FILTRATION

ELECTROMAGNETIC FILTRATION

Electromagnetic filtration is a simple, cost-effective way to remove suspended, magnetically susceptible material from process streams. Originally, electromagnetic filters (EMFs) were intended to remove magnetite (Fe_3O_4), which is present in most boiler condensate and in nuclear power systems, but they have also been proven effective in removing weakly magnetic species such as hematite (Fe_2O_3) and copper. Other materials such as cobalt, nickel, and chromium, which form spinel crystals or ferrites, can also be efficiently removed. (1, 2)

Modern EMFs are extremely efficient. They can easily remove over 95% of the magnetite present in a stream, and depending on the conditions in a particular application, they can remove over 90% of total iron and well over 50% of the copper found in typical boiler condensates (3, 4).

An EMF has six major components:

1. A pressure vessel containing the matrix through which the liquid to be filtered must flow
2. The matrix, which is either a bed of magnetizable steel balls or a fixed matrix made of expanded metal or compressed steel wool and wire mesh
3. A magnet coil that provides the magnetic field in the matrix
4. Massive iron assemblies to focus the magnetic field
5. Auxiliary equipment necessary for filter operation and flushing, including valves, a power supply, a control system, and, for the fixed-matrix filters, air accumulator tanks
6. A means of cooling the magnet coil

The operation of an EMF is simplicity itself. The magnet coil is energized by the power supply, creating a magnetic field in the filter matrix. The magnetic field in the matrix is intense (>5 kilogauss), and creates localized areas of higher intensity (high magnetic gradients) within the matrix. In a sphere matrix filter the highest gradients are found where the spheres touch each other, while in filamentary matrix filters the highest gradients are around and immediately adjacent to the fine filaments. Magnetically susceptible material suspended in the process liquid is attracted to the matrix material, especially at the areas of highest magnetic gradient, and is given up to the matrix. When the matrix is loaded, the filter is bypassed and flushed. The flushing operation, which is controlled by the programmable electronic controller in the power control unit, takes less than two minutes. The frequency of backflushing and the backflushing process differ with the type of filter.

Two types of EMFs are presently available in the United States:

Sphere matrix. The sphere matrix filter, available from B&W Nuclear Service Company (BWNS), was originally developed by Siemens of West Germany. The present B&W filter has benefited from extensive development over the old Siemens design. The matrix of this filter is composed of small (7/32-inch diameter) type 430 stainless steel balls, and has a void volume of 40%. The efficiency of a sphere matrix filter is unaffected by the micron size of the material to be filtered, from 20 microns down to 0.08 microns, and, when used in a system where the suspended material is predominantly magnetite, is independent of the flowrate through the filter up to the maximum design flowrate. The sphere matrix filter is flushed by degaussing the matrix, and reversing the flow of process fluid so that it flows upward through the matrix, causing the bed of spheres to tumble against each other for about 15 seconds. This mild tumbling action is instrumental in removing the accumulated crud from the spheres, and is crucial in obtaining the expected 40-year life of the matrix. Sphere matrix filters can hold up to 23 pounds of crud for each 1,000 pounds of spheres, but standard practice has been to use a value of 11 pounds of crud per 1,000 pounds of spheres as an outside limit when calculating backflush frequency.

Filamentary matrix. The filamentary matrix filters, available from Boliden-Allis, have a matrix composed of expanded metal, or in some instances, wire mesh and compressed steel wool. This filter is also considered permanent

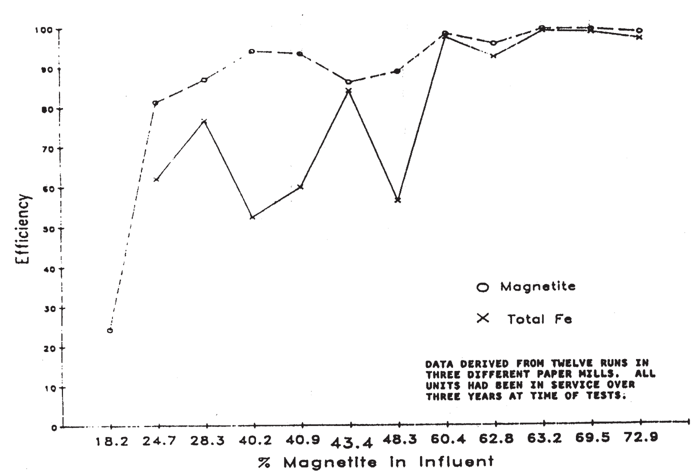

Figure 1. EMF efficiency for magnetite removal.

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equipment requiring only occasional matrix replacement (six months to two years) (5). Owing to the need for an air accumulator tank and extra valves, etc., for flushing, it is slightly more complex than the sphere matrix filter. Power consumption is moderate. Dirt-holding capacity of an expanded-metal mesh filter is approximately 4% of the weight of the matrix, which has a void volume of up to 95%. The filamentary matrix filter is flushed by high-velocity liquid driven by compressed air to forcibly remove the accumulated crud from the matrix. If the process temperature exceeds 285 °F, flushing can be accomplished by opening the flush outlet valve, and allowing the liquid to flash to steam within the matrix, creating enough force to clean the filter.

Some studies have shown that the filamentary matrix filter, sometimes known as a high-gradient magnetic filter (HGMF), is particularly effective in filtering out weakly magnetic material such as hematite. Field test results show, however, that the ability of this filter to remove weakly magnetic species is quite similar to that of the newer sphere matrix equipment. (3, 4, 6, 7)

Since these filters are magnetic devices, factors that influence the percentage of magnetite in the influent will obviously have an effect on the performance of the filter. Experience has shown in fact that the one factor most greatly affecting the efficiency of EMFs is the percentage of magnetite or strongly magnetic species present in the influent (3). With this in mind, it is understandable that a reducing environment in the influent stream and relatively high temperatures make ideal conditions for the use of an EMF. The pH of the process stream will affect the solubility of iron in the water, and since the filter cannot remove dissolved iron, will affect filter performance relative to total iron removal. Ideally, a pH between 9.3 and 9.5 should be maintained to minimize corrosion in the process piping and to insure that the iron present is not in solution.

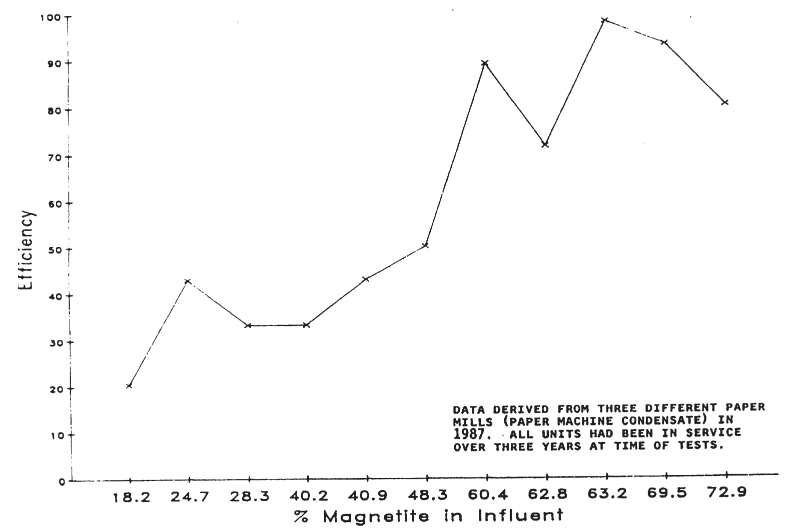

Figure 2. EMF efficiency for copper removal.

Flowrate is another variable that can impact filter performance, especially when there is a high percentage of weakly magnetic material present. This is easily understood, for the magnetic force that attracts and holds contaminant in the filter must exceed the dynamic forces of the flowing liquid that tend to wash the particles out of the matrix. Obviously, the greater the velocity of the liquid, the greater the dynamic force that must be overcome. Paramagnetic particles, such as FeO[OH] or Fe_2O_3, are not strongly held in the filter. In practice, a sphere matrix filter operating in a stream containing high percentages of magnetite gives superb efficiency at flows up to 1.1 feet per second through the matrix area. After that point the efficiency deteriorates quickly. The filamentary matrix filter, likewise, shows relatively constant efficiency in dealing with magnetite up to a flowrate of 450 gpm per square foot of media. When dealing with weakly magnetic species the flowrate of both types of filter can be reduced to achieve improved performance.

Removing weakly magnetic or nonmagnetic species with an EMF sounds paradoxical, but it does occur, and is quite predictable. It is known that some of the weakly magnetic ferrous materials will agglomerate with the strongly magnetic particles and be removed along with them. Copper, chromium, and nickel, on the other hand, appear to combine chemically with the magnetite, forming ferrites or spinel crystals that are strongly magnetic and that thus are easily removed. The elemental copper present in some streams is also effectively removed, apparently by plating or coating itself on to magnetite crystals. Experience has shown that a sphere matrix filter in a stream where over 50% of the iron present is magnetite will easily remove over 60% of the copper

TABLE A
EMF Steam Generator Blowdown (1989)
Shearon Harris Nuclear Station

Run	*Total Fe (ppb)*	*% Magnetite*	*Efficiency (Fe)*	*Efficiency (Mag)*	*Copper (ppb)*	*Copper efficiency*
1	10.6	60.4	88.7	98.4	6.1	78.7
2	11.4	68.4	71.1	94.9	4.7	78.7
3	15.7	66.2	89.2	95.2	5.8	82.8
4	22.3	67.7	89.2	91.4	14.7	85.0

Data from performance tests of an old design (S-Series) BWNS EMF. Total iron and magnetite removal are somewhat less than that achieved by the newer I-Series equipment that generated the results shown in Figures 1 and 2.

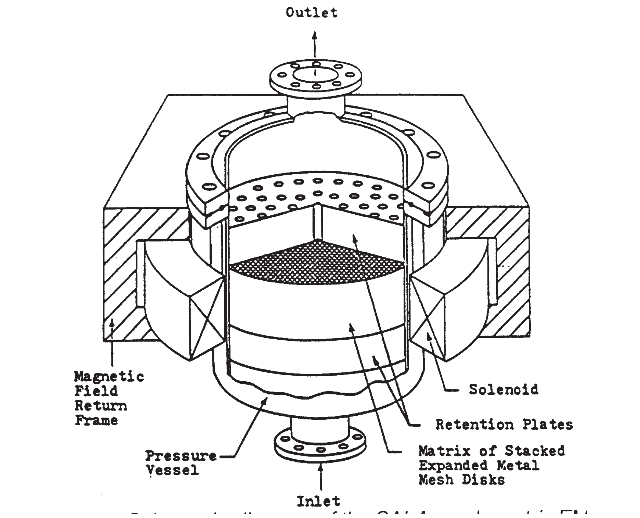

Figure 3. Schematic diagram of the SALA mesh-matrix EMF.

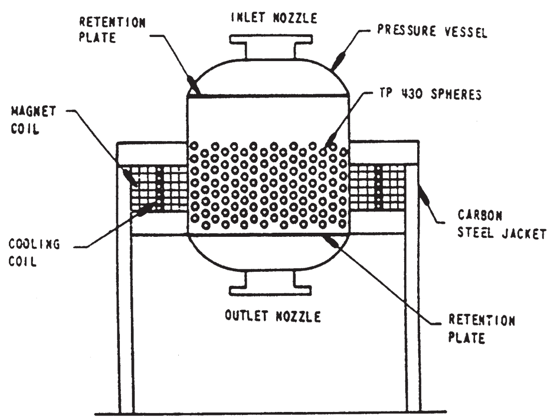

Figure 4. EMF assembly schematic diagram.

present in the stream, but there must be sufficient magnetite present to act as a carrier. A stream with no strongly magnetic species present will not be effectively filtered by any electromagnetic device.

Considering the number of boilers or heat exchangers operated in this country that require frequent chemical cleaning or other maintenance activities to remove magnetite, it appears that electromagnetic filtration is an underutilized technology. The filters, unlike ion exchange columns, can handle high temperatures; and unlike cartridge filters, can handle very large flows for a very reasonable cost. Electromagnetic filters generate no additional waste in addition to the material they remove. An EMF will have no effect on water chemistry other than to remove suspended, magnetically susceptible solids. Since modern EMFs operate automatically and the systems are so simple, maintenance is minimal. In short, it is difficult to understand why we are not making better use of this proven technology. ■

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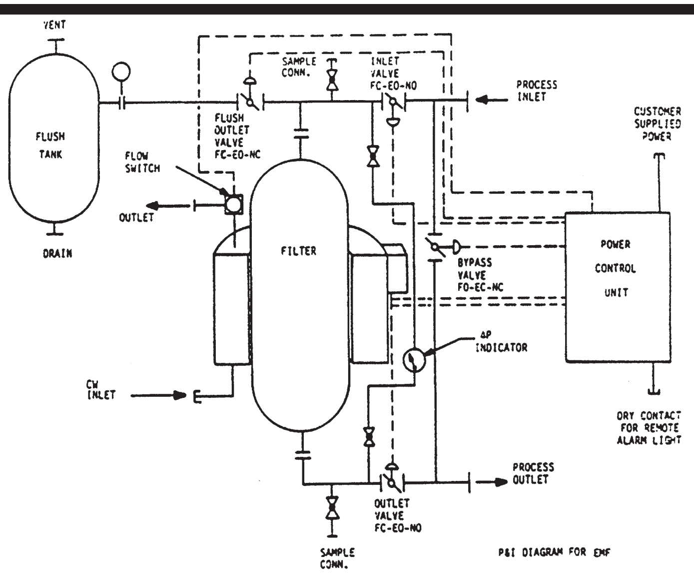

Figure 5. P & I diagram for EMF.