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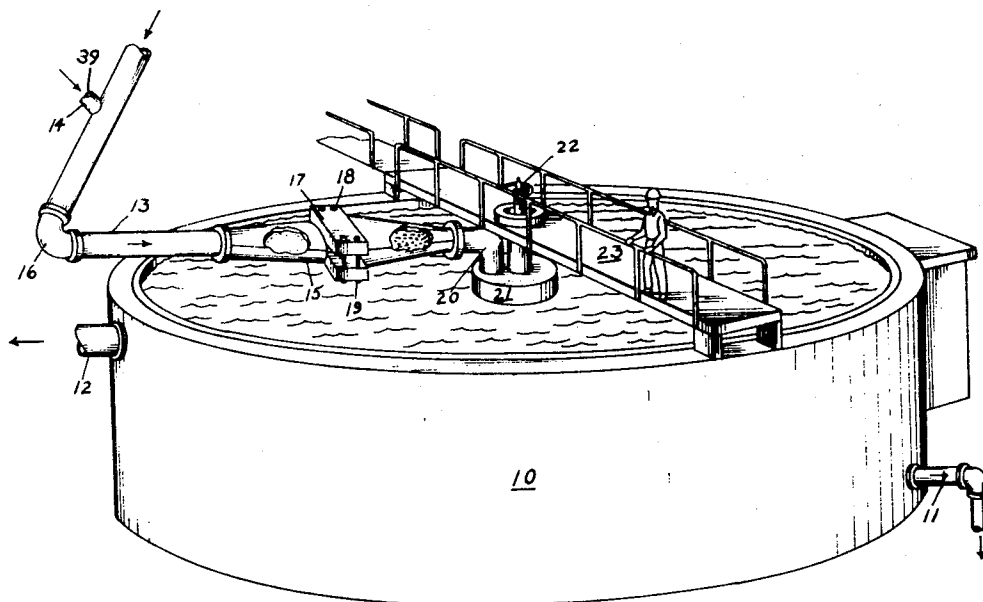
[54] **APPARATUS FOR MAGNETIC FLOCCULATION
OF AGGLOMERATES**
1 Claim, 4 Drawing Figs.

[52] U.S. Cl. 210/223
[51] Int. Cl. B01d 21/01
[50] Field of Search 210/42,
51—54, 222, 223; 209/214

[56] **References Cited**
UNITED STATES PATENTS

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ABSTRACT: The process and apparatus of removing fine suspended agglomerates containing existing or added ferromagnetic particles from liquids by the combination of magnetic flocculation and chemical flocculation. These fine suspended agglomerates are formed by adding suitable chemical flocculants to the liquid. The effluent will then flow through a suitable magnetic field to magnetize the agglomerates. These magnetically induced agglomerates will then attract each other and form large agglomerates which will settle in a suitable basin. The magnetic apparatus disclosed herewith could be added to existing chemical flocculation systems.



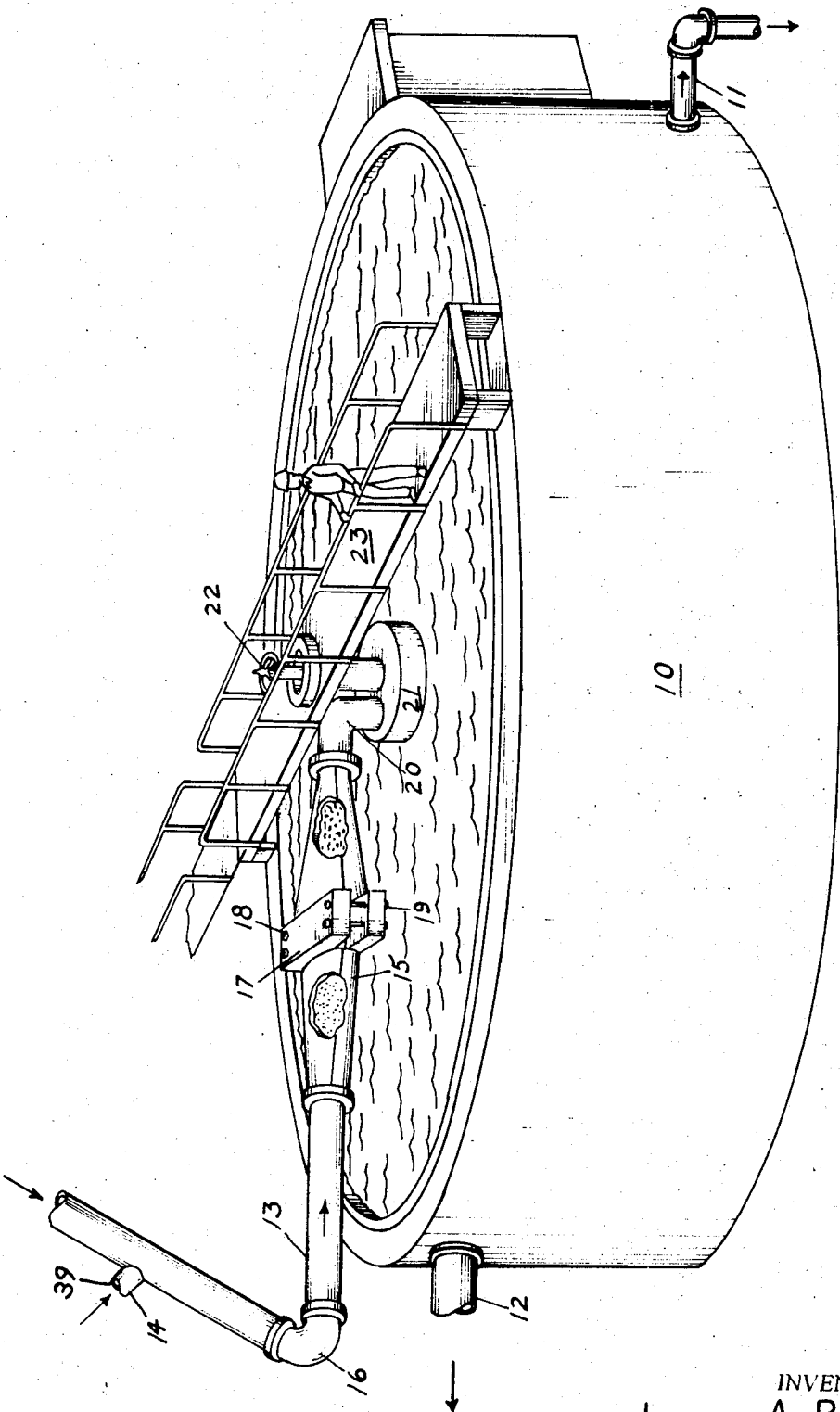


Fig. 1

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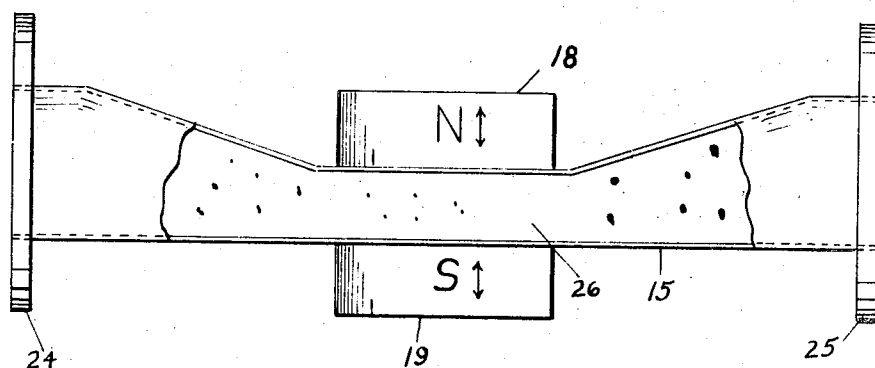


FIG. 2

SETTLING RATE CURVES

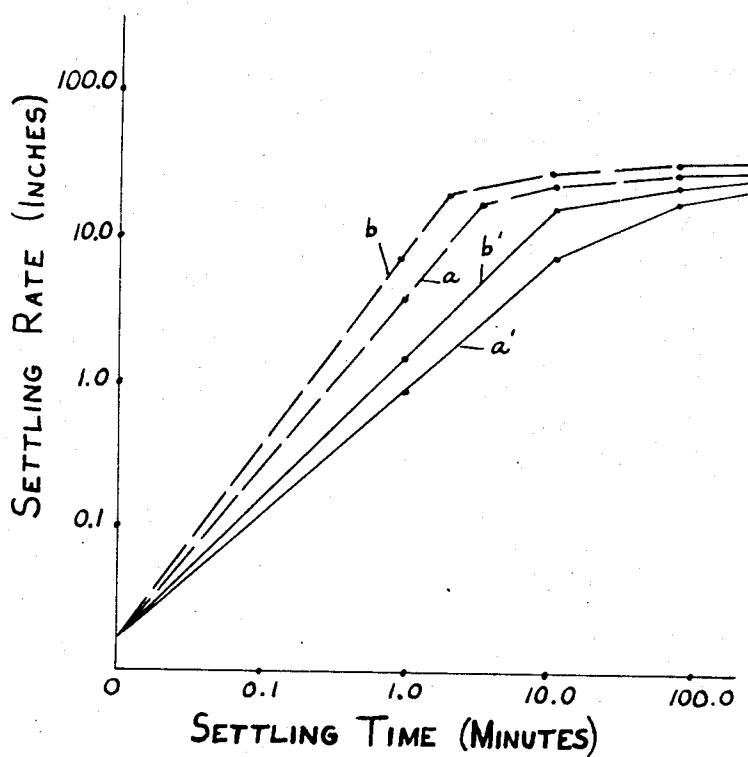


FIG. 3

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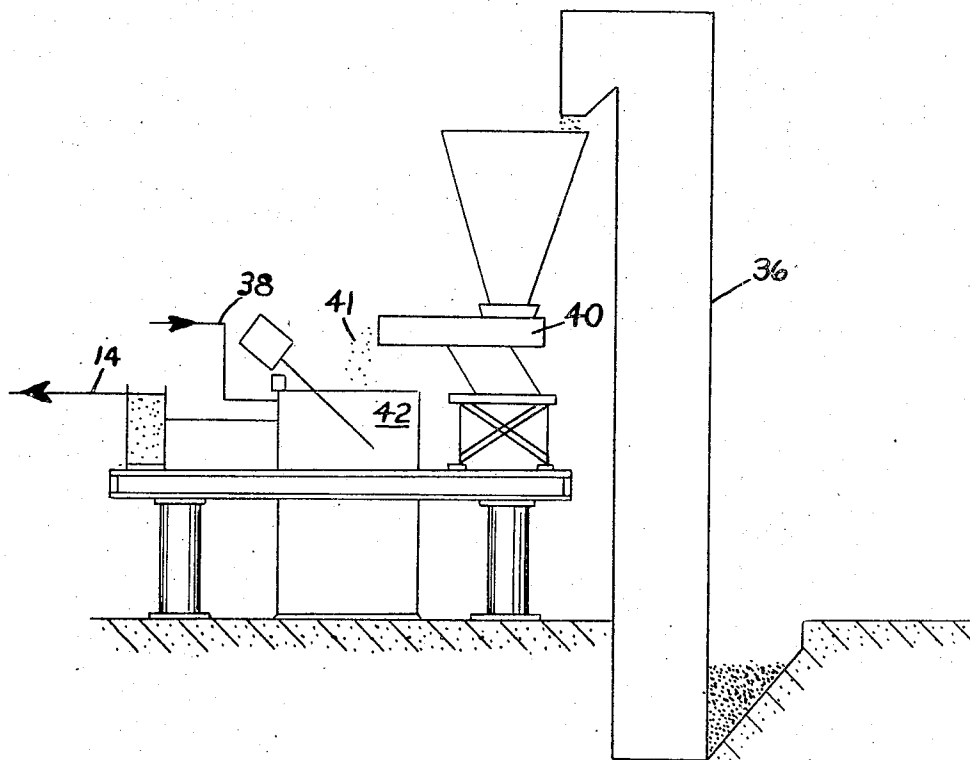


FIG. 4

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APPARATUS FOR MAGNETIC FLOCCULATION OF AGGLOMERATES

FIELD OF INVENTION

This invention relates to the separation of solids from liquids and, more particularly, to the removal of fine suspended solids from liquids by the combination of chemical flocculation and magnetic attraction.

DESCRIPTION OF PRIOR ART

Various methods and processes have been made to separate suspended ferromagnetic particles from liquids using magnetic fields without chemical flocculation. Examples of such attempts are shown in patents:

3,017,031 - L. L. Fowler
3,351,203 - W. L. Robb
3,042,211 - A. M. El-Hindi
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OBJECTS OF THE INVENTION

It is an object of the invention to provide an improved method of removing solids from liquids by the combination of the addition of flocculating chemicals, magnetization of the flocculated particles, and settling of the flocculated material, wherein the addition of flocculating chemicals is reduced.

Another object of the invention is to provide a method of carrying out a chemical magnetization process wherein the size and cost of settling basins over known processes may be reduced.

Another object is to apply the magnetic flocculation process to chemical flocculation effluents containing nonmagnetic solids.

With the above and other objects in view, the invention comprises the processes set forth in the specification, drawings, and recited in the appended claims. The invention will be better understood from a reference to the drawings and detailed specification wherein:

FIG. 1 is an outline view of an apparatus for carrying out the invention;

FIG. 2 is an enlarged view of one component of the apparatus;

FIG. 3 is a graph showing the relation of the process disclosed herein; and

FIG. 4 is a diagrammatic view of the feeding mechanism of the invention.

Flocculation is the process of coagulation or coalescence of finely divided particles, is commonly used in separating fine solids from liquids. It increases the solids settling rate, filtering rate and clarity of the supernatant liquid.

Floccule consists largely of finely divided solids loosely clustered in an aggregate predominantly aqueous, perhaps miscellar in form.

Forces disposing the particles to flocculate include magnetism, ionic forces of attraction and secondary entropic forces. Each particle has an unmeasurable but considerable surface tension. Reduction of the particles surface tension can be achieved by adherence to other particles, provided the surfaces are unionized with alike charge. Therefore, the best flocculation occurs at iso-electric point and accords with the second law of thermodynamics.

CHEMICAL MAGNETIC FLOCCULATION

In this process, by addition of chemical flocculants, small agglomerates are formed, made from fine nonmagnetic and ferromagnetic particles. These agglomerates will then be magnetically charged by passing through a suitable magnetic field of a flocculating magnet. A magnetic attraction between the unlike pole of the magnetized agglomerates will result in attraction and formation of large agglomerates with sufficient mass to settle rapidly in a suitable basin or thickener.

The chemical flocculants used in the process are polyelectrolytes of high molecular weight, water soluble, synthetic polymers, pH regulators and starches. They are usually added as solution in concentration of about 1 percent. Normal addition of chemical flocculants is between .10 and 10 parts per million, but using the process disclosed, the normal dosage of flocculant can be reduced by about 50 percent. In addition, the results so far conducted indicate that the settling rate after chemical-magnetic flocculation was more rapid than after chemical flocculation only.

Magnetic flocculators used for this application should have a field strength of approximately 800 gauss in the center line between the poles and allow a minimum residence time of the liquid in the magnetic area of one-twentieth of a second. Although, in some applications, higher fields and longer time of residence was required for the satisfactory flocculation.

DETAILED DESCRIPTION

The chemical magnetic flocculation system will consist of:

1. A volumatic feeder 40 for feeding the dry chemical flocculant.
2. A mixing tank 42 with a vibratory stirrer and water supply 38 to dissolve the chemical reagent.
3. A flow meter to control the flocculating reagents feed rate.
4. A pipeline 14 to feed the reagents.
5. A liquid injector 39 to spray the reagent in the pipeline with influent to be clarified. This should be performed about 10 feet in front of the flocculating magnet.
6. Stainless pipe section 15 around which flocculating magnets 17-19 are located.

In operation, the volumatic feeder 40 will uniformly feed the dry chemical reagent 41 into the mixing tank. A water flow valve controls the addition of water into the mixer tank to 1 percent concentration. This also regulates the amount of reagents added to the effluent to be clarified. Normally, by a plastic pipeline and spray nozzle, this solution is fed into the pipeline 13 carrying the effluent to be flocculated. This inlet should not be closer than 10 feet away from the flocculating magnet and, where possible, further than this.

After the correct amount of reagent has been added to the slurry and fine flocculation occurs, the agglomerates pass through the flocculator magnet and become magnetically charged. The magnetic flocculator should be placed as close as possible to the discharge point and around a stainless steel nonmagnetic pipeline 15. This pipeline could be rectangular or circular.

It must be kept in mind that vigorous agitation after chemical or magnetic flocculation will reduce the efficiency of this flocculation process.

APPLICATION OF THE PROCESS DISCLOSED

The chemical-magnetic flocculation process can be used to agglomerate the majority of the fine solid from liquids, as in the following examples:

1. Blast furnace dust.
2. Flyash dust.
3. B.O.F. dust.
4. Bessemer furnace dust.
5. Open hearth furnace dust.
6. Electric furnace dust.
7. Cupola dust.
8. Fine mill scale.
9. Machining and cutting lubricants.
10. Total steel plant effluent.
11. Red mud from Bayer Process (aluminum).

The flocculating and settling characteristics of nonmagnetic effluents is enhanced by addition of fine ferromagnetic particles, like B.O.F. dust, which will carry the magnetic charge.

TYPES OF CHEMICAL FLOCCULATING REAGENTS

The probability of particle adhesion can usually be increased by the addition of one or several reagents known as flocculants. These reagents act as flocculants through one or a combination of three possible mechanisms:

1. It is generally held that when solids are suspended in a liquid, a double layer of ions exists at the surface of the solid particles. The electrostatic nature of this double layer is such that like solid particles are repelled by each other due to like surface charges known as Zeta potential. The first class of flocculants, called electrolytes, acts by neutralizing this intermolecular repulsive force. This permits natural attractive forces, known as Van de Waal's cohesive force, to cause the particles to adhere. This electrolytic neutralization of the Zeta potential also makes the solids more amenable to further adhesion by one of the two other types of flocculants.

2. The second class of flocculants, called coagulants, consists of reagents that cause the precipitation, within a definite pH range, of voluminous metallic hydroxide flocs. These large gellike flocs physically entrap the fine particles in the suspension and sweep them down as they settle quite apart from any chemical effects.

3. The third class of flocculants, called polyelectrolytes, consists of either natural or synthetic long chain high molecular weight organic polymers that have a large number of active sites along their chain length. These polymers form a bridge between two or more particles when these particles are bonded to several active sites along the same polymer molecule, and they form a bridge between themselves when a single particle is bonded to an active site on each of several polymer molecules. This polymer active site to solid particle bonding may be by hydrogen bonding, chemical reaction or electrolytic attraction. Considerable effort has been expended in explaining the action of these polyelectrolytes and detailed accounts are available in the literature.

Electrolytes (pH regulators)	Coagulants	Polyelectrolytes
Sodium hydroxide, sulphuric acid.	Alum.....	Polymer of polyacrylamide.
Calcium hydroxide.....	Lime.....	Polymer of acrylamide.
Potassium hydroxide ammonia....	(prefer pH of 7)	Polymer of polyacrylamide.
Calcium carbonate hydrochloric acid.		Guar gum.
Nitric Acid.....		

TEST RESULTS

The test results indicate that the settling rate in chemically-magnetic flocculation process is doubled over the chemical flocculation only. At the same time, to attain this, about 50 percent of the chemical reagent is used. Clarity of the supernatants from the chemically-magnetic flocculated effluents in most cases is much clearer (less than 20 parts per million of solids).

Now with more particular reference to the drawings, the device shown in FIGS. 1 and 2 has a tank 10 where the liquid with entrained flocculated material is delivered and where the entrained liquid settles. The tank 10 has distributor 21 at approximately its center so that the material flows from the distributor in all directions into the tank. The tank has a sludge outlet 11 and an outlet for clean water for recirculation at 12 at the top of the tank. A conduit 13 connects a supply of liquid having the entrained particles therein and the flocculating chemical material is added at 14 and passes with the liquid through the elbow 16 to the magnet unit 15. The magnet unit 15 is flattened out adjacent the magnets 18 and 19 so that the passage between the magnet elements 18 and 19 is a relatively short distance compared to the diameter of the conduit 13. Valve 21 is provided in line 20 with handwheel 22 adjacent

catwalk 23. The magnet unit has the flanges 24 and 25 by which the magnet unit can be attached to the conduit 13 and the liquid passes between the flattened area 26 between the magnets.

The apparatus may be used to remove finely entrained particles, such as, for example, fly ash, blast furnace dust and other materials. The materials that may be used are shown in the following example:

EXAMPLE

A blast furnace dust slurry was made by adding blast furnace dust of the following size to water in the following weight percentage of dust to water:

1. Structure:					
Microns.....	+45	-45+30	-30+20	-20+10	-10
Percent weight.....	12.81	11.58	17.42	28.49	29.70
2. pH=8.9.					
3. Percent of Solids=0.28.					
4. Percent of Magnetic Iron in Solids=17.4.					

To determine the efficiency of the flocculation process, the following investigation was conducted:

The tests were performed on 1,000 ml. representative samples placed into 1,000 ml. measuring cylinders. In order to flocculate the solids, a predetermined amount of the chemical reagent was added and mixed gently with the slurry for 10 seconds. The settling and clarifying rates of the solids were then recorded. When the solids settled, half of the supernatant liquid from the measuring cylinder was syphoned off and solids content in PPM determined.

Next, the same flocculation tests were conducted with 75 percent and 50 percent of the original quantity of the chemical flocculating reagent and determined solids settling rate and solids content in the supernatant liquid.

Similar tests were conducted with the identical addition of chemical flocculating reagents, but after mixing the slurry in the measuring cylinders, was magnetized for one-tenth second at 1,000 gauss.

The results as shown on the attached chart, table 1, proved that the chemical-magnetic flocculation process is superior to the chemical flocculation process, requires less reagents and results in cleaner water.

All of the tests were conducted in duplicate and the agreement between the results was close.

TABLE I

Type of flocc.	Reagents		Settling rate, ft./hr.	Clarity, P.p.m. solids
	Description	P.p.m.		
Chem.....	H ₂ SO ₄ plus Alum.	(1) 50+20 (2) 37+15 (3) 25+10	(1) 4.0 (2) 3.1 (3) 1.0	(1) 82 (2) 91 (3) 98
Mag./chem., 1,000 gauss.....	do.....	(1) 50+20 (2) 37+15 (3) 25+10	(1) 5.0 (2) 4.2 (3) 3.5	(1) 62 (2) 80 (3) 85
Chem.....	Jaguar G-10.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 4.5 (2) 4.1 (3) 2.4	(1) 51 (2) 58 (3) 79
Mag./chem., 1,000 gauss.....	do.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 5.8 (2) 5.0 (3) 3.8	(1) 31 (2) 40 (3) 48
Chem.....	Separan AP30.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 5.0 (2) 4.8 (3) 2.9	(1) 64 (2) 78 (3) 91
Mag./chem., 1,000 gauss.....	do.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 6.9 (2) 6.4 (3) 5.0	(1) 38 (2) 42 (3) 57
Chem.....	Superfloc 16.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 5.0 (2) 4.1 (3) 2.9	(1) 48 (2) 65 (3) 98
Mag./chem., 1,000 gauss.....	do.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 7.2 (2) 5.8 (3) 4.4	(1) 26 (2) 31 (3) 45
Chem.....	Nalco A-672.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 5.0 (2) 4.8 (3) 4.7	(1) 32 (2) 35 (3) 39
Mag./chem., 1,000 gauss.....	do.....	(1) 1.0 (2) 0.75 (3) 0.50	(1) 8.1 (2) 8.0 (3) 7.8	(1) 10 (2) 10 (3) 12

TABLE II.—TEST RESULTS—MAGNETIZING CHEMICALLY FLOCCULATED SCRUBBER SLIMES

Flyash—Structure						
		Microns	Weight	Percent weight		
		+45.....	.2277	27.37		
		-45+30.....	.2143	25.75		
		-30+20.....	.1617	19.43		
		-20+10.....	.1332	16.01		
		-10.....	0.0952	11.44		
<hr/>						
pH=8.3		Solids=0.18%	Fe=23.2%	Mag. Fe=12.8%		
<hr/>						
Test series	Reagent	P.p.m.	Settling rate, ft./hr.	Clarity	Magnetizing	Clarity
56.....	None.....		1.0	Poor.....	0.2 Seconds at 800G	Poor.
57.....	do.....		0.1	Fair.....	do.....	Fair.
58.....	H ₂ SO ₄ (pH=7.0).....	10	1.0	Poor.....	do.....	Poor.
59.....	NH ₃	10	1.0	do.....	do.....	Do.
60.....	H ₂ SO ₄ plus NH ₃	20+10	1.0	Fair.....	do.....	Fair-Good.
61.....	Fe plus NH ₃	10+10	1.0	do.....	do.....	Do.
62.....	Lime.....	50	1.0	do.....	do.....	Do.
63.....	Alum.....	20	1.0	do.....	do.....	Do.
64.....	Lime and alum.....	50+20	5.0	Fair-Good.....	do.....	Do.
65.....	Jaguar C-10.....	1	5.0	do.....	do.....	Good.
66.....	Separan AP30.....	1	5.0	do.....	do.....	Excellent.
67.....	Superfloc 16.....	1	5.0	do.....	do.....	Do.
68.....	Nalco 672.....	1	5.0	do.....	do.....	Do.

COMMENTS.—Magnetic flocculation greatly improved the settling rate of the flyash and clarity of the Supernatant.

TABLE III.—TEST RESULTS—MAGNETIZING CHEMICALLY FLOCCULATED SCRUBBER SLIMES

Blast Furnace Dust—Structure						
		Microns	Weight	Percent weight		
		+45.....	0.541	12.81		
		-45+30.....	0.4892	11.58		
		-30+20.....	0.7355	17.42		
		-20+10.....	1.2035	28.49		
		-10.....	1.2541	29.70		
<hr/>						
pH=8.9		Solids=0.28%	Fe=48.5%	Mag. Fe=17.4%		
<hr/>						
Test series	Reagent	P.p.m.	Settling rate, ft./hr.	Clarity	Magnetizing	Clarity
81.....	None.....		1.0	Poor.....	0.2 Seconds at 800G	Poor.
82.....	do.....		0.1	Fair.....	do.....	Fair.
83.....	H ₂ SO ₄ (pH=7.0).....	10	1.0	Poor.....	do.....	Poor.
84.....	NH ₃	10	1.0	do.....	do.....	Do.
85.....	H ₂ SO ₄ plus NH ₃	20+10	1.0	Fair.....	do.....	Fair-Good.
86.....	Fe plus NH ₃	10+10	1.0	do.....	do.....	Do.
87.....	Lime.....	50	1.0	do.....	do.....	Do.
88.....	Alum.....	20	1.0	do.....	do.....	Do.
89.....	Lime and Alum.....	50+20	5.0	Fair-Good.....	do.....	Good.
90.....	Jaguar C-10.....	1	5.0	do.....	do.....	Excellent.
91.....	Separan AP30.....	1	5.0	do.....	do.....	Do.
92.....	Superfloc 16.....	1	5.0	do.....	do.....	Do.
93.....	Nelco 912.....	1	5.0	do.....	do.....	Do.

COMMENTS.—Magnetic flocculation greatly increases the rate of settling and clarity of the supernatant.

TABLE IV.—TYPICAL FLOCCULATION EXAMPLES

Type of Flocculation	Material			
	Natural Magnetite		Basic Oxygen Furnace Dust	
	Chemical	Chemical/Mag., 1,000 g.	Chemical	Chemical/Mag., 1,000 g.
Percent solids.....	1.0	1.0	0.5	0.5
Particle size, M.....	-380+5	-325+5	-20	-20
Temperature, ° C.....	20	20	20	20
pH.....	8.0	8.0	8.5	8.5
Chemical flocculator.....	(1)	(1)	(2)	(2)
P.p.m. of chemical flocc.....	10+20	10+10	1.0	1.0
Settling rate, ft./hr.....	4.2	4.8	3.0	5.0
Supernatant clarity (p.p.m. of solids).....	40	20	50	30

¹ H₂SO₄ plus Alum.² Jaguar C-10.

The foregoing specification sets forth the invention in its preferred practical forms but the process disclosed is capable of modification within a range of equivalents without departing from the invention which is to be understood is broadly novel as is commensurate with the appended claims.

We claim:

1. An apparatus for removing nonmagnetic suspended solids from a liquid containing magnetic particles comprising:
 - a relatively large settling tank;
 - means at the bottom of said tank to remove sludge from said tank;
 - means adjacent the top of said tank to remove clear liquid;
 - a conduit connected to the top of said tank for supplying liquid containing suspended solids;
 - addition means to add a chemical flocculant to said liquid in said conduit;
 - a magnet unit disposed between said addition means and said tank for magnetizing said particles;
 - said magnet unit comprising:
 - magnetic means disposed on opposite sides of said conduit whereby a magnetic field passes through said conduit and through said liquid, whereby said particles are magnetized;
 - a magnet conduit section having a flow passage substantially lesser in dimension in the direction said magnetic field passes through said conduit at said magnet unit than in the direction at right angles thereto; and
 - said magnet cross section being made of nonmagnetic material and said magnet has one pole on one side of said conduit and another pole on the other side.