# MAGNETIC CONDITIONING OF FLUIDS:

# AN EMERGING GREEN TECHNOLOGY

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## Abstract

The development and commercialization of new technologies that reduce the use of energy, water, and other resources is critically important to a society grappling with increasing resources shortages and environmental pollution. One emerging technology is the use of magnetic fields to alter the physical and flow characteristics of fluids. This paper describes potential benefits from three applications of magnetic technology-scale and hardness control, natural gas combustion, and golf course irrigation. The findings reported in this paper suggest the need for a cohesive and well-supported program of research to define operational conditions, explore new areas of application, and bring this emerging green technology to its full potential.

## Introduction

Mimetic water conditioning is used worldwide to control scale or to remove existing scale in a variety of applications. The acceptance of magnetic water conditioning has been slow, however, especially in the U.S., in part because of varying experimental results, lack of a clearly defined mechanism of action, and marketplace competition from traditional water technology, primarily chemical softening of water. Because of these impediments, the technology and potential applications are still emerging.

The scientific literature has produced studies, both positive and negative to magnetic water conditioning.  Since the 1990s, there has been renewed interest in research related to this technology. Troup and Richardson (1978) summarize earlier studies in a review of methods for preventing scale formation. Baker and Judd (1996) provide a review of the more recent literature.

## Mimetic Technology: What Is It and How Does It Work?

The general principal of operation for magnetic technology is a result of the physics of interaction between a magnetic field and a fluid. The magnetic field exerts a force on the charged species in the fluid and redirects the orientation of the charged species, which produces physicochemical changes in the fluid. Mechanisms of action have been proposed, but not proven. Parsons (1999) summarized proposed mechanisms for the magnetic treatment of hard water. Micro-contaminants, which affect crystal nucleation growth rates, may play a key role .The magnetic field may affect crystalline growth by acting ether directly on the solid crystal or at the solid-liquid interface, leading to changes in nucleation and crystal size. The magnetic field may cause structural changes in the aqueous solutions, which deforms the hydration sphere around ions or affects the average cluster size in water.

The magnetic technology discussed in this paper is a flow-through magnetic unit ([1]) in which the fluid passes through a series of alternating reversing polarity fields that are orthogonal to the fluid flow. The magnetic core is a single or multiple bars, multi-field, multi-pole cobalt alloy permanent magnet. According to the manufacturer the fluid velocity in the magnetic chamber is critical and varies with the spacing of the poles. The contact time of the fluid within each pole's flux path is 0.1 second. The magnetic field associated with each of the poles varies, depending on the fluid flow gap. Because there are no moving parts, the magnetic unit is low maintenance and does not use energy to produce the treatment. The manufactured units have a capacity that ranges from 1 gph up to 50,000 gpm for water conditioning.

[1]Developed by the Superior Manufacturing Division of Magnatech Corporation, Fort Wayne, TN.

The natural gas application ranges from 0.25-inch up to 20-inch diameter pipe.

Proper installation of the unit is critical. Parameters of interest to the manufacturer include fluid flow rate, proximity to electromagnetic fields, and in the case of water applications, water quality parameters such as hardness, iron, silica, and alkalinity.

## Scale and Hardness Control

Hard scale resulting from the mineral deposits from untreated hard water is a major problem throughout the world. The build up of scale on heat transfer surfaces reduces the heat transfer performance of the equipment and the build up of scale in tubing also decreases the flow rate of water (or increases the pressure drop across the heat transfer equipment), leading to increased energy usage and costs. Even a thin-film of scale (1/32 in. or 0.8mm) on a heat exchange surface can increase energy consumption by 8.5%, while a scale build up of 1/8 in. is associated with a 25% increase in energy consumption (U.S. DOE, 1998). Conventional treatment for scaling includes the use of scale-inhibiting and scale-removal chemicals and ion exchange and reverse osmosis systems. These methods consume energy and produce waste that increase overall operational and maintenance costs. Conventional treatment methods requiring the use of hazardous chemicals create both environmental and worker health and safety concerns.

In 1998, the DOE issued a Federal Technology Alert (U.S. DOE, 1998) that identified magnetic water conditioning as a technology that can be used as an energy-saving replacement for most water-softening equipment to remove or prevent scale. A major application of the technology is in cooling towers and boilers, both in once-through and re-circulating systems. In a hypothetical case study, the DOE computed a life-cycle cost comparison between traditional lime softening and alternative permanent magnetic treatment for re-circulating boiler water system with a flow of 1,000 gpm or 1.4 MGD (million gallons per day). The facility used extremely hard water (350 mg/L as $CaCO_3$). Makeup and blow down were estimated at 10% of the flow (140,000 gpd). Another assumption, thought to be representative of industry practices, was that the water-softening process substantially removed the hardness, but still required semiannual inspections and annual cleaning of the heat exchanger. Assumed costs included \$10/ton for delivered lime, \$5.80/1,000 $ft^3$ natural gas, and \$2/gallon for acetic acid for cleaning.

Using the NIST BLCC (ver.4.4-97) model, the DOE determined that magnetic conditioning of the boiler water would result in annual energy savings of 3,100 kWh of electricity and 40,000 MBtu of natural gas in comparison to traditional lime softening (life-cycle savings were 46,500 kWh and 600,000 MBtu, respectively). The total pollution reduction was calculated to be 21,128 Mg $CO_2$, 95 Kg for $SO_2$ and 16,469 for $NO_2$, (life cycle reductions of 316,925 Mg; 1,424 Kg; and 247,036 Kg, respectively).

The annual cost savings for electricity, natural gas, and chemicals was $232,635 in favors of the magnetic technology. The calculated life-cycle costs were $27.5 million for the magnetic technology versus $30.3 million for conventional lime softening. This represents a life cycle cost savings of $2.77 million. The simple payback is less than one year and the adjusted internal rate of return is 50.7% for the magnetic technology.

## Natural Gas Combustion

The combustion of natural gas generates carbon monoxide, carbon dioxide and other pollutants that contribute to air pollution and global warming. Innovations that reduce natural gas consumption will extend this resource, improve our nation's energy independence, produce economic benefits to industrial users, reduce air pollution and improve public health, reduce health care costs, and reduce global warming.

Magnetic fields were used in a pilot project to explore the potential application of this technology for the steel industry. In this pilot, a magnetic unit (Magnatech Corporation Kinetic EnergizerR) was installed at the LTV Steel Company's #2 Tinning Mill in East Chicago, Indiana, which produces 384,000 tons/yr of finished product in 1999.

The magnetic unit was installed on the #5 portable annealing furnace at the tinning mill. The average flow rate of natural gas to the #5 furnace was 3,373 $ft^3$/hr during both control and treatment periods. Data on fuel consumption were collected for a nine-month control period (from 5/27/97 through 2/25/98) before the installation of the technology. Fuel consumption data were also collected for a treatment period of nearly one year (from 2/28/98 through 2/8/99).

The results of the pilot project demonstrated a 7 % reduction in natural gas usage between the control and treatment periods. The reduction was statistically significant ([2]) based on an analysis of 33 cycles of fuel use data ($t=2.92$; $p<0.00024$). At 1999 prices, a 7 % reduction in natural gas usage translated into a cost savings of $120,000 for the facility's continuous annealing line and five portable annealing furnaces. The payback period of 1.3 years would be significantly reduced in today's natural gas market.

## Golf Course Irrigation

Irrigation and agriculture are important users of water resources and chemicals, including pesticides, fertilizers, and wetting agents to improve penetration. Resulting environmental issues include chemical contamination of surface and groundwater and water usage.

The Indianapolis 500 Brickyard Crossing Golf Course has 130 acres of greens, tees, fairways and rough. The water sources for the facility are a 122 ft well (1100 gallon per minute, gpm) and a drainage water collection system, which pumps into a 3-acre lake. The Flowtronics/PSI pump station can withdraw a maximum of 2000 gpm for distribution through the irrigation system. The facility is required to conform to the Indiana Department of Environmental Management for significant water use reporting requirements for well water withdrawals. Watering is accomplished through a fixed irrigation system, and portable sprayers are used to apply fertilizers, herbicides, insecticides and fungicides.

A Toro Network 8000 Site Pro irrigation management system, which controls the water application through a fixed irrigation system of 1200 sprinkler heads, were installed in September 1993. Each green has 5 to 7 watering points and 2 sprinklers at each watering point. The computerized system is integrated into an on-site weather station, which monitors temperature, relative humidity, dew point, wind speed, wind direction, solar radiation and precipitation. The Toro system establishes watering periods for each sprinkler head based on the evapo-transpiration rate for each day and the sprinkler nozzle type and rated precipitation flow rate. The magnetic unit, a 2000 gpm Magnawet MNW-2000-8 ([3]), was installed in 1999. Water is pumped from the retention pond to the magnetic unit via 25, 50, and 100 horsepower centrifugal pumps. As water leaves the magnetic unit, the pH is adjusted (from about 7.8 to about 6.0) with a sulfuric acid/urea solution.

According to the Course Superintendent, Jeffery Stuart, CGCS, a primary reason for investing in magnetic technology was to obtain better infiltration of water and thereby reduce water and chemical usage. Stuart noted that the magnetic technology, which effectively lowers the surface tension of the water, has dramatically improved the infiltration distribution of the water, substantially eliminating both wet and dry areas. Prior to installation of the unit, approximately 80 labor hours per week were spent on hand watering, even with the Toro system, and the golf course still had uneven infiltration of water. Since the installation of the magnetic unit, uniformity distribution problems have reduced dramatically. It is now unusual to allocate more than 10 labor hours per week hand watering slopes and knobs, and labor hours spent roping off wet areas and repairing cart damage have been eliminated, Table "1" shows some operational costs for pre- and post-magnetic unit installation. An analysis of water usage is in process.

[2]Statistical analysis conducted by Joseph W. Camp. Jr.. Ph.D., Purdue University, North Central.

[3]Manufactured by Magnatech Corporation in Fort Wayne, Indiana.

Table 1. A Comparison of Wetting Agent and Fertilizer Usage and Related Labor Costs Pre- Magnetic and Post-Magnetic Installation at the Brickyard Crossing Golf Course

| **Pre- Magnetic Unit** (Average of 1996-1998 data) | | | **Post- Magnetic Unit** (Average of 1999-2000 data) | |
|---|---|---|---|---|
| | Quantity | Cost/yr | Quantity | Cost/yr |
| Wetting Agent Usage | 1,149 lb/yr | $ 4,327 | 524 lb/yr | $1,996 |
| Fertilizer Usage | 26,470 lb/yr | $13,889 | 7,608 lb/yr | $4,398 |
| Labor Application Cost-Wetting Agent | NA** | $1,670 | NA | $1,054 |
| Labor Application Cost-Fertilizer | NA | $2,381 | NA | $768 |

| | | | | |
|---|---|---|---|---|
| Labor Application Cost-Hand watering | NA | $2,760 | NA | $345 |
| **Total Materials and Associated Cost** | **27,619 lb/yr** | **$25,027** | **8,132 lb/yr** | **$8,561** |

**Note Applicable ap

The data from the Brickyard golf course show a 71% reduction in the use of wetting agents and fertilizers and a related cost savings of 65% after the Installation of the magnetic unit. The payback time for the magnetic unit at this facility, which does not pay for its water, is about 4.5 years based only on the wetting agent and fertilizers usage. An anecdotal report from a facility in a hot weather region suggests a payback time of less than one year for facilities that pay for water.

## Summary

This paper provides additional evidence that magnetic fluid conditioning has the potential to contribute substantially to reduced consumption of energy and chemical resources, leading to cost saving and environmental improvements. Three diverse examples - scale and hardness control, natural gas combustion, and irrigation - demonstrate the wide-ranging applications for magnetic fluid conditioning technology and the magnitude of cost savings and environmental impact reductions. The technology has a historical basis of successful installations, however, it has not been widely embraced. An aggressive research program is needed to provide the marketplace with information it needs to determine the conditions under which it is effective, to define mechanism of action, and explore new applications.

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