Sept. 30, 1947. W. E. KECK 2,428,228

PROCESS OF SEPARATING VALUABLE MATERIALS FROM GRINDING DUSTS AND SLUDGES

Filed July 15, 1942 3 Sheets-Sheet 1

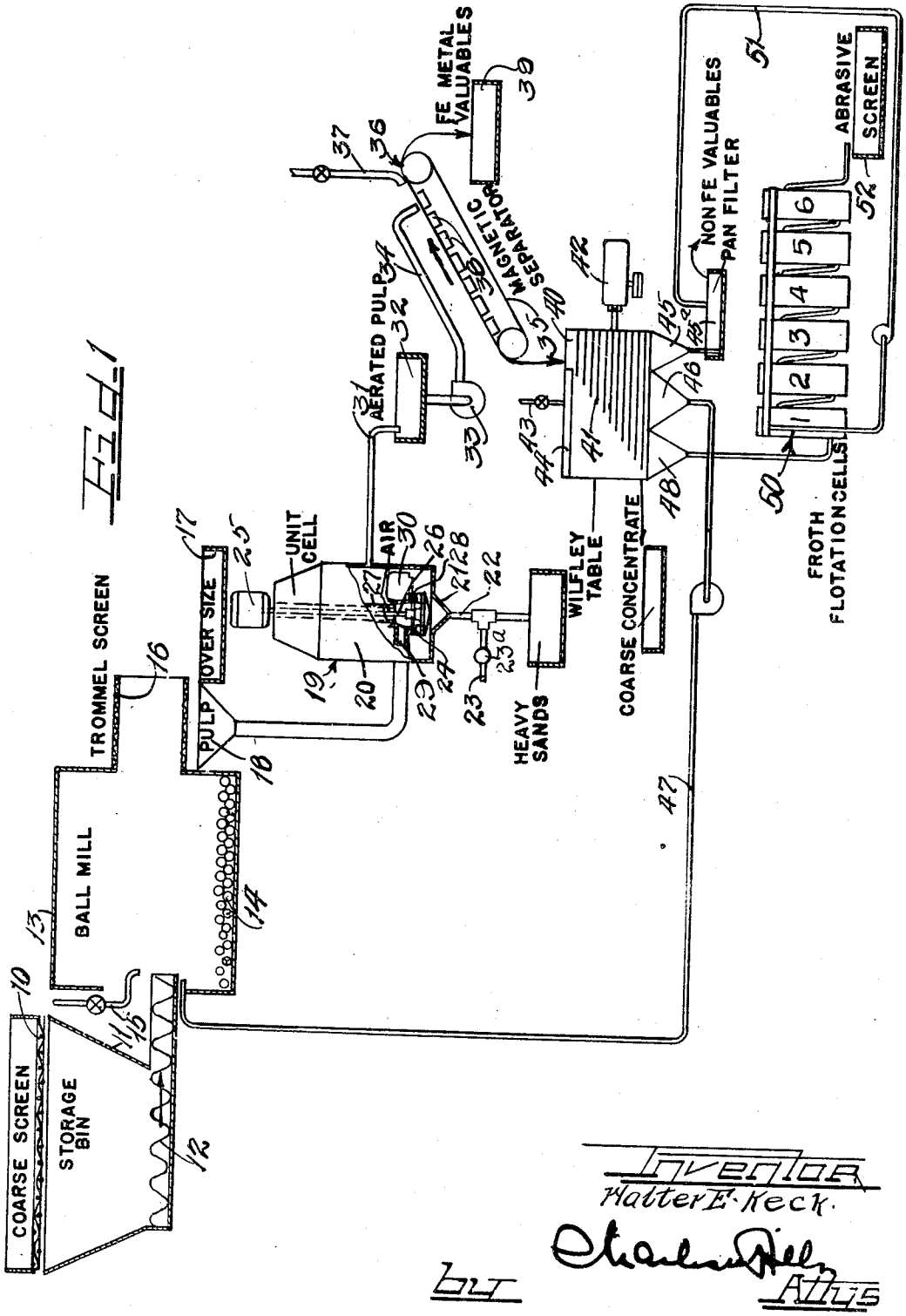


Fig. 1

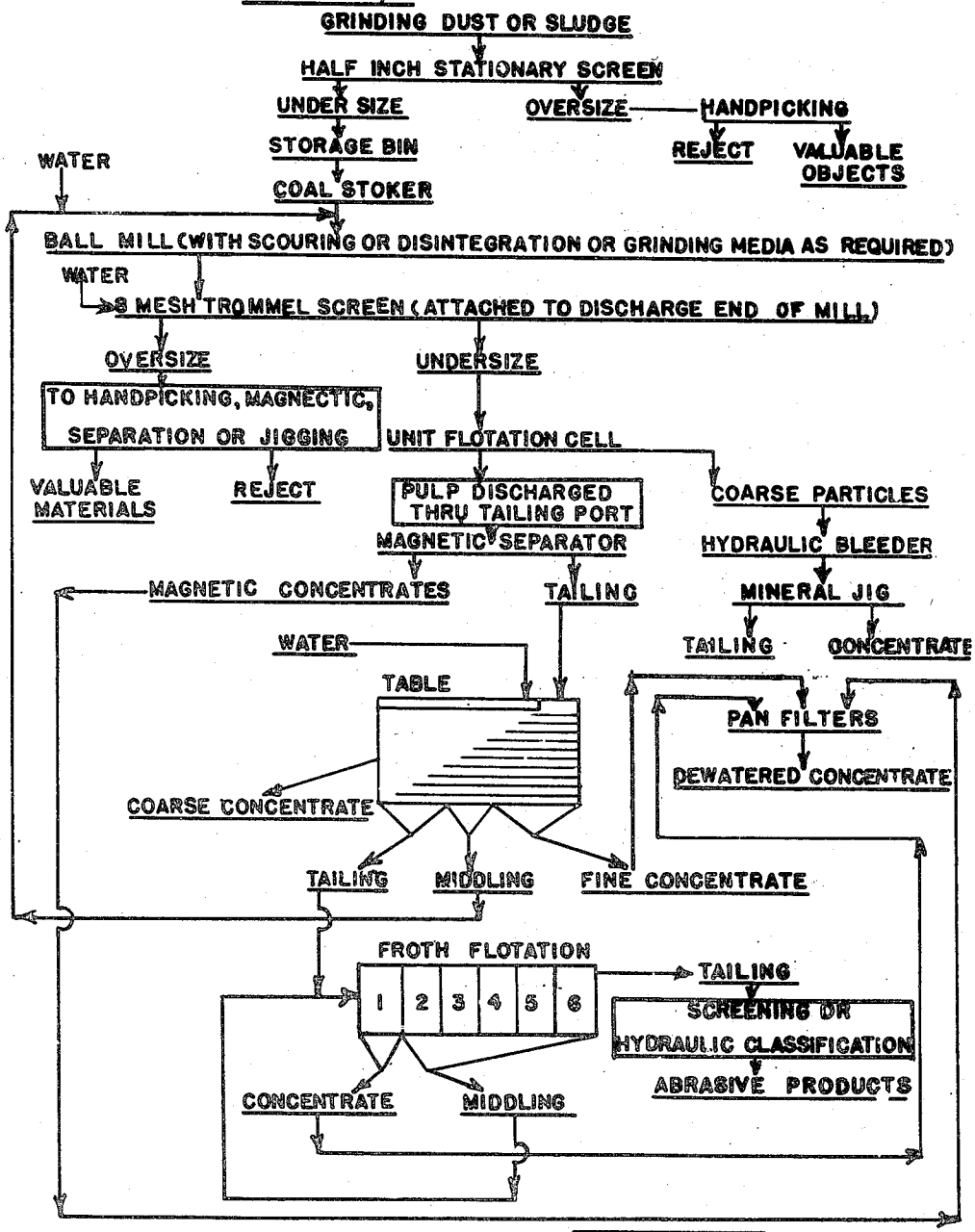
Inventor
Walter E. Keck.
by Charles Hall
Atty

Sept. 30, 1947. W. E. KECK 2,428,228

PROCESS OF SEPARATING VALUABLE MATERIALS FROM GRINDING DUSTS AND SLUDGES

Filed July 15, 1942 3 Sheets-Sheet 2

Fig. 2



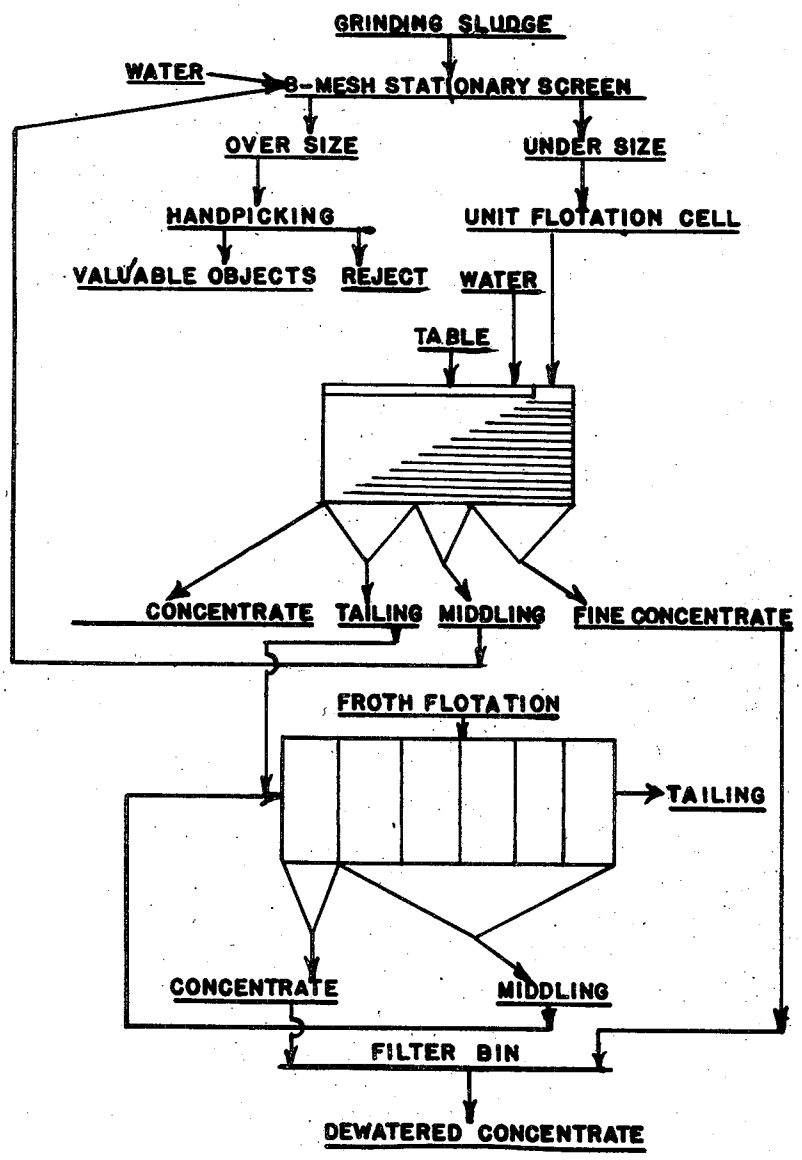
Inventor
Walter E. Keck.
By Charles Pfeiffer
Atty.

Sept. 30, 1947. W. E. KECK 2,428,228

PROCESS OF SEPARATING VALUABLE MATERIALS FROM GRINDING DUSTS AND SLUDGES

Filed July 15, 1942 3 Sheets-Sheet 3

Fig. 3



Inventor
Walter E. Keck.

By Charles Shelly Attys.

Patented Sept. 30, 1947

2,428,228

UNITED STATES PATENT OFFICE

2,428,228

PROCESS OF SEPARATING VALUABLE MATERIALS FROM GRINDING DUSTS AND SLUDGES

Walter E. Keck, Hancock, Mich., assignor, by mesne assignments, to Metals Recovery Company, Ann Arbor, Mich., a corporation of Michigan

Application July 15, 1942, Serial No. 451,000

7 Claims. (Cl. 209—2)

1

This invention relates to the recovery of valuables from the waste dust and sludges obtained from the grinding and abrading to shape and size of metal objects.

Specifically the invention relates to the recovery of valuable metals from grinding dust and sludges which are necessarily produced when metal cutting tools are ground to shape and size and are sharpened for reuse.

Grinding, and similar abrasion processes, are commonly used in the forming of metal objects to the desired shape, size and sharpness. In all of these processes extremely fine metal fragments are cut from the objects being ground. If the abrasion medium consists of unconsolidated abrasive particles these particles become intermixed with the extremely fine fragments. On the other hand, if the abrasion medium consists of abrasive particles consolidated with a binder, as, for example, in a grinding wheel, the grinding wheel is worn away during use, and the fine metal fragments from the object being ground are intermixed with the grinding wheel binder as well as with the grinding wheel abrasive.

These particles are commonly called grinding dust if the grinding has been done in a dry way. They are called grinding sludges if the grinding has been done in a wet way with a liquid for cooling, for lubrication, or for corrosion prevention.

The extremely fine metal particles in these grinding dusts and sludges are valuable, and even the particles of abrasive and binder are also valuable if these different kinds of particles are separated from each other. Heretofore such separation has been impossible and these materials were wasted. In the case of certain highly inflammable dusts, considerable expense was involved for safely disposing of the same, as they had to be admixed with earth or the like and deeply buried.

Although the process of this invention is suited for the reclamation of valuables from all types of grinding sludges and dusts, it is especially suited for the reclamation of grinding dusts and sludges from the shaping and sharpening of cutting tools, since these cutting tools contain very expensive metals such as chromium, cobalt, tungsten, and the like. Even such very valuable

2

dusts and sludges have heretofore been considered as waste material and have been used as road building material or fill-in material around industrial plants.

The sources of metal lost in the production and use of metal cutting tools are:

(*a*) Casting or forming.
(*b*) Grinding to shape and size.
(*c*) Use of the tool for metal cutting.
(*d*) Sharpening.
(*e*) The residual portion of the tool piece remaining after it has been used as completely as possible.

The metals lost in (*a*) and (*e*) have been salvaged since the casting gate, flash, and tool end piece can readily be remelted.

The metal lost by wear during actual use of the tool is only a very small portion of the total quantity of the metal going into the manufacture of the tool.

Therefore, the necessity for virgin metal in the manufacture of cutting tools is largely due to the fact that the fine cutting metal particles in the dust and sludges from (*b*) and (*d*) have not been reclaimed. The present invention, on the other hand, now provides for the recovery of the major part of these fine cutting metal particles and the invention is of great importance since it makes possible a tremendous reduction in requirement for virgin metals to produce cutting tools.

Briefly, the reclamation process of this invention may be described as the formation of a uniform aqueous pulp from the waste grinding dusts and sludges to be recovered. In some instances it may be necessary to add dispersion agents such as alkalies, alkali metal silicates, tannic acids and the like, to deflocculate the dust particles so that they will be wet with the water and uniformly dispersed throughout the pulp. These deflocculating or dispersing agents are especially useful when treating grinding sludges containing lubricants, coolants, or corrosion preventatives.

The aqueous pulp is then preferably treated on a magnetic separator to separate iron and steel from non-ferrous and non-magnetic alloy particles and to recover magnetic metal particles from the pulp. Some magnetic particles are, of

course, valuable and may be used in the production of high speed tool steels.

The tailings from the magnetic separator may contain valuable non-ferrous metals in addition to the abrasive grits and abrasive grit bonding materials. If so, it is desirable to separate the non-ferrous valuables from the abrasive material, and this is done by passing the tailings over a Wilfley table. In the Wilfley table operation, water is flowed over the riffled surface of the table with the tailings from the magnetic separator. In the customary Wilfley table separation, the heavy particles settle into the hollows between the riffles and are propelled by the jerking action to the concentrate side of the table, while the fine and light particles are washed over the top of the riffles to the tailing side of the table. The riffles are progressively longer toward the tailing side. However, it has been found that, although the metal particles in the tailings from the magnetic separator have greater specific gravity than the abrasive grits and binders, most of the metal particles are discharged off of the tailing side of the Wilfley table at the point where the lighter specific gravity materials usually are discharged, while only a small quantity of relatively coarse metal particles are discharged from the table in the normal way. This action of the Wilfley table therefore in the present process, is quite unexpected and contrary to the usual operation of the table. The non-ferrous metal concentrate from the Wilfley table is recovered.

The tailings discharged from the Wilfley may still contain an appreciable quantity of non-ferrous metal particles admixed with the abrasive material. A further separation of these tailings may be made. For this purpose a plurality of froth flotation cells can be provided to froth float off the abrasive materials from the metal particles. Frothing agents, depressants, collectors, activators, pH regulators, and deflocculators are preferably used in this froth flotation process.

It is, then, an object of this invention to recover valuables from grinding dusts and sludges.

A further object of this invention is to separate the metal and abrasive material ingredients of grinding dusts and sludges.

A still further object of the invention is to separate grinding dusts and sludges into their non-ferrous metal, ferrous metal, and abrasive grit constituents in order that these constituents can be reused.

Another object of the invention is to prepare a uniform deflocculated pulp from grinding sludges and dusts which can be treated for reclamation of the values therein.

A specific object of this invention is to provide a continuous process for recovering valuables from grinding dusts and sludges.

A further and more specific object of this invention is to continuously prepare uniformly dispersed aqueous slimes or pulp from grinding dusts and sludges, to subject the slimes and pulp to magnetic separation for recovering ferrous metal values therefrom, to subject the tailings from the magnetic separation treatment to a shake table operation for recovering non-ferrous metal valuables therefrom, and to further separate the tailings from the shake table operation into the abrasive material and metal particles material constituents thereof.

Other and further objects of the invention will be apparent to those skilled in the art from

the following detailed descriptions of the annexed sheets of drawings which diagrammatically illustrate the process and from the following examples which describe different embodiments of the process that have already been carried out.

On the drawings:

Figure 1 is a diagrammatic view of apparatus suitable for use in carrying out the process.

Figure 2 is a flow sheet illustrating a process according to this invention for treating different types of grinding dusts and sludges to recover therefrom a tungsten high speed tool steel product, a chromium-cobalt-tungsten cutting alloy product, and an abrasive product.

Figure 3 is a flow sheet of a process according to this invention for separating grinding dusts and sludges containing abrasive material and chromium-cobalt-tungsten alloy metal particles into the abrasive and metal constituents thereof.

As shown on the drawings:

In Figure 1 the reference numeral 10 designates generally a coarse stationary screen of about ½ inch mesh for screening out oversized rejects from grinding dusts and sludge. The screened material is deposited in the storage bin 11 from which it is fed by means of a screw conveyor or coal stoker 12 into a ball mill 13. The ball mill 13 has only a few balls, rods, or other attrition means 14 therein for breaking up the lumps of grinding dusts or sludge. Water is introduced into the ball mill with the grinding dust or sludge through a pipe line 15. A trommel screen 16 is connected to the discharge end of the ball mill 13 and rotates with the ball mill. This trommel screen 16 has an open end discharging into a collecting pan 17 for oversized materials. The ball mill serves as a flywheel for the process in that it introduces a constant supply of pulp to the process. This pulp flows through the screen 16 into a collector 18 from which it flows by gravity or by means of a pump (not shown) to a unit flotation cell 19. This unit flotation cell 19 is composed of a box-like container 20 having a sump bottom 21 connected to an outlet 22. Water controlled by a valve 23a can be bled into the outlet 22 from a pipe line 23 to hydraulically wash the heavy materials settling in the sump 21, and to carry upwardly to the beater 24 the lighter occluded particles in the sump. This hydraulic classification gives a heavy sand and coarse metal concentrate that can be separated in jigs and the like. Only relatively small amounts of such concentrate is obtained since most of the pulp can be disintegrated into a slime as hereinafter pointed out.

A beater 24 is mounted in the container 20 above the sump 21 thereof and has upstanding beating vanes thereon as shown. The beater is driven from a motor or other prime mover 25 and is supported on the drive shaft 26 from the prime mover.

An open ended stationary tube 27 surrounds the shaft 26 in spaced relation therefrom and provides an air passageway to the beater 24. An outturned base 28 can be provided at the bottom of the tube 27. The pulp from collector 18 is fed through a conduit 29 into the tube 27 where it will drop by gravity onto the beater 24 and be subjected to a beating operation by the beater. A stationary baffle 30 can be mounted in the container 20 above the beater to prevent the entire body of pulp in the container from rotating with the beater. As the beater receives

the incoming pulp it will fling the same outwardly by centrifugal force and will thereby draw in air through the tube 27. The pulp thus becomes aerated and is beaten into a uniform slime of creamy consistency. The beaten pulp is then flowed through an outlet 31 below the top of the container 20 into a collector 32 from which it can be pumped by a pump 33 through a pipe line 34 onto the upper end of an inclined belt 35 of a magnetic separator 36. The upper run of the belt 35 travels in an upward direction as indicated by the arrow. Water from a pipe 37 is introduced onto the upper run of the belt above the area of the belt receiving the pulp from the pipe 34. Magnets 38 are mounted under the upper run of the belt and act through the belt to cause the magnetic ingredients of the pulp to travel upward with the belt and be discharged off the upper end thereof into a collector 39. These magnetic metal particles represent ferrous metal valuables recovered from the pulp.

The tailings not removed by the magnetic separator are discharged off of the lower end of the belt. These tailings contain the abrasive particles and the non-magnetic metal particles and are discharged into a Wilfley table 40 having a plurality of riffles 41 of progressively increasing length from the feed to the tailing side thereof. A pitman and toggle mechanism 42 is provided for shaking the Wilfley table in a sidewise direction. The mechanism is of such design that reversal of direction at one end of the stroke is at a maximum velocity and at the other end of the stroke at a minimum velocity. The stroke toward the concentrate delivery point is at accelerated velocity and the reverse stroke is at retarded velocity. These velocities are so adjusted that the particle in contact with the table surface moves with it during the accelerated stroke toward the concentrate delivery point but after reversal of direction at maximum velocity, the particle does not move with the table during the return stroke. In this way the particle is propelled toward the concentrate delivery point.

Water is introduced from a pipe line 43 into a water inlet 44 on the table and will flow downwardly along the table to wash the tailings over the riffles 41. The metal particles in the tailings will be collected at 45 at the point of the table where the materials of least specific gravity are usually collected. The Wilfley table therefore operates on the tailings contrary to expectation in that the metal particles are discharged from the point of the table where normally the lighter specific gravity materials would be discharged. The material collected at 45 is fed to pan filters such as 45*a* where it can be dried and recovered as non-ferrous metal valuables.

A middling separation is obtained at 46 from the Wilfley table and these middlings can be pumped through a pipe line 47 back to the inlet of the ball mill 13. The tailings from the table are collected as at 48 and are fed to the first cell of a six-cell froth flotation unit 50 containing cells 1 to 6 as shown. This froth flotation unit can be a series of cells such as the unit cell 19 with each successive cell receiving the tailings of the preceding cell and with the material adhering to the bubbles that rise to the top of each cell being fed to the filter 45*a* through a pipe line 51. The material which has passed through all of the six cells and is discharged as tailings from the sixth cell represents the abrasive which can be recovered on a screen 52. Reagents are added to

the froth flotation cells to effect froth separation of the abrasive and metal ingredients.

The apparatus illustrated in Figure 1 will thus bring about the separation of the grinding dust and sludges into ferrous metal valuables, non-ferrous metal valuables, and abrasive ingredients.

The flow sheet of Figure 2 illustrates a more complete process than shown in the diagrammatic illustration of Figure 1. In this flow sheet, grinding dust or sludge is likewise separated into an abrasive concentrate, a magnetic concentrate, and a non-magnetic concentrate. Froth flotation separation can be carried out in the six cell unit shown with the froth from cells 2 to 6 being returned to cell 1 from which it is recovered and fed to the pan.

In the flow sheet of Figure 3 the magnetic separation treatment is omitted and the process illustrated by this flow sheet is especially adapted for use in treatment of grinding sludge and dust wherein the iron content is negligible or need not be separated from the non-ferrous metal content.

The following examples will illustrate various specific embodiments of the processes illustrated generally on the drawings:

Example I

Grinding sludge from the commercial grinding of tungsten and molybdenum high speed tool steel was found to contain several per cent of oil introduced during the grinding operation. Attempts to magnetically concentrate the steels in this sludge were unsuccessful both in a wet and dry process. In the dry state, the particles of tool steel and grinding wheel bond and adhesive cohered together to such an extent that no separation whatsoever could be made. In the wet state, it was found to be impossible to disperse the sludge with water.

The addition of a small quantity of sodium hydroxide to cut the oil and make the sludge wettable with water was found to be quite satisfactory. The grinding sludge was satisfactorily separated into the abrasive material and the tool steel material according to the following steps carried out in the order in which they are listed:

(*a*) About 10 pounds of sodium hydroxide in a water solution were added to each ton of dry sludge;

(*b*) The sodium hydroxide containing sludge was agitated with water to form a pulp. Agitation was allowed to proceed for about 5 minutes;

(*c*) The pulp prepared from step (*b*) was diluted with water to form a dilute pulp of about 20% solid concentration;

(*d*) The diluted pulp was agitated for about 5 minutes;

(*e*) The diluted and thoroughly dispersed agitated pulp was then subjected to a low power wet magnetic separation to form a magnetic concentrate and a non-magnetic tailing.

With the above procedure, 99.6% of iron in the feed to the magnetic separator was recovered in the magnetic concentrate and only 0.4% of iron remained with the non-magnetic tailing. The grade of the magnetic concentrate was 43.4% while only about 3% iron was found in the magnetic tailings. It should be understood, of course, that the iron content of these products is indicative of their high speed tool content.

This process also eliminated deleterious com-

mon iron and steel from a non-magnetic cutting alloy. For example the iron content of a cobalt-chromium-tungsten alloy concentrate was reduced to the extent that nearly all the common iron and steel particles were removed.

Example II

A grinding dust sample from the grinding room of a machine shop was collected and was found to contain tungsten high speed tool steel and grinding wheel bond and abrasive products. The following steps were performed on a representative part of the sample, in the order given:

(*a*) The dust was screened on a one-half inch screen to remove coarse trash, tool bits, and the like;
(*b*) Sodium hydroxide solution was aded to the screened dust of (*a*) sufficient to form a pulp of 50% solid content. The sodium hydroxide solution was of a concentration so that 10 pounds of sodium hydroxide were added to every ton of dust;
(*c*) The pulp from (*b*) was vigorously agitated with mild attrition in a ball mill containing a few balls for the purpose of breaking lumps and disentangling the particles;
(*d*) The pulp from (*c*) was diluted with water to form a pulp of about 20 per cent solid content;
(*e*) The diluted pulp from (*d*) was screened on a 10-mesh screen;
(*f*) The screened pulp was further agitated;
(*g*) The agitated screened pulp from (*f*) was subjected to a low power wet magnetic separation to form a magnetic concentrate and a non-magnetic tailing.

In step (*b*) the addition of a wetting and deflocculating agent is often highly desirable and even necessary because of the inherent non-wettability of the dusts and sludges and because of the presence on the dust particles of excess lubricant from the grinding machine. Another factor requiring the addition of such an agent is the presence on the grinding dust particles of a water-repellant material such as is used in the grinding operation for cooling, washing, or corrosion prevention on the material being ground.

Wetting and deflocculating agents such as sodium silicate, tannic acid and the like have also been used. Choice of the particular agent will depend to a large extent on whether tabling and/or flotation treatments are to be carried out on the tailings from the magnetic separation since these processes are markedly affected by the presence of different chemical compounds.

Grinding sludges containing high amounts of cutting oils can also be treated according to Example II.

With the treatment of the dust outlined in steps (*a*) to (*g*) in Example II the magnetic concentrate from (*g*) contained 85 per cent of the tungsten and the non-magnetic tailing contained only 15 per cent of the tungsten in the feed to the magnetic separator. The grades of the magnetic concentrate and the non-magnetic tailing were respectively 17.2 and 0.7 per cent tungsten.

The tungsten content of the non-magnetic tailing was due mainly to non-magnetic chromium-cobalt-tungsten cutting alloys. These extremely valuable alloys can be recovered by heating and a second magnetic separation as set forth in Example IV or by tabling as set forth in Example V, or by froth flotation as set forth in Example VI.

Example III

A sample of dust obtained from the grinding of tungsten carbide tool bits with a grinding wheel containing silicon carbide as the abrasive was separated into tungsten carbide particles and grinding wheel bond and abrasive particles by the following procedure:

(*a*) Sodium hydroxide solution was added to the grinding dust to form a pulp of 50% solids with the concentration of the sodium hydroxide solution being such that 10 pounds of sodium hydroxide were added per ton of dry dust.
(*b*) The pulp from (*a*) was vigorously agitated.
(*c*) The pulp from (*b*) was diluted with water to form a pulp of 20% solids content.
(*d*) The diluted pulp from (*c*) was thoroughly agitated and mixed.
(*e*) The pulp from (*d*) was subjected to a low power wet magnetic separation to obtain a magnetic concentrate and a non-magnetic tailing.

Microscopic examination of the product from step (*e*) showed that the magnetic concentrate contained about 80% tungsten carbide plus binder from the grinding wheel, while the non-magnetic tailing contained less than 5% of the same material. Of the weight of the feed to the magnetic separator, 24.6% was recovered in the magnetic concentrate and 75.4% in the non-magnetic tailing. The grade of the magnetic concentrate in respect to tungsten was 43%.

Experimentation with dusts from grinding of other tungsten carbide bits showed that some of the dusts were not readily concentrated by a low powered magnetic field, but required one of greater intensity. However, with the proper intensity of magnetic field, every tungsten carbide dust was satisfactorily separated into a tungsten carbide magnetic concentrate and a non-magnetic tailing that contained little tungsten carbide.

Example IV

A non-magnetic tailing from step (*g*) of Example II was subjected to the following treatment steps performed in the order in which they are herein listed:

(*a*) Water was removed from the non-magnetic tailing by filtering and heating.
(*b*) The dried tailing was roasted at red heat for about 5 minutes.
(*c*) The roasted material was cooled.
(*d*) The cooled roasted material was subjected to a low power dry magnetic separation to produce a magnetic concentrate and a non-magnetic tailing.

By this treatment, 57% of the tungsten in the non-magnetic tailing from step (*g*), Example II was recovered in the magnetic concentrate of step (*d*) of this example, while 43% of the tungsten remained in the non-magnetic tailing from the same step. The grades of these magnetic concentrates and non-magnetic tailing were respectively 5.06 and 0.22% tungsten.

The low power dry magnetic separation of step (*d*) of this example can also be done in a wet way. The results from the wet magnetic separation are as good or better than those from the dry separation, especially when the roasted material is very fine.

Example V

A grinding sludge produced in the commercial grinding of tool pieces from a well known cutting alloy of composition approximating 46% cobalt, 30% chromium, 18% tungsten and 2.25% carbon, hereafter referred to as alloy "C," was used in this example. In addition to alloy "C" particles, the sludge contained common steel and grinding wheel bond and abrasive. Grinding to produce this sludge had been done with water as the only coolant.

The following treatment steps were carried out on the sludge in the order in which they are listed:

(*a*) Addition of water to the sludge sufficient for a pulp of 20% solids content;
(*b*) Agitation of the pulp from (*a*) to thoroughly disseminate the sludge particles in the pulp;
(*c*) Tabling of the pulp from (*b*) on a Wilfley table with collection of the following products:
  (1) Fine alloy "C" concentrate;
  (2) Tailing;
  (3) Coarse alloy "C" concentrate.

By the Wilfley table treatment, 95.1% of the alloy "C" in the feed to the table was recovered in fine and coarse alloy "C" concentrates but most of the alloy "C" was recovered in the fine concentrate. The tailings from the table contained only 4.9% of the alloy "C" in the feed to the table. The grade of the concentrate was 87.7% while that of the tailing was only 7.7% alloy "C."

Although alloy "C" is of a higher specific gravity than the grinding wheel bond and abrasive, the finer alloy "C" concentrate was taken from that part of the Wilfley table normally delivering material of lowest specific gravity. This unexpected concentration of alloy "C" particles may be caused by a combination of various factors, such as:

(1) The major part of the alloy "C" particles are smaller than those of the grinding wheel bond and abrasive;
(2) The relative shapes of the alloy "C" particles and the bond and abrasive particles. The alloy "C" particles are thin, jagged and often crescent-shaped, whereas the bond and abrasive particles are more nearly spherical or cubical in shape;
(3) Preferential coating of the alloy "C" particles with excess lubricant from the grinding machines;
(4) Chemical nature of the alloy "C" particles, such as the presence of metal carbides and the like.

The last two factors (3) and (4) tend to prevent passage of the alloy "C" particles through the surface of the water. These two factors also bring about the adsorption of air on the surface of the alloy "C" particles and this condition, in turn, tends to cause the same particles to float on the surface of the water.

The sum tendency of these four factors was that the flowing water on the table tended to more readily carry the alloy "C" particles over the table riffles than the grinding wheel bond and abrasive.

In the Wilfley table concentration the fine alloy "C" particles were concentrated as individual particles and not as agglomerations or masses of particles.

The material taken from that part of the table usually delivering middling material constituted the tailing, and the coarse concentrate was taken from that portion of the table where, normally, collection is made of the heavy minerals.

Example VI

A tailing material from tabling as in Example V was found to contain a considerable amount of alloy "C" together with common steel and large amounts of grinding wheel bond and abrasives. To further recover the alloy "C," the following froth flotation steps were applied to the table tailing:

(*a*) The table tailing was transferred to a froth flotation machine.
(*b*) Sufficient water was added to the tailing to form a pulp of about 35% solids content.
(*c*) The watered pulp was agitated for about 1 minute to thoroughly disintegrate the solids.
(*d*) The disintegrated pulp was further diluted to about 25% solids content.
(*e*) 0.2 pound of pine oil per ton of dry table tailing was added to the diluted pulp from step (*d*).
(*f*) The machine was operated and froth was collected for about 5 minutes to obtain a concentrate.
(*g*) About 5 pounds of soda ash was added per ton of dry table tailings.
(*h*) About 0.2 pound sodium oleate (a collector for non-metallic minerals) was added per ton of dry table tailings.
(*i*) The machine was operated for the collection of froth until flotation ceased, to obtain a flotation tailing or rougher tailing and a concentrate.
(*j*) The concentrates from steps (*f*) and (*i*) were combined to form a rougher concentrate.

With the foregoing flotation treatment, a small additional recovery of alloy "C" was made from the table tailing as shown by the fact that the rougher concentrate contained 36.3% and the rougher tailing 63.7% of the alloy "C" in the feed to the flotation machine. The grade of the rougher concentrate was about 34.7% and that of the rougher tailing was about 18.6% alloy "C." The rougher concentrate undoubtedly could be enriched by cleaner flotation, or added without further treatment to the rich table concentrate. With the latter procedure, the relatively small quantity of rougher flotation concentrate would not greatly decrease the grade of the table concentrate.

Microscopic examination of the rougher flotation tailing showed that much of the alloy "C" was too coarse for normal flotation. This condition suggested the use of a mineral jig to recover the coarse alloy "C." Such a recovery is described in Example IX.

Example VII

Another commercially produced grinding sludge containing alloy "C," common steel, and grinding wheel bond and abrasive was treated according to the steps given below. Grinding for the production of this sludge was done with water as the only coolant:

(a) Addition of water to the sludge sufficient to form a pulp of 50% solids.
(b) Strong agitation of the pulp from (a) to break lumps followed by transfer to a flotation machine.
(c) Addition of water to pulp (b) to form a pulp of about 20 per cent solids and strong agitation of this pulp.
(d) Further addition of water to the pulp of (c) to form a pulp of about 11% solids.
(e) Addition of 0.4 pound of pine oil per ton of dry sludge.
(f) Collection of froth for 8 minutes from the flotation machine to obtain a flotation concentrate and a tailing.
(g) Transference of the tailing from (f) to a Wilfley table and tabling of the same tailing to obtain a table concentrate and a table tailing.

With the combination of flotation and tabling, the Crobalt in the feed was distributed as follows:

	Per cent
Flotation concentrate	28.2
Table concentrate	71.7
Table tailing	0.1

The grades of these products were respectively: 76.4%, 93.2%, 0.3%, Crobalt.

Example VIII

A sludge produced in the commercial grinding of a chromium-cobalt-tungsten cutting alloy was found to contain, in addition to the cutting alloy, some common steel together with the grinding wheel bond and grinding wheel abrasive. The following froth flotation steps were carried out on this sludge in the order in which they are given:

(a) Transfer of the sludge into a flotation machine.
(b) Addition of water sufficient to form a pulp of 20% solids content.
(c) Strong agitation of the pulp in the machine for 1 minute.
(d) Addition of 0.4 pound pine oil.
(e) Collection of froth for 6 minutes to obtain a first concentrate.
(f) Addition of 0.2 pound pine oil.
(g) Collection of froth for 9 minutes to obtain second concentrate.
(h) Addition of 0.5 pound potassium amyl xanthate (a collector for sulfides, oxides and native metal minerals).
(i) Conditioning for 3 minutes.
(j) Collection of froth for 15 minutes to obtain third concentrate.
(k) Addition of 0.5 pound potassium amyl xanthate.
(l) Conditioning for 3 minutes.
(m) Collection of froth for 10 minutes to obtain a fourth concentrate.
(n) Addition of 0.1 pound pine oil.
(o) Collection of froth for 10 minutes to obtain a fifth concentrate.

The first concentrate of Example VIII was found to contain 88.2% cutting alloy; the second concentrate 87.7% cutting alloy; the third concentrate 75.7% cutting alloy; the fourth concentrate 68.5% cutting alloy; the fifth concentrate 67.2% cutting alloy; and the tailing was found to contain only 32.1% cutting alloy. The flotation of common iron and steel was greatly depressed especially in the first concentrate.

A quite similar flotation with cationic collectors, such as alkyl amines (specifically a mixture of monohexadecyl, monooctadecyl and monooctadecenyl amines) instead of a xanthate collector produced good separation of the alloy from the abrasive.

In general, suitable collectors are materials that coat mineral particles with a water-repellant film which renders the filmed particles floatable.

Example IX

In this example the heavy or coarse product from the sump 21 of the unit cell 19 shown in Figure 1 was used. This material was relatively coarse alloy "C" and abrasive material. In the commercial operation that produced this product removed by hydraulic bleeding from the unit 19, the grinding dust was screened on an 8-mesh screen and the undersize from this screen was fed to a unit flotation cell where aeration and disintegration were performed preparatory to concentration on a Wilfley table.

Due to unusual operating conditions, coarse alloy "C" and abrasive particles tended to remain and concentrate in the cell until functioning of the cell was interfered with. To remedy this difficulty the coarse material was continuously removed with a hydraulic bleeder by forcing water through the pipe-line 23 illustrated in Figure 1. As the coarse material contained considerable alloy "C" it was further treated in a jig which produced a jig concentrate and a jig tailing. This operation made a considerable recovery of alloy "C" in a high grade concentrate.

Example X

A non-magnetic tailing from the magnetic separation of tungsten high-speed tool steel grinding dust was used in this Example X to determine whether the abrasive could be reclaimed from the same material. The non-magnetic tailing was wet screen analyzed and then the different sizes were examined with a microscope. Screen analysis and microscopic examination showed that nearly 80% of the non-magnetic tailing would pass through a 35-mesh screen and would be retained on a 100-mesh screen and that the metal particles, because of their relatively small size, would pass through the 100-mesh screen. It was noted that somewhat similar sizing could be made with hydraulic classification, and that the binder in this non-magnetic tailing, if of organic nature, could be reclaimed by flotation.

In connection with froth flotation of grinding dust and sludges it has been found that the following separations are possible:

A. Selective flotation of common iron and steel from cobalt-chromium-tungsten cutting alloy.

B. Selective flotation of cobalt-chromium-tungsten alloys from common iron and steel.

C. Flotation elimination of elemental sulfur.

D. Flotation elimination of sulfur containing oily material.

E. Flotation of oil containing sludges in the presence of a detergent or wetting agent.

F. Roasting of the dust or sludge to remove large quantities of oil prior to flotation.

Thus, for example, a combination of ammonium hydroxide, ammonium sulfate, and ammonium acid sulfate, either alone or with pine oil tended to activate common iron and steel and depress a chromium-cobalt-tungsten cutting

alloy in a sludge that contains relatively large quantities of cutting oils.

Sodium hydroxide, along with a collector tended to depress chromium-cobalt-tungsten cutting alloys considerably without affecting common iron and steel to the same extent.

Potassium dichromate along with a collector tended to activate flotation of a chromium-cobalt-tungsten cutting alloy and depress that of common iron and steel.

Ferric chloride with pine oil activated common iron and steel and depressed a chromium-cobalt-tungsten cutting alloy. When a collector was used with ferric chloride it activated the flotation of the cutting alloy and depressed the flotation of common iron and steel.

Sodium cyanide in the presence of a collector activated flotation of chromium-cobalt-tungsten cutting alloy and expedited its separation both from common iron and steel and from abrasives.

It has also been found that pine oil tends to float off elemental sulfur and particles of sludge coated with sulfur bearing cutting oil.

Similarly the bonding material of the grinding wheel, if it be of organic nature, can be floated with a frother as pine oil or with a frother and a collector.

In some sludges containing much cutting oil or other mater repellant material, the flotation operation should be carried out in the presence of a strong wetting or detergent agent. If these agents are not sufficient it may be advisable to burn them out of the sludge or dust by heating the same to a sufficiently high temperature before flotation separation is used.

Since there are many different types of grinding dusts and sludges which can be recovered by this process, the process can be modified throughout a wide range to accommodate each particular type of dust or sludge. Proper separation can be made by a combination of treatment steps such as magnetic separation and tabling; magnetic separation and magnetizing roasting followed by a second magnetic separation; froth flotation; and the like.

It will, of course, be understood that various details of the invention may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. The process of reclaiming valuables from metal grinding dusts and sludges which comprises forming an aqueous pulp of said material, magnetically separating the magnetic and non-magnetic ingredients of the pulp, recovering the magnetic concentrate, tabling the non-magnetic pulp portions, collecting a heavy metal concentrate from that part of the table which normally concentrates low specific gravity particles, froth floating the tailings from the table to separate the metal particles from abrasive particles, combining the froth floated metal concentrate with the heavy metal concentrate from the tabling operation, recovering the combined metal concentrate as non-ferrous metal valuables, and recovering the froth treated tailings as abrasive values.

2. The method of recovering valuables from grinding dusts and sludges which comprises screening said materials to eliminate oversize trash, feeding the screened material into a mild attrition mill, introducing water into the mill to produce a pulp, screening the pulp from the mill, disintegrating the pulp to produce a uniform slime, magnetically separating magnetic metal particles from the slime, tabling the non-magnetic particles, recovering a metal concentrate from the tabling operation, subjecting the tailings from the tabling operation to a froth flotation treatment, and recovering an abrasive concentrate and a metal concentrate from the froth flotation operation.

3. In the process of recovering non-ferrous metal valuables from grinding dusts and sludges the steps which comprise agitating and drawing air into an aqueous mass containing said metal valuables to form an aqueous aerated pulp, flowing the pulp onto a Wilfley table, washing the pulp over the table with additional water, shaking the table, and collecting the metal valuables from that portion of the table which usually collects materials of lighter specific gravity.

4. The method of recovering non-ferrous metal valuables from dusts and sludges produced by abrading operations on tool bits containing such metals which comprises forming an aqueous aerated pulp of the dusts and sludges, screening the pulp, tabling the screened pulp with additional amounts of water on a Wilfley table and collecting the metal valuables from that portion of the Wilfley table which normally delivers material of lowest specific gravity.

5. In the method of recovering valuables from metal grinding dusts and sludges, the steps which comprise forming an aqueous pulp of the dusts and sludges, treating the aqueous pulp with a dispersing agent, feeding said pulp and air to a rotating beater to produce an aerated slime, settling out heavy particles from the pulp as it is being beaten, flowing water upwardly through the settling heavy particles to wash the same and carry up to the beater the lighter occluded particles, recovering the washed heavy particles, magnetically separating the slime into ferrous and non-ferrous constituents, and separating the non-ferrous constituents into metal and non-metal concentrates.

6. The method of recovering valuables from grinding dusts and sludges which comprises screening said materials to eliminate oversized trash, roasting the material to burn out the oil content thereof, feeding the screened and roasted material into a mild attrition mill, introducing water into the mill to produce a pulp, screening the pulp from the mill, disintegrating the pulp to produce a uniform slime, magnetically separating magnetic metal particles from the slime, tabling the non-magnetic particles, recovering a metal concentrate from the tabling operation, subjecting the tailings from the tabling operation to a froth flotation treatment, and recovering an abrasive concentrate and a metal concentrate from the froth flotation operation.

7. In the method of recovering valuables from grinding dusts and sludges, the steps which comprise forming an aqueous pulp containing the grinding dust and sludges, treating said aqueous pulp with a suitable reagent to obtain a dispersion of the grinding dust and sludges therein, beating and drawing air into said aqueous pulp to produce a uniform aerated slime, removing said slime from said aqueous pulp, and magnetically separating magnetic metal particles from the slime.

WALTER E. KECK.

(References on following page)

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,052,227	Hood	Aug. 25, 1936
2,107,289	Denny	Feb. 8, 1938
1,208,880	Wright	Dec. 19, 1916
1,585,756	Borcherdt	May 25, 1926
2,174,553	Daman	Oct. 3, 1939
1,911,865	Weinig	May 30, 1933
1,984,386	Tschudy	Dec. 18, 1934
2,106,887	Earle	Feb. 1, 1938
1,063,893	Schwerin	June 3, 1913
2,230,344	Bair	Feb. 4, 1941
1,448,515	Borcherdt	Mar. 13, 1923
1,646,239	Frost	Oct. 18, 1927
788,247	Cattermole	Apr. 25, 1905