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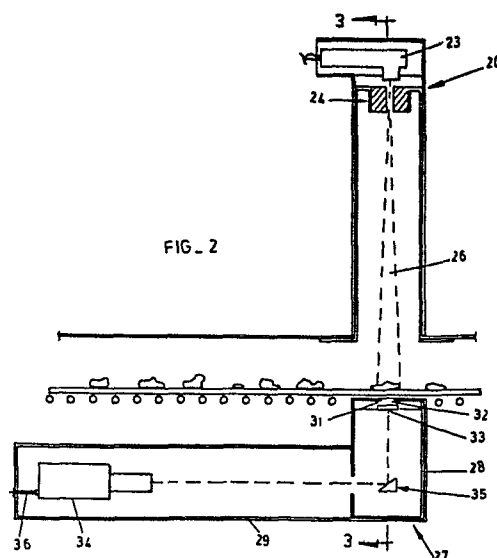
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54 Sorting particulate material.

57 An ore sorting apparatus in which the ore to be sorted is selected for sorting according to their absorption of atomic radiation. Ore particles are passed beneath an X-ray tube 23 while being supported on a conveyor belt. X-rays passing through the ore particles impinge on a fluorescent screen 33. Images formed on the screen 33 are scanned by a scan camera 34 to provide sorting control signals in dependence upon the amount of radiation absorbed by the ore particles.



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SORTING PARTICULATE MATERIAL

This invention relates to sorting of particulate material and has particular, but not exclusive, application to the sorting of ore rocks.

There are various known kinds of ore sorting equipment in which rocks to be sorted are moved in a stream past some form of detection system which determines the degree to which each rock possesses a certain characteristic and individual rocks are then diverted from the main stream according to the response of the detector. The rocks may for example be projected in a free flight path and the selected rocks deflected from that path by air blasts or other deflection means.

The characteristic of the rocks used as the basis of the sort varies according to the nature of the material to be sorted. In the case of radioactive material such as uranium, the detection system may include one or more scintillation detectors to measure the radioactivity of the ore rocks. In other cases, sorting is carried out by an examination of surface characteristics of the rock. For example, in a photometric sorter the rocks are illuminated with electromagnetic radiation and are optically scanned to obtain reflectivity measurements which are used as the basis of the sort. In some sorters an optical scanning system is used to detect fluorescence of the required material under ultra violet or x-radiation. It is also known to use detectors which provide an

indication of electrical resistivity or magnetic permeability of the ore rocks.

The effectiveness of operation of any of the above kinds of ore sorting equipment depends on rapid detection of a characteristic exhibited by the valuable material to a markedly different degree than by accompanying low grade or waste material. We have now determined that many valuable ores can be accurately and rapidly selected from the gangue material with which they are normally associated by measuring the degree to which they absorb atomic radiation. As used herein, the term "atomic radiation" is intended to include alpha, beta, gamma, x-radiation and neutron radiation.

It has been found that by sorting according to a measurement of absorption of atomic radiation it is possible to accurately and reliably separate ores which have proved difficult to identify with the known detection techniques. Some tungsten ores in particular have proved difficult to separate using the known detection techniques but are particularly susceptible to sorting by measurement of x-ray absorptivity as will be described in more detail hereinafter.

The present invention broadly provides a method of sorting particulate material comprising:

passing the particulate material through a beam of atomic radiation whereby it absorbs radiation from that beam selectively according to the composition of the particles therein;

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detecting radiation transmitted in said beam through the material as a measure of the absorption of the radiation by particles in the material passing through the beam; and

separating the particles of said material into fractions according to the absorption of radiation from the beam.

The invention further provides apparatus for sorting particulate material comprising:

means to produce a beam of atomic radiation;

material feed means operable to feed material to be sorted through the beam of atomic radiation such that it can absorb radiation from the beam selectively accordingly to the composition of the particles therein;

detector means to detect atomic radiation transmitted through the material in said beam as a measure of the absorption of radiation by particles in the material passing through the beam; and

separator means to separate the particles of said material into fractions according to their absorption of radiation as indicated by the detector means.

Conveniently, detector means may comprise a fluorescent screen which fluoresces when impinged on by the atomic radiation and optical scanning means

to scan the fluorescent screen. More specifically, therefore, the invention also provides apparatus for sorting particulate material comprising

an atomic radiation source to produce a beam of atomic radiation;

a fluorescent screen which fluoresces when impinged on by the atomic radiation and located so as to be in the path of said beam;

material feed means operable to feed material to be sorted through the beam between the radiation source and the fluorescent screen whereby to absorb radiation from the beam selectively according to the composition of the particles therein;

optical scanning means to scan the fluorescent screen so as to produce scanning signals indicative of the degree of atomic radiation absorption of particles in said material passing through the beam; and

separator means to separate particles of said material into fractions according to their degree of radiation absorption as indicated by the scanning signals.

The material feed means may comprise a belt conveyor having a substantially horizontal run on which to feed the particulate material through the radiation beam.

The radiation source may be located above the horizontal run of the conveyor and be operable to produce said beam passing downwardly through the material on that run and the fluorescent screen may be disposed beneath the horizontal conveyor belt run.

The fluorescent screen may be adapted to receive atomic radiation on one face and to produce fluorescence visible at an opposite face, said one face being presented to the radiation beam and the optical scanning means be operable to scan said opposite face of the screen.

In apparatus particularly adapted to produce fractions of differing tungsten content the radiation source may be an x-ray source adapted to produce an x-ray beam with an energy spectrum concentrated about an energy level of 75 Kev.

The invention further provides a method of sorting particulate material comprising

passing particulate material to be sorted through an atomic radiation beam whereby to absorb radiation from the beam selectively according to the composition of the particles therein;

causing the radiation beam to impinge on a fluorescent screen sensitive to that radiation after passing through said material so as to cause fluorescence of the screen;

optically scanning the fluorescent screen to derive scanning signals indicative of the degree of radiation absorption of particles in said material passing through the radiation beam; and

separating the particles of said material into fractions according to their degree of radiation absorption as indicated by the scanning signals.

The material to be sorted may include particles of a material which exhibits an absorption edge for atomic radiation at a particular energy level and the atomic radiation beam may then have an energy spectrum concentrated at or above that particular energy level. When sorting tungsten ore, for example, it is preferred that the radiation beam be an x-ray beam having an energy spectrum concentrated around an energy level of 75 Kev.

In order that the invention may be fully explained one particular embodiment will be described in detail with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic side elevation of an ore sorter constructed in accordance with the invention;

Figure 2 is a vertical cross-section through a part of the ore sorter which includes an x-ray beam generator, a fluorescent screen and an optical scanning

system;

Figure 3 is a cross-section on the line 3-3 in Figure 2;

Figure 4 is a block diagram of electronic processing circuitry used in the sorter;

Figure 5 is a circuit diagram of part of the processing circuitry; and

Figure 6 shows a plot of x-ray absorption against x-ray energy for tungsten ore as compared with the surrounding waste material.

The illustrated ore sorter comprises a belt conveyor denoted generally as 11 comprising an endless conveyor belt 12 having an upper horizontal run 13. Ore particles 14 are fed onto one end of the upper conveyor belt run by a chute 15 and are stabilized on the conveyor belt by a stabilizer 16 which may include a series of rollers, brushes or moving aprons to hold the particles against the conveyor belt.

After being stabilized on the upper run of the conveyor belt the ore particles are carried by the belt through a vertical x-ray beam produced by x-ray generating equipment denoted generally as 17. Absorption of the x-rays by the particles is measured by a detection system denoted generally as 18 installed beneath the horizontal upper run of the conveyor belt. The particles are subsequently carried by the belt to the end of the upper run from which they are projected in free flight trajectory past a series

of blast nozzles 19.

The blast nozzles 19 are disposed in a line across the end of the conveyor belt and are operated by air supply valves according to the x-ray absorption measurements obtained from the detection system 18 so that selected rocks are blasted with air to fall into one collection bin 21 whereas unblasted rocks continue in unimpeded free flight to be collected in a second bin 22.

The x-ray generating equipment 17 comprises a lead-lined housing 20 which contains an x-ray tube 23 and a lead collimator slit 24. The tube is electrically connected to a control unit and high voltage generator 25 which enables adjustment of the electrical power supply to vary the energy spectrum of the x-rays. Collimator slit 24 collimates the x-rays into a vertical beam 26 which passes downwardly through the conveyor belt run 13 and the ore rocks upon it.

Detection system 18 is mounted within a casing 27 which is installed immediately beneath the conveyor belt run 13 and which comprises a vertical tubular leg 28 and a horizontal tubular leg 29. The upper end of tubular leg 28 is closed by a thin aluminium strip 31 providing an x-ray window beneath which there is a fluorescent screen 33 which fluoresces under irradiation with x-rays. Screen 33 is exposed to the x-ray beam via window 31 and it fluoresces in response to the x-ray

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radiation so as to produce on its lower face a fluorescent image of the rocks passing through the beam with a contrast between regions of the rocks which exhibit differing degrees of x-ray absorption. This image produced by the fluorescent screen is continuously scanned by means of an intensified line scan camera 34 mounted within the horizontal leg 29 of casing 27 to view the fluorescent screen 33 via a reflecting mirror 35.

Line scan camera 34 has an output lead 36 which continuously provides electronic signals representing the x-ray absorption image on screen 33. These signals are passed to electronic processing equipment which analyses them and controls the operation of air blast nozzles 19 accordingly.

Figure 4 illustrates the electronic processing equipment in block form. This comprises a video processor 41 which receives the scanning output signals from the line scan camera 34 and which is connected to an analyser 42. The speed of the conveyor belt is measured by a suitable transducer 43 and is fed to a timing device 44. Output signals from the timing device are fed to the analyser 42 and to a blast controller 45 which controls a series of air valve actuators 46 to actuate the air supply valves for the air blast nozzles 19.

Video processor 41 operates on the scanning output signals to generate two sets of pulses. The first set indicates the presence and position of regions of high x-ray absorption within the various rocks and the second

set indicates the boundaries of the rocks.

This information is fed to the analyser 42 which takes into account the belt speed and the positions of the rocks to compute which nozzles are to be actuated and the time instants at which they are to be actuated. The analyzer 42 and the timing device 44 thus set the blast controller 45 which causes the appropriate air valves 46 to be actuated at the computed instants.

The video processor 41 comprises the electrical circuitry illustrated in Figure 5. As previously mentioned this processor determines the presence and position of high x-ray absorption regions within the rocks and also the boundaries of the rocks. It comprises a first twenty bit shift register 52, the first ten bits being fed to a logical AND gate 54, the second ten bits being fed to a logical AND gate 56, and a second twenty bit shift register 58. The outputs from the two AND gates 54 and 56 are fed to a third AND gate 59, the output from this AND gate going to a fourth AND gate 60. The input to the shift register 58 is also connected to the AND gate 60. The output from the AND gate 56 is fed to an AND gate 62, a second input to this AND gate being derived from the tenth bit 64 in the shift register 58. The output from the shift register 58 and the outputs from the AND gates 60 and 62 are fed to a logical OR gate 66 which in turn is connected to one trigger of a flip-flop 68. The

output of the shift register 52 is fed via an inverter 70 to a second trigger of the flip-flop 68.

The video processor effectively divides the scan into a series of channels across the conveyor belt, corresponding one channel to each of the blast nozzles. More specifically, the circuit of Figure 5 is clocked at a rate depending on the speed of the conveyor belt and the scanning speed of the line scan camera 34 such that scanning camera scans across one channel width during ten clock pulses. The information obtained from the line scan camera via the analysing circuitry when the camera is scanning a rock from one boundary to another is presented to the shift register 52 as a series of pulses of uniform amplitude, ten consecutive pulses indicating that the rock extends over one channel width. Regions of high x-ray absorptivity are detected by window comparators which are set for particular absorption levels. The presence of a high absorption region is indicated by a single pulse, the width of the pulse being proportional to the width of the high absorption region. The pulses corresponding to the high absorption regions are fed to the shift register 58. The flip-flop is triggered by a positive output appearing at either of the AND gates 60 or 62, or at the output of the shift register 58.

Data which is presented to the shift register 58 is simultaneously presented to the AND gate 60 and is

logically ANDED with the output of the AND gate 59.

In practice this means that an output only appears at the AND gate 60 if there is a positive input to the shift register 58 and each one of the twenty bits of the shift register 52 is also positive; in other words if the particle extends over a distance of at least two channel widths to one side of the position at which a region of high absorption is detected. Similarly, an output appears at the AND gate 62 when the last ten bits in the shift register 52 are positive and the tenth bit in the shift register 58 is also positive. This corresponds to the situation when a high absorption region occurs at least one channel width from a boundary of an ore particle. If a positive output does not appear at either of the AND gates 60 or 62 and a high absorption region is in fact present the flip-flop 68 is only triggered when a positive pulse appears at the output of the shift register 58.

The flip-flop is thus triggered by the detection of a high absorption region on a small particle or by the detection of a high absorption region at a position within a particle at least one channel width away from the boundary of the particle or by the detection of a high absorption region at a position within a particle at least two channel widths away from a boundary of the particle. In the latter cases the flip-flop output which corresponds to a treated form of the data input to the shift register 58 is employed to attribute the presence of the high absorption region to a portion of the particle extending one channel width and

two channel widths respectively in one direction from the point at which the feature was detected. The flip-flop output is maintained positive until triggered by a positive signal appearing on its other input. This positive signal only appears when all data has been moved out of the shift register 52. In other words the flip-flop is triggered by the absence of any bits in the shift register, a condition occurring when the optical system has scanned a particle and come to a boundary of the particle.

The circuitry of Figure 5 by its technique of delay and comparison therefore has the function of attributing the presence of a desirable high absorption region feature to all those channels on one side of the point at which the region is detected and into which the particle extends and on the other side of this point of attributing the high absorption region to the particle for one or two channel widths depending on the size of the particle in that direction.

The analyser 42 then responds as if the high absorption region were actually present in practically all the channels into which the particle extends and the corresponding nozzles are then actuated to force the particle into the collecting bin. If a high absorption region extends into adjacent channels or there are a plurality of such regions in different channels, the attribution of each region to practically all the other channels means that the particle will be selected and a sufficient number of air nozzles actuated to force the particle into the collecting bin.

Clearly, by extending the shift register 52 each high

absorption region can be attributed to more than two channels if desired.

As previously mentioned the apparatus of the present invention is particularly applicable to the sorting of tungsten ores. Tungsten occurs naturally in wolframite, which is a tungstate of iron and manganese. This generally appears as veins in quartz within gangue material comprised predominantly of diorite. Previously, the wolframite has been detected indirectly by looking for quartz with photometric scanning equipment. In some deposits there can be rocks which have a high wolframite content and little quartz and these particularly valuable rocks are rejected by a sorter which operates by detecting quartz content. However, because tungsten exhibits a K-shell absorption edge to x-rays at an energy level of 69.5 Kev, it can readily be detected directly in accordance with the present invention. Figure 6 shows a plot of x-ray absorption exhibited by tungsten and by the common surrounding waste material over a range of x-ray energy levels. The tungsten exhibits a strong absorption edge at 69.5 Kev whereas the waste material shows a steady decline in x-ray absorption with increasing x-ray energy. Consequently, a tungsten ore will exhibit a very much higher absorption of x-rays at energies immediately above the absorption edge than will the waste material. Accordingly, very efficient separation can be achieved by an apparatus according to the present invention in which the x-ray generating equipment is adjusted to provide an x-ray energy spectrum concentrated around an energy level of about 75 Kev as indicated by

the broken line in Figure 6 and in which the scanning system and analyser are set to measure the absorption of x-rays at that energy level.

The illustrated apparatus has been advanced by way of example only and it could be modified considerably. For example, the degree of radiation absorption could be measured by some means other than a fluorescent screen and optical scanning system. It would be possible to use scintillation detectors, proportional counters or diode arrays for this purpose. The fluorescent screen and optical scanning system is preferred because it enables high resolution imaging.

The invention is not limited to the use of x-rays and it would be possible to use gamma rays or alpha or beta rays provided by isotope sources.

The processing circuitry could be modified to provide for sorting on the basis of a measurement of a radiation absorption to size ratio. This might be necessary for materials which do not exhibit such a high absorption characteristic as tungsten, in which case the degree of radiation absorption could be markedly affected by the thickness of the particular particle. In most cases the thickness of the particle will be generally proportional to its overall size and an area measurement may therefore be used as an indication of its thickness to provide appropriate compensation. Such area measurement may be derived directly from the x-ray absorption scanning

system or alternatively it could be provided by a separate optical scanning system of conventional type.

It is accordingly to be understood that the invention is not in any way limited to the details of the particular apparatus and method described above by way of example and that many modifications and variations will fall within its spirit and scope which extends to every novel feature and combination of features herein disclosed.

CLAIMS:

1.

A method of sorting particulate material characterised by passing the particulate material through a beam of atomic radiation whereby it absorbs radiation from that beam selectively according to the composition of the particles therein; detecting radiation transmitted in said beam through the material as a measure of the absorption of the radiation by particles in the material passing through the beam; and separating the particles of said material into fractions according to the absorption of radiation from the beam.

2.

A method according to Claim 1, characterised by passing the particulate material through an X-ray beam of radiation.

3.

A method of sorting particulate material characterised by passing particulate material to be sorted through an atomic radiation beam whereby to absorb radiation from the beam selectively according to the composition of the particles therein; causing the radiation beam to impinge on a fluorescent screen sensitive to that radiation after passing through said material so as to cause fluorescence of the screen; optically scanning the fluorescent screen to derive scanning signals indicative of the degree of radiation absorption of particles in said material passing through the radiation beam; and separating the particles of said material into fractions according to their degree of radiation absorption as indicated by the scanning signals.

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4.

Apparatus for sorting particulate material characterised by means to produce a beam of atomic radiation; material feed means operable to feed material to be sorted through the beam of atomic radiation such that it can absorb radiation from the beam selectively according to the composition of the particles therein;

detector means to detect atomic radiation transmitted through the material in said beam as a measure of the absorption of radiation by particles in the material passing through the beam; and

separator means to separate the particles of said material into fractions according to their absorption of radiation as indicated by the detector means.

5.

Apparatus according to Claim 4, characterised in that the detector means comprises a fluorescent screen which fluoresces when impinged on by the atomic radiation and optical scanning means to scan the fluorescent screen.

6.

Apparatus for sorting particulate material characterised by an atomic radiation source to produce a beam of atomic radiation; a fluorescent screen which fluoresces when impinged on by the atomic radiation and located so as to be in the path of said beam; material feed means operable to feed material to be sorted through the beam between the radiation source and the fluorescent screen whereby to absorb radiation from the beam selectively according to the composition of the particles therein; optical scanning means to scan the fluorescent screen so as to produce scanning signals indicative of the degree of atomic radiation absorption of particles in said material passing through the beam; and separator means to separate particles of said material into fractions according to their degree of radiation absorption as indicated by the scanning signals.

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7.

Apparatus according to any one of Claims 4 to 6, characterised in that the material feed comprises a belt conveyor having a substantially horizontal run on which to feed the particulate material through the radiation beam.

8.

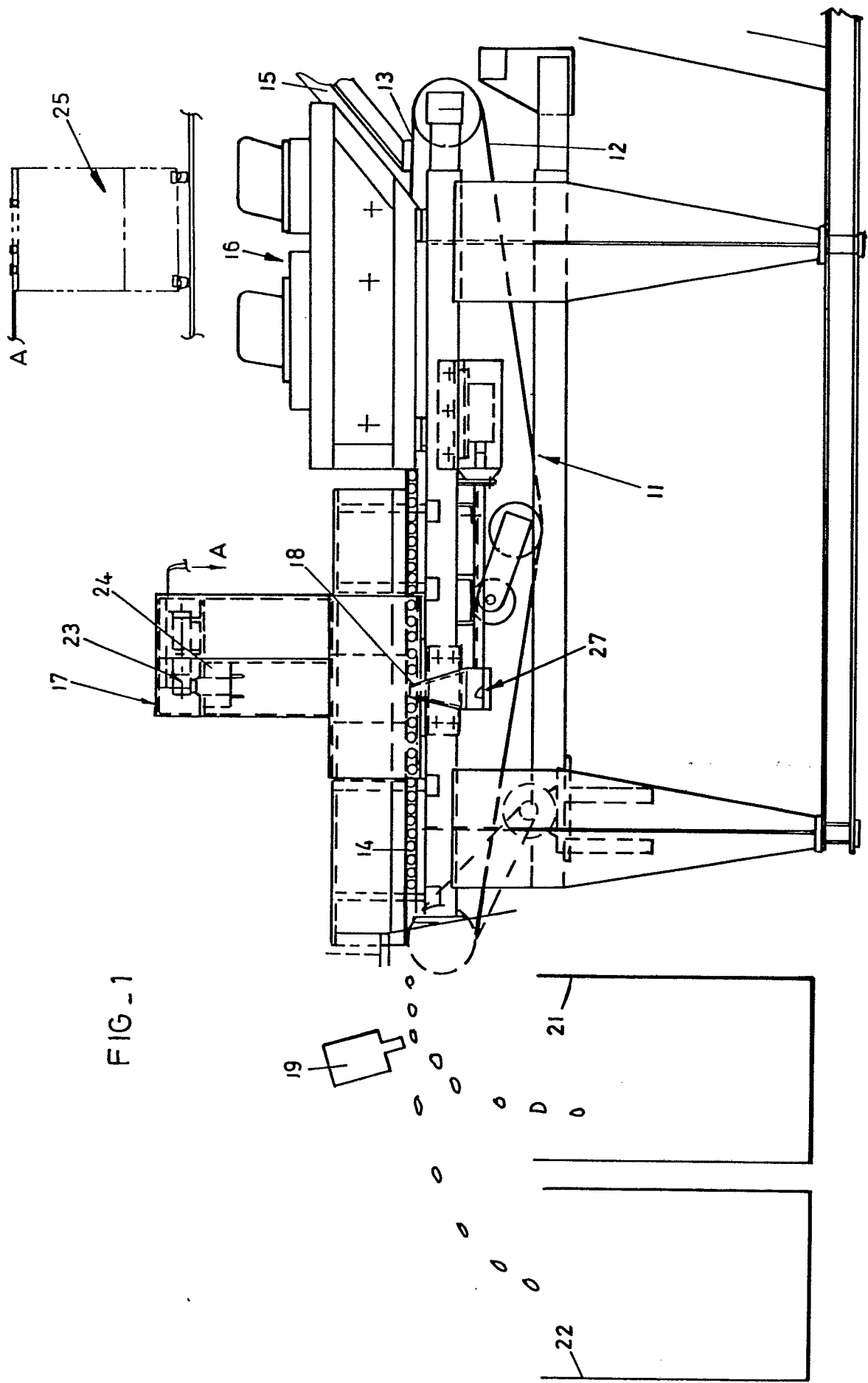
Apparatus according to Claim 7, characterised in that the radiation source is located above the horizontal run of the conveyor and operable to produce said beam passing downwardly through the material on that run and the fluorescent screen is disposed beneath the horizontal conveyor belt run.

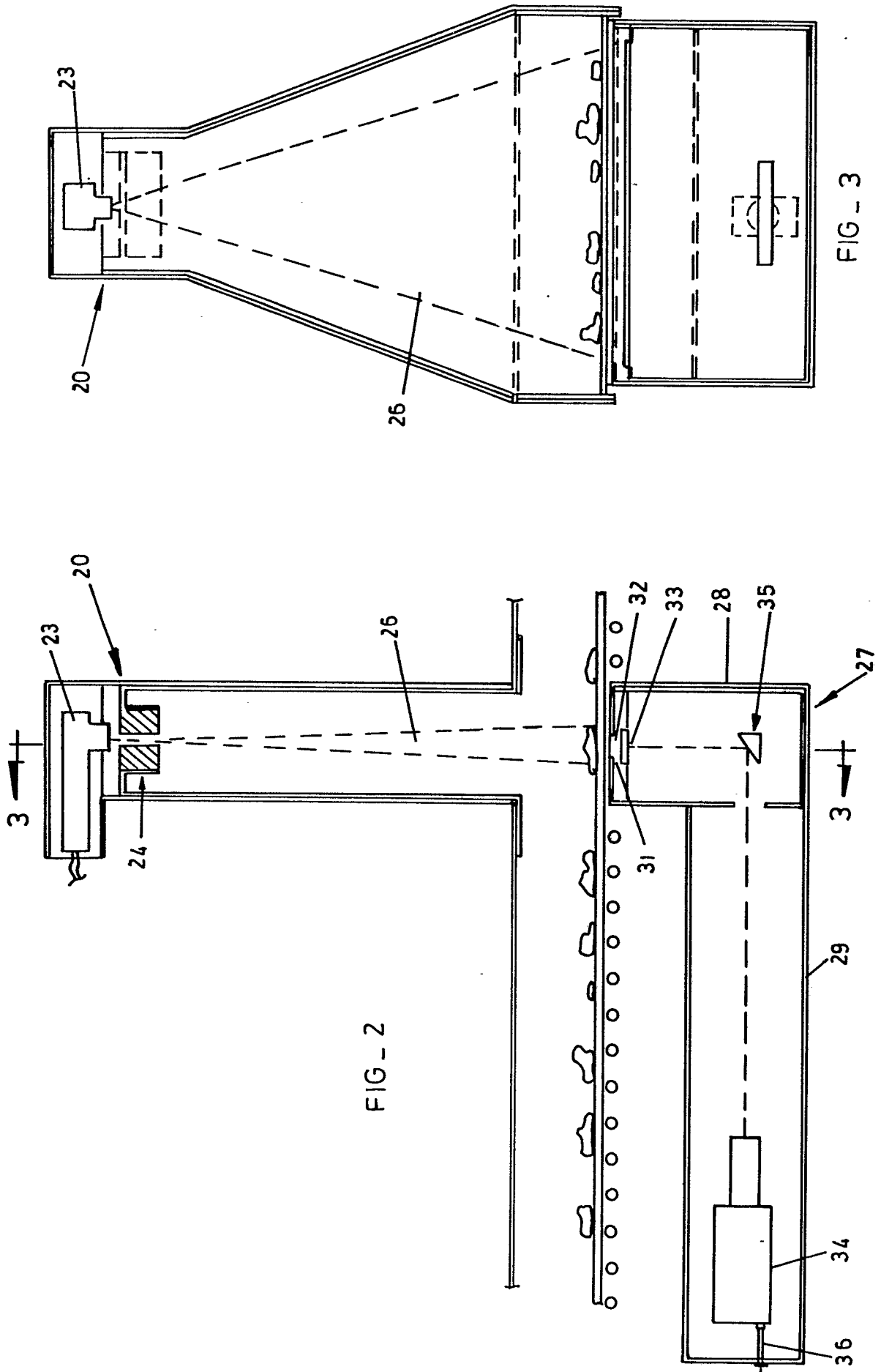
9.

) Apparatus according to any one of Claims 6 to 8, characterised in that the fluorescent screen is adapted to receive atomic radiation on one face and to produce fluorescence visible at an opposite face, said one face being presented to the radiation beam and the optical scanning means be operable to scan said opposite face of the screen.

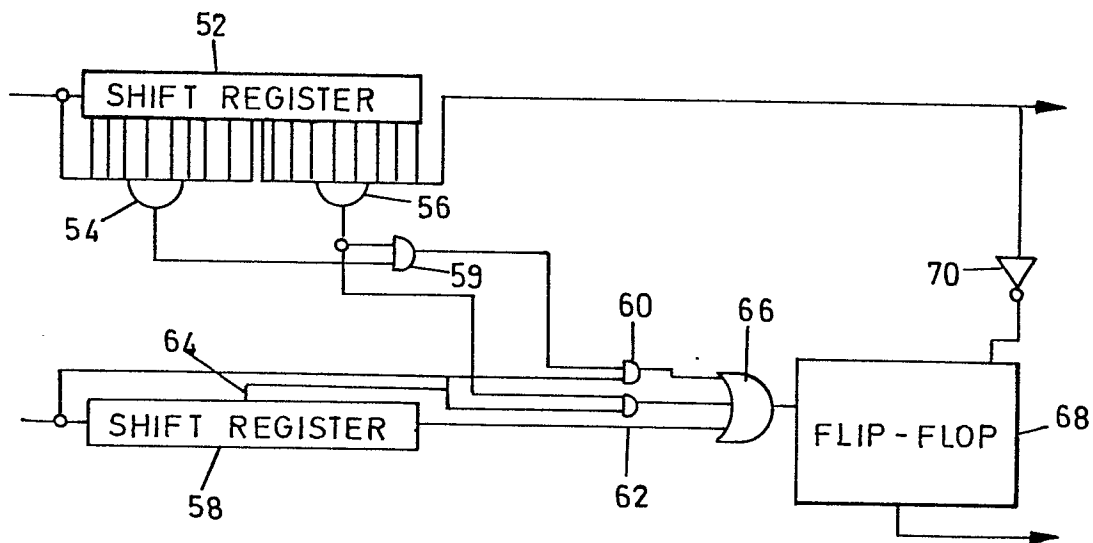
10.

Apparatus according to any one of Claims 4 to 9, arranged to produce fractions of differing tungsten content, characterised in that the radiation source is an X-ray source arranged to produce an X-ray beam which has an energy spectrum about an energy level of 75 Kev.

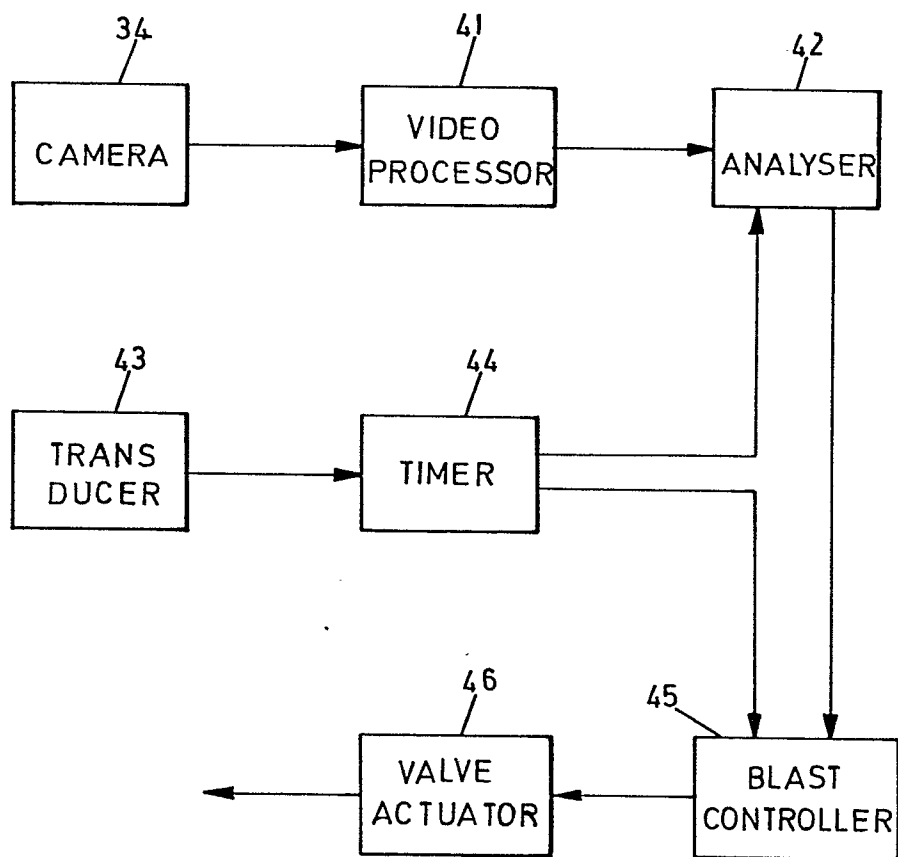




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FIG_5



FIG_4

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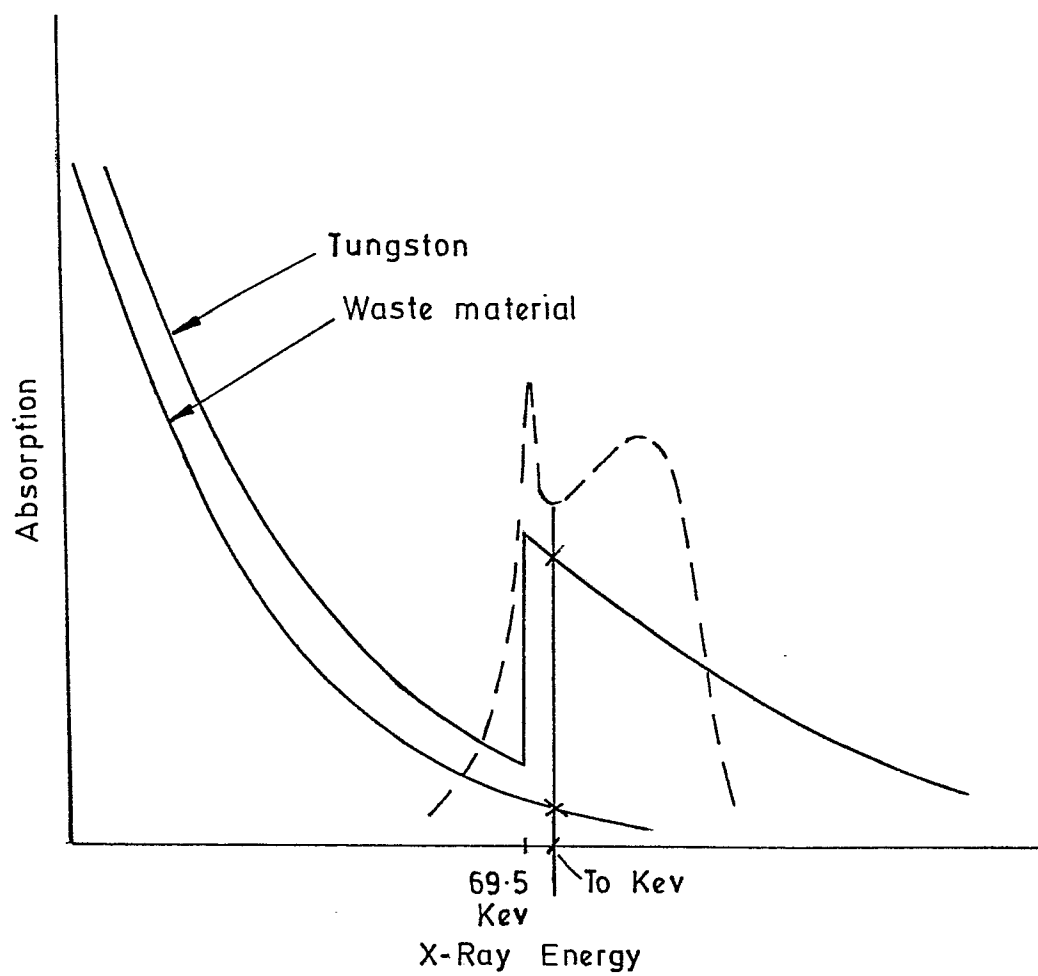


FIG - 6



European Patent
Office

EUROPEAN SEARCH REPORT

0064810

Application number

EP 82 30 1729

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X,Y	GB-A-1 103 591 (NATIONAL RESEARCH DEVELOPMENT CORP) *Figures 1 to 4; from page 1, line 30 to page 3, line 22; from page 3, line 99 to page 4, line 51; from page 4, line 92 to page 5, line 37; claims 7,8,9*	1-4, 6-10	B 07 C 5/346
Y	GB-A-1 135 232 (NATIONAL RESEARCH DEVELOPMENT CORP.) *Figure; from page 1, line 68 to page 2, line 51*	1-6,9	
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
			B 07 C 5/346 B 07 C 5/342
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 06-08-1982	Examiner PESCHEL W.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	