

[72] Inventor **Joseph R. Hradel**
6482 South Mission Road, Mount Pleasant,
Mich. 48858
 [21] Appl. No. **794,103**
 [22] Filed **Jan. 27, 1969**
 [45] Patented **July 27, 1971**

2,325,149	7/1943	Rakowsky	209/232 X
2,711,249	6/1955	Laurila	209/219
2,748,940	6/1956	Roth	209/219
3,294,237	12/1966	Weston	209/227 X
3,372,803	3/1968	De Lisle	209/214 X
3,289,836	12/1966	Weston	209/214

Primary Examiner—Frank W. Lutter
 Assistant Examiner—Robert Halper
 Attorney—C. Kenneth Bjork

[54] **PROCESS FOR BENEFICIATION OF
 NONMAGNETIC MATERIAL**
 6 Claims, 1 Drawing Fig.

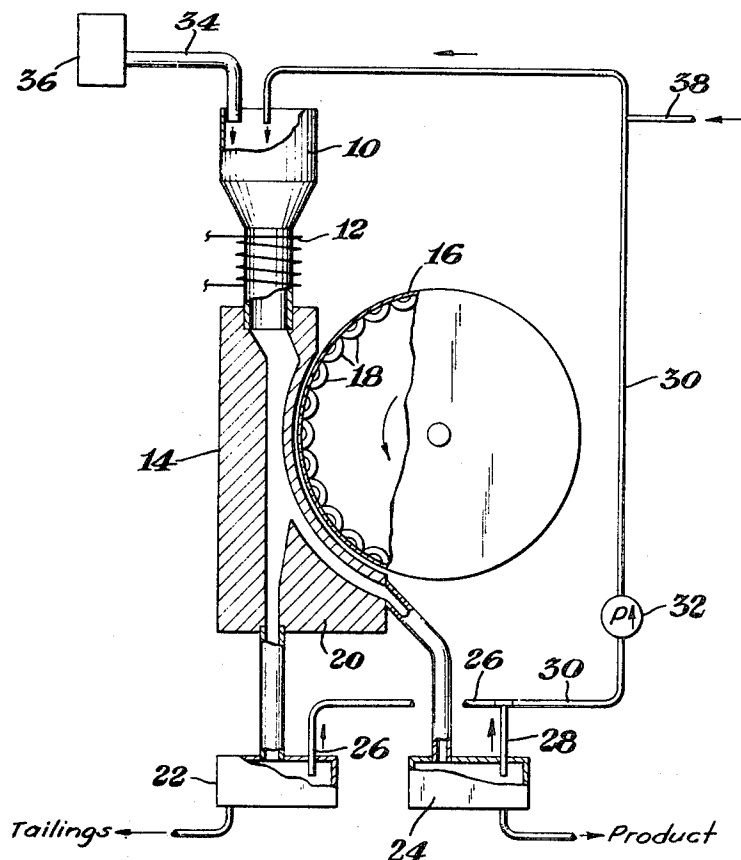
[52] U.S. Cl. 209/8,
 209/232, 209/214, 209/39

[51] Int. Cl. B03c 1/00

[50] Field of Search. 209/39, 40,
 219, 214, 215, 212, 213, 232, 220, 218, 478, 216,
 227, 131.1, 314, 8, 8.1; 210/222, 223

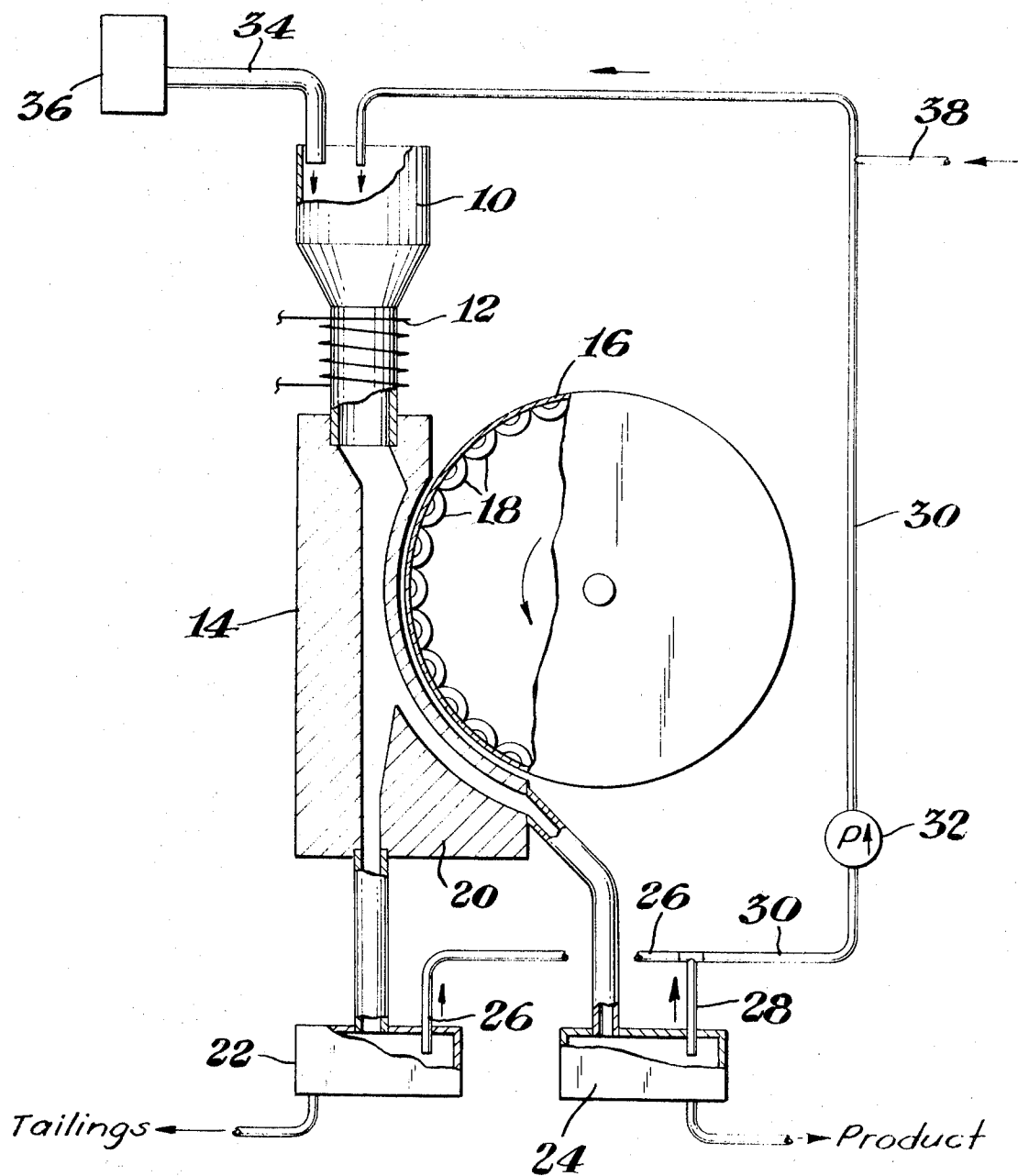
[56] **References Cited**
UNITED STATES PATENTS
 460,962 10/1891 Gouyard 209/219

ABSTRACT: A novel process for beneficiating nonmagnetic ores and other source materials, particularly lean iron ores, wherein paramagnetic material in such ores is given a temporary positive magnetic susceptibility, passed within the field of a moving permanent magnet system before the material decays to its natural state, and the so activated paramagnetic substance separated by deflection toward the magnet system and recovered from nondeflected diamagnetic material in admixture therewith.



PATENTED JUL 27 1971

3,595,386



INVENTOR.
Joseph R. Hradel

PROCESS FOR BENEFICIATION OF NONMAGNETIC MATERIAL

The present invention relates to a novel process for separating paramagnetic material from diamagnetic material and more particularly is concerned with a novel process for beneficiating ores which are not naturally magnetic such as, for example, lean nonmagnetic iron ores including tailings from conventional ore processing, to recover the bulk of the useful and desired metal values therefrom.

Current ore beneficiating employing electromagnetic and magnetic separatory techniques as exemplified by U.S. Patents Nos. 2,954,122, 2,325,149 and 2,558,635 are applicable only in separating and recovering from ore bodies the naturally magnetic portions of the ore or those metal values which can be given a prolonged magnetism from an induced electromagnetic force and which retain this magnetism until the material is demagnetized by passage through an opposing electric coil or other demagnetizing means.

Many lean ores, particularly ferrous ores, which are abundantly and widely distributed throughout the world are not presently mined because they are not susceptible to beneficiation by such known techniques. Additionally, nonmagnetic tailings resulting from beneficiation of magnetic ores contain a large percentage of iron values which at present are discarded because these values are unresponsive to separation by magnetic beneficiation techniques now practiced.

Now, unexpectedly I have discovered a novel process for separating and recovering nonmagnetic but paramagnetic metal values, particularly nonmagnetic iron values, from ores and other source materials including tailings from gangues resulting from conventional iron separatory techniques.

It is a principal object of the present invention to provide a novel process for separating and recovering paramagnetic materials which are nonmagnetic, i.e. are not naturally magnetic or will not hold any induced magnetism for a prolonged period of time, from diamagnetic materials.

It is also an object of the present invention to provide a novel process for beneficiating and recovering iron values from source materials which do not respond to and cannot be used in conventional magnetic beneficiating techniques.

These and other objects and advantages readily will become apparent from the detailed description presented hereinafter when read in accordance with the FIGURE of the appended drawing which shows a schematic flow diagram of one embodiment of the process of the present invention.

In general the process of the present invention comprises providing a particulate nonmagnetic source material which cannot be rendered permanently magnetic but which contains at least one paramagnetic substance to be separated and recovered. This source material is passed through or within the effective range of an electric coil thereby upsetting said material and imparting a temporary positive magnetic susceptibility to said paramagnetic material and a negative magnetic susceptibility to any diamagnetic material present therein. The so upset material is brought within the field of a moving permanent magnet system before the positive magnetic susceptibility in the paramagnetic material decays to a state where said paramagnetic material is not attracted by said magnetic system thereby deflecting and separating said paramagnetic material from diamagnetic materials present which received a negative magnetic susceptibility from exposure to said coil. The term "upset" for the purpose of this specification is defined as the act of disturbing the electromagnetic equilibrium of a paramagnetic or diamagnetic material from its natural state by electromagnetic means.

This method is particularly adapted for use in separating and recovering iron values from nonmagnetic ore bodies and other source materials as has been pointed out hereinbefore. Representative examples of such iron source materials are iron ores containing such paramagnetic materials as the spicular and cherty hematites consisting largely of Fe_2O_3 embedded in diamagnetic gangues of the nature of silica as are

found in the upper central United States. These materials, although lean, represent an economically beneficiable reserve beyond that which is currently being recovered if consideration is given to the fact that differences in magnetic susceptibility values constitute a basis for separation of iron compounds from their gangues. Other iron bearing compounds are contained in lean ores such as masearite, the nonmagnetic fraction of pyritic magnetite, pyrite, siderite, limonite, and the green potassium iron silicate as well as the tailings from previous beneficiations of these ores. All of these are available in abundant quantities in various parts of the United States as well as throughout the world. Hereinafter the term "ore" as used in the specification will mean and include both naturally occurring nonmagnetic ores such as the lean ores exemplified hereinbefore as well as tailings and other source materials resulting from prior beneficiation or separatory processes.

Ordinarily in carrying out the practice of the present invention, an ore is crushed or ground to break it down and effect separation of the paramagnetic metal values from diamagnetic gangue materials. Usually the ore is crushed to pass a number 60 U.S. Standard Sieve, and particulate materials ranging from 60 to 325 mesh or finer have been found to be particularly suited to the practice of the present invention. Coarser particles can be employed, if desired, provided that effective physical separation from gangue material is realized.

The crushed ore is subjected to the influence of an energized electric coil of sufficient energy and for a period of time to establish a temporary positive magnetic susceptibility in the paramagnetic materials present therein and a negative magnetic susceptibility in any diamagnetic substances which may be in admixture therewith. The resulting positive and negative magnetic susceptibilities in the upset material are not permanent or even prolonged in duration but are of short duration, i.e. exist from less than a second to a minute or more and ordinarily have a maximum of about several minutes.

The so upset ore is passed within the field of at least one rotating permanent magnet, usually a plurality of such magnets, before the positive magnetic susceptibility given to the paramagnetic material in the ore decays to a state where the material becomes unresponsive to the permanent magnet system. One particularly effective system employs a plurality of magnets mounted on a moving frame, for example, a rotating drum. This system has been found to be of a high utility since the rotation of the magnets serves to substantially eliminate undesirable buildup of the paramagnetic material, even for a short period of time, on the magnets or clogging of the deflection chamber, adjacent thereto if such is employed in the apparatus for carrying out the process.

Optimum in separation of the active paramagnetic material from diamagnetic material in admixture therewith is realized by utilizing a minimum period of time between upset and subjection to the magnetic field. The sooner the material is brought under the influence of the permanent magnet the more positive and greater will be the deflection and consequent separation of the desired paramagnetic product. As indicated hereinbefore, at a maximum about one minute is employed and preferably this time is from less than a second up to several seconds.

The deflected paramagnetic product after it is passed beyond the magnetic field is collected separately from the nondeflected diamagnetic byproduct. In some instances it is to be understood that the nondeflected diamagnetic material may be the desired product or both materials may be of interest.

Conveniently, the starting material is passed by gravity flow through an energizing coil past the magnet system and the separated materials further passed into a collection system. Alternatively, a liquid pumping system for handling an ore in aqueous suspension can be employed. This latter procedure assures that the throughput rates of the ore can be controlled by the pumping rates thus reducing to a minimum, e.g. a fraction of a second, the time required to transport the ore between the energized upset coil and the permanent magnet

system. This provides the added advantage that the flow rate through the coil can be adjusted and maintained to be the same as the flow rate past the moving permanent magnets thereby serving to further control the product distribution and eliminate congestion in the vicinity of the magnets and/or the collectors.

The collected paramagnetic product can be recovered and used directly, or, in the case of iron ores, can be further processed concentrated and otherwise converted, for use in particular situations.

Alternating current in the upset coil is preferred over direct current in that the former offers the further advantage that minimum clogging or buildup in the core is found. This is particularly true when utilizing silicate and sulfur based iron ores, e.g. marcasite, pyrite, and pyritic hematite. Oxide and hydroxide ores are less prone to clogging and a direct current source is just as effective as an alternating current for these latter materials.

One embodiment of a hydraulic system for carrying out the present process is shown schematically in the FIGURE of the drawing. In this embodiment, a mixing-holding-feed hopper 10, usually fitted with a valve near its bottom, is provided. This hopper 10 is connected at its bottom to the top of a flow through electrically powered upset coil 12. The bottom of the hopper 10 is connected to the top of a deflection chamber 14. This chamber 14 is curved along one side of its length so as to coincide generally with the contour of a cylindrical frame 16 holding a plurality of permanent magnets 18. Preferably the wall of the chamber adjacent the magnet system is in close proximity to this system. The bottom of chamber 14 is fitted with a divider 20 which serves to direct diamagnetic byproduct to a gangue thickener collecting vessel 22 and paramagnetic product to a product collector 24. Conveniently the intake at the top of the deflection chamber has a cross-sectional area about equal to that of the two discharge outlets of the bottom of this chamber. Ordinarily, the cross-sectional area of each of the discharge outlets is slightly smaller than 0.5 that of the intake. This, in turn, provides for a slight back pressure in the system thereby providing during operation cleaner cuts in a more rapid manner with less recycle. Each of the containers 22 and 24 is fitted respectively with a conduit 26 and 28 which fed to a common transport conduit 30. Conduit 30 in turn is connected through pump 32 to hopper 10. The hopper 10 is fitted with an ore supply conduit 34 which extends to an ore supply reservoir 36. Conduit 30 can be fitted with a makeup conduit 38 connected to a fluid supply source (not shown).

In operation of this system, in one embodiment a ground ore and a liquid carrier, usually water, with or without additional agents such as, for example surfactants, are blended in the hopper 10 to provide a slurry of predetermined consistency. This slurry is controllably fed through the coil 12 where the ore is upset and the paramagnetic material of the ore is given a temporary positive magnetic susceptibility. The so upset ore containing slurry is directed to the inlet of the deflecting chamber 14. As the slurry passes through this chamber 14 and past the revolving magnets 18 the paramagnetic material is deflected towards and attracted by the magnets. This material follows the contour of the chamber adjacent the magnets 18 and drops from outlets at the bottom of the collection chamber 14 into the collector 24. The nondeflected diamagnetic material falls directly into the gangue collector 22.

The materials are settled in their respective collectors, and recovered by conventional means. The supernatant liquid is removed from the collectors 22 and 24 by conduits 26 and 28 being pumped into conduit 30 and returned to hopper 10 for reuse. Such reuse of the carrier liquid provides for the maximum of product recovery as any useful values retained in the liquid will be again passed through the beneficiation process. The diamagnetic gangue can be recycled for further beneficiation if desired.

Alternatively, the hydraulic conduit and pumping system can be eliminated and dry material by gravity or force fed

from the hopper through the energizing coil, passed through the field of the moving permanent magnet system and on into the collection bins.

Other modifications can be employed. Also electrical assemblies, mechanical and hydraulic systems suitable for use in the practice of the invention for any particular applications are within the knowledge of one skilled in the art to which this process pertains.

The following examples will serve to further illustrate the present invention but are not meant to limit it thereto.

EXAMPLE 1.

Nonmagnetic cherty hematite tailings or spicular hematite having various amounts of iron (expressed as percent Fe_2O_3) and ground to pass a 60 mesh U.S. Standard Sieve but be retained on a 325 mesh sieve were passed dry through a 2,500 ohm upset coil energized by an alternating current circuit and operating at 16 volts. These tailings were discard nonmagnetic gangue products resulting from conventional magnetic ore beneficiation processes.

Each of the upset materials was retained for a predetermined period of time and then passed within the field of a revolving permanent magnet system. The amount of sample attraction, i.e. beneficiation of the iron source, by the permanent magnets was determined.

The results of this study which was designed to illustrate the operability of the present process for beneficiating paramagnetic, but not permanently magnetic, materials from diamagnetic substances admixed therewith are summarized in table I. These results also show the criticality of passing the upset material within the field of the permanent magnet system within a short period after being activated by the upset coil to achieve optimum in beneficiation.

TABLE I

Type	Iron source material percent iron (as Fe_2O_3)	Percent sample fraction in beneficiate (time in min. after being upset)*				
		1	2	4	4	5
Spicular hematite	78	68	30	10	5	3
Cherty hematite	72	80	8	2	1	0
Do	52	29	3	1	0	0
Do	25	9	7	5	3	2

*Time between upset and passage through magnet field.

EXAMPLE 2.

Using a separatory apparatus of general construction similar as that shown in the FIGURE of the drawing, an aqueous slurry of a cherty hematite tailing (one kilogram of iron source material) and having a known iron content (expressed as percent Fe_2O_3) and ground to a predetermined particle size range was pumped through an alternating current (16 volts) energized upset coil (2,500 ohms). The resulting upset iron source material was pumped into a deflection chamber which was adjacent a plurality of permanent magnets mounted on a revolving drum. The time between upset and passing of a given particle of the iron source material in the field of the magnets was a fraction of a second at a maximum. The product materials were collected in separate bins, the gangue material being recycled for a total treating time of five minutes. After this period of time, the beneficiated iron product was recovered and the iron content determined by conventional analytical techniques.

The results of this study are summarized in table II which follows.

TABLE II

Run No.	Ore particulation (mesh sieve)		Beneficiated product			Gangue (percent Fe_2O_3)
	Passed	Retained on	Fe in feed (percent Fe_2O_3)	Wt. percent of feed	Iron content (percent Fe_2O_3)	
1	60	100	72	75	95	5
2	100	200	52	65	87.2	12.8
3	200	325	25	50	65.2	25.0

EXAMPLE 3

Dry iron source materials of particle size ranging from about 60 to 325 mesh and which had been freed of all naturally magnetic materials were passed by gravity feed through an upset coil of 7,500 ohms and activated by alternating current at a potential of 16 volts. The upset material was passed through a deflection chamber adjacent a revolving magnet system in a single pass, the time period between the time of upset and contact with the field of the magnet being about 15 seconds. The diamagnetic materials, i.e. tailings, which were not attracted by the magnet system were collected separately from the paramagnetic iron product, i.e. beneficiate, that had received a temporary positive magnetic susceptibility and was deflected towards the magnet. This latter material was separated from the magnetic field and recovered. The iron contents of the recovered fractions were determined by conventional analytical techniques.

The results of a number of runs with various iron source materials are summarized in table III.

TABLE III

Run No.	Iron source material	Nature of iron values	Percent iron compounds in loading stock	Percent recovery from loading stock	Percent of iron compounds	
					In beneficiate product	In tails
1.....	Pyritic hematite.....	FeS-Fe ₂ O ₃ lustrous.....	88.4	89.3	90.0	25.5
2.....	Marcasite.....	FeS ₂ yellow.....	66.0	87.7	70.0	37.0
3.....	Pyrite.....	FeS black.....	96.5	98.3	98.0	30.0
4.....	Siderite.....	FeCO ₃ yellow.....	55.0	34.0	95.0	35.0
5.....	KFesilicate.....	Green ore.....	54.1	21.3	70.0	60.0
6.....	Limonite.....	Fe(OH) ₃ yellow.....	67.5	22.6	95.0	60.0
7.....	do.....	do.....	47.2	17.7	80.0	30.0
8.....	Cherty siderite.....	FeCO ₃ red.....	60.0	30.0	95.0	45.0
9.....	Hematite.....	Fe ₂ O ₃ spicular.....	78.0	56.8	70.0	25.0
10.....	do.....	Fe ₂ O ₃ cherty.....	72.0	69.3	90.0	37.0
11.....	do.....	do.....	52.0	38.0	60.0	20.0
12.....	do.....	do.....	25.0	52.0	35.0	10.0

EXAMPLE 4.

A number of studies were run to determine the current consumption for various diamagnetic and paramagnetic substances in an upset coil. For these studies, a coil of 2,500 ohms at a predetermined temperature was energized by alternating current of 16 volts potential and a core of a predetermined material placed within the coil. The time for consumption of a watt-hour of energy was measured. The results of these runs are summarized in table IV. The marked differences in power consumption rates for the various materials as shown in the table indicates the coil influences a given material in a specific manner, i.e. gives it a temporary positive or negative susceptibility, and thus provides the basis for the present process for recovering useful paramagnetic materials from nonmagnetic source materials.

TABLE IV

Run No.	Coil temp., ° F.	Core material	Sec./watt hr.
1.....	62	Hematite A 1, 2.....	605
2.....	62	Hematite B 1, 2.....	580
3.....	62	Hematite C 1, 2.....	529
4.....	66	Cu rod.....	572
5.....	66	Fe rod 1.....	532
6.....	66	Mg rod 1.....	630
7.....	66	Al rod 1.....	674
8.....	66	Zn dust.....	594
9.....	65	Bentonite.....	606
10.....	66	Boron powdered.....	573
11.....	66	Zirconium granulated.....	535
12.....	64	CuO 1.....	428
13.....	64	Steel Rod 1.....	567
14.....	50	FeS powdered 1.....	873

¹ Designates item to be paramagnetic.

² Separate samples from different sources.

Various modifications can be made in the present invention without departing from the spirit or scope thereof for it is understood that I limit myself only as defined in the appended claims.

I claim:

1. A process for separating nonmagnetic paramagnetic material from diamagnetic material which comprises:
 - a. providing a finely divided mixture of paramagnetic and diamagnetic material, said mixture being further characterized as being not naturally magnetic,
 - b. passing said mixture within the effective range of an electrically energized upset coil thereby upsetting said mixture and imparting a temporary positive magnetic susceptibility to said paramagnetic material of said mixture and a negative magnetic susceptibility to said diamagnetic material of said mixture, said temporary positive and negative magnetic susceptibilities existing in said materials for a period of time of from less than 1 second up to about several minutes

- c. bringing the so upset mixture within the field of a moving permanent magnet system within the time interval that the paramagnetic material retains its temporary positive magnetic susceptibility and is attracted and deflected towards said magnet system, and
- d. recovering the so deflected paramagnetic material.
2. The process as defined in claim 1 wherein the upset material is passed through said electrically energized upset coil.
3. The process as defined in claim 2 wherein the upset mixture is passed adjacent to a rotating system of a plurality of permanent magnets.
4. The process as defined in claim 3 wherein the mixture comprises nonmagnetic iron source material and the time interval between upset and passage within the field of said moving magnet system ranges from less than one second to about one minute.
5. The process as defined in claim 4 wherein the iron source material is a lean iron ore or tailings resulting from conventional ore processing operations, said material being substantially free from naturally magnetic substances and said material ranging from about 60 to about 325 mesh U.S. Standard Sieve.
6. The process as defined in claim 5 wherein the iron source material is provided as an aqueous slurry and including the step of pumping said slurry through said energized coil and adjacent said rotating system of permanent magnets.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,595,386 Dated July 27, 1971

Inventor(s) Joseph R. Hradel

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 11, after "beneficiating" insert --technology--

Column 1, line 67, change "form" to --from--

Column 3, line 26, delete the letter "s"

Column 3, line 45, before "is fitted" insert --also--

Column 3, line 62, change "form" to --from--

Signed and sealed this 18th day of January 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents