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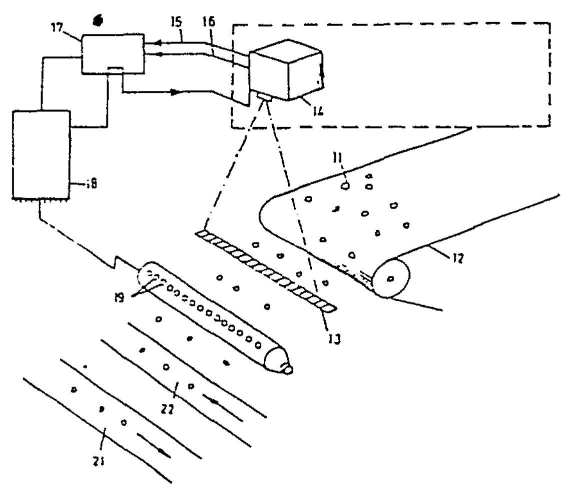
(54) Material sorting.

(57) Ore sorting is carried out by moving particles through a scanning zone 13 to measure spectral reflectance or emittance and sorting particles into fractions in accordance therewith. The sorting is carried out on the basis of at least two different wavelengths in the infra-red region of the electromagnetic spectrum.

FIG _ 3



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"SORTING MATERIAL"

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

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

The characteristic of the rocks used as the basis of the ort varies according to the nature of the material to be sorted. n the case of radioactive material such as uranium, the etection system may include one or more scintillation detectors o measure the radioactivity of the ore rocks. In other cases, orting is carried out by an examination of surface charact-ristics of the rock. For example, in a photometric sorter ne rocks are illuminated with electromagnetic radiation and re optically scanned to obtain reflectivity measurements nich are used as the basis of the sort. In some sorters an ptical scanning system is used to detect fluorescence of the equired material under ultra violet or x-radiation. It is lso known to use detectors which provide an indication of lectrical resistivity or magnetic permeability of the ore rocks.

The effectiveness of operation of any of the above kinds f ore sorting equipment depends on rapid detection of a naracteristic exhibited by the valuable material to a markedly ifferent degree than by accompanying low grade or waste material.

The present invention is concerned with the use of detectors which measure reflectance or emittance in the infra-red region of the electromagnetic spectrum. Remote sensing satellite and aerial survey programmes have demonstrated that the mid infra-red electromagnetic spectral region around 8 to 12 µm is capable of providing considerable compositional information regarding geological formations in the form of emittance minima caused by inter-atomic vibrations. For example, it has been established that distinguishable spectra are measurable remotely in which the wavelength features are determined by the metals associated with Si-O bonds in the 9 to 11 µm reststrahlen bands. Thus iron silicates can be distinguish from alumino-silicate rocks, and hence coarsely crystalline (granite) rocks from glass-rich (basalt) rocks. The present invention aims to make use of this effect to enable particles to be sorted on the basis of multi-spectral reflectance or emittance data. Simultaneous sensing at differing wavelengths enables significant enhancement of the sensitivity of detection of reflectance or emittance variations amongst ore rocks and enables compensation for effects such as surface texture changes where absolute emittance levels may vary without composition change but where emittance minima spectral positions remain unchanged.

The invention provides a method of sorting particulate material, comprising:

moving particles through a scanning zone;

scanning the particles to measure values of spectral reflectance or spectral emittance over their surfaces at a plurality of differing wavelengths in the infra-red region of the electromagnetic spectrum; and

separating the particles into fractions according to the measured reflectance or emittance values at the plurality of differing wavelengths.

Preferably, the spectral reflectance or spectral emittance values are detected at two differing wavelengths in the range 6 to 12 μm and the particles are separated according to a determination of an average ratio between the two values for each particle.

The invention also provides apparatus for sorting particulate material; comprising

material feed means to feed particles of material to be sorted through a scanning zone;

scanning and detection means to scan the particles individually as they pass through the scanning zone and to detect values of spectral reflectance or spectral emittance over their surfaces at a plurality of differing wavelengths in the infra-red region of the electromagnetic spectrum;and

separator means to separate the particles into fractions according to the detected reflectance or emittance values at the plurality of differing wavelengths.

In order that the invention may be more fully explained its application to the sorting of phosphate rocks will be described with reference to the accompanying drawings in which:-

Figures 1 and 2 illustrate infra-red spectral emittance characteristics of a number of typical phosphate rocks having varying compositions of P_2O_5 and SiO_2; and

Figure 3 illustrates diagrammatically a typical sorting apparatus constructed in accordance with the present invention.

In the sorting of phosphate rocks having varying amounts of P_2O_5 and SiO_2 it is desired to reduce the SiO_2 content to an acceptable level and also to upgrade the P_2O_5 content in the accepted material. Figures 1 and 2 illustrate infra-red spectral emittance characteristics determined experimentally on a number of typical phosphate ore rocks. The contents of P_2O_5 and SiO_2 were subsequently determined in each rock and have also been indicated on the figures. The concentration of FeO in each rock was also determined.

With reference to Figures 1 and 2 the changes in emittance values for the various rocks at a first narrow spectral band centred on 8.2 μm and a second such band at 9.5 μm will be considered. It is found that for a change in P_2O_5 from 6.3% to 21.9% and SiO_2 from 58.9% to 22.1% respectively, changes in single wavelength response are only of the order of 10%. However, if a ratio is formed from the spectral response at the two chosen wavelengths for each rock it is found that this emittance ratio varies by over 30%.

The advantage in taking more than one spectral reading can be most clearly seen by considering particle No. 7. This particle has a low SiO_2 content but it has a relatively high FeO content of 7% compared with less than 1% for all of the other particles considered. Probably due to the high FeO content, the response curve for particle No. 7 is displaced with the result that its response at 8.2 µm is similar to that of particles with high SiO_2 content. However, the shape of the response curve is appropriate to the low SiO_2 content and the ratio of the response at the two differing wavelengths will still indicate a low SiO_2 content. Thus by determining the ratio between the spectral emittance at the two selected wavelengths it is possible to remove the influence of such effects as high FeO content which may be responsible for altering the absolute level of emittance but not the relative spectral response in the regions of interest for P_2O_5 and SiO_2 measurement.

From the above it will be appreciated that the invention is particularly applicable to the sorting of phosphate rocks but it can be applied to other minerals. The emittance/reflectance characteristics of typical ores can be determined experimentally and appropriate detector wavelengths chosen according to where the minima occur in the particular minerals concerned. In the case of phosphate rocks a ratio of two carefully selected wavelength-filtered signals could be used as the sorting parameter. In other cases, the response at a number of selected wavelengths could be measured and a regression expression used to estimate the relevant mineral content of the particle being sorted. The coefficients of the regression formula may be built up from experimental measurements on large numbers of particles with known mineral content.

The form of the regression equation may be linear as in the following expression:-

$$\left(\begin{array}{l}\text{Mineral}\\ \text{concentration}\end{array}\right) = \chi_o + \sum_{i=1}^{n} \chi_i \cdot \lambda_i$$

where χ_o = constant

χ_i = experimentally determined linear regression coefficients

λ_i = measured response at wavelength i for particle under examination.

A typical apparatus constructed in accordance with the invention is illustrated diagrammatically in Figure 3. In this apparatus the particles 11 to be sorted are projected in free flight from the end of a belt conveyor 12 through a scanning zone 13. As they pass through zone 13 the rocks are scanned by an optical scanning system and a multi-spectral infra-red emittance detector system located in a housing 14. The detector system may comprise a linear array of two-colour photo-conductive detectors. The optical scanning system may be of conventional construction and arranged to provide a line scan across the surface of the particles as they pass through the scanning zone. Housing 14 will also contain a cooling system for the detectors. This may be in the form of a closed-cycle thermal engine system or a LN_2 system.

The detectors produce output signals indicating the spectral emittance of the two wavelengths chosen and these are fed by separate lines 15, 16 to an electronic processor 17 which generates a ratio between the two signals. The ratio signal is fed to a further processor 18 which provides rock imaging and controls the operation of a series of air blast nozzles 19 selectively to produce air blasts to divert individual particles from their free flight trajectory according to whether they are accepted or rejected. The accepted particles may be collected by an accept conveyor 21 and the rejected particles carried away by a reject conveyor 22.

In an apparatus according to the invention either of the complementary parameters of spectral emissivity (ε_λ) or spectral reflectance (r_λ) may be selected for sensing.These parameters are related by the formula

$$r_\lambda = (1 - \varepsilon_\lambda)$$

Where possible,it is preferred to carry out the multiple wavelength sensing on an ambient temperature emissivity basis so as to avoid the complication of having to provide a thermal source. In some cases, however, it may be necessary to view the particles as they pass through a chamber maintained at an elevated temperature. The particles would pass through the chamber very rapidly (in a few milliseconds) so there would be no significant change in the surface temperature of the particle. The reflected energy would be sensed at the appropriate wavelengths simultaneously and the particles would form a secondary selectively absorbing grey body radiator.

It will be appreciated that the precise form of the apparatus will depend on the nature of the material to be sorted and whether the particles need to be irradiated to obtain satisfactory detector sensitivity. It is accordingly to be understood that the invention is in no way limited to the particular apparatus illustrated herein, nor to the particular minerals which have been mentioned and that many variations will fall within the scope of the claims of this application.

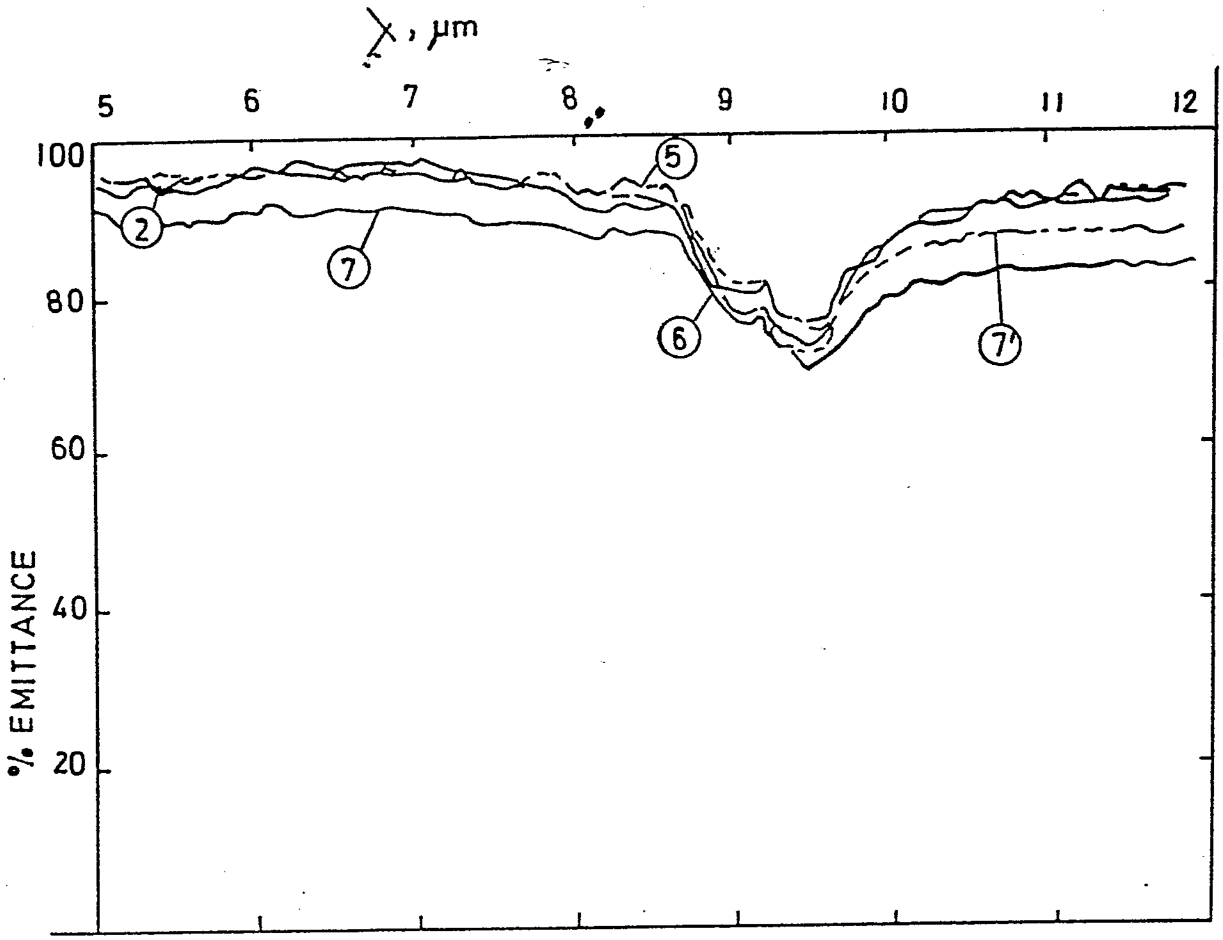
.AIMS:-

:ethod of sorting particulate material, comprising:
.ving particles through a scanning zone; scanning the
.rticles to measure values of spectral reflectance or
.ectral emittance over their surfaces at a plurality
: differing wavelengths in the infra-red region of the
:ectromagnetic spectrum; and
:parating the particles into fractions according to the
asured reflectance or emittance values at the plurality
: differing wavelengths.

method according to Claim 1, in which measuring the reflectance
r emittance is carried out at two wavelengths in the range 6 to
2 µm and separating the particles takes place according to an
verage ratio between two respective values for each particle.

n apparatus for sorting particulate material; comprising
aterial feed means to feed particles of material to be sorted
hrough a scanning zone; scanning and detection means to scan
he particles individually as they pass through the scanning
one and to detect values of spectral reflectance or spectral
mittance over their surfaces at a plurality of differing
avelengths in the infra-red region of the elctromagnetic
pectrum; and separator means to separate the particles into
ractions according to the detected reflectance or emittance
alues at the plurality of differing wavelengths.

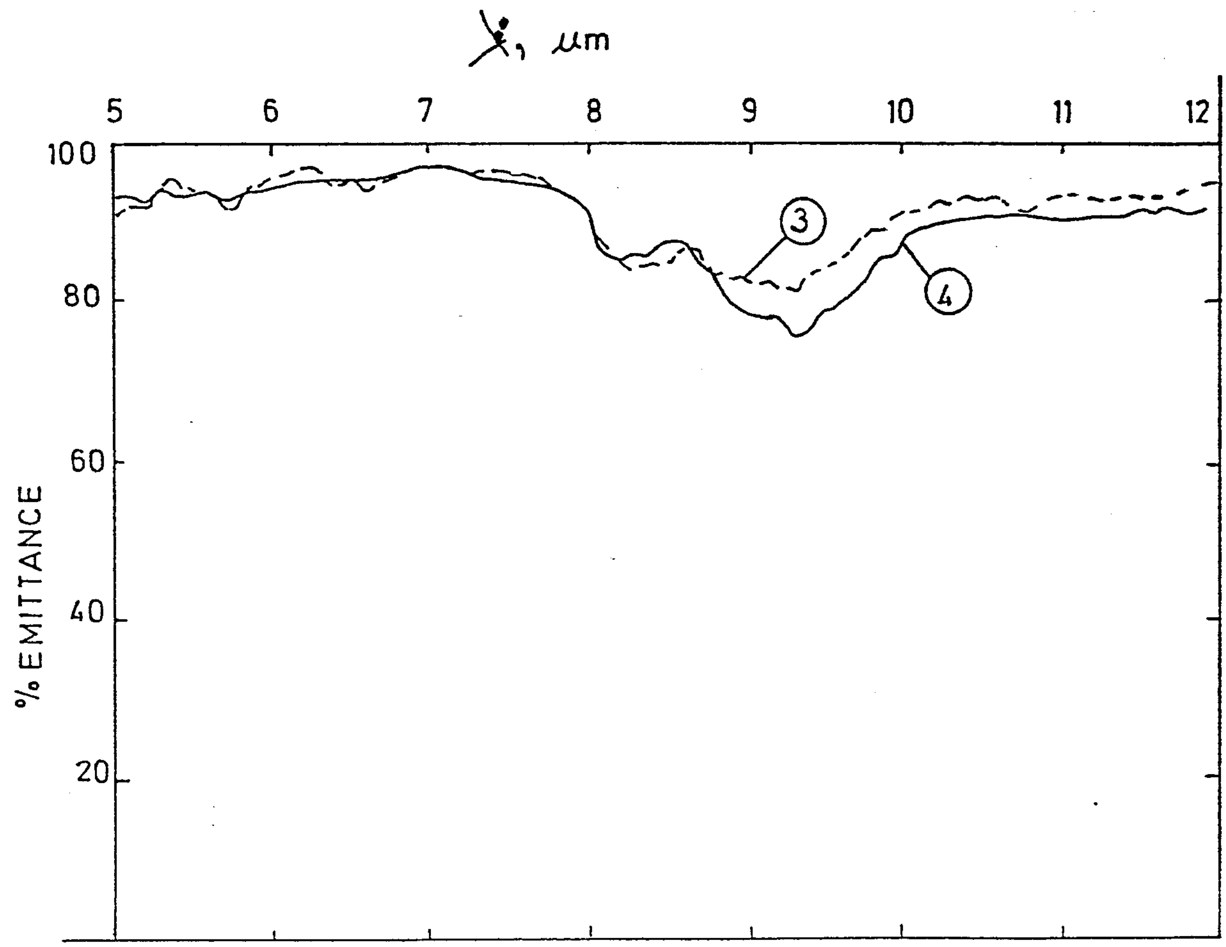
FIG_1



	% P_2O_5	% SiO_2
2	21·3	23·2
5	21·9	22·1
6	20·4	25·9
7	19·2	19·6
7'	19·2	19·6

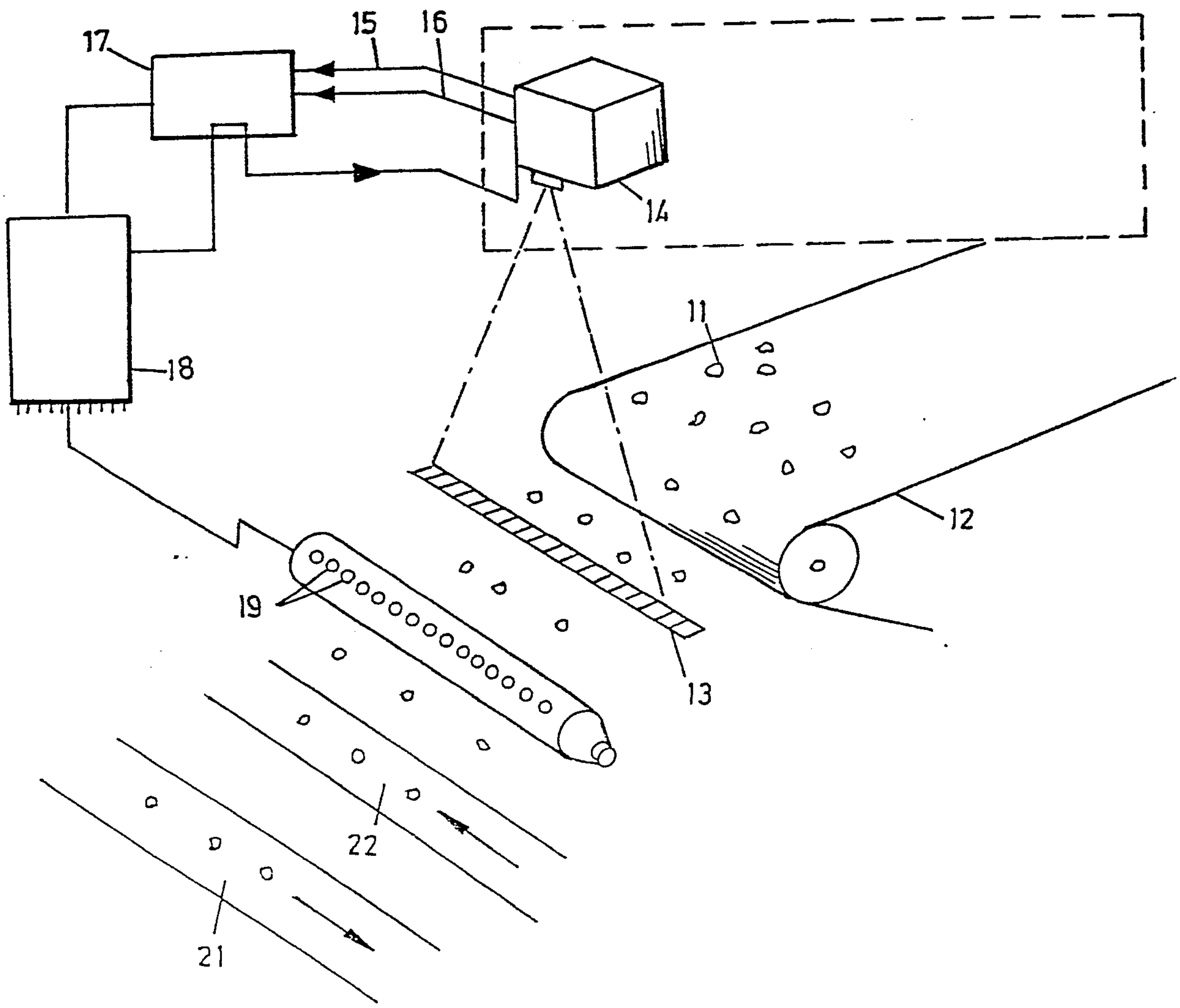
7·0% FeO may cause drop in general emittance level, but curve displaced vertically to illustrate similar spectral structure.

FIG_2



	% P_2O_5	% SiO_2
4	17·1	38·4
3	6·3	58·9

FIG _ 3



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EUROPEAN SEARCH REPORT

Application number

EP 82 30 2210

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	GB-A-2 057 123 (CSR LTD) *Figure 1; from page 1, line 26 to page 2, line 48; from page 2, line 84 to page 3, line 52; page 3, lines 73-92* ---	1,3	B 07 C 5/342
X	US-A-4 236 640 (KNIGHT) *Figures 1-3; from column 1, line 61 to column 2, line 16; from column 2, line 59 to column 2, line 37; from column 3, line 62 to column 4, line 9* ---	1-3	
A	US-A-3 917 070 (ASFOUR) *Figure 1; from column 2, line 30 to column 4, line 49* ---	2	
A	GB-A-2 060 166 (AG-ELECTRON) -----	1	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
			B 07 C 5/342

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06-08-1982	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
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