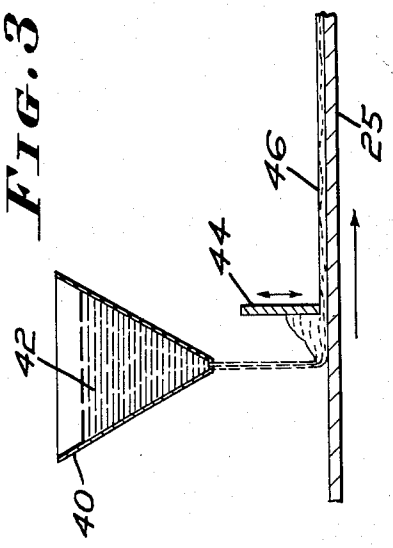
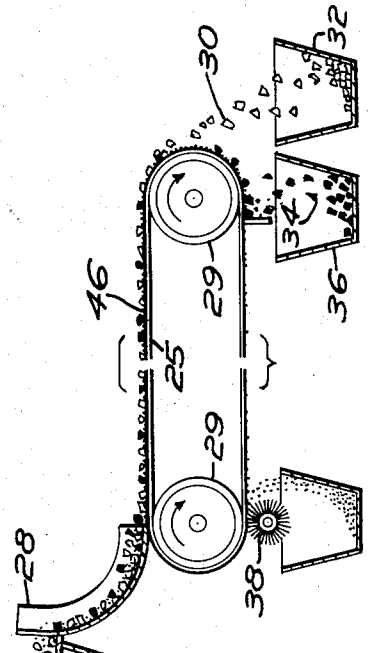
Dec. 17, 1963 R. J. BRISON 3,114,703

SEPARATION OF THERMALLY CONDUCTIVE MATERIALS

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FIG. 3





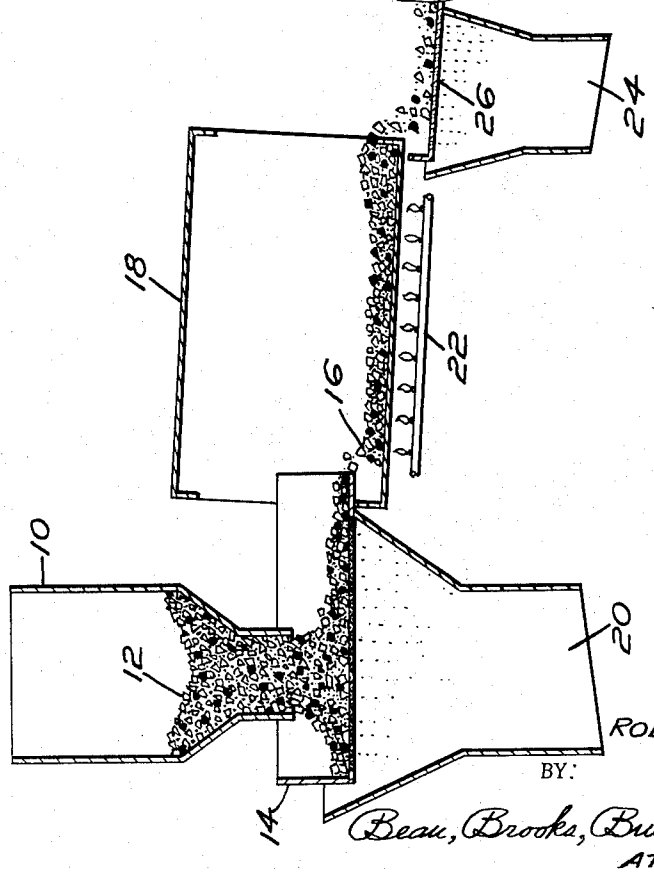


FIG. 1

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SEPARATION OF THERMALLY CONDUCTIVE MATERIALS

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FIG. 4

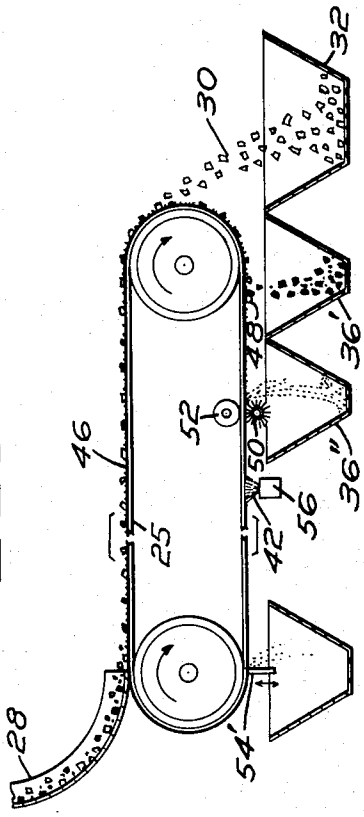
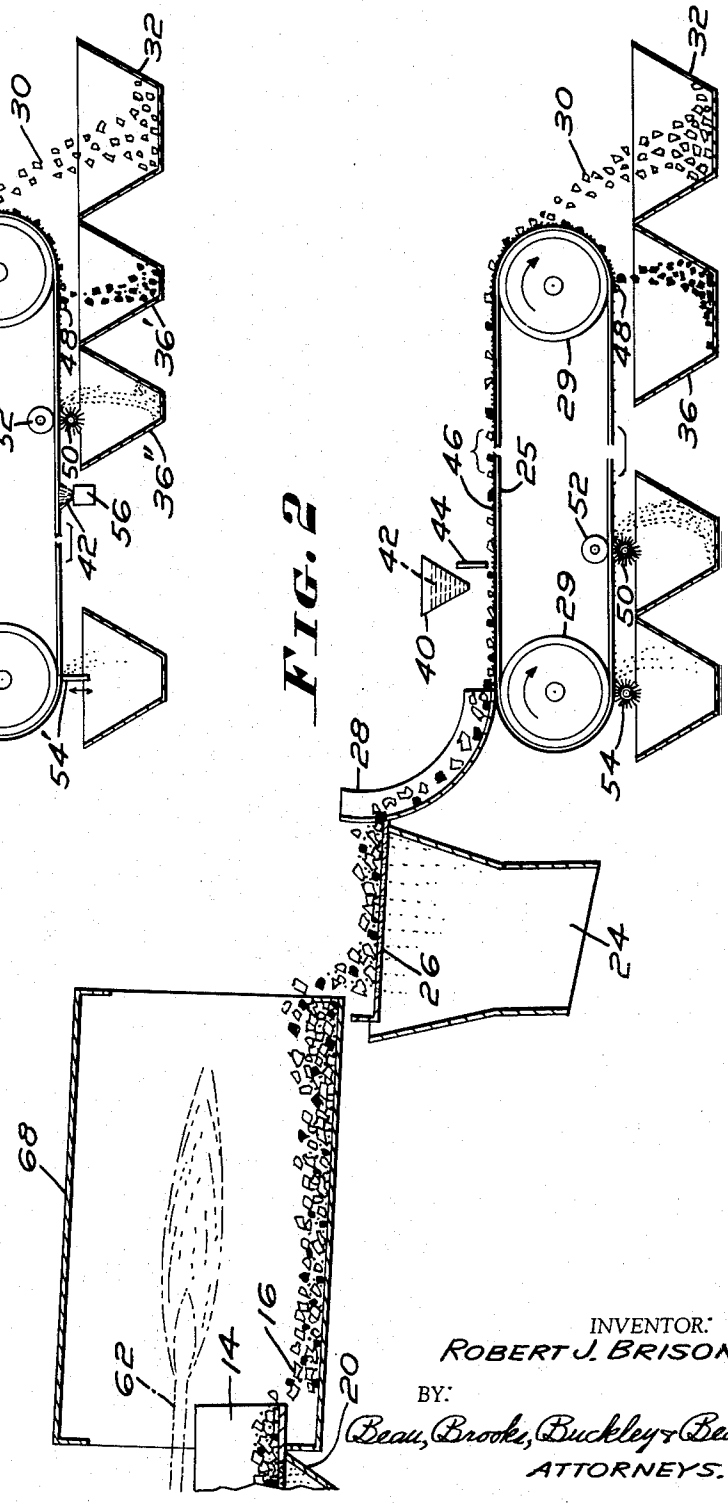


FIG. 2



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United States Patent Office 3,114,703 Patented Dec. 17, 1963

3,114,703

SEPARATION OF THERMALLY CONDUCTIVE MATERIALS

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Filed Aug. 21, 1958, Ser. No. 756,431
3 Claims. (Cl. 209—11)

This invention relates to the separation of materials and, more particularly, to a separation of materials which depend upon the thermal conductivities of the materials being separated.

In co-pending application, Serial No. 661,270, filed May 21, 1957, now Patent No. 2,907,456, there is disclosed a process for separating diathermanous materials from athermanous materials. In this process, the fragments of the materials are differentially heated upon exposure to radiant heat. The variably heated fragments of the material are then separated by any suitable method responsive to the differences in temperatures of the fragments.

This invention relates to the separation of materials differentially heated by contact heating and specifically involves the separation of materials having different heat or thermal conductivities. The term "contact heating" as used hereinafter and in the claims is intended to mean heating by means of conduction, or convection, or both. That is, in contact heating the material to be heated is in actual physical contact with a solid heat source, a liquid heat source, or a gaseous heat source. Many materials exhibit different degrees of thermal conductivity, as evidenced by the fact that some materials will conduct heat better than others. According to their thermal conductivities, the better heat conductors will be relatively hot, while the poor heat conductors will be relatively cool after subjection to contact heating, as, for example, by contact with a solid heat source, a liquid heat source, or a gaseous heat source. This invention contemplates, generally, utilization of the thermal conductivity of materials for the separation of materials from each other; that is, the hotter fragments of the better heat-conductive materials can be separated from the cooler fragments of the poorer heat-conductive materials by any method suitably responsive to the differences in temperatures of the fragments, such as, for example, through use of conveyor means, surface treated so as to be adhesive to greater degree to the fragments of higher temperature. When the heating step is conducted to produce differentially heated fragments according to their thermal conductivities, it preferably should be relatively rapid in order that conduction of heat from the better conductors to the poorer conductors is minimized. The time between the heating step and the separation step should be controlled in order to assure maximum temperature difference at the surface of the particle.

Generally, the procedural steps of the invention preferably include the step of differentially heating a mixture of fragments of materials of different thermal conductivities. This differential heating may be preferably accomplished in a rotary kiln which is either directly or indirectly fired. The size, slope, and speed of rotation of the kiln is selected to provide a relatively short period of contact of the materials with the heat source. The materials are then discharged and spread in a uniform layer, for example, on a conveyor belt coated with a heat-sensitive material, such as a thermoplastic resin. In this instance where the fragments have initially been differentially heated, the separation step should follow closely after the heating step. The fragments of better conducting material selectively adhere to the thermoplastic

resin, both because of its higher temperature and because it conducts heat more readily to the heat-sensitive thermoplastic resin surface. The fragments of the poorer conductive materials, because of the lower temperature, do not adhere to the heat-sensitive surface, or adhere to a less degree than do the better conducting materials. The heat-sensitive surface is then actuated so as to discharge the fragments of the poorer conductive materials separately from the fragments of the better conductive materials.

This invention is particularly applicable to the separation of materials differing appreciably in thermal conductivities, its applicability including utilization as a separating or concentrating process for as-mined materials as well as utilization as a means to separate such materials as metal scrap. The process is especially suitable in the case of mined materials wherein their main or valuable constituent contained therein has a thermal conductivity differing substantially from the gangue or earthy materials associated with it. An example of such as-mined material is found in diamond mining operations. Diamonds are highly thermally conductive as compared to the gangue or earthy material with which diamonds are naturally associated. The mined material, after preliminary size classification or reduction to substantially uniform fragment size if desired, may be fed into a rotary kiln, for example, wherein the diamond fragments are rapidly heated conductively by contact with the hot kiln walls. The ganguelike fragments associated therewith, being of a general earthy nature, are relatively very poor heat conductors and are, therefore, heated to a lesser degree than the diamond fragments. The differentially heated fragments of the mined material may then be separated by the manner referred to above and hereinafter more fully described.

Mention may be made of the utilization of this process also as a means for separating fragments of a mixture of metal scrap as a further example of this process. The thermal conductivities of some metals differ considerably from those of other metals. For example, based upon the approximate coefficients of thermal conductivity, aluminum is about five times more thermally conductive than steel, and both silver and copper are about ten times more thermally conductive than steel. Brass and zinc are approximately twice as conductive in comparison with steel, while nickel exihibits approximately the same thermal conductivity as steel. In the separation of a mixture consisting of fragments of aluminum, copper, silver, brass, and steel, the fragments can be differentially heated and then separated in accordance with their tendencies to adhere to a thermoplastic surface, the tendencies to adhere corresponding to the temperatures of the differentially heated fragments.

In the drawings:

FIG. 1 is a diagrammatic illustration of one form of apparatus, such as may be used by way of example in conjunction with the process of the present invention;

FIG. 2 is a diagrammatic illustration corresponding in part to FIG. 1 and showing a modified form of a feed heating means and a form of apparatus such as may be used in conjunction with the process of the present invention to apply and properly maintain the adhesive coating on the conveyor belt;

FIG. 3 is an enlarged detailed view of the adhesive coating-applying apparatus of FIG. 2, and

FIG. 4 is a diagrammatic illustration corresponding to FIG. 2 but showing another form of apparatus, such as may be used in conjunction with the process of the present invention to apply and properly maintain the adhesive coating on the conveyor belt.

Whereas it will be understood that either the fragments

of the more thermally conductive materials or the fragments of the materials of lesser thermal conductivities in any given mixture may comprise a more valuable material to be recovered from the "impurities" of the mixture being treated; for the sake of brevity and in the interest of simplification of the specification hereinafter, the highly conductive materials will be considered to be valuable or "pure" materials of the mixture and the poorly conductive materials will be considered to be the "impurities" or less desirable constituents of the mix. In the case of separation of metal scrap, of course, all of the separated scrap fragments may be valuable. Therefore, in such instances, such terms as "pure material" or "impurities" should be understood to respectively designate the more conductive materials and the lesser conductive materials and not to necessarily refer to separation of valuable material from worthless material.

By way of example, one form of suitable apparatus for segregation of highly thermally conductive fragments from poorly thermally conductive material fragments is illustrated diagrammatically in FIG. 1 wherein a feed hopper is indicated at 10 as being arranged to receive a mixture of fragmented materials, for example, a run-of-mine output previously prepared and conveyed thereto in any suitable manner, as indicated at 12. Any suitable feeder, such as a reciprocating feeder and preferably a reciprocating screen feed, as indicated at 14, is disposed beneath the hopper 10 for conveying therefrom at a prescribed rate of flow a feed supply of run-of-mine fragments, as indicated at 16, into a heater which may take the form of an inclined rotary kiln, as designated at 18. The aperture sizes of the reciprocating screen feeder 14 may of course be selected of any preferred dimension so as to permit the screen to pass dust and undesirably fine particles into a diversion hopper, as indicated at 20.

As is well known in the material handling art, the cylindrical rotary heating container or kiln 18 may be mounted in any conventional manner for rotation about its longitudinal axis whereby to simultaneously transport the feed material from the feed end to the discharge end thereof and to tumble the material granules along and in contact with the interior surface of the kiln walls during their passage from the feed end to the discharge end so as to conductively and convectively heat the material granules by contact with the heated walls of the kiln and the heated air contained in the kiln. The rotary heating container or kiln shown in FIG. 1 is an indirectly heated kiln heated by a suitable heating unit, such as a fuel gas burner, designated at 22, situated beneath the rotary kiln 18, so as to heat the walls thereof. Thus, as stated above, the tumbled material granules 16 become heated by the conductive transfer of heat from the hot walls of the kiln 18 to the granules. In addition, some heating of the granules will result from convective transfer of heat by the heated air in the interior of the kiln. The better conductors, such as constitute the relatively valuable constituents of the mixture, receive substantial quantities of heat therefrom, and become heated to substantially higher temperatures than do the poorer conductors in the mixture.

The cylinder 18 is arranged to discharge into some suitable chute device for feeding the differentially heated materials onto a separation belt which is indicated at 25. For example, as shown in FIG. 1, the discharge from cylinder 18 may be dropped onto a shaking feeder 26, the bottom of which may be solid or perforated to function as a supplemental dust-screening device as may be preferred. The discharge from the feeder 26 is thereupon delivered to an arcuate-shaped chute 28, designed to deliver the discharged stream of material therefrom onto the moving belt 25 at substantially the same rate of travel as the lineal speed of the belt. The belt 25, of course, may be carried by any suitable pulley device, such as indicated at 29—29 and driven by any suitable power means, as is well understood in the art. If the feeder 26 is perforated for the purpose of screening out any undesirably fine particles, a diversion hopper is provided therefor, as indicated at 24.

In order to enable the belt 25 to separate the relatively valuable and undesirable fragments, the belt may be coated with some suitable substance such as becomes tacky when heated, whereby the relatively hot valuable fragments tend to adhere to the belt to greater degrees than the relatively cool undesirable or impure fragments, as the belt conveys them to the discharge end thereof. The degree of differential heating; the adhesion characteristics of the coating material for the belt; the speed of belt travel; and the length of the belt from feed to discharge end portions thereof, are all selected and correlated so that by the time the fragments reach the discharge end portion of the belt the relatively valuable particles thereof are more firmly adhesively attached to the belt coating, while the relatively impure fragments are substantially unattached to the belt coating. Consequently, as the belt trains over the discharge end pulley thereof, the relatively impure fragments are centrifugally projected within a path range as indicated at 30 so as to be adapted to be caught in a receiver 32, while the relatively valuable particles tend to adhere to the belt throughout a longer length of travel around the end pulley, and subsequently discharge in a different stream or range as indicated at 34 so as to be caught for example in a second receiver 36. Obviously, any number of receivers may be used in lieu of the two receivers as shown to obtain any preferred number of separations of the feed material.

As indicated at 38, a revolving wire brush is preferably arranged to sweep lightly against the coated surface of the return strand of the belt 25 to prevent build-up of a dust layer on the belt coating material, such as would otherwise reduce or nullify the efficacy of the adhesive coating material. The brush 38 may, of course, be powered by any suitable means, such as, for example, by being geared to the conveyor mechanism.

Although the heater unit 18 is shown in FIG. 1 as the revolving cylinder type which is indirectly heated as by the fuel gas burner 22, it is to be understood that any other suitable device may be employed whereby the feed material may be uniformly subjected to contact with the heat source. Thus, the heating unit may be of the flat-bed type of suitable length and slope whereby the fragments of the materials will become heated by contact with the hot base of the flat bed. In addition, the walls of the cylindrical heater container 18 or the base of the flat-bed-type heater unit may be perforated so as to simultaneously remove particles of relatively fine size during the heating operation. Ordinarily, this is not to be preferred for the reason that the perforations decrease the amount of available heat-conductive surface area, and therefore decrease the amount of heat transmitted by conduction. It is also to be understood that suitable heat sources may be used other than a fuel gas burner as indicated at 22 in FIG. 1. For example, the walls of the cylindrical heating unit 18 may be heated by means of electrical heating coils suitably placed in the walls thereof. Alternatively, the heater container 18 may be directly heated in the manner of gas-fired direct-heat rotary kilns, a form of which is shown in FIG. 2, as to be explained.

The adhesive coating material for the belt 25 may be in the form of any suitable natural or synthetic thermoplastic substance or compound of substances. It is, of course, a prerequisite that the material, subsequent to application to the belt 25, will not be sticky at room temperature, because otherwise the valuable fragments will adhere thereto as well as the undesirable substances. Ordinarily the softening point of the adhesive material should be low enough that the pure or highly conductive fragments will stick to it even though they are heated only slightly during the process herein-above described. However, where a high degree of heating is desirable to obtain

a more effective separation, a resin of suitably high softening point should be used. It has been observed that various natural or synthetic adhesive compositions such as are suitable for this work are available on the market.

For example, a synthetic preparation manufactured and sold by the Pennsylvania Industrial Chemical Corporation of Clairton, Pennsylvania, under the trademark "Piccolastic A–50," has been found to provide very suitable results. This material is a soft solid at room temperature, and is defined as a resin polymer of styrene and its homologues, which are produced from mixtures of styrene and styrene homologues such as are obtained from the fractionation of crude solvents obtained from coke oven or gas house gas. These materials are permanently thermoplastic and therefore are readily brushed or spread onto the belt in the manner of any other "hot melt" compound, or by thinning the material with a suitable solvent and then brushing or spraying it on the belt, permitting the solvent to subsequently evaporate.

Another suitable adhesive material for the purpose herein is manufactured and sold by the same concern under the trademark "Piccoumaron"; this material being a coumaron-indene type resin produced by polymerization of the unsaturated petroleum hydrocarbons occurring in coal tar, light oil, etc. Another somewhat similar compound is manufactured and sold by the Nevill Chemical Corporation under the trademark "Paradene"; and another synthetic composition suitable for the purpose is sold under the trademark "Piccolyte" by the Pennsylvania Industrial Chemical Corporation; this composition comprising a pure hydrocarbon thermoplastic terpene resin. Whereas, the synthetic resin compounds referred to specifically hereinabove have been found to be suitable for the purposes herein, they by no means are exhaustive of the list of suitable available materials; and are cited herein merely by way of example.

The apparatus of FIG. 2 corresponds generally to FIG. 1, except that in FIG. 2 there is shown a direct heat rotary kiln and an apparatus by which to apply and properly maintain the adhesive coating on the conveyor belt. The parts of the apparatus in FIG. 2 which are the same as those in FIG. 1 are designated by the same identifying numeral. As in FIG. 1, the feed hopper **10** is arranged to receive the run-of-mine output previously prepared and conveyed thereto in any suitable manner as indicated at **12**. A suitable reciprocating screen feeder **14** is disposed beneath the hopper **10** for conveying therefrom at a prescribed rate of flow a feed supply of run-of-mine fragments as indicated at **16** into a direct fired and heated rotary kiln **68**. The undesirably fine particles which pass through the screen feeder **14** are collected in a diversion hopper, as indicated at **20**. The direct heat rotary kiln **68** is suitably fired by means of a fuel burner **62** which is suitably positioned in the same aperture through which the feed supply of fragments **16** also enter. The heated fragments are collected at the discharge end of the kiln **68** upon the shaking feeder **26** and passed through the arcuate chute **28** and onto the conveyor belt **25** in the same manner as described for the apparatus in FIG. 1. A separation belt **25**, pulley devices **29—29**, and receivers **32** and **36** are as shown in FIG. 1.

Optimum results are obtained by keeping the top surface of the adhesive coating on the belt **25** fresh and uncontaminated because if the adhesive coating picks up too much dust, for example, its effectiveness is reduced. However, it is desired to avoid as far as possible any interruptions to the operations to clean off the belt.

One solution of the problem is to initially apply a relatively thick adhesive coating to the belt, and then progressively remove the outer surface thereof as it becomes contaminated to expose successively fresh and uncontaminated surfaces. An apparatus suitable for carrying out this method is illustrated in FIG. 2 wherein the adhesive coating material can be supplied as from a reservoir **40** disposed upon the upper strand of belt **25** (FIGS. 2–3), and a spreader bar **44** is operatively associated therewith. The reservoir **40** can be heated in any conventional manner (not shown) to maintain the supply of adhesive material **42** therein in a suitably fluid state. The adhesive material is applied to the moving belt **25** as a "hot melt" and accumulates against and is leveled off by the spreader bar **44** which also can be heated in any suitable manner. Thus, the bar **44** spreads the adhesive material to form a coating **46** of, for example, about ⅛-inch thickness on belt **25**. It will be appreciated that control of the application of material **42** to belt **25** to provide the coating **46** can be accomplished in known manner by any conventional means which can include, for example, a discharge valve not illustrated for reservoir.

Once the coating **46** has been uniformly applied, the reservoir **40** is closed to shut off the supply of adhesive **42** and the spreader **44** is elevated, by appropriate means, to avoid interference with feed material being separated on belt **25**. Material is then fed to belt **25** from chute **28** and separation is carried out in the manner previously described. The fragments which are poor heat conductors will follow the path **30** into the receiver **32**, conductors will follow the path **30** into the receiver **32**, and the fragments which are better conductors will drop off the belt **25** and follow the path **34** into the receiver **36**. In this form, a wire **48**, disposed adjacent the return strand of belt **25**, is substituted for the scraper element of FIG. 1 and insures that any fragments which have not previously fallen off belt **25** are forcibly detached. A plastic or fiber bristle brush **50**, rotated in any conventional manner as, for example, by the mechanism driving the belt **25** can be arranged to brush against the coating **46** on the return strand to remove loose dust particles therefrom; and a small roller **52** can be positioned as shown to urge the return strand of the belt **25** against brush **50**.

To continuously clean coating **46** to maintain a fresh, uncontaminated surface thereon for receiving material from chute **28**, a device such as a scraper or wire brush **54** can be provided to bear against the coating **46** on the return strand of belt **25** and to brush the coating **46** in advance of its presentation at chute **28**. This removes the contaminated outer layer of coating **46** and thereby continuously exposes a fresh layer of resin to the material being fed onto belt **25** from chute **28**. When the coating **46** is dissipated, the feed is shut off and a new adhesive coating is applied to the belt as explained above. Thus the adhesive coating is continuously, gradually removed during the separation process to at all times present an uncontaminated, fresh surface or layer to receive the feed supply. Instead of the above-described spread-on method of applying the adhesive coating, brush or spray means such as are well known in the art could be used.

Another method of accomplishing the desired result is to continuously apply a fresh layer or surface of adhesive to the coating **46** concurrently with the separation process, and an apparatus suitable for carrying out this method is illustrated by way of example in FIG. 4. In this instance, the adhesive material **42** is applied to the belt by a suitable spray means as indicated at **56**. The adhesive material is sprayed against the return strand of belt **25**, either intermittently or continuously as may be preferred, without stopping the feed to the belt; and it can be applied as a solution in a volatile solvent, or it can be hot-sprayed thereon without dilution. The coating must be substantially free of solvent and cooled to room temperature by the time it has progressed to the point where the material to be separated is fed onto the belt. Thus, it will be seen that a fresh layer or surface is constantly maintained on the adhesive coating **46** by the addition of fresh adhesive material covering any contamination thereon. Dust particles tending to cling to the belt are removed as much as possible from the adhesive

coating, as by the plastic or fiber bristle brush 50, before application of the new coating by the spray device 56. To obtain a uniform distribution of the resin on the belt 25 the spray 56 can be arranged to traverse the width of the belt either continuously or intermittently. Receivers 36' and 36'' are positioned to receive more thermally conductive fragments and dust particles.

When the coating 46 has built up to an undesirable thickness on belt 25, it can be removed as by means of a brush or by the scraper 54' which can be heated to facilitate its operation. In the alternative, the position of spray means 56 and scraper 54' can be reversed to continuously maintain both a fresh surface and a coating of predetermined thickness.

It will be appreciated that the foregoing methods of, and apparatus for, applying the coating 46 and maintaining a fresh, uncontaminated surface thereon for receiving material to be separated, are given by way of example only and not in a limiting sense. Variations therein and modifications thereof, and other methods and apparatus will occur to those skilled in the art without departing from the spirit of the invention.

The feeder 26, employed as described hereinabove, is essentially for the purpose of leveling off the discharge from the heater 18. By this means, it is possible to obtain a substantially level and uniform flow of materials onto the arcuate-shaped chute 28 and thence to the belt 25. The slope and length of feeder 26 and chute 28 may be adjustable so as to control the length of time between the heating and separation step and thereby assure maximum temperature differential at the surface of the particles. Alternatively, the feeder 26, or chute 28, or both, may be eliminated if it is found that the time lapse from the time of discharge of the heated material from the kiln onto the conveyor belt 25 is such that the initial degree of differential heat in the material is dissipated.

It should be understood that this invention is not limited to the separation of materials whereby the better thermally conductive materials are kept in the hotter condition for adherence to the heat-sensitive coating on the conveyor belt. This invention also includes the separation of materials of different thermal conductivities wherein the materials are initially all heated to a uniform temperature, and then permitted to differentially cool. In this case, the cooling can occur while the fragments are being transported to the separation step by feeder 26 and/or chute 28, or any other suitable transporting means. In such instance, the better thermally conductive materials will loose their heat more rapidly than the poorer thermally conductive materials. When then passed to a conveyor belt, such as conveyor belt 25, the poorer thermally conductive materials being hotter than the better thermally conductive materials will adhere to a greater degree to the heat-sensitive coating than the better thermally conductive materials. Thus, this invention is directed to the separation of materials based upon their respective thermal conductivities regardless of whether the better thermally conductive material is hotter or cooler than the poorer thermally conductive material.

Whereas in the description hereinabove, the highly thermally conductive fragments have been assumed to be the "pure" or valuable constituents of the mixture being treated; it will, of course, be understood that such references were made by way of example only and that in lieu thereof the highly thermally conductive materials of the mix may, in fact, constitute the "impurities" or undesirable constituents while the poorer thermally conductive materials may constitute the "pure" or valuable constituents of the mixture being treated. In addition it is to be understood that this process is not limited only to the separation of valuable materials from undesirable materials for the reason that the process is applicable to the separation of fragments wherein all of the fragments may be valuable, as in the case of separation of metal scrap.

What is claimed is:

1. The process of separating fragments of materials of different thermal conductivities comprising the steps of heating a mixture of said fragments to a substantially uniform degree, then cooling said fragments for a relatively short period of time whereupon the better heat-conductive fragments dissipate their heat faster than the poorer heat-conductive materials, thereby producing a differentially heated mixture of fragments, then placing the mixture in contact with a thermoplastic surface, whereupon the fragments of the mixture tend to adhere thereto to different degrees, and thereupon separately removing from said surface the fragments according to their tendencies to adhere thereto.

2. The process of separating fragments of different thermal conductivities comprising the steps of heating a mixture of said fragments to a substantially uniform degree, then cooling the fragments for a relatively short period of time whereupon the better heat conductors dissipate their heat more rapidly than the poorer heat-conductive materials, thereby producing a differentially heated mixture of fragments, delivering the differentially heated mixture in the form of a flat layer onto a moving conveyor arranged to train around a direction-change device, the mixture receiving-and-conveying surface of said conveyor being of thermoplastic nature, whereby the fragments of the mixture settle upon said surface and tend to adhere thereto to different degrees and therefore project from the discharge end of said conveyor in divergent paths into separate receivers as the conveyor trains around said direction-change device.

3. The process of separating fragments of materials of different thermal conductivities comprising the steps of heating a mixture of said fragments to a substantially uniform degree, then cooling said fragments whereupon the better heat-conductive materials dissipate their heat more rapidly than the poorer heat-conductive materials, thereby producing a differentially heated mixture of materials, placing such differentially heated mixture in contact with a reusable thermoplastic body whereby the fragments of the mixture tend to adhere to said body to different degrees, separately removing the fragments from said body according to their tendencies to adhere thereto, and providing said body with a substantially fresh and uncontaminated surface between uses thereof.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,114,703 December 17, 1963

Robert J. Brison

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 24, strike out "conductors will follow the path 30 into the receiver 32,".

Signed and sealed this 5th day of May 1964.

(SEAL)
Attest:
ERNEST W. SWIDER

Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents