Pulling Out Pollution With Super Magnets

Water pollution can become a thing of the past, using superconducting magnets to literally pull the pollution out of the water — and at a fraction of the cost of current methods of pollution control. As usual, the real answer to an environmental problem is more technology, not less.

Water treatment is only one of a number of immediately available large-scale industrial applications of superconducting magnets, as used in a process called high-gradient magnetic separation. This means that while conventional magnets can separate only three common ferromagnetic elements (iron, nickle, and cobalt) superconducting magnets make it possible for a host of other elements which are paramagnetic to also be separated. The result is a technology that can redefine the term "resources" in mining and many other forms of raw materials exploitation.

Applying high magnetic fields, economically and scientifically feasible only with superconducting magnet technology, allows the manipulation of very small particles. This technique has been proposed not only for water pollution control, but also for desulfurization of coal, mineral beneficiation and other kinds of purification. In some cases, pilot plants have already been constructed.

Until the early 1970s there were essentially five methods for separating finely divided, or colloidal articles from a background substance. These included: gravity separation, a slow process requiring large settling tanks and chemicals; inertial separation, using a centrifuge, the cyclone, or other variations; electrostatic precipitation, which is limited to very dry materials having suitable electrical properties; froth flotation, requiring sudsing agents and large areas of overflow tanks; and filtration, a slow process in which the entire medium must flow through holes smaller than the particles to be removed.

While magnetic separation has been practiced by the mining industry for several decades, it has been largely limited to the mining of iron ore or the removal of relatively large particles. The use of superconducting magnet technology further extends beyond present bounds the application of magnetic fields to paramagnetic particles several microns in size.

Magnetic Filters

In order to separate paramagnetic particles down to colloidal size of 1-100 microns, Dr. Henry Kolm at the MIT Bitter Magnet National Laboratory developed the idea of using a filamentary ferromagnetic material, such as steel wool, formed into a ferromagnetic matrix. Such a material, including woven or felted steel fabric and wire mesh, has a low density and therefore large effective surface area. It acts as a strong magnetic trap to filter the magnetic components of a slurry passing through it. The basic principle is to make the magnetic force on weakly paramagnetic particles larger than the competing gravitational and hydrodynamic forces acting on the particle. Using a ferromagnetic matrix, particles in the colloidal size range can be manipulated. Using these extremely powerful magnetic fields, this process has been termed High Gradient Magnetic Separation (HGMS).

The first HGMS device was patented by Kolm in 1971. That same year, Magnetic Engineering Associates in Cambridge, Mass. patented a HGMS device which they had built for the kaolin industry. The first commercial application was to separate stained particles of titanium dioxide from kaolin clay. These particles cause unwanted discoloration and limit the brightness of the kaolin, which is a critical property in the clays used in paper coating. Since 1973 HGMS devices for the kaolin industry have been manufactured by MEA (which is now Sala Magnetics of Cambridge), Magnetic Corporation of America, and Aquafine. Previously employed purification techniques, such as acid leaching and flotation, have proven to be less effective and less cost efficient than the electromagnetic HGMS.

Almost as soon as the concept of HGMS was shown to be technologically feasible, work at MIT and at Magnetic Corporation of America (also a major producer of super-

What Is Superconductivity?

The phenomenon of superconductivity was discovered by Kamerlingh Onnes at the University of Leiden in Holland. In 1908 Onnes had succeeded in liquifying helium by achieving for the first time a temperature of 4.2 degrees Kelvin. (Zero degrees Kelvin is the absolute zero of temperature, the point where all molecular motion ceases.) Three years later Onnes discovered superconductivity while exploring how far the resistivity to the flow of an electrical current of a pure metal would drop as the temperature dropped. He found that materials brought down to 4.2 degrees Kelvin exhibited *no* resistance to electric current — that the current, once established, would continue to flow completely unimpeded and appeared capable of persisting forever: no resistance meant no loss of energy! The importance of the discovery of superconductivity can be seen from the following comparison. A conventional 12 gauge copper wire cannot carry a current greater than 20 amperes due to heating from resistance which would melt the copper wire. A comparable wire made of superconducting materials, such as the niobium-titanium alloy presently used, if kept at the temperature of liquid helium (4.2 degrees Kelvin) can carry a current of 50,000 amperes, with no significant loss or heating.

conducting magnets) on replacing the high-field electromagnets used in HGMS with superconducting technology. The replacement of conventional magnets with power saving higher-field superconducting magnets opens up magnetic separation to a large variety of areas which would be otherwise economically unfeasible.

(1)Mineral Mining and Beneficiation.

The vast majority of the earth's mineral resources are too finely divided to mine economically. Many remaining reserves of ores and minerals, particularly in the United States, are of too low a quality to be used in industrial processes without concentrating their properties.

Ten years ago the Mesabi iron ore Range, backbone of the Great Lakes steel industry, was exhausted. The only remaining ore was taconite which was too finely divided for use in blast furnaces. The invention of pelletizing averted disaster as the taconite was finely ground and concentrated by hundreds of magnetic drum separators, in what was the largest scale application of magnetic separation in the world.

A new crisis is now facing the Mesabi Range, however, because reserves of magnetic taconite are running out, leaving vast quantities of more highly oxidized ore rich in geolite, called semi- or non-magnetic taconite. It could not be concentrated by electromagnetic separation methods. In 1973 the scientists at MIT had promising results with laboratory tests of high gradient separators and a pilot plant using conventional magnets was constructed. However, a full-scale taconite concentrating plant would be unthinkable without using superconducting magnets. The ore mining industry has not yet made the decision to go to commercial-scale superconducting plants but the industry will face increasingly high costs either from the Mesabi Range, or from importing iron ore.

In addition to nonmagnetic taconite, preliminary investigations have shown that superconducting HGMS would be useful for uranium, molybdenum, and other transition metal elements.

(2) Water Pollution Control

Water pollution problems have become quite complex over the past two decades, requiring multistaged treatment processes which are expensive and time-consuming. This is the case for municipal treatment facilities, for decontamination of industrial waste, and for purification of natural bodies of water.

The impurities in water are diamagnetic and therefore require treatment with a metallic iron as a seed. Coliforn bacteria and other suspended and dissolved nutrients can be removed by seeding with iron oxide. For certain contaminants a chemical coagulant is needed in addition. Large-scale laboratory tests have been done at MIT on purifying water from the Charles River Basin and the Dear Island sewage system using HGMS. Flows of 50 to 150 gallons per minute per square foot have been obtained, or a magnitude faster than conventional purification techniques. Since municipal sewage treatment facilities can handle as much as .3 billion gallons per day, the savings is substantial.

Another important use for HGMS in water pollution control, is to stop the rapid eutrophication of large bodies of water, which can be alleviated by limiting the input of growth-promoting nutrients like phosphorous. At the present time this process requires large settling facilities and is very time-consuming. With HGMS, retention times of a few minutes are possible, with extremely rapid water flows.

(3) Magnetic Desulfurization of Coal

In 1973 a preliminary economic analysis in work done at MIT on magnetic desulfurization of coal showed promise for the commercial application of the superconducting magnetic process. Though there had been attempts to pretreat high sulfur coal previously, non-HGMS methods required using additives to enhance the magnetic susceptibility of the components to be separated.

In most of the commonly used pretreatment processes, such as dense media cyclone washing, the coal particles sink or float according to their densities. The heavier particles contain a larger amount of minerals, so that the float produces a product purer than the original coal. Unfortunately, however, in many coals the minerals are intimately mixed with the coal substance and grinding to a fine size is required prior to treatment. The problem is that there are not many preparation processes for fine size coals and the processing costs are higher than average. In magnetic separation the particle size does not limit the operation of the process.

Most importantly, using parameters established through experiments at MIT on various applications for HGMS, a computer projection of the rate of flow of the slurry, particle size, water component, and so on was verified by the small-scale experiment with a coal slurry at MIT. Initial projections are for commercial scale at 1,000 tons per hour.