Abstract: Dry processes are described for the separation and recovery of non-ferrous metals from a mixture of non-ferrous metal, plastic, and other components, comprising a series of screening, size reduction, and air gravity table separation steps. Also described are other dry processes for the separation and recovery of non-ferrous metals from a mixture of non-ferrous metal, plastic, and other components, comprising a series of screening and air gravity table separation steps.
DRY PROCESSES FOR SEPARATING OR RECOVERING NON-FERROUS METALS

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority from US provisional application serial No. 60/989,146 filed November 20, 2007.

FIELD OF THE INVENTION

[0002] The present invention relates to separating or recovering non-ferrous metals such as copper and/or zinc from a mixture of metals and other materials such as from the production of automobile shredder residue (ASR), electronic shredder residue (ESR), appliance and white goods shredder residue (WSR), and other multi-component mixtures, without the use of hydrocyclones, water tables or other wet processes or operations. The present invention also relates to separating non-ferrous metals such as copper or aluminum from a mixture such as that produced during the chopping of copper wire, the chopping of aluminum wire, ASR, ESR, WSR, and other multi-component mixtures, without the use of hydrocyclones, water tables or other wet processes or operations.

BACKGROUND OF THE INVENTION

[0003] Copper is recovered and recycled from an array of different sources. One such source is from automobiles. End of life vehicles are typically first processed by dismantlers who remove components for reuse and prepare vehicles for shredding, mainly by depolluting these vehicles. Reuse rates vary significantly depending on the vehicle model. Wheels, transmissions and engines, which all contain a significant amount of copper, are the most reused components. Battery
cables and wheels that are not reused are typically removed and disposed of separately. Wire harnesses often remain in the vehicle, as they are difficult to remove and are often not interchangeable with harnesses in other vehicles.

[0004] Shredding companies receive vehicles from dismantlers and process those, along with other waste, into materials of different classes and grades. Copper is included in several products. The fraction that is attached to ferrous metals is isolated from the ferrous stream. Copper wires and large copper parts may also be removed separately from the non-ferrous stream. A large amount of copper is also mixed in with brass and zinc in a product known as heavies. It is believed that another large amount of copper, mainly from wires and electronic components, is part of automotive shredder residue.

[0005] Customers of shredding companies have varying degrees of concern with the levels of copper in their raw materials. Steel mills have the most stringent requirements, as they can only process material with a minimal amount of copper. Shredding companies are aware of these requirements and they adjust their processes accordingly.

[0006] The Institute of Scrap Recycling Industries, Inc. (ISRI) issues a publication "Scrap Specification Circular" (ISRI, 2006) which defines grades and specifications for scrap. Regardless of this guide, customers of shredding companies often have their own specifications depending on their products and processes. One example is the copper content allowed in #2 shredded, which may vary significantly. Despite this added complexity, it is rare for non-conforming products to be shipped to a customer. If a batch contains too much copper (e.g., more than 0.20% in #2 shredded) it is typically blended with a batch that contains less copper in order to achieve a desired composition.
Thus, it will be appreciated that control of copper content in recycling and reclamation operations is of increasing interest.

Although wet processes for recovery of certain materials may be useful, such wet processes are typically not employed for recovering copper from particulate mixtures of metals and plastics, as are generated as a result of many shredding operations.

Wet processes require subsequent drying operations of separated copper and other metals, and drying of separated wet plastic. In addition, depending upon the sizes of copper particles, recovery may be poor if the copper particulates are relatively small. Yet another significant disadvantage of subjecting copper to one or more wet processes is that the copper may oxidize.

Accordingly, various dry separation processes have been proposed for separating or recovering copper or other non-ferrous metals from a ground or comminuted mixture of metals and/or plastics. US Patent 5,462,172 to Kumagai et al. describes a non-ferrous material sorting apparatus. US Patent 5,443,157 to Baker et al. is directed to separation and recovery of various components including copper from automobile shredder residue. US Patent 3,905,556 to Drage describes a process for recovery of various metals from crushed or ground scrap. Although satisfactory in many respects, none of these processes provide an efficient and simple separation or recovery of copper from a ground or comminuted mixture containing copper, one or more other non-ferrous metals, and in many instances, plastics.

It is particularly difficult to separate particulate copper from zinc due to the many similarities in their physical properties. The two metals are not readily separable by conventional density-based separation methods because their
densities are not sufficiently different from one another. As a result, most metal recovery operators employ workers to manually separate copper from zinc. As will be understood, this is labor-intensive, costly, and time-consuming.

Accordingly, a need exists for a dry process in which copper can be recovered efficiently and economically from a particulate mixture of other metals or metals and plastic. And, in particular, it would be beneficial to provide a dry process for separating copper from one or more other non-ferrous metals such as zinc.

SUMMARY OF THE INVENTION

The difficulties and drawbacks associated with previous separation and recovery methods are overcome in the present dry methods for recovering and/or separating copper from other non-ferrous metals such as zinc.

In one aspect, the present invention provides a process for recovering copper from a mixture comprising copper and aluminum, zinc, other metallic and non-metallic components. The process utilizes a particular combination of steps, some of which are optional, as follows. The process consists of optionally screening a feed mixture on a device with openings of sufficient size to pass most of the copper therethrough, thereby producing a copper-rich stream containing a higher concentration of copper than the feed, and a reject stream. The process also consists of reducing the particle size of the copper-rich stream to a particle size less than 12 mm, and preferentially reducing the size of zinc particles more than that of copper particles to form a size-reduced stream. The process also consists of screening the size-reduced material to produce at least two product streams, each stream having a narrower particle size distribution than that of the sized-reduced stream. The process also consists of using an air gravity table-type separator to
recover a copper product that is substantially free of non-copper components from one or more of the product streams generated in the screening operation. The process may include optionally recycling at least one product stream from the screening operation and directing that stream to the size reducing operation for additional size reduction. And, the process may include optionally recovering additional copper from the reject stream by directing the reject stream to at least one of the size reducing operations, the screening operation, and the air gravity separator operation. Additionally, the process may also include optionally further purifying the copper-rich stream from the air gravity separator operation using an air gravity table-type separator.

[0015] In another aspect, the present invention provides a dry process for separating copper from a mixture including copper and zinc. The process comprises providing a comminuted feed including copper and zinc. The process also comprises directing the feed to a size reducing operation to produce a first output, whereby zinc particles are reduced to a smaller average size than copper particles in the first output. The process additionally comprises directing the first output to a screening operation to produce at least a second output and a third output, each of the second output and the third output having a narrower particle size distribution than that of the first output. The process further comprises subjecting the second output to a first air gravity table separation operation to form a fourth output that includes copper and is substantially free of non-copper components. And, the process comprises subjecting the third output to a second air gravity table separation operation to form a fifth output that includes copper and is substantially free of non-copper components.

[0016] In yet another aspect, the present invention provides a process for separating copper and zinc from a feed derived from a shredding operation. The
process comprises obtaining a ground feedstock that includes copper and zinc. The process also comprises directing the ground feedstock to a size reducing operation producing particulates of zinc and copper, wherein the feedstock is subjected to impact forces such that the zinc fractures into a greater number of particulates than the copper. And, the process comprises separating the zinc particulates from the copper particulates on the basis of differences in size between the zinc particulates and the copper particulates.

[0017] In a further aspect, the present invention provides a process for separating copper particulates and zinc particulates from one another. The process comprises providing a feed derived from one or more shredding operations, the feed comprising copper and zinc. The process further comprises directing the feed to a first size reducing operation to produce a first stream including copper particulates and zinc particulates. The process also comprises directing the first stream to a first size separation operation to produce a second stream of large particulates and a third stream of relatively smaller particulates. The process additionally comprises selecting one of the second and the third streams and directing the selected stream to a first air gravity separation operation to remove organic materials from the selected stream and produce a fourth stream including copper particulates and zinc particulates. The process also comprises directing the fourth stream to a second size separation operation to produce a fifth stream of large particulates and a sixth stream of relatively smaller particulates. And, the process comprises directing the sixth stream to a second air gravity separation operation to produce a copper-rich stream and a zinc-rich stream.

[0018] As will be realized, the invention is capable of other and different embodiments and its several details are capable of modifications in various respects,
all without departing from the invention. Accordingly, the drawings and description are to be regarded as illustrative and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Figure 1 is a process schematic illustrating a preferred embodiment process for recovering a non-ferrous metal from a mixture.

[0020] Figure 2 is a process schematic illustrating another preferred embodiment process for recovering a non-ferrous metal from a mixture.

[0021] Figure 3 is a process schematic illustrating yet another preferred embodiment process for separating copper and zinc and recovering these metals from a mixture.

[0022] Figure 4 is a process schematic illustrating another preferred embodiment process for recovering non-ferrous metals from a mixture.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] Various preferred embodiment processes are provided whereby copper and zinc particulates can be readily separated from each other, and/or recovered and from a particulate mixture comprising non-ferrous metals and other materials such as various plastics. Additional preferred embodiment processes are provided for a dry recovery strategy whereby one or more non-ferrous metals such as copper can be recovered from a particulate mixture comprising plastic and potentially other metals. Each of these strategies are described in detail herein.

[0024] Each of these strategies and their associated preferred embodiment processes utilize at least two of the following operations: one or more coarse, medium, or fine screening operations, one or more size reducing operations, and
one or more air gravity table separations or the like. Before turning attention to the strategies and associated preferred embodiment processes in accordance with the present invention, it is instructive to review each of these operations individually.

SCREENING

The various screening operations described herein may include coarse screening, medium screening, and fine screening operations. The screening operations, as will be appreciated by those skilled in the art, generally involve depositing particulate, e.g. ground or comminuted, material upon a moving apertured member such as a screen, perforated plate or fabric. Typically, the motion is reciprocating and/or vibratory in nature. And, the path of motion may involve circular motion, elliptical motion, and/or straight line motion. Additional types of motion and combinations of these motions are also contemplated. One or more types of movement may be applied to the apertured member to accomplish varying degrees and types of separation of the particulate material deposited thereon. The apertured member may be oriented horizontally, or may be disposed at one or more angles of tilt during a screening operation. The apertures may be round, square or rectangular in shape.

[0025] Preferably, the screening operation is performed by a separator such as a round separator device such as those commercially available from Sweco, Inc. of Florence, Kentucky. Another example of a preferred separator is a screener available from Rotex Inc., of Cincinnati, Ohio.

[0026] In the description of a preferred embodiment process according to the present invention for dry recovery of non-ferrous metals, and typically from a mixture of such metals with ground plastic as provided herein, a screening operation is performed in such a manner that pieces of wire and cable, being non-ferrous metals,
can be readily separated by use of a screen or other apertured member having a plurality of openings in which the length of the openings is greater than the width of the respective opening. Screens exhibiting such a characteristic are referred to herein as a "rectang" screen. This is a significant feature that can be utilized in a wide array of applications. This feature is described in detail in conjunction with screening operations used in a preferred process for a dry recovery of non-ferrous metals from wire and cable pieces, described later herein.

SIZE REDUCTION

[0027] One or more size reduction operations may also be performed in the various preferred embodiment processes described herein. A preferred device for performing a size reduction operation is a granulator, pulverizer, or hammer mill. Typically, hammer mills utilize a series of rotating or spinning hammers, that upon impact with a solid feed, break or fracture the feed into smaller pieces. Granulators employ a series of rotating or spinning blades and one or more stationary blades. Feedstock is sheered in between the spinning "fly" blades and the stationary "bed" blades into smaller pieces. Pulverizers typically use some arrangement of fixed and moving blades to rip, shear, and shatter particles into smaller pieces. Yet another type of size reduction device may utilize a series of opposing plates or other members that crush or otherwise exert a compressive force on the feed material to break or otherwise fracture the material into smaller pieces. In all of these devices, grating is often used to remove the smaller pieces while the larger pieces remain in the cutting chamber and are again comminuted in between the moving and stationary blades.
An example of a preferred granulator for use in the preferred embodiment processes described herein are those available from Cumberland Engineering Corporation of South Attleboro, MA. Another example of a suitable granulator is a Nelmor granulator available from AEC, Inc. of Schaumburg, IL.

In the description of a preferred embodiment process for the dry separation of copper from zinc provided herein, a size reducing operation is performed in such a manner that zinc particles are preferentially reduced to an average smaller size than copper particles. This is a significant feature which can be used in numerous other applications and operations in accordance with the present invention. This feature is described in detail in conjunction with size reducing operations used in a preferred process for a dry separation of copper from zinc, described in detail later herein.

**AIR GRAVITY TABLE SEPARATION**

Air gravity tables and destoners operate by flowing dry particulate material over a tilted vibrating screen or other apertured member. Heavy particles tend to march up the table, while lighter particles lose traction due to the air flow and tend to move down the table. The separation of light and heavy particles can be due to differences in specific gravity or simply due to differences in size. The air flow may result from two configurations, either via a pressurized flow in which a fan is positioned under the vibrating screen and air is blown up through the screen, or a vacuum approach, in which the device is completely enclosed and uses a fan mounted away from and typically above the device that creates a suction or air flow through the screen. Destoners typically have only two outlets -- one at each end of
the vibrating screen. Gravity tables are inclined in two planes and have a plurality of outlets.

[0031] The basic principle of an air gravity table separation involves flowing dry material over an inclined, vibrating, screen covered deck. A steady air flow holds a portion of the material in stratified flotation above the deck. The lighter material stays in the upper strata as it flows down the inclined vibrating screened deck. The heavier material, such as stones, coarse sand, glass, metal, etc., travels up the inclined vibrating deck and out of the device. The screened deck transfers momentum to the heavier particles that are in contact with it and sends these particles up the slope. The lighter particles, partially suspended above the screened deck, lack sufficient hard contact for good momentum transfer from the deck, and tend to be carried downward by gravity.

[0032] More specifically, an air gravity table or a destoner is comprised of a deck, typically having a rectangular (or a rectangle with a truncated corner) shape, and covered with a screen or mesh. Optionally, on top of the mesh may be ripples, i.e. raised bars running perpendicular to the feed side of the table, mounted in a near flat position, on a supporting frame that allows the table to slide along a longitudinal axis of the table. Air is continuously injected or otherwise passed through the porous bed of the table.

[0033] A vibratory or reciprocating motion mechanism is attached to the table, and the mechanism moves the table along the longitudinal axis a distance adjustable between about 0.5 and 1.0 inches and then back to the starting position between 200 and 300 times per minute. This reciprocal movement is typically faster on the reverse stroke than it is on the forward stroke. This shaking movement promotes transport of the concentrates or heavy material to the higher end of the table. An
important operating variable of an air gravity table is the tilt adjustment. Typically, the feed is introduced near the middle of the table. The heavier products tend to move up the slope, while the lighter products move down the slope. Another important variable in an air gravity table operation is the volume of air, and this is typically adjusted by a series of valves, or plate type regulators, allowing more or less air to flow to the deck. It is important to have a uniform flow of air across the deck, to prevent "blow outs". Typically, multiple air regulator points are provided for air tables to promote uniformity.

[0034] Typically, the optimum operating settings are obtained for each particular application, by making minor adjustments to the air flow, longitudinal tilt, stroke length and frequency and the side tilt of the table. Generally, the frequency and stroke relationship are similar to screening operations, i.e., short stroke and high frequency are better for fines, e.g. -80 mesh, while longer stroke and lower frequency are better for coarse material, e.g. 0.125 inches to 80 mesh.

[0035] Preferably, and for certain applications, feed is introduced to the air gravity table in a narrow size range. For air tables to function effectively, the feed is preferably in a narrow size range, usually with a size ratio of about 5:1, from the smallest particle to the largest particle. Air gravity tables can also separate, somewhat, based upon particle shapes, as differing particle shapes react differently in the rising air columns. Such "shape selectivity" can be beneficial or detrimental, depending on the types of materials being separated.

[0036] The optional set of riffles is typically taller on the feed side of the table, and decreases in height towards the tailings side of the table. This allows for quick separation of the larger high density material, and allows more residence time for the
more difficult finer high density particles to separate from the finer low density material.

[0037] Air tables function similar to wet gravity tables, in that the material is preferably fed perpendicular to the riffles, the high density material remains behind the riffles, and the fluidizing air columns rise through the bed of material, relative to Stokes Law and Hindered Settling. This causes settling at differential rates, where the light density material flows above and over the riffles, while the high density material stays close to the desk surface, and follows the riffles to the concentrate discharge.

[0038] Air gravity tables or destoners are commercially available from several sources, such as Forsbergs, Inc. of Thief River Falls, Minnesota.

[0039] Various references and descriptions of processes and operations are provided herein which refer to "copper" and "zinc." It will be understood that those terms refer to the respective elements, i.e. in their metallic form, but also include alloys and compounds containing majority amounts of those elements. Thus, for example, the term "copper" encompasses particles of elemental copper, and/or particles of copper alloys in which copper is the primary component. Similarly, for example, the term "zinc" encompasses particles of elemental zinc and/or particles of zinc alloys in which zinc is the primary component.

**DRY SEPARATION OF COPPER FROM ZINC**

[0040] The present invention provides a preferred embodiment process for a dry separation of copper from zinc, or zinc from copper.

[0041] Non-ferrous mixed metal streams derived from automobile shredder operations, appliance and white goods shredder operations, electronics shredder
operations, or other shredder operations often contain a mixture of zinc, aluminum, and copper along with other tramp materials such as dirt, plastic, rubber, etc. The zinc is often in the form of small flat flakes, while the copper is substantially in the form of wire or chopped wire. Presently, this material is separated by hand into its components, since it is not suitable for even water-table processing. Traditional density-based separation methods are generally unable to separate zinc and copper due to their similar specific gravities or densities, as shown in Table 1 below.

Table 1
Density Values

<table>
<thead>
<tr>
<th>Material</th>
<th>Density Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper, Cu</td>
<td>8.96 g/cm³</td>
</tr>
<tr>
<td>Zinc, Zn</td>
<td>7.14 g/cm³</td>
</tr>
</tbody>
</table>

[0042] In accordance with the present invention, dry processing methods are provided to recover a substantial portion of the copper from this mixture, while simultaneously producing a zinc-rich by-product stream, and a reject stream rich in plastic, rubber, dirt, etc.

[0043] For materials derived from ASR, WSR, ESR, or other streams rich in copper and zinc particles, conventional dry or wet processing cannot recover sufficiently pure copper in an economical fashion. The present invention employs a unique combination of screening, particle size reduction, and air gravity table separation operations to concentrate the copper into a smaller portion of the total stream from which it can be economically separated and recovered.

[0044] A series of process steps described in accordance with the present invention are based upon the following observations. First, copper and zinc have similar specific gravities and cannot be easily separated by air gravity-type separators, or by wet processes such as water tables. Second, copper is primarily in
the form of chopped wire (i.e. truncated cylinders), whereas zinc is primarily in the form of flat flakes or chips (i.e. largely 2-dimensional particles). Third, air gravity-type separators are effective at separating feedstock materials that have a relatively narrow particle size range but dissimilar specific gravities. For example, they are effective for separating aluminum, plastic, and rubber (light components) from copper and zinc (heavy components). However, good separation on an air-gravity-type table is hampered by particles that have a significant difference in "shape factor" - for example a mixture of cylinders and flat flakes. Fourth, at near ambient temperatures, copper is relatively malleable and ductile while zinc is relatively brittle. Therefore in any chopping, hammer-milling, or other size reduction process, flat zinc flakes will tend to "shatter" more whereas copper particles will deform but be less reduced in size. Zinc is reduced in size by both impact and sheering, whereas the copper is reduced in size almost solely by sheering.

[0045] A preferred embodiment process includes a series of sequential operations that are performed on streams derived from automobile shredder residue, appliance and white goods shredder residue, and electronic shredder residue and/or the like for the recovery of non-ferrous metals. Shredder residue streams suitable as feed for this process are largely less than 1 inch top size, and are often less than 0.5 or 0.375 inch top size. For particles in these size ranges, the following process steps can be used - coarse screening, size reduction, fine screening, and air gravity table or destoner separation. Each of these operations are described in greater detail as follows.
Coarse screening

[0046] This operation is optional, but useful if the feed mixture contains zinc particles that are substantially larger than the copper particles. If the feed lacks a sufficient quantity of large zinc particles, or if the recovery of zinc in flake form is not desired, then this step can be by-passed.

[0047] The goal of this optional first screening step is to separate at least a portion of the larger zinc flakes from the bulk of the feed stream. A screen mesh is chosen such that a large fraction of the copper passes through the screen, while the larger zinc flakes remain on top of the screen. Square mesh screens of from about 3 to about 10 mm are particularly useful in this step. The screening means can be mounted on any type of commercially available screener, including a circular-shaped screener such as a Sweco or a square or rectangular-shaped screener such as a Rotex.

[0048] This process step produces two streams ~ an "overs" stream that is zinc-rich is produced, and an "unders" stream, containing a large percentage of the copper, which is leaner in zinc.

[0049] This optional step allows recovery of a portion of the zinc in flake form. However, it can result in the loss of some larger pieces of copper if they are the same size as the zinc flakes.

[0050] A screening step such as this, also protects down-stream equipment from unexpectedly large contaminants that may damage subsequent process equipment. It may be valuable for that reason alone. Should the "overs" contain significant amounts of copper, the "overs" can be further sized reduced off line and returned to the coarse screening operation of the process for subsequent copper recovery.
Size Reduction

[0051] The copper-rich stream from the previous step is subjected to additional size reduction to help limit the range of particle sizes in the mixture and to minimize differences in shape factor. Suitable devices include granulators such as those made by Cumberland, or hammer mills such as those made by Buffalo Hammer Mill Corp. of Buffalo, NY. Size reduction to less than 6 mm is useful. One can do a single reduction, or a multiple step reduction, in which each step produces a smaller particle top size than the previous step. Because of the sensitivity of zinc to impact, it has been found that a granulator with dull blades is actually more effective in this process than one with very sharp blades. Dull blades result in more size reduction by impact than by sheering, a feature which preferentially reduces the size of the zinc particles more than that of the copper particles.

[0052] A grating of 3/8 inch to 1/8 inch in size is useful in this portion of the process. Particles smaller than the grate opening escape the size reduction device, while larger particles are subjected to additional size reduction.

[0053] It is also possible to size reduce, externally screen, and recycle the oversized particles back through the size reduction device in this step.

[0054] A key feature of this step is that zinc, being more brittle than copper, tends to fracture more easily, and is preferentially reduced in particle size relative to the copper. For example, the product from a granulator with a 3.2 mm grate is entirely within 3.2 mm in some dimension. However, while the top size of copper particles may be close to the 3.2 mm grate size, the top size of most of the zinc particles may be less than 1 mm because zinc is more brittle. A key feature of this process is to select a grate and/or external screen combination such that at least
40% and more preferably 60% and even more preferably more than 70% of the zinc particles are smaller than the average size of the copper particles.

[0055] An important aspect of the preferred embodiment processes for performing a dry separation of copper from zinc, is that the size reducing operation is performed such that particulates of zinc, upon impact by a granulator, pulverizer or other like device, tend to fracture more readily and/or to a greater extent than correspondingly sized particulates of copper. Discovery and utilization of this phenomenon enables preferential size reducing operations of zinc over copper.

[0056] Although not wishing to be bound to any particular theory, it is believed that the tendency for zinc particulates to undergo a greater reduction in size as compared to corresponding copper particulates is due to copper being more ductile and more malleable than zinc. Malleability differs from ductility as malleability is the ability to deform upon application of a compressive force, whereas ductility is the ability to deform upon application of a tensile force. During a size reducing operation as described herein, it is believed that particulates are subjected to application of a variety of different forces including compressive, tensile, and shear forces. However, the majority of such forces are likely compressive and shear forces. Copper particulates tend to deform upon application of these forces, whereas zinc particulates tend to fracture and break into multiple pieces of smaller size.

[0057] Therefore, in accordance with a preferred aspect of the present invention, copper can be separated from other less ductile or less malleable metals such as zinc, by subjecting a mixture of copper and zinc, and potentially other metals or materials, to a size reducing operation in which the mixture is subjected to impact forces that fracture the zinc into a greater number of particulates than the resulting copper particulates. The zinc particulates can then be separated from the copper
particulates on the basis of size, as the zinc particulates will on average, be of a smaller size than the copper particulates. The reference to particle size herein, such as the sizes of the zinc particles and copper particles, is with respect to the maximum dimension or span of a particle. Thus, for a particle having a sphere shape, its size as that term is used herein would generally correspond to the diameter of that particle. For a particle having a relatively flat or two dimensional shape, its size would correspond to its maximum span in any one direction, such as its length.

[0058] During this step, a portion of the zinc can be converted into a powder sufficiently fine to be removed by a dust collection system.

Fine Screening

[0059] The granulated material from the previous step is separated into two or more streams each of a narrower particle size distribution than the feedstock to this step.

[0060] A mesh is chosen such that a large fraction of the copper passes through the screen, along with fine zinc, aluminum, dust and dirt. The copper particles are generally longer in one dimension than the other, while the fine zinc, aluminum, and other materials are more symmetrical. Screens with an opening of 3.2 mm or less are useful in this step.

[0061] The screening means can be mounted on any type of commercially available screener, including a circular-shaped screener such as a Sweco or a square or rectangular-shaped screener such as a Rotex.

[0062] The fine product stream is further processed via an air gravity table separation operation described below, while the coarse product stream can be
recovered as is, sent to a separate air-gravity-type separation, or recycled back to the size reduction operation for further particle size reduction.

**Air Gravity Table Separation**

[0063] The fine particles from the fine screening operation with a relatively narrow particle size distribution contain copper, zinc, plastic, aluminum, dirt, and other waste materials. The copper can now be recovered from this stream by an air gravity table-type means such as an air gravity table or a destoner. Typical models of both are manufactured by Forsberg in Thief River Falls, Minnesota. Simple screening is insufficient to produce a good quality copper product, since at least a portion of the zinc, aluminum, organic material and dirt are substantially the same size as the copper, and would report to the copper product stream as contaminants.

[0064] It is possible to separate the copper particles from the mixture on an air gravity table or destoner at this stage due to the resulting narrow particle size distribution. Further, the significant size reduction overcomes the differences in shape factor that would prevent separation of such a mixture in its original state.

[0065] The air gravity table-type separation process such as a destoner generally produces two product streams. A "heavy" product stream consisting of almost 100% copper particulates and/or wire fragments is produced. And, a "light" product stream consisting of virtually all of the plastic, aluminum, and other materials of specific gravity less than that of copper is produced.

[0066] Small particles of zinc also tend to report to the "light" fraction or the dust collector since they are lighter and smaller than the majority of the copper particles.

[0067] In the preferred embodiment process described herein, the output from a size reducing operation is directed to a screening operation. It will be appreciated
that the output from the size reducing operation typically comprises zinc particulates that are of a significantly smaller size than copper particulates in the output. After screening this mixture, one or more output(s) from the screening operation are directed to one or more air gravity table separation operations. These operations produce outputs of substantially all copper, or copper-rich outputs that are substantially free of non-copper components. These terms refer to copper concentrations of at least 80% by weight, more preferably at least 90%, more preferably at least 95%, and most preferably at least 98% by weight.

Although the preferred embodiment processes for separating copper and zinc, or for recovering copper from a mixed stream of non-ferrous metals, are dry; the present invention includes subjecting any of the outputs in the preferred embodiment dry processes to a wet process or operation such as the use of a water table or a hydrocyclone. Such wet processes may be used to optionally recover additional copper, such as from a reject stream.

EXAMPLES

The following Examples were conducted using a feedstock derived from the shredding of old automobiles also known as automotive shredder residue, or ASR. The feedstock contained copper, copper wire, zinc, aluminum, and electrical insulation, such as various plastic materials.

Example 1

The following steps were employed to recover the copper from 10,000 grams of feedstock using only dry separation techniques, as depicted in Figure 1.
Coarse Screening

[0071] The feedstock was screened on a circular square-mesh screen with a hole size of 4.75 mm. Processing 10,000 grams of feedstock produced 3100 grams of "overs" and 6900 grams of "unders". The overs consisted of zinc flakes with a small amount of copper contamination, while the unders consisted of a mixture comprising copper wire fragments, aluminum, dirt, dust, and insulation.

Size Reduction

[0072] The "unders" from the coarse screening operation were granulated in a Nelmore granulator with a grate size of 3.2 mm, creating a product stream that was entirely less than 3.2 mm in at least one dimension.

Second or Fine Screening

[0073] The granulated product from the size reduction operation was screened on a vibrating screener with screen sizes of 2 mm and 1.4 mm, producing three streams: 3.2 - 2.0 mm, 2.0 - 1.4 mm and -1.4 mm, with weights of 1850, 2050, and 3000 grams respectively.

Air Gravity Table-Type Separation

[0074] Each of the streams from the fine screening operation was subjected to an air gravity table-type separation on a Forsberg destoner using a steep angle and high air flow. Each separation produced a copper-rich "heavy product", and a reject "light product".

[0075] Processing the -1.4 mm fraction yielded 2908 grams of copper wire fragments with minimal contamination, and 92 grams of aluminum, plastic, dirt, etc.
Processing the 1.4 - 2.0 mm fraction yielded 1820 grams of copper wire fragments with minimal contamination, and 230 grams of aluminum, plastic, dirt, etc.

Processing the 2.0 - 3.2 mm fraction yielded 970 grams of copper wire fragments with minimal contamination, and 880 grams of aluminum, plastic, dirt, metal flakes, etc.

The total yield of copper from all three streams was 5698 grams, which represents more than 90% of the copper in the feedstock.

Example 2

The following steps were employed to recover the copper from 1,000 pounds of feedstock using only dry separation techniques as depicted in Figure 2. This feedstock contained approximately 50 percent by weight copper.

Coarse Screening

The feedstock was screened on a circular square-mesh screen with a hole size of 6.25 mm. Processing 1,000 pounds of feedstock produced 202 pounds of "overs" and 798 pounds of "unders". The overs consisted of predominantly zinc flakes with a small amount of copper contamination, while the unders consisted of a mixture comprising copper wire fragments, aluminum, dirt, dust, and insulation.

Size Reduction

The "unders" from the coarse screening were granulated in a Cumberland granulator with a grate size of 4.75 mm, creating a product stream that was all less than 4.75 mm. Some of the product from this step was lost as dust to the dust collector.
Fine Screening

[0082] The granulated product from the size reduction operation was screened on a vibrating screener with screen size of 1.4 mm, producing 545 pounds of -1.4 mm fine product and 220 pounds of +1.4 mm coarse product. The balance was lost as dust during granulation.

[0083] The fine product from the fine screening operation constituted feed to the air gravity table separation of the process, while the coarse product was put aside for future recycling, re-entering the process at the size reduction operation.

Air Gravity Table-Type Separation

[0084] The fine product from the fine screening operation was subjected to an air gravity table-type separation on a Forsberg destoner using a steep angle and high air flow.

[0085] The "heavy" product from the destoner was 453 pounds of copper wire particles with minimal contamination.

[0086] The "light" product from the destoner was 62 pounds of aluminum, plastic, dirt, and zinc dust.

[0087] Some of the fines in the feed to the Air Gravity table were lost to the dust collector.

[0088] First pass yield of copper was 453 pounds or about 90% of the copper in the feed. Copper product purity was measured at more than 98%. Additional copper can be recovered by this process from the coarse product generated in the fine screening operation by re-introducing it to the process sequence at the size reduction operation.
Example 3

[0089] Figure 3 is a process schematic of another preferred embodiment process in accordance with the present invention. In this preferred process, copper and zinc are efficiently separated from one another and can be independently recovered from a mixed material feed such as a course feed as for example, derived from automotive shredder residue.

[0090] Referring to Figure 3, a course feed is directed to a chopping or other size reduction operation. The size reducing operation can be in accordance with the description of that operation or series of operations as described herein. The stream exiting the chopping stage is then directed to a screening operation, also as described herein. The screening operation preferably separates the ground or comminuted materials on the basis of size. Particles or pieces that are too large are preferably redirected to the feed stream to the chopping operation.

[0091] The product stream from the screening operation is then directed to an air gravity separation operation, which as described herein can be performed using an air gravity table. The air gravity table is preferably operated to separate a relatively dense mixed metal stream and a lighter organic material stream.

[0092] The mixed metals stream is then preferably directed to a second screener which separates the mixed metals stream into two streams on the basis of particulate size. A primary stream containing copper, zinc, and potentially other metals and/or materials, is produced and a secondary stream of excessively sized particles is directed to a second chopping or other size reducing operation. The product from the size reducing operation is then directed to a third screener which removes any excessively sized particulates and redirects those back to the second
chopper. The other stream from the third screener is preferably combined with the primary stream from the secondary screener, and the resulting combined stream sent to a second air gravity separation operation. A copper-rich stream is produced. And a zinc-rich stream is produced. The zinc-rich stream may include amounts of other metals such as aluminum. And, the zinc-rich stream may include other materials such as dirt.

[0093] It will be appreciated that the present invention includes variants of this preferred process.

[0094] A preferred source or type of feed for the various preferred embodiment processes is a feed derived from automotive shredder residue (ASR).

**DRY RECOVERY OF NON-FERROUS METALS FROM WIRE AND CABLE**

[0095] The following description of additional preferred embodiment processes is based on the processing of copper wire and cable, although it is within the scope of the present invention to include aluminum wire and cable, automobile shredder residue (ASR), appliance shredder residue (also known as appliance and white goods shredder residue or WSR), electronic shredder residue (ESR), beneficiate streams derived from ASR, WSR and ESR, and other mixtures containing non-ferrous metals.

[0096] Copper wire and cable typically consists of two main parts, the copper conductor, herein referred to as "copper", and the rubber or plastic insulation, along with any cord, paper, fiber, etc. herein referred to generically as "plastic".

[0097] Current technology for copper recovery from a mixture of copper and plastic involves the chopping of the mixture to a particle size typically less than 20 mm, and often less than 3 to 5 mm, followed by an air gravity table-type separation
of the metallic portion from the plastic portion using devices such as a gravity tables, destoners, and the like. Two product streams result from this separation. A "heavy" product consisting of almost pure copper is produced. And, a "light" product stream consisting of most of the insulation found in the wire and cable, along with some copper wire fragments and copper dust is produced.

[0098] The "light" plastic insulation-rich stream from the air gravity table separation process typically contains 1 to 5 percent by weight copper. The copper is often in the form of copper "dust" and small wires or wire fragments that are not easily separated from the plastic by typical dry processing.

[0099] A common technology used to recover additional copper from the plastic insulation-rich stream is a water table, such as a Deister table. While some additional copper can be recovered, this technology suffers from several disadvantages, including, but not limited to generation of wet copper and wet plastic that require subsequent drying; poor recovery of copper due to the floating of small copper pieces and copper dust on the surface of the water (due to surface tension); potential degradation of the wet copper due to oxidation; loss of fine copper by adhesion to the plastic, fiber, paper, etc. in the feed to the water table; and loss of fine copper (and fine plastic) during any subsequent drying processes due to entrainment into the drying air stream.

[00100] The present invention provides an entirely dry process to recover substantially all of the fine copper from a plastic-rich stream, resulting in greater copper yields and higher copper quality.

[00101] The series of process steps utilized in the preferred embodiment processes focus on the segregation of the copper in a mixed component stream into
a progressively smaller and smaller volume of material, which can ultimately be separated by conventional dry processing equipment.

[00102] The preferred embodiment process for concentrating the copper is based on differences in the shape, size, and specific gravity of the particles. The sequence of process steps in the present invention is based upon several observations as follows. First, the copper wire fragments in the feed have a significant length to diameter ratio, whereas many of the plastic and rubber particles do not, allowing a sorting based on particle shape. Second, air gravity-type separators can separate small copper particles from a mixture only if the large plastic particles have already been removed by some other means. Air gravity-type separators are most effective at separating particles of similar size but dissimilar specific gravity. And third, plastic, rubber, light metals, and other materials can be separated from copper on an air table or destoner if all particles are within a narrow particle size distribution.

[00103] For materials largely derived from wire and cable, conventional processing using air gravity table separation methods has already recovered all of the economically recoverable copper from the wire and cable insulation residue. The present invention uses a unique combination of screening and air gravity table separation operations to concentrate the remaining copper into a smaller portion of the total stream from which it can be economically separated and recovered.

[00104] The present invention could also be used on any copper-rich or aluminum-rich stream regardless of whether it has been previously subjected to one or more recovery processes.

[00105] A preferred embodiment process will be first described as a series of sequential operations that are performed on a plastic-rich stream derived from the
chopping of copper wire and cable. However, it will be understood that the present invention can also be used for streams derived from aluminum wire and cable (wherein the goal is aluminum recovery) and other streams rich in non-ferrous metals.

**Wire and Cable Derived Feedstocks**

[00106] For a feedstock such as that derived from wire and cable fluff, the particle size is generally already small, with a top size less than 12 mm, and more typically less than 6 mm. For particles of this size, the following process steps can be used.

**Screening**

[00107] A variety of screening means can be used to enable the concentration of the copper fragments into a smaller volume stream.

[00108] The screening means can be mounted on any type of commercially available screener, including a circular-shaped screener such as a Sweco or a square or rectangular-shaped screener such as a Rotex.

[00109] Typical screens use a "square" mesh, where the holes in the screen have about the same width and length. If the copper particles are sufficiently small, such screens are very effective. Square mesh screens are also best when both the plastic insulation and the copper particles have the same general shape.

[00110] Streams that contain longer fragments of copper wire, however, can tend to "blind" the screen holes, decreasing screening efficiency, and ultimately ruining the screen. Longer fragments of copper wire are defined as those with a length to diameter ratio greater than 2.
For the removal of longer wire pieces from wire and cable chopping residue, it has been discovered that a hole that is "rectangular" in shape, i.e. where the length of the opening is greater than the width of the opening is more suitable. This is more conducive to the separation of long wire fragments or bent wire fragments from a large volume of plastic without the blinding and plugging issues associated with square screens. Such non-square screens are referred to as "rectang" screens. A provider of such screens is Buffalo Wire in Buffalo, New York.

It is also possible to use a metal or plastic plate with appropriately cut holes or slots instead of a woven screen.

The goal of this screening step is to separate the copper wires and copper dust from the bulk of the plastic. Slot sizes are chosen to allow passage of virtually all of the wire fragments, all of the copper dust, and only about 10% to about 25% of the plastic.

For typical wire and cable operations, a slot width of about 0.75 to about 1.0 mm is useful. The slot length can range from 1 to 50 mm or more. Thus, a range of suitable ratios of width to length for the slots is from about 150:1 to about 1:1. For other materials, the slot length and width can be adjusted to allow preferential passage of the non-ferrous metals while rejecting most of the plastic materials.

The longer the slot, the less stable the screen, so one would ideally select a slot length that is about 1 to 5 times the average length of a wire fragment in the feed. Preferably, the slot length is from about 1.5 to about 3 times the average length of the wire fragment.

This process step produces two streams. An "overs" stream that is essentially copper-free plastic is produced. And, an "unders" stream, containing
virtually all of the copper, and about 10% to 25% of the plastic in the feed is produced.

First Air Gravity Table Separation

[0017] The "unders" stream from the previous step contains plastic, copper wire fragments and copper dust. The copper wire fragments can now be removed by an air gravity table-type means such as an air gravity table or a destoner. Typical models of both are manufactured by Forsberg in Thief River Falls, Minnesota.

[0018] It is possible to separate the copper wire fragments from the plastic at this stage because the rectangular screening in the previous step has removed all of the large plastic particles, leaving only small, light weight plastic particles in the stream. These plastic particles can be more easily separated from the copper wire fragments than larger plastic particles.

[0019] The air gravity table-type separation process produces two product streams. A "heavy" product stream consisting of almost 100% copper wire fragments is produced. And, a "light" product stream consisting of virtually all of the plastic and much of the copper dust is produced. Copper dust is defined as copper particles that are smaller than about 1 mm in their largest dimension.

Secondary Screening

[0020] If there is a significant, i.e. economically attractive, quantity of copper dust in the "light" product from the first air gravity table separation, then it can be recovered by the following optional step.

[0021] The "light" product from the first air gravity table separation is screened over a 0.5 to 1 mm square mesh screen using conventional screener technology.
This includes circular-shaped screeners such as those made by Sweco and square and rectangular-shaped screeners such as those made by Rotex. It is possible to carry out this screening on a square mesh because the first air gravity table separation has removed virtually all of the large copper wire fragments that would tend to blind a conventional "square" screen. Furthermore, the copper and plastic particles are the roughly the same size and shape.

[00122] A "square" mesh screen is preferred because it tends to retain more of the plastic particles (especially flake-shaped particles) while still allowing all of the copper dust to pass through. However, one could use a rectangular-type screen for this step.

[00123] The screen can be woven by any conventional means, or can be in the form of a perforated plate.

[00124] The screening process produces two product streams. An "overs" stream consisting of virtually all plastic is produced. And, an "unders" stream consisting of virtually all of the copper dust, along with some fine plastic particles is produced.

[00125] A flat plate containing round or square holes can be used in lieu of a woven screen for this step.

Second Air Gravity Table-Type Separation

[00126] If there is a significant amount of fine plastic particles in the "unders" stream from the secondary screening separation in the secondary screening operation, the copper dust can be further purified by this optional air gravity table-type separation.
The mixture of copper dust and fine plastic can be easily separated into pure copper and pure plastic using conventional air gravity table-type separation devices such as a gravity table or destoner. Typical models of both devices are manufactured by Forsberg in Thief River Falls, Minnesota. The operating conditions for this separation may be different than those employed in the initial screening operation due to the different size and shape of the feedstock to the present operation.

It is possible to separate the copper dust from the very fine plastic particles because both the plastic particles and the copper particles are in the same size range. Air gravity table-type separation works because the copper and plastic particles have a large difference in specific gravity. Such a separation could not be made on an air gravity table-type separation device without the previous screening step that removed the large plastic particles.

This air gravity table-type separation process produces two product streams as follows. A "heavy" product stream consisting of almost 100% copper dust is produced. And, a "light" product stream consisting of virtually all of the fine plastic is produced.

The net result of all of these process steps is the following product streams. A "coarse" plastic stream that is virtually copper free; a "fine" plastic stream that is virtually copper free; a "very fine" plastic stream that is virtually copper free; a first copper stream consisting of wire fragments that is virtually plastic free; and a second copper stream consisting of "copper dust" that is virtually plastic free.

If necessary, additional size reduction steps can be employed before the first screening step or before the second screening step.
Example 1

[00132] The following Example, illustrated in Figure 4, was conducted using a feedstock derived from the chopping of copper wire and cable, although the present invention can also be used for streams derived from aluminum wire and cable (wherein the goal is aluminum recovery), and for streams derived from automobile shredder residue, appliance shredder residue, and electronic shredder residue for the recovery of non-ferrous metals.

[00133] The feedstock was produced by a wire chopper whose primary business is the recovery of copper from copper-containing wire and cable. The wire chopper chops the wire and cable through a series of granulators into pieces about 3 to 5 mm in size, and then recovers the free copper by means of an air gravity table-type device. The waste product from this process consists largely of the insulation from the wire.

[00134] The feedstock to this preferred embodiment process contained about 4 percent by weight copper in the form of wire fragments and copper dust. The copper content was determined by slurrying the feedstock in a solution with a specific gravity of 1.4, floating all of the polymeric material, and collecting the copper that settled. This copper was washed, dried, and weighed.

[00135] The following four operations were employed to recover the copper from 10,000 grams of feedstock using only dry separation techniques.

First Screening

[00136] The feedstock was screened on a circular screen with rectangular openings purchased from Buffalo Wire Products in Buffalo, New York. The slot
dimensions were approximately 0.9 mm x 37 mm. The screen was mounted on a Sweco circular-shaped screener.

[00137] Processing 10,000 grams of feedstock produced 9100 grams of "overs" and 900 grams of "unders". The overs consisted of virtually copper-free plastic, while the unders consisted of a mixture of fine plastic, copper wire fragments and copper dust.

Air Gravity Table-Type Separation

[00138] The "unders" from the first screening were subjected to an air gravity table-type separation on a Forsberg destoner using a steep angle and high air flow. Processing 900 grams of feed to the destoner resulted in 305 grams of "heavy" product and 595 grams of "light" product. The "heavy" product was almost pure copper wire fragments, while the "light" product consisted of plastic and copper dust.

Second Screening

[00139] The "light" product from the air gravity table-type separation was subjected to screening on a Sweco circular screener using a 0.5 mm screen with a square opening. Processing 595 grams of feed to this step produced 445 grams of "overs" and 150 grams of "unders". The "overs" consisted of essentially copper-free plastic, while the "unders" consisted primarily of copper dust with some fine plastic.

Second Air Gravity Table-Type Separation

[00140] The "unders" from the second screening were subjected to air gravity table separation on a Forsberg destoner using a steep angle and a lower air flow
than used in the air gravity table-type separation. The lower air flow is necessary to keep from blowing the finer materials off the table during the separation process.

[00141] Processing 150 grams of feed to the destoner resulted in 85 grams of "heavy" product and 55 grams of "light" product. Approximately 10 grams of the lightest material was lost as dust to the dust collector.

[00142] The "heavy" product was almost pure copper dust, while the "light" product consisted of fine plastic with a minor amount of copper dust.

[00143] The net results of the process are set forth below in Table 2.

<table>
<thead>
<tr>
<th>Coarse Plastic</th>
<th>9100 grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Plastic</td>
<td>445 grams</td>
</tr>
<tr>
<td>Very fine Plastic</td>
<td>55 grams</td>
</tr>
<tr>
<td>Copper wire fragments</td>
<td>305 grams</td>
</tr>
<tr>
<td>Copper dust</td>
<td>85 grams</td>
</tr>
</tbody>
</table>

[00144] Total copper recovery is 390 grams, for a total copper recovery of 3.9% or approximately 97% of the available copper in the feedstock.

[00145] Total plastic recovery is 9600 grams for a total plastic recovery of 96%.

[00146] The process steps and yields are shown graphically in Figure 3.

Comparative Example 2

[00147] This example is a comparative example, and does not practice the present invention.

[00148] A 10,000 gram aliquot of the same feedstock used in the previous example was processed in a wet system using a Deister water table. The feedstock was first slurried in water and then processed on the table using typical operating parameters.
During the separation process on the Deister table, it was noted that a portion of the fine copper dust floated on the water rather than sinking. Apparently surface tension caused this copper to resist “wetting out” and sinking, causing it to be lost to recovery.

Two product streams were generated as follows. A first product stream containing wet plastic insulation, still contaminated with copper was produced. And, a second product stream containing wet copper, contaminated with plastic insulation was generated.

Examination of the plastic-rich product revealed visible amounts of copper sticking to the wet insulation, especially the fibrous pieces.

Examination of the copper-rich product revealed visible amounts of plastic and fiber entangled with the copper wire fragments.

After drying the following weights were recorded for the product streams as set forth below in Table 3.

| Plastic rich stream | 9806 grams |
| Copper rich stream  | 202 grams  |

The copper recovery was about half of that recovered by the previously described preferred embodiment dry process of the present invention.

The recovered copper stream from this wet process was also of lower purity than that generated by the preferred embodiment dry process of the present invention. The copper stream in the wet process contained pieces of heavy plastic that could not be easily sorted on the Deister table.
Many other benefits will no doubt become apparent from future application and development of this technology.

All patents, published applications, and articles noted herein are hereby incorporated by reference in their entirety.

As described hereinabove, the present invention solves many problems associated with previous type devices. However, it will be appreciated that various changes in the details, materials and arrangements of operations or steps, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art without departing from the principle and scope of the invention, as expressed in the appended claims. In addition, it will be understood that any of the noted operations or steps described herein may be used in conjunction with other operations or steps described herein.
WHAT IS CLAIMED IS:

1. A process for recovering copper from a mixture comprising copper and aluminum, zinc, other metallic and non metallic components, the process consisting of the following steps:

   optionally screening a feed mixture on a device with openings of sufficient size to pass most of the copper therethrough, producing a copper-rich stream containing a higher concentration of copper than the feed, and a reject stream;

   reducing the particle size of the copper-rich stream to a particle size less than 12 mm, and preferentially reducing the size of zinc particles more than that of copper particles to form a size-reduced stream;

   screening the size-reduced material to produce at least two product streams, each stream having a narrower particle size distribution than that of the sized-reduced stream;

   using an air gravity table-type separator to recover a copper product that is substantially free of non-copper components from one or more of the product streams generated in the screening operation;

   optionally recycling at least one product stream from the screening operation and directing that stream to the size reducing operation for additional size reduction;

   optionally recovering additional copper from the reject stream by directing the reject stream to at least one of the size reducing operations, the screening operation, and the air gravity separator operation;
optionally further purifying the copper-rich stream from the air gravity separator operation using an air gravity table-type separator.

2. The process according to claim 1 further consisting of optionally recovering additional copper from the reject stream by directing the reject stream to a wet process being one of a water table and a hydrocyclone.

3. The process according to claim 1 wherein the process is conducted in one of a batch fashion and a semi-batch fashion.

4. The process according to claim 1 wherein the feed mixture is a mixture derived from shredding of automobiles, electronics goods, and/or appliances.

5. The process according to claim 1 wherein the feed mixture is a mixture derived from the shredding of wire and cable or other types of copper-rich material.

6. The process according to claim 1 wherein the size reducing operation results in at least 40% of the zinc particles having a size smaller than the average size of the copper particles.

7. The process according to claim 6 wherein the size reducing operation results in at least 60% of the zinc particles having a size smaller than the average size of the copper particles.
8. The process according to claim 6 wherein the size reducing operation results in more than 70% of the zinc particles having a size smaller than the average size of the copper particles.

9. A dry process for separating copper from a mixture including copper and zinc, the process comprising:

   providing a comminuted feed including copper and zinc;
   directing the feed to a size reducing operation to produce a first output, whereby zinc particles are reduced to a smaller average size than copper particles in the first output;
   directing the first output to a screening operation to produce at least a second output and a third output, each of the second output and the third output having a narrower particle size distribution than that of the first output;
   subjecting the second output to a first air gravity table separation operation to form a fourth output that includes copper and is substantially free of non-copper components; and
   subjecting the third output to a second air gravity table separation operation to form a fifth output that includes copper and is substantially free of non-copper components.

10. The process of claim 9 further comprising:

   prior to directing the feed to a size reducing operation, subjecting the feed to an initial screening operation, whereby an output having a copper concentration greater than that of the feed is produced and directed to the size reducing operation.
11. The process of claim 9 wherein the screening operation also produces a sixth output having a narrower particle size distribution than that of the first output.

12. The process of claim 11 further comprising:

subjecting the sixth output to a third air gravity table separation operation to form a seventh output that includes copper and is substantially free of non-copper components.

13. The process of claim 9 wherein the average particle size of the second output is larger than the average particle size of the third output.

14. The process of claim 11 wherein the average particle size of the third output is larger than that of the sixth output.

15. The process according to claim 9 wherein the size reducing operation results in at least 40% of the zinc particles in the first output having a size smaller than the average size of the copper particles in the first output.

16. The process according to claim 15 wherein the size reducing operation results in at least 60% of the zinc particles in the first output having a size smaller than the average size of the copper particles in the first output.
17. The process according to claim 15 wherein the size reducing operation results in more than 70% of the zinc particles in the first output having a size smaller than the average size of the copper particles in the first output.

18. A process for separating copper and zinc from a feed derived from a shredding operation, the process comprising:

   obtaining a ground feedstock that includes copper and zinc;
   directing the ground feedstock to a size reducing operation producing particulates of zinc and copper, wherein the feedstock is subjected to impact forces such that the zinc fractures into a greater number of particulates than the copper;
   separating the zinc particulates from the copper particulates on the basis of differences in size between the zinc particulates and the copper particulates.

19. The process of claim 18 wherein the size reducing operation is performed by a granulator.

20. The process of claim 18 wherein the feedstock includes at least one type of shredder residue selected from the group consisting of automobile shredder residue (ASR), electronic shredder residue (ESR), appliance and white goods shredder residue (WSR), and combinations thereof.

21. The process of claim 18 wherein the separating operation produces a first output and a second output, the first output comprising a greater proportion of copper particles than the proportion of copper particles in the second output, the process comprising:
directing the first output to a first air gravity table separation operation to form a third output comprising substantially all copper; and

directing the second output to a second air gravity table separation operation to form a fourth output comprising substantially all copper.

22. The process according to claim 18 wherein the size reducing operation results in at least 40% of the zinc particles having a size smaller than the average size of the copper particles.

23. The process according to claim 22 wherein the size reducing operation results in at least 60% of the zinc particles having a size smaller than the average size of the copper particles.

24. The process according to claim 22 wherein the size reducing operation results in more than 70% of the zinc particles having a size smaller than the average size of the copper particles.

25. A process for separating copper particulates and zinc particulates from one another, the process comprising:

  providing a feed derived from one or more shredding operations, the feed comprising copper and zinc;

  directing the feed to a first size reducing operation to produce a first stream including copper particulates and zinc particulates;
directing the first stream to a first size separation operation to produce a second stream of large particulates and a third stream of relatively smaller particulates;

selecting one of the second and the third streams and directing the selected stream to a first air gravity separation operation to remove organic materials from the selected stream and produce a fourth stream including copper particulates and zinc particulates;

directing the fourth stream to a second size separation operation to produce a fifth stream of large particulates and a sixth stream of relatively smaller particulates;

directing the sixth stream to a second air gravity separation operation to produce a copper-rich stream and a zinc-rich stream.

26. The process of claim 25 wherein the feed is derived from automotive shredder residue.

27. The process of claim 25 wherein the selected stream is the third stream.

28. The process of claim 25 further comprising:

directing the fifth stream to a second size reducing operation to produce a seventh stream;

directing the seventh stream to a third size separation operation to produce an eighth stream of large particulates and a ninth stream of relatively smaller particulates.
29. The process of claim 28 wherein the eighth stream is combined with the fifth stream and the ninth stream is combined with the sixth stream.

30. The process according to claim 25 wherein the first size reducing operation results in at least 40% of the zinc particles having a size smaller than the average size of the copper particles.

31. The process according to claim 30 wherein the first size reducing operation results in at least 60% of the zinc particles having a size smaller than the average size of the copper particles.

32. The process according to claim 30 wherein the first size reducing operation results in more than 70% of the zinc particles having a size smaller than the average size of the copper particles.
INTERNATIONAL SEARCH REPORT

International application No. PCT/US 08/84104

A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B03B 4/00; B02C 13/00 (2008.04)
USPC - 209/12.1 ; 241/24.25
According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC - 209/12 i ; 241/24.25

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 209/3.1,12.1,20, 21,44,138,233,599, 5; 241/24.25,69, 5
Search Terms Below

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PUBWest (USPT, PGBP, EPAB, JPAB); google.com
Search Terms Used: copper, zinc, separating, separation, particles, particulate, gravity, recycle, recycling, size, sizes, sized, cyclonic, eighth, seventh

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>X</td>
<td>US 2005/0173309 A1 (Bork et al.) 11 August 2005 (11.08.2005) entire document, especially Abstract, para [0015]; [0016]; [0021]; [0030]; [0034]; [0035]; [0037]; [0038]; [0057]; [0058]</td>
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<td>A</td>
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Further documents are listed in the continuation of Box C.

Date of the actual completion of the international search 19 December 2008 (19.12.2008)

Name and mailing address of the ISA/US
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Facsimile No. 571-273-3201

Date of mailing of the international search report

Authorized officer

Form PCT/ISA/210 (second sheet) (April 2007)