United States Patent

Hutter et al.

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[45] **Oct. 31, 1972**

[54] **METHOD OF AND APPARATUS FOR SORTING ORES**

[72] Inventors: **James Francis Hutter; Leonard Kelly,** both of Peterborough, Ontario, Canada

[73] Assignee: **Sphere-Investments Limited,** Nassau, Bahamas

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[52] **U.S. Cl.**.....**209/111.8**

[51] **Int. Cl.**.....**B07k 5/344**

[58] **Field of Search**.....209/111.8, 1, 8, 214, 111.5; 324/41

[56] **References Cited**

UNITED STATES PATENTS

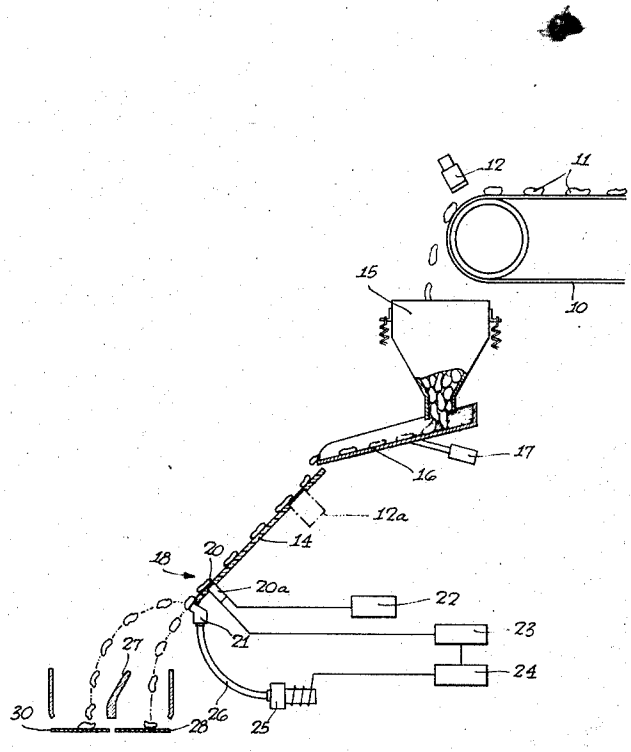
3,373,856	3/1968	Kusters et al.	209/111.8 R
3,356,211	12/1967	Mathews	209/111.5 X
3,478,876	11/1969	Littwin et al.	209/111.8 X
3,028,960	4/1962	Currie et al.	209/111.8
3,011,634	12/1961	Hutter et al.	209/111.8 X
3,539,005	11/1970	Nekvinda	209/111.8 X
2,045,769	6/1936	Geffcken et al.	209/111.8 X

Primary Examiner—Richard A. Schacher
Assistant Examiner—Gene A. Church
Attorney—Weir, Marshall, MacRae & Lamb

[57] **ABSTRACT**

In the machine sorting of objects which have a material with magnetic properties, an auxiliary magnetic field is provided in the sorting zone to enhance a magnetic characteristic of the material with magnetic properties. In one embodiment the objects are passed through a strong, steady magnetic field just prior to passing a magnetic field detector. The magnetic field detector provides a sorting signal related to remanence of the objects, and the objects are deflected or not in accordance with the sorting signal.

11 Claims, 10 Drawing Figures



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SHEET 1 OF 2

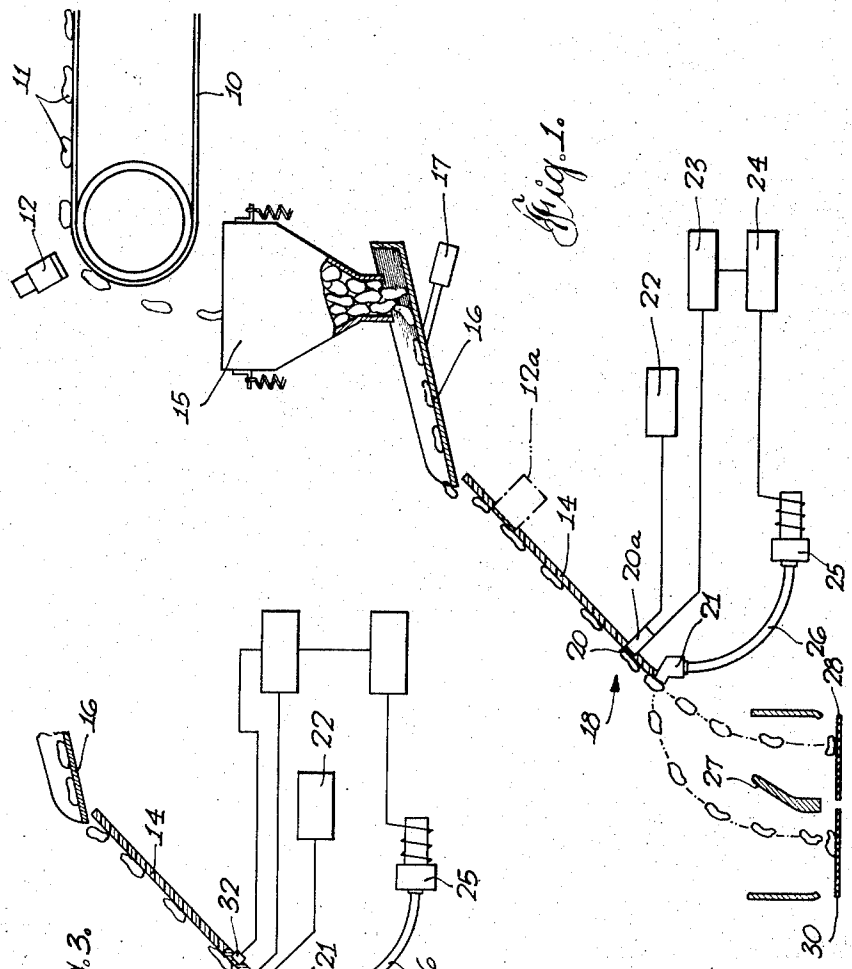


Fig. 1.

Fig. 3.

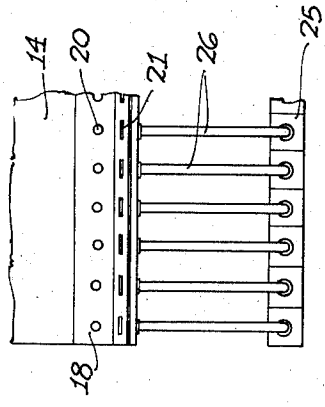


Fig. 2.

INVENTOR
JAMES F. HUTTER
LEONARD KELLY

BY Weir, Marshall, MacRae & Lamb.
PATENT AGENT

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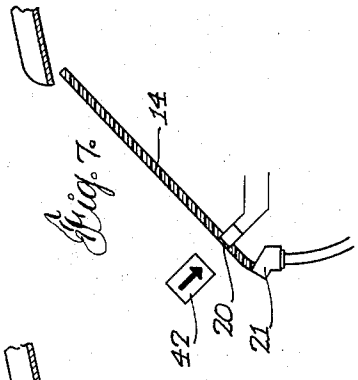


Fig. 7.

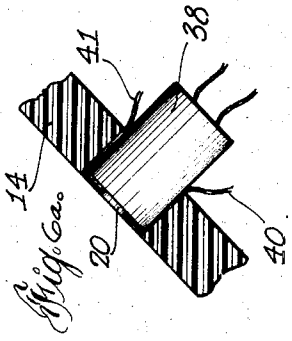


Fig. 6a.

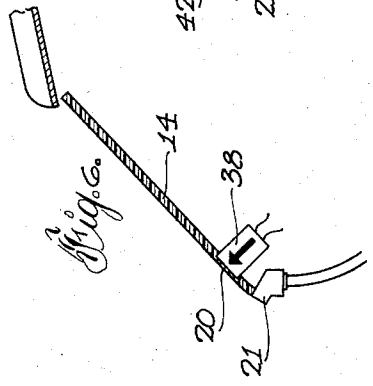


Fig. 6.

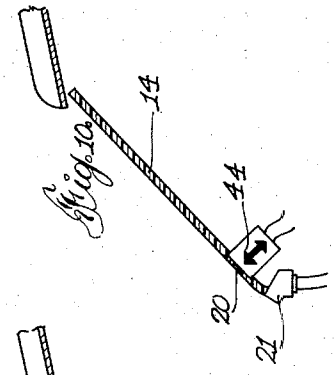


Fig. 10.

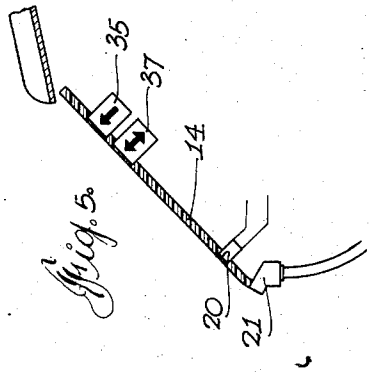


Fig. 5.

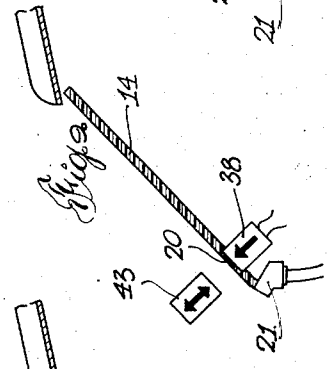


Fig. 9.

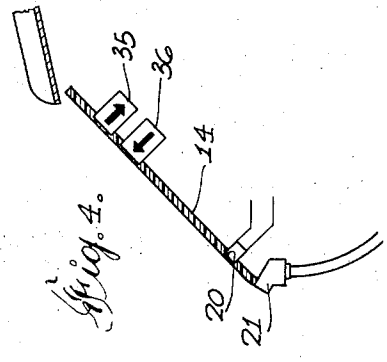


Fig. 4.

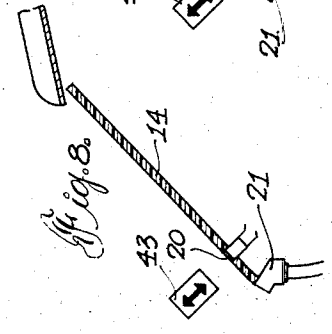


Fig. 8.

INVENTOR
JAMES F. HUTTER
LEONARD KELLY
BY Weir Marshall MacRae & Lamb.
PATENT AGENT

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METHOD OF AND APPARATUS FOR SORTING ORES

BACKGROUND OF THE INVENTION

The method and apparatus of this invention may be applied to the sorting of objects generally where the objects contain or incorporate material with magnetic properties. However, the method and apparatus of the invention are suited to the sorting of ore and will be described hereinafter mainly in connection with ore sorting.

The sorting of ores in accordance with a magnetic property or characteristic requires some consideration of the type of ore. The pieces of rock which make up an ore body are very complex in their detailed mineralogy. A particular piece of rock may contain a valuable or desirable mineral and waste in any proportion. Solid solutions, substitutions and impurities might be considered the rule rather than the exception, and it follows that the physical properties of pieces of rock are variable and gradational. No two ore bodies are the same and a number of variations in the sorting method and apparatus are desirable to adapt to the different ores.

To illustrate the complexity underlying a simple mineral name, the hematite ores may be considered. Hematite is alpha Fe_2O_3 (ferric oxide) which is antiferromagnetic with very weak remanence, but which may have varying degrees of ferromagnetism superimposed due to stray impurities. Hematite is also gamma Fe_2O_3 (maghemite) and maghemite is a double mineral $Fe_{2.67}O_4$ (oxymaghemite) and $HFe_{2.50}O_4$ (hydroxymaghemite). Solid solution exists between these and Fe_3O_4 (magnetite) and all are ferromagnetic to some degree. Also, hematite and $FeTiO_3$ (ilmenite) exist in solid solution and are ferromagnetic. It appears considerable difficulty would be experienced in sorting hematite ore. However, it has been found that there is a correlation between iron value and remanence and that, in accordance with the present invention, such an ore can be sorted.

It is known to upgrade ores having very strong magnetic properties, such as magnetite and pyrrhotite on the basis of an attractive magnetic force between individual pieces of rock and a powerful magnet. The pieces of rock containing these ores are moved past a powerful magnet which exerts sufficient attractive force on the pieces of rock containing ore to separate them from the pieces of rock containing no ore. However, the separation depends on both the attractive force and the mass of each piece of rock, and consequently it is difficult to get a satisfactory separation of pieces of rock containing various amounts of perhaps irregularly distributed magnetic minerals.

One example of an ore which is difficult to upgrade or sort using the powerful magnets as described above, is asbestos ore which has magnetite grains associated intimately with the veinlets of asbestos. There are some very large ore bodies of this type. Very often with this ore, the broken pieces of rock show asbestos on only one surface while the remainder of the piece of rock may be barren of both magnetite and asbestos. It will be obvious that the separation which may be achieved by means of a magnet depends very much on the orientation of the piece of rock relative to the magnet. Moreover, while the asbestos is associated with magnetite, the amount of magnetite is not directly related to the quantity or value of the asbestos.

It will be seen that the sorting of ores which contain magnetic material by relying on the magnetic attractive force between the piece of rock and a magnet is restricted to a very few ores and is not reliable.

SUMMARY OF THE INVENTION

The present invention seeks to provide a method of and an apparatus for sorting objects having material with magnetic properties, for example pieces of rock having minerals with magnetic properties, which does not rely on a magnetic attractive force to accomplish the actual separation. Rather the present invention involves the detection of a magnetic characteristic related to the value or worth of each object and uses the detected magnetic characteristic to control a separate deflection means to physically segregate the objects. In the sorting of objects by detected magnetic characteristics, the magnetic characteristics may sometimes be so weak that detection is difficult. This is often the case when sorting ore. Many minerals such as hematite are only weakly magnetic, and the magnetic flux density associated with a piece of rock might not be normally detectable even with a sensitive detector such as a Hall effect device. By providing a magnet means in the sorting zone in a particular arrangement, the magnetic characteristic may be enhanced considerably.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic side view of a sorting apparatus according to one form or embodiment of the invention,

FIG. **2** is a diagrammatic partial end view of the apparatus of FIG. **1**,

FIG. **3** is a diagrammatic side view of a sorting apparatus according to another form of the invention,

FIGS. **4–10** are diagrammatic side views showing other forms of the invention, and

FIG. **6***a* is an enlarged view of a portion of FIG. **6**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings an ore sorting apparatus is shown which sorts pieces of rock as the pieces move in a wide path random stream through the apparatus. The expression "wide path" as used herein is intended to mean a path of travel having sufficient width to permit a plurality of pieces of rock to move along the path beside one another. The term "random stream" as used herein is intended to mean that the pieces of rock moving in a given direction have a haphazard alignment and spacing. A description of a sorting apparatus of this general type may be found in British Specification 986,177.

However, it will be apparent that the present invention may be used to sort objects, for example pieces of rock, which move through a sorting zone in a single row. It is intended that the description, where is refers to sorting of a wide stream of objects, also include the simpler case of sorting objects in a single row.

Referring to FIGS. **1** and **2**, a moving belt **10** carries pieces of rock **11** to a sorting apparatus. In the embodiment shown in the drawings there is a magnet **12** which

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provides a strong constant magnetic field flux density through which the pieces of rock **11** pass. The magnet **12** may not be required depending on the type of ore being sorted and its magnetic properties. If the magnet **12** is required, the magnetic field flux density it provides may be selected in accordance with the type of ore being sorted, and, for example, with hematite ore the flux density might be of the order of 3 kilogauss.

In some instances it may be desirable to subject the pieces of rock to a magnetic field at some place in the sorting apparatus where the orientation of each piece of rock has been established. Such a place, for example, might be at slide plate **14** as will subsequently be described. The magnet positioned as at **12** would not be used in such a case, but rather the magnet would be positioned as indicated at **12***a*.

The pieces of rock **11** are discharged from the moving conveyor belt **10** into a storage bin **15**. The pieces of rock move downwards under the influence of gravity and are deposited on a vibrating table **16** driven or vibrated by a motor **17**. The pieces of rock move along the surface of table **16** forming a closely packed single layer of pieces and are discharged onto a slide plate **14**. The pieces of rock accelerate as they slide down plate **14** but they retain their orientation along the path of their slide. As was previously explained, the pieces of rock may slide through a magnetic field provided by magnet **12***a*. The slide plate **14** would, of course, be of a material which does not appreciably affect the magnetic field, or alternately, the magnet means would be positioned above slide plate **14**.

The bottom part **18** of slide plate **14** is preferably of ceramic material having embedded therein a series of Hall effect elements **20**. A Hall effect element is quite small and it is shown in the drawings at the end of a supporting member **20**a. The number of elements **20** is chosen depending on the size of the pieces of rock and they are spaced across the path of the pieces of rock as shown. A series of air blast nozzles **21** is positioned at the end of the slide plate, that is, at the end of and adjacent to bottom part **18**. The air blast nozzles **21** are in abutting side-by-side relationship extending across the width of the path. As shown, there is one air blast nozzle for each Hall effect element and the element is positioned transversely at the center of the transverse extent of the air blast nozzle. The Hall effect element and the respective air blast nozzle cooperate, and they may be considered as representing one of a number of imaginary channels extending across the path followed by the pieces of rock.

A Hall element driver **22** provides a constant current to each Hall effect element **20**, and the Hall effect voltage developed by each element **20** is applied to a respective signal processing and comparison circuit **23**. The circuit **23** receives the voltage from the Hall effect device, which is a signal representing a magnetic characteristic, amplifies and processes the signal as required, and compares it with a desired parameter. The desired parameter is, in this instance, a predetermined level or value, however the parameter could be variable as modified by size or other property of an object. The circuit **23** provides a decision signal corresponding to a particular piece of rock in the respective imaginary channel. A series of solenoid drivers **24** are connected each to a respective circuit **23** to receive the output signal therefrom and according to the output signal provide the required actuating signal to a respective one of solenoid valves **25**. Each solenoid valve **25** is connected to a source of air under pressure and to one end of a respective pipe **26**. The other end of each pipe **26** is connected to a respective air nozzle **21**.

In the operation of the apparatus pieces of rock **11** having magnetic properties are discharged from conveyor belt **10** into storage bin **15**. The pieces of rock are discharged from the bottom opening of bin **15** onto a vibrating table **16** and they move down the surface of table **16** in closely spaced relationship to be discharged onto slide plate **14**. As the pieces of rock slide down slide plate **14** they pass over Hall effect elements **20** and their magnetic properties are detected by an element over which they pass. The output of each element **20** is applied to a respective signal processing and handling circuit **23**, and if a particular piece of rock has magnetic properties of such a nature that it is to be deflected, a respective solenoid driver **24** actuates a respective valve **25** which opens to permit a flow of air under pressure through the respective pipe **26**. This flow of air causes an air blast through the respective nozzle **21** to deflect that piece of rock.

Below the end of slide plate **14** is a splitter plate **27** which functions in the normal manner to ensure separation between the pieces of rock following their uninterrupted path of fall onto a moving belt **28** and the pieces of rock which have been deflected to fall onto a moving belt **30**. It will be seen that the apparatus of FIGS. **1** and **2** sorts or separates pieces of ore according to the magnetic characteristic remanence, that is according to the magnetic flux density retained by the magnetic material.

The effect of magnet **12** is to enhance the magnetic characteristic detected, that is, it increases the remanence. That this is significant is illustrated by the following example.

A small piece of naturally occurring hematite ore, approximately $2 \times 3 \times \frac{3}{4}$ inches, when probed closely with a Hall effect gaussmeter gives readings across the surface of less than 5 milligauss. This is below the limit of reliable detection in a sorting apparatus. When subjected to a constant magnetic field flux density of 50 gauss the measured remanence was about 130 milligauss (an increase of about 26 times). After passing through a much stronger field of about 3 kilogauss, the piece exhibited surprisingly uniform field strengths of about 1.3 to 1.5 gauss over the flat surfaces. This is a gain of about 300 over the original readings. The piece of rock that passed through the 3 kilogauss field has a magnetic flux density that is easily sufficient for detection by a Hall effect device for sorting according to the invention.

It should be noted that even by using a 5 kilogauss magnet, the attractive force on hematite cannot be felt by hand. The magnetic force is well below the force which would be required to cause a piece of rock to be separated. The magnetic force could be considered as non-existent for the purpose of causing actual separation by a magnet.

As another example of pretreatment of ores having weak magnetic properties, asbestos ores having a magnetic mineral associated with the asbestos were passed

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through a 3 kilogauss field and an increase in detectability of between three times and 10 times was observed. A similar order of increase was found in ilmenite and nickel/pyrrhotite ores.

The apparatus of FIGS. **1** and **2** with the magnet as shown at **12** might be suitable for ores where the difference in remanence between ore and waste is so great that orientation of each piece of rock is not necessary, that is, proportional response is not required. With the magnet as shown at **12***a* the pieces of rock maintain the same orientation past the field detector as they had through the magnetic field from magnet **12***a*. Consequently there is a proportional relationship between mineral value and remanence. This arrangement makes it practical to use a quantitative cut-off, that is a specific desired value as the decision value between accepting and rejecting.

A variation would be to position magnet **12***a* on the opposite side of the path followed by the rocks, that is above the rock stream. This has advantages and disadvantages. It is mechanically desirable to position magnet **12***a* as shown under the slide plate as it involves no obstruction to the rock stream. However, flux density decreases as the square of the distance from the magnet in a direction normal to the slide plate **14**. The response of the field detector **20** also decreases as the square of the distance in a direction normal to the slide plate **14**. Thus, when the magnet **12***a* and field detector **20** are both on the same side of the rock stream, the location of magnetic material in a piece of rock in a direction normal to the slide plate becomes significant. If the magnet and the field detector are on opposite sides of the rock stream there is some compensation for differences in location of magnetic material. In other words, in a direction perpendicular to the slide plate, flux density increases while detector response decreases.

Referring now to FIG. **3**, another embodiment or form of the invention is shown. The apparatus is similar to that of FIGS. **1** and **2** but a rock size and position detector has been added. A photodiode **32** is embedded in slide plate **14** adjacent the field detector **20** as shown. The photodiode is conveniently embedded close to the wear surface of a translucent plastic portion of the slide plate. A DC light source **33** is mounted opposite the photodiode **32** so that the light illuminates the photodiode when no rock is interposed. The photodiode is eclipsed when a piece of rock passes between it and the light source **33** and it provides a signal to processing and comparison circuit **23** which represents size and position or time of passage of a piece of rock. The signal from the photodiode **32** may be used for two purposes.

The primary purpose of the signal from photodiode **32** is to provide timing, that is to provide for timing of initiation and of termination of a deflecting blast. The sorting signal from the field detector provides information for a decision whether or not to blast, but with no size indication the duration of a blast must be governed by the period during which a magnetic response is detected. This may not correspond to the length of the piece of rock. Also the timing may not be accurate when relying on the magnetic response to provide timing. This is important if the sizes of the pieces of rock are different, and sufficient separation between detection and deflection must be provided. A delay is therefore required between detection and deflection and accurate timing of the delay can be provided so that blast initiation and termination are accurate for each piece of rock. The size signal (i.e., representing size and position or timing) is also very desirable where waste is a minor component but is not detectable by magnetic means. To conserve air it is desirable to blast the waste pieces and this cannot be done unless they can be detected such as by optical means.

A secondary purpose of a size signal is to relate the sorting signal to size. In other words, the sorting signal may be compared to the size signal in some manner to compensate for differences in sizes of pieces of rock. This is equivalent to using the size signal to modify the desired decision level to provide a parameter for comparison with the sorting signal.

It will, of course, be apparent that other optical detectors could be used.

FIGS. **4–10** show other embodiments of the invention in diagrammatic form. The general apparatus is similar to the apparatus of the previously described embodiments and the description will deal mainly with the differences.

In FIG. **4** there are two magnets **35** and **36** shown embedded in slide plate **14**. The magnets may be permanent magnets or electromagnets as in the previous embodiments, and they provide steady magnetic fields of opposite polarity as indicated by the arrows in the blocks representing magnets **35** and **36**. This embodiment of the apparatus is useful to enhance the difference in coercivity between high energy (hard) and low energy (soft) materials. The terms "hard" and "soft" are here used with reference to the phenomenon of coercive force and do not relate to commonly understood physical property.

As the pieces of rock move down slide plate **14** they pass through the field from magnet **35** and then the field of opposite polarity from magnet **36**. The flux density or the field strength of magnet **35** is normally greater. The relative field strengths or intensities are selected to take advantage of the different magnetization curves of the two materials. If there is sufficient difference in coercive force it is possible to leave residual inductances not only of different magnitude but of different polarity.

FIG. **5** shows an embodiment quite similar to FIG. **4**. Two magnets **35** and **37** are shown embedded in slide plate **14**. The second magnet **37** provides a high frequency alternating field as indicated by the double ended arrow. Again this arrangement takes advantage of the different magnetization curves of the two materials, that is of ore and waste. The steady field magnetizes and the alternating field demagnetizes the soft material. The relative field strengths are adjusted so that as the soft material passes through the alternating field it is carried around a hysteresis curve which gets smaller and closer to the origin as the piece of rock gets farther from the center of the field. On the other hand, the coercivity of the hard material is not exceeded by the alternating field and it moves to the field detector with residual magnetism that was induced from the field of magnet **35** remaining.

In FIG. **6** there is shown a magnet **38** positioned at the same location as field detector element **20**. Refer-

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ring for the moment to FIG. 6*a*, there is shown an enlarged view of magnet **38** and element **20**. The element **20**, which is preferably a Hall detector element, is shown mounted on one end of magnet **30** forming a sub-assembly which is embedded in slide plate **14** with element **20** very close to the wear surface. Two of the leads from element **20** are indicated at **40** and **41**. The leads from element **20** are also embedded where they pass through the slide plate **14**. The leads **40** and **41** are not shown on FIG. **6** to simplify the drawing and because the scale of FIG. **6** would make it difficult.

Referring again to FIG. **6**, this embodiment is responsive to differences in permeability. A steady magnetic field is provided, originating substantially at field detector element **20**, and the field detector gives a steady output corresponding to the magnitude of the field. If a material is introduced into the field, and if the permeability of the field differs from that of air, a magnetic field is induced in the material causing a net change in the total field to which the field detector element **20** is subjected. The magnitude of the change in field is a measure of the permeability of the material.

FIG. **7** shows an embodiment quite similar to FIG. **6**. A magnet **42**, having a steady magnetic field, is positioned opposite the field detector element **20** so that pieces of rock pass between the field detector and the magnet. As a piece of rock moves down the slide plate **14** between them a change in the detected field is caused and this is a measure of the permeability of the material. As was discussed in connection with a variation of FIGS. **1** and **2**, where the magnet **12***a* was above the slide plate, the arrangement of FIG. **7** compensates to some extent for the distance effect. In other words, it provides some compensation for the discrepancies due to both field intensity and field detector sensitivity decreasing as the square of the distance therefrom normal to the slide plate.

Referring to FIG. **8**, the embodiment shown is similar to FIG. **7**. A magnet **43** is provided on the opposite side of the path of the pieces of rock from the field detector **20**. The magnet **43** provides an alternating field. The magnitude of the field detected by the field detector is affected by the permeability of the material introduced into the field, and ferromagnetic hysteresis will cause a phase shift which may be used as a measure of permeability to provide a sorting signal.

FIG. **9** shows an embodiment which, in effect, combines the fields of FIGS. **6** and **8**. A magnet **38** having a steady field is positioned substantially at the field detector **20**, and a magnet **43** having an alternating field is positioned opposite it. This arrangement is suitable when two materials are involved and there is a significant difference in the value of H, i.e., the intensity of a magnetizing field, required to produce saturation in each.

The permeability of a material is the ratio of B, the magnetic induction field or flux density, to H, the magnetizing force or intensity of magnetizing field. In ferromagnetics the permeability is not constant but a function of H. In particular, the permeability drops to a low value when H is high enough to saturate the material. The field strength of magnet **38** is selected to be of sufficient magnitude to saturate only one of the materials involved, and a lesser alternating field is superimposed by magnet **43**. The field detector **20** will detect an alternating field whose magnitude will depend on the amounts of the two materials and may be used to provide the sorting signal.

Referring now to FIG. **10**, there is shown an embodiment having a magnet **44** substantially at the location of the field detector element **20**. The magnet **44** provides a high frequency alternating field. Thus, there is a high frequency alternating field at the point of detection. If a piece of rock having conductive material is introduced into the field, currents will be produced in the conductive material which will in turn generate a magnetic field. There is produced a change in the total field associated with the amount of conductive material, and this change is detected by the field detector **20**. The magnitude of the change provides the sorting signal.

A number of embodiments of the invention have been described. It will be realized that a variety of modifications are possible and that any one may be desirable for practical and economic reasons. For example, the embodiment described in connection with FIG. **3** having optical means to provide a size signal (i.e., a signal representing the size and position of each piece of rock) may be associated with any of the arrangements of the embodiments of FIGS. **4–10**. In some cases it is necessary only that the deflection means be responsive to a decision signal representing detector output above a certain cut-off level, and in other cases it is desirable to provide timing for the deflection means in conjunction with the decision signal. For another example, as was previously mentioned, the pieces of rock may be in a single row with single magnet means, single field detector, single deflection means, etc., or the pieces of rock may be in a wide path random stream as has been described. For yet another example, the pieces of rock may be carried through the sorting zone on a belt rather than the slide plate arrangement described and may be discharged from the belt directly past the deflection means. For yet another example, it may be desirable to have multiple field detectors for each channel in a wide path sorter. The use of multiple field detectors will linearize the response laterally across the width of the stream and interference may be reduced by magnetic shielding.

Three tables are given below to illustrate the type of response when sorting ores with apparatus according to this invention. These tables show a relationship between magnetic characteristics of an ore and the value of the ore.

TABLE I

Range of Remanence as Measured by the Field Detector, in milligauss	Percentage Iron Content of Pieces in the Range Indicated
0 – 100	17.00
101 – 200	32.25
201 – 300	36.63
301 – 400	38.14
401 – 500	41.46
501 – 600	41.67
601 – 700	42.06
701 – 800	43.42
801 – 900	43.42
901 – 1000	47.05

Table I is for a banded iron ore comprising magnetite-hematite finely interbedded with siliceous

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laminae. The ore is from a large African ore deposit. The pieces of rock are passed through a steady magnetic field prior to the field detector. This is an ore of low average tenor with a more or less gradual range of iron content from quite low grade pieces up to medium grade.

TABLE II

Range of Reading Milligauss	Percentage Iron Content of the Group
0 – 100	27.27
101 – 200	29.53
201 – 300	37.38
301 – 400	41.00
401 – 500	Not Represented
501 – 600	Not Represented
601 – 700	64.87
701 – 800	67.28
801 – 900	66.38
901 – 1000	67.13

Table II is for a vesicular hematite ore from the same region in Africa, with readings taken under the same conditions.

TABLE III

Range of Reading Milligauss	Percentage Iron Content of the Group
0 – 50	29.11
51 – 100	32.60
101 – 1000	62.45
Above 1000	68.14

Table III represents an iron ore from an Australian deposit comprising hematite with minor contamination by particles of ferruginous shale. This shows an ore from which once the low grade material has been removed, i.e., that giving a response below 100 milligauss, the whole of the balance is of high enough grade to come within direct shipping specifications. The cut-off point of 1,000 was chosen to discriminate between high grade and very high grade ore. Pure hematite has an iron content of 70.0 percent so it is apparent the apparatus of this invention will discriminate or sort at high grades as well as through all the ranges of lower grades.

It will be seen that by using a cut-off level at a desired point in the apparatus according to the invention, it is possible to discard or reject all material having a response below the selected level. A crude iron ore can be upgraded to a degree which is the optimum for the economic working of the deposit. This is so for all ores and other objects having or containing a material with magnetic properties.

The method and apparatus according to this invention may be used with various other ores, for example, in the sorting of a diamond bearing peridotite which has three main waste materials shown in Table IV as A, B, C.

TABLE IV

	Diamond Bearing Peridotite	Waste Type A	Type B	Type C
Response range in Milligauss	15 to 120	<1 to 4	<1 to 8	all <1
Response average in Milligauss	63	1.6	4.5	<1

Another example is shown in Table V below which relates to asbestos ores in which there is a magnetite-asbestos association.

TABLE V

	Rejects % Wt.	Rejects $ Value	Accepts % Wt.	Accepts $ Value
Test 1	37.4	0.60	62.6	2.87
Test 2	39.6	0.58	60.4	3.44
Test 3	33.0	0.72	67.0	4.91
Test 4	39.0	0.71	61.0	4.69

In connection with Table V it should be pointed out that value of asbestos ore is heavily dependent upon fiber length and this factor would not be apparent from Table V which expresses grade of asbestos in terms of percentages of actual fiber.

Another application for the present invention is in the removal of impurities from some types of raw material For many industrial purposes, limestone is required to have a very low iron content. Deposits exist in which large zones of otherwise satisfactory stone are spoilt by the presence of narrow bands or seams of iron bearing material. The concentration of iron, though not at all high is nevertheless sufficient to render extensive portions of the deposit unmarketable.

The apparatus described is able to detect the iron bearing particles and discard these from the stream of crushed stone to produce a saleable commodity from rock which previously had to be left in place or mined and dumped as waste in order to gain access to better quality material.

In this type of application it is not possible to express the performance of the apparatus in terms of grade of material discarded with reference to signal measurements as the levels are in all cases very low. Tests have shown simply that it is effective in the lowering of iron contamination in limestones to acceptable levels.

It appears the apparatus would work equally well in the removal of similar contamination from other industrial minerals such as gypsum, feldspar, and the like.

We claim:

1. A method for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising the steps of

moving the objects through a sorting zone along a predetermined path,

providing a first steady magnetic field of one polarity and a second steady magnetic field of opposite polarity adjacent said path,

passing said objects through said first and second magnetic fields in succession,

detecting a magnetic characteristic in each object after it has passed through said first and second fields, the intensity of said first and second fields being selected so that the residual magnetism in each object and the detected characteristic of each object is related to coercivity,

developing a sorting signal representing the detected magnetic characteristic,

processing said sorting signal to produce a decision signal, and

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deflecting objects from said predetermined path in accordance with said decision signal.

2. A method for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising the steps of

moving the objects through a sorting zone along a predetermined path,

providing a first steady magnetic field and a second alternating field adjacent said path,

passing said objects through said first and second magnetic fields in succession,

detecting a magnetic characteristic in each object after it has passed through said first and second fields, the intensity of said first and second fields being selected so that the residual magnetism in each object and the detected characteristic of each object is related to coercivity,

developing a sorting signal representing the detected magnetic characteristic,

processing said sorting signal to produce a decision signal, and

deflecting objects from said predetermined path in accordance with said decision signal.

3. A method for sorting irregularly shaped objects having a first and a second naturally occurring magnetic material of different permeability, comprising the steps of

moving the objects through a sorting zone along a predetermined path,

providing a first steady magnetic field of an intensity sufficient to saturate only said first material and a second alternating field to reduce residual magnetism associated with said second material,

detecting a magnetic characteristic of each object in the area of said first and second fields, the magnetic characteristic detected being related to the permeability of said first material,

developing a sorting signal representing the detected magnetic characteristic,

processing said sorting signal to produce a decision signal, and

deflecting objects from said predetermined path in accordance with said decision signal.

4. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path, including means delivering said objects onto the upper surface of an inclined slide plate defining a portion of said path, said slide plate guiding said objects over its surface under the influence of gravity and discharging said objects at the lower end thereof,

magnet means in said sorting zone providing a magnetic field to enhance a magnetic characteristic of said material, said magnetic characteristic being related to one of the group of remanence, coercivity and permeability,

a magnetic field detector in a lower portion of said slide plate to detect said magnetic characteristic and to provide a sorting signal representing the detected characteristic,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

deflection means positioned at the lower end of said slide plate, said objects being discharged from said slide plate following said predetermined path past said deflection means, said deflection means being responsive to said decision signal to deflect a respective object from its predetermined path.

5. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

a first and second magnet in said sorting zone providing a field to enhance a magnetic characteristic of said material, each having a steady magnetic field, said first and second magnets being positioned adjacent one another and in sequence along said path so that said objects pass through the field of said first magnet and then said second magnet, the fields of said first and second magnets being of opposite polarity with the intensity of the first being greater and the intensities of both being selected so that the residual magnetism in each object after passing therethrough is related to coercivity,

a magnetic field detector in said sorting zone adjacent the path followed by said objects and spaced from said first and second magnets so that said objects pass said first and second magnets before said field detector, said detector providing a sorting signal representing the coercivity-related detected magnetism in each passing object,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path.

6. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

a first and second magnet in said sorting zone providing a field to enhance a magnetic characteristic of said material, said magnets being positioned adjacent one another and in sequence along said path so that objects pass through the field of said first magnet and then said second magnet, said first magnet having a steady magnetic field and the second an alternating magnetic field, the intensities of said fields being selected so that the residual magnetism in each passing object is related to coercivity,

a magnetic field detector in said sorting zone adjacent the path followed by said objects and spaced from said first and second magnets so that said objects pass said first and second magnets before said field detector, said detector providing a sorting signal representing the coercivity-related detected magnetism in each passing object,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

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deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path.

7. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

a magnet in said sorting zone providing a field to enhance a magnetic characteristic of said material, said magnet having a working face and providing a steady magnetic field, said magnet being mounted with its working field adjacent said path,

a magnetic field detector mounted substantially at said working face of said magnet to detect said magnetic characteristic which is related to permeability of said material and to provide a sorting signal representing the permeability-related detected characteristic,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path.

8. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

a magnet in said sorting zone providing a field to enhance a magnetic characteristic of said material, said magnet having a working face and providing a steady magnetic field, said magnet being mounted with its working field adjacent said path,

a magnetic field detector positioned on the opposite side of said predetermined path from said magnet and directly opposed, permitting objects to move along the path therebetween, said magnetic field detector detecting said magnetic characteristic which is related to permeability of said material and to provide a sorting signal representing the permeability-related detected characteristic,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path.

9. Apparatus for sorting irregularly shaped objects having first and second naturally occurring material of different permeability, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

a first and a second magnet in said sorting zone providing a magnetic field to enhance a magnetic characteristic of said material, said first magnet providing a steady magnetic field and said second magnet providing an alternating field, said first and second magnets being positioned on opposite sides of said path permitting objects to move along said predetermined path therebetween, said first magnet having a field with an intensity sufficient to saturate only said first material and said second magnet having a field with an intensity sufficient to reduce residual magnetism associated with said second material,

a magnetic field detector in said sorting zone positioned on the same side of said path as said first magnet and as close as possible thereto and directly opposed to said second magnet, said field detector providing a sorting signal representing a detected magnetic characteristic,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path.

10. Apparatus for sorting pieces of rock having naturally occurring material with magnetic properties, comprising

a wide path handling means for delivering a wide path random stream of pieces of rock for movement through a sorting zone in the apparatus along a predetermined path,

magnet means in said sorting zone providing a magnetic field to enhance a magnetic characteristic of said naturally occurring material, said magnetic characteristic being related to one of the group of remanence, coercivity and permeability,

a magnetic field detector in said sorting zone adjacent the path followed by the pieces of rock to detect said magnetic characteristic and to provide a sorting signal representing the detected characteristic, said field detector comprising a plurality of units in side by side relationship extending across the wide path random stream,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison, and

a plurality of deflection means, each associated with a respective one of said units in said field detector, positioned in the sorting zone so that pieces of rock pass the deflection means after passing the field detector, and responsive to said decision signal to deflect a respective piece of rock from its predetermined path.

11. Apparatus for sorting irregularly shaped objects having naturally occurring material with magnetic properties, comprising

means to move said objects through a sorting zone in the apparatus along a predetermined path,

magnet means in said sorting zone providing a magnetic field to enhance a magnetic characteristic of said naturally occurring material, said magnetic characteristic being related to one of the group of remanence, coercivity and permeability,

a magnetic field detector in said sorting zone adjacent the path followed by said objects to detect said magnetic characteristic and to provide a sorting signal representing the detected characteristic,

a signal processing and comparison means receiving said sorting signal, comparing said sorting signal with a desired parameter and providing a decision signal based on the comparison,

deflection means positioned in said sorting zone so that objects pass it after passing said field detector and being responsive to said decision signal to deflect a respective object from its predetermined path, and

optical means for determining at least the physical dimension of each object in the direction in which the objects are being moved, said optical means being connected to said deflection means to control the time of operation of said deflection means in accordance with said physical dimension of the object being deflected.

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