

Tratamiento magnético y su influencia en la eficiencia energética

Magnetic treatment and its effect on energy efficiency

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Resumen

De forma general, no existen dudas de la efectividad del tratamiento magnético (TM) al agua, aunque sí coexisten discrepancias en la explicación teórica del efecto que ejerce sobre las propiedades de los sistemas acuosos. Con el objetivo de estudiar el efecto del TM en el incremento de la eficiencia energética, se estudian el punto de ebullición (PE) y la capacidad de conservación de calor (CC) de muestras sometidas a un CM generado por imanes permanentes, para tres valores de intensidad (325mT, 268mT y 217mT), tres tiempos de exposición (1,37s; 2,74s y 4,11 s), y en los periodos de 0h, 48h y 72h, para investigar el fenómeno de la memoria magnética (MM).

Para estas condiciones experimentales, se observa que para las muestras con TM se alcanza la ebullición entre los 98°C - 99°C, y una mayor conservación de la temperatura durante los primeros 30 min. (para 217 mT se conservó la temperatura 1°C más que en la muestra control, mientras que para 268mT y 325 mT se conservó 2°C más que en la muestra control), existiendo relación directa entre la intensidad del CM y la CC. A partir de los 30 min se estabilizó el comportamiento de la temperatura en todas las muestras, alcanzando 23 °C a los 90 min. A las 48 h y 72 h, se mantienen los cambios provocados por el efecto del CM, sin variaciones notables, demostrando la presencia de MM.

Palabras clave: Tratamiento magnético, punto de ebullición, conservación de calor, memoria magnética, eficiencia energética.

Abstract

In general, there are no doubts about the effectiveness of water magnetic treatment (MT), although discrepancies do coexist in the theoretical explanation of its influence on the properties of aqueous systems. With the aim of studying the effect of TM on increasing energy efficiency, the boiling point (BP) and the heat conservation capacity (CC) of samples subjected to a MF generated by permanent magnets are studied, for three values of intensity (325mT, 268mT and 217mT), three exposure times (1.37s, 2.74s and 4.11 s), and in the periods of 0h, 48h and 72h, to investigate the phenomenon of magnetic memory (MM).

For these experimental conditions, it is observed that for the samples with TM, boiling is reached between 98°C - 99°C, and a greater conservation of temperature during the first 30 min. (for 217mT the temperature was conserved 1°C more than in the control sample, while for 268mT and 325mT it was conserved 2°C more than in the control sample), there being a direct relationship between the intensity of the magnetic field (CM) and the CC. After 30 min, the temperature behavior stabilized in all samples, reaching 23 °C at 90 min. At 48 h and 72 h, the changes caused by the CM effect were maintained, without notable variations, demonstrating the presence of MM.

Keywords: Magnetic treatment, boiling point, heat preservation, magnetic memory, energy efficiency

1. Introduction

The theories explaining the effect of magnetic applications on aqueous systems have not been fully clarified by researchers working on the subject. There are numerous publications that demonstrate the change in the properties of aqueous systems under the influence of CM, but discrepancies coexist in the explanation of the phenomenon observed, describing different types of mechanisms of action of CM that sometimes reach conclusions that conflict with each other. This issue becomes more complex if you take into account the influence of external parameters such as temperature, pipe material, and the wide possible range of frequencies, intensity, exposure time and fluid velocity, among others. [1]

Different approaches to the application of the TM have significantly different effects on the performance of each system. In addition, CM can be varied by changing the orientation and arrangement of the mag-nets. Different permanent magnet geometries can also exhibit different intensity values. When water flows through a uniform CM created by magnetic conditioners, the CM lines impinge on the ions of salts that are dissolved in the water, creating forces that move them from their equilibrium position and, it is said, that the water modifies some physical-chemical properties. The fundamental effect observed in the case of water is the reduction of salt incrustations, and even the dissolution of salts, because it directly affects the formation of crystals. [2]

The feed water of steam producing devices causes difficulties arising mainly from scale, which obstructs the passage of water through them, and when precipitating on the internal heating surfaces form sediments that have a very low coefficient of thermal conductivity, causing overheating of the metal. Several studies have found significant reductions in the degree of scaling due to a decrease in the concentration of dis-solved calcium carbonate (CaCO_3) and an increase in the degree of its precipitation under the effects of CM. [3-5]

This reduction is of great interest, since incrustations caused by the degree of total hardness present in the water are the main problem that afflicts most of the entities in Cuba, since Cuban groundwater has a high content of salts, mainly CaCO_3 , responsible for the carbonate hardness, which when reaching high temperatures favors the formation of such incrustations.

Studying the effect that CM produces on the boiling temperature of water to evaluate a possible reduction of the same, would imply the rapprochement between the initial and final temperatures in the water heating process, having a direct impact on the amount of heat and a consequent energy saving. From a practical point of view, this favors the use of TM as a complement to water treatment technologies, where the already known anti-scaling effects would be combined with the reduction of the boiling temperature.

The opportunities of the TM directed towards energy efficiency, allow to favor the appearance of savings due to the decrease in fuel consumption from a lower energy demand of water for the generation of the same amount of steam

2. Materials and Methods

2.1 Experimental system

The experimental system of the present study consisted of a peristaltic pump (Thermo Fisher Scientific, FH 100) to generate the fluid flow; a silicone tubing of 2.85 m length and 0.7 cm inner diameter, two beakers with a capacity of 1,000 ml each and two pairs of permanent magnets (magnetic conditioners) with north and south poles, located opposite each other to generate a

homogeneous CM. The size of each magnet is 5 cm x 3 cm x 0.1 cm (length, width and height) and the separation between each pair was 6.5 cm oriented in repulsion as shown in Figure 1.



Fig. 1. Experimental system for magnetic processing

The magnetic conditioners belong to the NOVAMAG brand, designed and built by CNEA, are devices based on rare earth magnets, made of an alloy of neodymium (Nd₂), iron (Fe₁₄) and boron (B), and were accredited in the magnetic characterization laboratories of CNEA. CM intensity values were measured with a LakeShore Hall effect Gaussmeter (model 41). Figures 2, 3 and 4 show the maps of the magnetic field induction (B) in gauss (G) value scales in the working area for the distances of 1.2 cm, 1.8 cm and 2.5 cm respectively between the polar faces, obtained by simulation using the professional software COMSOL Multiphysics 3.2.

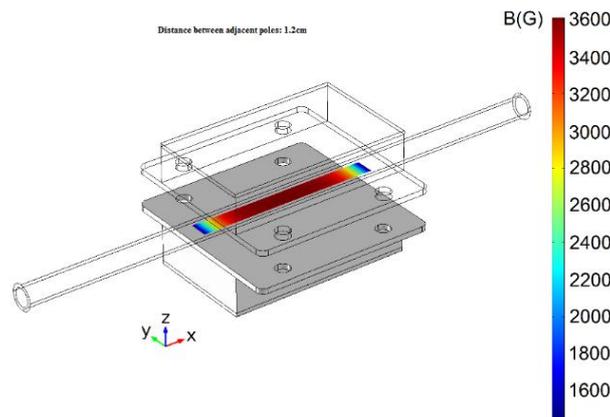


Fig. 2. Scale map of magnetic field induction values in the working area for a pole-to-pole distance of 1.2 cm

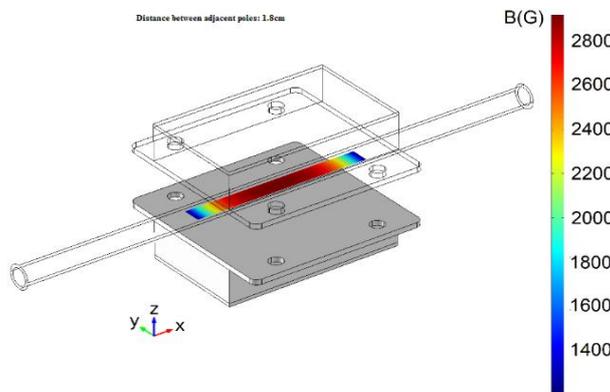


Fig. 3. Scale map of magnetic field induction values in the working area for a pole-to-pole distance of 1.8 cm.

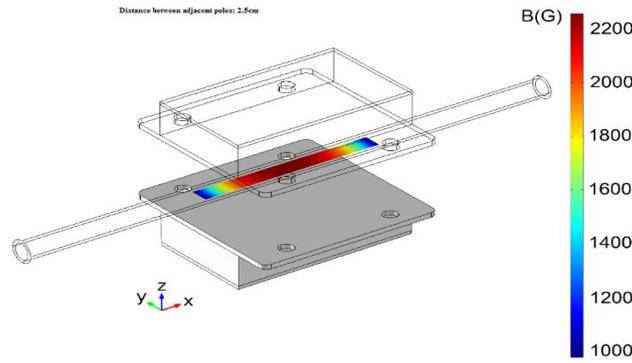


Fig. 4. Scale map of magnetic field induction values in the working area for a pole-to-pole distance of 2.5 cm.

2.2 Experimental procedure

Water samples were taken from the tap, supplied by the “Coscelluela” spring, and analyzed in the water quality laboratories of the company Aguas de La Habana. Measurements were made to study the effect of TM on water: boiling point and temperature (capacity to conserve heat after reaching the boiling point). The samples were exposed to three exposure times and three CM intensities generated by two pairs of permanent magnets. The behavior of PE and CC in the samples, before and after TM, was analyzed at the periods of 0 h, 48 h and 72 h in order to study also the phenomenon of magnetic memory.

For the study, four samples of 1 000 mL of water were taken, the first one without TM (STM), the other three samples were driven by the peristaltic pump with a constant rotation speed of 35 rpm. Each of the samples was analyzed for a different CM intensity value as shown in Table 1.

Table 1. Intensity parameters used and their nomenclature

Polar face spacing (cm)	Intensity (mT)	Nomenclature
1,2	325	TMA
1.8	268	TMB
2.5	217	TMC

The fluid passes through the system at an average constant flow velocity of 0.073 m/s. For each intensity value (325 mT, 268 mT and 217 mT) the behavior of PE and CC was analyzed for three different CM exposure times: (1.09s, 2.18s and 3.27s). The temperature of the samples was not controlled so it was kept equal to the ambient temperature of the medium ($22 \pm 1 \text{ }^\circ\text{C}$). The investigation was carried out in three stages, repeated several times:

- First stage: analysis of the properties of the sample to be studied without magnetic exposure.
- Second stage: application of CM at different intensities and exposure times to the remaining samples and analysis of PE and temperature after exposure to CM.
- Third stage: study of magnetic memory in the samples with TM, after 48 h and 72 h of exposure to CM.

2.3 Sample analysis

For the determination of the PE of the samples, an induction plate (IKA C-MAG HS 10), thermometer with a measuring range of $0 \text{ }^\circ\text{C} - 200 \text{ }^\circ\text{C}$ and an accuracy of $\pm 1 \text{ }^\circ\text{C}$, a beaker with a capacity of 100 mL and universal stand were used. The initial temperature of each sample was equal to the ambient temperature of the medium, approximately $22 \pm 1 \text{ }^\circ\text{C}$. The temperature of the plate was kept constant for all analyses ($350 \text{ }^\circ\text{C}$).

For the analysis of the temperature or CC behavior of the samples after having reached the EP, a study of the temperature variation over time was carried out using a thermometer with a measuring range of 0 °C - 200 °C and an accuracy of ± 1 °C, and a stopwatch.

3. Results and discussion

3.1 Effect of magnetic treatment on the boiling point of water

As a liquid approaches its boiling point, the increased thermal energy of the molecules causes them to overcome the attractive forces that create the surface tension, causing it to decrease. The stronger the intermolecular force present, the greater the amount of energy required to break them apart, thus the higher the boiling point.

Figure 5 shows the values obtained during the analysis of the different samples; an apparent decrease in the boiling point is observed. The sample without magnetic treatment (STM) reached it as natural for the temperature of 100 °C, while the samples with TM and field strengths of (325 mT, 268 mT and 217 mT) reached it at a temperature of 99 °C, 98 °C and 98 °C respectively. There was no direct influence of the different exposure times used (1.09s, 2.18s and 3.27s) on the variation of the results obtained.

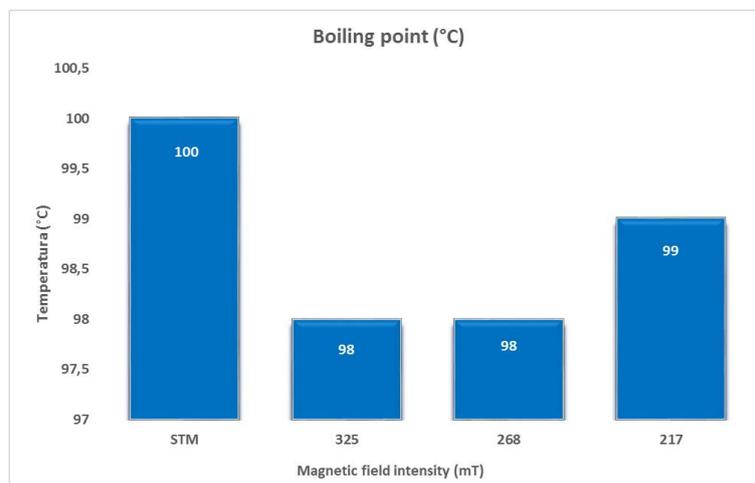


Fig. 5. Temperature at which the boiling point is reached for the samples analyzed.

These results are in agreement with those obtained by Wang et al. [6], who investigated the effect of TM on PE among other variables. For this purpose, they used permanent magnets at 100 mT, 200 mT, 300 mT and 400 mT; obtaining a decrease in PE with increasing intensity, being 300mT the CM intensity that obtained lower PE. The authors obtained a temperature difference range of 2.06 °C between the control sample and the sample treated at 300 mT; whereas, in the present study, the temperature difference between both extremes is approximately 2 °C, taking into account that the precision range of the thermometer used to perform the measurement is only ± 1 °C.

Acea [7], states in his work, that there is a general tendency towards the decrease of the boiling temperature of the water used as a consequence of the action of the CM, with a single exception in the treatment regime corresponding to the speed of 1m/s and the field generated by a current of 1A, where a slight increase arises. It is significant that the largest reductions in boiling temperature are obtained for the lowest value of magnetic induction, being higher when the speed is 1m/s, where the boiling temperature is 1.27% lower than the reference one.

Heat conservation capacity of water

Water has the highest specific heat capacity of all liquids (except ammonia) because a large amount of energy is required to break hydrogen bonds. Since the energy absorbed in this process is not available to increase the kinetic energy of water, a large amount of heat is needed to raise the temperature of water. In addition, a large amount of energy is needed to change water from a liquid

to a gaseous state, due to the energy needed to break the hydrogen bonds. Consequently, water has the highest heat of vaporization (amount of energy required to convert one (1) gram of water from liquid to gaseous state at constant temperature) of any liquid and, therefore, a very low volatility.

After reaching the PE of each of the samples, the behavior of the temperature decrease over time was analyzed to see if there was a direct influence of the CM on the heat conservation capacity of the water. Figure 7 shows the results obtained during this test. For the samples with TM, the boiling point is reached between 98°C - 99°C; moreover, in general, the behavior in each case is quite similar, although a higher temperature conservation is observed in the samples with TM.

For the three CM intensities involved, the temperature was preserved between 1°C - 2°C more than in the control sample on average. For 217 mT and 268 mT, in the first 25 min, a greater stability and difference of the CC was observed against the control sample, there being a direct relationship between the intensity of the CM and the CC. After 30 min, the temperature behavior stabilized in all samples, reaching 23 °C at 90 min. No dependence of the CC with the exposure time was found.

This recorded effect of the influence of CM on CC, as well as the result obtained in the decrease of PE, is evidence that TM can cause changes in the physical and chemical properties of aqueous systems. In this case, it could represent at industrial scale, and large volumes of water, a significant energy saving.

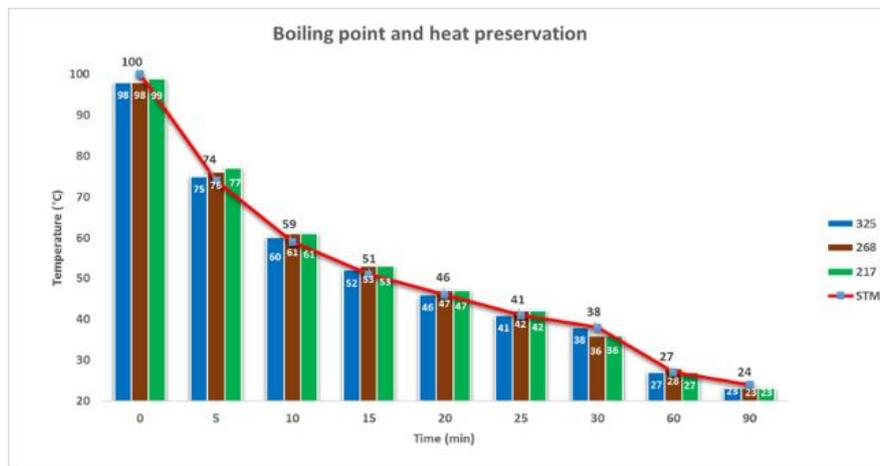


Fig. 6. Temperature at which the boiling point is reached and heat conservation over time.

The results of Wang et al [6] confirm the results obtained in this study. During their investigation, they posited that the behavior of the temperature curves of the samples over time behaved similarly. They report the effect of CM on the partial physical properties of water, with tap water and 4 types of treated water being measured in the same condition. They found that several water properties changed after TM: increased heat of evaporation, decreased specific heat and boiling point. They further summarize that the changes depend on the effect of magnetization.

Zhou et al. [8], presented the results of a Monte Carlo simulation of liquid water to study the influence of an external CM on the internal energy and heat capacity of pure water. They analyzed the structure of water by calculating the radial distribution function $g(r)$ of water molecules. They found a multipeak function of the magnetic effect vs. magnetic induction (B). They showed a significant change in internal energy and heat capacity at $B \sim 0.2$ T. With increasing B , the second peak of $g(r)$ increased markedly. They reported that CM of the order of 0.2 T increase the number of monomeric water molecules, but also the tetrahedrality.

Magnetic memory

The results obtained 48 h and 72 h after exposure of the samples to CM are shown below for the experimental conditions and the different parameters studied: The temperature values at which the different samples with TM reach the boiling point remain the same as those presented in Figure 9.

At 48 h and 72 h, this property maintains the changes caused by the CM effect, without other notable variations due to the precision of the measuring instrument used during the analysis. This deduces the existence of magnetic memory in the experimental conditions studied for this property.

The behavior of the temperature variation over time is similar to that obtained at 0h, so the influence of magnetic memory is observed in this parameter. Several studies confirm the existence of magnetic memory up to 200 h in some properties of water that have been modified after exposure of the fluid to a CM. [9-11]

Coey [12], the leading exponent of this line of research, with research dating back to 2000, adds in 2012 that CM not only influences the structure and morphology of CaCO₃ but also that water could acquire a long-lived magnetic imprint (memory). While acknowledging that memory effects in water have an unhappy history, his paper is based on evidence of a non-classical nucleation mechanism for CaCO₃ and compiles papers in which the classical nucleation theory is challenged, suggesting a theory in which CaCO₃ solutions (unsaturated) contain thermodynamically-stable pre-nucleated clusters or groups called DOLLOPs (Dynamically-Ordered Liquid-Like Oxyanion Polymers). These DOLLOPs, when subjected to a CM, alter their composition and deform, favoring a certain type of cluster structure, and these are the ones that allow to have a large magnetic memory in the solution.

The results obtained in the present study confirm what has been demonstrated in the literature about the effectiveness of TM to water, not only from the point of view of the variation in some of its physicochemical properties, but also from the approach of improving water quality and saving energy.

4. Conclusions

For the samples with TM, boiling was reached between 98°C - 99°C and a greater temperature conservation was observed in the samples with TM during the first 25 min. For 325 mT the temperature was conserved 1°C more than in the control sample, while for 268 mT and 217 mT it was conserved 2°C more than in the control sample, there being a direct relationship between the intensity of the CM and the heat conservation capacity. After 30 min, the temperature behavior stabilized in all samples, reaching 23°C at 90 min.

With the results obtained, it is evident the need to further investigate the influence of CM on surface tension, the physical quantity most involved in the boiling process, since under the effect of CM and when the boiling point is reached with the application of less energy, the decrease of this parameter is evident (greater facility to break hydrogen bonds between water molecules).

The effect of magnetic memory studied under the conditions established in the present study, was visible in the parameters analyzed, the properties studied (PE and CC) recorded behavior patterns very similar to those measured immediately after passing the samples through the CM.

The result obtained in the study of PE and CC, when related to the research carried out on the effect of TM in the reduction and elimination of undesired incrustations, reveals the need for a rigorous adjustment in the TM regime to be applied, in order to achieve that both effects are manifested simultaneously, and cause real savings by increasing energy efficiency, based on the variations that take place in the water due to the action of the CM.

In general, the results obtained in this research are of great interest, since the application of the TM would represent a considerable economic saving for steam production. In addition to being a clean and efficient technology, TM can be produced domestically, which makes its application more economical and profitable.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Contribución de los autores

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