No. 834,175. PATENTED OCT. 23, 1906.

G. H. WARING.

MAGNETIC ORE SEPARATOR AND CLASSIFIER.

APPLICATION FILED NOV. 16, 1905.

3 SHEETS—SHEET 1.

Fig. 1.

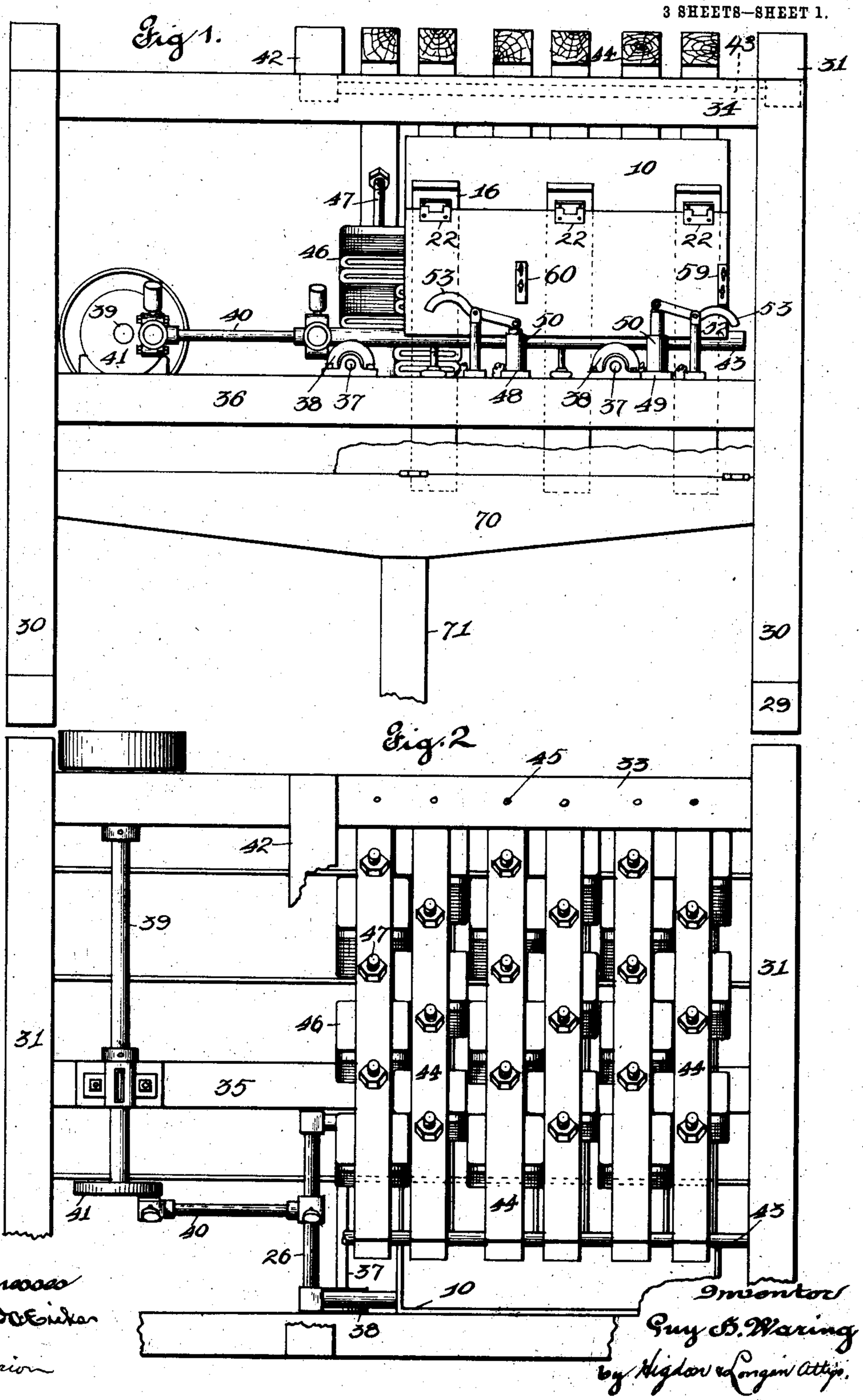

Fig. 2

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Fig. 3.

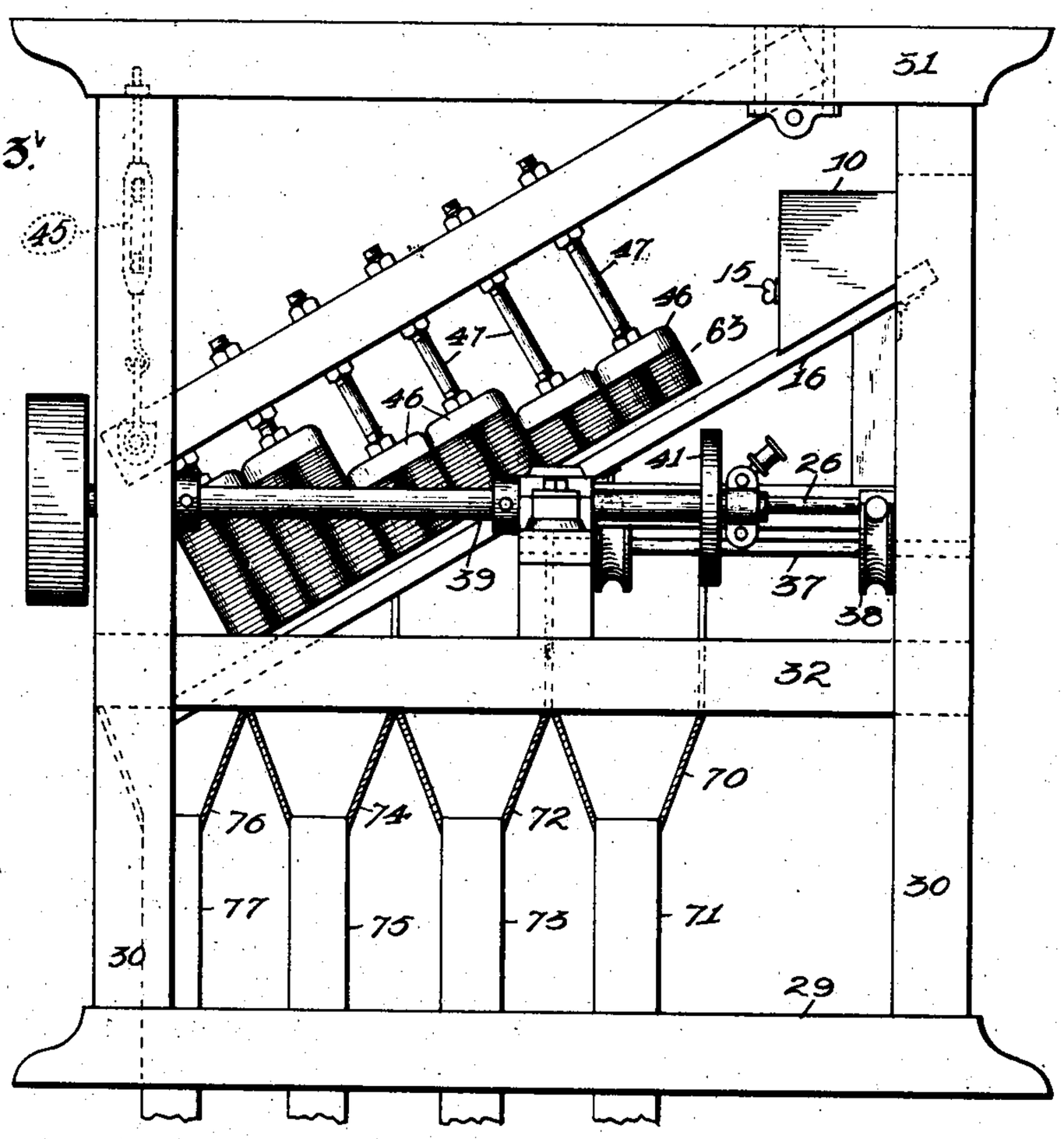
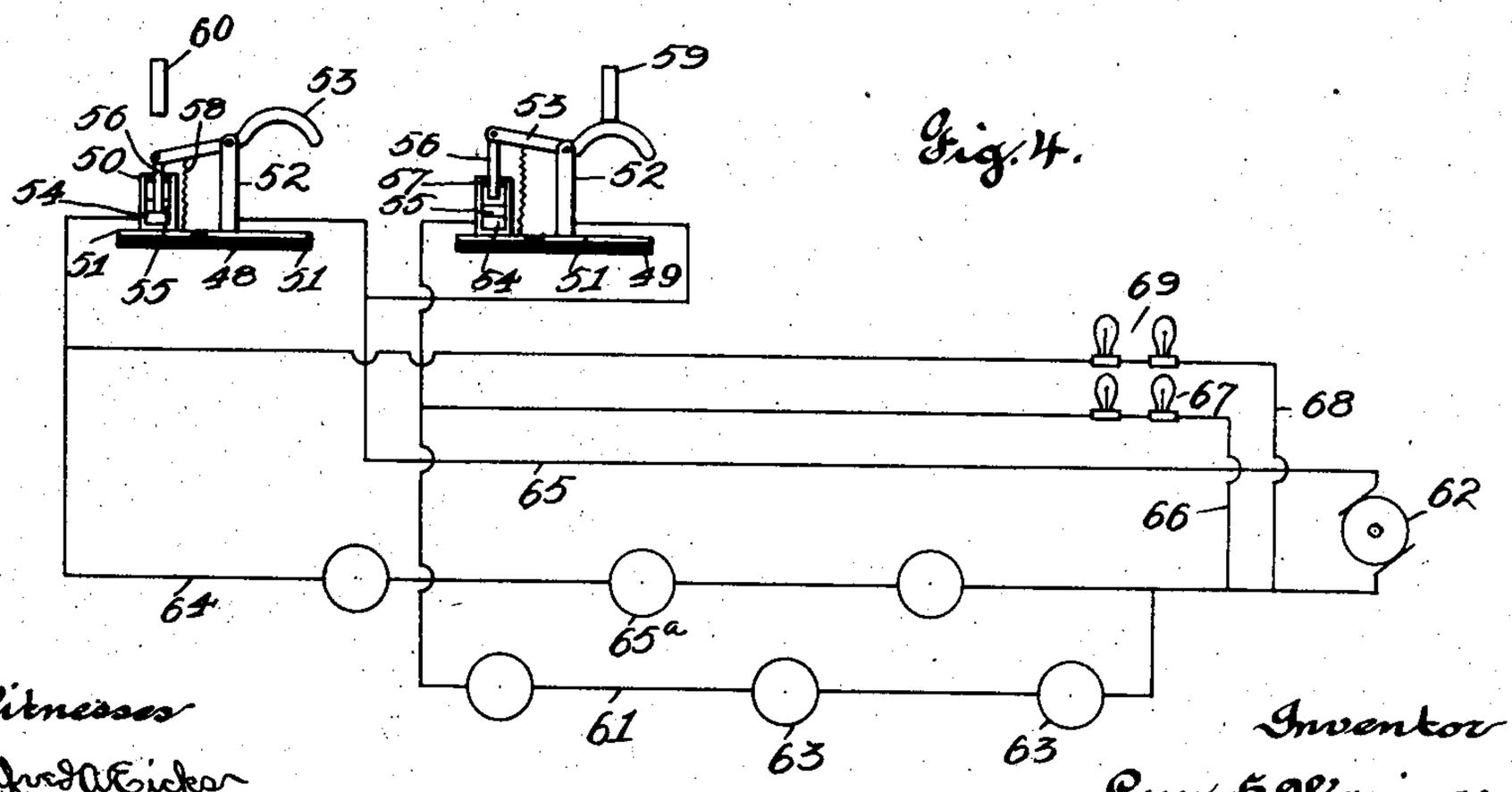


Fig. 4.



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3 SHEETS—SHEET 3.

Fig. 5.

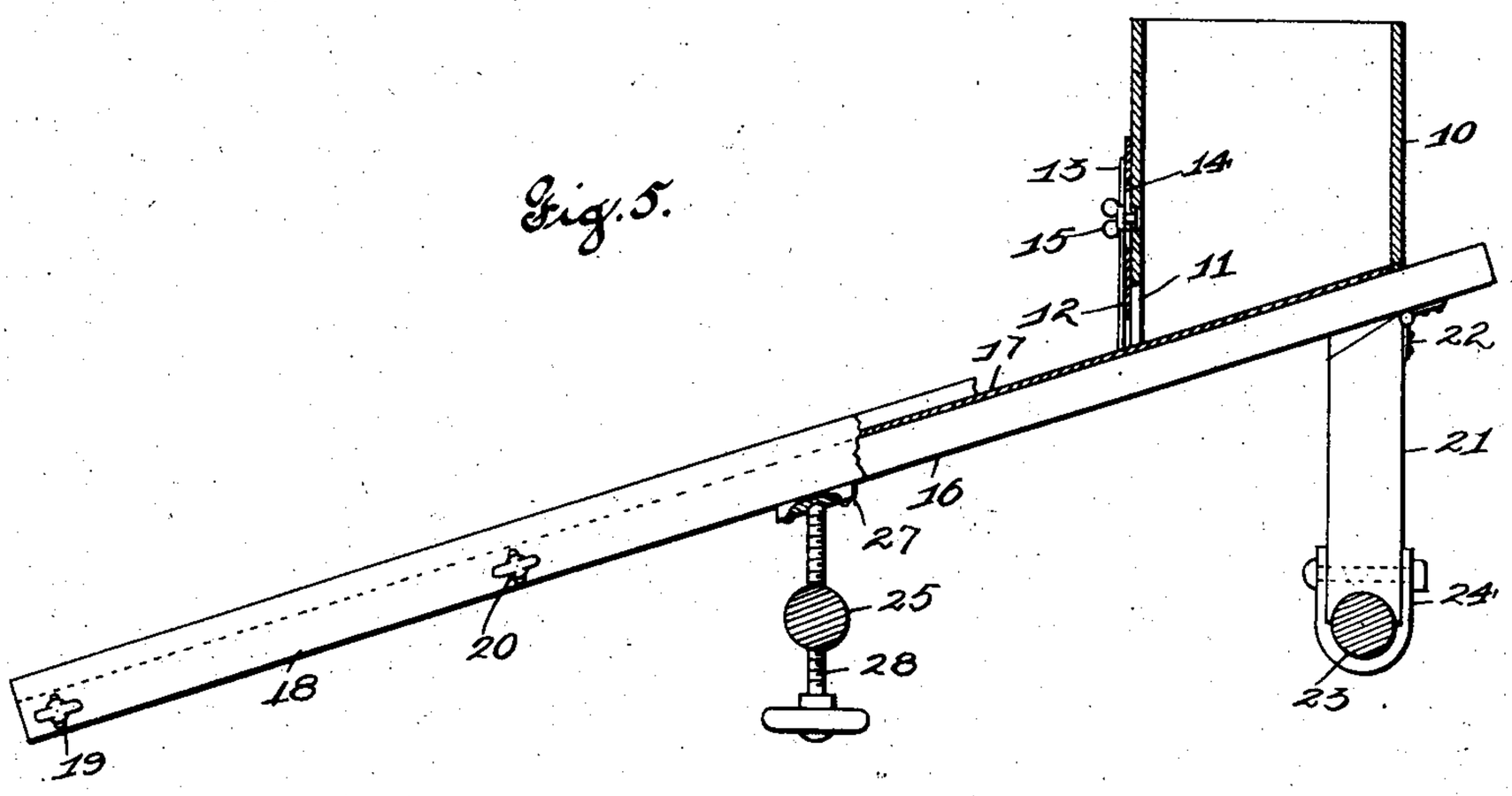
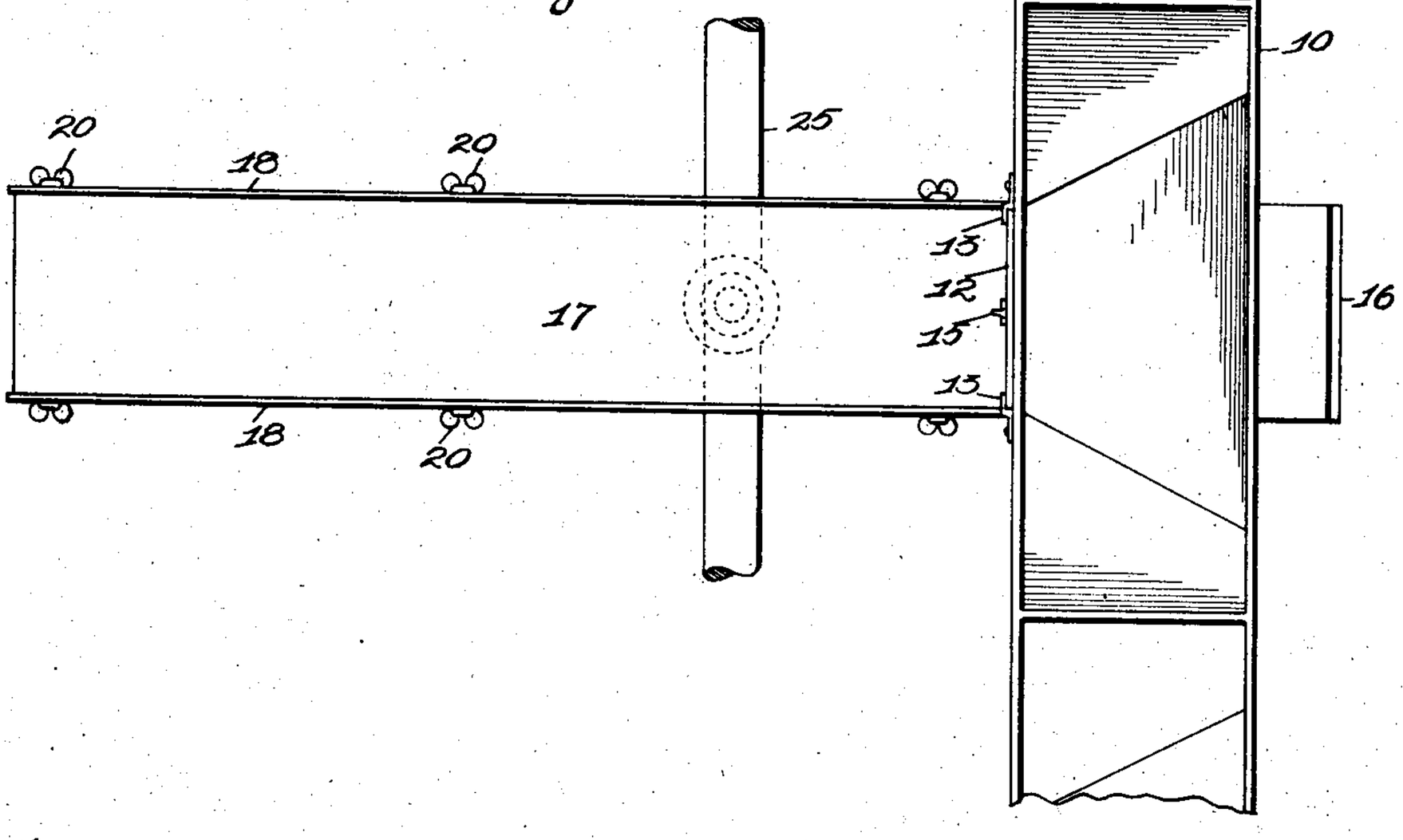


Fig. 6.



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UNITED STATES PATENT OFFICE.

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MAGNETIC ORE SEPARATOR AND CLASSIFIER.

No. 834,175. Specification of Letters Patent. Patented Oct. 23, 1906.

Application filed November 16, 1905. Serial No. 287,734.

To all whom it may concern:

Be it known that I, GUY H. WARING, a citizen of the United States, and a resident of Webb City, Jasper county, Missouri, have invented certain new and useful Improvements in Magnetic Ore Separators and Classifiers, of which the following is a specification containing a full, clear, and exact description, reference being had to the accompanying drawings, forming a part hereof.

My object is to produce an improved magnetic ore separator and classifier which shall not only separate the ore from the refuse, but which shall classify the ore after separation.

My invention consists, when stated specifically, of a machine having a suitable hopper to receive the ore; means for regulating the flow of ore through the hopper; an inclined bottom; a smooth non-magnetic surface for said bottom; adjustable non-magnetic sides adjacent said bottom and forming therewith a trough to receive the ore from the outlet of the hopper; means for adjusting the degree of inclination of the said trough; means for shaking the trough, so as to cause the ore to slide, roll, and tumble freely down the incline; magnets arranged above the trough in oblique pairs so that the planes of magnetic influence overlap longitudinally of the direction of the flow of the stream of ore through said trough, as required to subject the particles of ore to a practically constant magnetic influence as they roll and tumble along said trough; means for regulating the distance between the magnets and the ore by adjusting the relative position of the magnets and the ore; means for reciprocating a series of magnets or their sources of magnetic influence crosswise of said trough; a series of lamps in circuit with said magnets to take up the self-induction and lessen the spark and also to quicken the release action of the magnets; means for intermittently exciting the magnets, as required to pick up the ore and pass it over the edge of the said trough and then drop it, said magnets being graduated in strength, the weakest being at the top and the strongest at the bottom, as required to pick up the high-grade ore first and the low-grade ore last, and independent receptacles for each grade of ore.

It has hitherto been found impracticable to use reciprocating electromagnets of high power with bare poles intermittently excited when placed in close sets—that is, when the magnets momentarily cut out are in juxtaposition with others that are momentarily excited—whether the relation of the magnets to each other are staggered or in square sets without the introduction of insulating material in the most intensely active portion of the field in order to so weaken the total attractive force of the magnet that it may release the attracted material when cut out; but I have discovered that when the alternately-excited magnets are arranged in single pairs placed obliquely with regard to each other the induced magnetism in the shunted or cut-out magnet when it is cut out is so small in amount that the magnets can be operated with bare poles acting upon the material under any desired potential in an intermitting manner and at the same time quickly release the magnetic matetial when cut out. This arrangement, as I find, makes it possible, as I believe, for the first time in the practical use of intermittent electromagnets to dispense altogether with every form of shield or insulation between the pole-pieces and the attracted material. The more intense the magnetic field is the farther apart the magnets should be placed in the diagonal. Heretofore the principal difficulty encountered in operating intermittently-charged magnets with bare poles or bare pole-pieces has been attributed chiefly to residual magnetism remaining after the current is cut off and causing retention of material. My investigations have shown that with proper magnetic metal the residual magnetism causes no trouble whatever, provided the induced currents are reduced to a negligible quantity, which I find can be done by the oblique arrangement and in no other way.

A decided utility in the arrangement of intermittently-acting electromagnets in oblique pairs as applied to the extraction of magnetic particles from a descending stream of material in which all the particles have a free motion of their own, due to the combined effect of gravity and impact, arises from the fact that the magnets must necessarily move at a right angle to the lines of direction of the moving stream, so that as the upper magnet of each pair recedes from any such line the ma-

terial in such line immediately above the portion already acted upon by the receding magnet before its return and remagnetization, but will be exactly in the field of the lower magnet. Similarly, during the return stroke of the upper magnet the material which would otherwise pass down behind the receding lower magnet is acted upon, and in this way a definite area of descending material is constantly acted upon by a uniform magnetic potential.

Especial attention is called to the arrangement of intermittently-excited electromagnets arranged in oblique pairs with means for passing the material to be acted upon through the magnetic field surrounding the poles of such magnets in such a way that the individual particles of material may be in free movement with respect to each other, as in a free falling stream or having a rolling tumbling motion, as over an inclined plane, as distinguished from movement *en masse*, as when carried by a belt or pan, and without the intervention of bolts or insulation of any description between the material and the poles of the electromagnet, with means for interrupting the excitation of the magnets when not over or in front of the moving material and means for obtaining reciprocal lateral movement of the ore-carrier or the magnets.

The attractive power of a magnetic surface decreases in proportion to the square of the distance between it and the material acted upon, and it is readily seen why any device which will render the actual contact of the poles and magnetic material practicable in a magnetic separator must also very greatly diminish such waste of energy. The operation of separating the ore from the refuse is greatly facilitated by shaking the trough.

The following drawings illustrate one way of carrying out my invention.

Figure 1 is a rear elevation of the apparatus. Fig. 2 is a top plan view omitting the hopper. Fig. 3 is a side elevation, the receptacle for receiving the ore being shown in section. Fig. 4 is a diagrammatic view of the electric circuits. Fig. 5 is a detail of one of the hoppers and the inclined trough leading from the hopper and showing the means of adjusting the inclination of the trough. Fig. 6 is a top plan view of the parts shown in Fig. 5.

Referring to the drawings in detail, the hopper 10 has an outlet 11, and the passage of ore through the outlet is regulated by the adjustable slide 12. Z-bars 13 are attached to the front face of the front wall of the hopper in vertical parallel positions, one on each side of the outlet 11, as required to provide ways in which the slide 12 operates to open and close the outlet 11. A vertical slot 14 is formed in the center of the slide 12, and a thumb-screw 15 operates in said slot as required to tighten and hold the slide in any desired position. The hopper 10 is rigidly mounted upon the inclined bottom 16, and the upper surface of the bottom is covered by a smooth plate 17, of suitable non-magnetic material, such as zinc. The bottom 16 is provided with adjustable sides 18, said sides being strips of non-magnetic material, such as zinc, and having vertical slots 19, through which the thumb-screws 20 operate, as required to adjust the height of the sides above the bottom, thus producing an inclined trough down which the ore will readily slide, roll, or tumble from the outlet 11 in the hopper.

In the apparatus shown there are three hoppers 10, arranged in a row, and three inclined troughs leading from the hoppers. The hoppers are built together, and the troughs are rigidly connected to the hoppers. The back support 21 is connected to the rear upper ends of the troughs by the hinges 22, and the support 21 is in turn connected to the rod 23 by the clamps 24. A rod 25 is mounted parallel with the rod 23, the corresponding ends of said rods 23 and 25 being connected by the cross-rods 26.

Plates 27 are secured to the lower face of the troughs, and adjusting-screws 28 are screw-seated vertically through the rod 28, with their upper ends operating in recesses in the plates 27, so that the inclination of the troughs may be regulated by the adjusting-screws 28.

The frame consists of the sills 29; the posts 30, extending upwardly from the sills; the side top pieces 31, connecting the upper ends of the posts 30; the intermediate side pieces 32; connecting the centers of the posts 30; the front top piece 33, connecting the forward ends of the side top pieces 31; the rear top piece 34, connecting the rear ends of the side top pieces 31; the center timber 35; a corresponding front timber mounted in horizontal alinement vertically below the front top piece 33, and a rear timber 36 in horizontal alinement with the center timber 35.

Shafts 37 are mounted in bearings upon the timbers 35 and 36, and grooved wheels 38 mounted upon the shafts, and the rods 23 and 25 rest upon these grooved wheels, as required to support the hoppers and the inclined troughs. A driving-shaft 39 is mounted in bearings upon the center timber 25 and the corresponding front timber, and a pitman-rod 40 connects the cross-bar 26 to the crank-disk 41, carried by the driving-shaft 39, so that as the driving-shaft 39 is rotated the hoppers and troughs are reciprocated, thus shaking the ore and causing it to pass from the hoppers to the troughs and slide, roll, and tumble down the troughs.

A timber 42 is mounted on the top of the timbers 33 and 34, and a rod 43 (see dotted lines, Fig. 1) connects the timber 42 to one of the top pieces 31 near their rear ends, and magnet-supports 44 are pivotally connected

to this rod 43. The forward ends of these magnet-supports 44 are adjustably connected to the front top timber 33 by turnbuckle-rods 45, so that the supports 44 may be adjusted to and from the troughs by operating the turnbuckles.

There are two supports 44 for each trough, and magnets 46 are arranged in oblique pairs and adjustably connected to the supports 44 by rods 47. The magnets are graduated in force, the weakest at the top and the strongest at the bottom. The magnets are arranged in rows above the troughs, two rows for each trough, so that as the troughs are reciprocated one row of the magnets is over the trough and the other row of magnets is at one side of the trough, the relative position being changed at each movement of the trough. The magnets are arranged close together longitudinally of the trough, so that the planes of magnetic influence overlap in the direction of the flow of the ore, thereby subjecting the ore to a constant and increasing magnetic influence.

The circuit-breakers 48 and 49 are mounted upon the rear timber 36, said circuit-breakers being constructed as shown in Fig. 4. The dash-pot 50 is mounted upon the base 51 of insulation. A post 52 is mounted beside the dash-pot, and a lever 53 is pivotally connected to the upper end of the post. Mercury 54 is placed in the bottom of the dash-pot. Oil 55 is placed on top of the mercury, and a plunger 56 is connected to one end of the lever 53 and slides through the insulation 57 into the oil and mercury. A retractile coil-spring 58 connects the lever to the base, as required to pull the plunger down into the mercury. The opposite ends of the levers 53 from the plungers are curved upwardly, and the fingers 59 and 60 are adjustably attached to the support 21, so as to alternately engage the levers 53 as the troughs are reciprocated and pull the plungers out of the mercury. The line 61 leads from the generator 62 through the right-hand row 63 of each set of magnets to the dash-pot of the circuit-breaker 49. A similar line 64 leads from the generator through the left-hand row 65^a of each set of magnets to the dash-pot of the circuit-breaker 48. The return-wire 65 connects the generator with the posts 52 of the circuit-breakers 48 and 49. The shunt-wire 66 connects the wire 61 at each end of the row of magnets, as required to partly short-circuit the magnets. Said wire 66 passes through the incandescent lamps 67. A similar shunt-wire 68 connects the wire 64 on each side of the magnets 65 and passes through the incandescent lamps 69. The introduction of the shunt-wires 66 and 68 through the lamps 67 and 69 takes up self-induction, lessens the tendency to spark at the circuit-breakers and quickens the let-go action of the magnets. The circuit-breakers are arranged so as to excite the magnets when the magnets are directly over the stream of ore in the troughs and to deënergize the magnets after the troughs have been moved from under the magnets, as required to take up the ore from the troughs, carry it over the sides of the troughs, and drop it.

In order that the entire stream of ore may be subjected to the force of the magnets, the magnets are made broader than the troughs, so that the rounded edges of the magnets are projecting beyond the sides of the trough, as shown in Fig. 1.

The ore which drops from the first pair of magnets will fall into the receptacle 70 and pass downwardly through the spout 71, and the ore from the second pair of magnets will fall into the receptacle 72 and pass downwardly into the spout 73, and ore which falls from the last pair of magnets 74 will pass into the receptacle and the spout 75, and the refuse which passes the magnets will fall into the receptacle 76 and spout 77. The highest grade of ore will fall into the receptacle 70 and the middle grade into the receptacle 72 and the low grade into the receptacle 74. The refuse which falls into the receptacle 76 may contain some ore and may be reground and again passed through the apparatus. The receptacles run crosswise of the inclined trough, so that similar grades of ore from the different sets of magnets will fall into the same receptacle.

I am aware that magnetic separators of the drum type have been constructed to lift the magnetic material out of a stream of material moving over an inclined plane or falling freely through the air or conveyed in a quiescent mass by means of a belt; but heretofore the magnetic field generated about the plane of the moving material has been of greatly-varying intensity, the maximum force being exerted in a narrow line across the stream, as in the case of the use of rotating drum-magnets or in the case of stationary magnets having pointed or wedge-shaped pole-pieces, or else the field was much more powerful on one side of the stream than the other. My improved method is subject to none of the above objections.

By the use of my improved method I dispense entirely with the interposition of a belt or other carrier between the material and the magnets and provide a magnetic field of a comparatively large area, thereby greatly increasing the working capacity of the machine over the ordinary types, especially in the case of ores carrying high percentages of magnetic material. By arranging the magnets of different potentials the minerals may be classified according to their varying permeability, and by limiting the strength of the magnets to the power required only to lift material of definite permeability a great sav-

ing of power is accomplished and a more nearly equal intensity of magnetic attraction over the working area of the adjacent magnets is effected, which is peculiar entirely to the reciprocating or oscillating magnets traveling back and forth across the width of the stream of material.

I claim—

1. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through said trough, and causing the same to roll and tumble therein; a series of magnets arranged above said trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relatively to the said magnets, and means for intermittently exciting the said magnets, as required to pick up the ore, pass it over the sides of the trough and drop it therefrom, substantially as specified.

2. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through said trough, and causing the same to roll and tumble therein; a series of magnets arranged above said trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relatively to the said magnets, and means for intermittently exciting the said magnets, as required to pick up the ore, pass it over the sides of the trough and drop it therefrom; said magnets being graduated in strength, the weakest being at the top and the strongest at the bottom, substantially as specified.

3. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through said trough, and causing the same to roll and tumble therein; a series of magnets arranged above said trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relatively to the said magnets, means for intermittently exciting the said magnets, as required to pick up the ore, pass it over the sides of the trough and drop it therefrom; said magnets being graduated in strength, the weakest being at the top and the strongest at the bottom; and independent receptacles for each grade of ore, substantially as specified.

4. The improved magnetic ore separator and classifier consisting of a suitable hopper having an outlet, means for regulating the flow of ore through the said outlet, an inclined trough having a smooth non-magnetic surface, means for conducting the ore through said trough and causing the same to roll and tumble therein, a series of magnets arranged above the said trough in oblique pairs so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relative to the magnets, and means for intermittently exciting the magnets as required to pick up the ore, pass it over the sides of the trough and drop it, substantially as specified.

5. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through the trough, an inclined bottom having a smooth non-magnetic surface, adjustable non-magnetic sides adjacent said bottom, means for causing the ore to roll and tumble through the trough, a series of magnets arranged above the trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relative to the magnets, and means for intermittently exciting the magnets to pick up the ore, pass it over the sides of the trough and drop it, substantially as specified.

6. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through the trough, means for adjusting the incline of the trough, a series of magnets arranged above said trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relative to the magnets, and means for intermittently exciting the magnets to pick up the ore, pass it over the sides of the trough and drop it, substantially as specified.

7. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, means for conducting the ore through the trough, means for adjusting the incline of the trough, a series of magnets arranged above the said trough in oblique pairs, so that the planes of magnetic influence overlap longitudinally of the direction of the passing ore, means for reciprocating the trough crosswise relative to the magnets, means for intermittently exciting the magnets to pick up the ore, pass it over the sides of the trough and drop it; and means for regulating the distance between the magnets and the ore, substantially as specified.

8. The improved magnetic ore separator and classifier consisting of an inclined trough having a smooth non-magnetic surface, a series of magnets arranged above said trough in oblique pairs, so that the planes of mag-

netic influence overlap longitudinally of the direction of the passing ore, a series of lamps in the circuit to take up self-induction, lessen the spark and quicken the release of said magnets; and means for reciprocating the trough crosswise relative to the magnets, substantially as specified.

In testimony whereof I have signed my name to this specification in presence of two subscribing witnesses.

GUY H. WARING.

Witnesses:
M. P. SMITH,
E. M. HARRINGTON.