United States Patent Office

3,395,793

Patented Aug. 6, 1968

3,395,793

METHOD OF ORE SORTING BASED ON DIFFERENTIAL INFRARED EMISSION

Richard L. Thompson, Killarney Heights, New South Wales, and Francis B. Dwyer, Marrickville, New South Wales, Australia, assignors to The Colonial Sugar Refining Company Limited, Sydney, New South Wales, Australia, a company of Australia

No Drawing. Filed Nov. 10, 1965, Ser. No. 507,224
Claims priority, application Australia, Dec. 3, 1964, 52,477; May 7, 1965, 58,530
8 Claims. (Cl. 209—3)

ABSTRACT OF THE DISCLOSURE

Method of sorting rocks containing a mineral of relatively low thermal absorptivity ("absorptivity" is defined as $(k\rho c)^{1/2}$) from barren rocks of relatively high thermal absorptivity in which members of a batch of unsorted rocks are exposed individually to a heat flux for a period of time just sufficient to render exposed mineral detectably more infrared emissive than host rock, detecting the infrared emission from each rock by translating the detected infrared radiation into electrical signals diagnostic of the mineral content of the rock, and sorting the rocks in response to the electrical signals.

This invention relates generally to the sorting of rocks containing minerals of relatively low thermal absorptivity (as hereinafter defined) from barren rocks of relatively high thermal absorptivity. The term "barren rocks" as used herein is intended to mean rocks which either do not contain the required mineral or which contain the mineral in a quantity insufficient to enable economical separation from the rock.

The invention has been devised to provide a physical method of sorting rocks containing asbestos from barren rocks as a preliminary step in the process of separating asbestos from the host rock in which it is contained. The principal advantage resulting from this aspect of the invention is that asbestos can be separated more cheaply and quickly than hitherto because barren rock can be located and discarded prior to mill processing.

Asbestos deposits are frequently associated with a number of hard minerals. For example, crocidolite asbestos ore mined at Wittenoon, Western Australia, contains on the average 6–7% of crocidolite in a matrix of host rock comprising: quartzite (hardness 7 on the Mohs' scale), hematite and magnetite (both, hardness 5.5 to 6.5 on the Mohs' scale), together with accessory dolomite and chlorite. The crocidolite is separated from the ore comprising these minerals by a process which includes mill grinding, and because of the hardness of the host rock, it will be appreciated that there will be less wear and tear on the mill machinery when lumps of barren rock are eliminated before processing in an initial sorting step.

Apart from this aspect, the more significant advantage to be gained from sorting is that the output of asbestos can be very appreciably increased. The source of this increased output is to be found in two effects associated with the consequential reduction in the amount of barren rock being processed, viz (i) higher plant capacity, and (ii) less tailings, hence, less asbestos lost in tailings.

According to the prior art, the sorting of asbestos-containing rocks has been done by hand; and in the case of Wittenoom ore, about one quarter of the barren rock has been rejected in this way before mill processing. While hand picking is reliable, it suffers from the disadvantage of being slow, costly and wasteful of manpower.

The principle of electropneumatic sorting has been applied by D. Van Douwe in U.S. Patent No. 2,776,747 to the sorting of falling objects according to their reflectivity characteristics; and the same principle has been applied by James F. Hutter and Leonard Kelly in U.S. Patent No. 3,011,634 and Australia Patent No. 223,683 to the sorting of falling pieces of rock which naturally emit value-identifying radiations (e.g. rocks containing radioactive or fluorescent minerals).

While asbestos in asbestos-containing rock does not naturally emit value-identifying radiations which enable the asbestos to be distinguished by this means from barren rock, it has been found by the present inventors that it may be caused to emit such radiations artificially by taking advantage of the differential thermal absorptivity of naturally occurring asbestos fibres in relation to host rock. The "thermal absorptivity" of a material is here defined as $(k\rho c)^{1/2}$, i.e., the square root of the product of thermal conductivity, density and specific heat, in cal. ° C.$^{-1}$ cm.$^{-2}$ sec.$^{-1/2}$.

In Table 1 we give figures for selected thermal properties in the case of the major components of Wittenoon crocidolite ore. The components are herein identified as: (I) crocidolite; (II) quartzite; (III) quartzite containing hematite; (IV) quartzite containing magnetite.

TABLE 1

Component	k	$(k\rho c)^{1/2}$	D
I	(a) 0.001–0.002 (b) 0.005	(a) 0.0170–0.0278 (b) 0.0510	(a) 0.002–0.003 (b) 0.009
II	0.006	0.0604	0.01
III	0.005	0.0623	0.01
IV	0.005	0.0497	0.01

NOTES.—(i) k is the thermal conductivity in cal. ° C.$^{-1}$ cm.$^{-1}$ sec.$^{-1}$;
(ii) $(k\rho c)^{1/2}$ is the thermal absorptivity as hereinbefore defined;
(iii) D is the diffusivity, i.e., the thermal conductivity divided by the product of density and specific heat, in cm.^{2} sec.c.$^{-1}$;
(iv) Figures (a) for k, $(k\rho c)^{1/2}$ and D are in respect of properties measured normal to the long axis of the crocidolite fibres;
(v) Figures (b) for k, $(k\rho c)^{1/2}$ and D are in respect of properties measured parallel to the long axis of the crocidolite fibres;
(vi) Smaller values of figures (a) are associated with relatively loosely compacted fibres.

In naturally occurring ore, the seams of crocidolite are such that the long axis of the fibres is always normal to the rock in which they are embedded. It follows from the values of $(k\rho c)^{1/2}$ in Table 1 for component I(a) that when a heat flux impinges on a specimen of ore bearing exposed seams of the above components, the rate of inward diffusion of heat from the crocidolite surface will be relatively less than the rate of diffusion from the surface of the other components. Correspondingly, the temperature of and emission of radiant heat from asbestos can be expected to be relatively high compared with the temperature of and emission of radiant heat from these other components.

It has been found in practice that when an asbestos-containing rock specimen is heated by a directly impinging flame, the seams of asbestos rapidly attain a much higher temperature than the surrounding rock.

In the case of a typical rectangular block of crocidolite, 1 cm. x 3 cm. x 4 cm., heating for 2 seconds with a directly impinging coal/air flame (heat flux 25 watts per square centimetre) was shown to effect a rise in surface temperature from 20° C. to 280° C.; and after an interval of 3 seconds, the temperature of the same surface had fallen to 140° C. On the other hand, in the case of a typical rectangular block of quartzite having the same dimensions, heating for 2 seconds with the same flame was shown to effect a rise in quartzite surface temperature from 20° C. to 185° C.; and after an interval of 3 seconds, the temperature of the same surface had fallen to 95° C.

In Table 2 we give figures for selected thermal properties in the case of two major components of clinoptilolite

ore. The components are herein identified as (V) clinoptilolite; (VI) basalt.

TABLE 2

Component	k	$(k\rho c)2$	D
V	0.0015	0.0223	0.004
VI	0.005	0.0507	0.01

From Tables 2 and 1 it can be seen that the thermal properties of clinoptilolite and basalt closely resemble the thermal properties of crocidolite (measured normal to the long axis of the fibres) and quartzite respectively. It is to be expected therefore that when a clinoptilolite-containing rock is heated by a directly impinging flame, the seams of clinoptilolite rapidly attain a much higher temperature than the surrounding rock.

In the case of a typical rectangular block of clinoptilolite, 1.5 cm. x 1.5 cm. x 2.5 cm., heating for 2 seconds with a directly impinging coal gas/air flame (heat flux 25 watts per square centimetre) was shown to effect a rise in surface temperature from 20° C. to 280° C.; and after an interval of 4 seconds, the temperature of the same surface had fallen to 130° C. On the other hand, in the case of a typical rectangular block of basalt having the same dimensions, heating for 2 seconds with the same flame was shown to effect a rise in basalt surface temperature from 20° C. to 180° C.; and after an interval of 4 seconds, the temperature of the same surface had fallen to 90° C.

We have now developed a physical method of sorting rocks containing a mineral of relatively low thermal absorptivity from barren rocks of relatively high thermal absorptivity based on three procedural steps:

(a) Exposing unsorted rocks individually to a heat flux for a period of time sufficient only to render exposed mineral detectably more infrared emissive than host rock;

(b) Submitting the heated rocks while detachably differentially infrared emissive to individual examination by known infrared detection means in activating relationship with known sorting means;

(c) Activating the sorting means in response to signals received from the infrared detection means.

The success of the method has been found to depend primarily on control of heating whereby unsorted rocks are obtained in such a differentially infrared emissive condition that they are adapted for sorting by steps (b) and (c).

In a more particular embodiment of the invention, rocks containing a mineral of relatively low thermal absorptivity are sorted from barren rocks of relatively high thermal absorptivity by a method comprising:

(a) Exposing substantially dry unsorted rocks individually to a heat flux for a first period of time t_1 sufficient only to render exposed mineral detectably more infrared emissive than host rock;

(b) Submitting the heated rocks during a second period of time t_2 in which the rocks are still detectably differentially infrared emissive to individual examination by known infrared detection means in activating relationship with known sorting means;

(c) Activating the sorting means in response to signals received from the infrared detection means whereby to sort rocks containing said mineral of low thermal absorptivity from said barren rocks of relatively high thermal absorptivity;

said first period of time t_1 being characterized in not exceeding $W_a^2/8D_r$ seconds, and said second period of time t_2 being characterized in that the sum of t_1 and t_2 does not exceed $W_a^2/4D_r$ seconds, where W_a is the width in centimetres of the smallest mineral seam which by steps (a) and (b) can be detected as differentially infrared emissive in relation to host rock, and D_r is the diffusivity of the host rock in cm.^{2} sec.$^{-1}$.

The invention is described hereinafter with particular reference to the sorting of rocks containing crocidolite asbestos from barren rocks, but it will be understood that the method is equally applicable to the sorting of rocks containing other types of asbestos (e.g., chrysotile, amosite, tremolite, actinolite) from barren rocks. Similarly, the invention is applicable to the sorting of rocks containing other minerals of relatively low thermal absorptivity (e.g., clinoptilolite) from barren rocks of relatively high thermal absorptivity.

The following is a typical sequence of steps in applying the invention to the sorting of crocidolite ore:

(1) After mining, the ore is crushed to a suitable rock size, e.g., between +2.5 and −10 centimetres.

(2) The rocks are preheated in a hot gas stream to remove surface moisture and are subjected to a high velocity jet of air to remove surface dust.

(3) The rocks are contacted individually for a period of time between 0.01 and 0.1 second with the flame of a burner of appropriate heat flux (e.g., propane/air, with a heat flux of about 100 watts per square centimetre; or, acetylene/oxygen, with a heat flux in excess of 200 watts per square centimetre).

(4) The heated rocks are conveyed through 5–60 centimetres at a speed of 150–300 centimetres per second to an infrared detection zone where radiation emitted by each individual rock is focussed by mirrors on to a battery of detectors comprising, e.g., Kodak N2 lead sulphide cells. (Kodak is a registered trademark).

(5) When the signal from the infrared detection means reaches a predetermined level, a sorter mechanism is activated and rocks are thereby separated into those having a commercially valuable asbestos content and those which are barren, i.e., have an asbestos content so low that they are preferably discarded prior to mill processing. A suitable sorter mechanism is that described by Hutter and Kelly in previously noted U.S. Patent No. 3,011,634 and Australian Patent No. 223,683.

Actual signal to background ratios obtained in the infrared detection of differentially infrared emissive asbestos-containing rocks will depend, of course, on a number of factors. Important factors are discused in detail below.

CONDITION OF EXPOSED ASBESTOS

It is theoretically predictable and experimentally verifiable that the presence of loosely compacted fibres in an asbestos surface enhances the signal to background ratio obtained with an infrared detector. This effect is related to the relatively low value of $(k\rho c)^{\frac{1}{2}}$ for loosely compacted fibres (see Table 1, note (vi)). Thus, when a kerosene/air flame was applied for 5 seconds to a clean specimen of rock containing a 6 millimetres wide seam of exposed asbestos without loosely compacted fibres, infrared detection after a delay of 0.3 second indicated an average asbestos surface temperature of 120° C. and the signal to background ratio obtained was 4:1. However, when the same flame was applied to a clean specimen of rock containing a 6 millimetres wide seam of exposed asbestos bearing loosely compacted fibres, the loosened fibres reached a temperature of the order 1,000° C. during application of the flame and were seen to glow. At about 0.05 second after application of the flame the temperature of the loosely compacted fibres was of the order of 600° C.; and at about 0.3 second after application of the flame the average asbestos surface temperature was 150° C., the signal to background ratio then obtained being 8:1.

Using acetylene/oxygen flames we have recorded signal to background ratios as high as 700:1 in cases where there have been wide seams of exposed asbestos (i.e., seams of width greater than 6 millimetres) bearing loosely compacted fibres.

It seems probable that in some cases these improvements in performance for crocidolite containing loosely compacted fibres are related to local fusing of fibres to form a glassy material.

In practice, physical damage of asbestos surfaces is commonplace in mining and crushing operations; the ore is thus naturally made available with its surface asbestos in a loosely compacted condition favourable for the practice of the invention. Should this condition not be achieved naturally, it may be desirable in some cases to loosen asbestos surfaces by, for example, tumbling the pieces of ore in a revolving cylinder to cause attrition between the rock and asbestos seams.

SEAM WIDTH

From Table 1, it can be seen that the thermal conductivity value (*b*) for crocidolite (i.e., *k* measured parallel to the long axis of the fibres) is of the same order as the thermal conductivity values for the recorded host rock components.

As noted previously the fibres of crocidolite in naturally occurring ore are always normal to the rock in which they are embedded. Consequently, a heated seam of crocidolite loses heat comparatively rapidly to the adjacent host rock.

In general, the time taken for essentially all of a quantity of heat to travel a distance x in a solid material is given by $x^2/4D$, where D is the diffusivity of the material. It can be seen therefore that the rate at which heat can be lost from a seam of crocidolite in host rock is markedly dependent on the width of the seam.

In Table 3 we record comparative results for heating clean specimens of rock containing crocidolite asbestos seams of varying width. In each case: there were no loosely compacted fibres on the surface of the asbestos, a heat flux for 1 second was provided by a directly impinging acetylene/oxygen flame, and a period of 0.3 second elapsed between heating and infrared detection.

TABLE 3

Ore surface	Seam width (millimetres)	Detected temperature, ° C.	Ratio, signal to background
Rock		80	1:1
Asbestos	1.5	150	11:1
Do	4.5	170	20:1
Do	7.5	210	56:1

HEAT FLUX

To some degree, usefully differential heating of wide seams of asbestos in relation to host rock may be achieved by employing flames of relatively low heat flux (e.g., kerosene/air, coal gas/air). However, for a commercially successful separation of asbestos-containing rocks from barren rocks, it has been found that the applied heat flux should not be less than 70 watts per square centimetre. Preferably, the applied heat flux should not be less than 100 watts per square centimetre. Heat fluxes meeting this requirement can be provided by propane/air or fuel/oxygen flames.

In Table 4 we show comparative results for heating clean rocks containing crocidolite asbestos seams of width 1.5 millimetres with flames of different heat fluxes. In each case: there were no loosely compacted fibres in the surface of the asbestos, and a period of 0.3 second elapsed between heating and infrared detection.

TABLE 4

Flame	Heat flux (watts/cm.²)	Ore Surface	Detected temperature, ° C.	Ratio, signal to background
(i)	30–50	Rock	90	1:1
		Asbestos	100	2:1
(ii)	100	Rock	60	1:1
		Asbestos	120	10:1
(iii)	200	Rock	80	1:1
		Asbestos	150	11:1

NOTES.—(i) kerosene/air applied for 5 seconds; (ii) propane/air applied for 1 second; (iii) acetylene/oxygen applied for 1 second.

It will be understood that flame heating is a preferred rather than an essential method of providing the required heat flux. Alternative methods of heating are possible, but may be inconvenient (e.g., using a muffle or tube furnace at temperatures in excess of 1,000° C. or using focussed radiation from the sun or an electric art).

TIME FACTORS

The physical nature, shape and condition of pieces of asbestos ore make it necessary to observe certain limitations of time in respect of (a) the period of exposure to the heat flux, and (b) the period then allowed to elapse before transference to the infrared detection zone. These time factors are considered below.

Period of heating

When the surfaces of a rectangular solid are exposed uniformly to equal heat fluxes, it can be shown mathematically that the rise in temperature of a two- or three-dimensional corner is respectively twice or three times as great as the rise in temperature of a plane surface.

In the normal practice of the invention, the rise in temperature at a corner junction between any two facets of the same material will be greater than the rise in temperature occurring at either facet.

The relative temperature rise at a two- or three-dimensional corner of a uniformly heated solid is effectively distributed to a distance x from the corner proportional to $2(Dt)^{\frac{1}{2}}$, where D is the diffusivity of the solid in cm.² sec.$^{-1}$ and t is the period of exposure to the heat flux in seconds. It follows therefore that the distribution of temperature about a corner of a heated body can be reduced by reducing the period of heating.

In applying the above principles to the sorting of rocks containing asbestos according to the present invention it can be seen, firstly, that the possibility of interpreting the infra-red emission from a corner region of host rock as infrared emission from an asbestos seam will be low if the period of heating is adjusted to a suitably low figure.

Secondly, pieces of asbestos ore as mined are often found to have flakes of rock, e.g., 2–3 mm. in thickness, adhering to their surfaces. When such pieces are exposed to a heat flux beyond a certain period of time, these flakes can simulate the infrared emissive behaviour of asbestos seams.

Thirdly, prolonged exposure to a heat flux—apart from being uneconomical—is disadvantageous in the practice of the invention since it leads to a roughly uniform temperature over the whole surface of an asbestos-containing piece of rock and the differential infrared emission of asbestos in relation to host rock may then be reduced to an undetectably low value.

For reasons such as these it has been specified in the present invention that t_1, the period of exposure to the heat flux, preferably should not exceed $W_a^2/8D_r$, where W_a is the width in centimetres of the smallest seam of mineral of relatively low thermal absorptivity which can be rendered detectably infrared emissive in relation to host rock of relatively high thermal absorptivity, and D_r is the diffusivity of host rock (i.e., the quotient $k/\rho c$ in cm.² sec.$^{-1}$). This maximum has been deduced mathematically on the basis of a theoretical model and has been verified experimentally as valid in practice.

In general, pieces of rock containing seams of asbestos of width down to as little as 1.5 millimetres are regarded as attractive for commercial exploitation and the above specified maximum for t_1 (the period of exposing asbestos ore to the heat flux) corresponds in practice to a condition that a piece of rock containing a seam of exposed asbestos substantially 1.5 millimetres wide should be detectably differentially infrared emissive at 0.1 second after exposure to the heat flux. In general, the ore is regarded as detectably differentially infrared emissive when the difference in temperature between seams of asbestos and host rock is not less than 30 centigrade degrees.

There is no required minimum period of exposure to the heat flux, and—within limits imposed by the available infrared scanning equipment and signal analyser—preferred heating periods are the shortest possible.

Period between heating and detection

Signal to background ratios are also markedly affected by t_2, the time period allowed to elapse between heating and infrared detection. If this time lag is too long (greater than 4 seconds in the case of a seam of crocidolite of width 4.5 millimetres), heat diffuses from the asbestos to the surrounding host rock and the temperature difference is reduced to an undetectably smaller value.

In the case of substantially dry pieces of ore, it has been deduced mathematically and verified experimentally that (t_1+t_2), the total time elapsing between initial exposure to the heat flux and transference to the infrared detection zone, can have any value not exceeding $W_a^2/4D_r$, where W_a and D_r have the significance previously given herein. The presence on the ore of particles of dirt and/or stray asbestos fibres imposes additionally a lower limitation on the period that should elapse between heating and transference to the infrared detection zone. Such particles and/or fibres are raised rapidly to a very high temperature by an impinging flame, and—if not allowed to cool before transference to the infrared detection zone—can be recorded spuriously as regions of asbestos. These contaminants lose heat rapidly however, and it has been found in practice that they are not recorded provided the period between heating and transference to the infrared detection zone is not less than 0.1 second. Alternatively (as in step 2 of the typical sequence of steps outlined above), surface contaminants can be largely removed by subjecting the ore to a high velocity jet of air before exposing to the heat flux.

MOISTURE CONTAMINATION

Slightly moistened asbestos ore can be sorted by the method according to the invention, but the presence of moisture reduces the signal to background ratios recorded by the infrared detection means. Thus, when a propane/air flame was applied for 1 second to a specimen of wet rock containing a 3 millimetres wide seam of asbestos with loosely compacted fibres, infrared detection after a delay of 0.3 second indicated an average asbestos surface temperature of 140° C. and the signal to background ratio obtained was 17:1. However, when the same flame was applied to a specimen of substantially dry rock containing a 3 millimetres wide seam of asbestos with loosely compacted fibres, the average asbestos surface temperature was found to be 200° C. and the obtained signal to background ratio was 90:1. It is for this reason that it is preferred (as in step 2 of the typical sequence of steps outlined above) to dry the ore initially by preheating. "Substantially dry" ore is herein defined as ore containing not more than 0.5% water by weight based on the weight of a rock measuring 3 cm. x 3 cm. x 3 cm.

In practice, mining conditions are such that rock surfaces are usually both dirty and wet, i.e., muddy. While an initial drying operation will serve to remove moisture contaminations, the rock surfaces will still be contaminated with dirt. As previously explained, a certain amount of dirt can be tolerated provided a sufficient period is allowed to elapse between heating and infrared detection; alternatively, the dirt can be largely removed by means of an air jet. However, in some cases the dirt contamination may be so great that it may be advisable to precede the drying step by an initial washing step using water or an aqueous solution of a cleaning agent (e.g., detergent).

ROCK ORIENTATION

No deliberate orientation of rock surfaces is envisaged in the practice of the invention, nonetheless, it is important to ensure that orientation factors do not lead to spuriously low signal to background ratios.

Rock surfaces which are submitted to infrared detection must be the same as those which have been heated, and for this reason it is necessary to avoid re-orientation of rocks between the heating and detection zones. Suitably, this can be achieved by conveying rocks therebetween on a moving belt.

It is also advisable to ensure that those rock surfaces which are submitted to infrared detection are not unrepresentative either of the total surface or of that portion of the total surface which has been directly heated. Suitably, this can be achieved by heating and detecting as much of a total rock surface as possible. Substantially total rock surfaces in one plane can be detected, e.g., by using a revolving mirror drum and a single detector, or by employing a battery of suitably arranged detectors, say, thirty in number.

SHIELDING

It is clear that signal to background ratios are highly dependent on the degree to which the infrared detection zone is shielded from infrared radiation other than that being analyzed. Thus if the pieces of ore are conveyed in a straight line from the heating zone to the detection zone, a moving shield is preferably provided to prevent infrared radiation from the heating zone travelling along the same straight line. Alternatively, shielding can be effected by causing the pieces of ore to travel in a curved path between the two zones. The ultimate limit of sensitivity of the infrared scanning equipment, and hence the minimum usable temperature differential between asbestos and host rock, is dependent very largely on the efficiency of shielding between these zones.

We claim:

1. A method of sorting rocks containing a mineral of relatively low thermal absorptivity from barren rocks of relatively high thermal absorptivity, said method comprising:

(a) exposing unsorted rocks individually to a heat flux for a first period of time sufficient only to render exposed mineral detectably more infrared emissive than host rock;

(b) detecting the infrared radiation emitted by individual rocks during a second period of time in which the rocks are still detectably differentially infrared emissive by translating said infrared radiation into electrical signals diagnostic of the mineral content of each rock;

(c) sorting rocks containing said mineral of relatively low thermal absorptivity from said barren rocks of relatively high thermal absorptivity in response to said diagnostic electrical signals.

2. A method according to claim **1** of sorting rocks containing a mineral of realtively low thermal absorptivity from barren rocks of relatively high thermal absorptivity, characterized additionally in that the infrared radiation is detected in an infrared detection zone shielded from infrared radiation not emitted by the heated rocks.

3. A method according to claim **1** of sorting rocks containing a mineral of relatively low thermal arsorptivity from barren rocks of relatively high thermal absorptivity, characterised by a preliminary step in which the rocks are preheated to remove surface moisture.

4. A method according to claim 1 of sorting rocks containing a mineral of relatively low thermal absorptivity from barren rocks of relatively high thermal absorptivity, characterised by a preliminary step in which the rocks are subjected to a high velocity jet of air to remove surface dust.

5. A method of sorting rocks containing a mineral of relatively low thermal absorptivity from barren rocks of relatively high thermal absorptivity, said method comprising:

(a) exposing substantially dry unsorted rocks individually to a heat flux for a first period of time t_1 sufficient only to render exposed mineral detectably more infrared emissive than host rock;

(b) detecting the infrared radiation emitted by individual rocks during a second period of time t_2 in which the rocks are still detectably infrared emissive by translating said infrared radiation into electrical signals diagnostic of the mineral content of each rock;

(c) sorting rocks containing said mineral of relatively low thermal absorptivity from said barren rocks of relatively high thermal absorptivity in response to said diagnostic electrical signals;

said first period of time t_1 being characterised in not exceeding $W_a^2/8D_r$ seconds, and said second period of time t_2 being characterised in that the sum of t_1 and t_2 does not exceed $W_a^2/4D_r$ seconds, where W_a is the width in centimetres of the smallest mineral seam which by steps (a) and (b) can be detected as differentially infrared emissive in relation to host rock, and D_r is the diffusivity of the host rock in $cm.^2\ sec.^{-1}$.

6. A method according to claim 5 applied to the sorting of rocks containing asbestos from barren rocks of relatively high thermal absorptivity, characterised in that t_1 does not exceed 0.1 second, and the sum of t_1 and t_2 is selected from the range 0.1 to 0.3 second.

7. A method according to claim 5 applied to the sorting of rocks containing asbestos from barren rocks of relatively high thermal absorptivity, characterized additionally by a preliminary step in which the rocks are tumbled to render exposed asbestos loosely compacted.

8. A method of sorting rocks containing crocidolite asbestos from barren rocks of relatively high thermal absorptivtiy, said method comprising:

(i) crushing crocidolite asbestos ore to a suitable rock size;

(ii) preheating the rocks to remove surface moisture and subjecting them to a high velocity jet of air to remove surface dust;

(iii) contacting the rocks individually for a period of time selected from the range 0.01 to 0.1 second with a flame of heat flux at least 70 watts per square centimetre, rendering exposed asbestos detectably more infrared emissive than host rock;

(iv) conveying the heated rocks through between 5 and 60 centimetres at a speed of between 150 and 300 centimetres per second to an infrared detection zone substantially shielded from infrared radiation not emitted by the heated rocks;

(v) in said infrared detection zone detecting the infrared radiation emitted by individual differentially infrared emissive rocks by translating said infrared radiation into electrical signals diagnostic of the crocidolite asbestos content of each rock;

(vi) sorting rocks containing crocidolite asbestos from said barren rocks of relatively high thermal absorptivity in response to said diagnostic electrical signals.

References Cited

UNITED STATES PATENTS

3,011,634	12/1961	Hutter	209—111.5 X
3,114,703	12/1963	Brison	209—11

FRANK W. LUTTER, *Primary Examiner.*