Sept. 13, 1955 F. T. HOLMES 2,717,693

METHOD OF AND APPARATUS FOR SORTING RADIATION EMISSIVE MATERIAL

Filed Sept. 6, 1949 4 Sheets-Sheet 1

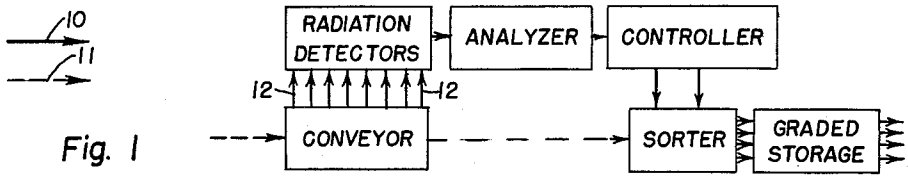

Fig. 1

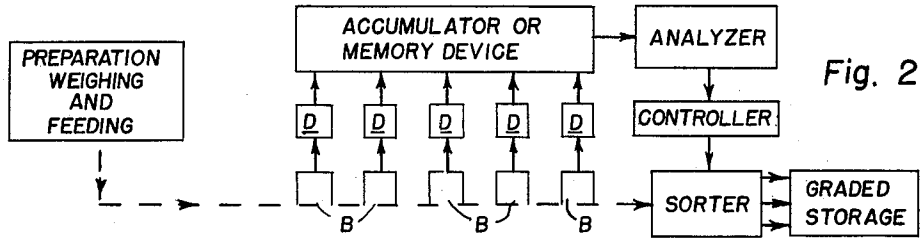

Fig. 2

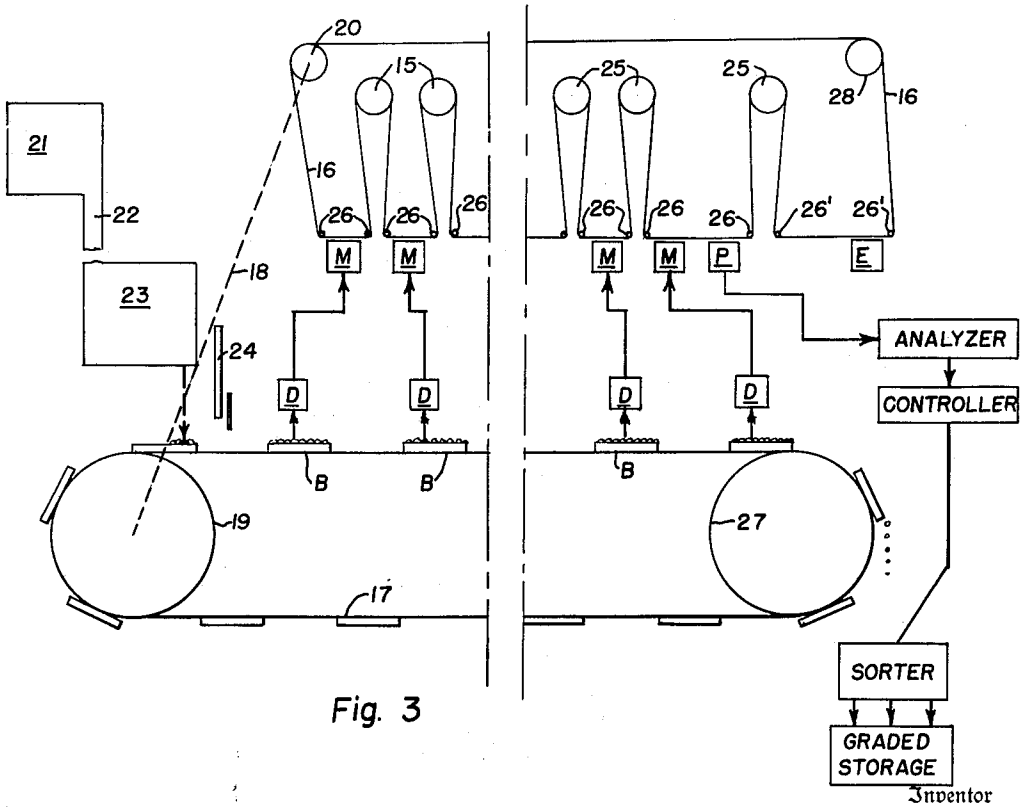

Fig. 3

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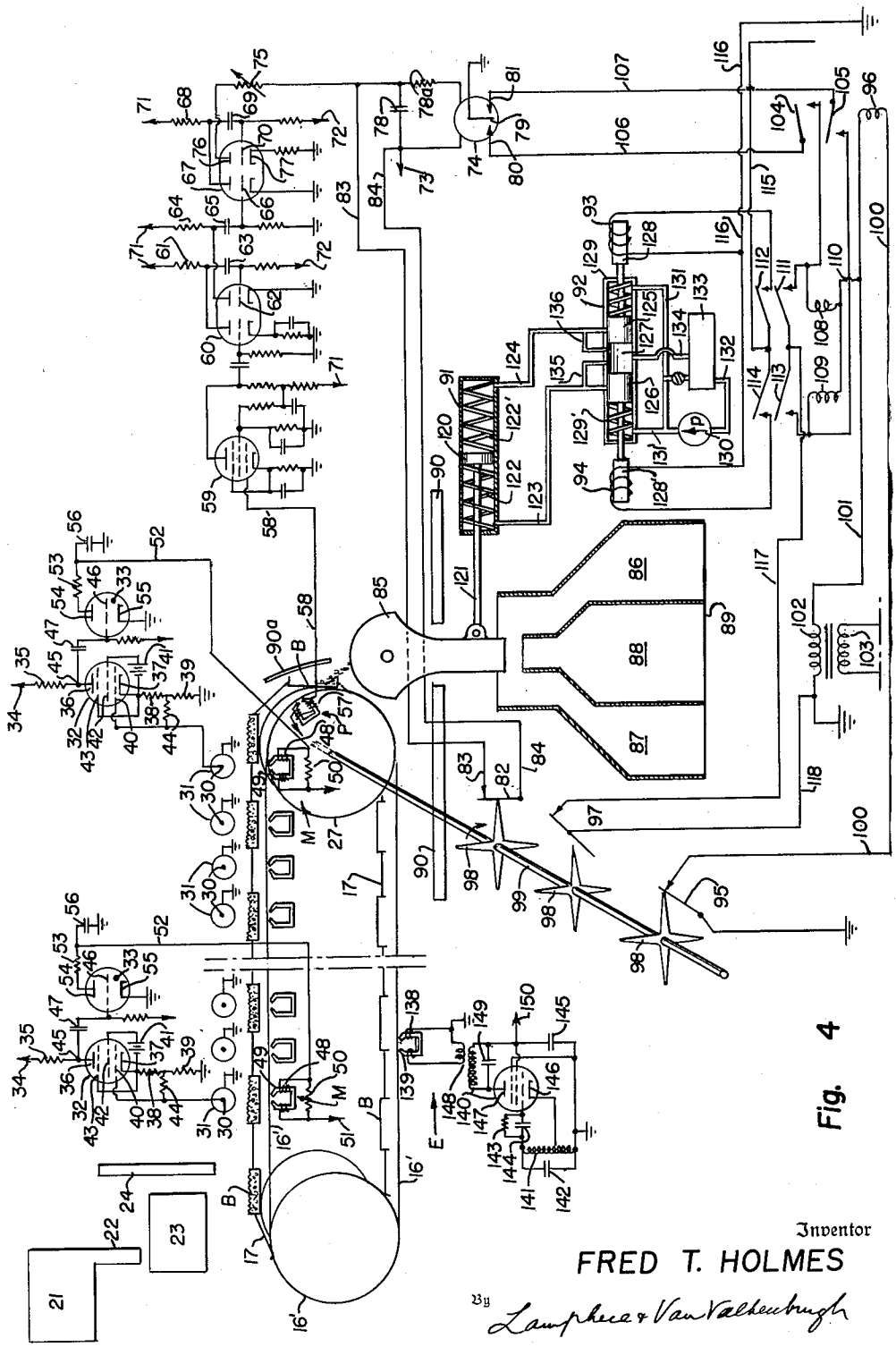

Fig. 4

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METHOD OF AND APPARATUS FOR SORTING RADIATION EMISSIVE MATERIAL

Filed Sept. 6, 1949 4 Sheets-Sheet 3

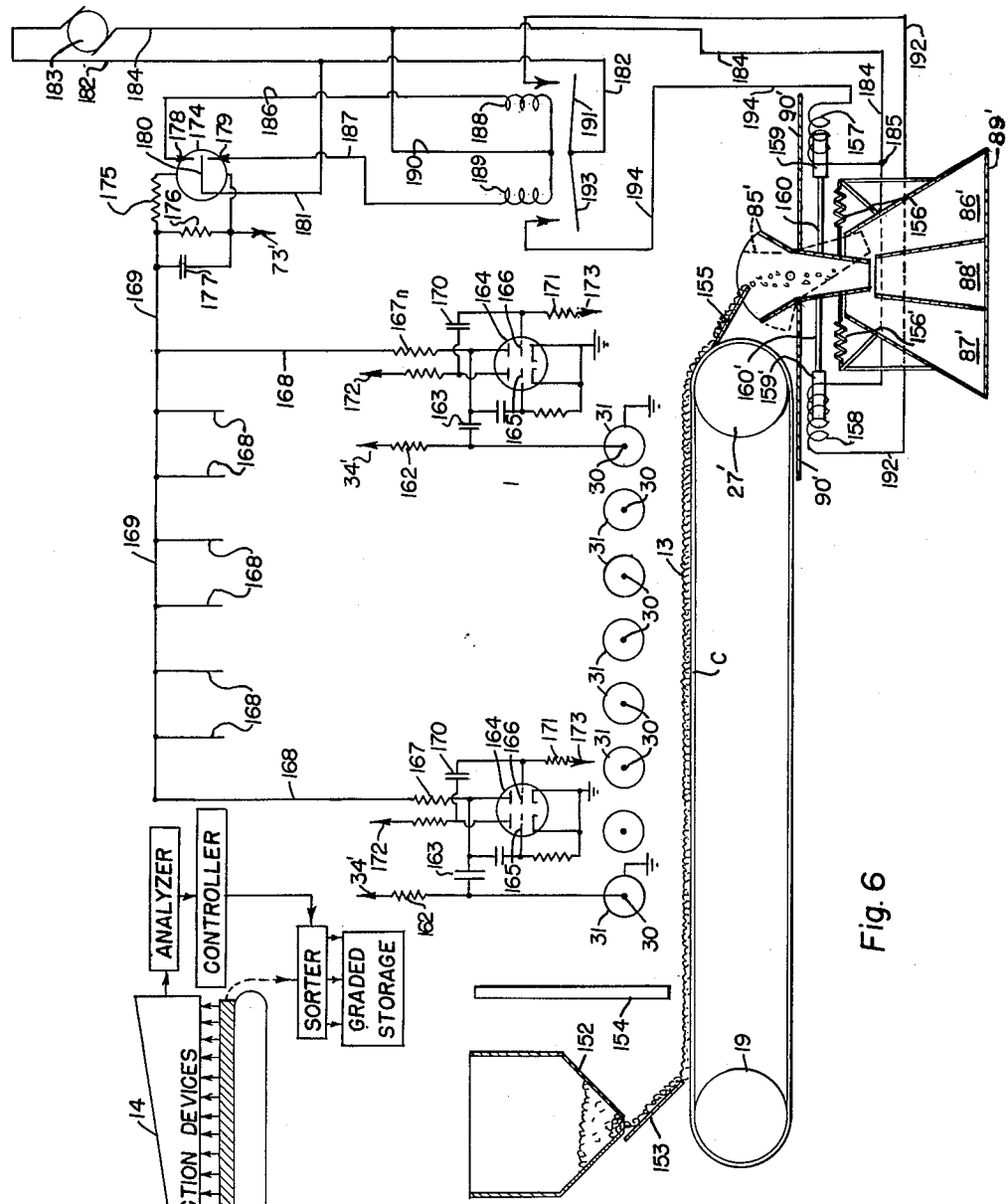

Fig. 5

Fig. 6

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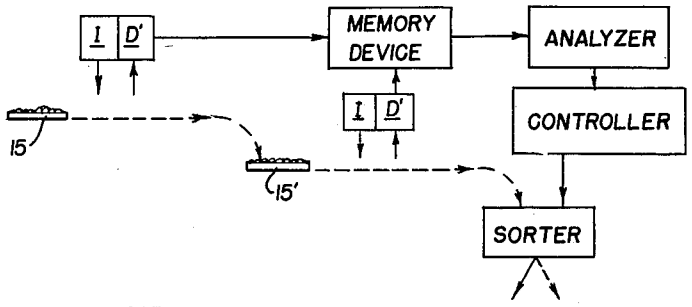

Fig. 7

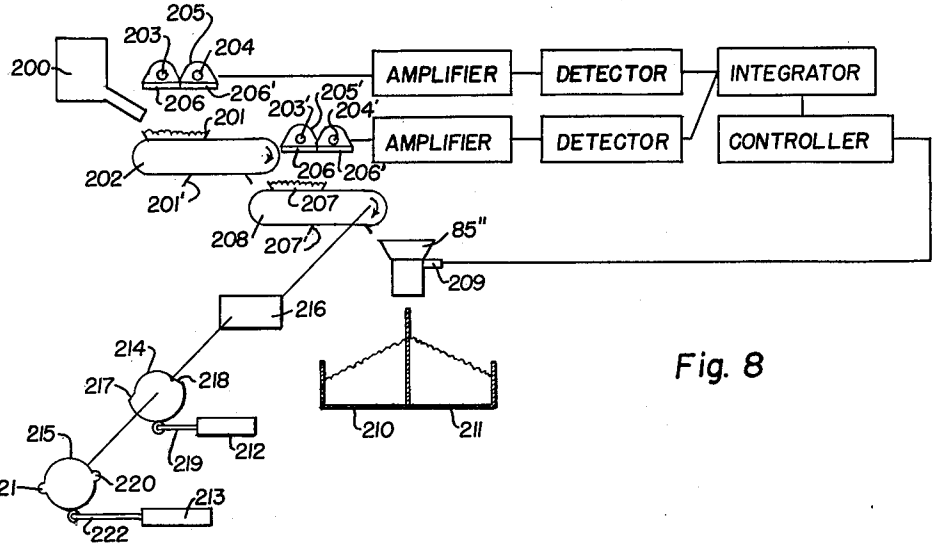

Fig. 8

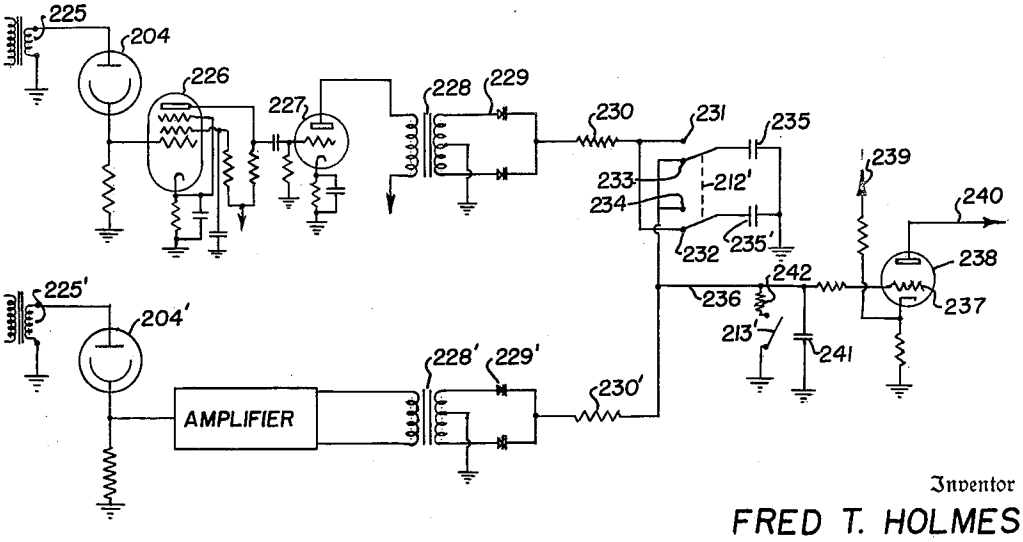

Fig. 9

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2,717,693

METHOD OF AND APPARATUS FOR SORTING RADIATION EMISSIVE MATERIAL

Fred T. Holmes, Denver, Colo.

Application September 6, 1949, Serial No. 114,152

31 Claims. (Cl. 209—72)

This invention relates to a method of and apparatus for sorting radiation emissive material of at least a predetermined emissive strength, from a mixture or batch containing varying amounts of such material, and material having less than such predetermined emissive strength. The principles of this invention are particularly applicable to the separation or sorting of radioactive material—normally naturally radioactive ore, such as ores containing uranium, radium, thorium, descendants of each, and the like—and also to the separation and sorting of material having induced radiation emissive properties, such as Scheelite, a tungsten ore, which will become fluorescent upon exposure to ultraviolet light. It will be understood that "radiation emissive" material, as used herein, refers to material which radiates or gives off any type of ray, particle or quantum radiation, which is susceptible of detection.

Among the objects of this invention are to provide a novel method of sorting or separating radiation emissive material, particularly from a mixture or batch containing varying amounts of such material which differ in emissive strength; to provide such a method which can be carried out continuously; to provide such a method which can be utilized in separating or sorting not only naturally radioactive or other radiation emissive material, but also material which has artificial or induced radiation emissive properties; to provide such a method which can be utilized in separating ore or other material of the above character into two or more categories, such as high grade ore, low grade ore, and rock to be discarded entirely; to provide such a method which in one form is particularly adapted to separate ore or material which contains periodic or intermittent concentrations of relatively high radiation emissive strength, such as resulting from nuggets, pockets or the like; to provide such a method which in another form is particularly adapted to separate out, on a pre-selected minimum basis, ore or material having a generally average concentration which may vary for different portions of the entire material; to provide such a method which is adapted particularly to separate out or sort material containing ore, such as Scheelite, which is responsive to excitation, as by ultraviolet light; to provide such a method which, in one form, is particularly useful in sorting material wherein the emission of radiation is primarily from the surface; to provide apparatus particularly adapted to carry out the above method; to provide such apparatus which can be operated substantially continuously and automatically; to provide such apparatus which is adapted to handle relatively large quantities of ore or other material at a sufficiently rapid rate to be economical, particularly when the emissive radiation may be relatively feeble in action upon a detection device; to provide such apparatus which can be adjusted to pre-selected standards for separating the ore or material into portions, such as which are respectively economically valuable for immediate further treatment or processing, are sufficiently promising to be retained for future use, and are sufficiently unpromising to warrant immediate discard, or into various gradations of the same; to provide such apparatus which is sufficiently accurate with respect to the radiation emissive characteristics of the valuable portions of the ore or other material, that the results of separation are economically reliable; to provide such apparatus which may exist in several forms, one of which is particularly adapted to separate material having individual chunks or pieces of relatively high grade ore, another of which is particularly adapted to separate material having varying or changing amounts of medium or lower grade ore, and still another of which is particularly adapted to separate material whose radiation emissive properties are primarily surface phenomena; and to provide such apparatus which is relatively readily constructed and installed in connection with a continuous mine or mill operation, or in connection with a further refining or treatment setup. Additional objects and the novel features of this invention will become apparent from the description which follows.

In general, the method of this invention, which is particularly adapted for use in separating radiation emissive material of at least a predetermined emissive strength from a mixture or batch containing varying amounts of such material, and also containing material having less than such predetermined emissive strength, comprises effecting relative movement of successive portions of such a mixture or batch with respect to a plurality of radiation detection devices, and separating successive portions of the mixture or batch in accordance with the cumulative effect on the radiation detection devices of the material. The material may be sorted in accordance with the total cumulative effect on the radiation detection devices by separate portions of the mixture or batch as each such portion passes each radiation detection device in turn, or in accordance with the effect on the radiation detection devices of all the material in position to affect the devices at a particular time.

When the radiation emissive properties are primarily a surface phenomenon, the material being sorted is turned over between two or more successive exposures to ultraviolet light, for instance, so that two or more sides of each particle or chunk will be activated. The radiation emissive material may be either naturally radiation emissive, or artificially or inductively so, while the radiation detection devices may be Geiger-Müller tubes, photoelectric cells, or other detection devices which are responsive to gamma rays, beta rays, light rays and the like.

Apparatus particularly adapted to carry out the above method is illustrated in the accompanying drawings, in which:

Fig. 1 is a simplified block diagram illustrating in general the method and the operation of apparatus of this invention;

Fig. 2 is a block diagram illustrating the method and the operation of apparatus of this invention, wherein the material is sorted portion by portion in accordance with the total cumulative effect on radiation detection devices by each separate portion of the mixture or batch as it passes each radiation detection device in turn;

Fig. 3 is a diagram illustrating in somewhat greater detail certain operating parts of apparatus constructed in accordance with this invention, which apparatus operates in accordance with the diagram of Fig. 2, and which includes memory means, such as a magnetizable wire, which is moved in synchronous relation with the movement of material past the detection devices, and which in turn controls the operation of a sorting device;

Fig. 4 is a diagram of apparatus also operating in accordance with the diagram of Fig. 2, but showing additional details of an electrical circuit, a hydraulically controlled sorting device, and certain other parts;

Fig. 5 is a block diagram illustrating the method and

operation of apparatus constructed in accordance with this invention, wherein the material is sorted in accordance with the total weighted cumulative effect of all material in position to affect the radiation detection devices at a particular time, with emphasis on portions nearest the sorter;

Fig. 6 is a diagram of apparatus operating in accordance with the diagram of Fig. 5, including a representative electrical circuit, shown in simplified form, and an electrically operated sorting device;

Fig. 7 is a block diagram illustrating generally the method and the operation of the apparatus of this invention, especially adapted to the sorting of material which is inductively radiation emissive, particularly from its surface;

Fig. 8 is a diagram illustrating apparatus operating in accordance with the diagram of Fig. 7; and

Fig. 9 is a diagram of an electrical circuit forming a part of the apparatus of Fig. 8.

The method of this invention, and the operation of apparatus constructed in accordance with this invention, is exemplified generally in the block diagram of Fig. 1. The arrows similar to the heavy arrow **10** represent, in general, transmission of control signals, while the arrows similar to the dotted arrow **11** represent the movement of the ore or material being sorted. Thus, the ore or material being sorted passes to a conveyor or other means for moving the same past a series of radiation detectors, the radiation indicated by arrows **12** passing from the material to the detectors. From the detectors, the control signal is transmitted to an analyzer, or analyzing means, and from thence to a controller or control means, which controls and/or operates in conjunction with a sorter, to which the ore or material has moved from the conveyor. The position of the sorter determines the particular bin, compartment, or space to which the material will pass, as to graded storage compartments. As shown, the material may be divided into three categories—for example, high grade, low grade, and unfit for further processing—although any other different number of grades may be utilized, with appropriate changes in the categories or classification. From graded storage, the high grade ore or material may be transferred to further processing or sale as desired, and the low grade ore or material may be stored or transported to bins, dumps or the like having a greater storage capacity, while the material unfit for further processing may be discarded, as by being moved to a tailings dump.

The block diagram of Fig. 1 represents generally the method and apparatus illustrated by the block diagrams of Figs. 2, 5 and 7, the latter two differing in the particular application of the method illustrated by the diagram of Fig. 1. The method illustrated by the block diagram of Fig. 2 is particularly applicable to the separation of ore or other material which contains periodic or intermittent concentrations of relatively high grade ore, such as coming from pockets or small veins. Thus, the ore or material first goes through a preparation and weighing or feeding device, from which it is controllably fed into a plurality of separate buckets or containers B, so that each bucket will contain substantially the same amount of material. The buckets then move in succession past the radiation detectors D, from which the control signals are passed to an accumulator or memory device, which records, at least for a sufficient time to effect the desired separation, the number of impulses received by each detection device as each bucket B in turn passes, the cumulative effect on all of the detection devices by the material in each bucket B being transmitted to an analyzer, through which a controller operates the sorter, to determine into which classification, as in graded storage, the material in each particular bucket B will fall. As indicated previously, while there are shown three grades of material, the material may be sorted into two grades, or into more than three grades.

The method illustrated generally by the block diagram of Fig. 5 is particularly applicable to ores or other materials in which the grade or concentration varies more gradually, such as ores from large and relatively uniform deposits, or ore containing varying proportions of high grade, rather than periodic or intermittent concentrations. For example, the material may be ore which comes from a wide vein or series of veins, which may perhaps vary relatively gradually in concentration or width, or both, as along the length or direction of mining. In this method, the ore or material is preferably fed from a feeding device onto a continuous conveyor, such as a belt conveyor C, the ore or material to be sorted preferably being deposited thereon in a relatively uniform layer **13**, having a sufficient depth to provide sufficient speed in sorting, but, of course, not so deep as to interfere seriously with the effective transmission of radiation from the lower layers of the radiation emissive material on the belt. The radiation emanating from the material on the belt, in position to affect the detection devices, will determine the number of actuating impulses received by the detectors per unit time, which will determine the signal that is transmitted or sent from the detection devices to the analyzer, the detection devices being illustrated as a trapezoidal block **14**, representative of tapered integration to emphasize that the weighted cumulative effect, with emphasis on those portions nearest the sorter, of all of the material on the belt at one time, in position to affect the detection devices, is transmitted to the analyzer. The analyzer, as before, transmits a control signal to a controller, which determines the position of the sorter, to determine into which of the respective grades, as of graded storage, the material coming off the conveyor belt will fall. As will be evident, the classification into which any particular increment of the material at the discharge end of the belt will fall is determined by the weighted average intensity of radiation from all of the material on the belt, in position to affect the detection devices, so that changes in classification are more gradual. Thus, the ore or material sorted by the method of Fig. 5 should generally be more nearly uniform in concentration over a relatively greater amount of material, than material sorted by the method of Fig. 2. The material will usually be sorted by the use of gamma rays, although beta ray sorting may be utilized if the material can be spread in a sufficiently thin layer on the belt.

The method illustrated generally by the block diagram of Fig. 7 is useful in sorting material whose effective radiation is primarily a surface phenomenon, and particularly in sorting materials characterized by the emission of beta rays or by the property of fluorescence under ultra-violet radiation, as in the case of Scheelite, a tungsten ore. In this method, when used for sorting a beta ray emissive material, for example, two or more sides of the material, such as the top and bottom, are oriented toward detectors whose response, when integrated and interpreted by the analyzer, determines the sorting or classification of each specified small batch or the like. Or alternatively, when this method is used for sorting fluorescent material, the latter is simultaneously irradiated and evaluated by joint action of detectors, memory device and analyzer, acting successively on two or more sides.

For sorting such materials, the material is preferably fed in small batches to one or more buckets **15**, the feed preferably being regulated so that a relatively thin and uniform layer of material will be deposited in the bucket. The material then passes beneath a first irradiator I, such as an ultra-violet lamp, and also beneath an adjacent detector D', such as embodying a photoelectric or other light sensitive cell, the signal from the first detector D' caused by the fluorescence induced in the material being sent to a suitable memory means or device, which is also adapted to receive the signal from the second detector D', above the path of a bucket **15'**. Between bucket **15** and

15', the material may be dumped or cascaded so as to be turned to a different position, preferably reverse or bottom side up, in bucket 15'. Thus, the ultra-violet radiation from the second irradiator I directed on the material in bucket 15', will produce fluorescence from different portions of the material, which in turn will produce a signal from detector D' to the memory device.

Of course, if the material being sorted emits beta rays or the like in sufficient quantities, and the same are utilized as the basis for sorting, the irradiators I or equivalent will normally be unnecessary, while the detector D' will be appropriate capable of detecting such beta rays or the like.

From the memory device, the combined signal or the cumulative effect of the signals, will pass to an analyzer, which in turn passes a signal on to a controller, the latter moving a sorter to a position corersponding to different amounts of radiation or responses to excitation of the material in each successive bucket, thereby determining whether the material from bucket 15' will pass to certain predetermined grade bins or the like. The memory device and analyzer of Fig. 7 are preferably responsive to the cumulative effect on the detection devices D' of different parts such as opposite or different surfaces of each successive portion of the material. The number of detectors, of course, may be increased, and the material partly turned, as by a screw, between each position, provision preferably being made for the material to be spread in a sufficiently thin layer, consonant with particle size, so that the signals received will be at least a close approximation of the average radiation emission propensities of the particles involved.

In the apparatus illustrated diagrammatically in Fig. 3, which operates generally to carry out the method of Fig. 2, the memory means is exemplified by a magnetizable wire 16 which is moved in synchronous relation with a belt or chain 17 on which are mounted the buckets B. Such synchronization may be effected by a direct drive connection 18 between a sprocket or pulley 19 for the chain or belt 17 and a drive roller 20 for wire 16, or by separate drives, synchronized electrically or in any other suitable manner. The ore or material to be separated is fed to a suitable size reducing device 21, such as a jaw crusher, from which the material passes through a chute 22 to a batch weigher and loader 23, to be fed in separate regulated amounts to the buckets B, all of this preferably with a minimum of mixing between the mine face and buckets B. During passage of the buckets therebeneath, the radiation emanating from the material in the buckets is placed up by the detection devices D, while a radiation shield 24, of lead or other suitable material, prevents material in the crusher or loader from affecting the detection devices. Each detection device D may include one or more Geiger-Müller tubes, together with the necessary circuit elements, and controls corresponding single or multiple magnetizers M, each of which produces a magnetic field that places a set of magnetic dipoles on the wire 16 in accordance with the number of reactions or discharges of the Geiger-Müller tube. Normally, the magnetizers M can be conveniently placed closer together than the distance between the buckets B, so that the wire 16 is preferably passed over a series of idler rollers 25, adapted to form a loop in the wire between each set of directing rollers 26, between which the wire passes in operative position with respect to a magnetizer M. In addition, the idler rollers 25 may permit the wire 16 to be run at a speed in excess of the buckets B, to provide better resolution between magnetic dipoles. As each bucket B passes one of the detection devices D, the same section of the wire 16 will be in operative relation to the corresponding magnetizer M, so that by the time a particular bucket B reaches the end conveyor roller or sprocket 27, the corresponding section of the wire 16 will have accumulated a total magnetization effect which corresponds to the cumulative effect of the radiation from the ore or material in the particular bucket, on each of the detection devices D in turn. An advantage of such accumulation of effect lies in the considerably greater amount of ore or material which can be sorted in a given period of time, or alternatively in the precision with which a given quantity of ore can be sorted in said given time, either concept being more strongly applicable as the richness of the ore is decreased. If each bucket were measured individually by a detection device, it would be a matter of considerable time before an accurate determination of the rate of radiation from the material could be secured, but by passing the same bucket of material past a plurality of detection devices, in turn, the total cumulative effect should correspond to that obtained if the bucket were allowed to remain in close proximity to one detection device for the total period of time that it is in proximity to all or the plurality of detection devices, taken individually. However, while one bucket is moving along the length of the conveyor, other buckets are also moving, so that by the time a particular bucket reaches the end of the conveyor, a number of additional buckets will have been moving past the detection devices. The present preferred arrangement also has an advantage over the arrangement if the same number of counters, for instance, were utilized individually on separate belts, since the former will operate at the same level of sensitivity for all ore whereas the latter would reflect different sensitivities for the various ore channels, unless carefully adjusted and maintained in adjustment.

When a particular bucket B reaches the discharge end of the conveyor, and the contents thereof are ready to drop into the sorter or sorting means, the corresponding section of the wire 16 will have reached a pickup station P which detects the number of dipoles on the wire and sends an impulse for each dipole to the analyzer. The analyzer, in turn, actuates the controller or control means to determine the position of the sorter, and thereby determines into which of the bins or compartments of graded storage the particular bucket of material will fall. The sorter is, of course, preferably shifted to a position determinative of the ore or material of each bucket, before the bucket begins to discharge its contents into the sorter. This may readily be accomplished by appropriate positioning of the pickup station P.

After the wire 16 leaves the pickup station P, it passes to an eraser E, which de-magnetizes the wire, placing it in condition to repeat the cycle, the wire conveniently being passed over the eraser E by directing rollers 26', and then over a slack or takeup roller 28, prior to returning to the drive roller 20. As indicated previously, the mechanical drive connection 18 between the conveyor and the wire 16 need not be utilized, but synchronization may be accomplished electrically, as by synchronous motors driving both the conveyor and the wire, and controlled so as to start and stop at the same time. Also, the length of the wire 16 may be different from the total length of the path around which a conveyor bucket B travels, and the speed of the wire may also be different, the necessary requirement being that the speed and length of the wire be correlated with the speed of travel and spacing between the buckets, so that the same section of wire will pass each magnetizer M at the same time that the bucket is passing the corresponding detection device D.

The apparatus illustrated diagrammatically in Fig. 4 is adapted to carry out the method illustrated generally in Fig. 2, for sorting radioactive ore, and operates in a manner similar to that of the apparatus of Fig. 3, the wire 16' either having substantially the same length and being moved around a path corresponding to that of the conveyor, as in Fig. 4, or driven in any other suitable manner, such as that represented in Fig. 3. It is desirable to reduce the ore or material to a size which will allow uniform loading of each of the buckets B, and for this purpose the jaw crusher 21, appropriately set, may be used. As before, the ore may be passed through chute

22 to the automatic batch weigher and loader 23, of any suitable conventional type, adapted to load substantially the same weight of material into each of the buckets B. Also, as before, as each bucket of material is moved along by the conveyor, it passes underneath successive detection devices which, as indicated previously, may include Geiger-Müller tubes, each of the latter including an anode 30, shown diagrammatically in end view, but in practice commonly a fine wire stretched longitudinally along the axis of a hollow metal cylinder 31 or cathode, both the anode and cathode commonly being enclosed within a glass tube, or the metal cathode itself may be the enclosing tube with suitable insulation for the anode, in either event the tube being evacuated and then filled to a predetermined pressure with a suitable gas or mixture of gases. A pentode vacuum tube 32 and a thyratron tube 33 may be included in the circuit with each Geiger-Müller tube and magnetizer M, for operation in the manner indicated below, although it will be understood that other circuits may be utilized.

As in Fig. 4, when a high voltage, such as 600 volts, is applied between a positive high voltage terminal 34 and ground, current will pass through a plate resistor 35 to plate 36 of pentode vacuum tube 32, and through the tube to cathode 37 and cathode resistances 38 and 39 to ground. The voltage drop in resistance 38 is preferably adjusted so as to place a small negative bias relative to the cathode through resistor 44 on control grid 40, which is connected to anode 30 of the Geiger-Müller tube, while a battery 41 may be employed to provide a positive potential on screen grid 42 and suppressor grid 43 may be connected directly to cathode 37. The voltage drop in resistance 39 is large enough to provide a proper operating potential for the Geiger-Müller tube. A rudimentary explanation of the action of the tube would be as follows: An occasional gamma ray, for instance, emitted from ore in bucket B, in passing through the wall or cathode of the Geiger-Müller tube, will liberate an electron from the material of which it is composed. Usually this electron is able to reach the gaseous volume between anode and cathode with sufficient residual energy to produce one or more positive ions and electrons by collision with the gaseous molecules. These electrons will also produce others by collision during and after their acceleration by the electric field. Successive multiplications follow in the familiar avalanche process until a large number of electrons has collided with the anode, thereby neutralizing some of its positive charge, which is equivalent to causing a current to pass from the anode 30 to the cathode 31. This in turn will produce a voltage drop in resistor 44, thereby decreasing the grid to cathode voltage between grid 40 and cathode 37 and hence the current flowing to tube plate 36, and this decrease in plate current causes a decrease in the potential drop across resistances 35, 38 and 39. The voltage across resistance 39 will fall until a point is reached at which the voltage supplied to the Geiger-Müller tube is insufficient to maintain gaseous discharge, and the current through the Geiger-Müller tube will cease to flow. At this point, the Geiger-Müller tube is said to be "quenched," and the circuit will return to its initial state, ready to be operated again. However, the decrease in current to plate 36 and then its return to normal, will result in a positive pulse at the junction point 45, which is coupled to grid 46 of thyratron 33 through a condenser 47. The thyratron 33 is normally in a state of non-conduction, but the application of the positive pulse to grid 46 will be sufficient to cause it to become conducting so that a current will flow through the coils 48 of magnetizer M, which may be wound in opposite directions about the poles of yoke 49 thereof. Coils 48 are in parallel with a resistance 50, and the current flows from a positive battery terminal 51, through coils 48 and resistance 50, and then through a wire 52 to a plate resistance 53 and through plate 54 across the tube 33 to cathode 55 and thence to ground, which is the negative return for the battery having positive terminal 51. As this current flows, a condenser 56, connected to wire 52, will discharge to ground, permitting the potential on plate 55 to decrease to the point at which the thyratron ceases to conduct, after which the condenser 56 will recharge to normal voltage. The current passing through the coils 48 of the magnetizer M, will cause a magnetic flux to pass between the poles of yoke 49, thus magnetizing wire 16' in a longitudinal direction, and thus producing a dipole thereon. As the wire passes successively over a series of magnetizers, it will acquire a small segment of magnetization or dipole for each operation of a Geiger-Müller tube, since a similar circuit is associated with each magnetizer M. As the wire 16' passes over pickup P, the magnetic dipole will generate a small voltage in the coils 57 which are connected through lead 58 to the grid of a substantially conventional pentode amplifier tube 59.

Various resistances, condensers and other components, are connected in the circuit with and/or to the plate, grid and cathode of the tube 59, and their use will be apparent to those skilled in the art. Thus, the flow of current and its amplification will be traced, but conventional details of operation omitted, in the case of tube 59 and a dual triode tube 60. Additional amplification is provided in the first section of dual triode tube 60, whose amplified output appearing across its plate resistor 61 is coupled by means of a capacitor 63 to the grid 62 of the second section, which acts as a "Clipper circuit." The grid 62 is normally biased to cutoff, so that only strong positive pulses will cause the second section of the tube to conduct. This will tend to eliminate small positive and all negative signals on the wire, thus discriminating against noise and other small unwanted signals. The resulting signal will appear as a negative pulse across the plate resistor 64, which is coupled through a condenser 65 to the grid 66 of the first section of another dual triode tube 67, which is operated with zero bias. A strong negative signal applied to grid 66 will drive the tube to cutoff, resulting in a large positive pulse appearing across plate resistor 68, which in turn is coupled by condenser 69 to the grid 70 of the second section of tube 67, grid 70 being biased to cut-off. Tubes 60 and 67 are supplied with current for operation through positive battery terminals 71, and negative bias terminals 72. The pulse to grid 70 permits current to flow from a positive battery terminal 73 (adjacent a metering portion of the circuit which includes a relay 74) through a variable resistance 75 to the plate 76, then through the tube 67 to the cathode 77 to ground. This current, when passing through the metering portion of the circuit will charge a condenser 78, and in turn will apply a like potential across relay 74 and a resistor 78a. The total increase of voltage on the condenser 78 will be determined by the number of current pulses applied, that is the total number of counts from the Gieger-Müller tubes recorded upon the segment of wire associated with a particular ore bucket. Thus, the potential across the condenser 78, and hence the current in relay 74, will be a measure of the quality of ore in a bucket corresponding to the wire segment passing over the pickup P. Relay 74 may be of a D'Arsonval type, with a movable arm 79 comprising one contact, and two adjustable contacts 80 and 81 adjusted so as to be responsive to the desired upper and lower limits of voltage across the relay 74. A switch 82, connected by leads 83 and 84 across condenser 78, is provided to discharge the condenser 78, after the required information relative to the quality of the ore has been received.

Before condenser 78 is discharged, arm 79 of relay 74 will be in one of three positions—against contact 80, against contact 81, or between the two, as shown in Fig. 4. In general, the position of arm 79 will determine the position of a pivoted chute 85, the circuit pref-

erably being so calibrated that the amount of magnetization or number of dipoles on the section of wire 16' corresponding to a particular bucket, will determine the position of relay arm 79, which in turn will determine the position of chute 85. For example, for a number of dipoles in excess of a predetermined number, arm 79 will be against contact 80 and chute 85 will be swung to a position over a "high grade" storage compartment 86. Again, for a number of dipoles less than a lower predetermined number, arm 79 will be against contact 81 (also its normal position when no signals are being transmitted), and the chute 85 will be over a "low grade" compartment 87. Similarly, for a number of dipoles between the upper and lower predetermined numbers, the arm 79 will be between the contacts, and chute 85 will be over a central or intermediate grade compartment 88. Compartments 86, 87 and 88 may be formed in a bin 89, or may be separate bins, or merely chutes or conveyors for carrying the ore or rock to other desired places. Also, chute 85 preferably extends through a radiation shield 90, of lead or other suitable material, which prevents ore stored in the bins from affecting the detection devices. Also, a curved plate 90*a* prevents the ore from dumping out of the bucket before the chute is properly positioned.

The chute 85 may be moved to different positions through hydraulic pressure in a cylinder 91, controlled by a valve having a housing 92, the valve being moved to right and left positions by solenoids having windings 93 and 94, respectively. Winding 93 is energized when relay arm 79 engages contact 80 while winding 94 is energized when relay arm 79 engages contact arm 81, the valve remaining in a central position, as shown, when arm 79 engages neither contact 80 nor 81. The solenoid windings 93 and 94 are not energized all of the time that arm 79 engages one of the contacts 80 or 81, but only at predetermined intervals, such as when a bucket B is ready to dump, determined by the closing of a normally open switch 95, which is in series with a relay winding 96. A normally open switch 97 is closed to cause the windings 93 and 94 to be deenergized after the bucket has dumped its ore or rock into chute 85, the chute then being returned to central or neutral position, and remaining there or moved to left or right, as the case may be, when the next bucket is ready to dump. Switch 82 is closed, to cause condenser 78 to discharge, preferably shortly after switch 95 is closed, so that relay 74 and the circuit associated therewith will be ready for the next bucket. Switches 82, 95 and 97 are operated at predetermined time intervals in synchronism with the movement of the buckets B, preferably through a suitable type of cam device, such as star wheels 98 mounted on a shaft 99 in turn driven in synchronism with belt 17, as from pulley 27. The position of the switches 82, 95 and 97, with respect to the respective star wheels 98 is such that each time an arm of the star wheel comes around the switch will be momentarily closed or opened, as the case may be. The speed of rotation of shaft 99 with respect to the speed of travel of belt 17 is correlated with the number and spacings of the arms of the star wheels 98, so that each switch will be actuated at the same predetermined position of each bucket. Thus, switch 95 is preferably closed after the pickup P has transmitted all of the information, i. e. magnetic dipoles impressed thereon, from a specific portion of the wire 16' corresponding to the bucket which has just passed the last Gieger-Müller tube, this information being transmitted to relay 74 through the amplification circuit which includes tubes 59, 60 and 67.

Switch 95 is connected to ground and by a lead 100 with relay winding 96, and when closed will cause relay winding 96 to be energized by current supplied through a lead 101 from the secondary 102 of a transformer 103. When relay winding 96 is energized, a pair of switches 104 and 105, respectively, in series with contacts 80 and 81 through leads 106 and 107, respectively, will be closed simultaneously. If arm 79 is in engagement with contact 80 when switch 104 closes, then a relay coil 108 will be energized, while if arm 79 is in engagement with contact 81 when switch 105 closes, then a coil 109 will be energized, the coils 108 and 109 being in series with switches 104 and 105, respectively, and also in parallel through a common lead 110, which connects the coils to lead 101 and thence to transformer secondary 102. When coil 108 is energized, switches 111 and 112 are closed simultaneously, switch 111 being a holding switch to maintain a flow of current through coil 108 after condenser 78 is discharged, and switch 112 being the primary control switch for solenoid winding 93. Similarly, when coil 109 is energized, a holding switch 113 for coil 109 and a control switch 114 for solenoid winding 94 are simultaneously closed. The solenoid windings 93 and 94 are supplied with current from a main line 115 which leads to the common terminal between switches 112 and 114, and a ground line 116 to which both solenoids are connected in parallel. Switch 97 is connected in series between coils 108 and 109, and transformer 103, as through a lead 117 from a common terminal between switches 111 and 113, and a lead 118 to transformer secondary 102. As will be evident, when normally closed switch 97 is opened momentarily after the bucket dumps, coil 108 or 109 will be deenergized to cause solenoid 93 or 94 to be deenergized and the chute 85 to return to its neutral or center position.

The hydraulic cylinder 91 is provided with a piston 120 whose rod 121 is pivotally connected to the chute 85, while springs 122 and 122' are installed within cylinder 91 to act against opposite sides of the piston 120, thereby tending to return the piston 120 to a central or neutral position. Spring 122 or 122' so acts whenever fluid pressure against one side of the piston does not exceed that against the opposite side, or fluid pressure on both sides is permitted to be discharged through a hydraulic line 123 or 124, respectively connected to the opposite ends of cylinder 91. The valve in valve cylinder 92 is provided with two spaced heads 125 and 126, respectively, mounted on a rod 127 which is provided at its opposite ends with solenoid cores 128 and 128', in position to be attracted by the respective winding 93 or 94. Within valve cylinder 92, but on the outside of heads 125 and 126, are compression springs 129 and 129'. respectively, which tend to return the valve to a central or neutral position when neither of the solenoids 93 and 94 is energized. A suitable hydraulic fluid, such as oil, under suitable pressure, is supplied by a pump 130 to the opposite ends of the cylinder 92 through lines 131 and 131' while fluid is supplied through an inlet line 132 to pump 130 from a tank 133 to which a discharge line 134 leads from the central portion of valve cylinder 92, primarily so that fluid can drain from either or both ends of hydraulic cylinder 91 through a branch line 135 or 136, respectively connected to hydraulic lines 123 and 124. As will be evident, in the position shown in Fig. 4, the springs 122 and 122' will maintain hydraulic piston 120 in central or neutral position in cylinder 91, and also will maintain chute 85 in corresponding position, since the pressure of springs 122 and 122' will tend to equalize each other and move the piston 120 to its central position, any excess fluid in either end of cylinder 91 being forced out through hydraulic line 123 or 124 and its branch line 135 or 136, into the central portion of hydraulic cylinder 92 and thence through drain line 134 to tank 133. The valve heads 125 and 126 will also be maintained in a central or neutral position, since the pressure from lines 131 and 131' and also of springs 129 and 129' will equalize. In the position shown, one of the buckets B is dumping into chute 85, and the material therein is being deposited in central bin 88, due to the position of the chute 85.

Assume that the next bucket B is moved around closer to the dumping position, and that the pickup P has been

actuated by the number of dipoles impressed on the wire 16' during travel of this particular bucket beneath the radiation detectors, and also assume that the number of dipoles impressed thereon is in excess of the upper predetermined value, indicative of high grade ore, so that the arm 79 will move against contact 80. Thus, as soon as switch 95 closes momentarily, solenoid 93 will be energized, through closing of switch 104 and then switch 112, and the hydraulic valve will be moved to the right. Upon such movement, the valve head 126 will uncover the port opening of hydraulic line 123 so that full fluid pressure will be supplied to the left end of cylinder 91, thereby moving piston 120 to the right and chute 85 along with it, compressing spring 122'. This will position the lower end of chute 85 over the mouth of bin 86 so that as this particular bucket dumps, the ore contained therein will fall into the high grade bin 86. After the bucket has dumped, switch 97 will open momentarily (switch 82 in the meantime having been closed to discharge condenser 78 and cause arm 79 to move back to its zero position in contact with contact 81), so that coil 108 will be deenergized and switch 112 will open to deenergize solenoid winding 93. Since spring 129 has been compressed, valve heads 125 and 126 will then be moved to the left, until head 126 closes the port of hydraulic line 123, whereupon the ports for both lines 135 and 136 will be open. This will release the fluid under pressure in the left end of hydraulic cylinder 91, which will drain into tank 133 in the manner previously described, and spring 122' will move piston 120 back to a central position, the hydraulic pressure in the opposite ends of the cylinder 91 in the meantime having been equalized. In the event that the next bucket to come around contains ore in the intermediate range, the relay arm 79 will move to a central position, and chute 85 will remain over center bin 88, which will receive the intermediate ore.

Assume further that the next bucket contains low grade ore, i. e. the number of dipoles impresed on wire 16' is less than the lower predetermined number, thus causing arm 79 of relay 74 to remain against contact 81. In this case, when switch 95 is closed, coil 109 will be energized through switch 105 and switch 114 will thereby be closed, to cause solenoid winding 94 to be energized. This will move the valve heads 125 and 126 to the left, compressing spring 129' and permitting valve head 125 to open the port to hydraulic line 124. This in turn causes the full pressure of fluid to be supplied to the right end of hydraulic cylinder 91, thereby moving piston 120 to the left and compressing spring 122. As will be evident, chute 85 will be moved to the left by piston 120 to position the lower end of the chute over the mouth of bin 87. When this particular bucket dumps, the rock or low grade ore will fall into the low grade bin 87, and the switch 97 will then be opened momentarily, switch 82 in the meantime again having been closed and condenser 78 discharged, so that coil 109 will be deenergized, and consequently solenoid winding 94 will also be deenergized. Since spring 129' was compressed, release of the holding force of solenoid winding 94 will permit the spring 129' to push the valve heads 125 and 126 to the right to close the port for line 124 and open the port for branch line 136. This in turn permits the high pressure fluid to drain from the right end of cylinder 91, also permitting the pressure in both ends of the cylinder to equalize, and further permits previously compressed spring 122 to move piston 120 back to the central or neutral position, chute 85, of course, moving along with it.

In the above manner, irrespective of whether successive buckets carry high grade, low grade or intermediate grade ore or rock, each bucket in turn will dump its ore in the bin preselected for it. The operation of the electro-hydraulic circuit may be made very fast, particularly since the springs 122 and 122' may be made relatively heavy to produce relatively quick movement of the piston 120. Thus, the buckets may be moved around by the belt 17 at a relatively rapid rate, so that large tonnages of ore can be handled and sorted expeditiously.

Returning now to wire 16', after it has passed the pickup P, and the information contained thereon utilized in the manner described above, the magnetization may be removed by an eraser E, as by the conventional application of a high frequency alternating magnetic field by a coil 138 wound about pole pieces 139, and supplied from a substantially conventional electron coupled oscillator. Such oscillator may include a pentode tube 140 and associated components, including a tuned frequency determining circuit coil which in turn includes a coil 141 and condenser 142, a grid leak 143 and condenser 144, and a screen by-pass condenser 145. These elements, together with the cathode 146, grid and screen of tube 140, act as a triode oscillator which modulates the electron stream passing from cathode 146 to plate 147 and through a plate tank circuit consisting of the primary of a transformer 148 and a condenser 149, current being supplied through a lead 150. Hence, a signal of suitable frequency will appear across the secondary of transformer 148, which is applied to the coil 138 of eraser E, to cause the information or magnetic dipoles on the wire 16' to be removed.

As indicated previously, the method illustrated diagrammatically in Fig. 5 is adapted to be utilized in sorting ore or the like which is more generally uniform, but various portions of which may vary in values. The apparatus of Fig. 6 is adapted to operate in accordance with the method illustrated in Fig. 5, and may include a bin 152 having a discharge opening at the lower end of a predetermined size, from which flows a sufficient amount of material so that, upon discharge down a chute or trough 153, a layer 13 of material having a relatively uniform thickness will be deposited upon the conveyor belt C, which is preferably operated at a uniform speed. Other suitable feed devices, such as including a screw conveyor, adapted to produce a layer of material of substantially uniform thickness on the belt, may be utilized. The detection devices positioned above the belt, or in any other desired position in which the radiation emitted from the material 13 will act upon the same to provide a reasonably accurate indication of the amount or intensity of radiation, may include a series of Geiger-Müller tubes having, as before, anode wires 30 within metal cathodes 31, as described previously. In the apparatus of Fig. 4, each of the Geiger-Müller tubes operated individually in connection with a magnetizer, but in the apparatus of Fig. 6, the tubes are connected in a manner described later, so that the total effect of the radiation impinging on all the tubes will determine the final setting of an ore directing chute 85', which is pivotally mounted above a bin 89' having compartments 86', 87' and 88'. Bin 89' may also be constructed similarly to bin 89 of Fig. 4, or troughs, chutes or conveyors provided for moving the ore or rock separated to other places of usage or storage. A shield 154 of lead or other suitable material is preferably placed in front of bin 152, so as to prevent radioactivity from affecting the Geiger-Müller tubes positioned above the belt conveyor. Also, the chute 85' may extend through a shield 90', which is adapted to prevent ore in one of the bins therebelow from unduly affecting the Geiger-Müller tubes above the conveyor belt.

As the belt conveyor C reaches an end pulley 27', the layer of material thereon will tend to fall off onto a guide plate 155, and thereby be directed into the upper end of chute 85', which may be maintained in a central or neutral position by a pair of tension springs 156 and 156', disposed on opposite sides of the chute and connected therewith. Also, a pair of solenoid windings 157 and 158 are disposed on opposite sides of the chute, the cores 159 and 159' associated therewith being connected by rods 160 and 160' with the chute. When solenoid winding 157 is energized, core 159 will be pulled therein, so that

rod 160 will pull the chute 85' to the dotted position of Fig. 6, with its lower end over the mouth of bin 86', and against the tension of spring 156'. The ore will thus fall into high grade compartment 86', until the position of the chute is changed. Solenoid winding 157 is energized when the detection and control parts of the apparatus, which will be described later, are indicative of the presence of high grade ore, while solenoid winding 158, on the opposite side of chute 85', is energized when the indications are those of low grade ore, pulling chute 85' to the opposite position, over bin 87' and against spring 156. When the indications are those of medium or intermediate grade ore, neither solenoid winding 157 nor 158 will be energized and the chute 85' will remain in the full position of Fig. 6, i. e., over the mouth of intermediate bin 88'. As will be evident, whenever winding 157 or 158 is deenergized, spring 156' or 156, respectively, will pull chute 85' back to a central position.

As indicated previously, the response of the detection devices of Fig. 6 is, in general, based upon the weighted evaluation of the rate of radiation of all of the material upon the belt at any given instant, since this form of the apparatus is particularly adapted for use when the changes in ore values are of a more gradual nature. Of course, for best results, the layer 13 of material should be as uniform in thickness as feasible, and, dependent upon the type of material and radiation, of a thickness consonant with the effective detection of emissive radiation and the handling of as great an amount of material as possible for a given belt width and speed. Ordinarily, the useful emissive radiation in the case of natural radioactive material will be preponderantly gamma rays, and this is particularly true if it is desired to place intermediate thicknesses of material upon the belt. However, beta rays or other types of radiation may be utilized under proper conditions, which would necessitate, in the case of beta or alpha rays, considerably thinner layers of material on the belt.

Radiation from the ore which passes through any of the Geiger-Müller tubes will cause a current between anode 30 and cathode 31, as previously described, with a resulting voltage drop in a resistance 162, which is coupled by a condenser 163 to a multi-vibrator circuit which includes a dual triode tube 164. In the latter, the first section, which includes a grid 165, is normally conducting, while the second section, which includes a grid 166, is normally made non-conducting by a bias voltage applied to lead 173. The negative voltage drop across resistance 162 is coupled to grid 165, which in turn sets off the multi-vibrator to cause the second section, which includes grid 166, to become conducting, and the resulting plate current then passes through a plate resistor 167 and a wire 168 to a metering circuit lead 169. The value of this current will be determined primarily by the size of the plate resistor 167, which is large compared to the resistance in the metering circuit and the plate to cathode resistance of the second section of tube 164, under the conditions of conduction. The multi-vibrator circuit, after providing a pulse of timed duration which is determined primarily by the time constant of a capacitor 170 and a resistor 171, will return to a stable condition, until again actuated by radiation affecting the Geiger-Müller tube associated therewith. Each of the Geiger-Müller tubes is associated with a similar circuit, each circuit being connected by a wire 168 to lead 169, and supplied with operating current through a high voltage terminal 34', a positive battery terminal 172, and a negative or cutoff battery terminal 173. The resistance 167 of each tube circuit may be the same, in which event the radiation resultant impulses from each tube will tend to have equal effects in determining the setting of chute 85'. However, it will usually be preferred to make plate resistance 167*n* of the circuit of the last Geiger-Müller tube, and each of the preceding plate resistances in succession, smaller than any of the preceding plate resistances, so that the tube nearest the chute 85' will produce the greatest influence, which will progressively decrease back toward the feed bin 152. With the plate resistance 167*n*, or any other corresponding plate resistance, having a smaller value than each preceding resistance 167, the result is a larger current flow to the metering circuit lead 169 from the circuits successively closer to the discharge end of belt C, as each multi-vibrator circuit is "triggered" by its associated Geiger-Müller tube, since the current flowing to lead 169 decreases with an increase in the resistance of the plate resistor 167. In this way, the ore closest to the chute 85' will have a greater effect on the setting of the chute, although the setting is determined in general by the cumulative effect on all the tubes by all of the ore on the belt at any given time.

The metering circuit, to which lead 169 extends, may include a D'Arsonval type relay 174, calibrating resistors 175 and 176, and a condenser 177, to filter the current pulses from the multi-vibrator circuits to provide an average value. Preferably, the values of the resistor 176 and the condenser 177 are so proportioned and correlated with the resistance of resistor 175 and the internal resistance of relay 174, that the time constant of that portion of the circuit which includes the same is a reasonable fraction of the travel time of the material on the belt, so that the effect of the variation of the resistances 167 is accentuated, or if the resistances 167 are equal in value, this portion of the circuit will independently cause the material on the belt nearest the chute 85' to produce a greater effect on the setting of the chute, because of its having traveled on the belt for a greater length of time than any of the other material on the belt. In other words, the condenser 177 may provide capacitor storage, to produce a memory device which will retain for a pre-determined period of time each signal received. Of course, the value of any specific signal will tend to diminish with time, since any specific charge will tend to drop. Such time constant may be varied by changing the value of the resistance of resistor 176 or the capacity of condenser 177, or both. If this time constant is materially less than the travel time for a specific particle of ore from one detection device to the next, then the memory effect will not be sufficiently great to alter the setting of the chute. Thus, the time constant is preferably greater than the travel time between two successive detection devices. The utilization of condenser 177 for capacitor storage is valuable in reducing within practical limits, the effect of the fluctuations in the background count produced by cosmic rays and igneous rock or the like adjacent to the installation. The memory effect, provided by such capacitor storage, coupled with the use of a plurality of detection devices, tends to cause the value of the signal transmitted to the relay 174 to be generally uniform when there is no material on the belt, so that the circuit may be calibrated with reference to a relatively uniform background count as a base. In addition, the memory effect provided by such capacitor storage tends to produce a truer reflection, in the signal transmitted to relay 174, of the average intensity of emissive radiation of the material on the belt, the same, of course, being weighted as described previously.

In relay 174, contacts 178 and 179 are adjusted for voltages applied to the relay to correspond to the lower and upper limits of radioactive ore concentration of medium grade, therefore, if the applied voltage is less than the lower limit or greater than the upper limit, the ore will be indicated as of lean or high concentration, respectively. Current is supplied to the metering circuit through a medium high voltage terminal 73', maintained at a suitable voltage, such as 300 volts. The movable arm 180 of the relay 174 is supplied current by a wire 181 which leads from a main line 182, in turn connected to one side of a generator 183 or other suitable source

of current. The other main line 184 leads from the opposite side of generator 183 to a common terminal 185 for one end of each of the solenoid windings 157 and 158, while the contacts 178 and 179 are connected by wires 186 and 187 in series with relay coils 188 and 189, respectively, the latter having a common terminal from which a wire 190 leads to main line 184.

As will be evident, when contact 178 is closed, relay coil 188 will be energized, and when contact 179 is closed relay coil 189 will be energized, the former causing a switch 191 to close, through which winding 158 is energized by current supplied through a wire 192, while the latter causes a switch 193 to close, to cause winding 157 to be energized by current supplied through a wire 194. Thus, when contact 179 is closed due to the current supplied to the metering circuit being greater than a predetermined upper limit of radioactive ore concentration of medium grade, winding 157 will be energized to cause chute 85' to swing to the dotted position of Fig. 6, thereby causing such ore to fall into the high grade bin 86'. Similarly, when contact 178 is closed due to the current supplied through lead 169 being less than a predetermined lower limit of radioactive ore concentration of medium grade, winding 158 upon energization will cause chute 85' to swing to the opposite position, thereby causing ore to fall into low grade bin 87'. Further, as long as neither contact 178 nor 179 is closed, neither winding 157 nor 158 will be energized, so that chute 85' will remain in the central or neutral position, shown in full in Fig. 6, so that the ore passing off the conveyor belt C will fall into the medium bin 88'. The change from high grade to medium grade, or to low grade, and vice versa, normally will not take place quickly but relatively slowly, so that the chute 85' will have time to swing from one position to another. Also, the ore will generally be sufficiently uniform for each portion thereof, so that the chute 85' will not be swinging rapidly from one position to another. However, a change in the concentration or weighted average concentration of the ore on the belt, will, if sufficient, cause the chute to swing from one position to another, so that the average concentration of the ore in bin 86' will be high, the ore in bin 88' will be medium, and the ore in bin 87' will be low.

The apparatus of Fig. 8 is adapted to be operated in accordance with the method illustrated diagrammatically in Fig. 7, as indicated previously. In the apparatus of Fig. 8, the ore is preferably fed intermittently from a feeding and measuring device 200 into a bucket 201, which may be formed by flanges attached to a continuous belt 202, two buckets 201 and 201' being mounted on the belt. The ore is preferably fed into buckets 201 and 201' so that it will form a layer of as uniform thickness as possible, and preferably as thin as is consonant with adequate evaluation and handling of a sufficiently large amount of material to be economical. The layer of ore in bucket 201 passes underneath a source of radiation excitation rays, such as an ultra-violet lamp 203, utilized when the ore is fluorescent. A detection device, such as a photoelectric cell 204, is preferably placed alongside the ultra-violet lamp 203, both preferably being shielded, as by being beneath a dual shield 205, while a light excluding housing enclosing the belts 202 and 203 as well as the irradiators and detectors should be provided. In addition, a suitable light filter 206 preferably closes the half of the shield 205 below lamp 203 to permit only ultra-violet light, or light of specific frequencies, to pass through, and a suitable filter 206' is preferably located below photoelectric cell 204, further to insure that only fluorescent rays will impinge on cell 204, to exclude ultra-violet radiation, and if desired to permit only a selected band of wave lengths to pass through. The signal produced by the photoelectric cell 204 passes through an amplifier and a detector to an integrator, such components being normally incorporated in an electrical circuit, a portion of which is shown in Fig. 9, described below. Or, a memory device such as that described previously, in connection with Figs. 3 and 4, may be utilized.

As soon as the bucket 201 reaches the opposite end of its path of travel, the ore therein will fall into a bucket 207, which may be formed by flanges, and mounted on a second continuous belt 208, but with as many of the ore surfaces as possible which were previously on top now on the bottom, and vice versa. After deposition in bucket 207, the ore will pass under a second source of inducing radiation, such as an ultra-violet lamp 203', and the fluorescent radiation produced will pass through filter 206' to a second photoelectric cell 204', the lamp 203' and the cell 204' again being shielded, as by being enclosed within a dual shield 205'. As before, the electric signal produced by photoelectric cell 204' will pass through an amplifier and a detector to the integrator. From the integrator, the resultant information, normally electrical, passes to a controller, which controls the position of a pivotally mounted chute 85'', which is actuated by suitable moving means 209, which may be operated electrically or hydraulically, such as in the manner previously described.

During continued movement of belt 202, when the bucket 201 has discharged the ore therein into bucket 207 on belt 208, bucket 201' on belt 202 will have come beneath the feeding and measuring device 200, which is adjusted to discharge a layer of as uniform thickness as possible into the bucket. The ore in bucket 201' will similarly pass beneath ultra-violet lamp 203 and photoelectric cell 204, and when bucket 201' reaches the opposite end of the path of travel of belt 202, the material therein will be discharged into bucket 207', the material then passing under lamp 203' and photoelectric cell 204', after which the material will be discharged into chute 85''. The setting of chute 85'' determines whether the material will fall into one of two or more bins, such as a lean bin 210 and a rich bin 211, it being understood that more than two bins or the like may be utilized, as indicated previously.

For operation of the integrator and control circuit, the principal portion of which is illustrated in Fig. 9, a pair of switches 212 and 213 of Fig. 8 may be respectively opened and closed at predetermined time intervals, such as through cams 214 and 215 which are driven in synchronous relation to belt 208, as through a reduction gear drive 216, or in any other suitable manner. Switch 212 is preferably a commutating control switch while switch 213 is preferably a discharge control switch, the cams 214 and 215 being rotated through 360° for one complete rotation of belt 208. Switch 212 may be a double-pole, double-throw switch, and the contour of cam 214 is preferably such that the double poles of switch 212 are closed in one position during rotation of cam 214 from a point 217 which, for purposes of illustration, may be taken as 0°, until an opposite point 218, at 180°, is reached. During this time a switch arm 219 maintains the double-pole switch 212 in position, while during rotation of cam 214 with the periphery of the cam in engagement with arm 219, between point 218 back to point 217, or between 180° and 360°, the double poles are thrown and held in the opposite position. Cam 215 may be provided with a pair of projections 220 and 221 at suitable positions, such as at 175° and 355°, respectively, so that discharge switch 213 will normally be open, but will be closed when projection 220 or 221 actuates control arm 222. If desired, of course, switches 212 and 213 may merely control relays which respectively operate a double-pole double-throw switch 212' and a discharge switch 213', each of Fig. 9.

As illustrated in Fig. 9, the electrical circuit for operation of the apparatus of Fig. 8 may include a pair of A. C. voltage sources 225 and 225', such as a generator or a transformer secondary, as shown, for supplying current to the anodes of photoelectric cells 204 and 204', re-

spectively. The current produced in the photoelectric cells 204 and 204' may pass through separate amplifiers, each of which may include a pentode amplifying tube 226 coupled with a triode amplifying tube 227, the tubes and associated parts being enclosed within a suitable box or the like, as indicated in connection with photoelectric cell 204'. The output of tube 227 is supplied to an output transformer 228 and thence through a rectifier 229 to a charging resistor 230. Similarly, the amplified output of photoelectric cell 204' passes through an output transformer 228' and thence from a rectifier 229' to a charging resistor 230'. The charging resistor 230 is connected to outside contacts 231 and 232 of the double-pole double-throw switch 212', while the charging resistor 230' is similarly connected to the inside contacts 233 and 234 of switch 212'.

The poles of switch 212' are respectively connected with a pair of integrating capacitors 235 and 235', which may be connected in parallel to ground. In general, capacitor 235 is first charged from cell 204, and then charged from cell 204', so that the total charge on capacitor 235 will be the resultant of the amount of fluorescent light received by the respective photoelectric cells from the material in bucket 201, for instance, and then from the same material but with different surfaces exposed in bucket 207. Similarly, capacitor 235' is first charged from photoelectric cell 204 and then from photoelectric cell 204', again with the material first with certain surfaces exposed and then with others. Also, while capacitor 235 is being charged from photoelectric cell 204, capacitor 235' is being additionally charged from photoelectric cell 204'. This is accomplished through the timed shifting of the poles of switch 212'.

In the position shown, with cam 214 of Fig. 8 in position to maintain the poles of switch 212' of Fig. 9, in engagement with contacts 232 and 233, respectively, capacitor 235 will be charged by the amplified and rectified current from photoelectric cell 204', while capacitor 235' will be charged by the amplified and rectified current from photoelectric cell 204. As capacitor 235 or 235' is being charged by the rectified output current due to the indication from cell 204', the capacitor is connected by lead 236 to the grid 237 of a triode measuring tube 238. The triode has a fixed bias voltage supplied by battery connection 239, so that when the voltage across the integrating capacitor is small, the plate current of the triode is small, and when the voltage across the integrating capacitor is large, the plate current is large. The plate current of triode tube 238 passes through a lead 240 to a suitable voltage source and control circuit for regulating the position of chute 85''. A small capacitor 241 is preferably connected from lead 236 to ground and is utilized to damp transients. The current in lead 240 may actuate any type of relay or arrangement of relays which is suitable for operating the positioning mechanism of chute 85''. As indicated previously, the actual movement of the chute may be accomplished electrically or hydraulically, or in any other suitable manner. As the cams 214 and 215 continue to rotate, just prior to the time that the poles of switch 212' are moved to the opposite contacts, discharge switch 213' will close momentarily. This will cause capacitor 235 to discharge through a resistor 242, since discharge switch 213' is connected to ground.

As soon as the cam 214 reaches a position in which point 218 engages arm 219, the poles of switch 212' of Fig. 9 will be thrown to the opposite position, i. e. with the poles in engagement with contacts 231 and 234, respectively, the discharge switch 213' in the meantime having been opened. With the switch 212' in the opposite position, capacitor 235 will be charged by the photoelectric cell 204, and capacitor 235' will receive an additional charge from photoelectric cell 204', it being noted that in the position shown in Fig. 9 capacitor 235 has previously been charged from photoelectric cell 204. Upon continued rotation of cam 215, when point 221 is reached, which is slightly ahead of point 217 on cam 214, discharge switch 213' will again be closed, but this time capacitor 235' will be discharged. In the meantime, the charge on capacitor 235' will have been measured by control tube 238 and the chute 85'' will have been properly positioned. As will be evident, only one capacitor at a time is discharged through the resistor 242, this taking place at a time just after the particular material involved discharges through chute 85''. Thus, the charge on either of the capacitors 235 and 235', at the time of discharge, will represent the cumulative effect of the material as it passes the two photoelectric cells in turn, the position of the material being reversed so that the total charge will be representative of the degree of fluorescence of more than one surface of the particles involved.

The integrating switch and capacitor unit is, in effect, a memory device operating from two different detection devices and is preferably used when the material can be alternated from one belt to another, or when only two detection devices are utilized.

The apparatus of Figs. 8 and 9, as illustrated, is particularly adapted to separate ore which contains fluorescent material. As indicated previously, the tungsten ore Scheelite or $CaWO_4$, may be separated in this manner. Other materials, with radiation emissive properties effectively confined to the surface of the particles or lumps of which it is composed may be separated by appropriate changes in the detecting coupling and analyzing devices. The "turnover" system may also be utilized in sorting material whose emitted radiation is preponderantly of the beta type, or soft gamma type. In such cases, the memory device may be of the type illustrated in Figs. 3 and 4, appropriate changes, of course, being made in the electrical circuit when Geiger-Müller tubes or the like are utilized in lieu of photoelectric cells. Or, the general arrangement may be similar to Figs. 8 and 9, such as involving a double-pole double-throw integrating switch coupled with integrating capacitors and a periodically operating discharge switch.

In all cases, other memory systems or devices may be utilized. For instance, a paper tape on which a mark is made for each count or activation of the radiation detective device, may be utilized, the paper tape being saved as a record of each day's run if desired. Or, a tape of non-magnetic material may have a layer of magnetic iron oxide, which is subjected to magnetization in a manner similar to the wire, but which also may be kept for record purposes. Also, other electro-mechanical systems and the like, of types well known, may be utilized if desired. Various detection devices, such as Geiger tubes, Geiger-Müller tubes with perforated cathodes or multiple electrodes of various types, a scintillation counter including a multiplier photocell or other light sensitive device actuated by a fluorescent material such as naphthalene, crystals such as diamond which in a proper circuit will produce a "trigger" action to provide a result similar to that of a Geiger-Müller tube, multiplier photocells, and others, may be utilized.

From the foregoing, it will be apparent that the method and apparatus of this invention fulfill to a marked degree the requirements and objects hereinbefore set forth. By moving the material to be sorted past a plurality of detection devices, and operating a sorting device in accordance with the cumulative effect of the emissive radiation upon the detection devices, a considerable amount of material may be processed in a given period of time. The method and apparatus of this invention eliminate the possibility of error through human judgment, since it may be made entirely automatic in operation. Also, in comparison with material moving at a given mass rate of flow past a single detection device more accurate results may be obtained since a plurality of detection devices are utilized. Furthermore, if a plurality of detection devices, such as Geiger-Müller tubes were employed in

sorting, one to each of a number of individual belts or the like, the results for the same mass rate of flow of material to be sorted would be neither as accurate nor as dependable, as pointed out previously. If a single photocell were utilized in conjunction with a single belt conveying material past an irradiator and the photocell, the results would not be entirely dependable, since only one side or surface of each lump or particle would be exposed. Thus, such a system might pass valuable ore to the tailings dump, particularly if the material is composed of large lumps, and the same would be true of a number of photocells operating individually, each in conjunction with a separate belt. Thus, it will be evident that the association of a plurality of detection devices with a memory device, the utilization of the cumulative effect of the material on all the detection devices, and the turn over between detection devices of material whose radiation is primarily a surface phenomenon as well, are valuable features of the present invention.

In accordance with the present invention, the cumulative effect may be either that of the same portion of the material on all of the detection devices, or that of all of the material in position at one time to affect all of the detection devices, the indications of the latter preferably being weighted. As indicated previously, the former is preferable in the case of sharp variations in the material, such as coming from lumps, pockets, narrow rich veins or the like, while the latter may be preferable for material which varies more gradually, such as that coming from wider or more uniform veins or deposits. Thus, the invention readily accommodates differences in material.

As will be evident, the material may be separated into two or more grades, and the apparatus may be adjusted to alter the separation points in accordance with the point or points of economic recovery. As has been indicated, the method and apparatus of this invention may be utilized not only in separating material the emissive radiation of which comes from deep within, but also in separating material whose emissivity is primarily a surface phenomenon.

While several different forms of apparatus of this invention have been illustrated and described, and several alternative methods of this invention have been described, it will be understood that other embodiments of the apparatus and other alternatives of the method may exist, and that additional changes and variations may be made therein, all without departing from the spirit and scope of this invention.

What is claimed is:

1. A method of sorting radiation emissive divided material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises effecting a relative movement of successive portions of said mixture with respect to a plurality of spaced radiation detection devices each capable of independently detecting radiations as material moves therepast; accumulating the effect of the radiations detected from the moving material and separating such successive portions of said mixture in accordance with the cumulative effect on said radiation detection devices of said material.

2. A method of sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 1, wherein the said material is sorted in accordance with the total cumulative effect on said radiation detection devices of separate portions of said mixture as such portions pass each radiation detection device in turn.

3. A method of sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 1, wherein the said material is sorted in accordance with the effect on said radiation detection devices of all the material in position to affect said devices at a particular time.

4. A method of sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises separating said mixture into portions; effecting a relative movement of successive separate portions of said mixture with respect to a plurality of radiation detection devices; and separating such successive portions of said mixture in accordance with the cumulative effect on said radiation detection devices of each portion of said mixture as it passes each radiation detection device in turn.

5. A method of sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises effecting a relative movement of successive portions of said mixture with respect to a plurality of independent radiation detection devices; shifting such portions to present different surfaces to successive detection devices; and separating such successive portions of said mixture in accordance with the cumulative effect on said detection devices of said material.

6. A method of sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises separating said mixture into portions; effecting a relative movement of successive separate portions of said mixture with respect to a plurality of radiation detection devices; shifting such portions to present different surfaces to successive detection devices; and separating such successive portions of said mixture in accordance with the cumulative effect on said radiation detection devices of each portion of said mixture as it passes each radiation detection device in turn.

7. Apparatus for sorting radiation emissive material of at least predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; means for effecting a relative movement of successive portions of said mixture with respect to and past said detection devices in turn; means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same for accumulating the radiation signals; and separating means for the material controlled by said responsive means.

8. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; means for effecting a relative movement of successive separate portions of said mixture with respect to said radiation detection devices; memory means operatively associated with said devices responsive to the cumulative effect on said radiation detection devices of material moving relatively to the same for accumulating the radiation signals; and separating means for the material controlled by said memory means.

9. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation and each adapted to produce a signal; means for effecting a relative movement of successive portions of said mixture with respect to said radiation detection devices; means operatively associated with

said devices responsive to the weighted cumulative effect on said detection devices of material moving relatively to the same for accumulating the radiation signals; separating means for the material controlled by said responsive means; and means operatively associated with said detection devices for so affecting the signals produced by said detection devices that stronger signals than otherwise will be received by said responsive means from the detection devices nearer said separating means.

10. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; means for effecting a relative movement of successive portions of said mixture with respect to said detection devices; means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same for accumulating the radiation signals; means for synchronizing said responsive means with the movement of said mixture; and separating means for the material controlled by said responsive means.

11. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; means for effecting a relative movement of successive separate portions of said mixture with respect to said radiation detection devices; memory means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same for accumulating the radiation signals, including a movable element synchronized in speed with the movement of said material past said radiation detection devices; and separating means for the material controlled by said memory means.

12. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 11, wherein said movable element is magnetizable.

13. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 12, including means for de-magnetizing said magnetizable element.

14. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, which comprises a plurality of radiation detection devices disposed in spaced relation; means for effecting a relative movement of successive separate portions of said mixture with respect to said detection devices; memory means, including an electrical circuit, responsive to the cumulative effect on said detection devices of material moving relatively to the same; and separating means controlled by said memory means.

15. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, such radiation being primarily a surface phenomenon, which comprises two radiation detection devices disposed in spaced relation; two conveyors having buckets for effecting a relative movement of successive portions of said mixture with respect to said detection devices, said conveyors and detection devices being arranged so that material in one bucket on the first conveyor will pass the first detection device, and then be deposited in a bucket on the second conveyor to pass the second detection device with different surfaces presented to said second detection device; memory means responsive to the cumulative effect on said detection devices of the same material on each conveyor in turn; separating means; and control means for actuating said separating means from said memory means in accordance with the portion of said material reaching said separating means.

16. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; a conveyor having a plurality of containers for effecting a relative movement of successive separate portions of said mixture with respect to said detection devices; loading means for depositing a substantially equal amount of such mixture in each said container; means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same; and separating means for the material controlled by said responsive means.

17. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises at least two radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; at least two conveyors having containers for effecting a relative movement of separate successive portions of said mixture with respect to said detection devices, said conveyors being constructed and arranged to cause said material to be turned so as to expose different surfaces in successive conveyors; means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same; and separating means for the material controlled by said responsive means.

18. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 17, including means for inducing such emissive radiation.

19. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, as defined in claim 18, wherein said inducing means comprise devices for directing ultra-violet light against said material and said detection devices are responsive to light rays in the visible range, each said detection device being coupled with an ultra-violet light directing device.

20. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; means for effecting a relative movement of successive separate portions of said mixture with respect to said detection devices, and for turning said separate portions to present different surfaces to each said detection device in turn; means operatively associated with said devices responsive to the cumulative effect on said detection devices of material moving relatively to the same; and separating means for the material controlled through said responsive means.

21. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices disposed in spaced relation; a conveyor having buckets disposed in substan-

tially equally spaced relation, for effecting a relative movement of successive separate portions of said mixture with respect to said detection devices; means for loading a substantially equal amount of said mixture into each said bucket; memory means including a magnetizable wire; a plurality of magnetizing means for impressing magnetic dipoles upon said wire, each said magnetizing means being controlled by a detection device; means for moving said wire in substantial synchronization with the movement of said material past said detection devices, so that the same portion of wire will pass each said magnetizing means at substantially the same time that the corresponding portion of said material is passing the corresponding detection device; pickup means responsive to the total number of dipoles on successive portions of said wire; means for demagnetizing said wire subsequent to said pickup means; and sorting means controlled by said pickup means, for separating successive portions of said material into predetermined grades in accordance with the cumulative effect of each such portion on said detection devices in turn.

22. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, which comprises a plurality of radiation detection devices each capable of an independent detection and resultant radiation signal disposed in spaced relation; a belt-type conveyor for effecting a relative movement of successive portions of said mixture with respect to said detection devices; loading means for depositing a substantially uniform layer of material on said conveyor; means operatively associated with said devices responsive to the weighted cumulative effect on said detection devices of material moving relatively to the same for accumulating the radiation signals; separating means for the material controlled by said responsive means; and means operatively associated with said detection devices for increasing to a greater extent than otherwise the result of the effect on the detection devices nearer said separating means.

23. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices disposed in spaced relation, each said device including a tube responsive to radiation; a conveyor having buckets disposed in substantially equally spaced relation for effecting a relative movement of successive separate portions of said mixture with respect to said detection devices; means for loading a substantially equal amount of said mixture into each said bucket; a shield between said loading means and said detection devices; memory means including a magnetizable wire; means for moving said wire in synchronization with the movement of said buckets; a plurality of magnetizing means for impressing magnetic dipoles upon said wire, each said magnetizing means being controlled by a detection device; means for moving said wire in substantial synchronization with the movement of said material past said detection devices so that the same portion of wire will pass each said magnetizing means at substantially the same time that the corresponding portion of said material in passing the corresponding detection device; electrical pickup means responsive to the total number of dipoles on each successive portion of said wire and positioned at a point corresponding to the point reached by each bucket in turn just prior to dumping; means for amplifying the electrical output of said pickup means; an electrical device controlled by said amplified output, and responsive to the character of said output as indicative of the emissive strength of the material in the corresponding bucket being low grade, intermediate grade or high grade; means for demagnetizing said wire subsequent to said pickup means; means forming separate receiving spaces for low grade, intermediate grade, and high grade ore; a pivoted chute for diverting material into said receiving spaces and positioned to receive material from each bucket in turn; a shield between said receiving space means and said detection devices; hydraulic means for moving said chute to different positions; and means controlled by said electrical device for controlling said hydraulic means.

24. Apparatus for sorting radiation emissive material of at least a predetermined emissive strength, from a mixture containing also material having less than such predetermined emissive strength, which comprises a plurality of radiation detection devices disposed in spaced relation, each said device including a tube responsive to radiation, and a circuit associated therewith including an element which may differ for each such circuit so as to vary the reported response for the said detection device; a conveyor having a belt for effecting a relative movement of successive portions of said mixture with respect to said detection devices; means for loading a substantially uniform layer of said mixture onto said belt; a shield between said loading means and said detection devices; an electrical device for receiving the total reported response of said detection devices, said elements in said detection device circuits differing so that the total reported response is weighted with emphasis on the response of the detection devices furthest from said loading means and said electrical device being responsive to the magnitude of said reported response as indicative of the emissive strength of the material on said belt as being low grade, intermediate grade, or high grade; means forming separate receiving spaces for low grade, intermediate grade, and high grade ore; a pivoted chute for diverting material into said receiving spaces and positioned to receive material from said belt; a shield between said receiving space means and said detection devices; means for moving said chute to different positions; and means controlled by said electrical device for controlling said chute moving means.

25. Apparatus for sorting material responsive to ultra-violet radiation, from a mixture containing material having varying degrees of response to ultra-violet light, which comprises two ultra-violet lamps disposed in spaced relation; a light responsive tube disposed closely adjacent each said ultra-violet lamp for detecting fluorescent light produced by ultra-violet rays directed against material passed in proximity to said lamp and tube; a shield and filters for each set including one said ultra-violet lamp and the adjacent light responsive tube; two conveyors having buckets for effecting a relative movement of successive portions of said mixture with respect to said sets of lamps and tubes, said conveyors and sets being arranged so that material in one bucket on the first conveyor will pass the first set, and then be deposited in a bucket on the second conveyor to pass the second set with different surfaces presented thereto; means for loading a substantially equal amount of said mixture into each bucket of said first conveyor; an integrator for producing a signal responsive to the cumulative effect on said light responsive tubes of the same material on each conveyor in turn; means forming spaces for reception of material of different ranges of response to ultra-violet light; a pivoted chute positioned to receive material from a bucket of said second conveyor and to direct such material to one of said spaces; a controller associated with said integrator; and means for moving said chute to different positions and actuated by said controller.

26. In apparatus for sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, a plurality of radiation detection devices each capable of an independent detection; memory means capable of cumulating the effects of the detected radiations, including an electrical circuit hav-

ing capacitor storage, controlled by said detection devices, and means for sorting in accordance with the cumulations.

27. A method of sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amount of each such material, which comprises effecting a relative movement of a substantially continuous layer of said mixture along a predetermined path; detecting a value of the strength of at least one radiation property of such material at each of a plurality of points spaced along said path; determining at successive times, for all of the material in position at any one time to affect the result of such detection at each of such points, the cumulative result of such detection with greater emphasis on the detection result at points closer to the end of said path; and separating successive portions of said mixture at the end of said path in accordance with such cumulative weighted result determination.

28. A method of sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, as defined in claim 27, wherein greater emphasis is placed on the detection result at each point than at any point further from said end of said path.

29. A method of sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, which comprises effecting a relative movement of a substantially continuous layer of said mixture along a predetermined path; independently detecting a value of the strength of at least one radiation property of such material at each of a plurality of points spaced along said path; determining at successive times, for all of the material in position at any one time to affect the result of such detection at each of such points, the cumulative result of such detection; and separating successive portions of said mixture at the end of said path in accordance with such cumulative result determination.

30. A method of sorting radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, from a mixture containing varying amounts of each such material, as defined in claim 29, wherein such radiation properties are at least in part induced at each point of detection along said path.

31. A method of determining the disposition of radiation emissive material of at least a predetermined emissive strength and material having less than such predetermined emissive strength, in a mixture containing varying amounts of each such material, which comprises effecting a relative movement of a substantially continuous layer of said mixture along a predetermined path; detecting a value of the strength of at least one radiation property of such material at each of a plurality of points spaced along said path; determining at successive times, for all of the material in position at any one time to affect the result of such detection at each of such points, the cumulative result of such detection with greater emphasis on the detection result at points closer to the end of said path; and effecting the disposition of successive portions of said mixture at the end of said path in accordance with such cumulative weighted result determination.

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