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The Effect of Magnetic Field on Scale Prevention in the Industrial Boilers

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Abstract

We have investigated the effect of magnetic field on the scale formation in the industrial boilers. It was found that passing water through a static magnetic field about 6000 G reduces the scale formation and protects the boiler from internal corrosion. It seems that the presence of the magnetic field modifies the local ionic concentrations via Lorentz Force $q\vec{V}\times\vec{B}$ and therefore changes the morphology of the mineral crystals. This effect causes the shape of the crystals change from a dendristic form to a disk-shape form that is less likely to form a scale.

Key words: magnetic water treatment, scaling, corrosion, Lorentz force.

Introduction

The magnetic technology has been cited in the literature and investigated since the turn of the 19^{th} century, when Lodestones and naturally occurring magnetic mineral formations were used to decrease the formation of scale in cooking and laundry applications. Today, advances in magnetic and electrostatic scale control technologies have led to their becoming reliable energy savers in certain applications [1-4].

For example, magnetic or electrostatic scale control technologies can be used as a replacement for most water-softening equipment. Specifically, chemical softening (lime or lime-soda softening), ion exchange, and reverse osmosis, when used for the control of hardness, could potentially be replaced by non-chemical water conditioning technology. This would include applications both to cooling water treatment and boiler water treatment in once-through and recirculating systems [5-6].

The general operating principle for the magnetic technology is a result of the physics of interaction between a magnetic field and a moving electric charge, in this case in the form of an ion. When ions pass through the magnetic field, a force is exerted on each ion. The forces on ions of opposite charges are in opposite directions. The redirection of the particles tends to increase the frequency with which ions of opposite charge collide and combine to form a mineral precipitate, or insoluble compound. Since this reaction takes place in a low-temperature region of a heat exchange system, the scale formed is non-adherent. At the prevailing temperature conditions, this form is preferred over the adherent form, which attaches to heat exchange surfaces.

The operating principles for the electrostatic units are much different. Instead of causing the dissolved ions to come together and form non-adherent scale, a surface charge is imposed on the ions so that they repel instead of attract each other. Thus the two ions (positive and negative, or cations and anions, respectively) of a kind needed to form scale are never able to come close enough together to initiate the scale-forming reaction. The end result for a user is the same with either technology; scale formation on heat exchange surfaces is greatly reduced or eliminated [7].

Donaldson emphasizes that in order to understand the effect, you first need to know what the scale is. Salt being heated, cooled, and mixed with chemicals in all sorts of heating and processing plants are not necessarily well-behaved [8].

For example, in desalination, an increase in temperature causes the following sequence:

$$2HCO_3^- \rightarrow CO_3^{2-} + CO_2 + H_2O$$
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3(calcite)$$
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3(aragonite)$$

The lime scale problem in hard water arises because the solubility of $CaCO_3$ decreases with increasing temperature [9].

Despite its ubiquity, there is relatively little scientific literature on magnetic water treatment. It is not clear now or even if, it works. Unlike chemical water, softening, magnetic treatment should have no direct effect on water chemistry (unless the magnets are in contact with the water) yet, it is claimed to alter the morphology and adhesion of calcium carbonate scale [10]. Published data are often contradictory. For example, there is some dispute as to whether the deposits of calcium carbonate from magnetically treated water are predominantly calcite or aragonite. These are the two common natural forms of $CaCO_3$, with rhombohedral and orthorhombic crystal structures , respectively.

The efficacy of magnetic treatment is reported to last from tens of minutes to hundred of hours; there is a review of the literature by Baker and Judd [11]. The authors claim the important factors which promote magnetic forces (responsible for the changes in crystallization) are the conductivity of the solution, the linear flow velocity of the fluid, and the flux density of the field.

Upon reviewing the Literature, we arrived at the conclusion that most reported successful applications of “AQUA CORRECT” have occurred in continuously recirculating systems enabling repeated treatment of the process water (specially in the industrial boilers)[12].

Experimental

To have a permanent magnet in a compact form a unit called" AQUA CORRECT” (H.P.S CO. DN= 25, 1 inch, Flow 4 m^3h^{-1}) was used. AQUA CORRECT has a free and smooth internal flow which exclude the presence of turbulence. The function is pure magnetic physical. So the crystal structure of lime scale will change and can easily remove it.

The coaxial magnetic system of this instrument can produce a static magnetic field about 6000 G and a stainless steel strainer was used before this instrument (fig. 1).

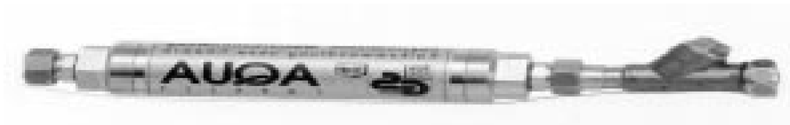


Figure 1: The magnetic instrument and stainless steel strainer.

The equipment was connected to a pipeline system and to the boilers. Water Pump was installed before the magnetic instrument in order to pump aging tap water through the AQUA CORRECT in the boilers (Fig. 2.).

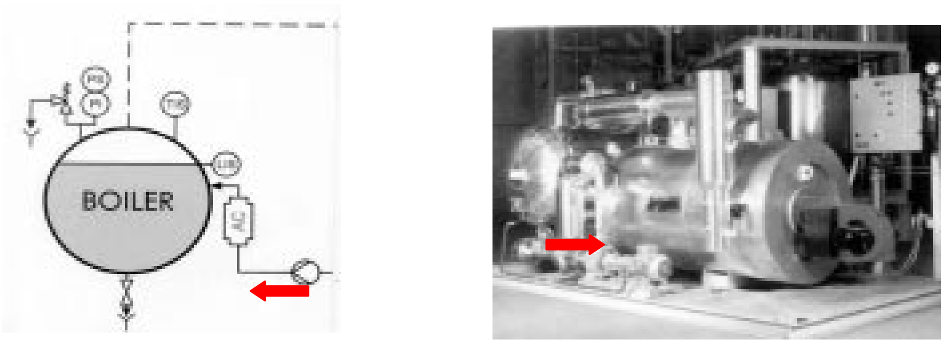


Figure 2: Installation of AQUA CORRECT on the industrial boilers.

In our experiment water had to flow through a coaxial magnetic gap, with a magnetic field area about 1.25 cm^2. The flow rate of water was checked before the installation. The direction of flow of water was adjusted to be perpendicular to the field. A stainless steel strainer was placed inside the equipment to capture the suspended impurities present in the water.

About 24 hours after installation the boiler’s Jacket was considered. The flow rate and condition of the pipelines and chemical properties of water were also checked.

Every three months thereafter the pipelines were opened and studied. After one year final observations were made with respect to the internal conditions of the pipeline and conditions of the boilers and so the chemical properties of water.

On the basis of over one year of research in this field, we have reached the following conclusions:

1. The magnetic water treatment will require a sufficiently fast, continuous flow of fluid. If magnetohydrodynamic forces are responsible for the action of the device, continuous fluid flow is required to generate these forces.
2. The magnetic field must be of sufficient strength and oriented $90^{\circ}c$ relative to the direction of fluid flow (Fig. 3.).

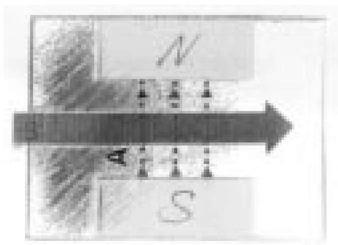
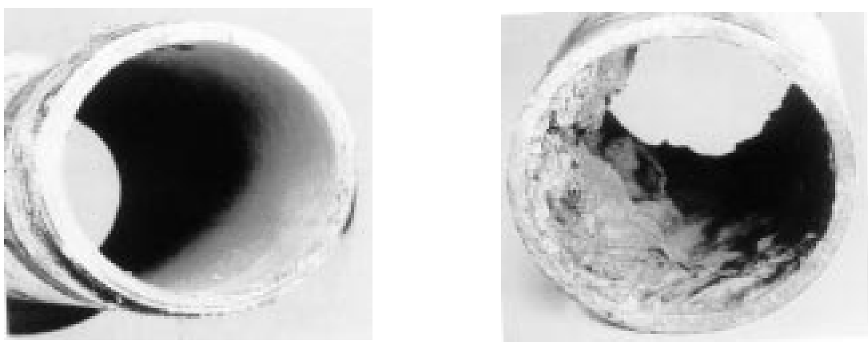


Figure 3: Effective factors in the magnetic field. A: Lines of the magnetic field. B: Direction of the fluid

3. The new pipeline fitted with the AQUA CORRECT was found to be well protected from scale formation and internal corrosion; whereas the pipe without the equipment was badly damaged by scale formation and internal, corrosion occurred inside the pipe (Fig. 4.).
4. After installation of the magnetic instrument on the boilers the boiler's Jackets and pipelines system were automatically cleared and the solid material became loose and fell off. Thus, the life span of the boilers could be increased [13-14].



(a) (b)

Figure 4: (a) Before installation the magnetic apparatus. (b) After installation the magnetic apparatus.

Results and discussion

The chemical properties of scaling water before and after the magnetic instrument was studied. In this order the lime scale was produced by heating the water to 80-85$^\circ c$ after waiting for few times and the scale was examined by powder X-ray diffraction. Our results from X-ray analysis showed that there was a difference in the amount of the two crystallographic forms of $caco_3$ if the model water was treated with a magnetic field which is in fair agreement with other experimental results [15-16] (Table 1).

Table 1: The change of mass percentages of crystal forms of calcium carbonate due to magnetic water treatment

Crystal forms of $CaCO_3$	Calcite %	Aragonite %
Tap water	65	35
Magnetic Water Treatment	27	73

The results show that the ratio of aragonite/calcite is remarkably has been increased in the magnetic water treatment. Therefore the presence of the magnetic field changes the direction of the crystal growth to the aragonite which is a softer type of scale and less likely to form an adhesive scale which can be easily removed . Comparing the scale formed in the surface of the boilers before and after magnetic treatments, shows a significant decrease of the scale. One explanation for this process is the presence of the Lorentz force $q\vec{V}\times\vec{B}$, Where *q*, *V* and *B* are the ionic charge, magnetic field and flow velocity, respectively. This force causes the opposite ionic charges move in opposite directions and therefore decreases the adhesion scale formation, on the jacket of boilers, and corrosion Considerably (Fig. 5.).

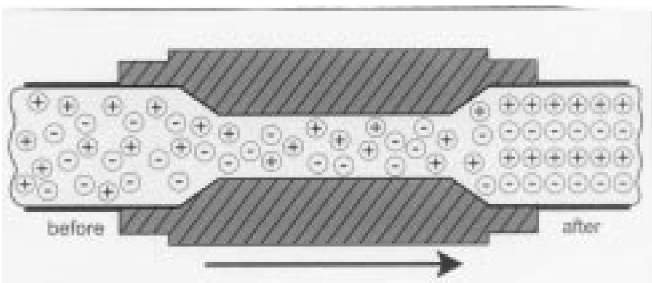


Figure 5: Configuration of ionic particles in magnetic field.

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