50
-5	-20.6	.0289	2.044	39	3.9	.2883	16.855	84	28.9	1.175	83.108	148	64.4	7.20	509.25
0	-17.8	.0377	2.667	40	4.4	.2478	17.527	86	29.4	1.213	85.795	150	65.6	7.57	535.42
1	-17.2	.0397	2.808	41	5.0	.2576	18.220	86	30.0	1.253	88.625	152	66.7	7.95	562.20
2	-16.7	.0419	2.964	42	5.6	.2677	18.934	87	30.6	1.293	91.454	154	67.8	8.35	590.59
3	-16.1	.0441	3.119	43	6.1	.2782	19.677	88	31.1	1.335	94.452	156	68.9	8.77	620.30
4	-15.6	.0464	3.282	44	6.7	.2891	20.448	89	31.7	1.378	97.466	158	70.0	9.20	650.71
5	-15	.0488	3.452	45	7.2	.3004	21.247	90	32.2	1.422	99.578	160	71.1	9.65	682.54
6	-14.4	.0514	3.636	46	7.8	.3120	22.068	91	32.8	1.467	103.76	162	72.2	10.12	715.78
7	-13.9	.0542	3.869	47	8.3	.3240	22.916	99	33.3	1.513	107.01	164	73.3	10.61	750.44
8	-13.3	.0570	4.032	48	8.9	.3364	23.794	93	33.9	1.561	110.41	166	74.4	11.12	786.52
9	-12.8	.0599	4.237	49	9.4	.3493	24.706	94	34.4	1.610	113.87	168	75.6	11.65	824.00
10	-12.2	.0629	4.449	50	10.0	.3626	25.64	95	35.0	1.660	117.41	170	76.7	12.20	862.90
11	-11.7	.0661	4.675	51	10.6	.3764	26.623	96	35.6	1.712	121.09	172	77.8	12.77	903.22
12	-11.1	.0695	4.916	52	11.1	.3906	27.627	97	36.1	1.765	124.84	174	78.9	13.37	945.66
13	-10.6	.0730	5.163	53	11.7	.4052	28.659	98	36.7	1.819	128.65	176	80.0	13.98	994.41
14	-10.0	.0767	5.425	54	12.2	.4203	29.728	99	37.2	1.875	132.62	178	81.1	14.63	1034.78
15	-9.4	.0806	5.701	55	12.8	.4359	30.831	100	37.8	1.933	136.72	180	82.2	15.29	1081.46
16	-8.9	.0847	5.990	56	13.3	.4520	31.970	101	38.3	1.992	140.89	182	83.3	15.98	1130.26
17	-8.3	.0889	6.288	57	13.9	.4686	33.144	102	38.9	2.052	145.14	184	84.4	16.70	1181.19
18	-7.6	.0933	6.599	58	14.4	.4858	34.360	103	39.4	2.114	149.52	186	85.6	17.44	1233.53
19	-7.2	.0979	6.924	59	15.0	.5035	35.612	104	40.0	2.178	154.05	188	86.7	18.21	1287.99
20	-6.7	.1028	7.271	60	15.6	.5218	36.906	105	40.6	2.24	158.43	190	87.8	19.01	1344.58
21	-6.1	.1078	7.625	61	16.1	.5407	38.244	106	41.1	2.31	163.39	192	88.9	19.84	1403.28
22	-5.6	.1131	7.999	62	16.7	.5601	39.616	107	41.7	2.38	168.34	194	90.0	20.70	1464.11
23	-5.0	.1186	8.388	63	17.2	.5802	41.037	108	42.2	2.45	173.29	196	91.1	21.59	1527.06
24	-4.4	.1243	8.792	64	17.8	.6009	42.501	109	42.8	2.52	178.23	198	92.2	22.52	1592.84
25	-3.9	.1303	9.216	65	18.3	.6222	44.008	110	43.3	2.60	183.89	200	93.3	23.47	1660.03
26	-3.3	.1366	9.662	66	18.9	.6422	45.564	112	44.4	2.75	194.51	202	94.4	24.46	1730.06
27	-2.8	.1432	10.128	67	19.4	.6669	47.169	114	45.6	2.91	205.82	204	95.6	25.48	1802.20
28	-2.2	.1500	10.609	68	20.0	.6903	48.825	116	46.7	3.08	217.85	206	96.7	26.53	1876.47
29	-1.7	.1571	11.112	69	20.6	.7144	50.529	118	47.8	3.26	230.58	208	97.8	27.63	1954.27
30	-1.1	.1645	11.635	70	21.1	.7392	52.283	120	48.9	3.45	244.02	210	98.9	28.76	2034.19
31	-0.6	.1723	12.186	71	21.7	.7648	54.044	122	50.0	3.64	257.45	212	100.0	29.92	2116.24
32	0.0	.1803	12.752	72	22.2	.7912	55.961	124	51.1	3.85	272.31	214	101.1	31.13	2201.82
				73	22.8	.8183	57.878	126	52.2	4.06	287.16	216	102.2	32.38	2290.24
				74	23.3	.8462	59.311	128	53.5	4.29	303.43	218	103.3	33.66	2380.77
				75	23.9	.8750	61.889	130	54.4	4.53	320.41	220	104.4	34.90	2414.48
				76	24.4	.9064	63.892	132	55.6	4.77	337.38				

Table V-1

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

DEW POINT TEMPERATURE °F

TABLE II

DRY BULB TEMP. °F	%RELATIVE HUMIDITY																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5	-35	-30	-25	-21	-17	-14	-12	-10	-8	-6	-5	-4	-2	-1	1	2	3	4	5
10	-31	-25	-20	-16	-13	-10	-7	-5	-3	-2	0	2	3	4	5	7	8	9	10
15	-28	-21	-16	-12	-8	-5	-3	-1	1	3	5	6	8	9	10	12	13	14	15
20	-24	-16	-11	-8	-4	-2	2	4	6	8	10	11	13	14	15	16	18	19	20
25	-20	-15	-8	-4	0	3	6	8	10	12	15	16	18	19	20	21	23	24	25
30	-15	-4	-3	2	5	8	11	13	15	17	20	22	23	24	25	27	28	29	30
35	-12	-5	1	5	9	12	15	18	20	22	24	26	27	28	30	32	33	34	35
40	-7	0	5	9	14	16	19	22	24	26	28	29	31	33	35	36	38	39	40
45	-4	3	9	13	17	20	23	25	28	30	32	34	36	38	39	41	43	44	45
50	-1	7	13	17	21	24	27	30	32	34	37	39	41	42	44	45	47	49	50
55	3	11	16	21	25	28	32	34	37	39	41	43	45	47	49	50	52	53	55
60	6	14	20	25	29	32	35	39	42	44	46	48	50	52	54	55	57	59	60
65	10	18	24	28	33	38	40	43	46	49	51	53	55	57	59	60	62	63	65
70	13	21	28	33	37	41	45	48	50	53	55	57	60	62	64	65	67	68	70
75	17	25	32	37	42	46	49	52	55	57	60	62	64	66	69	70	72	74	75
80	20	29	35	41	46	50	54	57	60	62	65	67	69	72	74	75	77	78	80
85	23	32	40	45	50	54	58	61	64	67	69	72	74	76	78	80	82	83	85
90	27	36	44	49	54	58	62	66	69	72	74	77	79	81	83	85	87	89	90
95	30	40	48	54	59	63	67	70	73	76	79	82	84	86	88	90	91	93	95
100	34	44	52	58	63	68	71	75	78	81	84	86	88	91	92	94	96	98	100
105	38	48	56	62	67	72	76	79	82	85	88	90	93	95	97	99	101	103	105
110	41	52	60	66	71	77	80	84	87	90	92	95	98	100	102	104	106	108	110
115	45	56	64	70	75	80	84	88	91	94	97	100	102	105	107	109	111	113	115
120	48	60	68	74	79	85	88	92	96	99	102	105	107	109	112	114	116	118	120
125	52	63	72	78	84	89	93	97	100	104	107	109	111	114	117	119	121	123	125

Problem: Given a "Dry-Bulb" temperature of 60F and a relative humidity of 25%. Find the Dew Point Temperature.

Solution: From a "Dry-Bulb" temperature of 60F in the left column, read across the table to the right. Where this line intersects the column of 25% relative humidity, we read a Dew Point Temperature of 25 F.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

FUNCTION OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Coverings are materials used to protect insulation from mechanical damage. These may be also used as pipe identification and as decorative surface. They are used indoors, but may not have the qualities necessary to be classed as a weather-barrier. Weather-barriers can be used indoors as coverings, but coverings not possessing good weather-resistant qualities must not be used outdoors. In many instances, the difference between insulation weather-barrier and insulation covering is not the material itself but the manner in which it is installed. To illustrate, many jackets installed outdoors with sealed joints to resist rain are weather-barriers. The same jackets installed indoors with unsealed joints are coverings.

In some instances, one single material may be used both as a weather-barrier and vapor-barrier or a covering and vapor-barrier. In other applications, two separate materials may be used where vapor control is required.

REQUIREMENTS IMPOSED ON WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS

To fulfill their function in protecting insulation, there are many demands imposed on weather-barriers, vapor-barriers, and coverings.

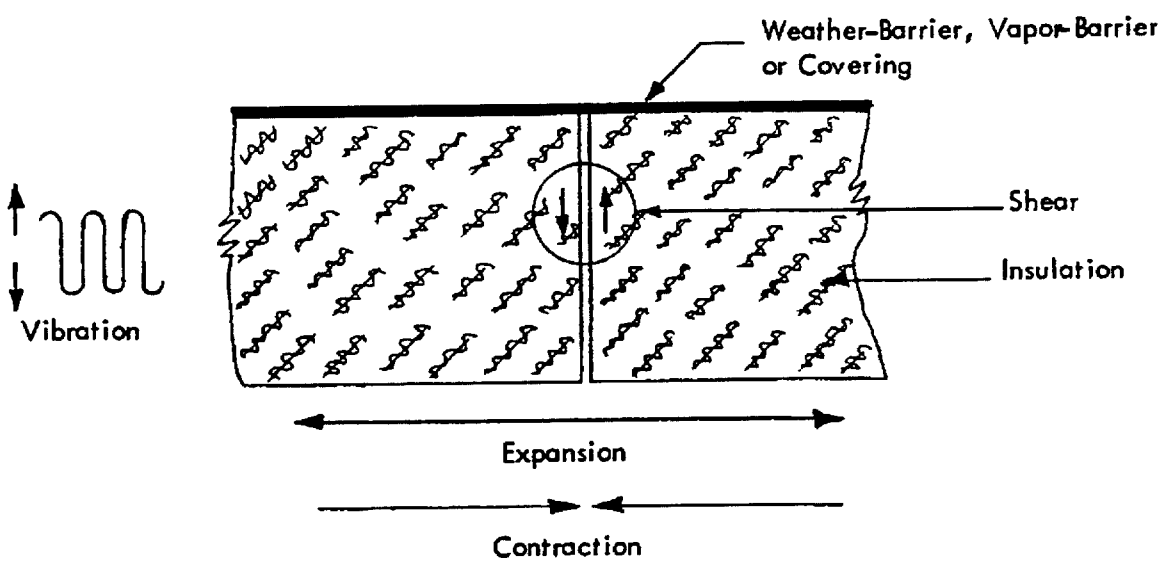
For successful protection of thermal insulation, the barriers and coverings must stay in place on the insulation and withstand movement caused by expansion and contraction without cracking or breaking. To accomplish this, the barriers, or coatings must possess mechanical strength. They must have sufficient flexibility and tensil strength to resist pulling action such as the expansion of surface transmits to the barrier. The barriers must have shear strength to resist pulling action such as the expansion the surface transmits to the barrier. The barriers must have shear strength to resist up and down motion of blocks and pipe insulation. These mechanical stresses imposed by internal sources to barriers are illustrated in Figure V-2.

Other than forces from internal sources, barriers and coverings are exposed to external forces. Most insulations are relatively soft, thus any load applied to the surface must be transferred by the weather-barrier to the insulation without damage to the barrier. Mechanical abuse, such as a man walking on insulation, forces of wind involving impact, shear, compressive loading, and abrasion are abuses to which weather-barriers are subjected. The barriers or coverings must resist all of these, which are illustrated in Figure V-3.

Of course, a weather-barrier's primary function is to resist the weather to which it is subjected. Weather is quite complex. In parts of the United States, the temperature may go as low as -40F and in other parts of the country it rises to 115F. The weather-barrier applied to thermal insulation may in winter be even colder than the cold winter air. Conversely, when weather-barriers are used on thermal insulations over hot surfaces, the effect of the heat from the pipe plus solar radiation will cause outer surfaces to be considerably higher than the ambient temperatures.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

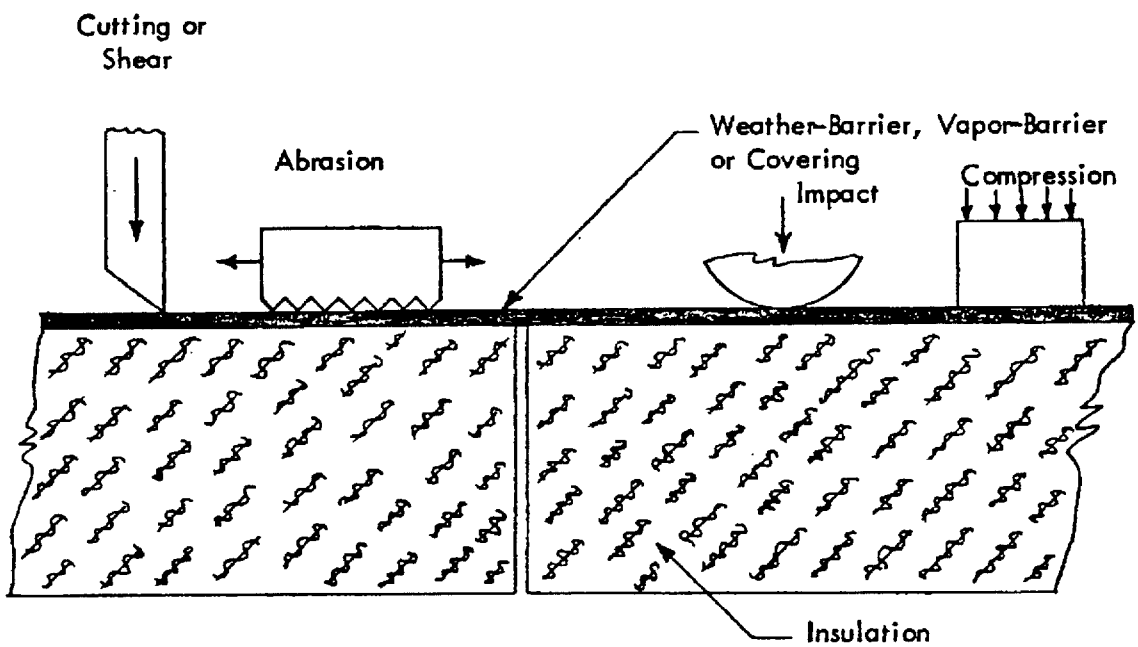


MECHANICAL STRESSES ON BARRIERS
FROM INTERNAL SOURCES

Figure V-2

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS



MECHANICAL STRESSES ON BARRIERS FROM EXTERNAL SOURCES

Figure V-3

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

REQUIREMENTS IMPOSED ON WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

In addition to weather, acid, caustics, and chemical fumes or spillage can damage weather barriers, vapor barriers, or coverings. It is of paramount importance that these be resistant to fumes and spillages to which they may be subjected.

The barriers or coverings used in chemical plants must not increase the fire hazard within the plant. Fire hazard can be increased in several ways. One is that the barrier or covering could contribute to a fire or assist it to spread. Another is that it might create toxic smoke by its combustion. Still another is that it could react with chemical spillage or fumes to cause an accidental fire. A good weather-barrier, vapor-barrier, or covering should resist fire and help protect the insulation so as to provide a thermal shield between the fire and piping and equipment.

These are the requirements imposed upon weather-barrier, vapor-barriers, and coverings. Each individual type of barrier or covering has its individual set of properties which make it more or less suitable to fulfill the requirements. Selection of materials to be used is based on its ability, including its associated economics.

PROPERTIES OF WEATHER-BARRIER, VAPOR-BARRIERS, AND COVERINGS

Many materials have been used as weather-barrier and coverings. In general, they fall into two classifications: jackets and mastics. Each of these has certain properties by which it is evaluated to fulfill the installation requirements.

Evaluation of each material as to its properties is beyond the scope of this manual. However, it is well to establish the relation of properties with requirements. This relationship between property and requirements is stated to be the significance. These lists, one for jackets and one for mastics, of the properties of weather-barriers and coverings follow:

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE

Application Properties

Definition: The properties which influence or affect proper installation of the jacket.

Cutting Characteristics

Definition: The ability of the jacket to be secured.

Significance: The ability of a material to be cut cleanly without ragged or jagged edges and without tearing. This property must be related to the use of proper tools and methods.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Application Properties - Contd

Ductility

Definition: The ability of the jacket to bend, flex, or be drawn.

Significance: The ability of the material to conform to required shape without tearing, or being otherwise damaged.

Service Properties

Definition: Properties which govern performance of the jacket after installation.

Abrasion Resistance

Definition: Ability of a jacket to withstand scuffing or scratching without damage.

Significance: This ability determines if a jacket is able to withstand mechanical abuses of scuffing or scratching or related abrasive action.

Appearance

Definition: The external view of the installed jacket.

Significance: The ability of the jacket to be applied cleanly and neatly. Its ability to provide an even and pleasing surface, to harmonize with its surroundings, and remain that way in service.

Conductivity, Thermal

Definition: The ability of the jacket to transmit heat.

Significance: When surface temperatures are high, the higher the thermal conductivity of a jacket the more likely it is to cause burns to anyone who comes in contact with it.

Emittance

Definition: The ability of a jacket to radiate energy due to its temperature being higher than the temperature of surrounding bodies.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Emittance - Contd

Significance: The ability of the jacket to transmit heat to ambient air and surrounding bodies affects the surface temperature. On high temperature installations, low surface emittance can cause surface temperatures to be sufficiently high to be hazardous to personnel. This is particularly true as the small amount of radiant heat causes no warning to a person that the surface is hot.

Flash Point

Definition: The temperature of the jacket, at which a spark will cause a flash flame. Burning will not continue unless the material is above fire point.

Significance: This temperature is that at which sparks and fire must be kept from the material to prevent flash flame.

Fire Point

Definition: The temperature of the jacket at which, when ignited by spark or flame, the material will continue to burn.

Significance: This is the critical temperature, at which a material is flammable. Fire point of a material affects the fire hazard to personnel and property.

Fire Self-Ignition Point (Autogenous Ignition)

Definition: The temperature of the jacket, at which, in presence of air, the jacket will burst into flame without being ignited by spark or flame.

Significance: This is the temperature at which the material will automatically burst into flame. As such, it affects fire hazard.

Flammability

Definition: The ability of a material to support combustion.

Significance: This is a general statement of the ability of material to support combustion. Flash point, fire point, fire self-ignition point, and flame travel are measures of degree of flammability.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Flame Travel

Definition: The rate, in respect to distance and time, flame will spread over the jacket surface.

Significance: High rate of flame spread is a contributing factor in accidental fire getting out of control.

Flame Resistance

Definition: The ability of the jacket to resist burning when subjected to flame.

Significance: This is a general statement of the ability of a material to resist combustion when subjected to a flame.

Hardness

Definition: The ability of a jacket to resist penetration.

Significance: This property determines the ability to resist puncture. This property affects service life of the jacket.

Heat Stability

Definition: This is a combination of related properties which affect the overall stability of the material.

Significance: High or low temperatures do cause change in the properties of the jacket. Either a peak temperature, or extended high or low temperature may adversely affect mechanical properties of the jacket.

Impact Strength

Definition: This, too, is a combination of other physical properties, including hardness, ductility, shear and tensile strength.

Significance: Although this is a combination of properties, comparative test methods have been devised to evaluate materials. The ability of a jacket to withstand a mechanical blow is one measure of its ability to remain water-tight.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Low Temperature Embrittlement

Definition: The temperature at which the jacket loses its flexibility.

Significance: This is the temperature at which the jacket becomes brittle, when relative slight strain or impact can cause it to break. This temperature indicates the service suitability of the material.

Melting Point

Definition: The temperature above which the joint changes from the solid state to the liquid state.

Significance: This temperature causes complete change of physical properties from those as a solid to those of a liquid. This temperature is important to fire hazards as molten drip may be source of secondary ignition.

Puncture Resistance

Definition: The ability of a material to resist penetration of a sharp object applied to its surface by mechanical force.

Significance: This property is similar to impact resistance except that puncture is associated with a sharp object. Puncture resistance affects the service suitability and service life of jackets.

Reflection Factor - Light

Definition: The ratio of the light reflected by a body to that incident on it.

Significance: The amount of light reflected by a jacket affects the need for over-coating with paint to obtain good lighting.

Reflectance - Light

Definition: The ratio of radiant light flux reflected by a body to that incident upon it.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Reflectance - Light - Contd

Significance: The amount of light reflected by a jacket affects the need for over-coating with paint to obtain good lighting.

Reflectance - Thermal

Definition: The ratio of radiant heat flux reflected by a body to that incident upon it. For an opaque body, the sum of reflectance and absorptance for the incident radiation is unity.

Significance: On low temperature applications located where they are subject to radiation, the reflectance greatly influences the amount of heat which reaches the insulation system.

Resistance to Acids, Caustics, Solvents

Definition: The ability of the jacket to resist deterioration when subjected to acids, caustics, or solvents in liquid or vapor state.

Significance: The ability of the jacket to resist the action of acids, caustics, and solvents under service conditions determines its serviceability for various applications.

Shear Strength

Definition: The ability of the jacket to resist cutting action of forces acting upon it in parallel and opposite directions.

Significance: The jacket must have the ability to resist shear in service. During high winds, the effects of lift cause high shearing action at securement bands. Conversely, the jacket must not be too difficult to cut; otherwise, installation cost becomes excessive.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Softening Point

Definition: The temperature above which the jacket begins to soften, becomes tacky, or loses its physical strength.

Significance: The softening point is one factor in setting the maximum service temperature to which a material should be subjected.

Tear Strength

Definition: The ability of a material to resist being pulled apart by externally applied force.

Significance: This property determines the ability of the jacket to withstand ripping.

Tensile Strength

Definition: The ability of the jacket to resist being pulled apart by equal and opposite forces.

Significance: This property determines the ability of the material to withstand the frictional pull imposed on it by the expansion of pipe and vessels upon which the insulation and jacket are installed. The ability of the jacket to enlongate under tension can assist in reducing the effect of the tension forces tending to pull it apart.

Temperature Limits

Definition: These are the high and low temperatures above and below which at least some of the properties of the jacket are so adversely affected that the jacket becomes unsatisfactory or unusable.

Significance: These limits determine the temperature range of usability of the jacket.

Thermal Shock Resistance

Definition: This is the ability of the material to resist impairment of its properties caused by sudden change in temperature.

Significance: A fast rate of change of temperature can have adverse effects on some types of plastic or laminated jackets.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF JACKETS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Water Vapor Permeability

Definition: The ability of the jacket to transmit moisture in the vapor state.

Significance: The ability to transmit moisture is desirable in some applications, such as when the insulation and jacket are applied on hot surfaces. When the insulation and jacketing is on cool or cold surfaces, then a low water vapor permeability is required. This water vapor permeability affects the selection of materials and the service life of the insulation.

Water Resistance

Definition: In most instances this is applied to two different properties. One, the ability of the jacket to retain its properties when subjected to water; two, the ability of the jacket to resist the passage of water.

Significance: This resistance to water determines and influences the life of the jacket when exposed to rain, sleet, snow, or water submersion. The resistance to water passage affects the efficiency of the insulation and its service life.

Weather Resistance

Definition: Is the ability of the jacket to withstand all of the ravages weather imposes on it.

Significance: The ability to resist weather is the basic function of the jacket when used in outdoor applications. Weather resistance affects both the performance and service life of the jacket.

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE

Mastics have many identical or similar properties, particularly in service as jackets. However, some of these that are similar may be just sufficiently different that there will be some difference in the definition and the significance. Therefore, in spite of some duplication, these same properties which apply will be repeated in the list of properties for mastics.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Application Properties

Definition: Properties which influence or affect the proper installation of weather barriers or coverings.

Build

Definition: The thickness to which a coating or mastic finish can be applied without sagging, running, sliding, or dripping.

Significance: Finishes for thermal insulation must be capable of application on vertical or overhead surfaces at specified coverage without subsequent reduction in thickness, caused by excessive flow or slump. Build also determines the number of coats required for optimum dry thickness.

Consistency

Definition: The resistance of a non-Newtonian material to deformation or flow.
NOTE: Consistency is not a fundamental property but is made up of viscosity, plasticity, and other rheological phenomena. In non-Newtonian behavior, which is the usual case with mastics and coatings for thermal insulation, the ratio of shearing stress to the rate of shearing strain varies with the shearing stress.

Significance: Consistency determines whether a mastic or coating can be troweled, gloved, brushed, or sprayed. It has a direct effect on application costs.

Corrosion or Solvent Attack

Definition: Harmful effect on metals or thermal insulation of contact with finishes.

Significance: Finishes must not chemically attack insulation or adjacent metals to cause deterioration of the installation.

Coverage

Definition: The rate in square feet per gallon (coatings) or gallons per 100 square feet (mastics) at which finish must be applied to obtain satisfactory performance.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Application Properties - Contd

Coverage - Contd

Significance: The performance of finishes is directly related to the dry film thickness applied. Performance properties must be defined in terms of dry thickness, and this value must be established for application purposes in terms of coverage. Coverage data are essential for estimating quantities and cost.

Drying Time or Curing Time

Definition: Elapsed time required for a mastic or coating finish to dry or set after application before it may be placed in operating service. NOTE: Drying time implies time during which applied finish is sensitive to local damage by weather or personnel. Curing time implies time required to reach optimum service properties.

Significance: Performance properties of finishes depend on adequate drying and curing. Premature service operation may lead to finish failure. Curing time data are needed to establish construction schedules.

Flash Point

Definition: The temperature of the jacket, at which a spark will cause a flash flame. Burning will not continue unless material is above fire point.

Significance: This temperature is that at which sparks and fire must be kept from the material to prevent flash flame.

Fire Point

Definition: The temperature of the jacket at which, when ignited by spark or flame, the material will continue to burn.

Significance: This is the critical temperature at which a material is flammable. Fire point of a material affects the fire hazard to personnel and property.

Fire Self-Ignition Point (Autogenous Ignition)

Definition: The temperature of the jacket, at which, in presence of air, the jacket will burst into flame without being ignited by spark or flame.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Application Properties - Contd

Fire Self-Ignition Point (Autogenous Ignition) - Contd

Significance: This is the temperature at which the material will automatically burst into flame. As such, it affects fire hazard.

Flammability (during application)

Definition: The ability of a material to support combustion.

Significance: Finishes which contain volatile flammable solvents may ignite readily from a source such as welding sparks and spatter, electrical short circuits, open flames, or personnel smoking. Such a fire could spread very rapidly over freshly finished surfaces.

Freeze-Thaw Resistance

Definition: Resistance to change in application and performance properties caused by exposure to alternate cycles of freezing and thawing.

Significance: Both application and performance properties can be affected by sub-standard freeze-thaw stability in water-base products. Susceptibility to freeze damage affects shipping methods, storage facilities, and application schedules.

Gap Filling and Bridging

Definition: The ability to bridge, fill, and level joints and gaps in installed thermal insulation.

Significance: Joints and gaps exist in installed block insulation. If these are not adequately filled or bridged, the protective value of the finish will be seriously impaired.

Shrinkage

Definition: Change in volume from wet to dry state observed after mastics and coatings have been applied and cured.

Significance: While all finishes containing volatile solvents will show shrinkage during curing, it is important that the finish not crack or delaminate during this process. Shrinkage value must be known to establish coverage rate.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Application Properties - Contd

Sizing and Sealing

Definition: The ability to prevent excessive absorption of finish into porous insulation.

Significance: Excessive penetration of finishes into insulation will affect adversely the performance of the finish and the conductivity of the insulation.

Storage Stability

Definition: Resistance to change in application or performance properties caused by prolonged storage. Storage life is the time during which the product can be stored under specified conditions and remain suitable for use.

Significance: Both application and service properties can be affected by sub-standard storage stability. This property affects purchasing, storage facilities, and construction scheduling.

Surface Wetting and Adhesion

Definition: The mutual affinity of and bonding between finish and surface to which it is applied.

Significance: Coatings and mastics must readily wet and bond to insulation surfaces without special treatments and/or application techniques. Ease of appli cation and cost of application require good surface wetting and adhesion.

Temperature and Humidity Range (during application)

Definition: The limiting temperatures and relative humidities between which practical application of finish can be made without harmful effect on properties.

Significance: Application of finishes under extreme atmospheric temperature and humidity conditions can hinder or prevent attainment of necessary coverage and proper cure, thus significantly changing performance properties. The temperature of the surface to which the finish is applied also must be considered.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Application Properties - Contd

Toxicity

Definition: Harmful physiological response to vapor inhalation or skin contact with finishes during application.

Significance: Finishes should not adversely affect health of personnel making application. Container labels must legally and adequately describe any health hazard involved in using the product.

Service Properties

Definition: Properties which govern performance of finishes after installation.

Abrasion Resistance

Definition: Ability to withstand scuffing, scratching, rubbing, or wind-scouring without loss of protective properties.

Significance: Abrasion resistance in severe service locations is essential to prevent water penetration through the finish. It affects service life and maintenance schedules.

Adhesion

Definition: The bonding of finish to insulation, usually by interfacial forces of attraction.

Significance: Mastics and coatings should bond strongly to insulation surfaces to afford maximum protection and resistance to delamination in service. This property is difficult to measure on insulation materials of low cohesive strength.

Chemicals and Water Resistance

Definition: Capability of withstanding exposure to designated acids, alkalies, salts, their vapors and solutions, and water, both pure and industrial.

Significance: Attack by or absorption of chemicals and water can materially reduce the performance and service life of finishes not resistant. Atmospheric contamination and spillage of chemicals are more common forms of chemical exposure of finishes.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Color

Definition: The aspect of appearance dependent upon special composition of the incident light and the spectral response of the observer.

Significance: Color of insulation finishes is dependent on incidence of area dirt and fallout, solar heat load, identification codes, and concealment, as well as aesthetic consideration. Color standards are to be established by agreement between buyer and seller.

Elongation

Definition: Extension produced by a tension force.

Significance: This property determines the ability to withstand pulling stresses exerted during expansion of substrates to which the finish is applied. Adequate elongation will ensure no cracking due to tension forces.

Flash Point

Definition: The temperature of the jacket, at which a spark will cause a flash flame. Burning will not continue unless material is above fire point.

Significance: This temperature is that at which sparks and fire must be kept from the material to prevent flash flame.

Fire Point

Definition: The temperature of the jacket at which, when ignited by spark or flame, the material will continue to burn.

Significance: This is the critical temperature, at which a material is flammable. Fire point of a material affects the fire hazard to personnel and property.

Fire Self-Ignition Point (Autogenous Ignition)

Definition: The temperature of the jacket, at which, in presence of air, the jacket will burst into flame without being ignited by spark of flame.

Significance: This is the temperature at which the material will spontaneously burst into flame. As such, it affects fire hazard.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Fire Hazard

Definition: Susceptibility to ignition and consequent surface spread of flame.

Significance: Low surface spread of flame is important to prevent fire growth away from an accidental fire. Fire hazard affects personnel safety, property values, and insurance rates.

Flexure

Definition: Ability of finishes to be deformed by bending or twisting without loss of protective properties.

Significance: Flexibility of finishes changes with temperature, so temperature limits of use must be considered in establishing flexure limits. Finishes often are installed over relatively soft insulation, which requires that they have good flexibility to maintain protective properties.

Impact Resistance

Definition: Ability to withstand mechanical blows without loss of protective properties.

Significance: The ability to resist mechanical blows is a measure of ability suitability and service life.

Mold and Mildew Resistance

Definition: Capability of resisting deterioration by fungi.

Significance: Growth of micro-organisms in the form of mildew or mold on the surface of finishes will cause unsightly appearance and can cause sub-standard performance.

Odor

Definition: Scent, emanation, effluvium, or smell from finish.

Significance: Odor from finishes may be undesirable if it could contaminate foods or other materials exposed to it.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF MASTICS AND THEIR SIGNIFICANCE - Contd

Service Properties - Contd

Temperature Limits

Definition: The limiting temperatures between which finishes will perform satisfactorily.

Significance: Temperature level, duration, and rate of change must be considered in evaluation. Temperature limits affect selection of finish, performance properties, and service life.

Water Vapor Transmission Rate

Definition: Between two specified parallel surfaces, the time rate of water vapor flow, normal to the surfaces, in a steady state, through unit area, under the specified conditions.

Significance: The flow of water vapor through a permeable finish is a function of the difference of vapor pressures at its surfaces. If such a flow results in accumulation of water within insulation, serious changes in thermal conductivity and physical damage can result. In some installations, a relatively high rate is desirable to permit evaporation of water from heated insulation.

Weather Resistance

Definition: Resistance of finishes to deterioration by exposure to various weather conditions.

Significance: Both physical and chemical changes can occur upon weather exposure and these changes can affect performance properties, service life, and maintenance schedules.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

PROPERTIES OF ACCESSORIES USED WITH WEATHER-BARRIER, VAPOR-BARRIERS, AND COVERINGS

Other than jackets and the mastics, a number of accessories are used with or are a part of the weather-barrier and covering systems. Some of these are tapes, fabric reinforcings for mastics, adhesives, sealers, caulking compounds, overcoatings, and intumescent paints.

In most instances, tapes would have the same list of properties as jackets, with the additional properties such as initial adhesion, service adhesion, slip, and peel resistance which would be of significance.

Reinforcing fabrics as part of the mastic weather-barrier or covering system influence the in-service properties of the mastic, thus in-service properties of mastics are measured with the proper reinforcing cloth as part of the mastic system.

Adhesives, sealers, caulking compounds, and overcoating also have approximately the same list of properties as listed for mastics, with emphasis placed on the individual property related to the function each performs.

Intumescent paint is a special overcoating used for fire protection, thus its properties include that of fire resistance and heat retardation.

TYPES OF WEATHER-BARRIER, VAPOR-BARRIERS, AND COVERINGS

Many types of materials have been used as weather barriers, vapor barriers, and coverings. All of those listed are, to some degree, being used in the insulation industry. Those used by Union Carbide Corporation are those which are selected to best fulfill our needs, including our fire safety requirements.

Jackets

Almost all jackets can be applied around straight pipe with relative ease. As barriers over fittings, valves, irregular surfaces, jackets are difficult to apply. However, factory-fabricated jackets partly solved this difficulty. Unless considerable care is exercised, the joints between jackets are not water-tight. Some of the materials used for weather-barrier jackets are:

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

TYPES OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Felt jackets are made of asbestos and asphalt, asbestos sheets, and asbestos-asphalt felt, and rag felt with asphalt. All of these have excellent weather-resistant characteristics, but most are combustible, or have a high index of flame spread.

Plastic jackets are made of heavy calendered plastics such as polyvinyl acetate, and Mylar. The properties of these cover a wide range, depending upon the plastic used.

Composition jackets are made by the combination of two or more materials bonded together. There are numerous combinations of materials used in making up this type of jacket. Some of the most common are:

Aluminum foil and craft paper
Aluminum foil and glass cloth
Aluminum foil and polyvinyl acetate
Polyvinyl acetate and glass cloth
Polyvinyl chloride and glass cloth
Polyvinyl acetate, aluminum foil, and glass fibers
Asbestos and polyvinyl acetate

Metal jackets are made of non-corrodable metal and/or metal treated to resist corrosion. In addition, especially for aluminum, an inner facing of treated craft paper may be bonded to the metal to reduce corrosion due to caustic action of the insulation. In some instances, these jackets are prerolled, precut, with preformed joints to reduce the difficulty of field installation. Some of the metals used for weather-barrier jackets are:

Aluminum
Aluminum with inner layer of craft paper
Galvanized steel
Galvanized and painted steel
Stainless steel

Tapes, which are a form of jackets, are also produced of many materials, such as rubber, fabric, aluminum foil, polyethylene, polyvinyl chloride, polyvinyl acetate, glass fabric, or glass fiber, or a combination of these materials. In most instances, they are produced with a pressure-sensitive adhesive on one or both sides. Presently, there are 400 to 500 different tapes on the market.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

TYPES OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Mastics - Weather Barriers

Similar to the jackets, there are many materials used as mastics for weather-barriers. In most instances, it is recommended that the mastics be reinforced with a membrane to provide higher tensile strength and tear resistance. For this reason, the membrane most commonly used with each mastic will be mentioned.

Cutback asphalt and fiber reinforced with 20 x 20 glass cloth is generally an excellent weather barrier and vapor barrier. However, due to high shrinkage and pinholing, it must be applied in two coats and heavy thickness. Recommended thickness is not less that 1/8 in. This coating is combustible in wet state. Additives are sometimes mixed into the material to reduce the burning rate after material has dried.

Asphalt-Gilsonite cutback reinforced with 20 x 20 glass fabric has characteristics similar to asphaltic cutback, with the exception that the Gilsonite tends to increase weather resistance and flexibility of the dry film.

Asphalt emulsion reinforced with one-inch hexagonal wire netting is one of the oldest materials used as a weather barrier. Due to water content, they are fire safe during application but will support combustion after the emulsion has dried. Because of high shrinkage, they must be applied in two or more coats to cover shrinkage cracks. Recommended dried thickness is 1/4 in. Dries to a hard, stiff, film with little flexibility.

Polyvinyl Acetate emulsion reinforced with Dynel cloth is basically a breathing-type mastic, meaning that it has high vapor transmission rate and is an excellent weather-barrier but poor vapor-barrier. This mastic is fire-safe during application, has a low rate of flame travel, and fire resistive. Because of its low shrinkage and good filming properties, it need only be 1/16 inch thick after it has dried.

Polyvinyl-Acetate-Acrylic modified emulsion reinforced with Dynel cloth has similar characteristics to the polyvinyl acetate emulsion.

Acrylic emulsion reinforced with Dynel cloth has similar characteristics to the polyvinyl acetate emulsion, with the exception that it has better elongation and flexibility than the PVA mastics at temperatures below 30F.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

TYPES OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Rubber latex emulsions reinforced with glass fabric or Dynel cloth have excellent flexibility at temperatures above 50F. Their weather resistance is not as good as other coatings and most formulations of these will support combustion after they have dried.

Vapor-Barrier mastics may be or may not be good weather-barriers. Various types of resins have been formulated as vapor-barriers. Some of these are vinyl chlorides, Hypolon, Monolar, acrylics, and other synthetic resins. In most instances when used outdoors in industrial applications, it is good practice to protect the vapor-barrier with a weather-barrier.

Coverings

Coverings are used over insulation installed indoors where it requires no weather-barrier. However, depending upon operating temperature, the insulation may or may not require vapor-barrier.

Covering Over Insulation Requiring Vapor-Barrier

Semivapor-resistant insulation which must be sealed with a vapor-barrier may use any of the previously mentioned types of vapor-barriers. The covering over this vapor-barrier may be needed to add strength, or simply to provide color to match surroundings. The covering may be a paint, jacket, or reinforced coating. Whichever type of finish is selected, it must be compatible with the vapor-barrier.

Coverings Over Insulation Not requiring Weather-Barrier

Insulated surfaces located indoors, where not subjected to washing down, need no weather-barriers. Typical is insulation installed on commercial building piping, equipment, and duct-work. As most insulation surfaces are not suitable as an exterior finish because of their softness, abrasiveness, or dustiness, a covering must be provided. A large number of finishes are available.

Many pipe insulations are obtainable with factory-attached jackets suitable as an outer surface, or suitable as a base for a finish. Such outer surface jackets may be asbestos laminated jackets, foil faced jackets, composition fire retardant jackets, or metal jackets. When such jackets are suitable, they must be selected to fulfill the service and appearance requirements.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

TYPES OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Factory-attached canvas is supplied with much pipe insulation as standard practice. It helps prevent damage to the insulation in shipping. In most instances this canvas is removed before the insulation is installed. However, the canvas can be repasted in place and provides a base for the surface finish. A polyvinyl acetate "lagging adhesive" of paint consistency is used as a paste to secure the canvas to the installed insulation. Additional coats of the polyvinyl acetate on the outside of the canvas provide the final surface or a base for an overcoating. Color can be added to the polyvinyl acetate coating if desired.

Where fire hazard is a consideration, glass cloth can be used instead of canvas. It is applied in the same manner as the canvas.

Equipment insulated indoors, such as in machinery rooms or power plants, also requires an outer finish. Depending upon the insulation used, and the manner of application, this finish is obtained by using jackets or polyvinyl acetate finish.

If a jacket is used, the surface to which it is applied must be smooth and even. The selection of a jacket is the same as stated for pipe covering.

When equipment is insulated with lags or a soft insulation, it must be given a 1/2 inch thick coating of insulating cement reinforced with one-inch hexagonal wire mesh. After this has dried to a 1/4 inch thickness, hard finish cement is troweled onto a smooth even surface. Canvas or glass cloth is then pasted to this surface with polyvinyl acetate "lagging adhesive." An additional coat, or coats, of the polyvinyl acetate is then brushed over the cloth to provide the finished surface.

The same procedure is followed when high temperature block is installed on flat surfaces such as boiler ducts.

If cylindrical equipment is insulated with prefabricated curved segments and heads, the 1/2 inch insulation cement coating can be eliminated and the 1/4 inch finish cement can be applied directly to the insulation. The balance of the procedure will be identical to that previously stated.

Overcoatings

Overcoatings are used for three main reasons: (1) protection from acids, caustics, or solvents that the finish, weather-or vapor-barrier cannot withstand; (2) to provide an appearance not possible from the insulation finish; (3) to provide fire resistance.

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WEATHER-BARRIERS, VAPOR-BARRIERS, COVERINGS

TYPES OF WEATHER-BARRIERS, VAPOR-BARRIERS, AND COVERINGS - Contd

Overcoatings for Acid, Caustic, or Solvent Protection

Weather-barriers, vapor-barriers, and finishes used with insulation are designed to function with the insulation under ordinary environmental conditions. They may, or may not, resist acid, caustic, or solvent contamination. Where the installation may be subjected to contamination, the weather-vapor-barrier, or finish under consideration must be checked to determine if it will withstand the contamination. In some instances, it may be found that a properly selected weather-vapor-barrier will perform both functions. In other instances, it may be necessary to overcoat with a coating which resists the chemical contamination. In addition to resisting the chemicals, the overcoating must be compatible with the finish, or vapor-barrier.

Overcoating for Appearance

In most instances, the jacket or the mastic used for the finish or weather-barrier is suitable in appearance. When color is required, polyvinyl acetate weather-barrier mastic can be obtained in most standard colors, or even special colors in quantity. However, in some instances, such as insulation exposed in buildings, it is desirable to paint the outer surface to match walls or ceilings, or to provide high gloss light reflective surfaces. In these cases, because of the small areas involved, it is economical to have the insulated surfaces overcoated by the painters as they paint the interior of the buildings.

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INSTALLATION REQUIREMENTS

The requirements that insulation materials must fulfill are more than just the requirements of application and service. Starting at the point of manufacture, materials must have the capability of being packaged, shipped, stored, fabricated, and handled before their application. Each of these imposes certain requirements on the materials.

After a material is manufactured, it must be packaged and shipped. During shipment it must resist movement, vibration, and mechanical abuses. The packages may be left out in the weather; thus, unless packages are weather-and water-resistant, the material may be exposed to water and moisture.

During storage, insulation materials are also subjected to mechanical abuses and moisture and water damage. Another consideration, due to amount of bulk which is stored, is that the material should not be a fire hazard.

Fabrication of materials imposes another set of requirements on the capabilities of materials. Some of the properties of material that influence the selection of material which must be fabricated are:

1. The ability to be cut, formed, or shaped.
2. The ability to provide smooth, even, and relatively dust-free surfaces.
3. The ability to be bonded to other surfaces with cement or adhesive.
4. The ability to stay straight, true, and dimensionally stable.
5. Sufficient physical strength to resist mechanical abuses to which it is subjected.

During application, materials must have most of these same properties, and they must be able to resist the cutting force of wire or bands used to secure them in place. Up to this point all the requirements that materials must have are those necessary to get them installed to perform their service function. To fulfill service requirements, the properties which insulation must have can be divided into the following basic divisions:

1. Thermal
2. Physical
3. Chemical
4. Moisture
5. Fire
6. Toxicity

Each of these divisions will be discussed in relation to individual properties necessary to fulfill service requirements.

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INSTALLATION REQUIREMENTS

THERMAL PROPERTIES

Temperature of pipe or equipment to which insulation is installed is one of the first considerations in the selection of an insulating material. Each insulation has a maximum service temperature and a minimum service temperature. The insulation used must have a temperature range suitable for the service temperature to which it is subjected.

If operating temperature is cyclic, the rate of this temperature change may cause some materials to crack or spall. For this reason, if change of temperature is rapid, or sudden, the thermal insulation must have sufficient thermal shock resistance to withstand the sudden temperature change without physical deterioration.

Another service consideration is the rate of time that insulation takes to change temperature. Where fast adjustment to temperature change is desired, a high rate of thermal diffusivity is necessary. If slow rate of temperature change is desired, then a low rate of thermal diffusivity is required. In such installations where insulation is used to retard freezing or as fire protection, then a material of low thermal diffusivity is needed. In other words, thermal diffusivity is the measure of rate of temperature change. Specific heat is the measure of quantity of heat required to raise the temperature of a body. In cyclic temperature operations, it determines the amount of heat gain or loss necessary to raise or lower the temperature of the insulation.

PHYSICAL PROPERTIES

The type of installation is, most frequently, the deciding factor as to what form of insulation is most practical. In general, these forms of materials are used for the following broad types of installation:

1. Rigid insulation is used where structural strength is needed. Installations on pipe, vessels and equipment and ducts exposed to mechanical abuses are typical.

2. Semi-rigid or flexible insulations are used in ceilings and other areas where it has external support, or where flexibility is desired to conform to curvatures.

3. Blanket and felt insulation is used for wrapping of ducts and where compressibility and expansionability are necessary. Blankets are frequently used between vessel walls and rigid insulation to provide a thermal and mechanical cushion.

4. Sprayed fiber insulations are practical for large hot surfaces such as large vessels and flue gas ducts.

5. Sprayed organic foams are useful for large moderate temperature surfaces such as storage vessels.

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INSTALLATION REQUIREMENTS

PHYSICAL PROPERTIES - Contd

6. Insulating cements are used to insulate small fittings, on contoured equipment, and in combination with rigid insulations to fill voids and as a leveling coat.

7. Poured or loose insulations are used for filling of cavities or tight enclosures.

With these general guidelines as to type of installations, it is possible to consider the forces exerted on the insulation in service and the properties of the insulation to withstand these forces.

The forces imposed on rigid insulations are generally those caused by the following:

1. Securements and supports.
2. Weight.
3. Movement from expansion and contraction.
4. Mechanical abuses.

The forces caused by its installation using various securements and by its own weight on supports is illustrated in Figure VI-1.

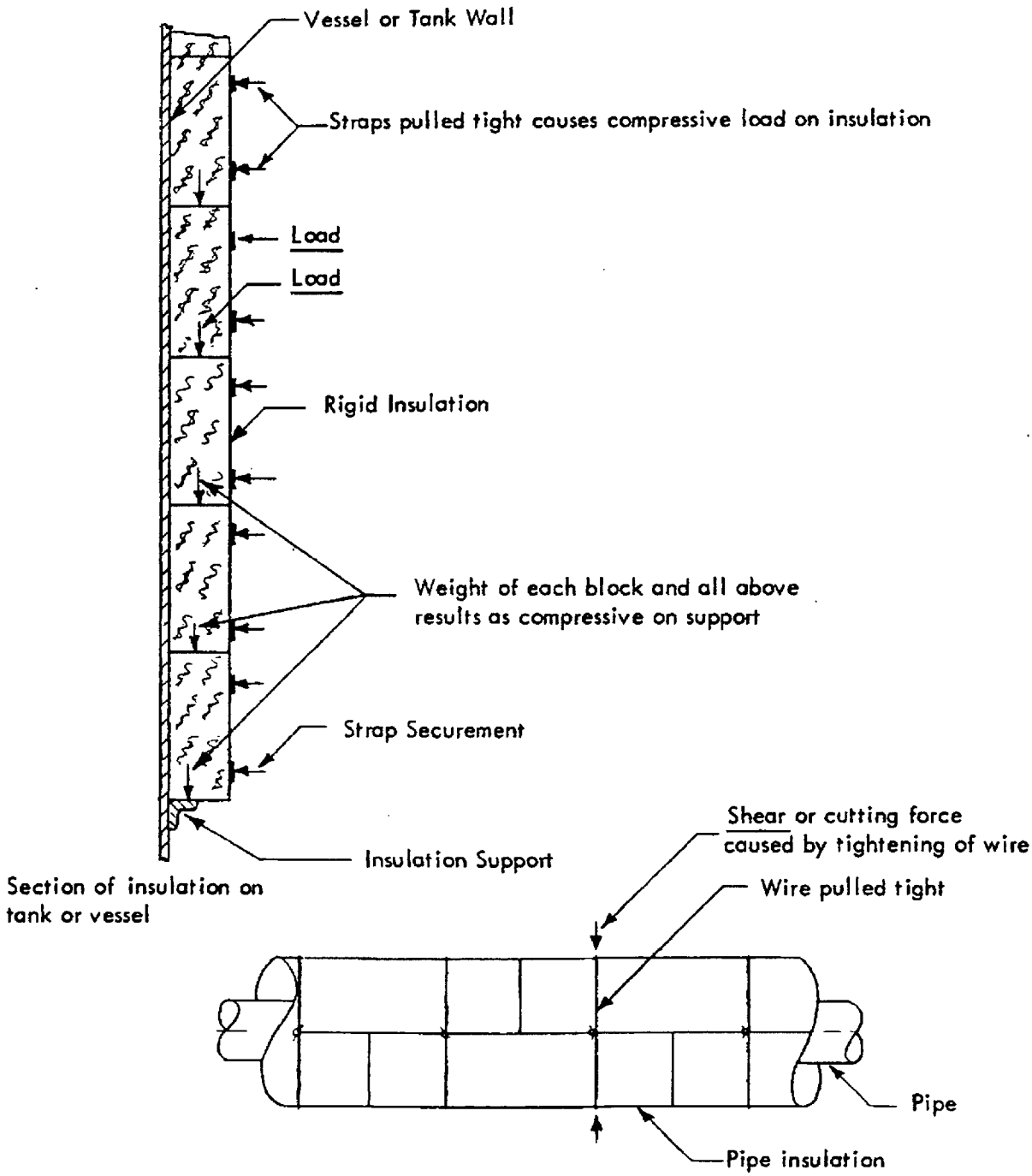
In addition to being subjected to its own weight, insulation may be required to support the weight of pipe and its contents or the weight of some object resting on it. These are illustrated in Figure VI-2.

When metal is heated, it expands (gets longer in length, width, and thickness) and when cooled it contracts (gets shorter in length, width, and thickness). This change in the dimensions of metal causes movement which, in turn, may impose tensile or compressive forces on the insulation. The growth of pipe due to being heated and the resultant tensile force, applied to insulation, is illustrated in Figure VI-3. Conversely, the compressive force applied to insulation when pipe contracts due to being lowered in temperature is shown in Figure VI-4. When operating temperature cycles from high to cold and back again to high temperatures, both tensile and compressive force are imposed on the insulation in turn.

To illustrate the amount of growth and shrinkage of pipe or vessels, the following table gives the expansion and contraction of various metals:

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INSTALLATION REQUIREMENTS



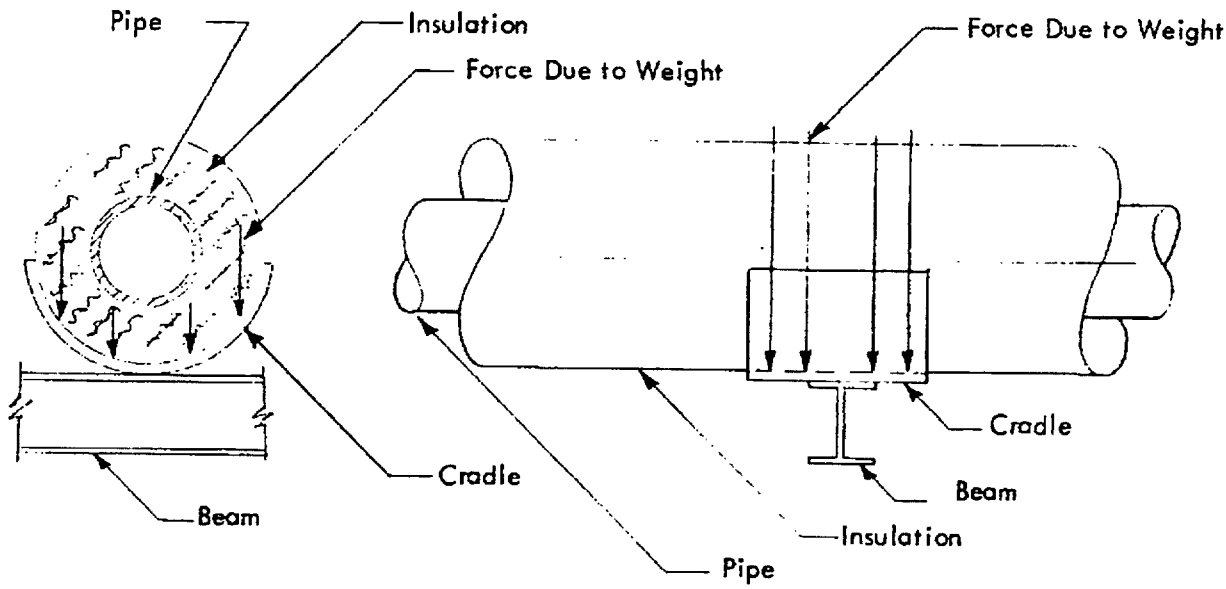
Pipe Insulation Secured To Pipe By Wire

FORCES IMPOSED ON RIGID INSULATIONS BY SUPPORTS AND SECUREMENTS

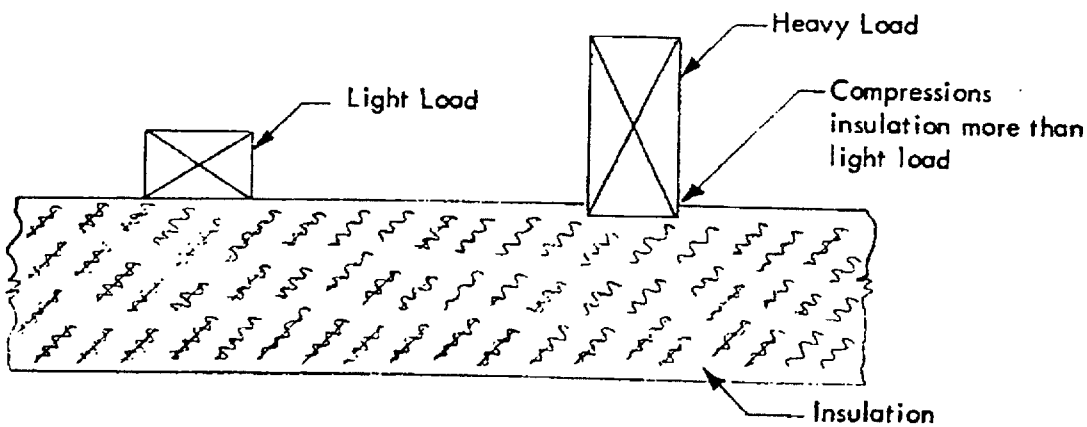
Figure VI-1

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INSTALLATION REQUIREMENTS



COMPRESSIVE FORCE ON INSULATION
SUPPORTED ON CRADLE



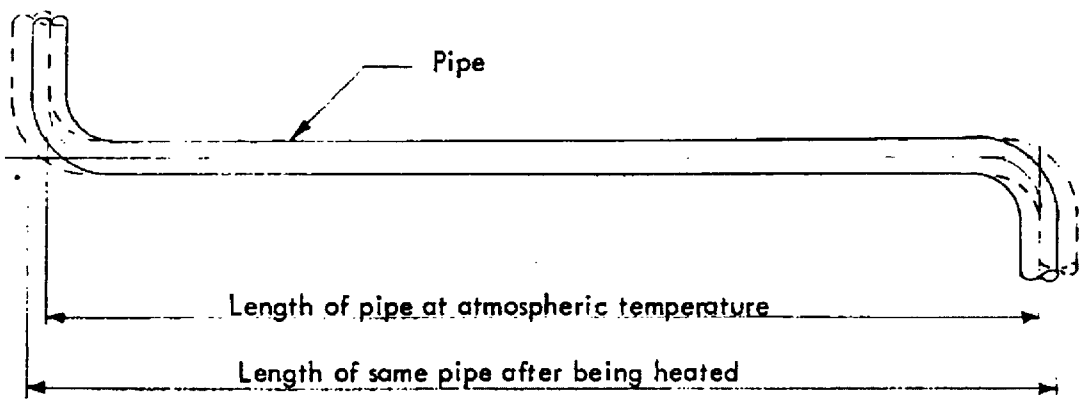
Weight Load On Top Of Insulation

COMPRESSION OF INSULATION DUE TO WEIGHT

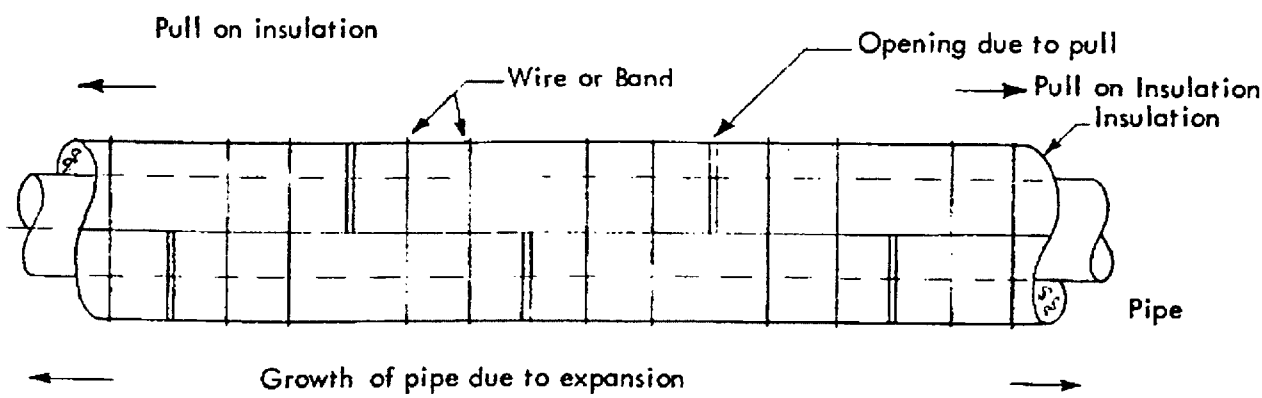
Figure VI-2

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INSTALLATION REQUIREMENTS



LENGTH OF PIPE CHANGE DUE TO EXPANSION



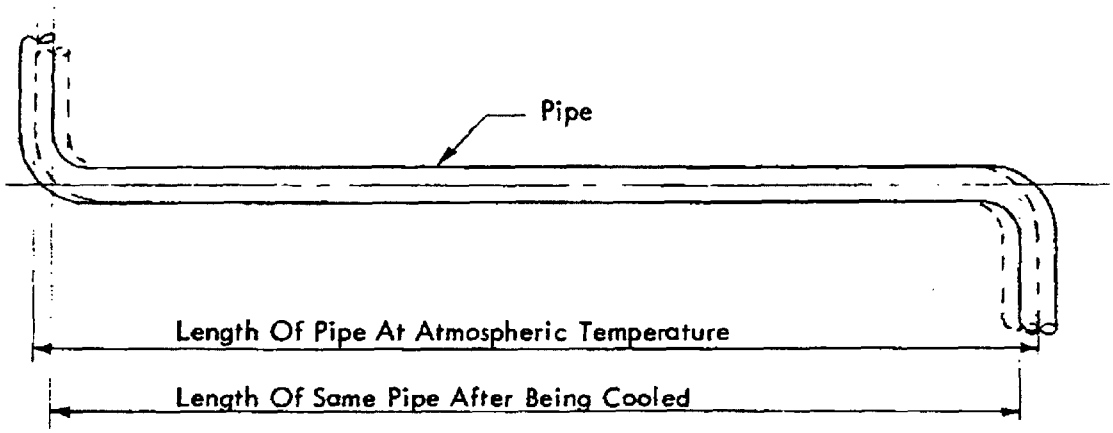
Tensile Force Exerted On Insulation Due To Increased Length Of Pipe

TENSIONAL FORCE APPLIED TO HIGH TEMPERATURE INSULATION

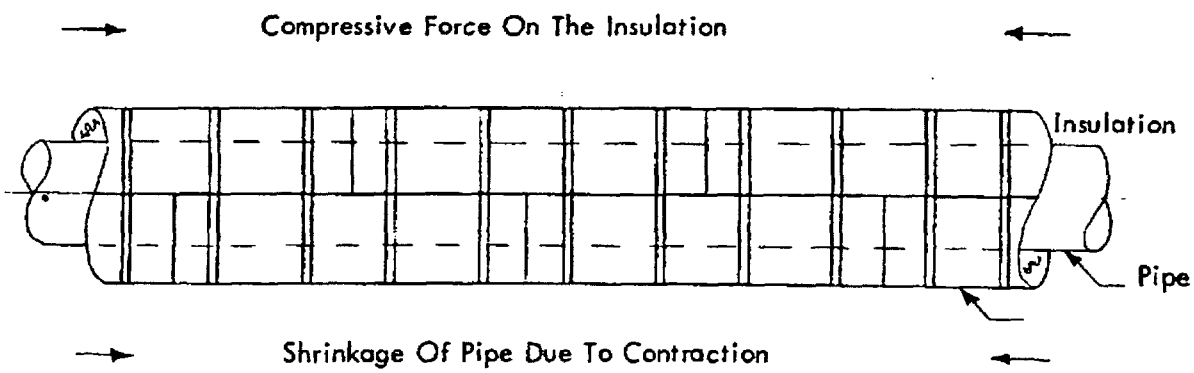
Figure VI-3

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INSTALLATION REQUIREMENTS



Length Of Pipe Change Due To Contraction



Compressive Force Exerted On Insulation
Due To Decreased Length Of Pipe

COMPRESSIVE FORCE APPLIED TO LOW TEMPERATURE INSULATION

Figure VI-4

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INSTALLATION REQUIREMENTS

PHYSICAL PROPERTIES - Contd

Inches of Linear Expansion Per 100 Feet
For Various Metals from 0°F

Temperature °	Carbon Steel	Cast Iron	Stainless Steel	Monel	Aluminum	Copper
-200	-1.28	-1.06	-2.03	-1.49	-2.69	-1.96
-100	-0.69	-0.59	-1.09	-0.82	-1.40	-1.04
0	0	0	0	0	0	0
100	0.75	0.66	1.12	0.85	1.50	1.13
200	1.55	1.37	2.23	1.73	3.08	2.29
300	2.37	2.11	3.38	2.65	4.74	3.46
400	3.23	2.88	4.56	3.68	6.48	4.67
500	4.15	3.72	5.80	4.73	8.27	5.91
600	5.10	4.59	7.04	5.86	10.10	7.18
700	6.08	5.50	8.31	6.98	11.95	8.47
800	7.11	6.46	9.61	8.16	13.83	9.79
900	8.17	7.45	10.93	9.35		11.16
1000	9.28	8.49	12.26	10.54		12.54

Vibration of pipe or vessels is another force that is transmitted from their surfaces to the insulation. In addition, at the interface surface, between the insulation and the vessel or pipe, the motion creates an abrasive action on the insulation.

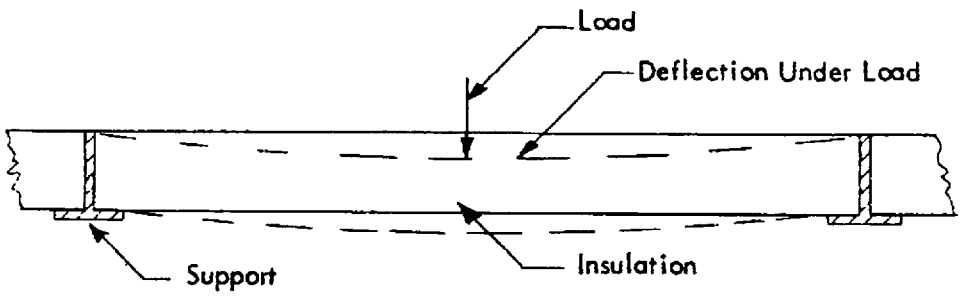
Insulation is also subject to external abuses such as objects being rested upon its impacts or external loads. External loads are of special consideration when the insulation is used as a structural member. Two examples of insulation used as structural member is shown in Figure VI-5.

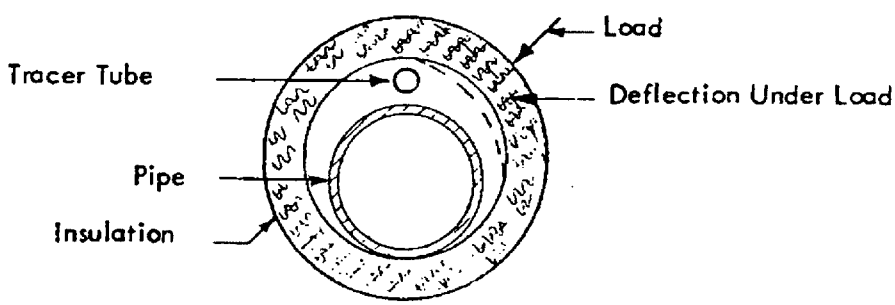
PHYSICAL PROPERTIES OF MATERIALS WHICH ARE NOT RIGID

Flexible Insulations, including flexible board pipe covering, blankets, batts, etc., are for use where installations require that the insulation be fitted around unever contours and where change in dimensions of the pipe or vessel require material which can change its dimension without physical breakdown. For this reason, flexibility of the material and its degree of recovery are of importance.

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INSTALLATION REQUIREMENTS





NOTE: Insulation must be sufficiently strong to withstand expected load without breaking.

EXAMPLES OF INSULATION USED AS STRUCTURAL MEMBERS

Figure VI-5

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INSTALLATION REQUIREMENTS

PHYSICAL PROPERTIES OF MATERIALS WHICH ARE NOT RIGID -

Mastic, Plastic, Cements, and Formed in Place Insulation are used for a variety of reasons. Where the installation has uneven contour, or where large areas are to be covered, these materials may be used because of their ability to be economically installed. Regardless of whether it is an insulating cement, sprayed or fibrous insulation, insulating mastic, or sprayed-on organic foam, they have physical properties to be considered in addition to their properties in their final form. These properties are:

Adhesion -- wet
Adhesion -- dry
Build
Expansion Ratio or Shrikage

Most of these rely on dry-adhesion to the substrate for their support in service. Sometimes they are reinforced with netting or other securements, but basically, for longlasting application, the bond between them and the substrate must remain unbroken. This means that the adhesion must be of sufficient strength to resist the forces imposed upon it by expansion and contraction, vibration and load, and the materials should have sufficient ability to elongate without shearing the bond.

During application, these materials must have sufficiently good wet adhesion to stay in place until dry or set.

Shrinkage of insulation cements, or expansion of foams, are properties which affect the application and final properties of the materials. These also affect the density of final set insulation.

CHEMICAL REQUIREMENTS

The chemical requirements which affect the selection of material must be broken down into several divisions, these being:

1. Chemical effect on the metal to which the insulation is applied.
2. Possible reaction with atmospheric or spillage contamination.
3. Resistance to chemicals of contamination.

The insulation should not cause rusting or corrosion to the metal to which it is applied. Various metals require different chemical properties of the applied insulation to ensure no rusting or corrosion. For example, insulation applied to steel should be slightly caustic, whereas an insulation used on aluminum should be neutral or slightly acid. Stress corrosion of stainless steel can be caused by any insulation containing chloride ions.

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INSTALLATION REQUIREMENTS

CHEMICAL REQUIREMENTS - Contd

When insulation becomes contaminated with chemical vapors or liquids, certain combinations can react. In some instances, this chemical reaction will produce sufficient heat to cause ignition with resultant dangerous fires.

Highly absorbent and adsorbent insulations can and do provide a means whereby large quantities of chemicals may be trapped. If these trapped chemicals are combustible, the saturated insulation will act as a wick to give off these liquids during a fire with resultant high contribution of fuel to the fire and its spread.

Another hazard to be considered is that of trapped toxic materials. An insulation may trap these for years. If moved or handled where it can contaminate an individual, it can prove very hazardous. In such cases, disposal of toxic-filled insulation is an almost unsolvable problem.

Of course, it is expected that the insulation material will resist fumes and chemicals to which it is subjected without deterioration.

MOISTURE REQUIREMENTS

To be thermally efficient, mass insulation depends upon trapped air or gas. If this trapped air is replaced by liquid (or ice), the insulation is no longer efficient.

Insulation indoors on hot lines or equipment with little or no chance of being wetted requires little concern for its efficient operation.

When insulation is located outdoors, or where it might be saturated with water or other liquids, then the insulation itself must be non-absorbent or be protected from water. This becomes a function of the weather-barrier, but in case of water leaks, then the properties of insulation which influence the extent of water damage are: (1) absorptivity, (2) capillarity.

Insulation installed on low-temperature pipe or vessel can become saturated with water from vapor in the ambient air.

Water vapor transmission is the amount of moisture in vapor phase which can pass through the insulation due to vapor pressure difference between its two sides. When the temperature of a surface is lower than that of the outside air, the moisture travel is to the cold surface. Where vapor is prevented from further travel by the cold surface, it becomes trapped and condenses. For this reason, when insulation is used on cold vessels or pipe, the vapor transmission must be very low, or it must be protected with an absolutely tight vapor-barrier which has sufficiently high resistance that gradual filling up of moisture is retarded long enough to obtain economic service.

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INSTALLATION REQUIREMENTS

FIRE SAFETY REQUIREMENTS

The safest of all insulations and weather-barriers are those which are non-combustible and fire-restant. As there is no clear definition as to what is required of insulation to meet these requirements in this manual, these terms are expected to mean the following:

The insulation shall contribute no fuel to the fire.

The insulation shall emit very little smoke.

The insulation shall emit no toxic gases.

The insulation shall have a melting point above 1600F.

Other than contributing to the hazard of a fire, an insulation may be expected to protect the vessel or pipe on which it is installed. In these cases the insulation shall have a high resistance to temperature change. It should not shrink or spall or deform when subjected to fire.

SUMMARY

There is no one insulation which fulfills all various requirements better than all others. For this reason, it is essentail that the insulation selected is the one that better serves all the essential needs. This means that all the requirements must be evaluated to select this material.

It might not be apparent to one not making a complete evaluation as to why a particular material was selected. Thus, if that individual substitutes a material for another, he may, without realizing it, be causing a failure or a hazard. For this reason, any substitution of materials should not be done without approval of those responsible for design.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

Thermal insulation installed, with its weather barrier or covering becomes an insulation system. The insulation system must fulfill its function and have satisfactory service life. As there is no one insulation or combination of insulations which will operate satisfactorily under all sets of conditions, each system must be designed to serve its particular set of service requirements. Each insulation system and its group of accessory materials must also be compatible with the other materials of the system.

As the temperature range of services requiring insulation is from -300F to 1800F, the first major factor to be considered in selecting an insulation system is the temperatures to which it will be subjected. It should be noted that the system must be suitable for the temperature imposed on it, for frequently the temperature limitation is not set by the basic insulation itself, but by some accessory component used in the system, or by the manner of application. This explains why it is necessary to have more than one specification for the same basic insulation used for different temperature ranges.

Material and Application Specifications provide the information necessary to purchase the correct materials and how these are to be installed to provide a suitable insulation system for the service intended.

Various thermal insulation systems in common use by Union Carbide Corporation, Group I, are described in the "Thermal Insulation Manual, Vol. I, Specifications". This publication is divided into three parts. Part GS, the General Specifications, provides information of a general nature essential to the use of the individual specifications. Part M is the Material Specification, which provides the necessary information needed for the purchase of insulation materials and the qualities required of these materials. The third part is made up of individual specifications containing essential information pertaining to the proper application of materials for the purpose intended.

A list of these individual specifications giving the specification number, basic insulations to be used, the temperature range for which the specification is suitable and what it is to be used to insulate is presented in Table VII-1.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

The system was devised so that the number would designate the insulation to be used and the letters the service or use.

A specification number can only indicate the use of that particular specification in a general way. It is impossible to designate all the details and limitations of that specification. For this reason, a summary of each of the specifications and its use follows:

SUMMARY OF INDIVIDUAL SPECIFICATIONS

Specification 10-H, 10-HSS

Insulation Materials: High temperature glass fiber insulation installed as inner layer cushion prior to installation of cellular glass.

Protective Cover: Most installations are protected with mastic reinforced with Dynel cloth. In some cases, where required, treated steel or stainless steel jacket may be specified.

Operating Temperature Range: 50F to 600F

Service: For use in storage or process vessels, equipment, and process piping located indoors or outdoors. This system is especially useful for installations where the absorption of vapor or liquids in the outer insulation cannot be tolerated. As the cellular glass insulation cannot become saturated, its conductivity in service remains constant. The system is suitable for installation on stainless steel surfaces. When exposed to external fire it will provide protection for the metal, to which it is applied, for approximately one hour.

Caution: To perform satisfactorily, proper installation of insulation expansion joints are essential.

Specification 10-J, 10-JSS

Insulation Materials: Cellular Glass

Protective Cover: Most installations are protected with mastic reinforced with Dynel cloth. In some cases, where required, treated steel or stainless steel may be specified.

Operating Temperature Range: 50F to 350F

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 10-J, 10-JSS - Contd

Service: For use on storage or process vessels and equipment and process piping located indoors or outdoors. This is the most vapor and water resistant system in the ambient to 400F range. This system is suitable for application where absorption of vapors or liquids in the insulation cannot be tolerated. The insulation is acid and caustic resistant; however, an outer covering must be selected which is resistant to the chemicals involved. The system is also suitable for use on electric traced lines operating below 212F where constant thermal conductivity is important. The system is suitable for installation on stainless steel surfaces.

Caution: When exposed to rapid change in operating temperature, the insulation will stress crack.

Specification 10-JU, 10-JUSS

Insulation Materials: Cellular glass

Protective Cover: Three coats of bituminous mastic and two layers of glass fiber reinforcing cloth.

Operating Temperature Limits: 50F to 350F

Service: Steam and process piping located underground. The only underground insulation system suitable for easy installation of steam or electric tracer systems.

Caution: Care must be exercised in the application of outer anti-abrasive coating on the inner surface of the straight pipe covering so that movement of pipe does not cause excessive abrasion wear of the insulation. Also, expansion chambers must be carefully installed to prevent breakage of the insulation by pipe movement. Water proofing must be installed to be absolutely water tight. Positive drainage of seepage water is essential to prevent buildup of water that would cause flotation of the insulation system.

Specification 10-L, 10-LSS

Insulation Materials: One layer of compressed fiber glass cushion blanket installed on cylindrical vessels and equipment prior to the application of cellular glass insulation. On piping, the cellular glass is installed directly to the pipe.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 10-L, 10-LSS - Contd

Protective Cover: Most installations are protected with mastic reinforced with Dynel cloth. In some instances, where required, treated steel jacket is used on the cylindrical section of vessels and on straight pipe covering.

Operating Temperature Range: -300 to 400F

Service: For low temperature refrigeration and process (with exception of oxygen) equipment located indoors or outdoors. Although high temperature limit is 400F this system is not recommended for service which is always above freezing. However, it is suitable for the high temperature caused by the thaw out system used with low temperature process lines. The system is suitable for use on stainless steel vessels and piping. This specification provides fire protection to the metal to which it is applied, for approximately one hour. If extended fire protection is required, specification 32-LFP should be used.

Caution: Properly constructed insulation expansion and contraction joints are essential.

Specification 10-LSP

Insulation Materials: Cellular glass

Protective Cover: Mastic reinforced with Dynel cloth

Operating Temperature Range: -40 to 150F

Service: A special system for the insulation of spheres in the -40 to 150F temperature range. Being non-combustible, the insulation will provide fire protection to the sphere to which it is applied for a period of approximately one hour.

Caution: The surface of the steel must be sandblasted and coated with inorganic zinc-silicate coating prior to the application of the insulation. Support of the insulation depends upon the bond between the steel, the coating, the adhesive and the cellular glass. Should this bond fail due to poor application of the coating or the adhesive, the installation will fail. Absolutely no other materials than those specified should be purchased or applied.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 10-OX

Insulation Materials: Heat treated glass fiber cushion on blanket installed on vessels and equipment prior to the application of cellular glass insulation. On piping the cellular glass is installed directly to the pipe.

Protective Cover: Mastic reinforced with Dynel cloth or stainless steel jacket.

Temperature Range: -300F to Atmos.

Service: Oxygen equipment and piping located indoors or outdoors.

Note: This specification only for oxygen service.

Caution: As oxygen can detonate when in contact with many different materials, all the materials used to insulate oxygen service must have been tested by Linde as being safe for oxygen service. All materials listed in the specification have been so tested. For this reason, absolutely no other materials than those specified should be purchased or applied.

Specification 12-H, 12-HSS

Insulating Material: Rigid urethane foam.

Protective Cover: Most frequently, equipment and fittings are protected with mastic reinforced with Dynel cloth. Straight pipe is more frequently weather protected with treated steel jacket.

Operating Temperature Range: 50F to 220F

Service: Process, hot water, and very low pressure steam equipment located outdoors and indoors.

Caution: This system gives very little protection from external fire. Protective devices must be sized as if equipment or vessels were bare. Steam vapor will saturate the material very rapidly and it is combustible, and emits dense smoke when burned. Not suitable for applications or vessels or piping operating at temperatures below ambient air temperature.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 14-J

Insulating Material: Flexible plastic foam.

Protective Cover: Where located indoors and concealed from view, no protective cover is required. Where located indoors and exposed to view the surface shall be painted with two coats of vinyl paint. Outdoor applications shall be protected with mastic reinforced with Dynel cloth.

Operating Temperature Range: 50F to 180F

Service: Particularly suitable for installation on tubing which might be bent to fit or installed after insulation is applied. Sheet insulation can be installed with adhesive to fit large flat or curved surfaces. For this reason it may be used to advantage on spheres or ducts operating at moderate temperatures.

Caution: This system gives very little protection from external fire. Protective devices must be sized as if the equipment or pipe was bare. The flexible plastic foam is combustible and emits dense smoke when burned.

Specification 15-H

Insulation Materials: Semi-rigid fibrous glass.

Protective Cover for Outdoor Service: Equipment is usually protected with mastic reinforced with Dynel cloth and straight pipe with treated steel jacket, or mastic reinforced with Dynel. Fittings and irregular surfaces are protected with mastic reinforced with Dynel cloth.

For Indoor Service: Glass cloth jacket finished with PVA coating on straight pipe. Mastic reinforced with Dynel cloth on fittings.

Operating Temperature Range: 70F to 750F

Service: For use on vessels and piping where abuses are moderate. Excellent for indoor applications. Fire spread and smoke index sufficiently low to pass most building codes.

Caution: This system gives little protection from external fires. Protective devices must be sized as if equipment or vessels were bare.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification Nos. 17-RX (external, 17-RY (internal)

Insulation Material: Semi-rigid glass fiber board.

Protective Cover:

External, indoors:	Where installed inside of duct, none when installed outside of duct and where concealed from view the factory applied jacket shall have joints sealed with tape and fire resistant adhesive. Where exposed to view, factory applied canvas jacket shall be painted with PVC paint.
External, outdoors:	The factory applied, vapor barrier jacket shall be sealed the same as required for indoors application, then coated with mastic reinforced with Dynel cloth.

Operating Temperature Range: 60F to 150F

Service: Either external or internal insulation for air conditioning and heating ducts.

Caution: When air conditioning duct operates at lower than ambient temperature, joints of factory applied vapor barrier jacketing must be vapor sealed with care to retard vapor from entering the insulation.

Specification Nos. 18-FX (external), 18-FY (internal)

Insulation Material: Flexible fibrous glass blanket

Protective Cover:

Internal:	None
External:	This application is used only on indoors applications, concealed from view. The factory-applied vapor barrier facing should be adhered to insulation with adhesive and its laps sealed with joint tape.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification Nos. 18-FX (external), 18-FY (internal) - Contd

Operating Temperature Range: 60F to 150F.

Service: Either external (FX) or internal (FY) insulation for air conditioning and heating ducts located where they are protected from physical abuses.

Caution: Care must be taken to obtain excellent sealing of jacket joints.

Specification 19-H, 19-J

Insulation Material: 19-J Fibrous glass side wall and roof insulation. 19-H Mineral Wool side walls, expended silica roof insulation.

Protective Cover: Factory-attached aluminum panel. 19-H has corrugated aluminum jacket, whereas 19-J is supplied with smooth aluminum panel.

Temperature Range: 60F to 450 F

Service: For vessels 12 feet and larger in diameter - where used when high winds are expected the 19-J system should not be used as light weight glass fiber roof insulation tends to lift then blow off. Also, 19-J cannot be used on vessels on which the use of stud welding is prohibited.

Caution: Both systems give little protection from external fire. Protection devices must be sized as if vessels were bare.

Care must be taken in panel layout to obtain a neat, clean insulation application.

Specification 21-H, 21-HSS

Insulation Material: Preformed asbestos fiber.

Protective Cover: Straight pipe, either metal jacket or mastic reinforced with Dynel cloth. Fittings, mastic reinforced with Dynel cloth.

Temperature Range: 212F to 1000F

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 21-H, 21-HSS - Contd

Service: For hot process and steam lines. Especially useful for high temperature steam traced lines. The material has high resistance to fracture, thus will not break into pieces when subjected to a blow or pressure between lines of support. Has good fire resistance for a limited time.

Caution: Weather-barrier must be excellently sealed as material is very absorbant. For this reason this system is not recommended where material may become saturated from combustibles due to flange leakage, etc. Mechanics should exercise care and take all safety precautions to prevent breathing of the asbestos fibers which may be floating in the air when the material is cut.

Specification 22-H, 22-HSS, and 22-HSP

Insulation Materials: Bonded Expanded Silica.

Note: On vessels over 400F or over 8'-0" in diameter the specified cushion blanket is to be installed prior to installation of the expanded silica.

Protective Cover: Straight pipe, and cylindrical sections of vessels either metal, or mastic reinforced with Dynel cloth. Fittings, heads and irregular surfaces of vessel protected with mastic reinforced with Dynel cloth.

Temperature Range: 50F to 1400F

Service: Steam and process equipment and piping. Used where fire protection is of importance. The only specification which should be used on traced lines operating below 212F. Also, this specification or 32-HFP are the specifications to be used on Ethylene Oxide and Acetylene services.

Special specification 22-HSP is for insulating of hot spheres. The temperature limitations on this specification, however, is 70F to 500F.

Caution: As bonded expanded silica is water repellent it requires special solvent type adhesive for cementing it together. Likewise ordinary insulating cements will not bond to its surface.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 23-H, 23-HSS

Insulation Material: Calcium Silicate.

Note: On vessels over 400F or 8'-0" in diameter, specified cushion blanket is to be installed prior to application of the calcium silicate.

Protective Cover: Straight pipe, and cylindrical sections of vessels either metal or mastic reinforced with Dynel cloth. Fittings, heads of vessels, and irregular surfaces protected with mastic reinforced with Dynel cloth.

Temperature Range: 212F to 950F

Service: Weather-barriers must be excellently sealed as material is very absorbant. Material contains asbestos fibers so safety precautions should be taken to prevent breathing in of the insulation dust.

Specification 25-H

Insulation Materials: High temperature calcium silicate and regular calcium silicate.

Note: On vessels high temperature cushion blanket should be installed prior to the installation of the two layers of calcium silicate.

Protective Cover: Straight pipe, and cylindrical sections of vessel either metal or mastic reinforced with Dynel cloth. Fittings, heads of vessels, and irregular surfaces protected with mastic reinforced with Dynel cloth.

Temperature Range: 1000F to 1600F

Service: Steam and process equipment in the 750F to 1200F range.

Caution: In this temperature range the proper construction of expansion joints is of utmost importance. This specification should not be used for fire protection, nor is it suitable for application to surfaces of stainless steel. The calcium silicate contains asbestos so safety precautions should be taken to prevent breathing in of the dust.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 31-H, 31-HSS

Insulation Material: All metal, stainless steel case enclosing reflective sheets of aluminum.

Protective Cover: Factory applied stainless steel jacket.

Temperature Range: 33F to 1000F

Service: For process pipe and equipment. For special installations where absorption of chemicals by insulation cannot be tolerated. Also very useful where fast removal or replacement of insulation is of importance. Advantageously used on heads or flanges of vessels, which may be insulated, but which require frequent removal for process purposes.

Caution: Reflective insulation is custom made to fit vessel or piping system. Does not lend itself for field cutting and fitting. Entire insulation, including its jacket, must be factory fabricated from vessel or piping drawings. Order of application of individual units must be in accordance with manufacturers recommendations.

Specification 32-HFP & 32-HFPSS

Insulation Materials: Inner and outer layer of expanded silica.

Note: On vessels over 400F operating temperature or over 8'-0" in diameter specified cushion blanket to be installed prior to application of the expanded silica.

Protective Cover: Straight pipe, and cylindrical sections of vessels either metal or mastic reinforced with Dynel cloth. Fittings, heads of vessels and irregular surfaces protected by mastic reinforced with Dynel cloth.

Temperature Range: 40F to1400F (operating)

Service: For insulating and fire protection of vessels, equipment or piping operating at ambient air temperature and above. This specification and 32-LFP are the only specifications to be used where the insulation is expected to serve as extended time fire protection. Specifically for use for protection of reactive chemicals.

Caution: Insulation must be installed in double layer broken joint construction to retard exposure to fire at joints.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 32-LFP, 32-LFPSS

Insulation Materials: Inner layer cellular glass and outer layer expanded silica.

Note: On all vessels, specified cushion blanket should be installed prior to application of the cellular glass and expanded silica insulations.

Protective Cover: Straight pipe and cylindrical sections of vessels, either metal or mastic reinforced with Dynel cloth. Fittings, heads of vessels and irregular surfaces protected by mastic reinforced with Dynel cloth.

Temperature Range: -300F to 400F (operating temperature)

Service: For insulating and fire protection of vessels, equipment or piping operating at temperatures below ambient during at least part of the operating cycle. This specification and 32-HFP are the only specifications to be used where the insulation is expected to serve as extended time fire protection specifically for use for protection of reactive chemicals.

Caution: Insulations must be installed in double layer, broken joint construction to retard exposure to fire at joints.

Specification 37-H

Insulation Materials: This specification is one for factory conduit cased insulation. The insulation may be of any type, as required.

Protective Cover: Steel conduit, galvanized and with factory applied water resistant heavy duty coating.

Temperature Range: As determined by the insulation specified, up to and including 750.

Service: For underground hot piping. Suitable for all ground conditions. Field installation of insulation is only required where sections of the assembly are field connected.

Caution: Water proofing of the field connected joints must be done with care as any leaks in these joints will adversely affect the entire system.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 38-H

Insulation Material: Foamed urethane.

Protective Cover: Heavy gauge PVC conduit.

Temperature Range: 50F to 220F

Service: For moderate temperature underground lines. Suitable for all ground conditions. Field installation of insulation is only required where sections of the assembly is field connected.

Caution: Waterproofing of the field connected joints must be done with care to prevent water seepage into the system.

Specification 39-H

Insulation Material: Bituminous Fill

Protective Cover: None

Temperature Range: Depending on type listed as follows:

Type A	220F to 300F
Type B	330F to 385F
Type C	385F to 520F

Service: For underground hot lines. Only recommended where soil drainage is excellent, and water table is considerably lower than the installation. In most installations corrosion protection and galvanic protection of lines are essential. Should be used only on lines operating at constant temperature.

Caution: Packing of bituminous fill insulation around, particularly underneath, of line is essential. Line should be put into service to cure the material before backfilling.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 40-J

Insulation Material: Cork filled PVA mastic.

Protective Cover: None

Temperature Range: 34F to 180F

Service: To retard condensate drip from vessel or piping operating at a temperature below ambient air dew point.

Caution: Mastic to be sprayed or troweled to surface. The surface must be dry during application and be above ambient dew point temperature until mastic has dried.

Specification 41-H and 42-H

Insulation Material: Sprayable asbestos fibers and inorganic binders.

Protective Cover: Cylindrical sections of vessel either metal or mastic reinforced with Dynel cloth. Large flat surfaces and irregular surfaces to be protected with mastic reinforced with Dynel cloth.

Temperature Range:

41-H, Amosite Asbestos Fibers	70F to 700F
42-H, Crocidolete Asbestos Fibers	70F to 1350F

Service: For process vessels, flue gas ducts and fire protection of steel. Used advantageously for very large hot surfaces.

Caution: Surface of steel must be clean and free of mill scale. During application all workmen in area should wear proper dust masks.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

SUMMARY OF INDIVIDUAL SPECIFICATIONS - Contd

Specification 43-H, 43-HSS

Insulation Material: Urethane liquid sprayed and foamed on surface to be insulated.

Protective Cover: Sprayed mastic.

Temperature Range: 50F to 250F

Service: For large area vessels, when fire protection by insulation is not important.

Caution: Not to be used on any vessels containing reactive chemicals. All fire safety devices must be calculated as if vessel was bare. Correct mix of two component liquids is important. Should not be sprayed when ambient conditions are less than 70F or when wind velocity is greater than 5 mph. Fresh air mask required when spraying indoors. Proper filtering mask essential when spraying outdoors.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE VII-1

SPECIFICATION NUMBER	INSULATION	OPERATING TEMPERATURE RANGE
10-H, 10-HSS	Cellular Glass (with glass fiber inner cushion blanket)	70F (21C) to 600F (316C)
10-J, 10-JSS	Cellular Glass	50F (10C) to 400F (204C)
10-JU, 10-JUSS	Cellular Glass - Underground	50F (10C) to 350F (177C)
10-L, 10-LSS	Cellular Glass (with glass fiber inner cushion blanket on equipment only)	-300F (-184C) to 400F (204C)
10-LSP	Cellular Glass	-40F (-40C) to 150F (66C)
10-OX	Cellular Glass (with heat treated fiber inner cushion blanket)	-300F (-184C) to Atmos.
12-H, 12-HSS	Rigid Urethane Foam	50F (10C) to 220F (104C)
14-J	Flexible Plastic Foam	50F (10C) to 180F (82C)
15-H	Fibrous Glass, Bonded	70F (21C) to 400F (204C)
19-H	Fibrous Glass Panels, Faced with Corrugated Aluminum	70F (21C) to 400F (204C)
19-J	Fibrous Glass Panels, Faced with Smooth Aluminum	70F (21C) to 400F (204C)
21-H, 21-HSS	Asbestos Fibers, Bonded	212F (100C) to 1000F (538C)
22-H, 22-HSS	Bonded Expanded Silica	40F (4C) to 1400F (760C)
23H, 23-HSS	Calcium Silicate	212F (100C) to 1000F (538C)
25-H	High Temperature Calcium Silicate (inner layer), Calcium Silicate (outer layer)	750F (399C) to 1600F (871C)
31-H, 31-HSS	Reflective, Stainless Steel Cased Reflective Shields	33F (1C) to 1000F (538C)
32-HFP, 32-HFPSS	Bonded Expanded Silica (double layer-broken joint construction)	40F (4C) to 1400F (760C)
32-LFP, 32-L	Cellular Glass (inner layer), Bonded Expanded Silica (outer layer)	-300F (-184C) to 400F (204C)
37-H	Steel Underground Conduit - Insulation as Selected - Underground	40F (4C to 750F (399C)
38-H	Molded Urethane Foam on Pipe in PVC Conduit - Underground	50F (10C) to 220F (4C)
39-H	Bituminous Fill - Underground	220F (104C) to 520F (271C)
40-J	Cork Filled PVA Mastic	34F (1C) to 180F (82C)
41-H	Sprayed Amoiste Asbestos	70F (21C) to 700F (371C)
42-H	Sprayed Crocitolite Asbestos	700F (371C) to 1350F (732C)
43-H, 43-HSS	Sprayed Urethane Foam	50F (10C) to 250F (121C)

Letters in Specifications:

H indicated Ambient to high temperature service.
J indicates Ambient or cyclic temperature service.
L indicates Low temperature service
SS indicates suitable for application steel surface.
SP indicates for application to sphere.
OX indicates for oxygen service.
FP indicates suitable for Fire Protection.
U indicates for underground service.

Metal Jackets

When metal jackets are specified add M to Spec. No. for stainless steel or MT for treated steel.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE I EQUIPMENT

FOR APPLICATION WHERE OPERATING TEMPERATURES ARE BELOW AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Process equipment except oxygen, oxide and acetylene	50F (10C) down to -300F (-185C)	Indoors or outdoors	10-L, 10-LSS	Cellular glass (glass blanket inner layer cushion blanket)	Dynel reinforced Mastic	Good fire resistance for limited time. For extended time, fire protection use Spec. 32-LFP.	Excellent resistance to vapor migration. Good resistance to solar radiation.	Easy to shop fabricate.
Oxygen equipment	50F (10C) down to -300F (-185C)	Indoors or outdoors	10-LOX, 10-LOXSS	Cellular glass (heat treated glass blanket inner layer cushion blanket)	Dynel reinforced Mastic	Good fire resistance for limited time. (For extended time fire protection use stainless steel jacket instead of Mastic)	Excellent resistance to vapor migration.	All materials and accessories have been tested to be safe for oxygen service.
Oxides, acetylene and other low temperature process equipment requiring extended time fire protection.	50F (10C) down to -300F (-185C)	Indoors or outdoors	32-LFP M or MT 32-LFP SS M or MT	Cellular glass and Expanded Silica, outer layer (glass blanket inner layer cushion blanket)	Metal jacket on cylindrical section. Dynel reinforced Mastic on heads and fittings.	Care must be taken that insulation is installed broken joint construction.	Excellent resistance to vapor migration. Two hour fire protection.	Metal on cylindrical sections selected suitable to resist surrounding contamination.
Process equipment, low temperature with thawout up to 400F	400F (205C) Thawout down to -300F (-185C)	Indoors or outdoors	Use appropriate system above					Exercise special care in design and construction of expansion-contraction joints.
Water and process equipment, to prevent condensate drip.	Slightly below ambient	Indoors	40-J	PVA cork filled Mastic (color as specified)	None	Not suitable for conservation of refrigeration. Thickness $\frac{1}{8}$" to $\frac{1}{4}$".	An insulating Mastic which retards condensate drip on vessels slightly below ambient temp.	Applied by palm, trowel or spray to required thick. Surface must be dry at time of application and until mastic sets.

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UCC 002749

SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE I EQUIPMENT

FOR APPLICATIONS WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Process and storage vessels except those containing reative chemicals.	50F (10C) to 250F (121C)	Outdoors	43-H, 43-HSS	Sprayed urethane foam	Mastic	Short time resistance to external fire. Must be used in accordance with Fire Protection recommendations.	Light weight. Water resistant.	Spray application of insulation and mastic. Use proper safety precautions during spraying.
Process and utility equipment except those containing reative chemicals.	50F (10C) to 400F (205C)	Indoors or outdoors	15-H, 15-HM, 15-HMT	Glass fiber	Glass cloth and PVA Coating indoors. Metal or Dynel reinforced mastic outdoors.	Relatively soft. Will not withstand heavy mechanical abuse. Short time fire resistance.	Good flexibility. Will meet building code requirements on flame spread and smoke density.	Not easily shop fabricated. Limited sizes of molded glass fiber fittings are marketed.
Process and storage vessels, except those containing reative chemicals.	50F (10C) to 400F (205C)	Outdoors	19-H, 19-J	Glass fiber panel with factory attached facing on side walls. 19-H expanded silica roof and heads. 19-H glass fiber roof insulation on roof.	Aluminum weather-barrier facing. 19-H is ribbed facing. 19-J is smooth facing.	Not suitable for vessels less than 12'0" OD in diameter. Short time fire resistance.	Light weight. Fast installation. Panels cover	19-H can be installed by strap or studs. 19-J requires studs be welded to vessel wall.
Process and storage vessels or equipment. (Especially if highly toxic chemicals are involved)	50F (10C) to 350F (178C)	Indoors and outdoors	10-J, 10-JSS	Cellular glass	Dynel reinforced Mastic.	Will crack if subjected to rapid change of operating temperature.	Excellent resistance to vapors and liquids. Will not become saturated by hazardous or toxic fumes or liquids. Good resistance to solar radiation.	Proper expansion and contraction joints are essential.
Process and storage vessels or equipment (where operating temperature is subject to rapid change).	50F (10C) to 600F (315C)	Indoors or outdoors	10-H, 10-HSS	Cellular glass and high temperature mineral fiber cushion blanket inner layer.	Dynel reinforced Mastic.	Inner mineral fiber inner layer is absorbent.	Most vapor and liquid resistant insulation system for rapid operating temperature change and temperature above 350F.	Proper expansion and contraction joints are essential.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE I EQUIPMENT

FOR APPLICATIONS WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Steam, and process including acetylene oxide and other reative chemical equipment. Also electric and steam traced vessels.	50F (10C) to 1400F (760C)	Indoors or outdoors	22-H, 22-HM, or MT 22-HSS, 22-HSS M or MT	Expanded silica	Metal and/or Dynel reinforced Mastic depending upon size, shape and conditions.	Although it is silicone treated to obtain repellency, it can be saturated by some chemicals.	Water repellent. Max. resistance to external fire. This, and Spec. 32-H, are only spec's suitable for Ethylene Oxide.	Is more difficult to fabricate than calcium-silicate.
Steam, and process equipment.	212F (100C) to 1000F (529C)	Indoors or outdoors	23-H, 23-HM, or MT 23-HSS, 23-H5M, or MT	Calcium silicate	Metal and/or Dynel reinforced Mastic depending upon size, shape and conditions.	Very absorbent. Subject to saturation by leaked or spilled liquids. Weather-barrier must be tight to prevent water damage.	Strong, can be cut and fabricated with ease. Max. resistance to external fire.	Must be protected from rain during installation.
Process equipment except stainless steel.	1000F (529C) to 1800F (982C)	Indoors or outdoors	25-H, 25-HM or MT	High temperature calcium silicate inner layer, calcium silicate outer layer.	Metal and/or Dynel reinforced Mastic depending upon size, shape and conditions.	Very absorbent. Subject to saturation by leaked or spilled liquids. Weather-barrier must be tight to prevent water damage.	Strong, can be cut and fabricated with ease. Max. resistance to external fire.	Must be protected from rain during installation.
Process equipment, where absorbance cannot be tolerated or where quick removal and replacement is necessary.	35F (2C) to 1000F (529C)	Indoors or outdoors	31-H, 31-HSS	Prefabricated units consisting of stainless steel jacket enclosing aluminum or stainless steel reflective sheets.	Factory fabricated units to fit side walls, heads and trim.	Prefabricated as a system, thus must be ordered from the manufacturer to fit the particular equipment. Detail information must be provided.	Advantageous for frequent removal and replacement. Desirable where absorption of hazardous liquids or vapor cannot be tolerated.	For temperatures above 1000F. Units made of special alloys are obtainable.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE I EQUIPMENT

FOR APPLICATION WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Process equipment, for extended time fire protection.	Ambient to 1400F (760C)	Indoors or outdoors	32-HM or MT 32-HSS M or MT	Expanded silica	Metal jacket on cylindrical sections. Dynel reinforced mastic on valves and fittings.	Same as specifications 22-H, 22-HSS	Installed in double layer--broken joint construction.	Suitable for application on reactive chemicals equipment, including oxide and acetylene.
Process equipment of irregular shape such as turbines. Large flat areas such as flue gas ducts.	70F (21C) to 700F (370C) 700F (370C) to 1350F (732C)	Indoors or outdoors Indoors or outdoors	41-H 41-H	Sprayed Amosite asbestos fibers Sprayed Crocidolite asbestos fibers	Dynel reinforced Mastic	Effective for insulation of large areas only. Do not use on small equipment.	Can be applied to any contour. Has sufficient extensionability to move with metal expansion.	Depends upon surface adhesion Surface must be properly cleaned or prepared before application.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE II PIPE AND PIPE FITTINGS

FOR APPLICATION WHERE OPERATING TEMPERATURES ARE BELOW AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Process lines except oxygen, oxide, and acetylene.	50F (10C) Down to -300F (-185C)	Indoors or outdoors	10-L, 10-LSS	Cellular glass	Dynel reinforced Mastic	Good fire resistance for limited time. For extended time fire protection use Spec. 32-LFP.	Excellent resistance to vapor migration.	Easy to shop fabricate.
Oxygen lines.	50F (10C) Down to -300F (-185C)	Indoors or outdoors	10-L OX, 10-L OXSS	Cellular glass	Dynel reinforced Mastic	Good fire resistance for limited time. For extended time fire protection use stainless steel jacket instead of mastic.	Excellent resistance to vapor migration.	All material and accessories must be safe for oxygen service.
Oxides, acetylene and other low temp. process lines requiring extended time fire protection.	50F (10C) Down to -300F (-185C)	Indoors or outdoors	32-LFP M or MT 32-LFPSS M or MT	Cellular glass and expanded silica (outer layer).	Metal jacket on straight pipe, Dynel reinforced Mastic on valves and fittings.	Care must be taken that insulation is installed broken joint construction.	Excellent resistance to vapor migration. Two hour fire resistance.	Metal on straight pipe selected to be suitable to resist surrounding contamination.
Process lines, low temperature with thaw-out up to 400F.	400F (205C) Thaw-out down to -300F (-185C)	Indoors or outdoors	Use appropriate system above.					Exercise special care in design and construction of expansion-contraction joints.
Water and process lines, to prevent condensate drip.	Slightly below ambient.	Indoors	40-J	PVA cork filled mastic.	None	Not suitable for conservation of refrigeration. Thickness $\frac{1}{8}$" to $\frac{1}{4}$". Should be used only on pipes 3" NPS and larger.	An insulating mastic which retards condensate drip from lines operating slightly below ambient.	Applied by palm, trowel or spray, surface must be dry at time of application and until mastic sets.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE II PIPE AND PIPE FITTINGS

FOR APPLICATION WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Water lines and instrument tubing to conserve heat or prevent condensate drip.	50F (10C) to 160F (71C)	Indoors or outdoors	14-J, 14-JSS	Flexible plastic foam	Vinyl paint	Poor fire resistance. Limited usage under building codes.	For semi-flexible instrument tubing and air cond. unit run outs.	Can be installed on tubing before tubing is bent and installed.
Process lines, for extended time fire protection.	Ambient to 1400F (760C)	Indoors or outdoors	32-HM or MT 32-HSS M or MT	Expanded silica	Metal jacket on straight pipe. Dynel reinforced mastic on valves and fittings.	Same as specification 22-H and 22-HSS	Suitable for application on reactive chemical lines, including oxide and acetylene.	Installed in double layer-broken joint construction.
Underground process, hot water and low pressure steam.	50F (10C) to 230F (110C)	Underground	38-H	PVC conduit encased urethane foam insulated pipe. Factory made.	Rigid PVC high impact plastic conduit.	Not available for pipe sizes over 10" N.P.S.	Fittings are factory insulated. Obtained as complete pipe and insulation system.	Field installed by welding pipe together and sealing PVC conduit with special couplings.
Underground process, and steam lines.	Special glass fiber up to 400F (205C). Calcium silicate up to 1000F (529C)	Underground	37-H	Pipe and insulation (as specified).	Factory formed and coated steel conduit.	System designed by the manufacturer.	Suitable for locations below ground water level.	Field installed by welding pipe together and sealing conduit with special couplings.
Underground process and traced lines	50F (10C) to 350F (173C)	Underground	10-JU	Cellular glass	Bituminous mastic with two layers of glass fabric.	Must be above height of water table and be provided with drainage for surface water.	Only system suitable for easy installation of tracing systems.	Where temperatures exceed 350F special system is required.
Underground process and steam lines	220F (104C) to 520F (271C) depending on grade.	Underground	39-H	Granulated bitumen fill type.	None	Must be in soil of excellent drainage. Not recommended on slopes or pipes with down time or cycle temp.	Heat causes material to form water barrier around pipe.	Galvanic protection of importance.

NOTES: (1) Where run of pipe is short between fittings, use Dynel reinforced mastic.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE II PIPE AND PIPE FITTINGS

FOR APPLICATION WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Process lines	1000F (529C) to 1800 (982C)	Indoors or outdoors	25-HM, 25-HMT	High temp. calcium-silicate inner layer. Calcium-silicate outer layer.	Metal jacket on straight pipe. Dynel reinforced Mastic on valves and fittings.(1)	Very absorbent. Subject to saturation by leaked or spilled liquids. Weather-barrier must be tight to prevent water damage.	Strong, can be cut or fabricated with ease. Max. resistance to external fires.	Metal on straight pipe selected to be suitable to resist surrounding contamination.
Process lines, where absorbence cannot be tolerated or where quick removal and replacement is necessary.	35F (2C) to 1000F (529C)	Indoors or outdoors	31-H, 31-HSS	Prefabricated units consisting of stainless steel jacket enclosing aluminum or stainless steel reflective sheets.	Factory jacketed pipe and fittings.	Prefabricated as a system, thus must ordered from manufacturer to fit the pipe system.	Advantageous for frequent removal and replacement. Desirable where absorption of hazardous liquids or vapor cannot be tolerated.	For temperatures above 1000F units are obtainable.
Process lines, high pressure steam traced process lines.	212F (100C) to 1000F (529C)	Indoors or outdoors	21-HM, 21-HMT 21-HSSM, 21-HSSMT	Asbestos fibers.	Metal jacket on straight pipe, Dynel reinforced Mastic on valves and fittings.(1)	Very absorbent. Subject to saturation by leaked or spilled. liquids. Weather-barrier must be tight.	Excellent bridging properties. Resists fracturing.	Fitting covers requiring block must be prefabricated with calcium-silicate.
Water and process lines to retard freezing.	Atmospheric	Outdoors	10-L, 10-LSS	Cellular glass	Dynel reinforced Mastic	Insulation, without heat source, will only retard freezing.	Excellent resistance to vapor and water migration.	Easy to shop fabricate.
Water, steam, process lines and utilities in buildings.	50F (10C) to 400F (205C)	Indoors	15-H	Glass fiber	Factory applied jacket on straight pipe. Fabric reinforced water emulsion coatings on fittings (where exposed).	Relatively soft. Will not withstand heavy mechanical abuse. Short time fire resistance.	Good flexibility, easy handling. Will meet building code requirements on flame spread and smoke density.	In pipe chases, over suspended ceiling, etc., jacket required. Where exposed, selected required jacket must be specified.

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SELECTION OF INSULATION MATERIAL AND APPLICATION SPECIFICATION TO FULFILL INSTALLATION REQUIREMENTS

TABLE II PIPE AND PIPE FITTINGS

FOR APPLICATIONS WHERE OPERATING TEMPERATURES ARE ABOVE AMBIENT

SERVICE	OPERATING TEMP. RANGE	LOCATION	SPECIFICATION NUMBER	INSULATION	PROTECTIVE COVER	LIMITATIONS	SPECIAL PROPERTIES	COMMENTS
Water and process lines except reactive chemicals.	50F (10C) to 220F (115C)	Outdoors	12-HM, 12-HSS M	Rigid Urethane Foam	Metal jacket on straight pipe Dynel reinforced Mastic on valves and fittings.(1)	Short time resistance to external fire. Must be used in accordance fire protection recommendations.	Light weight, water resistant.	Shop molded, PVC jacketed fitting covers may be used where available.
Steam and process, including acetylene, oxide, and other reactive chemical piping. Electric and steam traced lines.	50F (10C) to 1400F (760C)	Indoors or outdoors	22-HM, or 22-HMT 22-HSSM or 22-HSSMT	Expanded silica	Metal jacket on straight pipe. Dynel reinforced Mastic on valves and fittings. (1)	Although it is silicone treated to obtain repellency it can be saturated by some chemicals.	Water repellent. Max. resistance to external fire. This, and Spec. 32-H, are only spec's. suitable for Ethylene Oxide service.	Metal on straight pipe selected to be suitable to resist surrounding contamination.
Steam, process, electric traced lines (especially if highly toxic chemicals are involved).	50F (10C) to 400F (205C)	Indoors or outdoors	10-J, 10-JSS	Cellular glass	Dynel reinforced Mastic.	Will crack if subjected to rapid change of operating temperature.	Excellent resistance to vapors and liquids. Will not become saturated by hazardous fumes or liquids.	Proper expansion and contraction joints are essential.
Steam, process, electric traced lines (where operating temperature is subject to rapid change).	50F (10C) to 600F (315C)	Indoors or outdoors	10-H, 10-HSS	Cellular glass and high temperature mineral fiber cushion inner layer.	Dynel reinforced Mastic.	Inner mineral fiber cushion insulation is absorbent.	Specially useful for electric or steam traced aluminum lines.	Proper expansion and contraction joints are essential.
Steam, process, and steam traced lines.	212F (100C) to 1000F (529C)	Indoors or outdoors	23-HM or 23-HMT 23-HSSM or 23-HSSMT	Calcium silicate.	Metal jacket on straight pipe. Dynel reinforced Mastic on valves and fittings.(1)	Very absorbent. Subject to saturation by leaked or spilled liquids. Weather-barrier must be tight to prevent water damage.	Strong, can be cut and fabricated with ease. Max. resistance to external fires.	Metal on straight pipe selected to be suitable to resist surrounding contamination.

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TOOLS REQUIRED

In the application of thermal insulation a number of tools are required. Some are for very special purposes and others are commonly used. Some tools are hand tools and others are power tools. Where tools are used for a specific purpose such as in the spraying of fibrous insulation, their operation and use is described for that particular operation. The more commonly used tools will be discussed in this chapter.

A good workman keeps his tools clean and in good working condition. He uses each tool only for the purpose it was intended.

In general, tools are separated into two divisions; one division being hand tools and the other being power tools.

HAND TOOLS

The use and method of operating most hand tools are generally quite evident. For this reason, description of the purpose and method of using hand tools will not be covered in this chapter. For example, it is not necessary to state that a knife is a tool used to slice or cut materials. This is well known. Also, well known is that various types of knives have been designed to best cut particular types of materials. It is interesting to note that the insulator does have to become skilled in using a number of different tools to accomplish his task of installing insulation. The hand tools necessary to perform the various functions of installation are as follows:

I. Marking Tools

1. Pencil
2. Ink Pencil
3. Crayon
4. Soapstone
5. Chalk line
6. Scratch Awl
7. Scribes
8. Divider
9. Trammel Points

II. Guiding and Testing Tools

1. Straight edge
2. Mitre gauge
3. Mitre box
4. Framing square
5. Templates for mitres
6. Steel square
7. Special patterns and guides
8. Level

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TOOLS REQUIRED

HAND TOOLS - Contd

III. Measuring Tools

1. 6-Ft folding rule
2. 6 or 8-Ft pocket rule
3. 50-Ft tape

IV. Holding Tools

1. Clamps
2. Cutting frames
3. Springs
4. Rubber bands
5. Pressure sensitive tape
6. Wire
7. Rope

V. Cutting Tools - Sharp Edge

1. Butcher knife
2. Boning knife
3. Hawk-bill linoleum knife
4. Rubber knife
5. Shears
6. Pliers
7. Snips
8. Aviation snips
9. Shears
10. Nippers
11. Hatchet (steel and brass)

VI. Cutting Tools - Tooth

1. Hand saw
2. Key-hole (compass) saw
3. Hack saw
4. Rasps
5. Gritted paddles

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TOOLS REQUIRED

HAND TOOLS – Contd

VII. Hammer Type Tools

1. Masonry hammer
2. Mallet

VIII. Fastening Tools

1. Stretcher (Banding Machine)
2. End nippers
3. Screw driver
4. Pliers
5. Wrenches (Allen, spud, crescent, end)
6. Blind rivet gun
7. Punch

IX. Finishing and Coating Tools

1. Flat broad trowel
2. Pointing trowel
3. Margin trowel
4. Rubber palm
5. Rubber gloves
6. Paint brush

X. Sharpening Tools

1. Files (various shapes)
2. Whetstone

XI. Tool Holders

1. Tool box
2. Tool pouch

Most of the most common hand tools used by the insulators are illustrated on pages 155 thru 159.

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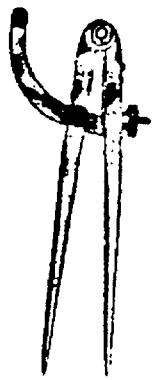
PAINT CRAYONS



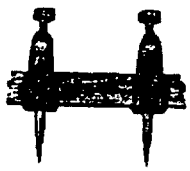
SCRATCH AWL



MARKING PENCIL

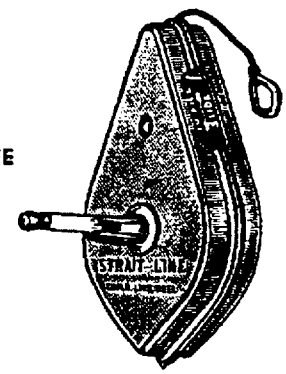


WING DIVIDERS

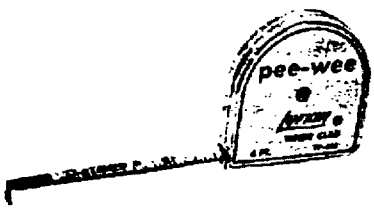


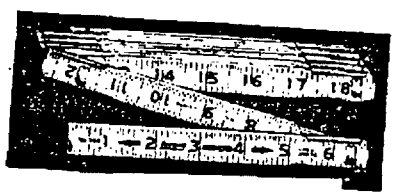
TRAMMEL POINTS

STRAIT-LINE CHALK REEL



MARKING TOOLS





HEAVY DUTY RULE



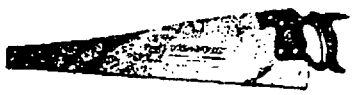
POCKET TAPE



ALUMINUM TORPEDO LEVEL

MEASURING TOOLS
INSULATORS HAND TOOLS

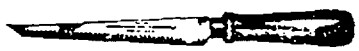
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SAW



ALUMINUM COMPASS SAW HANDLE



UTILITY SAW

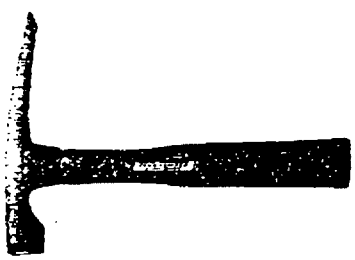


COMPASS SAW BLADE



RASP

TOOTH TYPE CUTTING TOOLS



HAMMER



RUBBER MALLET

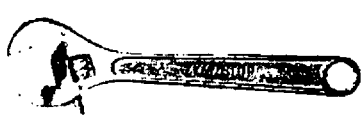


PADDLE TYPE MALLET

HAMMERING TOOLS



SCREWDRIVER



LOCKING ADJUSTABLE

FASTENING TOOLS

INSULATORS HAND TOOLS

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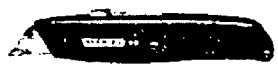
BONING KNIFE



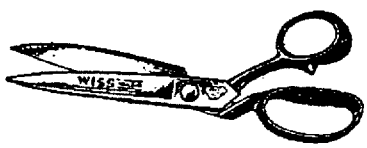
LINOLEUM KNIFE



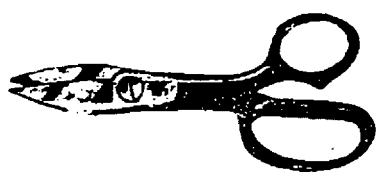
RUBBER KNIFE



UTILITY KNIFE



HEAVY DUTY SHEARS



CLAUSS SHEARS



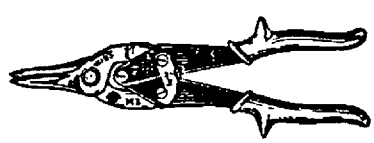
METAL CUTTING SNIPS



SIDE CUTTING PLIER



END CUTTING NIPPERS



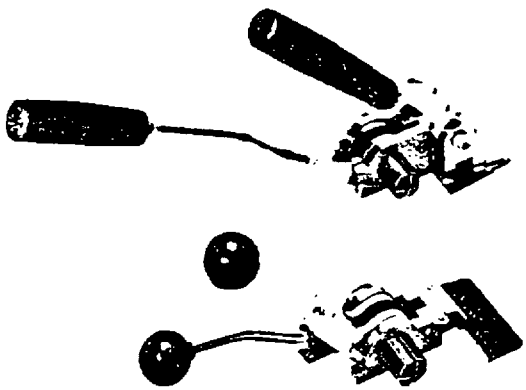
AVIATION SNIPS

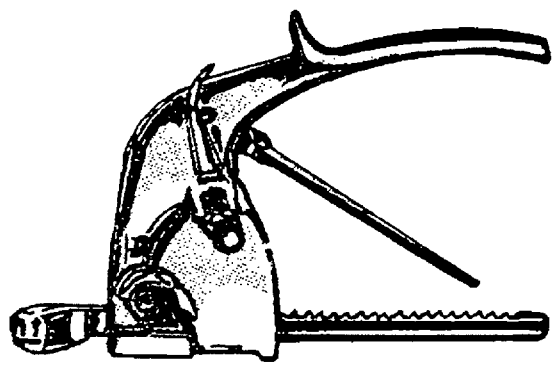
CUTTING TOOLS

INSULATORS HAND TOOLS

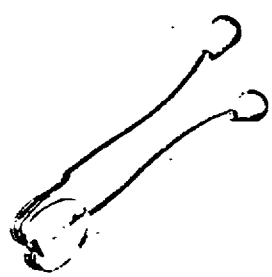
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STRETCHERS

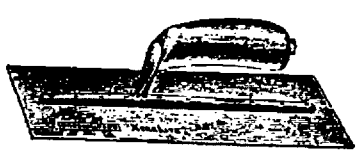


SEALER . .



CUTTER

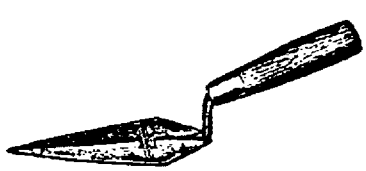
FASTENING TOOLS



BROAD TROWEL



PIPING TROWEL



POINTING TROWEL



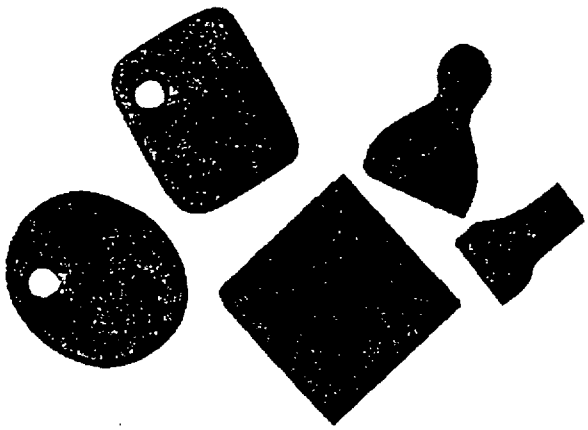
GOLDBLATT SPOON TROWEL

FINISHING AND COATING TOOLS

INSULATORS HAND TOOLS

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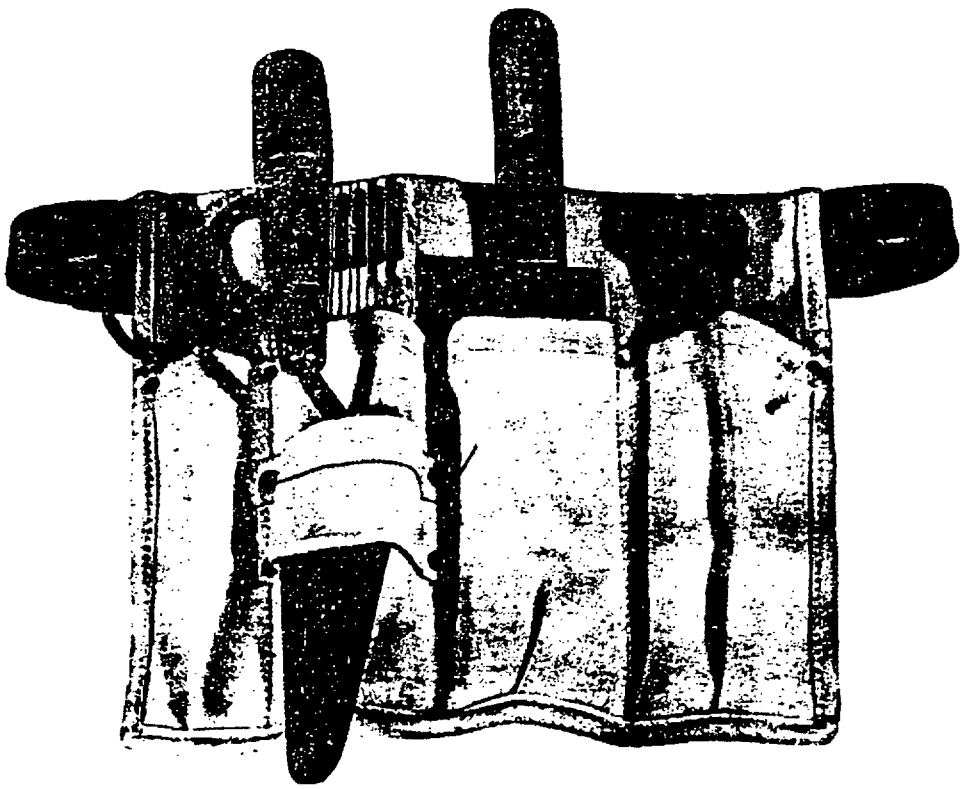


PALMS



RUBBER GLOVES

FINISHING AND COATING TOOLS



CANVAS
TOOL POUCH

INSULATORS HAND TOOLS

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TOOLS REQUIRED

POWER TOOLS

During the past few years many more power tools have come into use in the insulation craft. Power tools of both common and special types are used by the insulation shopman in the fabrication of insulation. Not all shops have the same fabrication equipment, as each obtains equipment most suitable for its production needs. However, the following tools are commonly used in insulation fabrication shops.

1. Band saw, horizontal or vertical
2. Inside and outside core grinders
3. Circular saw
4. Head grinder
5. Paint and mastic spray

A shopman will be given detailed instruction in the use of these machines by his supervisor. For this reason, the operation of these machines will not be discussed further. The field applicator uses many power tools also. Some of the very common variety are power saws and others are more specialized power equipment, such as sprays for mastic stud guns, etc. A short discussion on the use and operation of these special tools is given in this or other chapters of this manual.

Field applicators use the following power tools:

1. Circular saw
2. Skill saw
3. Sabre saw
4. Band saw
5. Drill
6. Disc grinders
7. Spray asbestos machine and gun
8. Spray foam machine and gun
9. Mastic (and paint) pump and spray gun
10. Pin and stud welders

The operation of power saws, drills and disc grinders are relatively simple and, with observation of safety precautions, a normal amount of practice can produce a skilled operator in their use.

The operation of a machine and gun to apply asbestos is given in Chapter XIX.

The operation of spray foam machine and gun is given in Chapter XX.

The operation of most spray pumps and guns is given in Chapter XXI.

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ESTIMATING THE INSTALLED COST

INTRODUCTION

The areas of thermal insulation usage are many, but can be generally placed into two main categories; namely, Industrial and Commercial. To further clarify these categories, the following examples are given:

A. Industrial

1. Chemical Plants
2. Refineries
3. Steam Power Plants

B. Commercial

1. Hotels
2. Hospitals
3. Department Stores

For the purpose of this text, emphasis will be placed on the cost estimation of thermal insulation as it applies to the industrial category in general and to the insulation of piping, piping auxiliaries and major equipment items in particular. Although the insulation requirements of the commercial category may appear to be less sophisticated, the same basic principles of cost estimating will be applicable.

The wide variety of insulation materials and installation techniques make full coverage of the subject at hand impracticable within the limits of this text; consequently the example estimate used will be confined to two basic specifications for purposes of demonstration.

INFORMATION FOR ESTIMATE BASIS

The type of information needed to develop the scope of work to be included in the cost estimate is derived from data listed below:

A. Process Flow Sheets and Plant Layout Drawings.
B. Pipe Sketches and Piping Arrangement Drawings.
C. Equipment Drawings.
D. Assembly Drawings.
E. Models.
F. Insulation Design.
G. Thermal Insulation Manual - Volume I - Specifications.
H. Thermal Insulation Manual - Volume II - Design.

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ESTIMATING THE INSTALLED COST

INFORMATION FOR ESTIMATE BASIS - Contd

I. Reference Data for Physical Characteristics of Insulation Materials and Accessories.
J. Insulation Material and Accessory Prices.
K. Field Measurement Surveys (where applicable).

Items A, D, and E convey to the estimator a fairly composite picture of the overall project enabling him to obtain some insight into job conditions. For example, working heights above ground level, crowded or close work areas, and possible location of material storage zones relative to work areas can be assessed from this data.

Items B, C, E, and K are tools necessary to accomplish an accurate, detailed material "take-off." Process Flow Sheets and Equipment Layout Drawings can be used to arrive at an estimate of cost; however, it is obvious such an estimate would be rather inaccurate. For example, an actual fitting and flange count is not possible; consequently, a factorial approach would be required to achieve a dollar value for this facet of the estimate. The use of factors to arrive at any estimate has a great tendency to dilute the estimate accuracy, and should be avoided where possible.

Item F will convey to the estimator a listing of the physical components of the project which are to be insulated, the type and thickness of the base insulant to be used, and other pertinent data needed to prepare the cost estimate. (See Figure IX-1.)

Item G supplemented by Item H will give the estimator the installation details plus greater detail on material specifications than indicated on the Insulation Design Schedule. Methods of attachment of base insulants, types of finishes, and other special application considerations are shown.

Item I is necessary to provide the estimator with the size, weight, and physical make-up of the materials the craftsmen must handle. On pipe insulation of a particular diameter, the estimator may question, "Is the pipe insulation section manufactured as two pieces per section or several"? On flat surface work, he may ask, "Are the insulation blocks available in sizes other than 6" wide by 36" long"? It can be readily seen from these examples that differences in the physical make-up of materials can greatly affect the labor cost of installation. This data should also contain the coverage capabilities of insulating cements, adhesives, mastics, etc.; the weights per lineal foot of wire, bonding materials, etc. (See Figure IX-2.)

Item J requires that a complete insulation and accessory material cost file be available. The file should be maintained and up-dated to reflect material price changes that frequently occur. Manufacturers' published price lists are used in developing the file and are usually available through the empoyers' purchasing department. The lists are usually supplemented with data that fulfills the requirements for Item I also.

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ESTIMATING THE INSTALLED COST

INSULATION DESIGN SCHEDULE

PROJECT- XYZ PLANT 69-1 JOB #K-68012 - 950-1234
LOCATION- INSTITUTE PLANT DATE - 9-1-69
SHEET 1 OF 1

ITEM No.	DESCRIPTION	SIZE	FROM	TO	SERVICE	TEMP °C	THICKNESS"	SPEC.
XYZ-201A	REACTOR							
(Z) -201B	"					260	3.0	23-H
(Z) -201C	"					260	3.0	"
-202A	FEED PREHEATER					260	3.0	"
-202B	"					150	1.5	"
-202C	"					175	1.5	"
XYZ-210	DOWTHERM HEATER					200	2.0	"
-211	DOWTHERM EXPANSION TANK					200	2.0	"
LINE NO.						150	1.5	"
(*) P-205	XYE 202E	1½"	XYE-201A	XYZ-201A	REACTION LIQUID	200	1.5	23-H
-206	-201A	1½"	-201B	-201B	"	260	2.0	"
-207	-201B	1½"	-201C	-201C	"	260	2.0	"
-208	-201C	1½"	-202E	-202E	"	260	2.0	"
-209	-202D	1½"	-202E	-202E	"	260	2.0	"
P-210	XYZ-202C	1½"	XYZ-202D	XYZ-202D	REACTION LIQUID	225	1.5	23-H
-211	-202E	1½"	-202C	-202C	"	200	1.5	"
-212	-202A	1½"	-202B	-202B	"	175	1.0	"
-213	-202A	1½"	-206	-206	"	125	1.0	"
(Z) D-201	XYZ-208, 209, D-202	3"	XYZ-201C, 21A, 211		DOWTHERM LIQUID	260	2.0	2LH
(Z) -202	D-201	3"	-201B, D-203		"	260	2.0	"
(Z) -203	XYZ-201C, D-202	3"	-204, D-204		"	260	2.0	"
(Z) -204	XYZ-201B, 201A, D-203	3"	-205, 209		"	260	2.0	"

SYMBOLS: (Z) STEAM TRACE FOR 20°C MINIMUM AND INSULATE - ASSIST SPECIAL HEAT TRANSFER CEMENT
(*) DO NOT INSULATE SECTION FROM P-204

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Figure IX-1

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ESTIMATING THE INSTALLED COST

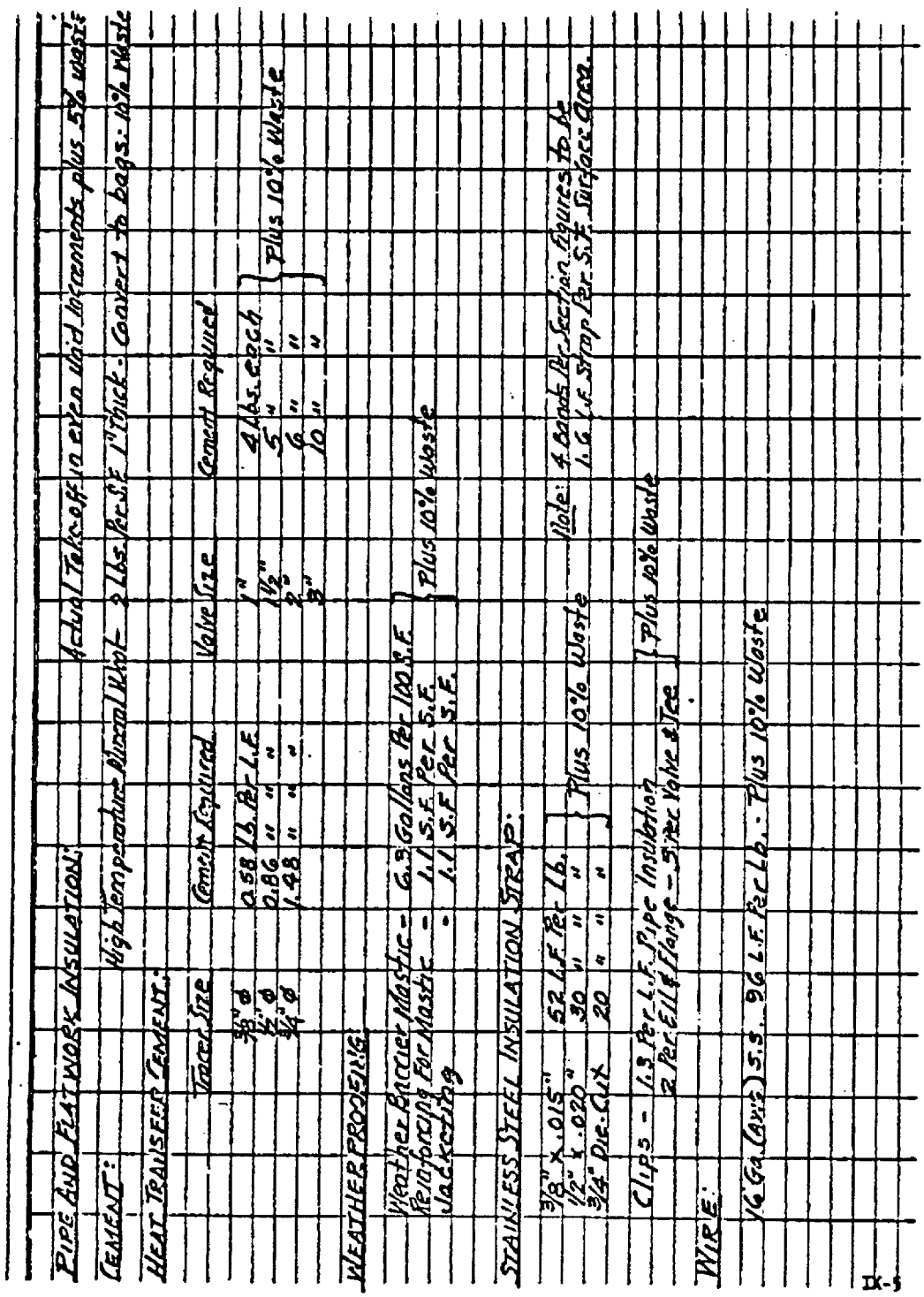


Figure IX-2

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ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE

General

The most important function in the preparation of the cost estimate is the development of a Bill of Material by making a quantity survey. Using the best data available (such as, equipment drawings, piping arrangement drawings and/or pipe sketches), the "take-off" should be done systematically. This can best be accomplished by using a prepared quantity survey form. (See Figure IX-3.)

Work requiring the use of different base insulants should be "taken off" in order of material specification and thickness. For example, list Calcium Silicate 1" thick, 1-1/2" thick, etc.; then Cellular Glass 1" thick, 1-1/2" thick, etc.

Procedure for Piping Insulation "Take-Off"

Straight pipe insulation should be taken off in linear feet, nearest to the next full section increment. For example, if the measurement is 29'-0" and the pipe insulation sections are in 3' long increments, the quantity should be noted as 30'-0" linear feet. Pipe insulation should be measured between fittings along the centerline of straight pipe only. (See Figure IX-4.) Since shop prefabricated fitting, flange, and valve covers will normally be used, flanges, valves, ells, or other fittings should not be included in this measurement.

Where the application of mitered pipe insulation is possible, bent pipe should be calculated on the basis of insulated pipe measured on the outside radius. Units should be figured in linear feet. Elbows of standard manufacture should not be considered as bent pipe.

Flanged valves and fittings should be counted as complete units only. For example, a flanged valve consisting of a valve body, bonnet flange, and two flanged connections should be taken as one unit, and not listed as a valve plus two (or three) pairs of flanges. Units should be counted as pieces. It is also important that all flanges, valves, and flanged fittings be identified as to pressure rating (150 lb, 300 lb, etc.) since the size of the prefabricated insulation cover varies as a function of the pressure rating. All other fittings should be counted as pieces and identified as to whether they are welded or screwed.

During the "take-off", special items such as steam tracing should be indicated, noting tracer size and whether or not heat transfer cement is to be used. Insulation requirements for hangers, supports, and special trim should also be listed.

After completing the "take-off" of the basic pipe insulation materials, the next step is to calculate the quantity of pipe insulation finish materials. Depending on the specification, these materials might be canvas, metal jacketing, mastics, etc. The usual procedure is to calculate the surface area of the pipe insulation and fitting, flange, and valve covers in square feet. If the finish is

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ESTIMATING THE INSTALLED COST

QUANTITY SURVEY SHEET: Thru Insulated

Work Order 930-1234 Location 512 Date 3-1-69

Line No.	Pipe Size	Spec	L.F.	Line Figs	Valves Figs	Valves Weld	Valves Scd	Elbows Figs	Elbows Weld	Elbows Scd	Tees Figs	Tees Weld	Tees Scd	Other Figs	Insulation Thk.	Insulation Spec.	Insulation Size	Remarks
P-205	1½	1E1	32	5	2	-	-	-	4	-	-	-	-	-	1.5	23-H	-	
-206	1½	"	18	3	2	-	-	-	3	-	-	-	-	-	2.0	"	-	
-207	1½	"	25	4	2	-	-	-	3	-	-	-	-	-	2.0	"	-	
-208	1½	"	15	3	1	-	-	-	2	-	-	2	-	-	2.0	"	-	
-209	1½	"	90	6	3	-	-	-	6	-	-	2	-	-	1.5	"	-	
-210	1½	"	73	5	3	-	-	-	5	-	-	1	-	-	1.5	"	-	
-211	1½	"	26	2	2	-	-	-	3	-	-	1	-	-	1.5	"	-	
-212	1½	"	20	2	1	-	-	-	2	-	-	-	-	-	1.0	"	-	
-213	1½	"	30	3	2	-	-	-	3	-	-	-	-	-	1.0	"	-	
D-201	3	1E8	60	2	-	2	-	-	4	-	-	2	-	-	2.0	2-H	3/8"	Use 4 Pcs Insul.
-202	3	"	40	2	-	2	-	-	3	-	-	2	-	-	2.0	"	3/8"	"
-203	3	"	80	2	-	2	-	-	5	-	-	2	-	-	2.0	"	3/8"	"
-204	3	"	75	2	-	2	-	-	5	-	-	2	-	-	2.0	"	3/8"	"

© Indicates Pairs of Flanges

Specs. 1E1 And 1E8 Are 300 Lb. Class.

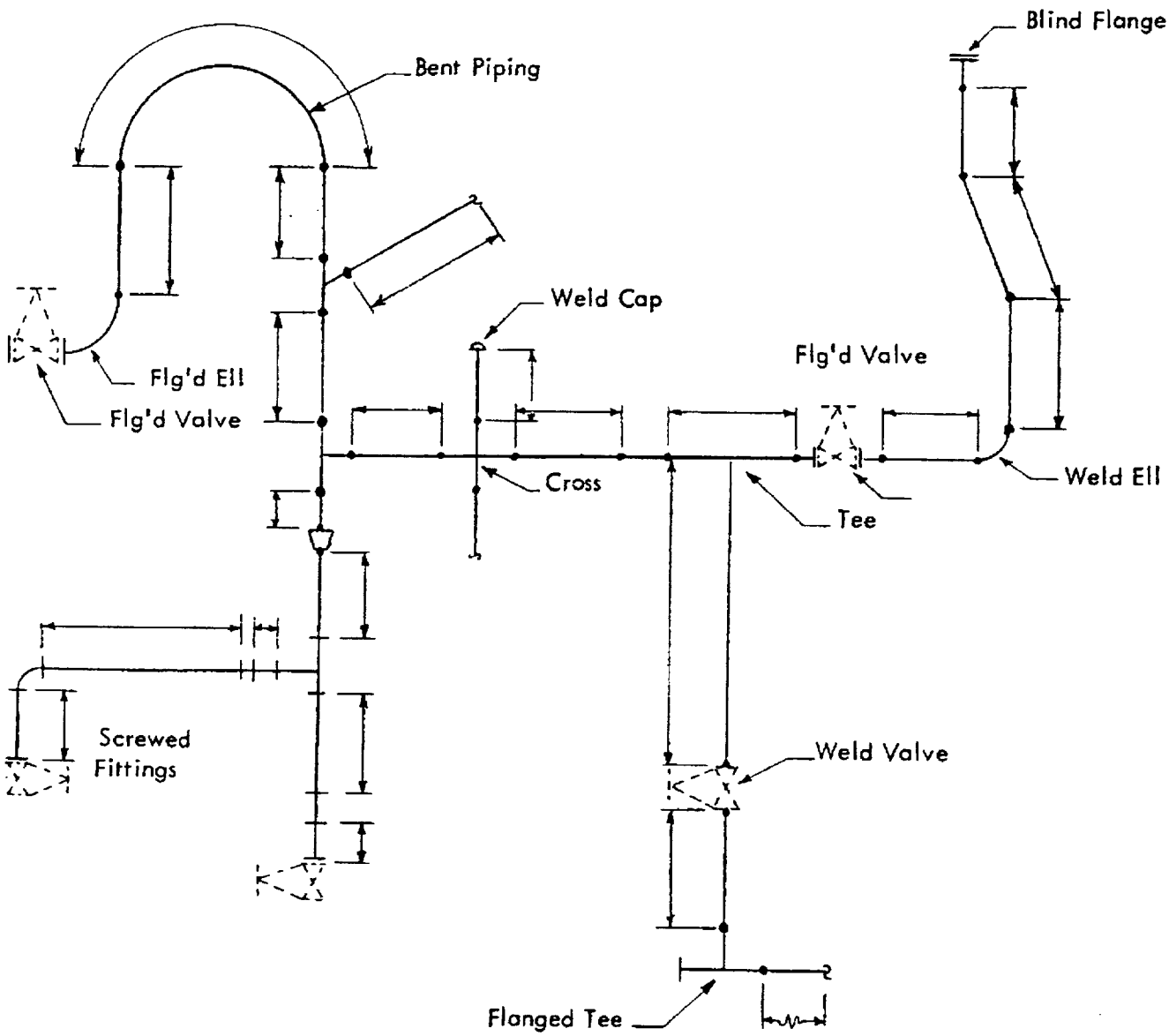
Special Hot Transfer Cement Required on Tracer

IX-9

Figure IX- 3

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ESTIMATING THE INSTALLED COST



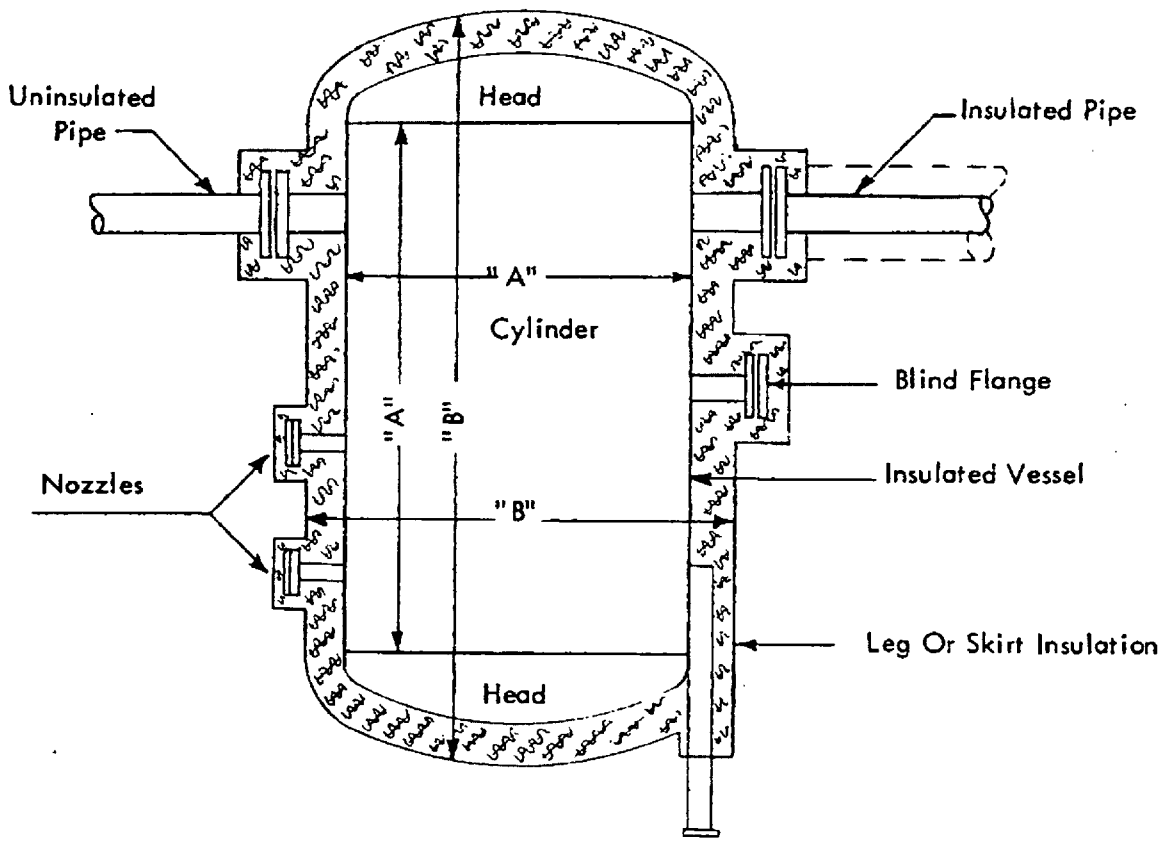
PIPING
METHOD OF MEASURING

Figure IX-4

Part 1 of 2

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ESTIMATING THE INSTALLED COST



Include All Appurtenances As Shown As Part Of Vessel Insulation

A - Bare Area - Measure Over Uninsulated Surface

B - Insulated Area - Measure Over Insulation Surface

EQUIPMENT
METHOD OF MEASURING

Figure IX-4

Part 2 of 2

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ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE - Contd

Procedure for Piping Insulation "Take-Off" - Contd

of the jacket type, this square footage plus an allowance for joint laps and waste fixes the quantity. In the case of mastic finishes, the coverage capability of the mastic must be considered and a conversion made to gallons, which is the common "norm" of purchase. Application labor for both jacket and mastic finishes is costed on a square foot basis.

The accessory material requirement will be dictated by the specifications applying to the particular job at hand. These materials generally fall into one of the following categories: attachment devices (wire, bonding, clips, etc.), insulating cements, adhesives, mastic and cement reinforcing items (Dynel cloth, wire mesh, etc.). The need for the accessories must be quantitated in the standard "norm" for procurement to pounds, insulating cement in pounds and converted to standard size bags, reinforcing items in square feet, etc. (See Figure IX-5.)

The Thermal Insulation Manual - Vol. I - Specification M - Article VI contains a listing of insulation fabrication and installation accessories. Reference must be made to the manufacturers' published data for a specific accessory in order to obtain purchase norms, covering capacities and other pertinent information.

An invaluable aid in the calculation of the surface area of prefabricated fitting, flange, and valve covers is the publication "ASTM Recommended Dimensional Standards for Prefabrication and Field Fabrication of Thermal Insulation Fitting Covers for N.P.S. Piping, Vessel Lagging and Dished Head Segments." A table such as shown in Figure IX-6 aids in the determination of pipe insulation surface areas.

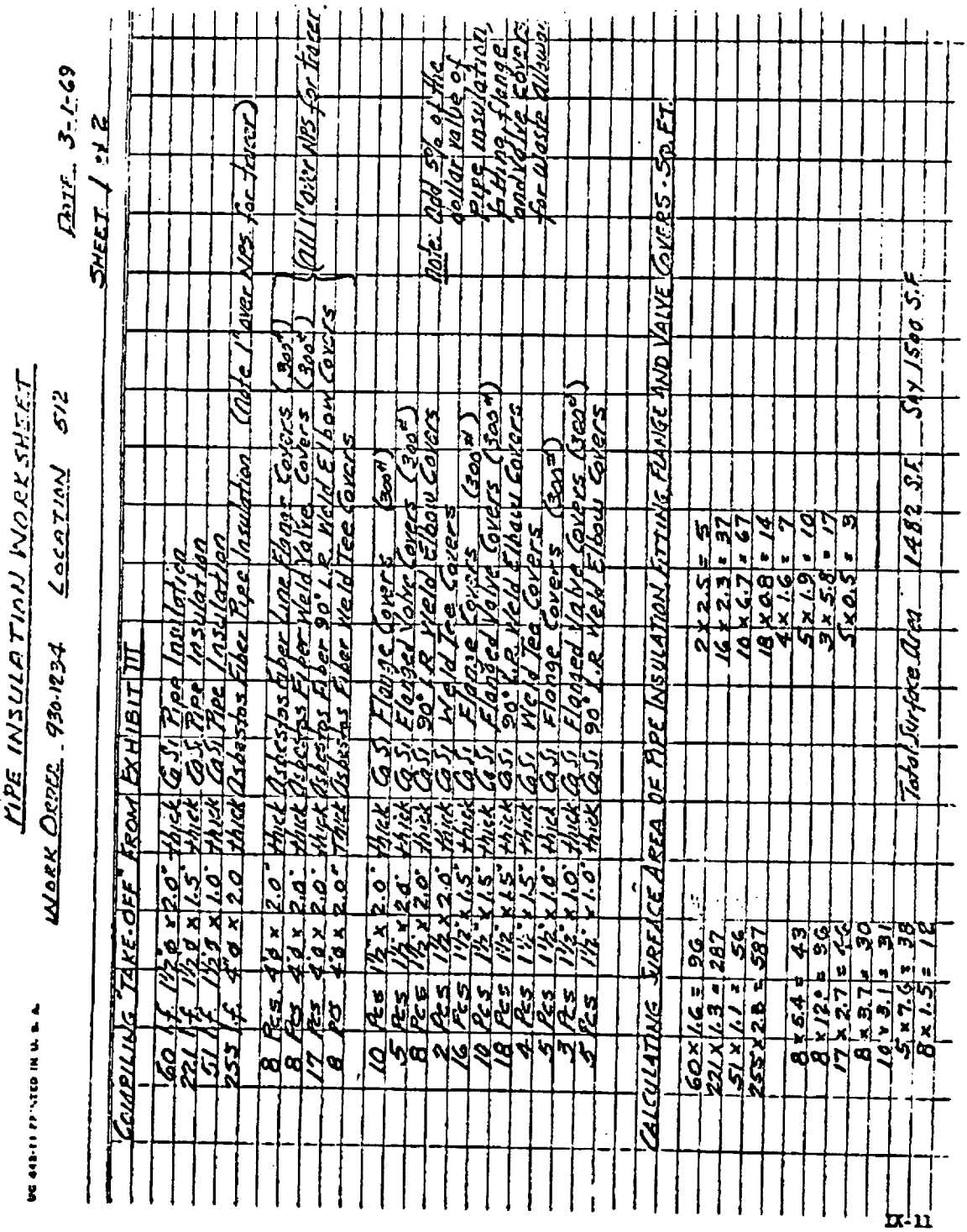
Figure IX-5 shows the application of the preceding discussion in developing the pipe insulation and accessory Bill of Material using Figures IX-1, -2, and -3. The Bill of Material is then listed on the estimate sheet (Figure IX-7) and priced from the appropriate manufacturers' price lists maintained in the previously mentioned cost file. Note that an allowance for waste has been applied as a percentage factor to the cost of the base insulation material. The allowance for waste of finish materials and accessories has been built in by rounding-out the quantities to purchasing norms. For example, the actual requirement for weather-barrier mastic is 95 gallons, so two standard 55-gallon drums are billed for procurement. Allowances for waste are judgment items and must be based on job conditions, types of materials and experience.

Estimating Installation Costs of Pipe Insulation

The accuracy of the Bill of Material can be established to a very high degree; however, determining accurate labor and other costs of installation presents a more difficult problem. There are many variables involved in estimating these costs. Each job must be analyzed as to its individual

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ESTIMATING THE INSTALLED COST



PIPE INSULATING WORKSHEET

WORK ORDER 930-1234 LOCATION 512 DATE 3-1-69 SHEET 1 OF 2

Covering Take-off from Exhibit III

60 L.F.	11¾ x 2.0" thick Gas. Pipe Insulation			
221 L.F.	11¾ x 1.5" thick Gas. Pipe Insulation			
51 L.F.	11¾ x 1.0" thick Gas. Pipe Insulation			
255 L.F.	4¾ x 2.0 thick Asbestos Fiber Pipe Insulation (Note 1 layer NPS for Jacer)			
8 Pcs.	4¾ x 2.0" thick Asbestos Fiber Line Flange Covers (300#)			
8 Pcs.	4¾ x 2.0" thick Asbestos Fiber Weld Valve Covers (300#) (Add 1 layer NPS for Jacer)			
17 Pcs.	4¾ x 2.0" thick Asbestos Fiber 90° L.R. Weld Elbow Covers			
8 Pcs.	4¾ x 2.0" thick Asbestos Fiber Weld Tee Covers			
10 Pcs.	11¾ x 2.0" thick Gas. Flange Covers (300#)			
5 Pcs.	11¾ x 2.0" thick Gas. Flanged Valve Covers (300#)			
8 Pcs.	11¾ x 2.0" thick Gas. 90° L.R. Weld Elbow Covers			
2 Pcs.	11¾ x 2.0" thick Gas. Weld Tee Covers			
16 Pcs.	11½ x 1.5" thick Gas. Flange Covers (300#)			
18 Pcs.	11½ x 1.5" thick Gas. Flanged Valve Covers (300#)			
4 Pcs.	11½ x 1.5" thick Gas. 90° L.R. Weld Elbow Covers			
5 Pcs.	11½ x 1.0" thick Gas. Weld Tee Covers (300#)			
3 Pcs.	11½ x 1.0" thick Gas. Flange Covers (300#)			
5 Pcs.	11½ x 1.0" thick Gas. Flanged Valve Covers (300#)			
5 Pcs.	11½ x 1.0" thick Gas. 90° L.R. Weld Elbow Covers			

Note: Add 5% of the dollar value of pipe insulation for flanges, valve flange and valve covers for waste allowance

Calculating Surface Area of Pipe Insulation Fitting, Flange and Valve Covers - Sq. Ft.

60 x 1.6 = 96	2 x 2.5 = 5	
221 x 1.3 = 287	16 x 2.3 = 37	
51 x 1.1 = 56	10 x 6.7 = 67	
255 x 2.8 = 587	18 x 0.8 = 14	
	4 x 1.6 = 7	
8 x 6.4 = 43	5 x 1.9 = 10	
8 x 12.0 = 96	3 x 5.8 = 17	
17 x 2.7 = 46	5 x 0.5 = 3	
8 x 3.7 = 30		
10 x 3.1 = 31		
5 x 7.6 = 38	Total Surface Area 1482 S.F. = 549 1/2 S.F.	
8 x 1.5 = 12		

IX-11

Figure IX-5

Part 1 of 2

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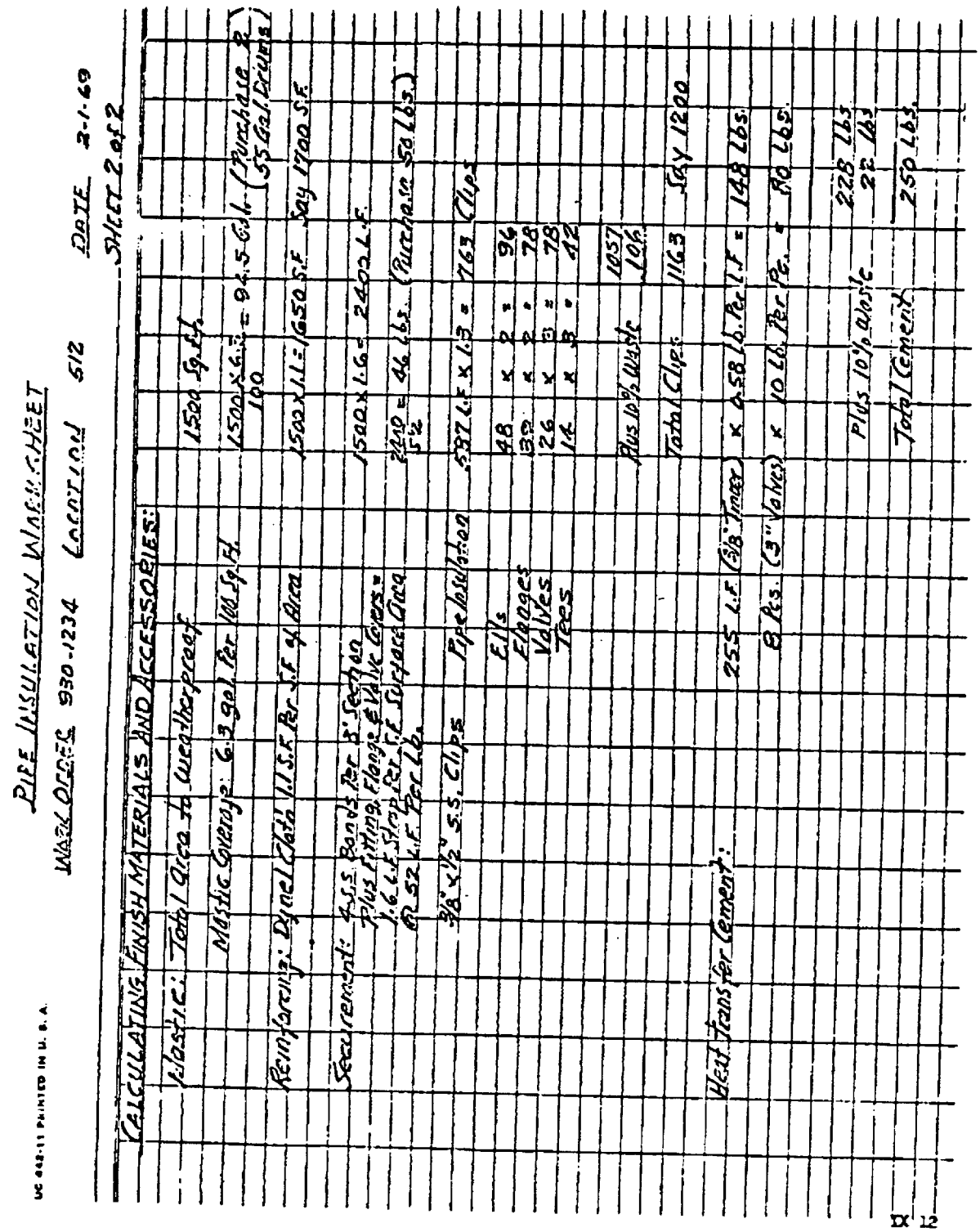


Figure IX-5
Part 2 of 2

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ESTIMATING THE INSTALLED COST

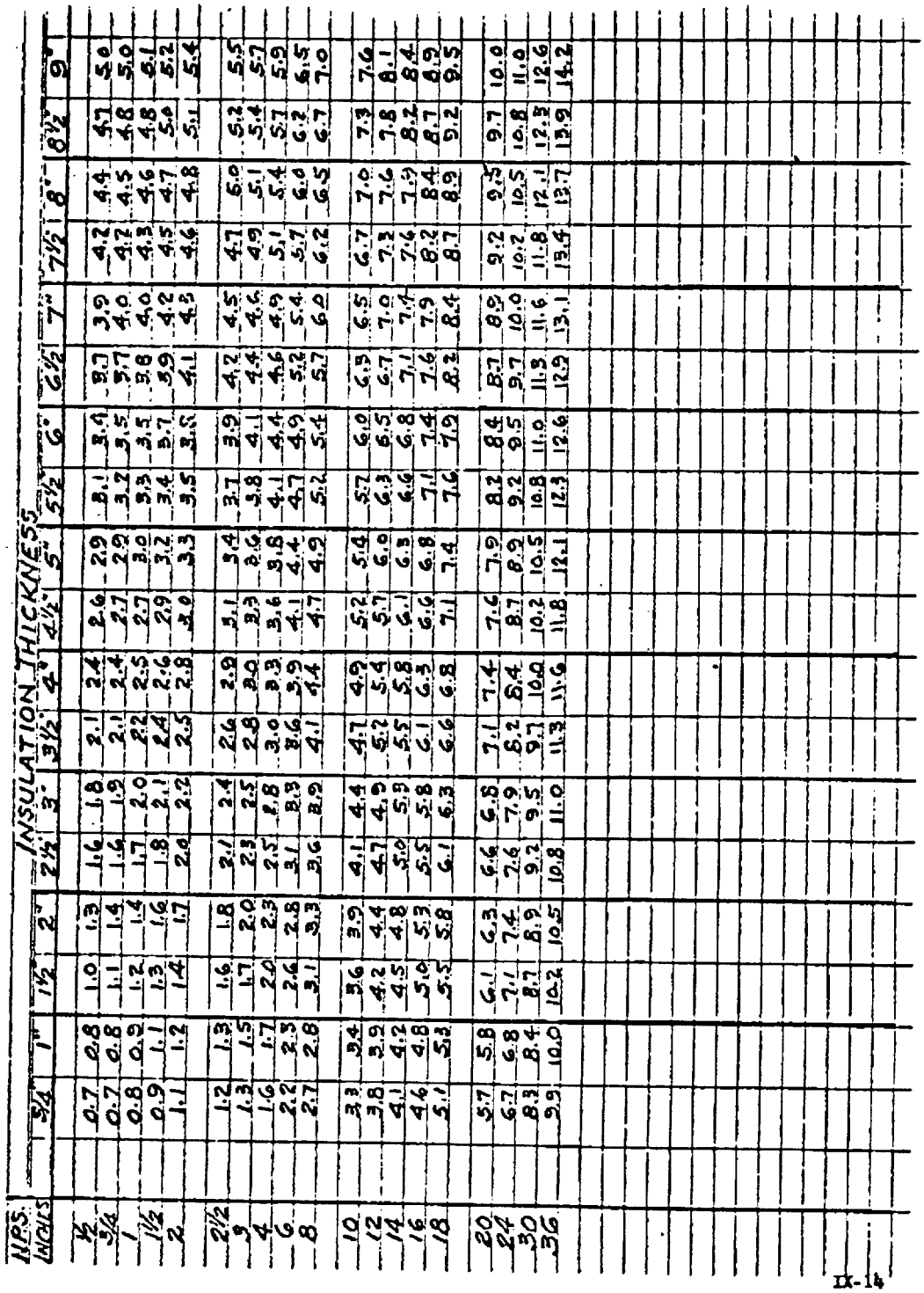


Figure IX-6

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ESTIMATING THE INSTALLED COST

ACCOUNT	DESCRIPTION	ESTIMATE BASIS	AMOUNT LABOR	AMOUNT MATERIAL	AMOUNT TOTAL
5590	PIPING INSULATION	Drawings & Specs.	1186	2322	3508
6600	EQUIPMENT INSULATION	Drawings & Specs.	689	1096	1785
	SUB-TOTAL		1875	3418	5293
	LOCATION EXPENSE-70% x LABOR	Current Rate			1312
	SUB-TOTAL				6605
	SII EXPENSE 2%	Current Rate			132
	SUB-TOTAL				6737
	ENGINEERING 10%	Historical Data			674
	SUB-TOTAL				7411
	CONTINGENCIES 10%	Estimator Judgment			
	TOTAL				$ 8152

ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ESTIMATE SHEET FOR PROJECT XYZ

TITLE INSULATION ESTIMATE
SUMMARY

SHEET NO 1 of 5
LOCATION 512
COST ENGINEER J. Doe
DATE 3-1-69
REQUEST NO
WORK ORDER 90-1234

IX-15

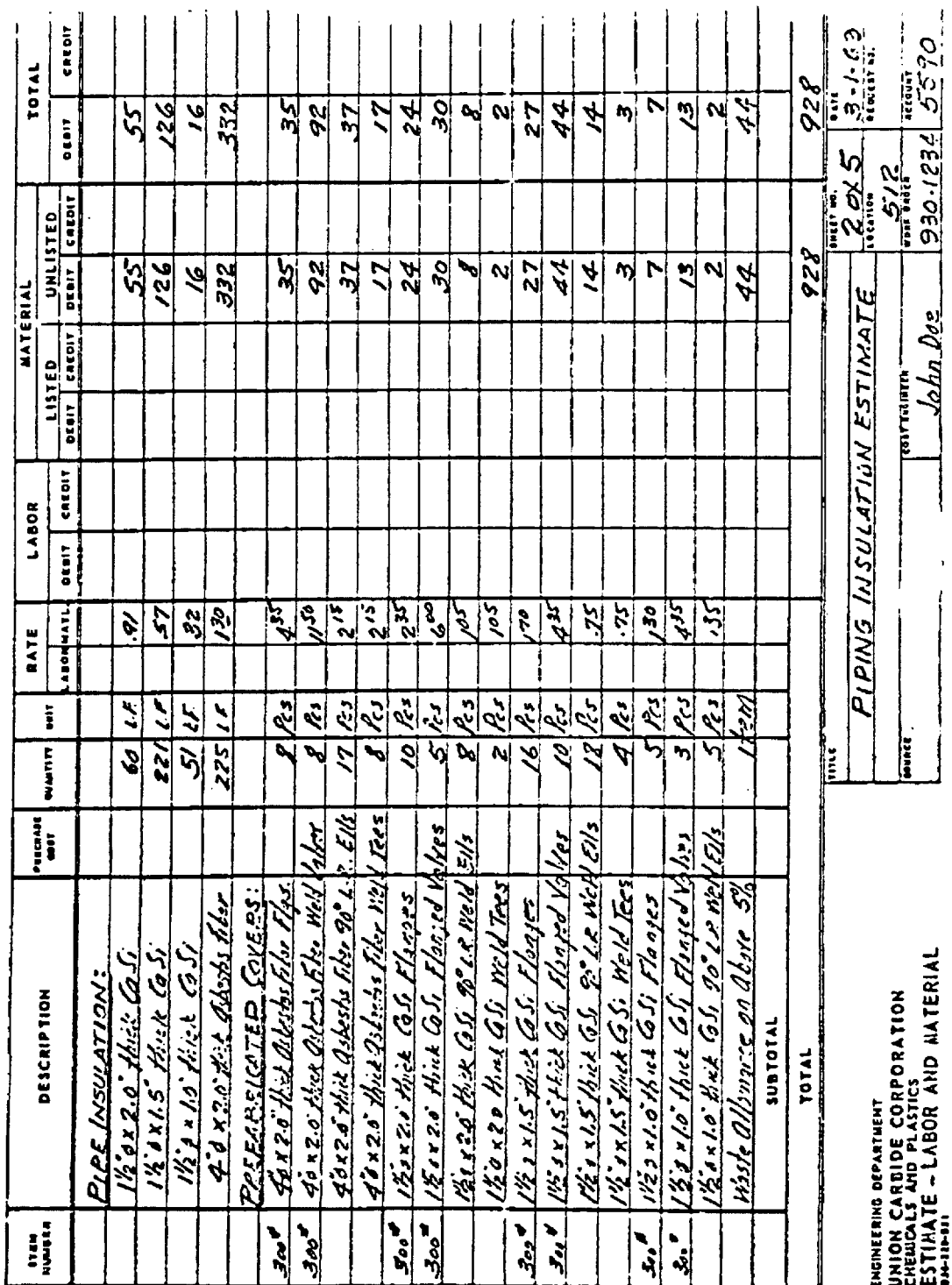
Figure IX-7

Part 1 of 5

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ESTIMATING THE INSTALLED COST



ITEM NUMBER	DESCRIPTION	PURCHASE COST	QUANTITY	UNIT	RATE LABOR	RATE MATL	LABOR DEBIT	LABOR CREDIT	MATERIAL LISTED DEBIT	MATERIAL LISTED CREDIT	MATERIAL UNLISTED DEBIT	MATERIAL UNLISTED CREDIT	TOTAL DEBIT	TOTAL CREDIT
	PIPE INSULATION:													
	1½"ø x 2.0" thick CaSi		60	L.F.	.91						55		55	
	1½" ø x 1.5" thick CaSi		221	L.F.	.57						126		126	
	1½" ø x 1.0" thick CaSi		51	L.F.	.32						16		16	
	4"ø x 2.0" thick Asbestos fiber		225	L.F.	1.30						332		332	
	PREFABRICATED COVERS:													
300#	4"ø x 2.0" thick Asbestos fiber flgs.		8	Pcs	4.35						35		35	
300#	4"ø x 2.0" thick Asbestos fiber Weld Elbow		8	Pcs	11.50						92		92	
	4"ø x 2.0" thick Asbestos fiber 90° L.R. Ells		17	Pcs	2.15						37		37	
	4"ø x 2.0" thick Asbestos fiber weld Tees		8	Pcs	2.15						17		17	
300#	1½"ø x 2.0" thick CaSi flanges		10	Pcs	2.35						24		24	
300#	1½"ø x 2.0" thick CaSi flanged Valves		5	Pcs	6.00						30		30	
	1½"ø x 2.0" thick CaSi 90° L.R. weld Ells		8	Pcs	1.05						8		8	
	1½"ø x 2.0" thick CaSi weld Tees		2	Pcs	1.05						2		2	
300#	1½"ø x 1.5" thick CaSi flanges		16	Pcs	1.70						27		27	
300#	1½"ø x 1.5" thick CaSi flanged Valves		10	Pcs	4.35						44		44	
	1½"ø x 1.5" thick CaSi 90° L.R. weld Ells		12	Pcs	.75						14		14	
300#	1½"ø x 1.5" thick CaSi weld Tees		4	Pcs	.75						3		3	
300#	1½"ø x 1.0" thick CaSi flanges		5	Pcs	1.30						7		7	
300#	1½"ø x 1.0" thick CaSi flanged Valves		3	Pcs	4.35						13		13	
	1½"ø x 1.0" thick CaSi 90° L.R. weld Ells		5	Pcs	.55						2		2	
	Waste Allowance on Above 5%		Lump								44		44	
	SUBTOTAL													
	TOTAL										928		928	

TITLE: PIPING INSULATION ESTIMATE — SHEET NO. 2 OF 5 — DATE 3-1-63

SOURCE — ESTIMATOR: John Doe — LOCATION 512 — WORK ORDER 930.1234 — ACCOUNT 5570

ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ESTIMATE - LABOR AND MATERIAL

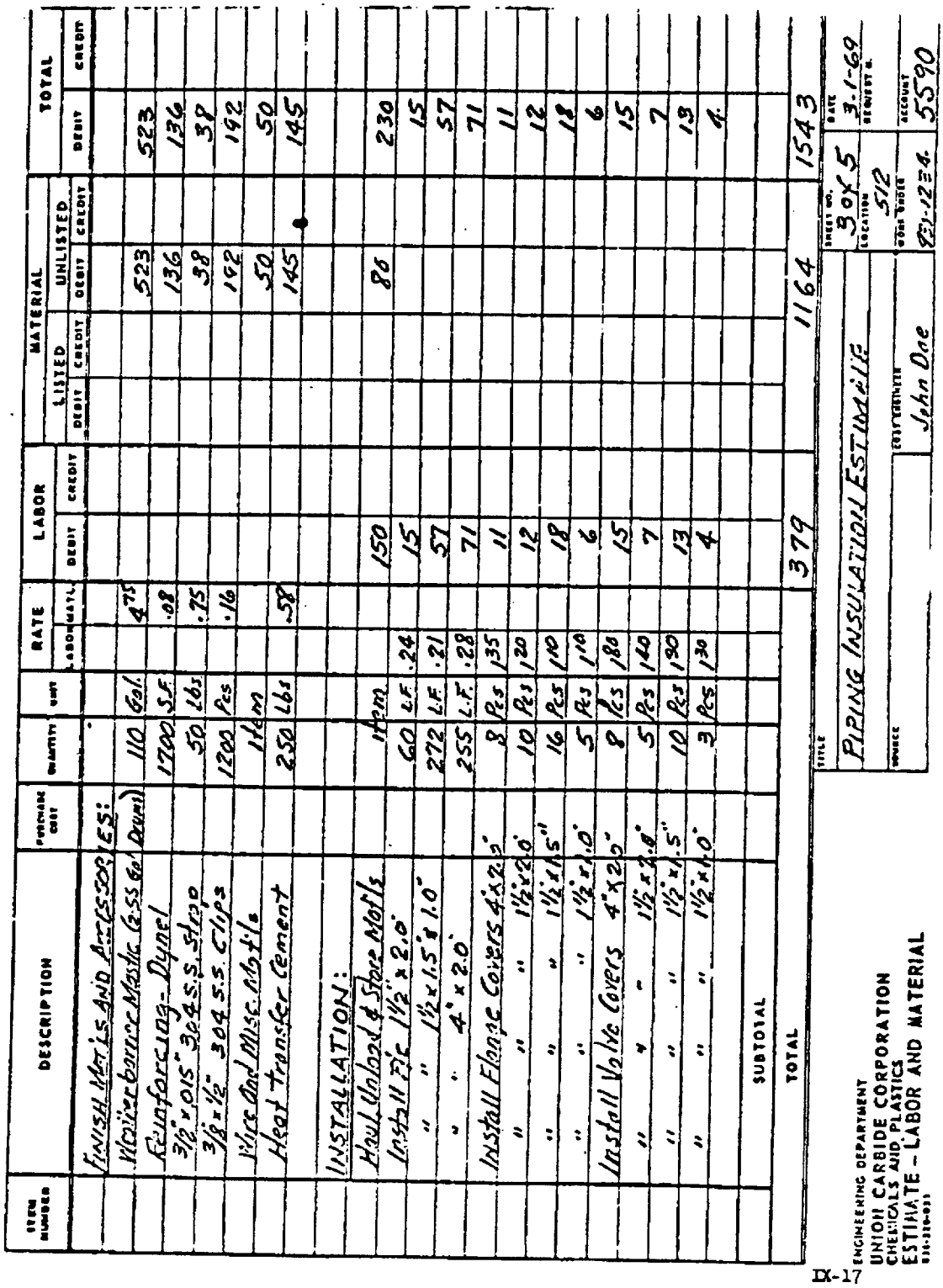
IX-16

Figure IX-7

Part 2 of 5

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ESTIMATING THE INSTALLED COST



ITEM NUMBER	DESCRIPTION	FOREMAN CODE	QUANTITY	UNIT	RATE LABOR	RATE MATERIAL	LABOR DEBIT	LABOR CREDIT	MATERIAL LISTED DEBIT	MATERIAL LISTED CREDIT	MATERIAL UNLISTED DEBIT	MATERIAL UNLISTED CREDIT	TOTAL DEBIT	TOTAL CREDIT
	FINISH MATLS AND ACCESSORIES:													
	Moisture barrier Mastic (Less 6a)	Drum	110	Gal		4.75					523		523	
	Reinforcing - Dynel		1700	S.F.		.08					136		136	
	3/8" x 015" 304 S.S. Strap		50	Lbs		.75					38		38	
	3/8" x 1/2" 304 S.S. Clips		1200	Pcs		.16					192		192	
	Wire and Misc. Matls		1	Item							50		50	
	Heat Transfer Cement		250	Lbs		.58					145		145	
	INSTALLATION:													
	Haul, Unload & Store Matls		1	Item			150		80				230	
	Install 3/4" x 2.0"		60	L.F.		.24	15						15	
	" " 1 1/2" x 1.5" & 1.0"		272	L.F.		.21	57						57	
	" " 4" x 2.0"		255	L.F.		.28	71						71	
	Install Flange Covers 4" x 2.0"		8	Pcs		1.35	11						11	
	" " " 1 1/2" x 2.0"		10	Pcs		1.20	12						12	
	" " " 1 1/2" x 1.5"		16	Pcs		1.10	18						18	
	" " " 1 1/2" x 1.0"		5	Pcs		1.10	6						6	
	Install V.P. Covers 4" x 2.0"		8	Pcs		1.80	15						15	
	" " " 1 1/2" x 4.0"		5	Pcs		1.40	7						7	
	" " " 1 1/2" x 1.5"		10	Pcs		1.90	13						13	
	" " " 1 1/2" x 1.0"		3	Pcs		1.30	4						4	
	SUBTOTAL						379		1164				1543	
	TOTAL													

ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ESTIMATE – LABOR AND MATERIAL

TITLE: PIPING INSULATION ESTIMATE
SHEET NO. 30 x 5
DATE 3-1-69
SOURCE
LOCATION 512
REQUEST #
ESTIMATOR John Doe
JOB NUMBER 81-1234
ACCOUNT 5590

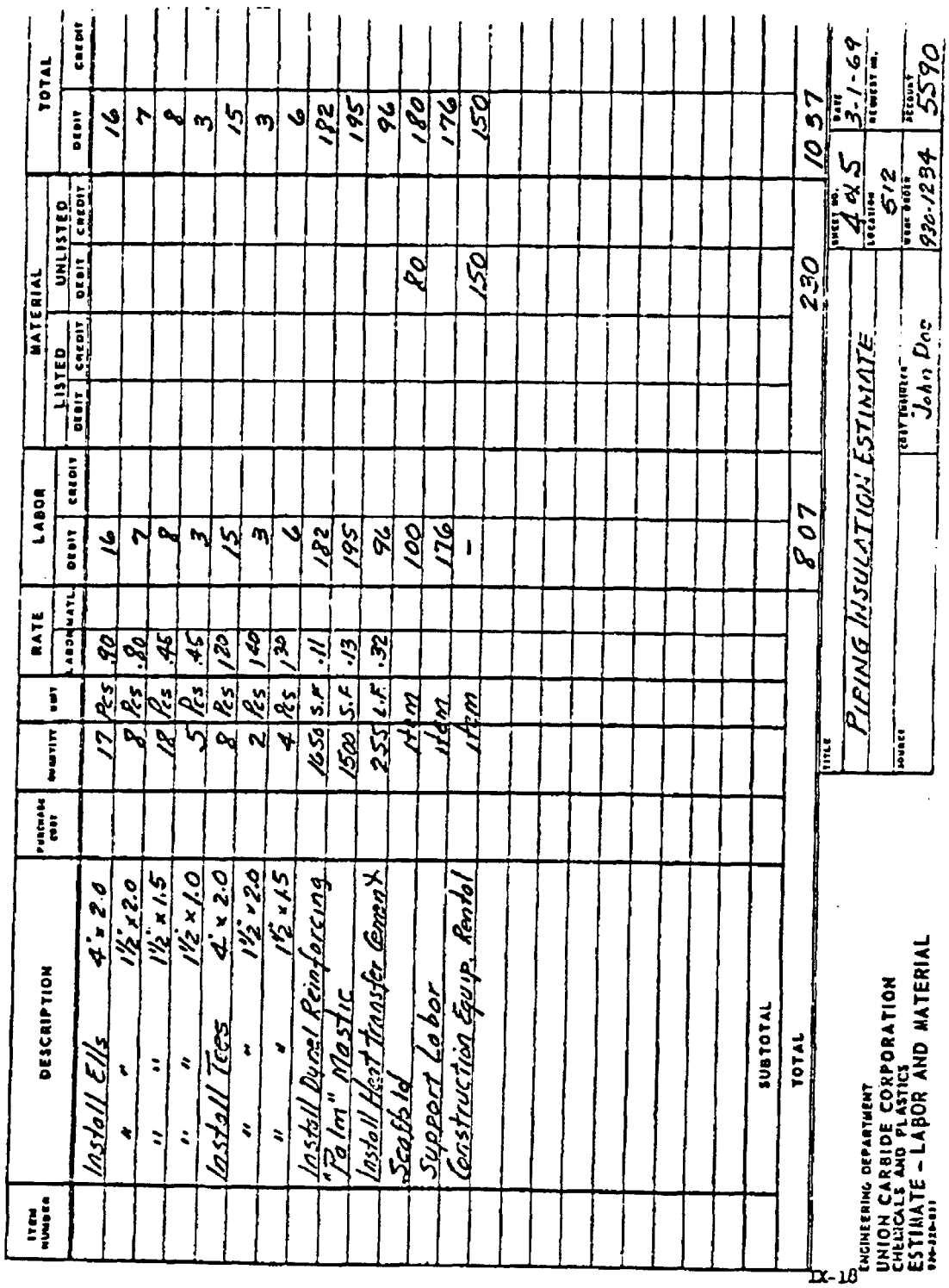
Figure IX-7

Part 3 of 5

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ESTIMATING THE INSTALLED COST



ITEM NUMBER	DESCRIPTION	PURCHASE COST	QUANTITY	UNIT	RATE LABOR	RATE MATL	LABOR DEBIT	LABOR CREDIT	MATERIAL LISTED DEBIT	MATERIAL LISTED CREDIT	MATERIAL UNLISTED DEBIT	MATERIAL UNLISTED CREDIT	TOTAL DEBIT	TOTAL CREDIT
	Install Ells 4"x2.0		17	Pcs	.90		16						16	
	" " 1½"x2.0		8	Pcs	.80		7						7	
	" " 1½"x1.5		12	Pcs	.45		8						8	
	" " 1½"x1.0		5	Pcs	.45		3						3	
	Install Tees 4"x2.0		8	Pcs	1.20		15						15	
	" " 1½"x2.0		2	Pcs	1.40		3						3	
	" " 1½"x1.5		4	Pcs	1.20		6						6	
	Install Dyzel Reinforcing		1650	S.F.	.11		182						182	
	"Palm" Mastic		1500	S.F.	.13		195						195	
	Install Heat Transfer Cement		255	L.F.	.32		96				80		96	
	Scaffold		12	Hrs			100						180	
	Support Labor		12	Hrs			176						176	
	Construction Equip. Rental		12	Hrs			-				150		150	
	SUBTOTAL						807				230		1037	
	TOTAL													

TITLE: PIPING INSULATION ESTIMATE
SHEET NO. 4 of 5
DATE 3-1-69
SOURCE
ESTIMATOR John Doe
LOCATION 512
WORK ORDER 930-1234
REQUEST 5590

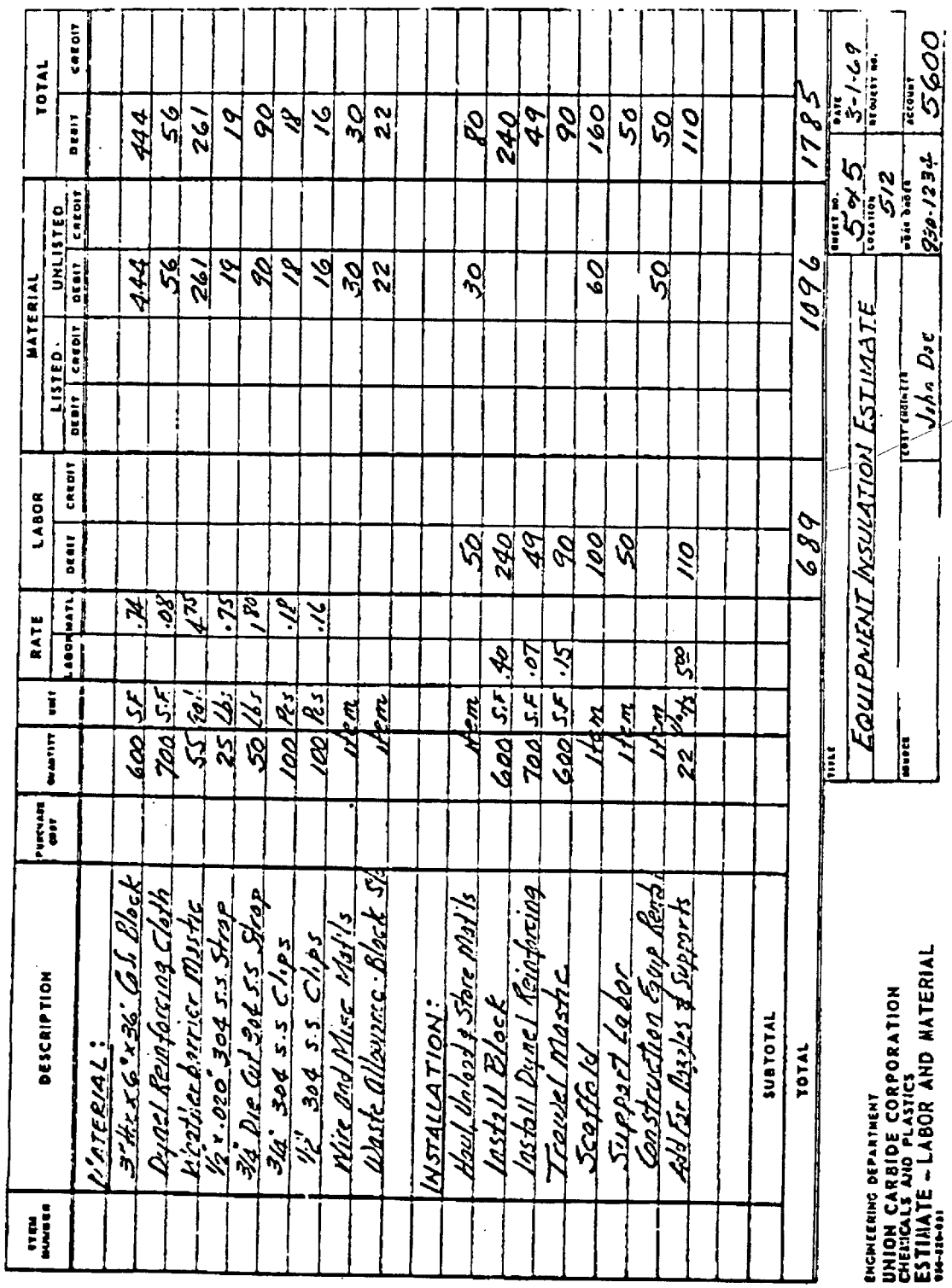
ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ESTIMATE - LABOR AND MATERIAL

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Figure IX-7
Part 4 of 5

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ESTIMATING THE INSTALLED COST



ITEM NUMBER	DESCRIPTION	PURCHASE COST	QUANTITY	UNIT	RATE LABOR	RATE MATL	LABOR DEBIT	LABOR CREDIT	MATERIAL LISTED DEBIT	MATERIAL LISTED CREDIT	MATERIAL UNLISTED DEBIT	MATERIAL UNLISTED CREDIT	TOTAL DEBIT	TOTAL CREDIT
	MATERIAL:													
	3"Hx36"x36" Gl Block		600	SF		.74			444				444	
	Dynel Reinforcing Cloth		700	S.F.		.08					56		56	
	Weather Barrier Mastic		55	Gal.		4.75					261		261	
	½"x.020" 304 S.S. Strap		25	Lbs.		.75					19		19	
	¾" Die Cut 304 S.S. Strap		50	Lbs		1.80					90		90	
	3/4" 304 S.S. Clips		100	Pcs		.18					18		18	
	½" 304 S.S. Clips		100	Pcs		.16					16		16	
	Wire and Misc Matls			Item							30		30	
	Waste Allowance - Block 5%			Item							22		22	
	INSTALLATION:													
	Haul Unload Store Matls			Item			50				30		80	
	Install Block		600	S.F.	.40		240						240	
	Install Dynel Reinforcing		700	S.F.	.07		49						49	
	Trowel Mastic		600	SF	.15		90				60		90	
	Scaffold		1	Item			100						160	
	Support Labor		1	Item			50				50		50	
	Construction Equip Rental		1	Item							50		50	
	Add for Nails & Supports		22	Pct	5.00		110						110	
	SUBTOTAL													
	TOTAL						689		1096				1785	

ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ESTIMATE - LABOR AND MATERIAL

TITLE: EQUIPMENT INSULATION ESTIMATE
BUDGET NO. 505 DATE 3-1-69
LOCATION 512 REQUEST NO.
COST CREDITED John Doe PHONE 930-1234 ACCOUNT 5600

Figure IX-7

Part 5 of 5

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ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE - Contd

Estimating Installation Costs of Pipe Insulation - Contd

characteristics; then the judgment and experience of the estimator become the prime factors in determining the accuracy of these facets of the estimate.

Referring to the sample estimate (Figure IX-7) under INSTALLATION, the major work components have been listed and norms established that make it easier to envision production rates. For example, pipe insulation is listed in linear feet, prefabricated fitting covers as pieces, finish in square feet, etc. The components designated as "item" are difficult to quantitate and consequently are costed by special methods. These methods will be explained later in the text.

Figure IX-8 should now be referred to for sample production rates established for the estimate at hand. From these production rates, a man-hour unit can be arrived at for the various components. Stated as a formula, man-hours per unit = $\frac{N}{P}$ where N equals the number of hours of work and P equals the production rate. For example,

$$\frac{\text{8 hours of work}}{\text{150 linear feet per 8-hour man-day}} = .053 \text{ man-hours per linear foot}$$

Multiplying man-hours per unit of work by the hourly wage rate gives the unit dollar cost per unit of work. For example, if the wage rate used is $4.00 per hour, the unit cost becomes $4.00 x .053 = $0.21 per linear foot. For unit cost per unit of work, the formula now becomes $\frac{N}{P} \times R$, where N and P are as heretofore stated and R is the wage rate per hour. This is the method and wage rate used to arrive at the labor figures for the sample estimate. The labor unit for the pipe and fitting work includes placement of the base insulant and its securement.

As previously mentioned, the installation part of the estimate includes several components of work that must be costed, but are difficult to quantitate. These have been designated as "item" and are as follows:

1. Haul, unload and store materials
2. Scaffolding
3. Construction Equipment Rental
4. Support labor

Each of these items must be analyzed in relation to the job that is being estimated. There is no fixed rule that can be applied to arrive at these particular costs. Knowledge of the job requirements and the experience of the estimator are the keys to estimating a realistic cost for these items.

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ESTIMATING THE INSTALLED COST

* PRODUCTION RATES

Calcium Silicate-Strapped (S/L)

Thickness	1" & 1.5	2"	2.5	3"
I.P.S.	Lineal Feet Per Man Day			
½" thru 1½"	150	135	115	105
2" thru 3"	140	125	105	100
3½ thru 4"	130	115	100	85
4½ thru 6"	110	100	90	75

Block Insulation (S/L)

Thickness	1"	1½"	2"	3"
Size	Square Feet Per Man Day			
6" x 36"	100	100	90	80
12" x 36"	180	180	160	145

Plastic And Auxiliaries

Weather Barrier - Trowel	150 S.F. Per Man Day
Palm	250 S.F. Per Man Day
Reinforcing (Dynel)	300 S.F. Per Man Day
Heat Transfer Cement -	150 L.F. Per Man Day (Trowel)

Fitting, Flange And Valve Covers - Strapped

Thickness	1" & 1.5	2"	2.5"	3"
Item	Pieces Per Man Day			
Flange Covers				
1/2" thru 1½"	30	27	23	20
2" thru 3"	28	26	22	19
3½ thru 4"	26	24	20	17
4½" thru 6"	24	22	18	15
Elbow Covers				
½" thru 1½"	45	42	40	38
2" thru 3"	43	40	38	35
3½ thru 4"	40	37	34	30
4½" thru 6"	38	35	32	28
Valve & Tee Covers				
½" thru 1½	25	23	21	18
2" thru 3"	23	21	19	17
3½ thru 4"	20	18	16	13
4½" thru 6"	17	15	13	11

* Per "Productive Man Day"

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Figure IX-8

UCC 002783

ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE - Contd

Estimating Installation Costs of Pipe Insulation - Contd

The costs for hauling, unloading, and storage of materials are dependent on the type of storage facilities required, size and weight of material containers to be handled, and the distance from storage areas to work areas.

Scaffolding requirements are obviously a function of working heights and the type of scaffold to be used (timber, tubular steel or other). Consultation with the Craft Foreman responsible for accomplishing this type of work is an invaluable aid in establishing costs for scaffolding needs.

Construction equipment such as air compressors, spray pumps with auxiliaries and trucks for hauling materials must not be overlooked. Costing is based on class of equipment used, length of time required and proper application of rental rates to this usage.

Support labor is that labor not directly involved in the application of insulation materials. Examples of this type of labor would be carpenters for scaffold erection, truck drivers, labor to keep "productive men" supplied with material, labor for clean-up, etc. The cost of this item can only be evolved through a study of the specific requirements of a particular job.

Reference to historical data from jobs of a similar nature and magnitude furnishes the best tool to aid in deriving a cost for the aforementioned items; in fact, this aid applies to practically all facets of the estimate.

For purposes of the sample estimate (Figure IX-7) arbitrary costs have been assumed for these work components.

Equipment Insulation

Within the confines of this text, the insulation of equipment is intended to be inclusive of such items as pumps, tanks, heat exchangers, ducting and other various forms of "flat work". "Flat work generally includes cylindrical shapes over 36" in diameter as well as flat surfaces.

Guidelines and reference data which have been previously discussed have been generalized and are applicable as well to (most of) this section of the text.

For purposes of demonstration of "take-off" procedure and estimate format, Item 201-A, listed on the Insulation Design Schedule (Figure IX-1) will be used. Its size and configuration, which normally would be provided by equipment drawings, is as shown on the sketch incorporated as a part of the material take-off sheet, Figure IX-9.

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ESTIMATING THE INSTALLED COST

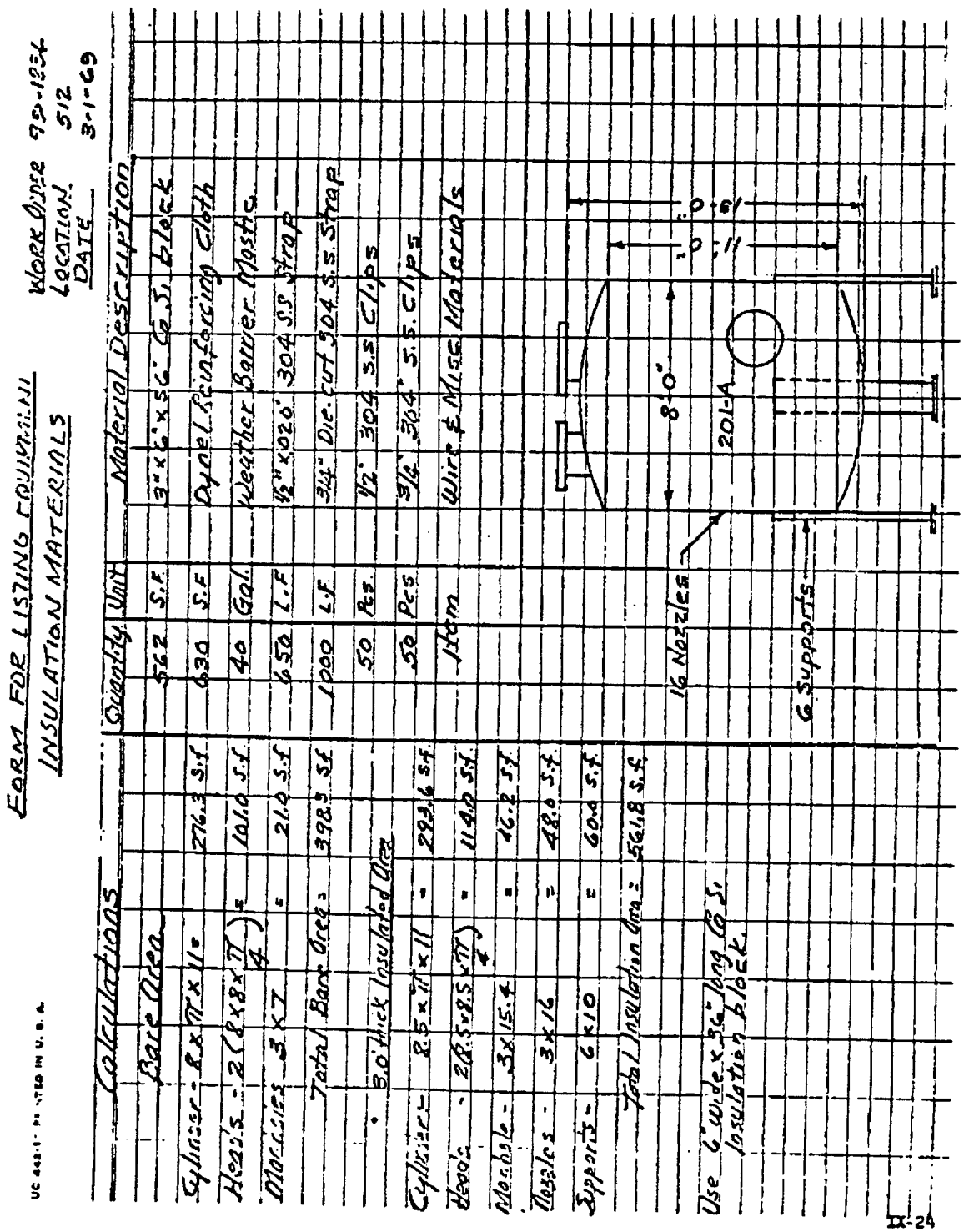


Figure IX-9

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ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE - Contd

Equipment Insulation - Contd

The take-off norm for most equipment, or "flat work" items, is the square foot. Special appurtenances, such as head covers or other items which may be furnished prefabricated, might be listed as pieces and costed accordingly.

The method of measurement for quantitating purposes is as shown on Figure IX-4. The quantities are generally estimated by increasing the bare vessel dimensions to the insulated dimensions. For example, if the bare vessel diameter is 8'-0" and the insulation thickness is 3", the area of the surface is calculated as if the diameter were 8'-6".

Study of Figure IX-9 will show the basis for development of the equipment insulation cost estimate for the case at hand. Production rates and man-hour conversions are required for labor costing following the principles as previously outlined.

The final step in the preparation of the total insulation cost estimate is the summarizing of the direct cost of the pipe and equipment components. To these direct costs will be added certain indirect costs to complete the estimate. (See Summary Sheet of Figure IX-7.)

Indirect Costs

The aforementioned indirect costs consist of the following items:

1. Location Expense
2. General Administration Expense
3. Engineering
4. Contingencies

Location expense is made up of costs incurred at the construction site. These costs may or may not be completely identified with a specific project, and are usually distributed to all active jobs at the site. The basis for distribution is the labor dollar flow per month per job. For example, the current rate used in the estimate is 70% of labor. Since the estimated total dollar flow for labor in the estimate is $1875, this expense figure becomes $1312 (70% x $1875).

There are many items that make up the location expense. A few examples are as follows:

1. Supervision
2. Insurance, Payroll Taxes, Workmen's Compensation
3. Utility Costs (Construction lighting, heating, etc.)
4. Temporary Construction (Field offices, store rooms, etc.)
5. Maintenance of Construction Area.

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ESTIMATING THE INSTALLED COST

PREPARATION OF THE ESTIMATE - Contd

Indirect Costs - Contd

The general administration overhead is also made up of costs which cannot be identified to a particular job. These costs are distributed as a standard percentage of total costs (labor, material, and location overhead). Examples of items included in this expense are as follows:

1. Procurement or Purchasing Costs.
2. Costs of Engineering Department, which are not purely engineering, or which cannot be identified to a specific project.
3. Home Office activities.
4. Vacation, Holidays, Illness, etc.

Engineering costs are inclusive of Process Engineering and Project Engineering efforts. These costs are estimated from historical data and/or manpower requirements projected over a given length of time. The figure arrived at is usually depicted as a percent of total cost (labor, material, and expense).

The contingency allowance is a judgment factor applied by the estimator. The amount to be used is dependent on the confidence that the estimator has in the information on which he has based the estimate. The allowance is also intended to include coverage of possible estimating errors, unforeseen construction problems, field changes, etc.

CONCLUSION

The purpose of this chapter has been to provide the Insulation Craftsman with an approach to insulation cost estimate preparation. The wide variety of specifications that exist for insulation work makes it impractical to cover the entire field within the limits of this text. Hopefully, the narrative and Figures contained in this chapter will have fulfilled the purpose.

In the final analysis, the degree of success the estimator attains in his cost forecast will be a function of information quality and adequacy and the estimator's knowledge and experience.

RESPONSIBILITY

The insulation applicator might question why this information on selection of insulation specification was contained in this manual, for in most instances the selection is the responsibility of the Engineering Department. However, in case of emergencies it might happen that the insulator

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ESTIMATING THE INSTALLED COST

RESPONSIBILITY - Contd

must make a selection of materials and the method of application. In addition, in any large organization there always exists a possibility of error. Should such occur and the insulation has a valid reason for questioning the selection it is his responsibility to question the correctness of the selection.

Another reason for presenting this information to the insulator is to give him the basic reasons of why certain materials are selected and applied. No specification can be written that covers every detail of an application and when a craftsmen knows why such is done in general he can do much better in following this in each detail.

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SHOP AND FIELD FABRICATION

Prefabrication of thermal insulation provides a means to obtain more economical and more quickly installed insulation of better quality. In addition, for maintenance, it is possible to remove and replace fitting covers. In spite of these apparent advantages, development of prefabrication systems has been a relatively recent development.

In the development of the insulation industry the major manufacturers produced their pipe insulation to their own system of thicknesses and sizes. By 1940 the industry was producing insulation using five different methods of sizing. These were:

1. Standard and double standard thicknesses.
2. Combination thickness, which was used for high temperatures using diatomaceous earth insulation inner layer and 85% magnesia outer layer.
3. The 1/2 in. increment system, wherein the thickness increased in even 1/2 in. increments.
4. Thicknesses based on the number of laminations or plies.
5. Ice water, brine, and heavy brine sizes, wherein the thickness was based on specific operating temperature and pipe size.

Then, the existing practices of producing pipe insulation required stocking a total of 600 sizes to obtain thicknesses from one to three inches. Regardless of the great number of sizes then being produced, insulations could not be used in combination because they would not fit to each other.

All factors pointed to the need for a better system of pipe insulation to eliminate the costly waste and confusion. The problem indicated that insulation must fit insulation as well as the pipe. It was reasonable to conclude that the only manner in which this could be accomplished was to make the outside diameter of each piece of insulation equal to the outside diameter of some standard nominal pipe size (NPS). On this basic premise, the writer developed the Dimensional Standard System of Thickness. This system has been adopted by the major producers of insulation, by the U. S. Military Services as Military Specification MIL-I-2781B, and by industry as ASTM Standard Practice for Determining Outside Diameter of Rigid Pipe Insulation C-521. The inner and outer diameters of pipe insulation and approximate thicknesses for both NPS pipe and tubes are shown in Tables X-1 and X-2.

The standardizing of pipe insulation made it possible to devise a practical method of prefabrication to improve over the old hand-applied method shown in Figure X-1.

The total number of covers required for fittings, flanges, and valves, from 1 to 7-1/2 inches in thickness is approximately 9,000. If tracer systems are installed on the pipe system, each fitting is slightly different than when the insulation is installed snugly to the pipe. This increased the number of fittings to approximately 7,000. A manual of design of these fittings was compiled

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SHOP AND FIELD FABRICATION

OUTSIDE DIAMETERS AND AVERAGE THICKNESSES FOR PIPE INSULATION
ASTM Recommended Practice

NPS Pipe		Insulation Thickness							
		1/2 Nominal		1" Nominal		1½" Nominal		2" Nominal	
NOM SIZE	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches
1/8	0.405	0.45	1.315	0.98	2.375	1.54	3.500	2.05	4.500
1/4	0.540	0.55	1.660	1.16	2.875	1.72	4.000	2.22	5.000
3/8	0.675	0.49	1.680	1.09	2.875	1.66	4.000	2.16	5.000
1/2	0.840	0.52	1.900	1.00	2.875	1.57	4.000	2.07	5.000
3/4	1.050	0.42	1.900	0.91	2.875	1.47	4.000	1.97	5.000
1	1.315	0.52	2.375	1.09	3.500	1.59	4.500	2.12	5.563
1¼	1.660	0.60	2.875	0.91	3.500	1.66	5.000	1.94	5.563
1½	1.900	0.48	2.875	1.04	4.000	1.54	5.000	2.36	6.625
2	2.375	0.55	3.500	1.05	4.500	1.58	5.563	2.11	6.625
2½	2.875	0.55	4.00	1.05	5.000	1.86	6.625	2.36	7.625
3	3.500	0.49	4.500	1.02	5.563	1.55	6.625	2.05	7.625
3½	4.000	0.49	5.000	1.30	6.625	1.80	7.625	2.30	8.625
4	4.500	0.54	5.563	1.05	6.625	1.55	7.625	2.05	8.625
4½	5.000	0.80	6.625	1.30	7.625	1.80	8.625	2.30	9.625
5	5.563	0.49	6.625	0.99	7.625	1.49	8.625	1.99	9.625
6	6.625	0.46	7.625	0.96	8.625	1.46	9.625	2.02	10.750
7	7.625					1.52	10.750	2.02	11.750
8	8.625					1.52	11.750	2.02	12.750
9	9.625					1.52	12.750	2.15	14.000
10	10.750					1.59	14.00	2.09	15.000
11	11.750					1.59	15.000	2.09	16.000
12	12.750					1.58	16.000	2.08	17.000
14	14.000					1.45	17.00	1.95	18.000
15	15.000					1.45	18.00	1.95	19.000
16	16.000					1.45	19.000	1.95	20.000
17	17.000					1.45	20.000	1.95	21.000
18	18.000					1.45	21.000	1.95	22.000
19	19.000					1.45	22.000	1.95	23.000
20	20.000					1.45	23.000	1.95	24.000
21	21.000					1.45	24.000	1.95	25.000
22	22.000					1.45	25.000	1.95	26.000
23	23.000					1.45	26.000	1.95	27.000
24	24.000					1.45	27.000	1.95	28.000
25	25.000					1.45	28.000	1.95	29.000
26	26.000					1.45	29.000	1.95	30.000
27	27.000					1.45	30.000	1.95	31.000
28	28.000					1.45	31.000	1.95	32.000
29	29.000					1.45	32.000	1.95	33.000
30	30.000					1.45	33.000	1.95	34.000
31	31.000					1.45	34.000	1.95	35.000
32	32.000					1.45	35.000	1.95	36.000
33	33.000					1.45	36.000	1.95	37.000
34	34.000					1.45	37.000	1.95	38.000
35	35.000					1.45	38.000	1.95	39.000
36	36.000					1.45	39.000	1.95	40.000

Table X-1

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SHOP AND FIELD FABRICATION

OUTSIDE DIAMETERS AND AVERAGE THICKNESSES FOR PIPE INSULATION
ASTM Recommended Practice

NPS Pipe		Insulation Thickness							
		2½" Nominal		3" Nominal		3½" Nominal		4" Nominal	
NOM SIZE	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches
1/8	0.405	2.57	5.563	3.10	6.625	3.60	7.625	4.10	8.625
1/4	0.540	2.50	5.563	3.04	6.625	3.54	7.625	4.04	8.625
3/8	0.675	2.44	5.563	2.97	6.625	3.47	7.625	3.97	8.625
1/2	0.840	2.89	6.625	3.39	7.625	3.89	8.625	4.39	9.625
3/4	1.050	2.78	6.625	3.28	7.625	3.78	8.625	4.28	9.625
1	1.315	2.64	6.625	3.15	7.625	3.65	8.625	4.15	9.625
1¼	1.660	2.48	6.625	2.98	7.625	3.48	8.625	3.98	9.625
1½	1.900	2.86	7.625	3.36	8.625	3.86	9.625	4.42	10.750
2	2.375	2.61	7.625	3.11	8.625	3.61	9.625	4.17	10.750
2½	2.875	2.86	8.625	3.36	9.625	3.92	10.750	4.42	11.750
3	3.500	2.55	8.625	3.05	9.625	3.61	10.750	4.11	11.750
3½	4.000	2.80	9.625	3.36	10.750	3.86	11.750	4.36	12.750
4	4.500	2.55	9.625	3.11	10.750	3.61	11.750	4.11	12.750
4½	5.000	2.86	10.750	3.36	11.750	3.86	12.750	4.49	14.000
5	5.563	2.56	10.750	3.06	11.750	3.56	12.750	4.18	14.000
6	6.625	2.52	11.750	3.02	12.750	3.65	14.000	4.15	15.000
7	7.625	2.52	12.750	3.15	14.000	3.65	15.000	4.15	16.000
8	8.625	2.65	14.000	3.15	15.000	3.65	16.000	4.15	17.000
9	9.625	2.65	15.000	3.15	16.000	3.65	17.000	4.15	18.000
10	10.750	2.59	16.000	3.09	17.000	3.59	18.000	4.09	19.000
11	11.750	2.59	17.000	3.09	18.000	3.59	19.000	4.09	20.000
12	12.750	2.58	18.000	3.08	19.000	3.58	20.000	4.08	21.000
14	14.000	2.45	19.000	2.95	20.000	3.45	21.000	3.95	22.000
15	15.000	2.45	20.000	2.95	21.000	3.45	22.000	3.95	23.000
16	16.000	2.45	21.000	2.95	22.000	3.45	23.000	3.95	24.000
17	17.000	2.45	22.000	2.95	23.000	3.45	24.000	3.95	25.000
18	18.000	2.45	23.000	2.95	24.000	3.45	25.000	3.95	26.000
19	19.000	2.45	24.000	2.95	25.000	3.45	26.000	3.95	27.000
20	20.000	2.45	25.000	2.95	26.000	3.45	27.000	3.95	28.000
21	21.000	2.45	26.000	2.95	27.000	3.45	28.000	3.95	29.000
22	22.000	2.45	27.000	2.95	28.000	3.45	29.000	3.95	30.000
23	23.000	2.45	28.000	2.95	29.000	3.45	30.000	3.95	31.000
24	24.000	2.45	29.000	2.95	30.000	3.45	31.000	3.95	32.000
25	25.000	2.45	30.000	2.95	31.000	3.45	32.000	3.95	33.000
26	26.000	2.45	31.000	2.95	32.000	3.45	33.000	3.95	34.000
27	27.000	2.45	32.000	2.95	33.000	3.45	34.000	3.95	35.000
28	28.000	2.45	33.000	2.95	34.000	3.45	35.000	3.95	36.000
29	29.000	2.45	34.000	2.95	35.000	3.45	36.000	3.95	37.000
30	30.000	2.45	35.000	2.95	36.000	3.45	37.000	3.95	38.000
31	31.000	2.45	36.000	2.95	37.000	3.45	38.000	3.95	39.000
32	32.000	2.45	37.000	2.95	38.000	3.45	39.000	3.95	40.000
33	33.000	2.45	38.000	2.95	39.000	3.45	40.000	3.95	41.000
34	34.000	2.45	39.000	2.95	40.000	3.45	41,000	3.95	42.000
35	35.000	2.45	40,000	2.95	41.000	3.45	42.000	3.95	43.000
36	36.000	2.45	41.000	2.95	42.000	3.45	43.000	3.95	44.000

Table X-1 (Continued)

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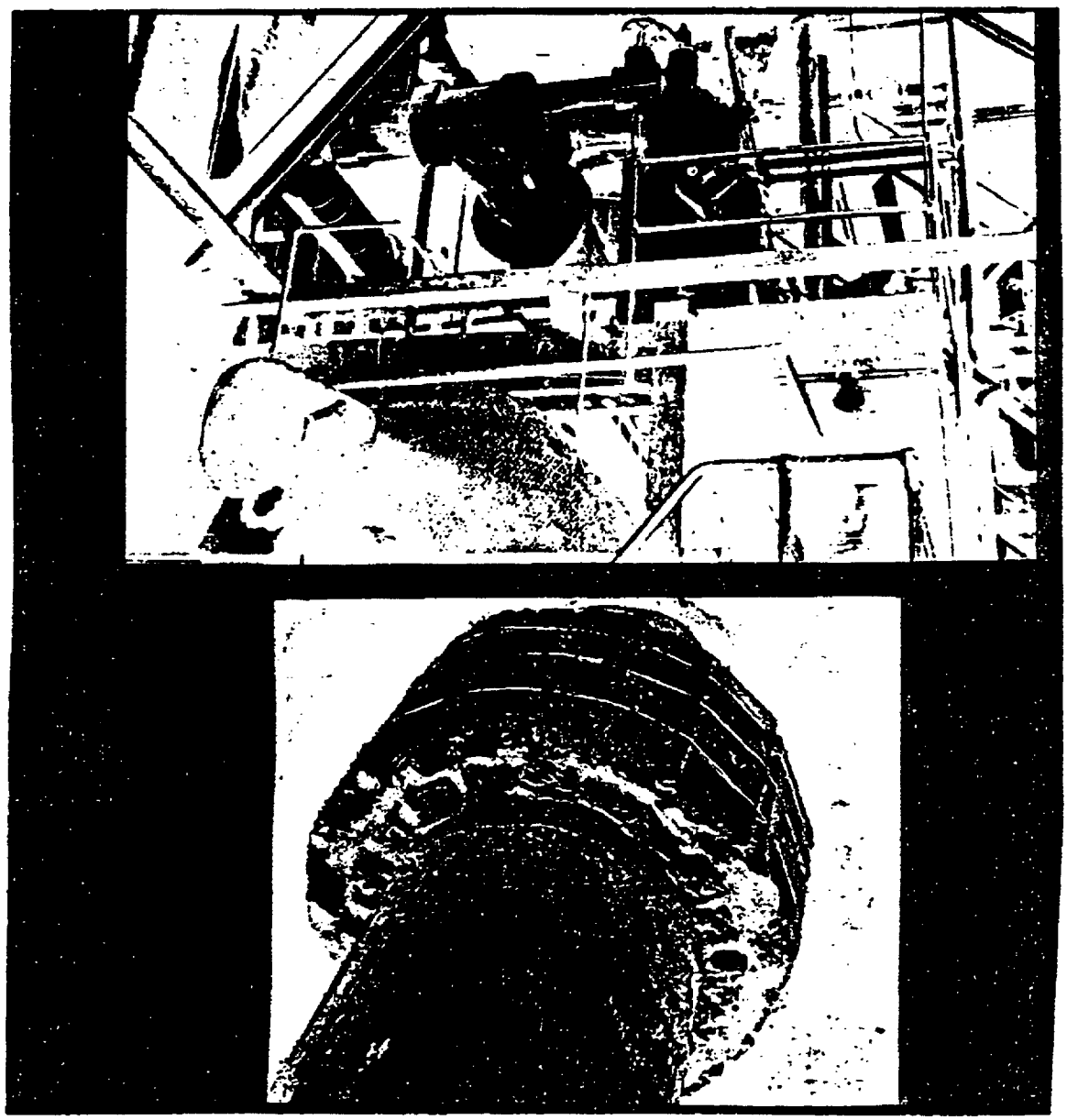
SHOP AND FIELD FABRICATION

BASIC OUTSIDE DIAMETERS FOR TUBE INSULATION
ASTM Recommended Practice

Tube Size	O.D.	Nominal Thickness of Insulation							
		1/2	1	1½	2	2½	3	3½	4
1/4	0.250	1.315	2.875	3.500	4.500	5.625	6.625	7.625	8.625
3/8	0.375	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
1/2	0.500	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
1/2	0.625	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
3/4	0.750	1.900	2.875	4.000	5.000	5.625	7.625	8.625	9.625
3/4	0.875	1.900	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1	1.000	2.375	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1	1.125	2.375	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1¼	1.250	2.375	3.500	4.500	5.563	6.625	7.625	8.625	9.625
1½	1.500	2.875	4.000	4.500	5.563	6.625	7.625	8.625	9.625
1½	1.625	2.875	4.000	4.500	5.563	6.625	7.625	8.625	9.625
2	2.000	3.500	4.000	5.000	6.625	7.625	8.625	9.625	10.750
2	2.125	3.500	4.500	5.563	6.625	7.625	8.625	9.625	10.750
2½	2.500	3.500	4.500	5.563	6.625	7.625	8.625	9.625	10.750
2½	2.625	4.000	5.000	5.563	6.625	7.625	8.625	9.625	10.750
3	3.000	4.000	5.000	6.625	7.625	8.625	9.625	10.750	11.750
3	3.125	4.500	5.563	6.625	7.625	8.625	9.625	10.750	11.750
3 5/8	3.625	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750
4	4.000	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750
4	4.125	5.563	6.625	7.625	8.625	9.625	10.750	11.750	12.750
5	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750	14.000
5	5.125	6.625	7.625	8.625	9.625	10.750	11.750	12.750	14.000
6	6.000	7.625	8.625	9.625	10.750	11.750	12.750	14.000	15.000
6	6.125	7.625	8.625	9.625	10.750	11.750	12.750	14.000	15.000
8	8.000			11.750	12.750	14.000	15.000	16.000	17.000
8	8.125			11.750	12.750	14.000	15.000	16.000	17.000
10	10.000			12.750	14.000	15.000	16.000	17.000	18.000
10	10.125			14.000	14.000	15.000	16.000	17.000	18.000
12	12.000			15.000	16.000	17.000	18.000	19.000	20.000
14	14.333			18.000	19.000	20.000	21.000	33.000	23.000
16	16.333			20.000	21.000	22.000	23.000	24.000	25.000
18	18.333			22.000	23.000	24.000	25.000	26.000	27.000
20	20.333			24.000	25.000	26.000	27.000	28.000	29.000
24	24.333			28.000	29.000	30.000	31.000	32.000	33.000

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SHOP AND FIELD FABRICATION



Old Method Of Insulating Fittings
Figure X-1
UCC 002793

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SHOP AND FIELD FABRICATION

by Mr. R. E. Estep and the writer. This manual was adopted by ASTM as Standard Practice C-450. Later, Mr. K. B. Lanham revised and improved the manual and this revision was adopted as Standard Practice C-450-657 by ASTM in 1965.

DESIGN OF FITTING AND VESSEL INSULATION COVERS

Basically all flanged fitting covers were designed to fit over the adjacent pipe insulation. In most installations, the straight pipe insulation is installed prior to the fitting covers being installed. Therefore, flange fitting covers which fit over the adjacent pipe covering adopt themselves to proper installation sequence. This type of installation has another advantage in that the overlapping insulation can be installed to function as a slip joint and act as an insulation expansion and contraction joint.

Fitting Insulation, General

1. All insulation fittings are designed to use standard pipe insulation for the main body, but may be fabricated of flat block insulation cut into curved segments.

2. Due to difference in requirements, the method of fabrication for low temperature rigid insulation flanged fitting covers is different than the fabrication of high temperature fitting covers. The C-450 Manual is divided into sections with all flanged fitting covers of each temperature range separated into their proper groups.

3. Likewise, covers that are dimensioned to fit snugly to standard NPS pipe are listed separately from fitting covers that are dimensioned to fit standard NPS with clearance for heat tracers.

Fitting Fabrication - Design Details

1. Flanged Valve Bonnets

   Valves manufactured by various companies for the same pressure and nominal (NPS) size do not have standardized bonnet dimensions or height of bonnet flange above centerline of valve. Because of this, the valve insulation cover was designed to fit the largest valve of a size, type and pressure.

   For valves smaller than dimensions given it is necessary to make field cuts on the top of the insulation cover to produce a fit around the packing gland. For this reason, bonnet top is made with a removable broken joint dutchman, permitting cutting of bonnet length, and field fitting, and bonding of the dutchman around packing gland.

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SHOP AND FIELD FABRICATION

DESIGN OF FITTING AND VESSEL INSULATION COVERS - Contd

Fitting Fabrication - Design Details - Contd

1. Flanged Valve Bonnets - Contd

To assist in field fitting and to add additional strength to top of valve cover, when bonnet dutchman is 2-1/2 inches thick, the two layers of the bonnet shall be made with 1 inch thickness on the bottom layer and 1-1/2 inches thickness on the top layer.

A typical sheet which provides dimensions for a valve cover is shown in Figure X-2.

2. Elbow Covers

The manual presents dimensions for both short and long radius ells. Thus, care must be taken that proper dimensions are used for the ell or ells to be covered.

3. Heat Traced Welded Ells and Tees

Where single-layer welded ell and tee covers are to be used on heat traced piping the ends are to be "Broken Joint Construction" as noted in the manual. This means that 3 inch long and 6 inch long cylindrical sections are placed on alternate and opposite ends of the two halves of the fitting cover. This permits offset tie-ins with the adjacent pipe insulation to obtain mechanical stability. The fittings are oversize in diameter to allow space for the tracer.

4. All Flanged Fittings

The insulation thickness of all flanged fitting covers is no less than 1-1/2 inches to provide sufficient mechanical strength. Flanged covers of one inch thickness, or less, are too fragile.

Vessel Insulation

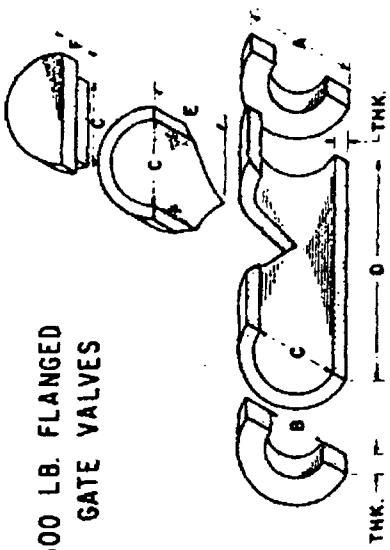
1. Sidewalls

Although curved sectorial segments are recommended for sidewall insulation, the economic fabrication of curved segments depends upon thickness and width of flat blocks available, from which the curved sectors may be cut with a minimum of waste. The number of possible combinations make recommended tables for this prefabrication impractical.

Where flat lagging might be used satisfactorily, the dimension for cutting it are presented in the manual.

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SHOP AND FIELD FABRICATION



SIZE		1	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20	24
C-BODY I.D.		6¾	6¾	7⅞	8¾	9⅜	9⅜	11⅜	12⅝	14	17	20	24	26	29	31	34	40
D-BODY LENGTH		12	12	15	16	18	18	20.	23	24	25	27	29	30	43	44	29	56
E-BON. HT.		8	9	10	12	12	12	14	15	17	19	23	26	28	31	33	35	39
F-BON. DUTCH. THK.		2	2	2	2	2	2	2	2	24	24	24	24	24	24	24	24	24
	THICKNESS																	
	1	A 9¾	9¾	10⅞	11⅜	12⅝	14	15	17	17	20	23	27	29	33	34	37	40
		B 4¾	5	5⅜	6⅜	7⅛	7⅛	8⅛	9⅜	9⅜	11⅜	14	16	17	19	21	23	27
	1½	A 9¾	9¾	10⅞	11⅜	12⅝	14	15	17	18	21	24	28	30	33	35	38	42
		B 5	5⅜	6⅜	7⅛	7⅛	8⅛	9⅜	9⅜	10⅝	12⅝	15	17	18	20	22	24	28
	2	A 10⅞	10⅞	12⅛	12⅝	14	15	16	18	19	22	25	29	31	34	36	39	43
		B 6⅜	6⅜	7⅛	8⅛	8⅛	9⅜	10⅝	10⅝	11⅞	14	16	18	19	21	23	25	29
	2½	A 11⅜	11⅜	12⅝	14	15	16	17	19	20	23	26	30	32	35	37	40	44
		B 7⅛	7⅛	8⅛	9⅜	9⅜	10⅝	11⅞	11⅞	13⅛	15⅛	17	19	20	22	24	26	30
	3	A 12⅝	12⅝	14	15	16	17	18	20	21	24	27	31	33	36	38	41	45
		B 8⅛	8⅛	9⅜	9⅜	10⅝	11⅞	11⅞	13⅛	14⅜	16⅜	18	20	21	23	25	27	31
	3½	A 14	14	15	16	17	18	19	21	22	25	28	32	34	37	39	42	46
		B 9⅜	9⅜	9⅜	10⅝	11⅞	11⅞	13⅛	14⅜	15⅝	17⅝	19	21	22	24	26	28	32
	4	A 15	15	16	17	18	19	20	22	23	26	29	33	35	38	40	43	47
		B 10⅝	10⅝	10⅝	11⅞	13⅛	13⅛	14⅜	15⅝	16⅞	18⅞	20	22	23	25	27	29	33
	4½	A 16	16	17	18	19	20	21	23	24	27	30	34	36	39	41	44	48
		B 11⅞	11⅞	11⅞	13⅛	14⅜	14⅜	15⅝	16⅞	18⅛	20⅛	21	23	24	26	28	30	34
	5	A 17	17	18	19	20	21	22	24	25	28	31	35	37	40	42	45	49
		B 13⅛	13⅛	13⅛	14⅜	15⅝	15⅝	16⅞	18⅛	19⅜	21⅜	22	24	25	27	29	31	35
	5½	A 18	18	19	20	21	22	23	25	26	29	32	36	38	41	43	46	50
		B 14⅜	14⅜	14⅜	15⅝	16⅞	16⅞	18⅛	19⅜	20⅝	22⅝	23	25	26	28	30	32	36
	6	A 19	19	20	21	22	23	24	26	27	30	33	37	39	42	44	47	51
		B 15⅝	15⅝	15⅝	16⅞	18⅛	18⅛	19⅜	20⅝	21⅞	23⅞	24	26	27	29	31	33	37
	6½	A 20	20	21	22	23	24	25	27	28	31	34	38	40	43	45	48	52
		B 16⅞	16⅞	16⅞	18⅛	19⅜	19⅜	20⅝	21⅞	23⅛	25⅛	25	27	28	30	32	34	38
	7	A 21	21	22	23	24	25	26	28	29	32	35	39	41	44	46	49	53
		B 18⅛	18⅛	18⅛	19⅜	20⅝	20⅝	21⅞	23⅛	24⅜	26⅜	26	28	29	31	33	35	39
	7½	A 22	22	23	24	25	26	27	29	30	33	36	40	42	45	47	50	54
		B 19⅜	19⅜	19⅜	20⅝	21⅞	21⅞	23⅛	24⅜	25⅝	27⅝	27	29	30	32	34	36	40
	8	A 23	23	24	25	26	27	28	30	31	34	37	41	43	46	48	51	55
		B 20⅝	20⅝	20⅝	21⅞	23⅛	23⅛	24⅜	25⅝	26⅞	28⅞	28	30	31	33	35	37	41

● NO DUTCHMAN NEEDED
DOUBLE DUTCH THK. AND ADD TO BODY LENGTH

Figure X-2

UCC 002796

SHOP AND FIELD FABRICATION

DESIGN OF FITTING AND VESSEL INSULATION COVERS - Contd

Vessel Insulation - Contd

2. Dished Heads

The manual gives dimensions for segments of insulation for dished heads based on the dished head radius being equal to the diameter of the tank. The head insulation is not designed to fit the radius of the knuckle. The insulation should be fitted over the vessel wall insulation which was trimmed at the proper angle to butt to underside of the head segments. This leaves a slight void at the knuckle.

The common practice for cutting dished head covers is to cut pie shaped segments as shown in Figure X-3. However, such arrangement requires that each ring be cut differently than the other rings. Also, when applied these rings must be installed in proper sequence.

A different method which is very suitable for the cutting and application of cellular glass or expanded silica is to shape the blocks in double curved beveled squares. This is illustrated in Figure X-4. The instructions for cutting these are given in Figures X-5 and X-6. Application of these square segments is similar to installation of tile floors. Starting at center segments are installed in a straight line in one direction and another line starting at center is installed 90 degrees from first line. The space between the lines are then installed starting at the apex. Such is shown in a picture shown in Figure X-7 which has cellular glass and calcium silicate fit on top a dished head.

SHOP AND SHOP PRACTICES

As would be expected, this depends on needs and materials to be fabricated. However there are some items of equipment which are common to most insulation shops.

For ordinary cutting of many insulations, modified carpenter tools are used.

Tools

Band Saws

The most essential piece of equipment is a band saw. Both vertical and horizontal band saws can be used advantageously. The minimum cutting depth should be 22 inches and saws with 40 inch cutting depth are used advantageously for fabrication of 36 inch sections

Blade speed for fabrication of inorganic foams should be approximately 1040 ft. per minute. A 1" blade, 3 pitch, raker tooth chrome plated blade is recommended for cutting inorganic foam, particularly when foam pieces have been bonded together with hot asphalt. For unbonded

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SHOP AND FIELD FABRICATION

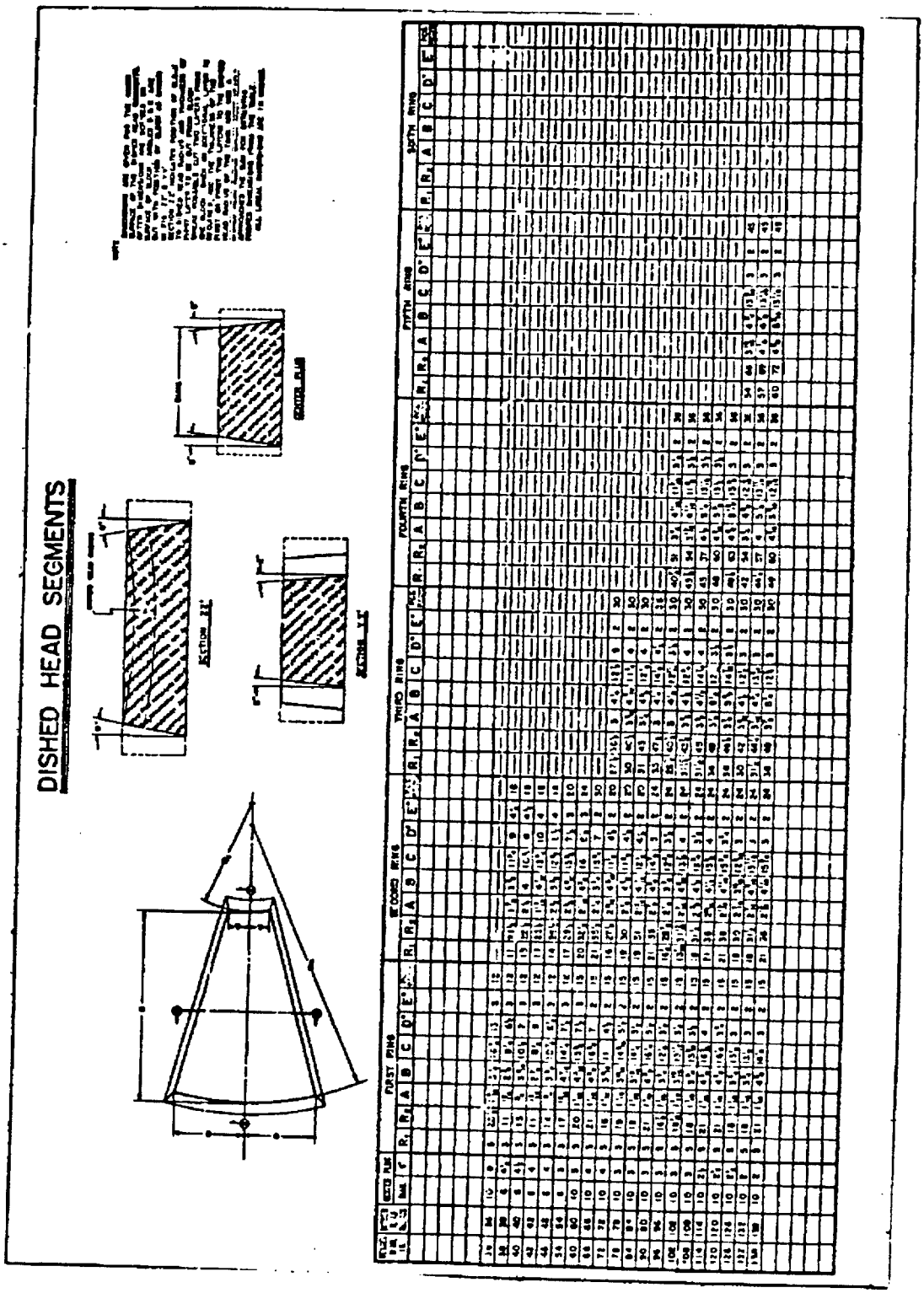


Figure X-3

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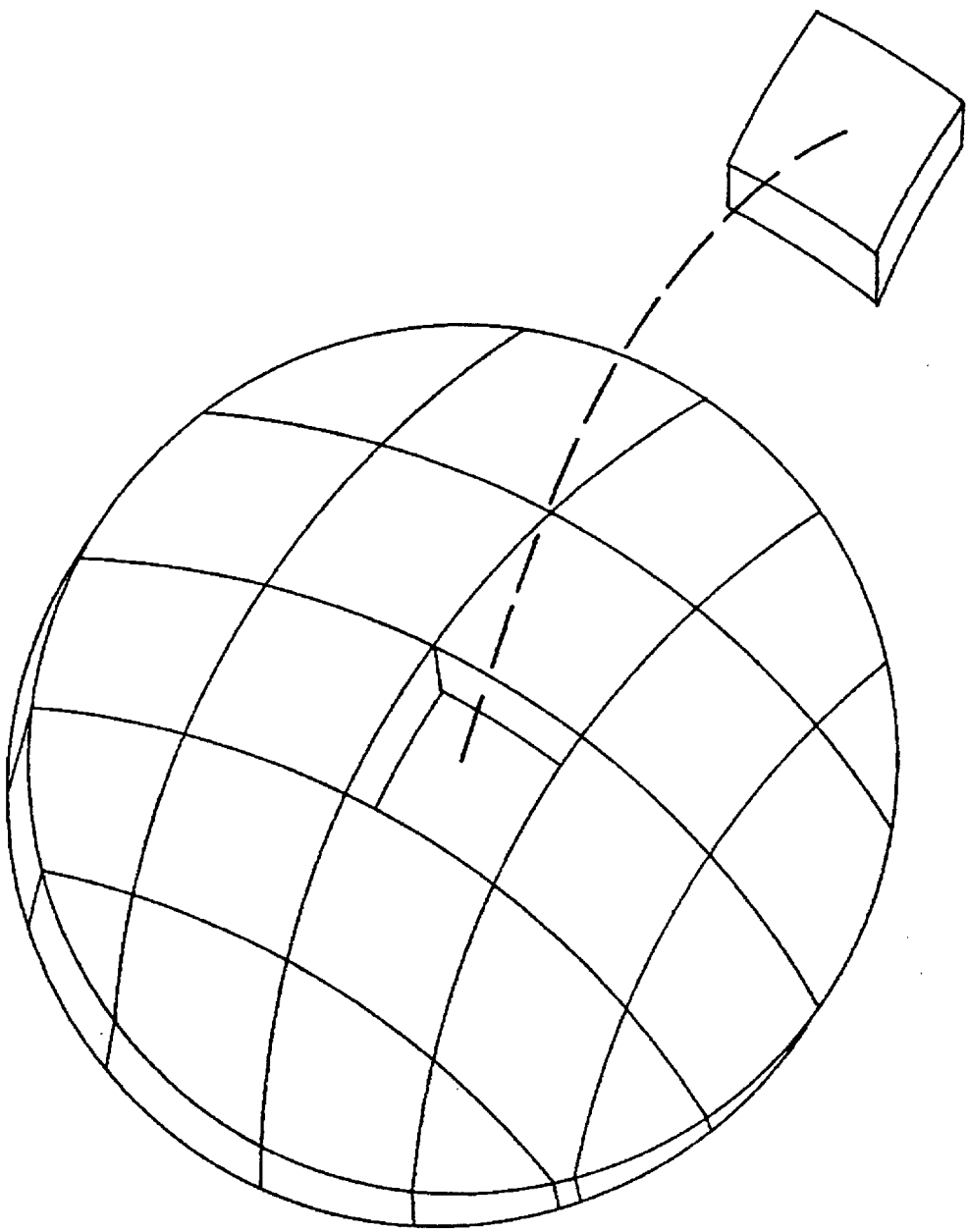
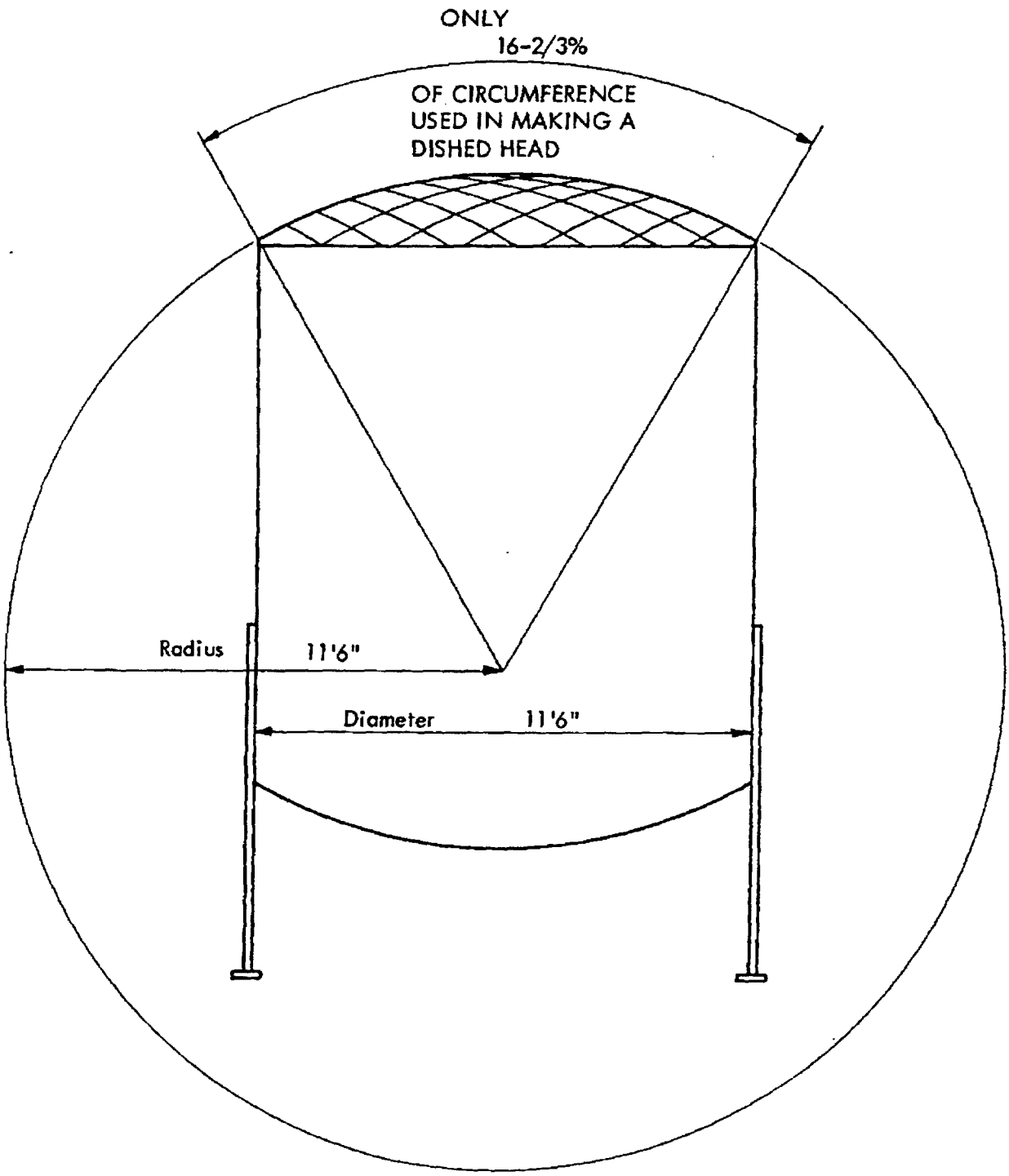


Figure X-4

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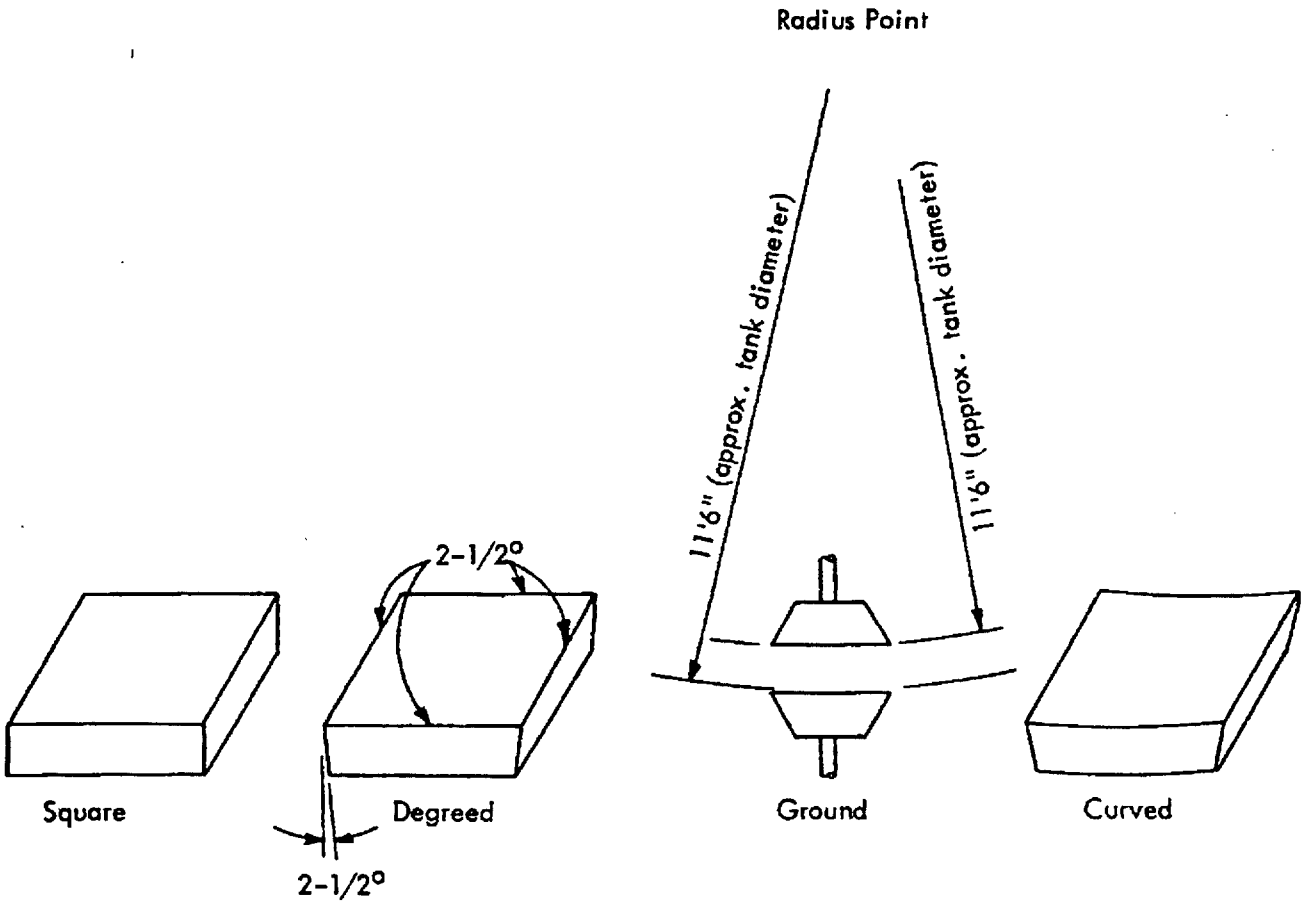


Note: The radius of a dished head is equal to approx. the tank diameter.

Figure X-5

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SHOP AND FIELD FABRICATION



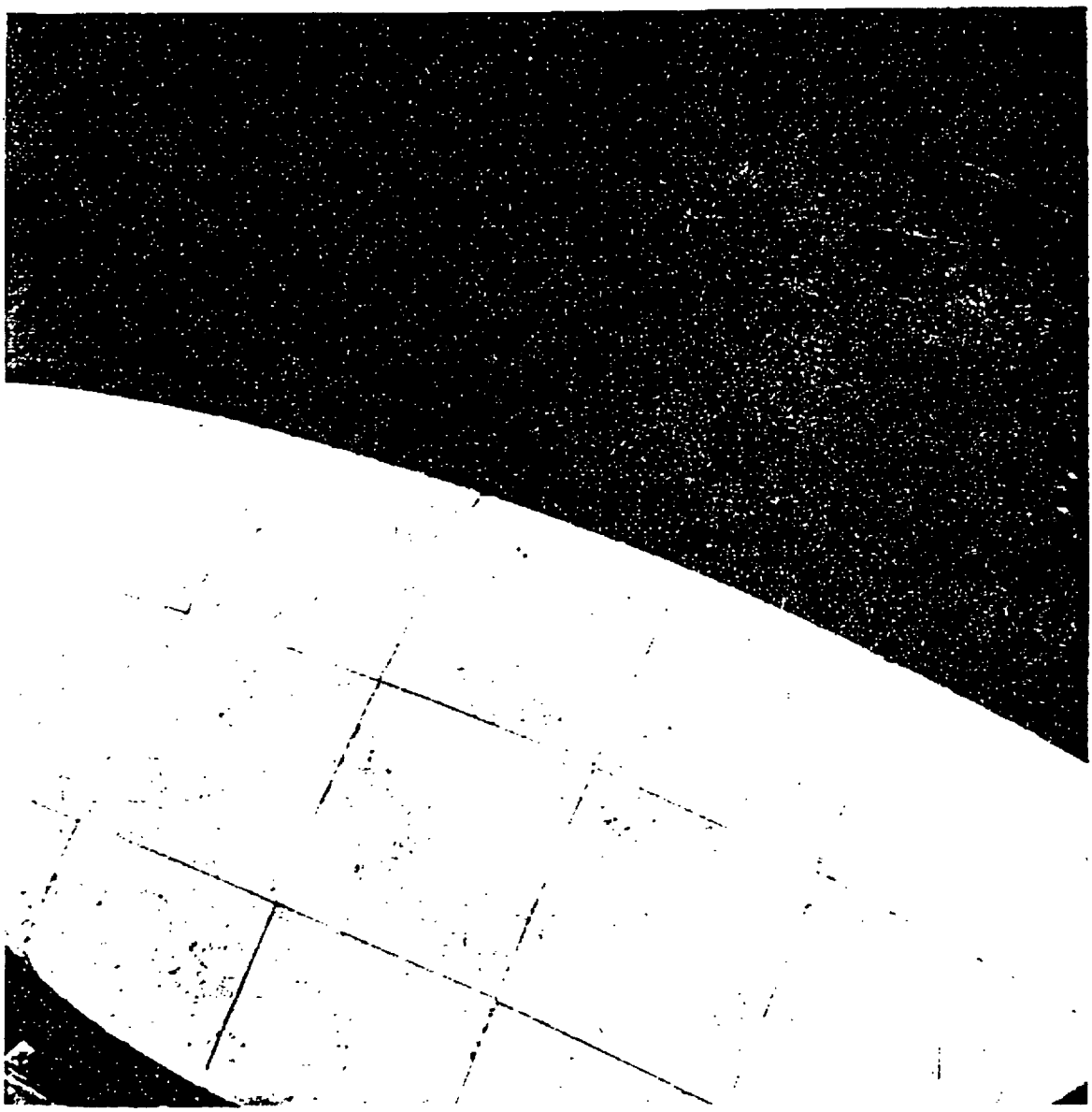
Note: To find the degree double the diameter of vessel multiply by P_1, divide into 180°

Example: To make 11'6" tank head
11'6" doubled = 23'
23' x P_1 = 72'
72 ⟌180 2-1/2 degree

Figure X-6

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SHOP AND FIELD FABRICATION



Demonstration Application of Cellular Glass and Calcium Silicate Installed in Dished Head

Figure X-7

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Tools - Contd

Band Saws - Contd

inorganic foams, 3/16" or 1/2" carbide tipped blades provide means for cutting smaller radius cuts with less thickness of saw cut. For the cutting of calcium-silicate, diatomaceous and asbestos fiber block and pipe covering, blades 1/2" x 0.035" thick, skip tooth, five per inch, are used.

Materials being cut by band saws are cut to line marked on the insulation, by cutting to jigs, or by placement on a swinging arm.

A picture of craftsmen cutting insulation on a vertical bandsaw is shown in illustration Figure X-8.

Grinders

Grinders used are not standard carpenter tools and are therefore designed for particular uses.

Inside grinders are made so that the mandrel is coated with a grit. This mandrel rotation grinds the inside diameter into a recentagular block of insulation. An outside grinder shapes the insulation by allowing the insulation to rotate against the spinning grit mandrel. Small to moderate size organic foam is shaped by this method. A grinder of this type is shown in illustration Figure X-9.

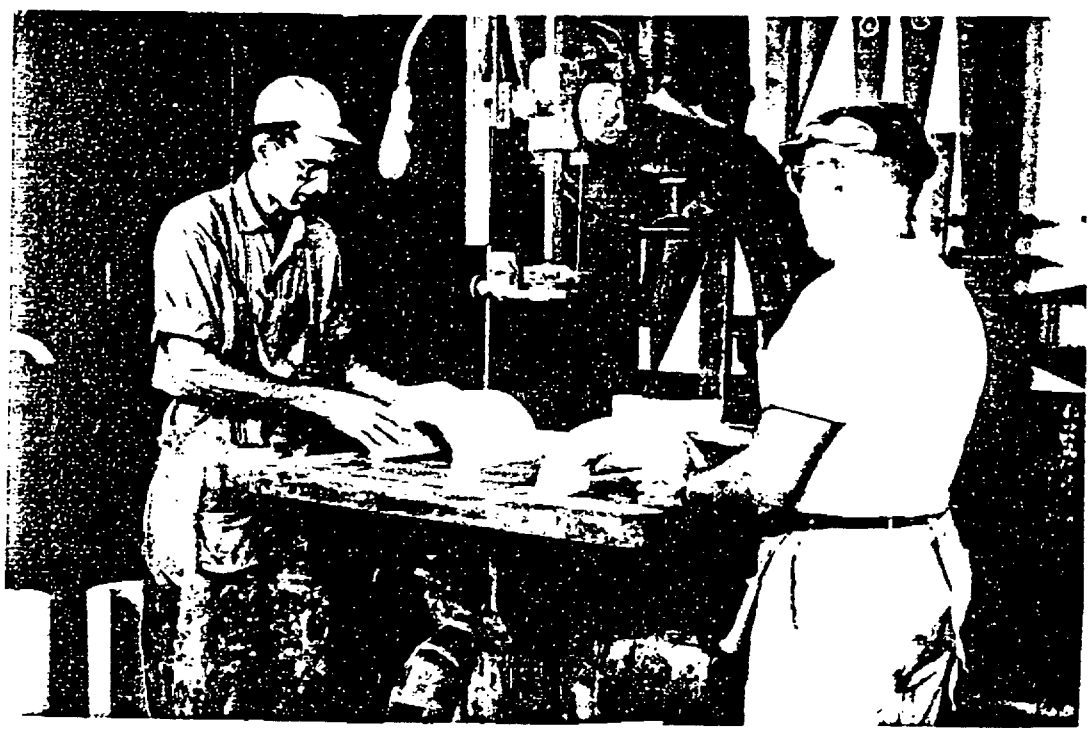
Head segment grinder is a machine for shaping double curvature head segments. This machine consists of an O.D. and I.D. circular section grinding spool, whose axes are simultaneously orientable in a vertical plane through a vertical axis and a swinging block holder pivoted in the same axis so that the block can be swung through the two spools. A picture of grinding spools is shown in Figure X-10. The holder is shown in Figure X-11, and the block to be swung through the two spools is shown in Figure 12.

Other special grinders are circular edge shapers and plane edge shapers for the shaping of circular and straight edges of block insulation.

Grinders may use grinding stones, grit paper, or grit glued to mandrel. Where grit is glued to mandrels, grit sizes 16 to 24 are recommended. For relatively fast moving mandrels, the finer grit size is recommended.

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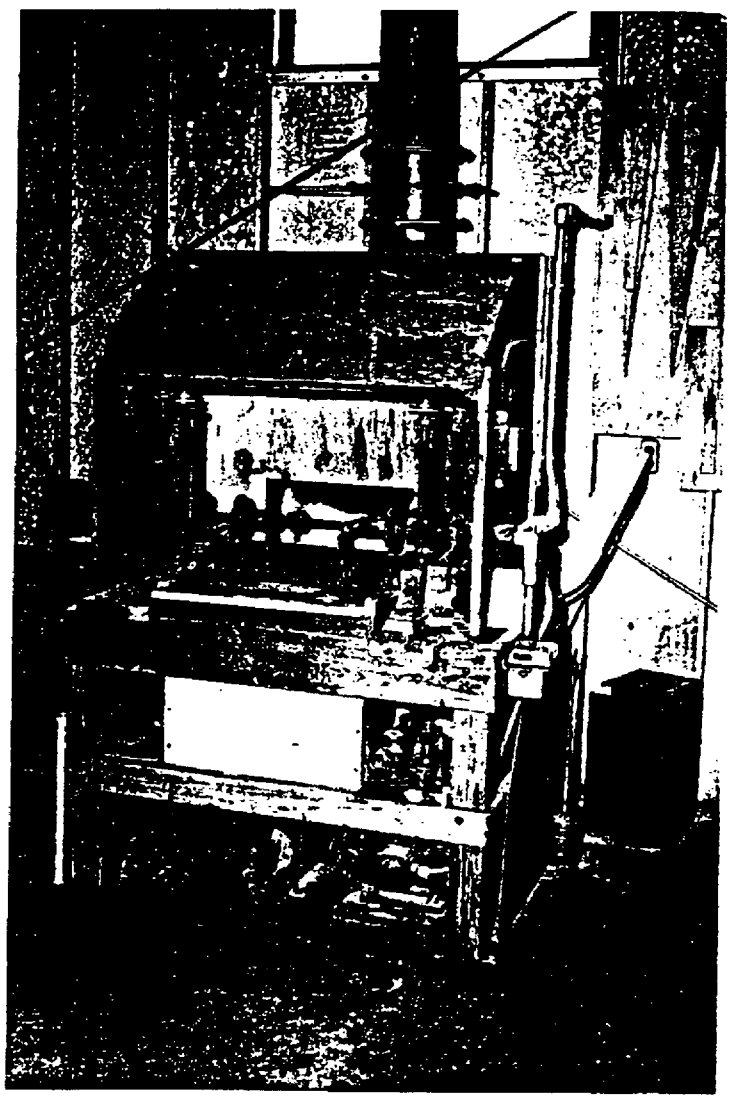


BAND SAW OPERATION

Figure X-8

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SHOP AND FIELD FABRICATION



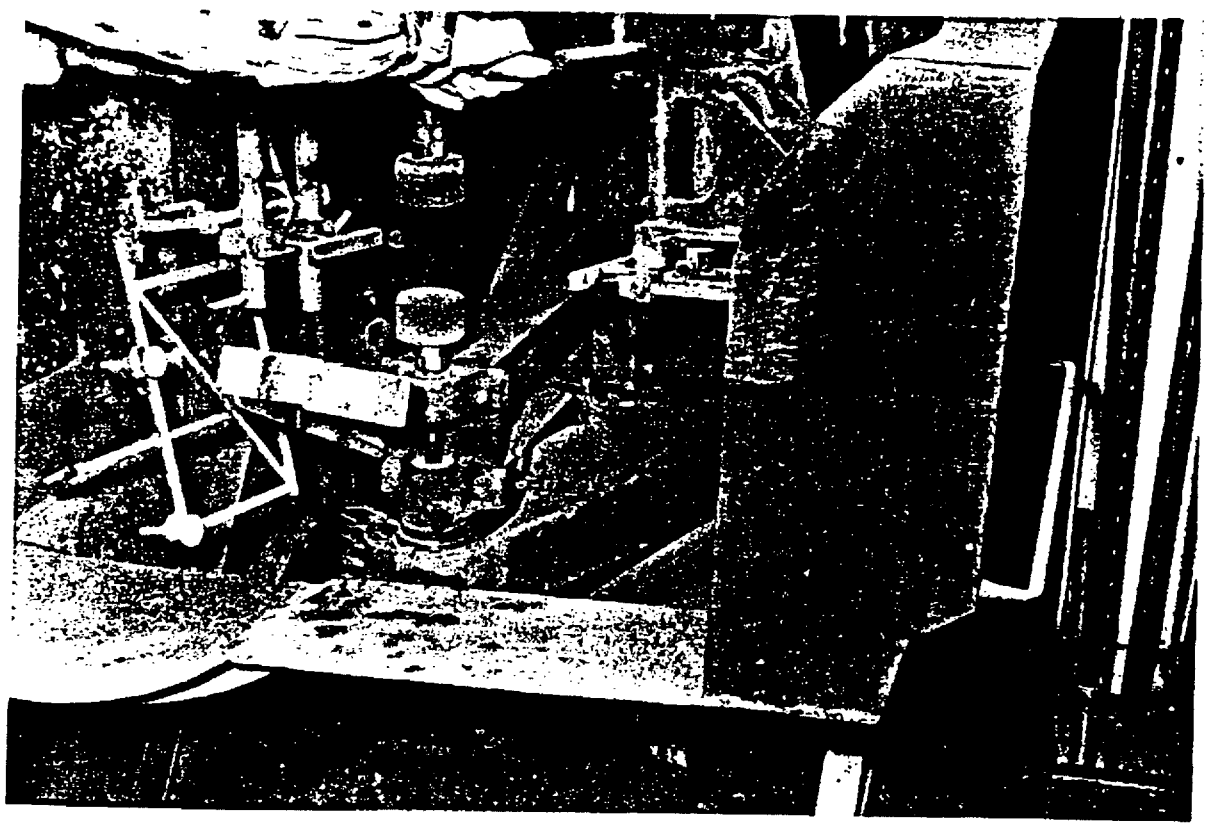
OUTSIDE GRINDER

Figure X-9

UCC 002805

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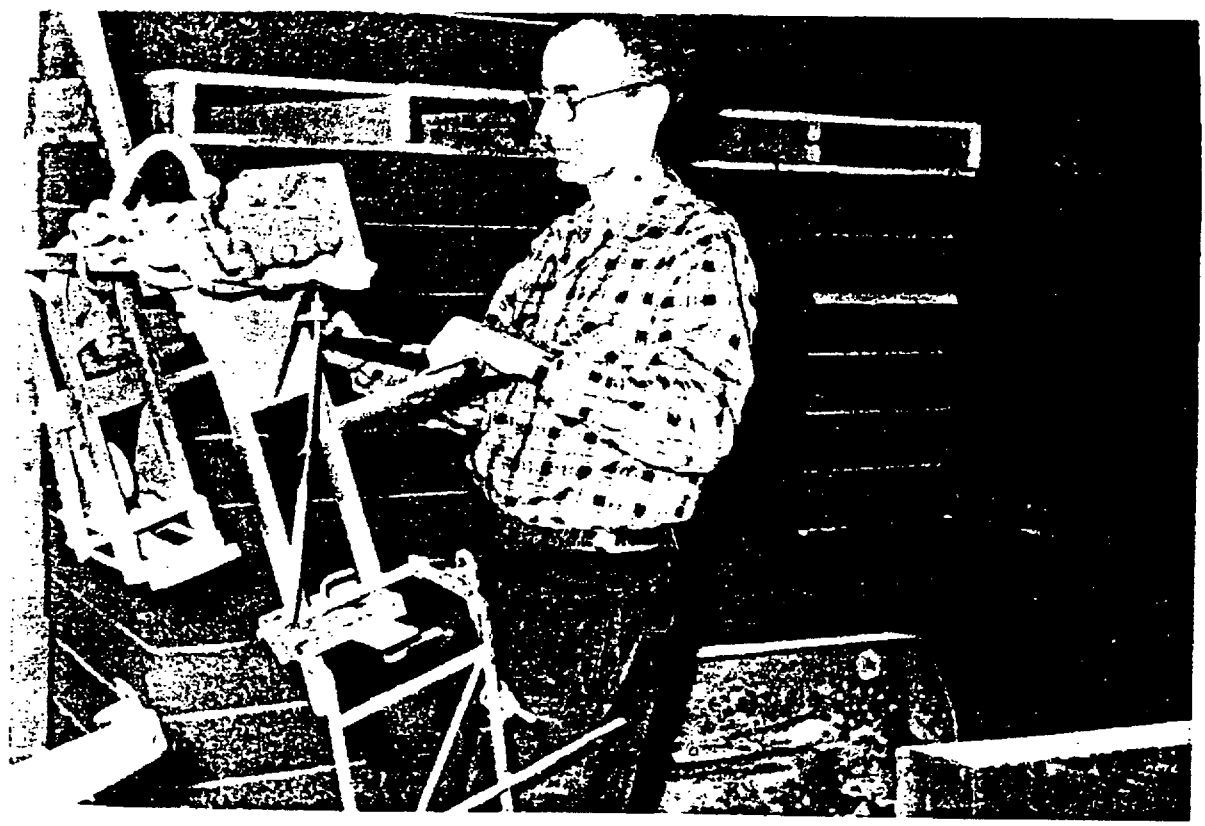


Grinding Spool

Figure X -10

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SHOP AND FIELD FABRICATION

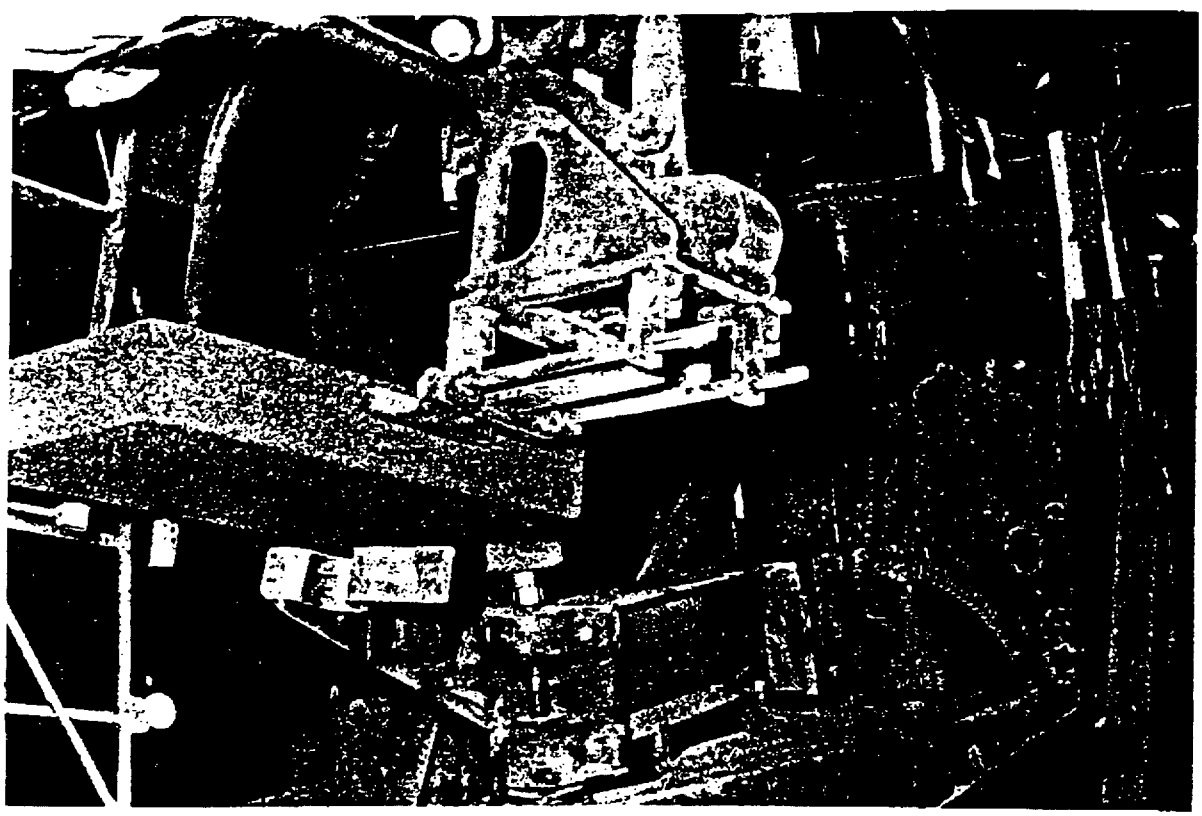


Insulation Holder

Figure X-11

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SHOP AND FIELD FABRICATION



Insulation To Be Formed By Grinding Spools

Figure X-12

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Asphalt Rollers

As rigid low temperature inorganic foams are cemented together with hot asphalt, a heated pot with rollers which extend into the liquid asphalt is a basic machine used in shop fabrication. Such a hot asphalt roller is shown in Figure X-13.

Assembly Tables

After pieces of insulation have been cut to form the parts of a fitting, these parts must be bonded together to complete the assembly. This operation requires assembly tables. Such assembly tables should be sufficient in size to permit efficient working by the craftsmen and be located for minimum handling of parts and finished item.

Dust Collection

Removal of dust around the saws is necessary for good fabrication and working conditions. The amount of air required to remove dust for each band saw is a minimum of 450 CFM, and for each inside or outside grinder a minimum of 1750 CFM, for asphalt pot hoods and block dust removal grills a minimum of 500 CFM.

Dust is collected in a dust collector of sufficient size and capacity for the individual shop.

Ventilation

Where fine air borne dust is a problem, it should be vented away from workers by a separate ventilation system. Collectors should be located so that dust is drawn away from the workmen. The airborne dust concentration where workmen are present must be within allowable limits for asbestos and other pneumoconiosis-producing dusts as established by governmental and professional agencies.

Should dust count exceed these limits, then the operator must wear approved respiratory equipment.

Shop Fabrication

One typical method of shop operation is to have the clerk and timekeeper prepare orders for the fittings and fill in the dimensions for the parts and pieces from the C-450 Fabrication Manual. These can then be used to draw stock, provide detailed information for the cutting and assembly operations. Typical of such shop orders with the detailed information is shown in Figure X-14, X-15, X-16, and X-17.

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SHOP AND FIELD FABRICATION

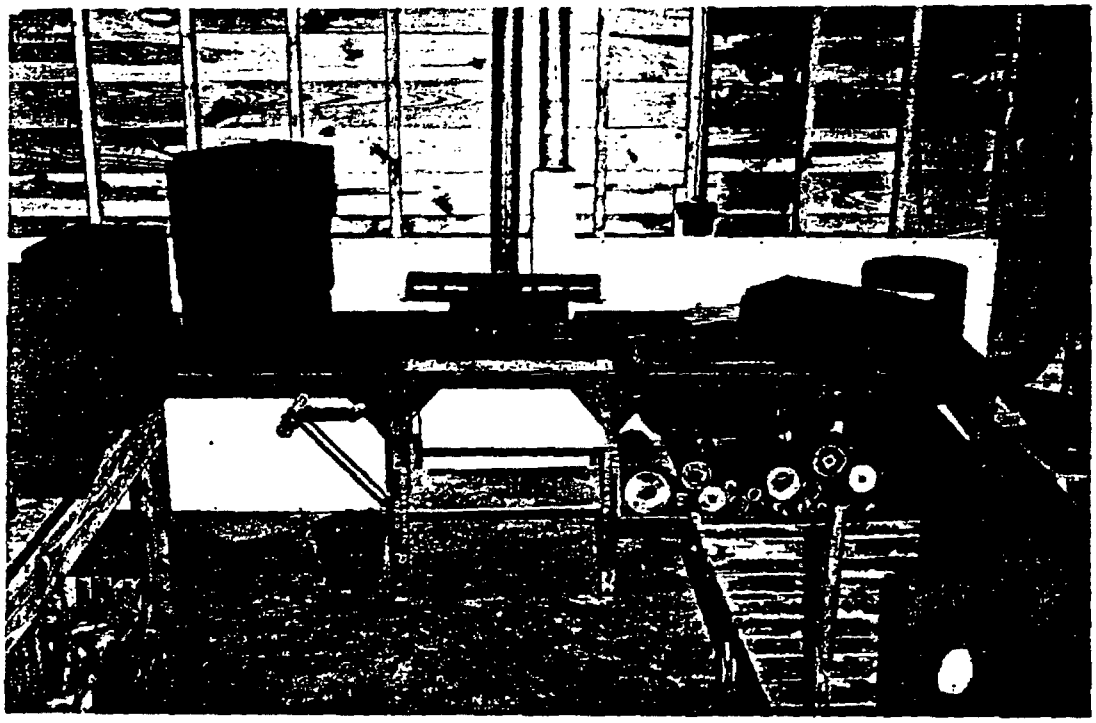
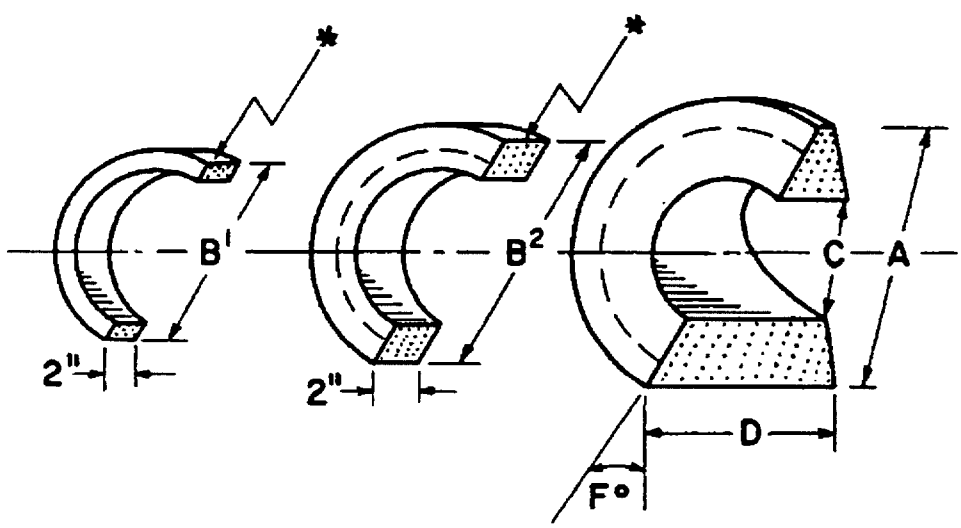


Figure X- 13

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SHOP AND FIELD FABRICATION

45° & 90° WELDED TUBE TURN SEGMENTS



A_____ B'_____ B²_____ C_____ D_____ E_____ F_____
O.D. D.C.D. D.O.D. I.D. SEG.LEN. NO.SEG. DEGREE

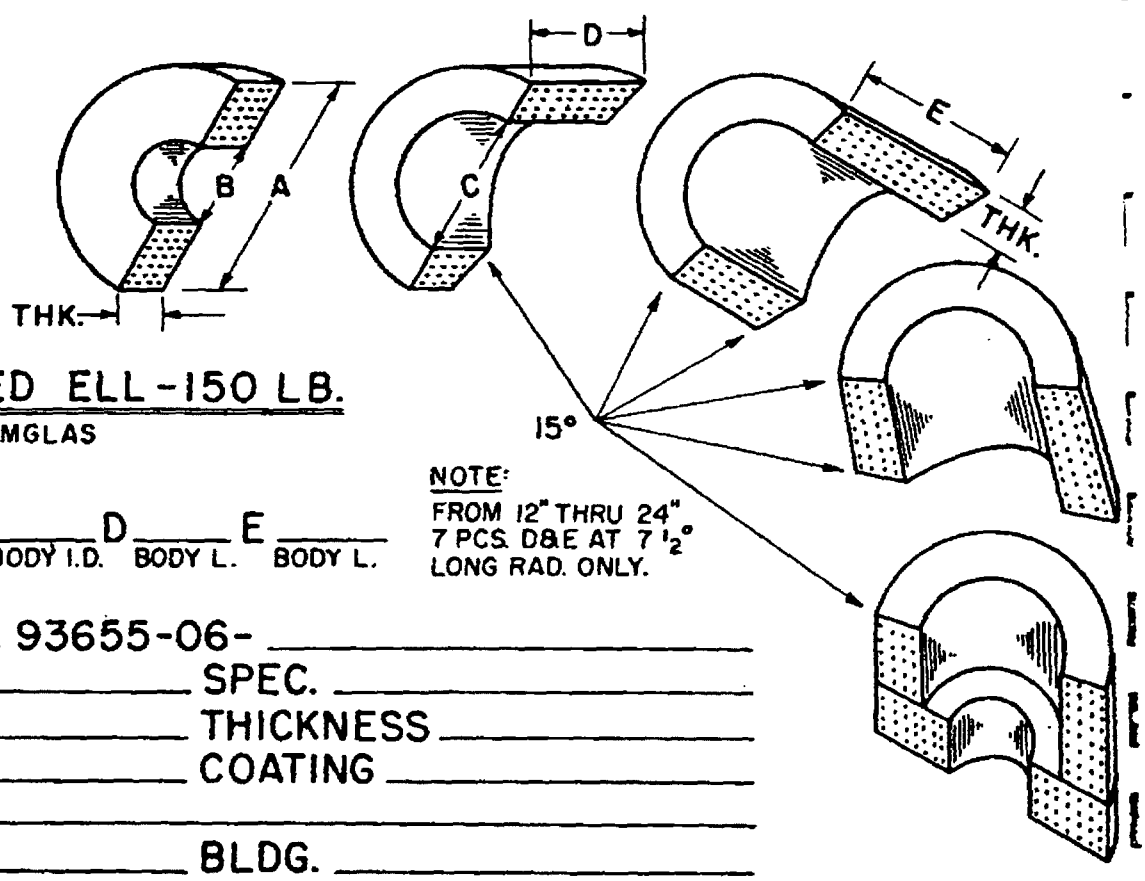
FAB. ORDER NO. 93655-06_____
SIZE_____ THICKNESS_____
MATERIAL_____ SPEC._____
NO. REQ'D._____
RADIUS_____
COATING_____
FOREMAN_____
BLDG._____
PLANT_____
REF. CHARGE_____

*WHEN NEEDED

Figure X-14

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SHOP AND FIELD FABRICATION



90° FLANGED ELL-150 LB.

FOAMGLAS

A ____ B ____ C ____ D ____ E ____
O.D. D.I.D BODY I.D. BODY L. BODY L.

NOTE:
FROM 12" THRU 24"
7 PCS. D&E AT 7 1/2°
LONG RAD. ONLY.

FAB. ORDER NO. 93655-06- _____
MATERIAL _____ SPEC. _____
SIZE _____ THICKNESS _____
RADIUS _____ COATING _____
NO. REQD. _____
FOREMAN _____ BLDG. _____
PLANT _____ REF. CHG. _____

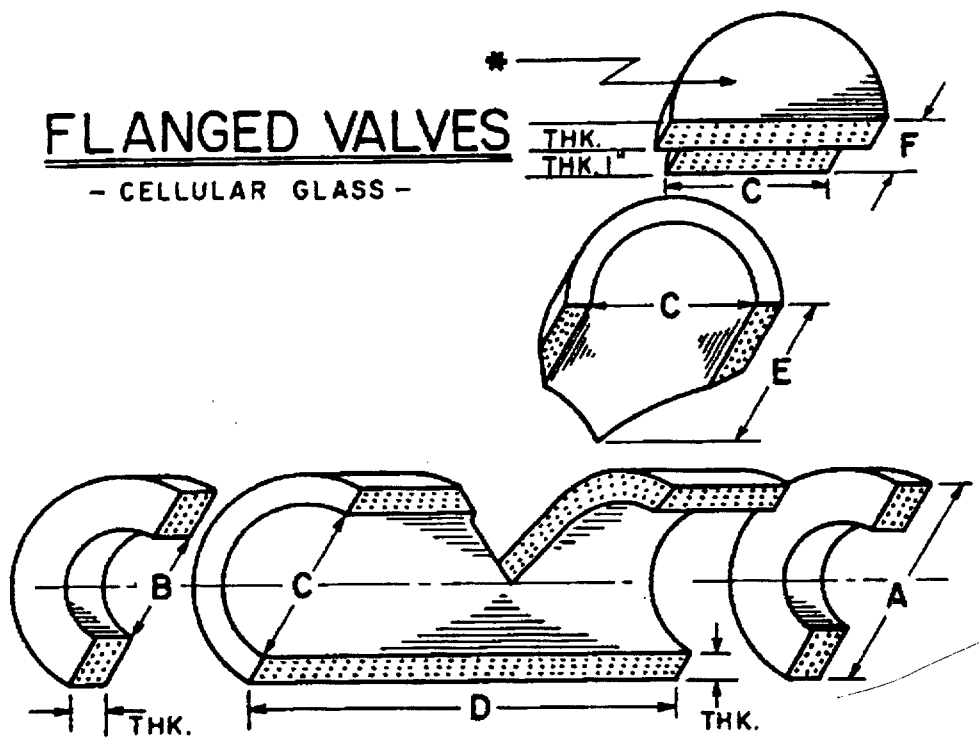
Figure X-15

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SHOP AND FIELD FABRICATION

FLANGED VALVES

– CELLULAR GLASS –



A____ B____ C____ D____ E____ F____

A: O.D | B: D.I.D. | C: BODY I.D. | D: BODY L. | E: BON. HT. | F: BON. D. THK.

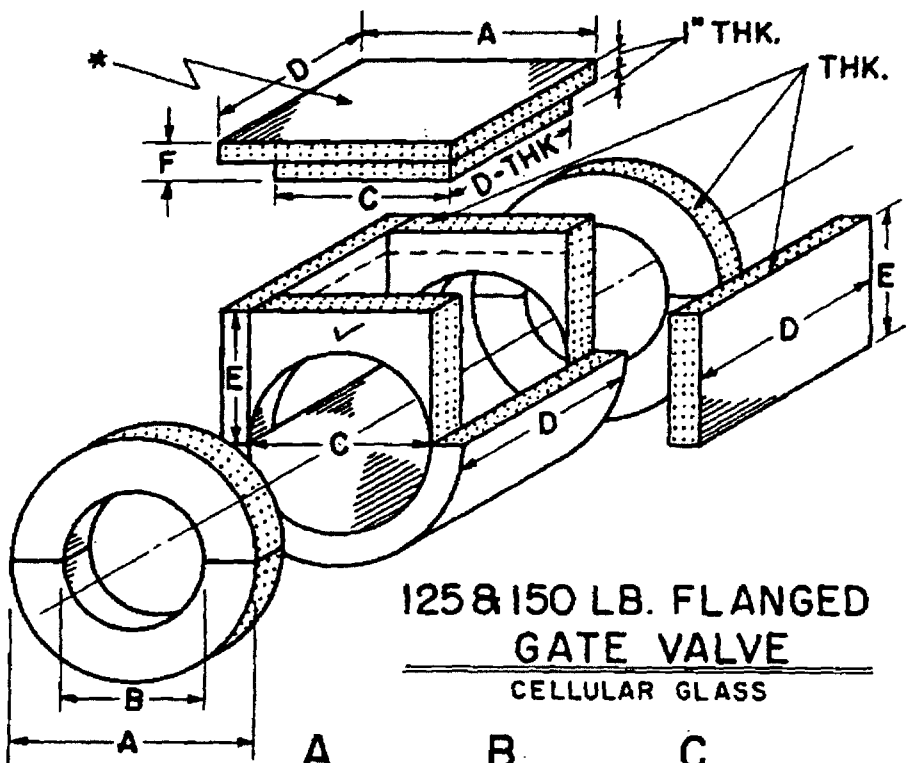
FAB. ORDER NO. 93655-06-_____
MATERIAL _____ SPEC. _____
SIZE _____ THICKNESS _____
PRESSURE _____ COATING _____
NO. REQ'D. _____ TYPE _____
FOREMAN _____
BLDG. _____
PLANT _____
REF. CHARGE _____

* DO NOT STICK

Figure X-16

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SHOP AND FIELD FABRICATION



125 & 150 LB. FLANGED GATE VALVE
CELLULAR GLASS

A_____ B_____ C_____
O.D. D. I. D. BODY I.D.

D_____ E_____ F_____
BODY L. BON. HT. BON. D THK.

1 PC. _____ X _____ X _____ THK.
1 PC. _____ X _____ X _____ THK.
2 PCS. _____ X _____ X _____ THK.
2 PCS. - _____ X _____ X _____ THK.
1 PC. P.C. - _____ I. D. _____ O. D. _____ LONG
4 PCS. DUTCH. - _____ I. D. _____ O. D. _____ LONG

FAB. ORDER NO. 93655-06- _____
MATERIAL _____ SPEC. _____
SIZE _____ THICKNESS _____
NO. REQ'D. _____ COATING _____
FOREMAN _____ BLDG. _____
PLANT _____ REF. CHG. _____
*DO NOT STICK

Figure X-17

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Shop Fabrication - Contd

Following the dimensions, pieces for fabrication are cut ready for assembly. Figure X-18 shows the pieces and assembly of a welded elbow cover. Figure X-19 shows the assembly and pieces of flange globe valve cover, and Figure X-20 shows the pieces and assembly of a flange gate valve cover. Figure X-21 shows the projected assembly of pieces to form the flanged gate valve cover.

The assembly of pieces into a complete cover requires that the pieces be bonded together. The cements used for the assembly are determined by the insulation and its service requirements. Each cement must be applied by the proper method. Some of the most commonly used cements and their method of application follow:

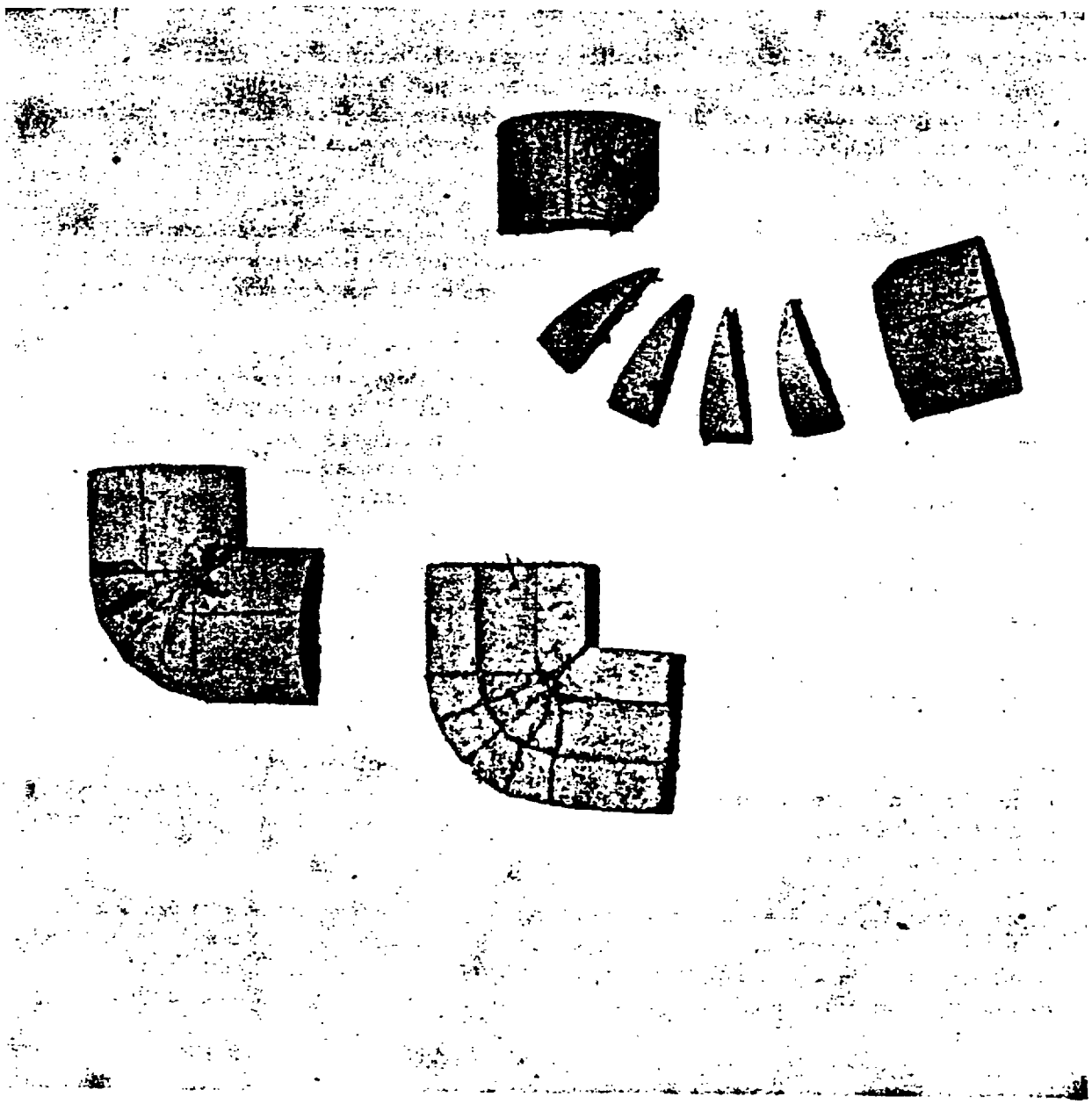
1. Hot Asphalt Cement is applied to insulation in hot liquid state. It is usually heated in a pot located near, or in the assembly work bench. The pot is equipped with rollers that pick up and deposit hot asphalt on the surfaces to be adhered, when these surfaces are passed over, and in contact with the rollers. Coated surfaces are pressed together while asphalt is in liquid state. The asphalt hardens to a bond when its temperature drops. The use of hot asphalt cement is restricted to foamed insulation which will not be attacked by the high temperature of the asphalt or by its chemical composition. Hot asphalt must not be used on piping or equipment that will operate at temperatures that will remelt the asphalt.

2. Catalyst Type - Vapor Resistant Cement is a two-part mixture, usually one part powder and the other part liquid. After the two parts are mixed together, the resultant mix will set up within a given time - called pot life. For this reason, only the amount of material that can be used within this pot life should be mixed. This catalyst-type cement is most frequently applied with a brush. It is used mostly with foamed insulation in service on surfaces which cycle from low temperatures to higher temperatures which are above the melting point of asphalt.

3. Keene's Cement is a water mix hydraulic-setting cement. The cement powder is mixed with water. Being hydraulic setting, the mixed cement must be used before it begins to harden. This cement is applied by brush or trowel. It is generally used to bond cellular glass together when this insulation is to be used in high-temperature service.

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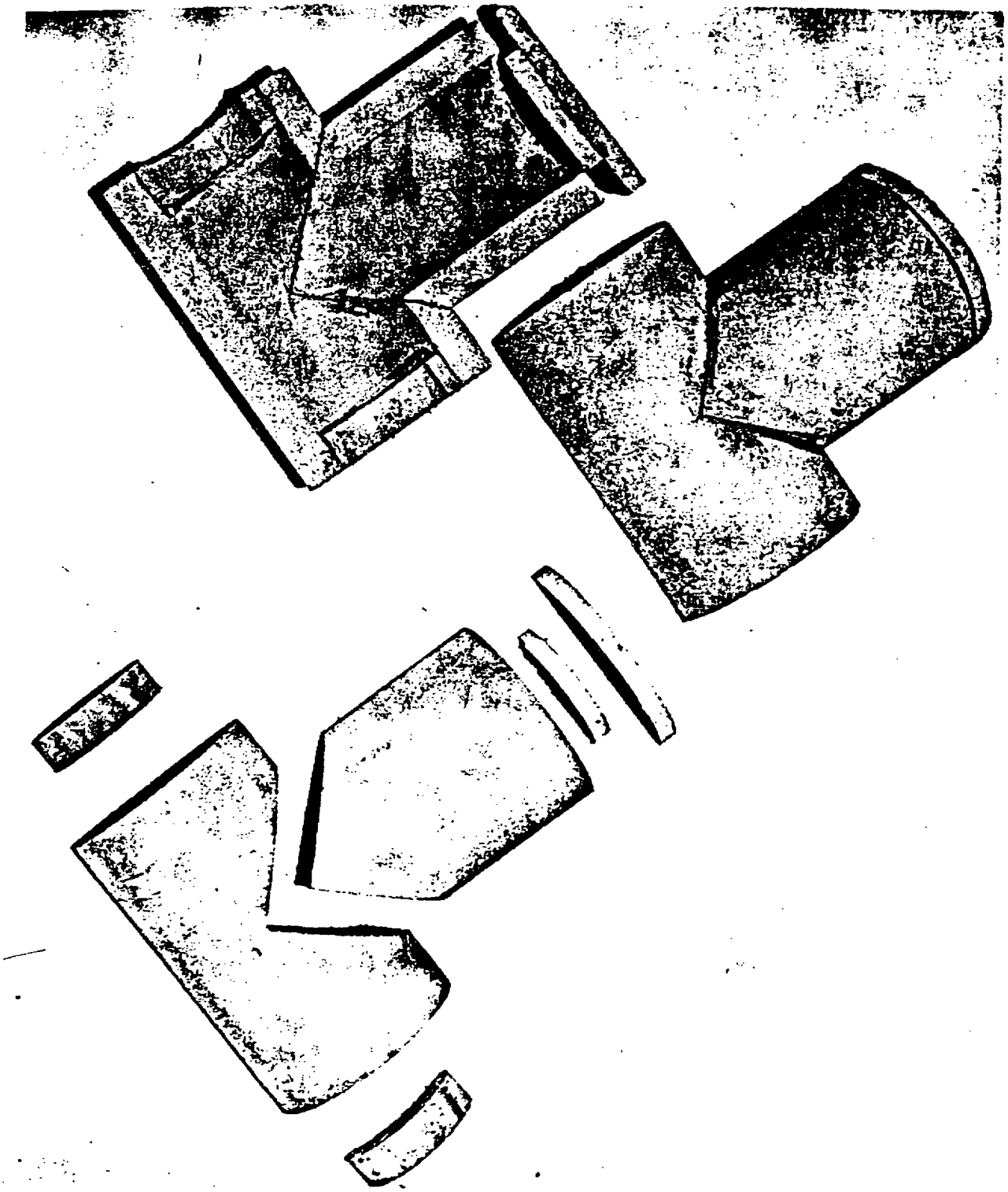


Welded Elbow Cover

Figure X-18

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SHOP AND FIELD FABRICATION



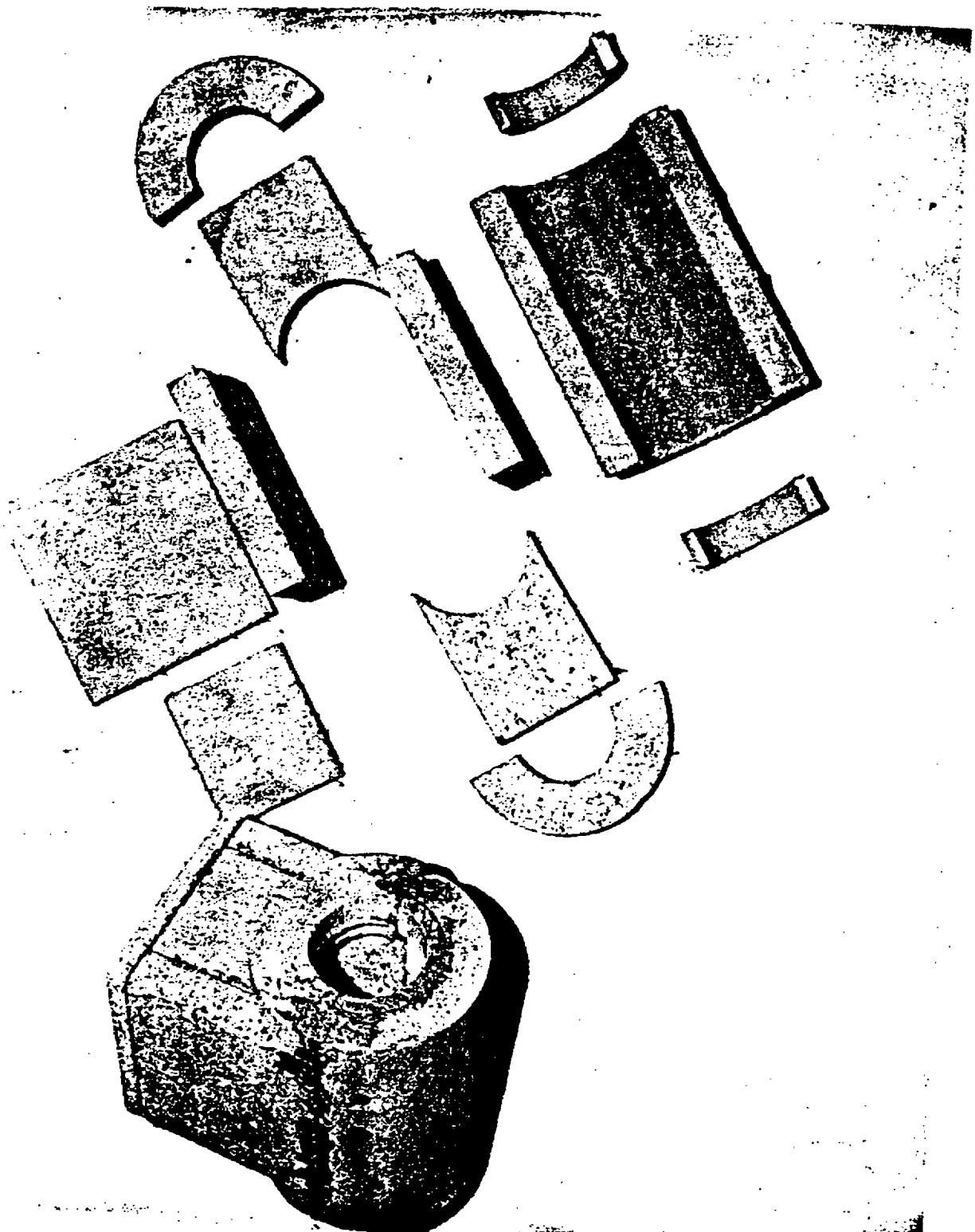
Flanged Globe Valve Cover

Figure X-19

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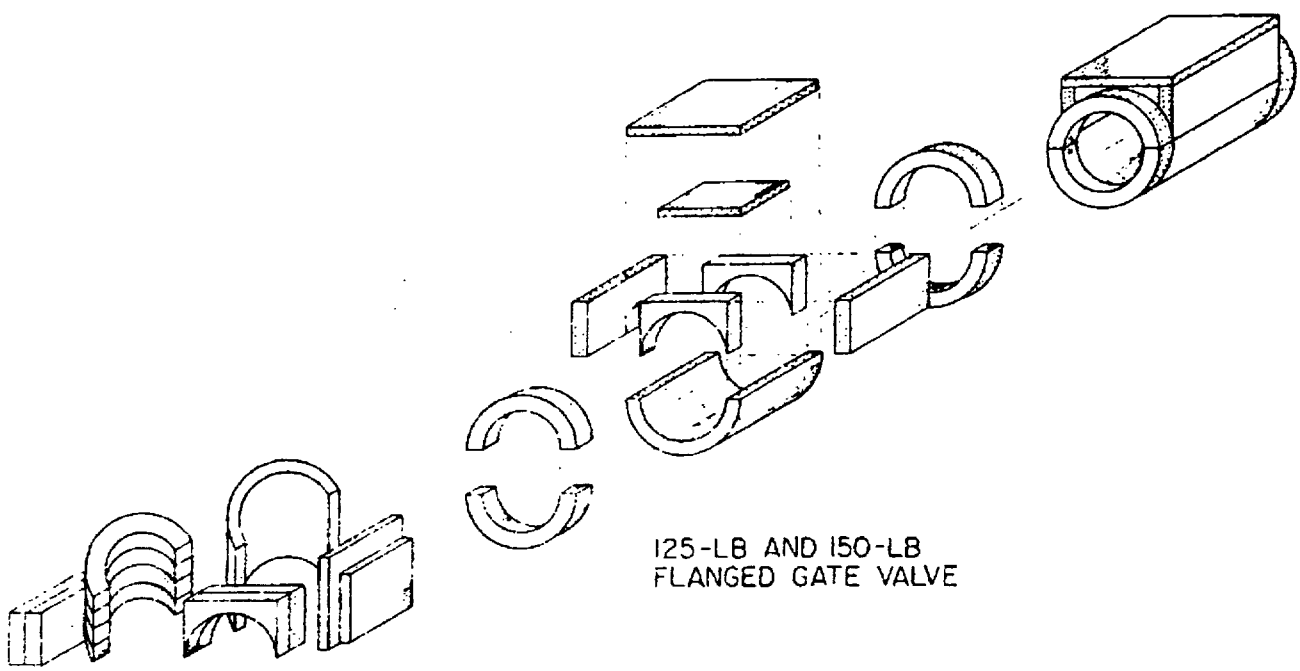
SHOP AND FIELD FABRICATION



Flanged Gate Valve Cover
Fiaure X-20

UCC 002818

SHOP AND FIELD FABRICATION



Projected assembly

Figure X-21

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Shop Fabrication - Contd

4. Insulation Adhesive Cements are premixed cements of fire clays, binders, and silicates. These cements depend upon dissipation of moisture for their setting. They have almost unlimited pot life and can be used as received from the manufacturer. They are best applied to insulation surfaces by trowel. They are generally used to bond high-temperature insulations such as calcium silicate, asbestos fibers, or similar absorbent insulations.

5. Insulation Adhesive Cements for Non-Absorbent Insulations are made of fire clays, binders, and special solvents. This type depends on slight dissipation of moisture, or solvents, for setting. It is best applied by trowel and is used to bond moisture-resistant, high-temperature insulation such as bonded expanded silica.

6. Resin Adhesive Cements are made of organic resins and solvents. They have almost unlimited pot life and can be used as received from the manufacturer. They can be applied by brush or trowel. They are used to bond glass fiber and foamed organic insulation. In most instances their upper temperature limit is approximately 350F.

Typical application of an insulation adhesive cement to bond the pieces of a Flanged Globe Valve together is shown in Figure X-22.

Field Installation of Prefabricated Fitting Covers

Preformed fitting covers provide an efficient means of field installation. In general the practice should be to install all welded and screwed fitting covers prior to the application and installation of straight pipe insulation. The reason is that it is easier to cut the straight pipe covering to dimensions where the pipe and fitting covers butt together.

With flanged fitting covers the opposite is true. The straight pipe covering is installed first, then the flanged fitting covers are installed. This is proper procedure because the flanged fitting covers are designed to fit over the adjacent pipe insulation. A picture of the manner in which a flanged globe valve cover fits over the valve and adjacent pipe insulation is shown in Figure X-23. The final securement of this valve cover in position is shown in Figure X-24.

Precision cut and assembled fitting covers are much more effective than the loosely fitted and cemented covers of the past. Prefabrication is one of the most important steps taken in the insulation industry to keep pace with industrial advancement of other industries.

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SHOP AND FIELD FABRICATION



Cementing Flanged Globe Valve Covers

Figure X-22

UCC 002821

SHOP AND FIELD FABRICATION



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SHOP AND FIELD FABRICATION



Flanged Globe Valve Cover
Secured In Position

Figure X-24

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Field Fabrication

A prefabrication shop may well be set up on the job site. Preforming fittings in a shop with power equipment is shop fabrication regardless of the location of the shop. Field fabrication, in our use of the terminology, is where the cutting and fitting is done with hand tools.

In some installations of small jobs or maintenance it is necessary to field hand cut fittings. Flange covers, tee covers and elbow covers can be field fabricated with relative accuracy. However, it is quite difficult to cut all the parts sufficiently accurate to make good fabricated globe and gate valve covers. Conversely, plug valve covers should always be made of pipe covering by hand method in the field.

When tee or flange covers are hand made in the field, the dimensions in C-450 should be followed. Welded elbow covers, hand made, in the field can be made more efficiently in the field when slightly different set of dimensions are used. The set of dimensions for such hand cut welded elbow covers are given in Figure X-25 and X-26.

Where cylindrical vessels are to be insulated with flat blocks, in mitered form, the outside maximum width of the mitered block should be in accordance with the following table:

Diameter of Vessel	Maximum Outside Width of Miter
14" to 24"	3"
25" to 30"	3-1/2"
31" to 36"	4"
37" to 42"	4-1/2"
43" to 48"	5"
49" to 54"	5-1/2"
55" and larger	6"

To determine the angle of cut for the mitered blocks:

1. Add twice the thickness of the block to be used to the diameter of the vessel. Multiply this outside diameter of the insulation by 3.1416 to find the outside circumference of the insulation.

2. Divide circumference of insulation by width of miter from table above to determine number of miters; if this number is not whole, increase to next largest number. Multiply by two.

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SHOP AND FIELD FABRICATION

DIMENSIONS FOR MITERED SEGMENTS FOR SHORT RADIUS ELLS

NOMINAL INSULATION THICKNESSES

Pipe Size	1"				1½"				2"				2½"			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
3"	3	3½	⅛	2.22	—	—	—	—	—	—	—	—	—	—	—	—
3½"	3	3⅜	⅛	2.00	—	—	—	—	—	—	—	—	—	—	—	—
4"	3	3⅜	¾	1.66	2	6½	⅛	1.66	—	—	—	—	—	—	—	—
4½"	4	3⅜	⅛	1.50	3	4⅜	¾	1.50	—	—	—	—	—	—	—	—
5"	4	3½	¼	1.33	4	3⅜	⅛	1.33	3	5½	¼	1.33	—	—	—	—
6"	6	2⅝	¼	1.11	6	2⅞	⅛	1.11	4	4½	⅛	1.11	3	6⅛	¾	1.11
7"	—	—	—	—	6	3¼	¼	1.00	6	3⅜	⅛	1.00	4	5⅝	⅛	1.00
8"	—	—	—	—	6	3⅝	⅛	.88	6	3⅞	¼	.88	6	3⅝	⅛	.88
9"	—	—	—	—	8	3½	½	.75	8	3½	⅜	.75	8	3¼	¾	.75
10"	—	—	—	—	8	3⅝	⅛	.66	8	3⅝	½	.66	8	3⅝	⅛	.66
11"	—	—	—	—	8	3⅞	⅛	.66	8	3⅞	⅛	.66	8	3⅝	½	.66
12"	—	—	—	—	8	3⅞	⅛	.58	8	4⅛	⅛	.58	8	4⅛	⅛	.58
14"	—	—	—	—	8	4⅞	1¾	.50	8	4⅝	1⅛	.50	8	4⅛	⅝	.50
16"	—	—	—	—	8	5	1¼	.41	8	5⅛	1⅜	.41	8	5⅜	1⅛	.41
18"	—	—	—	—	8	5⅝	1½	.33	8	5⅞	1⅜	.33	8	5⅜	1¼	.33
20"	—	—	—	—	8	6⅛	1⅜	.28	8	6¼	1⅜	.28	8	6⅜	1½	.28
22"	—	—	—	—	8	6⅜	1⅞	.28	8	6⅜	1¾	.28	8	7	1⅜	.28
24"	—	—	—	—	8	7⅜	2⅛	.25	8	7⅜	2	.25	8	7½	1⅜	.25

Pipe Size	3"				3½"				4"				4½"				5"			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
8"	3	6¾	½	.88	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9"	6	4⅝	¼	.75	6	4⅛	½	.75	—	—	—	—	—	—	—	—	—	—	—	—
10"	8	3⅞	½	.66	8	3⅜	⅜	.66	8	3⅞	⅛	.66	—	—	—	—	—	—	—	—
11"	8	3⅞	⅛	.66	8	4	⅜	.66	8	4⅛	⅛	.66	8	4⅜	⅛	.66	—	—	—	—
12"	8	4⅛	½	.58	8	4⅛	⅜	.58	8	4⅛	¼	.58	8	4⅜	¼	.58	8	4⅜	⅛	.58
14"	8	4⅜	⅛	.50	8	4⅜	⅛	.50	8	5⅛	¼	.50	8	5¾	¼	.50	—	—	—	—
16"	8	5¼	1	.41	8	5⅝	⅛	.41	—	—	—	—	—	—	—	—	—	—	—	—
18"	8	5⅞	1¼	.37																
20"	8	6½	1⅜	.29																
22"	8	7	1⅜	.29																
24"	8	7⅜	1⅜	.20																

A — Number of Miters

B — Greater Dimension of outside face of pipe insulation

C — Lesser or throat dimension on outside face of pipe insulation

D — Number of short radius ells available from a linear foot of pipe insulation, based on alternating the cuts and allowing for saw kerf and waste

Dimensions are to nearest 1/32"

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Figure X-25

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SHOP AND FIELD FABRICATION

DIMENSIONS FOR MITERED SEGMENTS FOR LONG RADIUS ELLS

NOMINAL INSULATION THICKNESSES

Pipe Size	1"				1½"				2"				2½"				3"			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
[illegible]	4	2	3/8	2.33	4	2 1/2	3/32	2.33	—	—	—	—	—	—	—	—	—	—	—	—
2 1/2"	4	2 11/32	11/32	2.00	4	2 9/32	5/32	2.00	—	—	—	—	—	—	—	—	—	—	—	—
[illegible]	4	2 13/16	5/32	1.66	4	3	1/32	1.66	3	4 3/16	1/32	1.66	3	4 15/32	1/32	1.66	—	—	—	—
4½"	4	3 5/32	3/16	1.41	4	3 15/32	5/64	1.41	4	3 27/32	3/64	1.41	4	3 25/32	1/64	1.41	—	—	—	—
4"	6	2 3/4	11/64	1.20	6	2 11/32	3/64	1.20	6	2 11/16	3/64	1.20	6	2 9/16	3/64	1.20	4	4 1/16	1/16	1.20
3½"	6	2 3/4	5/32	1.03	6	2 7/8	5/64	1.03	6	3	1/32	1.03	6	3 1/8	1/16	1.03	6	3 1/4	1/16	1.03
5"	6	2 15/16	3/32	.93	6	3 1/4	7/64	.93	6	3 1/16	1/64	.93	6	3 1/32	1/64	.93	6	3 15/32	3/64	.93
6"	6	3 1/2	1 1/4	.75	6	3 5/8	1 1/8	.75	6	3 3/8	1	.75	6	3 3/8	7/8	.75	6	4	3/8	.75
7"	—	—	—	—	6	4 1/8	1 1/16	.66	6	4 1/4	1 1/32	.66	6	4 1/8	1 1/32	.66	6	4 1/2	7/16	.66
8"	—	—	—	—	8	3 1/2	1 1/32	.58	8	3 15/32	1 1/16	.58	8	3 29/32	1	.58	8	3 7/8	5/16	.58
9"	—	—	—	—	8	3 7/8	1 1/32	.53	8	4	1 1/32	.53	8	4 1/16	1 1/32	.53	8	4 1/16	1 1/32	.53
10"	—	—	—	—	8	4 5/32	1/4	.50	8	4 1/32	1 1/32	.50	8	4 1/32	1 3/16	.50	8	4 1/32	1 1/32	.50
11"	—	—	—	—	8	4 11/16	1 3/16	.43	8	4 5/32	1 1/32	.43	8	4 1/8	1 1/32	.43	8	5	1 1/32	.43
12"	—	—	—	—	8	5 1/16	1 1/32	.41	8	5 1/32	1 1/16	.41	8	5 1/32	1 1/16	.41	8	5 1/16	1 1/32	.41
14"	—	—	—	—	8	5 3/4	2 1/16	.33	8	5 7/8	2 1/32	.33	8	5 31/32	2 1/16	.33	8	6 1/16	2 1/32	.33
16"	—	—	—	—	8	6 15/32	2 1/32	.29	8	6 15/32	2 1/16	.29	8	6 3/4	2 1/16	.29	8	6 7/8	2 1/16	.29
18"	—	—	—	—	8	7 15/32	3/32	.25	8	7 1/16	3 1/16	.25	8	7 1/2	3 1/16	.25	8	7 7/8	3	.25
20"	—	—	—	—	8	8 1/8	3 1/16	.20	8	8 1/4	3 1/32	.20	8	8 3/16	3 1/32	.20	8	8 3/16	3 1/16	.20
22"	—	—	—	—	8	8 7/8	4	.20	8	9	4	.20	8	9 1/16	3 7/16	.20	8	9 1/16	3 1/16	.20
24"	—	—	—	—	10	7 1/16	3 1/32	.166	10	7 1/16	3 1/32	.166	10	7 1/16	3 1/16	.166	10	8	3 1/16	.166

Pipe Size	3½"				4"				4½"				5"			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
2"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2½"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3½"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4½"	6	3 1/16	3/32	1.03	—	—	—	—	—	—	—	—	—	—	—	—
5"	6	3 1/16	1/16	.93	4	5 1/16	3/32	.93	—	—	—	—	—	—	—	—
6"	6	4 1/16	3/32	.75	4	6 1/16	1/16	.75	4	6 1/4	1/32	.75	4	6 3/32	1/32	.75
7"	6	4 11/16	1/16	.66	6	4 5/32	1/16	.66	6	4 1/16	1/32	.66	6	5 1/16	1/32	.66
8"	8	3 29/32	1/16	.58	8	4	5/64	.58	8	4 1/32	1/32	.58	8	4 1/4	1/32	.58
9"	8	4 1/32	1	.53	8	4 13/32	5/64	.53	8	4 1/16	1/16	.53	8	4 7/32	1/32	.53
10"	8	4 1/16	1 1/16	.50	8	4 7/32	1 1/32	.50	8	4 7/32	1	.50	8	4 7/32	1/32	.50
11"	8	5 1/16	1 1/16	.43	8	5 1/16	1 1/32	.43	8	5 5/32	1 1/16	.43	8	5 1/16	1 1/32	.43
12"	8	5 13/32	1 1/16	.41	8	5 1/16	1 1/32	.41	8	5 1/16	1 1/16	.41	8	5 1/16	1 1/32	.41
14"	8	6 1/32	2 1/16	.33	8	6 1/16	1 1/32	.33	8	6 1/16	1 5/32	.33	—	—	—	—
16"	8	6 11/16	2 1/16	.29	—	—	—	—	—	—	—	—	—	—	—	—
18"	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

A = Number of Miters

B = Greater Dimension on outside face of pipe insulation

C = Lesser or throat dimension on outside face of pipe insulation

D = Number of long radius ells available from a linear foot of pipe insulation based on alternating the cuts and allowing for saw kerf and waste.

Dimensions are to nearest 1/32"

Dimensions based on formula—Chord length = $2r \sin \frac{A°}{2}$

Where r = radius to outside of insulation (where segments are circular graphically) A° = 90° Divided by number of segments used.

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Figure X-26

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SHOP AND FIELD FABRICATION

SHOP AND SHOP PRACTICES - Contd

Field Fabrication - Contd

3. Divide 360 degrees by above result, which will give angle of cut for miter.

Example:

a 48" diameter vessel is to be insulated with 2" thick flat blocks cut into lags or mitered form. Outside diameter of insulation = 48" + 2" + 2" = 52". Circumference of outside of insulation = 52" x 3.1416 = 163.36".

From the above table the outside maximum width of miter for a 48" diameter vessel is 5".

$$\frac{163.36"}{5} = 32.67 \text{ pieces}$$

Increase to 33 pieces.

Outside width of miter =

$$\frac{163.36"}{33} = 4.95" = \text{approximately } 4\frac{61"}{64}$$

Angle of cut on each side of miter =

$$\frac{360}{2 \times 33 \text{ pcs}} = \frac{360}{66} = 5.45$$

NOTE: Sectional pipe insulation, where available, may be used more economically for 18" and smaller diameter vessels. Curved equipment blocks are available to insure snug fit for equipment up to 54" in diameter.

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INSULATION SUPPORTS AND SECUREMENTS

Insulation supports are the appendages, or objects which carry the weight of the insulation. Frequently supports are attached to vessel walls; thus, the insulation support acts to transmit the weight of the insulation to those walls. In other instances, such as horizontal pipe, the pipe itself is the insulation support.

Insulation securements are accessories which attach insulation in position. Insulation securements are such items as wire and strapping.

SUPPORTS

Insulation supports are designed to fulfill the requirements of the weight of the insulation, strength of the insulation, operating temperatures, and configuration of the vessel or equipment.

The insulation supports for the insulation installed on the cylindrical section of a vertical vessel is shown in Engineering Standard EQ-64 and horizontal vessels in EQ-65. These particular supports are welded to the vessel by the vendor and is a preferred method of attachment. In cases of vessels which are converted from one service to another, or which may have been purchased without supports, the supports may be bolted on as shown in EQ-68 and EQ-69. In both cases, the area of the support on which the insulation rests is such that all the weight of the insulation above will not exceed the compressive strength of the insulation. This is illustrated in Figure XI-1.

In both cases the lowest support ring and uppermost support ring are slotted so that bands can be inserted through the slots for fastening the head insulation in position. The weight of the bottom head insulation is supported by the bottom support ring.

Where it is necessary to insulate the heads of vessels with a skirt, proper support rings are shown in EQ-64 and EQ-70. EQ-64 supplies the information to obtain welded-on supports, whereas EQ-70 provides the means of installing a ring in the field. Wherever possible, method presented in EQ-64 is preferred to the method given in EQ-70.

The support shown in EQ-68 is an arrangement whereby the cylindrical insulation on a large diameter vessel is broken up into sections with each section being separately secured by bands fastened to vertical angles. This eliminates the difficulty of trying to space, install, and pull up bands all the way around a large vessel.

On very large bottom heads the weight of the insulation makes it impractical to attempt to hold up the insulation by straps fastened to the supports around the cylinder. In addition, even if it were practical, the expansion of a large vessel would exert such stresses on the strap that either

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WELDED-ON INSULATION SUPPORTS FOR VERTICAL VESSELS, INCLUDING TANKS, OVER 3-FT O.D.

(Designed for use with preformed shapes, panel, and block form insulation)

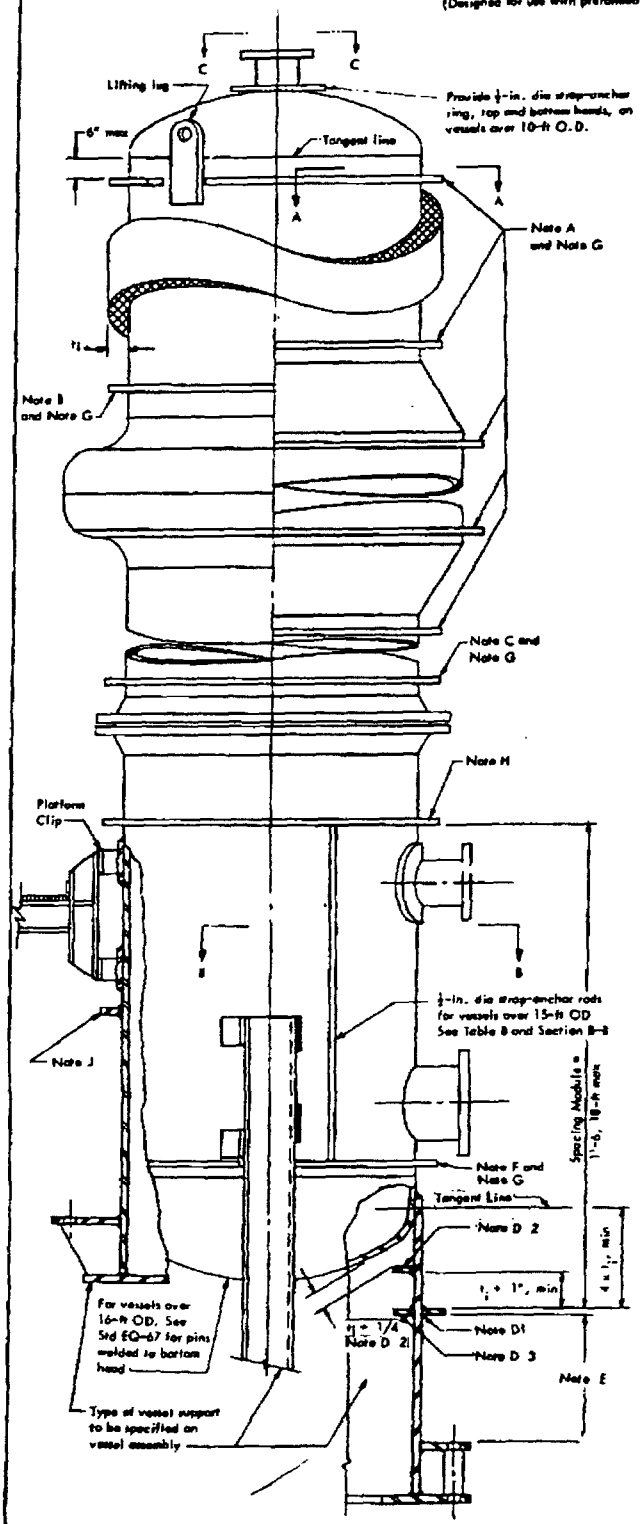


TABLE A

Insulation Thickness, t_1 (in.)	Bar Size		Weld Size, t_w (in. x 45°)
	Thickness, t_r (in.)	Width, w_r (in.)	
$1 < t_1 \leq 1\text{-}1/2$	3/16	1	3/16
$1\text{-}1/2 < t_1 \leq 3\text{-}1/2$	3/16	1-1/2	3/16
$3\text{-}1/2 < t_1 \leq 9$	1/4	3	1/4

GENERAL NOTES

All support rings shall be slotted except where noted otherwise. Provide insulation support rings at maximum spacing of 18-ft. Shorter spaces shall be a multiple of 1-ft 6-in. Select support ring size from Table A.

Material for supports shall be as noted on vessel assembly drawing or in the vessel specifications. Welding procedure for attaching supports to a new vessel shall be equal to that for the pressure-containing enclosure. Attachment of supports to an existing (used) ASME Code Vessel shall be in conformance with the applicable Code requirements including postweld heat treatment when required. Stiffening rings should be spaced as insulating support ring modules, if practicable, and may be used in lieu of standard insulating support rings on vessels subject to external pressure. Do not use stiffening rings.

SPECIFIC NOTES

A. Provide insulation support rings at the top and bottom of each shell transition section. For dished top heads, provide ring on the straight flange of the head or on the shell adjacent to the head.

B. Provide support ring above shell expansion joint.

C. Provide an insulation support ring above each flanged shell joint. Clearance between the top (back) of the flange and the top of the ring shall be sufficient to provide access for tightening flange bolts but not less than 9-inches.

D. Provide the following insulation support rings on vessel skirts:

1. One ring on the outside of the skirt at $4 \times t_1$ inches minimum, below the head tangent line.
2. One ⅜-in. x 1-in. slotted ring inside skirt. Locate this ring to provide t_1 + ½-in. clearance between the bottom head and the inner edge of the ring. Weld on low side only.
3. On vessels designed for service below 0° C (32° F), provide a second (lower) ring inside the skirt opposite the ring of D.1. above. The lower inside ring shall be of the same thickness and width as the outside (opposite) ring. Slots are not required in the inside, lower ring.

E. Welded-on insulation support ring on the outside of skirt with double-ring type base for use with prestressed anchor bolts must be spaced at least 3-ft 2-in. above the top base ring. Install bolted-on insulation support ring per Std EQ-68 where this clearance cannot be obtained.

F. For leg or lug-supported vessels with dished bottom heads, provide an insulation support ring on the straight flange of the bottom head or on the shell adjacent to the bottom head.

G. Locate rings and rods to provide minimum clearance of 1-inch between the ring or rod attachment weld and the vessel circumferential or longitudinal seam edges. Ring or rod attachment welds shall not cross seams in the vessel.

H. Locate rings and rods to clear shell connections, reinforcement pads, lifting lugs, etc., where possible. Ring locations above nozzles are preferred to those below nozzles.

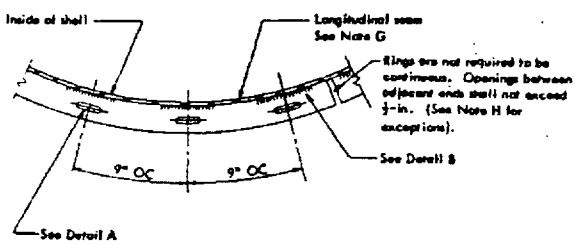
Where impossible to avoid interference between shell openings or attachments and rings, an opening of minimum practicable length shall be left in the ring. Provide 1-inch, minimum, clearance between ring or rod attachment welds and attachment weld of the interfering item.

J. Provide support ring below Platform Clip Attachment. Locate at nearest multiple of 9-inches above next lower ring.

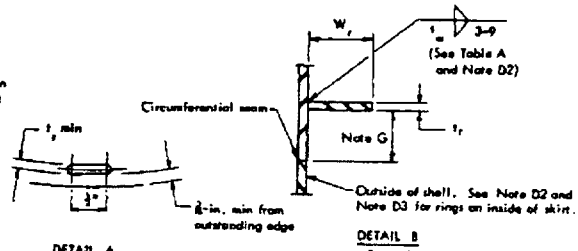
(SEE OVER FOR TYPICAL DETAILS)

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WELDED-ON INSULATION SUPPORTS FOR VERTICAL VESSELS, INCLUDING TANKS, OVER 3-FT O.D.



SECTION A-A
Typical

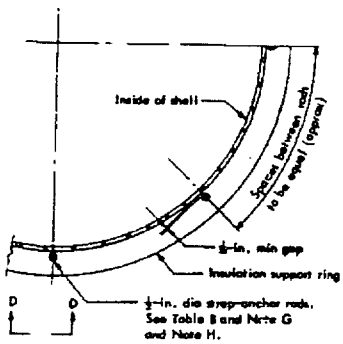


DETAIL A
Typical

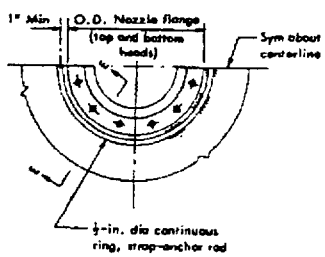
DETAIL B
Typical

TABLE B

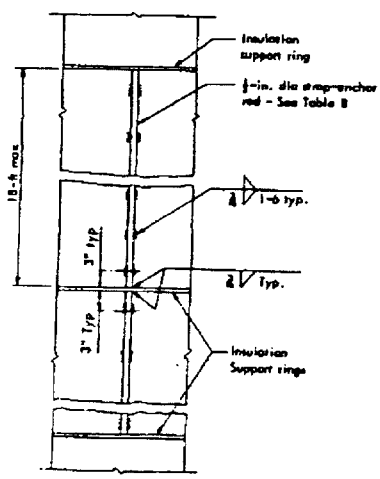
O.D. of Vessel	No. of Strap-Anchor Rods Required
15'-0 to 27'-0	4
27'-1 to 36'-0	8
36'-1 to 50'-0	16
Over 50'-0	One rod for each 9-ft of circumference or fraction thereof



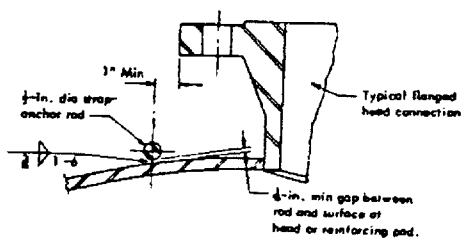
SECTION B-B
Typical



VIEW C-C
Typical



ELEVATION D-D
Typical



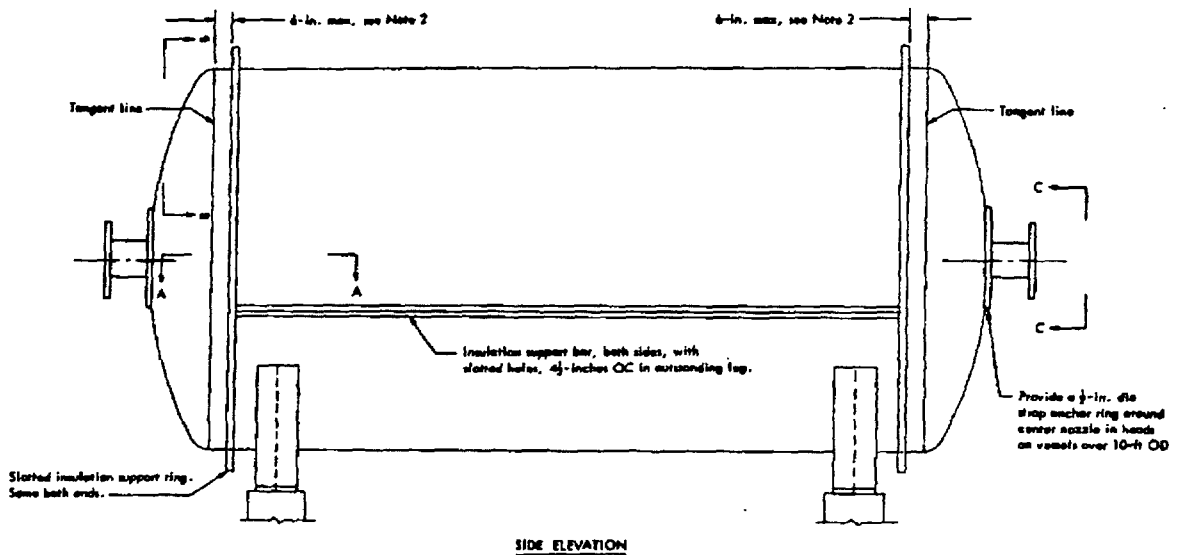
SECTION E-E
Typical

UCC 002830

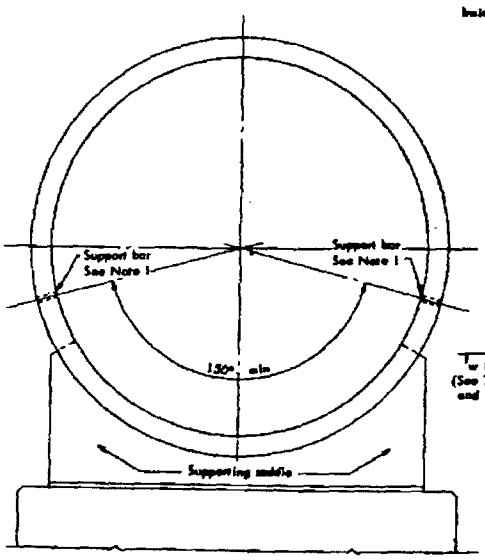
Union Carbide trial exhibit UC-2312: Union Carbide Chemicals and Plastics, Insulation Applicator Training Manua…
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ACL Doc 17302 · Page 232 of 495
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WELDED-ON INSULATION SUPPORTS FOR HORIZONTAL VESSELS OVER 3-FT O.D.

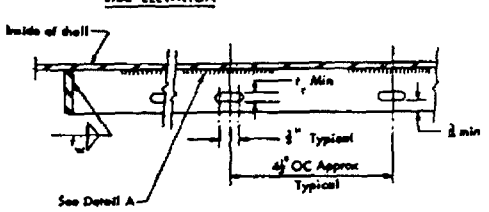
(Designed for use with preformed shapes, panel, and block form insulation)



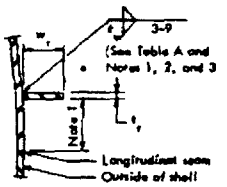
SIDE ELEVATION



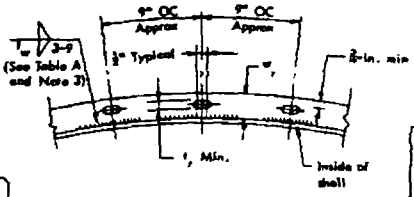
END ELEVATION



SECTION A-A
Typical



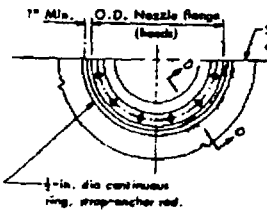
DETAIL A
Typical



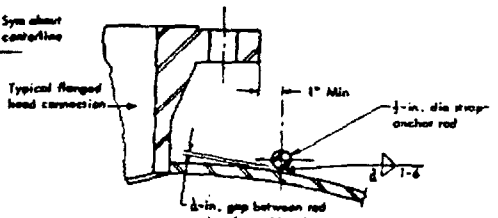
SECTION B-B
Typical

TABLE A

Insulation Thickness, t_i (in.)	Bar Size		
	Thickness, t_r (in.)	Width, W_r (in.)	Weld Size, t_w (in. x 45°)
$1 < t_i \leq 1\frac{1}{2}$	$\frac{3}{8}$	1	$\frac{3}{8}$
$1\frac{1}{2} < t_i \leq 3\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{3}{8}$
$3\frac{1}{2} < t_i \leq 9$	$\frac{1}{2}$	3	$\frac{1}{2}$



VIEW C-C
Typical



SECTION D-D
Typical

GENERAL NOTES

Material for support rings and bars shall be as specified in the Vessel Specifications. Select ring (bar) size from Table A.

Welding procedure for attaching supports to a new vessel shall be equal to that for the pressure-containing enclosure. Attachment of supports to an existing (used) ASME Code vessel shall be in conformance with the applicable Code requirements including postweld heat treatment when required.

DETAIL NOTES

1. Locate horizontal support bars to provide minimum clearance of 1-inch between the bar attachment weld and the vessel longitudinal seam edges.
2. Locate rings and bars to clear shell connections and reinforcement pads. Provide minimum clearance of 1-inch between ring or bar attachment welds and attachment weld of any adjacent item.
3. Support attachment welds shall not cross longitudinal or circumferential welds in the vessel.

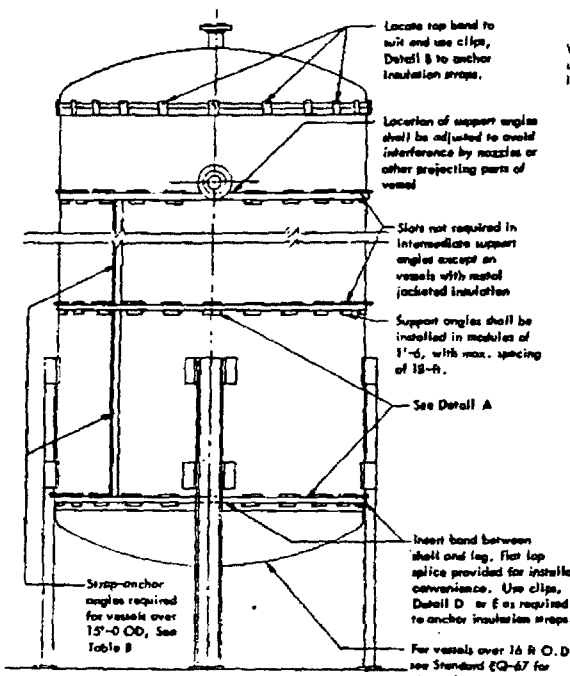
ENGINEERING STANDARD EQ-65

UCC 002831

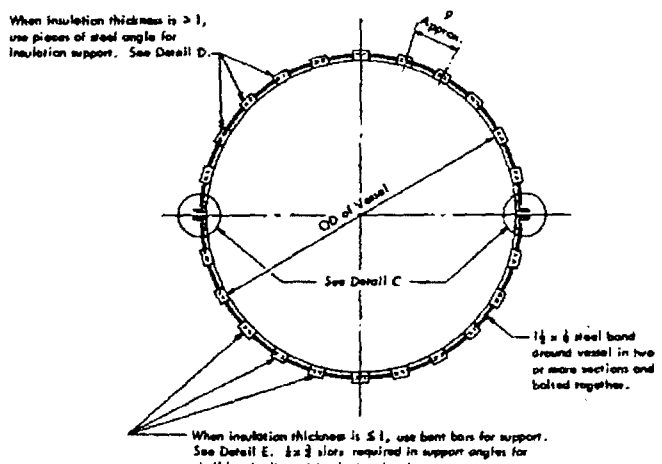
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BOLTED-ON[1] INSULATION SUPPORTS FOR VERTICAL VESSELS OVER 3-FT O.D.

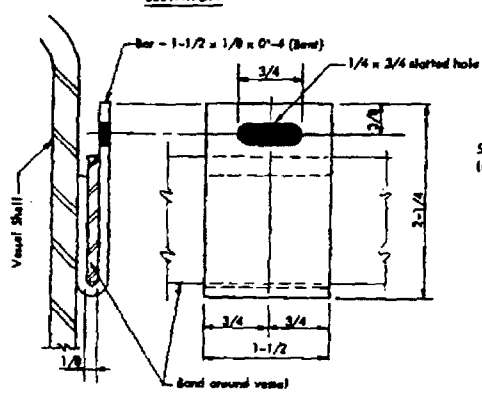
(Designed for use with preformed shapes, panel, and block form insulation)



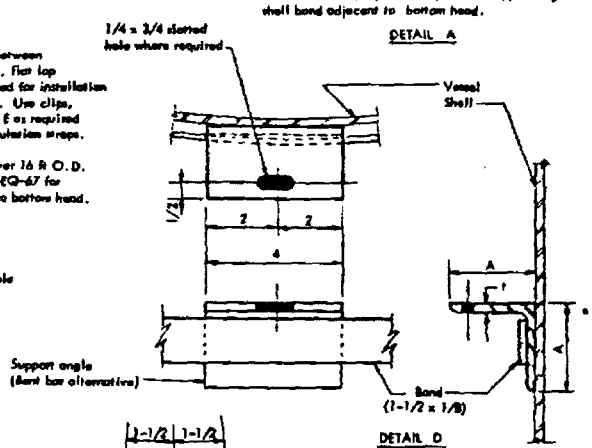
ELEVATION



DETAIL A

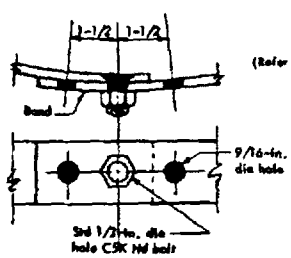


DETAIL B



DETAIL D

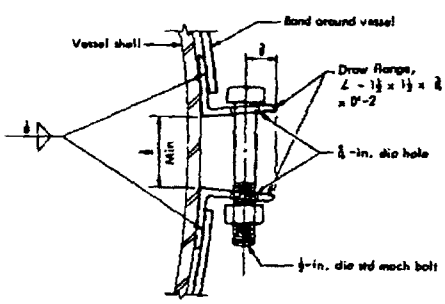
(Refer to Table A for dim A and t)



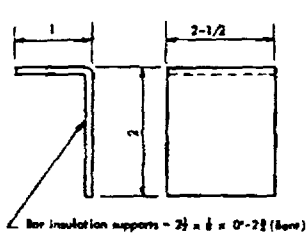
BAND SPLICE

TABLE A

Insulation Thickness, t_1 (in.)	Angle Thickness, t (in.)	Angle Leg A (in.)
$1 < t_1 \leq 3\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$
$3\frac{1}{2} < t_1 \leq 9$	$\frac{1}{2}$	3



DETAIL C



DETAIL E

[1] Bolted-on insulation supports are to be used only for FIELD INSTALLATIONS on vessels on which welding is either not permissible without postweld heat treatment or because of area conditions, or when welded-on insulation supports are not otherwise practicable.

NOTE:

Bolts shall be ½-in. dia standard machine bolts with square heads and hex nuts, unless otherwise indicated.

All steel parts shall be coated, or otherwise protected the same as the vessel to which they are attached, prior to the attachment.

Use stainless steel bands and aluminum clips on aluminum vessels.

REFERENCES:

Bolted on Insulation Support Angle for Inside of Skirt for Vertical Vessels . . . . . Std EQ-70

Strap-Anchor Angles for Vessels Over 15-ft OD . . . . See Over

UNLESS OTHERWISE INDICATED, ALL DIMENSIONS GIVEN IN INCHES.

PAGE 1

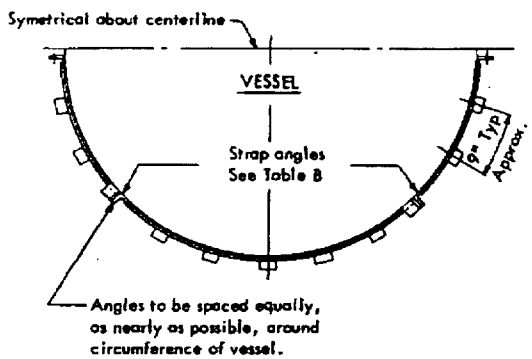
ENGINEERING STANDARD EQ-68

UCC 002832

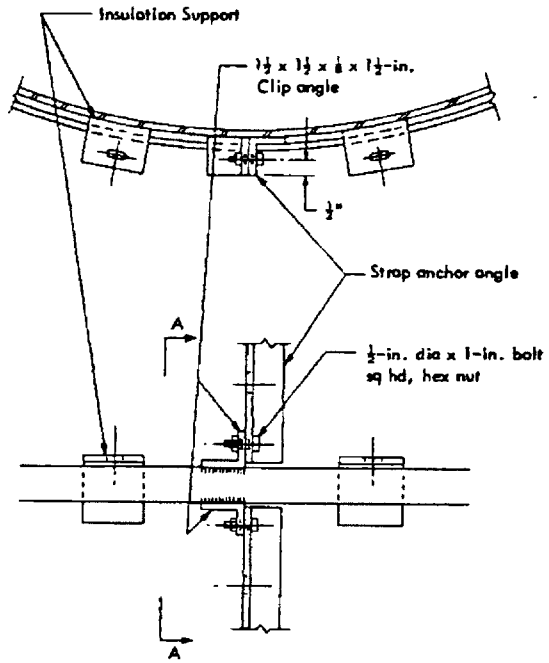
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BOLTED-ON INSULATION SUPPORTS FOR VERTICAL VESSELS OVER 3-FT O.D.

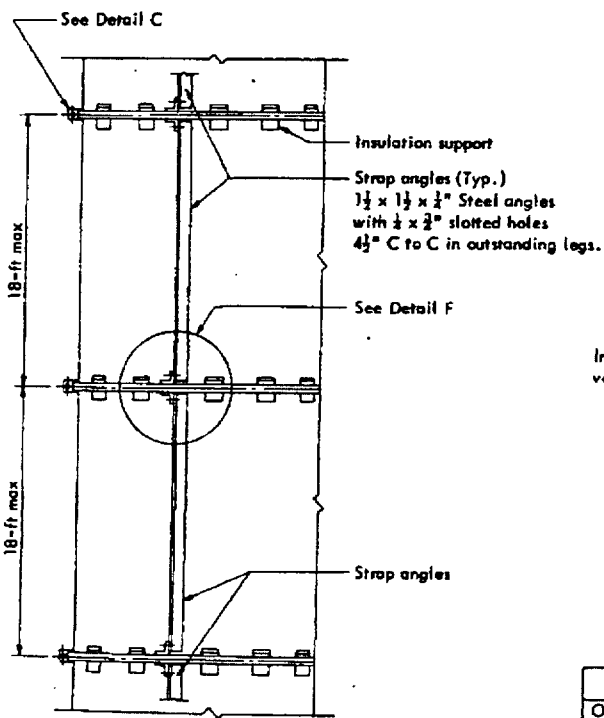
STRAP-ANCHOR ANGLES FOR VESSELS OVER 15-FT O.D.



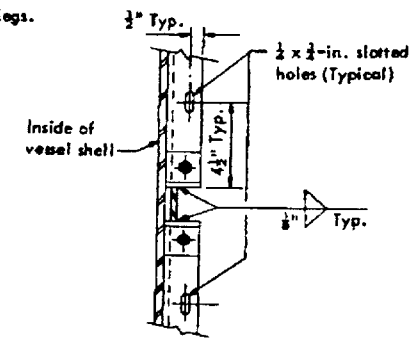
PLAN



DETAIL F



ELEVATION



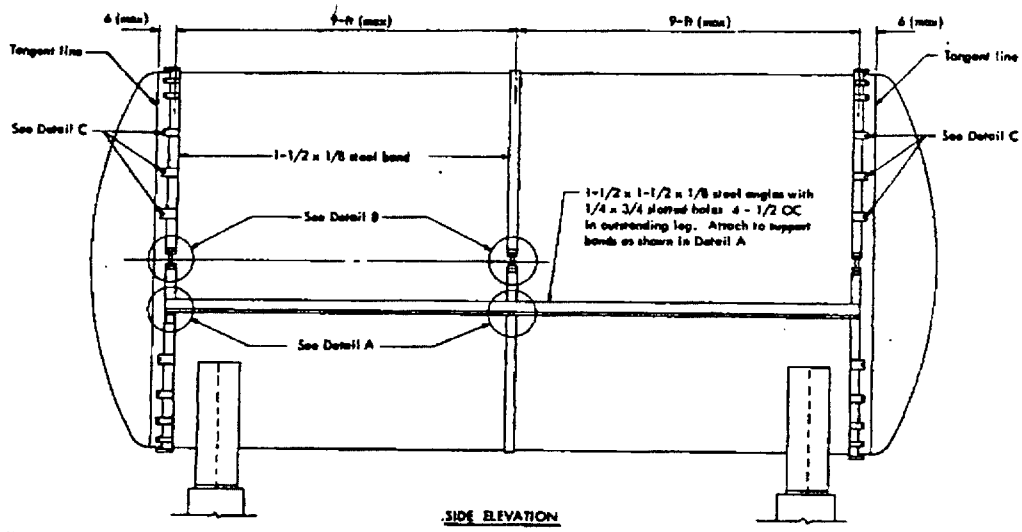
SECTION A-A

TABLE B	
Outside Diameter of Vessel	Number of Vertical Angles Required
15'-0 to 27'-0	4
27'-1 to 36'-0	8
36'-1 to 50'-0	16
Over 50'-0	One angle for each 9-ft of circumference, or fraction thereof

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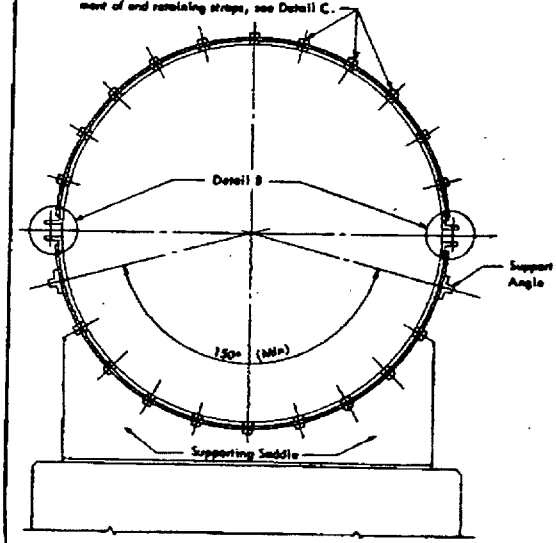
BOLTED-ON[1] INSULATION SUPPORTS FOR HORIZONTAL VESSELS OVER 3-FT OD

(Designed for use with preformed shapes, pervit, and block form insulation)

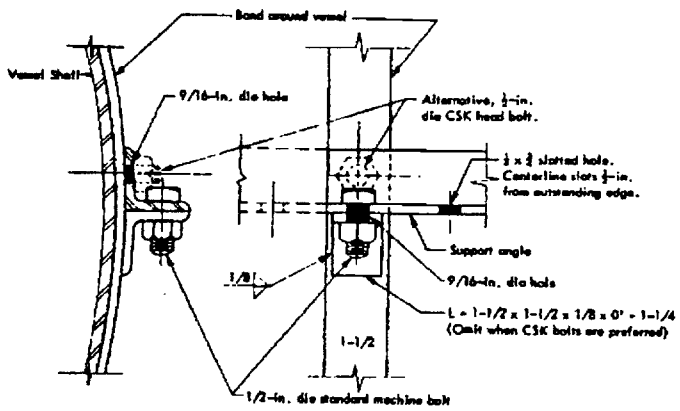


SIDE ELEVATION

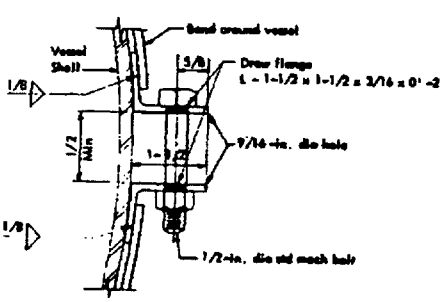
Slip-on friction clips for end bands only, spaced approx 9" C-to-C. For attachment of end retaining straps, see Detail C.



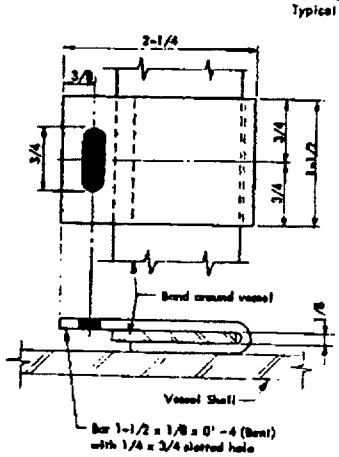
END ELEVATION



DETAIL A
Typical



DETAIL B



DETAIL C

NOTE:

Bolts shall be ½-in. dia standard machine bolts with square heads and hex nuts, unless otherwise indicated.

All steel parts shall be coated, or otherwise protected the same as the vessel to which they are attached, prior to the attachment.

Use stainless steel bands and aluminum clips on aluminum vessels.

[1]Bolted-on insulation supports are to be used only for FIELD INSTALLATIONS on vessels on which welding is either not permissible without postweld heat treatment or because of area conditions, or when welded-on insulation supports are not otherwise practicable.

UNLESS OTHERWISE INDICATED, ALL DIMENSIONS GIVEN IN INCHES.

ENGINEERING STANDARD EQ-69

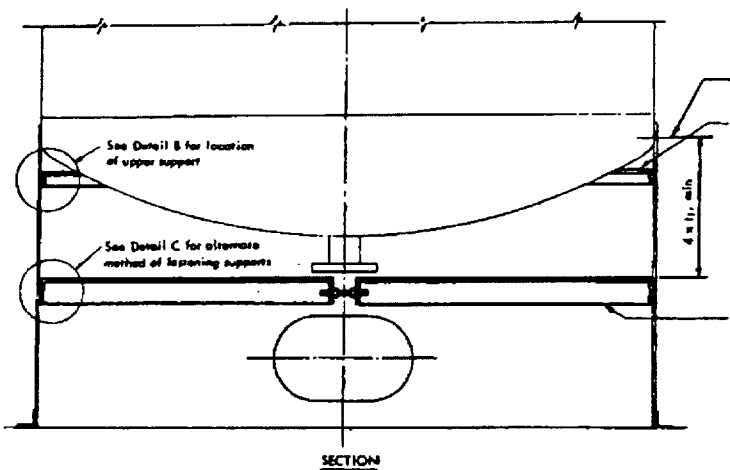
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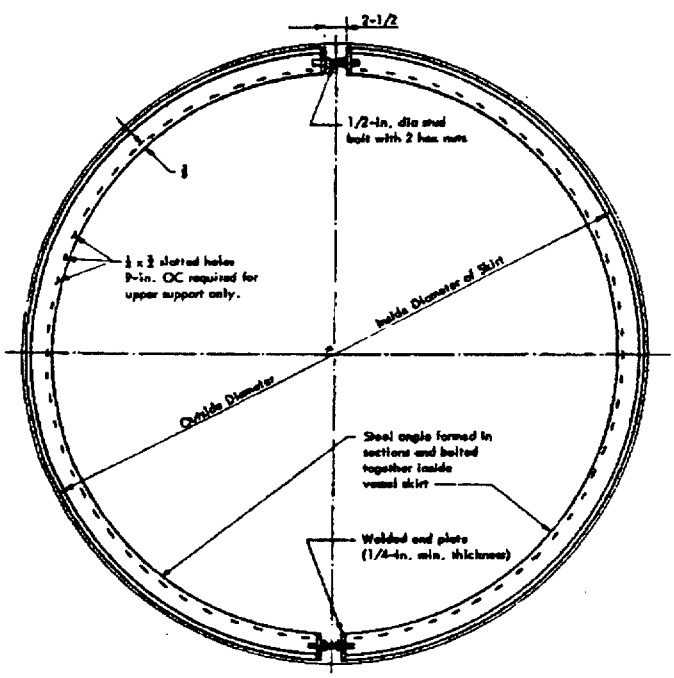
UNION CARBIDE STANDARD CHEMICALS AND PLASTICS

BOLTED-ON[1] INSULATION SUPPORT ANGLE FOR INSIDE OF SKIRT FOR VERTICAL VESSELS

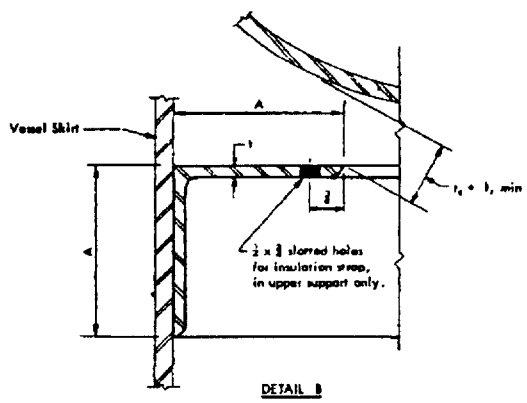
(Designed for use with Preformed Shapes, Panel, and Block Form Insulation)



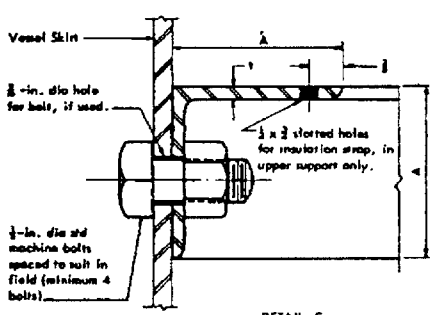
SECTION



DETAIL A
(Bottom View)



DETAIL B



DETAIL C
Alternate method of fastening angle support.

Dimensions "t" and "A" for Details B and C.

Insulation Thickness, t_1 (in.)	Angle Thickness, t (in.)	Angle Leg "A" (in.)
1 < t_1 ≤ 3½	⅛	1½
3½ < t_1 ≤ 9	¼	3

[1]Bolted-on insulation supports are to be used only for FIELD INSTALLATIONS on vessels on which welding is either not permissible without postweld heat treatment or because of area conditions, or when welded-on insulation supports are otherwise not practicable.

NOTE:

All steel parts shall be coated, or otherwise protected the same as the vessel to which they are attached, prior to the attachment.

Use aluminum angles on aluminum vessels.

REFERENCES:

Bolted-On Insulation Supports for Vertical Vessels Over 3-ft OD . . . . . Std EQ-68

UNLESS OTHERWISE INDICATED, ALL DIMENSIONS GIVEN IN INCHES.

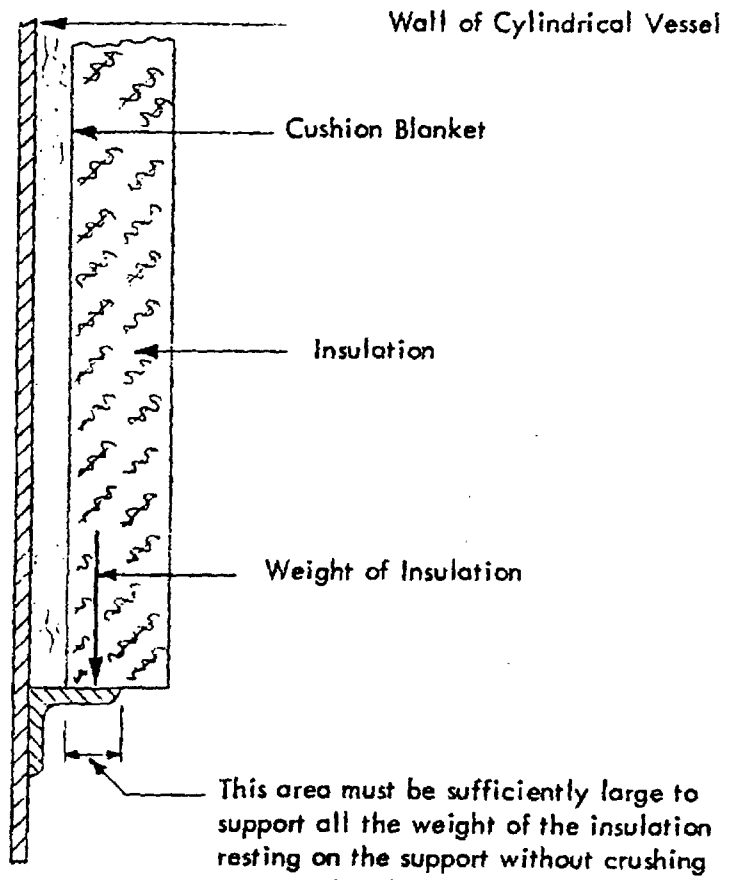
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ENGINEERING STANDARD EQ-70

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INSULATION SUPPORTS AND SECUREMENTS



INSULATION SUPPORT ON
VERTICAL CYLINDRICAL VESSEL

Figure XI-1

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INSULATION SUPPORTS AND SECUREMENTS

SUPPORTS - Contd

the insulation would be damaged or the strap would be pulled apart at the clips. For these reasons large bottom head insulation is supported by rectangular welding pieces as shown in EQ-67. The insulation is secured in position by wires fastened to these welding pieces.

Because ot its special shape the support rings for spheres require a special arrangement for support rings to secure insulation on spheres operating below 70C as shown in EQ-66. The insulation on spheres above this temperature is secured by pins and speed clips.

Insulation installed on horizontal pipe is supported by the pipe. As shown in Figure XI-2, the upper section of insulation rests on the pipe and the lower section is held up snug by the securement wire or strap.

Where wire is used to secure insulation it should be drawn taut by twisting the two ends together with sufficient tension that the sections of insulation are tightly butted together. The twisted ends must be bent back or embedded in the insulation so that sharp cut ends are embedded in the insulation.

Straps should be installed in a similar manner, being drawn taut by banding tool so that insulation is drawn tightly together. Cut end of strap must be bent back toward clip to prevent a sharp projection.

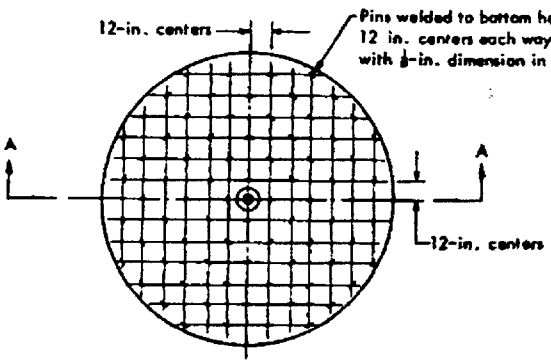
On low temperature installations and for some small size moderate and high temperatures the pipe and insulation are installed in cradles. Under these conditions the entire weight of the pipe, its contents and the insulation are supported directly by theinsulation. To prevent the insulation from being crushed where the pipe crosses the beam, a metal cradle is inserted to spread the weight load over a large area of the insulation. Such an installation is shown in Engineering Standard P-82.

Vertical pipe presents a different support problem. In the case of short lines with a bottom welded elbow, the vertical pipe insulation is supported by the elbow insulation. On all long vertical lines and lines with flanged valves, flanges, or elbows, an insulation support should be provided. This is illustrated in Figure XI-3. The reasons for this is that, in the case of long vertical lines, the excessive weight of insulation on the elbow cover will attempt to push it down and around the elbow with a resultant crack developing on the outer radius of the cover. In the case of flanged fittings, the insulation should always be secure so that fittings can be received without insulation slipping down the vertical pipe.

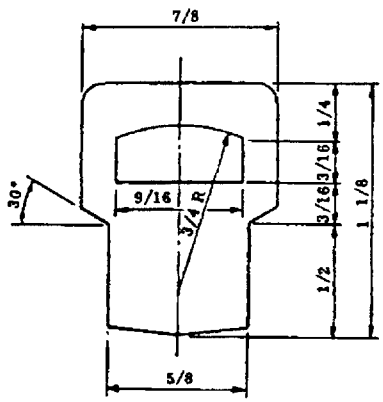
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INSULATION SUPPORT PINS FOR WELDING TO CARBON STEEL BOTTOM HEADS OR TO FLAT SURFACES

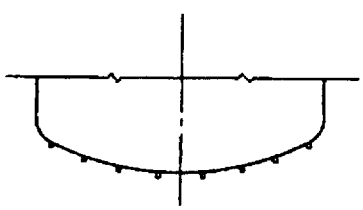
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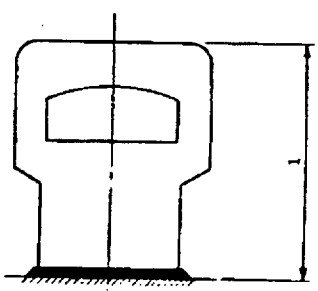
VIEW OF BOTTOM HEAD



Before Welding

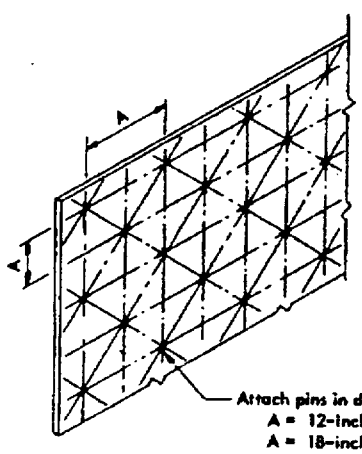


ELEVATION A-A



After Welding

Front Elevations of Pin



Attach pins in diamond pattern as follows:
A = 12-inch centers for bottom surfaces.
A = 18-inch centers for side surfaces.
A = 24-inch centers for top surfaces.

TYPICAL FLAT SURFACES

NOTE:

This standard applies to flat surfaces and to bottom heads of carbon steel vessels over 16-ft OD for operating temperatures above 70F.

Pins shall be as manufactured by KSM Products, Inc., Moorestown, New Jersey, or other approved securement.

Pins shall be welded to vessel with a KSM-CD-60 Capacitor Discharge Stud Welding Unit (or approved equal) with accessory chuck to suit pins.

Pins shown are ¼-in. thick.

Pins shall be welded to vessels subject to postweld heat treatment before the final heat treatment.

Pins may be welded in the field to vessels and other equipment not subject to postweld heat treatment.

All dimensions given in inches.

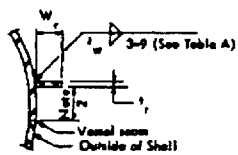
ENGINEERING STANDARD EQ-67

UCC 002838

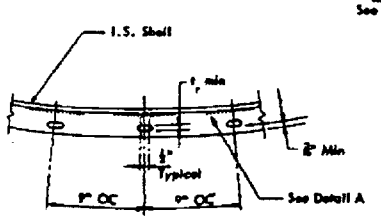
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WELDED-ON INSULATION SUPPORTS FOR SPHERICAL VESSELS FOR OPERATING TEMPERATURES LOWER THAN 70F (21C)

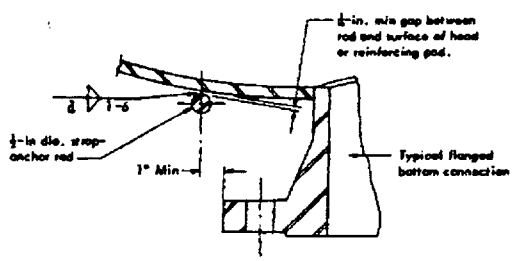
(Designed for use with preformed shapes, panel, and block form insulation)



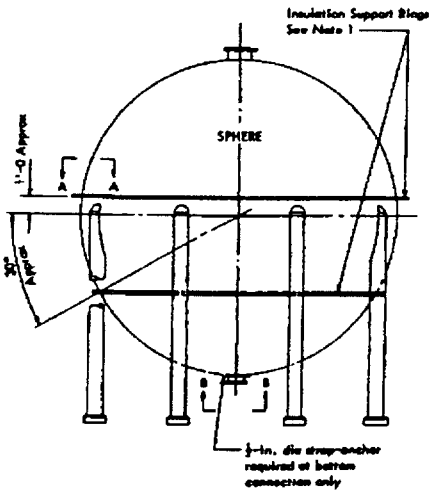
DETAIL A
See Notes 2 & 3



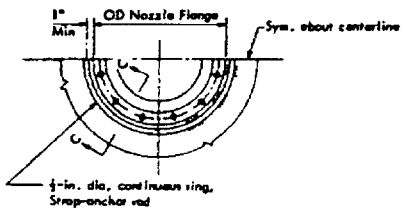
SECTION A-A
Typical



SECTION C-C



ELEVATION



VIEW B-B

TABLE A

Insulation Thickness, t_i (in.)	Bar Size Thickness, t (in.)	Bar Size Width, W (in.)	Weld Size, t_w (in. x 45°)
$1 < t_i \leq 1\text{-}1/2$	1/2	1	1/2
$1\text{-}1/2 < t_i \leq 3\text{-}1/2$	1/2	1 1/2	1/2
$3\text{-}1/2 < t_i \leq 9$	1	3	1

GENERAL NOTES

Provide each sphere with two slotted insulation support rings as shown on this Standard. Other insulation supports, where required, shall be as specified in the Vessel Specifications. Select support size from TABLE A.

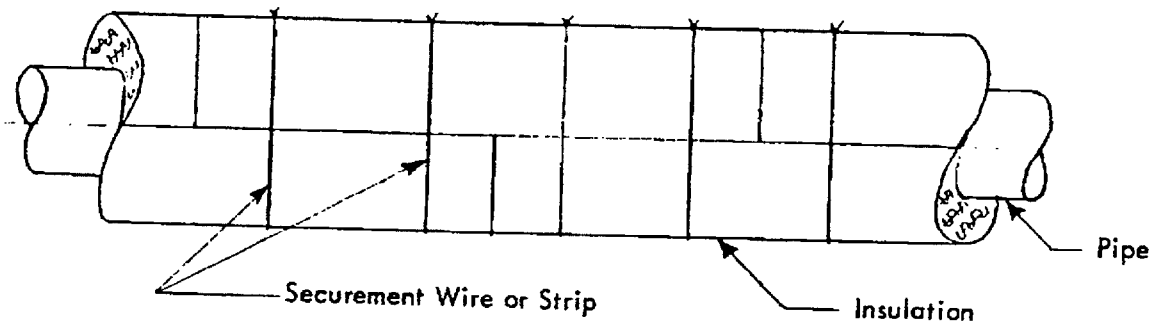
Material for supports shall be as noted in the Vessel Specifications. Welding procedure for attaching supports to sphere shall be equal to that for the pressure containing enclosure.

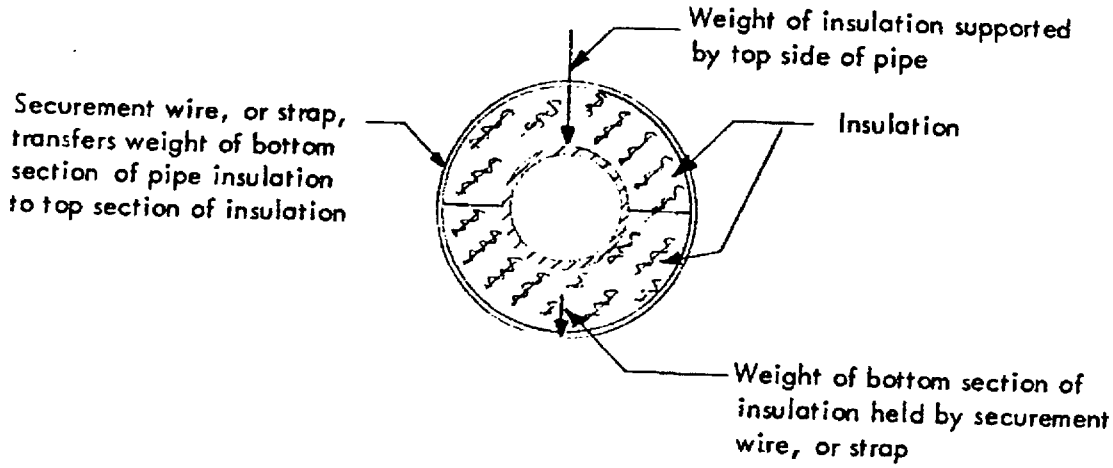
DETAIL NOTES

1. Support rings shall be provided for all spheres to be insulated for operating temperatures lower than 70F (21C). Rings are not to be continuous. Openings between adjacent ends shall not exceed 1/4-inch.
2. Adjust ring location, if necessary, to provide minimum clearance of 1-inch between the ring attachment weld and sphere girth weld edges. Locate rings to clear shell connections and reinforcement pads. Provide minimum clearance of 1-inch between ring attachment welds and attachment weld of any adjacent item.
3. Support attachment welds shall not cross meridional welds.

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INSULATION SUPPORTS AND SECUREMENTS





SUPPORT OF INSULATION INSTALLED ON HORIZONTAL PIPE

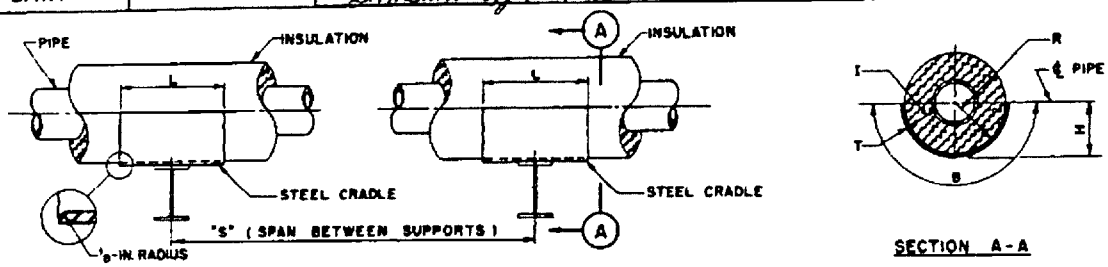
Figure XI-2

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UNION CARBIDE CORPORATION
CHEMICALS, OLEFINS, PLASTICS

CRADLE SUPPORTS FOR INSULATED PIPES

CLASSIFICATION	SPONSOR	REVIEWED BY	APPROVED BY	ISSUED (AS S-19)	REVISED
DATA	DEPT 936	J.H. Smith, Jr.	L.S. Greco	5-25-51	9-1-65



LEGEND:
H = DIMENSION FROM ℄ OF PIPE TO BOTTOM OF CRADLE
T = CRADLE THICKNESS
L = CRADLE LENGTH

B = PLATE WIDTH BEFORE FORMING
R = BENDING RADIUS FOR PLATE ("H" MINUS "T")
S = SPAN, IN FEET, BETWEEN SUPPORTS.

NOM PIPE SIZE	DIMENSIONS	"I" INSULATION THICKNESSES (NOMINAL) 1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	"L" CRADLE LENGTH "S" SPAN 10-FT	12-FT	15-FT	18-FT	20-FT	25-FT	NOM PIPE SIZE
½	H	1½	2	2½	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	—	—	—	—	—							
	T	14 GA				⅛				3/16			¼							10	—	—	—	—	—	½
	B	4½	6¼	7¾	10⅜	12	13½	15	17	18½	20	22	23½	25	—	—	—	—	—							
¾	H	1½	2	2½	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	—	—	—	—	—							
	T	14 GA				⅛				3/16			¼							10	—	—	—	—	—	¾
	B	4½	6¼	7¾	10⅜	12	13½	15	17	18½	20	22	23½	25	—	—	—	—	—							
1	H	1¾	2¼	2⅞	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	—	—	—	—	—							
	T	14 GA				⅛				3/16			¼							10	10	—	—	—	—	1
	B	5½	7	8¾	10⅜	12	13½	15	17	18½	20	22	23½	25	—	—	—	—	—							
1½	H	2	2½	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¾							
	T	14 GA				⅛				3/16			¼						5/16	10	10	—	—	—	—	1½
	B	6¼	7¾	10⅜	12	13½	15	17	18½	20	22	23½	25	26½	28	30	31½	33	36							
2	H	2¼	2⅞	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¾							
	T	14 GA				⅛				3/16			¼						5/16	10	10	10	—	—	—	2
	B	7	8¾	10⅜	12	13½	15	17	18½	20	22	23½	25	26½	28	30	31½	33	36							
3	H	2⅞	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	12¼							
	T	14 GA				⅛				3/16			¼						5/16	10	10	10	—	—	—	3
	B	8¾	10⅜	12	13½	15	17	18½	20	22	23½	25	26½	28	30	31½	33	34½	37½							
4	H	3½	4	4½	5	5½	6	6½	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	11¾	12¾							
	T	⅛				3/16				¼								5/16		10	10	10	12	—	—	4
	B	10⅜	12	13½	15	17	18½	20	22	23½	25	26½	28	30	31½	33	34½	36	39							
6	H	4½	5	5½	6	6½	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	11¾	12¼	12¾	13⅞							
	T	⅛			3/16				¼							5/16			⅜	10	10	12	16	16	—	6
	B	13½	15	17	18½	20	22	23½	25	26½	28	30	31½	33	34½	36	37½	39	42½							
8	H		6	6½	7¼	7¾	8¼	8¾	9¼	9⅞	10¼	10¾	11¼	11¾	12¼	12¾	13⅜	13⅞	14⅞							
	T	—	3/16				¼					5/16						⅜		10	12	16	18	20	—	8
	B		18½	20	22	23½	25	26½	28	30	31½	33	34½	36	37½	39	40¾	42½	45½							
10	H		7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	11⅞	12¼	12¾	13⅜	13⅞	14⅜	14⅞	15⅞							
	T	—	3/16				¼					5/16					⅜		7/16	12	16	20	20	24	—	10
	B		22	23½	25	26½	28	30	31½	33	34½	36	37½	39	40¾	42½	44	45½	48¾							
12	H		8¼	8¾	9¼	9¾	10¼	10¾	11¼	11¾	12¼	12⅞	13⅜	13⅞	14⅜	14⅞	15⅜	15⅞	16⅞							
	T	—			¼					5/16					⅜				7/16	12	16	20	24	24	—	12
	B		25	26½	28	30	31½	33	34½	36	37½	39	40¾	42½	44	45½	47	48¾	51¾							
14	H		8¾	9¼	9¾	10¼	10¾	11¼	11⅞	12¼	12⅞	13⅜	13⅞	14⅜	14⅞	15⅜	15⅞	16⅜	17⅜							
	T	—		¼					5/16					⅜				7/16		16	20	24	24	30	36	14
	B		26½	28	30	31½	33	34½	36	37½	39	40¾	42½	44	45½	47	48¾	50¼	53½							
16	H		9¾	10¼	10¾	11¼	11¾	12¼	12¾	13⅜	13⅞	14⅜	14⅞	15⅜	15⅞	16⅜	16⅞	17⅜	18½							
	T	—	¼				5/16					⅜				7/16			½	16	20	24	30	36	42	16
	B		30	31½	33	34½	36	37½	39	40¾	42½	44	45½	47	48¾	50¼	51¾	53½	56½							
18	H		10¾	11¼	11¾	12¼	12¾	13⅜	13⅞	14⅜	14⅞	15⅜	15⅞	16⅜	16⅞	17⅜	17⅞	18½	19½							
	T	—	5/16				⅜				7/16				½					20	24	30	36	36	42	18
	B		33	34½	36	37½	39	40¾	42½	44	45½	47	48¾	50¼	51¾	53½	55	56½	59½							
20	H		11¾	12¼	12¾	13⅜	13⅞	14⅜	14⅞	15⅜	15⅞	16⅜	16⅞	17⅜	17⅞	18½	19	19½	20½							
	T	—	5/16				⅜				7/16				½					24	24	30	36	42	48	20
	B		36	37½	39	40¾	42½	44	45½	47	48¾	50¼	51¾	53½	55	56½	58	59½	62½							
24	H		13⅞	14⅜	14⅞	15⅜	15⅞	16⅜	16⅞	17⅜	17⅞	18½	19	19½	20	20½	21⅛	21⅝	22⅝							
	T	—	⅜				7/16				½					5/8				30	30	36	42	48	54	24
	B		42½	44	45½	47	48¾	50¼	51¾	53½	55	56½	58	59½	61	62½	64½	66	69							

ALL DIMENSIONS GIVEN IN INCHES

(OVER)

938-130-003

ENGINEERING STANDARD P-82

P-82

UCC 002841

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ENGINEERING STANDARD NO. P-82

NOTE:

Dimensional insulation data is taken from standard insulation tables. It should be noted that the insulation OD and ID are standardized to match the OD of standard nominal pipe sizes, and for thicknesses over 2 1/2-in., multilayer construction is used.

Cradle design is based on a maximum bearing value of 20 lb per sq in. for cellular glass, with one percent allowable deformation without damage to the insulation. Other types of insulation will tolerate greater pressures and higher percentages of deformation without loss of insulation values.

The bottom 120° arc has been established as the effective cross-sectional bearing area for insulation and supporting cradles, with the first inch of insulation next to the pipe absorbing the greatest proportion of the load pressure. Cradle material beyond the 120° arc is useful for installation and retention only.

The following equations are the results of complex formulae reduced to simplified ratios for ease of application.

$$T = .0125\, D_2 \qquad L = .0125\, \frac{12wS}{D_2} \quad \text{or} \quad .15\, \frac{wS}{D_2}$$

Where:

T = thickness of cradle in inches
L = length of cradle in inches
D_1 = OD of bare pipe in inches
D_2 = OD of insulation in inches
S = span between supports in feet
w = unit wt per foot of pipe, water, and insulation, plus 10% safety factor.
f = (20 lb/sq in.) bearing value for insulation
c = (1.5) coefficient of friction for longitudinal movement.

"T" and "L" have been adjusted to increments most suitable for practical application. "L" has been further controlled by the greater of three minimum values as follows:

(1) ten inches (2) one pipe diameter (3) $\frac{wcS}{D_1 f}$

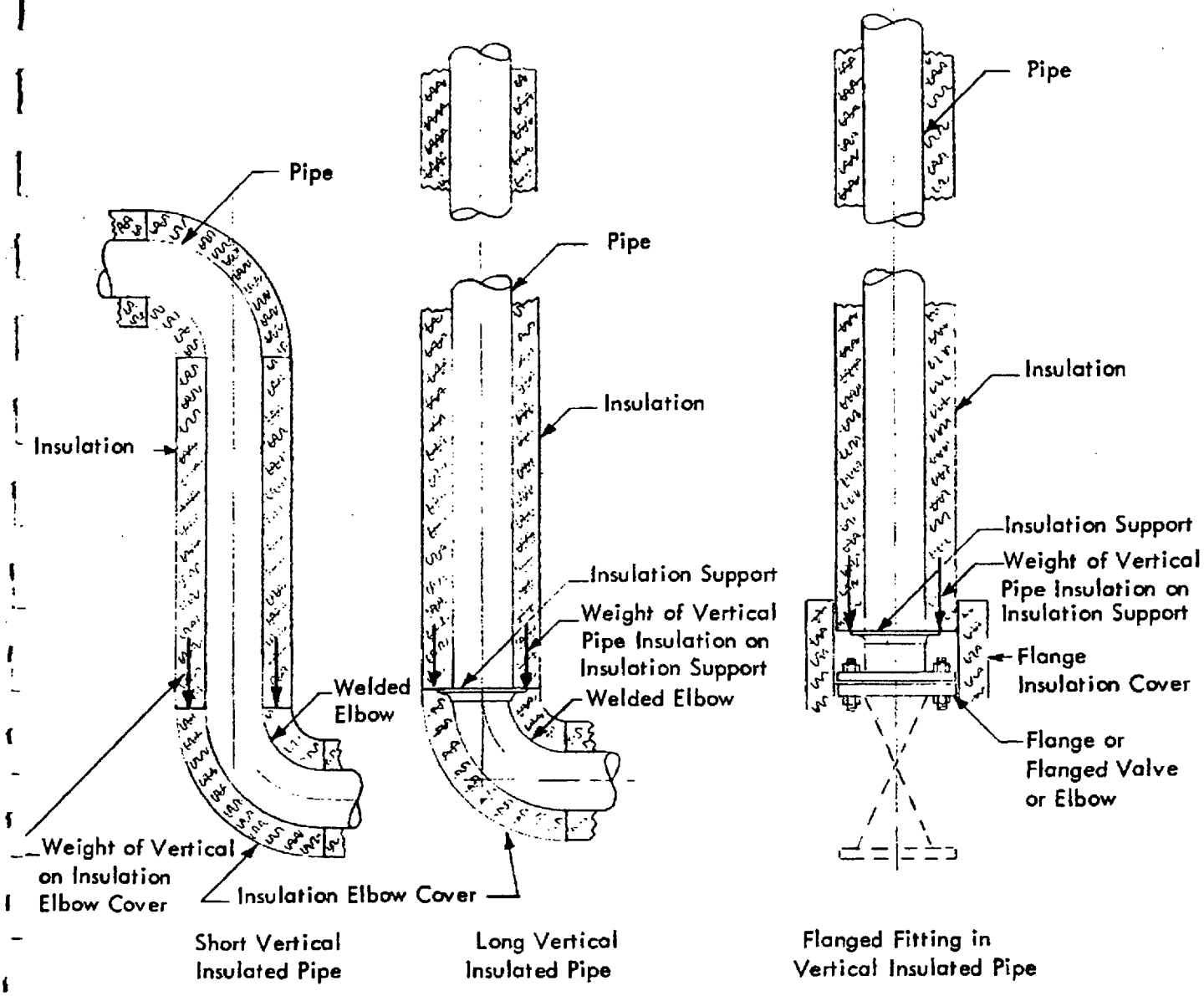
Cradles are intended for use in straight run horizontal piping with flanges and fittings, short vertical runs less than S/2, and installations not subject to vibration.

Runs including valves or long vertical portions shall be treated with special consideration.

Where severe vibration is anticipated, such as in compressor lines, the insulation between the cradle and the pipe shall be resistant to vibration.

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INSULATION SUPPORTS AND SECUREMENTS



SUPPORT OF INSULATION ON VERTICAL PIPE

Figure XI-3

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INSULATION SUPPORTS AND SECUREMENTS

SUPPORTS - Contd

Horizontal equipment less than 4 feet in diameter is insulated the same as horizontal pipe. If horizontal equipment is greater than 4 feet in diameter, difficulty is experienced when it is attempted to pull up the bottom insulation by securement bands. Due to friction and weight, before the sag at the bottom is drawn out, the bands begin to crush into the top insulation. For this reason, support angles are located 60° from the vertical center on lower half of the vessel to which the bands can be attached. These angles carry the weight of the insulation. To provide supports for the head insulation, cylindrical supports are provided at each end of the vessel. The insulation supports for horizontal vessels are shown in Engineering Standard EQ-69.

The support of insulation on large flat or curved surfaces such as ducts or spheres can be quite difficult. In these installations the insulation supports must be attached to the surface to be insulated. For this type of installation, rectangular welding pins, split pins, and regular welding pins are welded to the metal surface and become the insulation supports. The insulation is secured to these supports by wire, strap, or speed clips.

A typical application, using rectangular pins for support of insulation installed on a large flat surface, is shown in Figure XI-4. As shown, this installation uses wire fastened to the pins for the insulation securement.

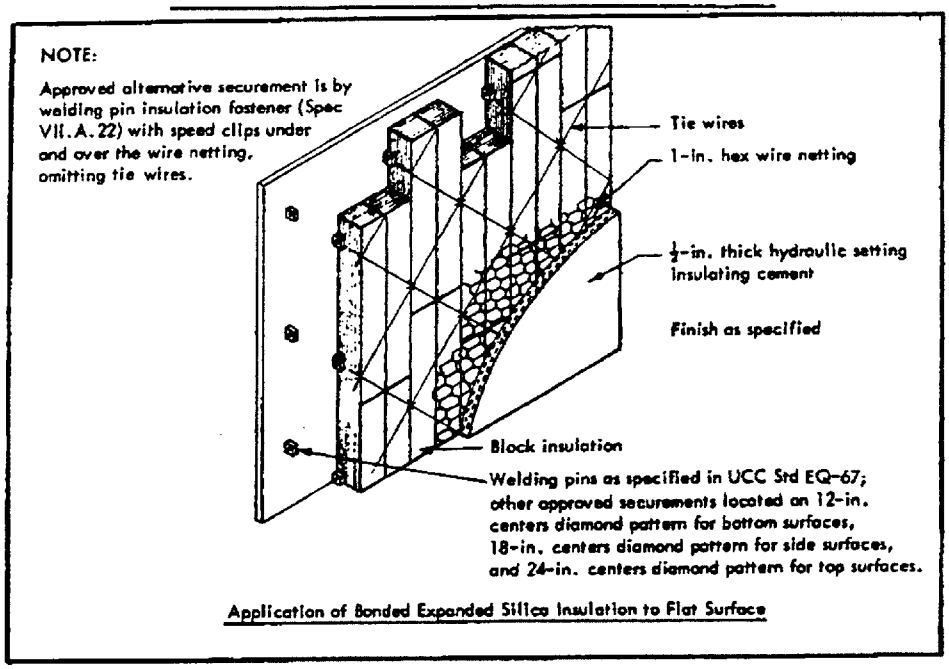
The use of regular pins as supports and speed clips for the securement of insulation is shown in Figure XI-5.

In some instances the insulation provides its own support by adhesion to the surface to which it is applied. Sprayed urethane foam has excellent adhesion and needs no additional supports. Sprayed asbestos insulation of thickness one-inch or less, like sprayed urethane, requires no additional supports. When the thickness is greater than one-inch, regular welding pins or split pins must be attached to the surface to support. Such an application to the bottom side of a turbine is shown in Figure XI-6.

Adhesives are used both for the support and the securement of insulation. On air conditioning ducts, they are used to support the insulation on installations in the interior of ducts or on applications where the insulation is installed in the exterior of the duct. Use of adhesives to install industrial insulation has been relatively limited; however, for the installation of cellular glass or spheres the use of adhesives has proven to be the only satisfactory method. For such an application a special catalyst-type adhesive is necessary. Illustration of the use of adhesives to support insulation is shown in Figure XI-7.

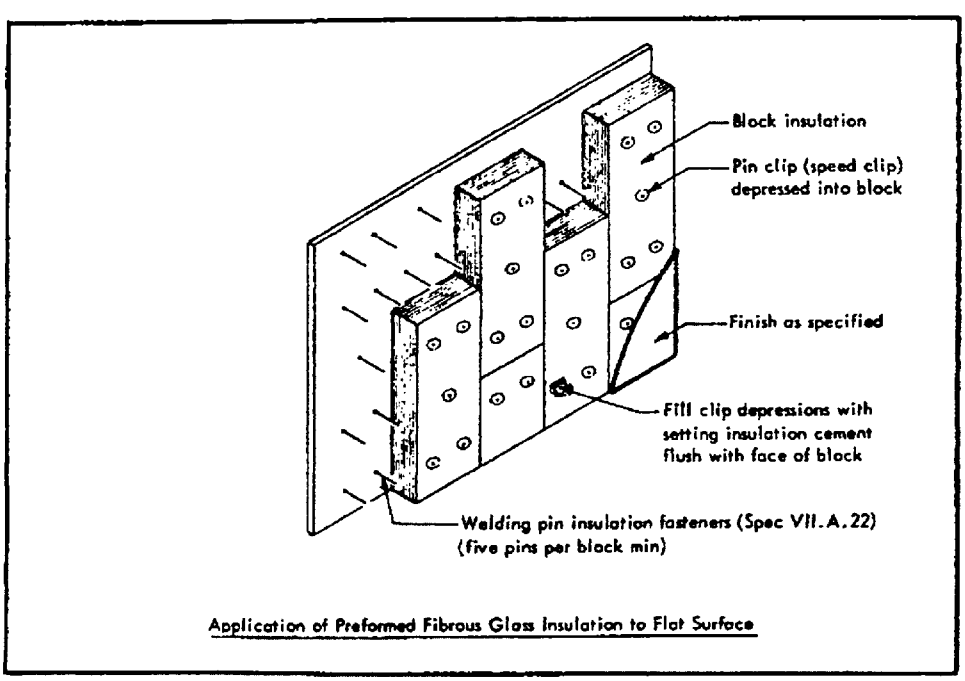
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INSULATION SUPPORTS AND SECUREMENTS



Application of Bonded Expanded Silica Insulation to Flat Surface

Figure XI - 4



Application of Preformed Fibrous Glass Insulation to Flat Surface

Figure XI - 5

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INSULATION SUPPORTS AND SECUREMENTS

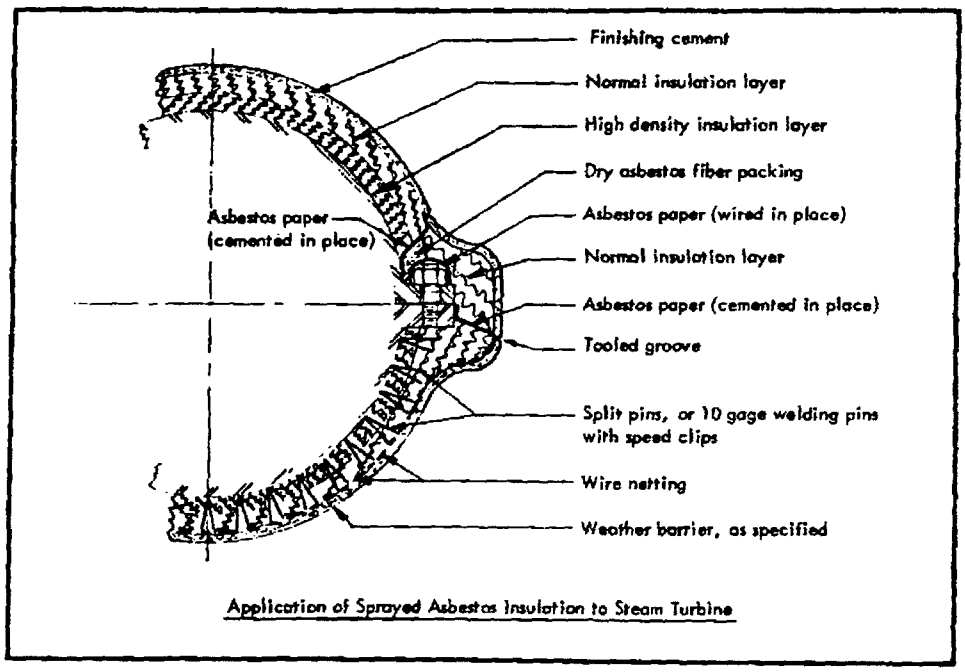
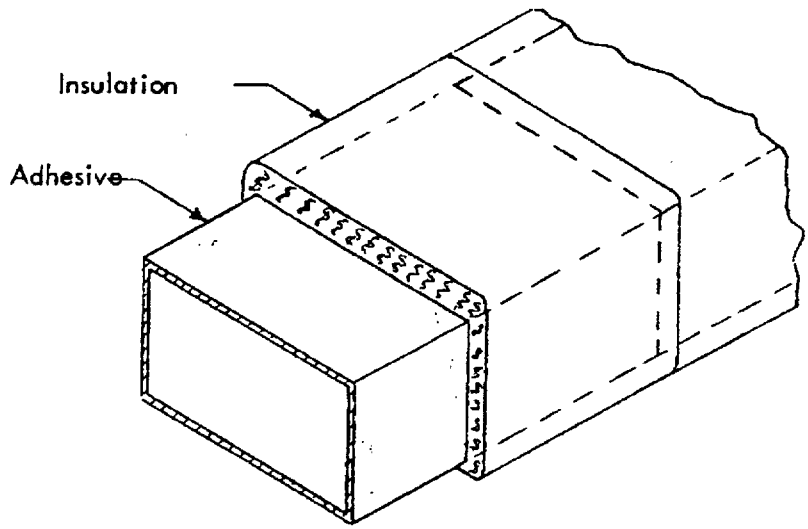


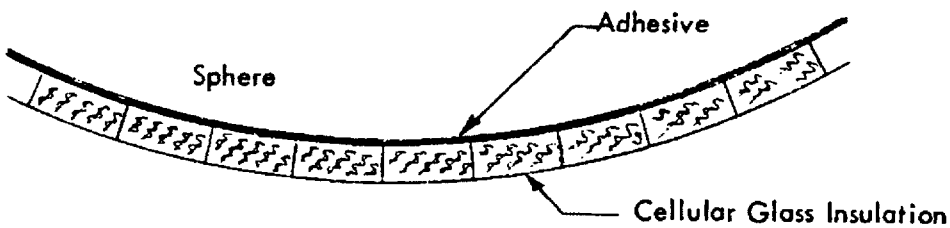
Figure XI - 6

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INSULATION SUPPORTS AND SECUREMENTS



Application of Insulation to Duct by Adhesive



Application of Cellular Glass Insulation to Shpere or Adhesive

TYPICAL USE OF ADHESIVE
INSULATION SUPPORT

Figure XI-7

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INSULATION SUPPORTS AND SECUREMENTS

SUPPORTS - Contd

The angle insulation supports, and supports which require welding to equipment or pipe are most frequently installed by crafts other than the insulators. For this reason it might be questioned as to why this explanation of insulation supports is included in an insulation manual. The reason is that the insulators are responsible to make certain that the proper supports are furnished to facilitate the correct application of insulation. If insulation is installed without correct supports, the insulation application will fail. If such failures occur the insulator is blamed for the failure.

SECUREMENTS

Securements are fasteners to fix and hold insulation in position, either to itself, or its supports. An insulation securement may be strap, wire, tape, clips, screws, or adhesive.

Equipment Insulation Securement

Rigid insulation installed around the cylindricd section of columns and vessels is more frequently secured in position with straps. As shown in Figure XI-8, the insulation on the cylindrical insulation is secured in place by straps on 9-inch centers. The top and bottom head insulation is secured to slotted support rings.

Where vessel is of large diameter, strap shall be divided in lengths of not over 15 feet so that individual sections of the circumferential band can be tensioned without damaging the insulation.

Strap should be installed to cylindrical insulation, stretching to suitable tightness with approved banding machine, and clamping in place at joint. Strap joint shall consist of double-pronged clip.

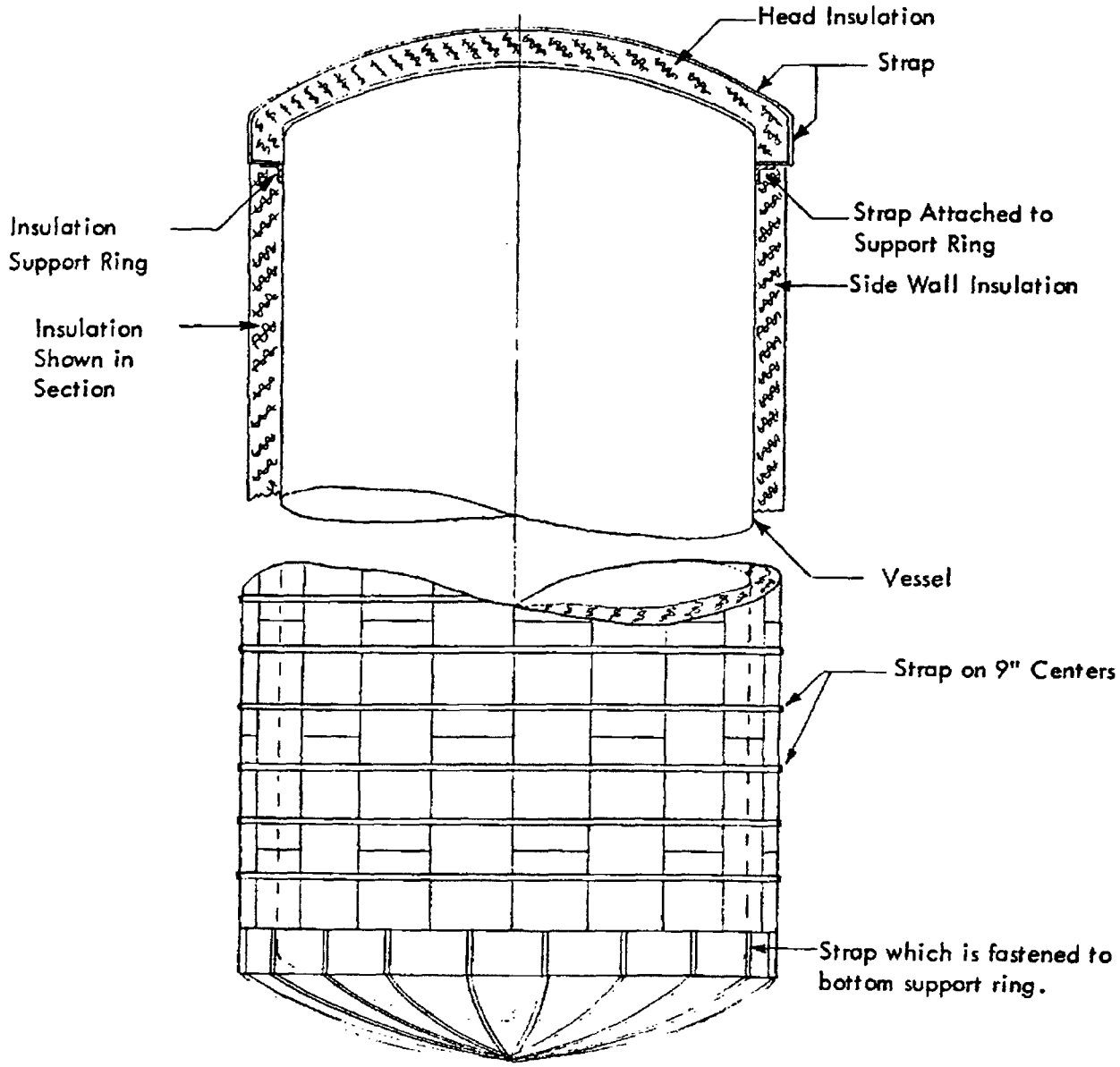
Where shape of vessel or appendages prevent complete encirclement of strap, strap should be fastened to tie wire, wire cables or other devices. Such an application is shown in Figure XI-9.

Where the bands completely encircle very large hot vessels such as over 20 feet in diameter, it is necessary to allow for expansion of the vessel. This is done by using expansion bands or expansion springs in each 30-foot section of strap. This is especially essential when factory-produced insulated metal panel insulation is installed. Two typical installations are shown in Figure XI-10. Due to corrosion factors the securement strap used on these applications should be manufactured of stainless steel. Its size is 1/2-inch wide and 0.02 inches in thickness.

On large flat surfaces, irregular surfaces, and the bottom heads of large diameter vessels, wire fastened to rectangular pins is used to secure the insulation in place. Wire is also used to secure insulation around projections. These are illustrated in Figures XI-5 and XI-11.

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INSULATION SUPPORTS AND SECUREMENTS

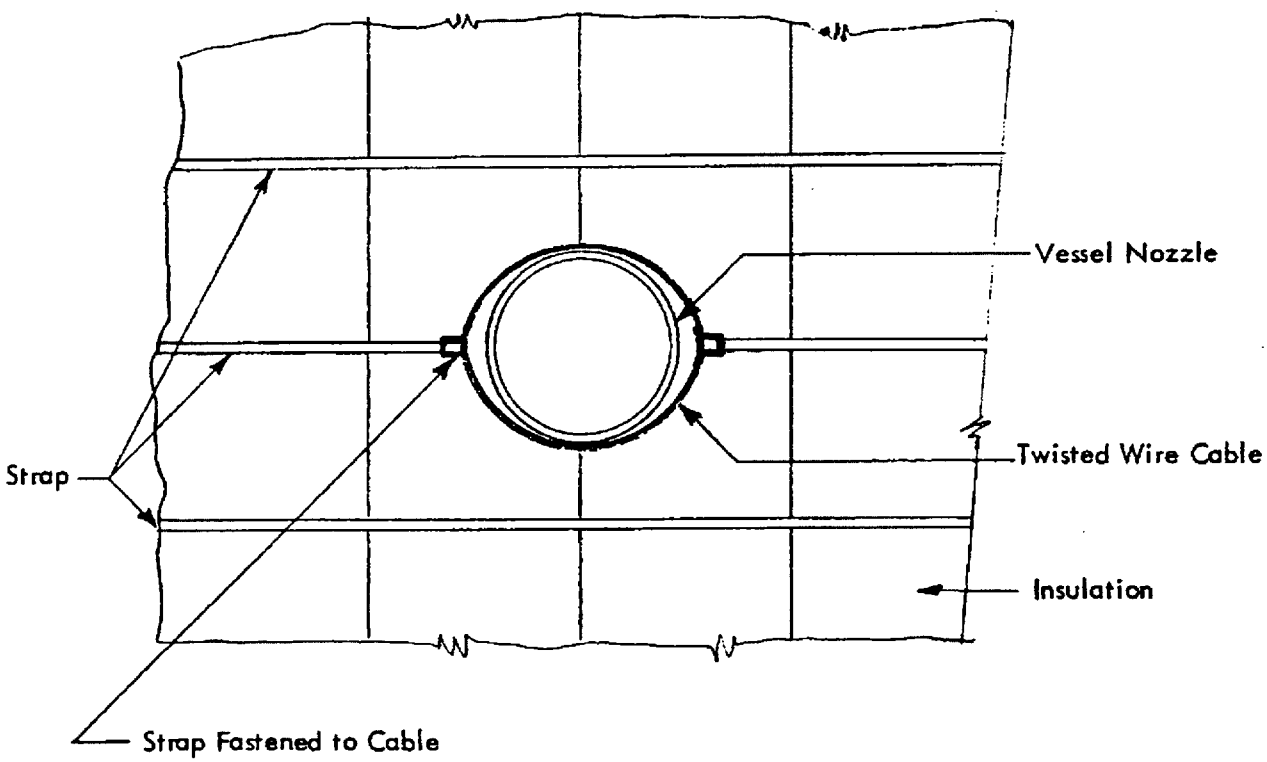


APPLICATION OF STRAP
TO SECURE VESSEL INSULATION

Figure XI-8

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INSULATION SUPPORTS AND SECUREMENTS



USE OF TWISTED WIRE CABLE FOR FASTENING OF STRAP

Figure XI-9

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INSULATION SUPPORTS AND SECUREMENTS

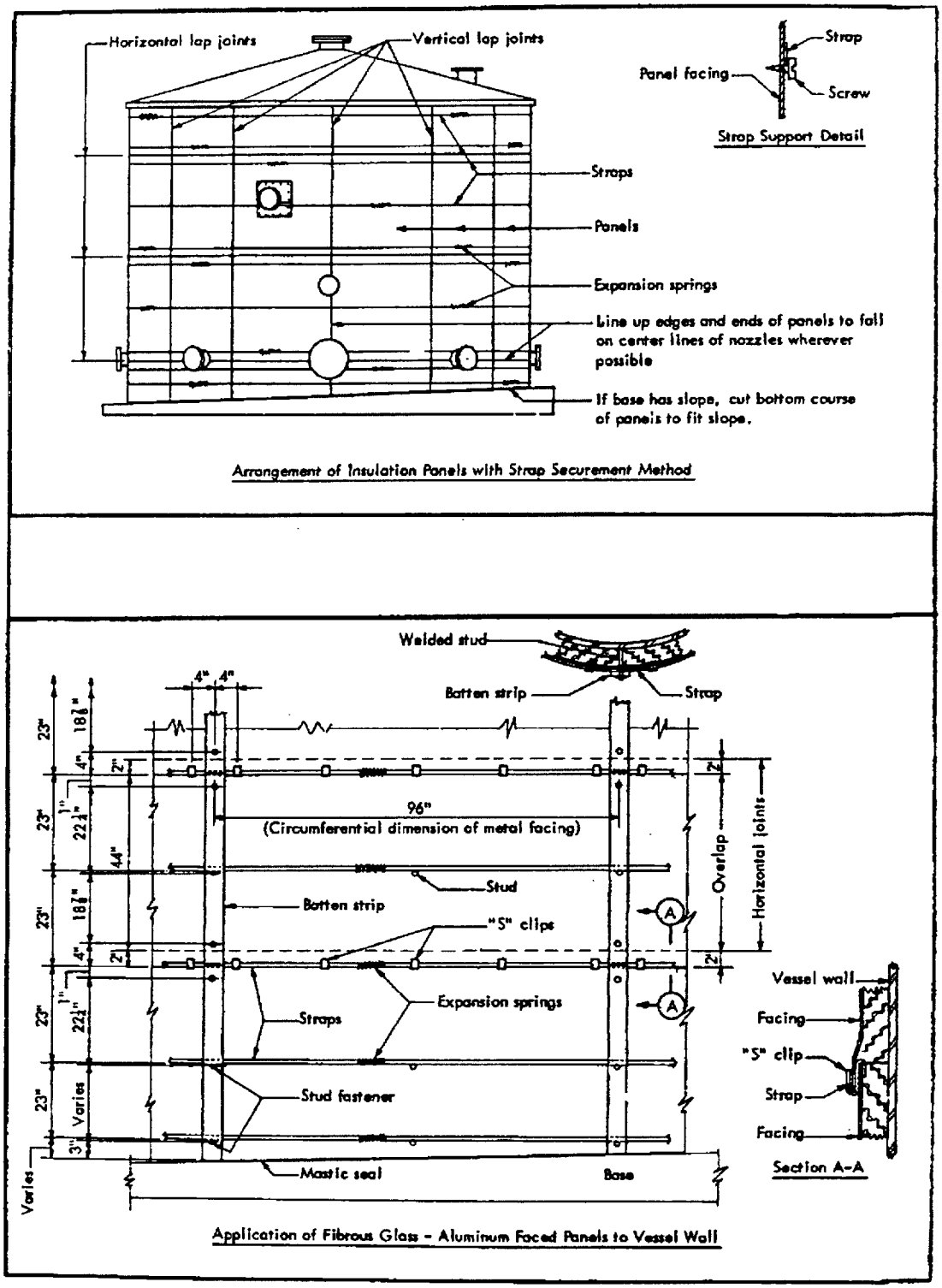


Figure XI-10

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INSULATION SUPPORTS AND SECUREMENTS

SECUREMENTS - Contd

Equipment Insulation Securement - Contd

Clips pressed on pins which extend through the insulation are another securement. These are used on large flat or curved surfaces. Typical installation of the use of clips to secure insulation is shown in Figure XI-5 and Figure XI-12.

Pipe Insulation Securement

Wire is used for securement of inner layers of pipe insulation (with exception of low temperature cellular glass installations), and outer layers up to and including 12-inch OD. Wire is also used to secure pipe insulation above 12-inch OD where the weather-barrier is specified to be metal jacket. Wire shall be applied at proper intervals, looped around the circumference of the insulation, then drawn taut and ends twisted together. Twisted ends should be pressed into insulation to prevent projection. Pipe insulation above 12-inch OD shall be secured with stainless steel strap.

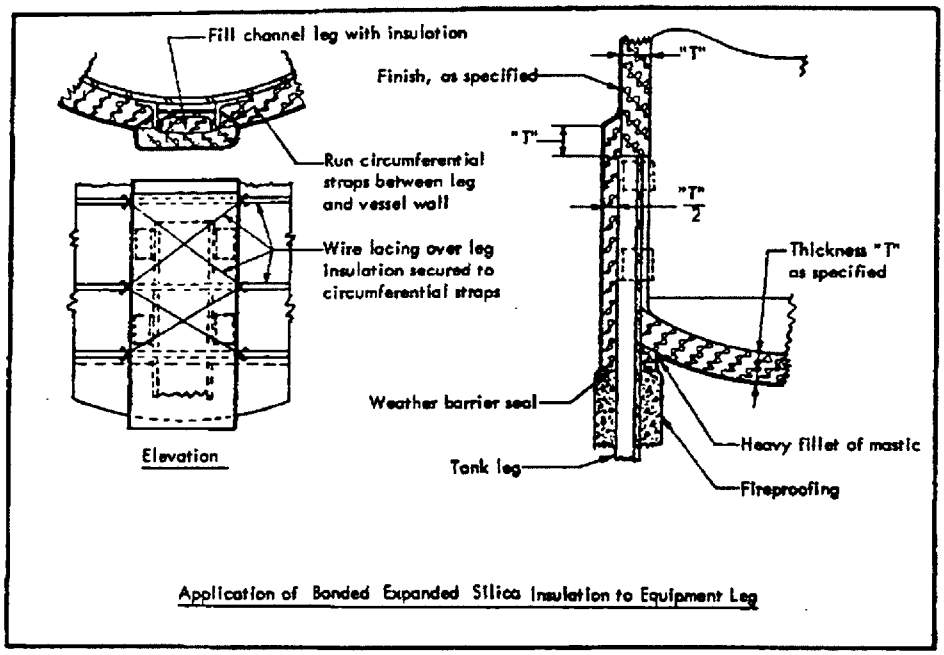
Cellular glass low temperature pipe installations up to 4-1/2 inches in outside diameter are secured in position with glass fiber strapping tape. Above this diameter, inner layers should be secured with wire and outer layers are secured with stainless steel strap.

Stainless steel strap should be applied to pipe insulation at proper intervals, looped around the circumference and be stretched to correct tightness with banding machine. Joint shall be held together by double-pronged clip. Clips should be located on the vertical side of horizontal pipe insulation.

Spacing of insulation strap and/or wire shall be based on lengths of insulation block or section for equipment or pipe. Where 36-inch lengths are applied in staggered arrangement, four loops will be required at approximately 9-inch intervals so that no loop is more than 4-1/2 inches from any end joint. Where 24-inch lengths are applied in staggered arrangement, three loops per length will be required. Where 18-inch lengths are applied in staggered arrangement, two loops will be required. Spacing of wire and strap is shown in Figures XI-13 and XI-14.

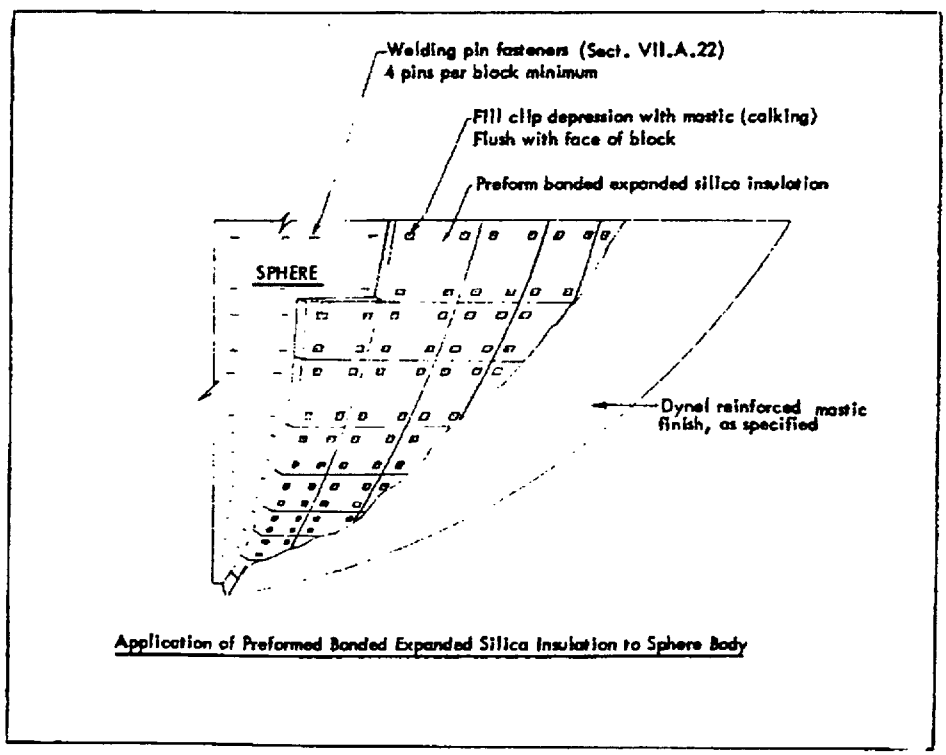
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INSULATION SUPPORTS AND SECUREMENTS



Application of Bonded Expanded Silica Insulation to Equipment Leg

Figure XI - 11



Application of Preformed Bonded Expanded Silica Insulation to Sphere Body

Figure XI - 12

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INSULATION SUPPORTS AND SECUREMENTS

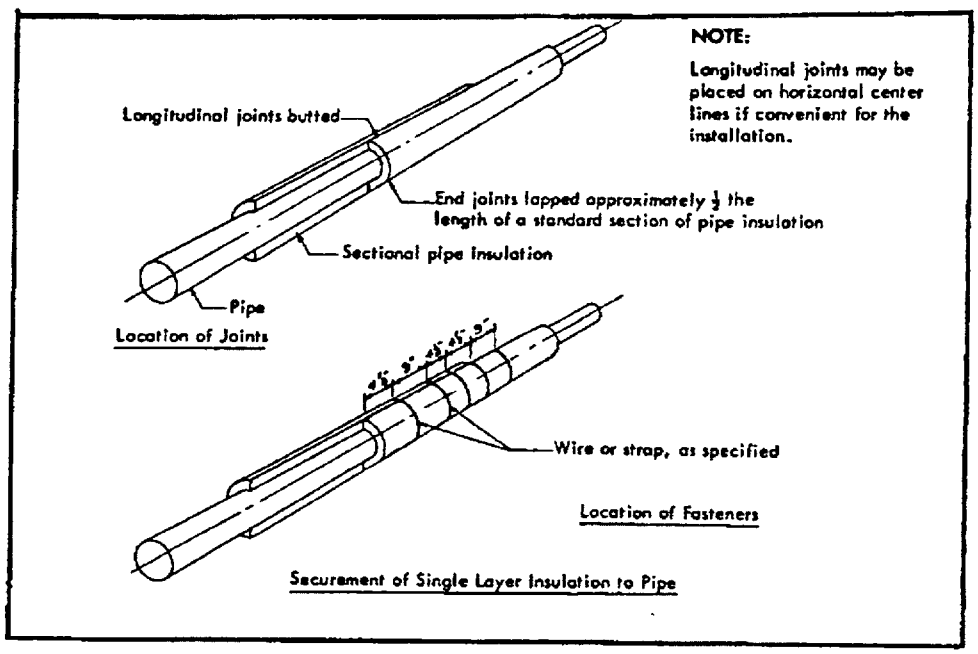


Figure XI-13

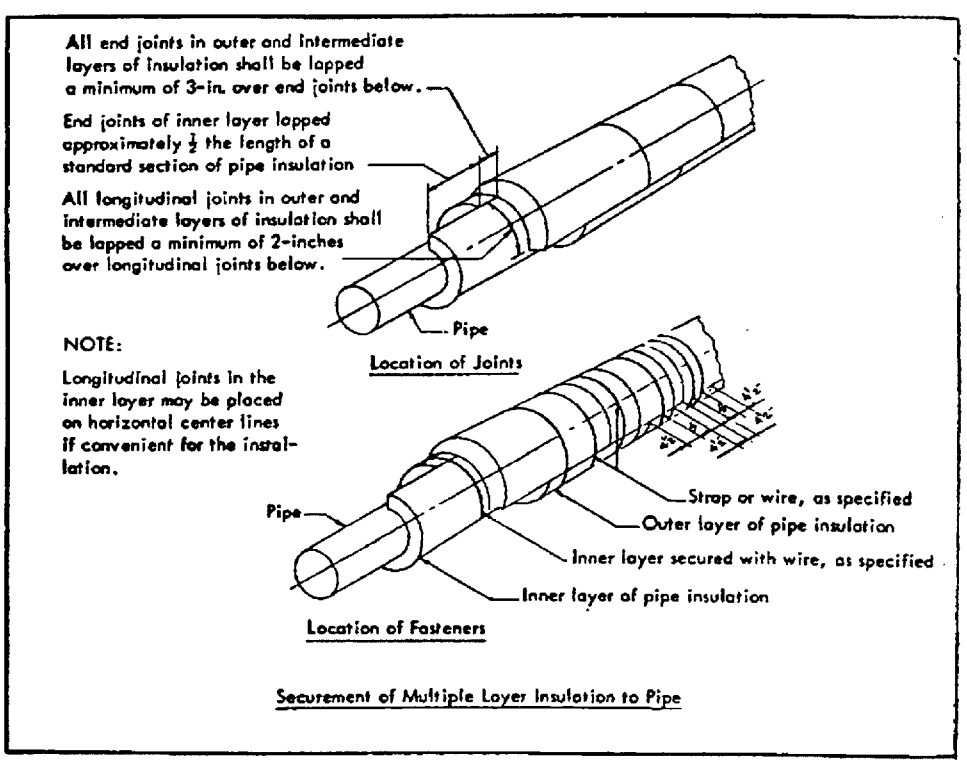


Figure XI-14

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

There are a number of things which must be done in preparation for the actual application of insulation. These are listed in order to assist the insulator in the organization of his work.

GENERAL PREPARATION OF INSULATION SYSTEMS

Materials

From the insulation list, drawings, and specifications, it should be determined what materials are required. Based on this requirement, it should be determined if the correct quantities, sizes and thickness of insulation are at the job site and that the insulation is in good condition. Broken or wet material should be rejected and replaced. It should be further determined that fabricated valve, fitting and/or flange covers are of the right material, correct size and thickness and in good condition.

Of utmost importance is to check to find out if all accessories supplied are as specified and of proper quantity to do the job. Lack of a single accessory can delay the application just as much as the lack of the primary insulation material. A listing of these accessories which might be required is as follows:

1. Wire
2. Strap
3. Strap springs or expansion bands
4. Clips
5. Tape
6. Wire Netting
7. Expansion joint sleeve metal
8. Welding pins and clips
9. Cushion blanket
10. Sheet metal screws
11. Adhesive

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

GENERAL PREPARATION OF INSULATION SYSTEMS - Contd

Materials - Contd

12. Sealers
13. Caulking compounds
14. Anti-abrasive coatings
15. Insulating cements
16. Heat transfer cement
17. Flashing
18. Jacketing - metal or plastic
19. Weather-barrier plastics
20. Vapor-barrier
21. Fabric reinforcing for mastics

It is well to inspect such items as weather-barrier mastics, sealers, and adhesives to make sure that their consistency, and other application characteristics are suitable. Likewise, it is well to check insulation cements or other materials mixed with water to determine that they have been kept dry and are in good condition.

Scaffolding

Although scaffolding is erected by others, the insulator should inspect the scaffolding in reference to his needs for safe and efficient working conditions. If there are areas which need scaffolding for application, he should request that scaffolding be erected.

Surface Preparation

The insulator should determine if surface to be insulated should be painted, or otherwise treated prior to the application of the insulation. When surface painting is required, the paint must be completely dry before insulation is installed.

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

GENERAL PREPARATION OF INSULATION SYSTEMS - Contd

Surface Preparation - Contd

Any dirt, oil, or other contamination must be removed from surface before insulation is applied.

Masking for Spray Applications

Where insulation or coatings are applied by spray, it is necessary to protect the surfaces that are not to be insulated. Prior to the spray application, flanges, manholes and all other surfaces not to be insulated shall be wrapped with suitable coverings secured in position with wire or tape. These coverings shall be removed after application.

Instruments and all other areas which are to be kept free of insulation should be protected with suitable covering. All equipment and piping within 25 feet of spray application must be covered or screened against overspray, rebound and drift.

Supports

With the exception of insulation which depends completely on adhesion for its support, all insulation in vertical vessels, large horizontal vessels, and long vertical lines requires supports.

The insulator should assure himself that proper insulation supports have been provided for his application of insulation. These have been discussed in Chapter XI; however, to summarize the support requirements, the following listing is presented:

1. Rigid insulation on vertical equipment exceeding 1'-5" OD by 10'-0" high shall have supports in accordance with Engineering Standard EQ-64 or EQ-68.

2. Rigid insulation or dished heads of vertical vessel shall have supports in accordance with Engineering Standard EQ-64 or EQ-68.

3. Rigid insulation installed on horizontal vessels shall be supported in accordance with Engineering Standard EQ-69.

4. Rigid insulation installed on dished heads inside of skirts shall be supported in accordance with Engineering Standard EQ-64 or EQ-70.

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

GENERAL PREPARATION OF INSULATION SYSTEMS - Contd

Supports - Contd

5. Rigid insulation installed on bottom head of large high temperature vessels shall be supported by rectangular pins spaced as shown in Engineering Standard EQ-67.

6. Where sprayed asbestos insulation requires support, it shall be supported by straight pins and clips or split pins. These are shown on Figures XI-5 and XI-6, Chapter XI.

7. Rigid insulation installed on high temperature spheres shall be supported by straight pins and clips.

8. Rigid insulation installed on low temperature spheres shall be supported in accordance with Engineering Standard EQ-66.

In most instances, supports are not installed by the insulators. The supports are the base from which insulation starts. If this base is not correct, the insulation application is not correct and the probability is that a failure will occur. Thus, it is essential that the insulator knows what supports are required and insists that these be provided so that he can install a good insulation system.

Types of Tracing System

Traci ng systems are systems using pipe, tubes, coils, or electric cable attached to the outside of equipment or pipe to heat or cool that equipment or pipe. These can be installed in several ways, and may employ various mediums to supply refrigeration or heat.

Cooling medium to reduce temperature of coils, pipe or tubes may be brine or other refrigerant.

Heating medium to raise temperature may be steam, hot vapor, hot liquid or electricity. In the case of where steam, vapor or liquids are used as the heating medium, the tracers used may be plate coils, tubes or pipes. Where electricity is used as the heating medium, the tracers are electric cables or electric strip attached to the equipment or pipe. Installation of these various tracers to the equipment, or pipe, is by various methods depending upon the need.

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

GENERAL PREPARATION OF INSULATION SYSTEMS - Contd

Air Convection Tracer System - Piping

Tracers may be installed as a single or multiple system, however, multiple tracer air convection systems cannot be economically justified as a single system connected by heat transfer cement is less expensive to install. Thus, air convection systems are limited to one single parallel tracer.

The air convection system functions by heating the air in the annulus space between the pipe and the inside of the insulation. This system is sufficiently effective to be used where it is only necessary to maintain the pipe temperature at a considerable lower temperature than the steam.

There are two methods of installing air convection traced systems. One is to wire the tracer tubing to the pipe and the other is to hold the tracer from the process pipe with spacers then secure in position with straps directly over the tubing at the spacers. These two systems are shown in Figure XII-1.

The use of spacers are necessary when the tracer line is at a temperature which might cause degradation of the process material and direct contact to the process line might cause excessive spot temperatures. Another instance when the spacers are required are when tracers are applied to aluminum lines. When aluminum pipe it to be traced, the piping must be separated from the tracer assembly by not less than two wrappings of glass cloth tape applied to the line. Care must also be taken that the tracer line does not contact the aluminum process line at any point. Where a tracer may touch the aluminum line between supports, the line must be wrapped with glass to prevent this contact. Manner of installing steam tracers is shown in Standard P-140. Recommended numbers of feet of tubing for tracing valve bodies is shown in Table XII-1.

HEAT TRANSFER CEMENTED TRACER SYSTEMS - PIPING

Surface Preparation

Where tracers are thermally connected to pipe with heat transfer cement, proper surface preparation of the surfaces, to which the tracer system is to be applied, is of utmost importance. The proper functioning of the systems depends completely upon the obtaining of a thermal and a mechanical bond between the surface and the heat transfer cement. For this reason the surface treatments of the metal surfaces as listed below must be followed with extreme care:

Carbon Steel Pipe operating at temperature above 150 F shall be cleaned of all scale,

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

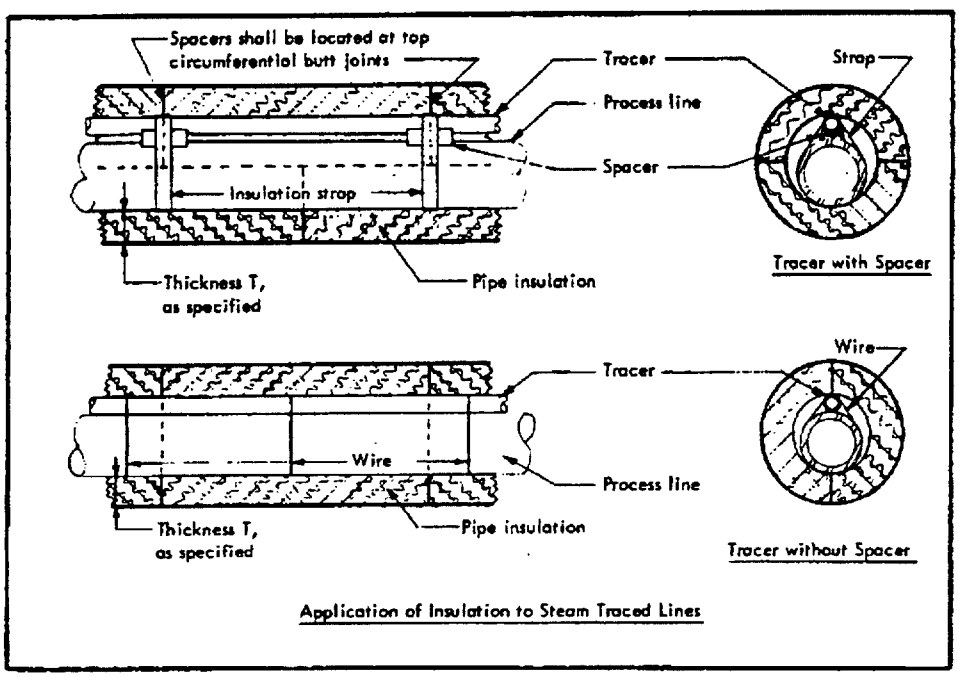
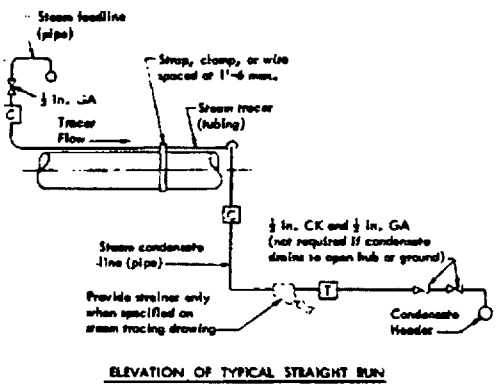


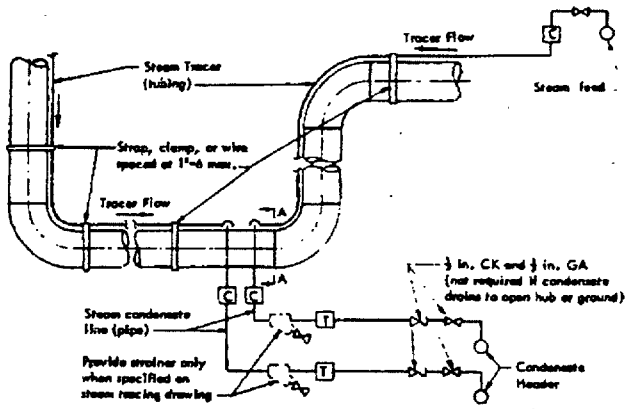
Figure XII-1

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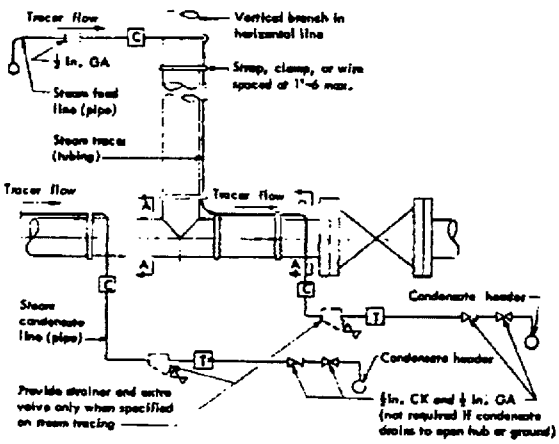
STEAM TRACING SYSTEM DETAILS AND MATERIALS



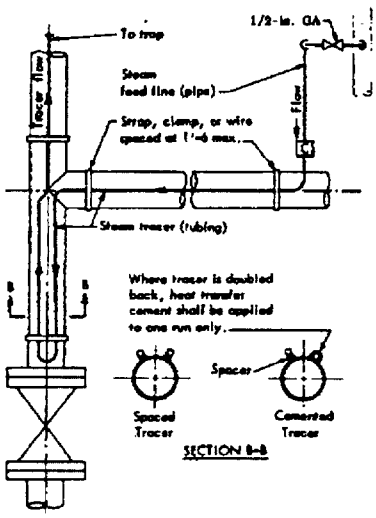
ELEVATION OF TYPICAL STRAIGHT RUN

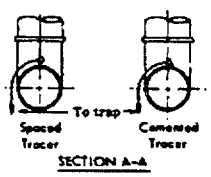


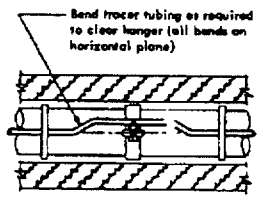
ELEVATION OF POCKET IN VERTICAL RUN



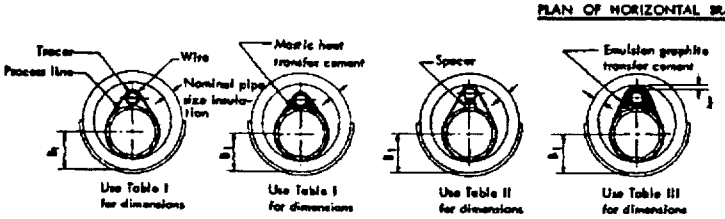
ELEVATION OF VERTICAL BRANCH IN HORIZONTAL LINE



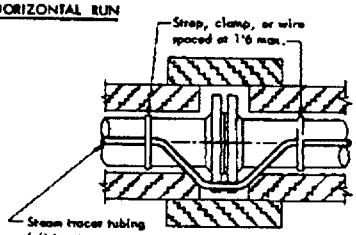


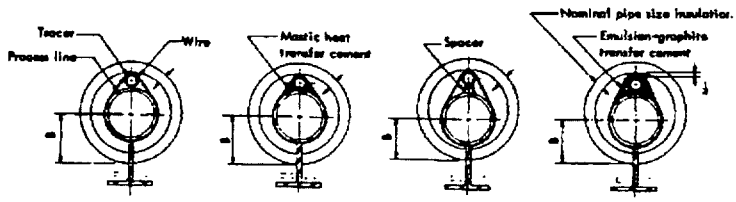


PLAN OF HORIZONTAL BRANCH IN HORIZONTAL RUN



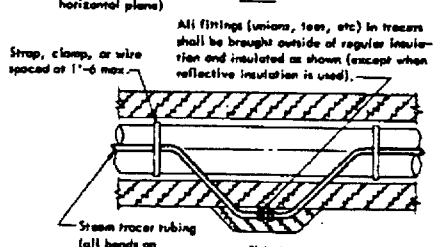
SUPPORTED ON INSULATION





SUPPORTS ATTACHED TO PROCESS PIPE

DETAILS OF STEAM TRACER ATTACHMENT



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.

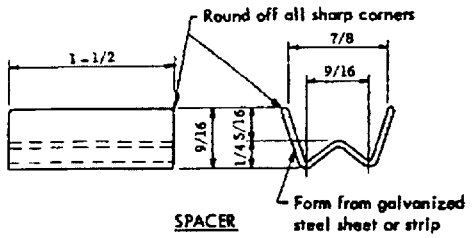
Unless otherwise indicated, all dimensions given in inches.

PAGE 1

ENGINEERING STANDARD P-140

UCC 002861

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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 "Utilitube", 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 "Swagelok", 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 "Swagelok", 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.
	stainless steel (any 18-8 type) 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	Thermon Manufacturing Company, Houston, Texas, or approved equal.		

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

COVERAGE FOR VALVES

VALVE SIZE	FEET OF TUBING REQUIRED			
	TUBING SIZE			
	3/8"	1/2"	5/8"	3/4"
1 1/2"	2 — 3	1 — 2	—	—
2"	3 — 5	2 1/2 – 3 1/2	—	—
3"	4 — 7	3 1/2 – 4 1/2	—	—
4"	6 — 10	5 — 7	4 1/2 – 5 1/2	3 1/2 – 4 1/2
6"	9 — 15	7 — 11	5 — 9	4 — 8
8"	12 — 20	9 — 15	7 — 12	6 — 10
10"	15 — 25	10 — 20	8 — 14	7 — 12
12"	18 — 30	15 — 25	12 — 20	8 — 13
14"	—	21 — 35	16 — 28	12 — 20
16"	—	24 — 40	20 — 32	16 — 25
18"	—	27 — 45	24 — 35	20 — 30
20"	—	30 — 50	25 — 40	20 — 35
24"	—	36 — 60	30 — 50	25 — 40
30"	—	45 — 75	40 — 60	35 — 50
36"	—	54 — 90	45 — 70	40 — 60

Table XII-1

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

HEAT TRANSFER CEMENTED TRACER SYSTEMS - PIPING - Contd

Surface Preparation - Contd

rust, dirt, or oil. These should be removed by wire brushing and suitable solvents. All mill varnish or protective organic coating shall be removed with suitable varnish strippers.

Carbon Steel pipe operating at temperature below 150F must be sandblasted and coated with inorganic silica zinc coating in accordance with UCC Coating Specification. Exception is where existing pipe which has been previously painted, the area to which tracer is to be installed should be with varnish strippers. After tracing and cement is installed paint shall be touched up.

Stainless Steel pipe at all operating temperatures shall be cleaned of all dirt and oil. Backs of flanges and six inches on either side of welds shall be coated with silicone graphite coating in accordance with UCC Coating Specification. Due to process or atmospheric conditions it is sometimes necessary to protect the entire line with the coating. Such shall be done where specifically specified.

Aluminum piping should be cleaned of oil, dirt and grease. When water mix heat transfer cement is to be used, the surface in contact with the cement must be coated with an aluminum primer (ALP). Resin heat transfer cement requires no primer.

The surfaces of galvanized steel pipe, copper pipe and tubing must be cleaned of dirt, grease, oil and other contaminates.

Installation of Tracers

The general installation of the tracer tubing is done by pipe fitters and the electric tracers by electricians. The final securement and thermal bonding is to be done by the insulators.

Types of Heat Transfer Cement

Heat transfer cements are a family of products designed to conduct heat from a source to a point of use. Each particular heat transfer cement is designed for a particular set of conditions. Some of the conditions affecting the selection are (1) Source temperature, (2) heat source medium, (3) type of tracer, (4) metal or surface coating on tracer and process pipe to which it is attached, (5) atmospheric or process contamination, (6) application temperature, (7) required physical characteristics, (8) curing requirements, (9) differential expansion and elongation requirements, (10) method of application, (11) overall heat transfer characteristics.

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

HEAT TRANSFER CEMENTED TRACER SYSTEMS - PIPING - Contd

Types of Heat Transfer Cement - Contd

As the material is selected to fulfill these requirements, care must be taken that the heat cement specified is the one used.

Of this family of heat transfer cements, basically, there is the water mixed types and the resin types.

These types of heat transfer cements and their basic properties and limitations are shown in Figure XII-2. Because of the differences in the cements and installation requirements, several systems of application are required.

Two systems are used for the installation of water mixed heat transfer cements. One is by trowelling into position, completely covering the tracer and bonding it to the pipe. With this system care must be taken to press the cement tightly between the tracing tubing (or electrical tracer) and the process pipe. The cement must cover the tracer by 1/4". This 1/4" coverage is required to ensure that the mechanical strength is sufficient to withstand the force exerted by the expansion of the tracer tubing. Base of the cements in contact with the process pipe must be a minimum of three times the outside diameter of the tracer. This configuration is shown as Section 1 in Figure XII-2. The lineal feet per gallon, per tracer is given in Table XII-2.

The other system is to install the water-mix heat transfer cements with metal channels. These channels may be factory filled or they may have to be filled by trowel at the time of installation. The filled channels are pressed over the tracer and secured in place by straps. This installation is shown in Figure XII-3. Application arrangement of multiple systems are shown in Figure XII-4. Lineal feet coverage of water mix cement is shown in Table XII-2. This system should be used where pipe cannot be properly cleaned.

Both systems can be used for either steam or electric tracing however, it is advisable to use the metal channel system for all electrical traced systems and critical steam traced systems which are bonded to the process pipe or equipment with water-mix cement.

Like the steam tracing which is installed by the pipe fitters, the electric tracing system is installed by the electricians but cement bonding and final securement is done by the insulators. The installation of electric tracing on pipe and fittings are shown in Figure XII-5.

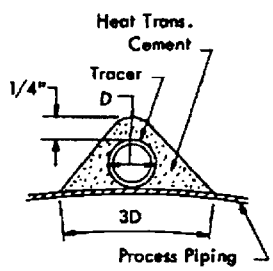
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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

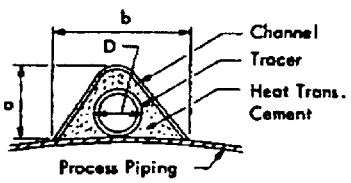
HEAT TRANSFER CEMENTS

GENERIC TYPE	NO.	SHELF LIFE	STORAGE	APPLICATION					CURED MATERIAL	SERVICE TEMPERATURE F			
				INSTALL. CROSS SECTION	MINIMUM AMBIENT TEMP F	HAZARDS	CURING	SOLVENTS FOR CLEAN UP		Continuous MIN.	Continuous MAX.	Intermittent MIN.	Intermittent MAX.
Emulsion Mastic	"Std"	1 Yr	Store Above 32F	Sec. 4 or Channel	33F	Alkaline Keep Away From Eyes	* Heat 160 to 212 4 Hours	Soap and Water	Hard Solid	32	600	-320	750
Emulsion Mastic	T-63	1 Yr	Store Above 32F	Sec. 1 or Channel	33F	Alkaline Keep Away From Eyes	Heat 160 to 212 4 Hours	Soap and Water	Hard Solid	32	1250	-320	1250
Solvent Resin	T-85	60 to 90 Days	Refrig. Below 40F	Sec. 2	70F or With Heated Gun	Sticky Wear Gloves	None Protect From Rain	MEK Toluene Turpentine	Elastic Solid	-200	375	-200	375
Solvent Resin	T-80	60 to 90 Days	Refrig. Below 40F	Sec. 2	40F	Sticky Wear Gloves	None Protect From Rain	MEK Toluene Turpentine	Elastic Solid	-200	325	-200	325
Two-Component Resin	T-802	1 Yr	Ordinary	Sec. 2	33F	Toxic to Skin Wear Gloves	2-Part Mix Working Time 3/4 to 2 Hrs	Trichloro-ethane Toluene MEK	Elastic Solid		275		275
Resin	T-5	1 Yr	Ordinary	Sec. 3	33F	Sticky Wear Gloves	None Req'd.	MEK Toluene Toluene	Remains Plastic	-200	180	-200	180

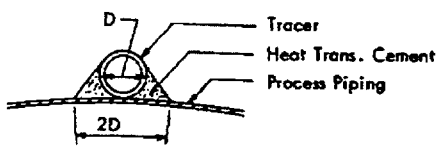
* No curing procedure required when installed by channel system



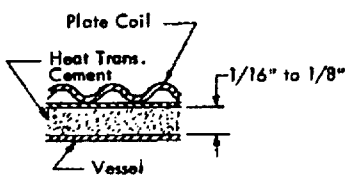
SECTION 1



CHANNEL SYSTEM



SECTION 2



SECTION 3

TRACER SIZE	CHANNEL DIMENSION a	CHANNEL DIMENSION b
3/8 OD	7/8	1-3/16
1/2 OD	7/8	1-3/16
5/8 OD	7/8	1-5/16
3/4 OD	1-1/4	1-11/16
7/8 OD	1-1/4	1-11/16

FIGURE XII-2

UCC 002866

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

CEMENT COVERAGE PER SINGLE PARALLEL TRACER WATER-MIXED HEAT TRANSFER CEMENT

TROWELLED ON

TRACER SIZE	PROCESS LINE SIZE	FEET OF TRACER PER GALLON
1/4 OD	1/2" through Flat	50
3/16 OD	1/2" through Flat	49
3/8 OD	1/2" through 1-1/4"	45
	1-1/2" through Flat	48
1/2 OD	1/2" through 1-1/4"	30
	1-1/2" through Flat	33
5/8 OD	1/2" through 1-1/4"	23
	1-1/2" through Flat	28

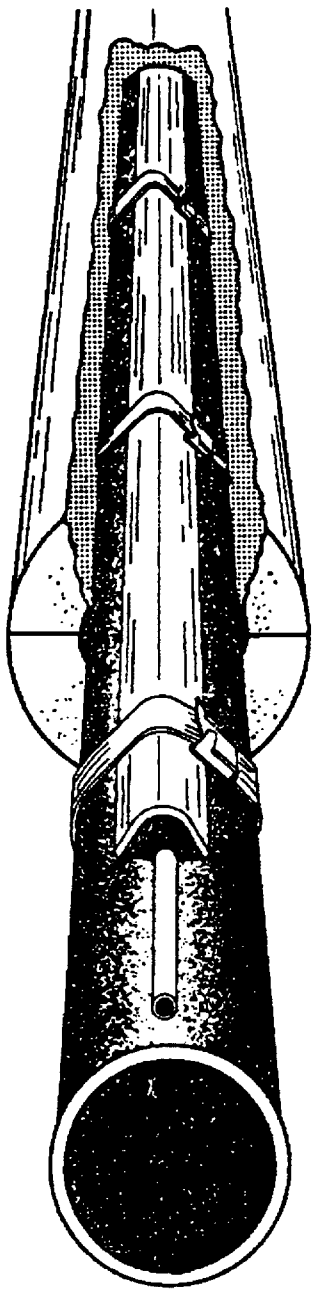
IN METAL CHANNELS

3/8 OD	1/2" through 2"	37 to 41
	2-1/2" through Flat	34 to 37
1/2 OD	1-1/2" through 2"	43 to 47
	2-1/2" through Flat	40 to 43
5/8 OD	1-1/2" through 2"	44 to 48
	2-1/2" through 2-1/2"	39 to 32
3/4 OD	4" through Flat	28 to 30

TABLE XII-2

Union Carbide trial exhibit UC-2312: Union Carbide Chemicals and Plastics, Insulation Applicator Training Manua...
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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

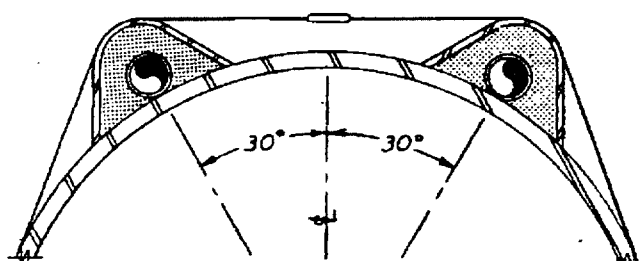


CHANNEL SYSTEM FOR INSTALLING HEAT TRANSFER CEMENT

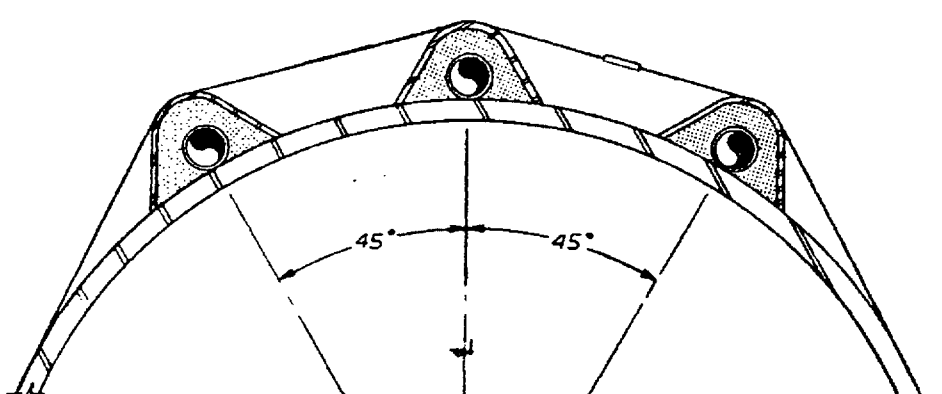
Figure XII-3

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS



DOUBLE TRACER



TRIPLE TRACER

SPACING OF MULTIPLE TRACERS
ON STRAIGHT PIPE

FIGURE XII-4

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

HEAT TRANSFER CEMENTED TRACER SYSTEMS - PIPING - Contd

Types of Heat Transfer Cement - Contd

Close attention to application of heat conductive cement to the electric and steam tracers on fittings and valves is of utmost importance. Electric traced elbows must have sufficient tracer length so that the equivalent length of traces to surface area is the same as the pipe. On elbows in vertical lines electric tracer must be installed as shown in top left illustration in Figure XII-5. In similar manner, additional tracing length must be installed on flanges as shown in Figure XII-6.

Should parts of electric tracers not be thermally connected with heat transfer cement these spots cannot transfer the heat generated to the process pipe. In turn this will cause a temperature rise at that spot with the possibility that the temperature may exceed the limits of the cable and will result in a burn-out.

Because of their large outside area as compared to pipe valves also require additional tracer length and very careful installation of the heat transfer cement. This additional length of electric tracing required is shown in Figure XII-5. The amount of heat transfer cement used to cement traces to the valve body is greater than would be used for equivalent lengths of pipe. The amount of water-mix type heat transfer cement required per valve is given in the Table XII-3.

In summary, insulation specification can only point out the intent. Specifications cannot describe in detail such as was done in this manual. The insulation craftsmen must know and be able to perform the detail installation. To illustrate this fact the manner in which the application of water-mix cement is specified is illustrated in Figure XII-7 and the resin type in Figure XII-8. It is evident from the preceding that it is impractical to attempt to cover all installation details in an "Insulation" Specifications.

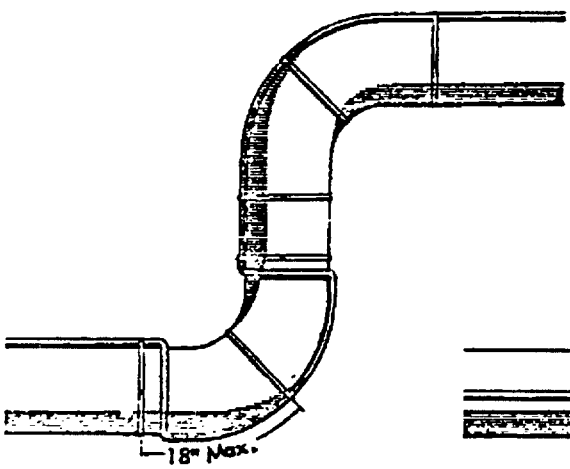
HEAT TRANSFER CEMENTED TRACER SYSTEMS - EQUIPMENT

Surface Preparation

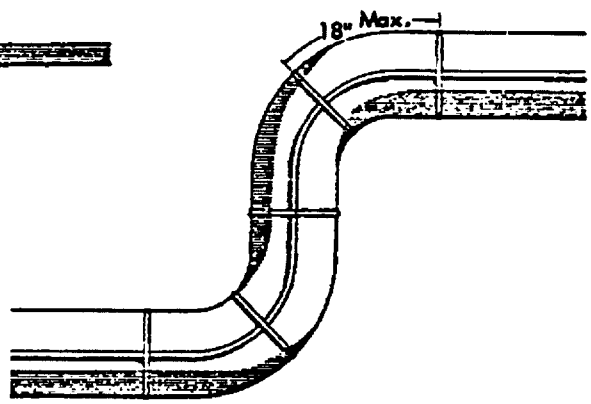
The surface preparation for vessels and equipment which are to have heat cemented tracer systems shall be the same as listed for piping with one exception. This exception is that stainless steel vessels shall be entirely coated with specified protective coating.

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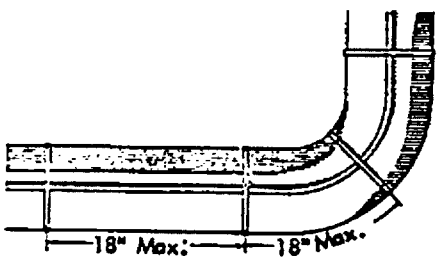
GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS



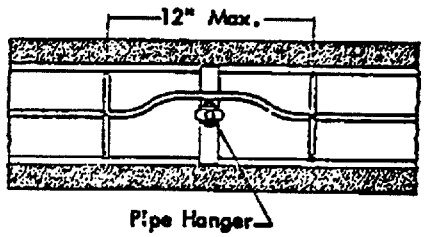
MI ELECTRIC HEATER ON VERTICAL PIPE RUN OF 3" NOM. SIZE AND LARGER

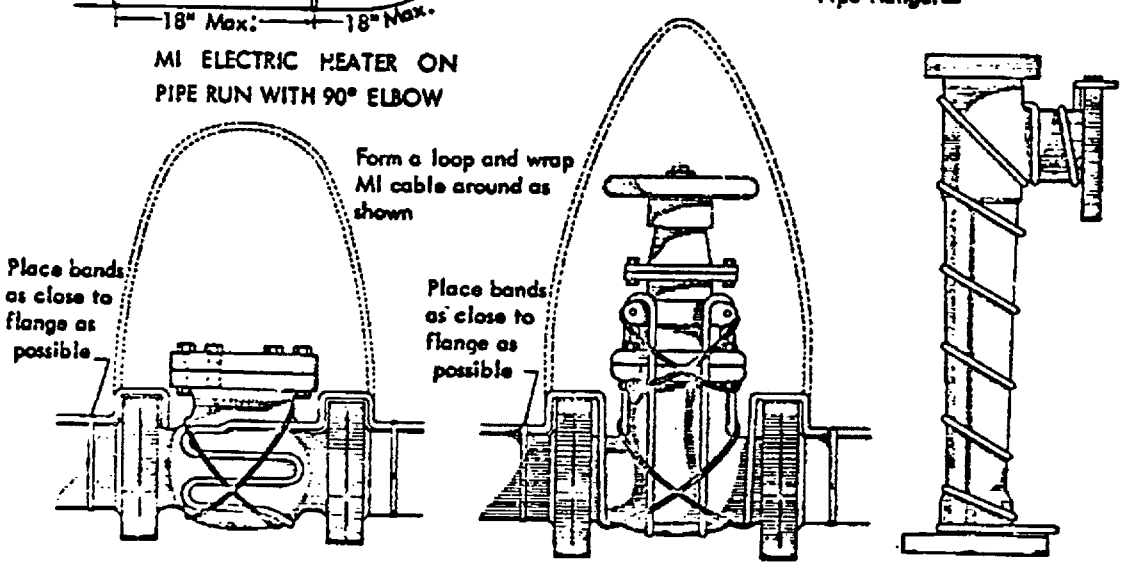


MI ELECTRIC HEATER ON VERTICAL PIPE RUN OF LESS THAN 3" NOM. SIZE



MI ELECTRIC HEATER ON PIPE RUN WITH 90° ELBOW





MI ELECTRIC HEATER APPLIED TO CHECK VALVE

MI ELECTRIC HEATER APPLIED TO GLOBE OR GATE VALVE

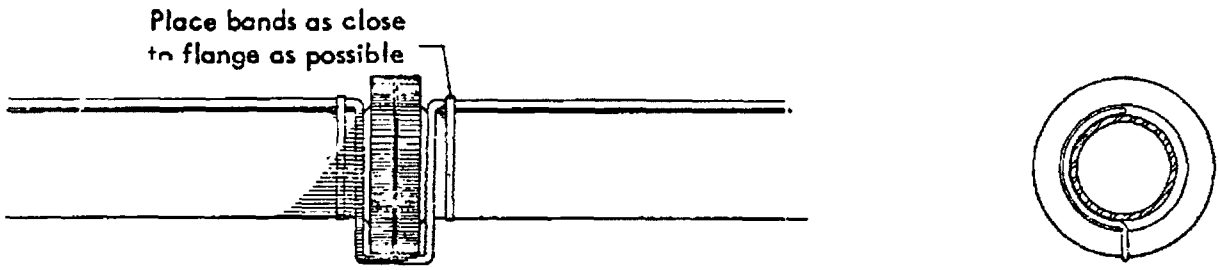
MI ELECTRIC HEATER APPLIED TO ROTAMETE

MI ELECTRIC HEATER INSTALLATION DETAILS

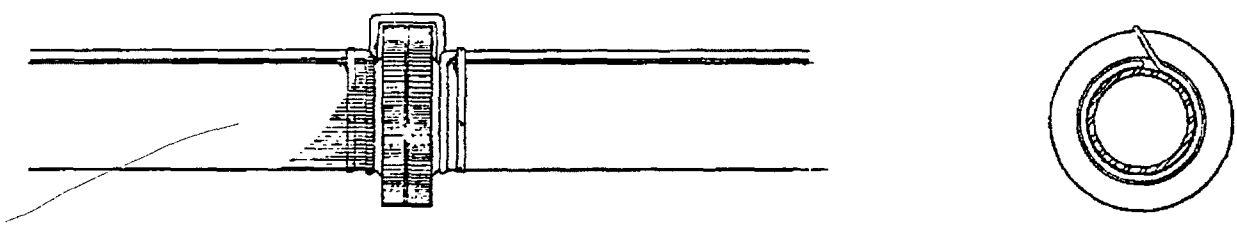
Figure XII-5

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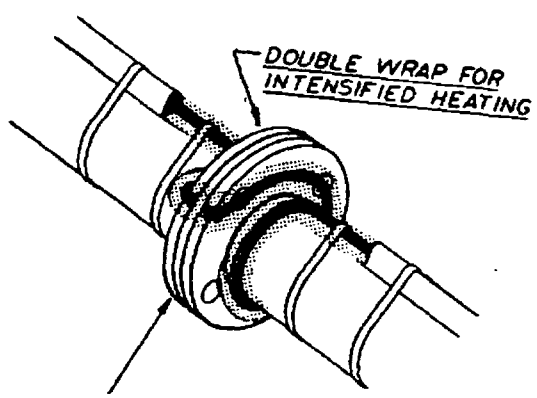
GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS



MI ELECTRIC HEATER ON PIPE FLANGE 2" AND SMALLER



MI ELECTRIC HEATER ON PIPE FLANGE LARGER THAN 2"



APPLICATION OF HEAT TRANSFER
CEMENT TO PIPE FLANGE ELECTRIC HEATER

FIGURE XII-6

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

CEMENT COVERAGE FOR BODY OF VALVE

VALVE SIZE NPS	GALLONS OF WATER-MIX HEAT TRANSFER CEMENT PER VALVE
1-1/2	0.36
2	0.43
3	0.71
4	1.00
6	1.43
8	2.00
10	2.50
12	3.00
14	3.50
16	4.00
18	4.50
20	5.00
24	6.00
30	7.50
36	9.00

TABLE XII-3

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

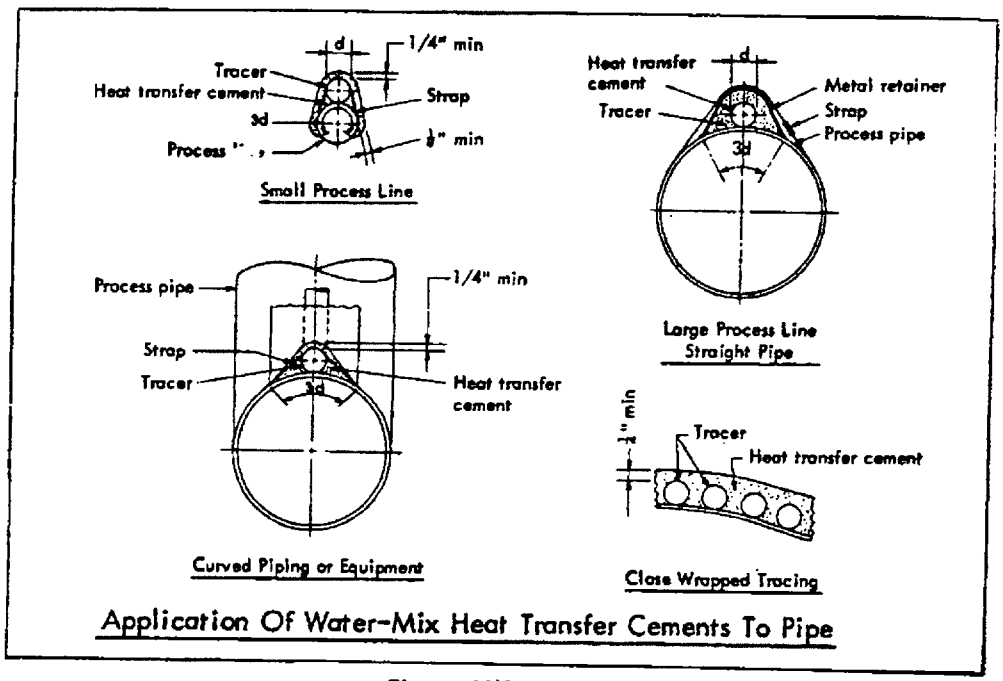


Figure XII-7

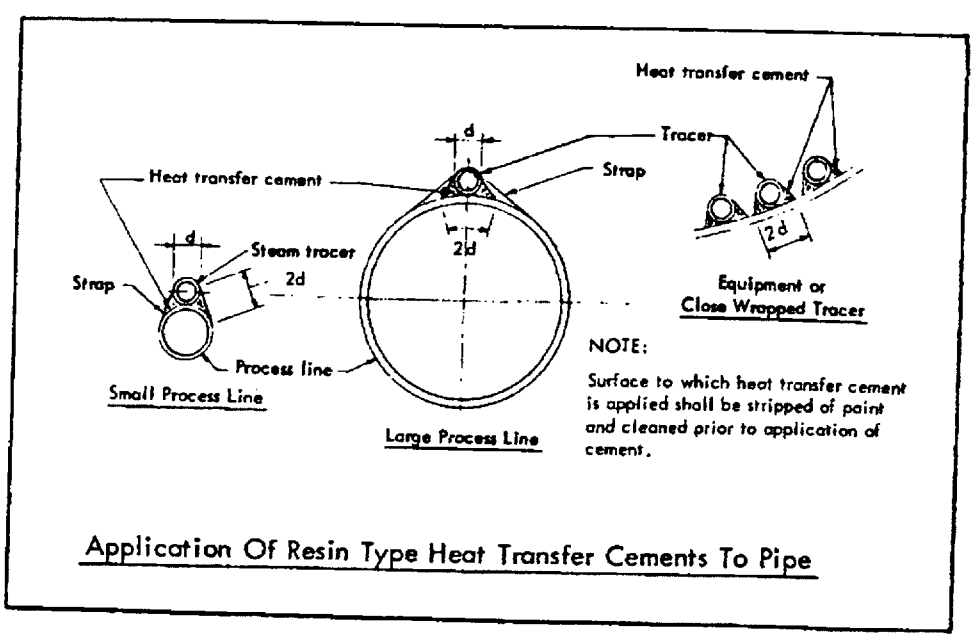


Figure XII-8

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

HEAT TRANSFER CEMENTED TRACER SYSTEMS - EQUIPMENT - Contd

Installation of Tracers

Tracers should always be installed in hair-pin fashion rather than completely encircle the vessel. Reason for this is that when tracers are in a complete circle the expansion causes the diameter of the circle to become larger. This enlargement of the circle cannot be restrained by the bond and tensile strength of the heat transfer cement. When installed in parallel hair-pin fashion the extensibility of the cement is sufficient to allow linear movement without loss of bond. Proper installation is illustrated in Figure XII-9.

Application of Heat Transfer Cement

The application of both the water-mix and resin type cements in vessels and equipment shall be the same as given for piping.

Plate Coils

Plate coils are made for the heating and cooling of vessels. These also should be thermally attached by heat transfer cement. The surface preparation at the area of installation of plate coils should be identical with those already listed.

Because of the area involved water-mix cements are not satisfactory for the application of plate coils. Moisture towards the center would be difficult to remove even after long periods of airing. For this reason a special heat transfer cement is used for the bond of plate coils to vessels. This is a resin type, named T-5.

Plate coils can be obtained with heat transfer cement already applied. In such installations clean properly treated surfaces to which the coil is securely attached by bands, straps, bolts or studs, is all that is required.

Where plate must be coated with the heat transfer cement its surface must be cleaned and coated as previously described. The heat transfer cement should be 1/16" to 1/8" thickness between the two surfaces, with no voids. Installation of plate coil to vessel is shown in Figure XII-10.

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS

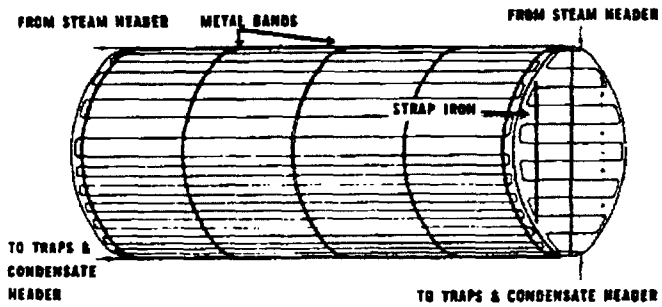
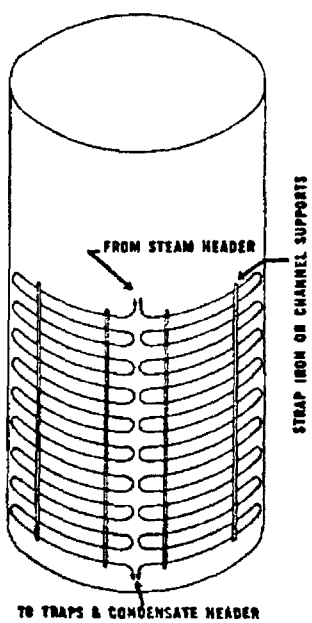
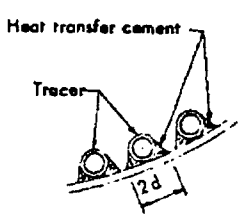
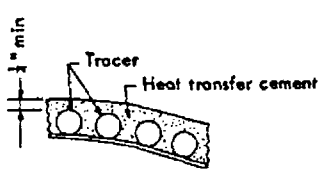


FIGURE 5 — Tubing layout for a horizontal vessel.



Tubing layout for vertical vessel with a high heat load and rather long individual tracing runs.





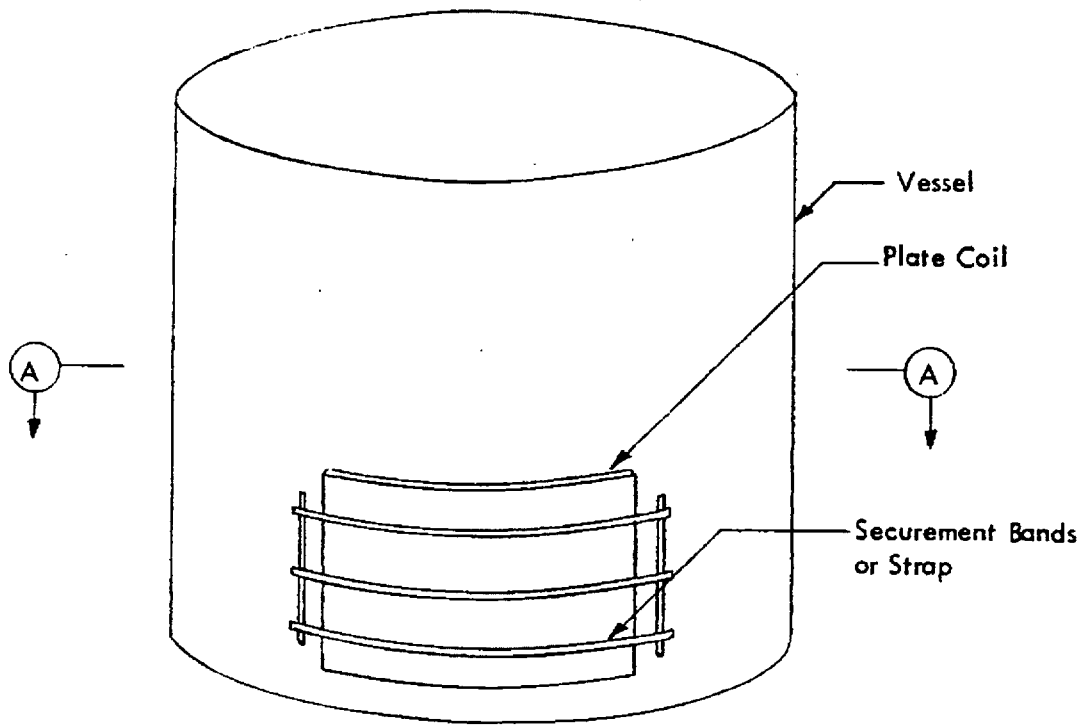
Close Wrapped Tracing

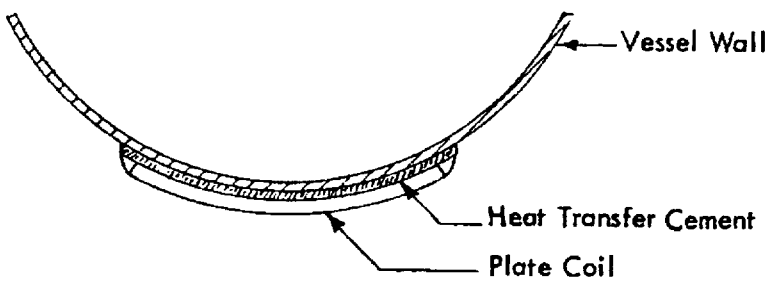
CEMENTING DETAIL

Figure XII-9

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GENERAL PREPARATION OF INSULATION SYSTEMS AND APPLICATION OF HEAT TRACER SYSTEMS





SECTION AA

INSTALLATION OF PLATE COIL TO VESSEL

Figure XII-10

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

GENERAL

Application procedure of insulation for hot service depends upon the type of insulation. Soft flexible materials are installed in a different manner than rigid materials. For this reason it is necessary to discuss the installation as it applies to each particular type of insulation.

EQUIPMENT

Supports

This type of insulation is supported by rings attached to the vessels. The only exception is where rigid insulation is installed on spheres it is secured by pins and speed clips.

Surface Preparation

Surfaces to be insulated should be properly cleaned. Painting of carbon steel vessels under the insulation is only required where vessel temperature is less than 150F or where it might be expected to be out of operation for relatively long periods of time.

Stainless steel vessels and equipment should be coated with Thermalox No. 70 in accordance with UCC Coating Specifications prior to application of the insulation.

The surfaces of vessels or equipment of aluminum, copper, or galvanized steel must be cleaned of all dirt, grease, oil and other contamination prior to application of the insulation.

Application of Insulation

The temperature, size, and shape of the equipment also affects the manner of installation. The service temperature of equipment dictates the amount of dimensional change which will occur when the vessel is placed in service. Size and shape affects the method of supporting and securing of insulation so that it remains in position, and intact.

On cylindrical vessels less than 400 F service temperature and less than 8 feet in diameter, rigid block insulation can be applied directly to the vessel surface. Insulation block should be properly shaped to curved sectors to fit contour of the vessel. Base on first course of block should rest firmly on support so that all lateral joints run in parallel line with center of the vessel. The first course shall have alternate half blocks so that end joints are in staggered position. The blocks shall be secured in position with strap, pulled taut and fastened together with two-pronged clip. This installation is illustrated in Figures XIII-1 and XIII-2.

Where the cylindrical vessel is greater than 400F service temperature or greater than 8'-0" in diameter, a 1" thick cushioning blanket must be installed over the entire surface of the vessel prior to the installation of the rigid block. The rigid block should be formed to be two inches

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APPLICATION – RIGID INSULATION
HIGH TEMPERATURE SERVICE

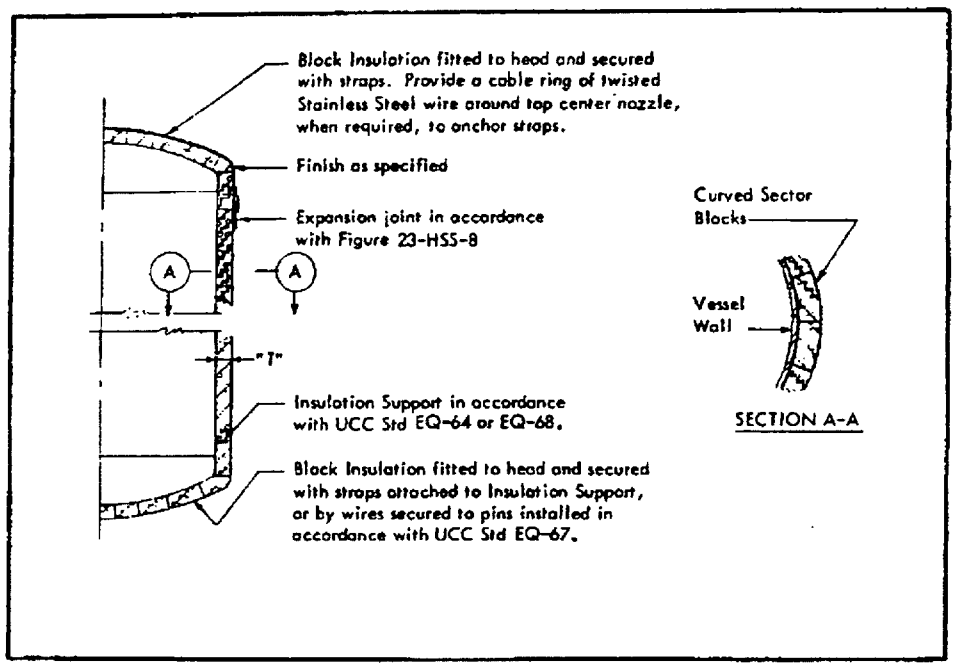


Figure XIII-1

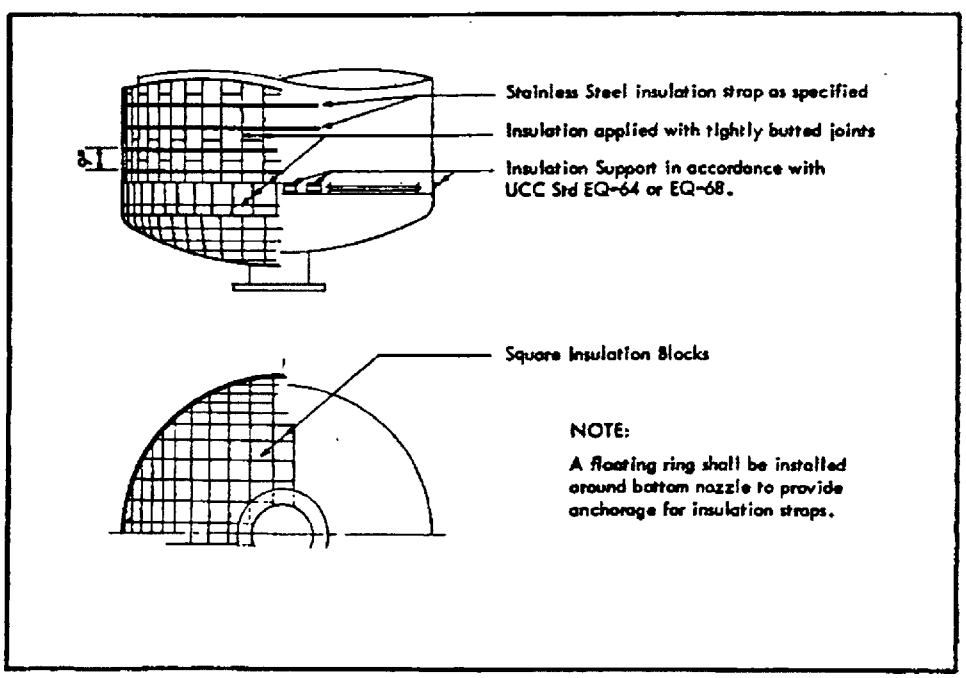


Figure XIII-2

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

EQUIPMENT - Contd

Application of Insulation - Contd

greater in inside diameter than the outside diameter of the vessel shell to allow for the increase in vessel diameter when it is heated. When vessel is heated and expands, the cushion blanket is compressed, allowing the outer diameter of the rigid insulation to stay the same. This is illustrated in Figure XIII-3.

The vessel also grows in length as it is heated. For this reason, it is necessary to allow for this change in dimension by providing slip joints in the insulation on vertical vessels. Slip joints at a vessel flange and insulation supports are shown in Figures XIII-4 and XIII-5.

When the vessel expands, its change in dimensions causes the nozzles and pipe connections, on the cylindrical sides, to change location in relation to the cylindrical side wall insulation. If the insulation is secured tightly to the nozzle and to the side wall, a break must occur. For this reason, it is necessary to allow for this differential change. This is accomplished by the use of oversize flange covers which will allow movement. These are shown in Figures XIII-6 XIII-7.

Flat surfaces such as large ducts which operate at high temperature present a major problem of support and securement of insulation to prevent expansion caused opening of joints. No truly good manner of installation has ever been developed. On these flat surfaces the insulation must be secured to the surface itself. As this surface expands, the movement is transmitted to the insulation block and will cause opening of the butt joints. On very high temperatures it is desirable to use multi-layer broken joint construction to minimize heat leak. On the outer surface of either single or multiple layer block, wire netting should be installed, over which 1/2 inch thick insulation cement is troweled to a smooth, even surface. The insulation cement reinforced with wire netting has more elasticity than rigid block; therefore, it has a tendency to elongate as the metal surface elongates. Such an application is illustrated in Figure XIII-8.

Block insulation which terminates at any location should be tapered to provide water shed, or, where it terminates at a fire-proofing or base of equipment, it must be sealed off to prevent the entry of water. Such terminations are shown in Figures XIII-9, XIII-10, and XIII-11.

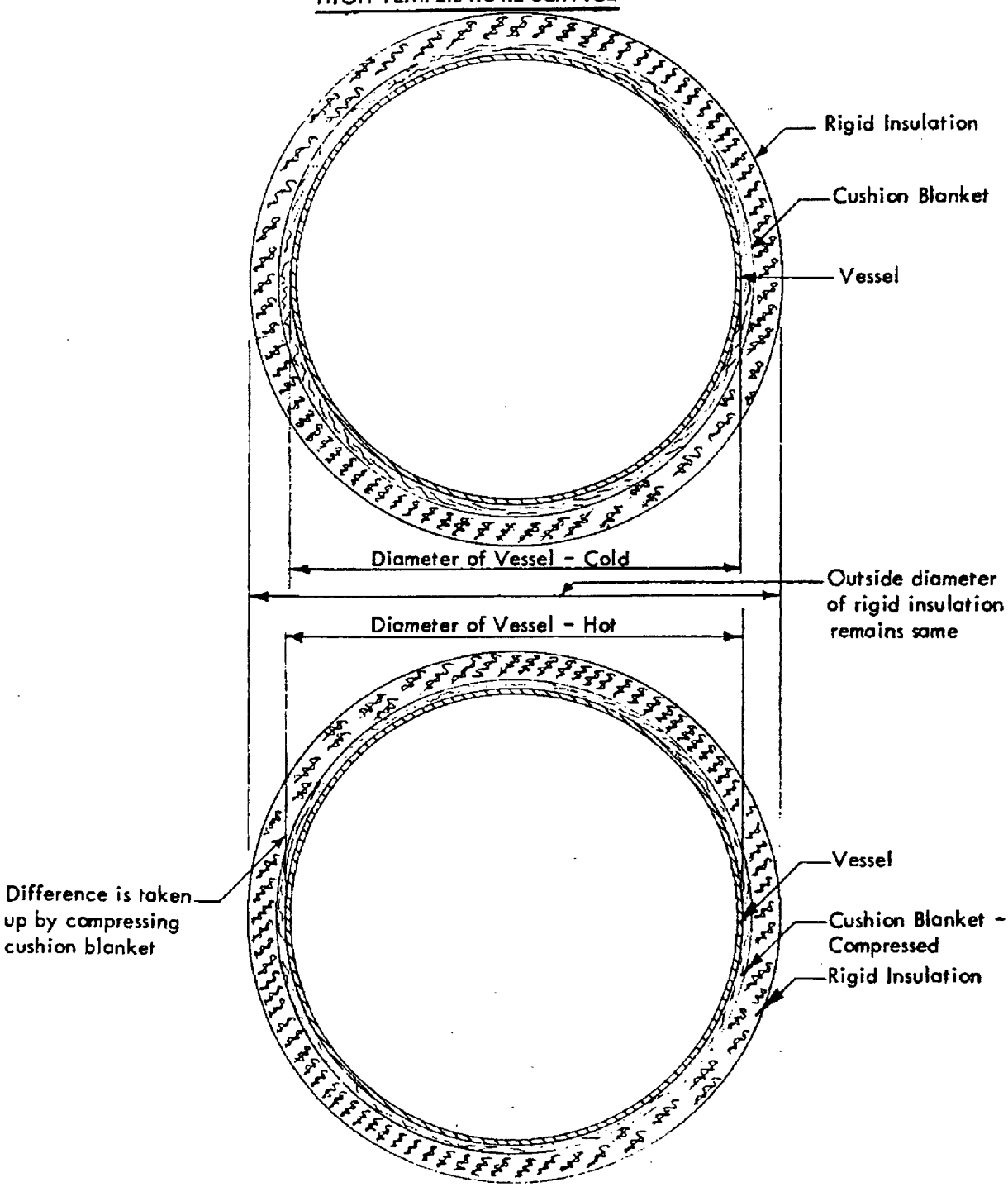
PIPING

Surface Preparation

Surface preparation of piping shall be identical to insulation except stainless steel pipe shall be coated only behind flanges and elsewhere as specifically specified.

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE



USE OF CUSHION BLANKET
UNDER RIGID INSULATION

Figure XIII-3

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

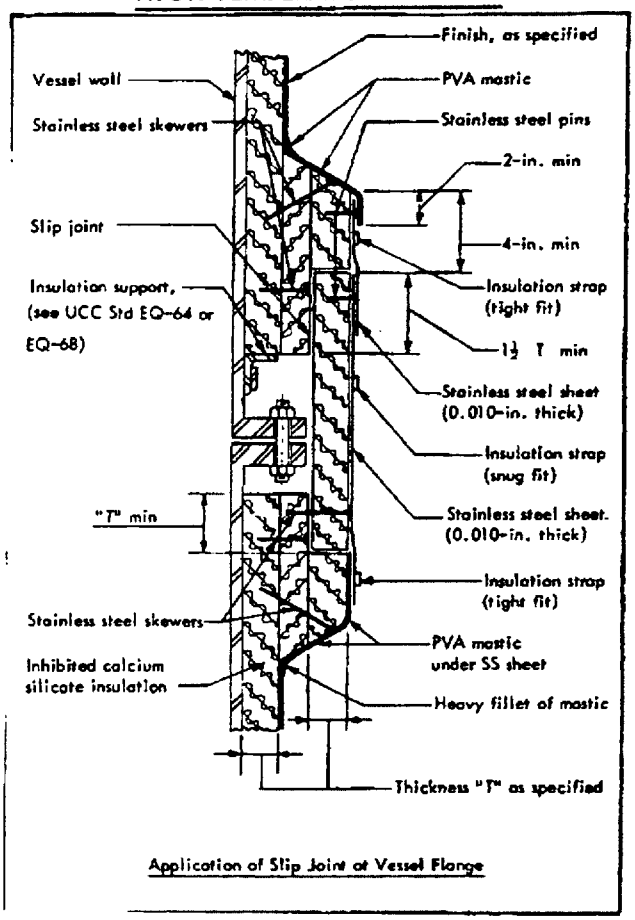


Figure XIII-4

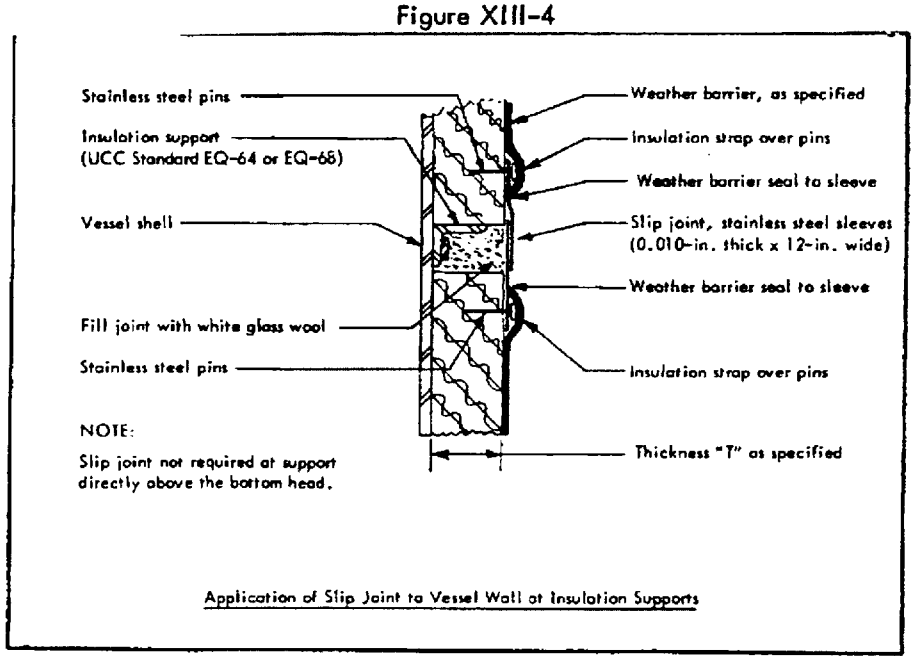
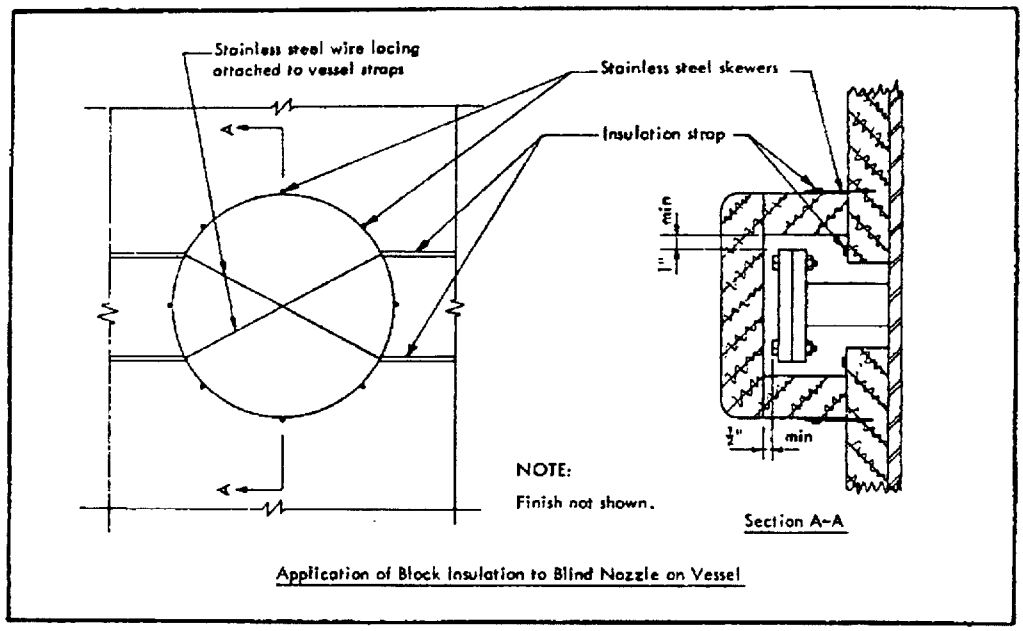


Figure XIII-5

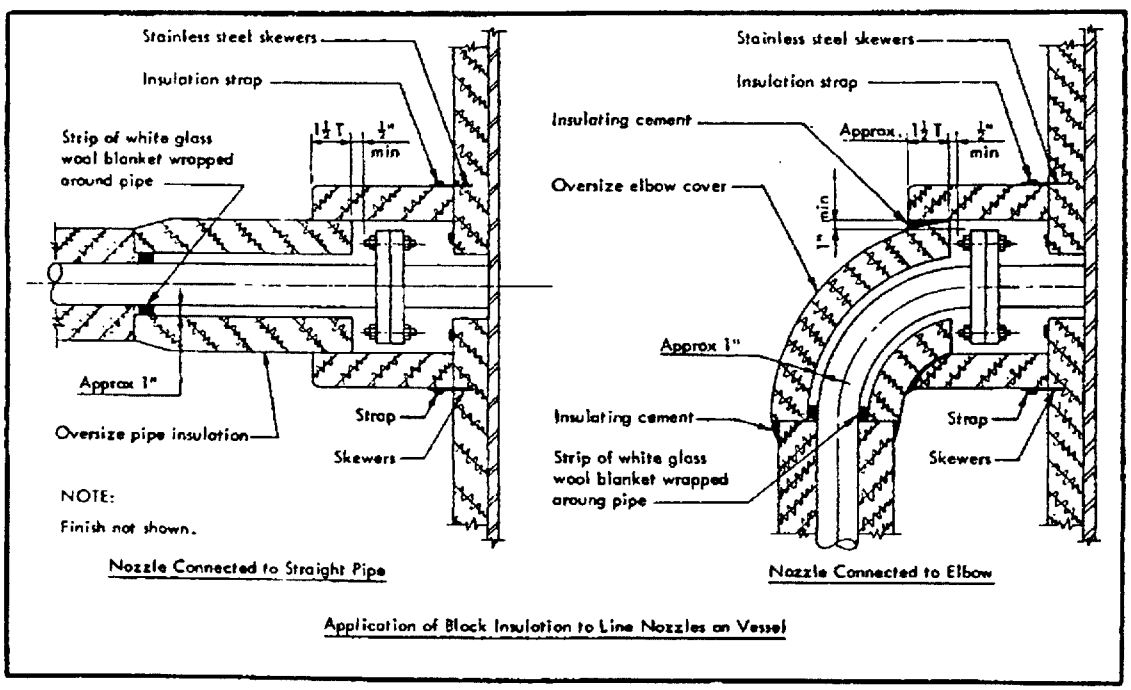
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APPLICATION - RIGID INSULATION
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Application of Block Insulation to Blind Nozzle on Vessel

Figure XIII - 6



Application of Block Insulation to Line Nozzles on Vessel

Figure XIII - 7

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APPLICATION - RIGID INSULATION
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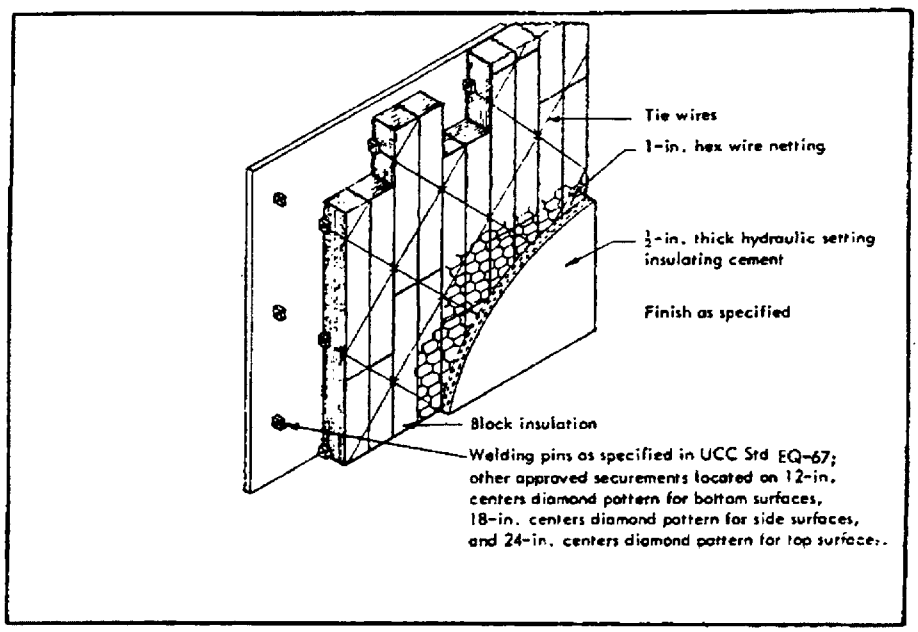


Figure XIII-8.

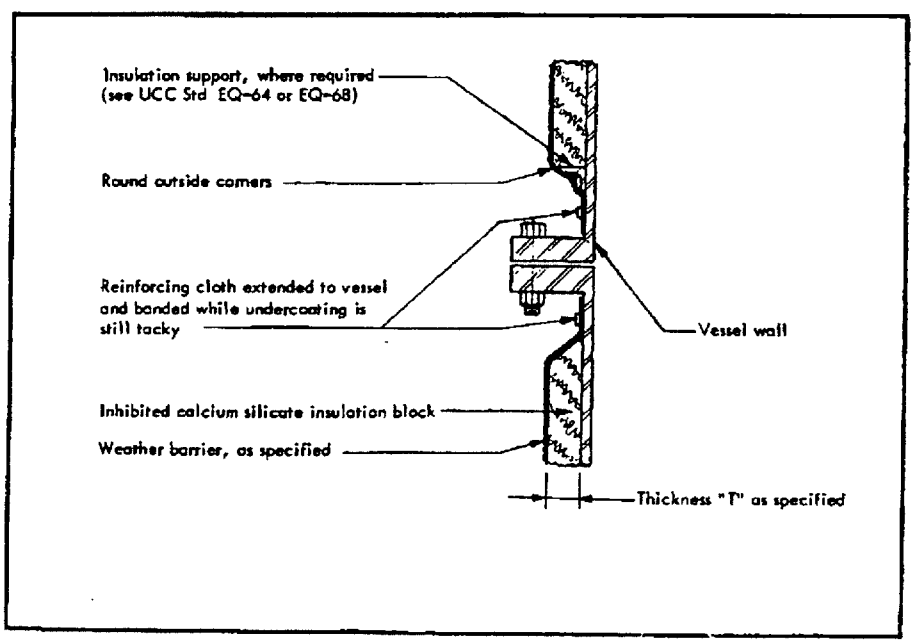


Figure XIII-9

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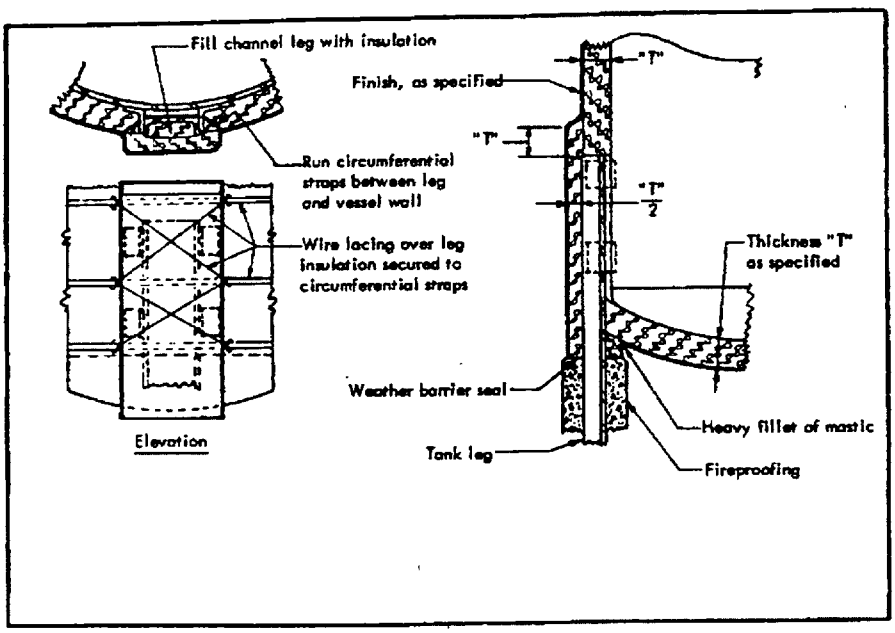


Figure XIII-10

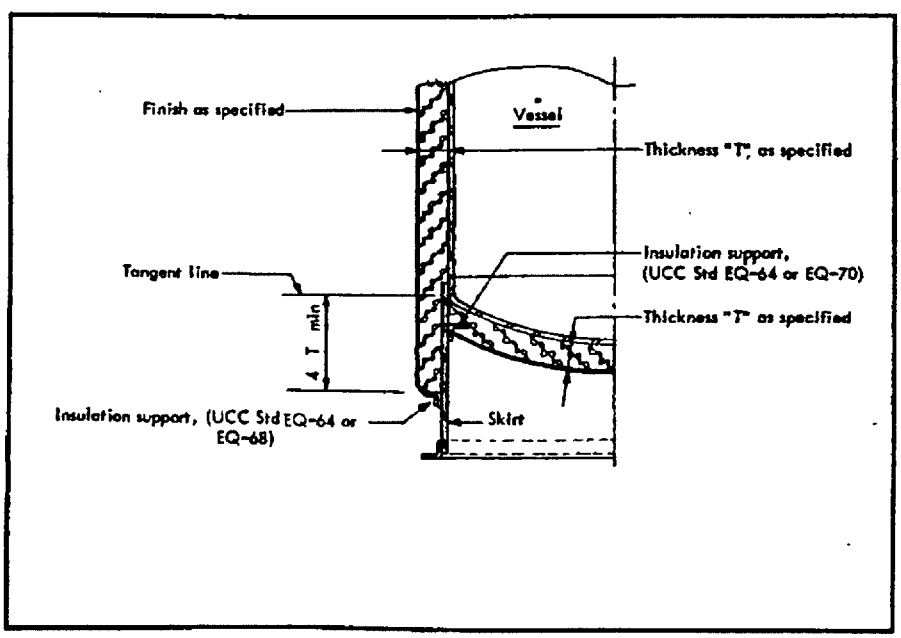


Figure XIII-11

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation

The service temperature of piping not only influences the thickness of insulation to be used but it also dictates the method of installation. As in the case of equipment, the higher the temperature the greater the dimensional change of the pipe. For that reason, the manner of supporting the insulation and the use of insulation covers as slip joints and the proper location of insulation expansion joints are important.

With the exception of ball and plug valves and welded fittings on piping 3" NPS and under, all fitting insulation covers should be shop preformed wherever possible. Covers should be fabricated or modeled in accordance with dimensional standards as given in ASTM Recommended Practice C-450.

Prefabricated fittings for welded fittings should be installed prior to installation of a straight pipe insulation. Such a prefabricated elbow cover is shown in Figure XIII-12.

On vertical pipe lines, 4" NPS and larger, extending more than 15 feet above the bottom elbow, the insulation shall be supported by an insulation support located directly above the elbow. Typical installation is shown in Figure XIII-13. A pipe insulation support shall also be installed above each pair of flanges or flanged valve in vertical lines. In addition, if vertical pipe extends more than 15 feet, additional supports shall be installed on approximately 15-foot centers to provide for installation of insulation expansion joint. This is also illustrated in Figure XIII-13.

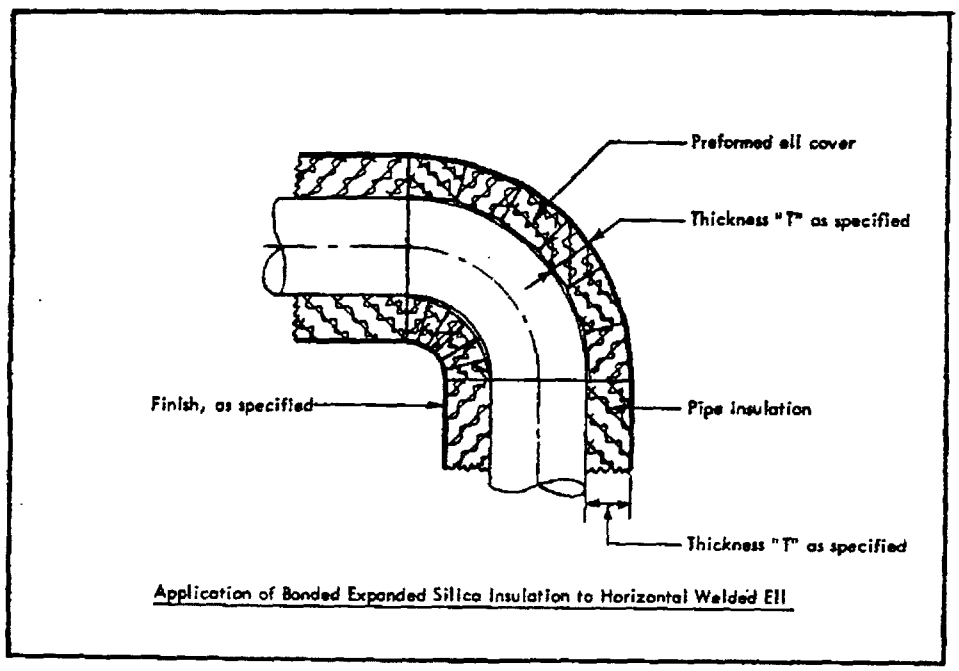
Installation of proper insulation expansion joints directly below top elbow of long vertical lines is essential for proper performance of insulation. These expansion joints are formed by leaving a 1-inch open void between the butt ends of the insulation. Depending upon the temperature, this void is packed tight with mineral wool or fiber glass. Over this joint, a slip-type sleeve of 0.010" thick stainless steel jacketing is installed so that when the pipe expands, this void will further open, but will remain insulated by the fibrous insulation which expands as the pressure against it is released. Construction of these expansion joints is shown in Figures XIII-13 and XIII-14.

Securement of pipe insulation and fitting covers shall be by stainless steel wire or strap as stated in Chapter XI - Pages 23, 24, 25 and 26.

On horizontal piping, an expansion joint shall be installed in each 21 feet of straight piping not interrupted by flanges or flanged valves and insulated with multiple-layer insulation, and each 42 feet of insulated lines with single-layer insulation. These distances should be measured from pipe anchor.

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE



Application of Bonded Expanded Silica Insulation to Horizontal Welded Ell

Figure XIII - 12

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APPLICATION – RIGID INSULATION
HIGH TEMPERATURE SERVICE

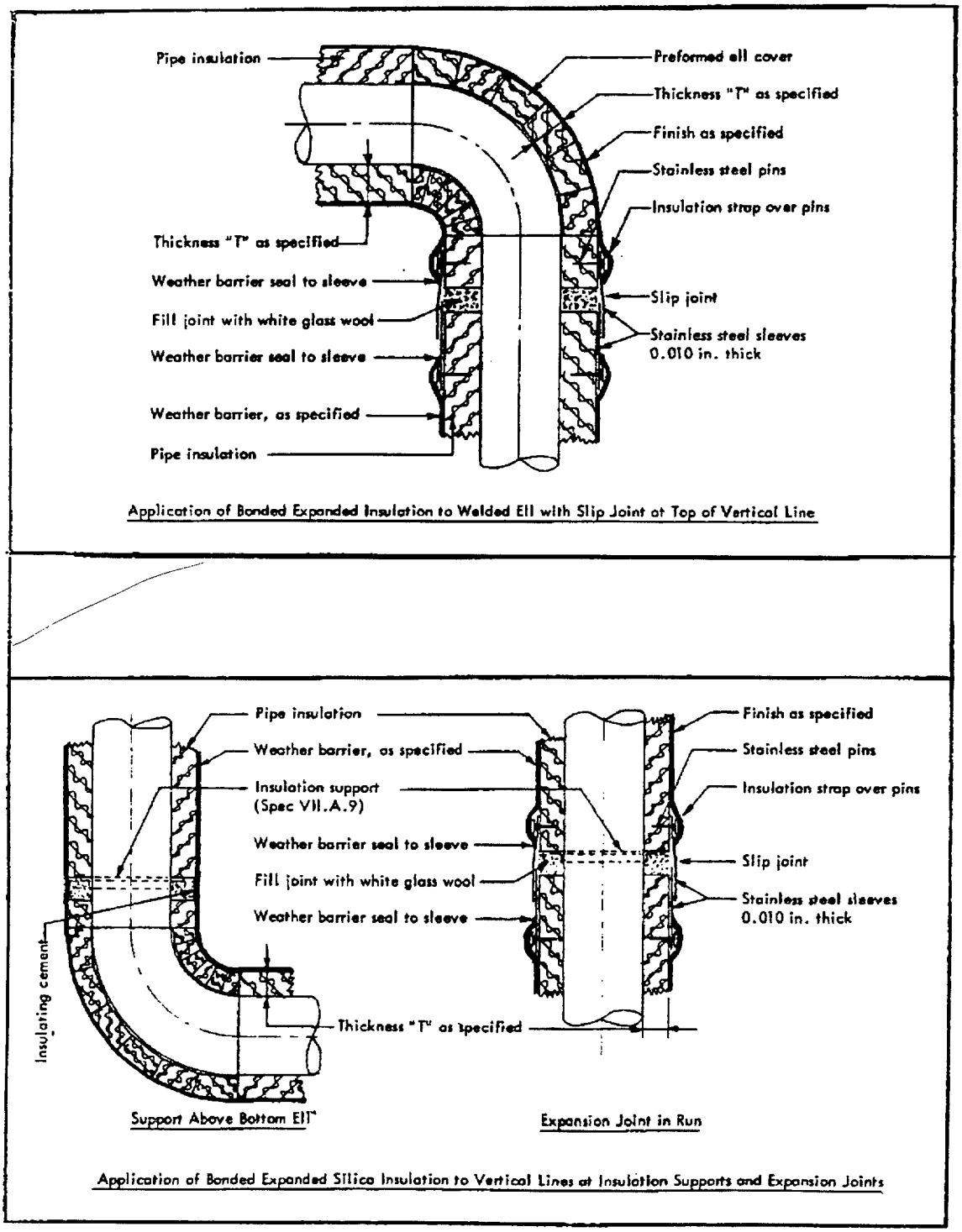
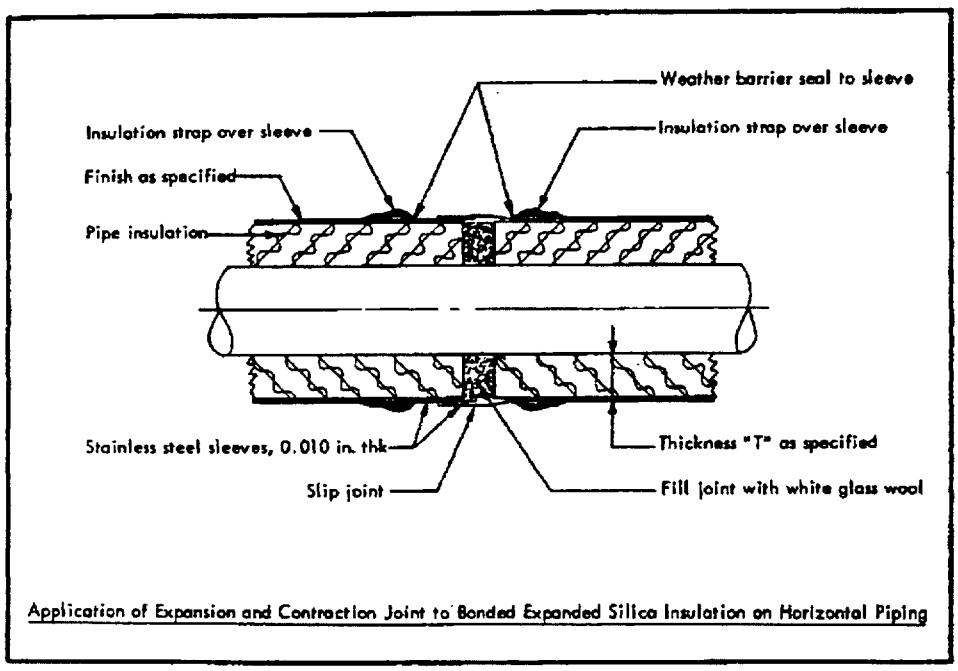


Figure XIII-13

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APPLICATION - RIGID INSULATION
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Application of Expansion and Contraction Joint to Bonded Expanded Silica Insulation on Horizontal Piping

Figure XIII-14

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation - Contd

A flanged fitting insulation cover is installed over adjacent insulation; these too act as expansion joints. A preformed insulation flange cover and flanged valve cover are shown in Figure XIII-15.

WEATHER-BARRIER

Weather-barrier fittings and irregular surfaces shall be mastic reinforced with Dynel fabric installed in the manner as described in Chapter XXI "Application of Weather-Barriers".

Straight pipe and cylindrical sections of vessels should be insulated with mastic reinforced with Dynel or metal jackets whichever is specified. Installation of each should be in the manner described in Chapter XXI.

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APPLICATION - RIGID INSULATION
HIGH TEMPERATURE SERVICE

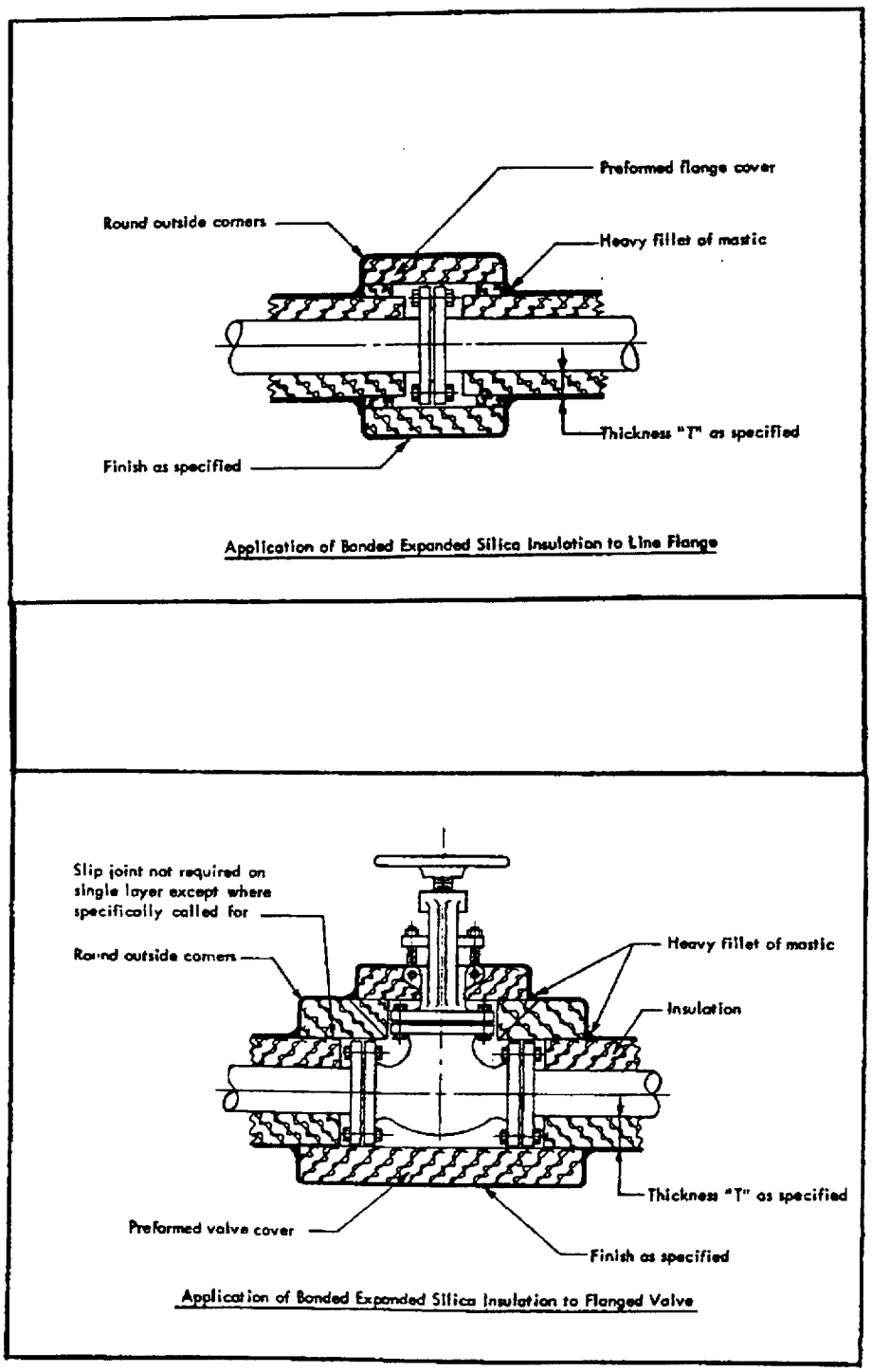


Figure XIII-15

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

GENERAL

Application of rigid insulation on low-temperature service is different from that for high-temperature service in that the installation must be constructed to resist vapor migration. This creates a particularly difficult problem because of movement of the surfaces which are insulated.

As previously discussed, the migration of moisture vapor to a cold surface where it condenses to water or freezes to ice is difficult to control. If an insulation is not almost completely vapor resistant, then control of the moisture vapor inward depends almost completely upon a vapor-barrier on the hot side (outer surface). Such a vapor-barrier is almost impossible to construct sufficiently tight under field conditions.

For these reasons, an insulation which is almost completely vapor resistant in itself is essential to obtain long-lasting low-temperature insulation installations in our type of industrial usage. Cellular glass is the only insulation that does have almost perfect resistance to vapor migration. Thus this discussion is limited to the application of cellular glass for low-temperature service.

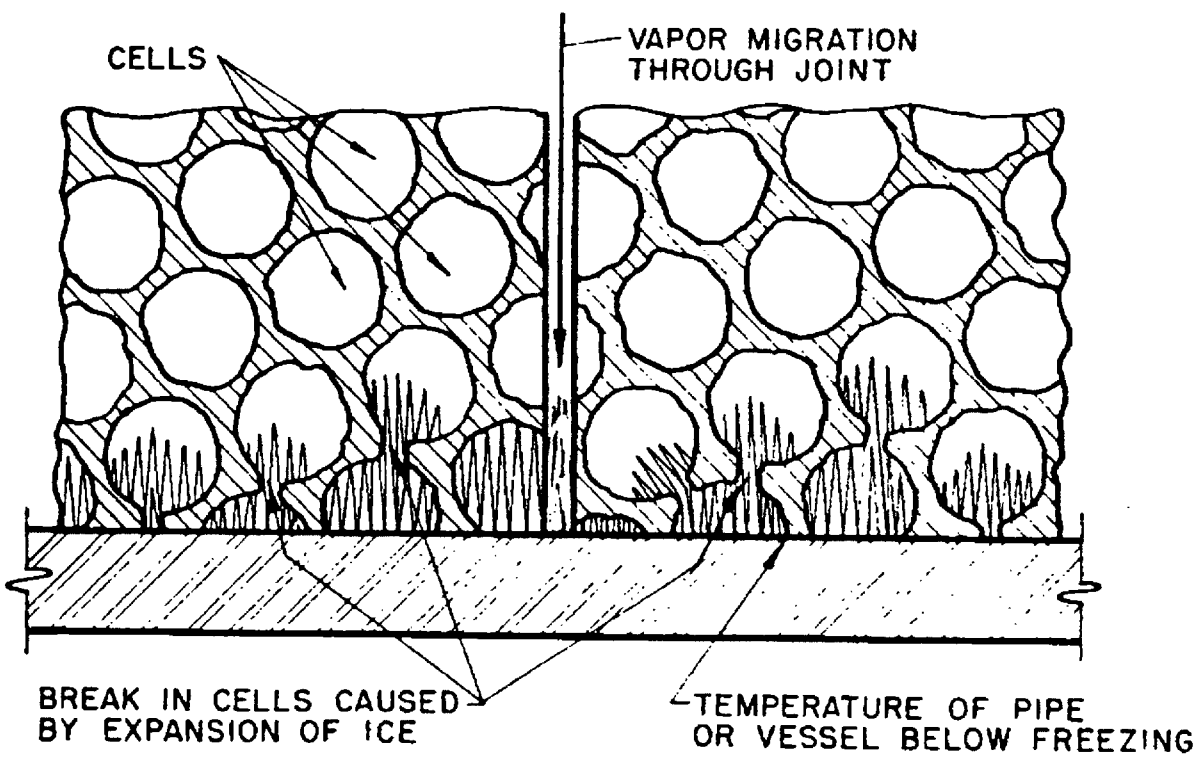
Although cellular glass is highly vapor resistant, it is important to prevent vapor from migrating through the joints and getting to the inner surfaces of the insulation, particularly where temperature alternates between freezing and thawing. This freezing and thawing action will eventually break from cell to cell, causing failure of the insulation. Such action is illustrated in Figure XIV-1. If the exposed layers of cells are filled with mastic which does not freeze, then this action cannot occur. Such mastic-filled cells are illustrated in Figure XIV-2.

Such an approach to vapor sealing cellular glass installations on low-temperature surfaces is much more effective than depending upon a thin vapor-barrier on the outer surface. As almost all materials do have some vapor transmission, the greater the thickness of the vapor resistant material, the smaller the amount of vapor migration. To illustrate this, on Figure XIV-3 is shown an external vapor-barrier and a joint seal vapor-barrier. In the case of an external vapor passage of moisture through the 1/8" vapor-barrier allows the vapor to enter the insulation. However, with cellular glass being a vapor-barrier in itself, the total thickness of vapor-barrier, as illustrated, is 2".

When temperatures are sufficiently low to warrant multi-layer construction, the problem of the proper use of sealing mastics becomes very important. Most mastics containing asphalt freeze at -50F. If such a mastic is used below this temperature, it can damage the cellular glass just as much as water freezing into ice. Thus it is necessary to use sealers which do not freeze at the temperature to which they are subjected. Unfortunately, the sealers which can be used at very low temperatures are most often not as vapor resistant as those which freeze at a somewhat higher temperature. This is why different sealers are used on different layers of cellular glass insulation.

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

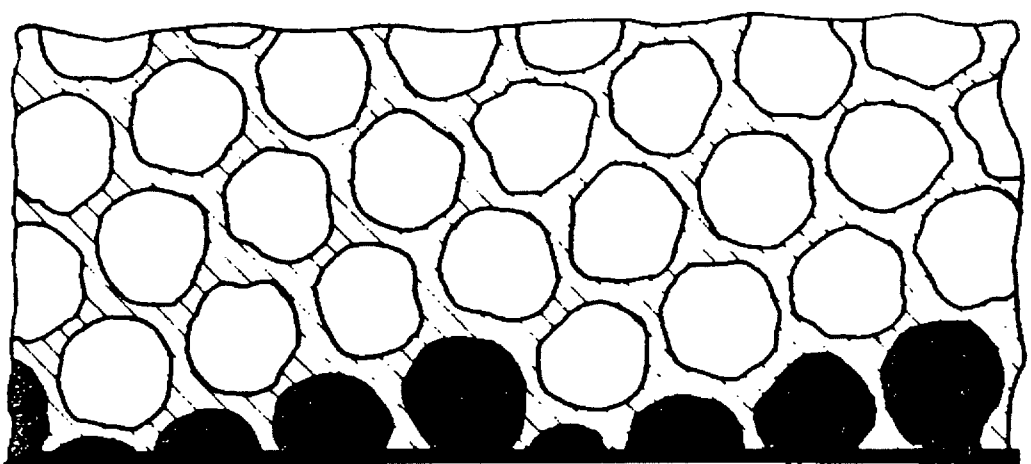


MICROSCOPIC SECTION OF CELLULAR GLASS INSULATION INSTALLED ON PIPE OR VESSEL

Figure XIV-1

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APPLICATION - RIGID INSULATION
LOW-TEMPERATURE SERVICE



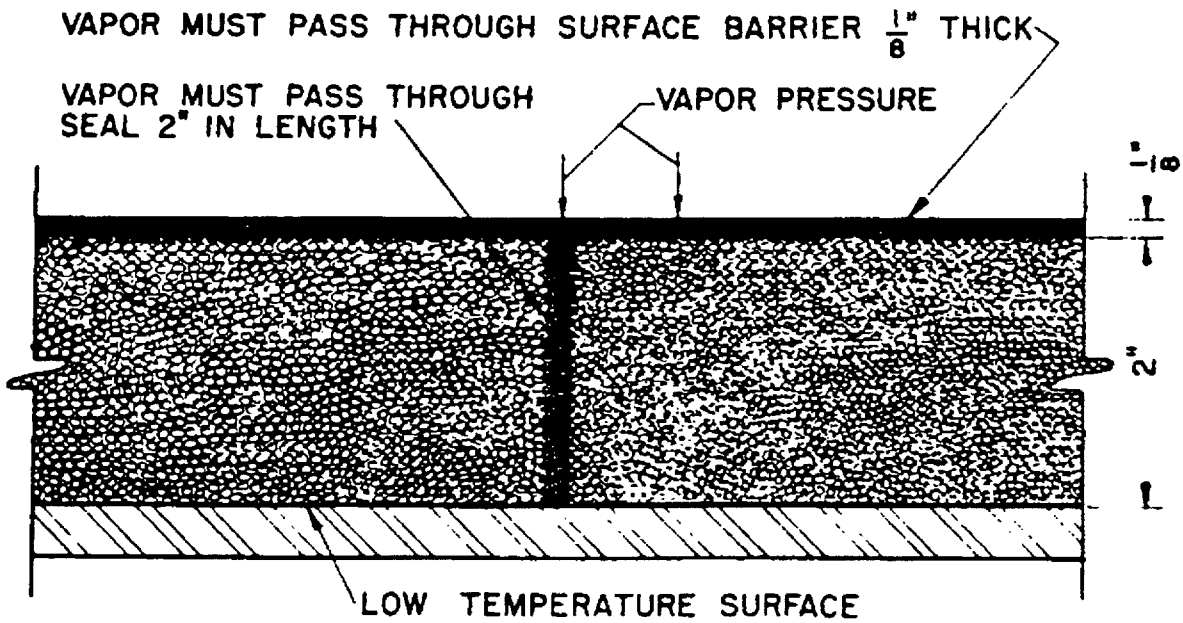
APPLY THIN LAYER OF SURFACE COATING JUST SUFFICIENT TO COVER SURFACE AND FILL HALF CELLS OF CELLULAR GLASS INSULATION EXPOSED ON SURFACE-

MICROSCOPIC SECTION OF CELLULAR GLASS INSULATION SURFACE PROTECTED BY SURFACE COATING

Figure XIV-2

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



COMPARISON OF LENGTH OF VAPOR TRAVEL THROUGH SURFACE VAPOR BARRIER AND JOINT SEAL

Figure XIV-3

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

GENERAL - Contd

Cellular glass is rigid; thus, it is most important that it be fitted closely and joints made just as thin as possible. Butt ends of insulation should be coated with just sufficient sealer mastic to provide complete seal. Pieces of cellular glass should be installed with all sealed joints pressed tightly together.

Cellular glass is more vapor resistant than any available mastic or plastic film; thus, when its joints are sealed; it requires no external vapor-barrier. For this reason, it requires only a weather-barrier for its outer protective cover. The mastic effectively fills the outer layer of cut cells and retards freeze and thaw from weather and serves to protect the insulation from mechanical abuses and ravages of weather.

An additional consideration in many items of our Company's process equipment and lines is that these are subject to thawout by the use of hot gas. In most instances, hot nitrogen gas, over 212F, is used to thaw out and clean the equipment and pipe. This heating process causes equipment and pipe to expand. For this reason, the systems designed for our services are designed with insulation contraction and expansion joints.

Where metal projects through insulation installed on low-temperature surfaces, it will provide a joint of entry of ice - called ice creep. The formation of ice on the metal will crush any insulation. This is shown in Figure XIV-4.

Where it is necessary to have metal projecting through the insulation, such as supports, hanger rods, etc., these must be insulated for a distance outward to protect the main body of insulation. It has been found that if these were insulated out four times the insulation thickness with one half the thickness of the main insulation, this frost creep would be restricted to practical limits. This is shown in Figure XIV-5. However, when atmospheric temperature is near or lower than freezing, frost will be present where the metal projection extends its protective insulation.

EQUIPMENT

Supports

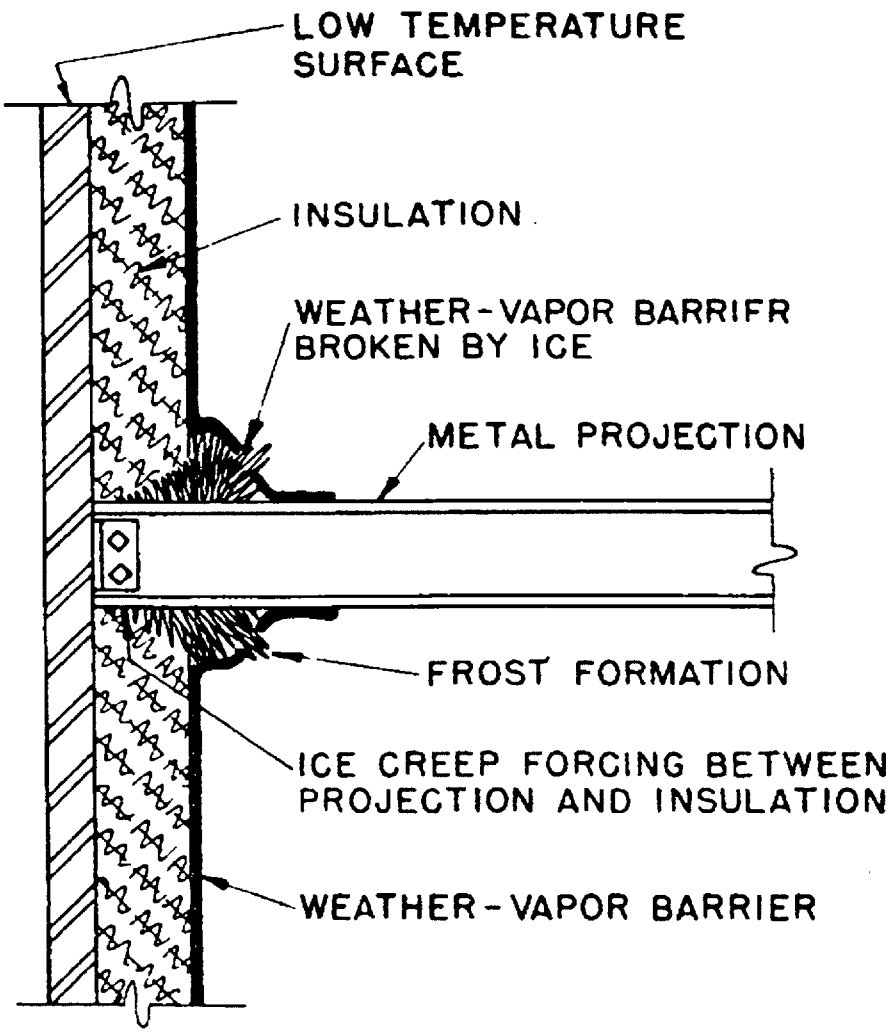
Rigid low temperature insulation is supported by rings attached to vessels in accordance with the Engineering Standards.

Surface Preparation

Carbon steel surfaces operating below 0°F continuously need not be painted or coated. The surfaces should be clean of mill scale, rust, dirt or other contamination prior to application of the insulation.

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

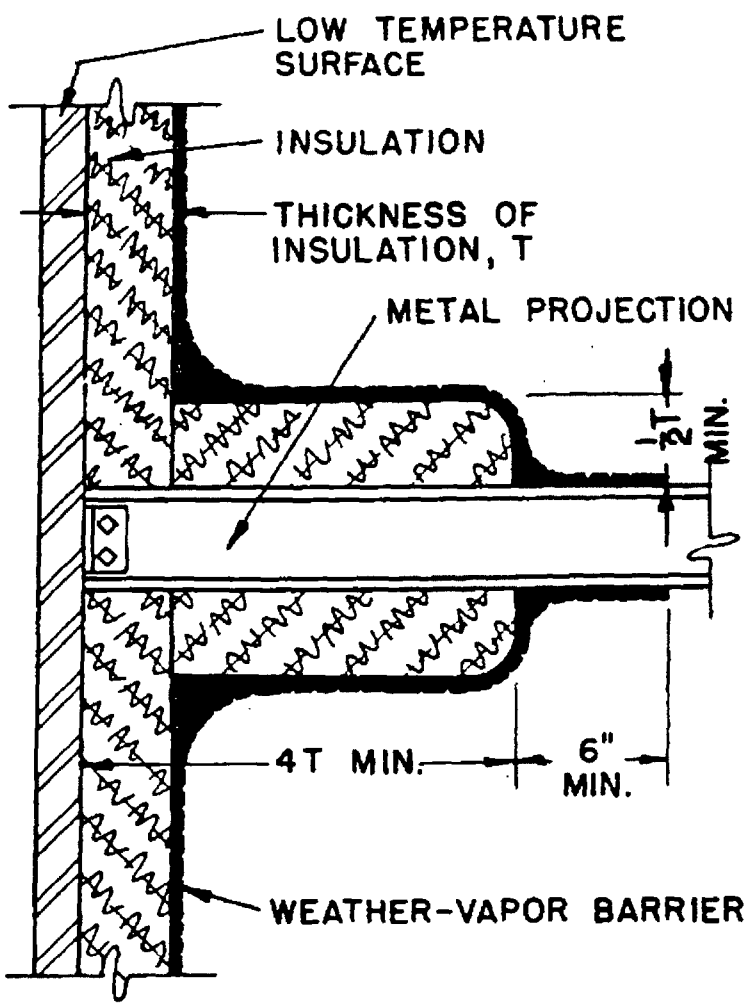


ICE CREEP ALONG METAL PROJECTION THROUGH INSULATION

Figure XIV-4

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



APPLICATION OF INSULATION TO METAL PROJECTION ATTACHED TO LOW TEMPERATURE SURFACE

Figure XIV-5

UCC 002898

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

EQUIPMENT - Contd

Surface Preparation - Contd

Carbon steel vessels operating above 0°F temperature which cycle (hot thawout, etc.) or that are expected to be out of operation for relatively long periods of time should be corrosion protected as called for in UCC Coating Specifications.

Stainless steel surfaces should be coated with Thermalox No. 70 in accordance with UCC Coating Specifications.

The surfaces of vessels or equipment of aluminum, copper, or galvanized steel must be cleaned of all dirt, grit, oil or other contamination prior to application of the insulation.

Preparation for Installation

Similar to hot service, the temperature, size and shape of equipment affects the manner of installation. The service temperature (low and high) dictate the amount of dimensional change which will occur.

Unless equipment is less than 20 inches in diameter, cushion blanket should be installed prior to the application of the cellular glass insulation.

On all equipment operating with a top temperature lower than 350F, a 1/2-inch cushioning blanket shall be applied over the entire surface before application of the cellular glass insulation. Blanket shall be held in place with a minimum amount of stainless steel wire. Blanket is required under rigid block installed on low temperature to provide a cushion spacer between the vessel that contracts and the cylinder of rigid insulation. The need for the cushion blanket is illustrated in Figure XIV-6 and 6A.

On all equipment where top temperature might exceed 350F, a 1-inch-thick cushioning blanket shall be installed over the entire surface.

The cellular glass insulation shall be shop fabricated and fitted to allow 1/2-inch space for the cushion blanket between the insulation and vessel on equipment with top operating temperature less than 350F. A 1-inch space shall be allowed on equipment which has peak temperature above 350F.

The base of first course of cellular glass side wall curved sectors should rest firmly on insulation support so that all lateral joints run parallel with center of vessel. The first course shall have alternate half-length blocks so that end joints are in staggered position. All butt edges and ends of formed insulation shall be sealed with a buttered coat of the specified sealer. This coating shall be of sufficient thickness to provide proper adhesion and seal between the individual tightly fitted block.

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

EQUIPMENT - Contd

Preparation of Installation - Contd

Multiple layers of insulation should be applied so that the butt joints of one layer do not coincide with those of any other layer. Care must be exercised to make sure that correct sealer is used with each layer. Application is illustrated in Figure XIV-6.

Where the contour of vessel permits firm and effective attachment, all layers of cellular glass shall be secured in place with stainless steel strap. Where required, insulation strap shall be anchored to strap anchor angles.

Where insulation is applied to dished or elliptical heads in multiple layers, the inner layers shall be held in place with stainless steel strap fastened to the insulation support. Outer layer of bottom head insulation on vertical vessels or heads on horizontal equipment shall be secured by strap to special anchor clips as illustrated in Figure XIV-7.

Installation of insulation on flat heads requires that cellular glass flat insulation be used directly on the surface to the thickness required to bring the surface of the insulation flush to the top of the stud bolts. This is followed with the application of the cushion blanket and specified thickness of the insulation. This is illustrated in Figure XIV-8.

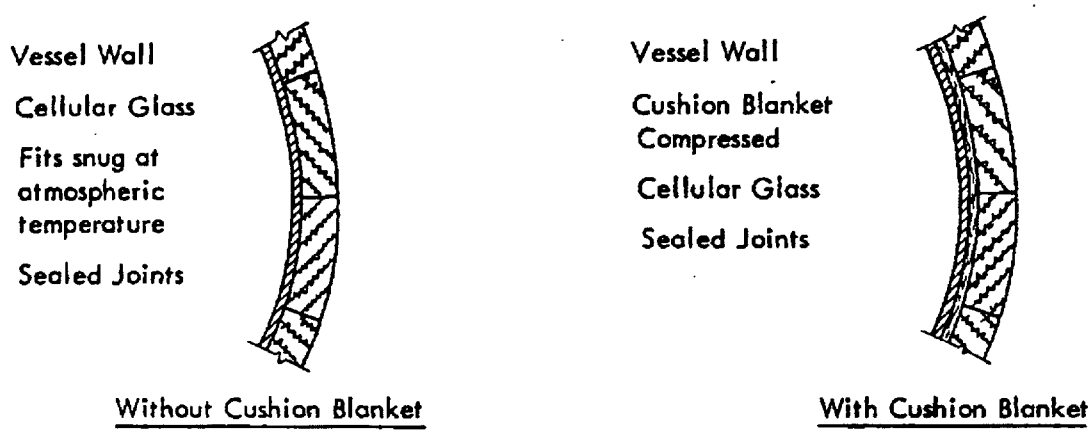
Expansion-contraction joints must be installed over each insulation support and vessel flange. When the movement occurs where one area of insulation overlaps the other, non-setting sealer should be applied to these over-lapping surfaces. Application of insulation expansion-contraction joint at vessel flange is shown in Figure XIV-9, and joint at insulation support is shown in Figure XIV-10.

The change in dimension of a vessel as it expands or contracts changes the relative position of nozzles or pipe connections in reference to the cylindrical insulation of the sides. Space must be provided by the use of oversize flange covers and pipe insulations at the point of connection to the vessel to prevent this movement from breaking the insulation or its seal. The proper application of cellular glass insulation at nozzles or connecting piping is shown in Figure XIV-11.

Wherever the insulation terminates on low-temperature equipment or vessels, such as on a skirt, leg, support, or cradle, the projecting metal of these should be insulated for not less than four times the specified insulation thickness. The recommended procedures for insulating these are shown in Figures XIV-12, XIV-13, XIV-14, and XIV-15. It is essential that all insulation terminating points be sealed to prevent entry of moisture.

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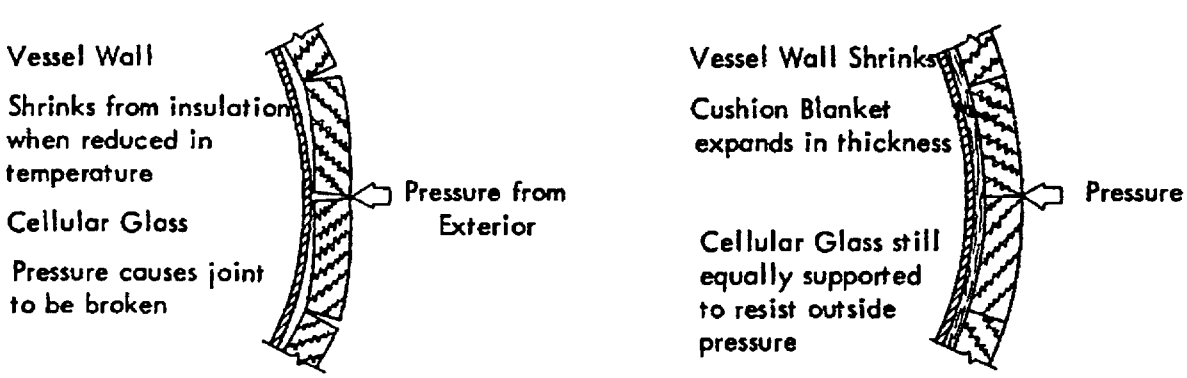
APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Without Cushion Blanket

With Cushion Blanket

AS INSTALLED AT ATMOSPHERIC TEMPERATURE



Without Cushion Blanket

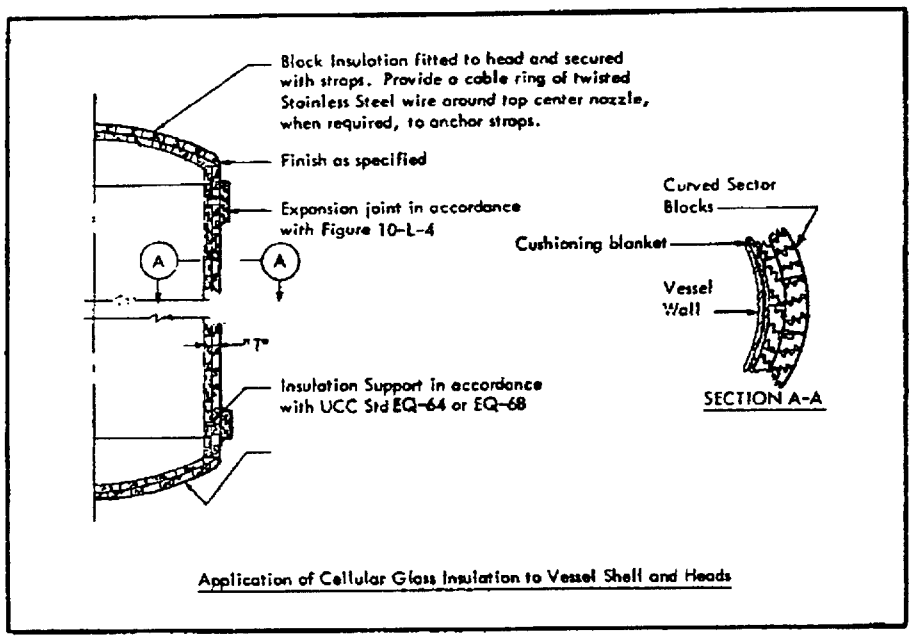
With Cushion Blanket

INSTALLATION AFTER VESSEL HAS CONTRACTED
DUE TO REDUCTION IN TEMPERATURE

Figure XIV-6

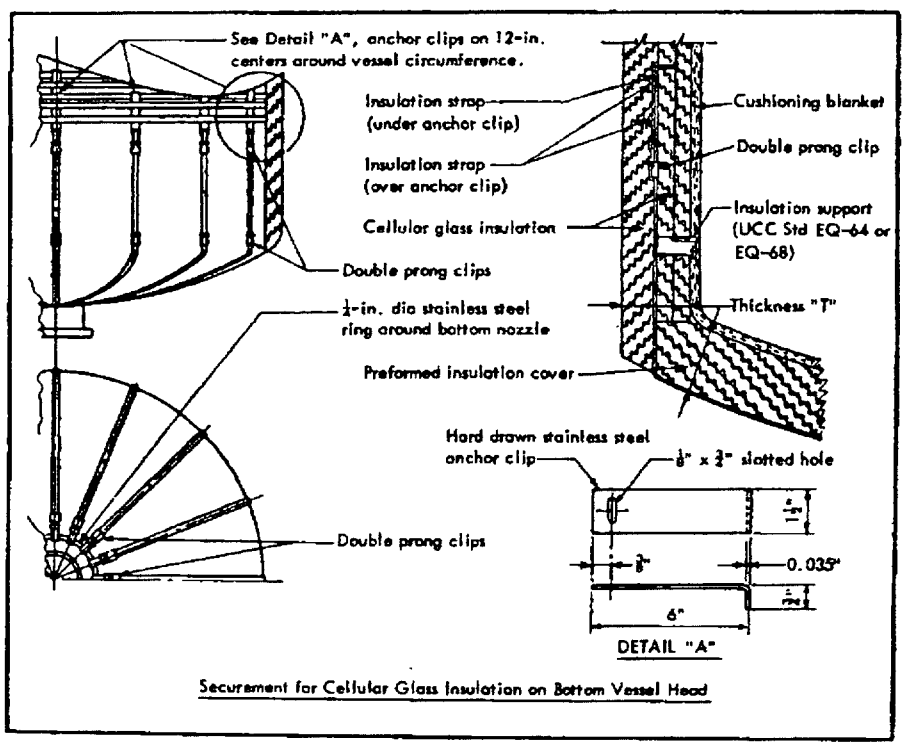
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Vessel Shell and Heads

Figure XIV-6A



Securement for Cellular Glass Insulation on Bottom Vessel Head

Figure XIV-7

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APPLICATION - RIGID INSULATION
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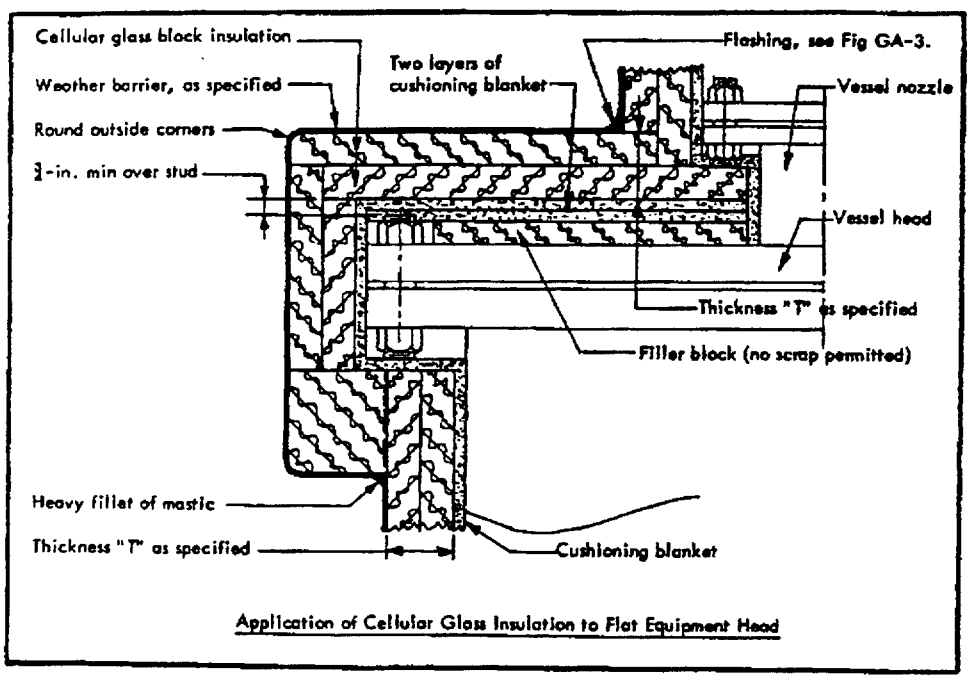
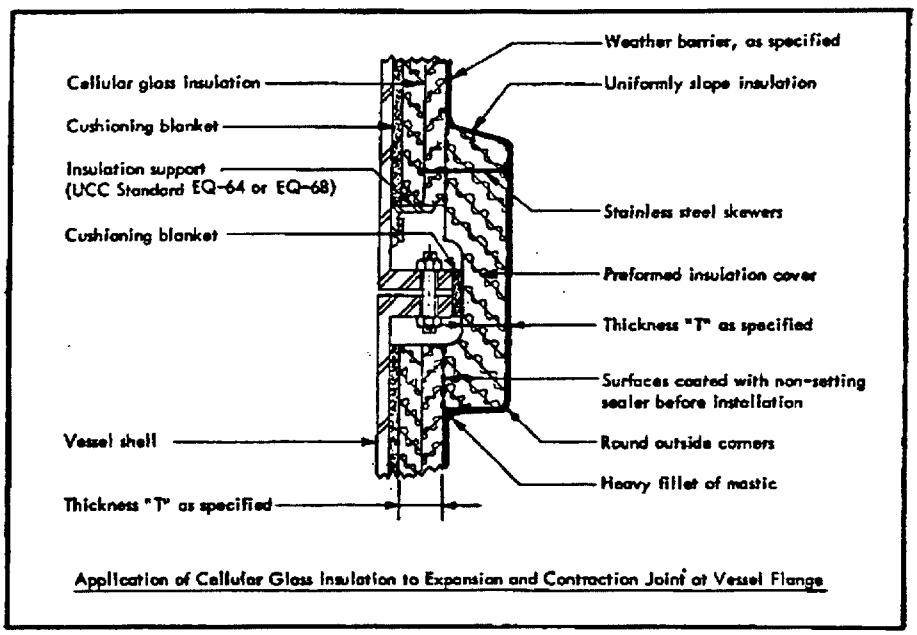


Figure XIV - 8

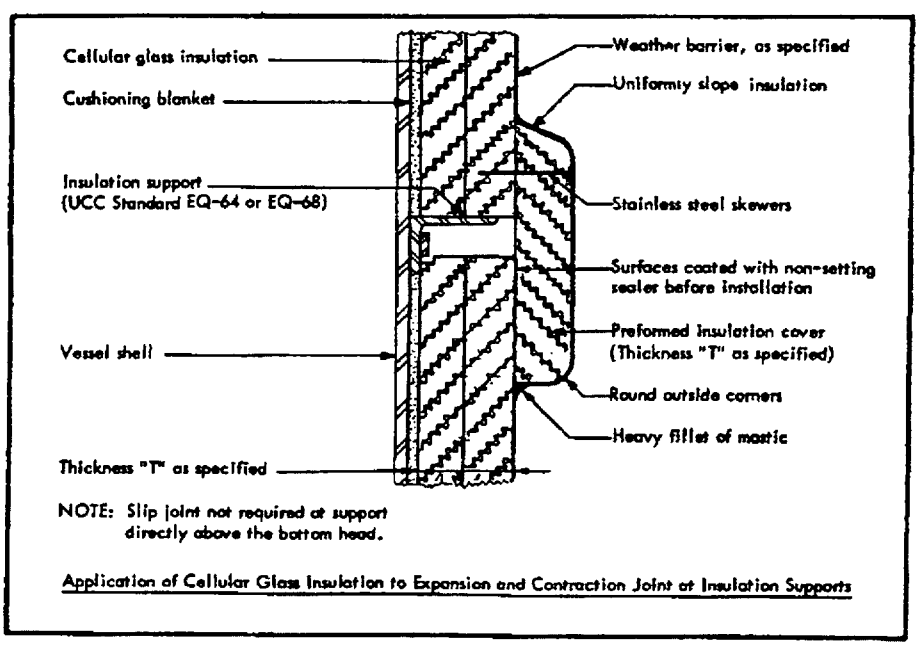
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Expansion and Contraction Joint at Vessel Flange

Figure XIV-9

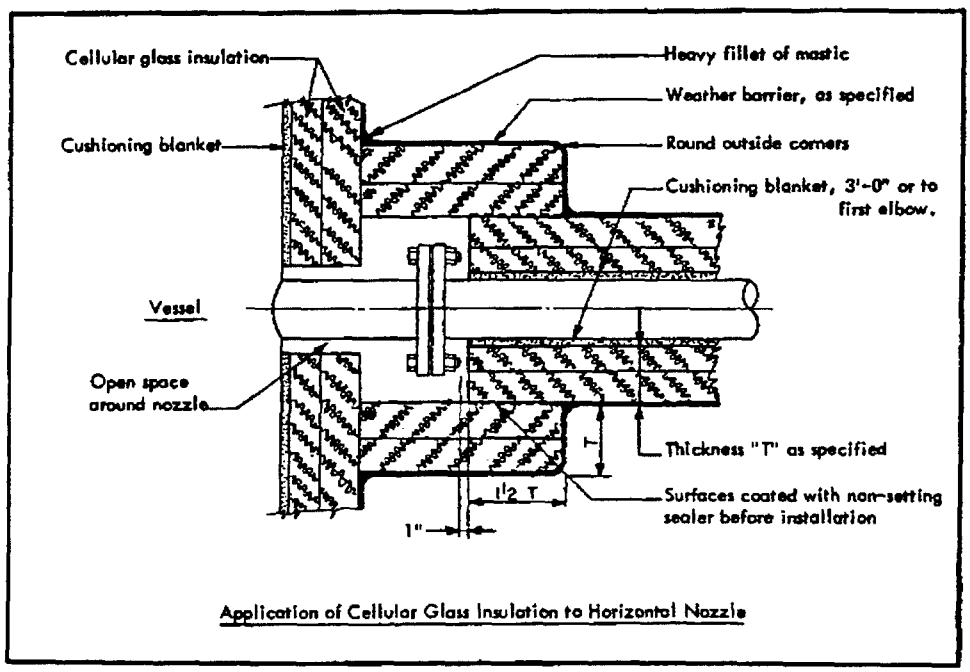


Application of Cellular Glass Insulation to Expansion and Contraction Joint at Insulation Supports

Figure XIV-10

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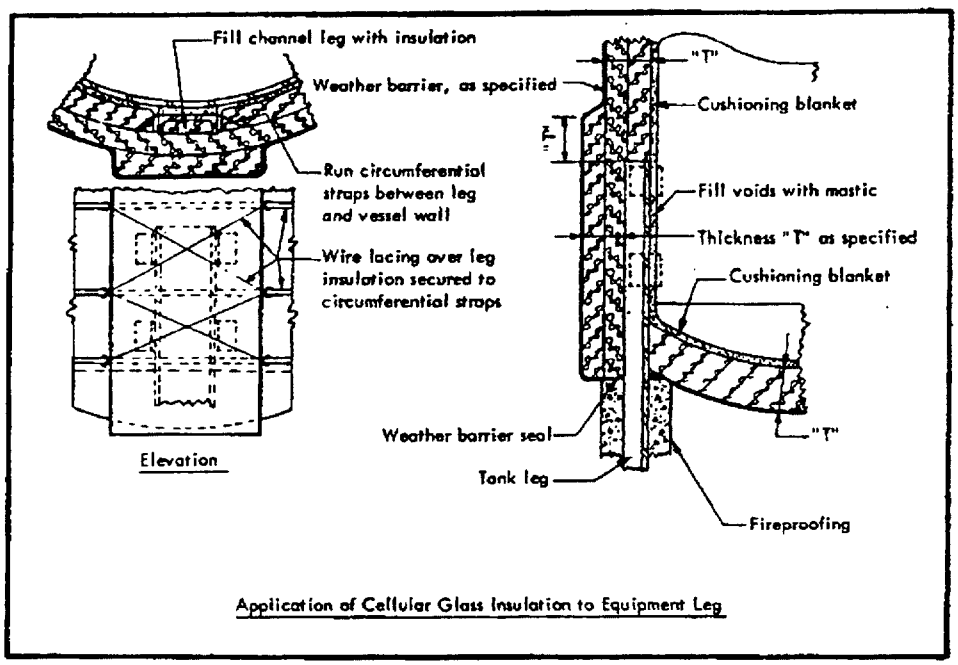


Application of Cellular Glass Insulation to Horizontal Nozzle

Figure XIV - 11

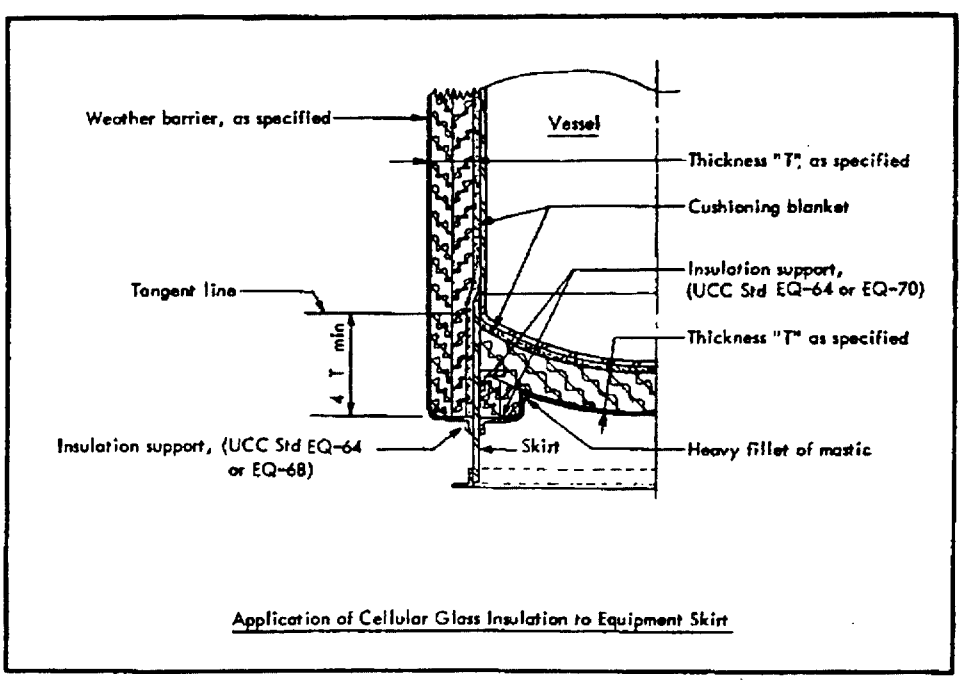
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Equipment Leg

Figure XIV-12

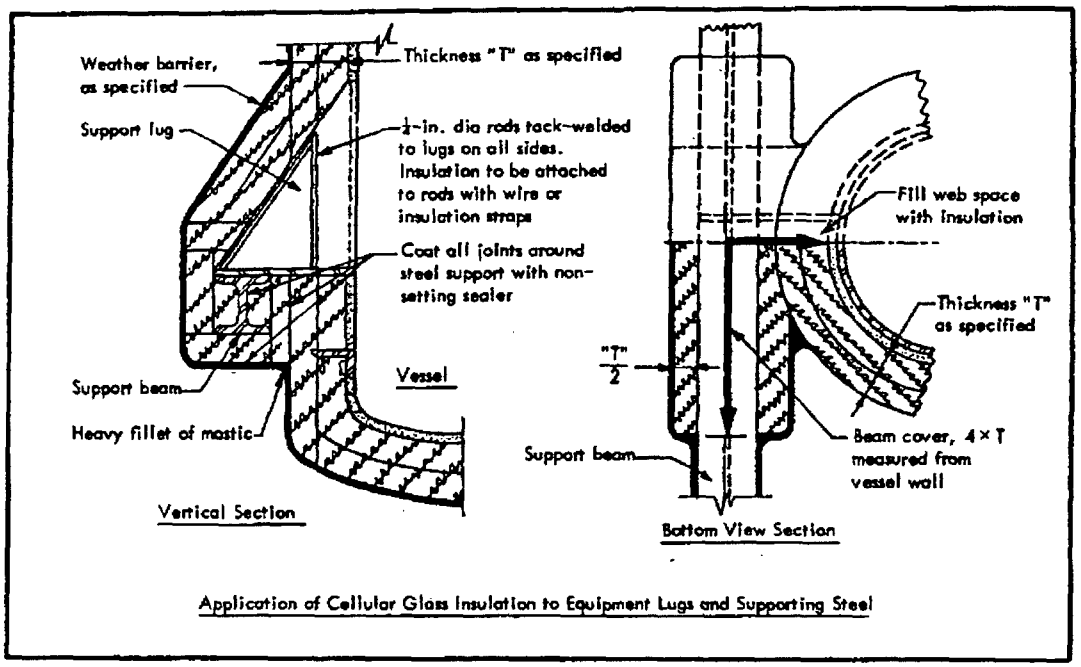


Application of Cellular Glass Insulation to Equipment Skirt

Figure XIV-13

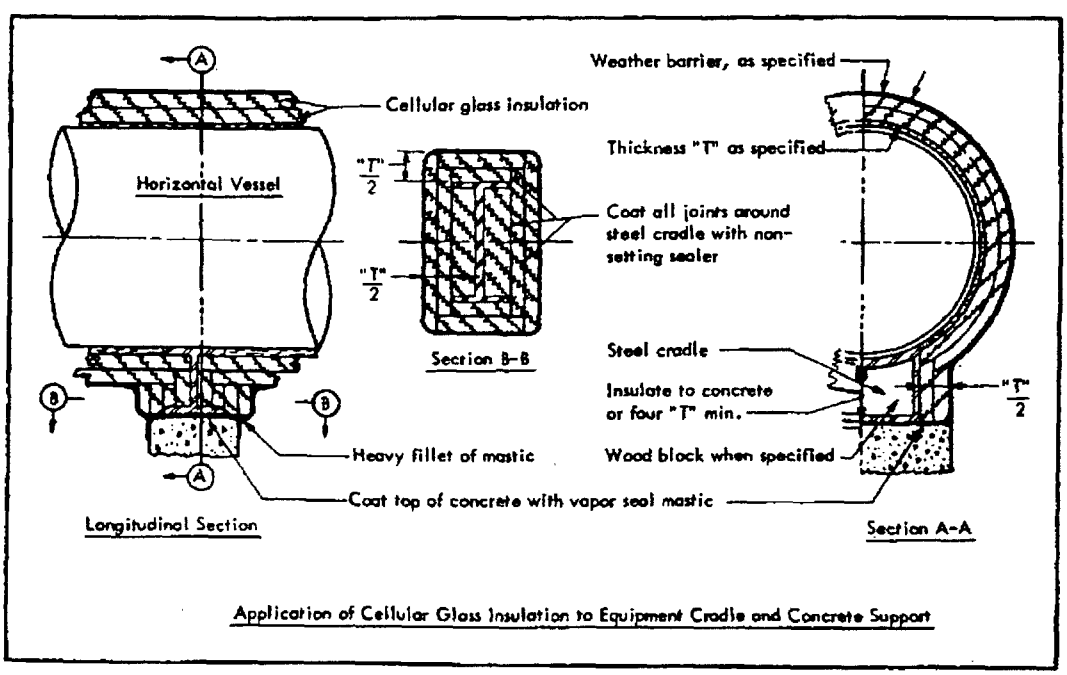
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Equipment Lugs and Supporting Steel

Figure XIV-14



Application of Cellular Glass Insulation to Equipment Cradle and Concrete Support

Figure XIV-15

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

PIPING

Surface Preparation

Surface preparation of pipe surfaces shall be same as for vessels except stainless steel pipe shall be coated only behind flanges and elsewhere where specifically specified.

Application of Insulation

As with equipment, the maximum and minimum service temperatures of the piping, besides influencing the thickness of insulation to be used, also dictates the method of application.

The dimensional change of pipe must be considered in design of its support and anchorage. As low-temperature service piping must be insulated to retard the migration of vapor moisture inward, all piping, wherever possible, should be supported by cradles outside the insulation. Metal connections to the pipe which extend straight through the insulation should be avoided.

As the pipe, in most instances, is supported by the insulation and as the change of dimension of insulation, due to expansion and contraction, is different than the pipe, the correct use of insulation expansion-contraction joints is vital to the efficient operation of the insulation. Location and distances between these expansion joints depend upon service temperature and configuration of the piping.

Where pipe is subjected to sudden change in temperature or excessive vibration, a cushion blanket should be applied to bare pipe before installation of the cellular glass. Fittings and pipe insulation must be oversized to allow for this cushion where it is required.

All fitting, flange, and valve covers should be prefabricated before installation on pipe. These should be of dimensions as given in ASTM Recommended Practice C-450.

Prefabricated welded fittings should be installed prior to the application of straight pipe insulation. Typical welded insulation covers are shown in Figures XIV-6 and XIV-17.

On vertical lines 4-inch NPS and over, and over 15 feet above the bottom elbow, an insulation support should be installed to prevent all the weight of the pipe insulation from resting on this elbow. A pipe insulation support shall also be installed above each pair of flanges or flanged valve located in the vertical line.

Pipe insulation shall be installed in staggered position. All butt edges and ends of both layers (or single layer) of cellular glass insulation should be buttered with joint sealer before application. The joints shall be drawn together when insulation is applied so that only a very thin, vapor-tight, vapor seal coat separates the sections of the insulation. Insulation should be applied with all

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

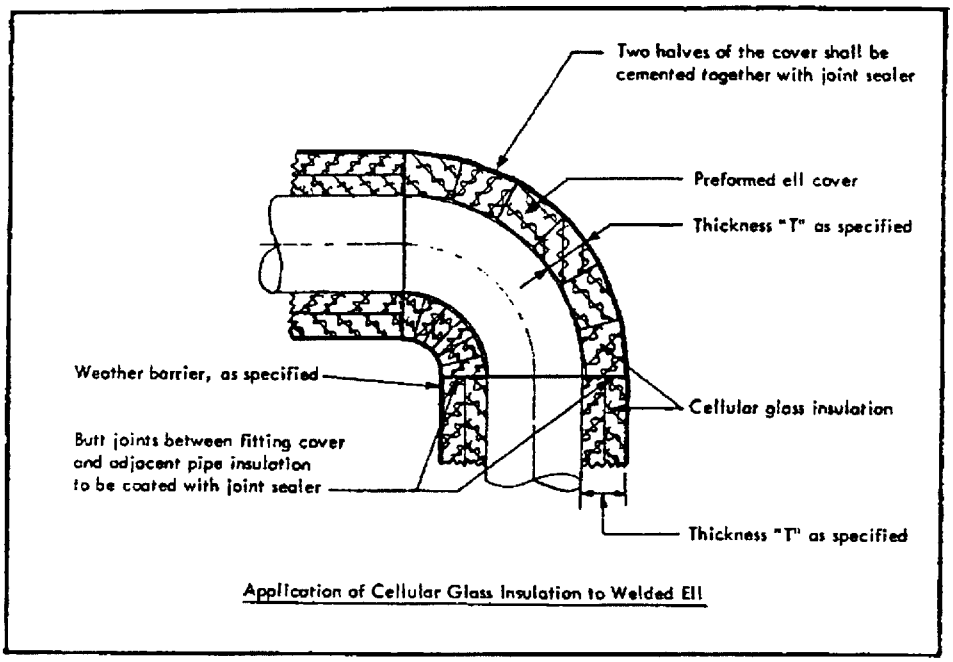


Figure XIV-16

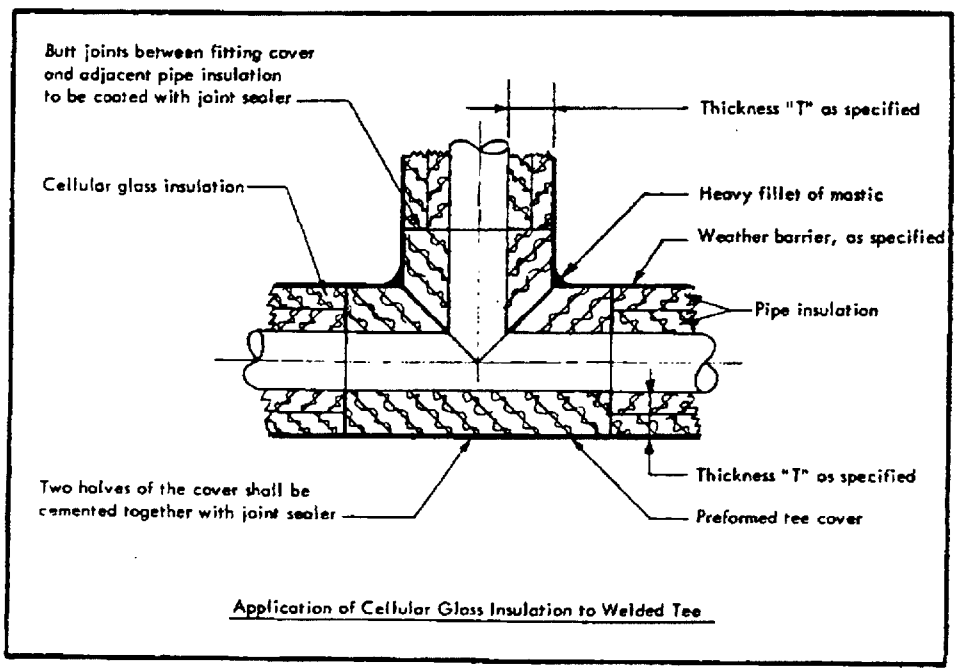


Figure XIV-17

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation

joints tightly butted and fitted, to eliminate voids. Large voids shall not be filled with sealer, but should be eliminated by either refitting or replacing the insulation. Any rounded corners on the insulation surfaces shall be trued up before the insulation is installed.

Inner layers and outer layers of cellular glass pipe insulation up to 4-1/2-inch outside diameter shall be secured in position with strapping tape.

Outer layers of straight pipe insulation, welded fitting covers over 4-1/2-inch outside diameter and all flange (and flanged valve) covers shall be secured in position with 3/8-inch stainless steel strap.

Location of securement tape and strap on the pipe insulation shall be as shown in Figures XI-13 and XI-14 in Chapter XI.

Insulation expansion and contraction joints shall be constructed with the straight pipe insulation so cut and fitted that a 1/2-inch void is left between the butt ends of adjoining runs of pipe coverings. Over this void, a section of pipe insulation shall be installed of equal thickness to the specified thickness. The outer layer of the pipe covering and inner surface of the expansion joint cover shall be coated with non-setting sealer. The expansion joint cover should be installed over the pipe covering sufficiently tight that the non-setting sealer fills the void between the two, but not tight enough to bind. These joints shall be installed in both horizontal and vertical straight run at intervals, as follows:

Up to 2-1/2 inches thick insulation - one for each 60 feet.
Up to 5 inches thick insulation - one for each 45 feet.
Up to 7-1/2 inches thick insulation - one for each 30 feet.

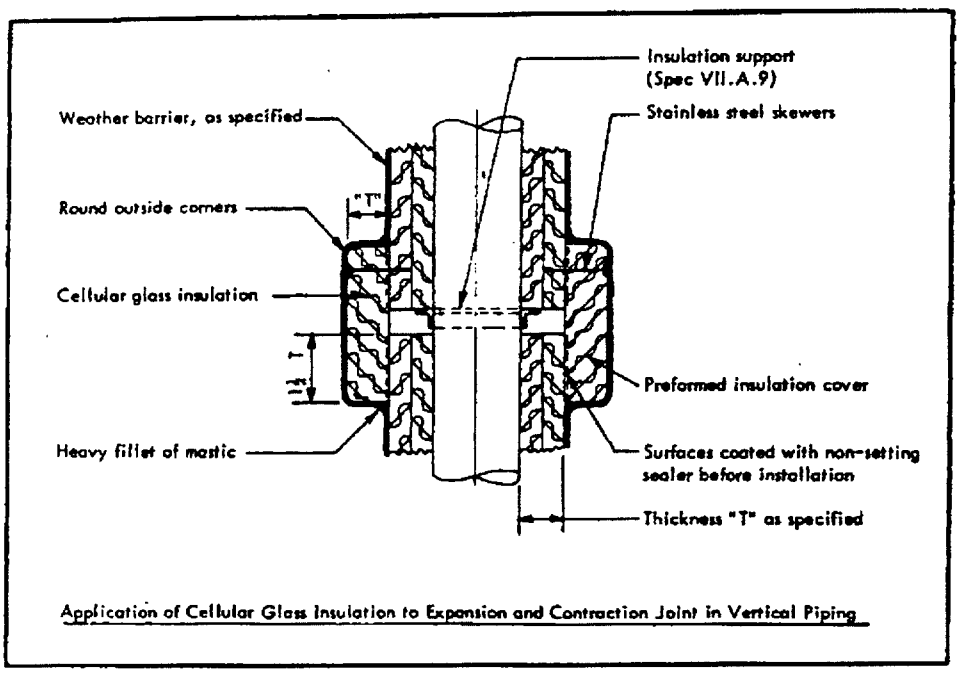
These expansion joints shall be located one-half the distance between pipe supports, one-half the distance between points where pipe changes direction, or at the specified distances starting measurement from a pipe anchor.

Typical construction of expansion joints for vertical and horizontal lines are shown in Figures XIV-18 and XIV-19.

Flange, fitting and valve covers shall be installed over the adjacent pipe insulation. The joint between the pipe covering and these covers shall be buttered and sealed with non-setting sealer to form a slip joint as called for in expansion joints. Where these covers occur where expansion-contraction joints are required, they serve as the expansion-contraction joint. The two halves of

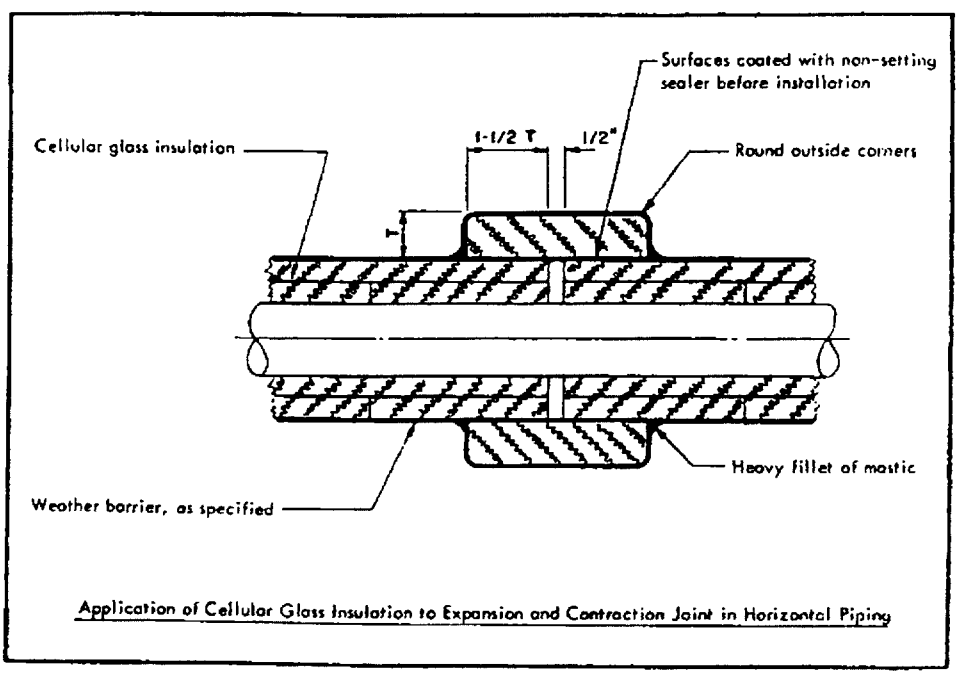
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Expansion and Contraction Joint in Vertical Piping

Figure XIV-18



Application of Cellular Glass Insulation to Expansion and Contraction Joint in Horizontal Piping

Figure XIV-19

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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation - Contd

the cover shall be cemented together with joint sealer and secured in position with 3/8-inch stainless steel strap.

All valves shall be packed and filled around valve stem and packing gland assembly with joint sealer to avoid water and vapor entry.

A typical flange, flanged elbow, and flanged valve cover are illustrated in Figures XIV-20, XIV-21, and XIV-22.

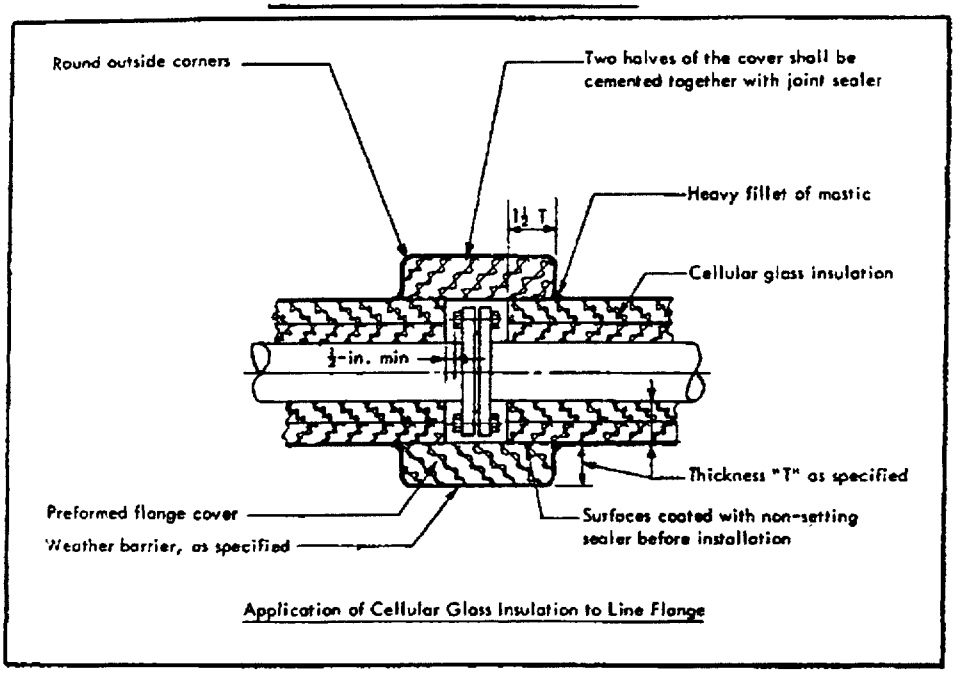
Where pipe must be supported by hangers, the rod should be insulated up to four times the specified insulation thickness to prevent ice creep. This is shown in Figure XIV-23.

WEATHER-BARRIERS

The cellular glass insulation shall be weather protected with specified mastic reinforced with Dynel fabric in the manner as described in the Chapter on Weather-Barrier application.

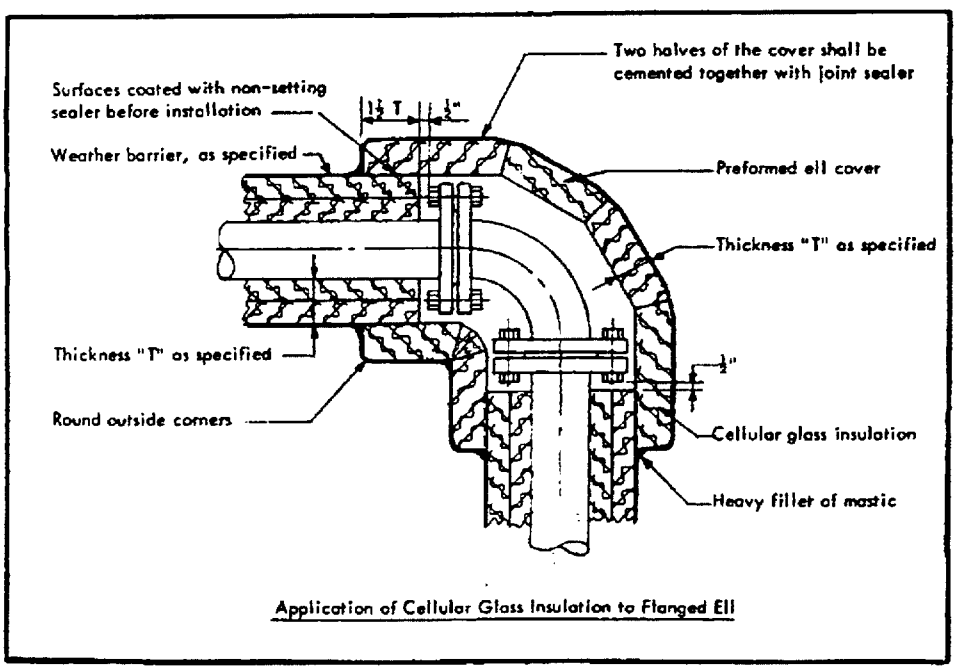
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Line Flange

Figure XIV-20

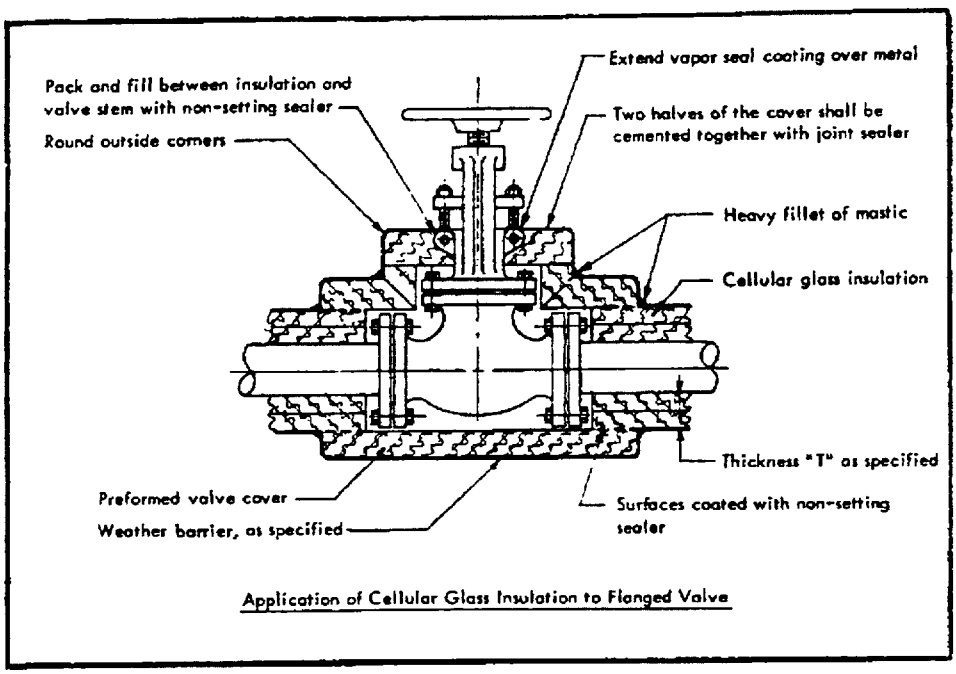


Application of Cellular Glass Insulation to Flanged Ell

Figure XIV-21

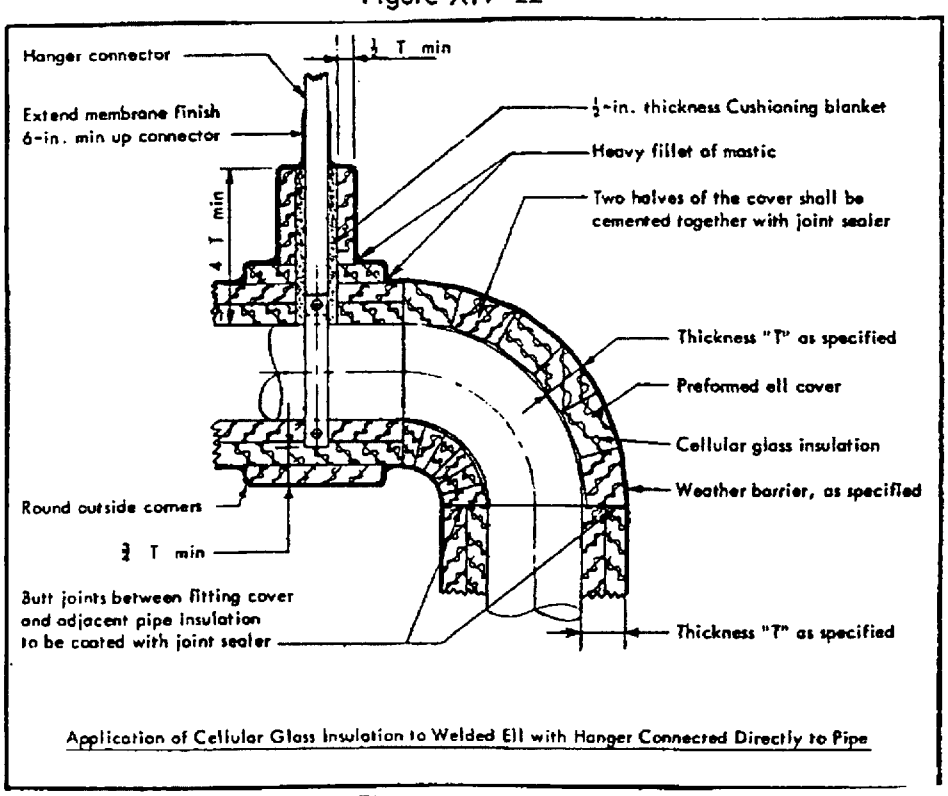
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APPLICATION - RIGID INSULATION
LOW TEMPERATURE SERVICE



Application of Cellular Glass Insulation to Flanged Valve

Figure XIV-22



Application of Cellular Glass Insulation to Welded Ell with Hanger Connected Directly to Pipe

Figure XIV-23

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APPLICATION OF SEMI-RIGID INSULATION MODERATE AND HOT TEMPERATURE SERVICE

GENERAL

Semi-rigid insulation is most generally mineral fibers bonded together into panels, boards, or pipe insulation. The density and amount of bonding material controls the rigidity. In this Chapter, the method of installation is concerned with a type of material which is semi-rigid, i.e. it is somewhat flexible but does have sufficient strength to maintain its form without support.

EQUIPMENT

Supports

With this type of insulation it may be supported either by support rings, or by pins and speed clips. Where welding is permitted, the insulation may be supported by a flat bar or angle welded to the vessel. Where welding is not permitted, insulation supports must be bolted on as shown in Chapter IX, "Supports and Securements."

On surfaces where welding is permitted, insulation is frequently secured in position by pins as illustrated in Figure XV-4.

Surfaces to be insulated should be properly cleaned and where required should be coated with proper paint or coating material prior to installation of the insulation.

Surface Preparation

Carbon steel surfaces operating at temperatures below 150F must be blast cleaned and coated with inorganic zinc coating in accordance with UCC Coating Specifications.

Stainless steel surfaces shall be coated with Thermalox No. 70 in accordance with UCC Coating Specifications.

The surfaces of vessels or equipment of aluminum, copper, or galvanized steel must be cleaned of all grit, oil, dirt or other contamination prior to application of the insulation.

Application of Insulation

On cylindrical equipment less than 30 inches in diameter, preformed glass pipe insulation of a size to fit the vessel surface is used in place of block. This is insialled in the same manner as pipe insulation, discussed later in this Chapter.

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APPLICATION OF SEMI-RIGID INSULATION MODERATE AND HOT TEMPERATURE SERVICE

EQUIPMENT - Contd

Application of Insulation - Contd

On vessels larger than 30 inches and up to 30 feet in diameter, the glass block or board should be cut to proper size lagging or curved sectors to fit vessel surface. Vessels above 30 feet in diameter may be insulated by flat board pulled to curvature of vessel by the securement strap.

Fibrous glass block for vessel heads should be precut to fit contour of the head.

The block or lagging should be applied in staggered position with all joints tightly butted. Multiple layers should be applied so that butt joints of one layer do not coincide with those of any other layer.

Application is similar to rigid insulation with the exception that the expansion cushion blanket is not used under the semi-fibrous glass insulation as the insulation is sufficiently flexible to compensate for the circumferential expansion of the vessel. The installation of the semi-rigid insulation is the same as rigid insulation illustrated in Figure XIII-1 and XIII-2 in preceding chapter. Slip joints to compensate for lateral expansion must be installed as shown in Figure XV-1.

The insulation should be secured in position by stainless steel straps on 9-inch centers, pulled just sufficiently taut to hold insulation snug to the vessel. Where vessel exceeds 25 feet in diameter, the strap should be "expanded bands" or should have one expander spring installed for every 30 feet of strap.

The vessel flanges and manholes, or nozzles, should be insulated with precut covers unless specifically stated to be left uninsulated. The insulation manhole or nozzle covers are illustrated in Figure XV-2.

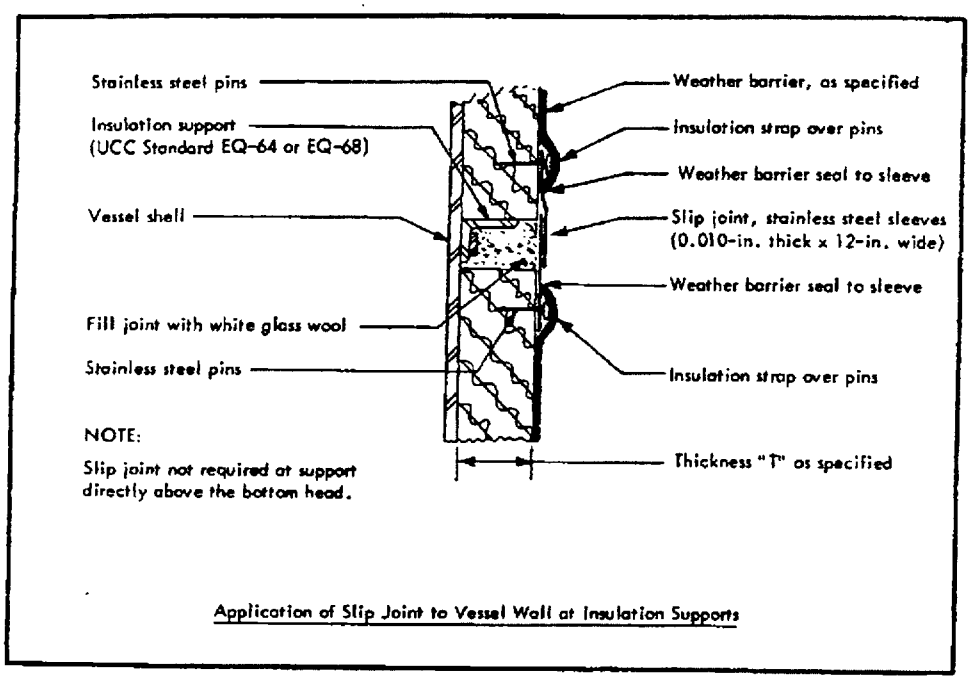
Where block or lagging insulation terminates at any location, it should be tapered to provide water shed and to provide for its proper seal off to prevent entry of water. This taper and seal off is shown in Figure XV-3.

Application - Flat Surfaces

Block or board insulation is installed by impaling it on pins welded to the surface to be insulated. The blocks or boards should be installed in staggered position with all joints tightly butted. Multiple layers should be installed so that the butt joints of one layer do not coincide with those of any other layer.

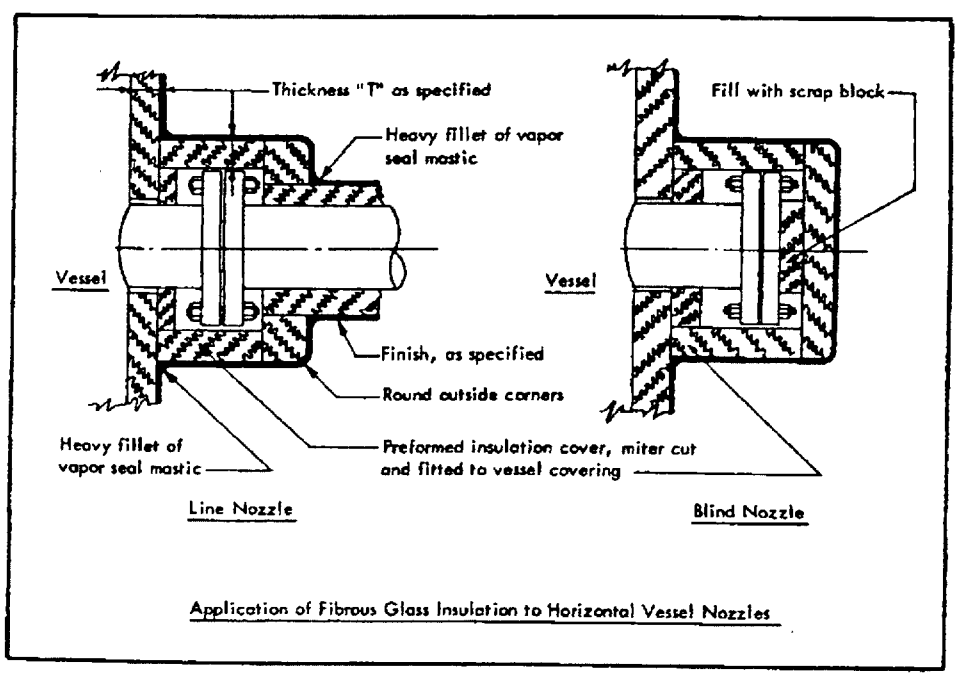
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APPLICATION OF SEMI-RIGID INSULATION
MODERATE AND HOT TEMPERATURE SERVICE



Application of Slip Joint to Vessel Wall at Insulation Supports

Figure XV-1



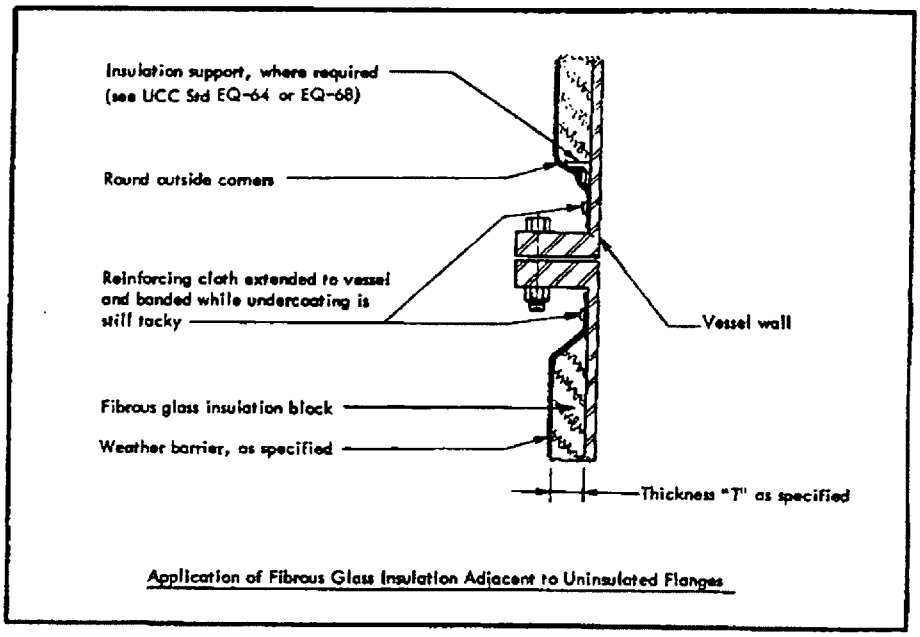
Application of Fibrous Glass Insulation to Horizontal Vessel Nozzles

Figure XV-2

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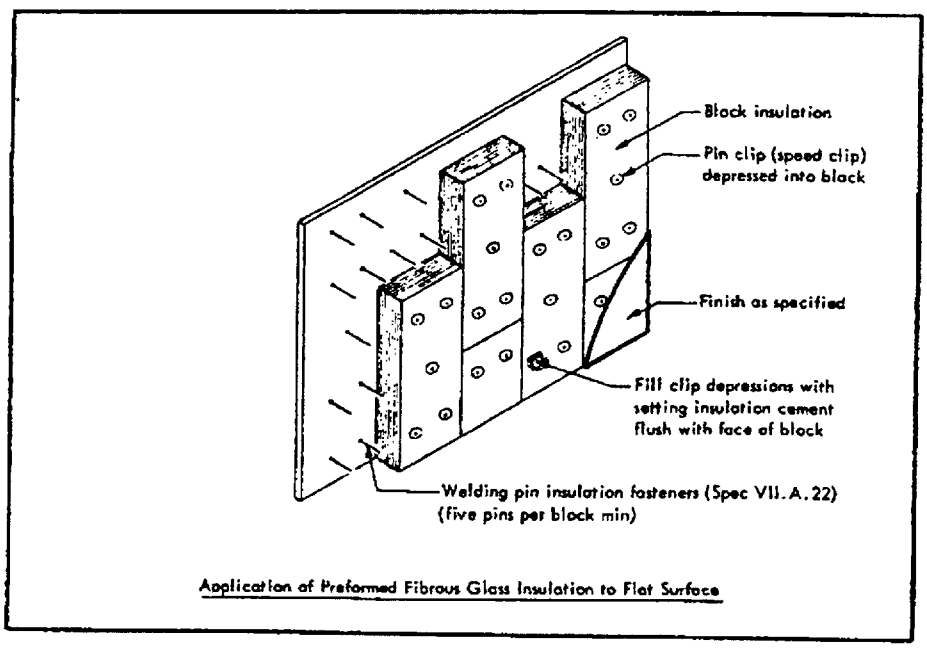
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APPLICATION OF SEMI-RIGID INSULATION
MODERATE AND HOT TEMPERATURE SERVICE



Application of Fibrous Glass Insulation Adjacent to Uninsulated Flanges

Figure XV-3



Application of Preformed Fibrous Glass Insulation to Flat Surface

Figure XV-4

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APPLICATION OF SEMI-RIGID INSULATION MODERATE AND HOT TEMPERATURE SERVICE

EQUIPMENT - Contd

Application - Flat Surfaces - Contd

Pins should be 1/4-inch longer than total thickness of insulation. The pins should be placed so as to provide a minimum of five attachments per block. The insulation should be secured in position by pressing the pin clips over the pins. Clips should be pressed into the insulation just sufficiently to allow pins to be cut off below adjacent uncompressed insulation surface. These depressions at pin and clips should be pointed up flush with insulation cement. This installation is illustrated in Figure XV-4.

Vessel legs and vessel skirts should be insulated in the same manner as discussed in Chapter XIII and as shown in Figures XIII-10 and XIII-11.

The weather-barrier for outdoor service should be either mastic reinforced with fabric or metal jacket for cylindrical section of vessels. Flat surfaces, irregular surfaces, flanges and other fittings, should be protected with mastic reinforced with fabric. Application of these materials is given in Chapter XXI "Weather-Barriers."

For indoor applications not subject to wash down by hose or liquid spillage, the equipment and vessels may be coated with bonding adhesive in which glass cloth is imbedded. After this has dried, the entire surface should be coated with PVA finish coating of specified color.

PIPING

Surface Preparation

Pipe surfaces shall be coated and cleaned the same as called for equipment except that stainless steel pipe shall only be coated behind flanges and elsewhere where specifically specified.

Application of Insulation

The application of straight pipe insulation depends upon the type of outer jacketing or coating which is to be applied as a weather-barrier or indoor covering.

When the jacketing is installed separately, the straight pipe insulation should be installed in staggered joint construction. All joints should be tightly butted to eliminate voids. When insulation with factory applied jacketing is used, it should be installed with each cylindrical section butted tightly against adjacent sections.

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APPLICATION OF SEMI-RIGID INSULATION MODERATE AND HOT TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation

Insulation on 4-inch NPS pipe and larger on vertical lines shall be supported by a pipe insulation support located directly above the elbow. A pipe insulation support should be located above each pair of flanges or flanged valve in a line. These are shown in Figure XV-5.

With the exception of ball and plug valves and welded and screwed fittings below 3" NPS, all fitting covers should be prefabricated or premolded. These fitting covers should be in accordance with the description given in ASTM Recommended Practice C-450.

Prefabricated fittings for welded pipe fittings should be installed prior to installation of the straight pipe insulation. Flanged fittings should be installed after the installation of the straight pipe.

Welded and screwed fittings on 3-inch NPS pipe and smaller may be insulated by troweling or palming insulation cement over the fitting flush to the adjacent straight pipe insulation.

Pipe covering on piping above 212°F and installed in staggered position should have expansion joints installed in uninterrupted straight runs exceeding 21 feet in length. Such an expansion joint and its details of construction are shown in Figure XV-6. In some instances, a large crack will develop in the pipe insulation after one line is in service, indicating the need for an expansion joint at that location. When this occurs, an expansion joint should be built into the system at that location.

Securement of pipe insulation installed in staggered joint construction should be by stainless steel wire on 9-inch centers. Fitting covers should also be secured in position with stainless steel wire.

WEATHER-BARRIER

Straight pipe insulation indoors with a plastic, glass fiber reinforced, factory applied, fire resistant jacket should be secured in position by adhering the lap down over the adjoining edge of the jacket. In some instances these laps require a lap adhesive; in others, the adhesive is factory installed with release paper over the adhesive. Where this self-sealing adhesive is furnished, the paper should be stripped off the adhesive, the lap set in place at the center, and the lap sealed toward either end by pressing the head with the blunt edge of a knife. The circumferential joints are sealed with butt joint strips furnished with the pipe insulation.

Fittings, indoors where no liquid exposure is expected, are finished with bonding adhesive, glass cloth, and PVA finish coatings.

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APPLICATION OF SEMI-RIGID INSULATION
MODERATE AND HOT TEMPERATURE SERVICE

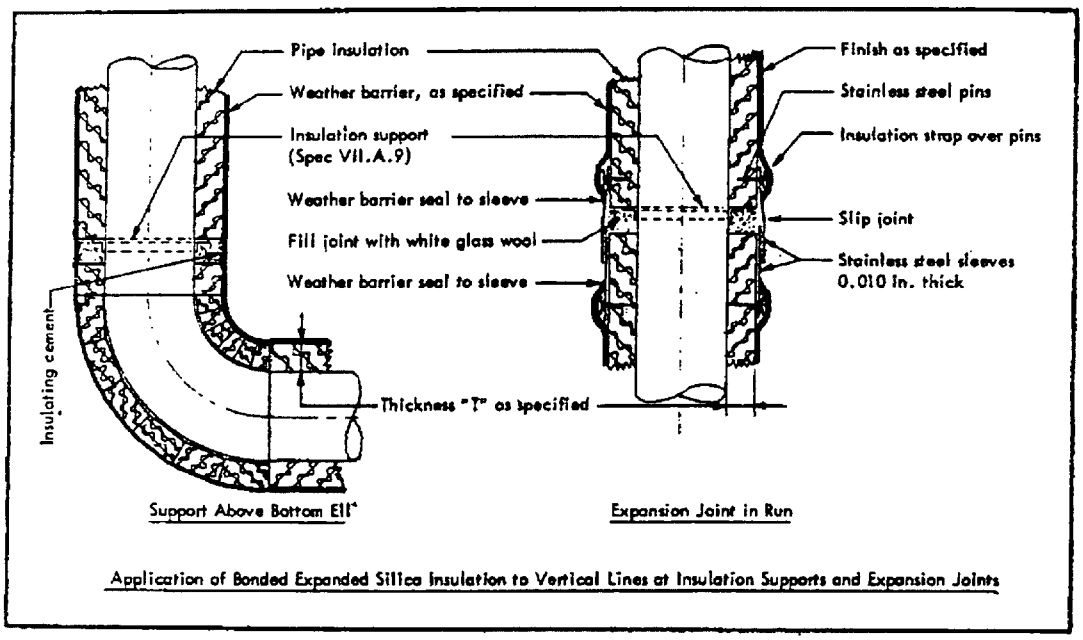


Figure XV-5

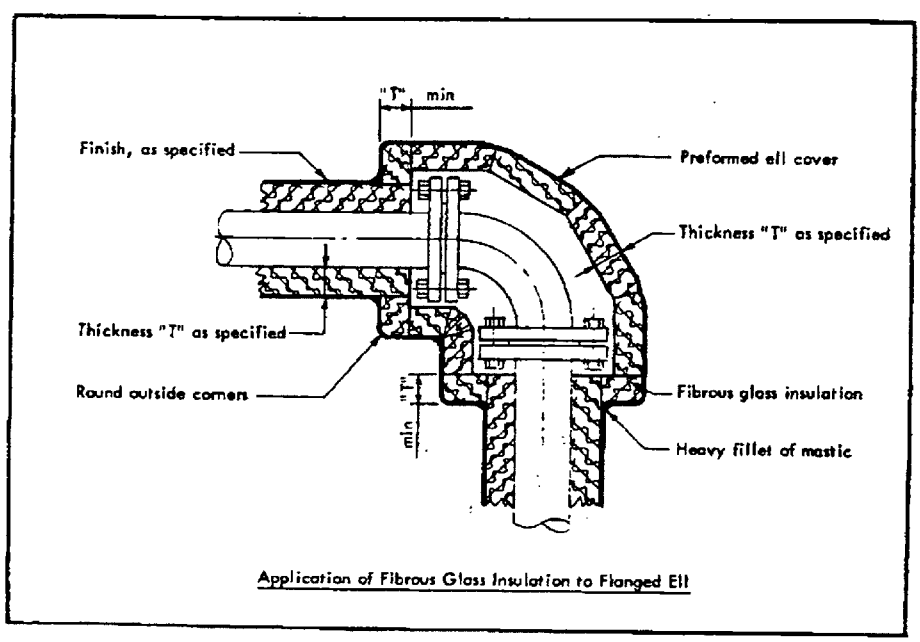


Figure XV-6

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
MODERATE TEMPERATURE SERVICE

GENERAL

Flexible cellular insulation is a compressible elastic material. Because of these properties it must be installed in a different manner than the rigid or semi-rigid insulations. Because of its flexible nature it can be installed over tubing before the tubing is installed; and where tubing is deflected to fit, the insulation will also deflect without cracking or breaking. When it is secured in position to another surface or to itself, the major means of securement is with contact adhesive.

EQUIPMENT

Surface Preparation

Surface preparation of equipment, vessels, or ducts to which flexible cellular insulation is to be applied is of utmost importance, as satisfactory installation and service depend upon the adhesion bond between the surface and the insulation.

Carbon steel equipment, vessels, and ducts must be sandblasted and coated with zinc-silicate inorganic coating in accordance with Coatings Specifications prior to application of the insulation.

Stainless steel vessels and equipment must be coated with Thermalox No. 70 in accordance with UCC Coating Specifications prior to application of the insulation.

The surfaces of vessels or equipment of aluminum, copper, or galvanized steel must be cleaned of all dirt, grease, oil, and other contaminants prior to application of the insulation.

Application of Insulation

Each sheet should be cut to be approximately 1/8-inch longer in each direction than the surface to be covered.

The surface to be insulated and the inner surface of the insulation (cut cell side) should be completely coated with contact adhesives. The coated surface should be allowed to dry until it is non-tacky to the touch. The length of drying time will change with ambient temperature conditions. Basically, the lower the ambient temperature, the longer will be the time required for the adhesive to dry to a non-tacky state.

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
MODERATE TEMPERATURE SERVICE

EQUIPMENT - Contd

Application of Insulation - Contd

The insulation is positioned so that its edges overlap butting surfaces, or previously installed sheets, by 1/8 inch. The center of the insulation sheet is then pressed to the surface. Working outward, to avoid trapping air, the sheet is pressed firmly to the coated surface. The edges are compressed to take up for the 1/8-inch overlap; the expansion of the sheet will then assure tight butt joints. The joint should then be spread open and, by means of a small brush, contact adhesive applied to the two edges of the butt joint. This will assure that the joint will be firmly bonded with adhesive when the sheet is released to expand back in position. The sheets are then pressed into final complete contact by firmly pressing with a small hand roller.

When a double layer of insulation is required, the outer surface of the inner layer and the inner surface of the outer layer of flexible insulation should be coated with contact adhesive then applied as described above. However, the outer layer should be applied so that the butt joints of the second layer do not coincide with those of the first layer.

At the termination points and where the insulation butts to metal, exposed cut edges of cut insulation should be coated with flexible sealer and inside corners caulked with this sealer.

On square or rectangular ducts, the application method of installing the flexible insulation is the same as described; however, the sequence of installation should be as follows:

1. The insulation should first be applied to the bottom surface, neatly fitting the width of the duct.

2. The sides of the duct should be insulated next, with insulation extending from the top edge of the duct down over the edges of the bottom insulation to the flat outer surface of the bottom insulation.

3. The insulation should then be applied to the top surface of the duct, extending from outer surface to outer surface of side insulation.

The insulation over standing duct seams should be the same as the thickness of that applied to the duct. Illustration of this application is shown in Figure XVI-1.

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
MODERATE TEMPERATURE SERVICE

PIPING

Surface Preparation

Carbon steel pipe in the temperature range up to 150F shall be coated in accordance with the UCC Coating Specifications.

Stainless steel piping shall be coated only behind flanges and elsewhere when specifically specified.

Aluminum, copper, or galvanized steel pipe must be cleaned of all dirt, grease, oil and other contaminants prior to application of the insulation.

Application of Insulation on Straight Pipe

Flexible foam insulation is furnished in slit or unslit cylindrical shapes to fit NPS pipe up to 5-inch NPS and tubes up to 4-1/8-inch OD.

When piping is already erected, the slit insulation is installed by applying the insulation on the pipe. The butt edges are then coated with contact adhesive and held open until the adhesive had dried tack-free to touch. Then the edges are pressed together to form a bond. Around curves in the pipe where the butt joint may have a tendency to gap, the seam may be pulled tight by a wrapping of pressure sensitive tape until the contact adhesive has an opportunity to set to final bond. All butt end joints should be cemented together in a similarly manner to the longitudinal edge joints.

Pipe or tubing above the sizes of available cylindrical sections are insulated with sheet insulation. The sheet insulation should be cut to fit around the pipe loosely, i.e., without stretching. The pipe and cut side of the insulation should be coated with adhesive and installed in the same manner as described in the "Equipment" section. All butt edges should be carefully sealed.

When insulation is installed on pipe prior to erection, the unslit sections are slipped over the pipe. Open ends of the pipe or tube should be closed with plugs prior to slipping the insulation over to prevent mica dust from the insulation from entering the pipe or tube. The insulation should be slightly longer than the pipe or tube surface it is to cover. When the pipe or tube is erected, the insulation should be pushed back 6 to 8 inches from the ends to allow for connection. This is illustrated in Figure XVI-2. After erection, all butt joints and joints to fitting covers should be cement bonded together.

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
MODERATE TEMPERATURE SERVICE

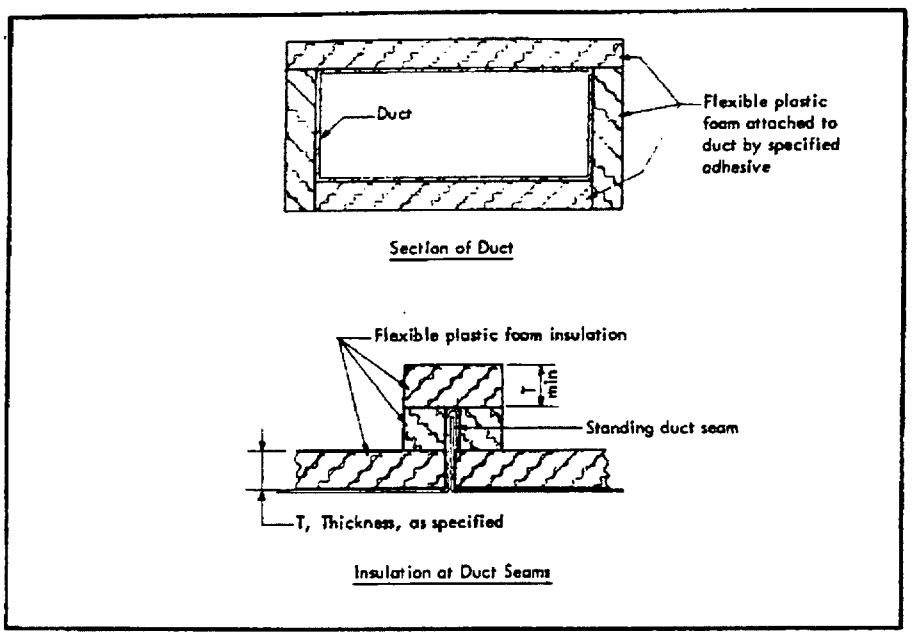


Figure XVI-1

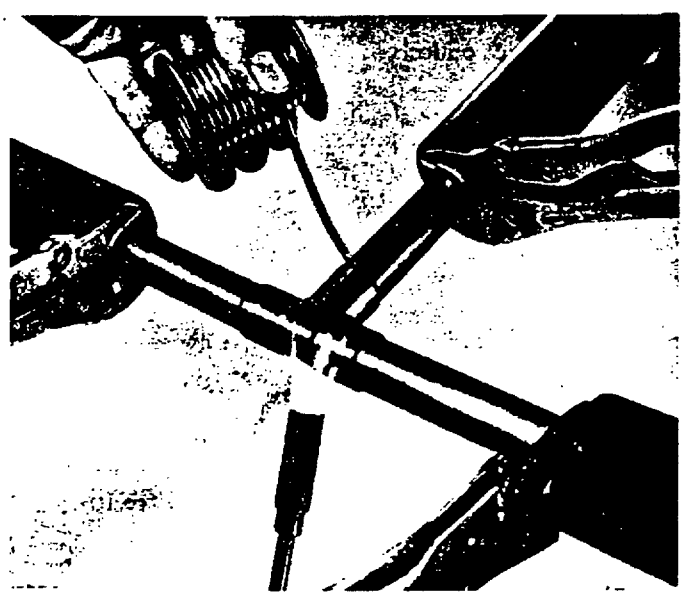


Figure XVI-2

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
MODERATE TEMPERATURE SERVICE

PIPING - Contd

Application of Insulation on Piping Fitting and Valve Covers

As insulation for cylindrical pipe is only available up to 5 NPS and 4-1/8 tube sizes, the number of fittings which can be fabricated from pipe insulation is limited. Those that can be produced from pipe insulation should be in accordance with ASTM Recommended Practice C-450, latest revision. The material is most easily cut by a sharp knife, rather than by a saw. The fitting parts can be cut by a sharp knife, as illustrated in Figure XVI-3. Individual pieces are cemented together with contact cement.

Large size fitting covers shall be fabricated out of sheet insulation cut to fit the valve, elbows, or flanges. The sheet material is installed on the fittings in the same manner as described in the "Equipment" section. Sheets are cemented to the fitting with contact cement and all butt joints bonded together with contact cement. Dimensions for cutting sheet insulation for 90 degree long and short radius elbows are given in Figure XV-4.

Supports and Hangers

Because of the flexible nature of the insulation, it compresses with load. For this reason when horizontal pipe is supported by cradles, another insulation must be used to support the pipe at the cradles. Rigid urethane foam insulation should be installed between the cradle and the pipe at beam crossings. The rigid urethane should be of sufficient length to extend a minimum of 2 inches beyond both ends of the cradle. Joints between the rigid insulation and the flexible insulation should be bonded with contact adhesive.

Pipe hangers which connect directly to the pipe should be insulated with pipe insulation for a distance of 6 inches beyond where they project through the insulation.

FINISH AND WEATHER-BARRIERS

Indoors

Where the pipe or ductwork in buildings are concealed in pipe chases or suspended ceilings, the insulation requires no finish or coating.

Where exposed indoors, all equipment should be painted with two coats of vinyl finish of the color specified. Also, ductwork or piping which are located where subject to mechanical abuse or washing down with water shall be painted with two coats of vinyl finish.

Piping and ductwork exposed to view, but not subject to wash down or mechanical abuse, are to be finish painted with two coats of water emulsion PVA paint of color specified.

Equipment and piping located outdoors shall be protected outdoors with mastic reinforced with Dynel cloth of type specified and applied in accordance with instruction given in "Weather-Barrier" Chapter XXI.

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APPLICATION OF FLEXIBLE CELLULAR INSULATION
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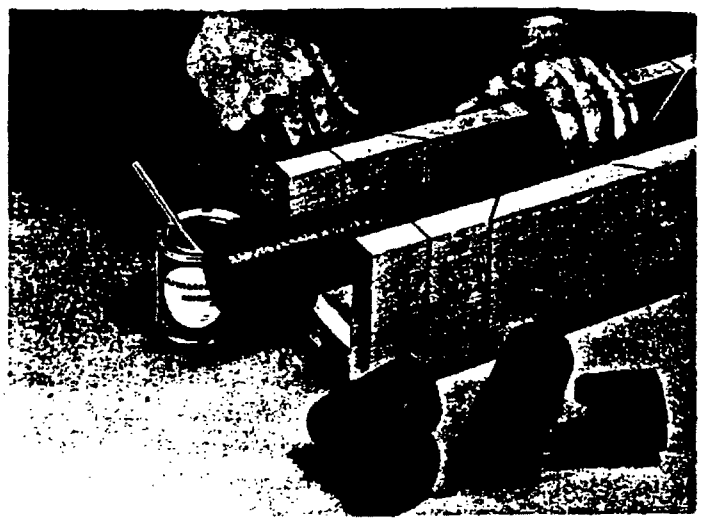
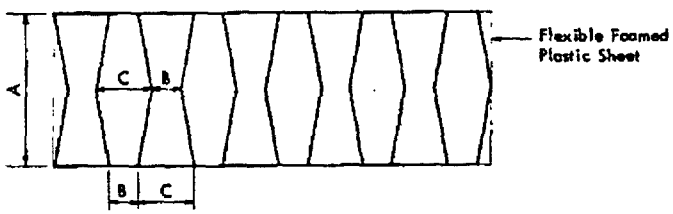


Figure XVI-3



Dimension "A" is a job-site measure of the elbow circumference.

TABLE FOR DIMENSIONS B AND C					
Nominal Pipe Size	Number of Segments	Long Radius 90° ELL "B", In.	Long Radius 90° ELL "C", In.	Short Radius 90° ELL "B", In.	Short Radius 90° ELL "C", In.
5	3	2-5/32	5-21/32	29/32	4-9/16
	4	1-19/32	4-1/4	1/2	3-5/16
6	3	2-21/32	6-27/32	1-5/32	5-13/32
	4	2	5-5/32	13/16	3-27/32
	6	1-5/16	3-7/16	9/16	2-19/32
	8	15/16	2-5/16	13/32	1-31/32
8	6	1-13/16	4-1/2	13/16	3-13/32
	8	15/16	2-5/16	19/32	2-19/32
10	6	2-11/32	5-19/32	1-1/16	4-1/4
	8	1-3/4	4-3/32	13/16	3-3/16
12	8	2-27/32	6-19/32	1-5/16	5-1/16
	10	2-3/32	4-31/32	1	3-13/16
16	8	3	6-13/32	1-29/32	6-1/2
	10	2-13/32	5-5/32	1-13/32	4-27/32
18	8	3-13/32	7-3/16	2-5/32	7-1/4
	10	2-11/16	5-13/16	1-19/32	5-7/16
20	8	3-3/4	8	2-13/32	8-1/16
	10	3	6-13/32	1-13/16	6-1/16
24	8	4-9/16	9-21/32	2-31/32	9-21/32
	10	3-21/32	7-11/16	2-3/16	7-1/4

Dimensions for Cutting Flexible Sheet Insulation

Figure XVI - 4

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APPLICATION OF PREFABRICATED PANEL INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

GENERAL

Prefabricated panel insulation is insulation which is affixed to metal panels by the manufacturer. The insulation is semi-rigid fibrous glass and the panels are either smooth or ribbed aluminum sheet. This type of insulation is useful for insulation of vessels over 12 ft 0 in. in diameter, and on flat surfaces, operating above ambient temperatures up to approximately 450F.

Due to their construction, the insulation and the weather-barrier must be installed at the same time. For this reason the installation layout, providing proper overlapping of the aluminum facing, or the installation of bottom strips, for rain shield is of upmost importance. The panels can be installed by the use of insulation supports and securement straps, or by the use of studs, nuts and pins. Where welding to vessel is not permitted, securement straps must be used as the method of installation.

The ribbed panel facing is furnished in a different size than the smooth panel. Thus, ribbed are made to dimensions to permit overlap of the ribs to form a water barrier and still form standard size insulation dimension of 96 in. x 48 in. The smooth panels are made to a 96 in. x 48 in. dimension and the butt joints are covered with a batten strip. Because of these differences, spacing of securements is also different, thus details of installation of these panels on vessel sidewalls must be described separately. In addition, the panels are installed differently when installed by straps than if installed by studs and nuts.

INSTALLATION OF RIBBED JACKETED PANELS TO VESSELS

Supports

1. Flat and cone head vessels should have an angle or plate continuously welded to the intersection of vessel head and sidewalls, to provide for insulation securement and water shed. This is shown in Figure XVII-1. Where welding is not permitted, bolted-on support and flashing should be installed as shown in Figure XVII-3.

2. If panel insulation on the sidewall of vessel does not extend to the base of the vessel, an angle or flat bar extending 1/2-inch greater in width than the insulation thickness should be installed around the vessel at the level where the panel insulation is to terminate.

3. Where welding to the vessel is permitted, the panels shall be fastened to the cylindrical section of the vessel by studs, welded to the vessel, that extend through factory-punched holes in the aluminum facing. Dimensions of panel and stud arrangement are shown in Figure XVII-2.

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

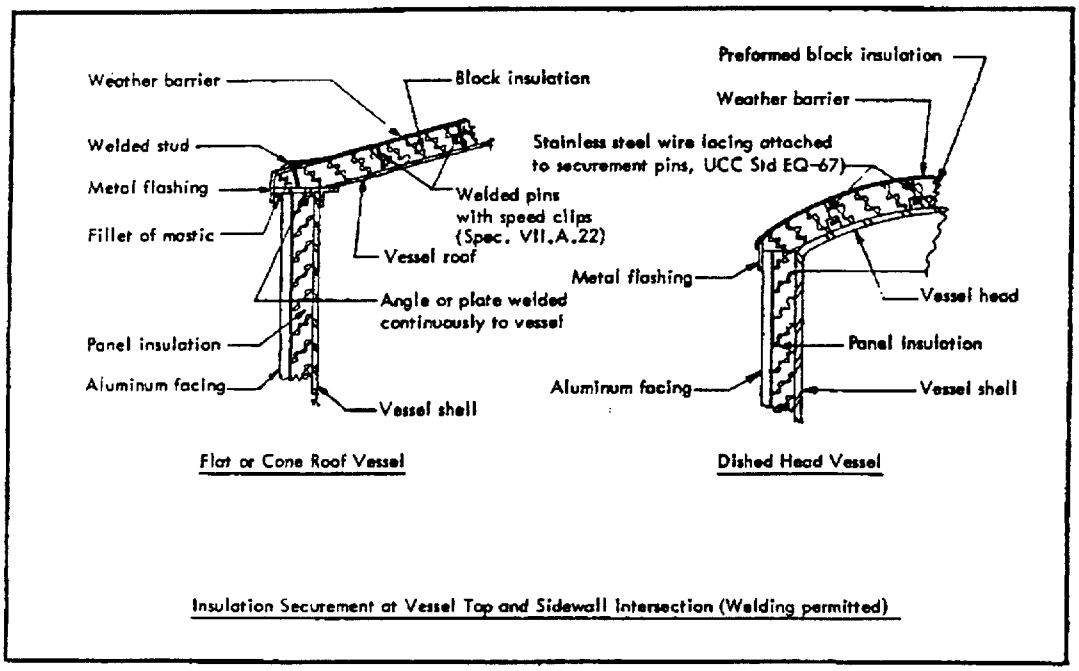


Figure XVII-1

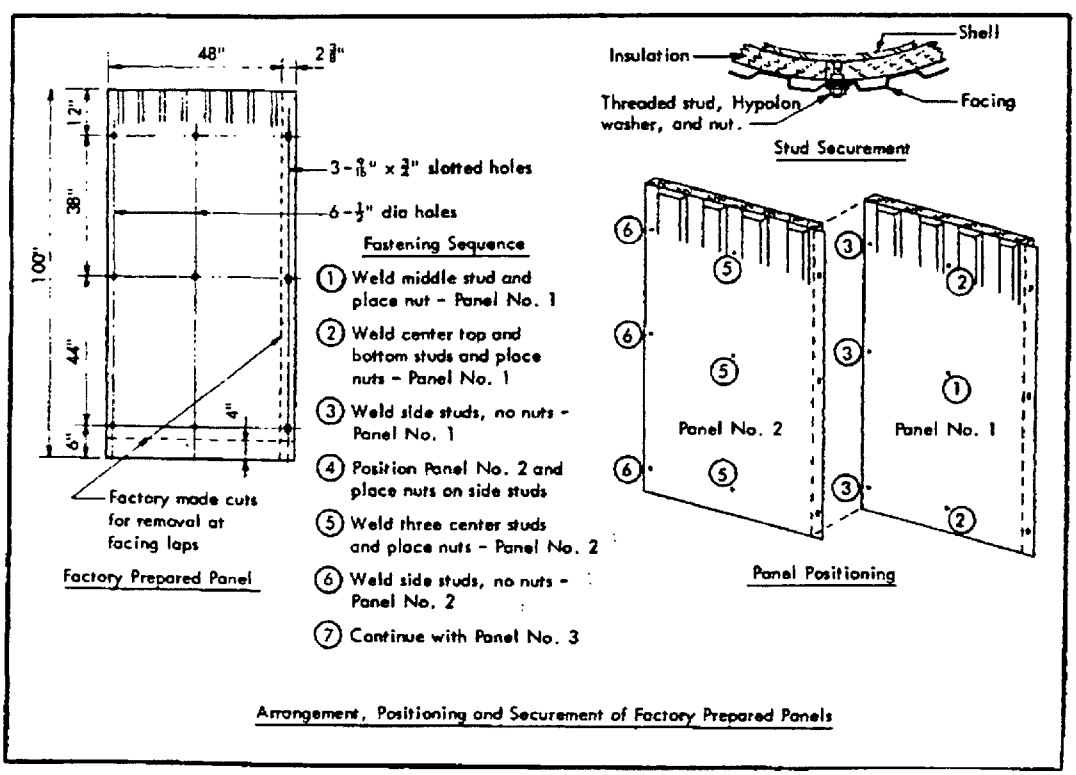


Figure XVII-2

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

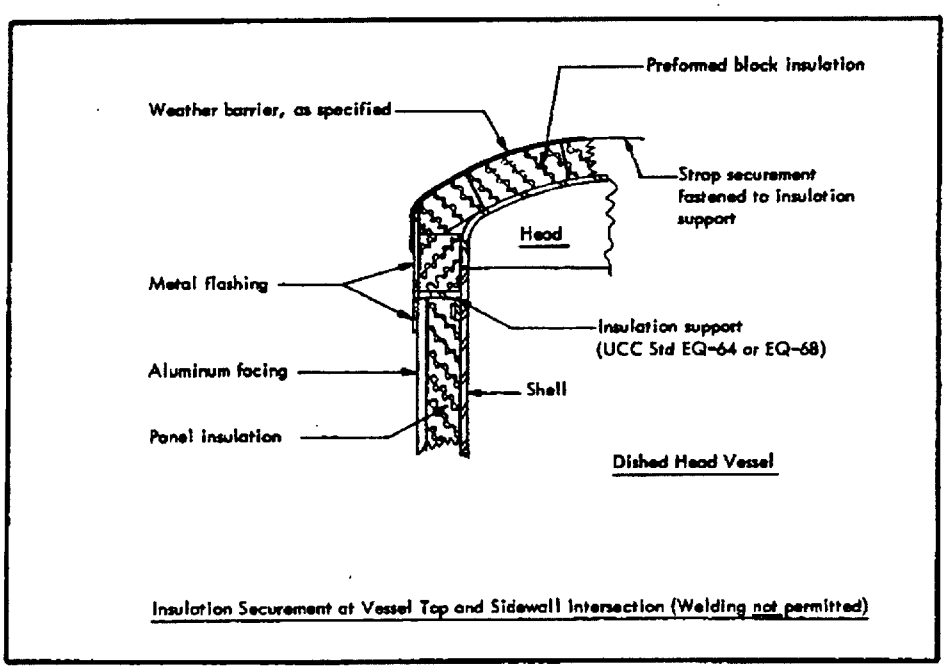


Figure XVII - 3

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APPLICATION OF PREFABRICATED PANEL INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

INSTALLATION OF RIBBED JACKETED PANELS TO VESSELS - Contd

Supports - Contd

4. Where welding to the vessel is not permitted, insulation supports must be bolted on as shown in Chapter IX "Supports and Securements."

Surface Preparation

Due to the type of construction involved this installation is restricted to the insulation of carbon steel vessels. Vessel operating above 0°F up to 150°F must be painted in accordance with UCC Coating Specifications.

APPLICATION - SIDEWALL INSULATION

Panels must be installed in vertical position so that their edges are parallel with the center line of the cylindrical section of the tank. If vessel foundation is sloped for drainage, where the panels abut the vessel foundation, their bottom edges shall be cut to the slope of the foundation so that the top edges form a continuous horizontal line around the circumference of vessel. This is illustrated in Figure XVII-4.

The arrangement of panels shall be as follows:

1. Cutouts for nozzles, located at the same elevation may be simplified by arranging for horizontal lap to occur at this elevation.

2. The vertical laps between panels should be arranged, where possible, to fall on center lines of nozzles which do not occur at horizontal laps.

When the vessel is on a low pad, where the level of rain or water can reach the bottom of the panel, the fibrous insulation should be cut and stripped from the bottom of the first course to an elevation greater than the highest expected water level. In no case should this be less than 9 inches. This amount of stripped-out fibrous insulation should be replaced with cellular glass insulation of equal thickness and preformed to fit the diameter of the vessel.

Where welding is permitted and the panels are to be secured to the vessel by studs, the panels must be positioned in accordance with predetermined reference lines. After positioning the panel in place, a stud shall be welded in the middle hole. The panel should then be secured

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION - SIDEWALL INSULATION - Contd

to the vessel by washers and nuts. After final positioning, additional studs should be welded to the vessel and the panel secured in position. Before the second panel is installed, 2 to 3 inches of insulation should be removed from the panel edge to allow overlapping of the aluminum sheet. A bead of sealer should be applied to the first panel edge at this overlap. The second panel should be positioned, then secured in position as previously described. This procedure is followed around the vessel until first course of panels is installed.

"S" clips should be installed on the top edge of the bottom course of panels to support the next course of panels. "S" clips should have sufficient length to provide 2 to 4 inches of overlap, depending upon the panel layout. A strip of insulation, of a width equal to that of the overlap, must be removed from the bottom of the second course panel. The second course panel is positioned with edges lined up with edges of the first course, then secured as previously described. Special care should be taken that no studs go through both sheets of overlapping ends of two courses of panels, as each course of panels must be free of other courses so as to provide a slip expansion joint. Fastening sequence for additional courses is the same as described for the first two courses. Fastening sequence and stud details are illustrated in Figure XVII-2.

Where welding is not permitted the panels must be secured to the vessel by strap. These panels should be without factory-punched holes for studs. The first panel should be located and positioned in the same manner as described in the welded stud secured section. Insulation on overlap edge (2 to 3 inches) shall be removed before the panel is installed. As each panel is installed a bead of lap sealer shall be placed between the overlapping faces of the aluminum. Panels are to be held in position by temporary rubber or nylon bands until permanent straps can be installed. The straps should be installed on 24-inch centers and at various intervals sheet metal screws should be set below the straps, with heads slightly protruding to prevent strap from slipping downward. Vessels over 12 feet in diameter should be strapped with expander strap or with expansion springs installed in each strap. Where springs are used, a spring should be installed in 30 ft of strap. Straps should be tightened to stretch each spring approximately 3 inches. The overlapped rib sections are to be joined together with sheet metal screws on approximately 24-inch centers.

On vertical side wall panels "S" clips should be installed on 24-inch centers along top edge of each course of panels to support the next course of panels. Two to four inches of insulation should be removed from the bottom of second, and subsequent courses of panels to provide for overlap. The second course should be positioned, with edges lined up with first course, and

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APPLICATION OF PREFABRICATED PANEL INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION - SIDEWALL INSULATION - Contd

with the aluminum sheet supported by the "S" clips. A strap should be installed at each horizontal overlap, positioned so as to ride behind the front leg of the "S" clip. Straps at mid sections of the panel should be installed as previously described. The overlapped rib sections are joined together with sheet metal screws, but care must be taken that sheet metal screws do not fasten two courses of panels together. Details of installation is shown in Figure XVII-4 and XVII-7.

As mentioned, cutouts for manholes and nozzles should be located at the intersection of two panels where panel arrangement makes this possible. Where it is necessary to cut out to fit over a manhole or nozzle, the opening should be closed by one or two sections of panel cut to fit around the nozzle or manhole. These sections should be sealed to the panel facing and secured with sheet metal screws. Cutouts should be cut to fit tightly around base pipe nozzle or the insulation cover on insulated nozzles or piping. The junction must be sealed with mastic to prevent water entry. Details of the application are shown in Figure XVII-5.

Roof Application

As ribbed panels do not lend themselves for most roof or head applications, these are most frequently insulated with rigid block insulation. On the cylindrical part at the junction of a roof or head with the panel, the thickness of the rigid insulation should be increased to the thickness of the panel insulation plus the depth of the ribs in the aluminum so that a metal flashing can be installed to shed water. This is shown in Figure XVII-3. The installation of the rigid insulation is as described in Chapter XIII - Rigid Insulation.

INSTALLATION OF SMOOTH JACKET PANELS TO VESSELS

Preparation

The preparation for installing smooth panels on vessels is similar to that of ribbed panels except that the dimensions for stud welding are different because battens strips are used on the vertical joints, and that the panels are installed with the long dimension in vertical position.

Because it is necessary that battens be stud welded in position and roof or head insulation is secured in position with welded pins and clips, this application is restricted to vessels to which this welding is permitted as indicated in Figure XVII-6.

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

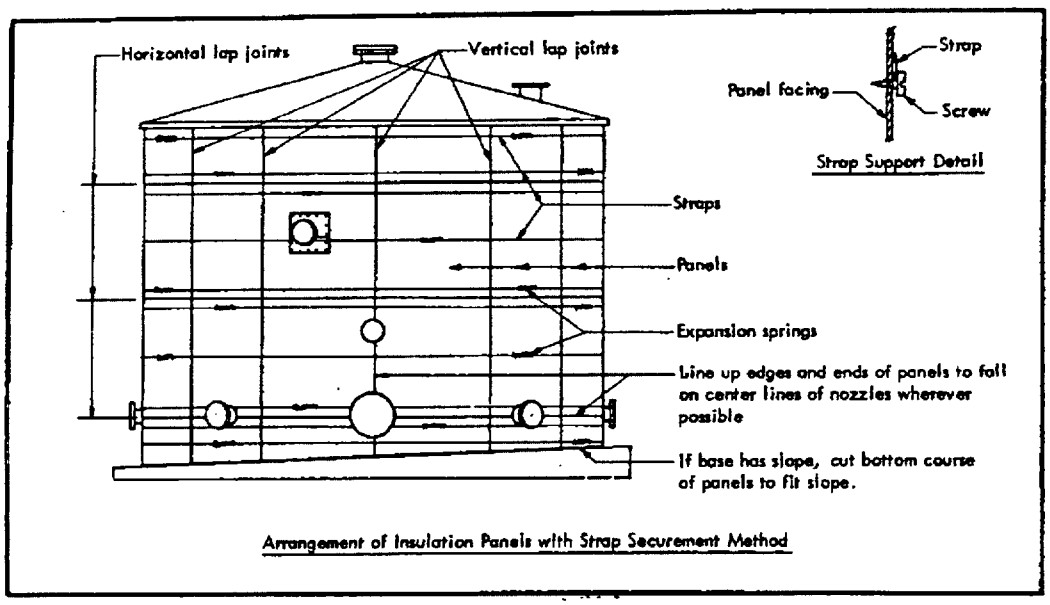


Figure XVII-4

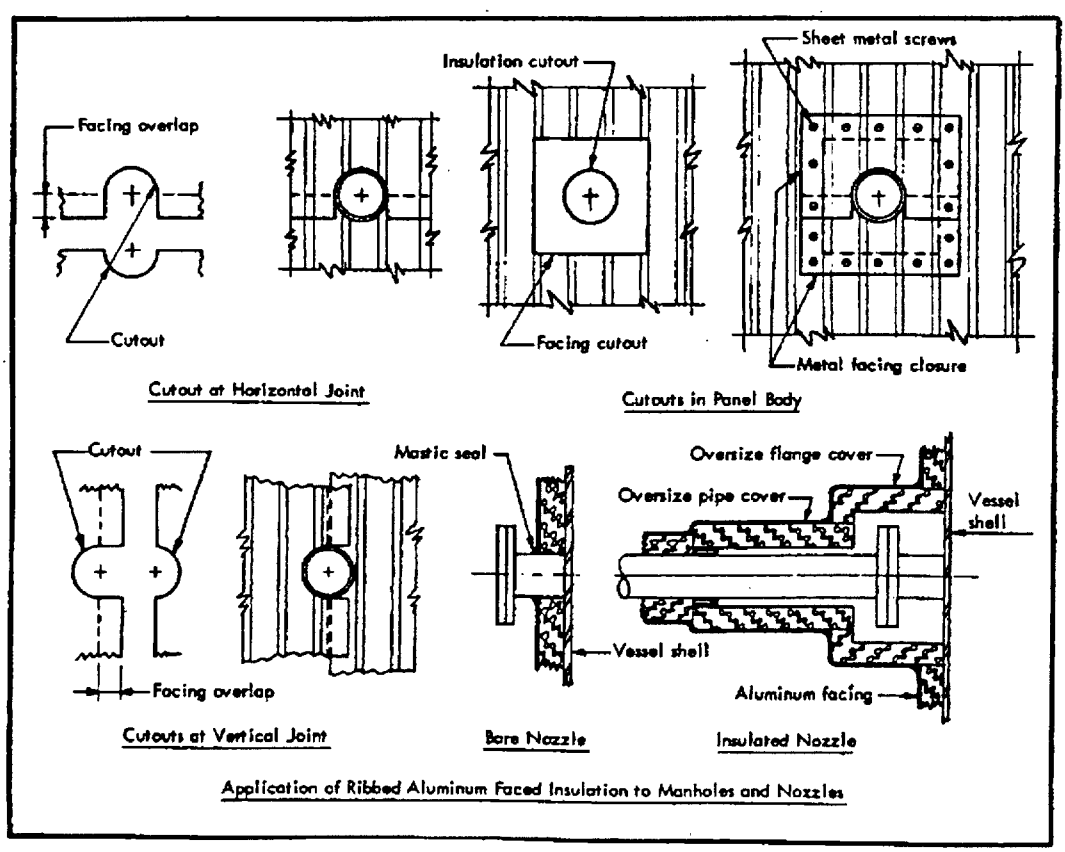


Figure XVII-5

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APPLICATION OF PREFABRICATED PANEL INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

INSTALLATION OF SMOOTH JACKET PANELS TO VESSELS - Contd

Preparation - Contd

The studs to attach the batten strips should be installed in vertical rows, spaced to circumferential dimensions of 96 inches. The vertical spacing should be as follows:

First row - three inches above base or support.
Additional rows - as shown in Figure XVII-7.
Top row - three inches from top angle or support.

These should be arranged to have centers of largest number of nozzles fall on edges or ends of panels. Details of stud spacing is shown in Figure XVII-7.

APPLICATION - SIDEWALLS

Panels must be installed in a horizontal position so that their end edges are parallel with the centerline of the vessel. If vessel foundation is sloped for drainage, where the panels abut the vessel foundation, the bottom edge should be cut to slope off the foundation.

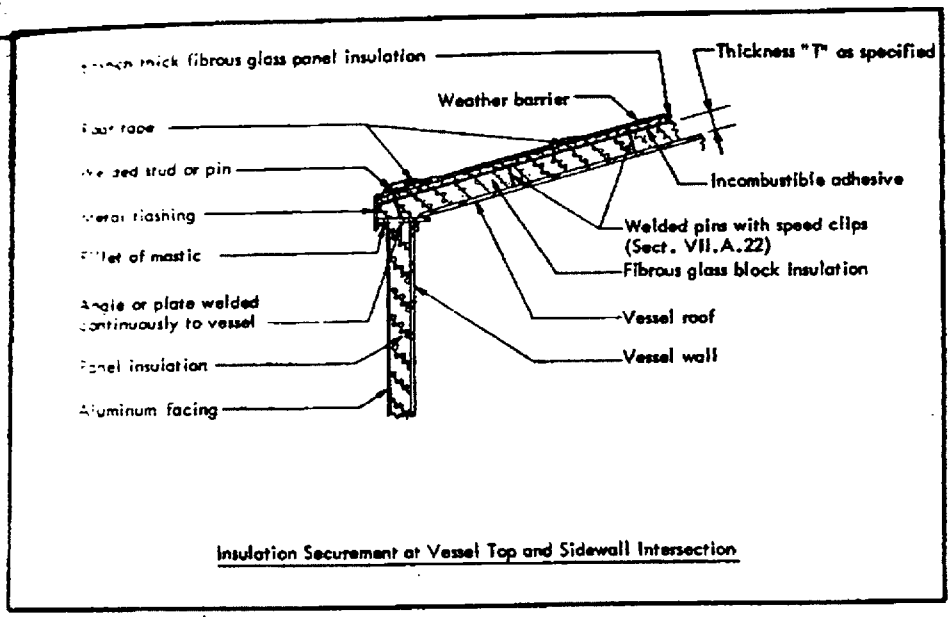
Where vessel is on a low pad where level of rain or drainage water can reach bottom edge of panel, the fibrous glass insulation should be removed from the first course of panels to an elevation greater than the highest expected water level. In no case should this be less than nine inches. The stripped out fibrous glass insulation is replaced with cellular glass insulation of the same thickness preformed to fit the shape of vessel.

The fibrous glass aluminum panels are to be positioned so that alternate rows of studs are between ends of panels and other rows are at approximate centerline of the panel. The first course of panels should rest on vessel base or foundation or on lower support ring. After the panels are in position, they are impaled on the centerline studs. They are then secured with grooved caps or nuts, depending upon the type of stud assembly. Insulation straps shall be installed on a vertical spacing as shown in Figure XVII-7. Insulation straps shall be installed on the batten and over the top of the bottom and second stud. Vessels 12 to 20 feet in diameter should have one expansion spring installed in each band. Vessels over 20 ft in diameter should have an expansion spring installed at approximately 30 feet intervals. The batten strip, over the first course, should be cut two inches less than the height of the top edge of the panel, then should be installed by impaling it over the studs.

"S" clips shall be installed along the top edge of first course of panels to support the second course. A clip should be placed four inches from each end, and three others should be spaced equally from the end clips. Two inches of the fibrous glass insulation (which is not adhered to the aluminum facing) should be removed from the bottom of each panel which is used on the

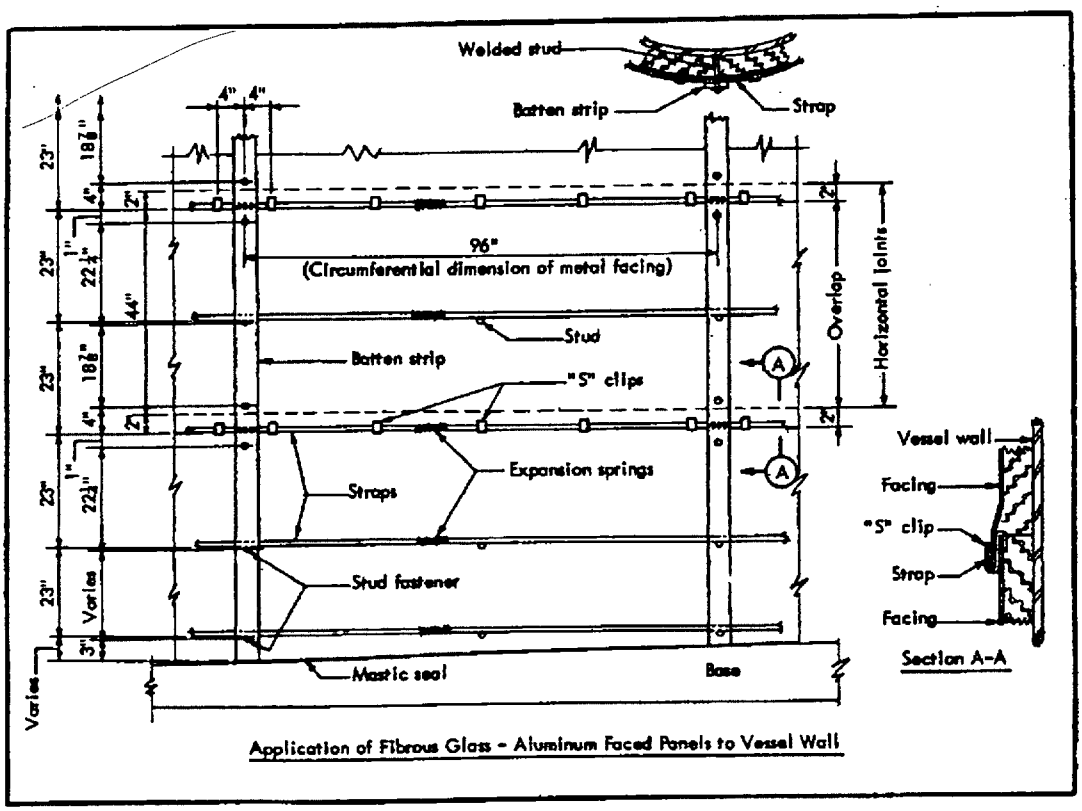
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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE



Insulation Securement at Vessel Top and Sidewall Intersection

Figure XVII-6

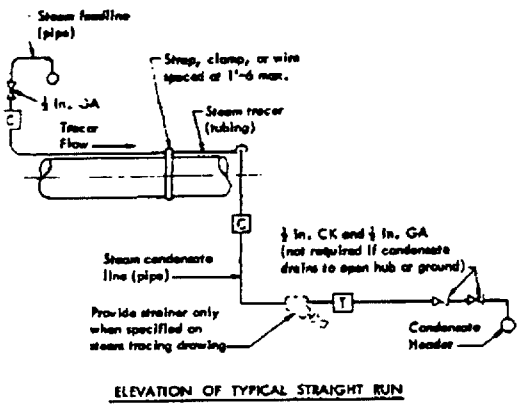


Application of Fibrous Glass - Aluminum Faced Panels to Vessel Wall

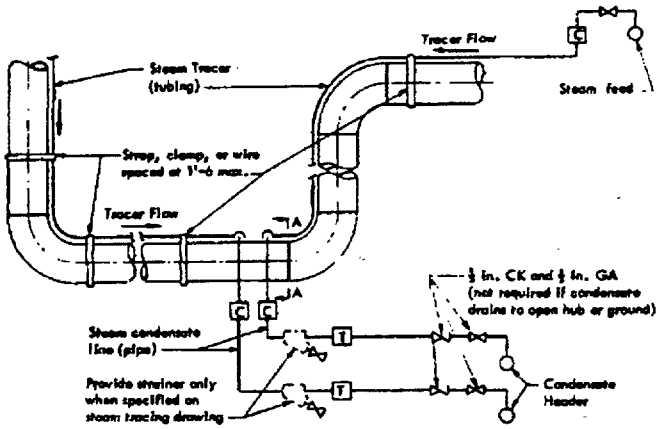
Figure XVII-7

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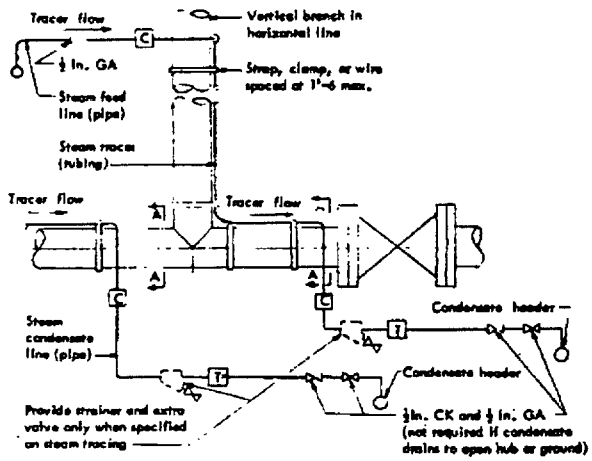
STEAM TRACING SYSTEM DETAILS AND MATERIALS



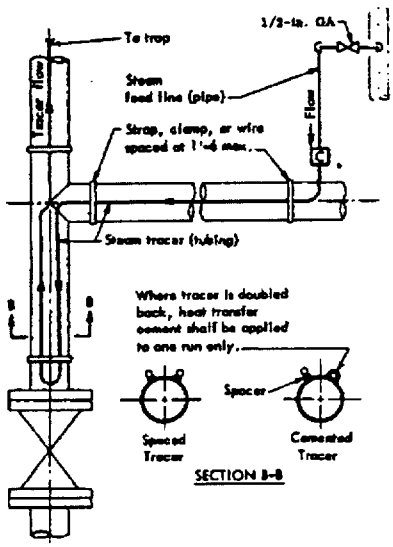
ELEVATION OF TYPICAL STRAIGHT RUN



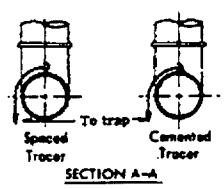
ELEVATION OF POCKET IN VERTICAL RUN



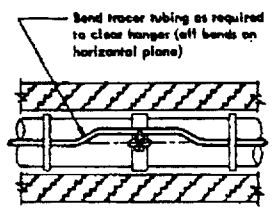
ELEVATION OF VERTICAL BRANCH IN HORIZONTAL LINE



SECTION B-B

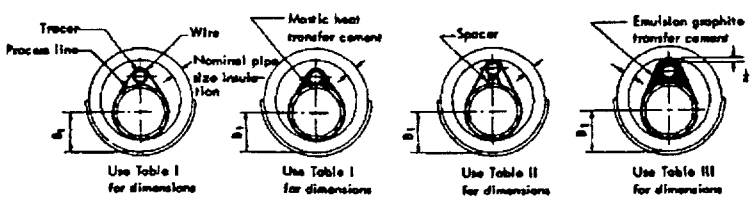


SECTION A-A

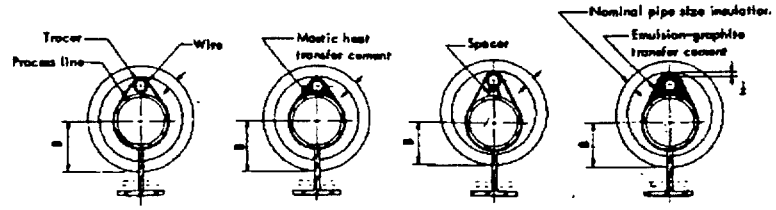


PLAN

PLAN OF HORIZONTAL BRANCH IN HORIZONTAL RUN



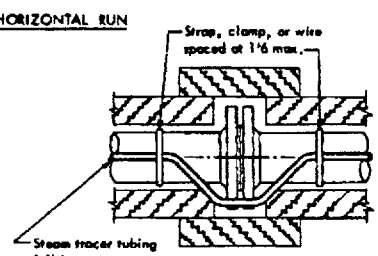
SUPPORTED ON INSULATION



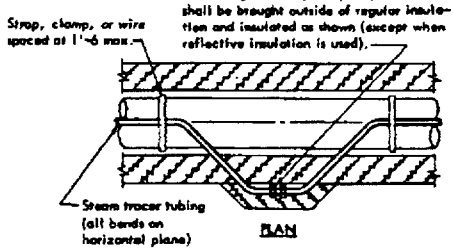
SUPPORTS ATTACHED TO PROCESS PIPE

DETAILS OF STEAM TRACER ATTACHMENT

NOTE:
Refer to Std P-140A for Tables I, II and III.



PLAN



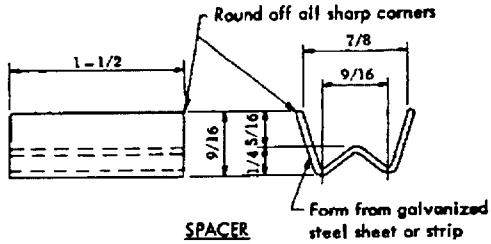
PLAN

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.

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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 "Utilitube", 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 "Swagelok", 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 "Swagelok", 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.
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	Thermon Manufacturing Company, Houston, Texas, or approved equal.		

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APPLICATION OF PREFABRICATED PANEL INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION - SIDEWALLS - Contd

second and successive courses. This provides for two inches overlap of facing. The second and subsequent courses shall be installed in same manner as first course. Details of stud layout and panel installation are shown in Figure XVII-7 and XVII-8.

Cutouts for manholes and nozzles should, wherever possible, be located at the intersection of two panels. Where it is necessary to cut out a panel to fit around a nozzle, the opening should be closed up by one or two sections of panel cut to fit around the nozzle, then sealed to panel facing with non-setting sealer and secured in place with sheet metal screws. All cutouts should be cut to fit around the bare nozzle, or around the insulation cover of insulated nozzles or flanges. Junction shall be sealed with caulking mastic. Details of application are shown in Figure XVII-9.

Roof Application

The roof insulation consists of two layers of fibrous glass insulation installed in broken joint construction.

If vessels have a maximum operating temperature below 220F the roof is insulated with roof panels as received. If vessel has a maximum temperature above 250F the roof panels used on the first layer shall have the wrap around weather-barrier at edges of panels field trimmed from the board before the board is installed.

The first layer of fibrous glass should be full specified thickness. It should be impaled on pins welded to the vessel roof. These pins should be located four inches from the edges and corners of the insulation, using no less than three pins on each of the sides and the ends. After insulation is impaled, it should be secured tightly to vessel roof by pin clips forced on the welded pins.

The outer "cap" layer of one-half inch thick fibrous glass roof insulation shall be installed in broken joint construction by embedding it in non-combustible adhesive spread over first layer of insulation at a uniform rate of two and one-half gallons per 100 square feet. On roofs with curvature such that top insulation does not bed firmly with the first layer, it may be necessary to cut through the asphalt cap sheet in straight lines to allow insulation board to bend. Joints must be tightly butted. The joints and cuts in the cap sheet should be covered with roof tape embedded in adhesive. Tape end joints should be lapped a minimum of four inches.

The insulation on the roof and side wall must be carefully flashed to prevent entry of water. The edge of exposed cut roof insulation where it extends over the side walls should be flashed with formed aluminum sheet to fit the circumference and curvature of the roof. Drip leg shall extend a minimum of one inch below shed angle or plate. It should extend a minimum of six inches up over the roof insulation. This flashing is impaled on studs then secured in position with caps or nuts. The junction of the flashing with underside of shell angle or plate should be caulked with caulking mastic. Tape embedded in adhesive shall be applied over junction of insulation and edge flashing.

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

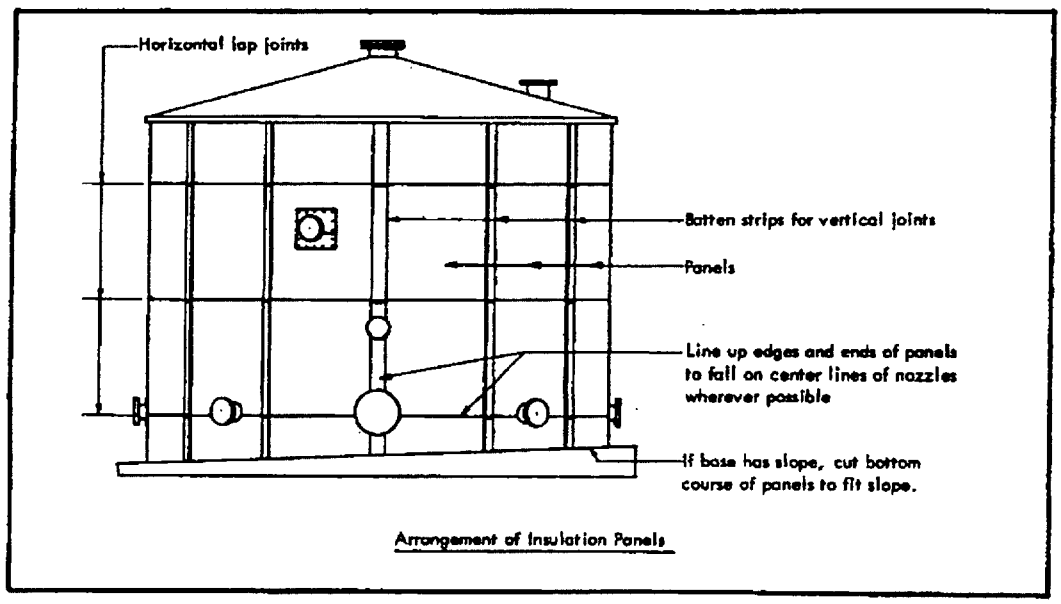


Figure XVII-8

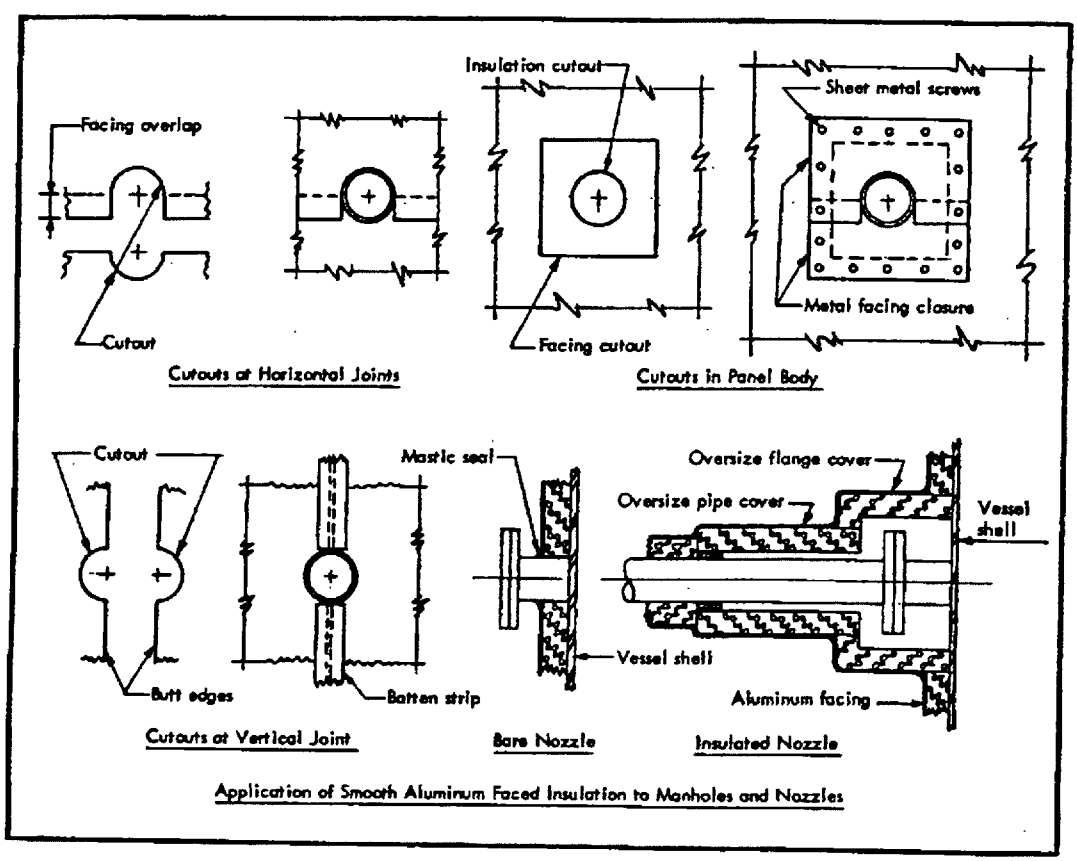


Figure XVII-9

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APPLICATION OF PREFABRICATED PANEL INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION - SIDEWALLS - Contd

Roof Application - Contd

The roof insulation should be covered with weather-barrier mastic reinforced with Dynel fabric as described in Chapter XXI - "Weather-Barriers."

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

GENERAL

Reflective insulation is thermal insulation which depends for its efficacy largely on reduction of radiant heat transfer across its thickness by use of surfaces of high reflectance and low emittance. The insulation is composed of units containing heat reflective sheets separated by low conductive supports, end enclosures, and outer casing arranged to form isolated gas (air) chambers between the sheets and the end closures. Although reflective insulation is used in applications, particularly buildings, where the sheets are field cut and erected, the application discussed here will be restricted to factory prefabricated panels, pipe covering, and fitting covers. Flat and curved panel reflective insulation for equipment is shown in Figure XVIII-1, and pipe insulation and typical fitting insulation are shown in Figure XVIII-2.

APPLICATION OF PREFABRICATED REFLECTIVE INSULATION

Supports and Securement

Reflective insulation is furnished in prefabricated units to be installed by straps and clips, hinges and snap-lock, buckles, and occasionally by sheet metal screws. The buckle-secured insulation is most often used where fast removal and replacement of the insulation is a requirement of the installation. Insulation support rings shall be installed in accordance with manufacturer's requirements. Insulation supports should be checked to determine that they are in accordance with the drawings.

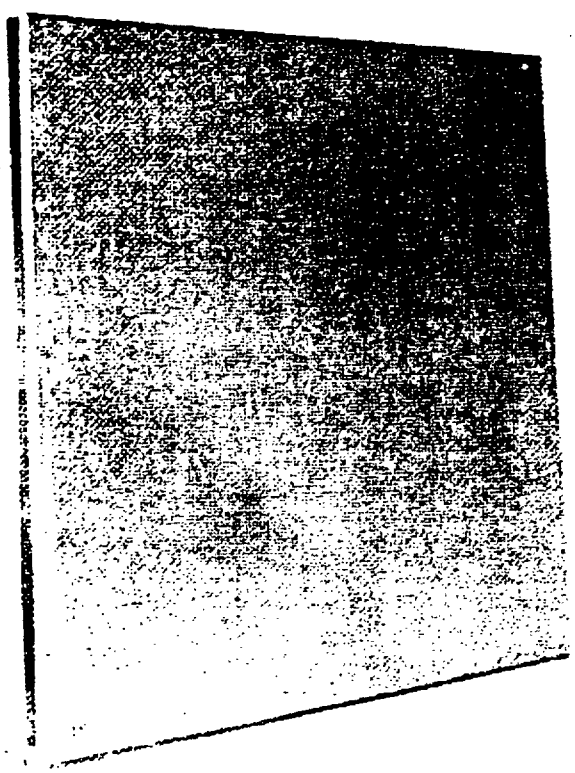
Surface Preparation

Surfaces of equipment to be insulated must be clean, protective requirement is same as listed in Chapter XIII, Rigid Insulation High Temperature Service.

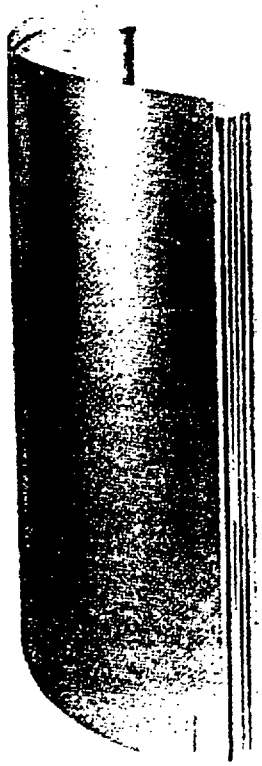
Because this insulation is custom-made to fit the vessel or the piping system, the applicator should familiarize himself with the drawings and installation instructions prior to starting erection. The sequence of application of the custom-made insulation units is of prime importance. If the installation is started with the wrong unit, it is likely that the final assemblies cannot be installed as designed. In general, installation is started at the bottom of pipe or vessel and proceeds upward. The manufacturer provides a drawing showing each insulation unit and its identification mark number plus packaging list identifying units in each shipment. Also, the manufacturer furnishes installation instructions which provide the installation sequence by insulation unit mark numbers.

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE



Flat Panel



Curved Panel

Figure XVIII-1

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

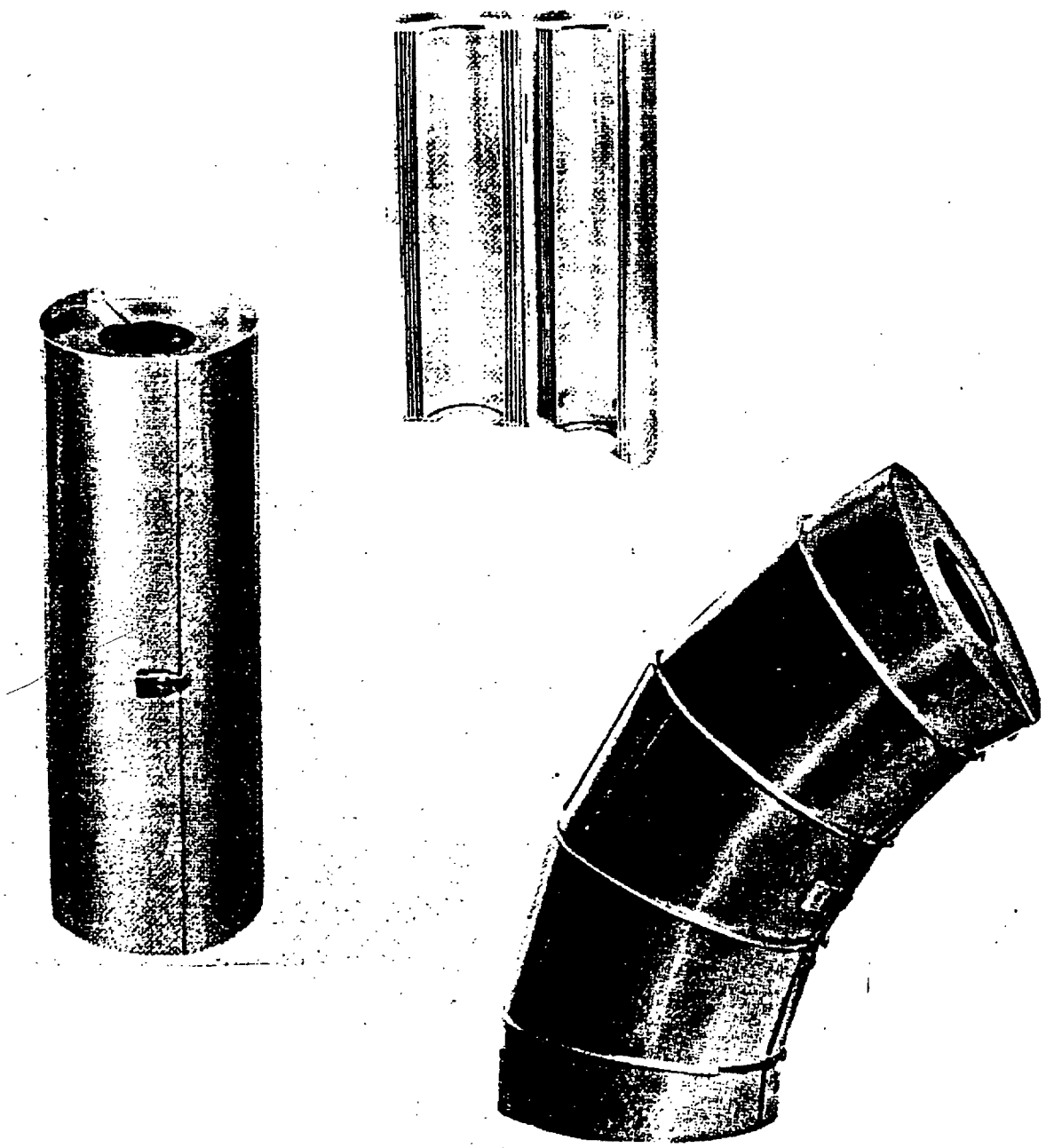


Figure XVIII-2

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION OF PREFABRICATED REFLECTIVE INSULATION - Contd

Application of Insulation

The panels for curved equipment surfaces should be applied with edges and ends closely abutted and with outer casing laps, or trim strips arranged to shed water.

Where stainless steel straps are provided for securement, strap supports are installed on the panels (by the manufacturer) to position the straps. Straps should be installed to draw up the cylindrical panels snug but care should be taken not to tension the band too tight and cause deformation of the panel.

Where stainless steel screws are provided for the securement, the screws should fit the two screw holes provided by the manufacturer. The proper screws and lock washers are provided by the manufacturer. As the panels are erected the screws should be pulled snug, but not tight. After the entire assembly is complete then all screws should be tightened.

Fast removal insulation should be placed in position and secured in position by fastening the buckle.

A typical installation using strap and screws is shown in Figure XVIII-3.

Fast removal and replacement insulation cover for vessel is shown in Figure XVIII-4.

Piping

The installation and sequence of installation instructions furnished by the manufacturer must be followed so that all pieces fit together as designed. A typical sketch showing sequence of installation is shown in Figure XVIII-5.

Insulation supports, where required, should be located as indicated on the manufacturers' sketches.

The insulation should be applied with the overlapping end of each section placed over the flush separator end of abutting section. The extended longitudinal edges of each section shall be lapped over flush edges of opposing half section so that all joints are tightly butted. In general, these lapped edges of the outer shell shall be placed so as to shed water.

The fittings, flanges, valves, and bent piping should be insulated in a manner similar to that for straight piping. The fitting covers should be applied with telescoping joint connections to the adjacent piping.

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE



Figure XVIII-3

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

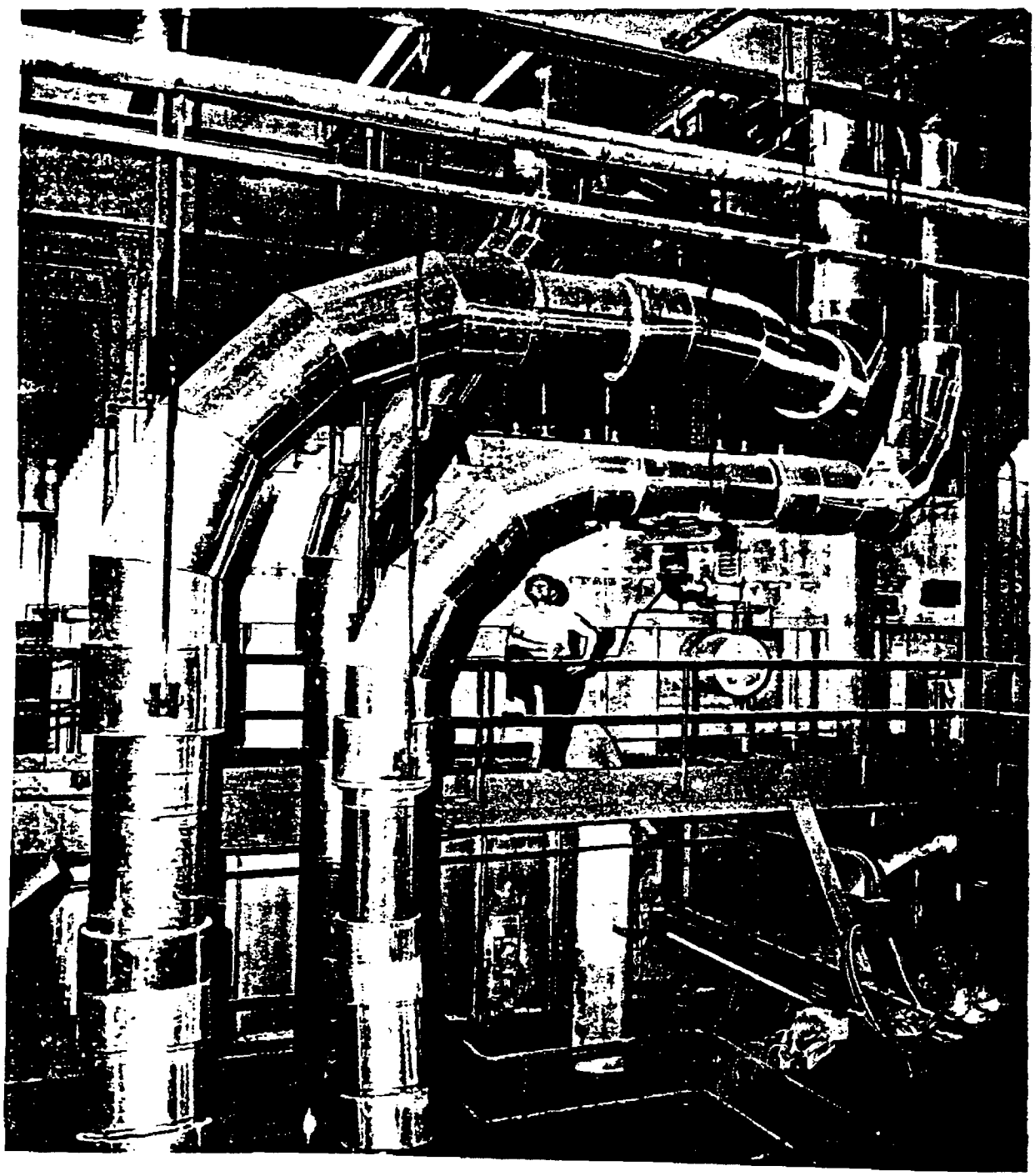


Figure XVIII-4

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION
MODERATE AND HIGH TEMPERATURE SERVICE

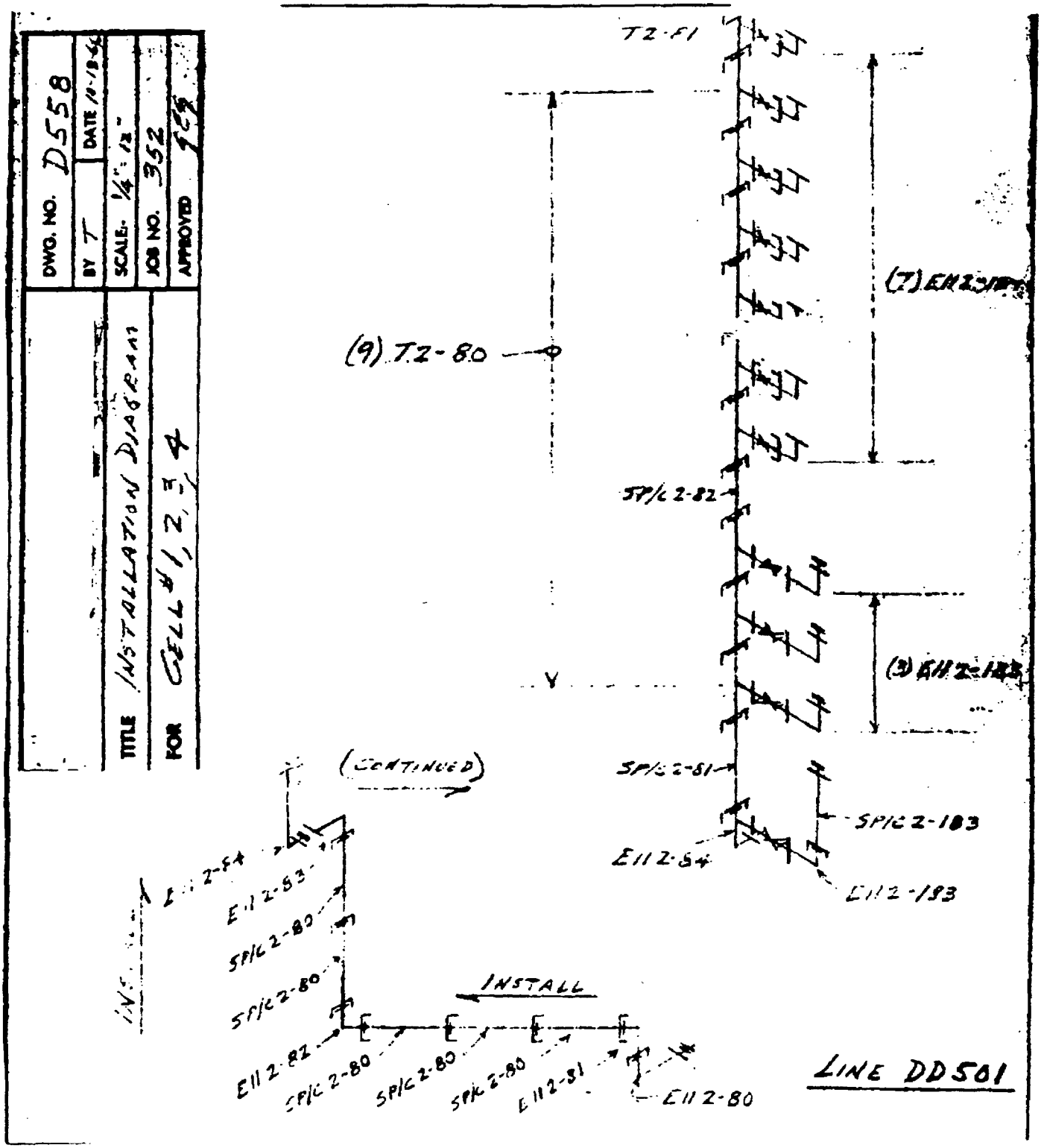


Figure XVIII-5

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APPLICATION OF PREFABRICATED REFLECTIVE INSULATION MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION OF PREFABRICATED REFLECTIVE INSULATION - Contd

Piping - Contd

The securement of the insulation should be by strap, snap-lock, buckles, or screws, depending upon service requirements. During application and securement, care should be taken to prevent crushing or other abuses to the insulation.

Where any field cutting or fitting around supports or nozzles is required, the fitting should be clean, neat, and tight with a closure installed to provide seal of the individual air chambers in the insulation.

Provision should be made in the assembly of the insulation of the units to allow for expansion and contraction of the surfaces insulated without damage to the insulation. Screws should not be used to secure telescoping sections together where the movement between the adjacent sections is needed for allowance of expansion and contraction.

Where equipment or piping is located outdoors, or where otherwise required, joints or openings in outer shell of insulation shall be flashed to form a water shed.

A completed installation of reflective insulated piping is shown in Figure XVIII-6.

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MODERATE AND HIGH TEMPERATURE SERVICE

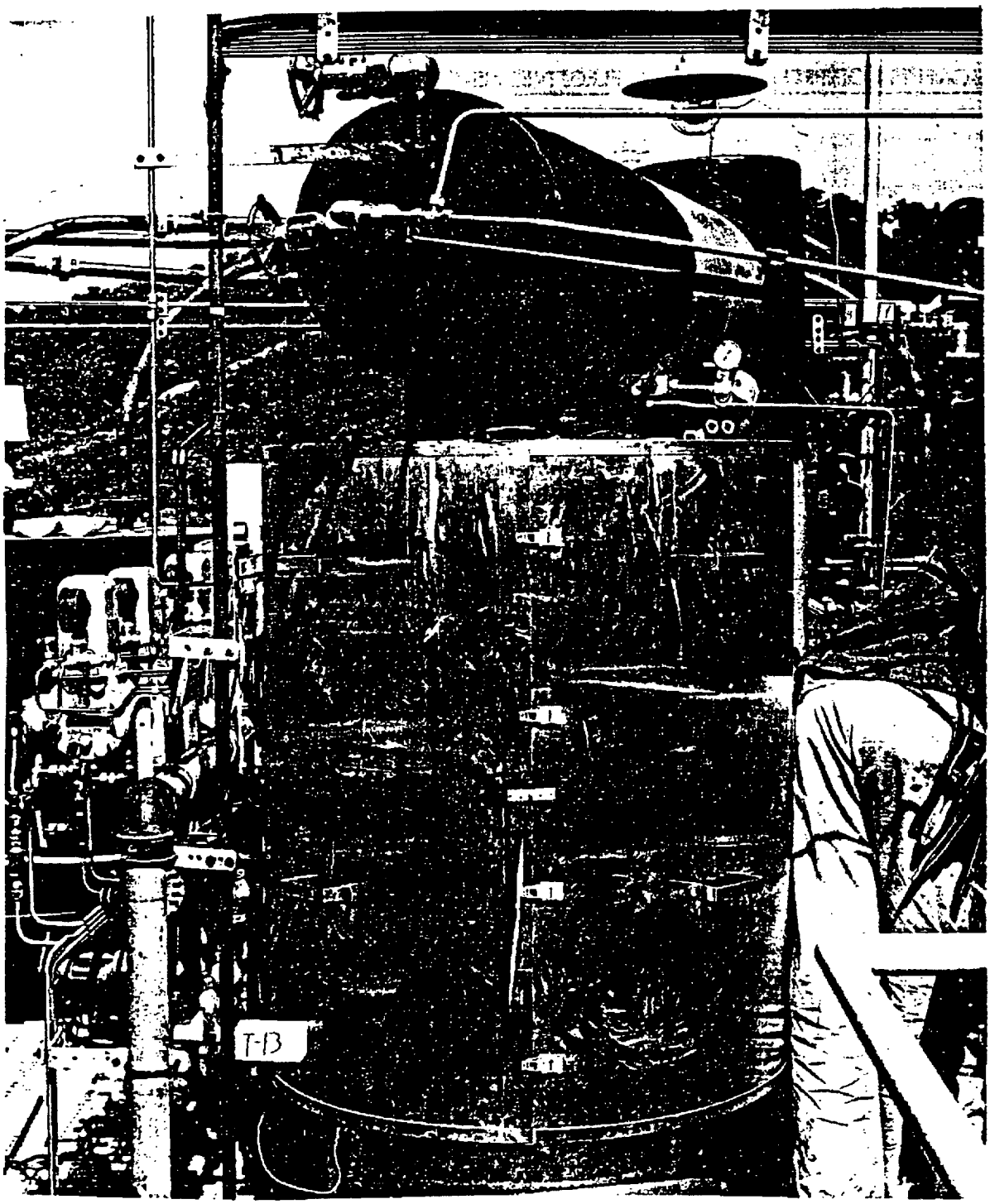


Figure XVIII-6

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APPLICATION OF SPRAYED ASBESTOS HIGH TEMPERATURE SERVICE

GENERAL

Asbestos insulation for spraying is a mixture of asbestos fibers and inorganic binders supplied in dry bulk form. The insulation is packaged in bags.

Application to the surfaces is by spray apparatus which pneumatically delivers the dry blend through a hose to a spray gun where the asbestos and binders are mixed with a fine water spray before it strikes the surface to which it adheres. To obtain a good application of sprayed asbestos insulation one must have a complete understanding of the spray machine and the proper application techniques.

APPLICATION OF SPRAYED ASBESTOS INSULATION

Supports

Supports and securements are necessary for large surfaces and for insulation over two inches in applied thickness. The insulator should inspect the surfaces to be insulated to assure himself that all cylindrical vessels over 24 inches in diameter, square ducts and equipment to be insulated with two inches or greater thickness have 10 gage pins welded to the surfaces to be insulated. These pins should be spaced 18 inches on center on sides and 12 inches on centers on bottom surfaces and edges, as illustrated in Figure XIX-1. The sides and bottom of vessels and equipment, such as turbine casings, insulated with 2-1/2 inches thickness and over should have split pins welded 18 inches on centers on sides, 12 inch centers on bottom with additional pins around the edges on 12 inch centers for attachment of wires for fastening of hexagonal wire netting. This is shown in Figure XIX-2.

If the insulation on the side walls of vessels or equipment does not extend down to base of vessel, an angle or flat bar with an outstanding leg equal to that of the thickness of the insulation should be welded around the base of the vessel to provide a termination and water seal barrier at the bottom.

Surface Preparation

Surfaces to be insulated must be clean and where protective coating is required, the coating should be dry, before the installation is started.

As adhesion to the surface is of paramount importance, the insulator should assure himself that the sprayed asbestos insulation will bond with the coating on the metal surface. An applied test patch is recommended. Should there be any question as to the ability of the coating to withstand the temperature to which it will be subjected, such question should be referred back to the Engineering Group for decision. It should be pointed out that where metal is coated or painted, if the coating or paint fails then the bond between the sprayed insulation and the metal surface is lost.

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APPLICATION OF SPRAYED ASBESTOS
HIGH TEMPERATURE SERVICE

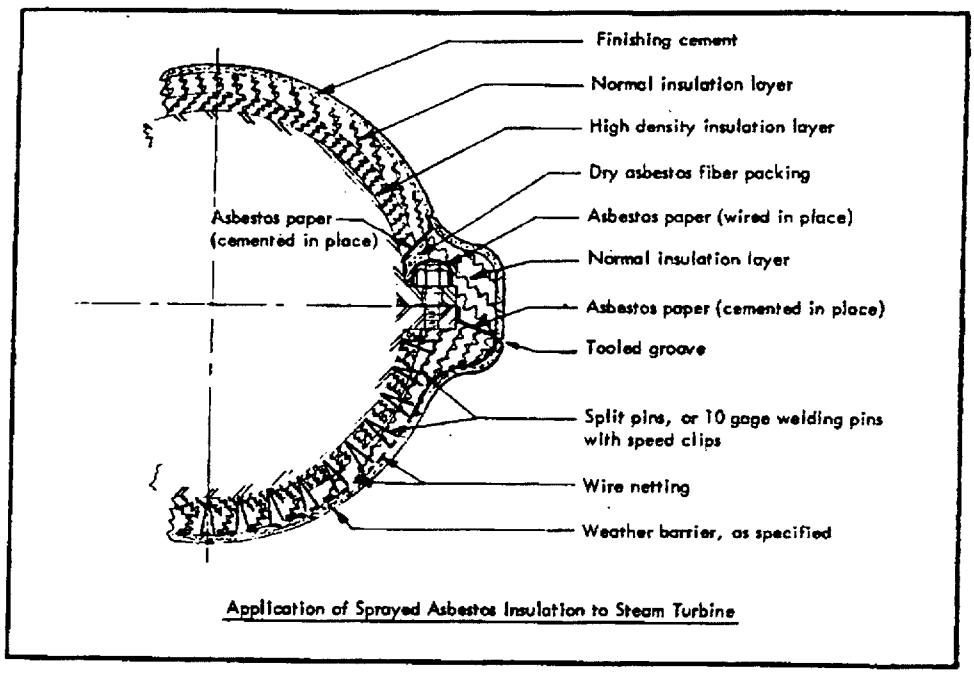


Figure XIX-1

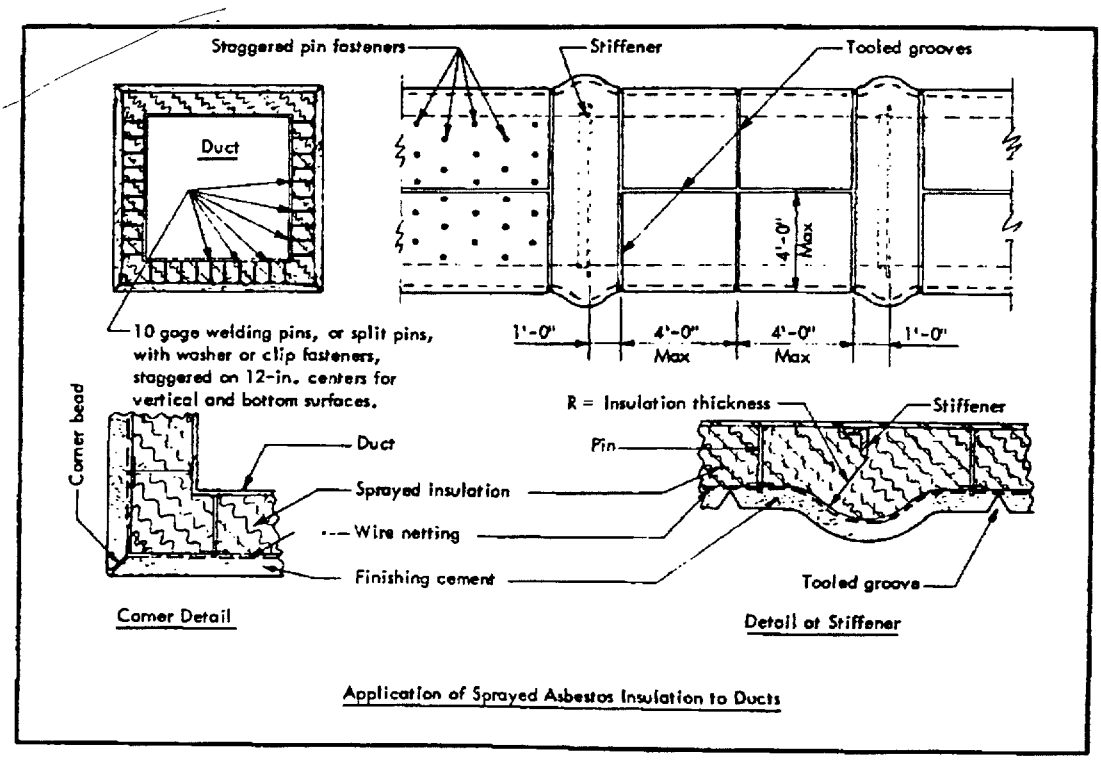


Figure XIX-2

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APPLICATION OF SPRAYED ASBESTOS HIGH TEMPERATURE SERVICE

APPLICATION OF SPRAYED ASBESTOS INSULATION - Contd

Operation of the Spray Machine

The machine serves to transfer the fiber mixture from the hopper to gun nozzle where it is mixed with water spray before it strikes surface being insulated. A typical spray machine and list of parts are shown in Figures XIX-3 and XIX-4.

The basic components of the machine are:

1. Hopper to hold the fiber mixture.
2. Automatic Feeder to control the fiber mixture flow.
3. Cording Brushes, which comb out the fibers just before they enter the impeller chute.
4. Fiber Impeller System, which pushes the fiber mixture through the blowing hose at required speed and density.

The machine functions as follows:

The fiber mixture in the hopper is fed to a screw conveyor which carries the mixture to the carding brushes which comb out the fibers and drop them into the impeller chute. The fibrous mixture is picked up by the impeller and carried by air through the blowing hose where, after leaving the spray gun, is wetted in mid-air with atomized water. The wet mix material is deposited in wet form on the surface being insulated. The amount deposited depends upon the insulation mechanic handling the spray gun.

Before starting application an inspection should be made of the machine to determine if it is in good operating condition and is properly connected with air, water and electric power. The inspection procedure should be as follows:

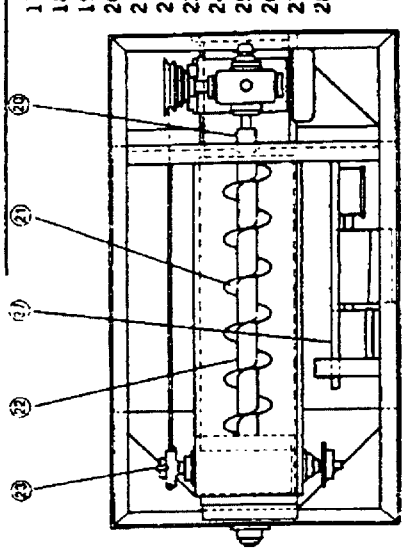
1. Inspect the spray gun to see that all three valves are operating properly. Disassemble and repack with water pump grease when necessary.
2. Make sure the air and fluid hose connections are secure and not broken.
3. Check to see whether there are any breaks in the air, fiber and fluid hoses.
4. Check the voltage in the machine to make sure that the machine is wired to coincide with the voltage supplied.

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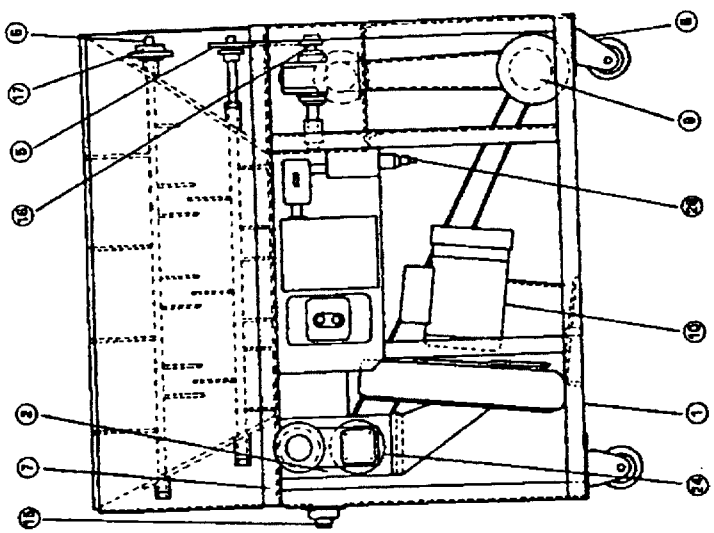
APPLICATION OF SPRAYED ASBESTOS
HIGH TEMPERATURE SERVICE

Parts List—H·T Machine

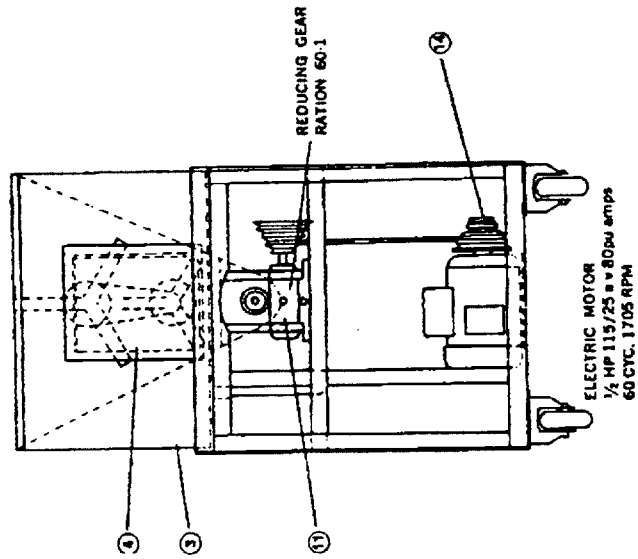
1. Frame
2. Pan with Chute
3. Asbestos Hopper
4. Access Door
5. Small Agitator
6. Large Agitator
7. Shield
8. Caster Wheel
9. Electric Motor ½ HP 115/230 V 8.0/4.0 Amps 60 CYC 1725 RPM
10. Electric Motor 1 HP 115/230 V 11/5.5 Amps 60 CYC 3450 RPM
11. Reducing Gear 60-1
12. Bearing ⅝"
13. Bearing 1"
14. Pulley 4 Grooves
15. Pulley 1 Groove
16. Sprocket 40 BSK 12T ¾" Bore
17. Sprocket 40 BSK 24T ¾" Bore
18. Sprocket 40 BSK 12T ⅝" Bore
19. Sprocket 40 BSK 24T ⅝" Bore
20. Coupling ¾" x 1" bore 2" Long
21. Screw Feeder 23" Long
22. Shaft 1" Dia. x 35" Long
23. Shaft ⅝" Dia. x 15½" Long
24. Brush 5" Dia. x 7" Long (1 Brush with Groove/1" Shaft)
25. Blower, Fiber Impeller & Outlet
26. Shaft Collar—4w ⅝" Bore, 3w ¾" Bore, 1w 1" Bore
27. Panel-Switches & Power Line Plug
28. Air Switch



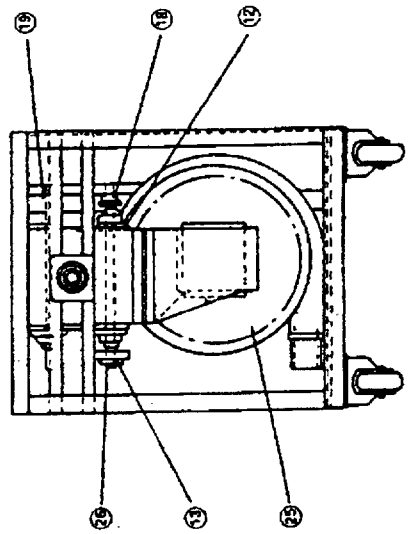
Top View



Side View



End View



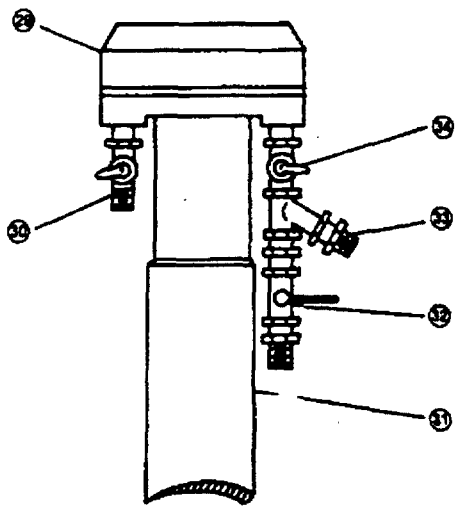
End View

Figure XIX-3

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APPLICATION OF SPRAYED ASBESTOS
HIGH TEMPERATURE SERVICE



SPRAY GUN

29. Spray Gun Head
30. Water Line Connection & Control Valve
31. 2½" Fiber Blowing Hose
32. Air Control Valve for Air Switch No. 28
33. Air Supply Connection
34. Atomizing Air Valve

Figure XIX-4

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APPLICATION OF SPRAYED ASBESTOS HIGH TEMPERATURE SERVICE

APPLICATION OF SPRAYED ASBESTOS INSULATION - Contd

Operation of the Spray Machine - Contd

5. Inspect the brushes, and impeller to see they are not excessively worn.

6. Check machine while empty to see that all moving parts are functioning properly. This can be done by pressing the master switch starting up the blower mechanism and then turning on the test feed switch which starts the feed mechanism. However, machine should be run only a short period of time when air is not on.

7. The 1/4" air hose should be connected to the air switch to test the switch for proper function.

8. Moving parts should be lubricated as noted on Maintenance Instruction Sheet.

Connecting the Machine to Required Services

Air is required at a volume of at least 5.5 C.F.M. at 60 psi. This can be obtained by the use of plant air or an air compressor. Air supply must be supplied with an air filter and pressure regulator. The air supply hose is connected to air connection on spray gun and the air line from gun is connected to the air switch located on the panel. The air is turned on and the regulator adjusted to 40 psi.

Water is required at a delivery rate of at least 0.5 gallon per minute. The water supply must be supplied with fluid filter and pressure regulator. The water hose is connected to water supply connection. The water is turned on and the regulator adjusted to 25 to 30 psi.

Electricity may be either 115 or 230 volts as machine is equipped for both voltages. Electric supply cord is attached to proper voltage connection. However, care must be exercised to see that correct voltage is supplied to the machine. Low voltage will damage the electrical system. Where question exists, an electrician should be called in to test the voltage supplied to the machine.

Fiber Hose is connected to the machine, where it is secured in place by tie wire, and to spray gun at other end.

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APPLICATION OF SPRAYED ASBESTOS HIGH TEMPERATURE SERVICE

APPLICATION OF SPRAYED ASBESTOS INSULATION - Contd

Operation of the Machine:

1. The hopper of the machine is filled with the fiber mixture. It should not be pushed or tamped causing a compression of the mixture.

2. The machine is activated by pushing the master switch to "ON" position.

3. The air supply is turned on to atomize the water.

4. At the gun, the water valve is turned on. The spray pattern of water should be even and smooth.

5. Also at the gun, the air feed switch is turned in counter-clockwise direction. This starts the fiber flow.

Spraying of Fiber

The fibrous insulation is sprayed by the operator onto the surface to be insulated. The build up in insulation thickness is controlled by the operators use of the gun. The operator should hold the gun at least 12 inches from the surface being insulated. The optimum distance is approximately 18 inches. The insulation should be sprayed on at an angle between 60 to 40 degrees. Spray angle should not be perpendicular to the surface. Proper quantity and atomization of water to make the applied insulation damp is essential to obtain good consolidation of the insulation and to give it good surface adhesion. The operator and those in immediate spray area should wear masks capable of removing asbestos particles from the air.

Vessels and Equipment Details

When a vessel is on a low pad where the level of rain or drainage water can reach the bottom of the insulation, a course of water repellent insulation, preformed to the diameter of the vessel, and of specified thickness, shall be installed to an elevation greater than the highest expected water level. In no case shall this be less than nine inches. On vessels below 212F, cellular glass shall be used as the water repellent insulation and on vessel above 250F expanded silica insulation shall be used.

Thickness up to one and one-half inches should be applied in sufficient quantity so that, when consolidated to specified thickness, the density of the insulation, after drying, will be between 8 and 13 lbs. per cubic foot. Consolidation is accomplished by tamping the sprayed insulation with flat trowels or other flat surface. Where necessary to consolidate the insulation where pins project, the use of 1/2-inch thick organic rigid insulation fastened to board will allow pin to penetrate the organic foam which presses the damp fibrous mixture down around the pin.

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APPLICATION OF SPRAYED ASBESTOS HIGH TEMPERATURE SERVICE

APPLICATION OF SPRAYED ASBESTOS INSULATION - Contd

Vessels and Equipment Details - Contd

When insulation exceeds 1-1/2 inches in thickness the sprayed insulation shall be applied in two layers. First layer should be applied and consolidated with edge of flat trowel, forming a criss-cross pattern, to 55 percent of its applied thickness. The split pins used for reinforcement should be pulled apart to form a V prior to application of second layer. The last layer is applied as described for single layer application. This last layer must be applied within 30 minutes of the application of the first layer. This is shown in Figure XIX-1.

On the top heads of vertical vessels and the top quadrant of horizontal cylindrical vessels the sprayed insulation should be consolidated to approximate 20 lb. density, when dry, so that its compressive strength is sufficient to permit it to be walked upon without mechanical damage.

The reinforcing of the insulation should be 4 by 4 inch squares of hardware cloth inserted over the pin and pressed into the surface of the insulation for a distance of 1/4 inch. A speed clip should be forced over the pin and pressed down to firmly secure the hardware cloth in position. Pin should then be clipped off so its top will be lower than the finished insulation surface. Fibrous insulation should then be troweled over the hardware cloth, flush with adjacent surfaces. Application is shown in Figure XIX-5.

APPLICATION OF INSULATION TO FLANGES AND FLANGE BOLTS

Flange bolts or studs should be wrapped with asbestos paper secured in position with stainless steel wire. The space between the bolts or studs should be packed with dry asbestos fiber. The sprayed insulation should be applied with a taper inward to vessel surface at the flange. Over these tapered edges asbestos paper should be installed, adhered to the insulation with asbestos paper adhesive. The asbestos paper should then be applied over the entire bolt and flange area to the tapered insulation asbestos paper. Sprayed insulation should then be installed as described in preceding section. This application is shown in Figure XIX-6.

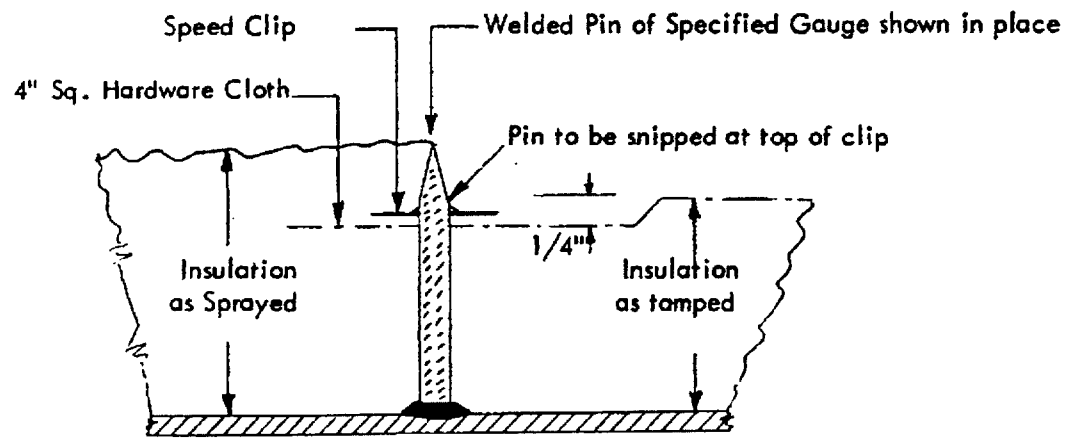
Finish

Where the insulation is to be covered with metal jacket it requires no finish cement.

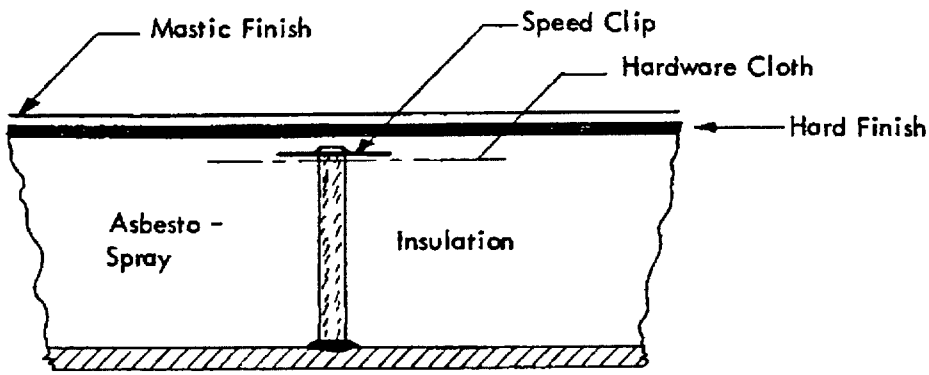
Where the insulation is to be covered with fabric reinforced mastic it should be covered with a hard finish cement sprayed or troweled to a thickness of 1/4 inch over hexagonal wire mesh. This cement is to be scored with a cement finisher's tool in squares approximately 4 feet by 4 inches to allow for expansion and contraction. It is important that scoring is through the cement finish to the surface of the sprayed fibrous insulation.

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APPLICATION OF SPRAYED ASBESTOS
HIGH TEMPERATURE SERVICE



SECTION Left Insulation as Sprayed
Center Support Detail
Right Insulation as Tamped

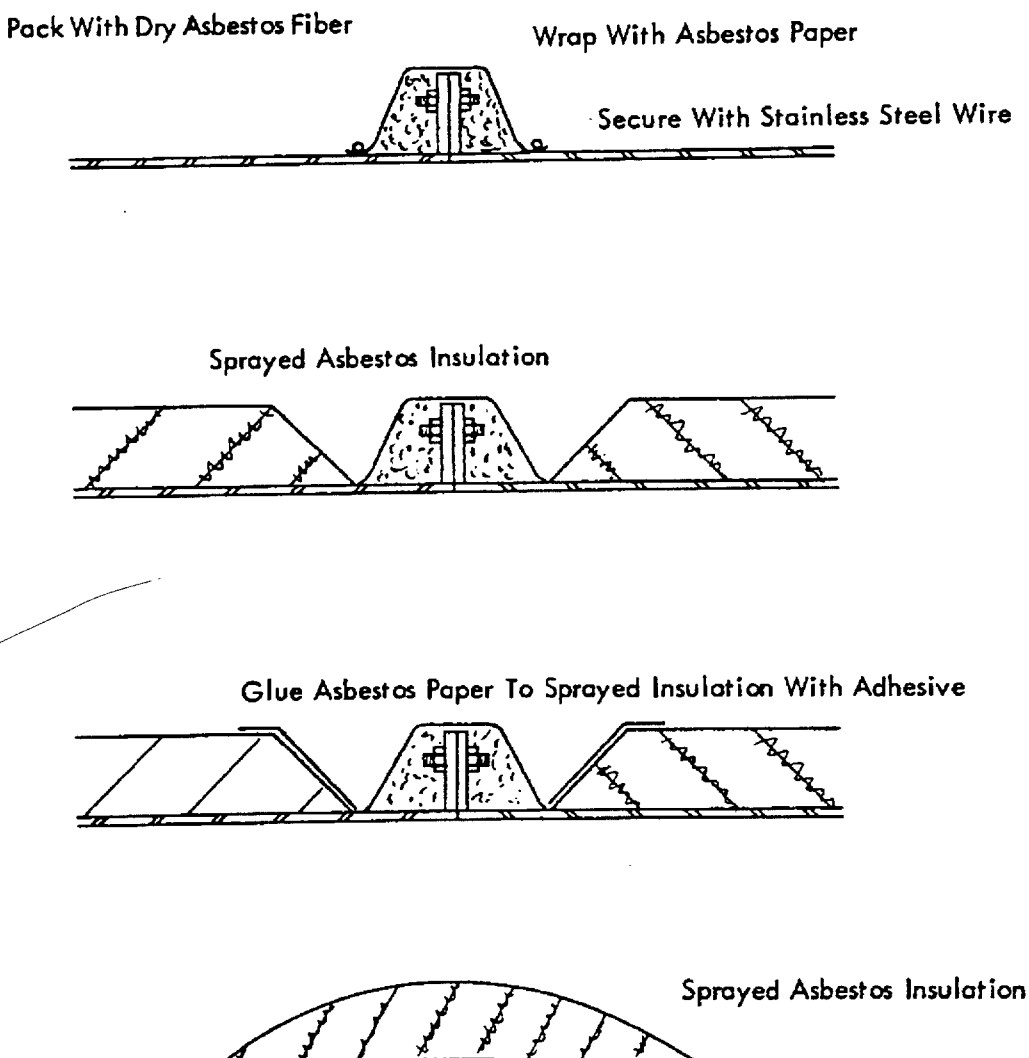


SECTION Finished Application

Figure XIX-5

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APPLICATION OF SPRAYED ASBESTOS
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APPLICATION OF INSULATION TO FLANGES AND FLANGE BOLTS

Figure XIX-6

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

Sprayed urethane insulation is supplied as two liquids: the resin component and the activator component. These, when mixed together in equal proportions, expand to approximately thirty times their original volume due to generation of gas filled cells entrapped in the mixture.

Application to the surfaces to be insulated is by spray equipment which delivers the two components to the gun in proper proportions, at which point the two liquids are mixed together and sprayed on the surface. The liquid on the surface expands to foam the thermal insulation.

APPLICATION OF SPRAYED URETHANE

Preparation of Surfaces To Be Insulated

Surfaces to be insulated must be clean, and where coating is required, the coating must be completely dry before application is started.

Unpainted carbon steel should be cleaned of rust, mill scale, dirt, grease or other contaminations.

If steel is painted with long oil red lead primers or long oil oleoresinous paints the urethane may cause softening of the paint with resultant poor bonding of the sprayed insulation. When such is suspected, a test patch should be installed and inspected prior to spray application of the vessel or equipment. Most other paint systems are compatible with the urethane if they are fully dry and free of dirt, grease and oil.

Stainless steel surfaces should be coated with Thermalox No. 70 in accordance with UCC Coating Manual prior to application of urethane foam. This coating must be completely dry before installation is started.

Heavy aluminum may be coated with sprayed urethane provided it is clean. However, thin gage aluminum (less than 1/16" thick) requires special coating treatment before application of the urethane foam insulation.

Copper and brass need no special surface treatment other than that they be clean and dry.

Protection of Surfaces Not To Be Insulated

Urethone spray, like all sprayed liquids, has a certain amount of drift and rebound particles which drift in the air from the point of spraying. For this reason areas not to be insulated must be protected from these drift particles which have excellent adhesion to surfaces in which they come in contact.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

APPLICATION OF SPRAYED URETHANE - Contd

Protection of Surfaces Not To Be Insulated - Contd

All flanges, manholes and all other surfaces on the vessel not to be insulated should be wrapped with suitable coverings and secured in place with suitable wire or tape. This covering is removed after the application of the sprayed insulation. Instruments and all other areas which are to be kept free of insulation or overspray should be protected in like manner. Piping and equipment within 25 feet of spraying operation should be covered or screened for protection from over-spray or drift.

Material

The urethane liquid and the activator liquid should be of the UCC type as specified.

EQUIPMENT AND ITS OPERATION

Application of Sprayed Urethane Insulation

Whenever possible, spraying should be done when ambient air temperature is above 50F, in dry weather, at moderate relative humidity conditions and when wind velocity is less than 15 mph. Wind shields should be used if wind velocities exceed 15 mph. For best results the temperature of the surface being insulated should be between 70F and 120F. When ambient air temperature is less than 50F the feed tanks and the hose to spray gun should be heated.

Generally, the spray gun should be held approximately 36 inches from the surface being coated. Surface ripples will occur when gun is held too close to the surface, when gun movement is too slow for the speed of foam rise, or when spray material throughput is too high. The liquid should be sprayed onto the surface using a 50 percent overlap pattern and fast aim movement. To obtain even distribution of film requires gun triggering and feathering on the overlap.

Operation of Pumps and Spray Gun

1. Equipment Required

   The proportioning pump should consist of an air motor and two volume balanced cylinders to insure an accurate 1:1 ratio. The air motor should have sufficient capacity to insure adequate air pressure to atomize the materials properly.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Operation of Pumps and Spray Gun - Contd

1. Equipment Required - Contd

The feed system should be defined in terms of size of material supply containers, either 5-gallon pail feed or 55-gallon drum feed. If a gravity feed system is used, the supply drums should be elevated to insure positive flow. If the feed pumps are to be used, the distance from the supply drum to the proportioning pump will influence feed pump selection. Longer distances require higher pressure pumps.

The feed pump used on the "A" or isocyanate side should be divorced above the bung to prevent moisture contaminating the material.

The heating system should include high pressure heaters capable of handling 3/4 gpm of each material at normal operating temperatures of 100-110 . The desired material temperature may vary between foam systems. Insulated hoses equipped with a heating wire or tape should be specified to maintain the material temperature at the gun. The length of hose required will vary depending on the type of application.

Spray gun should be an internal mix airless spray gun for best results. The gun should be capable of delivering 10-12 lbs. per minute of mixed materials. The gun should be easily flushed and be of a design to permit quick and easy disassembly. Check valves should be included on both material inlet ports to prevent materials from crossing over to one another.

Solvent pump should be constructed of materials which are resistant to the common solvents used, such as methylene chloride and butyl cellusolve. Pump packings should be Teflon.

A nitrogen pressurization kit should be included to supply a nitrogen head to both material supply drums. This will prevent loss of the blowing agent on the "B" side and moisture contamination of the "A" side. A pressure relief valve should be included to prevent overpressurization.

If the unit is to be used for spraying outdoors at ambient temperature below 50F, a freon injector should be included. This is necessary to get good quality foam at low temperatures. This device adds an additional blowing agent, normally UCON or equivalent, to the "B" side. This is necessary because Freon 11 or equivalent, the normal blowing agent contained on the "B" side, turns from a liquid to a gas at 75F. At ambient temperatures below 50F, additional freon is required to initiate the foaming action.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Operation of Pumps and Spray Gun - Contd

2. Operating Instructions

The first step in installing the machine is to hook up the air supply hose from the compressor. Twenty CFM is required and 1/2" air hose should be used.

Solvent should be pumped through the system to clean out the oil and to check for leaks. The solvent pump itself should be checked for leaks.

The check valves on the static mix gun inlet parts should be checked to insure that they seat properly. This can be done by first connecting the solvent hose to one material inlet port and turning the gun to spray position. Start the solvent pump and spray solvent. Check for leakage at the other material port. Repeat this procedure with the other material inlet.

Protective clothing should be worn, including goggles. If the spraying is being done indoors, an air mask or respirator should be used. If isocyanate gets on your skin, wash immediately.

The inbound air pressure on the proportioning pump should be set at 40 psi and adjusted upward depending on the tip being used, the output desired, etc. The maximum limit is 120 psi.

The heaters should be set at mid-range initially and adjusted from there, depending on the spraying temperature recommended by the material supply. The heaters should be allowed to warm up for approximately 20 minutes prior to spraying.

We are now ready to begin spraying. The substrate being sprayed on should be dry and free of drit and grease. Any rust or foreign matter should be removed by wire brushing or sandblasting. Foam can be applied directly to wood or clean steel surfaces. It should not be applied directly to untreated aluminum surfaces.

Foam should not be sprayed outdoors if the wind velocity is more than 15 mph. High winds will result in overspray, which can cause contamination on painted surfaces or glass windows in the area. Parked cars are a particularly good target for overspray. Overspray will also cause a lack of good thickness control and can produce poor foam because of loss of exotherm.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Operation of Pumps and Spray Gun - Contd

2. Operating Instructions - Contd

Urethane foam sprays best when the ambient temperature is between 65F and 100F. Below 60F, it is a good idea to spray a light coat of foam first as a flash coat. This will insulate the surface you are spraying. The lower the ambient temperature, the more difficult it is to produce good controllable foam. Exothermic heat is lost and the UCON blowing agent is hard to handle. The combination of these causes the foam density to increase from the 2 lb/cu ft level normally desired. If the ambient temperature is below 40F, drum heaters should be used to heat the material before entering the proportioning machine. The 208-036 freon injector will help in cold weather spraying.

The spray gun should be held approximately 18 inches from the surface being sprayed and moved perpendicular to the surface. If the operator is too close to the work surface, ripples will result. If the operator is too far away, he will get overspray and poor thickness control.

A good operator should cover 15-20 board ft. per minute. An area 3' to 4' wide can be covered in one pass. The height of the area that can be covered depends on the spray tip used and the distance from the surface. Normally, 8 inch to 12 inch band can be covered. The foam should be put on 3/4 inch to 1 inch thick per pass. If thicknesses greater than 1 inch are required, multiple passes can be made. Urethane foam will bond to itself nicely. You should not spray into rising foam. If the spray gun starts spitting, flush and check for a plugged tip by unscrewing the tip holder and removing the tip.

An important point to remember in troubleshooting is to shut the air off and remove the pressure from the system. If no material is discharging from the gun, first check the material level in the supply containers. If material supply is all right, then check the ball valves on the pump inlets to insure they are open and passing material to the proportioning pump.

If the material is feeding into the proportioning pump properly, disconnect the gun at the inlet ports and check material blow. If material is flowing from the hoses, the gun is jammed.

If no material is flowing out of the hoses, disconnect them from the pump outlet. If material flows from the pump outlet, your hose is plugged. If no material is coming out of the pump outlet, your problem is probably in the pump ball check or packings.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Operation of Pumps and Spray Gun - Contd

2. Operating Instructions - Contd

If you are spraying poor quality foam, the first thing to check is the heaters and heated hose to insure the proper temperatures are being maintained. The next thing to check is the ratio of the materials, which may be incorrect. The characteristics of the foam will give you a good idea as to which component is off ratio.

If too little of the "A" or isocyanate side is being delivered, the foam will be lighter in color, will rise fast, display larger cells and lower density, and have poor adhesion.

If too little of the "B" or resin side is being delivered, the foam will be dark in color, have a slow rise, and be higher in density.

Once you have determined which component is short, check that side starting with the material drum, suction hose or feed pump, pump inlet ball valve, gun inlet check valve, heated hose, etc., until the restriction is located.

At the end of the day, the pumping unit should be flushed thoroughly with solvent. The pumps should always be stopped at the bottom of a downstroke. This will prevent any buildup of isocyanate on the displacement rod. The spray tip should be removed and immersed in DMF to remove foam particles. A good method preventing foam buildup on the gun is to coat with a mold release such as silicone prior to use. Under no circumstances get DMF on the skin as it can be quite harmful.

For longer shutdown periods, the entire unit should be flushed with a 50/50 mixture of methylene chloride and DOP. Then a light preservative oil should be pumped through and left in the system.

Film thickness applied should be approximately 35 mils per inch of required insulation thickness. This requires approximately 0.18 to 0.2 lbs of material per square foot, per inch thick insulation.

Liquids up to approximately 70 mils thick can be applied in one coat. This will produce about 2 inches thickness of insulation. If greater thickness of insulation is required it is necessary to apply additional coats. In such cases the preceding coating should be completely foamed, dry, and tack-free to touch before another coat is applied.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Operation of Pumps and Spray Gun - Contd

Should spray equipment apply liquid which does not react to produce foam, the application should be stopped and unreacted liquid removed. After the difficulty is corrected, this area should be resprayed.

Surfaces To Be Insulated

Cylindrical, flat, and irregular surfaces of vessels and equipment to be insulated with "foamed in place" urethane should be sprayed in manner described. The final insulation thickness should be as specified. The installation should be performed as described above.

Flanges

In most cases manhole flanges, blind flanges and vessel flanges are not insulated on moderate temperature vessels insulated with "foamed in place" urethane. The body insulation should be tapered down to the vessel around these flanges to permit removal of bolts and to allow the application of weather-barrier mastic. This is illustrated in Figure XX-1 and XX-3. Where blind flanges and vessel flanges are required to be insulated, the spray insulation should be the same as if they were not to be insulated. After the spray application is completed these should be insulated with preformed flange covers of urethane insulation. This application is illustrated in Figure XX-2 and XX-4.

Vessel Legs

If a vessel is equipped with concrete-filled structural tubing legs, the legs should be insulated the same as and as part of the vessel. If, however, the vessel is equipped with channel legs and these legs require fire protection, as would be indicated by the concrete encasement around their lower section, then these legs must be insulated with fire-resistant high temperature insulation. The fire resistant insulation should be installed completely around the legs as shown in Figure XX-5.

Vessel Skirts

The bottom head of vessels with skirts should be insulated same as the main body of the vessel. The inside of the skirt should not be insulated unless so specified. The spray application of foam urethane applied to the vessel shall extend down the outside of the skirt for a distance not less than eight times the specified insulation thickness, or to the concrete pad, whichever is nearer. This application detail is shown in Figure XX-6.

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APPLICATION OF SPRAYED URETHANE
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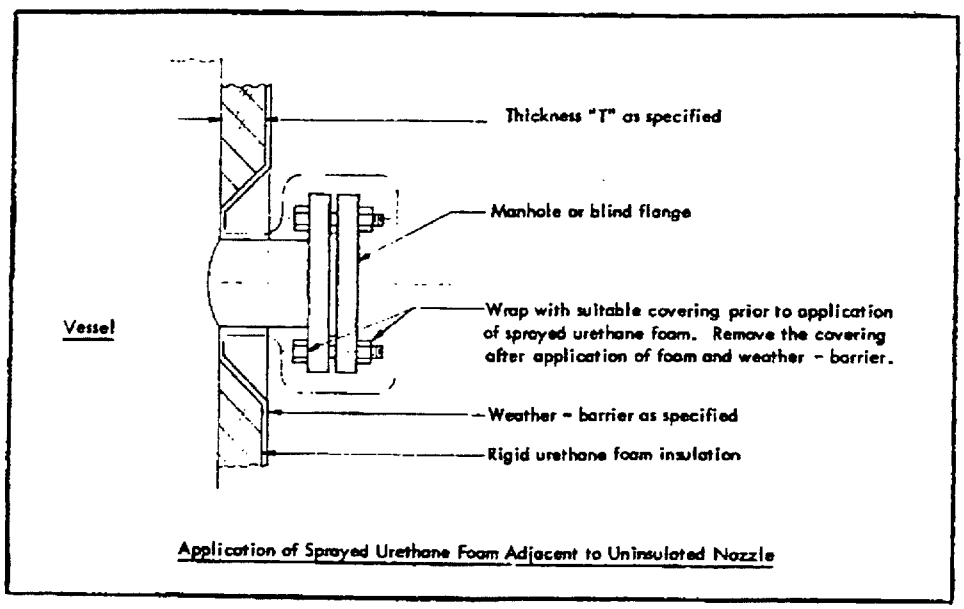


Figure XX-1

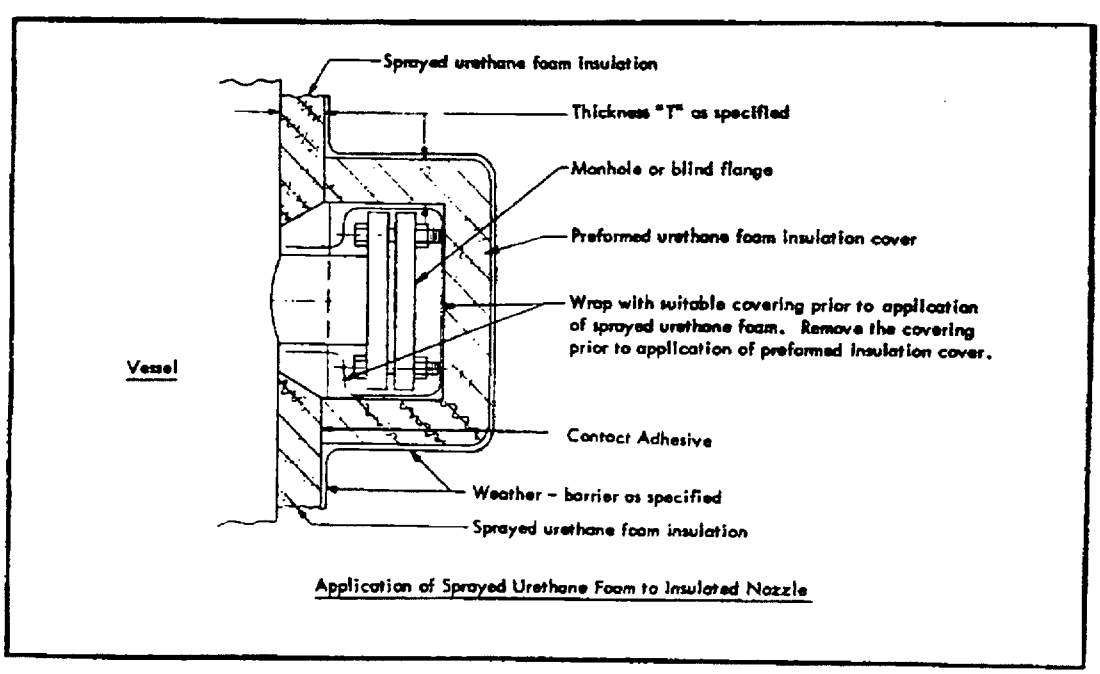
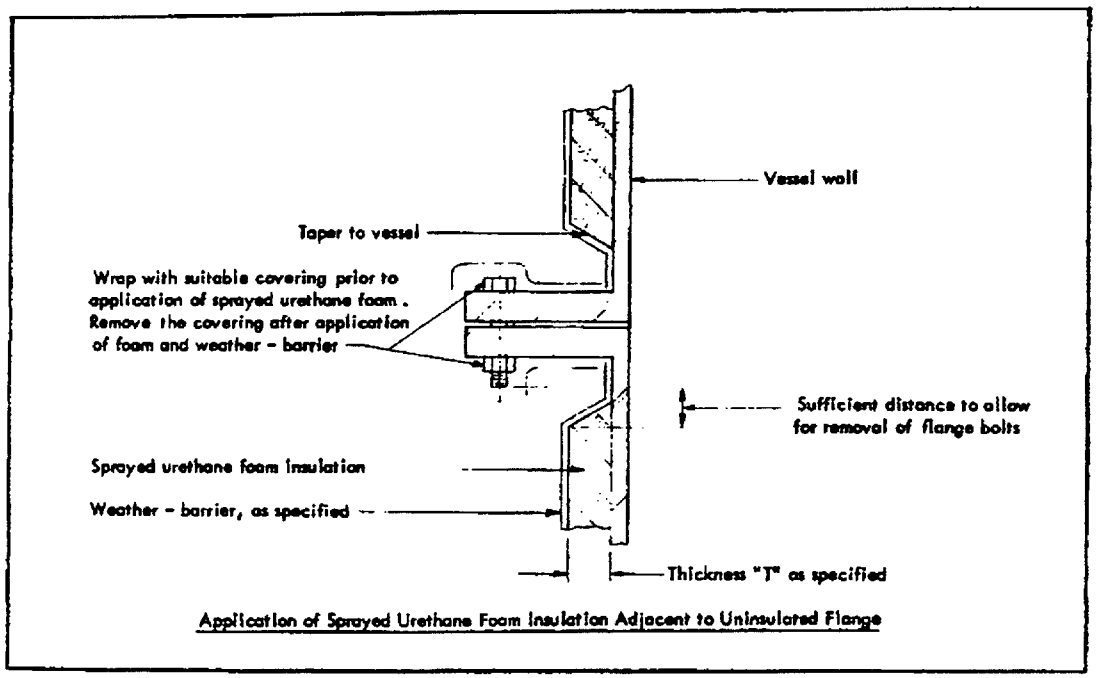


Figure XX-2

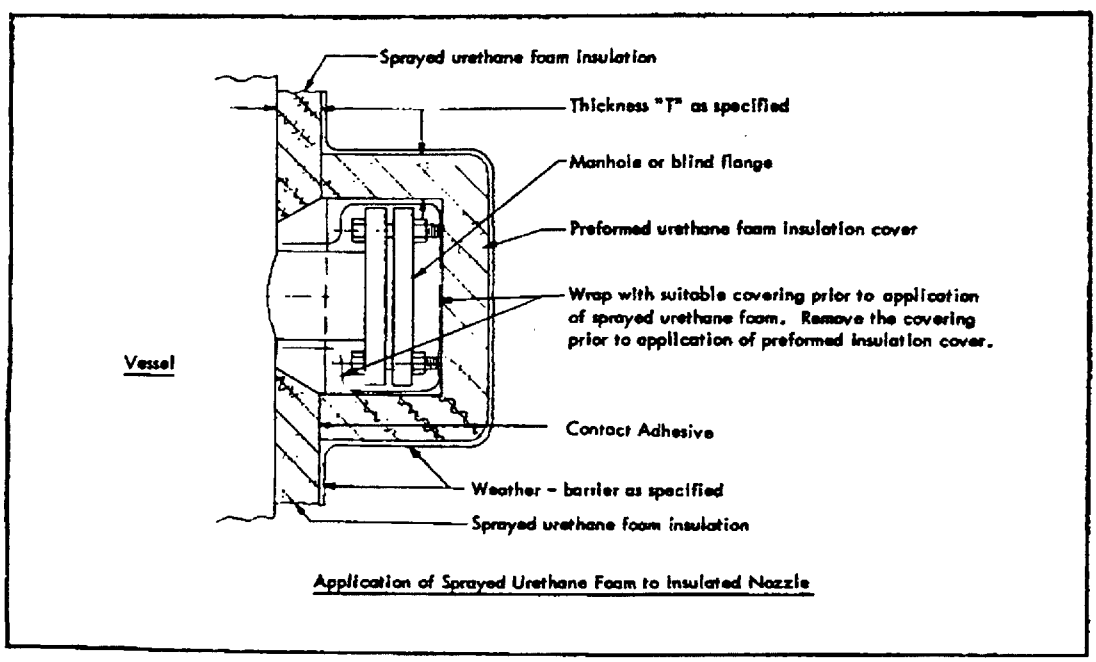
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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE



Application of Sprayed Urethane Foam Insulation Adjacent to Uninsulated Flange

Figure XX-3



Application of Sprayed Urethane Foam to Insulated Nozzle

Figure XX-4

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APPLICATION OF SPRAYED URETHANE
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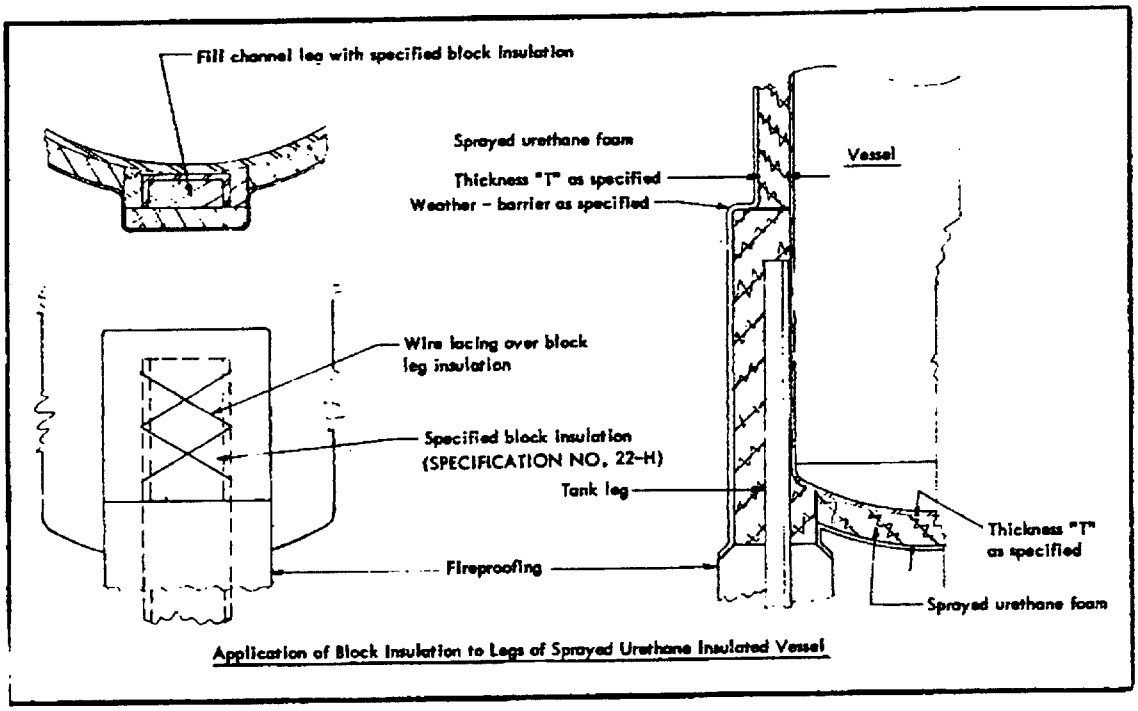


Figure XX-5

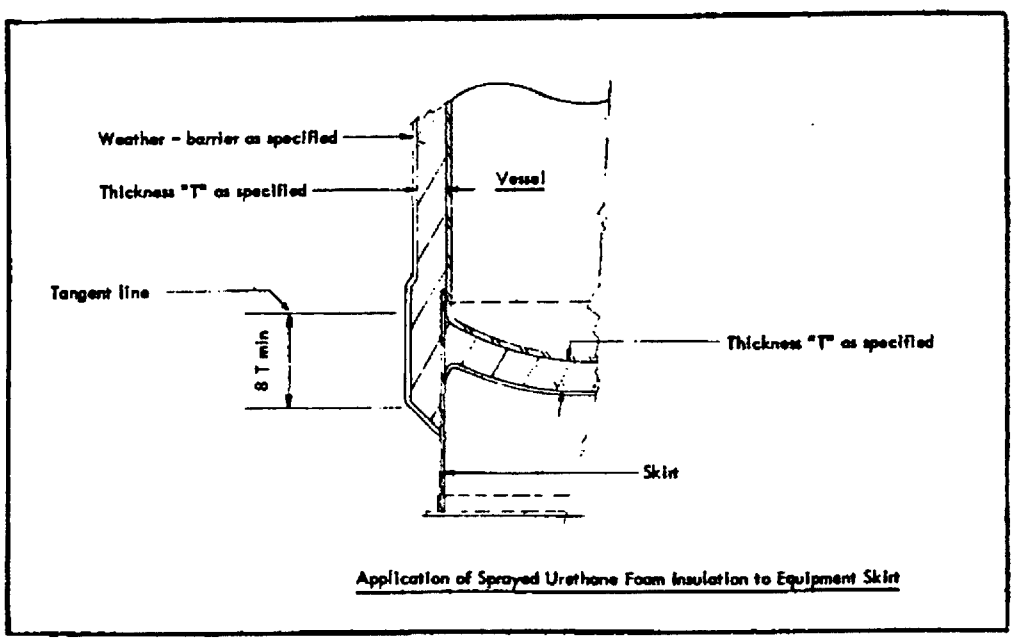


Figure XX-6

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APPLICATION OF SPRAYED URETHANE MODERATE TEMPERATURE SERVICE

EQUIPMENT AND ITS OPERATION - Contd

Surface Finishing

Where there may be excessive buildup or irregularities of insulation surface these should be cut off to be flush with the adjacent surfaces. If a smooth surface is required for sake of appearance the insulation should be smoothed off by sanding the surface with a power sander.

Safety Precautions

The spraying of urethane foam releases fumes and minute particles into the air. The spray operator, and anyone close to the operation of the spray, must wear masks capable of protection against isocyanate vapors and atomized particles. Cannister and cartridge masks for use with solvent vapors are recommended. These should be worn where ventilation is good. When spraying in enclosed or confined areas a full fresh air face mask must be used by the applicator.

The foaming of urethane is caused by a chemical reaction which produces heat. Because of the insulating properties of the foam this heat can develop excessive temperature rise on the inner masses if the heat cannot dissipate to the surroundings. For this reason no more than one inch of insulation should be applied at one time over a combustible material such as wood, nor should over four inches be installed at one time over incombustible surfaces, such as steel.

APPLICATION OF WEATHER-BARRIER

After the foam application is completed and the insulation is cured to tack free consistency the weather-barrier mastic may be installed. The application of the weather-barrier mastic should be done as soon as practical to protect the foam from the weather.

Weather-barrier material should be weather-barrier mastic, of specified color, and be spray grade. The mastic should be water-emulsion type as described in Weather-Barrier Chapter of this Manual.

Surfaces not insulated should be protected by suitable covering the same as described in Preparation Section of this Chapter.

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APPLICATION OF SPRAYED URETHANE
MODERATE TEMPERATURE SERVICE

APPLICATIONS OF WEATHER-BARRIER - Contd

The spray application of mastic over the urethane foam is to be done in two coats. After the first coat has taken its set, a second coat should be applied. The combined thickness of the two coats should be not less than 50 mils when dry. Details of application of weather-barrier mastic is discussed in Weather-Barrier Chapter XXI. It should be noted, however, that no reinforcing cloth is required in the application of the mastic.

NOTE: Additional instructions for spray equipment can be obtained in the following:

1. Graco Equipment - Instruction Manual Set No. 306991

   Gray Company Inc.
   Minneapolis, Minnesota 55413

2. Manual

   Gusmer Coatings Inc.
   Old Bridge, N. J. 08857

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APPLICATION OF WEATHER-BARRIERS

Weather-barriers, to fulfill their function in protecting insulation, must have strength, flexibility, and resistance to weather. There are two basic forms of weather-barriers used to protect insulation; one is mastics and the other is jackets. Because of their complete difference in form, they must be applied differently.

APPLICATION OF MASTIC WEATHER-BARRIER

There are numerous types of weather-barrier mastics, each of which may require some differences in the method of application. However, as we specify only the heavy body resin-type mastic, this application discussion will be limited to that particular type of mastic.

Preparation

The first item is to check materials to determine if all materials required are available. For the installation of a mastic weather-barrier, the following are needed:

1. Weather-barrier mastic.
2. Reinforcing cloth.
3. Caulking mastic.
4. Heat resistance sealer (for high-temperature service).
5. Lap sealer (for low-temperature service).
6. Expansion strip (for high-temperature service).

The mastic itself should be inspected to determine if it is in good condition and suitable for use. Also, it should be determined that the proper grade of mastic was delivered. If several grades are available, trowel grade is required when material is to be palmed or troweled. Where it is to be sprayed -- spray grade is required.

As these mastics are water-base materials, after they are delivered to the job site they must be kept from freezing if the atmospheric temperature falls below 32°F.

The insulation should be installed as specified prior to the application of the mastic. During the period between its application and until it is weather protected, all absorbent insulation shall be protected from rain, snow, or other liquids by temporary wrapping with protective coverings. Should absorbent insulation get wet due to circumstances beyond control of the insulator, it is necessary for it to be dried out before the final weather-barrier mastic is applied. This should be done by keeping the insulation covered with the temporary protective plastic sheet or tarp until the line or vessel is heated for a sufficiently long time to drive out the moisture.

The installed insulation should be smooth, even, and free of voids.

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APPLICATION OF WEATHER-BARRIERS

APPLICATION OF MASTIC WEATHER-BARRIER - Contd

Preparation - Contd

On outside installations, any insulation in relatively horizontal position shall be sloped for water drainage.

Sharp outside corners of insulation should all be rounded off. This is illustrated in Figure XXI-1.

A heavy fillet of caulking mastic should be installed to all inside corners of insulation and to the inside corners where metal projects through moderate and low-temperature insulation. Caulking shall be allowed to dry and set before the application of the weather-barrier mastic. The application of caulking to inside corners is illustrated in Figure XXI-1.

A heavy fillet of heat resistant sealer should be applied around all metal projection which will be above 180°F in service. The sealer shall be applied outward from the junction of the projection for a distance six inches over the metal and six inches over the surface of the insulation.

As the mastic is a water-base material, it cannot be applied when air temperatures are low. As most manufacturers make a special winter grade, it is possible to spray this special grade below freezing. The limitation for its application is as follows:

Standard grade should not be applied when ambient air temperature is less than 32°F nor when the temperature is expected to be as low as 20°F within the next 24 hours.

Winter grade should not be applied when ambient air is less than 20°F nor when the temperature is expected to be less than 15 within the next 24 hours.

Troweled or Palmed Application

Troweled or palmed application of mastic should be done by first bonding the reinforcing cloth to the insulation surface with the weather-barrier mastic. In some instances trowel grade mastic requires slight thinning with water to obtain a first coat into which the cloth will embed for good adhesion. The cloth shall be pulled taut with all joints overlapped two inches. All inside corners, rounded off with caulking as previously described, and outside rounded-off corners shall be reinforcing cloth overlapped as illustrated in Figure XXI-1. The trowel grade weather-barrier mastic shall be troweled or palmed over the cloth, pressing

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APPLICATION OF WEATHER-BARRIERS

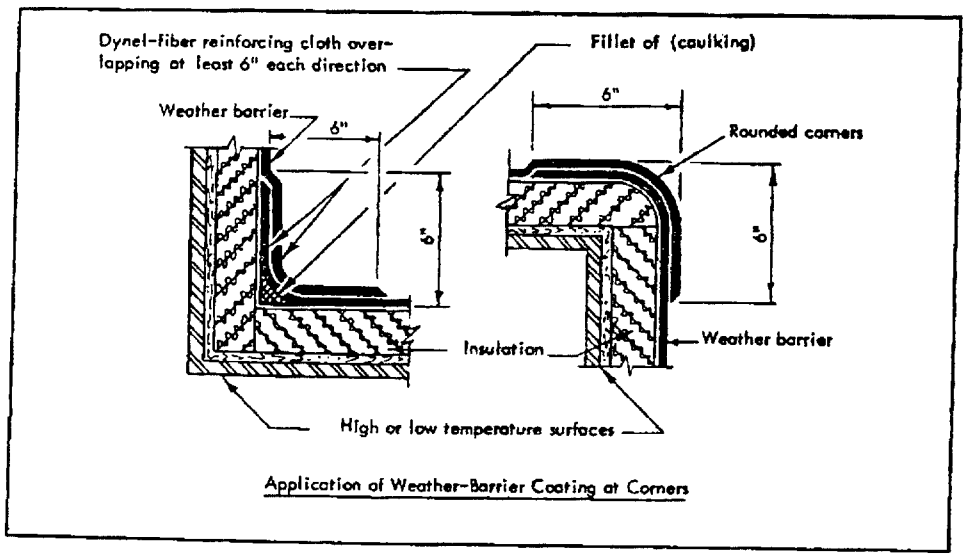


Figure XXI - 1

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APPLICATION OF WEATHER-BARRIERS

APPLICATION OF MASTIC WEATHER-BARRIERS - Contd

Troweled or Palmed Application - Contd

it through the mesh to bond it to surface and mastic underneath. Care shall be exercised that the mastic is troweled or palmed over the cloth in a manner to completely seal all the openings in the weave of the cloth. After the mastic has partly set, it should be softly brushed by brush wet with water to produce an even, smooth surface. The combined wet thickness of the weather-barrier coating and mastic when wet should be between 3/32 and 1/8 inch in thickness. To achieve this thickness, for each 15 to 16 sq ft of surface covered one gallon of mastic must be applied. The dried thickness of the material should not be less than 1/16 inch thick.

This weather-barrier shall be carried out six inches onto metal beyond termination of insulation at supports, skirts, or other projections, and shall be sealed from the metal.

Spray Application

Prior to spray application, adjacent areas not to be coated such as structural steel, floors or walls shall be meshed or screened to protect them from overspray or drip. Valve stems, handles, gauge glasses, instruments, and other such items shall be wrapped with plastic sheet to protect them from splatter.

Operation of Spray Equipment

Mastic to be sprayed must be of spray consistency. Spray equipment is to be 30:1 ratio airless pump and airless mastic gun. In most instances a .837 reverse-a-clean tip will give most satisfactory results.

The first step is to properly hook up the compressors, pump hose and gun. The compressor should be located well away from overspray. Instructions for connecting operating and maintaining pump is given in following instruction sheets 1, 2, 3, and 4. The instructions for operating and maintaining the spray gun is given in instruction sheets 5, 6, and 7.

The spray application shall be used only on equipment or large piping over 30 inches in diameter, of sufficient surface area to warrant the use of spray.

The insulation surface is covered with a smooth, even coat of mastic of just sufficient thickness to embed the fabric. The fabric shall be applied to the wet mastic, pulled taut, then smoothed and passed by gloved hand to embed it into the mastic. Joints in cloth shall be not less than 2 inches in width and be bonded together by the mastic. All inside and outside corners, previously rounded out, shall be overlapped with two layers

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APPLICATION OF WEATHER-BARRIERS

AIR REQUIREMENTS

Air input pressure required to operate pump is 20 to 120 p.s.i. Use lowest air pressure needed to obtain desired material atomization and coverage. DO NOT exceed the 120 p.s.i. maximum.

For average spraying at 1 g.p.m., the pump supplying material to one spray gun will require approx. 30 c.f.m. of free air. Air consumption and flow rate figures for this unit spraying a 56,000 centipoise thixotropic apparent viscosity mastic with 50, 60, and 80 p.s.i. air supply pressure, using tip sizes .029 in. through .071, are given in Form 306-737 supplied with the Reverse-A-Clean spray nozzle.

NOTE

Pump delivers 1 gal. of material every 21 cycles or 3 gal. per minute at 63 cycles per minute. (63 cycles per minute is the recommended maximum for continuous pump operation.)

CAUTION

Pump develops material pressure approx. 30 times the inbound air pressure. The working pressure of material hose supplied with this unit is strong enough to provide and adequate safety margin as long as pump is operating at not more than 120 p.s.i. air pressure.

INSTALLATION

1 PREPARING UNIT FOR USE

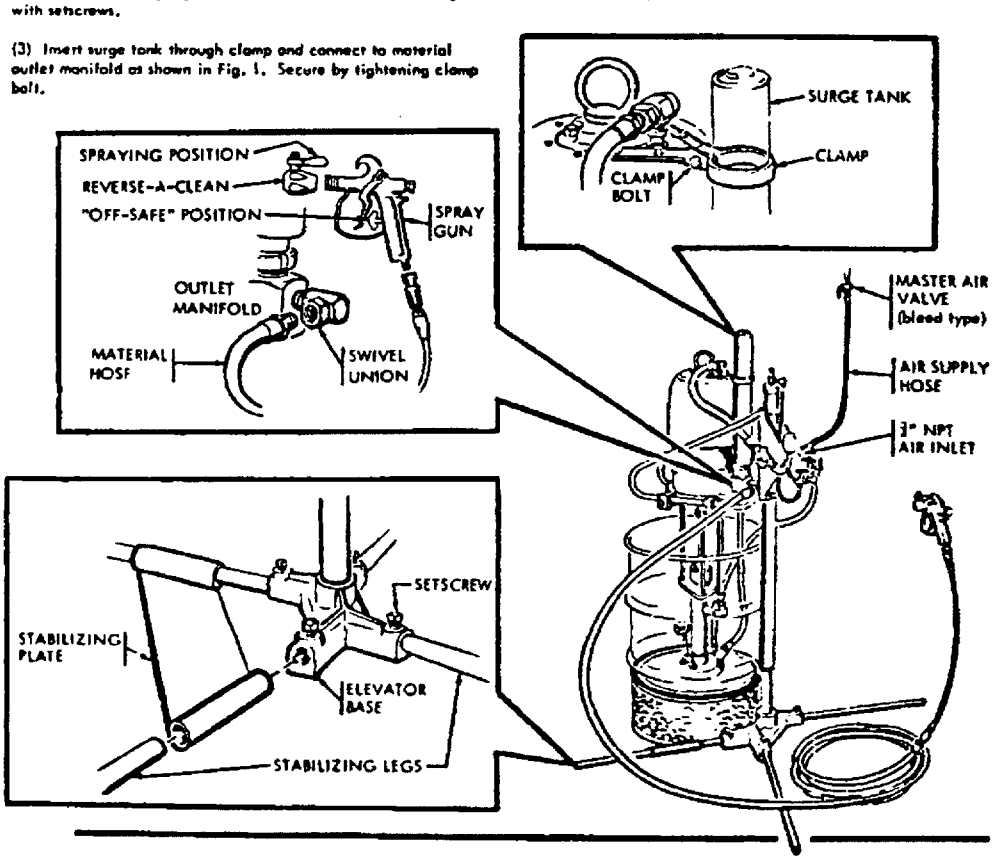
(1) Place unit in desired work area, making sure that unit air controls are accessible to the operator and sufficient overhead clearance (8½ ft. min.) is available to raise pump completely.

(2) Insert two stabilizing legs through stabilizing plate tubes and install legs in elevator base as shown in Fig. 1. Install the other two stabilizing legs in elevator base and secure all legs with setscrews.

(3) Insert surge tank through clamp and connect to material outlet manifold as shown in Fig. 1. Secure by tightening clamp bolt.

(4) Connect material hose to swivel union at outlet manifold and to spray gun as shown in Fig. 1. Attach Reverse-A-Clean to spray gun.

(5. Connect a ¼ in. i.d. (min.) air supply hose to ¾-in. n.p.t. (f) air inlet union. Refer to Fig. 1. Main air line should include a bleed type master air valve.



Instruction Sheet 1

UCC 002977

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APPLICATION OF WEATHER-BARRIERS

OPERATION

2 CHECKS BEFORE STARTING

(1) Unit is factory tested with a light, rust-inhibiting oil. The first few cycles during initial pumping will normally remove this oil. However, to prevent contamination of any material, the system should be solvent flushed prior to use. Refer to paragraph 7 and follow the instructions that apply.

(2) See that material pump wetting cup is filled with a compatible solvent or light oil. See Fig. 2.

(3) Check the dump valve of outlet manifold to see that it is closed. Refer to Fig. 2.

(4) Check the material for heavy fillers, dirt or other coarse particles that might clog spray tip in Reverse-A-Clean.

(5) Perform the necessary lubrication services as indicated in separate pump, spray gun and elevator instruction forms.

3 REMOVING AIR TRAPPED UNDER INDUCTOR PLATE

(1) Close pump ON-OFF air valve. Then open master air valve to energize unit. Refer to Fig. 2.

(2) Open air vent valve of inductor plate. Refer to Fig. 2.

(3) Pull knob of push-pull valve to raise unit. Refer to Fig. 2.

(4) Place an opened 55-gal. drum of material on stabilizer plate under the raised unit, so drum bottom touches elevator base.

(5) Smooth the top surface of the material until nearly level to lessen the amount of air that will be trapped under inductor plate.

(6) Push knob of push-pull valve to lower unit -- guide inductor plate into drum.

(7) Rock or jiggle pump to firmly seat inductor plate on top of material and to exhaust air trapped under plate.

(8) Continue action until material appears at vent opening in plate -- then close air vent valve. Refer to Fig. 2.

4 STARTING & ADJUSTING PUMP FOR SPRAYING

CAUTION

HANDLE GUN WITH CARE. NOZZLE VELOCITY DANGEROUS. At close range, the pressure released can penetrate the skin and cause other injuries. Refer to separate gun instruction Form 306-721 for other safety precautions.

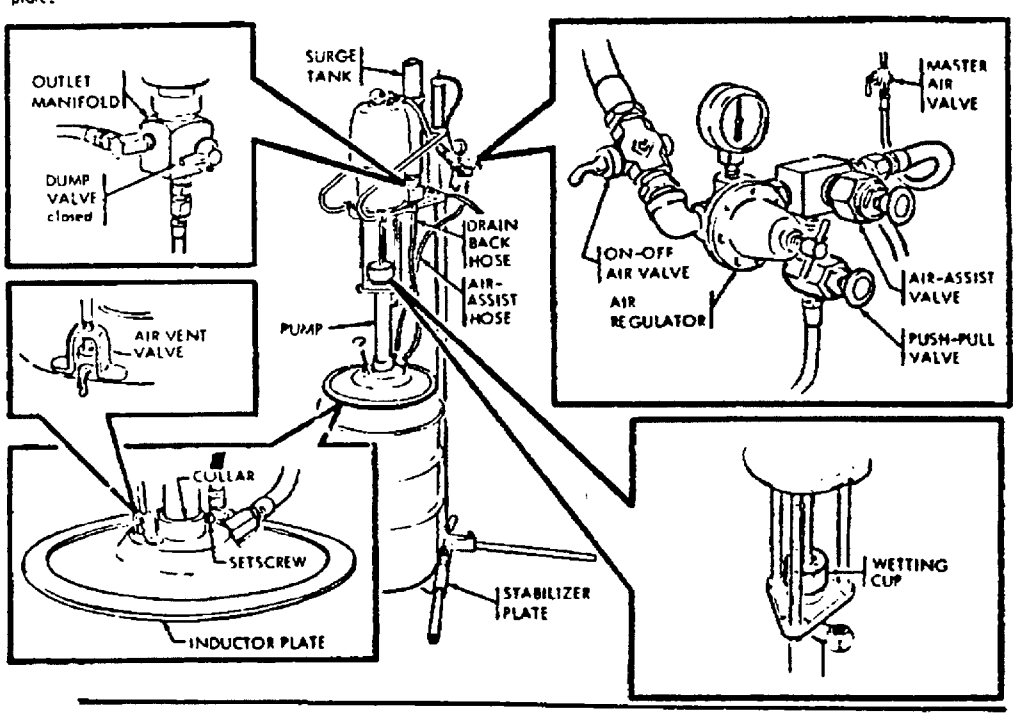
(1) Open pump ON-OFF air valve fully.

(2) Turn lever of Reverse-A-Clean into spray position (pointing toward rear of gun) and turn safety latch of spray gun into "OFF-SAFE" position. Refer to Fig. 1.

(3) Aim and trigger gun into a waste container. Turn regulator "T" handle adjusting screw clockwise to start pump -- run slowly until about one-quart of material is sprayed or until clean material is spraying from gun. Refer to Fig. 2.

(4) Set air regulator at a trial setting of about 60 p.s.i. and spray on a test panel, holding gun about 12 in. away. Vary the distance to suit the kind of material being sprayed.

(5) If spray pattern is not fully atomized, gradually increase the pump material pressure with air regulator until full atomization is attained.



Instruction Sheet 2

UCC 002978

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APPLICATION OF WEATHER-BARRIERS

CAUTION
Always use lowest air pressure necessary to atomize the material. DO NOT exceed the maximum recommended air pressure of 120 p.s.i.

(6) If spray pattern becomes ragged or if spraying stops, swing lever of Reverse-A-Clean 180° to front and remove obstruction by using line pressure.

(7) Follow the instructions given in spray gun literature for proper spraying technique.

5 OPERATING PRECAUTIONS & CARE OF THE UNIT

(1) Always stop pump at the bottom of its stroke and be sure wetting cup is filled, to prevent material drying on displacement rod.

(2) Keep pump, hose and gun filled with material to minimize the necessity for flushing -- NEVER leave unit with air pumped into the system.

(3) When gun is not in use, keep Reverse-A-Clean immersed in clean, compatible solvent. Do not remove gun or material hose unless to service or to clean.

(4) When unit is temporarily shutdown, relieve pressure in system by closing pump ON-OFF air valve and triggering gun open.

(5) Drain surge tank whenever there is excessive surge at spray gun. Release pressure in system (see step (4) above) before opening dump valve at outlet manifold.

(6) If spraying a water base material be sure to flush out with a mineral spirit solvent, daily. Refer to paragraph 7.

6 REMOVING EMPTIED DRUM

(1) Press and hold in knob of air-assist valve to free inductor plate and raise it to top of drum.

NOTE
If while raising, inductor plate stops at a drum rolling hoop, use elevator to raise plate past hoop, then release elevator and continue using air-assist valve.

(2) When inductor plate reaches top of drum, simultaneously, release air-assist knob and pull elevator push-pull knob to raise plate above drum. Refer to Fig. 2.

7 FLUSHING PROCEDURE

NOTE
Unit should be flushed according to general operating conditions and kind of material pumped -- water base material or solvents (such as Ketone) that are harmful to rubber hose or packings must be flushed out with a mineral spirit solvent, daily. Also flush when changing to an incompatible material. The last working day of the week is a good time to flush unit.

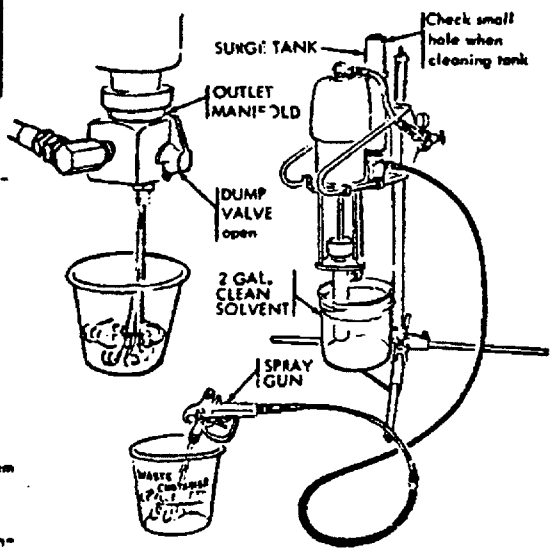
(1) Remove drum as explained in paragraph 6.

(2) Push knob of push-pull valve to lower unit. Refer to Fig. 2.

(3) Disconnect material drain back hose from outlet manifold and air-assist hose from inductor plate, loosen setscrews in inductor plate collar and remove plate from pump intake. Refer to Fig. 2.

(4) Turn safety latch of spray gun into "ON-SAFE" position. Remove Reverse-A-Clean from gun and soak in clean, compatible solvent.

(5) Aim and trigger open gun into a material container, decrease pump to a slow speed with air regulator and pump air to force material from system. Close gun and open dump valve to drain material from surge tank. Close dump valve after tank is drained. See Fig. 3.



(6) Raise unit and lower pump intake into a pail containing about 2 gal. of clean, compatible solvent. Open dump valve and pump solvent through dump valve into a waste container until solvent is fairly clean. Then close dump valve, trigger gun and pump solvent through gun into waste container until clean solvent comes from gun. Refer to Fig. 3. Increase pump to high speed and circulate solvent through gun back into solvent container, for several minutes. Clean inductor plate and drain back hose, while solvent is circulating.

(7) Stop pump with ON-OFF air valve, drain surge tank with dump valve, close dump valve and start pump to refill dump valve with solvent. Drain and refill several times.

(8) Release solvent pressure by closing pump air valve and holding gun trigger open or opening dump valve. Then remove surge tank and spray gun, and clean with new solvent. Check small hole near top of surge tank body and clean, if plugged. Reinstall surge tank. See separate Instruction Form 306-721 for gun cleaning procedure and Form 306-737 for Reverse-A-Clean cleaning procedure.

(9) Remove pump from solvent container and then pump air to remove solvent from system.

(10) Shut off air to pump and reconnect gun to hose. Place pump intake into a container of clean solvent. Start pump and operate slowly, with gun closed, until pump stalls out, then release pressure in the filled system. Leave solvent in system until ready to resume spraying.

NOTE
It may be necessary to repeat step 7 (6) several times using clean solvent, before system is clean enough to be stored. DO NOT store with solvents (such as Ketone) harmful to rubber.

Instruction Sheet 3

UCC 002979

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APPLICATION OF WEATHER-BARRIERS

(11) Remove solvent container, pump air through system to remove solvent, and drain solvent from surge tank and from loops in material hose.

(12) Reinstall inductor plate, and drain back hose and air-assist hose. Recharge unit with material (refer to par. 3 & 4) and then pump about one-quart of material to waste or until material has forced all remaining solvent from system. Reinstall Reverse-A-Clean, perform necessary checks before starting (refer to par. 2) and resume spraying.

MAINTENANCE

CAUTION
ALWAYS RELEASE AIR AND MATERIAL PRESSURES BEFORE SERVICING UNIT!

8 TROUBLESHOOTING CHART

Listed below are troubles which may occur during the use of this unit and their probable causes and possible remedies. Service instructions are given here or in the separate Instruction Forms for the spray gun, pump, regulator, etc. for the less common troubles only. The operator should be able to remedy the more common troubles with the aid of the troubleshooting chart. Check all other possible remedies before disassembling pump.

TROUBLES:

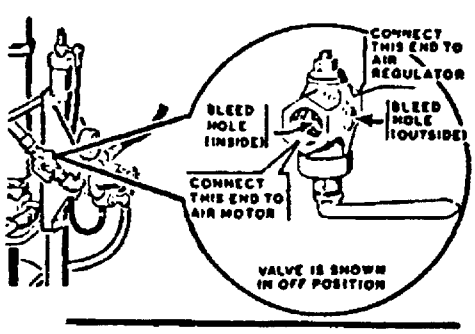
- Pump fails to operate properly
- Insufficient pressure or volume with pump operating
- Excessive surge at spray gun
- Insufficient material breakup
- Too heavy a coating thickness
- Tails or fingers in spray pattern
- Spitting at spray gun

PROBABLE CAUSES: / **POSSIBLE REMEDIES:**

Probable Causes	Possible Remedies
Restricted air supply line	Clear
Air capacity insufficient	Inspect air leaks, see AIR REQUIREMENTS
Closed or clogged air valve, regulator, etc.	Open or clean
Air regulator setting too low or inoperative	Adjust or service
Air regulator setting too high (120 p.s.i. max.)	Adjust
Material too viscous or cold	Warm the material
Clogged Reverse-A-Clean, gun or mat. hoses	Clear, service (Form 306-721 & 306-737)
Material hose too long (pressure drop results)	Remove added hose (50' max.)
Dried material seizure of displacement rod	Fill wetting cup, clean rod
Worn packings or obstructed pump valves	Clear, service (Form 306-735)
Inoperative pump air motor	Service (Form 306-735)
Material supply insufficient	Change to full drum
High flow rate	Change tip (Form 306-737)
Surge tank air head lost	Check top plug, relieve pressure & replace "o" ring seal or drain
Improper or worn spray gun tip	Change, replace (Form 306-737)
Worn, damaged or obstructed gun parts	Service (Form 306-721)
Improper spraying technique	See Form 306-721

9 PUMP ON-OFF AIR VALVE REPLACEMENT

Install new or serviced valve as shown in Fig. 4 so that valve will relieve pressure in air motor when closed.



10 PUSH-PULL OR AIR-ASSIST VALVE SERVICE

To replace air seals or packings, shut off air supply, remove valve and disassemble as shown in parts illustrations on page 7. Inspect parts for damage or wear and replace as necessary.

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APPLICATION OF WEATHER-BARRIERS

OPERATION

1 CONNECTING HOSE, FLUSHING & INSTALLING TIP

(1) Connect a grounded material hose (½ in. ID min.) to gun inlet (½ in. NPSM). See Fig. 1.

> **NOTE**
> Flush system with a suitable solvent to remove lubricant. Check system under pressure for leaks at connections.

(2) Relieve pressure (stop pump and trigger gun) and install tip (see Fig. 1) and/or accessory REVERSE-A-CLEAN TIP or filter assy. (See page 3).

NOTE, tighten tip retainer nut with moderate tension only.

2 HOW TO USE GUN

> **CAUTION**
> 1. BE SURE BOTH object being sprayed and the spraying equipment are grounded.
> 2. KEEP AWAY from high pressure spray to prevent serious injury.
> 3. ALWAYS RELIEVE PRESSURE before removing tip or disconnecting gun ... stop pump and trigger gun.

(1) Check tightness of spray tip retainer nut.

(2) Check material to be sprayed for particles that could clog spray tip.

(3) Start pump and set air regulator at about 60 psi. Release trigger safety (see Fig. 1) and test spray a small area.

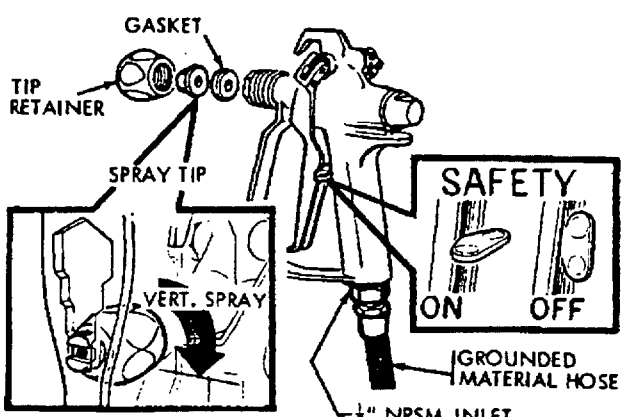


Fig. 1

(4) Adjust fluid pressure until proper atomization is obtained - use lowest possible air pressure.

> **NOTE**
> The fluid pressure and spray tip (orifice size and spray angle) control atomization and pattern length, as well as the flow rate -- which in turn determines the spraying speed.

(5) Use a FULL-OPEN, FULL-CLOSE triggering action. Hold gun about 12 in. away and perpendicular to surface -- do not arc gun. See Fig. 2. A short practice period is advisable to determine proper distance and speed of strokes.

(6) When spraying complex shaped objects, use gun movements that will prevent material build-up and sags.

(7) Whenever gun is left unattended, engage trigger safety to prevent accidental triggering. Refer to Fig. 1.

(8) Clean tip often (at least twice daily during continuous spraying). Remove and clean tip and tip filter (if used) in a clean, compatible solvent and blow dry with air.

> **NOTE**
> A clogged tip may be cleaned by blowing out obstruction with air from the front of tip ... this prevents forcing obstruction deeper into tip orifice. If obstruction cannot be dislodged, soak in solvent overnight then blow out with air. USE EXTREME CARE to prevent damage to - knife-like edge of tip orifice.
>
> When spraying materials that dry, harden or set up quickly, be sure to clean tip often and keep nozzle immersed in suitable solvent during shutdown periods.

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APPLICATION OF WEATHER-BARRIERS

3 SHUTDOWN & CARE OF GUN

(1) Relieve pressure in system and remove and clean spray tip and tip filter (if used). See (8), par. 2.

NOTE

Check valve seat tightness before reinstalling tip—use from 190 to 210 in.-lb of torque.

(2) With gun connected to hose, immerse nozzle in solvent until ready to start spraying again. This will keep air from drying the material and lessen cleaning of hose and gun.

(3) Flush out gun whenever rest of system or unit (pump, hose, etc.) is being flushed.

(4) Gun passageways, needle, diffuser , and spring should be thoroughly cleaned and inspected regularly -- depending on usage and type of material being sprayed. Disassemble parts, soak and scrub clean (use supplied brushes) in clean compatible solvent. Inspect parts, replace if worn or damaged, and reassemble on gun. See Fig. 3.

CAUTION

Handle diffuser and needle carefully, to prevent damage to the hard carbide portions.

NOTE

DO NOT change position of adjusting nut on needle. If needle is to be replaced, refer to par. 6 for trigger stroke adjustment.

(5) To clean trigger safety latch, remove trigger hand grip (see Fig. 3) and scrub latch clean.

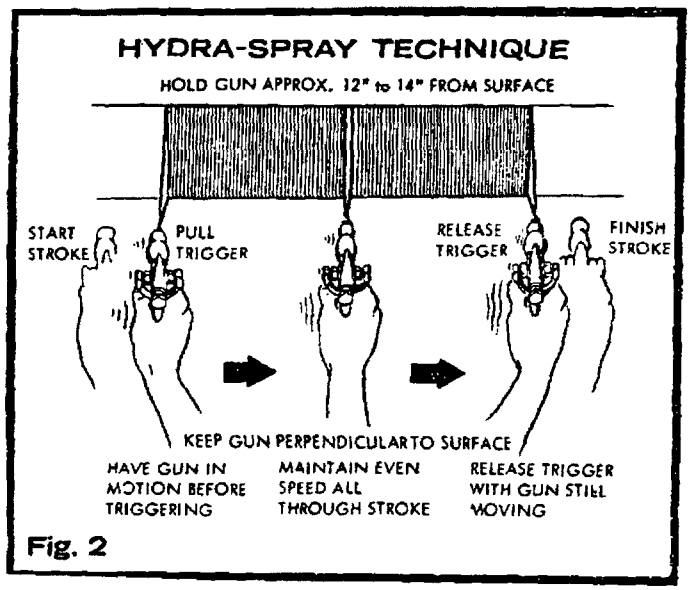


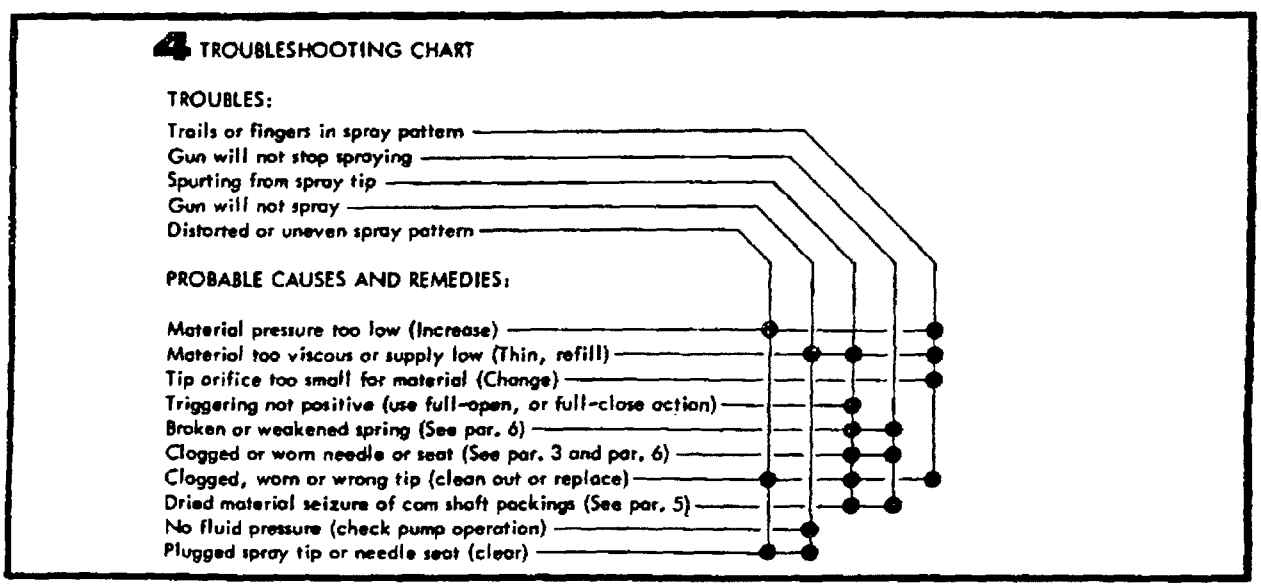
Fig. 2

MAINTENANCE

CAUTION

ALWAYS relieve pressures before servicing gun or tip

4 TROUBLESHOOTING CHART



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APPLICATION OF WEATHER-BARRIERS

5 IF GUN LEAKS AT TRIGGER PACKING NUT

Replace cam shaft packings as follows:

(1) Remove trigger.

(2) Unscrew packing nuts and remove packings, glands, and cam shaft. See Fig. 4. If cam shaft is tight, loosen spring retainer to relieve tension. Refer to Fig. 3.

(3) Clean and inspect parts. Soak new leather packings in light oil until pliable. Assemble parts reverse from disassembly. NOTE: When assembling trigger, insert cam shaft into cam lever so flats on shaft ends will fit into the forked clamps of trigger. Reclamp trigger to shaft, tightening the bottom screws first. Refer to Fig. 3.

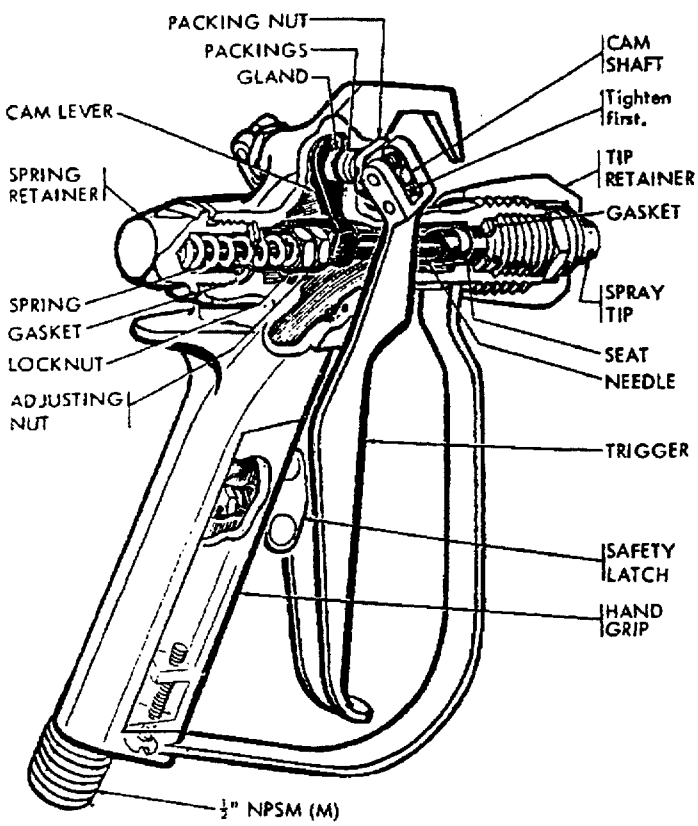


Fig. 3

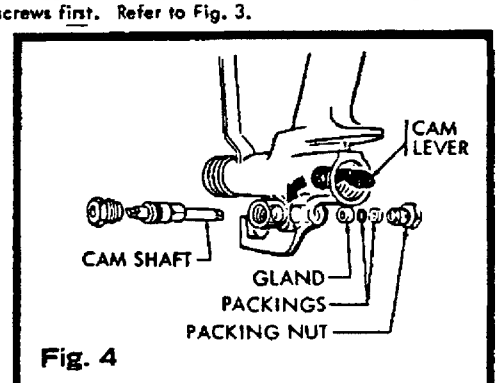


Fig. 4

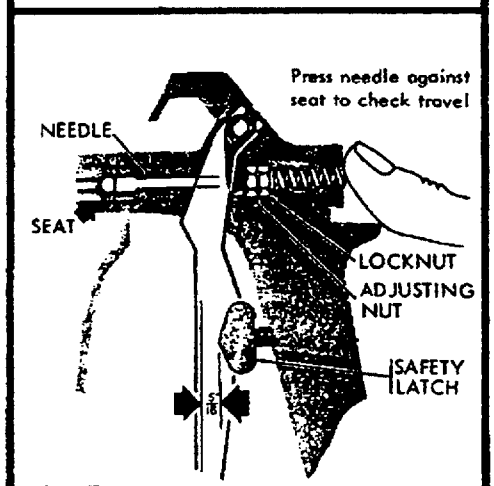


Fig. 5

6 IF GUN LEAKS AT NOZZLE

(1) Tighten valve seat torque from 190 to 210 in. lbs. If leakage continues, replace needle, or valve seat – SEE STEPS (3) & (4) Par. 3.

(2) If needle is worn or damaged, remove lock and adjusting nuts and using same number of turns, install on a new needle.

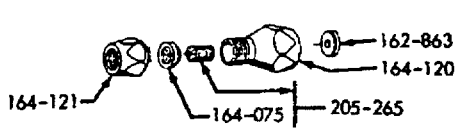
(3) When installing needle and spring in gun body, check trigger stroke for approx. 5/16 in. travel as shown in Fig. 5. Turn adjusting nut in or out as needed, and lock in place. Reassemble parts reverse from disassembly.

ACCESSORIES (Must be purchased separately)

205-614 Reverse-A-Clean

Tip stoppages cleared with paint pressure by reversing tip in nozzle. Includes tip of choice.





207-012 Filter Adapter Kit

Permanent edge-type filter with .009 in. spacing and mounting parts.

Instruction Sheet 7

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APPLICATION OF WEATHER-BARRIERS

APPLICATION OF MASTIC WEATHER-BARRIERS - Contd

Operation of Spray Equipment - Contd

of cloth as shown in Figure XXI-1. After the first coat has taken its set, a second coat shall be spray applied. This second coat must completely fill all the voids in the cloth and cover it from view. The total combined thickness of the reinforcing cloth and the wet mastic should measure 3/32 to 1/8 inch in thickness. If the sprayed surface is pebbled or unsmooth, it should be smoothed down by water brushing.

The weather-barrier shall be carried out six inches onto metal beyond termination of insulation at supports, skirts, or other projections, and shall be sealed to the metal.

The heavy-build mastic used for trowel, palm, or spray application requires 4 to 8 hours to dry to touch. During this period of time it should be protected from being washed off by rain or other liquid water. As the material requires approximately 48 hours to cure, it should be protected from mechanical abuses while it is still soft.

After curing, any shrinkage cracks which might appear, particularly at inside corners and at projections, should be pointed up with mastic to ensure a water-tight installation.

Flashing

After trowel or spray application of weather-barrier additional flashing of a cant of mastic over which a trowel coat of mastic, reinforcing cloth and second coat of mastic should be installed around the projections such as nozzles. This is illustrated in Figure XXI-2.

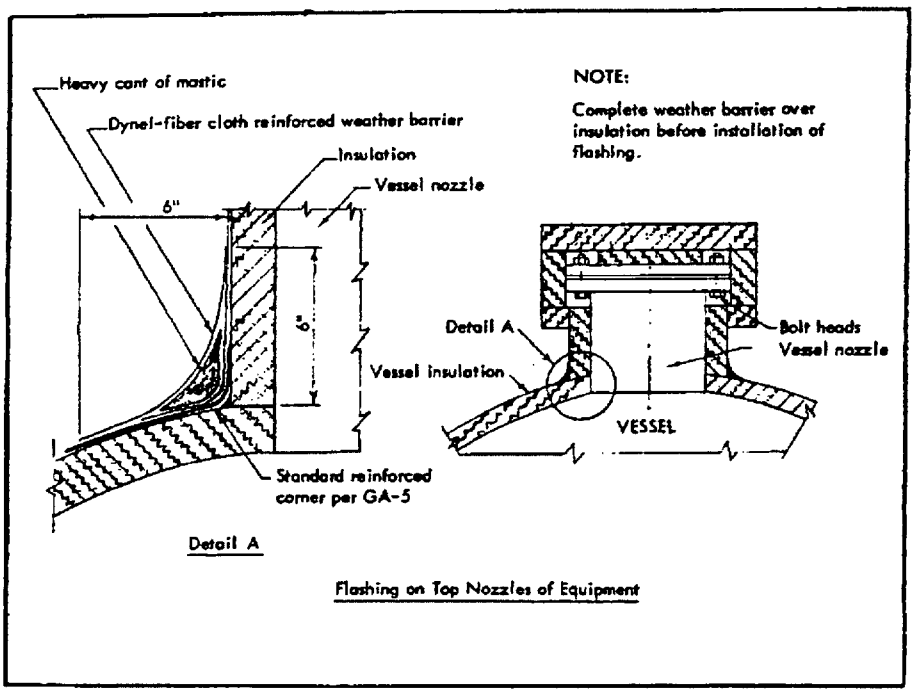
Expansion-Contraction Joints

Expansion joints in weather-barrier in high-temperature insulations should be constructed with an expansion strip as shown in Figure XXI-3. Joints installed in vertical position shall be constructed to shed water. Joints in horizontal position shall be constructed in a similar manner except that a bed of non-setting sealer shall be placed between the two layers of expansion strip so as to prevent entry of water, but not restrict the movement between the sheets.

The metal strips shall be of 0.008- to 0.010-inch thick stainless steel. Each strip should be sealed to the insulation beneath it by embedding it in the mastic and securing it in position by stainless steel strap. The weather-barrier mastic, with its reinforcing cloth, should be extended over each of the strips but must not be extended over the sheets where they overlap.

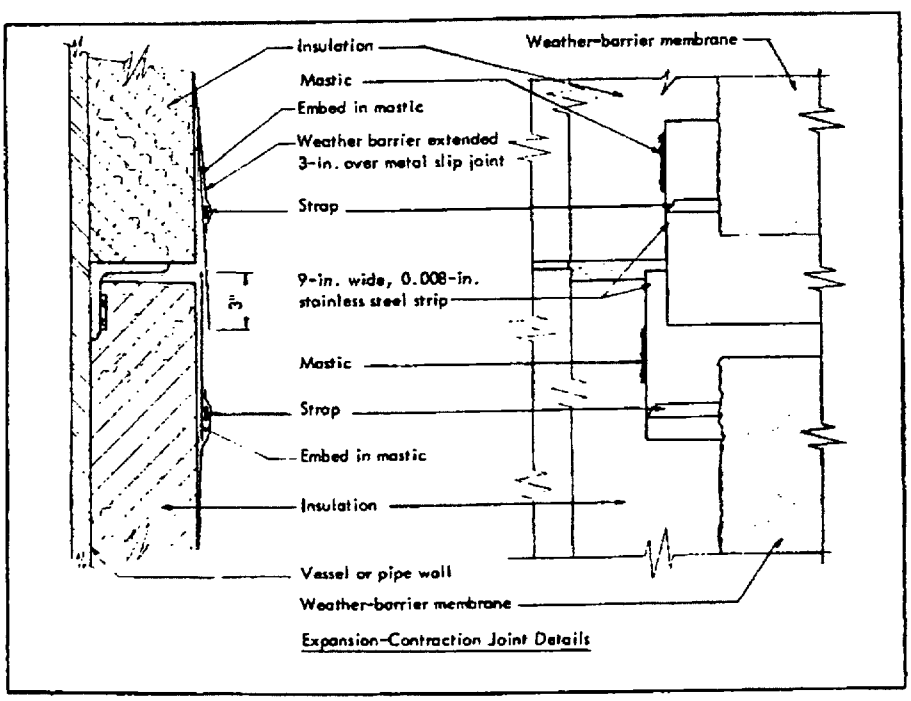
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APPLICATION OF WEATHER-BARRIERS



Flashing on Top Nozzles of Equipment

Figure XXI-2



Expansion-Contraction Joint Details

Figure XXI-3

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APPLICATION OF WEATHER-BARRIERS

APPLICATION OF MASTIC WEATHER-BARRIERS - Contd

Expansion-Contraction Joints - Contd

Expansion joints in low-temperature insulation are constructed with the insulation as described in Chapter XIV - Application of Rigid Insulation - Low Temperature.

APPLICATION OF METAL JACKET WEATHER-BARRIER

Jackets may be of plastics, laminates, or metal. The specified metal weather-barrier jacketing used in our installations are treated steel and stainless steel, with the exception that aluminum may be used in areas of little fire hazard. When factory aluminum prejacketed insulation is specified, the entire panel is installed as a unit; thus, this is described in the insulation application and will not be described in this chapter.

Preparation

The materials required for application of metal weather-barriers on equipment are as follows:

1. Metal jacket as specified.
2. Steel metal screws.
3. Equipment insulation strap.
4. Clips for equipment insulation strap.
5. "S" clips.
6. Jacket support clips.
7. Stainless steel wire.
8. Flashing strip.
9. Lap sealer.
10. Non-setting lap sealer.
11. Heat-resistant sealer.

The materials required to install metal weather-barriers on straight pipe are:

1. Preformed metal jacket.
2. Pipe insulation strap.
3. Clips for pipe insulation strap.
4. Closure bands, with factory installed sealer.
5. Stainless steel wire.
6. Heat-resistant sealer.

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APPLICATION OF WEATHER-BARRIERS

APPLICATION - EQUIPMENT

The equipment insulation strap clips shall be embedded into the insulation to provide a smooth, even surface for application of the jacket.

On vertical vessels, the metal jacket is installed, starting at the bottom. The first course is supported by jacket support clips, attached to the insulation support. Each vertical joint must be lapped a minimum of three inches or in the case of deep corrugations the metal should be lapped two corrugations. A bead of lap sealer should be placed between the layers of metal on all vertical joints before the joint is fastened together with screws on six-inch centers. Care should be taken to prevent screws being installed in a manner that two courses of metal are fastened together. It is essential that relative movement be allowed between each two courses of metal to provide for the expansion and contraction dimension change of the vessel. The jacket shall be held in position by insulation strap, which should be tightened just sufficiently to secure the jacket.

Second and subsequent courses of jacket shall be supported by "S" clips. Each subsequent course of metal jacketing should overlap the preceding layer 3 inches to shed water.

At top of vessel, a six-inch-wide stainless steel flashing strip should be installed. This should be bonded in place, overlapping the last course of metal jacket. It should not be attached to the metal jacket so as to form a slip expansion and contraction joint. The mastic weather-barrier used over the vessel head shall be applied down over the flashing to provide water shed.

Details of this construction are illustrated in Detail A, Figure XXI-4.

Horizontal vessels should always be jacketed with smooth metal jacket. This is because it is practically impossible to water-seal circumferential joints of corrugated metal. The smooth metal jacket shall be installed around the vessel with each course of jacketing overlapped a minimum of three inches with the preceding one. Each circumferential joint should be sealed with a bead of non-setting lap sealer which was placed on the lap area of the installed metal prior to application of the overlapping next course. The circumferential joint should be secured by strap placed directly over the joint. Intermediate straps shall be installed between circumferential joints and shall be on centers not greater than 18 inches. Horizontal joints shall also have a minimum 3-inch overlap.

They should be located on sides of vessel so as to shed water. They shall be secured with screws on six-inch centers. All sharp edges shall be bent under to prevent a hazard. Details of construction are shown in Figure XXI-5.

On either horizontal or vertical vessels, if heads or special contours are covered with metal jacketing, the jacketing must be preformed to properly fit. All joints of preformed jackets shall be so formed and fastened together to form a water-tight assembly. Where these jackets fit

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APPLICATION OF WEATHER-BARRIERS

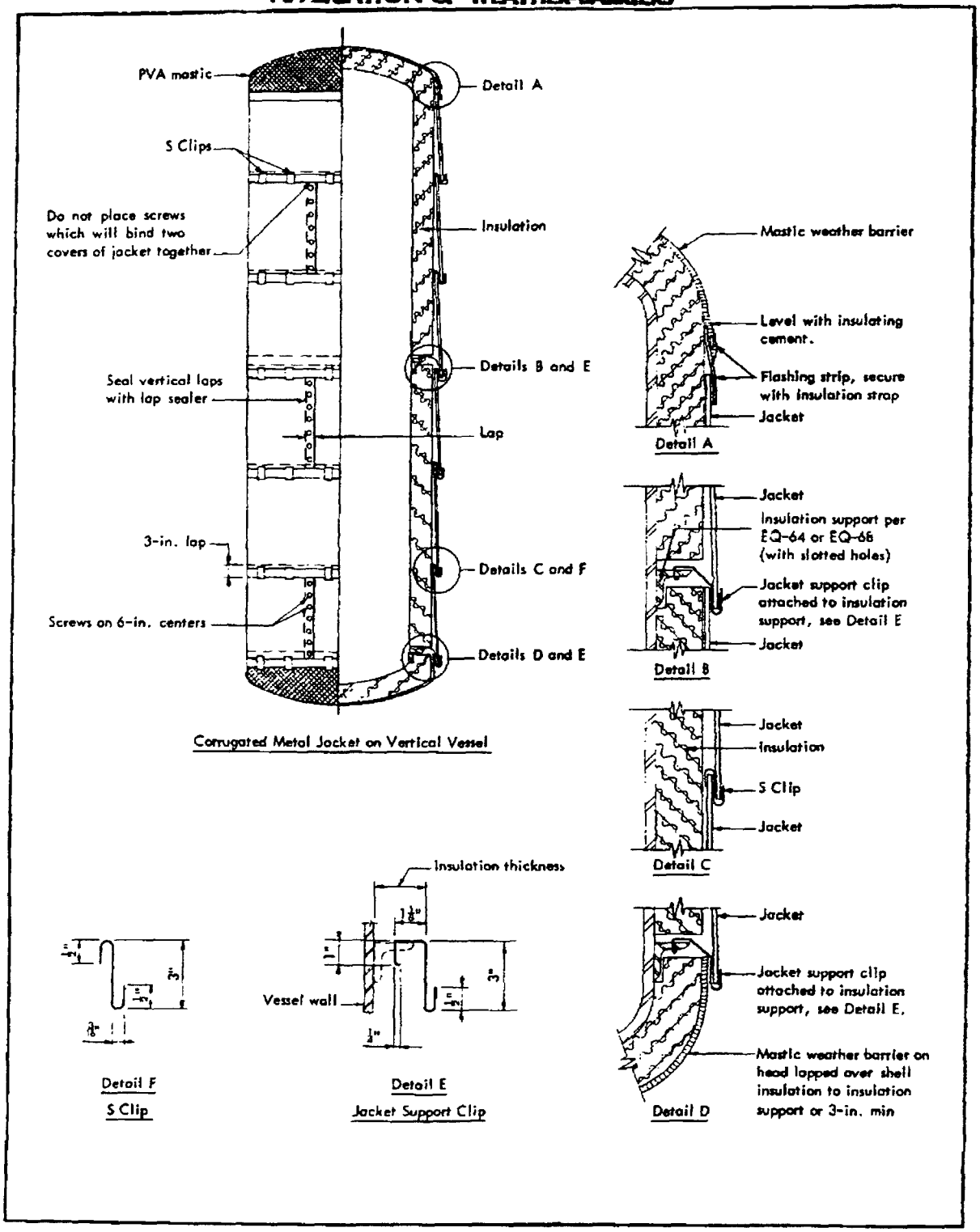


Figure XXI - 4

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APPLICATION OF WEATHER-BARRIERS

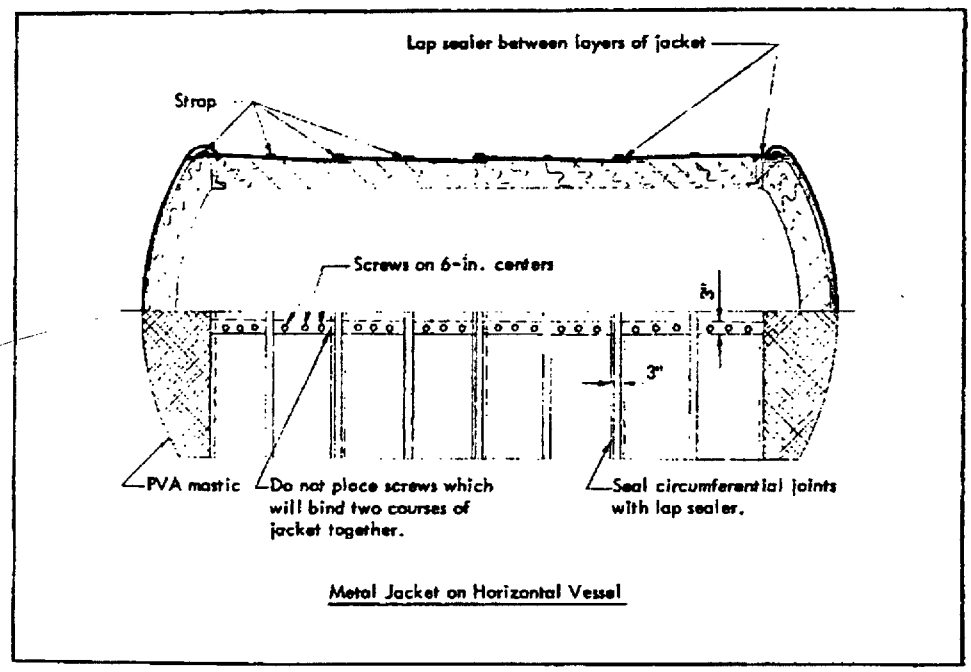


Figure XXI - 5

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APPLICATION OF WEATHER-BARRIERS

APPLICATION - EQUIPMENT - Contd

together to the cylindrical jacketing the laps should all be sealed with lap sealer.

All projections through the jacket must be suitably fastened and sealed with sealer suitable for the temperature to which it is to be subjected.

APPLICATION - PIPING

Straight piping insulated with metal jacketing should be weather-protected with preformed jacketing with longitudinal "Z" joint. The metal jacket may be supplied factory applied to the insulation. If the jacketing is not factory applied, the pipe insulation should be secured with stainless steel wire. Ends of wire shall be twisted and embedded in surface of insulation so as to provide a smooth, even surface for application of the jacket.

Jacket (or pipe insulation with jacket attached) should be installed by placing the jacketing in position and engaging the "Z" joint. Longitudinal joint on horizontal pipe shall be located on horizontal centerline of pipe with open end down to ensure runoff of water. The jacketing (or pipe insulation and jacketing) should be secured by strap drawn tight and fastened with clip. On diameters of pipe insulation 6-5/8 inches and under, one strap shall be used at center of assembly. Larger diameters should be secured with two straps, each approximately 12 inches from end of assembly.

The butt joint between adjacent assemblies shall be sealed with a closure band. These bands shall be furnished with sealing compound on each of the edges, so as to make a water-tight joint. Some of the excess sealing compound should be located between the strips of compound directly at the closure of the "Z" joint to provide a seal at the closure overlap. The closure bands shall be tightly secured in position with pipe insulation strap. This assembly is shown in Figure XXI-6.

Where the straight pipe is metal jacketed and fittings weather-protected with mastic, the mastic should be installed in the manner described in the first part of this chapter. The weather-barrier mastic and fabric reinforcing should be lapped over the metal jacket for a minimum of one inch.

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APPLICATION OF WEATHER-BARRIERS

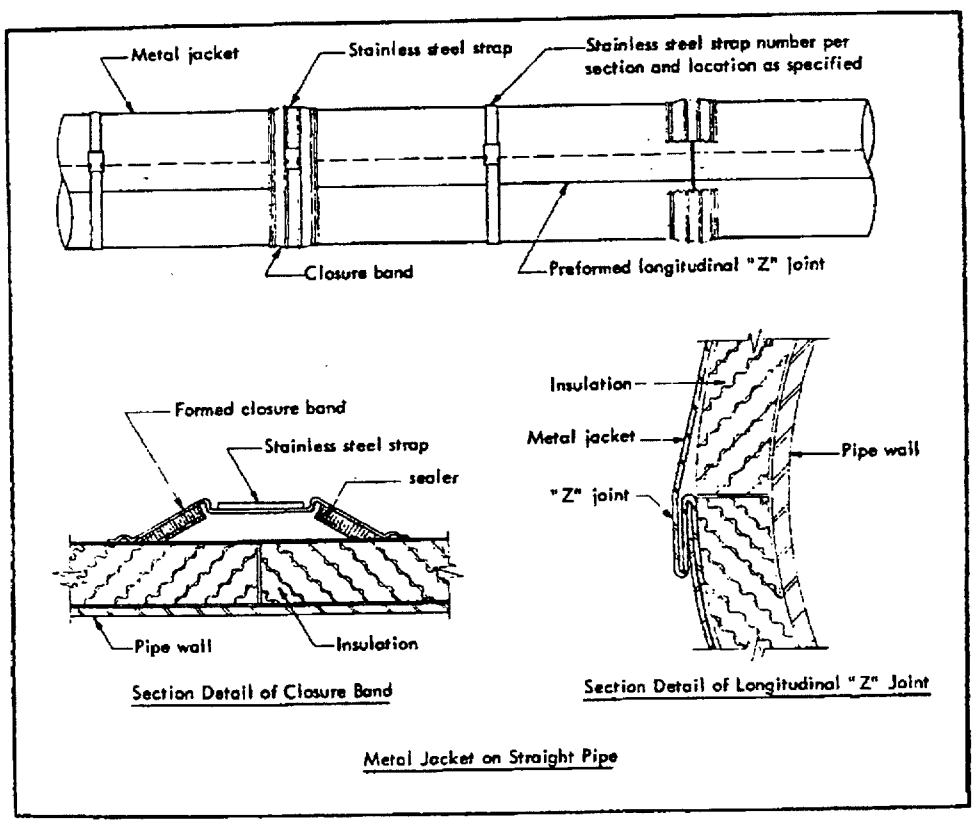


Figure XXI - 6

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APPLICATION TO UNDERGROUND PIPING MODERATE AND HIGH TEMPERATURE SERVICE

There are three basically different systems used to insulate warm and hot lines underground. One is the field applied insulation; another is the factory insulated piping conduit systems; and the third is the fill type of applications. Whenever it is necessary to provide heat tracing for a line the field applied insulation is most frequently used due to the complex problems of securing properly designed traced piping from the manufacturer of preinsulated conduit enclosed pipe.

FIELD APPLIED INSULATION

General

As all underground lines are subjected to ground pressure and water, the insulation must have high compressive strength and be water and vapor resistant. These requirements restrict the choice of insulation down to one-cellular glass.

Preparation

The trench in which the insulated pipe is used must be properly prepared, otherwise the finished installation may be damaged by any sharp projection or uneven contours when the assembly is placed in position. A typical trench is shown in Figure XXII-1. The sand bed at the bottom of the trench is essential to spread the compressive load imposed on the bottom of the cellular glass when the insulated pipe is lowered into the trench. The digging of the trench and its preparation is not done by the insulators, however, the insulator should make sure that this work is done in accordance with the specification.

The pipe to be insulated should be cleaned of all oil, grease, dirt, rust, or scale. Where coating is required, it must be coated in accordance with the coating schedule and specifications. The coating should be completely dry before insulation application is started.

If the pipe is to be steam traced or electric traced, the tracing should be installed in accordance with the specifications and in the manner described in Chapter XII - Application - General.

All of the cellular glass insulation pipe covering and fitting covers should be prefabricated to dimensions required.

All the insides of the pipe covering should be coated with anti-abrasive coating to prevent pipe movement from wearing away the insulation. This coating applied on the inner bore and edges of the pipe covering must be dry before the insulation is installed. If the insulation is to be installed on stainless steel pipe, the bore coating should be a silicon-graphite, anti-abrasive coating. Installed on pipe of other metals, the anti-abrasive coating should be formed of a water solution of Keene's cement.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

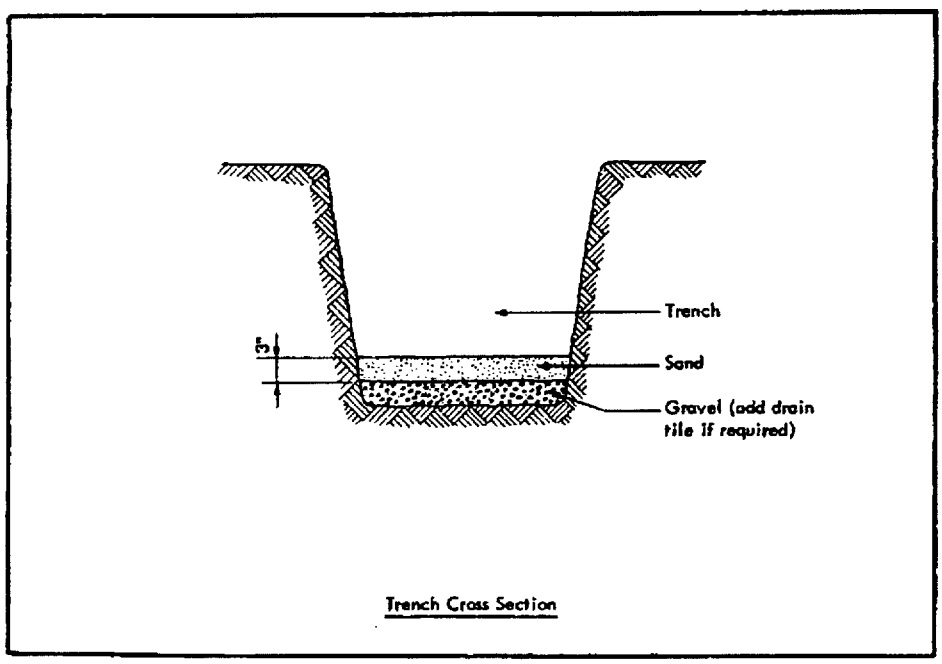


Figure XXII - 1

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

FIELD APPLIED INSULATION - Contd

Preparation - Contd

The accessory materials required for an application of cellular glass to pipe which is to be located underground is as follows:

1. Stainless steel wire
2. Pipe insulation strap
3. Clips for pipe insulation strap
4. Anti-abrasive coating
5. Anti-abrasive coating (for application to stainless steel)
6. Concrete support pads (field poured)
7. High temperature fabrication cement
8. Joint sealer
9. Reinforcing cloth (glass fabric)
10. Water-barrier coating
11. Graphite pipe slides for support pads

Application

Being installed underground, the cellular glass insulation on the outside of the pipe cannot move. Any movement of the insulation would cause cracks in the water barrier which would allow entry of liquid water from the soil. For these reasons the pipe movement, due to expansion and contraction, must be free to take place without hindrance inside of the insulation. Thus, expansion chambers must be built into the insulation to provide space for the movement of the pipe.

In this application, its water barrier must be so constructed as to a water-tight conduit as well as an insulation. Thus, every joint must be water tight and the system so constructed that pipe movement will not exert forces on the insulation to break it and cause it to lose its water tightness.

Straight Pipe

Insulation up to 2-1/2 inches in thickness is to be installed in single layers. Installations of 3 inches thickness and greater is to be installed in multiple layers. This pipe insulation is to be applied in staggered positions. Where multiple layer insulation is used, butt joints of one layer must not coincide with those of any other layer.

The cellular glass insulation must be fitted with very tight joints. Large voids should not be filled with coating or cement, but the insulation should be recut and refitted to eliminate voids.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

FIELD APPLIED INSULATION - Contd

Straight Pipe - Contd

All installations where installation of insulation is on piping whose service temperature is less than 212F shall have all longitudinal and circumferential butt edges buttered with joint sealer before application. These joints should be drawn together when the insulation is applied so that only a thin, vapor-tight and water-tight seal separates the sections of insulation.

Insulation installed on piping operating above 212F should be installed without sealer in butt joints, however all butt edges and joints should have been previously coated with abrasive resistant cement. Wherever it is necessary to field cut and immediately install pieces, the field cut butt edges should be buttered with sealing compound to prevent abrasion of these butt joints.

All inner and outer layers up to and including 12 inch OD shall be secured with stainless steel wires. All single, or outer layers of cellular glass over 12 inch OD shall be secured by stainless steel strap and double pronged clips. Spacing of the wire or the strap should be as shown in Chapter XI - Figure XI-14.

Expansion Chamber

An expansion chamber, constructed of insulation of larger inside diameter than the outside diameter of the pipe, shall be provided to allow for pipe movement at lead-off lines, expansion loops, and where pipe direction changes at elbows.

The inside diameter of these expansion chambers must be sufficiently large to accommodate all the movement of the pipe without the exerting of forces on the cellular glass. The inside diameter of the insulation for the expansion chamber should never be less than four inches greater than the outside diameter of the pipe. However, if pipe movement is greater than two inches in either direction, this inside diameter must be increased to allow for free movement of the pipe.

Expansion chambers should never be constructed of cellular glass insulation less than 2 inches in thickness. If, for temperature consideration, the cellular glass requires greater thickness than 2 inches then, of course, this greater thickness shall be used.

The expansion chambers shall be constructed in such a manner that concrete pad supports molded to fit the bottom of the expansion chamber will support the bare pipe. Between the concrete pads and the bare pipe, graphite pipe slides shall be installed to permit free movement of the pipe.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

FIELD APPLIED INSULATION - Contd

Expansion Chamber - Contd

A table for determining the lengths and spacing of these concrete pads is given in Figure XXII-2. Detail of installation of the graphite slides is shown in Figure XXII-3.

A general assembly of an expansion chamber at lead-off pipe is shown in Figure XXII-4 and at elbows (or expansion loop) is shown in Figure XXII-5. In all cases, the oversized pipe insulation used to construct the expansion chamber should overlap the pipe covering on the straight pipe at least 6 inches. This overlapping joint shall be sealed with lap sealer.

Water-Barrier Application

Being underground, the assembly of the insulation plus the water-barrier must be a water tight conduit which keeps the pipe dry. Thus, the outer finish over the insulation must be installed with different materials and methods than ordinary weather-barriers.

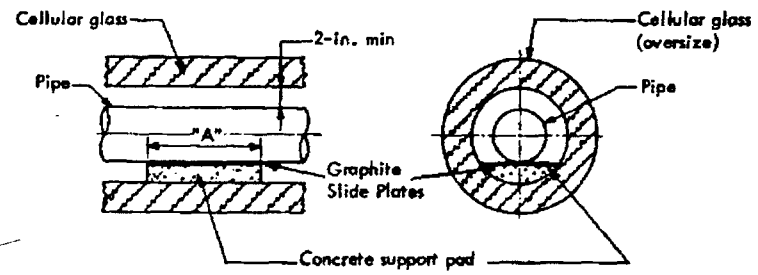
The outer surface of the insulation shall be sprayed, brushed, or gloved with water-barrier mastic to a thickness not less than 1/8-inch in thickness. While the coating is still tacky, tar impregnated glass fabric reinforcing cloth shall be laid smooth and embedded in the mastic. All edges of cloth shall be overlapped a minimum of three inches to provide a joint of equal strength to that elsewhere. While the first coat is still tacky, a second coat of 1/8-inch thickness should be applied in the same manner as the first coat. A second layer of the glass reinforcing cloth shall be installed in the second coat of mastic in the manner described for the installation of the first cloth reinforcing. Finally, before the second coat is completely dry to touch, the third coat of water-barrier of 1/8-inch thickness should be applied. The coating and layers of cloth shall be installed in a uniform manner to prevent uneven contraction and a tendency toward surface cracks.

Installation in Trenches

After the water-barrier mastic has dried the assembly should be carefully laid in the trench on the sand bed. During the moving of the assembly, care must be taken to prevent bending of the assembly which would crack the insulation and water-barrier. Should the assembly be inadvertently cracked, the insulation and the water-barrier finish should be carefully repaired to be as crack free as all other parts. Care must be taken to prevent trenches from filling with water, and if so, located so that its water level could not rise above lower third of assembly. The trenches should be equipped with drain tile to drain water away. It must be remembered that hot gas or steam lines insulated with cellular glass might be lighter than their displacement of water; and if the trench became filled with water, might float to the surface.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE



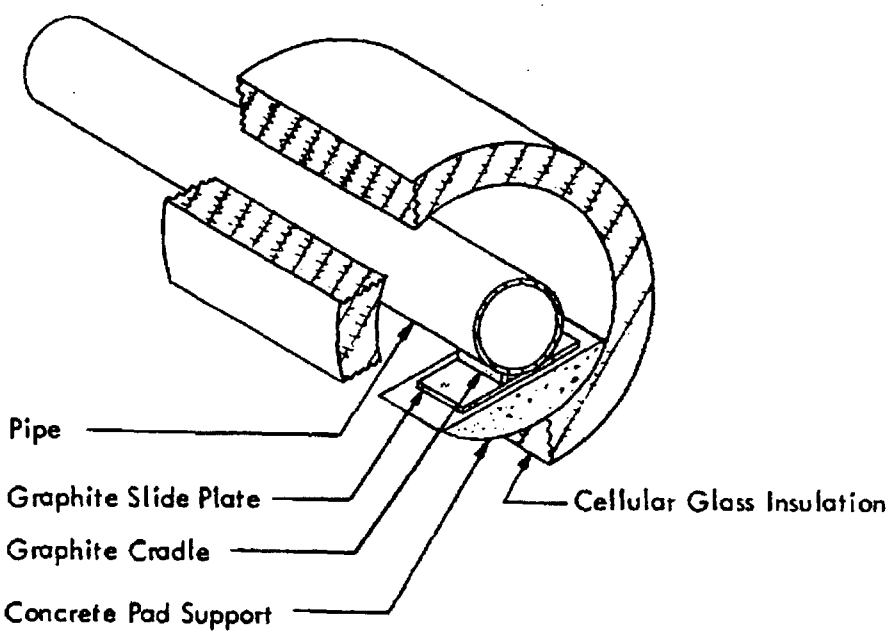
Nominal Pipe Size (Inches)	Length of Concrete Pad Dim "A" (Inches)	Max C-to-C Spacing (feet)
3 and smaller	6	8
4	6	5
5	12	8
6	12	6
8	12	4
10	12	3
12	Continuous	—

Size and Spacing of Concrete Support Pads

Figure XXII - 2

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

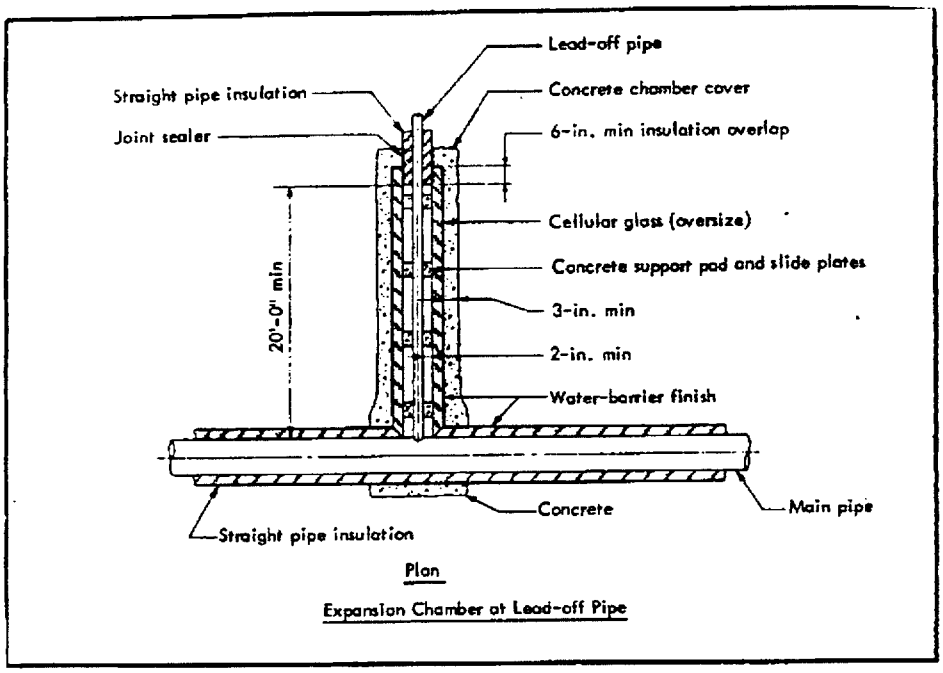


INSTALLATION OF GRAPHITE CRADLE AND SLIDE PLATE BETWEEN PIPE AND CONCRETE PAD

Figure XXII-3

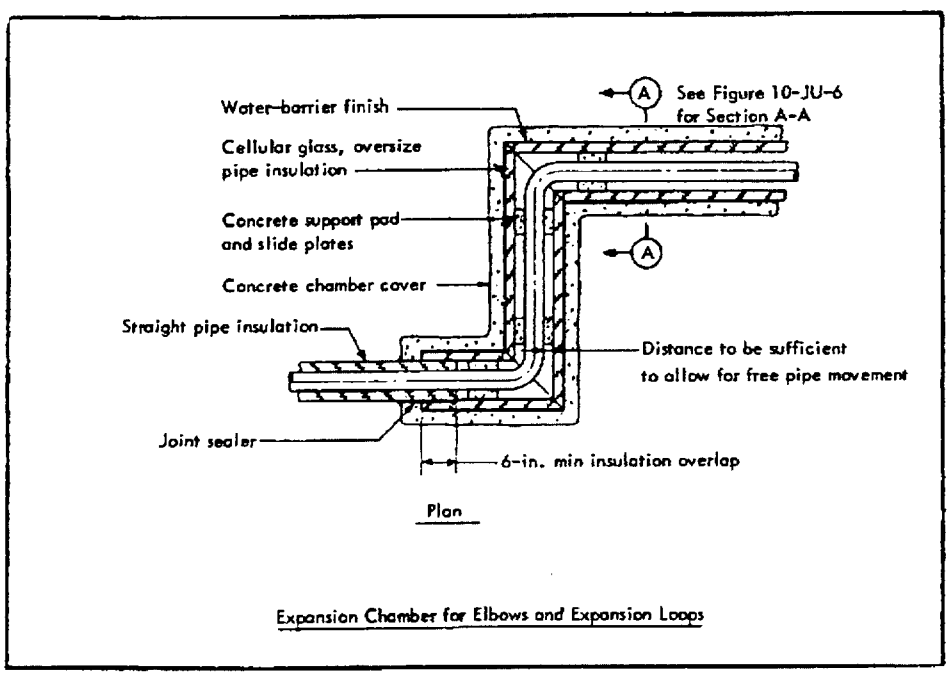
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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE



Expansion Chamber at Lead-off Pipe

Figure XXII-4



Expansion Chamber for Elbows and Expansion Loops

Figure XXII-5

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

FIELD APPLIED INSULATION - Contd

Installation in Trenches - Contd

Backfill over the assembly shall be with a minimum of three inches of sand around the outside of the insulation. For one foot above the assembly, the backfill should be rock free earth. Above that the trench may be filled with any fill material available.

A section of completed straight pipe so insulated and installed in a trench is shown in Figure XXII-7. A section of the expansion chamber is shown in Figure XXII-6.

FACTORY INSULATED PIPE AND CONDUIT

General

Factory insulated pipe includes the pipe, insulation, outer conduit and accessories for the joining together of the pipe, insulation, and conduit sections. As such, the pipe insulation and conduit must be ordered as a "package" to comply with the piping design. One type of preinsulated pipe and conduit is pipe insulated with urethane foam in PVC jackets. Another type is pipe insulated with any specified insulation, factory installed in steel conduit. As each of these must be installed in a particular manner, the presentation regarding their installation is separated.

URETHANE FOAM INSULATION, PVC JACKET CONDUIT

This type of preinsulated pipe conduit is used on systems normally operating at temperatures from 50F to 250F. As the insulation itself is water-resistant, it is particularly advantageous when used on piping operating at less than 212F, but at a higher temperature than the ground in which it is buried.

As a factory insulated system, the insulator is responsible for application of the insulation at the connections between the individual sections and fittings.

Preparation

The trench in which the insulated pipe conduit is to be laid must be in accordance with the drawings. The bottom of the trench should be uniform and smooth.

It is essential to determine that all straight insulated conduit, all factory insulation fittings, insulation stock, and compression couplings are available at start of installation as these are custom made and not readily available. Types of fittings are shown in Figures XXII-8 and XXII-9.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

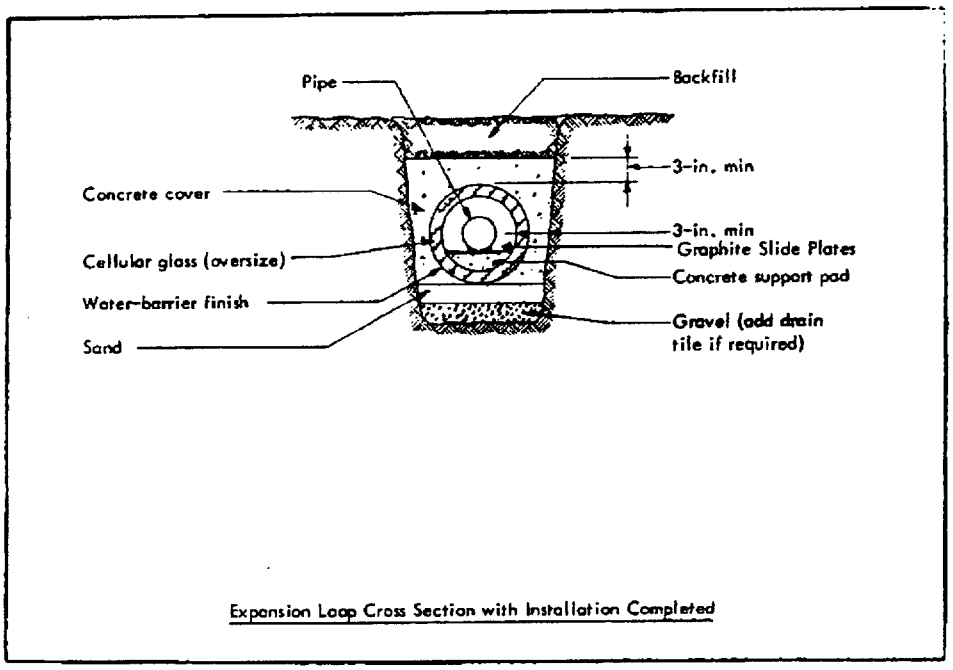


Figure XXII-6

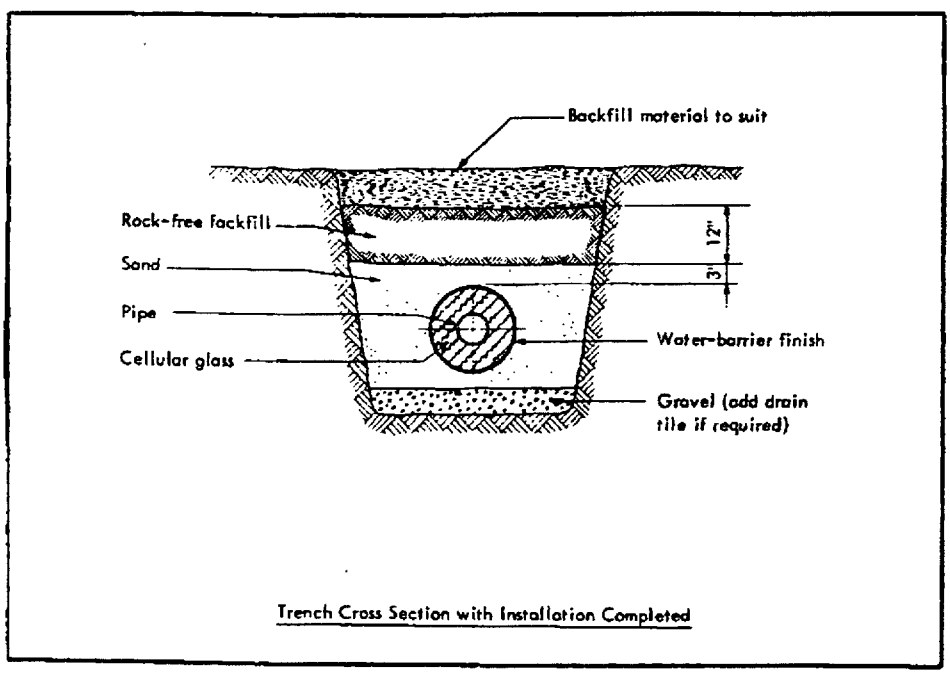
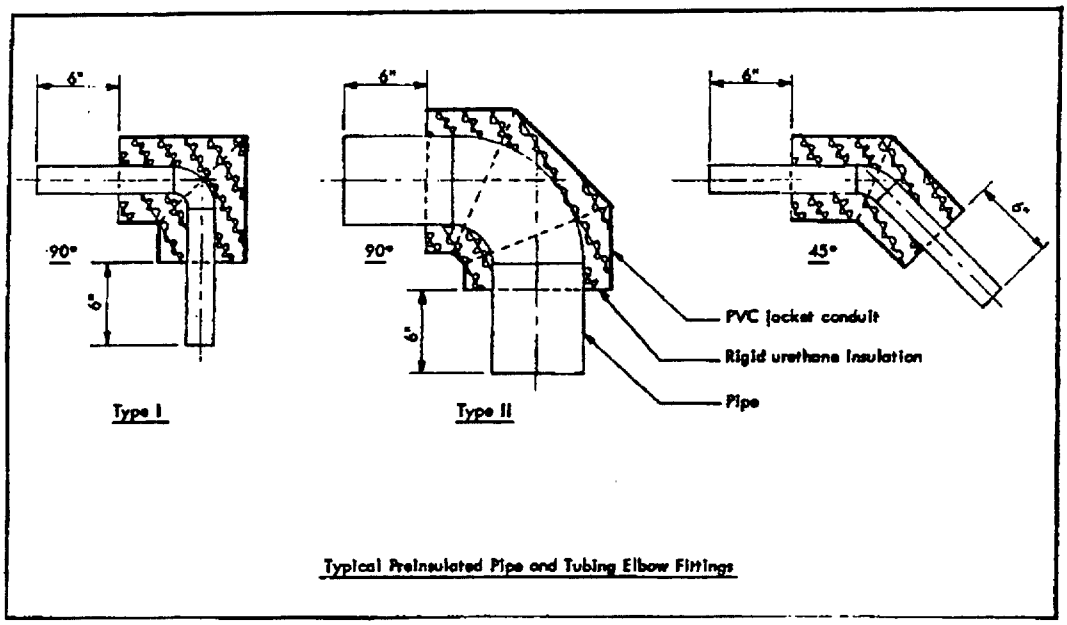


Figure XXII-7

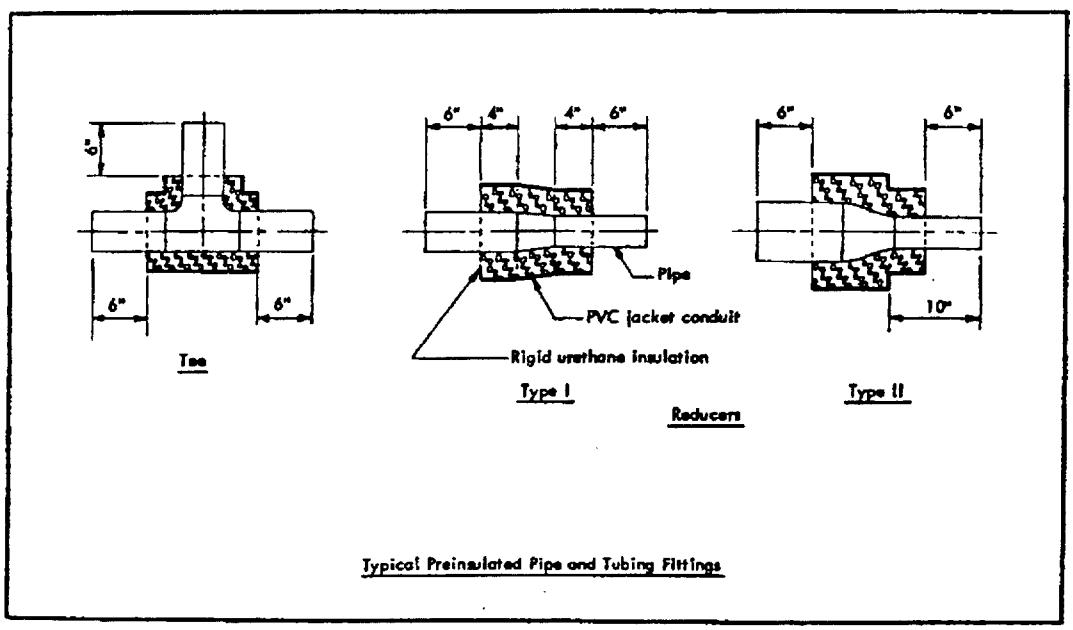
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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE



Typical Preinsulated Pipe and Tubing Elbow Fittings

Figure XXII-8



Typical Preinsulated Pipe and Tubing Fittings

Figure XXII-9

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APPLICATION TO UNDERGROUND PIPING MODERATE AND HIGH TEMPERATURE SERVICE

URETHANE FOAM INSULATION, PVC JACKET CONDUIT - Contd

Preparation - Contd

Prior to installation of any pipe or fittings, the compression coupling and its components must be placed around the conduit adjacent to the section or fittings to be jointed. This is of utmost importance as after the pipe is welded together, there is no way in which these can be put in position around the conduit.

Application

After the piping has been welded together, the loose scale, paint, dirt, grease, and other contaminate materials should be removed from the exposed ends of the pipe. Pipe should then be tested.

The urethane insulation stock furnished to cover the exposed pipe ends should be fitted in between adjacent factory installed insulation. This pipe insulation shall be secured in position with stainless steel wire. The joining sleeve should then be slid into position over the joint insulation. When in position, the stainless steel clamp rings shall be pulled tight by the bolts compressing the rubber seal around the PVC conduit. Assembled coupling around joint is shown in Figure XXII-10.

Anchors and terminals require special treatment. The anchors are supplied with steel welded directly to the pipe. The insulation is installed around the pipe butted up to anchor steel. The sections of preinsulated pipe conduit are installed to this anchor as previously described. However, as the outer sleeve coupling must also butt up to the anchor steel, it is furnished in two sections which after being placed in position are solvent welded to obtain its outer seal. After the insulation and sleeve are installed the concrete anchor is poured around the assembly.

INSULATED METAL CONDUIT

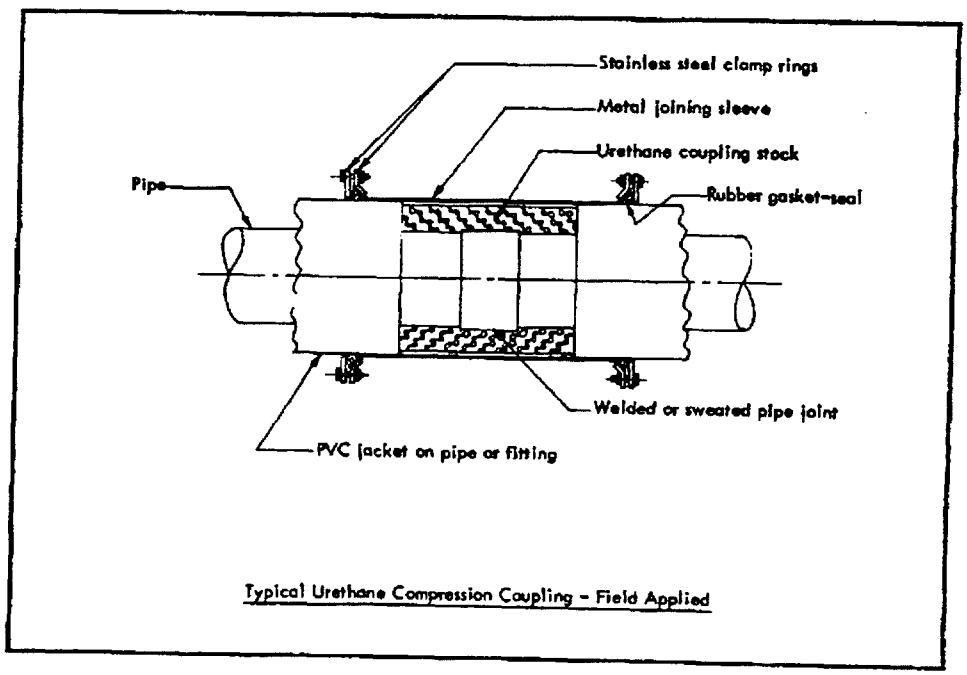
This type of preinsulated pipe is used for systems normally operating at elevated temperatures. The top limit of operation is determined by the insulation specified. The preinsulated conduit can be obtained with glass fiber insulation having a maximum temperature of 450F, calcium silicate with a maximum temperature of 1000F, expanded silica with a maximum temperature of 1400F, or with high-temperature calcium silicate with a maximum temperature of 1800F. However, generally, the ordinary usage is up to 750F, as special design is required for the higher temperature.

Similar to other factory-applied conduit systems, the field insulator is responsible for application of the insulation and water proofing at the field-connected junction between individual sections and fittings.

A typical anchor assembly is shown in Figure XXII-11 and a conduit terminator assembly is shown in Figure XXII-12.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

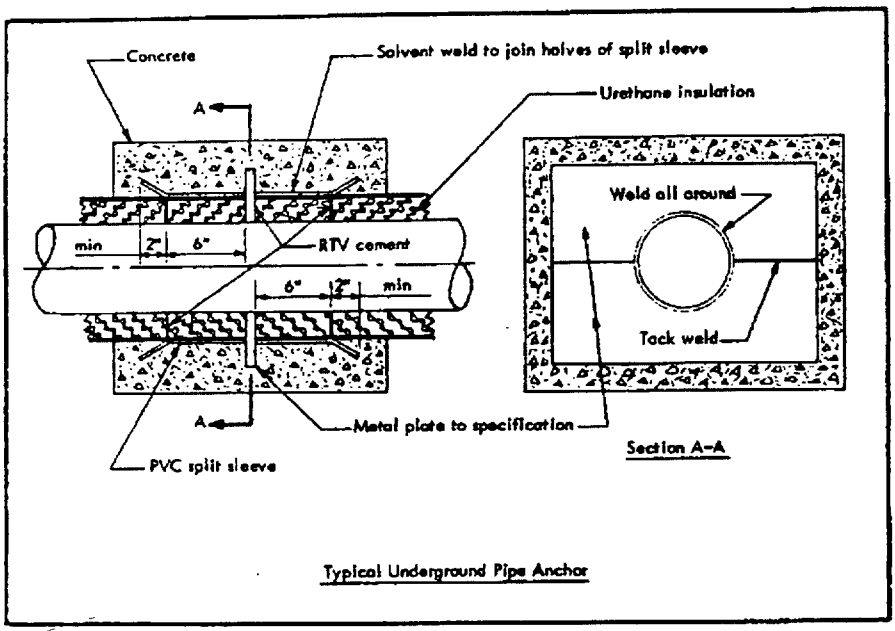


Typical Urethane Compression Coupling - Field Applied

Figure XXII - 10

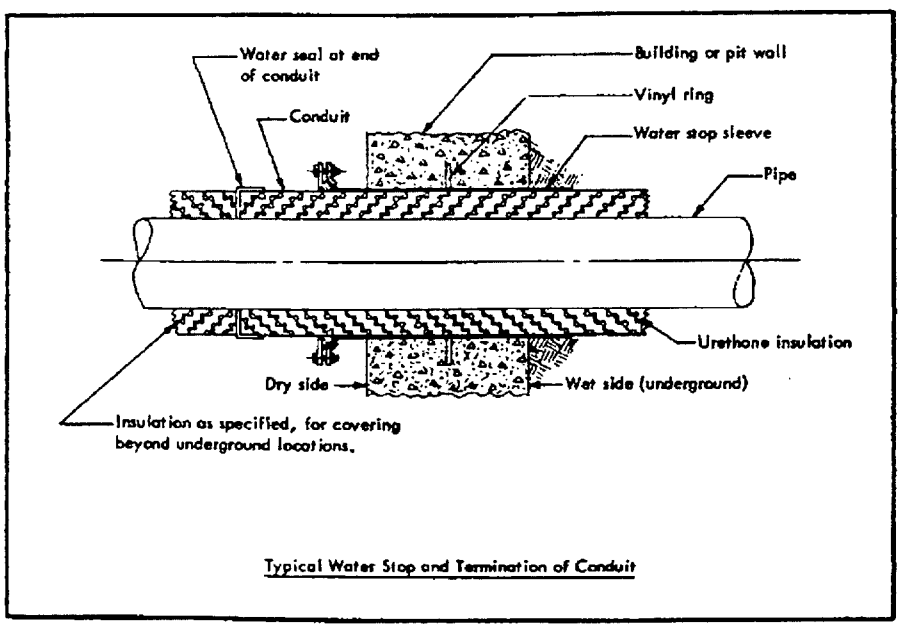
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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE



Typical Underground Pipe Anchor

Figure XXII - 11



Typical Water Stop and Termination of Conduit

Figure XXII-12

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

INSULATED METAL CONDUIT - Contd

Preparation

The trench in which the insulated pipe conduit is to be laid must be in accordance with the drawings. The bottom of the trench should be uniform and smooth.

As the insulated pipe conduit is custom made, it is essential to check to determine that all of the sections and fittings specified are available before the installation is started.

After the lines are welded and tested, all loose paint, dirt, rust, scale, or other extraneous materials should be removed from the exposed ends of the pipe before the insulation and water proofing is installed.

Application

The connections between sections of preinsulated conduit are water sealed in two different ways depending upon the particular conduit obtained from the manufacturer.

Insulation Installation

1. The specified insulation is fitted to the exposed pipe ends which were welded together, shown in Figure XXII-13. The sectional insulation is secured in position by insulation straps and clips. This operation is shown in Figure XXII-14 and XXII-15.

2. The welder positions the cylindrical conduit closure and then seam-welds it to the conduit. This operation is shown in Figure XXII-16.

Water Sealing of Bituminous Covered Conduit

1. All metal surfaces should be covered with a brush coat of water proofing coating - furnished by the manufacturer.

2. The areas between the connection band and the shop coating should be wrapped with impregnated blanket, embedded in the water proofing coating to bring the surface of this equal in height to the connection band.

3. Over the area between the ends of the shop coating in the conduit, cover with the water proofing coating. One side of the impregnated blanket should be covered with the coating, then with coated side of the blanket inward. The blanket should be firmly pressed in position. After blanket has set in place, its entire surface should be covered with the water-proofing coating to obtain a minimum thickness of the field joint of not less than 1/8 inch.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

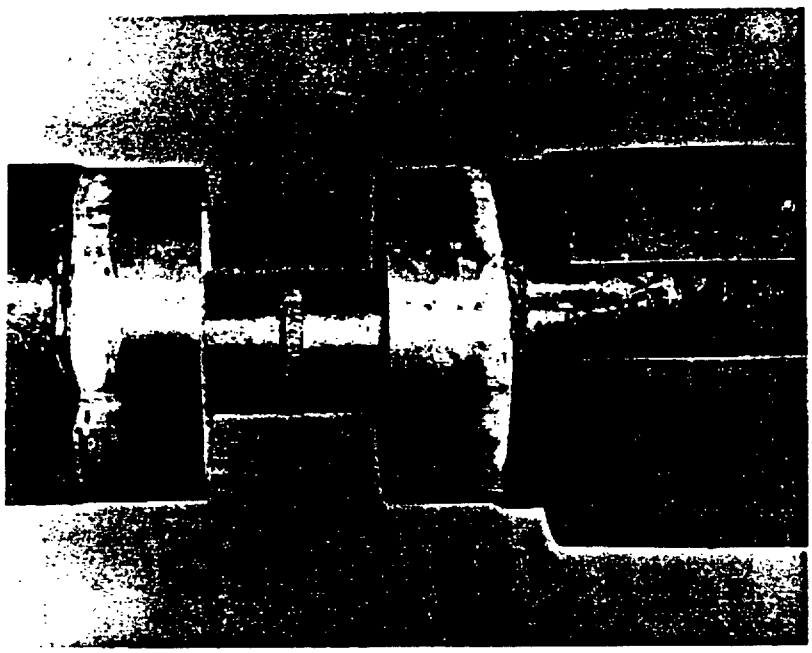


Figure XXII-13

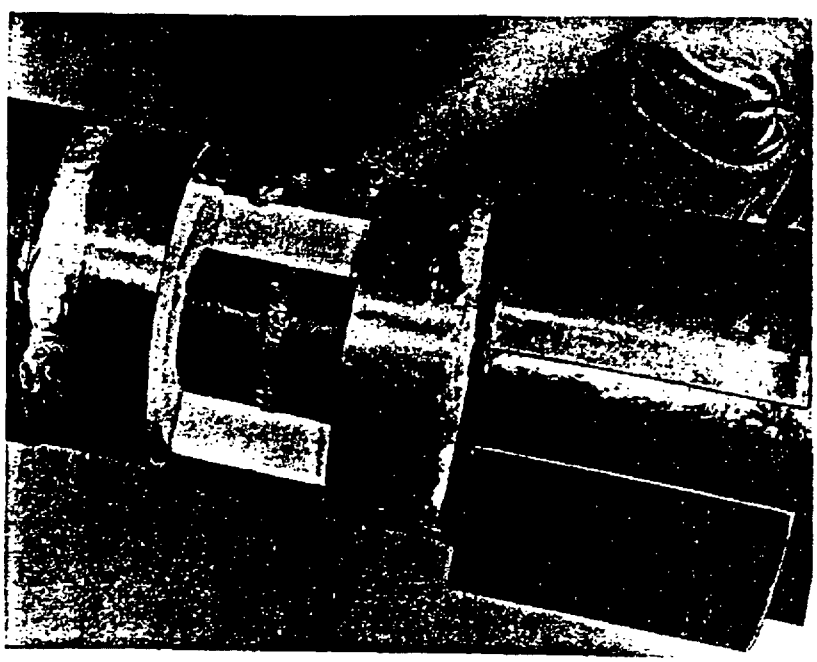


Figure XXII-14

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

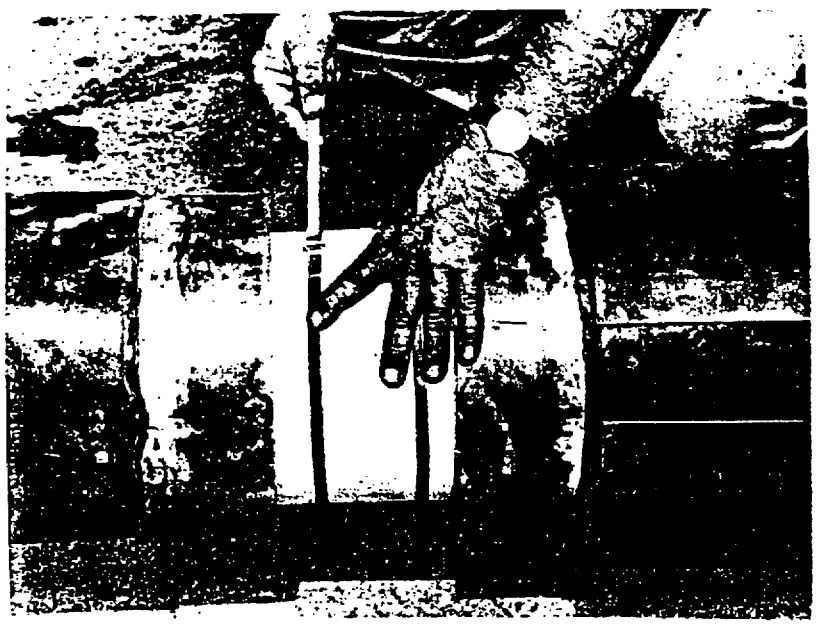


Figure XXII-15

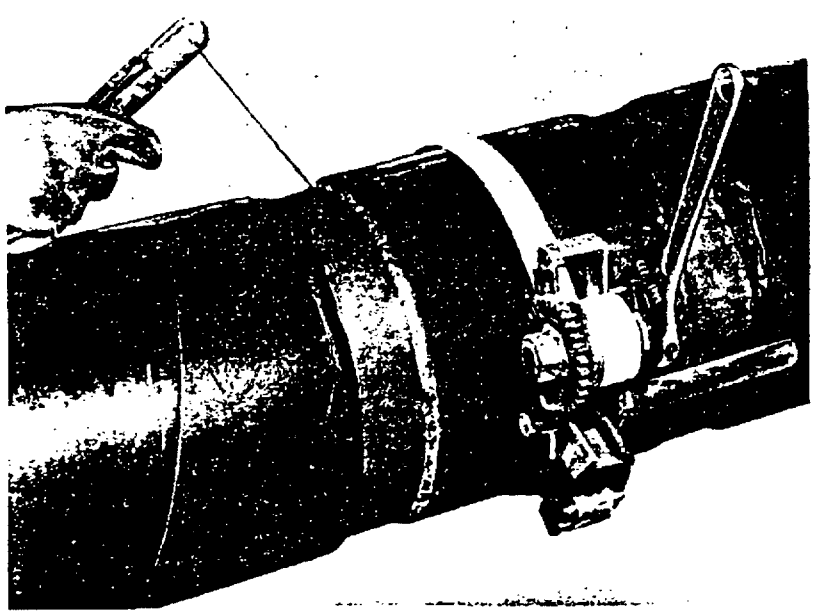


Figure XXII-16

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

INSULATED METAL CONDUIT - Contd

Water Sealing of Bituminous Covered Conduit - Contd

4. Drape the top and sides of these field joints with 15-lb asbestos pipe line felt before backfilling.

Water Sealing of Epoxy Coated Conduit

1. All high spots of welds and burned coating should be removed by grinding or filing. The entire joint surface should then be cleaned with acetone, methyl ethyl ketone, or xylol.

2. The epoxy coatings furnished, for this water and corrosion sealing, are a two-part-mix catalyst type. The contents of the catalyst should be added to the epoxy coating, then stirred for four or five minutes.

3. The mixed coating should be applied to the entire joint area and over the factory-coated conduit. This must be allowed to dry for a minimum of eight hours before proceeding with next coat.

4. The second coat of epoxy should be applied while the first coat is still soft. Two layers of 6-inch-wide glass cloth, overlapping 2 inches on each wrap, should be spiral-wrapped over the joint, and 6 inches over the adjacent factory-applied conduit wrapping. Each layer should be wrapped in opposite directions, and each layer should be brush-coated with the epoxy coating. After thirty minutes, when coating over last layer of glass cloth has set tack-free a final heavy coat of epoxy coating should be applied giving a completely smooth outer surface. Backfilling should not be started before coating is hard.

Note: The curing time of epoxy coatings is affected by temperature and humidity. As temperature goes down, the curing time of the epoxy is increased. Also, when humidity increases, the time of curing is increased. At ambient temperatures of 60F or above, no heat need be applied to accelerate the cure of the epoxy coating. If ambient temperature below 60F is encountered and it is necessary to backfill trenches with a minimum delay, heat may be applied to the joints to accelerate the cure. This may be accomplished by the use of infra-red electric bulbs or radiant heaters. Care must be taken that the coating is not heated above 150F, as temperatures above this will burn or deteriorate the coating.

Trench Backfilling

The backfilling material should be free of rocks and concrete debris. No backfilling should be done on both sides of the conduit simultaneously. The soil should be deposited in uniform layers, not over six inches in thickness and tamped.

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APPLICATION TO UNDERGROUND PIPING
MODERATE AND HIGH TEMPERATURE SERVICE

FILL TYPE INSULATION

This type of insulation is a bituminous fill which is poured and tamped around the pipe in the trench. When heated it fuses around the pipe to form a protective envelope. Proper grade of material, depending upon temperature of pipe, must be used to obtain this fushion.

PREPARATION

The trench must be properly prepared to allow sufficient space for installation of the insulation. The pipe installed in the trench must be supported to allow for sufficient insulation between the bottom of pipe and bottom of trench. Minimum dimension for trench to accommodate various sizes of pipe is shown in Figure XXII-17. Where width of trench is greater than required, a leap-frog form should be constructed for side walls.

Special trenching is required at expansion loops with allowance provided for pipe movement. Dimensions of trenches at loops are given in Figure XXII-18.

Process lines must be completely welded and tested before installation of the fill insulation. Also, all loose paint, rust, dirt, and scale must be removed prior to application of insulation.

All standing water in the trench shall be removed before commencing application.

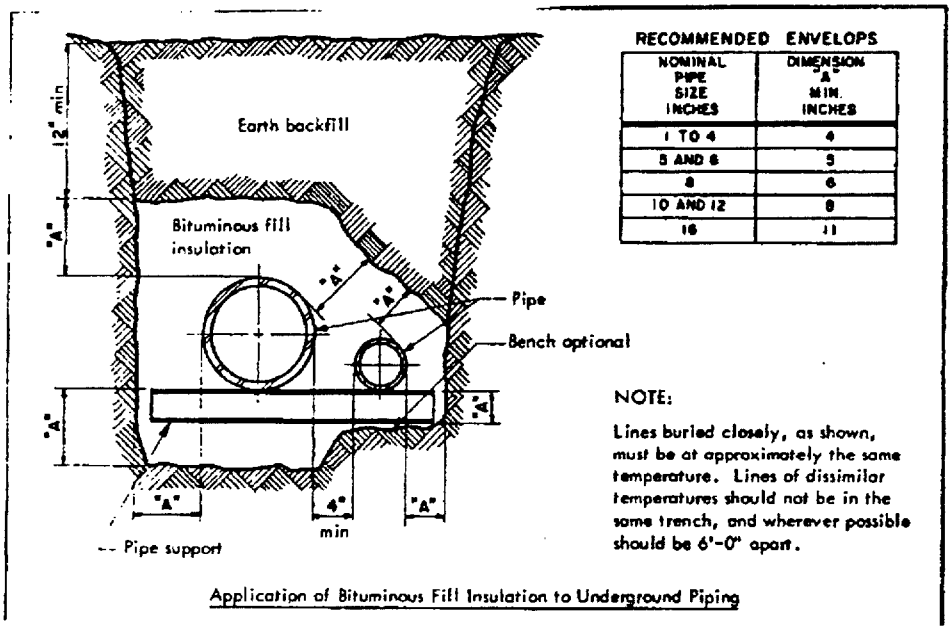
APPLICATION

The fill insulation should be removed from the bags with a minimum of free fall, in order to reduce the dust. Generally it is installed most efficiently by placing unopened bag on the pipe, then slitting it, then carefully pouring the insulation out of the bag around the pipe. The fill insulation shall be installed in successive layers approximately six inches in thickness. Each layer must be thoroughly consolidated by knifing vigorously with a round shovel point or similar tool. Care must be taken to compact the material solidly against the bottom and around sides of pipe. When the top layer has been knifed thoroughly it should be leveled and tamped. Tamping should be done with 8" x 8", 1/4" thick steel plate attached to handle of suitable length. This application may be made in the trench cavity or be in side wall forms.

Where the bituminous fill insulation system emerged above the surface, a transition consisting of a 20 gauge galvanized steel jacket shall be provided for the fill insulation to extend above the ground surface. The junction of the bituminous fill insulation and the above-grade insulation shall be sealed with a weather-barrier coating. This is illustrated in Figure XXII-19.

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APPLICATION TO UNDERGROUND PIPING
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RECOMMENDED ENVELOPS

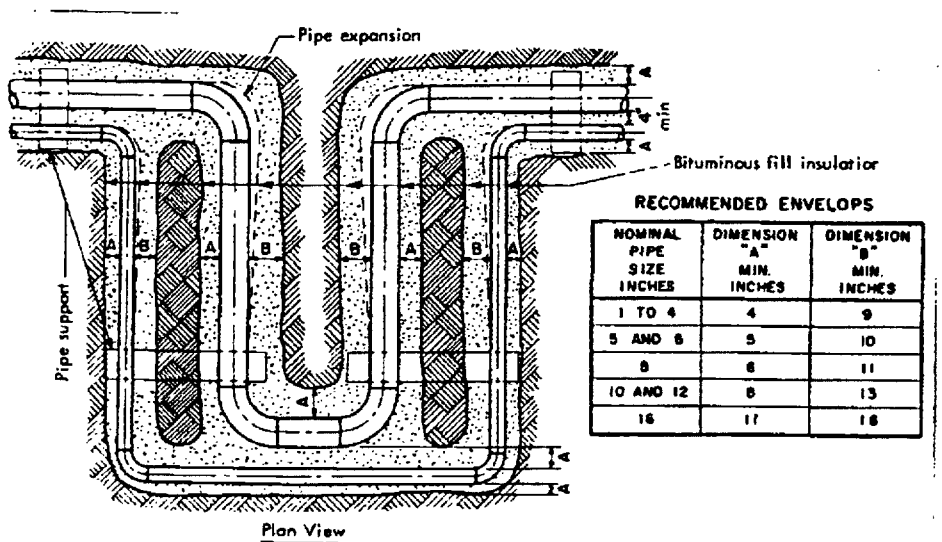
NOMINAL PIPE SIZE INCHES	DIMENSION "A" MIN. INCHES
1 TO 4	4
5 AND 6	5
8	6
10 AND 12	8
16	11

NOTE:

Lines buried closely, as shown, must be at approximately the same temperature. Lines of dissimilar temperatures should not be in the same trench, and wherever possible should be 6'-0" apart.

Application of Bituminous Fill Insulation to Underground Piping

Figure XXII-17



RECOMMENDED ENVELOPS

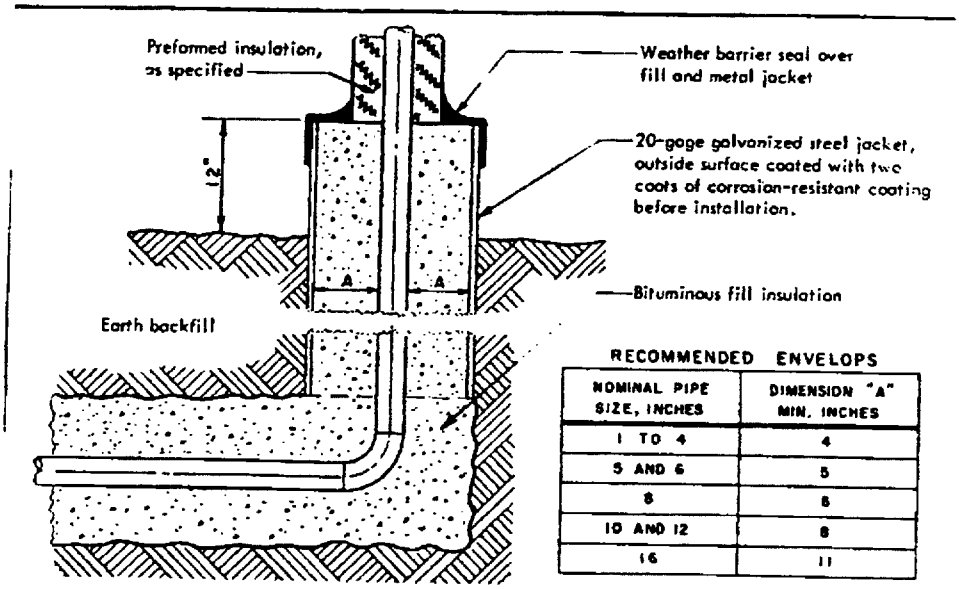
NOMINAL PIPE SIZE INCHES	DIMENSION "A" MIN. INCHES	DIMENSION "B" MIN. INCHES
1 TO 4	4	9
5 AND 6	5	10
8	6	11
10 AND 12	8	13
16	11	18

Application of Bituminous Fill Insulation to Underground Expansion Loops

Figure XXII-18

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APPLICATION TO UNDERGROUND PIPING
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RECOMMENDED ENVELOPS

NOMINAL PIPE SIZE, INCHES	DIMENSION "A" MIN. INCHES
1 TO 4	4
5 AND 6	5
8	8
10 AND 12	8
16	11

Transition and Termination of Bituminous Fill Insulation

Figure XXII-19

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APPLICATION TO UNDERGROUND PIPING MODERATE AND HIGH TEMPERATURE SERVICE

APPLICATION - Contd

Where lines insulated with bituminous fill enter a manhole or building wall, the pipe shall be inserted in a sleeve projecting through the wall. Space between sleeve and pipe must be packed with asbestos rope or lead packing.

When application is completed the insulation must be cured at the temperature and time as specified by the manufacturer.

TRENCH BACKFILLING

The backfilling material should be free of rock or concrete debris. The soil should be compacted in uniform layers not over six inches in thickness and tamped for consolidation. Backfill shall not be less than 12 inches over the top of the bituminous insulation.

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SAFETY AND HEALTH

DEFINITION

The dictionary definition of safety is: The condition of being safe from undergoing or causing hurt, injury or loss.

In this sense safety covers more than just the prevention of personal injuries but also covers prevention of damage to personal health, and prevention of property and production loss.

Safety means the prevention of accidents, the definition of accident being: an accident is an unintentional interruption to an orderly process - a turning aside of an intended procedure.

Thus, safety is the orderly manner to achieve desired results free of loss due to injuries, health, time, or property. To accomplish safety in our complex construction of plants and their operation requires highly intelligent craftsmen.

SAFETY REGULATIONS

City and State Construction Laws and Regulations

The laws and regulations of cities and states governing construction differ in each community, thus it is impossible to present in this chapter any reasonable summary of these laws. However, even though there may be differences, these laws were passed for the protection of the individual and they should be followed.

Recommended safety practices for construction have been set forth in a manual "Manual of Accident Prevention in Construction" by the Associated General Contractors of America, Inc. All Union Carbide Corporation construction personnel or contractors are expected to abide by the practices set forth in this manual.

Company Regulations and Safety Practices

Each plant has developed safety practices for its particular set of conditions. These too were developed for the protection of the individual and it is of extreme importance that each individual abide by these for his own protection and those of his fellow employees.

These following statements are made to further establish the company's safety policy for construction and maintenance craftsmen. The more particular circumstances in which the insulator must take precautions are presented in this chapter.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES

Protection from Falls

To install insulation on equipment, on columns, vessels and pipes at elevations above ground level requires that the applicator work from scaffolding and ladders.

Ladders

Falls from ladders are one of the most common construction accidents. Intelligent use of ladders is necessary to prevent accidents.

Use of Ladders

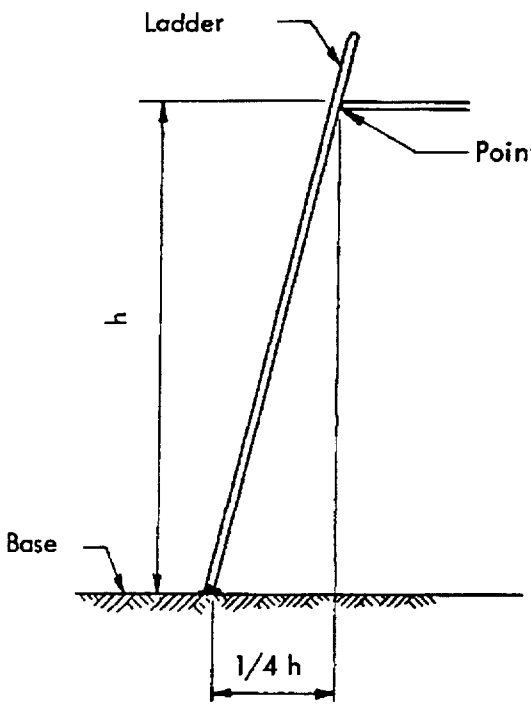
1. The ladder selected for a particular job must be one intended for that use, and in good safe condition.
2. The foot of the ladder should be placed approximately 1/4 of its length from the vertical plane of its top support.
3. Ladder feet should be placed on substantial, level base.
4. Both top and bottom of the ladder must be secured to prevent movement. Securement should be as shown in Figure XXIII-1.
5. Ladders leading to platforms, or walkways, must extend at least 36" above that level.
6. Long ladders must be braced at intermediate points as necessary to prevent spring.
7. Ladders must be climbed or descended properly, by facing the ladder and using both hands to hold onto rungs.
8. Objects should not be carried in hands while climbing or descending a ladder.
9. Metal ladders must not be used around electrical circuits, because if they accidentally come in contact with a "hot" wire they become a conductor of electricity.

Scaffolds

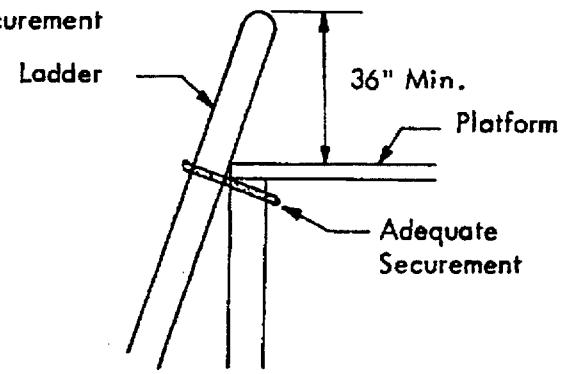
Other than falls, the use of scaffolds has one other potential hazard; that is, objects laid on scaffold boards falling off causing damage or injury.

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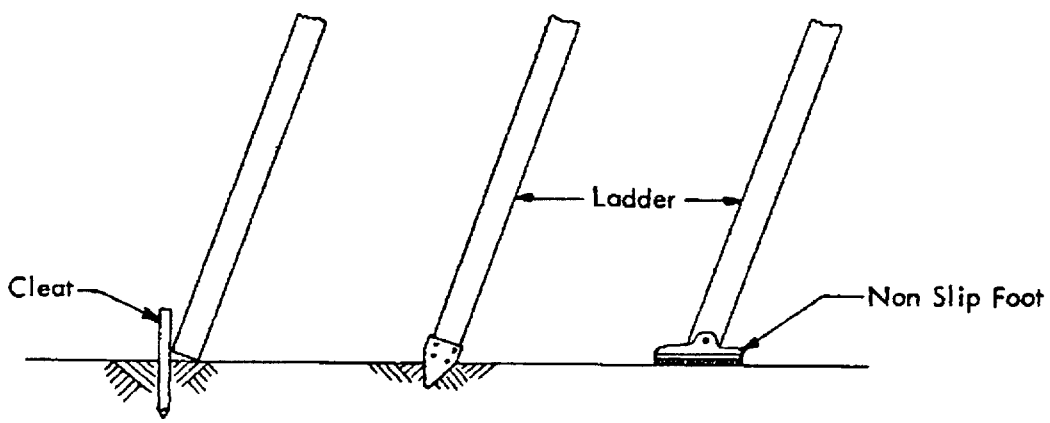
SAFETY AND HEALTH



PROPER LEAN OF LADDER



LADDER - TOP SECUREMENT



LADDER - BOTTOM SECUREMENT

Figure XXIII-1

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Protection from Falls - Contd

Scaffolds - Contd

Although it is not the responsibility of the insulation applicator to build scaffolds, he should make it his responsibility not to work on any scaffold that is unsafe. To help him judge scaffolds the following is presented.

1. The scaffolding must be on firm footing. Footing should be secured against movement by recessing, staking or other means.

2. All uprights must be plumb. For steel scaffolds less than 75 ft. high, 2" diameter tubing is recommended. For scaffolding above this height, 2-1/2" diameter tubing is minimum.

3. Platform of wood planks must be firm and steady. All lap joints should be at ledgers, minimum 6" drop lap on each side of ledger. All planks should be secured by wire and/or nails to provide solid footing and prevent them being blown off by wind.

4. Guardrails and toe boards are recommended.

5. Install overhead danger signs.

Use of Scaffolds

1. Scaffold working platforms should be free of ice, snow, oil, slick dust, or other debris while being used.

2. No open fire should be permitted upon or near wooden scaffolds, or flammable components such as canvas or polyethylene covers.

3. Scaffold structures should be protected from trucks or other vehicles.

4. No materials should be stockpiled on scaffolds.

5. Swing stage scaffolds should be tested with four times the load before being used. All suspension ropes or cables, blocks and sheaves should be frequently inspected. No more than two workmen should be permitted on a swinging scaffold. Workman should be equipped with safety harness with harness snaps attached to "edge" in 1/4" steel rope every 5 ft. which is anchored to a secure overhead attachment.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Protection from Burns

Applicators of insulation must be careful to prevent burns to themselves and others. There are three major hazards contributing to accidental burns; these are: (1) fire, (2) hot surfaces, and (3) chemicals or solvents.

Protection from Burns by Fires

Everyone knows that fire can cause serious burns, and no one attempts to come in contact with fire or flame. The important factor is preventing accidental fires. As this is such a broad and important subject it will be discussed later in this chapter as a separate subject.

Protection from Burns by Hot Surfaces

Many burns are caused by an individual coming into contact with a hot surface.

Our safety requirements state that hot piping or vessels operating at high temperatures shall be insulated 6'0" above grade or operating levels to prevent burns. Unfortunately for the construction and maintenance insulation workers, they must apply insulation at levels where hot pipe or vessels are not insulated. For this reason, no bare pipe or projection should be used for hand support or for climbing until it is determined that it is not too hot. Any blackened copper tube or pipe is most likely hot. Aluminum pipe or aluminum jacketed insulation can be very deceptive. Because of its low emittance, aluminum radiates very little heat, thus gives little warning that the surface is hot. However, where in direct contact, its high conductivity will transmit heat to the skin rapidly, causing severe burns.

Protection from Exposure to Solvents or Chemicals

Many chemicals, such as acids or caustics can cause burns, or be very toxic. Care must be taken not to come into contact with liquids or vapors of unknown chemicals. Take extreme caution in working near a leaky flange, valve and any vent valves. Vent valves are dangerous as they might be discharged unexpectedly.

When removing insulation, do not handle any saturated insulation with unprotected hands unless it has been previously determined that the liquid is nontoxic and nonburning to the skin.

In cases where a person inadvertently does come into contact with chemicals he should immediately wash in a safety shower and use nearest eye bath. Foreign matter in the eye should be flushed out with water. The eye should not be rubbed under any circumstance. As soon as possible report to the Medical Department for a checkup.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Protection from Exposure to Solvents or Chemicals - Contd

Before starting work in a chemical unit, the applicator or his foreman should check with unit head operator to determine location and nature of hazard in that unit. Each insulator must be advised of these hazards. In all cases, when working in areas of toxic chemicals, proper protective clothing, safety glasses and masks must be worn to prevent injuries.

Many materials used such as adhesives, sealers and insulation contain compounds which will burn the skin, are toxic, or cause eye irritation. When these are hand mixed, applied, or sprayed, the first most important step is to read the instructions and warnings on the can or container. These instructions must be followed.

Prevention from Exposure to Excessive Noise

Extended exposure to loud noise can cause reduction in hearing ability. When work must be performed in noisy locations proper ear protection devices as recommended by plant safety group must be worn.

Prevention of Cuts and Electrical Shock

Cuts are most generally caused by the improper use of power tools, hand tools, or from coming into contact with a sharp projection. All insulators must use tools which can cause bad cuts.

Power Tools

Other than cuts, electric power tools may cause an electric shock to the user if a tool is improperly connected or grounded. Most permanently placed electric-driven equipment, properly connected by the electricians, is free of electrical hazard. The major cause of electrical shock is in the use of portable electrically driven equipment in improper condition. Some of the main points to be remembered are:

1. Check Operating Department to be sure that electrical tools are suitable for use in the area. (Hazardous Work Permit)

2. If extension cords are used, make connections at the tool and then toward the power source. An improper connection, or short, then will blow the fuse rather than shock the user.

3. Check frequently for cable insulation breaks, especially at the socket and at the point of attachment to the tool.

4. Make sure that all tools are properly third-wire grounded or are of the double grounded type.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Prevention of Cuts and Electrical Shock - Contd

Power Tools - Contd

5. When electric tools are used in wet areas, an insulated platform and rubber gloves should be used.

Use of Power Tools

Other than cuts, proper precautions from eye injuries must be taken when using power saws, drills or other cutting equipment.

1. Damaged or worn tools should not be used. They must be repaired or replaced before use.
2. Safety equipment, such as guards, must be used.
3. Proper eye protection must be worn.
4. Saw blades must be regularly checked and kept in good condition.
5. Blade used must be as recommended for material being cut.
6. Approved type respirators must be worn when operator is exposed to harmful dust.

Use of Hand Tools

1. The weight, size and type of tool should be selected to fit the job.
2. All cutting tools should be kept sharp, as sharp tools improve accuracy and are safer to use than dull tools.
3. All tools should be protected against damage from corrosion. Keep adjustable parts lubricated to prevent wear and for efficient operation.
4. All tools should be placed in tool holders, or secured in proper manner so that they cannot fall from scaffold.
5. When required, such as when sheet metal is being installed, proper protective gloves must be worn.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Prevention of Cuts and Electrical Shock - Contd

Sharp Projections

1. Care should be taken at all times not to fall, slip, or walk against any projection which can cause injury.

2. Wire, with ends twisted to secure insulation, should have twisted ends bent back and embedded in insulation.

3. Sharp, cut ends of straps, or clips, should be end down and back to prevent sharp projection.

4. Any sharp corners of metal jackets should be rounded off.

4. Sharp edges of metal jackets should either be folded or bent back so as not to be a hazard.

Protection from Eye Injuries

1. Care must be taken to prevent any splashing, drip, or vapor of chemicals coming into contact with the eyes.

2. Care must be taken to prevent particles of solids from getting into the eyes.

3. Approved eye protection must be worn at all times.

Protection from Falling Objects

1. Before entering any construction area observe what hazards may exist overhead. Do not stand or work where there is danger of falling objects.

2. Wear hard hat at all times in plant or construction areas.

3. Remove all loose objects from ledges or scaffold platforms prior to performing work in that area.

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SAFETY AND HEALTH

PROTECTION FROM PERSONAL INJURIES - Contd

Protection from Moving Equipment

1. When necessary to work near or over moving or rotating equipment, it is necessary that when working above this equipment a deck must be provided, and when close to the sides a barricade should be erected.

Protection from High Pressure Spray Equipment

If not handled carefully, any compressed air operated pump or spray gun can be dangerous. Loosened jets or tips can be ejected under pressure, hose or container can be split by pressure, thus thorough knowledge of equipment being used is important. Unfortunately, due to all the types and manufactures of pumps and equipment, it is impossible to give detailed instructions in this manual and only the fundamental precautions can be given.

1. Never exceed the recommended air pressure of the equipment being used.

2. Even though unit is stopped and air to pump is shut off, there still remains dangerous pressure in the system. This pressure must be relieved to prevent accidents while servicing or handling.

3. Handle gun with care. Nozzle velocity is dangerous. At close range the pressure stream CAN PENETRATE THE SKIN TO CAUSE SERIOUS INJURY.

4. Always use extreme care when removing hose from gun. A plugged line contains liquid paint, mastic or chemicals under pressure. Always release pressure in system by closing pump air valve and opening dump valve or spray gun.

5. Precautions for handling gun is given in following chart.

Protection from Compressed Air

1. Hose and equipment must be in good safe condition.

2. Plant air must never be used to clean dust off clothes.

FIRST AID, REPORT OF ACCIDENTS, AND GENERAL POLICY ON EMERGENCY SITUATIONS

It is important to all craftsmen to know what to do in case of an accident or emergency. Each Plant and each Department within a Plant have different rules covering such safety items. The training covering these safety items should be given all employees in General Craft Training. Most Plant Training Programs will include:

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SAFETY AND HEALTH

FIRST AID, REPORT OF ACCIDENTS, AND GENERAL POLICY ON EMERGENCY SITUATIONS - Cont.

1. Emergency reporting procedure using emergency alarm boxes to provide emergency aids such as Fire Protection, First Aid Rescue Squads, Operating Supervision, and Doctors when on duty.
2. Dispensary reporting system for injuries other than emergency.
3. Unsafe working condition reporting system.
4. Job Hazardous Analysis system.
5. First Aid general instructions.

HEALTH PROBLEMS

Health problems can be caused by the materials being produced in the plant (or unit) in which work is being done by the applicator. Likewise, health problems can be caused by the materials (insulation or accessories) being applied by the applicator.

Chemical plants produce liquids and gases which are toxic. For this reason care must be taken in working in a chemical plant not to come into contact with toxic liquids, nor breath toxic fumes. As each unit within a plant is probably different from others within that plant, safety precautions not only differ from plant to plant, but also unit to unit. For this reason the craftsman must become familiar with the safety precautions necessary in each unit where he is working. These safety precautions must be followed.

During application of some insulation materials and accessories the installation itself may be a health hazard unless proper precautions are taken.

PRECAUTIONS IN APPLICATION

Spraying of Urethane Foam Insulation

Where urethane systems are sprayed to produce foam insulation, the fumes and droplets in the surrounding air are toxic and hazardous. When sprayed indoors or a confined area, fresh air masks must be worn. In all cases eyes should be protected by safety glasses.

When mastics or other coatings mixed with toxic solvents are sprayed, safety precautions stated above should be followed.

Various solvents are toxic, so in mixing, spray or brush application, care must be taken. Epoxy compounds are an example of such materials that might cause skin rashes, severe itching, eye irritation and respiratory ailments. Materials of this type must never be used without adequate

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Spraying of Urethane Foam Insulation - Contd

ventilation. Confined fumes and solvent vapors can seriously irritate the eyes, lungs and respiratory tract. Likewise confined fumes may be a fire and explosion hazard. In cases where fumes or solvents come into contact with the skin they should be immediately washed off with soap, water and scrubbing brush.

Protection from Dust Hazards

Dusts of various kinds cause respiratory and lung ailments. In the past few years considerable attention has been given to dust associated with insulation materials. It has been shown that excessive exposure to dust containing asbestos has a detrimental effect. The lungs of workers of excessive exposure to the inhalation of asbestos contain small microscopic size structures composed of fiber coated with layers of protein and iron. This non-malignant lung disease is called asbestosis. The risk of asbestosis can be eliminated by proper protective measures and use of proper breathing equipment.

Safety Practices for Handling and Applying Thermal Insulation Products Containing Asbestos

Pipe and Block Insulation

Warehousing, Storage and Handling

Under normal conditions, the handling, storage and warehousing of undamaged cartons of pipe and block insulations, containing asbestos, present no health safety problems. If cartons are broken or materials damaged while insulation is being handled, the following steps should taken:

1. Care should be taken to avoid generating dust when piling, stacking or placing pieces into containers.

2. If spillage occurs, debris should be cleaned up immediately. Repack usable materials.

3. When cleaning spillage, vacuum equipment is recommended for picking up dust and small particles.

4. If large quantities of spillage occurs and cleaning involves sweeping and/or shoveling that could create excessive airborne dust, the waste should be wet down with water and should this not be possible or dust still occurs, approved breathing equipment should be worn.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Safety Practices for Handling and Applying Thermal Insulation Products Containing Asbestos - Contd

Pipe and Block Insulation - Contd

Warehousing, Storage and Handling - Contd

5. Only usable material should be returned from the job site to the warehouse.

6. When returning material from the job site, clean dust and debris off cartons. Repack odd lot pieces. Close cartons.

Fabrication in Warehouse and Job Site Shops

1. Open and remove the material from cartons with care.

2. Handle and stack pieces of material in a manner that will avoid breakage and generating dust.

3. Mechanical dust collecting systems adequately designed to remove dust at the source should be installed on power-operated, fixed and portable equipment in the warehouse shop and/or in the job site shop.

4. All machines should be furnished with suitable waste containers for the collection of scrap and waste to prevent the material from falling on the floor and generating dust.

5. Shop-fabricated pieces of Thermal Insulation such as fittings, segments, etc., should be placed in containers. Care should be taken when handling these pieces during piling, stacking and packing.

6. Containers should be closed after packing and remain closed until the material is used.

Application Procedures

1. Unpacking and application of the material should be cone in a manner that will minimize airborne dust.

2. Avoid dropping, throwing or unnecessary rough handling of insulation materials.

3. Keep floors and surfaces clean of scrap, shavings and debris. Put unusable material into waste containers immediately.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Safety Practices for Handling and Applying Thermal Insulation Products Containing Asbestos - Contd

Application Procedures - Contd

4. Hand sawing, cutting, jacket stripping, etc. should be done in a manner that will create minimal airborne dust. Use of proper methods and tools will help considerably towards dust abatement.

5. When working in confined spaces, portable dust collectors or exhaust blowers should be provided to remove dust from the source.

6. If conditions prevent collecting or exhausting dust from the source, use exhaust blowers to provide general room air changes.

7. Avoid exhausting into other working areas.

8. In confined spaces, if mechanical exhaust equipment cannot be used, approved breathing equipment should be worn.

9. When wiring or banding insulation and applying jackets or facings, care should be taken to avoid generating excessive dust, using the precautionary measures described above.

10. Surplus usable materials should be placed in cartons, which should be closed and returned to the warehouse.

Cements

Warehousing, Storage and Handling

Handling and storage of closed bags containing cements do not present health safety hazards, provided bags are unopened and not broken.

1. When unloading railroad cars and trucks, if there is excessive loose material resulting from opened or broken bags, respirators should be worn during clean-up and unloading.

2. Spillage should be cleaned up and open or broken bags repacked, resealed or discarded immediately to prevent distribution of dust into other areas.

3. If bags are damaged and spillage occurs in the warehouse, material should be cleaned up immediately to prevent distribution into other areas. Vacuum equipment is recommended for this cleaning.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Cements - Contd

Warehousing, Storage and Handling - Contd

4. If large quantities of spillage occurs and cleaning involves sweeping and/or shoveling that could create excessive dust, respirators should be worn.

Application of Cements

Opening, dumping and discarding of bags should be done with the utmost care to avoid generating excessive dust.

1. Open the bag wide enough to empty without shaking.
2. When dumping, keep bag on the mortar box mixing level to avoid dropping.
3. Do not shake bags.
4. Place empty bags in a container, wet down contents, and discard.
5. Mixing area should be well ventilated, but free from heavy drafts that will cause dry material to become airborne.
6. Material should be mixed in a mortar box, pail or tub and not on the floor.
7. Wet the material and mix into a slurry as quickly as possible.
8. When mixing cement in a confined space where proper ventilation is inadequate, respirators should be worn.

Cleaning

1. Bag breakage, cleaning up dry cement and discarding bags at the mixing area should be handled in the same manner as recommended under Warehousing, Storage and Handling.
2. Wet down tools, mortar boxes, wheelbarrows, mixing containers, and any spillage before scraping and cleaning.
3. Cements should be handled wet whenever possible. Wet material will create no dust problem.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Cements - Contd

Spraying of Thermal Insulation

Spraying Areas

Spraying of Thermal Insulation Products containing asbestos requires special precautionary measures. Refer to the Sprayed Mineral Fiber Manufacturers Association for Sprayed Fiber Application Practices.

1. The equipment and machinery to be sprayed should be shielded by adequate wind breaks and, where practicable, drop cloths to prevent excessive dust and contamination in adjacent areas.

2. Workers not engaged in the spraying operations should wear respirators when entering an area within 15 feet of the spraying machine, nozzle or equipment.

3. Where Sprayed Fiber Application Practices cannot be followed and excessive airborne dust is generated, it is recommended that portable mechanical exhaust ventilation be used to remove airborne dust. Exhaust must be located to avoid contamination of other occupied areas.

Application

1. All personnel in the immediate area engaged in the machine feeding and spraying operation should wear respirators, whether in confined or open areas, ventilated or not ventilated.

2. Respirators should be worn after the spraying operation has been concluded and until the generated dust concentration has cleared.

Other Workmen

All personnel not involved with the machine feeding and spraying operation should be kpet from the spraying area until the generated dust concentration has cleared.

Cleaning

1. Spillage and excess spraying materials should be cleaned up immediately after spraying operations have been completed.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Cements - Contd

Spraying of Thermal Insulation - Contd

Cleaning - Contd

2. Settled dust and fly material should be removed from all surfaces to avoid airborne contamination. Vacuum cleaning is recommended for this purpose.

3. Scrap spray material should be wet down and placed in closed containers for disposal.

4. Tools, ladders, etc. should be cleaned wet.

5. Avoid brushing, sweeping and shoveling dry material whenever possible.

6. Respirators should be worn during clean-up.

Stripping of Thermal Insulation

Stripping Area

Careful work methods, use of proper tools, and wetting down will minimize excessive dusts in stripping operations.

1. The area in whichstripping takes place should be confined by means of curtains, portable partitions, etc., to prevent excessive dust contamination in adjacent areas.

2. If area cannot be confined, only workmen engaged in stripping should be permitted in the work location.

Stripping and Tearing Off

1. All personnel in the stripping area engaged in tearing off, handling, cleaning and disposing of material should wear respirators.

2. Where circumstances permit, materials should be wetted down prior to and during removal.

3. Where applicable, portable mechanical exhaust ventilation should be used to remove airborne dust.

4. Avoid unnecessary re-handling of scrap.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Cements - Contd

Stripping of Thermal Insulation - Contd

Stripping and Tearing Off - Contd

5. Locate truck, "Dumpster" bucket or final disposal equipment as close to stripping site as possible.

6. Wet down scrap material before shoveling, hauling or dumping.

7. Do not permit accumulation of scrap and debris on floor and other surfaces.

8. Vacuum equipment is recommended for cleaning up during and after stripping.

Other Workmen

1. Personnel not involved in the stripping and tearing off operation should not be permitted in the stripping area.

2. If it is essential for other workmen to be in the work area, respirators should be worn by them.

Safety Practices for Handling and Applying Thermal Insulation Products Containing Mineral Fibers

Tests indicate that mineral fibers can cause respiratory difficulties and skin irritation. For this reason they should also be handled in a manner not to generate dust. Listed below are the protective measures to follow when these materials are used.

Housekeeping

An organized housekeeping program should be maintained in all areas and on all operations at all times.

A major source of excessive airborne dust is from loose materials, scrap, and debris distributed throughout the job area and disintegrated by trampling on, running over, etc. Much of the airborne contamination can be eliminated by exercising simple good housekeeping practices.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Safety Practices for Handling and Applying Thermal Insulation Products Containing Mineral Fibers - Contd

Housekeeping - Contd

Specific standards and practices designed for providing safe, clean and orderly working conditions should be defined.

Efficient supervisory control, planning of systematic cleaning plus day to day follow-up are the basic requirements for dust control and health protection.

Physical Contact with Mineral Fibers

1. If particles accumulate on exposed skin areas, do not rub or scratch. Remove the particles by washing thoroughly with soap and warm water. If water is not available, use dry wash materials (waterless soap and paper towels).

2. Long-sleeve shirts, long trousers and caps should be worn to cover maximum skin areas to avoid contact with the mineral fibers. Clothing should be loose fitting at collars, wrist bands and waist bands and waist to eliminate skin irritation.

3. Barrier creams applied to exposed skin areas will provide protection against skin irritation. They should be used prior to handling the material and applied according to instructions.

4. Good personal hygiene practices are essential. Thoroughly wash exposed skin areas periodically and shower at end of the work day. Change and launder work clothing frequently, separately from other articles.

5. Proper work methods and practices that will eliminate the creation of excessive dust should be adhered to at all times.

6. Suitable gloves should be worn when handling abrasive materials.

7. Mineral fiber slivers that superficially penetrate the skin should be removed by thorough washing. Those embedded in the skin should be removed immediately and medical treatment administered.

8. Safety glasses, goggles or face shields should be worn when applying materials overhead, or in areas where airborne particles may get into the eyes.

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SAFETY AND HEALTH

PRECAUTIONS IN APPLICATION - Contd

Safety Practices for Handling and Applying Thermal Insulation Products Containing Mineral Fibers - Contd

Exposure to Excessive Mineral Fiber Dusts

1. When mineral fiber materials are machine sawed, die cut, slit, etc., mechanical dust collecting systems adequately designed to remove dust at the source should be installed.

2. Hand cutting, jacket stripping, etc., should be done in a manner that will create minimal airborne dust. Proper methods and tools will help considerably to abate dust.

3. When working in confined spaces, dust collecting systems adequately designed should be provided to remove dust from the source. If conditions prevent collecting dust, use exhaust blowers to provide general room air changes. Avoid exhausting into other work areas. If mechanical exhaust equipment cannot be used to remove excessive dusts, respirators should be worn.

4. When applying mineral fiber insulation overhead, workers should be clothed as described under "Physical Contact with Mineral Fibers", wear eye protection and respirators if excessive dust is generated.

5. When mineral fiber thermal insulations are stripped from piping or other surfaces, the area in which stripping takes place should be confined by means of curtains, portable partitions, etc., to prevent excessive dust concentrations in adjacent areas. All workers in the stripping area engaged in tearing off, handling, cleaning and disposing of material should be clothed as described under "Physical Contact with Mineral Fibers", wear eye protection and respirators.

   Where circumstances permit, materials should be wetted down prior to and during removal. Where applicable, portable mechanical exhaust ventilation should be used to remove airborne dusts from the area.

6. Avoid unnecessary rehandling of scrap by locating disposal equipment as close to working area as possible. Do not permit accumulation of scrap and debris on floor and other surfaces.

FIRES AND EXPLOSION HAZARDS

Similar to other hazards previously mentioned, the hazard of fire and explosion involving insulation may be during the period of installation, or possibly after the installation is completed. In the first instance, the preventing fires or explosions during the time of application can generally

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SAFETY AND HEALTH

FIRES AND EXPLOSION HAZARDS - Contd

be controlled by safe installation practices. All plant safety regulations must be followed, such as wearing of hard hats, safety glasses and no smoking. Fires caused by coatings or insulations after installation may be the fault of incorrect design, or selection of materials over which the applicator has no control. However, when an applicator substitutes a material from that specified, he may, without knowing it, be the cause of a fire or explosion.

Safety Practices to Prevent Fires and Explosions During Application

Welding

Whenever welding is required, such as for the attachment of securement pins, when in an operating plant a hazardous work permit must be obtained and all precautions taken as required by the plant. The following are some of the fundamental safe practices which should be followed:

1. Frame of all welding machines should be grounded.
2. Remove all loose combustible materials from area of welding.
3. Remove all volatile materials such as solvents or paint from area of welding.
4. Wet down any combustible material with water and have standby water hose.
5. Shield all wood scaffold planking with asbestos felt or metal.
6. Provide metal bucket for disposal of hot electrode stubs.
7. Wear proper protective clothing such as eye shields, flame-resistant gauntlet gloves, flame-resistant aprons and caps.

Handling and Application of Combustible Coatings and Solvents

Coatings and solvents should be carefully handled to prevent damage to the cans and their identification. Care should be exercised to prevent contamination. All drums should be grounded in accordance with Standard EL-64, to make them safe from static build-up when material is poured from drum into smaller containers. Adequate fire extinguishing equipment should be provided at storage locations.

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SAFETY AND HEALTH

FIRES AND EXPLOSION HAZARDS - Contd

Handling and Application of Combustible Coatings and Solvents - Contd

When any combustible insulation, coating, sealer or adhesive is used, care must be taken that none is installed or spilled on hot surfaces which might cause ignition. Particular care must be used in the installation of materials in units, pipes, or vessels already in operation.

Fire and Explosion Hazards of Insulations and Coatings in Service

Chemical leakage and atmospheric contamination may be absorbed by many insulations. Insulation saturated by chemicals can be a hazard in two ways: One, due to the large amount of liquid it can absorb, saturated insulation is capable of holding up to five times its own weight of a liquid. With the amount of insulation used on vessels and pipes it thus, when saturated with a combustible, can provide large quantities of fuel for a fire, and be responsible for fire spread. Two, many chemicals react (such as oxide) in the presence of insulation to cause fires, or their flash point and flame point temperature is so reduced by the chemical contamination that they are easily ignited.

In one year the Process Safety Department, in one plant, reported 35 fires caused by flammable chemicals in insulation. This resulted in initiating tests to determine self-ignition of chemicals in contact with insulation. From this program certain guidelines for the use of insulation been developed.

1. Vessels and pipe containing ethylene oxide should be insulated with expanded silica insulation. For ordinary temperature control Spec. 22-H, or where longer term fire protection is necessary 32-HFP, should be used.

2. Acetylene lines and vessels operating above ambient temperature should be insulated with expanded silica insulation Spec. 32 HFP, and below ambient temperature should be insulated with a combination of inner layer (or layers of cellular glass and outer layer of expanded silica in accordance with Spec. 32 LFP.

3. No copper wire or tracing are to be used where there is acetylene or acetone present.

4. Combustible insulations, such as urethane, should never be installed on reactive or toxic service vessels or lines. (See attached recommendation from Fire Protection Department.)

5. When urethane insulation is used on any vessels or lines containing combustibles, all safety devices or spray protection must be calculated as for a base (uninsulated) vessel or pipe.

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SAFETY AND HEALTH

FIRES AND EXPLOSION HAZARDS - Contd

Fire and Explosion Hazards of Insulations and Coatings in Service - Contd

6. Because of water channeling and other problems, any vessel insulated with urethane insulation requires special placement of spray heads.

7. Urethane insulation should only be used in accordance with fire protection regulations that follow.

In addition to the insulation the weather-barrier may be a potential fire hazard. If the weather-barrier is of mastic it may be of a material which reacts with other chemicals, or it may not resist chemical attack, allowing the chemical to saturate the insulation. In addition, any mastic which has high surface burning rate can spread fire.

Aluminum jacketing melts very rapidly in a fire, thus will not protect insulation from direct fire exposure. As the hot molten metal drips, it can be a secondary ignition source for combustibles which may be below.

Treated steel and stainless steel jackets and fire-resistant mastic have been found to be the most satisfactory of weather-barriers. However, treated steel jacket should never be used on Ethylene Oxide lines because iron oxide reduces the self-ignition temperature of the material.

Hot surfaces may cause the ignition of chemicals from pressure relief valves or leaks. Where such hazards exist, it is of utmost importance that all surfaces which might be so contaminated be insulated so as to have a safe surface temperature. This necessitates that the correct thickness of insulation and the correct weather-barrier be used. In such applications the installation of aluminum jacketing can be very dangerous as it will raise the surface temperature on the insulation on hot lines or vessels 75°F to 125°F.

PREVENTION OF POTENTIAL FIRES BY USE OF LEAK INDICATORS

Leaks of certain chemicals from flanges are very hazardous, particularly where these are hidden and can be absorbed by the insulation. These chemicals require that a leak indicator be installed around the flanges before the insulation is installed. At present leak detectors are to be installed in accordance with IC4 Piping Specification. When insulation is installed care must be taken to prevent any insulation getting into the tube.

A Piping Standard is being developed and will be issued at a later date to cover in more detail the fabrication and installation of these indicators.

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SAFETY AND HEALTH

FIRE PROTECTION RECOMMENDATIONS

FOR USE OF RIGID POLYURETHANE INSULATION

The following recommendations are intended as a guide from a fire protection standpoint, for the use of self-extinguishing type rigid polyurethane foam insulation on chemical processing and storage equipment. Each case should be engineered separately as there are "gray areas" between each of the definitions shown. 11/6/67 - The self-extinguishing type is no longer required on outdoor piping only.

SERVICE OR USE	FIRE RETARDANT OUTER COVER (Weather-Barrier)	NONCOMBUSTIBLE OUTER LAYER INSUL. (Min. 1" Thick)	WATER SPRAY PROTECTION	OTHER
Ethylene Oxide, Acetylene, Peracetic Acid, and Other Unstables	Required	Required	Required	Full 0.24 gpm/ft^2 Standard Water Water Spray Application rate.
LPG, Olefins Plants, etc.	Required	Not Required	Required	No allowance for insulation in SV sizing. Full .24 gpm/ft with reduced allowance for rundown, requiring additional spray nozzles.
Stable (Ordinary) Flammables	Required	Not Required	Not Required	No allowance for insulation SV sizing. Water spray ordinarilyp not required. However, if needed, use full .24 gpm/ft^2 and additional spray nozzles as for LPG and Olefins Plants
Aluminum Lines and Equipment with Stable Flammables	Required	Required (1-1/2" When LPG)	Not Required	
Aluminum Lines and Equipment with Unstable Flammables	Required	No Polyurethane. Full Fire Resistive Insulation Required.	Required	Full .24 gpm/ft^2 water spray application rate.

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SAFETY AND HEALTH

MAINTENANCE OF INSULATION

In addition to safety practices already recommended, there are two additional recommendations which should be followed.

1. In repair or replacement of insulation installed on vessels or lines containing combustible and reactive chemicals, the Engineering Standard Specification recommendation was developed for safe installation and operation. If deviation from the standard or substitution of materials is felt desirable, the proper engineering representative responsible for insulation should be consulted before such deviation or substitution is made.

2. Weather-barriers should be kept in excellent repair, not only to keep insulation efficient, but also to prevent entry of toxic fumes or flammables into the insulation, the result of which may be quite hazardous.

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SAFETY AND HEALTH

LIST OF REACTIVE CHEMICALS

Acetaldehyde
Acetaldehyde monoperacetate
Acetaldol
Acetic anhydride
Acetone
Acetyl chloride
Acetylene
Acrolein
Acrolein dimer
Acrylic acid
Acrylonitrile
Allyl chloride
Aluminum chloride
Amyl aldehydes, primary
Antimony trichloride
Bis(2-cyclopentenyl) ether
Boron trifluoride ethyl etherate
1,3-Butadiene
Butadiene peroxide
Butyl acrylate
1,2-Butylene oxide
Butyl peroxide
Butyraldehyde
Butyric anhydride
Calcium carbide
Calcium hexammoniate
Calcium hypochlorite
Calcium metal
Calcium oxide
3-Chloropropionaldehyde
Chlorosulfonic acid
Chlorotrifluoroethylene
Copper acetylide
Crotonaldehyde, 91%
Croton oil
Crotylidene dicrotonate
Cyclopentadiene
Cyclopentadiene
Cyclopentenyl chloride
Decyl acrylate, primary
Diacetylene

Diacetyl peroxide
Dibenzoyl peroxide
Dibutyl fumarate
Dibutyl maleate
2,3-Dichloropropionaldehyde
Dicyclopentadiene, 92%
Diethyl acetal
Di(2-ethylhexyl)fumarate
Di(2-ethylhexyl)maleate
Diethyl maleate
Diethyl sulfate
Dihexyl maleate
2,4-Dihydroxy-3,3-dimethylbutyronitrile
Diisobutylaluminum chloride
Diisopropyl maleate
Diisopropyl peroxydicarbonate
Diketene
Dilauroyl peroxide
Di(methylamyl)maleate
Di(methyl CELLOSOLVE) maleate
Dimethyl maleate
Dipropionyl peroxide
Dipropyl peroxide
Di(tert-butyl) peroxide
Dripolene "C"
Epichlorohydrin
2-Ethyoxy-3,4-dihydro-2H-pyran
3-Ethyoxypropionaldehyde
Ethyl acetoacetate
Ethyl acrylate
2-Ethylbutyl acrylate
Ethylene cyanohydrin
Ethylene oxide
2-Ethylhexyl acrylate
Ethyl 1-propenyl ether
2-(5-Ethylpyrid-2-yl)ethyl acrylate
Formaldehyde
Glutaraldehyde, 25% in water
Glycidyl acrylate
Glyoxal, 30% in water
2,4-Hexadienal

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SAFETY AND HEALTH

LIST OF REACTIVE CHEMICALS - Contd

Hexaldehyde
Hydrazine
Hydrogen cyanide, 96%
Hydrogen fluoride
Hydrogen peroxide
N-(2-Hydroxyethyl)ethylenimine
a-Hydroxyadipaldehyde, 25% in water
Isobutyraldehyde
Isoprene
Isopropyl peroxide
Isopropyl sulfate
Ketene
Maleic anhydride
Methacrolein
3-Methoxybutyraldehyde
Methylacetylene
Methyl acrylate
2-Methylbutyraldehyde
Methyl isocyanate
Methyl isopropenyl ketone
Methyl methacrylate
2-Methylpentaldehyde
Nickel carbonyl
Nitric acid
Paraldehyde
4-Pentenal
Peracetic acid
Peracetic acid (25% in ethyl acetate)
Perchloride acid
2-Phenoxyethyl methacrylate
Phosgene
Phosphorous oxychloride
POLYOX catalyst
Potassium hydroxide
Potassium persulfate
Potassium sorbate
Propadiene
Propionaldehyde
Propylene oxide
Pyruvic aldehyde, 40% in water
Silicon tetrachloride
Silver acetylide
Sodium aryl(2-methacryloxyethoxy)benzene sulfonate
Sodium crotonate
Sodium hydroxide
Sodium metal
Sodium methylate
Sodium sorbate
Styrene
Styrene oxide
Sulfuric acid
Tetraisopropyl titanate
Tolylene diisocyanate
Tridecyl aldehyde (mixed isomers)
Triisobutylaluminum
Valeraldehyde
Vinyl acetate
Vinyl butoxyethyl ether
Vinyl butyl ether
Vinyl S-butylmercaptoethyl ether
Vinyl butyrate
Vinyl chloride
Vinyl 2-chloroethyl ether
Vinyl cyclohexene monoxide
Vinyl ethyl CARBITOL
Vinyl ethyl ether
Vinyl 2-ethylhexanoate
Vinyl 2-ethylhexyl ether
Vinyl S-ethylmercaptoethyl ether
Vinylidene chloride, 1% phenol and 3.2% acetone
Vinylidene chloride monomer
Vinyl isobutyl ether
Vinyl isopropyl ether
Vinyl methoxyethyl ether
Vinyl methyl ether
Vinyl propionate
Vinyl 2,6,8-trimethyl-4-nonyl ether

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APPENDIX

TEMPERATURE AND HEAT

TEMPERATURE CONVERSION TABLE

FAHRENHEIT SCALE LISTED IN EVEN NUMBERS

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
0	-273.2	-459.7	0
0.4	-272.8	-459	0.7
1.0	-272.2	-458	1.7
1.5	-271.7	-457	2.7
2.1	-271.1	-456	3.7
2.6	-270.6	-455	4.7
3.2	-270.0	-454	5.7
3.8	-269.4	-453	6.7
4.3	-268.9	-452	7.7
4.9	-268.3	-451	8.7
5.4	-267.8	-450	9.7
6.0	-267.2	-449	10.7
6.5	-266.7	-448	11.7
7.1	-266.1	-447	12.7
7.6	-265.6	-446	13.7
8.2	-265.0	-445	14.7
8.8	-264.4	-444	15.7
9.3	-263.9	-443	16.7
9.9	-263.3	-442	17.7
10.4	-262.8	-441	18.7
11.0	-262.2	-440	19.7
11.5	-261.7	-439	20.7
12.1	-261.1	-438	21.7
12.6	-260.6	-437	22.7
13.2	-260.0	-436	23.7
13.8	-259.4	-435	24.7
14.3	-258.9	-434	25.7
14.9	-258.3	-433	26.7
15.4	-257.8	-432	27.7
16.0	-257.2	-431	28.7
16.5	-256.7	-430	29.7
17.1	-256.1	-429	30.7
17.6	-255.6	-428	31.7
18.2	-255.0	-427	32.7
18.8	-254.4	-426	33.7
19.3	-253.9	-425	34.7
19.9	-253.3	-424	35.7
20.4	-252.8	-423	36.7
21.0	-252.2	-422	37.7
21.5	-251.7	-421	38.7
22.1	-251.1	-420	39.7
22.6	-250.6	-419	40.7
23.2	-250.0	-418	41.7
23.8	-249.4	-417	42.7
24.3	-248.9	-416	43.7
24.9	-248.3	-415	44.7
25.4	-247.8	-414	45.7
26.0	-247.2	-413	46.7
26.5	-246.7	-412	47.7
27.1	-246.1	-411	48.7
27.6	-245.6	-410	49.7
28.2	-245.0	-409	50.7
28.8	-244.4	-408	51.7
29.3	-243.9	-407	52.7
29.9	-243.3	-406	53.7
30.4	-242.8	-405	54.7
31.0	-242.2	-404	55.7
31.5	-241.7	-403	56.7
32.1	-241.1	-402	57.7
32.6	-240.6	-401	58.7
33.2	-240.0	-400	59.7
33.8	-239.4	-399	60.7
34.3	-238.9	-398	61.7
34.9	-238.3	-397	62.7
35.4	-237.8	-396	63.7
36.0	-237.2	-395	64.7
36.5	-236.7	-394	65.7
37.1	-236.1	-393	66.7
37.6	-235.6	-392	67.7
38.2	-235.0	-391	68.7
38.8	-234.4	-390	69.7
39.3	-233.9	-389	70.7
39.9	-233.3	-388	71.7
40.4	-232.8	-387	72.7
41.0	-232.2	-386	73.7
41.5	-231.7	-385	74.7
42.1	-231.1	-384	75.7
42.6	-230.6	-383	76.7
43.2	-230.0	-382	77.7
43.8	-229.4	-381	78.7
44.3	-228.9	-380	79.7
44.9	-228.3	-379	80.7
45.4	-227.8	-378	81.7
46.0	-227.2	-377	82.7
46.5	-226.7	-376	83.7
47.1	-226.1	-375	84.7
47.6	-225.6	-374	85.7
48.2	-225.0	-373	86.7
48.8	-224.4	-372	87.7
49.3	-223.9	-371	88.7
49.9	-223.3	-370	89.7
50.4	-222.8	-369	90.7
51.0	-222.2	-368	91.7
51.5	-221.7	-367	92.7
52.1	-221.1	-366	93.7
52.6	-220.6	-365	94.7
53.2	-220.0	-364	95.7
53.8	-219.4	-363	96.7
54.3	-218.9	-362	97.7
54.9	-218.3	-361	98.7
55.4	-217.8	-360	99.7
56.0	-217.2	-359	100.7
56.5	-216.7	-358	101.7
57.1	-216.1	-357	102.7
57.6	-215.6	-356	103.7
58.2	-215.0	-355	104.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
58.8	-214.4	-354	105.7
59.3	-213.9	-353	106.7
59.9	-213.3	-352	107.7
60.4	-212.8	-351	108.7
61.0	-212.2	-350	109.7
61.5	-211.7	-349	110.7
62.1	-211.1	-348	111.7
62.6	-210.6	-347	112.7
63.2	-210.0	-346	113.7
63.8	-209.4	-345	114.7
64.3	-208.9	-344	115.7
64.9	-208.3	-343	116.7
65.4	-207.8	-342	117.7
66.0	-207.2	-341	118.7
66.5	-206.7	-340	119.7
67.1	-206.1	-339	120.7
67.6	-205.6	-338	121.7
68.2	-205.0	-337	122.7
68.8	-204.4	-336	123.7
69.3	-203.9	-335	124.7
69.9	-203.3	-334	125.7
70.4	-202.8	-333	126.7
71.0	-202.2	-332	127.7
71.5	-201.7	-331	128.7
72.1	-201.1	-330	129.7
72.6	-200.6	-329	130.7
73.2	-200.0	-328	131.7
73.8	-199.4	-327	132.7
74.3	-198.9	-326	133.7
74.9	-198.3	-325	134.7
75.4	-197.8	-324	135.7
76.0	-197.2	-323	136.7
76.5	-196.7	-322	137.7
77.1	-196.1	-321	138.7
77.6	-195.6	-320	139.7
78.2	-195.0	-319	140.7
78.8	-194.4	-318	141.7
79.3	-193.9	-317	142.7
79.9	-193.3	-316	143.7
80.4	-192.8	-315	144.7
81.0	-192.2	-314	145.7
81.5	-191.7	-313	146.7
82.1	-191.1	-312	147.7
82.6	-190.6	-311	148.7
83.2	-190.0	-310	149.7
83.8	-189.4	-309	150.7
84.3	-188.9	-308	151.7
84.9	-188.3	-307	152.7
85.4	-187.8	-306	153.7
86.0	-187.2	-305	154.7
86.5	-186.7	-304	155.7
87.1	-186.1	-303	156.7
87.6	-185.6	-302	157.7
88.2	-185.0	-301	158.7
88.8	-184.4	-300	159.7
89.3	-183.9	-299	160.7
89.9	-183.3	-298	161.7
90.4	-182.8	-297	162.7
91.0	-182.2	-296	163.7
91.5	-181.7	-295	164.7
92.1	-181.1	-294	165.7
92.6	-180.6	-293	166.7
93.2	-180.0	-292	167.7
93.8	-179.4	-291	168.7
94.3	-178.9	-290	169.7
94.9	-178.3	-289	170.7
95.4	-177.8	-288	171.7
96.0	-177.2	-287	172.7
96.5	-176.7	-286	173.7
97.1	-176.1	-285	174.7
97.6	-175.6	-284	175.7
98.2	-175.0	-283	176.7
98.8	-174.4	-282	177.7
99.3	-173.9	-281	178.7
99.9	-173.3	-280	179.7
100.4	-172.8	-279	180.7
101.0	-172.2	-278	181.7
101.5	-171.7	-277	182.7
102.1	-171.1	-276	183.7
102.6	-170.6	-275	184.7
103.2	-170.0	-274	185.7
103.8	-169.4	-273	186.7
104.3	-168.9	-272	187.7
104.9	-168.3	-271	188.7
105.4	-167.8	-270	189.7
106.0	-167.2	-269	190.7
106.5	-166.7	-268	191.7
107.1	-166.1	-267	192.7
107.6	-165.6	-266	193.7
108.2	-165.0	-265	194.7
108.8	-164.4	-264	195.7
109.3	-163.9	-263	196.7
109.9	-163.3	-262	197.7
110.4	-162.8	-261	198.7
111.0	-162.2	-260	199.7
111.5	-161.7	-259	200.7
112.1	-161.1	-258	201.7
112.6	-160.6	-257	202.7
113.2	-160.0	-256	203.7
113.8	-159.4	-255	204.7
114.3	-158.9	-254	205.7
114.9	-158.3	-253	206.7
115.4	-157.8	-252	207.7
116.0	-157.2	-251	208.7
116.5	-156.7	-250	209.7
117.1	-156.1	-249	210.7
117.6	-155.6	-248	211.7
118.2	-155.0	-247	212.7
118.8	-154.4	-246	213.7
119.3	-153.9	-245	214.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
119.9	-153.3	-244	215.7
120.4	-152.8	-243	216.7
121.0	-152.2	-242	217.7
121.5	-151.7	-241	218.7
122.1	-151.1	-240	219.7
122.6	-150.6	-239	220.7
123.2	-150.0	-238	221.7
123.8	-149.4	-237	222.7
124.3	-148.9	-236	223.7
124.9	-148.3	-235	224.7
125.4	-147.8	-234	225.7
126.0	-147.2	-233	226.7
126.5	-146.7	-232	227.7
127.1	-146.1	-231	228.7
127.6	-145.6	-230	229.7
128.2	-145.0	-229	230.7
128.8	-144.4	-228	231.7
129.3	-143.9	-227	232.7
129.9	-143.3	-226	233.7
130.4	-142.8	-225	234.7
131.0	-142.2	-224	235.7
131.5	-141.7	-223	236.7
132.1	-141.1	-222	237.7
132.6	-140.6	-221	238.7
133.2	-140.0	-220	239.7
133.8	-139.4	-219	240.7
134.3	-138.9	-218	241.7
134.9	-138.3	-217	242.7
135.4	-137.8	-216	243.7
136.0	-137.2	-215	244.7
136.5	-136.7	-214	245.7
137.1	-136.1	-213	246.7
137.6	-135.6	-212	247.7
138.2	-135.0	-211	248.7
138.8	-134.4	-210	249.7
139.3	-133.9	-209	250.7
139.9	-133.3	-208	251.7
140.4	-132.8	-207	252.7
141.0	-132.2	-206	253.7
141.5	-131.7	-205	254.7
142.1	-131.1	-204	255.7
142.6	-130.6	-203	256.7
143.2	-130.0	-202	257.7
143.8	-129.4	-201	258.7
144.3	-128.9	-200	259.7
144.9	-128.3	-199	260.7
145.4	-127.8	-198	261.7
146.0	-127.2	-197	262.7
146.5	-126.7	-196	263.7
147.1	-126.1	-195	264.7
147.6	-125.6	-194	265.7
148.2	-125.0	-193	266.7
148.8	-124.4	-192	267.7
149.3	-123.9	-191	268.7
149.9	-123.3	-190	269.7
150.4	-122.8	-189	270.7
151.0	-122.2	-188	271.7
151.5	-121.7	-187	272.7
152.1	-121.1	-186	273.7
152.6	-120.6	-185	274.7
153.2	-120.0	-184	275.7
153.8	-119.4	-183	276.7
154.3	-118.9	-182	277.7
154.9	-118.3	-181	278.7
155.4	-117.8	-180	279.7
156.0	-117.2	-179	280.7
156.5	-116.7	-178	281.7
157.1	-116.1	-177	282.7
157.6	-115.6	-176	283.7
158.2	-115.0	-175	284.7
158.8	-114.4	-174	285.7
159.3	-113.9	-173	286.7
159.9	-113.3	-172	287.7
160.4	-112.8	-171	288.7
161.0	-112.2	-170	289.7
161.5	-111.7	-169	290.7
162.1	-111.1	-168	291.7
162.6	-110.6	-167	292.7
163.2	-110.0	-166	293.7
163.8	-109.4	-165	294.7
164.3	-108.9	-164	295.7
164.9	-108.3	-163	296.7
165.4	-107.8	-162	297.7
166.0	-107.2	-161	298.7
166.5	-106.7	-160	299.7
167.1	-106.1	-159	300.7
167.6	-105.6	-158	301.7
168.2	-105.0	-157	302.7
168.8	-104.4	-156	303.7
169.3	-103.9	-155	304.7
169.9	-103.3	-154	305.7
170.4	-102.8	-153	306.7
171.0	-102.2	-152	307.7
171.5	-101.7	-151	308.7
172.1	-101.1	-150	309.7
172.6	-100.6	-149	310.7
173.2	-100.0	-148	311.7
173.8	-99.4	-147	312.7
174.3	-98.9	-146	313.7
174.9	-98.3	-145	314.7
175.4	-97.8	-144	315.7
176.0	-97.2	-143	316.7
176.5	-96.7	-142	317.7
177.1	-96.1	-141	318.7
177.6	-95.6	-140	319.7
178.2	-95.0	-139	320.7
178.8	-94.4	-138	321.7
179.3	-93.9	-137	322.7
179.9	-93.3	-136	323.7
180.4	-92.8	-135	324.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
181.0	-92.2	-134	325.7
181.5	-91.7	-133	326.7
182.1	-91.1	-132	327.7
182.6	-90.6	-131	328.7
183.2	-90.0	-130	329.7
183.8	-89.4	-129	330.7
184.3	-88.9	-128	331.7
184.9	-88.3	-127	332.7
185.4	-87.8	-126	333.7
186.0	-87.2	-125	334.7
186.5	-86.7	-124	335.7
187.1	-86.1	-123	336.7
187.6	-85.6	-122	337.7
188.2	-85.0	-121	338.7
188.8	-84.4	-120	339.7
189.3	-83.9	-119	340.7
189.9	-83.3	-118	341.7
190.4	-82.8	-117	342.7
191.0	-82.2	-116	343.7
191.5	-81.7	-115	344.7
192.1	-81.1	-114	345.7
192.6	-80.6	-113	346.7
193.2	-80.0	-112	347.7
193.8	-79.4	-111	348.7
194.3	-78.9	-110	349.7
194.9	-78.3	-109	350.7
195.4	-77.8	-108	351.7
196.0	-77.2	-107	352.7
196.5	-76.7	-106	353.7
197.1	-76.1	-105	354.7
197.6	-75.6	-104	355.7
198.2	-75.0	-103	356.7
198.8	-74.4	-102	357.7
199.3	-73.9	-101	358.7
199.9	-73.3	-100	359.7
200.4	-72.8	-99	360.7
201.0	-72.2	-98	361.7
201.5	-71.7	-97	362.7
202.1	-71.1	-96	363.7
202.6	-70.6	-95	364.7
203.2	-70.0	-94	365.7
203.8	-69.4	-93	366.7
204.3	-68.9	-92	367.7
204.9	-68.3	-91	368.7
205.4	-67.8	-90	369.7
206.0	-67.2	-89	370.7
206.5	-66.7	-88	371.7
207.1	-66.1	-87	372.7
207.6	-65.6	-86	373.7
208.2	-65.0	-85	374.7
208.8	-64.4	-84	375.7
209.3	-63.9	-83	376.7
209.9	-63.3	-82	377.7
210.4	-62.8	-81	378.7
211.0	-62.2	-80	379.7
211.5	-61.7	-79	380.7
212.1	-61.1	-78	381.7
212.6	-60.6	-77	382.7
213.2	-60.0	-76	383.7
213.8	-59.4	-75	384.7
214.3	-58.9	-74	385.7
214.9	-58.3	-73	386.7
215.4	-57.8	-72	387.7
216.0	-57.2	-71	388.7
216.5	-56.7	-70	389.7
217.1	-56.1	-69	390.7
217.6	-55.6	-68	391.7
218.2	-55.0	-67	392.7
218.8	-54.4	-66	393.7
219.3	-53.9	-65	394.7
219.9	-53.3	-64	395.7
220.4	-52.8	-63	396.7
221.0	-52.2	-62	397.7
221.5	-51.7	-61	398.7
222.1	-51.1	-60	399.7
222.6	-50.6	-59	400.7
223.2	-50.0	-58	401.7
223.8	-49.4	-57	402.7
224.3	-48.9	-56	403.7
224.9	-48.3	-55	404.7
225.4	-47.8	-54	405.7
226.0	-47.2	-53	406.7
226.5	-46.7	-52	407.7
227.1	-46.1	-51	408.7
227.6	-45.6	-50	409.7
228.2	-45.0	-49	410.7
228.8	-44.4	-48	411.7
229.3	-43.9	-47	412.7
229.9	-43.3	-46	413.7
230.4	-42.8	-45	414.7
231.0	-42.2	-44	415.7
231.5	-41.7	-43	416.7
232.1	-41.1	-42	417.7
232.6	-40.6	-41	418.7
233.2	-40.0	-40	419.7
233.8	-39.4	-39	420.7
234.3	-38.9	-38	421.7
234.9	-38.3	-37	422.7
235.4	-37.8	-36	423.7
236.0	-37.2	-35	424.7
236.5	-36.7	-34	425.7
237.1	-36.1	-33	426.7
237.6	-35.6	-32	427.7
238.2	-35.0	-31	428.7
238.8	-34.4	-30	429.7
239.3	-33.9	-29	430.7
239.9	-33.3	-28	431.7
240.4	-32.8	-27	432.7
241.0	-32.2	-26	433.7
241.5	-31.7	-25	434.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
242.1	-31.1	-24	435.7
242.6	-30.6	-23	436.7
243.2	-30.0	-22	437.7
243.8	-29.4	-21	438.7
244.3	-28.9	-20	439.7
244.9	-28.3	-19	440.7
245.4	-27.8	-18	441.7
246.0	-27.2	-17	442.7
246.5	-26.7	-16	443.7
247.1	-26.1	-15	444.7
247.6	-25.6	-14	445.7
248.2	-25.0	-13	446.7
248.8	-24.4	-12	447.7
249.3	-23.9	-11	448.7
249.9	-23.3	-10	449.7
250.4	-22.8	-9	450.7
251.0	-22.2	-8	451.7
251.5	-21.7	-7	452.7
252.1	-21.1	-6	453.7
252.6	-20.6	-5	454.7
253.2	-20.0	-4	455.7
253.8	-19.4	-3	456.7
254.3	-18.9	-2	457.7
254.9	-18.3	-1	458.7
255.4	-17.8	0	459.7
256.0	-17.2	1	460.7
256.5	-16.7	2	461.7
257.1	-16.1	3	462.7
257.6	-15.6	4	463.7
258.2	-15.0	5	464.7
258.8	-14.4	6	465.7
259.3	-13.9	7	466.7
259.9	-13.3	8	467.7
260.4	-12.8	9	468.7
261.0	-12.2	10	469.7
261.5	-11.7	11	470.7
262.1	-11.1	12	471.7
262.6	-10.6	13	472.7
263.2	-10.0	14	473.7
263.8	-9.4	15	474.7
264.3	-8.9	16	475.7
264.9	-8.3	17	476.7
265.4	-7.8	18	477.7
266.0	-7.2	19	478.7
266.5	-6.7	20	479.7
267.1	-6.1	21	480.7
267.6	-5.6	22	481.7
268.2	-5.0	23	482.7
268.8	-4.4	24	483.7
269.3	-3.9	25	484.7
269.9	-3.3	26	485.7
270.4	-2.8	27	486.7
271.0	-2.2	28	487.7
271.5	-1.7	29	488.7
272.1	-1.1	30	489.7
272.6	-0.6	31	490.7
273.2	0	32	491.7
273.8	0.6	33	492.7
274.3	1.1	34	493.7
274.9	1.7	35	494.7
275.4	2.2	36	495.7
276.0	2.8	37	496.7
276.5	3.3	38	497.7
277.1	3.9	39	498.7
277.6	4.4	40	499.7
278.2	5.0	41	500.7
278.8	5.6	42	501.7
279.3	6.1	43	502.7
279.9	6.7	44	503.7
280.4	7.2	45	504.7
281.0	7.8	46	505.7
281.5	8.3	47	506.7
282.1	8.9	48	507.7
282.6	9.4	49	508.7
283.2	10.0	50	509.7
283.8	10.6	51	510.7
284.3	11.1	52	511.7
284.9	11.7	53	512.7
285.4	12.2	54	513.7
286.0	12.8	55	514.7
286.5	13.3	56	515.7
287.1	13.9	57	516.7
287.6	14.4	58	517.7
288.2	15.0	59	518.7
288.8	15.6	60	519.7
289.3	16.1	61	520.7
289.9	16.7	62	521.7
290.4	17.2	63	522.7
291.0	17.8	64	523.7
291.5	18.3	65	524.7
292.1	18.9	66	525.7
292.6	19.4	67	526.7
293.2	20.0	68	527.7
293.8	20.6	69	528.7
294.3	21.1	70	529.7
294.9	21.7	71	530.7
295.4	22.2	72	531.7
296.0	22.8	73	532.7
296.5	23.3	74	533.7
297.1	23.9	75	534.7
297.6	24.4	76	535.7
298.2	25.0	77	536.7
298.8	25.6	78	537.7
299.3	26.1	79	538.7
299.9	26.7	80	539.7
300.4	27.2	81	540.7
301.0	27.8	82	541.7
301.5	28.3	83	542.7
302.1	28.9	84	543.7
302.6	29.4	85	544.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
303.2	30.0	86	545.7
303.8	30.6	87	546.7
304.3	31.1	88	547.7
304.9	31.7	89	548.7
305.4	32.2	90	549.7
306.0	32.8	91	550.7
306.5	33.3	92	551.7
307.1	33.9	93	552.7
307.6	34.4	94	553.7
308.2	35.0	95	554.7
308.8	35.6	96	555.7
309.3	36.1	97	556.7
309.9	36.7	98	557.7
310.4	37.2	99	558.7
311.0	37.8	100	559.7
311.5	38.3	101	560.7
312.1	38.9	102	561.7
312.6	39.4	103	562.7
313.2	40.0	104	563.7
313.8	40.6	105	564.7
314.3	41.1	106	565.7
314.9	41.7	107	566.7
315.4	42.2	108	567.7
316.0	42.8	109	568.7
316.5	43.3	110	569.7
317.1	43.9	111	570.7
317.6	44.4	112	571.7
318.2	45.0	113	572.7
318.8	45.6	114	573.7
319.3	46.1	115	574.7
319.9	46.7	116	575.7
320.4	47.2	117	576.7
321.0	47.8	118	577.7
321.5	48.3	119	578.7
322.1	48.9	120	579.7
322.6	49.4	121	580.7
323.2	50.0	122	581.7
323.8	50.6	123	582.7
324.3	51.1	124	583.7
324.9	51.7	125	584.7
325.4	52.2	126	585.7
326.0	52.8	127	586.7
326.5	53.3	128	587.7
327.1	53.9	129	588.7
327.6	54.4	130	589.7
328.2	55.0	131	590.7
328.8	55.6	132	591.7
329.3	56.1	133	592.7
329.9	56.7	134	593.7
330.4	57.2	135	594.7
331.0	57.8	136	595.7
331.5	58.3	137	596.7
332.1	58.9	138	597.7
332.6	59.4	139	598.7
333.2	60.0	140	599.7
333.8	60.6	141	600.7
334.3	61.1	142	601.7
334.9	61.7	143	602.7
335.4	62.2	144	603.7
336.0	62.8	145	604.7
336.5	63.3	146	605.7
337.1	63.9	147	606.7
337.6	64.4	148	607.7
338.2	65.0	149	608.7
338.8	65.6	150	609.7
339.3	66.1	151	610.7
339.9	66.7	152	611.7
340.4	67.2	153	612.7
341.0	67.8	154	613.7
341.5	68.3	155	614.7
342.1	68.9	156	615.7
342.6	69.4	157	616.7
343.2	70.0	158	617.7
343.8	70.6	159	618.7
344.3	71.1	160	619.7
344.9	71.7	161	620.7
345.4	72.2	162	621.7
346.0	72.8	163	622.7
346.5	73.3	164	623.7
347.1	73.9	165	624.7
347.6	74.4	166	625.7
348.2	75.0	167	626.7
348.8	75.6	168	627.7
349.3	76.1	169	628.7
349.9	76.7	170	629.7
350.4	77.2	171	630.7
351.0	77.8	172	631.7
351.5	78.3	173	632.7
352.1	78.9	174	633.7
352.6	79.4	175	634.7
353.2	80.0	176	635.7
353.8	80.6	177	636.7
354.3	81.1	178	637.7
354.9	81.7	179	638.7
355.4	82.2	180	639.7
356.0	82.8	181	640.7
356.5	83.3	182	641.7
357.1	83.9	183	642.7
357.6	84.4	184	643.7
358.2	85.0	185	644.7
358.8	85.6	186	645.7
359.3	86.1	187	646.7
359.9	86.7	188	647.7
360.4	87.2	189	648.7
361.0	87.8	190	649.7
361.5	88.3	191	650.7
362.1	88.9	192	651.7
362.6	89.4	193	652.7
363.2	90.0	194	653.7
363.8	90.6	195	654.7

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
364.3	91.1	196	655.7
364.9	91.7	197	656.7
365.4	92.2	198	657.7
366.0	92.8	199	658.7
366.5	93.3	200	659.7
367.1	93.9	201	660.7
367.6	94.4	202	661.7
368.2	95.0	203	662.7
368.8	95.6	204	663.7
369.3	96.1	205	664.7
369.9	96.7	206	665.7
370.4	97.2	207	666.7
371.0	97.8	208	667.7
371.5	98.3	209	668.7
372.1	98.9	210	669.7
372.6	99.4	211	670.7
373.2	100.0	212	671.7
377	104	220	680
383	110	230	690
389	116	240	700
394	121	250	710
400	127	260	720
405	132	270	730
411	138	280	740
416	143	290	750
422	149	300	760
427	154	310	770
433	160	320	780
439	166	330	790
444	171	340	800
450	177	350	810
455	182	360	820
461	188	370	830
466	193	380	840
472	199	390	850
477	204	400	860
483	210	410	870
489	216	420	880
494	221	430	890
500	227	440	900
505	232	450	910
511	238	460	920
516	243	470	930
522	249	480	940
527	254	490	950
533	260	500	960
539	266	510	970
544	271	520	980
550	277	530	990
555	282	540	1000
561	288	550	1010
566	293	560	1020
572	299	570	1030
577	304	580	1040
583	310	590	1050
589	316	600	1060
594	321	610	1070
600	327	620	1080
605	332	630	1090
611	338	640	1100
616	343	650	1110
622	349	660	1120
627	354	670	1130
633	360	680	1140
639	366	690	1150
644	371	700	1160
650	377	710	1170
655	382	720	1180
661	388	730	1190
666	393	740	1200
672	399	750	1210
677	404	760	1220
683	410	770	1230
689	416	780	1240
694	421	790	1250
700	427	800	1260
705	432	810	1270
711	438	820	1280
716	443	830	1290
722	449	840	1300
727	454	850	1310
733	460	860	1320
739	466	870	1330
744	471	880	1340
750	477	890	1350
755	482	900	1360
761	488	910	1370
766	493	920	1380
772	499	930	1390
777	504	940	1400
783	510	950	1410
789	516	960	1420
794	521	970	1430
800	527	980	1440
805	532	990	1450
811	538	1000	1460
816	543	1010	1470
822	549	1020	1480
827	554	1030	1490
833	560	1040	1500
839	566	1050	1510
844	571	1060	1520
850	577	1070	1530
855	582	1080	1540
861	588	1090	1550
866	593	1100	1560

KELVIN K	CELSIUS C	FAHRENHEIT F	RANKINE R
872	599	1110	1570
877	604	1120	1580
883	610	1130	1590
889	616	1140	1600
894	621	1150	1610
900	627	1160	1620
905	632	1170	1630
911	638	1180	1640
916	643	1190	1650
922	649	1200	1660
927	654	1210	1670
933	660	1220	1680
939	666	1230	1690
944	671	1240	1700
950	677	1250	1710
955	682	1260	1720
961	688	1270	1730
966	693	1280	1740
972	699	1290	1750
977	704	1300	1760
983	710	1310	1770
989	716	1320	1780
994	721	1330	1790
1000	727	1340	1800
1005	732	1350	1810
1011	738	1360	1820
1016	743	1370	1830
1022	749	1380	1840
1027	754	1390	1850
1033	760	1400	1860
1039	766	1410	1870
1044	771	1420	1880
1050	777	1430	1890
1055	782	1440	1900
1061	788	1450	1910
1066	793	1460	1920
1072	799	1470	1930
1077	804	1480	1940
1083	810	1490	1950
1089	816	1500	1960
1094	821	1510	1970
1100	827	1520	1980
1105	832	1530	1990
1111	838	1540	2000
1116	843	1550	2010
1122	849	1560	2020
1127	854	1570	2030
1133	860	1580	2040
1139	866	1590	2050
1144	871	1600	2060
1150	877	1610	2070
1155	882	1620	2080
1161	888	1630	2090
1166	893	1640	2100
1172	899	1650	2110
1177	904	1660	2120
1183	910	1670	2130
1189	916	1680	2140
1194	921	1690	2150
1200	927	1700	2160
1205	932	1710	2170
1211	938	1720	2180
1216	943	1730	2190
1222	949	1740	2200
1227	954	1750	2210
1233	960	1760	2220
1239	966	1770	2230
1244	971	1780	2240
1250	977	1790	2250
1255	982	1800	2260
1261	988	1810	2270
1266	993	1820	2280
1272	999	1830	2290
1277	1004	1840	2300
1283	1010	1850	2310
1289	1016	1860	2320
1294	1021	1870	2330
1300	1027	1880	2340
1305	1032	1890	2350
1311	1038	1900	2360
1316	1043	1910	2370
1322	1049	1920	2380
1327	1054	1930	2390
1333	1060	1940	2400
1339	1066	1950	2410
1344	1071	1960	2420
1350	1077	1970	2430
1355	1082	1980	2440
1361	1088	1990	2450
1366	1093	2000	2460

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APPENDIX

TEMPERATURE AND HEAT

TEMPERATURE CONVERSION TABLE
(Centigrade Scale Listed in Even Numbers)

1/16	-268	-450 4	5 7	68 16	-185	301 0	158 7	173 16	-100	-148 0	311 7	258 16	-15	5 0	464 2	393 16	70	158 0	617 7	923	850	1202	1661
1/8	-268	-450 4	9 1	69 16	-184	299 2	160 5	174 16	-99	-146 2	313 5	259 16	-14	6 8	466 5	344 16	71	159 8	619 5	933	860	1220	1679
3/16	-268	-450 4	9 3	90 16	-183	297 4	162 3	175 16	-98	-144 4	315 3	260 16	-13	8 6	468 3	345 16	72	161 6	621 3	943	870	1238	1697
4/16	-267	-448 8	10 1	91 16	-182	295 6	164 1	176 16	-97	-142 6	317 1	261 16	-12	10 4	470 1	346 16	73	163 4	623 1	953	880	1256	1715
5/16	-266	-448 8	10 9	92 16	-181	293 8	165 9	177 16	-96	-140 8	318 9	262 16	-11	12 2	471 8	347 16	74	165 2	624 9	963	890	1274	1733
6/16	-265	-445 0	11 7	93 16	-180	292 0	167 7	178 16	-95	-139 0	320 7	263 16	-10	14 0	473 7	348 16	75	167 0	626 7	973	900	1292	1751
7/16	-264	-443 2	12 5	94 16	-179	290 2	169 5	179 16	-94	-137 2	322 5	264 16	-9	15 8	475 5	349 16	76	168 8	628 5	983	910	1310	1769
8/16	-264	-441 4	13 3	95 16	-178	288 4	171 3	180 16	-93	-135 4	324 3	265 16	-8	17 6	477 3	350 16	77	170 6	630 3	993	920	1328	1787
9/16	-263	-439 6	14 1	96 16	-177	286 6	173 1	181 16	-92	-133 6	326 1	266 16	-7	19 4	479 1	351 16	78	172 4	632 1	1003	930	1346	1805
10/16	-262	-437 8	14 9	97 16	-176	284 8	174 9	182 16	-91	-131 8	327 9	267 16	-6	21 2	480 9	352 16	79	174 2	633 9	1013	940	1364	1823
11/16	-261	-436 0	15 7	98 16	-175	283 0	176 7	183 16	-90	-130 0	329 7	268 16	-5	23 0	482 7	353 16	80	176 0	635 7	1023	950	1382	1841
12/16	-260	-434 2	16 5	99 16	-174	281 2	178 5	184 16	-89	-128 2	331 5	269 16	-4	24 8	484 5	354 16	81	177 8	637 5	1033	960	1400	1859
13/16	-258	-432 4	17 3	100 16	-173	279 4	180 3	185 16	-88	-126 4	333 3	270 16	-3	26 6	486 3	355 16	82	179 6	639 3	1043	970	1418	1877
14/16	-257	-430 6	18 1	101 16	-172	277 6	182 1	186 16	-87	-124 6	335 1	271 16	-2	28 4	488 1	356 16	83	181 4	641 1	1053	980	1436	1895
15/16	-256	-428 8	18 9	102 16	-171	275 8	183 9	187 16	-86	-122 8	336 9	272 16	-1	30 2	489 9	357 16	84	183 2	642 9	1063	990	1454	1913
16/16	-255	-427 0	19 7	103 16	-170	274 0	185 7	188 16	-85	-121 0	338 7	273 16	0	32 0	491 7	358 16	85	185 0	644 7	1073	1000	1472	1931
17/16	-254	-425 2	20 5	104 16	-169	272 2	187 5	189 16	-84	-119 2	340 5	274 16	1	33 8	493 5	359 16	86	186 8	646 5	1083	1010	1490	1949
18/16	-253	-423 4	21 3	105 16	-168	270 4	189 3	190 16	-83	-117 4	342 3	275 16	2	35 6	495 3	360 16	87	188 6	648 3	1093	1020	1508	1967
19/16	-252	-421 6	22 1	106 16	-167	268 6	191 1	191 16	-82	-115 6	344 1	276 16	3	37 4	497 1	361 16	88	190 4	650 1	1103	1030	1526	1985
20/16	-251	-419 8	23 9	107 16	-166	266 8	192 9	192 16	-81	-113 8	345 9	277 16	4	39 2	498 9	362 16	89	192 2	651 9	1113	1040	1544	2003
21/16	-250	-418 0	24 7	108 16	-165	265 0	194 7	193 16	-80	-112 0	347 7	278 16	5	41 0	500 7	363 16	90	194 0	653 7	1123	1050	1562	2021
22/16	-249	-416 2	25 5	109 16	-164	263 2	196 5	194 16	-79	-110 2	349 5	279 16	6	42 8	502 5	364 16	91	195 8	655 5	1133	1060	1580	2039
23/16	-248	-414 4	26 3	110 16	-163	261 4	198 3	195 16	-78	-108 4	351 3	280 16	7	44 6	504 3	365 16	92	197 6	657 3	1143	1070	1598	2057
24/16	-247	-412 6	27 1	111 16	-162	259 6	200 1	196 16	-77	-106 6	353 1	281 16	8	46 4	506 1	366 16	93	199 4	659 1	1153	1080	1616	2075
25/16	-246	-410 8	28 9	112 16	-161	257 8	201 9	197 16	-76	-104 8	354 9	282 16	9	48 2	507 9	367 16	94	201 2	660 9	1163	1090	1634	2093
26/16	-245	-409 0	30 7	113 16	-160	256 0	203 7	198 16	-75	-103 0	356 7	283 16	10	50 0	509 7	368 16	95	203 0	662 7	1173	1100	1652	2111
27/16	-244	-407 2	32 5	114 16	-159	254 2	205 5	199 16	-74	-101 2	358 5	284 16	11	51 8	511 5	369 16	96	204 8	664 5	1183	1110	1670	2129
28/16	-243	-405 4	34 3	115 16	-158	252 4	207 3	200 16	-73	-99 4	360 3	285 16	12	53 6	513 3	370 16	97	206 6	666 3	1193	1120	1688	2147
29/16	-242	-403 6	36 1	116 16	-157	250 6	209 1	201 16	-72	-97 6	362 1	286 16	13	55 4	515 1	371 16	98	208 4	668 1	1203	1130	1706	2165
30/16	-241	-401 8	37 9	117 16	-156	248 8	210 9	202 16	-71	-95 8	363 9	287 16	14	57 2	516 9	372 16	99	210 2	669 9	1213	1140	1724	2183
31/16	-240	-400 0	39 7	118 16	-155	247 0	212 7	203 16	-70	-94 0	365 7	288 16	15	59 0	518 7	373 16	100	212 0	671 7	1273	1150	1742	2201
32/16	-239	-398 2	41 5	119 16	-154	245 2	214 5	204 16	-69	-92 2	367 5	289 16	16	60 8	520 5	383	110	230	686	1213	960	1760	2219
33/16	-238	-396 4	43 3	120 16	-153	243 4	216 3	205 16	-68	-90 4	369 3	290 16	17	62 6	522 3	393	120	248	707	1243	970	1778	2237
34/16	-237	-394 6	45 1	121 16	-152	241 6	218 1	206 16	-67	-88 6	371 1	291 16	18	64 4	524 1	403	130	266	725	1253	980	1796	2255
35/16	-236	-392 8	46 9	122 16	-151	239 8	219 9	207 16	-66	-86 8	372 9	292 16	19	66 2	525 9	413	140	284	743	1263	990	1814	2273
36/16	-235	-391 0	48 7	123 16	-150	238 0	221 7	208 16	-65	-85 0	374 7	293 16	20	68 0	527 7	423	150	302	761	1273	1000	1832	2291
37/16	-234	-389 2	50 5	124 16	-149	236 2	223 5	209 16	-64	-83 2	376 5	294 16	21	69 8	529 5	433	160	320	779	1283	1010	1850	2309
38/16	-233	-387 4	52 3	125 16	-148	234 4	225 3	210 16	-63	-81 4	378 3	295 16	22	71 6	531 3	443	170	338	797	1293	1020	1868	2327
39/16	-232	-385 6	54 1	126 16	-147	232 6	227 1	211 16	-62	-79 6	380 1	296 16	23	73 4	533 1	453	180	356	815	1303	1030	1886	2345
40/16	-231	-383 8	55 9	127 16	-146	230 8	228 9	212 16	-61	-77 8	381 9	297 16	24	75 2	534 9	463	190	374	833	1313	1040	1904	2363
41/16	-230	-382 0	57 7	128 16	-145	229 0	230 7	213 16	-60	-76 0	383 7	298 16	25	77 0	536 7	473	200	392	851	1323	1050	1922	2381
42/16	-229	-380 2	59 5	129 16	-144	227 2	232 5	214 16	-59	-74 2	385 5	299 16	26	78 8	538 5	483	210	410	869	1333	1060	1940	2399
43/16	-228	-378 4	61 3	130 16	-143	225 4	234 3	215 16	-58	-72 4	387 3	300 16	27	80 6	540 3	493	220	428	887	1343	1070	1958	2417
44/16	-227	-376 6	63 1	131 16	-142	223 6	236 1	216 16	-57	-70 6	389 1	301 16	28	82 4	542 1	503	230	446	905	1353	1080	1976	2435
45/16	-226	-374 8	64 9	132 16	-141	221 8	237 9	217 16	-56	-68 8	390 9	302 16	29	84 2	543 9	513	240	464	923	1363	1090	1994	2453
46/16	-225	-373 0	66 7	133 16	-140	220 0	239 7	218 16	-55	-67 0	392 7	303 16	30	86 0	545 7	523	250	482	941	1373	1100	2012	2471
47/16	-224	-371 2	68 5	134 16	-139	218 2	241 5	219 16	-54	-65 2	394 5	304 16	31	87 8	547 5	533	260	500	959	1383	1110	2030	2489
48/16	-223	-369 4	70 3	135 16	-138	216 4	243 3	220 16	-53	-63 4	396 3	305 16	32	89 6	549 3	543	270	518	977	1393	1120	2048	2507
49/16	-222	-367 6	72 1	136 16	-137	214 6	245 1	221 16	-52	-61 6	398 1	306 16	33	91 4	551 1	553	280	536	995	1403	1130	2066	2525
50/16	-221	-365 8	73 9	137 16	-136	212 8	246 9	222 16	-51	-59 8	399 9	307 16	34	93 2	552 9	563	290	554	1013	1413	1140	2084	2543
51/16	-220	-364 0	75 7	138 16	-135	211 0	248 7	223 16	-50	-58 0	401 7	308 16	35	95 0	554 7	573	300	572	1031	1423	1150	2102	2561
52/16	-219	-362 2	77 5	139 16	-134	209 2	250 5	224 16	-49	-56 2	403 5	309 16	36	96 8	556 5	583	310	590	1049	1433	1160	2120	2579
53/16	-218	-360 4	79 3	140 16	-133	207 4	252 3	225 16	-48	-54 4	405 3	310 16	37	98 6	558 3	593	320	608	1067	1443	1170	2138	2597
54/16	-217	-358 6	81 1	141 16	-132	205 6	254 1	226 16	-47	-52 6	407 1	311 16	38	100 4	560 1	603	330	626	1085	1453	1180	2156	2615
55/16	-216	-356 8	82 9	142 16	-131	203 8	255 9	227 16	-46	-50 8	408 9	312 16	39	102 2	561 9	613	340	644	1103	1463	1190	2174	2633
56/16	-215	-355 0	84 7	143 16	-130	202 0	257 7	228 16	-45	-49 0	410 7	313 16	40	104 0	563 7	623	350	662	1121	1473	1200	2192	2651
57/16	-214	-353 2	86 5	144 16	-129	200 2	259 5	229 16	-44	-47 2	412 5	314 16	41	105 8	565 5	633	360	680	1139	1483	1210	2210	2669
58/16	-213	-351 4	88 3	145 16	-128	198 4	261 3	230 16	-43	-45 4	414 3	315 16	42	107 6	567 3	643	370	698	1157	1493	1220	2228	2687
59/16	-212	-349 6	90 1	146 16	-127	196 6	263 1	231 16	-42	-43 6	416 1	316 16	43	109 4	569 1	653	380	716	1175	1503	1230	2246	2705
60/16	-211	-347 8	91 9	147 16	-126	194 8	264 9	232 16	-41	-41 8	417 9	317 16	44	111 2	570 9	663	390	734	1193	1513	1240	2264	2723
61/16	-210	-346 0	93 7	148 16	-125	193 0	266 7	233 16	-40	-40 0	419 7	318 16	45	113 0	572 7	673	400	752	1211	1523	1250	2282	2741
62/16	-209	-344 2	95 5	149 16	-124	191 2	268 5	234 16	-38	-38 2	421 5	319 16	46	114 8	574 5	683	410	770	1229	1533	1260	2300	2759
63/16	-208	-342 4	97 3	150 16	-123	189 4	270 3	235 16	-38	-36 4	423 3	320 16	47	116 6	576 3	693	420	788	1247	1543	1270	2318	2777
64/16	-207	-340 6	98 1	151 16	-122	187 6	272 1	236 16	-37	-34 6	425 1	321 16	48	118 4	578 1	703	430	806	1265	1553	1280	2336	2795
65/16	-206	-338 8	100 9	152 16	-121	185 8	273 9	237 16	-36	-32 8	426 9	322 16	49	120 2	579 9	713	440	824	1283	1563	1290	2354	2813
66/16	-205	-337 0	102 7	153 16	-120	184 0	275 7	238 16	-35	-31 0	428 7	323 16	50	122 0	581 7	723	450	842	1301	1573	1300	2372	2831
67/16	-204	-335 2	104 5	154 16	-119	182 2	277 5	239 16	-34	-29 2	430 5	324 16	51	123 8	583 5	733	460	860	1319	1583	1310	2390	2849
68/16	-203	-333 4	106 3	155 16	-118	180 4	279 3	240 16	-33	-27 4	432 3	325 16	52	125 6	585 3	743	470	878	1337	1593	1320	2408	2867
69/16	-202	-331 6	108 1	156 16	-117	178 6	281 1	241 16	-32	-25 6	434 1	326 16	53	127 4	587 1	753	480	896	1355	1603	1330	2426	2885
70/16	-201	-329 8	109 9	157 16	-116	176 8	282 9	242 16	-31	-23 8	435 9	327 16	54	129 2	588 9	763	490	914	1373	1613	1340	2444	2903
71/16	-200	-328 0	111 7	158 16	-115	175 0	284 7	243 16	-30	-22 0	437 7	328 16	55	131 0	590 7	773	500	932	1391	1623	1350	2462	2921
72/16	-199	-326 2	113 5	159 16	-114	173 2	286 5	244 16	-29	-20 2	439 5	329 16	56	132 8	592 5	783	510	950	1409	1633	1360	2480	2939
73/16	-198	-324 4	115 3	160 16	-113	171 4	288 3	245 16	-28	-18 4	441 3	330 16	57	134 6	594 3	793	520	968	1427	1643	1370	2498	2957
74/16	-197	-322 6	117 1	161 16	-112	169 6	290 1	246 16	-27	-16 6	443 1	331 16	58	136 4	596 1	803	530	986	1445	1653	1380	2516	2975
75/16	-196	-320 8	118 9	162 16	-111	167 8	291 9	247 16	-26	-14 8	444 9	332 16	59	138 2	597 9	813	540	1004	1463	1663	1390	2534	2993
76/16	-195	-319 0	120 7	163 16	-110	166 0	293 7	248 16	-25	-13 0	446 7	333 16	60	140 0	599 7	823	550	1022	1481	1673	1400	2552	3011
77/16	-194	-317 2	122 5	164 16	-109	164 2	295 5	249 16	-24	-11 2	448 5	334 16	61	141 8	601 5	833	560	1040	1499	1683	1410	2570	3029
78/16	-193	-315 4	124 3	165 16	-108	162 4	297 3	250 16	-23	-9 4	450 3	335 16	62	143 6	603 3	843	570	1058	1517	1693	1420	2588	3047
79/16	-192	-313 6	126 1	166 16	-107	160 6	299 1	251 16	-22	-7 6	452 1	336 16	63	145 4	605 1	853	580	1076	1535	1703	1430	2606	3065
80/16	-191	-311 8	127 9	167 16	-106	158 8	300 9	252 16	-21	-5 8	453 9	337 16	64	147 2	606 9	863	590	1094	1553	1713	1440	2624	3083
81/16	-190	-310 0	129 7	168 16	-105	157 0	302 7	253 16	-20	-4 0	455 7	338 16	65	149 0	608 7	873	600	1112	1571	1723	1450	2642	3101
82/16	-189	-308 2	131 5	169 16	-104	155 2	304 5	254 16	-19	-2 2	457 5	339 16	66	150 8	610 5	883	610	1130	1589	1733	1460	2660	3119
83/16	-188	-306 4	133 3	170 16	-103	153 4	306 3	255 16	-17	-0 4	459 3	340 16	67	152 6	612 3	893	620	1148	1607	1743	1470	2678	3137
84/16	-187	-304 6	135 1	171 16	-102	151 6	308 1	256 16	-17	1 4	461 1	341 16	68	154 4	614 1	903	630	1166	1625	1753	1480	2696	3155
85/16	-186	-302 8	136 9	172 16	-101	149 8	309 9	257 16	-14	3 2	462 9	342 16	69	156 2	615 9	913	640	1184	1643	1763	1490	2714	3173
86/16	-185	-301 0	138 7	173 16	-100	148 0	311 7	258 16	-13	5 0	464 7	343 16	70	158 0	617 7	923	650	1202	1661	1773	1500	2732	3191

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APPENDIX

TEMPERATURE AND HEAT

THERMAL EXPANSION OF METALS (Based on Expansion from 0 F to Listed Temperature)

INCHES OF LINEAR EXPANSION PER 100 FEET

Temperature, Degrees Fahrenheit	"A" Nickel	Monel	Carbon and Low-Alloy Steel	Cast Iron	Wrought Iron	18-8 Stainless Steel	Copper	Brass 70-30 to 85-15	25 and 15 Aluminum	"Hastelloy" Alloy B (Rolled)	"Hastelloy" Alloy C (Cast)	Silicon Bronze (Everdur-1010)	Lead	Temperature, Degrees Fahrenheit
-300	-2.04	-2.28												-300
-280	-1.89	-2.04												-280
-260	-1.78	-1.92												-260
-240	-1.67	-1.80												-240
-220	-1.56	-1.66												-220
-200	-1.44	-1.49	-1.28	-1.06	-1.29	-2.03	-1.96	-2.07	-2.69					-200
-180	-1.32	-1.39	-1.18	-0.98	-1.18	-1.85	-1.78	-1.89	-2.42					-180
-160	-1.19	-1.22	-1.07	-0.89	-1.07	-1.67	-1.61	-1.71	-2.18					-160
-140	-1.03	-1.08	-0.95	-0.79	-0.96	-1.48	-1.43	-1.51	-1.92					-140
-120	-0.89	-0.96	-0.83	-0.69	-0.83	-1.30	-1.24	-1.31	-1.66					-120
-100	-0.72	-0.82	-0.69	-0.59	-0.73	-1.09	-1.04	-1.09	-1.40					-100
- 80	-0.60	-0.66	-0.56	-0.48	-0.57	-0.88	-0.84	-0.89	-1.13					- 80
- 60	-0.46	-0.48	-0.43	-0.37	-0.44	-0.67	-0.63	-0.67	-0.86					- 60
- 40	-0.30	-0.34	-0.29	-0.25	-0.29	-0.45	-0.42	-0.45	-0.58					- 40
- 20	-0.12	-0.18	-0.15	-0.13	-0.15	-0.23	-0.21	-0.23	-0.30					- 20
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
20	0.18	0.12	0.15	0.13	0.15	0.22	0.24	0.23	0.30	0.27	0.18	0.23	0.40	20
32	0.24	0.24	0.23	0.21	0.25	0.36	0.37	0.37	0.46	0.35	0.28	0.37	0.61	32
40	0.36	0.30	0.29	0.26	0.31	0.45	0.45	0.47	0.60	0.37	0.35	0.46	0.76	40
60	0.48	0.48	0.45	0.39	0.47	0.67	0.68	0.69	0.90	0.47	0.50	0.69	1.16	60
80	0.65	0.70	0.58	0.52	0.63	0.89	0.89	0.92	1.20	0.57	0.65	0.93	1.55	80
100	0.84	0.85	0.75	0.66	0.79	1.12	1.13	1.15	1.50	0.67	0.80	1.16	1.92	100
120	0.98	1.03	0.91	0.79	0.96	1.34	1.37	1.39	1.81	0.82	1.00	1.39	2.32	20
140	1.20	1.20	1.06	0.92	1.11	1.55	1.58	1.63	2.12	0.92	1.15	1.62	2.70	40
160	1.34	1.37	1.22	1.07	1.28	1.78	1.80	1.87	2.43	1.07	1.35	1.86	3.10	160
180	1.50	1.56	1.38	1.22	1.45	2.00	2.05	2.10	2.76	1.22	1.50	2.09	3.48	180
200	1.68	1.73	1.55	1.37	1.63	2.23	2.29	2.34	3.08	1.37	1.70	2.33	3.86	200
212	1.79	1.76	1.64	1.45	1.72	2.36	2.43	2.47	3.26	1.47	1.80	2.47	4.10	212
220	1.82	1.92	1.71	1.51	1.78	2.46	2.52	2.58	3.40	1.57	1.85	2.56		220
240	2.01	2.11	1.88	1.65	1.96	2.68	2.76	2.83	3.73	1.72	2.00	2.80		240
260	2.17	2.30	2.04	1.80	2.13	2.92	2.99	3.07	4.06	1.87	2.20	3.03		260
280	2.34	2.48	2.21	1.96	2.31	3.13	3.22	3.32	4.42	2.07	2.40	3.26		280
300	2.54	2.65	2.37	2.11	2.48	3.38	3.46	3.57	4.74	2.28	2.59	3.50		300
320	2.76	2.86	2.55	2.27	2.65	3.62	3.69	3.82	5.08	2.37	2.70	3.74		320
340	2.90	3.08	2.72	2.42	2.84	3.84	3.94	4.07	5.43	2.57	2.90	3.97		340
360	3.10	3.26	2.88	2.57	3.02	4.08	4.18	4.32	5.78	2.77	3.05			360
380	3.38	3.48	3.07	2.73	3.19	4.35	4.42	4.56	6.12	2.92	3.25			380
400	3.49	3.68	3.23	2.88	3.37	4.56	4.67	4.83	6.48	3.07	3.40			400
420	3.70	3.86	3.42	3.06	3.57	4.80	4.91	5.08	6.82	3.23	3.60			420
440	3.89	4.08	3.59	3.22	3.75	5.05	5.15	5.36	7.18	3.35	3.80			440
460	4.08	4.32	3.78	3.38	3.94	5.34	5.41	5.60	7.54	3.49	3.98			460
480	4.27	4.51	3.96	3.56	4.13	5.54	5.65	5.93	7.90	3.63	4.15			480
500	4.50	4.73	4.15	3.72	4.33	5.80	5.91	6.12	8.27	3.77	4.30			500
520	4.70	4.93	4.34	3.89	4.53	6.05	6.15	6.38	8.63	3.91	4.50			520
540	4.91	5.16	4.53	4.06	4.71	6.32	6.41	6.65	8.99	4.05	4.70			540
560	5.15	5.39	4.72	4.24	4.91	6.57	6.65	6.92	9.37	4.19	4.85			560
580	5.34	5.62	4.91	4.41	5.12	6.80	6.92	7.17	9.73	4.33	5.05			580
600	5.60	5.86	5.10	4.59	5.30	7.04	7.18	7.44	10.10	4.47	5.20			600
620	5.77	6.05	5.29	4.77	5.51	7.29	7.43	7.72	10.46	4.60	5.40			620
640	6.00	6.28	5.48	4.96	5.69	7.55	7.69	7.98	10.83	4.80	5.60			640
660	6.20	6.50	5.69	5.13	5.92	7.80	7.95	8.24	11.19	4.95	5.75			660
680	6.43	6.73	5.88	5.32	6.11	8.06	8.19	8.52	11.57	5.15	5.95			680
700	6.67	6.98	6.08	5.50	6.33	8.31	8.47	8.79	11.95	5.30	6.15			700
720	6.88	7.20	6.28	5.68	6.52	8.57	8.71	9.05	12.30	5.45	6.35			720
740	7.10	7.44	6.49	5.88	6.75	8.85	8.99	9.32	12.69	5.65	6.50			740
760	7.32	7.68	6.69	6.07	6.95	9.07	9.26	9.60	13.07	5.80	6.70			760
780	7.56	7.92	6.90	6.26	7.16	9.35	9.53	9.87	13.45	6.00	6.90			780
800	7.79	8.16	7.11	6.46	7.36	9.61	9.79	10.15	13.83	6.20	7.10			800
820	8.00	8.39	7.32	6.65	7.61	9.87	10.07	10.43		6.35	7.30			820
840	8.22	8.64	7.52	6.84	7.80	10.14	10.31	10.69		6.50	7.45			840
860	8.47	8.87	7.74	7.05	8.04	10.40	10.61	10.98		6.60	7.65			860
880	8.69	9.10	7.95	7.25	8.25	10.66	10.97	11.25		6.75	7.85			880
900	8.94	9.35	8.17	7.45	8.49	10.93	11.16	11.55		6.90	8.05			900
920	9.12	9.59	8.40	7.67	8.72	11.20	11.42	11.82		7.00	8.25			920
940	9.36	9.80	8.61	7.86	8.94	11.46	11.71	12.12		7.10	8.45			940
960	9.59	10.06	8.83	8.07	9.15	11.73	11.98	12.42		7.20	8.65			960
980	9.84	10.30	9.05	8.28	9.39	11.99	12.27	12.72		7.35	8.85			980
1000	10.10	10.56	9.28	8.49	9.62	12.26	12.56	13.08		7.45	9.05			1000
1050			9.81	9.06	10.25	12.88				7.60	9.55			1050
1100			10.41	9.56	10.85	13.58				8.25	10.05			1100
1150			11.01	10.06	11.45	14.28				8.80	10.60			1150
1200			11.61	10.46	12.05	14.98				9.50	11.10			1200
1250			12.21	11.26	12.65	15.58				10.10	11.65			1250
1300			12.81	11.86	13.25	16.28				10.80	12.20			1300
1350			13.41	12.46	13.95	16.98				11.45	12.75			1350
1400			14.11	13.06	14.55	17.58				12.10	13.35			1400
1450										12.75	13.95			1450
1500										13.40	14.50			1500
1550										14.05	15.15			1550
1600										14.70	15.75			1600
1650										15.40	16.40			1650
1700										16.00	17.00			1700
1750										16.70	17.70			1750
1800										17.30	18.35			1800

NOTE:

Tabulated data is intended primarily for calculating expansion and contraction in piping systems due to temperature changes.

For reference material used in developing this tabulation, refer to development file M-110, Standards Section, Department of Construction and Design.

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APPENDIX

THERMAL PROPERTIES OF MATERIAL

THERMAL CONDUCTIVITY OF MATERIALS

k = Btu in/ hr, sq ft, in, °F

Miscellaneous Solid Materials	Mean Temp °F	k
Asbestos, 36 lb density	200	1.32
Asbestos, wool, 25 lb density	212	0.696
Asbestos paper, 61 lb density	212	1.089
Asbestos millboard, 60 lb density	86	0.84
Ashes, soft wood, 12 lb density	68	0.216
Ashes, volcanic, 51 lb density	300	1.476
Asphalt, 132 lb density	68	5.16
Bricks		
Building	70	5.0
Refractory, average	1000	9.0
Basalt	32-210	8.88-19.32
Carbon black, 12 lb density	133	0.144
Cardboard, corrugated		0.444
Celluloid, 87 lb density	86	1.44
Concrete, sand and gravel 142 lb density	75	12.6
Concrete, cinder 97 lb density	75	4.92
Charcoal, powder, 12 lb density	63	0.348
Cotton wool, 5 lb density	100	0.420
Earth plus 42% water, frozen, 108 lb density	0	7.44
Glass		3.6-7.32
Glass, pyrex, 139 lb density	200	7.08
Glass, soda lime	200	7.08
Gravel, 116 lb density	68	2.64

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTIVITY OF MATERIALS - Continued

k = Btu in/hr, sq ft, in, °F

Miscellaneous Solid Materials	Mean Temp °F	k
Gypsum plaster, sand aggregate		5.55
Gypsum plaster, light wt aggregate		1.56
Gypsum board, 51 lb density	99	0.744
Ice, 57.5 lb density		15.12
Leather, sole, 62.4 lb density		1.104
Mica, 122 lb density		3.0
Rubber, hard, 74.3 lb density	100	1.104
Rubber, soft, 68 lb density	86	0.96
Sand, dry, 94.8 lb density	68	2.26
Sawdust, dry, 13.4 lb density	68	0.504
Soil, dry	68	0.90
Soil, dry, including stones, 127 lb density	68	3.6
Soil, wet		to 12.0
Snow, 7 to 31 lb density	32	4.08-15.6
Titonium oxide, 52 lb density	1000	0.492
Wool, pure, 5.6 lb density	86	0.252
Wood, average		1.2

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTIVITY OF MATERIALS

k = Btu in/hr, sq ft, in, °F

Metals	Mean Temp °F	k
Aluminum	64	1404
	212	1428
	930	1855
Antimony	32	127
	212	116
Bismuth	64	56
	212	47
Brass (20% Cu, 30% Zn)	32	672
	212	720
Bronze		1308
Cadmium	64	644
	212	626
Copper, pure	64	2688
	212	2616
Gold	64	2028
	212	2040
Iron, pure	64	468
	212	439
Iron, wrought	64	419
	212	415
Iron, cast	129	332
	216	322
Lead	64	241
	212	238
Magnesium	32-212	1104
Mercury	32	58
Nickel	64	432

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTIVITY OF MATERIALS - Continued

k = Btu in/hr, sq ft, in, °F

Metals	Mean Temp °F	k
Platinum	64	482
	212	503
Silver	64	2904
		2856
Sodium	32	384
Steel, 1% carbon content	64	314
	212	311
Steel, mild	212	312
Steel, 13% Cr, 0.2% Ni	932	199
Steel, 18% Cr, 8% Ni	932	149
Steel, 23% Cr, 12% Ni	932	130
Steel Wool, density 6.3 lbs/cu ft	50-212	0.607
Tantalium	64	384
Tin	64	432
Zinc	212	308
	64	780
	212	768

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THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTIVITY OF MATERIALS

k = Btu in/hr, sq ft, in, °F

Gases	Mean Temp °F	k
Air	32	0.168
Ammonia	32	0.151
Argon	32	0.110
Carbon dioxide	32	0.101
	212	0.154
Carbon monoxide	32	0.162
Chlorine	32	0.052
Ethane	32	0.127
Ethylene	32	0.121
Helium	32	0.982
Hydrogen	32	1.159
	122	1.488
Methane	32	0.210
Neon	32	0.0307
Nitrogen	32	0.168
Oxygen	32	0.170
Steam	32	0.117

Liquids	Mean Temp °F	k
Acetone	68	1.236
Ammonia	45	3.480
Ethyl alcohol	68	1.260
Methyl alcohol	68	1.488
Petroleum oil (Average)	68	1.00
Sulphur dioxide	68	2.34
Water	68	4.10

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTIVITY OF MATERIALS
k = Btu in/hr, sq ft, in, °F

Woods, Oven Dried (heat flow across grain)	Density lb/cu ft	Mean Temp °F	k
Aspen	26	85	0.828
Bald cypress	24	85	0.756
Balsa	10	85	0.408
Balsam wool	2.2	90	0.27
Boxwood	56	68	10.45
Basswood	24	85	0.696
Douglas fir	29	85	0.756
Elm rock	48	85	1.164
Elm, soft	34	75	0.88
Fir, white	26	85	0.828
Hemlock	29	85	0.792
Larch, western	36	85	0.936
Maple, sugar	43	85	1.128
Maple, soft	36	75	0.089
Oak, red	42	85	1.188
Pine, southern yellow	35	85	0.936
Pine, white	25	85	0.72
Red cedar, western	21	85	0.636
Redwood	25	85	0.744
Redwood, California	22	75	0.66
Spruce	21	85	0.624

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THERMAL PROPERTIES OF MATERIALS

THERMAL CONDUCTANCES OF AIR SPACES
Btu/hr, sq ft, ° F

MEAN TEMPERATURE ° F	Width of Air Space, Inches						
	0.128	0.250	0.364	0.493	0.713	1.00	1.50
20	2.300	1.370	1.180	1.100	1.040	1.030	1.022
30	2.385	1.425	1.234	1.148	1.080	1.070	1.065
40	2.470	1.480	1.288	1.193	1.125	1.112	1.105
50	2.560	1.535	1.340	1.242	1.168	1.152	1.149
60	2.650	1.590	1.390	1.295	1.210	1.195	1.188
70	2.730	1.648	1.440	1.340	1.250	1.240	1.228
80	2.819	1.702	1.492	1.390	1.295	1.280	1.270
90	2.908	1.757	1.547	1.433	1.340	1.320	1.310
100	2.990	1.813	1.600	1.486	1.380	1.362	1.350
110	3.078	1.870	1.650	1.534	1.425	1.402	1.392
120	3.167	1.928	1.700	1.580	1.467	1.445	1.435
130	3.250	1.980	1.750	1.630	1.510	1.485	1.475
140	3.340	2.035	1.800	1.680	1.550	1.530	1.519
150	3.425	2.090	1.852	1.728	1.592	1.569	1.559

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THERMAL PROPERTIES OF MATERIALS

SPECIFIC HEATS AND WEIGHTS OF MATERIALS

Material	Temperature °F	Mean Specific Heat	Weight lbs/cu ft
Aluminum		0.215	168
Asbestos	32-212	0.20	150
Bakelite - Phenolic	32-212	0.3-0.4	
Brass, yellow	32-212	0.088	534
Brass, red	32-212	0.09	534
Bronze	32-212	0.014	509-554
Brick	32-212	0.20-0.22	125-143
Carbon	32-212	0.165	139
Chalk	32-212	0.215	143
Charcoal	32-212	0.20	25
Cinders	32-212	0.18	
Coal	32-212	0.24-0.3	81-94
Concrete	32-212	0.156	137
Cork	32-212	0.485	
Coke	32-212	0.203	75
Copper	32-212	0.094	556
Glass	32-212	0.12-0.19	162
Graphite	32-212	0.201	135
Gold		0.031	1205
Granite	32-212	0.195	168
Gypsum	32-212	0.259	155
Humus (soil)	32-212	0.44	76-100
Ice		0.465	56
Ice	32	0.487	64
Iron, cast		0.130	442
Iron, wrought	32-212	0.110	485
Iron, wrought	32-572	0.122	485
Iron, at high temperatures	1382-1832	0.213	485
Lead		0.031	710
Limestone		0.217	155-162

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THERMAL PROPERTIES OF MATERIALS

SPECIFIC HEATS AND WEIGHTS OF MATERIALS - Continued

Material	Temperature °F	Mean Specific Heat	Weight lbs/cu ft
Marble	32-212	0.210	170
Mercury	32-212	0.033	850
Masonry, brick	32-212	0.20-0.22	
Nickel		0.109	537
Oil, machine	0.	0.400	
Porcelain	32-212	0.22	
Quartz	32-212	0.17-0.28	165
Sand	32-212	0.195	100-125
Sandstone	32-212	0.22	143
Silver		0.056	655
Silica		0.191	
Steel, mild		0.116	485
Steel, high carbon		0.117	485
Stone, average		0.200	150
Tin		0.056	459
Water		1.000	62.4
Wood, fir		0.650	25-32
Wood, oak		0.570	42-54
Wood, pine		0.67	27-42
Zinc		0.095	440

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THERMAL PROPERTIES OF MATERIALS

HEAT UNITS FOR WATER AT VARIOUS TEMPERATURES

Temp., deg.F	Lb. per cu. ft.	B.t.u. per lb.	Temp., deg.F	Lb. per cu. ft.	B.t.u. per lb.	Temp., deg.F	Lb. per cu. ft.	B.t.u. per lb.	Temp., deg.F	Lb. per cu. ft.	B.t.u. per lb.
32	62.41	0.	91	62.10	58.99	150	61.19	117.84	208	59.92	175.98
33	62.41	1.01	92	62.08	59.98	151	61.17	118.85	209	59.90	176.99
34	62.42	2.01	93	62.07	60.98	152	61.15	119.85	210	59.87	177.99
35	62.42	3.02	94	62.06	61.97	153	61.13	120.85	211	59.85	179.00
36	62.42	4.03	95	62.05	62.96	154	61.11	121.85	212	59.82	180.00
37	62.42	5.03	96	62.04	63.96	155	61.09	122.85	214	59.81	182.02
38	62.42	6.04	97	62.02	64.95	156	61.07	123.85	216	59.77	184.03
39	62.42	7.04	98	62.01	56.94	157	61.05	124.85	218	59.70	186.04
40	62.42	8.05	99	62.00	66.94	158	61.03	125.85	220	59.67	188.06
41	62.42	9.05	100	61.99	67.93	159	61.01	126.85	230	59.42	198.15
42	62.42	10.05	101	61.98	68.92	160	60.99	127.85	240	59.17	208.26
43	62.42	11.05	102	61.96	69.92	161	60.97	128.85	250	58.89	218.39
44	62.42	12.05	103	61.95	70.91	162	60.95	129.85	260	58.62	228.55
45	62.42	13.05	104	61.94	71.91	163	60.93	130.85	270	58.34	238.74
46	62.41	14.06	105	61.93	72.91	164	60.91	131.85	280	58.04	248.95
47	62.41	15.06	106	61.91	73.90	165	60.89	132.85	290	57.74	259.20
48	62.41	16.06	107	61.90	74.90	166	60.87	133.85	300	57.41	269.48
49	62.41	17.06	108	61.89	75.90	167	60.85	134.85	310	57.08	279.80
50	62.40	18.06	109	61.87	76.89	168	60.83	135.85	320	56.75	290.17
51	62.40	19.06	110	61.86	77.89	169	60.81	136.85	330	56.40	300.59
52	62.40	20.06	111	61.84	78.89	170	60.79	137.85	340	56.02	311.05
53	62.39	21.06	112	61.83	79.89	171	60.77	138.85	350	55.65	321.55
54	62.39	22.06	113	61.81	80.89	172	60.75	139.85	360	55.25	332.10
55	62.38	23.06	114	61.80	81.89	173	60.73	140.85	370	54.85	342.71
56	62.38	24.05	115	61.78	82.89	174	60.71	141.85	380	54.47	353.39
57	62.38	25.05	116	61.77	83.88	175	60.68	142.86	390	54.05	364.14
58	62.37	26.05	117	61.75	84.88	176	60.66	143.86	400	53.62	374.96
59	62.37	27.05	118	61.74	85.88	177	60.64	144.86	410	53.19	385.86
60	62.36	28.05	119	61.72	86.88	178	60.62	145.86	420	52.74	396.84
61	62.35	29.05	120	61.71	87.88	179	60.60	146.87	430	52.33	407.91
62	62.35	30.05	121	61.69	88.88	180	60.57	147.87	440	51.87	419.07
63	62.34	31.05	122	61.68	89.88	181	60.55	148.87	450	51.28	430.3
64	62.34	32.04	123	61.66	90.88	182	60.53	149.87	460	51.02	441.7
65	62.33	33.04	124	61.64	91.88	183	60.51	150.87	470	50.51	453.2
66	62.32	34.04	125	61.63	92.87	184	60.49	151.87	480	50.00	465.0
67	62.32	35.04	126	61.61	93.87	185	60.46	152.87	490	49.50	477.0
68	62.31	36.03	127	61.60	94.87	186	60.44	153.88	500	48.78	489.1
69	62.30	37.03	128	61.58	95.87	187	60.42	154.88	510	48.31	501.6
70	62.30	38.03	129	61.56	96.86	188	60.40	155.88	520	47.62	514.2
71	62.29	39.03	130	61.55	97.86	189	60.37	156.89	530	46.95	527.0
72	62.28	40.02	131	61.53	98.86	190	60.35	157.89	540	46.30	540.0
73	62.27	41.02	132	61.51	99.86	191	60.33	158.90	550	45.66	553.2
74	62.26	42.02	133	61.50	100.86	192	60.30	159.90	560	44.84	566.7
75	62.25	43.01	134	61.48	101.85	193	60.28	160.90	570	44.05	580.4
76	62.25	44.01	135	61.46	102.85	194	60.26	161.91	580	43.29	594.4
77	62.24	45.01	136	61.44	103.85	195	60.23	162.91	590	42.37	608.7
78	62.23	46.00	137	61.43	104.85	196	60.21	163.92	600	41.49	623.2
79	62.22	47.00	138	61.41	105.84	197	60.19	164.92	610	40.49	638.0
80	62.21	48.00	139	61.39	106.84	198	60.16	165.93	620	39.37	653.4
81	62.20	49.00	140	61.37	107.84	199	60.14	166.93	630	38.31	669.5
82	62.19	50.00	141	61.36	108.84	200	60.11	167.94	640	37.17	686.6
83	62.18	51.00	142	61.34	109.84	201	60.09	168.95	650	35.97	705 2
84	62.17	52.00	143	61.32	110.84	202	60.07	169.95	660	34.48	725.3
85	62.16	53.00	144	61.30	111.84	203	60 04	170.96	670	32.89	747.5
86	62.15	54.00	145	61.28	112.84	204	60.02	171.96	680	31.06	772.6

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

STEAM TABLES

1—SAT PRESSURES

Abs press Psia	Temp F	Specific vol Sat liquid	Specific vol Sat vapor	Enthalpy ("Heat") Sat liquid	Enthalpy ("Heat") Evap	Enthalpy ("Heat") Sat vapor
0.50	79.58	0.01608	641.6	47.6	1048.8	1096.4
1.0	101.74	0.01614	333.6	69.7	1036.3	1106.0
2.0	126.08	0.01623	173.73	94.0	1022.2	1116.2
3.0	141.48	0.01630	118.71	109.4	1013.2	1122.6
4.0	152.97	0.01636	90.63	120.9	1006.4	1127.3
5.0	162.24	0.01640	73.52	130.1	1001.0	1131.1
6.0	170.06	0.01645	61.98	138.0	996.2	1134.2
7.0	176.85	0.01649	53.64	144.8	992.1	1136.9
8.0	182.86	0.01653	47.34	150.8	988.5	1139.3
9.0	188.28	0.01656	42.40	156.2	985.2	1141.4
10	193.21	0.01659	38.42	161.2	982.1	1143.3
14.7	212.00	0.01672	26.80	180.0	970.4	1150.4
15	213.03	0.01672	26.29	181.1	969.7	1150.8
20	227.96	0.01683	20.089	196.2	960.1	1156.3
25	240.07	0.01692	16.303	208.5	952.1	1160.6
30	250.33	0.01701	13.746	218.8	945.3	1164.1
40	267.25	0.01715	10.498	236.0	933.7	1169.7
50	281.01	0.01727	8.514	250.1	924.0	1174.1
60	292.71	0.01738	7.175	262.1	915.5	1177.6
70	302.92	0.01748	6.206	272.6	907.9	1180.6
80	312.03	0.01757	5.472	282.0	901.1	1183.1
90	320.27	0.01766	4.896	290.6	894.7	1185.3
100	327.81	0.01774	4.432	298.4	888.8	1187.2
110	334.77	0.01782	4.049	305.7	883.2	1188.9
120	341.25	0.01789	3.728	312.4	877.9	1190.4
130	347.32	0.01796	3.455	318.8	872.9	1191.7
140	353.02	0.01802	3.220	324.8	868.2	1193.0
150	358.42	0.01809	3.015	330.5	863.6	1194.1
160	363.53	0.01815	2.834	335.9	859.2	1195.1
170	368.41	0.01822	2.675	341.1	854.9	1196.0
180	373.06	0.01827	2.532	346.1	850.8	1196.9
190	377.51	0.01833	2.404	350.8	846.8	1197.6
200	381.79	0.01839	2.288	355.4	843.0	1198.4
250	400.95	0.01865	1.8438	376.0	825.1	1201.1
300	417.33	0.01890	1.5433	393.8	809.0	1202.8
350	431.77	0.01913	1.3269	409.7	794.2	1203.9
400	444.59	0.0193	1.1613	424.0	780.5	1204.5
450	456.28	0.0195	1.0328	437.2	767.4	1204.6
500	467.01	0.0197	0.9278	449.4	755.0	1204.4
600	486.21	0.0201	0.7698	471.6	731.6	1203.2
700	503.10	0.0205	0.6554	491.5	709.7	1201.2
800	518.23	0.0209	0.5687	509.7	688.9	1198.6
900	531.98	0.0212	0.5006	526.6	668.8	1195.4
1000	544.61	0.0216	0.4456	524.4	649.4	1191.8
1200	567.22	0.0223	0.3619	571.7	611.7	1183.4
1500	596.23	0.0235	0.2765	611.6	556.3	1167.9

2—SAT TEMPERATURES

Temp F	Abs press Psia	Specific vol Sat liquid	Specific vol Sat vapor	Enthalpy ("Heat") Sat liquid	Enthalpy ("Heat") Evap	Enthalpy ("Heat") Sat vapor
32	0.08854	0.01602	3306	0.00	1075.8	1075.8
35	0.09995	0.01602	2947	3.02	1074.1	1077.1
40	0.12170	0.01602	2444	8.05	1071.3	1079.3
45	0.14752	0.01602	2036.4	13.06	1068.4	1081.5
50	0.17811	0.01603	1703.2	18.07	1065.6	1083.7
55	0.2141	0.01603	1430.7	23.07	1062.7	1085.8
60	0.2563	0.01604	1206.7	28.06	1059.9	1088.0
65	0.3056	0.01605	1021.4	33.05	1057.1	1090.2
70	0.3631	0.01606	867.9	38.04	1054.3	1092.3
75	0.4298	0.01607	740.0	43.03	1051.5	1094.5
80	0.5069	0.01608	633.1	48.02	1048.6	1096.6
85	0.5959	0.01609	543.5	53.00	1045.8	1098.8
90	0.6982	0.01610	468.0	57.99	1042.9	1100.9
95	0.8153	0.01612	404.3	62.98	1040.1	1103.1
100	0.9492	0.01613	350.4	67.97	1037.2	1105.2
105	1.1016	0.01615	304.5	72.95	1034.3	1107.3
110	1.2748	0.01617	265.4	77.94	1031.6	1109.5
115	1.4709	0.01618	231.9	82.93	1028.7	1111.6
120	1.6924	0.01620	203.27	87.92	1025.8	1113.7
125	1.9420	0.01622	178.61	92.91	1022.9	1115.8
130	2.2225	0.01625	157.34	97.90	1020.0	1117.9
135	2.5370	0.01627	138.95	102.9	1017.0	1119.9
140	2.8886	0.01629	123.01	107.9	1014.1	1122.0
145	3.281	0.01632	109.15	112.9	1011.2	1124.1
150	3.718	0.01634	97.07	117.9	1008.2	1126.1
155	4.203	0.01637	86.52	122.9	1005.2	1128.1
160	4.741	0.01639	77.29	127.9	1002.3	1130.2
165	5.335	0.01642	69.15	132.9	999.3	1132.2
170	5.992	0.01645	62.06	137.9	996.3	1134.2
175	6.715	0.01648	55.78	142.9	993.3	1136.2
180	7.510	0.01651	50.23	147.9	990.2	1138.1
185	8.383	0.01654	45.31	152.9	987.2	1140.1
190	9.339	0.01657	40.96	157.9	984.1	1142.0
200	11.526	0.01663	33.64	168.0	977.9	1145.9
210	14.123	0.01670	27.82	178.1	971.6	1149.7
212	14.696	0.01672	26.80	180.0	970.4	1150.4
220	17.186	0.01677	23.15	188.1	965.2	1153.4
240	24.969	0.01692	16.323	208.3	952.2	1160.5
260	35.429	0.01709	11.763	228.6	938.7	1167.3
280	49.203	0.01726	8.645	249.1	924.7	1173.8
300	67.013	0.01745	6.466	269.6	910.1	1179.7
350	134.63	0.01799	3.342	321.6	870.7	1192.3
400	247.31	0.01864	1.8633	375.0	826.0	1201.0
450	422.6	0.0194	1.0993	430.1	774.5	1204.6
500	680.8	0.0204	0.6749	487.8	713.9	1201.7
550	1045.2	0.0218	0.4260	549.3	640.8	1190.0

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

STEAM TABLES

3 — SUPERHEATED STEAM

Abs Pressure Psi (Sat temp)		Sat liquid	Sat vapor	Temperature, degrees F								
				300	400	500	600	700	800	900	1000	1200
15	v	0.02	26.29	29.93	33.97	37.99	41.99	45.98	49.97	53.95	57.93	65.89
(213.03)	h	181.1	1150.8	1192.8	1239.9	1287.1	1334.8	1383.1	1432.1	1482.1	1532.8	1636.5
20	v	0.02	20.09	22.36	25.43	28.46	31.47	34.47	37.46	40.45	43.44	49.41
(227.96)	h	196.2	1156.3	1191.6	1239.2	1286.6	1334.4	1382.9	1432.1	1482.1	1532.8	1636.4
40	v	0.017	10.498	11.040	12.628	14.168	15.688	17.198	18.707	20.20	21.70	24.68
(267.25)	h	236.0	1168.7	1186.0	1236.5	1286.8	1333.1	1381.9	1431.3	1481.4	1532.4	1636.0
60	v	0.017	7.175	7.259	8.357	9.403	10.427	11.441	12.449	13.452	14.454	16.451
(292.71)	h	262.1	1177.6	1181.6	1233.6	1283.8	1331.8	1380.9	1430.5	1480.8	1531.9	1636.6
80	v	0.018	5.472	.....	6.270	7.020	7.797	8.562	9.322	10.077	10.830	12.332
(312.03)	h	282.0	1183.1	.....	1230.7	1281.1	1330.5	1379.9	1429.7	1480.1	1531.3	1636.2
100	v	0.018	4.432	.....	4.937	5.589	6.218	6.835	7.446	8.052	8.656	9.860
(327.81)	h	298.4	1187.2	.....	1227.6	1279.3	1329.1	1378.9	1428.9	1479.5	1530.8	1635.7
150	v	0.018	3.015	.....	3.273	3.681	4.113	4.537	4.944	5.352	5.758	6.564
(358.42)	h	330.5	1194.1	.....	1219.4	1274.1	1325.7	1376.3	1426.9	1477.8	1529.4	1634.7
200	v	0.018	2.288	.....	2.361	2.726	3.060	3.380	3.693	4.002	4.309	4.917
(381.79)	h	355.4	1198.4	.....	1210.3	1268.9	1322.1	1373.6	1424.8	1476.2	1528.0	1633.7
250	v	0.0187	1.8438	.....	.....	2.151	2.427	2.688	2.942	3.192	3.439	3.928
(400.95)	h	376.0	1201.1	.....	.....	1263.4	1318.5	1371.0	1422.3	1474.5	1526.6	1632.7
300	v	0.0189	1.5433	.....	.....	1.7675	2.006	2.227	2.442	2.652	2.859	3.269
(417.33)	h	393.8	1202.8	.....	.....	1257.6	1314.7	1368.3	1420.6	1472.8	1525.2	1631.7
400	v	0.0193	1.1613	.....	.....	1.2851	1.4778	1.6608	1.8361	1.9767	2.134	2.445
(444.59)	h	424.0	1204.5	.....	.....	1245.1	1306.9	1362.7	1416.4	1469.4	1522.4	1629.6
500	v	0.0197	0.9278	.....	.....	0.9227	1.1591	1.3044	1.4405	1.5715	1.6996	1.9504
(467.01)	h	449.4	1204.4	.....	.....	1231.3	1298.6	1357.0	1412.1	1466.9	1519.6	1627.6
600	v	0.0201	0.7698	.....	.....	0.7947	0.9643	1.0732	1.1899	1.3013	1.4096	1.6208
(486.21)	h	471.6	1203.2	.....	.....	1215.7	1289.9	1351.1	1407.7	1462.5	1516.7	1625.5
700	v	0.0209	0.5687	.....	.....	.....	0.8279	0.9233	0.9763	1.0633	1.0470	1.2098
(503.23)	h	509.7	1198.6	.....	.....	.....	1270.7	1338.6	1398.6	1455.4	1511.0	1621.0
800	v	0.0216	0.4456	.....	.....	.....	0.5140	0.6084	0.6878	0.7604	0.8294	0.9615
(518.21)	h	542.4	1191.8	.....	.....	.....	1248.8	1325.3	1389.2	1448.2	1505.1	1617.3
900	v	0.0225	0.3585	.....	.....	.....	0.3815	0.4719	0.5552	0.6293	0.6990	0.8318
(531.98)	h	574.6	1183.7	.....	.....	.....	1224.5	1312.2	1379.3	1440.3	1498.1	1613.8
1000	v	0.0235	0.2995	.....	.....	.....	.....	0.3849	0.4552	0.5172	0.5751	0.6868
(544.61)	h	605.8	1174.9	.....	.....	.....	.....	1298.4	1369.3	1433.0	1492.8	1610.2
1100	v	0.0246	0.2555	.....	.....	.....	.....	0.3208	0.3837	0.4378	0.4877	0.5833
(556.31)	h	636.3	1165.4	.....	.....	.....	.....	1283.6	1358.9	1425.4	1486.9	1606.5
1200	v	0.0257	0.2213	.....	.....	.....	.....	0.2731	0.3294	0.3777	0.4220	0.5059
(567.22)	h	667.2	1155.4	.....	.....	.....	.....	1268.0	1348.2	1417.6	1481.0	1602.7
1300	v	0.0269	0.1945	.....	.....	.....	.....	0.2369	0.2884	0.3324	0.3722	0.4477
(577.46)	h	698.6	1144.5	.....	.....	.....	.....	1251.4	1337.2	1409.6	1475.0	1599.0
1400	v	0.0282	0.1732	.....	.....	.....	.....	0.2085	0.2557	0.2962	0.3328	0.4008
(587.10)	h	730.6	1133.1	.....	.....	.....	.....	1233.6	1325.8	1401.5	1468.8	1595.3
1500	v	0.0296	0.1555	.....	.....	.....	.....	0.1846	0.2290	0.2661	0.2991	0.3618
(596.23)	h	763.3	1121.1	.....	.....	.....	.....	1215.1	1313.8	1393.1	1462.5	1591.6
1600	v	0.0312	0.1410	.....	.....	.....	.....	0.1646	0.2060	0.2400	0.2701	0.3279
(604.92)	h	797.2	1108.6	.....	.....	.....	.....	1196.0	1301.5	1384.5	1456.1	1587.9
1700	v	0.0330	0.1294	.....	.....	.....	.....	0.1481	0.1862	0.2175	0.2457	0.2997
(613.30)	h	832.5	1095.3	.....	.....	.....	.....	1176.0	1288.9	1375.6	1449.3	1584.1
1800	v	0.0351	0.1196	.....	.....	.....	.....	0.1346	0.1696	0.1986	0.2247	0.2749
(621.43)	h	870.3	1080.9	.....	.....	.....	.....	1154.9	1275.2	1365.8	1441.8	1580.3
1900	v	0.0375	0.1113	.....	.....	.....	.....	0.1232	0.1557	0.1829	0.2072	0.2535
(629.34)	h	911.1	1065.4	.....	.....	.....	.....	1132.1	1260.8	1354.9	1433.4	1576.4
2000	v	0.0406	0.1042	.....	.....	.....	.....	0.1134	0.1437	0.1690	0.1917	0.2348
(636.99)	h	956.6	1048.1	.....	.....	.....	.....	1108.1	1245.8	1343.5	1424.5	1572.3
2100	v	0.0447	0.0981	.....	.....	.....	.....	0.1048	0.1331	0.1567	0.1780	0.2182
(644.47)	h	1008.3	1028.8	.....	.....	.....	.....	1082.1	1230.1	1331.5	1415.1	1568.1
2200	v	0.0507	0.0929	.....	.....	.....	.....	0.0973	0.1236	0.1457	0.1657	0.2032
(651.76)	h	1080.9	1007.4	.....	.....	.....	.....	1054.4	1213.2	1318.8	1405.4	1563.8
2300	v	0.0617	0.0885	.....	.....	.....	.....	0.0907	0.1153	0.1360	0.1548	0.1900
(658.91)	h	1189.1	982.7	.....	.....	.....	.....	1024.7	1195.2	1305.9	1395.5	1558.9
2400	v	0.0503	0.0843	.....	.....	.....	.....	0.0847	0.1080	0.1276	0.1453	0.1784
(665.93)	h	902.7	902.7	.....	.....	.....	.....	990.8	1176.9	1292.8	1385.4	1553.9

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

PSYCHOMETRIC INFORMATION

VAPOR PRESSURES
at 100% Relative Humidity

TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE		TEMP.		VAPOR PRESSURE	
°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.	°F	°C	In. of Hg.	Lbs./Sq.Ft.
-40	-40	.0029	.2758	32	0.0	.1803	12.752	77	25.0	.9352	66.147	134	56.7	5.03	355.77
-35	-37.2	.0052	.3678	33	0.6	.1878	13.283	78	25.6	.9666	68.367	136	57.8	5.30	374.87
-30	-34.4	.0070	.4951	34	1.1	.1955	13.827	79	26.1	.9989	70.652	138	58.9	5.59	395.38
-25	-31.7	.0064	.6648	35	1.7	.2035	14.393	80	26.7	1.032	72.993	140	60.0	5.88	415.89
-20	-28.9	.0126	.8912	36	2.2	.2218	14.981	81	27.2	1.066	75.398	142	61.1	6.19	437.82
-15	-26.1	.0167	1.181	37	2.8	.2403	15.582	82	27.8	1.102	77.944	144	62.2	6.51	460.45
-10	-23.3	.0220	1.556	38	3.3	.2492	16.211	83	28.3	1.138	80.490	146	63.3	6.85	484.50
-5	-20.6	.0289	2.044	39	3.9	.2383	16.855	84	28.9	1.175	83.108	148	64.4	7.20	509.25
0	-17.8	.0377	2.667	40	4.4	.2478	17.527	86	29.4	1.213	85.795	150	65.6	7.57	535.42
1	-17.2	.0397	2.808	41	5.0	.2576	18.220	86	30.0	1.253	88.625	152	66.7	7.95	562.20
2	-16.7	.0419	2.964	42	5.6	.2677	18.934	87	30.6	1.293	91.454	154	67.8	8.35	590.59
3	-16.1	.0441	3.119	43	6.1	.2782	19.677	88	31.1	1.335	94.452	156	68.9	8.77	620.30
4	-15.6	.0464	3.282	44	6.7	.2891	20.448	89	31.7	1.378	97.466	158	70.0	9.20	650.71
5	-15	.0488	3.452	45	7.2	.3004	21.247	90	32.2	1.422	99.578	160	71.1	9.65	682.54
6	-14.4	.0514	3.636	46	7.8	.3120	22.068	91	32.8	1.467	103.76	162	72.2	10.12	715.78
7	-13.9	.0542	3.869	47	8.3	.3240	22.916	99	33.3	1.513	107.01	164	73.3	10.61	750.44
8	-13.3	.0570	4.032	48	8.9	.3364	23.794	93	33.9	1.561	110.41	166	74.4	11.12	786.52
9	-12.8	.0599	4.237	49	9.4	.3493	24.706	94	34.4	1.610	113.87	168	75.6	11.65	824.00
10	-12.2	.0629	4.449	50	10.0	.3626	25.64	95	35.0	1.660	117.41	170	76.7	12.20	862.90
11	-11.7	.0661	4.675	51	10.6	.3764	26.623	96	35.6	1.712	121.09	172	77.8	12.77	903.22
12	-11.1	.0695	4.916	52	11.1	.3906	27.627	97	36.1	1.765	124.84	174	78.9	13.37	945.66
13	-10.6	.0730	5.163	53	11.7	.4052	28.659	98	36.7	1.819	128.65	176	80.0	13.98	994.41
14	-10.0	.0767	5.425	54	12.2	.4203	29.728	99	37.2	1.875	132.62	178	81.1	14.63	1034.78
15	-9.4	.0806	5.701	55	12.8	.4359	30.831	100	37.8	1.933	136.72	180	82.2	15.29	1081.46
16	-8.9	.0847	5.990	56	13.3	.4520	31.970	101	38.3	1.992	140.89	182	83.3	15.98	1130.26
17	-8.3	.0889	6.288	57	13.9	.4686	33.144	102	38.9	2.052	145.14	184	84.4	16.70	1181.19
18	-7.6	.0933	6.599	58	14.4	.4858	34.360	103	39.4	2.114	149.52	186	85.6	17.44	1233.53
19	-7.2	.0979	6.924	59	15.0	.5035	35.612	104	40.0	2.178	154.05	188	86.7	18.21	1287.99
20	-6.7	.1028	7.271	60	15.6	.5218	36.906	105	40.6	2.24	158.43	190	87.8	19.01	1344.58
21	-6.1	.1078	7.625	61	16.1	.5407	38.244	106	41.1	2.31	163.39	192	88.9	19.84	1403.28
22	-5.6	.1131	7.999	62	16.7	.5601	39.616	107	41.7	2.38	168.34	194	90.0	20.70	1464.11
23	-5.0	.1186	8.388	63	17.2	.5802	41.037	108	42.2	2.45	173.29	196	91.1	21.59	1527.06
24	-4.4	.1243	8.792	64	17.8	.6009	42.501	109	42.8	2.52	178.23	198	92.2	22.52	1592.84
25	-3.9	.1303	9.216	65	18.3	.6222	44.008	110	43.3	2.60	183.89	200	93.3	23.47	1660.03
26	-3.3	.1366	9.662	66	18.9	.6422	45.564	112	44.4	2.75	194.51	202	94.4	24.46	1730.06
27	-2.8	.1432	10.128	67	19.4	.6669	47.169	114	45.6	2.91	205.82	204	95.6	25.48	1802.20
28	-2.2	.1500	10.609	68	20.0	.6903	48.825	116	46.7	3.08	217.85	206	96.7	26.53	1876.47
29	-1.7	.1571	11.112	69	20.6	.7144	50.529	118	47.8	3.26	230.58	208	97.8	27.63	1954.27
30	-1.1	.1645	11.635	70	21.1	.7392	52.283	120	48.9	3.45	244.02	210	98.9	28.76	2034.19
31	-0.6	.1723	12.186	71	21.7	.7648	54.044	122	50.0	3.64	257.45	212	100.0	29.92	2116.24
32	0.0	.1803	12.752	72	22.2	.7912	55.961	124	51.1	3.85	272.31	214	101.1	31.13	2201.82
				73	22.8	.8183	57.878	126	52.2	4.06	287.16	216	102.2	32.38	2290.24
				74	23.3	.8462	59.311	128	53.5	4.29	303.43	218	103.3	33.66	2380.77
				75	23.9	.8750	61.889	130	54.4	4.53	320.41	220	104.4	34.90	2414.48
				76	24.4	.9064	63.892	132	55.6	4.77	337.38				

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

PSYCHOMETRIC INFORMATION

TABLE II

DEW POINT TEMPERATURE °F

DRY BULB TEMP. °F	% RELATIVE HUMIDITY																				
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5	-35	-30	-25	-21	-17	-14	-12	-10	-8	-6	-5	-4	-2	-1	1	2	3	4	5
10	-31	-25	-20	-16	-13	-10	-7	-5	-3	-2	0	2	3	4	5	7	8	9	10
15	-28	-21	-16	-12	-8	-5	-3	-1	1	3	5	6	8	9	10	12	13	14	15
20	-24	-16	-11	-8	-4	-2	2	4	6	8	10	11	13	14	15	16	18	19	20
25	-20	-15	-8	-4	0	3	6	8	10	12	15	16	18	19	20	21	23	24	25
30	-15	-4	-3	2	5	8	11	13	15	17	20	22	23	24	25	27	28	29	30
35	-12	-5	1	5	9	12	15	18	20	12	24	26	27	28	30	32	33	34	35
40	-7	0	5	9	14	16	19	22	24	26	28	29	31	33	35	36	38	39	40
45	-4	3	9	13	17	20	23	25	28	30	32	34	36	38	39	41	43	44	45
50	-1	7	13	17	21	24	27	30	32	34	37	39	41	42	44	45	47	49	50
55	3	11	16	21	25	28	32	34	37	39	41	43	45	47	49	50	52	53	55
60	6	14	20	25	29	32	35	39	42	44	46	48	50	52	54	55	57	59	60
65	10	18	24	28	33	38	40	43	46	49	51	53	55	57	59	60	62	63	65
70	13	21	28	33	37	41	45	48	50	53	55	57	60	62	64	65	67	68	70
75	17	25	32	37	42	46	49	52	55	57	60	62	64	66	69	70	72	74	75
80	20	29	35	41	46	50	54	57	60	62	65	67	69	72	74	75	77	78	80
85	23	32	40	45	50	54	58	61	64	67	69	72	74	76	78	80	82	83	85
90	27	36	44	49	54	58	62	66	69	72	74	77	79	81	83	85	87	89	90
95	30	40	48	54	59	63	67	70	73	76	79	82	84	86	88	90	91	93	95
100	34	44	52	58	63	68	71	75	78	81	84	86	88	91	92	94	96	98	100
105	38	48	56	62	67	72	76	79	82	85	88	90	93	95	97	99	101	103	105
110	41	52	60	66	71	77	80	84	87	90	92	95	98	100	102	104	106	108	110
115	45	56	64	70	75	80	84	88	91	94	97	100	102	105	107	109	111	113	115
120	48	60	68	74	79	85	88	92	96	99	102	105	107	109	112	114	116	118	120
125	52	63	72	78	84	89	93	97	100	104	107	109	111	114	117	119	121	123	125

Problem: Given a "Dry-Bulb" temperature of 60F and a relative humidity of 25% Find the Dew Point Temperature.

Solution: From a 'Dry-Bulb' temperature of 60F in the left column, read across the table to the right. Where this line intersects the column of 25% relative humidity, we read a Dew Point Temperature of 25 F.

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APPENDIX

THERMAL PROPERTIES OF MATERIALS

PSYCHROMETRIC INFORMATION

PERCENT RELATIVE HUMIDITY ABOVE WHICH CONDENSATION WILL OCCUR ON SURFACE OF EQUIPMENT OR PIPE NOT INSULATED

EQUIP. OR PIPE TEMP. F	AMBIENT AIR TEMPERATURE ° F												
	40	45	50	55	60	65	70	75	80	85	90	95	100
35	82	68	57	48	39	33	28	24	20	17	15	13	11
40		82	68	57	48	40	33	28	24	20	17	15	14
45			82	69	57	48	41	34	29	25	21	18	16
50				82	69	57	49	41	35	30	26	22	19
55					83	70	59	50	42	36	31	27	23
60						84	70	60	51	43	37	32	27
65							84	71	60	52	44	38	33
70								84	71	61	52	45	38
75									84	72	62	53	46
80										85	73	63	54
85											85	73	63
90												86	74
95													86

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APPENDIX

WATER VAPOR PERMEABILITY TABLE
MISCELLANEOUS MATERIALS

MATERIAL	PERMEABILITY, perms
Aluminum foil, 0.0025 inch thickness	0.005 to 0.01
Aluminum foil, 0.001 inch thickness	0.01 to 0.05
Aluminum foil, cloth backed	0.004
Aluminum tape, paper backed	0.006
Asphalt-saturated 15 lb felt, coated with 25 lb asphalt per 100 sq. ft.	0.05
Calcium-silicate insulation, one inch thickness	21 to 35
Cellular glass insulation, one-half inch thickness	0.00005
Cork, one inch thickness	3 to 7
Duplex laminated kraft paper (30-30-30)	0.20
Duplex laminated kraft paper, reinforced	0.70
Fiberboard, 3/4 inch thickness	12.5
Foil-faced kraft paper	0.01
Foil-faced reflective insulation, double faced	0.08 to 0.13
Friction tape, single layer	2.34
double layer	1.45
Gypsum lath, metallic aluminum backing	0.09 to 0.39
Laminated paper and foil	0.01
Mineral wool, unprotected, 4 inch thickness	29.07
Plaster, fiberboard or gypsum lath	19.7 to 20.6
Plywood, 2 coats aluminum paint	1.29
Plywood, 2 coats asphalt paint	0.43
Polyethylene, 0.004 inch thickness	0.10
Polyethylene, 0.03 inch thickness	0.002
Roll roofing, smooth 40-65 lb per 108 sq. ft.	0.13 to 0.17
Sheating paper, asphalt-impregnated, glossy	0.17 to 2.05
Vinyl membrane, 0.004 inch thickness	0.80 to 2.0

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APPENDIX

PIPE AND TUBE INSULATION DIMENSIONS

OUTSIDE DIAMETERS AND AVERAGE THICKNESSES FOR PIPE INSULATION
ASTM Recommended Practice

NPS Pipe		Insulation Thickness							
		1/2 Nominal		1" Nominal		1½" Nominal		2" Nominal	
NOM SIZE	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches
1/8	0.405	0.45	1.315	0.98	2.375	1.54	3.500	2.05	4.500
1/4	0.540	0.55	1.660	1.16	2.875	1.72	4.000	2.22	5.000
3/8	0.675	0.49	1.660	1.09	2.875	1.66	4.000	2.16	5.000
1/2	0.840	0.52	1.900	1.00	2.875	1.57	4.000	2.07	5.000
3/4	1.050	0.42	1.900	0.91	2.875	1.47	4.000	1.97	5.000
1	1.315	0.52	2.375	1.09	3.500	1.59	4.500	2.12	5.563
1¼	1.660	0.60	2.875	0.91	3.500	1.66	5.000	1.94	5.563
1½	1.900	0.48	2.875	1.04	4.000	1.54	5.000	2.36	6.625
2	2.375	0.55	3.500	1.05	4.500	1.58	5.563	2.11	6.625
2½	2.875	0.55	4.00	1.05	5.000	1.86	6.625	2.36	7.625
3	3.500	0.49	4.500	1.02	5.563	1.55	6.625	2.05	7.625
3½	4.000	0.49	5.000	1.30	6.625	1.80	7.625	2.30	8.625
4	4.500	0.52	5.563	1.05	6.625	1.55	7.625	2.05	8.625
4½	5.000	0.80	6.625	1.30	7.625	1.80	8.625	2.30	9.625
5	5.563	0.49	6.625	0.99	7.625	1.49	8.625	1.99	9.625
6	6.625	0.46	7.625	0.96	8.625	1.46	9.625	2.02	10.750
7	7.625					1.52	10.750	2.02	11.750
8	8.625					1.52	11.750	2.02	12.750
9	9.625					1.52	12.750	2.15	14.000
10	10.750					1.59	14.00	2.09	15.000
11	11.750					1.59	15.000	2.09	16.000
12	12.750					1.58	16.000	2.08	17.000
14	14.000					1.45	17.00	1.95	18.000
15	15.000					1.45	18.00	1.95	19.000
16	16.000					1.45	19.000	1.95	20.000
17	17.000					1.45	20.000	1.95	21.000
18	18.000					1.45	21.000	1.95	22.000
19	19.000					1.45	22.000	1.95	23.000
20	20.000					1.45	23.000	1.95	24.000
21	21.000					1.45	24.000	1.95	25.000
22	22.000					1.45	25.000	1.95	26.000
23	23.000					1.45	26.000	1.95	27.000
24	24.000					1.45	27.000	1.95	28.000
25	25.000					1.45	28.000	1.95	29.000
26	26.000					1.45	29.000	1.95	30.000
27	27.000					1.45	30.000	1.95	31.000
28	28.000					1.45	31.000	1.95	32.000
29	29.000					1.45	32.000	1.95	33.000
30	30.000					1.45	33.000	1.95	34.000
31	31.000					1.45	34.000	1.95	35.000
32	32.000					1.45	35.000	1.95	36.000
33	33.000					1.45	36.000	1.95	37.000
34	34.000					1.45	37.000	1.95	38.000
35	35.000					1.45	38.000	1.95	39.000
36	36.000					1.45	39.000	1.95	40.000

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APPENDIX

PIPE AND TUBE INSULATION DIMENSIONS

OUTSIDE DIAMETERS AND AVERAGE THICKNESSES FOR PIPE INSULATION
ASTM Recommended Practice

NPS Pipe		Insulation Thickness							
		2½" Nominal		3" Nominal		3½" Nominal		4" Nominal	
NOM SIZE	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches	Avg. Thk. Inches	O.D. Inches
1/8	0.405	2.57	5.563	3.10	6.625	3.60	7.625	4.10	8.625
1/4	0.540	2.50	5.563	3.04	6.625	3.54	7.625	4.04	8.625
3/8	0.675	2.44	5.563	2.97	6.625	3.47	7.625	3.97	8.625
1/2	0.840	2.89	6.625	3.39	7.625	3.89	8.625	4.39	9.625
3/4	1.050	2.78	6.625	3.28	7.625	3.78	8.625	4.28	9.625
1	1.315	2.64	6.625	3.15	7.625	3.65	8.625	4.15	9.625
1¼	1.660	2.48	6.625	2.98	7.625	3.48	8.625	3.98	9.625
1½	1.900	2.86	7.625	3.36	8.625	3.86	9.625	4.42	10.750
2	2.375	2.61	7.625	3.11	8.625	3.61	9.625	4.17	10.750
2½	2.875	2.86	8.625	3.36	9.625	3.92	10.750	4.42	11.750
3	3.500	2.55	8.625	3.05	9.625	3.61	10.750	4.11	11.750
3½	4.000	2.80	9.625	3.36	10.750	3.86	11.750	4.36	12.750
4	4.500	2.55	9.625	3.11	10.750	3.61	11.750	4.11	12.750
4½	5.000	2.86	10.750	3.36	11.750	3.86	12.750	4.49	14.000
5	5.563	2.56	10.750	3.06	11.750	3.56	12.750	4.18	14.000
6	6.625	2.52	11.750	3.02	12.750	3.65	14.000	4.15	15.000
7	7.625	2.52	12.750	3.15	14.000	3.65	15.000	4.15	16.000
8	8.625	2.65	14.000	3.15	15.000	3.65	16.000	4.15	17.000
9	9.625	2.65	15.000	3.15	16.000	3.65	17.000	4.15	18.000
10	10.750	2.59	16.000	3.09	17.000	3.59	18.000	4.09	19.000
11	11.750	2.59	17.000	3.09	18.000	3.59	19.000	4.09	20.000
12	12.750	2.58	18.000	3.08	19.000	3.58	20.000	4.08	21.000
14	14.000	2.45	19.000	2.95	20.000	3.45	21.000	3.95	22.000
15	15.000	2.45	20.000	2.95	21.000	3.45	22.000	3.95	23.000
16	16.000	2.45	21.000	2.95	22.000	3.45	23.000	3.95	24.000
17	17.000	2.45	22.000	2.95	23.000	3.45	24.000	3.95	25.000
18	18.000	2.45	23.000	2.95	24.000	3.45	25.000	3.95	26.000
19	19.000	2.45	24.000	2.95	25.000	3.45	26.000	3.95	27.000
20	20.000	2.45	25.000	2.95	26.000	3.45	27.000	3.95	28.000
21	21.000	2.45	26.000	2.95	27.000	3.45	28.000	3.95	29.000
22	22.000	2.45	27.000	2.95	28.000	3.45	29.000	3.95	30.000
23	23.000	2.45	28.000	2.95	29.000	3.45	30.000	3.95	31.000
24	24.000	2.45	29.000	2.95	30.000	3.45	31.000	3.95	32.000
25	25.000	2.45	30.000	2.95	31.000	3.45	32.000	3.95	33.000
26	26.000	2.45	31.000	2.95	32.000	3.45	33.000	3.95	34.000
27	27.000	2.45	32.000	2.95	33.000	3.45	34.000	3.95	35.000
28	28.000	2.45	33.000	2.95	34.000	3.45	35.000	3.95	36.000
29	29.000	2.45	34.000	2.95	35.000	3.45	36.000	3.95	37.000
30	30.000	2.45	35.000	2.95	36.000	3.45	37.000	3.95	38.000
31	31.000	2.45	36.000	2.95	37.000	3.45	38.000	3.95	39.000
32	32.000	2.45	37.000	2.95	38.000	3.45	39.000	3.95	40.000
33	33.000	2.45	38.000	2.95	39.000	3.45	40.000	3.95	41.000
34	34.000	2.45	39.000	2.95	40.000	3.45	41,000	3.95	42.000
35	35.000	2.45	40,000	2.95	41.000	3.45	42.000	3.95	43.000
36	36.000	2.45	41.000	2.95	42.000	3.45	43.000	3.95	44.000

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APPENDIX

PIPE AND TUBE INSULATION DIMENSIONS

INSIDE DIAMETERS FOR PIPE INSULATION
ASTM Recommended Practice

IRON PIPE NOM SIZE	IRON PIPE O.D. Inches	Nominal Insulation I.D. Inches	Insulation I.D. Tolerance, Inches Minus	Insulation I.D. Tolerance, Inches Plus	Minimum Insulation I.D. Inches	Maximum Insulation I.D. Inches
1/8	0.405	0.421	0	1/16	0.421	0.483
1/4	0.540	0.556	0	1/16	0.556	0.618
3/8	0.675	0.691	0	1/16	0.691	0.753
1/2	0.840	0.856	0	1/16	0.856	0.918
3/4	1.050	0.066	0	1/16	1.066	1.128
1	1.315	1.331	0	1/16	1.331	1.393
1¼	1.660	1.676	0	1/16	1.676	1.738
1½	1.900	1.916	0	1/16	1.916	1.978
2	2.375	2.406	1/64	3/32	2.391	2.499
2½	2.875	2.906	1/64	3/32	2.891	2.999
3	3.500	3.531	1/64	3/32	3.516	3.624
3½	4.000	4.031	1/64	3/32	4.016	4.124
4	4.500	4.531	1/64	3/32	4.516	4.624
5	5.000	5.031	1/64	3/32	5.016	5.124
6	5.563	5.641	1/32	3/32	5.610	5.734
7	6.625	6.703	1/32	3/32	6.672	6.796
8	7.625	7.703	1/32	3/32	7.672	7.796
9	8.625	8.703	1/32	3/32	8.672	8.796
10	10.750	10.828	1/32	3/32	10.797	10.921
11	11.750	11.828	1/32	3/32	11.797	11.921
12	12.750	12.844	3/64	5/32	12.797	13.000
14	14.000	14.094	3/64	5/32	14.047	14.250
15	15.000	15.094	3/64	5/32	15.047	15.250
16	16.000	16.094	3/64	5/32	16.047	16.250
17	17.000	17.094	3/64	5/32	17.047	17.250
18	18.000	18.094	3/64	5/32	18.047	18.250
19 thru 32	.000	.094	3/64	5/32	.047	.250
33	33.000	33.094	3/64	5/32	33.047	33.250

OUTER SIZE FOR PIPE INSULATION
ASTM Recommended Practice
Expressed in Nominal Iron Pipe Size

IRON PIPE SIZE	IRON PIPE O.D. Inches	Nominal Thickness 1	1½	2	2½	3	3½	4
1/2	0.84	2½	3½	4½	6	7	8	9
3/4	1.05	2½	3½	4½	6	7	8	9
1	1.32	3	4	5	6	7	8	9
1¼	1.66	3	4½	5	6	7	8	9
1½	1.90	3½	4½	5	6	7	8	9
2	2.38	4	5	6	7	8	9	10
2½	2.88	4½	6	7	8	9	10	11
3	3.50	5	6	7	8	9	10	11
3½	4.00	6	7	8	9	10	11	12
4	4.50	6	7	8	9	10	11	12
4½	5.00	7	8	9	10	11	12	14
5	5.56	7	8	9	10	11	12	14
6	6.63	8	9	10	11	12	14	15
7	7.63	9	10	11	12	14	15	16
8	8.63	10	11	12	14	15	16	17
9	9.63	11	12	14	15	16	17	18
10	10.75	12	14	15	16	17	18	19
11	11.75	14	15	16	17	18	19	20
12	12.75	15	16	17	18	19	20	21
14	14.00	16	17	18	19	20	21	22
15	15.00	17	18	19	20	21	22	23
16	16.00	18	19	20	21	22	23	24
17	17.00	19	20	21	22	23	24	25
18	18.00	20	21	22	23	24	25	26
19	19.00	21	22	23	24	25	26	27
20	20.00	22	23	24	25	26	27	28
21	21.00	23	24	25	26	27	28	29
22	22.00	24	25	26	27	28	29	30
23	23.00	25	26	27	28	29	30	31
24	24.00	26	27	28	29	30	31	32
25	25.00	27	28	29	30	31	32	33
26	26.00	28	29	30	31	32	33	34
27	27.00	29	30	31	32	33	34	35
28	28.00	30	31	32	33	34	35	36
29	29.00	31	32	33	34	35	36	37
30	30.00	32	33	34	35	36	37	38
31	31.00	33	34	35	36	37	38	39
32	32.00	34	35	36	37	38	39	40
33	33.00	35	36	37	38	39	40	41
34	34.00	36	37	38	39	40	41	42
35	35.00	37	38	39	40	41	42	43
36	36.00	38	39	40	41	42	43	44

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APPENDIX

PIPE AND TUBE INSULATION DIMENSIONS

BASIC OUTSIDE DIAMETERS FOR TUBE INSULATION
ASTM Recommended Practice

Tube Size	O.D.	Nominal Thickness of Insulation							
		1/2	1	1½	2	2½	3	3½	4
1/4	0.250	1.315	2.875	3.500	4.500	5.625	6.625	7.625	8.625
3/8	0.375	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
1/2	0.500	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
1/2	0.625	1.660	2.875	3.500	4.500	5.625	6.625	7.625	8.625
3/4	0.750	1.900	2.875	4.000	5.000	5.625	7.625	8.625	9.625
3/4	0.875	1.900	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1	1.000	2.375	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1	1.125	2.375	3.500	4.000	5.000	6.625	7.625	8.625	9.625
1¼	1.250	2.375	3.500	4.500	5.563	6.625	7.625	8.625	9.625
1½	1.500	2.875	4.000	4.500	5.563	6.625	7.625	8.625	9.625
1½	1.625	2.875	4.000	4.500	5.563	6.625	7.625	8.625	9.625
2	2.000	3.500	4.000	5.000	6.625	7.625	8.625	9.625	10.750
2	2.125	3.500	4.500	5.563	6.625	7.625	8.625	9.625	10.750
2½	2.500	3.500	4.500	5.563	6.625	7.625	8.625	9.625	10.750
2½	2.625	4.000	5.000	5.563	6.625	7.625	8.625	9.625	10.750
3	3.000	4.000	5.000	6.625	7.625	8.625	9.625	10.750	11.750
3	3.125	4.500	5.563	6.625	7.625	8.625	9.625	10.750	11.750
3 5/8	3.625	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750
4	4.000	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750
4	4.125	5.563	6.625	7.625	8.625	9.625	10.750	11.750	12.750
5	5.000	6.625	7.625	8.625	9.625	10.750	11.750	12.750	14.000
5	5.125	6.625	7.625	8.625	9.625	10.750	11.750	12.750	14.000
6	6.000	7.625	8.625	9.625	10.750	11.750	12.750	14.000	15.000
6	6.125	7.625	8.625	9.625	10.750	11.750	12.750	14.000	15.000
8	8.000			11.750	12.750	14.000	15.000	16.000	17.000
8	8.125			11.750	12.750	14.000	15.000	16.000	17.000
10	10.000			12.750	14.000	15.000	16.000	17.000	18.000
10	10.125			14.000	14.000	15.000	16.000	17.000	18.000
12	12.000			15.000	16.000	17.000	18.000	19.000	20.000
14	14.333			18.000	19.000	20.000	21.000	33.000	23.000
16	16.333			20.000	21.000	22.000	23.000	24.000	25.000
18	18.333			22.000	23.000	24.000	25.000	26.000	27.000
20	20.333			24.000	25.000	26.000	27.000	28.000	29.000
24	24.333			28.000	29.000	30.000	31.000	32.000	33.000

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APPENDIX

SURFACE AREAS OF NPS PIPE INSULATION

SURFACE AREAS OF PIPE INSULATION
Based on NPS Pipe and ASTM Dimensional Standard
Pipe Insulation - Square Feet per linear foot

NOM. PIPE SIZE	Nominal Insulation Thicknesses											
	BARE	1	1½	2	2½	3	3½	4	4½	5	5½	6
1/8	0.106	0.62	0.92	1.18	1.46	1.73	2.00	2.26				
1/4	0.141	0.75	1.05	1.30	1.46	1.73	2.00	2.26				
3/8	0.177	0.75	1.05	1.30	1.46	1.73	2.00	2.26				
1/2	0.220	0.75	1.05	1.30	1.73	2.00	2.25	2.52				
3/4	0.275	0.75	1.05	1.30	1.73	2.00	2.25	2.52				
1	0.344	0.92	1.18	1.46	1.74	2.00	2.26	2.52				
1 1/4	0.435	0.92	1.31	1.46	1.74	2.00	2.26	2.52				
1 1/2	0.498	1.05	1.31	1.74	2.00	2.26	2.52	2.81				
2	0.622	1.18	1.46	1.73	2.00	2.26	2.52	2.81				
2 1/2	0.753	1.31	1.73	2.00	2.26	2.52	2,81	3.08				
3	0.917	1.46	1.73	2.00	2.26	2.52	2.81	3.08	3.34			
3 1/2	1.047	1.73	2.00	2.26	2.52	2.81	3.08	3.34	3.67			
4	1.178	1.73	2.00	2.26	2.52	2.81	3.08	3.34	3.67			
4 1/2	1.309	2.00	2.26	2.52	2.81	3.08	3.34	3.67	3.67			
5	1.456	2.00	2.26	2.52	2.81	3.08	3.34	3.67	3.93	4.19		
6	1.734	2.26	2.52	2.81	3.08	3.34	3.67	3.93	4.18	4.45		
7	1.996		2.81	3.08	3.34	3.67	3.93	4.19	4.45	4.71	4.97	
8	2.258		3.08	3.34	3.67	3.93	4.19	4.45	4.71	4.97	5.24	
9	2.520		3.34	3.67	3.93	4.19	4.45	4.71	4.97	5.24	5.50	
10	2.814		3.67	3.93	4.19	4.45	4.71	4.97	5.24	5.50	5.76	
11	3.076		3.93	4.19	4.45	4.71	4.97	5.24	5.50	5.76	6.02	
12	3.338		4.19	4.45	4.71	4.97	5.24	5.50	5.76	6.02	6.28	6.54
14	2.665		4.45	4.71	4.97	5.24	5.50	5.76	6.02	6.28	6.54	6.81
16	4.189		4.97	5.24	5.50	5.76	6.02	6.28	6.54	6.81	7.07	7.33
18	4.712		5.50	5.76	6.02	6.28	6.54	6.81	7.07	7.33	7.59	7.85
20	5.236		6.02	6.28	6.54	6.81	7.07	7.33	7.59	7.85	8.12	8.38
22	5.759		6.54	6.81	7.07	7.33	7.59	7.85	8.12	8.38	8.64	8.90
24	6.283		7.07	7.33	7.59	7.85	8.12	8.38	8.64	8.90	9.16	9.42
26	6.807		7.59	7.85	8.12	8.38	8.64	8.90	9.16	9.42	9.69	9.95
28	7.331		8.12	8.38	8.64	8.90	9.16	9.42	9.69	9.95	10.21	10.47
30	7.854		8.64	8.90	9.16	9.42	9.69	9.95	10.21	10.47	10.73	11.00

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APPENDIX

VOLUMES OF NPS PIPE INSULATION

VOLUMES OF PIPE INSULATION

Cubic Feet Per Linear Foot

NPS PIPE SIZE	Nominal Insulation Thickness																	
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9
¼	0.013	0.040	0.083	0.133	0.231	0.313	0.400	0.498										
3/4	0.010	0.038	0.082	0.130	0.228	0.310	0.398	0.496										
1	0.018	0.056	0.100	0.154	0.225	0.307	0.394	0.493										
1¼	0.029	0.051	0.122	0.148	0.219	0.302	0.388	0.487										
1½	0.027	0.071	0.120	0.218	0.300	0.388	0.486	0.611										
2	0.038	0.082	0.137	0.208	0.289	0.377	0.474	0.600										
2½	0.044	0.093	0.191	0.273	0.360	0.458	0.583	0.709										
3	0.044	0.098	0.169	0.251	0.338	0.437	0.562	0.688	0.818	1.003	1.162	1.331						
3½	0.049	0.148	0.229	0.317	0.414	0.540	0.665	0.796	0.892	0.982	1.140	1.309						
4	0.055	0.126	0.208	0.294	0.393	0.518	0.643	0.774	0.960	1.118	1.288	1.468						
6	0.082	0.169	0.268	0.393	0.518	0.649	0.834	0.993	1.162	1.342	1.533	1.734	1.948	2.171	2.405	2.651	2.908	3.174
8		0.223	0.349	0.480	0.666	0.823	0.993	1.173	1.363	1.565	1.778	2.002	2.237	2.482	2.738	3.005	3.283	3.573
10		0.257	0.442	0.600	0.769	0.949	1.140	1.342	1.554	1.778	2.013	2.258	2.514	2.782	3.060	3.349	3.649	3.960
12		0.343	0.513	0.693	0.883	1.086	1.298	1.522	1.757	2.003	2.258	2.525	2.803	3.093	3.393	3.703	4.025	4.356
14		0.328	0.508	0.698	0.900	1.113	1.337	1.571	1.817	2.073	2.340	2.618	2.908	3.207	3.518	3.840	4.173	4.516
16		0.363	0.573	0.786	1.009	1.243	1.489	1.745	2.013	2.291	2.580	2.88	3.191	3.513	3.845	4.189	4.543	4.909
18		0.414	0.638	0.873	1.118	1.374	1.642	1.920	2.209	2.509	2.820	3.142	3.474	3.818	4.173	4.538	4.914	5.302
20		0.458	0.703	0.960	1.228	1.505	1.794	2.094	2.405	2.728	3.060	3.403	3.758	4.123	4.500	4.887	5.285	5.694
24		0.546	0.834	1.134	1.445	1.768	2.100	2.443	2.798	3.163	3.540	3.927	4.325	4.734	5.154	5.585	6.027	6.480
30		0.677	1.031	1.397	1.773	2.160	2.558	2.968	3.388	3.818	4.259	4.713	5.176	5.651	6.136	6.633	7.139	7.658
36		0.808	1.222	1.658	2.100	2.553	3.016	3.491	3.976	4.473	4.980	5.498	6.027	6.567	7.118	7.679	8.253	8.836

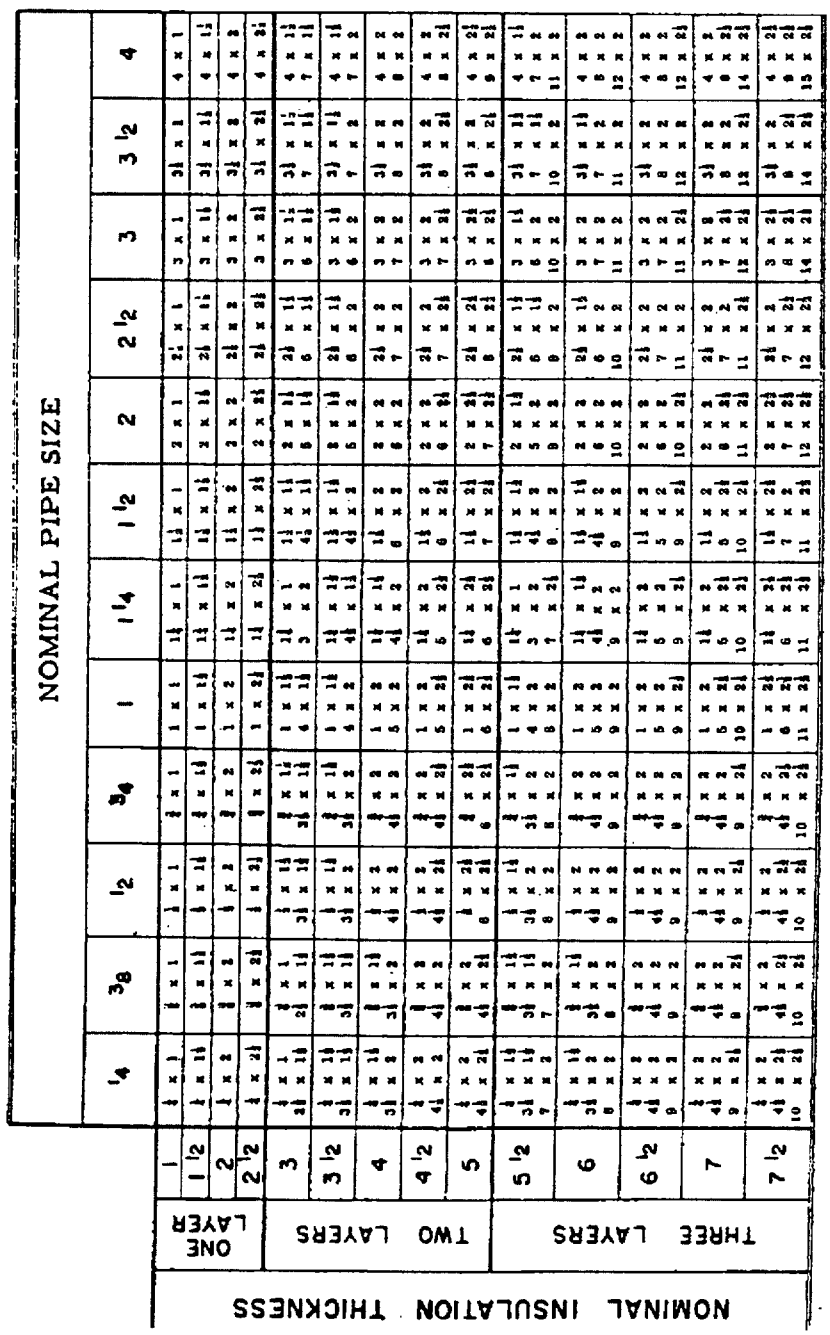
Note: Density of insulation in lbs/cu ft times the cu ft per linear ft = lbs per linear ft

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APPENDIX

RECOMMENDED SIZES OF INSULATION LAYERS TO OBTAIN TOTAL NOMINAL THICKNESS

NPS X NOMINAL LAYER THICKNESS



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APPENDIX

RECOMMENDED SIZES OF INSULATION LAYERS TO OBTAIN TOTAL NOMINAL THICKNESS

NPS X NOMINAL LAYER THICKNESS

NOMINAL PIPE SIZE	ONE LAYER	TWO LAYERS					THREE LAYERS				
NOMINAL INSULATION THICKNESS	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
4 1/2	4½ x 1	4½ x 1½	4½ x 2	4½ x 2½	4½ x 3	4½ x 3½	4½ x 4	4½ x 4½	4½ x 5	4½ x 5½	4½ x 6
5	5 x 1	5 x 1½	5 x 2	5 x 2½	5 x 3	5 x 3½	5 x 4	5 x 4½	5 x 5	5 x 5½	5 x 6
6	6 x 1	6 x 1½	6 x 2	6 x 2½	6 x 3	6 x 3½	6 x 4	6 x 4½	6 x 5	6 x 5½	6 x 6
8	8 x 1	8 x 1½	8 x 2	8 x 2½	8 x 3	8 x 3½	8 x 4	8 x 4½	8 x 5	8 x 5½	8 x 6
10	10 x 1	10 x 1½	10 x 2	10 x 2½	10 x 3	10 x 3½	10 x 4	10 x 4½	10 x 5	10 x 5½	10 x 6
12	12 x 1	12 x 1½	12 x 2	12 x 2½	12 x 3	12 x 3½	12 x 4	12 x 4½	12 x 5	12 x 5½	12 x 6
14	14 x 1	14 x 1½	14 x 2	14 x 2½	14 x 3	14 x 3½	14 x 4	14 x 4½	14 x 5	14 x 5½	14 x 6
16	16 x 1	16 x 1½	16 x 2	16 x 2½	16 x 3	16 x 3½	16 x 4	16 x 4½	16 x 5	16 x 5½	16 x 6
18	18 x 1	18 x 1½	18 x 2	18 x 2½	18 x 3	18 x 3½	18 x 4	18 x 4½	18 x 5	18 x 5½	18 x 6
20	20 x 1	20 x 1½	20 x 2	20 x 2½	20 x 3	20 x 3½	20 x 4	20 x 4½	20 x 5	20 x 5½	20 x 6
22	22 x 1	22 x 1½	22 x 2	22 x 2½	22 x 3	22 x 3½	22 x 4	22 x 4½	22 x 5	22 x 5½	22 x 6
24	24 x 1	24 x 1½	24 x 2	24 x 2½	24 x 3	24 x 3½	24 x 4	24 x 4½	24 x 5	24 x 5½	24 x 6

NOMINAL PIPE SIZE	THREE LAYERS				
NOMINAL INSULATION THICKNESS	6 1/2	7	7 1/2		
4 1/2	4½ x 6½	4½ x 7	4½ x 7½		
5	5 x 6½	5 x 7	5 x 7½		
6	6 x 6½	6 x 7	6 x 7½		
8	8 x 6½	8 x 7	8 x 7½		
10	10 x 6½	10 x 7	10 x 7½		
12	12 x 6½	12 x 7	12 x 7½		
14	14 x 6½	14 x 7	14 x 7½		
16	16 x 6½	16 x 7	16 x 7½		
18	18 x 6½	18 x 7	18 x 7½		
20	20 x 6½	20 x 7	20 x 7½		
22	22 x 6½	22 x 7	22 x 7½		
24	24 x 6½	24 x 7	24 x 7½		

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APPENDIX

AREAS

RADIATING AREA OF FLANGED FITTINGS

(Including accompanying flanges in square feet and in equivalent length of same size pipe standard weight fittings)

Pipe size, in.	Flanged couplings		90° ells		Long radius ells		Tees		Crosses	
	Area, sq.ft.	Pipe length, ft.	Area, sq.ft.	Pipe length ft.	Area sq.ft.	Pipe length, ft.	Area, sq. ft.	Pipe length ft.	Area, sq. ft.	Pipe length ft.
1	.32	.93	.79	2.31	.89	2.59	1.24	3.59	1.62	4.72
1 1/4	.38	.88	.96	2.20	1.08	2.49	1.48	3.40	1.94	4.47
1 1/2	.48	.95	1.19	2.35	1.34	2.68	1.82	3.64	2.38	4.78
2	.67	1.08	1.65	2.65	1.84	2.96	2.54	4.08	3.32	5.34
2 1/2	.84	1.12	2.09	2.78	2.32	3.08	3.21	4.26	4.19	5.56
3	.95	1.03	2.38	2.60	2.68	2.93	3.66	3.99	4.77	5.70
3 1/2	1.12	1.07	2.98	2.85	3.28	3.13	4.48	4.28	5.83	5.56
4	1.34	1.14	3.53	2.90	3.96	3.36	5.41	4.59	7.03	5.97
4 1/2	1.47	1.13	3.95	3.01	4.43	3.38	6.07	4.63	7.87	6.01
5	1.62	1.11	4.44	3.05	5.00	3.43	6.81	4.67	8.82	6.06
6	1.82	1.05	5.13	2.95	5.99	3.45	7.84	4.53	10.08	5.81
7	2.17	1.05	6.17	3.09	7.38	3.70	9.37	4.69	12.00	6.01
8	2.41	1.07	6.98	3.09	8.56	3.79	10.55	4.67	13.44	5.96
9	3.00	1.19	8.71	3.46	10.57	4.20	13.18	5.23	16.78	6.66
10	3.43	1.22	10.18	3.61	12.35	4.38	15.41	5.47	19.58	6.95
12	4.41	1.32	13.08	3.92	16.35	4.90	19.67	5.89	24.87	7.45
14	5.39	1.47	16.38	4.47	20.17	5.47	24.81	6.78	31.48	8.60
16	6.69	1.60	20.17	4.82	25.41	6.07	30.32	7.23	38.34	9.15

AREAS, SIZES AND CAPACITIES OF STANDARD PIPE

(All dimensions and weights are nominal)

Size, in.	Diameter, in.		Thickness, in.	Circumference, in.		Transverse areas, sq. in.		External surface area, sq.ft. lin ft. of pipe	Length of pipe containing cu.ft.	Wt of water per foot, lb.
	External	Internal		External	Internal	External	Internal			
1/8	0.405	0.269	0.068	1.272	0.845	0.129	0.057	0.1060	2533.775	0.025
1/4	0.540	0.364	0.088	1.696	1.144	0.229	0.104	0.1414	1383.789	0.045
3/8	0.675	0.493	0.091	2.121	1.549	0.358	0.191	0.1767	754.360	0.083
1/2	0.840	0.622	0.109	2.639	1.954	0.554	0.304	0.220	473.906	0.132
3/4	1.050	0.824	0.113	3.299	2.589	0.866	0.533	0.275	270.034	0.231
1	1.315	1.049	0.133	4.131	3.296	1.358	0.861	0.344	166.618	0.375
1 1/4	1.660	1.380	0.140	5.215	4.335	2.164	1.495	0.435	96.275	0.65
1 1/2	1.900	1.610	0.145	5.969	5.058	2.835	2.036	0.498	70.733	0.88
2	2.375	2.067	0.154	7.461	6.494	4.430	3.355	0.622	42.913	1.45
2 1/2	2.875	2.469	0.203	9.032	7.757	6.492	4.788	0.753	30.077	2.07
3	3.500	3.068	0.216	10.996	9.638	9.621	7.393	0.917	19.479	3.20
3 1/2	4.000	3.548	0.226	12.566	11.146	12.566	9.886	1.047	14.565	4.29
4	4.500	4.026	0.237	14.137	12.648	15.904	12.730	1.178	11.312	5.50
4 1/2	5.000	4.506	0.247	15.708	14.156	19.635	15.947	1.3009	9.030	6.91
5	5.563	5.047	0.258	17.477	15.856	24.306	20.006	1.4586	7.198	8.67
6	6.625	6.065	0.280	20.813	19.054	34.472	28.891	1.7384	4.984	12.51
7	7.625	7.023	0.301	23.955	22.063	45.664	38.738	1.996	3.717	16.80
8	8.625	8.071	0.277	27.096	25.356	58.426	51.161	2.2350	2.815	22.18
8	8.625	7.981	0.322	27.096	25.073	58.426	50.027	2.2058	2.878	21.70
9	9.625	8.941	0.342	30.238	28.089	72.760	62.786	2.5220	2.294	27.20
10	10.750	10.192	0.279	33.772	32.019	90.763	81.585	2.8174	1.765	35.37
10	10.750	10.136	0.307	33.772	31.843	90.763	80.691	2.8104	1.826	34.20
10	10.750	10.020	0.365	33.772	31.479	90.763	78.855	2.8104	1.826	34.20
11	11.750	11.000	0.375	36,914	34.558	108.434	95,033	3.076	1.515	41.20
12	12.750	12.090	0.330	40.055	37.892	127.676	114.800	3.338	1.254	49.70
12	12.750	12.000	0.375	40.055	37.699	127.676	113.097	3.338	1.273	49.00

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APPENDIX

AREAS

AREAS OF TANKS FOR INSULATION COVERAGE

Area of dished head equals $\frac{2\pi DH}{12}$

Area of flat head equals $0.7854\ D^2$

Area per lin. ft. equals πD

D equals diameter in feet
R equals head radius in feet
H equals 1.608 R equals 1.608D

Tank with dished heads where R equals D

Tank Diameter Ft.	Dished Head Area Sq. Ft.	Flat Head Area Sq. Ft.	Area Per L.F. of Cyl. Sq. Ft.	"H" Dimension Inches
1'-0"	.84	.79	3.14	1.61
1'-1"	.99	.92	3.40	1.75
1'-2"	1.14	1.07	3.66	1.88
1'-3"	1.32	1.23	3.93	2.01
1'-4"	1.50	1.40	4.19	2.15
1'-5"	1.69	1.58	4.45	2.28
1'-6"	1.89	1.77	4.71	2.41
1'-7"	2.11	1.97	4.97	2.54
1'-8"	2.34	2.18	5.23	2.68
1'-9"	2.58	2.41	5.50	2.81
1'-10"	2.87	2.64	5.76	2.95
1'-11"	3.09	2.89	6.02	3.08
2'-0"	3.37	3.14	6.28	3.22
2'-1"	3.65	3.41	6.54	3.35
2'-2"	3.95	3.69	6.81	3.48
2'-3"	4.25	3.98	7.07	3.61
2'-4"	4.57	4.28	7.33	3.75
2'-5"	4.91	4.51	7.59	3.88
2'-6"	5.21	4.91	7.85	4.02
2'-7"	5.61	5.24	8.11	4.15
2'-8"	5.98	5.58	8.37	4.28
2'-9"	6.36	5.94	8.64	4.42
2'-10"	6.74	6.31	8.90	4.55
2'-11"	7.15	6.68	9.17	4.68

Tank Diameter Ft.	Dished Head Area Sq. Ft.	Flat Head Area Sq. Ft.	Area Per L.F. of Cyl. Sq. Ft.	"H" Dimension Inches
3'-0"	7.56	7.07	9.43	4.82
3'-1"	8.00	7.47	9.69	4.96
3'-2"	8.43	7.88	9.95	5.09
3'-3"	8.87	8.30	10.21	5.22
3'-4"	9.32	8.73	10.47	5.35
3'-5"	9.81	9.17	10.73	5.49
3'-6"	10.30	9.62	11.00	5.62
3'-7"	10.77	10.01	11.26	5.75
3'-8"	11.32	10.56	11.52	5.89
3'-9"	11.82	11.05	11.73	6.02
3'-10"	12.34	11.54	12.04	6.16
3'-11"	12.92	12.05	12.30	6.30
4'-0"	13.45	12.57	12.57	6.44
4'-1"	14.03	13.09	12.83	6.57
4'-2"	14.60	13.47	13.09	6.70
4'-3"	15.19	14.18	13.35	6.83
4'-4"	15.78	14.73	13.61	6.96
4'-5"	16.39	15.32	13.88	7.09
4'-6"	17.05	15.90	14.14	7.22
4'-7"	17.64	16.50	14.40	7.36
4'-8"	18.32	17.11	14.66	7.50
4'-9"	18.95	17.72	14.92	7.63
4'-10"	19.63	18.35	15.18	7.77
4'-11"	20.35	18.99	15.44	7.91

Tank Diameter Ft.	Dished Head Area Sq. Ft.	Flat Head Area Sq. Ft.	Area Per Lin. Ft. of Cyl. Sq. Ft.	"H" Dimension Inches
5'-0"	21.10	19.64	15.71	8.04
5'-1"	21.74	20.30	15.97	8.17
5'-2"	22.48	20.97	16.23	8.30
5'-3"	23.17	21.65	16.49	8.44
5'-4"	23.93	22.34	16.76	8.57
5'-5"	24.68	23.05	17.02	8.70
5'-6"	25.50	23.76	17.28	8.84
5'-7"	26.18	24.48	17.54	8.98
5'-8"	27.00	25.22	17.80	9.11
5'-9"	27.82	25.97	18.06	9.25
5'-10"	28.64	26.73	18.33	9.38
5'-11"	29.49	27.49	18.59	9.52
6'-0"	30.20	28.27	18.85	9.64
6'-1"	31.13	29.07	19.11	9.78
6'-2"	32.03	29.87	19.37	9.92
6'-3"	32.98	30.68	19.64	10.06
6'-4"	33.79	31.49	19.90	10.20
6'-5"	34.69	32.29	20.16	10.33
6'-6"	35.60	33.17	20.42	10.47
6'-7"	36.49	34.04	20.68	10.60
6'-8"	37.43	34.91	20.95	10.73
6'-9"	38.37	35.79	21.21	10.86
6'-10"	39.28	36.67	21.47	10.99
6'-11"	40.29	37.50	21.73	11.12

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APPENDIX

AREAS

AREAS OF TANKS
FOR INSULATION COVERAGE

Tank Diameter Ft.	Dished Head Area Sq.Ft.	Flat Head Area Sq.Ft.	Area Per L.F. of Cyl. Sq. Ft.	"H" Dimension Inches
7'-0"	41.30	38.49	21.99	11.25
7'-1"	42.20	39.41	22.25	11.39
7'-2"	43.21	40.34	22.51	11.52
7'-3"	44.25	41.28	22.78	11.66
7'-4"	45.26	42.24	23.04	11.80
7'-5"	46.33	43.20	23.30	11.93
7'-6"	47.50	44.16	23.56	12.06
7'-7"	48.37	45.16	23.82	12.19
7'-8"	49.46	46.16	24.09	12.32
7'-9"	50.56	47.17	24.35	12.46
7'-10"	51.63	48.19	24.61	12.60
7'-11"	52.76	49.22	24.87	12.73
8'-0"	53.85	50.27	25.13	12.86
8'-1"	54.96	51.32	25.39	13.00
8'-2"	56.15	52.38	25.66	13.13
8'-3"	57.31	53.46	25.92	13.27
8'-4"	58.45	54.54	26.18	13.40
8'-5"	59.64	56.64	26.64	13.53
8'-6"	60.65	56.75	26.70	13.66
8'-7"	61.96	57.89	26.97	13.80
8'-8"	63.24	58.99	27.23	13.93
8'-9"	64.34	60.13	27.49	14.06
8'-10"	65.60	61.28	27.75	14.20
8'-11"	66.88	62.45	28.01	14.33
9'0"	68.10	63.62	28.27	14.46
9'-1"	69.33	64.80	28.54	14.59
9'-2"	70.65	66.00	28.80	14.72
9'-3"	71.97	67.20	29.06	14.86
9'-4"	73.22	68.42	29.32	15.00
9'-5"	74.61	69.64	29.58	15.13
9'-6"	76.00	70.88	29.85	15.26
9'-7"	77.14	72.13	30.11	15.40
9'-8"	78.64	73.39	30.37	25.54
9'-9"	79.96	74.66	30.63	25.67
9'-10"	81.37	75.94	30.89	15.80
9'-11"	82.81	77.93	31.15	15.95

Tank Diameter Ft.	Dished Head Area Sq. Ft.	Flat Head Area Sq.Ft.	Area Per L.F. of Cyl. Sq.Ft.	"H" Dimension Inches
10'-0"	84.15	78.54	31.42	16.08
10'-1"	85.34	79.85	31.63	16.21
10'-2"	86.96	81.18	31.94	16.34
10'-3"	88.37	82.52	32.20	16.48
10'-4"	89.78	83.86	32.46	16.61
10'-5"	91.26	85.22	32.73	16.74
10'-6"	92.71	86.59	32.99	16.87
10'-7"	94.15	87.97	33.25	17.00
10'-8"	95.68	89.35	33.51	17.14
10'-9"	97.22	90.76	33.77	17.27
10'-10"	98.69	92.11	34.03	17.40
10'-11"	100.26	93.60	34.30	17.53
11'-0"	101.89	95.03	30.56	17.68
11'-1"		96.48	34.82	
11'-2"		97.93	35.08	
11'-3"		99.40	35.34	
11'-4"		100.88	35.60	
11'-5"		102.37	35.87	
11'-6"	111.22	103.87	36.13	18.47
11'-7"		105.38	36.39	
11'-8"		106.90	36.65	
11'-9"		108.43	36.91	
11'-10"		109.98	37.18	
11'-11"		111.53	37.44	
12'-0"	121.18	113.10	37.70	19.31
12'-1"		114.67	37.96	
12'-2"		116.26	38.22	
12'-3"		117.86	38.48	
12'-4"		119.47	38.75	
12'-5"		121.09	39.01	
12'-6"	131.49	122.72	39.27	20.09
12'-7"		124.36	39.53	
12'-8"		126.01	39.79	
12'-9"		127.67	40.06	
12'-10"		129.35	40.32	
12'-11"		131.04	40.58	

Tank Diameter Ft.	Dished Head Area Sq.Ft.	Flat Head Area Sq.Ft.	Area Per L.F. of Cyl. Sq.Ft.	"H" Dimension Inches
13'-0"	142.22	132.73	40.84	20.91
13'-1"		134.44	41.10	
13'-2"		136.16	41.36	
13'-3"		137.89	41.63	
13'-4"		139.63	41.89	
13'-5"		141.38	42.15	
13'-6"	153.36	143.14	42.41	21.72
13'-7"		144.91	42.67	
13'-8"		146.69	42.94	
13'-9"		148.36	43.20	
13'-10"		150.30	43.46	
13'-11"		152.11	43.72	
14'-0	164.94	153.94	43.98	22.53
14'-6"	176.93	165.13	45.55	23.31
15'-0"	189.34	176.31	47.12	24.13
15'-6	202.18	188.69	48.70	24.94
16'-0'	215.43	201.06	50.27	25.75
16'-6"		213.83	51.84	
17'-0"		226.98	53.41	
17'-6"		240.53	54.98	
18'-0"		254.47	56.55	
18'-6"		268.80	58.12	
19'-0"		283.53	59.69	
19'-6"		298.65	61.26	
20'-0"		314.16	62.83	
21'-0"		346.36	65.97	
22'-0"		380.13	69.11	
23'-0"		415.58	72.26	
24'-0"		450.79	75.40	
25'-0"		490.86	78.54	

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APPENDIX

AREAS AND VOLUMES - CYLINDERS

Diameter	Surface Area Sq. Ft. Per Linear Ft.	Volume Cu. Ft. Per Linear Ft.	Capacity Gals. Per Linear Ft.
0'-6"	1.5708	0.1963	1.4688
1'-0"	3.1416	0.7854	5.8752
1'-6"	4.7124	1.7671	13.219
2'-0"	6.2832	3.1416	23.501
2'-6"	7.8540	4.9087	36.720
3'-0"	9.4248	7.0686	52.877
3'-6"	10.9956	9.6211	71.971
4'-0"	12.5664	12.566	94.003
4'-6"	14.1372	15.904	118.97
5'-0"	15.7080	19.635	146.88
5'-6"	17.2788	23.758	177.72
6'-0"	18.8496	28.274	211.51
6'-6"	20.4204	33.183	248.23
7'-0"	21.9912	38.485	287.88
7'-6"	23.5620	44.179	330.48
8'-0"	25.1328	50.265	376.01
8'-6"	26.7036	56.745	424.48
9'-0"	28.2744	63.617	475.89
9'-6"	29.8452	70.882	530.24
10'-0"	31.4160	78.540	587.52
10'-6"	32.9868	86.590	747.74
11'-0"	34.5576	95.033	710.90
11'-6"	36.1284	103.87	776.99
12'-0"	37.6992	113.10	846.03
12'-6"	39.2700	122.72	918.00
13'-0"	40.8408	132.73	992.91
13'-6"	42.4116	143.14	1070.8
14'-0"	43.9824	153.94	1151.3
14'-6"	45.5532	165.13	1235.3
15'-0"	47.1240	176.71	1321.9
15'-6"	48.6948	188.69	1411.5
16'-0"	50.2656	201.06	1504.0
16'-6"	51.8364	213.82	1599.5
17'-0"	53.4072	226.98	1697.9
17'-6"	54.9780	240.53	1799.3
18'-0"	56.5488	254.47	1903.6
18'-6"	58.1196	268.80	2010.8
19'-0"	59.6904	283.53	2120.9
19'-6"	61.2612	298.65	2234.0
20'-0"	62.8320	314.16	2350.1
20'-6"	64.4028	330.06	2469.0
21'-0"	65.9736	346.36	2591.0
21'-6"	67.5444	363.05	2715.8
22'-0"	69.1152	380.13	2843.6
22'-6"	70.6860	397.61	2974.3
23'-0"	72.2568	415.48	3108.0
23'-6"	73.8276	433.74	3244.6
24'-0"	75.3984	452.39	3384.1
24'-6"	76.9692	471.44	3526.6
25'-0"	78.5400	490.87	3672.0
25'-6"	80.1108	510.71	3820.3
26'-0"	81.6816	530.93	3971.6
26'-6"	83.2524	551.55	4125.8
27'-0"	84.8232	572.56	4283.0
27'-6"	86.3940	593.96	4443.1
28'-0"	87.9648	615.75	4606.1
28'-6"	89.5356	637.94	4772.1
29'-0"	91.1064	660.52	4941.0
29'-6"	92.6772	683.49	5112.9
30'-0"	94.2480	706.86	5287.7
30'-6"	95.8188	730.62	5465.4
31'-0"	97.3896	744.77	5646.1
31'-6"	98.9604	779.31	5829.7
32'-0"	100.5312	804.25	6016.2
32'-6"	102.1020	829.58	6205.7
33'-0"	103.6728	855.30	6398.1
33'-6"	105.2436	881.41	6593.4
34'-0"	106.8144	907.92	6791.7
34'-6"	108.3852	934.82	6992.9
35'-0"	109.9560	962.11	7197.1
35'-6"	111.5268	989.80	7404.2
36'-0"	113.0976	1017.9	7614.2
36'-6"	114.6684	1046.3	7827.2
37'-0"	116.2392	1075.2	8043.1
37'-6"	117.8100	1104.5	8262.0
38'-0"	119.3808	1134.1	8483.8
38'-6"	120.9516	1164.2	8708.5
39'-0"	122.5224	1194.6	8936.2
39'-6"	124.0932	1225.4	9166.8
40'-0"	125.6640	1256.6	9400.3
40'-6"	127.2348	1288.2	9636.8
41'-0"	128.8056	1320.3	9876.2
41'-6"	130.3764	1352.7	10119
42'-0"	131.9472	1385.4	10364
42'-6"	133.5180	1418.6	10612
43'-0"	135.0888	1452.2	10863
43'-6"	136.6586	1486.2	11117
44'-0"	138.2364	1520.5	11374
44'-6"	139.8012	1555.3	11634
45'-0"	141.3720	1590.4	11897
45'-6"	142.9428	1626.0	12163
46'-0"	144.5136	1661.9	12432
46'-6"	146.0844	1698.2	12704
47'-0"	147.6552	1734.9	12978
47'-6"	149.2260	1772.1	13256
48'-0"	150.7968	1809.6	13536
48'-6"	152.3676	1847.5	13820
49'-0"	153.9384	1885.7	14106
49'-6"	155.5092	1924.4	14396
50'-0"	157.0800	1963.5	14683
60'-0"	188.50	2827.4	21150
70'-0"	219.91	3848.5	28789
80'-0"	251.33	5026.5	37601
90'-0"	282.74	6361.7	47589
100'-0"	314.16	7854.0	58752
110'-0"	345.58	9503.3	71090
120'-0"	377.00	11,309.7	84602
130'-0"	408.41	13,273.2	99290
140'-0"	439.82	15,393.8	115154
150'-0"	471.24	17,671.5	132192
175'-0"	549.78	24,052.8	179927
200'-0"	628.32	31,415.9	235007

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APPENDIX

AREAS AND VOLUMES – SPHERES

Diameter	Surface Area in Sq. Ft.	Volume in Cu. Ft.	Total Capacity in Gallons
0'-6"	.7854	.0654	.4892
1'-0"	3.1416	.5236	3.917
1'-6"	7.0686	1.7671	13.22
2'-0"	12.566	4.1888	31.33
2'-6"	19.635	8.1812	61.20
3'-0"	28.274	14.137	105.8
3'-6"	38.485	22.449	167.9
4'-0"	50.265	33.510	250.7
4'-6"	63.617	47.713	356.9
5'-0"	78.540	65.450	489.6
5'-6"	95.033	87.114	651.7
6'-0"	113.10	113.10	846.1
6'-6"	132.73	143.79	1076
7'-0"	153.94	179.59	1343
7'-6"	176.71	220.89	1652
8'-0"	201.06	268.08	2005
8'-6"	226.98	321.56	2405
9'-0"	254.47	381.70	2855
9'-6"	283.53	448.92	3358
10'-0"	314.16	523.60	3917
10'-6"	346.36	606.13	4534
11'-0"	380.13	696.91	5213
11'-6"	415.48	796.33	5957
12'-0"	452.39	904.78	6768
12'-6"	490.87	1022.7	7650
13'-0"	530.93	1150.3	8605
13'-6"	572.56	1288.2	9637
14'-0"	615.75	1436.8	10748
14'-6"	660.52	1596.3	11941
15'-0"	706.86	1767.1	13219
15'-6"	754.77	1949.8	14586
16'-0"	804.25	2144.7	16044
16'-6"	855.30	2352.1	17595
17'-0"	907.92	2572.4	19243
17'-6"	962.11	2806.2	20992
18'-0"	1017.9	3053.6	22843
18'-6"	1075.2	3315.2	24799
19'-0"	1134.1	3591.4	26866
19'-6"	1194.6	3882.4	29042
20'-0"	1256.6	4188.8	31334
20'-6"	1320.3	4510.9	33744
21'-0"	1385.4	4849.0	36273
21'-6"	1452.2	5203.7	38926
22'-0"	1520.5	5575.3	41706
22'-6"	1590.4	5964.1	44615
23'-0"	1661.9	6370.6	47655
23'-6"	1734.9	6795.2	50832
24'-0"	1809.6	7238.2	54146
24'-6"	1885.7	7700.1	57601
25'-0"	1963.5	8181.2	61200
25'-6"	2042.8	8682.0	64946
26'-0"	2123.7	9202.8	68842
26'-6"	2206.2	9744.0	72890
27'-0"	2290.2	10306.0	77094
27'-6"	2375.8	10889.0	81455
28'-0"	2463.0	11494.0	85981
28'-6"	2551.8	12121.0	90671

Diameter	Surface Area in Sq. Ft.	Volume in Cu. Ft.	Total Capacity in Gallons
29'-0"	2642.1	12770.0	95526
29'-6"	2734.0	13442.0	100553
30'-0"	2827.4	14137.0	105752
30'-6"	2922.5	14856.0	111131
31'-0"	3019.1	15599.0	116689
31'-6"	3117.2	16366.0	122426
32'-0"	3217.0	17157.0	128343
32'-6"	3318.3	17974.0	134463
33'-0"	3421.2	18818.0	140760
33'-6"	3525.7	19685.0	147254
34'-0"	3631.7	20580.0	153949
34'-6"	3739.3	21501.0	160839
35'-0"	3848.5	22449.0	167930
35'-6"	3959.2	23425.0	175231
36'-0"	4071.5	24429.0	182741
36'-6"	4185.4	25461.0	190462
37'-0"	4300.8	26522.0	198398
37'-6"	4417.9	27612.0	206552
38'-0"	4536.5	28731.0	214923
38'-6"	4656.6	29880.0	223518
39'-0"	4778.4	31059.0	232338
39'-6"	4901.7	32269.0	241389
40'-0"	5026.5	33510.0	250672
40'-6"	5153.0	34783.0	260195
41'-0"	5281.0	36087.0	269950
41'-6"	5410.6	37423.0	279944
42'-0"	5541.8	38792.0	290184
42'-6"	5674.5	40194.0	300672
43'-0"	5808.8	41630.0	311414
43'-6"	5944.7	43099.0	322403
44'-0"	6082.1	44602.0	333646
44'-6"	6221.1	46140.0	345151
45'-0"	6361.7	47713.0	356918
45'-6"	6503.9	49321.0	368847
46'-0"	6647.6	50965.0	381245
46'-6"	6792.9	52645.0	393312
47'-0"	6939.8	54362.0	406656
47'-6"	7083.2	56115.0	419769
48'-0"	7238.2	57906.0	433167
48'-6"	7389.8	59734.0	446841
49'-0"	7543.0	61601.0	460808
49'-6"	7697.7	63506.0	475058
50'-0"	7854.0	65450.0	489,600
55'-0"	9,503	87,116	651,673
60'-0"	11,310	113,097	846,024
65'-0"	13,273	143,788	1,075,609
70'-0"	15,394	179,595	1,343,464
75'-0"	17,672	220,894	1,652,402
80'-0"	20,106	268,083	2,005,400
85'-0"	22,698	321,556	2,405,406
90'-0"	25,447	381,704	2,855,344
95'-0"	28,353	448,920	3,358,155
100'-0"	31,416	523,598	3,916,785

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APPENDIX

BARE AREA OF PIPE FITTINGS

(Including accompanying flanges in square feet and in equivalent length of same size pipe standard weight fittings)

Pipe size In.	Flanged couplings		90° ells		Long radius ells		Tees		Crosses	
	Area Sq. Ft.	Pipe length Ft.	Area Sq. Ft.	Pipe length Ft	Area Sq. Ft.	Pipe length Ft	Area Sq. Ft.	Pipe length Ft.	Area Sq. Ft.	Pipe length Ft.
1	.32	.93	.79	2.31	.89	2.59	1.24	3.59	1.62	4.72
1¼	.38	.88	.96	2.20	1.08	2.49	1.48	3.40	1.94	4.47
1½	.48	.95	1.17	2.35	1.34	2.68	1.82	3.64	2.38	4.78
2	.67	1.08	1.65	2.65	1.84	2.96	2.54	4.08	3.32	5.34
2½	.84	1.12	2.09	2.78	2.32	3.08	3.21	4.26	4.19	5.56
3	.95	1.03	2.38	2.60	2.68	2.93	3.66	3.99	4.77	5.70
3½	1.12	1.07	2.98	2.85	3.28	3.13	4.48	4.28	5.83	5.56
4	1.34	1.14	3.53	2.90	3.96	3.36	5.41	4.59	7.03	5.97
4½	1.47	1.13	3.95	3.01	4.43	3.38	6.07	4.63	7.87	6.01
5	1.62	1.11	4.44	3.05	5.00	3.43	6.81	4.67	8.82	6.06
6	1.82	1.05	5.13	2.95	5.99	3.45	7.84	4.53	10.08	5.81
7	2.17	1.05	6.17	3.09	7.38	3.70	9.37	4.69	12.00	6.01
8	2.41	1.07	6.98	3.09	8.56	3.79	10.55	4.67	13.44	5.96
9	3.00	1.19	8.71	3.46	10.57	4.20	13.18	5.23	6.78	6.66
10	3.43	1.22	10.18	3.61	12.35	4.38	15.41	5.47	19.58	6.95
12	4.41	1.32	13.08	3.92	16.35	4.90	19.67	5.89	24.87	7.45
14	5.39	1.47	16.38	4.47	20.17	5.47	24.81	6.78	31.48	8.60
16	6.69	1.60	20.17	4.82	25.41	6.07	30.32	7.23	38.34	9.15

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APPENDIX

OUTSIDE SURFACE AREAS OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Line Flange	150	½	0.9	1.4	1.8	2.1	2.3	2.8	3.4	4.0	4.7	5.4	6.0	6.8	7.6	8.5
"	"	¾	0.9	1.4	2.1	2.1	2.3	2.9	3.4	4.0	4.7	5.4	6.1	6.8	7.6	8.5
"	"	1	1.2	1.8	2.4	2.5	2.8	3.3	3.9	4.6	5.3	6.0	6.7	7.5	8.4	9.2
"	"	1¼	1.6	2.1	2.7	3.0	3.3	3.9	4.6	5.3	6.0	6.8	7.5	8.3	9.2	10.1
"	"	1½	1.6	2.1	2.7	3.0	3.3	3.9	4.6	5.3	6.0	6.8	7.5	8.3	9.2	10.1
"	"	2	1.9	2.6	3.1	3.9	3.9	4.5	5.1	5.8	6.6	7.3	8.2	9.1	10.0	10.9
"	"	2½		3.0	3.5	3.8	4.8	4.9	5.6	6.3	7.0	7.8	8.7	9.6	10.5	11.5
"	"	3		3.0	3.6	4.5	4.8	4.9	5.6	6.4	7.1	8.0	8.8	9.7	10.7	11.6
"	"	3½		3.3	3.9	4.3	5.2	5.3	6.0	6.7	7.5	8.3	9.2	10.1	11.1	12.1
"	"	4		3.8	4.5	4.8	5.8	5.9	6.7	7.5	8.3	9.2	10.1	11.1	12.1	13.2
"	"	5		4.3	5.0	5.3	6.2	6.4	7.1	8.0	8.8	9.8	10.7	11.7	12.8	13.9
"	"	6		4.6	5.3	5.6	6.7	6.7	7.5	8.4	9.3	10.2	11.2	12.2	13.3	14.4
"	"	8		5.4	6.1	6.4	7.5	7.6	8.4	9.3	10.2	10.8	11.8	12.9	14.0	15.1
"	"	10		6.2	7.0	7.3	8.4	8.5	9.5	10.4	11.4	12.5	13.6	14.7	15.8	17.0
"	"	12		7.7	8.6	9.0	9.4	10.6	11.3	12.4	13.5	14.6	15.7	16.9	18.2	19.5
"	"	14		9.2	10.2	10.6	11.2	12.6	14.1	14.3	15.4	16.6	15.3	19.3	20.5	21.9
"	"	16		10.9	11.9	12.3	12.8	13.9	15.1	17.4	17.5	18.8	20.2	21.6	23.0	24.5
"	"	18		11.1	12.2	12.6	13.1	14.2	16.5	16.6	18.5	19.2	20.2	21.9	23.4	24.8
"	"	20		13.2	14.4	14.8	15.2	16.5	17.8	20.3	20.5	21.9	23.4	24.9	26.4	28.0
"	"	24		16.6	16.8	17.3	17.8	19.4	20.6	23.3	23.4	24.9	26.5	28.1	29.7	31.4
"	300	½	1.2	1.7	2.6	2.4	2.7	3.2	3.8	4.5	5.1	5.8	6.5	7.3	8.1	9.3
"	"	¾	1.6	2.2	2.7	3.0	3.2	3.8	4.6	5.2	5.9	6.7	7.4	8.2	9.1	10.4
"	"	1	1.6	2.2	2.7	3.0	3.2	3.8	4.6	5.2	5.9	6.7	7.4	8.2	9.1	10.4
"	"	1¼	1.6	2.2	2.7	3.5	3.5	3.9	4.7	5.3	6.0	6.8	7.5	8.4	9.3	10.4
"	"	1½	1.9	2.3	3.1	3.5	4.3	4.4	5.0	5.7	6.5	7.2	8.0	8.9	9.8	10.8
"	"	2	2.0	2.7	3.3	4.1	4.3	4.7	5.3	6.0	6.7	7.5	8.4	9.3	10.2	11.2
"	"	2½		3.1	3.7	4.0	5.0	5.1	5.8	6.6	7.3	8.1	9.0	9.9	10.9	11.9
"	"	3		3.7	4.3	4.8	5.7	5.8	6.6	7.4	8.1	9.1	10.0	11.0	11.9	13.0
"	"	3½		4.1	4.8	5.2	5.5	7.0	7.1	7.8	8.7	9.6	10.5	11.5	12.6	13.6
"	"	4		4.7	5.4	5.8	6.1	7.7	7.8	8.6	9.5	10.5	11.6	12.5	13.6	14.7
"	"	5		5.3	5.9	6.2	6.6	8.2	8.3	9.2	10.1	11.1	12.1	13.2	14.3	15.5
"	"	6		5.8	6.3	6.7	7.2	8.7	8.8	9.7	10.7	11.7	12.8	13.9	15.0	16.2
"	"	8		6.6	7.5	7.8	8.3	9.9	11.0	11.1	12.6	13.2	14.3	15.4	16.6	17.9
"	"	10		8.6	9.5	10.0	10.4	11.4	13.4	13.5	14.7	15.8	17.1	18.3	19.6	21.0
"	"	12		10.4	11.4	11.9	12.3	13.4	14.6	16.8	17.0	18.2	19.5	20.9	22.3	23.7
"	"	14		11.8	12.9	13.4	13.9	15.1	16.3	17.5	20.0	20.1	21.5	22.9	24.3	25.8
"	"	16		14.2	15.4	15.9	16.4	17.7	19.0	20.4	21.7	22.4	22.7	24.9	26.4	28.0
"	"	18		15.4	16.2	17.2	17.7	19.0	20.4	21.8	23.2	26.0	26.3	27.8	29.5	31.1
"	"	20		17.9	19.2	19.7	20.3	21.7	23.2	24.7	26.3	27.9	29.9	31.2	32.9	34.5
"	"	24		22.1	23.6	24.2	24.8	26.4	28.0	29.7	31.4	33.1	34.9	38.3	38.6	40.5
"	400	½	1.3	1.8	2.5	2.5	2.8	3.3	3.9	4.6	5.3	6.0	6.7	7.5	8.3	9.5
"	"	¾	1.7	2.3	2.9	3.1	3.4	4.0	4.7	5.4	6.1	6.8	7.6	8.4	9.4	10.2
"	"	1	1.7	2.3	2.9	3.1	3.4	4.0	4.7	5.4	6.1	6.8	7.6	8.4	9.4	10.2
"	"	1¼	1.7	2.3	2.9	3.4	3.4	4.0	4.8	5.5	6.2	6.8	7.7	8.6	10.2	10.4
"	"	1½	2.4	2.7	3.2	3.6	4.1	4.6	5.3	6.0	6.7	7.5	8.3	9.2	10.2	11.1
"	"	2	2.4	2.7	3.3	4.1	4.1	4.7	5.4	6.1	6.9	7.6	8.5	9.4	10.3	11.3
"	"	2½		3.2	3.7	4.1	5.1	5.2	5.9	6.7	7.4	8.2	9.1	10.0	10.9	12.0
"	"	3		3.7	4.3	4.8	5.8	5.9	6.7	7.5	8.3	9.2	10.1	11.1	12.1	13.8
"	"	3½		4.2	5.0	5.4	5.7	6.7	7.3	8.0	8.9	9.8	10.8	11.8	12.8	13.9
"	"	4		4.7	5.6	6.0	6.3	7.5	8.0	8.8	9.8	10.7	11.7	12.8	13.9	15.0
"	"	5		5.4	6.1	6.5	6.9	8.5	8.6	9.5	10.5	11.5	12.5	13.7	14.7	15.9
"	"	6		5.8	6.1	7.0	7.5	9.0	9.2	10.1	10.5	12.3	13.2	14.3	15.0	16.7
"	"	8		6.9	7.8	8.2	8.6	10.3	10.4	11.5	12.5	13.6	14.7	15.9	17.1	18.4
"	"	10		8.8	9.7	10.2	10.7	11.7	13.7	13.9	15.0	16.2	17.4	18.7	19.7	21.3
"	"	12		10.9	12.2	12.5	12.9	14.0	15.2	17.5	17.7	18.9	20.2	21.7	23.1	24.5
"	"	14		12.4	13.5	14.0	14.5	15.7	17.0	18.2	20.7	20.9	22.3	23.7	25.2	26.8

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches 1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Line Flange	400	16	14.7	15.8	16.4	17.0	18.3	19.6	20.9	22.3	25.1	25.3	26.9	28.4	30.1
"	"	18	16.9	17.1	17.7	18.3	19.6	21.0	22.4	23.8	26.7	26.9	28.5	30.1	31.8
"	"	20	18.6	20.0	20.5	21.1	22.6	24.1	25.6	27.1	29.8	31.9	32.1	33.9	35.7
"	"	24	23.0	24.5	25.1	25.8	27.3	29.0	30.7	32.4	34.1	35.9	39.4	39.7	41.6
"	600	½ 1.3	1.8	2.5	2.5	2.8	3.3	3.9	4.6	5.3	6.0	6.7	7.5	8.3	9.5
"	"	¾ 1.7	2.3	2.8	3.1	3.4	4.0	4.7	5.4	6.1	6.8	7.6	8.4	9.7	10.4
"	"	1 1.7	2.3	2.8	3.1	3.4	4.0	4.7	5.4	6.1	6.8	7.6	8.4	9.7	10.4
"	"	1¼ 1.7	2.3	2.8	3.6	3.6	4.0	4.8	5.5	6.2	6.8	7.7	8.6	10.2	11.1
"	"	1½ 2.4	2.7	3.2	3.6	4.1	4.6	5.3	6.0	6.8	7.5	8.3	9.2	10.2	11.1
"	"	2 2.4	2.7	3.3	4.1	4.1	4.7	5.4	6.1	6.9	7.6	8.5	9.4	10.3	11.3
"	"	2½	3.2	3.7	4.7	4.7	5.2	5.9	6.7	7.4	8.2	9.1	10.0	11.0	12.0
"	"	3	3.7	4.3	4.8	5.8	5.9	6.7	7.5	8.3	9.2	10.1	11.1	12.1	13.1
"	"	3½	4.2	5.0	5.4	6.3	6.5	7.3	8.0	8.9	9.8	10.8	11.8	12.8	13.9
"	"	4	5.1	5.7	6.1	6.5	8.1	8.2	9.1	10.0	11.0	12.0	13.0	14.1	15.3
"	"	5	6.9	7.7	8.2	8.7	9.6	10.5	11.4	12.4	13.5	14.6	15.7	16.9	18.2
"	"	6	6.9	7.7	8.2	8.7	9.6	11.1	11.4	12.4	13.5	14.6	15.7	16.9	18.2
"	"	8	8.8	9.7	10.2	10.6	10.7	11.7	12.8	14.8	15.0	16.2	17.2	20.0	21.4
"	"	10	10.8	11.9	12.5	13.0	14.3	15.6	16.6	19.0	19.2	20.5	21.9	23.3	24.8
"	"	12	12.0	12.1	13.7	14.2	15.3	16.8	17.8	20.2	20.4	21.8	23.2	24.7	26.2
"	"	14	13.7	14.9	15.4	16.0	17.3	18.5	19.9	21.3	23.8	24.1	25.6	27.2	28.8
"	"	16	16.3	17.5	18.1	18.7	20.1	21.5	22.9	24.4	25.9	28.9	29.1	30.7	32.4
"	"	18	19.0	20.4	21.1	21.7	23.1	24.6	26.2	27.7	29.3	31.0	34.3	34.5	36.3
"	"	20	21.1	22.5	23.1	23.8	25.3	26.9	28.5	30.1	31.8	33.6	36.9	37.2	39.0
"	"	24	26.6	28.2	28.9	29.7	31.4	23.1	34.9	36.7	38.8	40.5	42.4	46.2	48.5
"	900	½ 1.8	2.4	2.9	3.2	4.0	4.2	4.9	5.6	6.3	7.2	7.9	8.7	9.6	10.6
"	"	¾ 1.8	2.6	3.0	3.3	4.4	4.4	5.0	5.7	6.4	7.2	7.9	8.8	9.7	11.1
"	"	1 2.3	2.9	3.6	3.9	4.9	5.8	5.8	6.5	7.3	8.1	9.0	9.9	10.9	11.9
"	"	1¼ 2.3	2.9	3.6	3.9	4.9	5.8	5.8	6.5	7.3	8.1	9.0	9.9	10.9	11.9
"	"	1½	3.5	4.0	4.4	5.4	6.2	6.3	7.1	7.9	8.7	9.6	10.6	11.6	12.8
"	"	2	4.0	4.6	5.2	5.6	6.9	7.1	7.8	8.8	9.7	10.7	11.7	12.6	13.8
"	"	2½	4.5	5.4	5.8	6.2	7.0	7.5	8.7	9.5	10.5	11.5	12.5	13.6	14.7
"	"	3	4.5	5.4	5.8	6.2	7.6	7.7	8.7	9.5	10.5	11.5	12.5	13.6	14.7
"	"	3½	5.4	5.8	6.7	7.2	7.7	8.7	9.5	10.3	11.5	12.5	13.6	14.6	15.7
"	"	4	5.9	6.7	7.2	7.6	8.5	10.2	10.3	11.3	12.3	13.4	14.6	15.7	16.9
"	"	5	7.2	8.1	8.6	9.1	10.4	11.0	12.9	14.1	15.0	16.2	17.4	18.7	20.0
"	"	6	8.0	8.7	9.2	9.7	10.7	11.6	13.7	13.9	15.0	16.2	17.4	18.7	20.0
"	"	8	10.8	11.8	12.3	12.9	14.1	15.2	16.4	17.7	20.0	20.3	21.7	23.1	24.6
"	"	10	13.0	14.1	14.7	15.3	16.5	17.7	19.1	20.4	21.7	24.5	24.7	26.2	27.8
"	"	12	14.6	15.7	16.6	16.9	18.2	19.5	20.9	22.3	23.7	26.6	26.8	28.4	30.0
"	"	14	16.7	18.0	18.6	19.3	20.7	22.0	23.5	25.0	26.6	28.2	29.8	31.5	33.2
"	"	16	18.3	19.6	20.3	20.9	22.4	23.9	25.8	27.3	28.5	30.2	33.3	33.6	35.3
"	"	18	22.4	23.8	24.6	25.3	26.9	28.5	30.0	31.8	33.5	35.3	37.1	40.6	40.9
"	"	20	25.8	27.4	28.2	28.9	30.6	32.3	34.1	35.9	37.7	39.6	41.5	43.5	47.3
"	"	24	36.5	38.4	39.4	40.3	42.3	44.3	46.3	48.4	50.6	52.8	55.1	57.1	59.6
"	1500	½ 1.8	2.4	2.9	3.2	3.5	4.2	4.9	5.6	6.3	7.1	7.9	8.7	9.6	10.6
"	"	¾ 1.8	2.5	2.9	3.3	4.2	4.2	5.0	5.7	6.4	7.2	8.0	8.8	9.7	11.1
"	"	1 2.3	2.9	3.6	3.9	4.9	5.8	5.8	6.5	7.3	8.1	9.0	9.9	10.9	11.9
"	"	1¼ 2.3	2.9	3.6	3.9	4.9	5.8	5.8	6.5	7.3	8.1	9.0	9.9	10.9	11.9
"	"	1½	3.5	4.0	4.4	5.4	6.2	6.3	7.1	7.9	8.7	9.6	10.6	11.6	12.6
"	"	2	4.1	4.6	5.2	5.6	7.0	7.1	7.8	8.9	9.7	10.7	11.7	12.6	13.8
"	"	2½	4.6	5.4	5.8	6.2	6.9	8.5	8.7	9.5	10.5	11.5	12.5	13.6	14.7
"	"	3	5.6	6.3	6.8	7.2	8.1	9.8	10.0	10.9	11.9	12.7	13.8	15.0	16.2
"	"	3½	6.3	6.8	7.7	8.1	8.6	10.0	11.9	11.9	12.7	13.8	15.0	16.2	17.2
"	"	4	7.0	7.7	8.2	8.7	9.8	10.7	12.5	12.7	13.7	15.0	16.2	17.2	18.6
"	"	5	8.9	10.5	10.5	10.9	12.0	13.0	14.1	16.3	16.6	17.8	19.1	20.4	21.8
"	"	6	9.8	10.7	11.2	11.9	12.8	14.0	15.2	16.4	17.7	18.9	20.3	21.8	23.1

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			½ 1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Line Flange	1500	8		12.5	13.6	14.2	14.8	16.1	17.3	18.6	19.9	22.5	22.7	24.5	25.7	27.1
"	"	10		16.6	17.8	18.6	19.3	20.7	22.0	23.5	25.0	26.4	28.1	31.0	31.4	33.1
"	"	12		21.4	22.9	23.7	24.4	26.0	27.6	29.2	30.9	32.6	34.3	36.1	38.0	41.5
"	"	14		25.6	27.2	28.1	28.9	30.6	32.3	34.1	36.0	37.8	39.7	41.6	43.7	45.7
"	"	16		29.9	31.7	32.6	33.6	35.4	37.2	39.1	41.0	43.0	45.1	47.2	49.3	51.4
"	"	18		34.6	36.5	37.0	40.4	42.3	44.4	46.4	48.5	50.2	52.9	55.1	57.4	60.0
"	"	20		39.9	41.9	43.0	44.0	46.1	48.2	50.4	52.6	54.8	57.1	59.4	61.8	64.2
"	"	24		52.6	54.8	56.1	57.2	59.6	62.1	64.5	67.0	69.5	72.1	74.7	77.3	79.2
Screwed Globe Valve		¼	1.2	1.2	1.6	2.1	2.6	3.3	3.9	4.7	5.5	6.5	7.4	8.4	9.4	10.5
"		⅜	1.3	1.3	1.7	2.3	2.8	3.4	4.1	4.8	5.7	6.7	7.7	8.6	9.7	10.8
"		1	1.5	2.1	2.7	3.0	3.6	4.8	5.2	6.0	7.0	8.0	9.0	10.0	11.0	12.4
"		1¼	1.9	1.9	2.5	3.0	3.6	4.8	5.2	6.0	7.0	8.0	9.0	10.0	11.0	12.4
"		1½	2.5	2.9	3.1	3.4	4.1	5.1	5.6	6.6	7.6	8.6	9.7	10.6	11.9	13.4
"		2	2.6	2.9	3.2	3.8	4.6	5.4	6.2	7.3	8.2	9.3	10.4	11.2	12.8	14.2
"		2½	3.7	3.7	4.4	5.2	6.0	7.0	8.0	9.1	10.2	11.4	12.6	13.9	15.2	15.9
"		3	3.9	3.9	4.7	5.6	6.4	7.4	8.4	9.5	10.6	11.8	13.1	14.4	15.7	17.0
"		3½														
"		4														
"		5														
"		6														
"		8														
"		10														
"		12														
"		14														
"		16														
"		18														
"		20														
"		24														
Flanged Globe Valve	150	¼														
"	"	⅜														
"	"	1														
"	"	1¼														
"	"	1½														
"	"	2	5.6	5.6	6.2	6.7	7.7	8.8	9.9	11.0	12.1	12.3	14.5	17.0	17.3	19.4
"	"	2½		6.8	8.0	8.0	9.5	10.3	11.4	12.6	13.8	15.1	16.5	18.0	19.4	21.0
"	"	3		7.2	8.1	8.8	9.6	10.8	11.8	13.1	14.3	15.7	17.1	18.5	20.0	21.0
"	"	3½		8.1	8.8	9.6	10.8	13.1	14.3	15.7	17.1	18.5	20.0	21.0	22.3	24.4
"	"	4		9.9	10.8	11.5	12.7	14.0	15.2	16.2	17.9	19.2	21.2	22.3	24.4	26.0
"	"	5		11.9	12.6	13.4	14.7	16.0	17.5	18.9	20.4	22.2	23.9	25.5	27.9	28.6
"	"	6		12.8	13.6	14.3	15.6	16.9	18.6	20.1	21.6	23.2	24.9	26.7	28.5	30.9
"	"	8		16.8	18.8	19.7	20.7	22.3	24.0	25.7	27.5	29.4	31.3	33.2	35.2	37.3
"	"	10		21.5	23.2	24.2	35.3	27.0	29.0	31.0	32.9	34.9	36.9	39.1	41.2	43.6
"	"	12		24.9	26.8	27.2	29.0	30.9	32.9	34.8	36.9	39.0	41.1	43.5	45.6	48.0
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														
"	300	¼														
"	"	⅜														
"	"	1	2.9	3.8	4.5	5.2	5.8	6.7	7.9	8.9	10.1	11.3	12.5	13.8	15.2	16.4
"	"	1¼	3.3	4.0	4.8	5.3	5.8	6.7	7.9	8.9	10.1	11.3	12.5	13.8	15.2	16.2

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Globe Valve	300	1½	3.3	4.3	5.0	5.6	6.1	6.9	8.0	9.0	10.1	11.3	12.5	13.8	15.2	16.2
"	"	2		7.1	8.1	8.4	9.4	10.7	11.8	13.2	15.7	15.7	17.1	18.5	20.0	21.5
"	"	2½		8.3	9.4	10.3	10.6	12.2	13.4	14.7	16.1	17.5	19.0	20.5	22.0	23.7
"	"	3		9.4	10.8	11.2	12.2	13.5	14.8	16.2	17.6	19.1	20.7	22.1	23.8	25.6
"	"	3½		11.6	12.9	13.8	14.4	15.8	17.3	18.7	20.2	21.8	23.4	25.2	26.9	28.7
"	"	4		14.3	15.9	16.5	17.4	19.0	20.4	22.0	23.6	25.4	26.7	29.7	30.9	32.8
"	"	5		14.7	16.5	17.4	19.0	20.4	20.8	21.6	24.9	26.7	28.0	30.4	32.3	34.0
"	"	6		15.2	16.6	17.5	18.5	20.0	21.6	23.3	24.9	26.7	28.0	30.4	32.3	34.3
"	"	8		20.8	22.5	23.4	24.4	26.2	28.0	30.0	31.9	33.8	35.9	38.0	40.1	42.4
"	"	10		27.4	29.1	30.7	32.3	33.7	35.7	37.8	40.0	42.2	45.4	46.8	49.2	51.7
"	"	12		36.8	38.9	40.3	41.6	44.0	46.3	48.9	51.2	53.7	56.3	58.9	61.6	64.3
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														
"	400	¾														
"	"	¾														
"	"	1														
"	"	1¼														
"	"	1½	6.5	6.8	7.6	7.8	8.5	9.7	10.9	11.5	12.6	13.9	15.2	16.6	18.0	19.5
"	"	2		7.9	8.8	9.6	10.6	11.6	13.0	14.3	15.6	17.0	18.5	20.0	21.8	23.2
"	"	2½		9.3	10.3	11.2	12.7	13.2	14.5	15.9	17.3	18.8	20.3	21.9	23.5	25.3
"	"	3		9.8	10.9	11.9	12.8	14.0	15.4	16.8	18.3	19.8	21.4	23.0	24.7	26.4
"	"	3½		11.9	12.8	14.0	15.4	16.8	17.3	18.3	19.8	21.4	23.0	24.7	26.4	28.9
"	"	4		13.8	15.1	14.8	16.5	17.1	18.7	19.8	21.9	23.6	25.3	27.0	28.9	30.9
"	"	5		15.8	17.1	18.1	19.1	21.0	22.7	25.1	26.2	27.9	29.8	31.9	33.9	35.9
"	"	6		20.4	22.2	23.3	24.4	26.1	27.9	29.8	31.7	33.9	36.4	38.0	40.2	42.4
"	"	8		26.0	26.9	28.0	28.1	31.2	33.2	35.3	37.4	39.5	41.8	43.5	46.0	48.2
"	"	10														
"	"	12														
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														
"	600	¾														
"	"	¾														
"	"	1	3.3	4.3	5.2	5.9	6.6	7.6	8.8	9.8	11.1	12.4	13.7	15.0	16.5	18.0
"	"	1¼	3.9	4.9	5.4	6.8	7.2	7.6	9.4	10.5	11.6	12.9	14.1	15.5	16.9	18.3
"	"	1½		6.9	7.9	8.5	9.4	10.5	11.7	12.8	14.0	15.5	16.8	18.3	19.7	21.2
"	"	2		7.7	8.7	9.4	10.3	11.5	12.7	14.0	15.3	16.7	18.2	19.7	21.2	22.8
"	"	2½		8.9	11.1	11.7	12.6	13.9	15.2	16.7	18.0	19.5	21.1	22.7	24.4	26.1
"	"	3		10.2	11.7	12.5	13.3	14.6	16.0	17.5	18.9	20.5	22.1	23.7	25.4	27.2
"	"	3½		11.7	12.5	13.6	14.6	16.0	17.5	18.9	20.5	22.1	23.7	25.4	27.2	29.3
"	"	4		12.9	14.2	15.3	16.0	17.5	19.1	20.8	22.2	23.9	25.5	27.4	29.3	31.1
"	"	5		18.0	19.5	20.8	21.6	23.3	25.0	26.7	28.7	30.6	32.8	34.5	36.6	38.7
"	"	6		20.2	22.0	23.1	24.1	25.8	27.6	29.6	31.6	33.6	35.6	37.7	39.9	42.0
"	"	8		30.0	32.0	33.3	34.5	36.6	38.8	41.9	43.2	45.7	47.9	50.8	52.8	55.4
"	"	10														
"	"	12														
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pressure psi	Nominal pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Globe Valve	900	¼														
"	"	⅜														
"	"	1														
"	"	1¼														
"	"	1½		9.7	10.8	11.9	12.7	14.0	15.3	16.8	18.3	19.8	21.4	23.0	24.7	26.6
"	"	2		13.7	15.1	16.1	17.1	18.6	20.3	22.0	23.7	25.4	27.1	29.1	31.0	33.0
"	"	2½		15.7	16.9	18.0	19.0	19.7	22.4	24.1	25.9	27.6	29.6	32.1	34.1	36.2
"	"	3		15.7	16.9	18.0	19.0	19.9	22.6	24.5	26.3	27.9	30.3	33.3	34.7	36.8
"	"	3½		16.9	18.0	19.0	19.9	22.6	23.2	25.9	27.9	29.6	31.8	33.8	35.0	37.4
"	"	4		17.5	19.1	20.2	21.3	23.1	24.8	26.8	28.4	30.4	32.4	34.4	36.5	38.6
"	"	5		21.0	22.8	24.0	24.6	27.1	29.0	30.9	32.1	35.1	37.3	39.4	41.7	44.0
"	"	6		25.4	27.3	28.5	29.8	31.7	33.9	36.1	38.2	40.5	42.7	45.1	48.2	50.1
"	"	8		35.4	37.4	38.9	40.6	42.9	45.4	45.9	50.3	53.0	56.2	58.1	60.9	63.6
"	"	10														
"	"	12														
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														
"	1500	¼														
"	"	⅜														
"	"	1														
"	"	1¼														
"	"	1½														
"	"	2		13.1	14.5	15.4	16.3	17.9	19.5	21.1	22.7	24.4	26.1	28.0	29.4	31.9
"	"	2½		14.2	15.7	16.6	17.6	19.1	20.8	22.5	24.1	25.9	27.7	29.6	31.6	33.6
"	"	3		19.4	21.1	22.4	23.6	25.5	27.2	29.0	31.0	33.1	35.7	37.3	39.4	41.5
"	"	3½		22.4	23.8	25.5	25.9	27.2	31.0	33.1	35.2	37.3	39.4	41.5	43.8	44.0
"	"	4		24.6	26.4	27.6	28.9	30.8	33.0	35.0	37.2	39.5	41.6	43.8	46.2	49.6
"	"	5		31.3	32.4	34.8	36.3	38.7	40.9	43.2	45.6	48.2	50.8	53.3	55.8	58.6
"	"	6		34.6	36.8	38.5	40.0	42.3	44.6	47.3	49.8	52.3	55.0	57.5	60.3	63.0
"	"	8														
"	"	10														
"	"	12														
"	"	14														
"	"	16														
"	"	18														
"	"	20														
"	"	24														
Screwed Gate Valve		¼														
"		⅜														
"		1														
"		1¼														
"		1½														
"		2	5.1	5.1	6.3	7.5	8.9	10.5	12.1	13.7	15.5	17.4	19.4	21.3	23.7	26.0
"		2½	6.2	6.2	7.5	8.8	10.4	12.0	13.6	15.4	17.3	19.3	21.4	23.6	26.0	28.3
"		3	7.3	7.3	8.6	10.2	11.8	13.4	15.2	17.0	19.1	21.2	23.3	25.7	28.0	30.6
"		3½	7.6	7.6	8.9	10.5	12.1	13.8	15.6	17.5	19.6	21.8	23.8	26.1	28.5	31.1
"		4	8.6	8.6	10.2	11.7	13.4	15.2	17.0	19.0	24.1	23.3	25.6	28.0	30.6	33.2
"		5		11.2	13.6	14.5	15.2	19.0	19.3	23.3	25.6	28.0	30.6	33.2	36.5	39.4
"		6		13.2	15.4	17.3	19.4	21.5	23.7	26.1	28.5	31.1	33.8	36.5	39.4	42.4

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Screwed Gate Valve		8		17.6	19.7	21.7	24.1	26.5	29.0	31.6	34.3	37.1	40.0	43.0	46.2	49.5
"		10		20.9	23.2	25.5	28.0	30.6	33.2	36.1	38.9	42.0	45.1	48.3	51.5	55.0
"		12														
"		14														
"		16														
"		18														
"		20														
"		24														
Flanged Gate Valve	150	½														
"	"	¾														
"	"	1	4.1	4.4	4.8	5.3	5.8	6.5	9.3	10.4	12.0	12.6	13.9	15.2	16.5	18.0
"	"	1½	4.3	4.8	5.3	5.8	6.9	9.0	10.4	11.2	12.4	13.6	15.0	16.3	17.7	19.2
"	"	1½	4.6	4.9	5.7	6.3	7.4	10.1	11.3	12.4	13.6	14.9	16.3	12.7	19.2	20.6
"	"	2		5.0	6.1	7.2	8.6	10.2	11.8	13.4	15.4	17.4	19.5	21.8	24.1	26.3
"	"	2½		5.6	7.0	8.1	9.7	11.3	13.0	14.8	16.5	18.8	20.6	23.4	25.7	28.3
"	"	3		7.0	8.1	9.6	11.1	12.7	14.5	16.5	18.6	20.8	23.0	25.4	28.0	30.6
"	"	3½		7.3	8.4	9.6	11.2	12.9	14.7	16.5	18.7	20.5	23.2	25.6	27.6	30.6
"	"	4		8.4	9.7	11.0	12.5	14.3	16.2	18.3	20.5	22.8	25.2	27.7	30.3	33.0
"	"	5		10.0	11.5	12.9	15.3	16.3	17.2	20.5	22.8	25.2	27.8	30.4	33.1	36.0
"	"	6		13.0	13.7	16.0	17.9	19.9	22.2	24.6	27.1	29.7	32.0	35.3	38.2	41.3
"	"	8		16.7	18.3	20.3	21.8	24.1	26.1	29.2	32.0	34.8	37.3	40.8	44.0	48.1
"	"	10		19.8	21.5	23.4	25.4	27.5	30.2	32.9	35.9	38.9	41.9	45.3	48.6	52.1
"	"	12		25.5	27.4	30.2	31.7	33.9	36.6	39.6	42.8	46.2	49.5	53.1	55.2	60.1
"	"	14		26.7	31.8	34.0	36.3	39.2	41.9	43.8	47.2	50.7	54.4	58.0	61.8	63.4
"	"	16		39.8	42.8	45.4	48.0	50.8	53.7	56.5	59.8	64.1	68.1	72.5	76.8	81.1
"	"	18		41.2	43.7	46.4	49.0	51.8	54.7	57.7	61.3	65.1	69.3	73.5	77.9	82.3
"	"	20		48.1	50.9	53.4	56.7	59.5	62.4	65.9	6.97	73.9	78.3	82.8	88.4	89.3
"	"	24		60.0	62.5	67.2	69.3	72.6	76.1	79.5	83.7	88.5	93.5	98.3	103.2	108.6
"	300	½														
"	"	¾														
"	"	1	4.1	5.2	6.1	6.6	6.9	8.5	9.3	10.4	12.0	12.6	13.9	15.2	16.5	18.0
"	"	1½	4.6	5.6	6.6	7.3	7.8	9.0	10.4	11.2	12.4	13.6	15.0	16.3	17.7	19.2
"	"	1½	6.8	6.8	7.6	8.2	9.0	10.1	11.3	12.4	13.6	14.9	16.3	17.7	19.2	20.8
"	"	2		7.2	8.1	8.7	9.6	10.7	11.8	13.0	14.3	16.0	17.1	18.5	20.0	21.5
"	"	2½		8.2	9.1	10.0	10.7	11.8	13.1	14.3	15.7	17.1	18.5	20.0	21.5	23.2
"	"	3		9.7	11.0	11.8	12.5	13.8	15.1	16.5	18.3	19.7	21.4	22.9	24.8	26.5
"	"	3½		9.8	11.2	11.8	12.5	13.8	15.1	16.5	18.3	19.7	21.4	22.9	24.8	26.5
"	"	4		12.2	13.4	14.2	14.9	16.4	17.9	19.3	20.9	22.4	24.1	25.9	27.8	29.4
"	"	5		14.7	16.0	16.6	17.8	19.2	20.8	22.4	24.0	25.8	27.6	29.4	31.3	33.2
"	"	6		16.8	17.9	19.2	19.8	21.3	23.0	24.6	26.4	28.3	30.1	32.0	34.0	36.1
"	"	8		20.8	22.6	23.4	24.4	26.2	28.0	29.9	31.8	33.7	35.7	37.8	40.0	42.1
"	"	10		27.1	28.7	29.8	21.2	33.2	35.2	37.3	39.3	41.7	43.9	46.1	48.2	50.8
"	"	12		35.1	37.2	38.5	39.6	42.0	43.9	46.4	48.8	51.1	53.5	56.1	58.7	61.4
"	"	14		40.0	46.6	50.2	51.3	64.1	56.6	59.2	62.0	64.7	67.6	69.6	73.3	75.8
"	"	16		55.0	57.5	59.2	60.7	63.5	66.2	69.3	72.1	75.0	78.3	81.3	84.3	87.5
"	"	18		60.1	63.1	64.3	66.2	68.9	72.0	74.9	78.1	81.0	84.2	87.3	90.8	94.0
"	"	20		71.8	74.8	76.5	78.4	81.6	84.1	87.9	91.2	94.5	98.1	101.5	105.0	108.4
"	"	24		93.6	96.9	98.9	100.9	104.3	107.9	111.6	114.2	119.0	122.8	126.6	130.5	134.5
"	400	½														
"	"	¾														
"	"	1	4.6	5.7	6.7	7.3	7.8	9.0	10.1	11.2	12.4	13.7	15.0	16.3	17.7	19.2
"	"	1½	4.7	5.9	6.9	7.8	8.1	9.3	10.4	11.6	12.8	14.0	15.4	16.7	18.2	19.7

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line press psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches												
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Gate Valve	400	1½	4.9	8.0	8.9	7.6	8.1	9.4	10.4	11.6	12.8	14.0	15.4	16.7	18.2	19.6
"	"	2		8.1	9.2	10.1	10.7	11.9	13.1	14.4	15.8	17.2	18.6	20.1	21.6	23.3
"	"	2½		9.8	11.0	11.9	12.4	13.7	15.0	16.5	17.8	19.3	20.9	22.4	24.1	25.9
"	"	3		10.3	11.8	12.5	13.3	14.6	16.0	17.5	18.9	21.0	22.1	23.7	25.4	27.2
"	"	3½		13.8	15.1	16.1	17.0	18.5	20.2	21.8	23.4	25.2	26.9	28.8	30.8	32.7
"	"	4		13.8	15.1	16.1	17.0	18.5	20.2	21.8	23.4	25.2	26.9	28.8	30.8	32.7
"	"	5		18.0	19.6	20.7	21.7	23.4	25.1	26.9	28.8	30.8	32.8	34.7	36.8	38.9
"	"	6		18.8	20.2	21.3	22.4	24.0	25.8	27.5	29.5	31.5	33.4	35.4	37.6	39.7
"	"	8		26.3	27.2	28.2	29.4	31.4	33.5	35.6	37.7	39.8	42.1	44.3	46.9	49.1
"	"	10		31.0	33.1	34.4	35.7	37.8	40.0	42.2	44.5	47.0	49.3	51.7	54.2	56.8
"	"	12		37.0	41.0	42.4	43.8	46.1	49.4	51.0	53.5	56.1	58.7	61.3	64.1	66.9
"	"	14		48.3	47.8	49.3	51.7	54.3	56.9	59.6	62.3	65.1	67.9	70.8	73.7	86.6
"	"	16		57.4	60.1	61.8	63.5	66.3	69.3	72.2	75.2	78.3	81.3	84.6	87.7	91.1
"	"	18		63.0	65.8	67.5	69.3	72.2	75.2	78.2	81.3	84.9	87.7	91.1	94.4	97.8
"	"	20		74.1	78.2	80.0	81.9	85.1	88.3	91.7	95.0	98.5	101.9	105.4	109.0	112.6
"	"	24		96.6	100.0	102.0	104.2	107.7	111.4	115.1	118.9	122.4	128.6	129.5	134.5	138.5
"	600	¾														
"	"	¾														
"	"	1	4.0	5.1	5.9	6.6	7.2	8.1	9.4	10.4	11.6	12.8	14.0	15.4	16.7	18.8
"	"	1½	5.1	6.3	7.4	8.0	8.6	10.0	11.1	12.3	13.5	14.8	16.2	17.8	19.1	20.6
"	"	1½		7.3	8.3	8.9	9.7	10.9	12.0	13.2	14.5	15.9	17.3	18.7	20.3	21.8
"	"	2		10.5	11.7	12.5	13.2	14.5	15.9	17.4	18.4	20.3	21.8	23.5	25.3	27.0
"	"	2½		11.2	12.5	13.5	14.1	15.4	16.9	18.4	19.9	21.4	23.0	24.8	26.6	28.3
"	"	3		12.9	14.2	15.0	15.9	17.4	18.9	20.5	22.0	23.8	25.4	27.2	29.0	30.9
"	"	3½		16.2	18.0	19.3	20.7	22.9	25.0	27.2	29.7	32.1	34.7	37.4	40.1	42.9
"	"	4		18.3	19.1	21.1	22.1	23.8	25.6	27.3	29.3	31.3	33.3	35.3	37.4	39.5
"	"	5		21.4	23.3	24.4	26.5	27.4	29.2	31.2	33.3	35.4	37.5	39.7	41.9	44.2
"	"	6		25.9	27.8	28.8	30.2	32.2	34.3	36.5	38.6	40.9	43.1	45.4	48.0	50.3
"	"	8		34.1	36.4	37.8	39.2	41.5	43.9	46.3	48.7	51.3	53.7	56.3	59.0	8.17
"	"	10		41.6	44.0	45.4	46.9	49.5	51.8	54.4	57.0	59.7	62.4	65.2	68.0	70.9
"	"	12		48.8	51.6	52.9	54.4	57.1	59.8	62.5	65.3	68.1	71.1	74.0	77.0	80.1
"	"	14		57.6	60.4	62.0	63.5	66.8	69.4	72.4	75.4	78.4	81.5	84.7	88.0	91.2
"	"	16		66.0	69.0	70.7	72.4	75.4	78.5	81.6	84.8	88.1	91.4	94.7	98.1	101.5
"	"	18		79.1	82.3	84.2	86.1	89.4	92.8	96.2	99.6	103.1	106.7	110.4	114.0	117.8
"	"	20		90.5	93.9	95.9	98.0	101.6	105.2	108.8	112.5	116.2	119.2	123.9	127.8	131.8
"	"	24		120.8	124.8	127.2	129.6	133.7	137.8	141.9	146.2	150.4	154.9	159.2	161.7	168.2
"	900	¾														
"	"	¾														
"	"	1		8.7	9.7	10.7	11.4	12.6	13.9	15.2	16.7	18.2	19.6	21.2	22.7	24.5
"	"	1½		9.3	10.4	11.4	12.2	13.5	14.9	16.2	17.8	19.3	20.8	22.4	24.0	25.8
"	"	1½		9.9	10.9	12.0	12.9	14,2	15.5	17.0	18.5	20.0	21.6	23.3	24.9	26.7
"	"	2		13.3	14.7	15.6	16.5	18.0	19.7	21.3	23.0	24.6	26.4	28.3	30.2	32.2
"	"	2½		16.7	18.2	19.2	20.3	22.0	23.7	25.5	27.2	29.1	31.1	33.1	35.2	37.2
"	"	3		17.1	18.7	19.2	20.8	22.5	24.3	26.1	27.8	29.8	31.8	33.8	35.9	38.0
"	"	3½		17.8	19.4	20.5	21.8	23.3	25.0	26.7	28.6	30.6	32.5	34.5	36.6	38.7
"	"	4		20.6	21.4	22.5	23.6	25.3	27.1	28.9	30.9	31.9	34.9	37.0	39.2	41.3
"	"	5		26.7	28.7	29.7	31.1	33.2	35.3	37.4	39.8	41.9	44.1	46.7	48.9	51.4
"	"	6		31.1	33.2	34.8	36.9	38.0	40.3	42.6	44.9	47.4	49.7	52.2	54.8	57.4
"	"	8		38.2	40.5	41.9	43.3	45.7	48.2	50.8	53.2	55.8	59.5	61.2	64.0	66.8
"	"	10		47.6	50.2	51.8	53.6	56.1	58.8	61.5	64.4	67.2	70.2	73.1	76.2	79.3
"	"	12		59.1	61.7	63.6	65.3	68.3	71.2	74.3	77.4	81.0	83.8	87.0	90.4	93.7
"	"	14		69.5	72.6	74.5	76.4	79.6	82.9	86.2	89.5	92.9	96.3	99.9	103.4	107.1
"	"	16		81.7	85.1	87.1	89.1	92.6	96.0	99.6	103.1	106.8	110.4	114.2	118.0	121.9
"	"	18		95.9	99.5	101.7	104.0	107.6	111.4	115.2	119.0	122.9	126.9	130.9	134.9	139.0
"	"	20														
"	"	24														

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line press psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches: 1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Gate Valve	1500	½														
"	"	¾														
"	"	1	7.9	8.9	9.5	10.6	11.8	13.0	14.3	15.7	17.2	18.6	20.1	21.7	23.3	
"	"	1¼	9.3	10.5	11.5	12.3	13.6	14.9	16.3	17.9	19.4	20.9	22.5	24.1	25.9	
"	"	1½	9.7	10.9	12.0	12.8	14.1	15.5	16.9	18.4	20.0	21.6	23.2	24.9	26.7	
"	"	2	13.1	14.4	14.6	16.3	17.4	19.4	21.0	22.5	24.3	26.0	27.9	29.8	31.7	
"	"	2½	16.4	17.8	18.8	19.9	21.5	23.2	25.0	26.7	28.6	30.6	32.5	34.5	36.6	
"	"	3	19.5	21.1	22.4	23.6	25.3	27.2	29.1	31.0	33.1	35.2	37.3	39.5	41.7	
"	"	3½	21.8	23.6	24.9	26.0	27.9	29.8	31.8	33.9	36.0	38.2	40.4	42.7	44.9	
"	"	4	20.2	21.8	25.1	28.6	30.6	32.7	34.8	36.9	39.1	41.4	43.7	46.0	48.6	
"	"	5	35.2	37.4	39.0	40.5	42.8	45.2	47.6	50.2	52.9	55.4	58.0	60.8	63.6	
"	"	6	40.2	43.0	44.0	45.5	48.0	50.5	53.3	56.8	58.5	61.2	64.0	66.9	69.9	
"	"	8	51.7	54.5	56.3	57.9	60.7	63.6	66.4	69.4	72.4	75.4	78.6	81.8	85.0	
"	"	10	68.3	71.5	73.6	75.6	78.8	82.1	85.5	88.9	92.3	95.8	99.4	103.0	106.7	
"	"	12	81.3	86.7	89.1	91.3	94.9	98.5	102.1	105.9	109.0	113.5	117.4	121.4	125.3	
"	"	14	96.7	100.4	103.0	105.5	109.3	113.3	117.2	121.3	125.3	129.5	133.6	137.9	142.2	
"	"	16	116.0	120.0	122.8	125.4	129.6	133.8	138.0	142.4	146.9	151.2	155.7	160.2	164.9	
"	"	18														
"	"	20														
"	"	24														
Welding Tee		¾														
"		¾	.7	1.1	1.6	2.6	3.3	4.0	4.9	5.9	6.8	7.9	9.3			
"		1	.9	1.3	1.8	2.6	3.3	4.0	4.9	5.9	6.8	7.9	9.3			
"		1¼	.9	1.3	1.8	2.6	3.3	4.0	4.9	5.9	6.8	7.9	9.3			
"		1½	1.1	1.6	2.5	3.2	4.0	4.8	5.8	6.8	7.8	9.3	10.5			
"		2	1.3	1.8	2.5	3.2	4.0	4.8	5.8	6.8	7.8	9.3	10.5	11.3	11.7	12.9
"		2½	1.5	2.5	3.2	3.9	4.7	5.7	6.7	7.8	9.2	10.4	11.7	13.1	14.5	16.1
"		3	1.8	2.5	3.2	3.9	4.7	5.7	6.7	7.8	9.2	10.4	11.7	13.1	14.6	16.1
"		3½	2.3	3.0	3.8	4.6	5.6	6.6	7.7	9.1	10.3	11.6	13.0	14.5	16.0	17.6
"		4	2.4	3.0	3.8	4.6	5.6	6.6	7.7	9.1	10.3	11.6	13.0	14.5	16.0	17.8
"		5	3.0	3.7	4.4	5.3	5.8	6.7	7.8	9.1	10.3	11.6	13.0	14.5	16.0	17.6
"		6	3.7	4.4	5.3	6.2	7.1	8.3	9.3	10.5	11.7	12.9	14.4	15.8	17.3	18.8
"		8		6.2	7.1	8.3	9.3	10.5	11.7	13.0	14.4	15.8	17.3	18.8	20.4	22.1
"		10		9.2	10.3	11.5	12.8	14.1	15.6	17.1	18.6	20.2	21.9	23.7	25.5	27.4
"		12		11.5	12.8	14.1	15.6	17.1	18.6	20.2	21.9	23.7	25.5	27.4	29.3	31.3
"		14		12.8	14.1	15.6	17.1	18.6	20.2	21.9	23.7	25.5	27.4	29.3	31.3	33.4
"		16		15.6	17.1	18.6	20.2	21.9	23.7	25.5	27.4	29.3	31.3	33.4	35.5	37.7
"		18		18.6	20.2	21.9	23.7	25.5	27.3	29.3	31.3	33.4	35.5	37.7	39.9	42.3
"		20		21.9	23.7	25.5	27.3	29.3	31.3	33.4	35.5	37.7	39.9	42.3	44.7	47.1
"		24		29.3	31.3	33.4	35.5	37.7	39.9	42.3	44.7	47.1	49.6	52.2	54.9	57.8
Screwed Tee		¾	1.0	1.5	1.8	2.2	2.7	3.3	3.9	4.6	5.3	6.0	7.2	7.7	8.5	9.5
"		¾	1.1	1.6	2.6	3.2	4.0	4.8	5.9	6.9	8.0	9.3	10.5	11.8	13.2	14.7
"		1	1.3	1.8	2.6	3.2	4.0	4.8	5.9	6.9	8.0	9.3	10.5	11.8	13.2	14.7
"		1¼	1.6	2.6	3.3	4.0	4.8	5.9	6.9	8.0	9.3	10.5	11.8	13.2	14.7	16.2
"		1½	1.6	2.6	3.3	4.0	4.8	5.9	6.9	8.0	9.3	10.5	11.8	13.2	14.7	16.2
"		2	1.6	2.6	3.3	4.0	4.8	5.9	6.9	8.0	9.3	10.5	11.8	13.2	14.7	16.2
"		2½	2.5	3.2	3.9	4.8	5.8	6.8	7.8	9.2	10.4	11.7	13.1	14.6	16.2	17.7
"		3	3.1	3.9	4.8	5.7	6.7	7.8	9.1	10.4	11.7	13.0	14.5	16.1	17.7	19.4
"		3½	3.1	3.9	4.8	5.7	6.7	7.8	9.1	10.4	11.7	13.0	14.5	16.1	17.7	19.4
"		4	3.1	3.9	4.8	5.7	6.7	7.8	9.1	10.4	11.7	13.0	14.5	16.1	17.7	19.4
"		5		4.6	5.3	6.0	6.9	8.0	9.1	10.4	11.7	13.0	14.5	16.1	17.7	19.4
"		6		5.1	6.1	7.0	7.9	8.7	9.6	10.6	11.7	13.0	14.5	16.1	17.7	19.4
"		8		7.5	8.7	9.3	10.6	11.2	12.7	13.4	15.0	15.6	17.3	18.1	20.0	20.8
"		10		10.4	11.4	12.5	13.6	14.7	15.9	17.1	18.4	19.7	21.1	22.5	23.9	25.4
"		12		11.7	13.6	14.7	15.9	17.1	18.4	19.7	21.1	22.8	23.9	25.4	26.9	28.5
"		14														

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Screwed Tee		16														
"		18														
"		20														
"		24														
Flanged Tee	150	½														
"	"	¾														
"	"	1	3.0	3.8	5.2	4.9	5.3	6.0	6.8	7.7	8.5	10.3	11.2	12.2	13.4	14.6
"	"	1½	3.8	4.7	5.2	6.2	6.6	7.5	8.6	9.5	10.5	11.6	12.6	13.8	15.0	16.2
"	"	1½	3.9	4.9	5.9	6.1	6.6	7.5	8.6	9.5	10.5	11.6	12.6	13.8	15.0	16.2
"	"	2	4.8	5.9	6.9	8.2	8.5	9.5	10.5	11.6	12.7	13.8	15.1	16.3	17.6	18.9
"	"	2½		7.2	8.1	8.8	10.1	10.4	11.4	12.5	13.6	14.9	16.1	18.2	18.7	20.0
"	"	3		7.8	8.6	10.3	10.9	11.0	12.1	13.2	14.3	15.1	17.4	18.7	20.1	21.4
"	"	3½		8.5	9.6	10.4	11.9	12.1	13.2	14.3	15.6	16.9	18.2	19.6	20.9	22.4
"	"	4		9.8	11.2	11.9	13.3	13.6	14.9	16.1	17.4	18.8	20.2	21.6	24.1	24.6
"	"	5		12.2	13.5	14.2	15.0	17.1	17.9	18.9	20.0	21.8	23.3	24.8	26.5	28.1
"	"	6		13.4	14.7	15.5	17.4	17.5	18.1	19.8	21.8	23.3	24.8	26.5	28.1	29.8
"	"	8		16.1	17.5	18.5	20.8	21.0	22.5	24.0	25.6	27.2	28.9	30.6	32.4	34.2
"	"	10		20.5	22.0	22.9	25.2	25.4	27.0	28.8	30.5	32.2	34.1	35.9	37.8	39.9
"	"	12		25.2	26.9	27.9	28.8	32.1	32.3	34.1	36.0	37.9	40.0	41.8	43.8	46.7
"	"	14		31.2	33.1	34.1	35.2	37.1	40.9	41.1	43.3	45.3	47.4	49.6	51.9	54.1
"	"	16		34.7	38.7	39.8	40.9	43.1	45.0	49.1	49.4	51.6	53.9	56.2	58.6	61.0
"	"	18		40.3	42.4	43.6	44.9	47.8	51.4	51.7	54.4	56.7	59.5	62.0	64.1	66.6
"	"	20		48.2	50.3	51.5	52.7	55.1	57.4	62.1	62 3	64.9	67.4	70.0	72.7	75.4
"	"	24		62.9	65.4	66.9	68.3	71.0	73.7	79.0	79.2	82.1	85.0	87.9	90.9	93.9
"	300	½														
"	"	¾														
"	"	1														
"	"	1½														
"	"	1½														
"	"	2	6.5	6.7	7.8	9.4	9.4	10.5	11.7	12.9	14.2	15.5	16.9	18.4	19.9	21.5
"	"	2½		7.9	9.0	9.8	11.6	11.7	13.0	14.5	15.6	17.1	18.6	20.0	21.6	23.2
"	"	3		9.1	10.5	11.5	13.2	13.6	14.9	16.3	17.8	19.2	20.8	22.4	24.1	25.8
"	"	3½		11.2	12.5	13.3	14.0	16.5	16.9	18.3	19.7	21.4	23.1	24.7	26.7	28.4
"	"	4		13.3	14.1	14.9	15.8	18.1	18.2	20.4	22.0	23.7	25.3	27.2	29.0	31.0
"	"	5		14.5	15.9	16.8	17.7	20.5	20.9	22.5	24.2	25.9	27.9	29.6	31.4	33.5
"	"	6		16.3	17.7	18.7	19.4	21.1	24.2	26.0	27.9	29.8	31.7	33.7	35.6	37.7
"	"	8		20.1	22.0	23.0	24.1	27.2	27.6	29.6	31.5	33.4	35.9	37.5	39.8	41.8
"	"	10		26.4	28.3	29.4	30.7	32.8	36.3	36.8	39.0	41.1	43.4	45.8	48.0	50.3
"	"	12		32.8	34.9	36.2	37.5	39.5	41.8	46.1	46.7	48.8	51.3	53.8	56.4	58.8
"	"	14		39.9	41.5	43.0	43.8	46.6	48.6	50.3	56.4	57.6	59.5	62.2	65.0	67.8
"	"	16		47.4	50.0	51.6	53.0	55.6	58.2	60.3	63.8	68.6	69.2	72.3	75.3	77.5
"	"	18		55.0	57.4	59.0	60.6	63.5	66.3	69.0	72.2	77.5	79.6	82.7	85.8	89.2
"	"	20		63.0	65.8	67.4	69.4	72.0	75.2	78 3	81.4	84.4	90.5	91.3	94.3	98.2
"	"	24		79.0	81.6	84.0	85.2	88.5	91.8	95.2	98.5	102.0	105.0	112.0	113.0	116.7
"	400	½	2.9	3.8	4.5	4.6	5.3	6.1	6.9	7.9	8.8	9.7	10.6	11.6	12.8	13.9
"	"	¾	3.2	4.1	4.9	6.1	6.4	6.6	7.6	8.6	9.4	10.5	11.4	12.5	13.7	14.9
"	"	1	4.1	5.2	5.3	6.8	7.1	8.0	9.2	10.1	11.2	12.3	13.3	14.5	15.8	17.1
"	"	1½	5.5	5.7	6.2	7.4	7.8	8.3	9.5	10.5	11.6	12.7	13.7	15.0	16.3	17.6
"	"	1½	5.5	6.1	7.2	7.7	9.4	9.5	10.7	11.6	12.7	13.7	15.0	16.3	17.6	18.8
"	"	2	5.7	6.9	8.0	9.5	9.7	10.5	11.6	12.7	13.9	15.1	16.4	17.8	19.1	20.5
"	"	2½		8.7	9.8	10.6	12.5	12.7	13.9	15.1	16.3	17.7	19.2	20.6	22.0	23.5
"	"	3		10.2	11.4	12.4	14.2	14.3	15.7	17.0	19.4	19.8	21.3	22.8	24.3	25.9
"	"	3½		11.6	13.1	13.9	14.6	17.1	17.3	18.7	20.2	21.6	23.2	23.7	26.3	28.0
"	"	4		13.3	14.7	15.5	16.6	18.7	19.2	20 6	22.1	23.7	25.3	27.0	28.7	30.4
"	"	5		15.3	16.7	17.6	18.4	21.3	21.5	23.0	24.6	26.2	28.0	29.7	31.5	33.3
"	"	6		17.1	18.5	19.5	20.5	23.3	23.5	25.2	27.5	28.5	30.3	32.1	33.9	35.8

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line press psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Tee	400	8		21.7	23.5	24.4	25.4	28.6	28.7	30.5	32.3	34.2	35.1	38.1	39.1	42.1
"	"	10		27.3	29.6	30.7	31.9	33.9	38.1	37.7	39.8	41.8	44.0	45.3	48.3	50.5
"	"	12		35.0	37.1	38.3	39.5	41.6	43.8	47.1	48.3	50.4	52.7	55.1	57.5	60.0
"	"	14		40.4	42.6	43.9	45.1	47.4	49.8	52.0	56.5	56.8	58.2	61.7	64.3	66.9
"	"	16		48.2	50.5	52.1	52.3	55.7	57.2	60.7	63.2	66.1	68.5	71.2	73.9	75.7
"	"	18		53.4	56.7	58.1	59.6	62.1	64.7	67.4	70.0	75.2	75.5	77.3	81.2	84.1
"	"	20		63.8	66.2	67.7	69.3	72.0	74.9	77.7	78.5	83.5	89.1	89.5	92.5	95.6
"	"	24		82.3	85.3	87.0	88.8	91.9	95.1	98.2	101.5	104.7	108.1	114.4	114.8	118.3
"	600	½														
"	"	¾														
"	"	1	4.1	5.2	5.3	6.6	7.1	8.0	9.2	10.1	11.2	12.3	13.3	14.5	15.8	17.0
"	"	1¼	4.3	5.3	6.2	7.2	7.6	8.1	9.5	10.5	11.6	12.7	13.8	15.0	15.8	17.6
"	"	1½	5.2	6.3	7.2	7.8	9.3	9.5	10.5	11.6	12.7	13.7	15.0	16.3	18.0	18.8
"	"	2	5.7	6.9	8.0	9.5	9.8	10.5	11.6	12.8	13.9	15.1	16.4	17.8	19.1	21.5
"	"	2½		8.8	9.8	10.6	12.5	12.7	13.9	15.2	16.3	17.8	19.2	20.6	22.0	23.5
"	"	3		10.1	11.3	12.3	14.2	14.4	15.7	17.0	18.4	19.7	21.3	22.9	24.3	26.0
"	"	3½		11.6	13.1	13.9	14.6	17.1	17.3	17.7	20.2	21.8	23.2	24.7	26.4	28.0
"	"	4		13.8	15.0	15.9	17.0	19.8	20.0	21.4	23.0	24.7	26.2	28.0	29.7	31.5
"	"	5		19.2	20.8	22.0	22.9	24.5	26.1	29.4	29.7	31.6	33.4	35.3	37.2	39.2
"	"	6		20.6	21.8	22.9	23.9	25.6	28.8	29.0	30.9	32.8	34.7	36.6	38.6	40.7
"	"	8		27.0	28.9	29.9	31.0	33.0	35.1	38.8	39.1	41.1	42.3	45.3	47.8	49.8
"	"	10		35.1	37.3	38.7	39.7	42.1	44.3	46.6	51.1	51.4	53.6	56.0	58.5	61.3
"	"	12		39.7	41.9	43.2	44.6	46.8	49.1	51.5	56.0	56.2	58.8	61.3	63.9	66.5
"	"	14		45.2	47.6	48.9	50.3	53.1	55.3	57.8	60.1	64.9	66.3	68.0	73.6	76.4
"	"	16		59.7	59.9	60.1	60.2	62.8	65.5	68.2	71.0	73.7	79.1	79.5	83.4	85.4
"	"	18		65.0	67.8	69.5	71.1	74.9	76.8	79.8	83.7	85.7	88.9	94.6	95.1	98.2
"	"	20		73.9	76.8	78.6	80.4	83.4	86.5	89.6	92.7	95.0	99.2	105.4	105.8	109.2
"	"	24		96.4	99.7	101.8	103.8	106.3	110.8	114.3	117.8	121.4	125.1	128.8	135.9	136.3
"	900	½														
"	"	¾														
"	"	1	5.6	6.8	7.8	8.5	10.2	10.4	11.8	12.2	13.8	15.0	16.3	17.6	19.0	20.4
"	"	1¼	5.9	7.0	8.2	8.5	10.6	10.8	12.0	12.6	14.8	15.6	16.9	18.3	19.6	21.1
"	"	1½	6.3	8.4	9.4	10.0	11.0	13.3	13.4	14.5	15.8	17.0	18.5	19.8	21.3	22.7
"	"	2		10.9	12.1	13.2	14.1	16.5	16.7	18.2	19.7	21.1	22.7	24.3	25.8	27.8
"	"	2½		13.2	14.4	14.6	16.2	17.6	20.4	20.6	22.3	23.6	25.4	27.0	28.1	30.6
"	"	3		13.9	14.6	14.7	16.3	17.6	20.4	20.8	22.4	23.9	25.4	27.2	28.4	30.8
"	"	3½		14.7	15.6	16.3	17.2	19.2	22.1	22.6	23.4	25.7	27.8	29.6	31.4	32.0
"	"	4		16.0	17.5	18.5	18.8	21.0	24.0	24.2	25.9	27.5	29.7	31.2	33.0	34.8
"	"	5		20.9	22.6	23.7	24.9	26.6	28.3	31.8	33.8	35.7	37.7	39.7	41.8	43.9
"	"	6		23.1	25.2	26.3	27.5	29.2	31.0	34.8	35.1	37.1	39.0	41.1	43.3	45.4
"	"	8		33.0	36.1	36.4	38.1	39.9	42.0	44.3	46.5	51.0	52.2	54.6	57.1	59.6
"	"	10		44.1	43.4	44.8	46.2	48.6	50.9	53.5	55.8	58.3	63.1	63.5	66.1	68.8
"	"	12		49.0	51.6	53.1	54.6	57.3	59.8	62.4	65.1	67.8	73.0	73.4	76.2	79.2
"	"	14		56.0	58.9	60.8	62.3	66.0	67.8	70.6	73.4	78.4	79.3	84.9	85.3	88.4
"	"	16		64.3	67.0	68.8	70.6	73.5	76.4	79.4	82.4	85.5	88.6	94.6	94.8	98.2
"	"	18		76.2	79.2	81.2	83.1	86.2	89.4	92.6	95.8	97.8	102.6	106.0	112.5	113.0
"	"	20		88.7	92.0	94.1	96.1	99.5	102.9	106.3	109.9	113.4	117.1	120.6	124.3	131.3
"	"	24		124.2	128.1	130.6	133.0	136.9	141.0	145.0	149.2	153.3	157.5	161.8	166.0	170.4
"	1500	½														
"	"	¾														
"	"	1	5.6	6.8	7.9	8.5	10.2	10.4	11.8	12.2	13.8	15.0	16.3	17.6	19.0	20.4
"	"	1¼		7.1	8.2	8.5	10.6	10.8	12.0	12.6	14.8	15.6	16.9	18.3	19.6	21.1
"	"	1½		8.4	9.4	10.0	11.0	13.3	13.4	14.5	15.8	17.0	17.5	19.8	21.3	22.7
"	"	2		10.9	12.1	13.2	14.1	16.5	16.7	18.2	19.7	21.1	22.7	24.3	25.8	27.8
"	"	2½		12.7	14.4	14.6	16.2	17.6	20.3	21.0	22.4	23.7	25.3	27.0	28.0	30.5
"	"	3		15.4	16.9	17.9	18.8	20.4	23.5	23.8	25.4	27.1	28.8	30.7	32.8	34.5

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line press psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Tee	1500	3½		17.3	18.6	19.2	20.7	22.8	25.0	26.4	27.3	29.3	32.7	33.3	35.0	38.0
"	"	4		19.7	21.3	22.4	23.6	25.4	26.3	30.4	30.5	32.6	34.6	36.6	38.6	40.7
"	"	5		26.3	28.3	29.7	31.0	33.0	34.9	37.0	41.2	41.5	43.7	45.9	48.2	50.6
"	"	6		29.1	31.1	32.5	33.8	35.7	38.0	40.2	44.0	44.7	47.0	49.3	51.7	54.3
"	"	8		38.2	40.4	42.0	43.5	45.2	48.2	50.6	53.2	58.1	58.4	60.9	63.5	66.3
"	"	10		52.0	53.9	55.7	58.2	60.9	63.9	66.5	69.3	72.2	75.2	80.1	81.2	84.2
"	"	12		67.0	70.9	72.8	74.6	77.8	80.9	84.1	87.4	90.6	94.4	97.3	100.6	107.1
"	"	14		81.6	85.4	87.1	89.7	93.1	96.6	100.2	103.7	107.2	110.9	114.5	118.3	122.0
"	"	16		97.3	101.2	103.4	104.7	106.4	110.1	113.8	117.6	121.4	125.3	129.2	133.2	137.2
"	"	18		115.2	119.1	121.8	124.5	128.4	132.5	136.6	140.8	144.9	149.2	153.3	157.8	162.2
"	"	20		133.5	138.4	140.6	143.4	147.8	152.1	156.4	160.9	165.4	170.0	174.5	179.1	183.8
"	"	24		179.0	183.9	187.2	190.4	195.3	200.4	205.4	210.6	215.7	220.9	226.1	231.3	235.4
Welding Ell		½	.3	.5	.9	1.6	2.1	2.8	3.5	4.3	5.2	6.2	7.2			
90°		¾	.3	.5	.9	1.6	2.2	2.8	3.5	4.3	5.2	6.2	7.2			
"		1	.4	.7	1.0	1.6	2.2	2.8	3.5	4.3	5.2	6.2	7.2			
"		1½	.4	.8	1.0	1.6	2.2	2.8	3.5	4.3	5.2	6.2	7.2			
"		1½	.5	.8	1.5	2.0	2.6	3.3	4.1	5.0	5.9	7.1	8.3			
"		2	.8	1.1	1.5	2.0	2.6	3.3	4.1	5.0	5.9	7.1	8.3	9.3	10.6	12.7
"		2½	1.0	1.6	2.0	2.6	3.3	4.1	4.7	5.9	7.0	8.2	9.4	10.6	11.9	13.3
"		3	1.2	1.6	2.0	2.6	3.3	4.1	4.7	5.9	7.0	8.2	9.4	10.6	11.9	13.3
"		3½	1.8	2.2	2.7	3.2	3.9	4.7	5.7	6.8	7.8	9.0	10.2	11.6	12.9	14.3
"		4	1.8	2.2	2.7	3.2	3.9	4.7	5.7	6.8	7.8	9.0	10.2	11.6	12.9	14.3
"		5	2.4	2.9	3.6	4.4	4.9	5.8	6.5	7.8	8.4	9.7	10.9	12.5	14.1	15.3
"		6	3.0	3.8	4.4	5.2	5.9	7.1	7.7	8.5	9.4	10.4	11.8	13.5	15.0	16.8
"		8		4.8	5.4	6.2	7.0	7.8	8.6	9.1	10.3	11.8	12.6	14.7	14.9	15.5
"		10		6.9	7.7	8.5	9.4	10.3	11.5	11.5	13.5	14.7	15.7	17.0	18.3	19.6
"		12		11.6	12.6	13.8	14.9	16.5	17.5	18.7	20.2	21.5	22.6	24.6	26.0	27.6
"		14		13.8	15.2	16.4	18.0	19.2	20.4	21.8	23.3	25.0	26.3	27.9	29.7	31.7
"		16		17.8	19.5	20.7	22.6	23.5	25.0	26.6	28.3	30.0	31.8	33.5	36.3	37.1
"		18		22.1	23.4	24.9	26.5	28.3	30.0	31.7	33.0	35.3	37.0	38.9	40.7	42.8
"		20		26.1	27.6	29.4	31.1	32.9	34.8	36.6	38.4	40.3	42.0	44.3	46.6	48.0
"		24		36.2	38.3	40.4	42.3	44.0	46.2	48.7	51.1	53.2	55.3	57.6	60.2	62.8
Screwed Ell		½	.7	1.3	1.3	1.8	2.1	2.7	3.2	3.8	4.4	5.1	5.9	6.7	7.5	8.3
90°		¾	.8	1.3	1.7	2.1	2.7	3.2	3.8	4.4	5.1	6.0	6.7	7.5	8.3	8.7
"		1	1.0	1.3	1.8	2.1	2.7	3.2	3.8	4.4	5.1	6.0	6.7	7.5	8.3	8.7
"		1½	1.1	1.9	2.5	3.1	3.7	4.6	5.4	6.3	6.4	6.7	6.7	7.5	8.3	8.7
"		1½	1.1	1.9	2.5	3.1	3.7	4.6	5.4	6.3	6.4	6.7	6.7	7.5	8.3	8.7
"		2	1.3	1.9	2.5	3.1	3.7	4.6	5.4	6.3	6.7	6.7	7.5	8.3	8.7	10.2
"		2½	1.9	2.5	3.1	3.7	4.6	5.1	5.4	6.3	6.4	6.7	7.5	8.3	8.7	10.2
"		3	1.9	2.5	3.1	3.7	4.6	5.1	5.5	6.3	6.7	7.5	8.3	8.7	10.2	11.2
"		3½	2.5	2.8	3.7	4.6	5.1	5.4	6.3	6.7	7.5	8.3	8.7	10.2	11.2	12.2
"		4	2.6	3.2	3.8	4.4	5.1	6.0	6.7	7.5	8.3	8.7	10.2	11.2	12.2	13.2
"		5		3.8	4.4	5.1	6.0	6.7	7.5	8.3	8.7	10.2	11.2	12.2	13.2	14.4
"		6		4.4	5.1	6.0	6.7	7.5	8.3	8.7	10.2	11.2	12.2	13.2	14.4	15.6
"		8		6.0	6.7	7.5	8.3	8.7	10.2	11.2	12.2	13.2	14.4	15.6	16.7	17.9
"		10		8.3	8.7	10.2	11.2	12.2	13.2	14.4	15.6	16.7	17.9	19.3	20.5	21.9
"		12		10.2	11.2	12.2	13.2	14.4	15.6	16.7	17.9	19.3	20.5	21.9	23.3	24.8
"		14														
"		16														
"		18														
"		20														
"		24														
"		½	.7	.9	1.0	1.4	1.7	2.1	2.5	3.0	3.6	4.1	4.8	5.4	6.0	6.7
45°		¾	.8	1.0	1.4	1.7	2.1	2.5	3.0	3.6	4.1	4.8	5.4	6.0	6.7	7.4
"		1	.8	1.0	1.4	1.7	2.1	2.5	3.0	3.6	4.1	4.8	5.4	6.0	6.7	7.4
"		1½	.9	1.4	2.2	2.3	2.7	3.4	4.0	4.6	5.5	6.3	7.1	8.0	8.7	9.8

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line pres psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Screwed Ell		1¼	.9	1.4	2.2	2.3	2.7	3.4	4.0	4.6	5.5	6.3	7.1	8.0	8.7	9.8
45°		2	1.3	1.6	2.3	2.5	2.9	3.6	4.3	4.9	5.7	6.6	7.5	8.3	9.2	9.1
"		2½	1.4	1.8	2.4	2.7	3.2	3.9	4.5	5.3	6.0	6.8	7.7	8.6	9.6	10.5
"		3	1.7	2.3	2.6	3.2	3.7	4.3	5.2	5.8	6.7	7.4	8.4	9.4	10.3	11.4
"		3½	1.7	2.3	2.6	3.2	3.7	4.3	4.8	5.7	6.7	7.4	8.4	9.4	10.3	11.4
"		4	2.3	2.8	3.3	3.8	4.3	4.8	5.7	6.4	7.1	7.5	8.7	9.5	10.4	11.6
"		5		3.3	3.8	4.3	5.7	6.4	6.4	7.1	7.5	8.7	9.5	10.4	11.4	12.4
"		6		3.8	4.3	5.2	5.8	6.4	7.1	7.9	8.8	9.7	10.0	11.4	12.4	13.3
"		8		5.0	5.7	6.5	7.3	8.1	9.0							
"		10		7.7	8.1	8.9	10.1	11.2	12.3							
"		12		8.9	10.1	10.9	12.2	13.5	14.8							
"		14														
"		16														
"		18														
"		20														
"		24														
Flanged Ell	150	¾														
Short Rad. 90°	"	¾														
"	"	1	2.4	3.2	3.8	4.3	4.8	5.7	6.4	8.5	9.4	10.8	12.2	13.7	15.5	17.2
"	"	1¼	3.3	3.9	4.3	5.0	6.0	7.2	8.6	9.9	11.2	12.6	14.3	16.0	17.7	19.3
"	"	1½	3.3	3.9	4.3	5.0	6.0	7.2	8.6	9.9	11.2	12.8	14.3	16.0	17.7	19.3
"	"	2	4.7	4.3	5.0	6.0	7.2	8.0	8.4	10.0	11.4	12.8	15.3	16.4	18.3	19.7
"	"	2½		5.9	5.9	6.3	7.2	8.0	8.9	10.2	11.6	13.1	15.6	16.9	18.7	20.3
"	"	3		5.9	5.9	6.7	7.2	8.0	8.9	10.4	11.8	13.3	15.9	17.7	19.0	20.9
"	"	3½		6.7	7.6	8.4	9.0	10.0	11.7	12.7	14.2	15.9	17.5	19.4	21.0	23.3
"	"	4		7.9	9.0	9.7	10.3	11.3	11.7	14.1	15.8	17.4	19.3	21.1	23.4	25.4
"	"	5		8.7	10.0	10.6	11.3	13.4	14.0	15.0	17.0	18.8	20.1	22.1	23.7	25.8
"	"	6		11.4	12.5	13.2	14.1	15.3	16.5	17.8	19.4	21.6	23.6	25.7	28.0	30.3
"	"	8		11.6	12.9	13.8	14.8	16.2	17.8	19.4	21.2	23.3	24.6	27.6	29.8	32.2
"	"	10		15.4	17.5	18.4	19.3	20.6	22.1	24.2	25.7	27.3	29.0	30.6	32.7	35.1
"	"	12		20.1	21.5	22.5	23.6	24.9	26.5	28.6	30.3	32.7	35.1	37.7	40.5	43.4
"	"	14		25.4	27.0	28.1	29.2	30.9	32.7	34.5	36.3	38.2	40.1	42.0	44.4	47.4
"	"	16		31.0	32.7	33.9	35.1	37.0	38.9	40.8	42.8	44.9	46.9	49.0	51.2	53.4
"	"	18		33.4	35.8	37.1	39.3	40.2	42.2	44.3	46.3	48.4	50.6	52.8	56.0	57.4
"	"	20		39.6	41.6	42.8	44.1	46.2	48.3	50.5	52.6	55.0	57.2	59.5	62.0	64.4
"	"	24		53.0	55.2	56.8	58.3	60.7	62.5	65.6	68.2	70.8	73.4	76.0	78.8	81.5
Flanged Ell	150	¾														
Long Rad. 90°	"	¾														
"	"	1	2.4	3.2	3.8	4.3	4.8	5.7	6.4	8.5	9.4	10.8	12.2	13.8	15.5	17.2
"	"	1¼	3.1	3.9	4.4	5.0	6.0	7.2	8.6	10.0	11.2	12.6	14.3	16.0	17.7	19.3
"	"	1½	3.1	3.9	4.5	5.0	6.0	7.2	8.6	10.0	11.2	12.6	14.3	16.0	17.7	19.3
"	"	2	5.7	5.7	6.5	7.0	7.8	9.0	10.7	12.1	13.6	15.4	17.0	18.8	20.3	22.2
"	"	2½		5.7	6.5	7.0	7.8	9.0	10.7	12.1	13.6	15.4	17.0	18.8	20.3	22.2
"	"	3		6.0	6.5	7.0	7.8	9.0	10.7	12.1	13.6	15.4	17.0	18.0	20.3	23.2
"	"	3½		6.7	7.6	8.5	9.0	10.0	11.7	12.7	14.2	15.9	17.5	19.4	21.0	23.3
"	"	4		7.9	9.0	9.7	10.3	11.3	11.7	14.1	15.9	17.5	19.3	21.2	23.4	25.4
"	"	5		8.7	10.0	10.6	11.3	13.4	14.0	15.0	17.0	18.8	20.1	22.1	23.7	25.8
"	"	6		11.4	12.5	13.2	14.1	15.3	16.5	17.8	19.5	21.6	23.6	25.7	28.0	30.3
"	"	8		11.6	12.9	13.8	14.8	16.2	17.8	19.4	21.2	23.3	24.6	27.6	29.8	32.2
"	"	10		15.4	17.5	18.4	19.3	20.6	22.1	24.2	25.7	27.3	29.0	30.6	32.7	35.1
"	"	12		20.1	21.5	22.6	23.6	24.9	26.5	28.6	30.3	32.7	35.1	37.7	40.5	43.4
"	"	14		25.4	27.0	28.1	29.2	30.9	32.7	34.5	36.3	38.2	40.1	42.0	44.4	47.4
"	"	16		31.0	32.7	33.9	35.1	36.9	38.9	40.8	42.8	44.9	46.9	49.0	51.2	53.4
"	"	18		33.4	35.8	37.1	39.3	40.2	42.2	44.3	46.3	48.4	50.6	52.8	56.0	57.4
"	"	20		40.0	41.6	42.8	44.1	46.2	48.3	50.5	52.6	55.0	57.2	59.5	62.0	64.4
"	"	24		53.0	55.2	56.8	58.3	60.7	62.5	65.6	68.2	70.8	73.4	76.0	78.8	81.5

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APPENDIX

OUTSIDE SURFACE AREA OF FITTING COVERS

Fitting cover	Line press psi	Nom pipe size inch	Outside surface area in square feet — Nominal insulation thickness—inches													
			1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Flanged Ell	150	½														
45°	"	¾														
"	"	1	1.2	1.6	1.9	2.1	2.4	2.8	3.2	4.2	4.7	5.4	6.1	6.9	7.7	8.6
"	"	1¼	1.3	1.6	2.0	2.2	2.5	3.0	3.6	4.3	4.9	5.6	6.3	7.1	8.0	8.8
"	"	1½	1.5	1.9	2.2	2.4	2.6	3.1	3.8	4.5	5.1	5.7	6.5	7.4	8.1	9.0
"	"	2	1.5	1.9	2.2	2.4	2.6	3.1	3.8	4.5	5.1	5.7	6.5	7.4	8.1	9.0
"	"	2½		1.9	2.2	2.4	2.6	3.1	3.8	4.5	5.1	5.7	6.5	7.4	8.1	9.0
"	"	3		2.6	2.9	3.3	3.6	4.0	4.4	5.2	5.9	6.6	7.9	8.7	8.5	10.4
"	"	3½		3.4	3.8	4.2	4.5	5.0	5.8	6.4	7.1	8.0	8.8	9.7	10.5	11.6
"	"	4		3.9	4.5	4.8	5.2	5.7	5.8	7.0	7.9	8.7	9.7	10.6	11.7	12.7
"	"	5		4.3	5.0	5.3	5.7	6.7	7.0	7.5	8.5	9.4	10.1	11.1	11.8	12.9
"	"	6		5.7	6.2	6.6	7.0	7.6	8.2	8.9	9.8	10.8	11.8	12.9	14.0	15.2
"	"	8		5.8	6.4	6.9	7.4	8.1	8.9	9.7	10.6	11.6	12.3	13.8	14.9	16.1
"	"	10		7.7	8.8	9.2	9.6	10.3	11.1	12.1	12.9	13.7	14.5	15.3	16.7	17.6
"	"	12		10.1	10.7	11.2	11.8	12.5	13.3	14.4	15.2	16.3	17.6	18.8	20.3	21.7
"	"	14		12.7	13.5	14.0	14.5	15.4	16.3	17.2	18.2	19.1	20.0	21.0	22.2	23.7
"	"	16		15.6	16.4	17.0	17.5	18.5	19.4	20.4	21.4	22.4	23.4	24.5	25.6	26.7
"	"	18		16.7	17.9	18.5	19.4	20.1	21.1	22.1	23.1	24.2	25.3	26.4	28.0	28.7
"	"	20		19.8	20.8	21.4	22.1	23.1	24.2	25.2	26.3	27.5	28.6	29.8	31.0	32.2
"	"	24		26.5	27.6	28.4	29.2	30.4	31.3	32.8	34.1	35.4	36.7	38.0	39.4	40.8

Table B-29 Square feet of insulation on duct work

1" Insulation				2" Insulation				1" Insulation				2" Insulation			
Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul	Semi perim	Sq ft insul
8	1.67	65	11.17	8	2.00	65	11.50	37	6.50	94	16.00	37	6.83	94	16.34
9	1.83	66	11.34	9	2.17	66	11.66	38	6.66	95	16.17	38	7.00	95	16.50
10	2.00	67	11.50	10	2.34	67	11.83	39	6.83	96	16.34	39	7.17	96	16.66
11	2.17	68	11.66	11	2.50	68	12.00	40	7.00	97	16.50	40	7.34	97	16.83
12	2.34	69	11.83	12	2.67	69	12.17	41	7.17	98	16.66	41	7.50	98	17.00
13	2.50	70	12.00	13	2.84	70	12.34	42	7.34	99	16.83	42	7.66	99	17.17
14	2.66	71	12.17	14	3.00	71	12.50	43	7.50	100	17.00	43	7.83	100	17.34
15	2.83	72	12.34	15	3.17	72	12.66	44	7.66	101	17.17	44	8.00	101	17.50
16	3.00	73	12.50	16	3.34	73	12.83	45	7.83	102	17.34	45	8.17	102	17.66
17	3.17	74	12.66	17	3.50	74	13.00	46	8.00	103	17.50	46	8.34	103	17.83
18	3.34	75	12.83	18	3.66	75	13.17	47	8.17	104	17.66	47	8.50	104	18.00
19	3.50	76	13.00	19	3.83	76	13.34	48	8.34	105	17.83	48	8.66	105	18.17
20	3.66	77	13.17	20	4.00	77	13.50	49	8.50	106	18.00	49	8.83	106	18.34
21	3.83	78	13.34	21	4.17	78	13.66	50	8.66	107	18.17	50	9.00	107	18.50
22	4.00	79	13.50	22	4.34	79	13.83	51	8.83	108	18.34	51	9.17	108	18.66
23	4.17	80	13.66	23	4.50	80	14.00	52	9.00	109	18.50	52	9.34	109	18.83
24	4.34	81	13.83	24	4.66	81	14.17	53	9.17	110	18.66	53	9.50	110	19.00
25	4.50	82	14.00	25	4.83	82	14.34	54	9.34	111	18.83	54	9.66	111	19.17
26	4.66	83	14.17	26	5.00	83	14.50	55	9.50	112	19.00	55	9.83	112	19.34
27	4.83	84	14.34	27	5.17	84	14.66	56	9.66	113	19.17	56	10.00	113	19.50
28	5.00	85	14.50	28	5.34	85	14.83	57	9.83	114	19.34	57	10.17	114	19.66
29	5.17	86	14.66	29	5.50	86	15.00	58	10.00	115	19.50	58	10.34	115	19.83
30	5.34	87	14.83	30	5.66	87	15.17	59	10.17	116	19.66	59	10.50	116	20.00
31	5.50	88	15.00	31	5.83	88	15.34	60	10.34	117	19.83	60	10.66	117	20.17
32	5.66	89	15.17	32	6.00	89	15.50	61	10.50	118	20.00	61	10.83	118	20.34
33	5.83	90	15.34	33	6.17	90	15.66	62	10.66	119	20.17	62	11.00	119	20.50
34	6.00	91	15.50	34	6.34	91	15.83	63	10.83	120	20.34	63	11.17	120	20.66
35	6.17	92	15.66	35	6.50	92	16.00	64	11.00			64	11.34		
36	6.34	93	15.83	36	6.66	93	16.17								

Semi-perimeter is the sum of the two adjacent sides. For example: A duct 4" x 6" has a semi-perimeter of 10 inches.

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CEMENT IN POUNDS REQUIRED TO INSULATE SCREWED OR WELDED FITTINGS 1" THICK INSULATION

	90 ELLS			45 ELLS			VALVES AND TEES			CROSSES		
Pipe Size	85% Mag.Cem.	H.T.Cem.	Asb.Cem.	85% Mag.Cem.	H.T.Cem.	Asb.Cem.	85% Mag.Cem.	H.T.Cem.	Asb.Cem.	85% Mag.Cem.	H.T.Cem.	Asb.Cem.
1/2"	.29	.42	1.10	.15	.21	.55	.36	.52	1.37	.38	.56	1.46
3/4"	.34	.50	1.33	.17	.25	.66	.43	.62	1.66	.45	.66	1.77
1"	.43	.63	1.66	.22	.32	.83	.54	.78	2.07	.57	.84	2.20
1-1/4"	.65	.94	2.50	.33	.47	1.25	.81	1.17	3.12	.86	1.25	3.33
1-1/2"	.86	1.25	3.33	.43	.63	1.66	1.07	1.56	4.16	1.14	1.66	4.43
2"	1.00	1.50	4.40	.50	.75	2.20	1.25	1.87	5.50	1.33	2.00	5.85
2-1/2"	1.14	1.65	5.75	.57	.83	2.87	1.42	2.06	7.18	1.52	2.20	7.65
3"	1.72	2.50	6.60	.86	1.25	3.30	2.15	3.12	8.25	2.28	3.33	8.77
3-1/2"	2.00	2.92	7.75	1.00	1.46	3.87	2.50	3.65	9.68	2.66	3.88	10.30
4"	2.24	3.25	8.60	1.12	1.62	4.30	2.80	4.07	10.75	2.98	4.32	11.40
4-1/2"	2.58	3.75	10.00	1.29	1.82	5.00	3.23	4.70	12.50	3.43	5.00	13.30
5"	2.92	4.20	11.30	1.46	2.10	5.65	3.66	5.25	14.10	3.88	5.58	15.00
6"	3.62	5.25	14.00	1.81	2.62	7.00	4.53	6.56	17.50	4.81	6.98	18.60
7"	4.65	6.75	18.00	2.33	3.37	9.00	5.82	8.45	22.50	6.18	8.98	24.00
8"	5.00	7.20	19.30	2.50	3.60	9.65	6.25	9.00	24.10	6.65	9.57	25.70
9"	6.37	9.30	24.60	3.19	4.65	12.30	8.00	11.60	30.75	8.47	12.36	32.70
10"	7.40	10.70	28.60	3.70	5.35	14.30	9.25	13.30	35.75	9.84	14.23	38.00
11"	8.44	12.25	32.50	4.22	6.12	16.25	10.52	15.20	40.60	11.22	16.29	43.20
12"	9.48	13.80	36.60	4.74	6.90	18.30	11.80	17.20	45.75	12.60	18.35	48.70

The above quantities are approximate for estimating purposes.

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APPENDIX

TABLE OF GAUGES AND WEIGHTS FOR WIRE, BANDS AND FLAT SHEET METAL

MATERIAL	GAUGE	DIAMETER OR THICKNESS	LINEAR FOOT PER POUND
Galvanized or B.A. Wire	W & M		
12 Gauge	W & M	0.1055" Dia.	33.30
14 Gauge	W & M	0.0800" Dia.	58.82
16 Gauge	W & M	0.0625" Dia.	95.23
18 Gauge	W & M	0.0475" Dia.	166.66
Soft Copper Wire	B & S		
12 Gauge	B & S	0.0808" Dia.	52.63
14 Gauge	B & S	0.0640" Dia.	83.33
16 Gauge	B & S	0.0508" Dia.	142.85
18 Gauge	B & S	0.0403" Dia.	250.00
Galvanized Steel Bands			
1/2" Wide	----	.015" thk.	39.26
1/2" Wide	----	.020" thk.	29.45
3/4" Wide	----	.020" thk.	19.63
1-1/4" Wide	----	.035" thk.	6.73
Stainless Steel Bands 18-8 Chrome			
1/2" Wide	----	.015" thk.	39.26
1/2" Wide	----	.020" thk.	29.45
3/4" Wide	----	.015" thk.	26.18
3/4" Wide	----	.020" thk.	19.63

MATERIAL	GAUGES	THICKNESS	WEIGHT IN LBS. PER SQ. FT.
Flat Black Sheet Metal			
18 Gauge	U.S. Standard	.05"	2.00
20 Gauge	U.S. Standard	.0375"	1.50
22 Gauge	U.S. Standard	.03125"	1.25
24 Gauge	U.S. Standard	.025"	1.00
26 Gauge	U.S. Standard	.01875"	0.75
28 Gauge	U.S. Standard	.015625"	0.625
30 Gauge	U.S. Standard	.0125"	0.50
Flat Galvanized Sheet Metal			
18 Gauge	U.S. Standard	.0540"	2.1563
20 Gauge	U.S. Standard	.0415"	1.6563
22 Gauge	U.S. Standard	.03525"	1.4063
24 Gauge	U.S. Standard	.0290"	1.1563
26 Gauge	U.S. Standard	.02275"	.9063
28 Gauge	U.S. Standard	.019625"	.7813
30 Gauge	U.S. Standard	.0165"	.6563

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