

July 28, 1942.

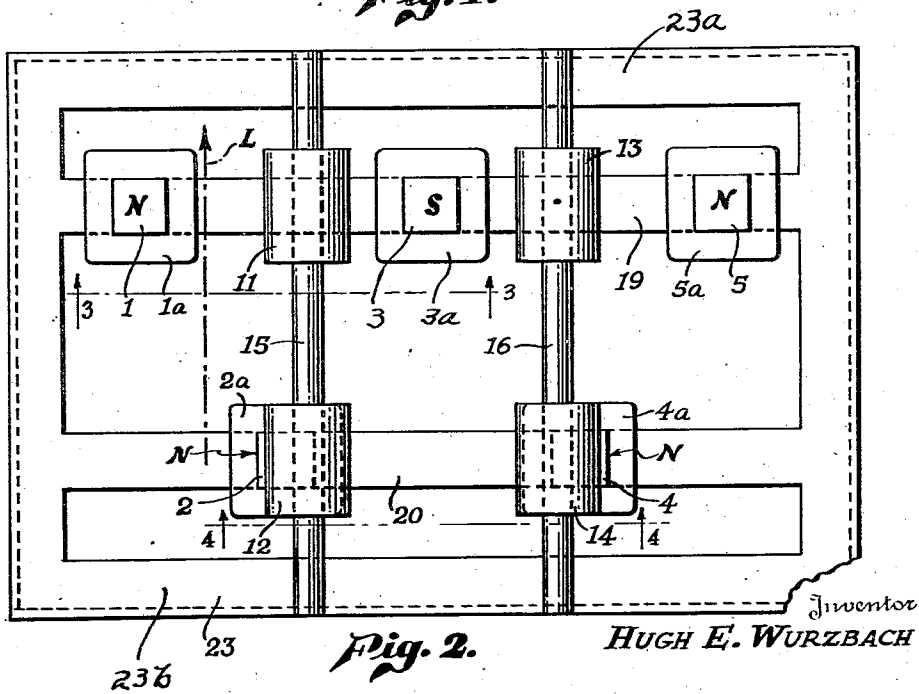
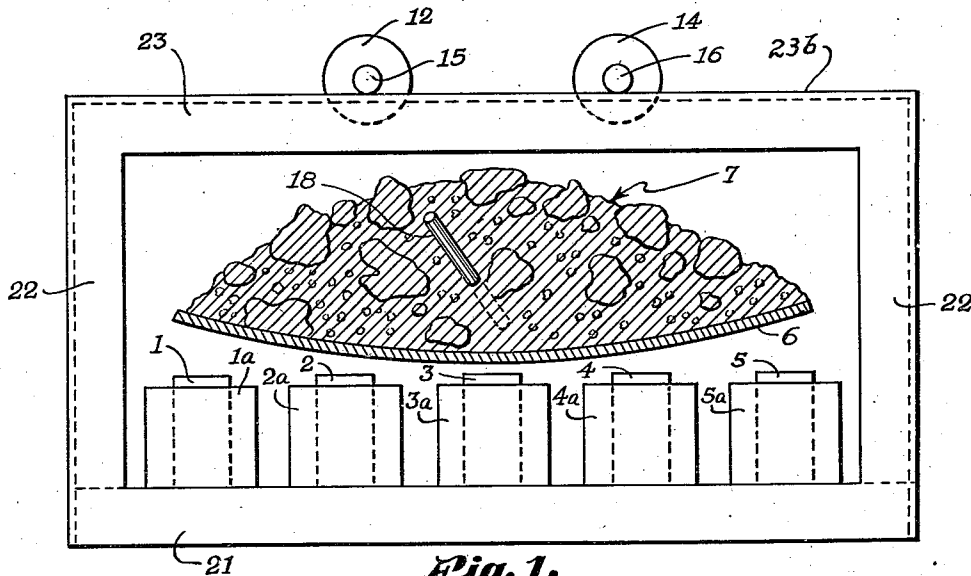
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2,290,930

MAGNETIC MATERIAL DETECTOR

Filed Jan. 13, 1941

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

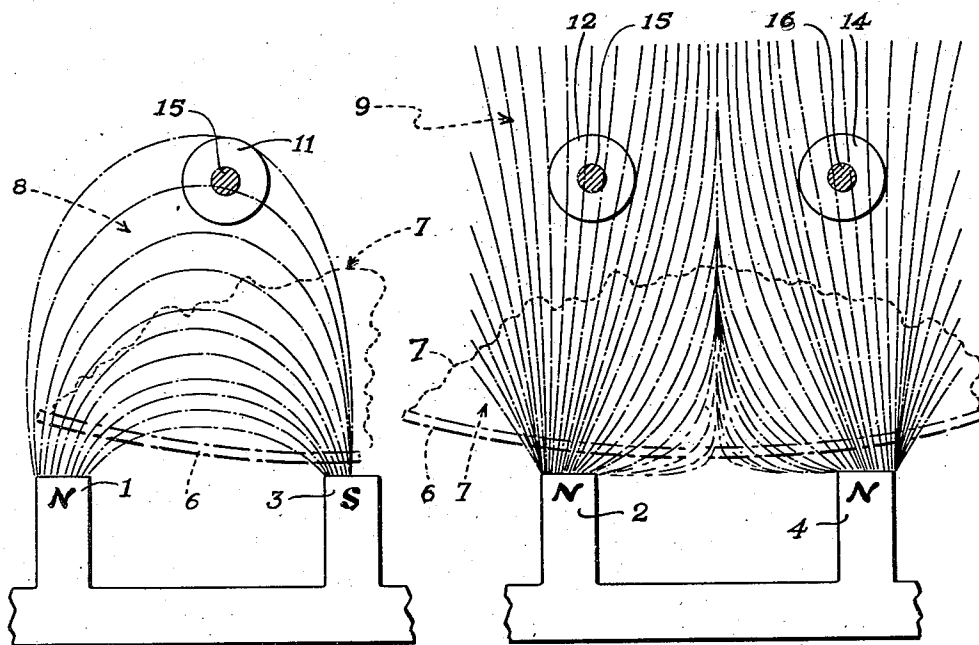


Fig. 3.

Fig. 4.

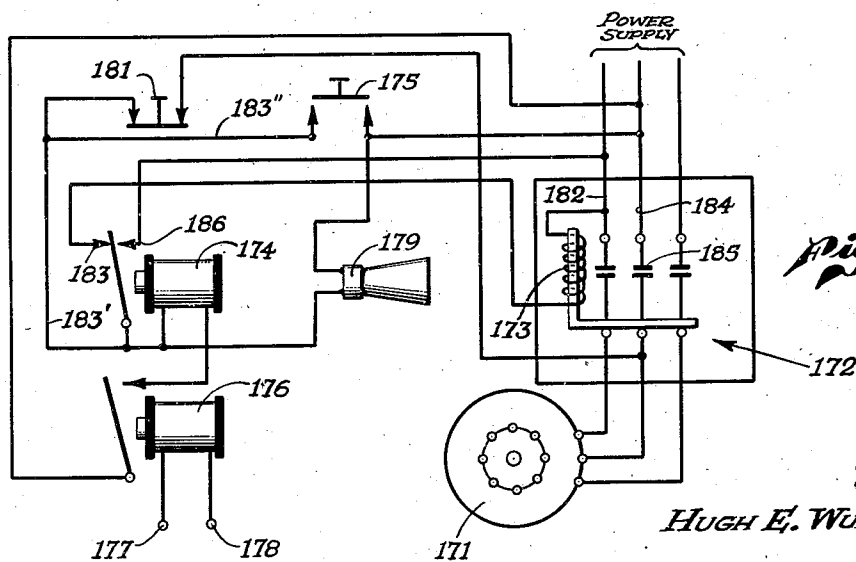


Fig. 5.

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4 Sheets-Sheet 3

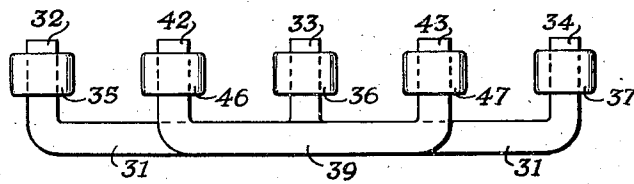
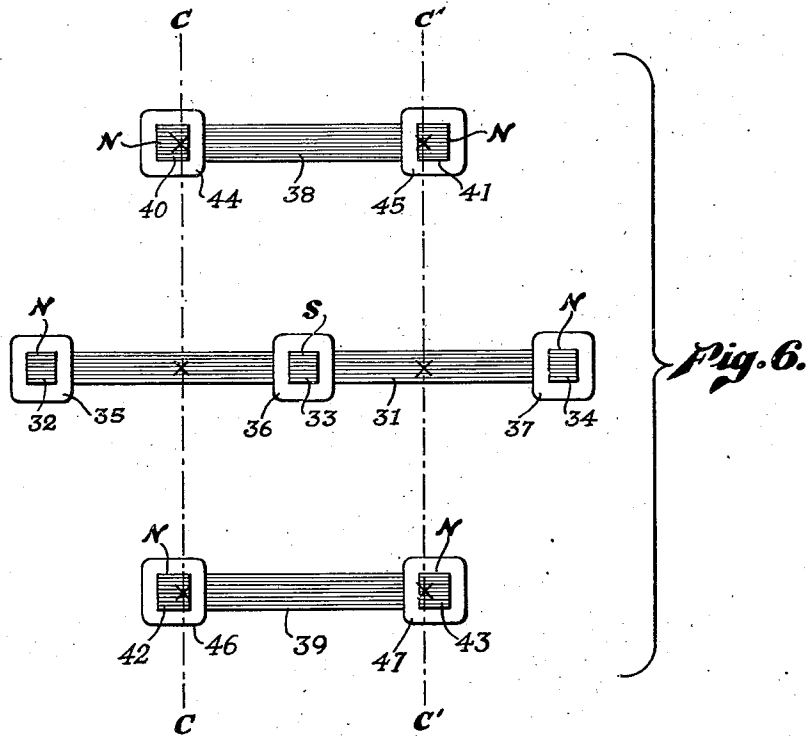


Fig. 7.

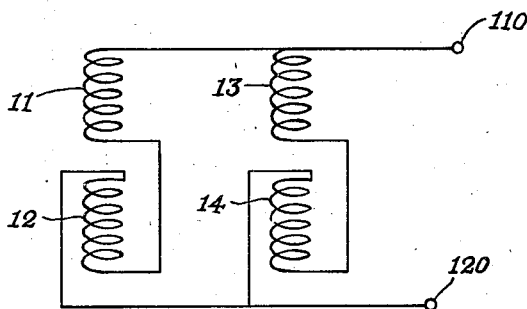


Fig. 8.

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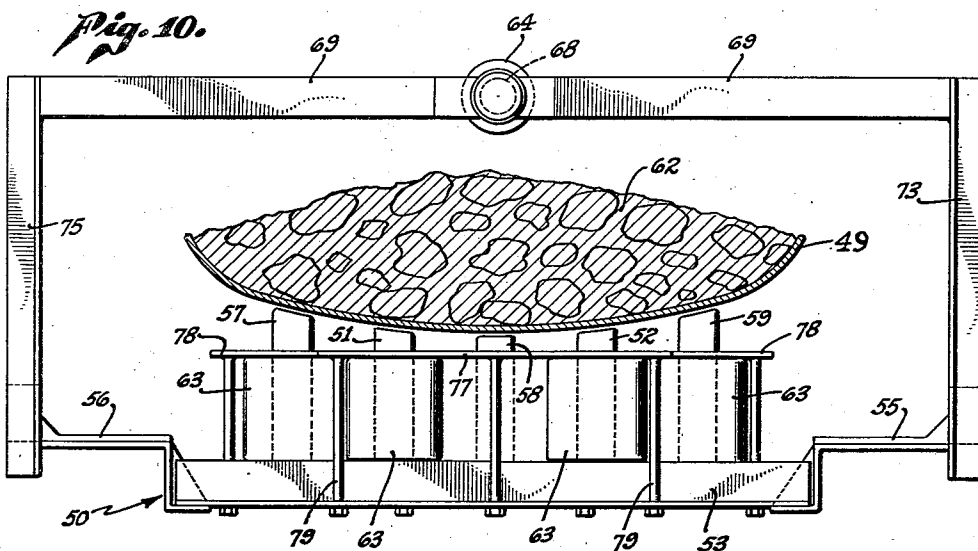
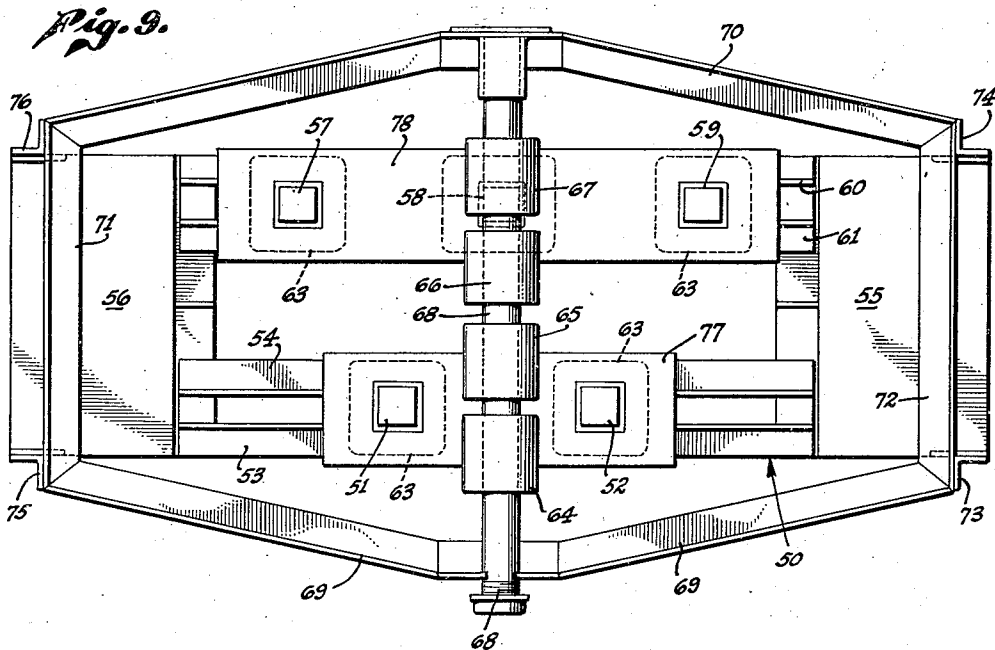
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UNITED STATES PATENT OFFICE

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MAGNETIC MATERIAL DETECTOR

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Application January 13, 1941, Serial No. 374,183

9 Claims. (Cl. 175-183)

This invention relates to devices for detection of ferromagnetic objects, and pertains particularly to a device for detecting tramp iron in a moving body of ore or like material. This invention is directed to improvements in devices of the general character set forth in my issued United States Patents Nos. 2,228,293 and 2,228,294.

It is well known that in milling operations in which crushing machinery or the like is used to pulverize ores in the process of handling the material for further concentration in the recovery of the mineral values, it is not unusual for mine drills or parts thereof, or parts of mining machinery, or other ferromagnetic objects, all of which come under the designation of "tramp iron," to be present in the ore. If the tramp iron is of sufficient size to cause damage when allowed to enter the crushing machinery, it is essential that the presence thereof be noted and that it be removed before entering the crushing machinery. In large operations, where considerable tonnage of ore is involved, it is common to cause this ore to be conveyed from one position to another in the mill through the agency of rather wide, heavy capacity conveyor belts, which owing to their width present a rather wide zone which must be subjected to scrutiny in order to detect and remove the offending tramp iron. It will be appreciated that if a comparatively small piece of tramp iron is present in the ore being handled, such as a tobacco tin or nail or the like, there is no necessity for removing it from the ore stream inasmuch as the possibility of such a small object causing any damage is quite remote and elimination of the expense and delay attendant the shut-down for removal of such a non-objectionable object is desirable. It is therefore a problem in the industry to provide a detecting means which will be responsive to any piece of tramp iron whose size is above an allowable lower limit, irrespective of the position of that piece of tramp iron in the body of ore as it passes through the detection zone on the conveying belt, and which will at the same time be insensitive to all pieces of tramp iron which may be in the moving body of ore which are smaller than this allowable size.

It is, therefore, one of the particular objects of this invention to provide a device for the detection of tramp iron in a moving body of ore or like material, which will serve to indicate the presence of any piece of tramp iron which is above the established allowable size, independent of the position of that piece of tramp iron

within the ore body carried by the conveyor belt which is under scrutiny.

A further object of the invention is to provide a device which serves to subject a given body of ferromagnetic material such as tramp iron in a moving body of non-magnetic material (diamagnetic or feebly paramagnetic material) such as ore to substantially the same degree of scrutiny independent of the shape of such ferromagnetic body, wherefore a given mass of tramp iron will be subjected to substantially identical scrutiny whether it happens to pass through the detection zone in close proximity to the conveying surface or whether it is high in the body of ore on the belt, even though it is an irregularly shaped body with its major axis extending horizontally, vertically, or at some other angle. These considerations apply to all hitherto-suggested forms of detecting means but have not been all realized in one compact apparatus.

A further object of the invention is to provide a ferromagnetic material detector adapted to subject a rather large body of moving material (such as may be carried by a conveyor belt or the like) to uniform scrutiny, and which will be substantially uniformly responsive to ferromagnetic objects located at all positions across the width of the belt whether closely adjacent the belt or upwardly removed from the belt surface, and which is at the same time substantially insensitive to external magnetic disturbances and to internal magnetic disturbances resulting from variations in the energizing power supply, and the like.

The invention comprises, essentially, the provision of means defining two cooperating magnetic fields or groups of lines of flux, one group being so arranged as to extend from below the belt upwardly through the material on such belt in a generally vertical relation, and the other group being arranged to extend transversely through the material and the space immediately above the material in a generally horizontal relation, together with a detector coil assembly positioned to have an appreciable voltage induced therein in response to the disturbance produced in either of the groups of lines of force by the presence of a ferromagnetic object above a given minimum size.

As a preferred broad example of my invention as above defined and as applied to the detection of the presence of tramp iron in the non-magnetic material carried in a longitudinal path on a moving conveyor belt, my apparatus may comprise frame means defining a pair of longitudi-

nally spaced low-reluctance magnetic circuits extending around the belt. Carried on the frame means below the belt is magnet means defining a plurality of respectively vertically and respectively horizontally extending magnetic fields positioned to extend through the material on the belt, whereby substantially all of the material is caused to pass through at least one horizontally extending and one vertically extending field in its movement past the frame means along the path of the belt. Also carried on the frame means is detector coil means located above the belt in spaced relation to the material carried thereon and having a magnetic core portion included in both the low reluctance magnetic circuits.

The movement of a ferromagnetic body above a given size through one or both of the above-mentioned vertically or horizontally extending fields acts to induce a voltage in the above-mentioned detector coil means, which voltage may be communicated to a suitable work circuit associated with the detector coil means to effect operation of a signal, cessation of movement of the belt, or other operations, as required by a particular installation. The low reluctance magnetic circuits surrounding the belt assist in distributing the flux lines for the greatest advantage and at the same time minimize the effects of stray magnetic fields produced by electrical equipment operated in the vicinity of the apparatus. In this last connection, it is preferable that the detector coil means include a plurality of spaced detector coils connected to have opposed voltages induced therein by the action of foreign stray fields or by a uniform change in the field's strength so that substantially no current will flow in the detector circuit from these influences.

Other objects and features of the invention will be brought out in the ensuing description of certain preferred embodiments thereof, or will be apparent from such description. The accompanying drawings illustrate such embodiments, and referring thereto:

Fig. 1 is an end elevation of one form of the device, the view being taken transversely through the conveyor belt and illustrating an advantageous relative disposition of the flux generating means and the detector coil means with relation to the conveying belt and the material carried thereby;

Fig. 2 is a plan view of the form of construction shown in Fig. 1, with the conveyor belt and its carried material being omitted;

Fig. 3 is a transverse section through a portion of the device, as taken along line 3-3 in Fig. 2;

Fig. 4 is a view corresponding to Fig. 3, taken on line 4-4 in Fig. 2;

Fig. 5 is a schematic representation of a signal circuit which may be associated with the detector coil means in the form of construction shown herein;

Figs. 6 and 7 illustrate an alternative layout of electromagnets to establish a desired arrangement of flux, taken in plan and side elevation, respectively;

Fig. 8 is a wiring diagram illustrating one way of connecting the detector coils illustrated herein;

Fig. 9 is a plan view of a preferred form of construction with the conveyor belt omitted; and

Fig. 10 is an end elevation of the form of con-

struction shown in Fig. 9, the view being taken transversely through the conveyor belt.

Referring to Figs. 1-4 of the drawings and more particularly to Figs. 1 and 2, the apparatus is shown as comprising a plurality of ferromagnetic pole members 1, 2, 3, 4, and 5 disposed beneath a conveyor belt 6. The outer pole members 1 and 5 are preferably located with their outer edges substantially below the lateral edges of the belt 6 and, as may be seen by inspection of Fig. 2, each pole member is spaced from its adjacent pole member by substantially the same distance.

The respective pole members are provided with coils 1a, 2a, 3a, 4a, and 5a, which are adapted upon connection to a suitable source of direct current (not shown) to polarize the upper ends of the poles 1, 2, 4, and 5 similarly, for example to provide north poles, and to polarize the upper end of the pole 3 oppositely, for example to provide a south pole. The pole members and their energizing coils provide means defining two co-operating magnetic fields or groups of lines of flux. The adjacent like poles 1 and 2, 2 and 4, and 4 and 5 provide groups of magnetic fields or lines of flux which extend generally vertically upward through the belt 6 and the material 7 carried thereon. The adjacent unlike poles 1 and 3, 2 and 3, 3 and 4, and 3 and 5 provide magnetic fields or groups of lines of flux which extend between the poles of these respective pairs of poles and pass through the belt and the material carried thereon in a generally horizontal direction. Obviously, for these last-mentioned lines of flux to pass through the material on the belt above the poles requires that they also extend in a vertical direction. However, at positions in the space between these unlike pole pairs the direction of the lines of flux is generally horizontal.

Still referring to Figs. 1-4, but with particular reference to Figs. 3 and 4, the groups of lines of flux as produced by pairs of unlike and like poles are diagrammatically indicated at 8 and 9 in Figs. 3 and 4 respectively. It will be understood, of course, that the illustration of the flux lines is not theoretically perfect, no attempt being made to show the actual density of the field or the distortion thereof produced by ferromagnetic core members in the field as by the subsequently described ferromagnetic detector core members. The main purpose of the figures is to show the general direction of the lines. The position of the conveyor belt 6 and the outline of the material carried thereon are indicated in dot-dash lines at 6 and 7 in Figs. 3 and 4. It will be noted from Fig. 3 that except at positions closely adjacent the faces or upper ends of the pole members 1 and 3 the flux lines 8 for the most part extend in a generally horizontal direction through the material 7. From Fig. 4 it may be seen that the flux lines from the poles 2 and 4 for the most part extend in a generally vertical direction through the material 7.

The device is further provided with detector coil means comprising a plurality of detector coils 11, 12, 13, and 14, which are located above the belt 6 adjacent the material 7. The coils may be mounted in pairs on ferromagnetic core members with their axes in substantial parallel alignment, with the coils 11 and 12 on a core member 15 and the coils 13 and 14 on a parallel core member 16 for example.

Although the detector coils may be connected in numerous ways, as in series or parallel or

series-parallel, when the coils are arranged in this embodiment, it has been found advantageous to connect the coils 11 and 12 in series in opposition to one another and the coils 13 and 14 in series and in opposition to one another and then to connect the series-connected coils in parallel, as shown in Fig. 8. The coils so connected are shown connected to a pair of terminals 110 and 120. The coils on either one of the cores 15 or 16 are said to be connected in opposition when a uniform change in flux throughout the length of either one of the cores generates equal and opposite voltages in the coils carried by that core.

The detector coils are each preferably so positioned as to be linked by lines of flux from the above-mentioned dissimilar groups of lines of flux; and each of the coils preferably has its turns so positioned that a distortion or movement of the flux linking the coil (as produced by movement of a magnetic object through one or more of the groups of lines of flux) will induce appreciable voltage in the coil.

It is well known that an elongated ferromagnetic object in passing through a magnetic field will change and/or redistribute the flux lines in the field to a greater or less extent dependent upon the orientation of its longitudinal axis with respect to the direction of the flux lines. It will be noted from inspection of Figs. 1-4 that in the zone of detection which extends through the space occupied by the belt between the pole members and the detector coil, any object traveling on the belt passes successively through two dissimilar groups of flux lines. For example, an object in passing through the detection zone along the dot-dash arrow L will first be subjected to the substantially vertically extending field produced through the cooperation of like pole members 1 and 2 and then subjected to the substantially horizontally extending field produced by cooperation of the unlike pole members 1 and 3.

If an elongated piece of tramp iron, such as shown at 18 in Fig. 1, has its axis so aligned as to materially change the reluctance of the magnetic circuit and/or redistribute the flux lines in the horizontally extending field it may have little effect on the vertically extending field and vice versa. In other words, with a field arrangement having all lines of flux directed in substantially one direction it is possible for a piece of tramp iron above the allowable minimum size to pass through the field without operating the detector, depending upon the orientation of the piece of iron with respect to the field lines. With my arrangement a piece of tramp iron located at any position in the material on the belt is subject to scrutiny by both types of fields, i. e., a vertically directed and a horizontally directed field. Obviously then, irrespective of the orientation of the iron, its presence is indicated by its effect on either one or both of the fields.

It is to be pointed out that in previously proposed detectors utilizing only the field between oppositely polarized poles, the effective field was too weak in the central area between the poles and this weakness had to be compensated for by highly amplifying the pickup or detector circuit so as to give it strength enough to operate a commercial relay when the iron passed through the weak area. This makeshift, however, has the disadvantage of giving an extremely high degree of detection over the strong part of the protected area while it affords only normal or minimum

protection over the weak area. Another serious fault of the simple use of the known art is that the shape of the body passing through the protected zone materially governs the degree of detection. For example, if an elongated body, whose lineal dimension is several times its diameter, such as an iron rod one inch in diameter by eight inches long, passes through the weak area of a simple magnetic field in which a detector is placed, the amount of current induced in the detector circuit will greatly depend on whether the rod passes through the magnetic field with its axis parallel to the lines of force or at right angles to them, the ratio of detection being approximately in the ratio of six to one. By using the field arrangement disclosed herein, the degree of detection is sufficiently uniform and high throughout the area under scrutiny as to make it unnecessary to use amplification.

It should be borne in mind that detection is required for a substantial vertical distance as well as for a substantial horizontal distance. This problem is not the same as obtaining either uniform detection or ultimate detection through a small vertical or horizontal distance.

The pole members 1, 3, and 5 are preferably carried on a ferromagnetic core member 19 which extends transversely of the conveyor belt, and the pole members 2 and 4 are preferably carried on another ferromagnetic core member extending generally parallel to the first core member. These core members are preferably tied together by a rectangular ferromagnetic core member 21 which is provided at its corners with uprights 22 of angle iron or the like which extend upwardly along the sides of the conveyor belt to a position above the level of the material 7. The framework is further provided with an upper rectangular frame 23 of angle iron or the like which joins the side frame members 22 and supports the cores 15 and 16. The framework provides a lower reluctance return path for the flux from the pole members.

As may be seen by inspection, the upper frame 23 and lower frame 21 in combination with the side frame members or posts 22, define a plurality of low reluctance magnetic circuits extending around the belt. For example, laterally extending frame members 23a and 23b of the upper frame 23 constitute parts of two circuits around the belt. These circuits help produce a desirable distribution of the flux lines through the material and help in decreasing the effect of stray magnetic fields. The cores 15 and 16 extend between the laterally extending members 23a and 23b and are also included in both of the above-mentioned low reluctance magnetic circuits.

Although the detector coils may be positioned in a number of different ways, I prefer, in order to secure the maximum strength and uniformity of detection, to position them substantially as shown in Figs. 9 and 10 when employing the energizing arrangement illustrated in Figures 1, 2, 9 and 10, although the arrangement shown in Figs. 1 and 2 may be employed with satisfactory results. With such an arrangement as shown in Figs. 1 and 2 the longitudinal spacing of the coils is not extremely critical, but it is preferable to place the coils 11 and 13 directly above the transversely aligned poles 1, 3, and 5, and the coils 12 and 14 directly above the transversely aligned poles 2 and 4. It is also preferable to locate the detector coils at a height above the upper end of the pole 3, which is about equal to

the spacing between adjacent poles, substantially as shown. The lateral spacing of the detector coils is somewhat more critical than the longitudinal spacing thereof, and it is preferable to place them with their axes located substantially in line with the inner edges of the poles 2 and 4, as illustrated in Figs. 1 and 2.

Another modification of my invention is illustrated in Figs. 6 and 7 and is shown as comprising a central core member 31 provided with three upstanding spaced pole members 32, 33, and 34 each provided with a suitable energizing coil 35, 36, and 37. The apparatus further comprises a pair of core members 38 and 39 respectively provided at their ends with upstanding pole members 40, 41, 42, and 43, the last-mentioned pole members being provided with energizing coils 44, 45, 46, and 47, respectively. All of the upstanding pole members are shown located at equal distances from the pole member 33, and each pole member is spaced the same distance from its adjacent pole member.

All of the energizing coils are adapted for connection to a suitable source of direct current and are preferably connected thereto in such manner as to polarize the central pole 33 in one manner and the remaining poles in an opposite manner. For example, the central pole may be a south pole and all the remaining poles may be north poles. With such an arrangement positioned beneath a conveyor belt (not shown), it is obvious that any piece of material carried on the belt will be subjected to a field produced by two unlike poles and another field produced by two like poles in the same manner as in the arrangement illustrated in Fig. 1.

The detector coils which may be used with the apparatus illustrated in Figs. 6 and 7 are not shown, but they may be located in accordance with the teachings of Figs. 1 and 2, as at the positions designated by the "x" marks along the center lines C-C and C'-C'. Obviously the cores 31, 38, and 39 may be interconnected by suitable paramagnetic members to form a rigid framework, and such framework may be continued about the conveyor belt to support the detector coils and provide the low-reluctance magnetic circuits around the belt in the same manner as illustrated in Fig. 1.

A form of work circuit which may be associated with the apparatus above described, as by connection to the terminals 110 and 120 of the detector coil assembly of Fig. 8, is illustrated in Fig. 5. Referring to said figure, a motor 171 which may be used to operate the conveyor belt 6 in Fig. 1, is shown connected through a starting switch 172 to a three-phase power supply. One lead 182 of the power supply is shown connected through actuating coil 173 of a starting switch 172, thence through back contact 183 of a relay 174 and connections 183' and 183'' to another lead 184 of the power supply, through a normally open push-button 175. Upon pressing push-button 175 the circuit of the coil 173 is closed, operating the starting switch 172 and maintaining coil 173 in energized relation by establishing contact through normally closed push-button 181, contact 185 of the starting switch 172 to line connection 184, rendering the push-button 175 inoperative.

A normally open relay is shown at 176 with its terminals 177 and 178 adapted for connection to a pair of the above-mentioned detector coil terminals. This relay should be of sufficient sensitivity to close its contact upon receiving a mini-

mum voltage impulse from the associated detector coils in response to the presence of a body of magnetic material of given minimum size. Upon receiving an impulse this relay will momentarily close, energizing the coil of relay 174 for a sufficient time to establish connection at its front contact 186. This relay 174 may be of a type will known to the art which will close its contact in response to a short energizing impulse and will maintain its contact closed for a given time interval after the cessation of the impulse, returning to its position in contact with its back contact 183 at the end of the time interval. Such a relay may be dashpot or motor operated after a manner well known to the art and need not be described in detail herein. The break of the circuit of relay 174 with its back contact 183 will break the circuit to coil 173, opening switch 172 to stop the motor 171. Closing of relay 174 with its front contact 186 will energize a warning horn 179 and operate the horn for the above-mentioned given time interval. Upon return of the relay 174 to a position contacting its back contact 183, the motor 171 may be set in operation again by pushing the start button 175.

Although the forms of the invention in the preceding figures give substantially uniform response, the particular arrangement illustrated in Figs. 9 and 10 is preferred in that it appears to give the most uniform response. Referring to these figures the detector is shown as comprising a suitable base framework 50 fabricated from iron angles and plates. The magnetic field is provided by a plurality of pole members comprising a pair of pole members 51 and 52 located beneath a conveyor belt 49 and held between a pair of iron angle bars 53 and 54 which are suitably secured to iron plate members 55 and 56. The space between the pole members 51 and 52 is preferably bridged by an iron core having substantially the same section as the poles and which extends between the bases thereof and is located between the angles 53 and 54.

A second set of pole members are indicated at 57, 58 and 59 and are held between iron angles 60 and 61 which are secured at their ends to the plates 55 and 56. The magnetic circuit between these pole members is preferably bridged by core members of substantially the same section as the pole members and which extend between the angles 60 and 61.

The line joining the center of the poles 51 and 52 is preferably parallel to the line joining the centers of the poles 57, 58, and 59, and these lines preferably extend to right angles to the path of movement of the conveyor belt 49 and the material thereon indicated at 62. The spacing between the poles 51 and 52 is preferably substantially equal to the spacing between poles 57 and 58 and between the poles 58 and 59. Furthermore, it is preferable that the distance between the above-mentioned parallel lines joining the poles of the respective sets is substantially equal to the distance between poles 51 and 52. It is also preferable to position the magnet pole substantially symmetrically with respect to the line of travel of the belt. Thus the pole 58 is located substantially beneath the center of the belt and the distance from the center of the belt to the pole 51 is substantially equal to the distance from the center of the belt to pole 52.

Each of the poles is provided with a coil or winding 63 which is adapted for connection to a suitable source of direct current. The coils 63 are so connected as to polarize the upper ends of

the poles 51, 52, 57, and 59 similarly, for example to make them north poles, and to polarize the upper end of the pole 58 oppositely, for example to make it a south pole.

The type of field produced by this energizing arrangement is quite comparable to that produced by the arrangement illustrated in Figs. 1 to 4. The adjacent unlike poles produce groups of lines of flux which extend in a generally vertical direction through the material 62 and the adjacent unlike poles produce groups of lines of flux which extend in a generally horizontal direction through the material 62. From an inspection of Figs. 9 and 10 it may be seen that substantially every particle of material carried on the belt is subjected to the action of both of these groups of lines of flux in passing through the detector.

With this embodiment of my invention the detector coils indicated at 64, 65, 66, and 67 are carried at spaced positions on a single ferromagnetic core member 68 which is preferably located directly above the central pole 58 and extends parallel to and in the direction of movement of the conveyor belt 53. The detector coils are obviously located sufficiently above the belt to clear the material 62 and the axis of the coil is preferably located at a distance above the pole 58 which is slightly greater than the distance between the poles 51 and 52. As a preferred limit the lowest portion of the detector coil is located at a distance above the pole 58 which is substantially equal to the distance between the poles 51 and 52. The coils 64, 65, 66 and 67 may be spaced substantially equally from one another.

The core 68 is shown supported on a frame comprising cross frame members 69 and 70 which are tied together at their ends by longitudinally extending frame members 71 and 72. These members are in turn supported by vertically extending posts 73, 74, 75, and 76 which are attached at their lower ends to the plates 55 and 56. This frame is preferably fabricated from ferromagnetic material such as angle iron and forms part of the magnetic circuit between the detector coils and the energizing magnets. The frames and posts cooperate to form a pair of low-reluctance magnetic circuits which extend around the belt. The two circuits are defined by the cross frame members 69 and 70 of the upper frame, and the ferromagnetic core portion 68 bridges these circuits and is included in both of them.

The faces of the poles are preferably chamfered to conform to the contour of the conveyor belt and each of the faces thereof are preferably spaced the same distance from the bottom of the belt. This practice may be employed with the arrangement illustrated in Fig. 1. In order to prevent the material carried on the belt and other extraneous material from falling into the magnet windings I have provided guard plates 77 and 78 of non-magnetic material such as copper or brass which fit over the pole members and are supported above the magnet coils 63 by means of suitable support members such as pins 79 which are attached to the base framework 50.

As brought out above, any magnetic body above a given minimum size and irrespective of its orientation, upon being subjected to lines of flux from both groups, will change the reluctance and/or redistribute the flux lines in such manner as to induce an appreciable voltage in the detector coils. The detector coils may be suitably connected to an electrical circuit such as illus-

trated in Fig. 5, as to the terminals 177 and 178 thereof, whereby the above-mentioned induced voltage may be utilized to perform operations such as sounding a warning and stopping the conveyor belt. It is preferred that the detector circuit be substantially insensitive to a uniform change in magnetic field such as caused by outside influence or by variation in the energizing current supplied to the magnet coils. This may be accomplished by connecting the coils 64 and 65 so that the voltages induced therein by such a uniform change are additive and are opposed to the voltages induced in the coils 66 and 67.

It is to be understood that my invention is subject to considerable modification without departing from the spirit thereof. Hence I do not choose to be limited to the examples described herein, but rather to the scope of the appended claims.

I claim:

1. In a device for detecting tramp iron in the material carried generally along a plane by a belt conveyor or the like, magnet means disposed on one side of such plane and defining a zone of magnetic detection extending the full width of such belt, and comprising: a plurality of magnetic pole members of one polarity arranged to establish a plurality of groups of magnetic lines of force directed through such material in a generally vertical direction and transversely with respect to the direction of travel of material along such plane; an additional magnetic pole member of opposite polarity magnetically coupled to the respective first-mentioned pole members and cooperating therewith to establish a plurality of additional groups of magnetic lines of force directed generally horizontally through such material and transverse to the direction of travel of such material; and detector coil means located adjacent to such plane and disposed on the other side of such plane in position to be linked by flux from all of said groups of lines of force and responsive to changes in flux linkage therein produced by passage of a magnetic body carried by said belt through one or more of said groups of magnetic lines of force.

2. A device as set forth in claim 1, and comprising in addition an external ferromagnetic circuit means surrounding the zone of detection defined by said pole members and said detector coil means, said external ferromagnetic circuit comprising a ferromagnetic framework having portions extending upwardly on opposite lateral sides of said zone and other portions extending between said upwardly extending portions above and below said belt, one of said other portions being magnetically connected to said pole members, said pole members extending toward said belt from said one of said other portions.

3. In a device for detecting tramp iron in the material carried along a plane by a belt conveyor, means defining a zone of magnetic detection, which comprises: flux producing means including spaced magnetic pole members of one polarity arranged to establish a group of magnetic lines of force directed transversely through such material with respect to the direction of travel thereof along such plane, and an additional magnetic pole member of opposite polarity magnetically coupled to said first-mentioned pole members to establish an additional group of magnetic lines of force directed through such material transversely of said first-mentioned groups of lines of force; and detector coil means located adjacent such plane in spaced relation to

said plane and to said flux producing means in position to be linked by both of said groups of lines of force and responsive to changes in flux linkage therein produced by passage of a magnetic body through said groups of lines of force.

4. In an apparatus for detecting the presence of tramp iron in non-magnetic material carried on a conveyor belt in a longitudinal path, the combination which comprises: frame means defining a pair of longitudinally spaced low-reluctance magnetic circuits extending around said belt; magnet means carried on said frame means below the belt and defining a plurality of respectively horizontally and respectively vertically extending magnetic fields positioned to extend through the material on said belt whereby substantially all of such material is caused to pass through at least one horizontally extending and one vertically extending field in its movement past said frame means along said path; and detector coil means carried on said frame means above the belt in spaced relation to the material carried thereby and having a ferromagnetic core portion included in both of said low-reluctance magnetic circuits.

5. In an apparatus for detecting the presence of tramp iron in non-magnetic material carried on a conveyor belt in a substantially horizontal path, the combination which comprises: a pair of frames of ferromagnetic material located respectively above and below the belt and extending substantially parallel to the path of the belt, said frames each comprising members extending longitudinally of the belt and members extending transversely of the belt; a plurality of polar projections mounted on one of said frames with their faces disposed toward the belt; coils carried by said projections for polarizing the face of at least one of said projections with one magnetic polarity and polarizing the faces of a plurality of the remaining projections with another magnetic polarity, said projections being so polarized and located that the path of material carried on the belt passes through a field produced by adjacent similarly polarized poles as well as through a field produced by adjacent oppositely polarized poles; ferromagnetic members located on laterally opposite sides of the belt and connecting the frames; a ferromagnetic core member extending longitudinally of the belt in spaced relation thereto and supported between laterally extending members on the other one of said frame members; and a plurality of spaced detector coils on said core member.

6. In a device for detecting tramp iron in the material carried generally along a plane by a belt conveyor or the like, magnet means disposed below such plane and defining an upwardly extending zone of magnetic detection extending the full width of such belt, and comprising: a plurality of magnetic pole members of one polarity arranged to establish a plurality of groups of magnetic lines of force directed upwardly through such material and transversely with respect to the direction of travel thereof along such plane, and an additional magnetic pole member of opposite polarity magnetically coupled to the respective first-mentioned pole members and cooperating therewith to establish a plurality of additional groups of magnetic lines of force directed generally horizontally through

such material and transversely of said first-mentioned plurality of groups of lines of force; and detector coil means located adjacent such plane but upwardly removed therefrom in position to be linked by all of said groups of lines of force and responsive to changes in flux linkage therein produced by passage of a magnetic body along said belt in said plane and passing through one or more of said groups of magnetic lines of force.

7. The improvement set forth in claim 6, and comprising in addition an external ferromagnetic circuit means surrounding the zone of magnetic detection defined by said pole members and said detector coil means, said external ferromagnetic circuit comprising a ferromagnetic framework extending below said pole members and magnetically connected thereto and having portions extending upwardly on opposite lateral sides of said zone and across the top of said zone to provide a common magnetic return for the magnetic flux of said plurality of groups of lines of magnetic flux.

8. The improvement set forth in claim 6, and comprising in addition an external ferromagnetic circuit means surrounding the zone of magnetic detection defined by said pole members and said detector coil means, said external ferromagnetic circuit comprising a ferromagnetic framework extending below said pole members and magnetically connected thereto and having portions extending upwardly and opposite lateral sides of said zone and across the top of said zone to provide a common magnetic return for the magnetic flux of said plurality of groups of lines of magnetic flux, and ferromagnetic core members extending through said detector coil means and magnetically connected to said external ferromagnetic circuit.

9. In a device for detecting tramp iron in the material carried generally along a plane by a belt conveyor or the like, magnet means disposed below such plane and defining an upwardly extending zone of magnetic detection extending the full width of such belt, and comprising: a plurality of magnetic pole members of one polarity arranged to establish a plurality of groups of magnetic lines of force directed upwardly through such material and transversely with respect to the direction of travel thereof along such plane, and an additional magnetic pole member of opposite polarity magnetically coupled to the respective first-mentioned pole members to establish a plurality of additional groups of magnetic lines of force directed upwardly through such material and transversely of said first-mentioned plurality of groups of lines of force; and detector coil means located adjacent such plane but upwardly removed therefrom in position to be linked by flux from all of said groups of lines of force and responsive to changes in flux linkage therein produced by passage of a magnetic body along said belt in said plane and passing through one or more of said groups of magnetic lines of force, said additional magnetic pole member of opposite polarity being symmetrically disposed with respect to said plurality of pole members of one polarity, and substantially uniformly spaced from each of said pole members of one polarity.

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