

# Magnetic treatment of water: background and current state

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Dermatologists consider their patients the best: they neither die, nor recover. In fact, they die after all, because of other diseases, unconnected with skin cover. We can say something like that about magnetic water treatment. Its “secret” is not assumed to be completely clear and the technology is still included into the range of water treatment methods. This results to new discussions, concerns, and speculations. There is another medical analogy. Both magnetic treatment problem and a chronic disease have their attacks and remissions. Sometimes it is discussed widely, the experiments are resumed, other times such discussions are judged to be out of science-based subject and the problem transfers from research and technology one into a “technological religion” with a dilemma of “believe-disbelieve”. Such surges in interest are also connected with new generations of engineers who must decide how to protect exchanger equipment from deposits and corrosion and not always possess exhaustive information about previous researches. This report aims to close the gap.

Nowadays the “magic” water treatment technology is discussed worldwide again. Some responsible and less responsible companies offer to add magnetic devices to heat-exchangers. Such devices are said to improve easily operating of equipment: diminish number of chemical or mechanical cleanings, consumption of reagents, wastewater volume, etc. Additionally, if the device contains permanent magnet rather than electromagnet, the argument for energy saving appears. At that, they refer to papers and hypotheses of 40-50 years ago in which magnetic water treatment effects were supposedly proved by theory and practice. The keywords “physical methods of water treatment” track down numerous sites containing catalogues of such equipment and attempts to describe their effect to the water. As a rule, surfing similar sites make us draw a conclusion that the only science is founded – marketology.

This report is written to investigate whether it true or not. Anyway, if a reader don't find here clear and final answers at least he (she) will get questions to those who offer easy and quick solutions of rather complicated research, technology, and budgeting problem.

Magnetic water treatment originates from the magnetic theory. For a long time (XVII-XIX centuries) it was very popular among learned or mostly ignorant rich people (aristocrats) in the Old and New World saloons described, for example, in Tolstoy's novels “War and peace” and “Anna Karenina”. Electricity and a magnet were believed to possess magic (“psychoactive”) properties till the end of nineteenth century when the rigorous theory of electromagnetic field appeared. Although, nowadays a lot of people try to put a magnet to an animal to fix its reaction or attach a magnet to the hose and water the garden or fill the swimming pool...

In sixties of last century Ukraine Power and Electrification Ministry conducted full-scale industrial experiment “being tired” of analyzing numerous experimental and half-industrial data on magnetic water treatment. To this end it was chosen Starobeshevskaya power plant in Donbas Region. The surface water there is known to be highly mineralized one that caused fouling in condenser pipes and subsequently, excess fuel consumption. There were four turbines installed at the power station and

each had two condensers. The magnet device was inserted to a condenser inlet and treated eighth part of total water volume. So, after installation the apparatus scale formation decreased in “experimental” condenser and also in the rest seven units. Designers of the magnetic apparatus (among them V. Minenko from Kharkov Institute of Civil Engineering) explained that the device treated whole water in the cooling pond and improved water-chemistry conditions of service water system. Although, critics noted that during the experiment (2 – 3 years) people in the settlement nearby began to use washing powder instead of soap. The grey wastewaters were disposed into the pond and phosphate concentration there increased sharply (phosphates are known to enter composition of washing powders and also they are effective antiscaling agents). Besides, the well known phenomenon “turn attention to the object” influenced there.

At one time a lot of articles were issued concerning magnetic treatment of concrete. As a rule, the water for mixing concrete passed through magnetic devices. Experimental data were unstable and discrepant. For full-scale industrial study the magnetic device was installed at one of Moscow mortar plants. The quality of concrete turned to be much better after magnetic treatment. Although, opinions about the phenomenon varied: the skeptics considered that due to control of all technology processes they were fulfilled rigorously. So, effect of magnetic treatment can be explained by more careful operation of equipment.

There is another spectacular example of “turning attention to the object”. About forty years ago it was reported that “magnetic” water increases fruitfulness of crop. The experiment was carried out at all-Russia research institute of irrigated farming in Volgograd: one part of the field watered as usual, another part – with “magnetic” water. The fruitfulness increased by 20-30% comparing with the check field, watered by usual irrigation system. Although, it was noted that during atomizer replacement for magnetic ones all the system was also cleaned and dimensioned. The skepticism is indirectly proved by world-wide practice: if something cheap and reagentless was to be capable of increasing fruitfulness even by 2-3% this “something” would be applied on the fields all over the world. Nevertheless, even now we can buy special accessories for faucets with permanent magnet installed in a lot of appliance shops.

At one time three powerful institutions (Science and Technology State Committee, Academy of Sciences, and Ministry of Education) organized several committees to reveal phenomenon of magnetic water treatment. Scientific community, theoretical physicists and technologists, rejected any influence of magnetic field on pure water, but numerous articles and books kept the problem alive. The author worked closely with the last of such committees (it was headed by foremost authority in magnetic fields, academician, director of Institute for Physical Problems of Academy of Sciences of the USSR A.C. Borovik-Romanov).

This committee assigned to study effect of magnetic treatment to several institutes. Anyways, at the Shubnikov Institute of Crystallography it was shown that magnetic treatment has no influence on crystal growth. Although, a lot of articles claim that it leads to change in the salt solubility or change in crystal form of solid phase precipitate: for example, precipitation of flocculent aragonite instead of solid calcite. The same negative conclusions were given by the other organizations. Theoretical physicists, taking part in the committee investigation (academician Ya.B. Zeldovich, Nobel Prize Winner A.M. Prokhorov and others) enforced the results of these “academician” tests with conclusions that if a non-superhigh magnetic field has some influence on pure water it is blocked by other factors (for example, thermal action). A great deal of reports concerning successful results in this branch followed from simple scientific ignorance or poor statistical analysis of experimental data. There is a typical example. At one

time the magnetic water treatment was reported to increase heat transfer by 3 -5% in the heat exchangers installed after magnetic devices. However, it was hidden, consciously or unconsciously, that heat transfer coefficient can be measured with accuracy of 10 – 15% at that date and even presently. Here is another typical example. It was studied influence of magnetic treatment on water viscosity. The water passed many times through a thin glass capillary placed within the gap of magnetic device. It was shown that the operation changed properties of water considerably. Although, afterwards the water turned to solubilize silica from the glass due to long-term contact with the capillary and transferred it to the active elements of viscosity indicator as a thin film. The experiments repeated with the same capillary without magnetic field showed the similar result. There is a pressing problem of qualitative and quantitative water composition treated by magnet. The great deal of articles doesn't touch on the problem or deal with it casually ("tap water", "sea water", "condensate" without quantitative water composition). This makes difficult to analyze publications concerning magnetic water treatment.

It is rather difficult to analyze current publications on magnetic water treatment for a number of reasons. First, the articles often appear in non-core periodicals and booklets beyond vision of researches. Second, the articles in such magazines are not reviewed and contain promotional information passing it off as scientific one. In particular, they contain references to some investigations carried out by well-known research institutes assigned by manufacturers of magnetic devices. These tests are said to confirm efficiency of discussed technology. Although, as a rule, these well-known research institutes don't publish the results in the specialized scientific magazines and that causes disquiet.

A lot of magnetic water supporters consider that some confederacy against this water treatment technology exists. They believe, the manufacturers of expensive water treatment units based on thoroughly studied technologies (coagulation, filtration, ion exchange, membrane technologies, distillation, dosage of special chemicals, etc) are afraid of new competitor and stifle to make the problem clear.

We should remember the water treatment is an important branch of industry having multi-billion turnovers and profits, involving a big deal of large responsible companies being in competition with each other, being controlled by the state authorities and scientific community. A confederacy between such companies is almost impossible. There is an example connected with power engineering. A number of those who work for alternative power engineering (solar, wind power, bio power, tidal power, etc.) also believe in reaction from the conventional ones.

Nevertheless, magnetic treatment technology attracts inexperienced manufacturers, being simple, non-waste, and reagentless one. Any other water treatment method (except for ultrasonic) requires chemicals, dosage units and waste water disposal. Besides, addition of chemicals requires taking into account sanitary, and hygienic factor, and organoleptic properties of water in open water draw-off.

The department "Technology of Water and Fuels" of Moscow Power Engineering Institute where the author studied and work also took part in solving the problem of magnetic water treatment. The experiments carried over there showed the following mechanism of decreasing fouling in the heat exchangers with magnetic apparatuses installed before them. We don't state that the revealed mechanism is only possible. But definitely, the phenomena observed during the magnetic water treatment could be represented on laboratory or industrial scale at any time.

First, B. T. Gusev and E. F. Tebenihin proved that the water passing through a magnetic device must be already supersaturated with a scale-forming substance. Some of following effects can be observed only

in this case. The basic low-temperature scale-forming substance (up to 80 °C) in natural water is calcium carbonate. In water being heated or moreover being boiled the carbonic acid equilibrium shifts: carbonic acid goes over to bicarbonate ion which in turn transforms into carbonate ion and finally, if water contains sufficient calcium hardness, calcium carbonate precipitates. Depending on carbonic acid equilibrium and calcium concentration, the natural water can be aggressive (for example, dissolves concrete), stable, or unstable, supersaturated with calcium carbonate. So, magnetic field can change something in scale formation processes only in the third case.

Second, V.A. Kishnevskiy showed contribution of ferromagnetic iron oxides in colloidal and coarse forms presented in water passing through the magnetic apparatus. Iron presents almost in all natural and technological water systems in a varying degree in soluble form and/or in colloidal mixtures. Most people associate iron with a magnet reminding how easy iron nails can be gathered with it. Although, not all ferrous compounds presented in water offer ferromagnetic properties. As a rule, they possess paramagnetic properties, broadly speaking, these substances don't attract to a magnet. Often ground waters contain much iron. Due to low pH the iron occurs in soluble form. If the water is raised to a surface and pressure is relieved, carbonic acid evolves such that pH increases and soluble forms of iron compounds transforms into insoluble ones. As a rule, ferromagnetic admixtures are black and usually appear in circulating water system having high temperatures, for example, in water or steam heating system. The author managed to put together two factors ("carbonic acid" and "iron") and offer a possible explanation of magnetic water treatment [2-6].

Fig. 1 shows design of the heat exchanger (the first heater) of adiabatic distilling apparatus used by the author to carry out half-industrial experiments for decrease scale formation. Water from the Black Sea being heated to 60°C entered the heat exchanger, reheated there by steam up to 80°C, and entered the vacuum chamber where it adiabatically boiled without heat supply.

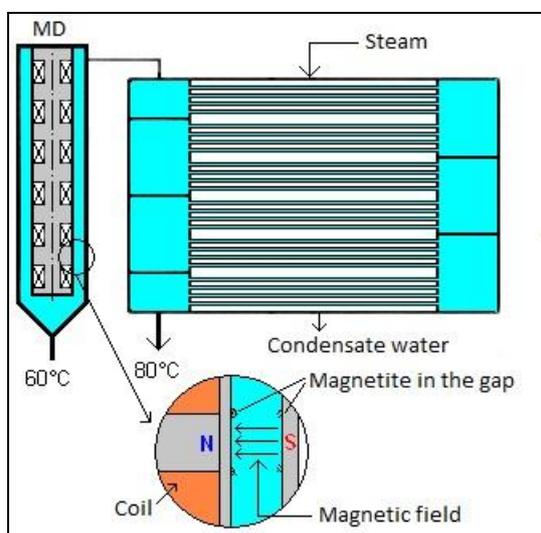


Figure 1. Connection of electromagnetic apparatus to the inlet of heat exchanger of water distilling system

The developed steam condensed into distilled water. The output unevaporated water entered the next chamber with increased vacuum where still part of water boiled. There were three chambers (the apparatus having about fifty chambers also existed). Condensation heat of the secondary steam transferred to the source Black Sea water which mixed with a part of the third chamber blowdown, see Fig. 2.

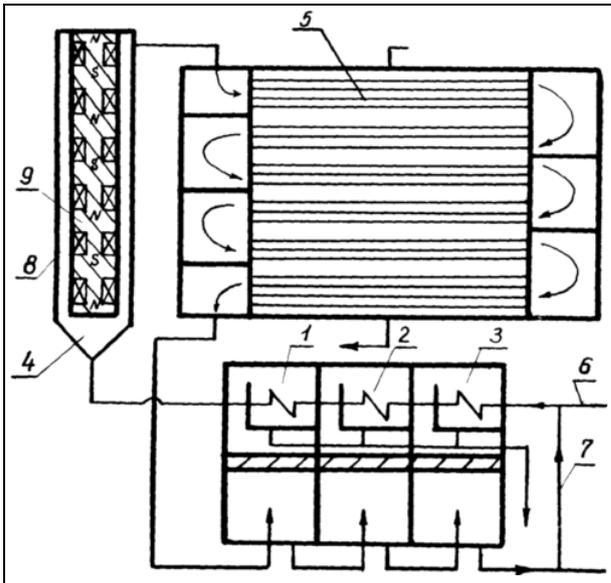


Figure 2. Scheme of three-stage adiabatic distilling system: 1-2 –distilled water collectors, 4 – magnetic apparatus, 5 – the first heater, 6 –source sea water, 7 – bypass of the hot sea water, 8 – gap of magnetic device, 9 – core of magnetic device.

So, installing of industrial magnetic device such as EMA-50 to the inlet of the first heater resulted in qualitative changes of scale formation. Instead of dense layer of scale evenly covering inner surface of pipes and tube plate of the first heater it was observed blockage of the pipes by sludge, at that, the heat exchange surfaces were clean having metallic luster, see Fig. 3. This astonished even workers of the shipyard where the experiments were carried out. Although, they opened a lot of such heaters from ship distilling systems for repair.

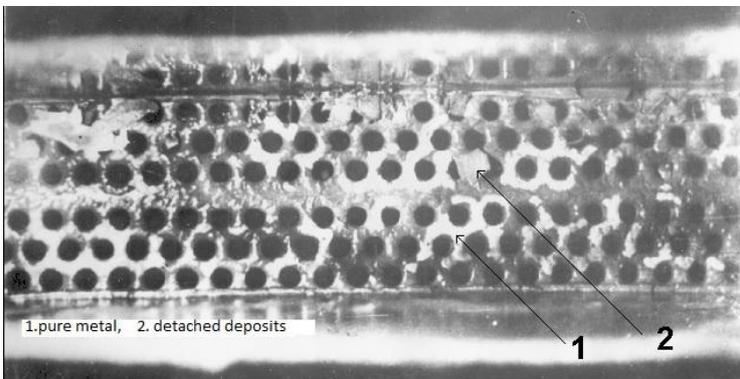


Figure 3. Picture of the tube plate of the first heater with scale

Figure 4 shows type of blockage of the first heater by sludge. The primary scale formation (vegetation of salts from the supersaturated solution) covers heat-exchange surface with an even layer, while the secondary blocks with sludge separate pipes of the heater, and Figure 4 shows percentage ratio of such pipes in each row. It was clear that magnetic treatment of sea water shifted dramatically scale formation from primary to secondary one.

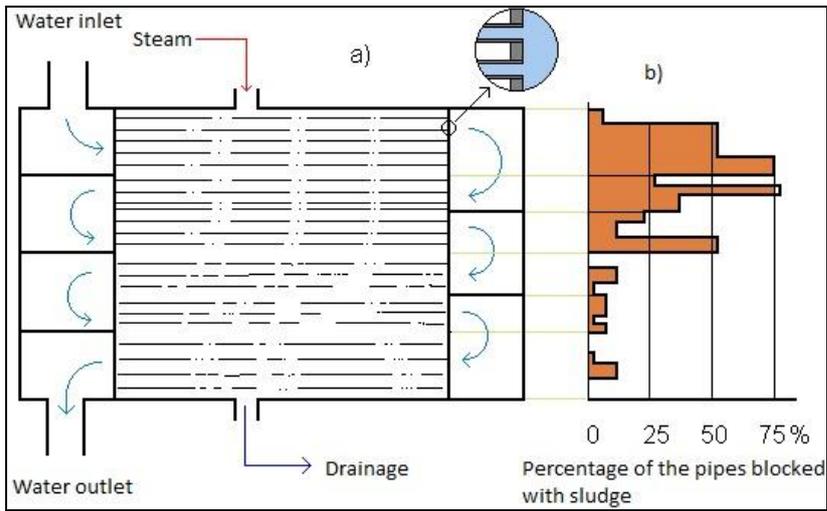


Figure 4. Blockage of the first heater by sludge

The most interesting was inside of the magnetic device that was a bowl with a core having six magnet coils, which produced magnetic field of high gradient and alternating polarity, see Fig. 5.

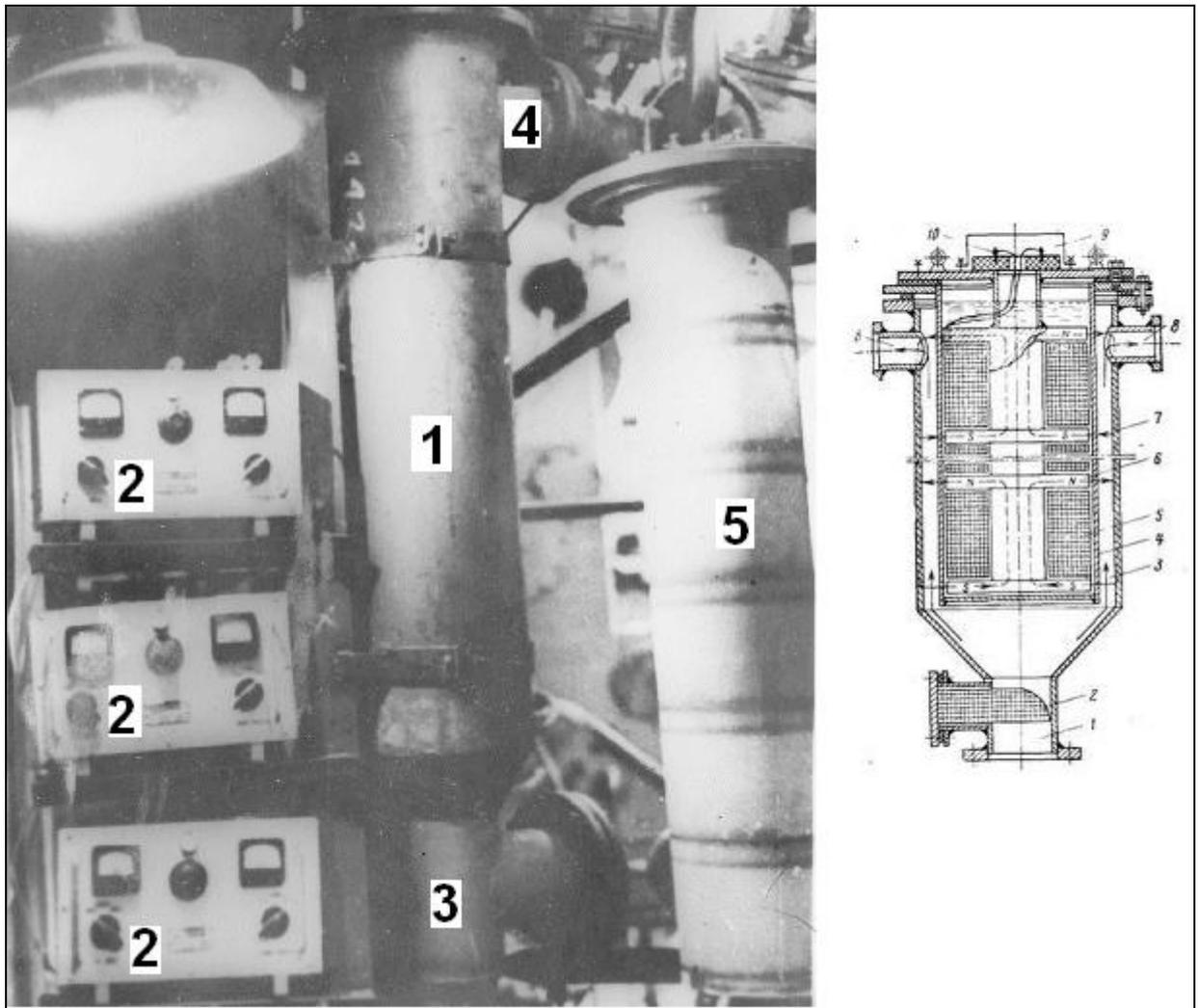


Figure 5. Photograph of electromagnetic device with the core taken out of the vessel: 1 – vessel of the electromagnetic device, 2 – three rectifiers, each feeds two coils of the device, 3 – water inlet, 4 – water outlet, 5 – core

The outer surface of the magnetic core was covered with even layer of sandy scale, transformed into black one by the location of increased gradient of magnetic field. These were traces of ferromagnetic admixtures filtered in the magnetic device. This phenomenon was noted long ago and considered harmful; it was believed that ferromagnetic admixtures blocked (bridged) the gap of the magnetic device setting magnetic field off the water which should be treated by magnet. Figure 6 shows such bridges.



Figure 6. Photograph of the ferromagnetic admixtures filtered from passing water in the gap of electromagnetic device

Although, additional experiments, carried out on the stand shown on Fig. 7, proved that the bridges can play a key role in scale-control and corrosion preventing effects of magnetic water treatment.

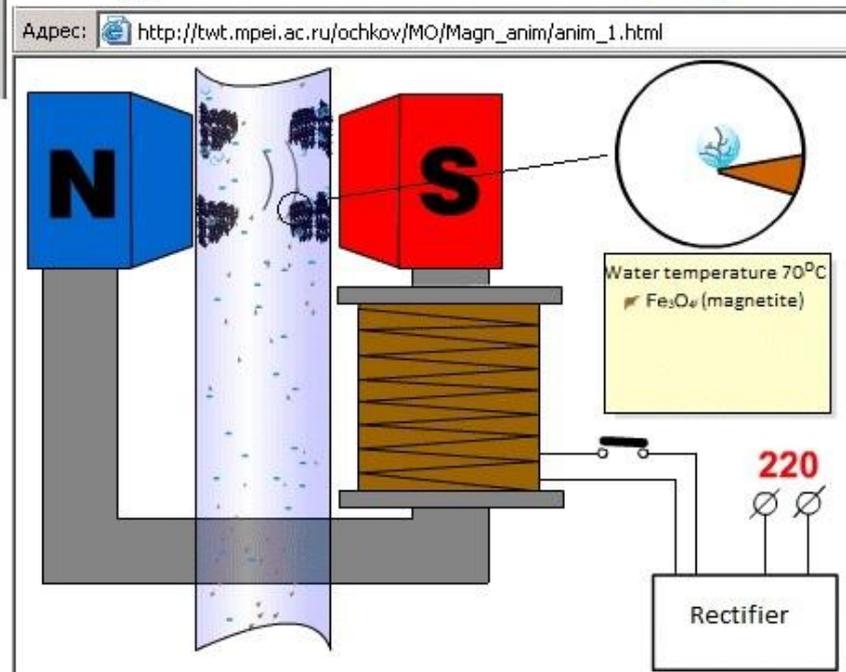
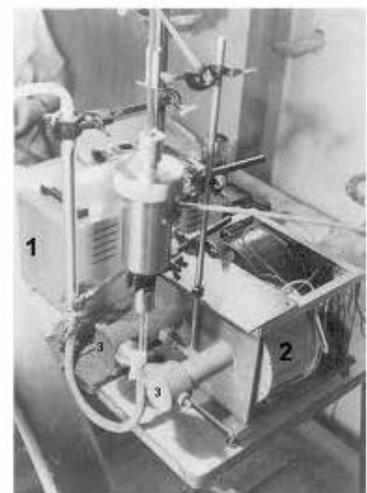
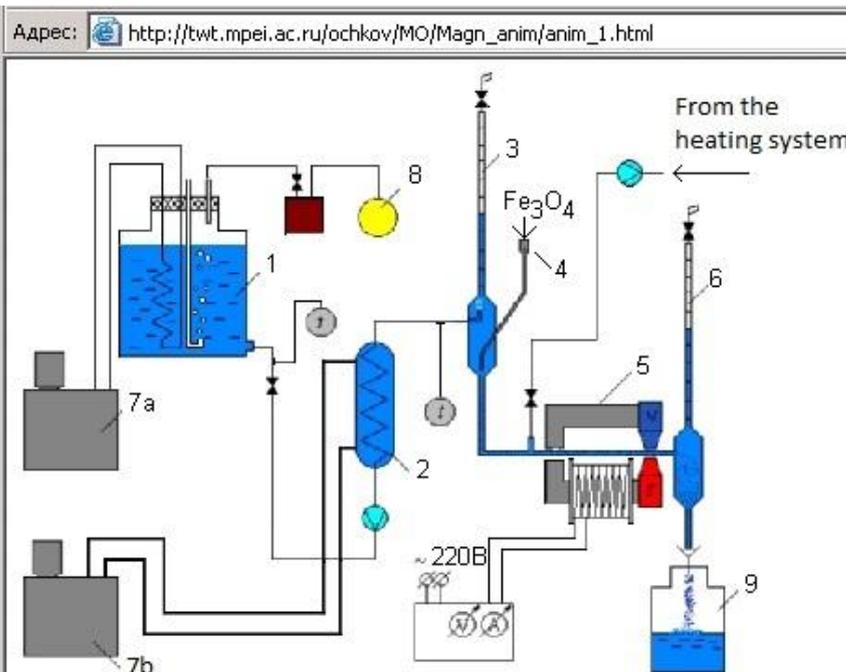


Figure 7. Scheme of the laboratory stand for studying effect of magnetic field on water solutions: 1 – thermostatic vessel containing initial water saturated with oxygen and nitrogen by bubble aeration, 2 – heat exchanger for water heating up to 70-80°C, 3, 6 - burette for measuring the volume of air evolved from water, 4 - dosing unit of ferromagnetic admixtures into the water, 5 – electromagnetic device, 7a, 7b – thermostats, 8 – vacuum pump, 9 – vessel for water collection

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These experiments are notable for their easy repeatability as distinct from many others. The water supersaturated with oxygen and nitrogen (distilled water at room temperature was bubbled and then heated) entered the magnetic device and the volume of gas evolved in its gap was measured. The

experiments carried out not in two modes (as everybody did before) but in three modes: a) the magnetic device is switched off:  $H=0$ , b) the magnetic device is switched on  $H\neq 0$ , and, finally, c) the magnetic device is switched on  $H\neq 0$  and a bed of ferromagnetic admixtures is held in its gap  $G\neq 0$ . The bed can be collected, for example, by passing water from the closed heating system (heating of buildings) for a long time or by addition of suspension of broken magnetic iron oxide. So, magnetic field took no effect (within the limits of experimental scatter) on velocity of gas phase evolving from the supersaturated solution, see Fig. 8.

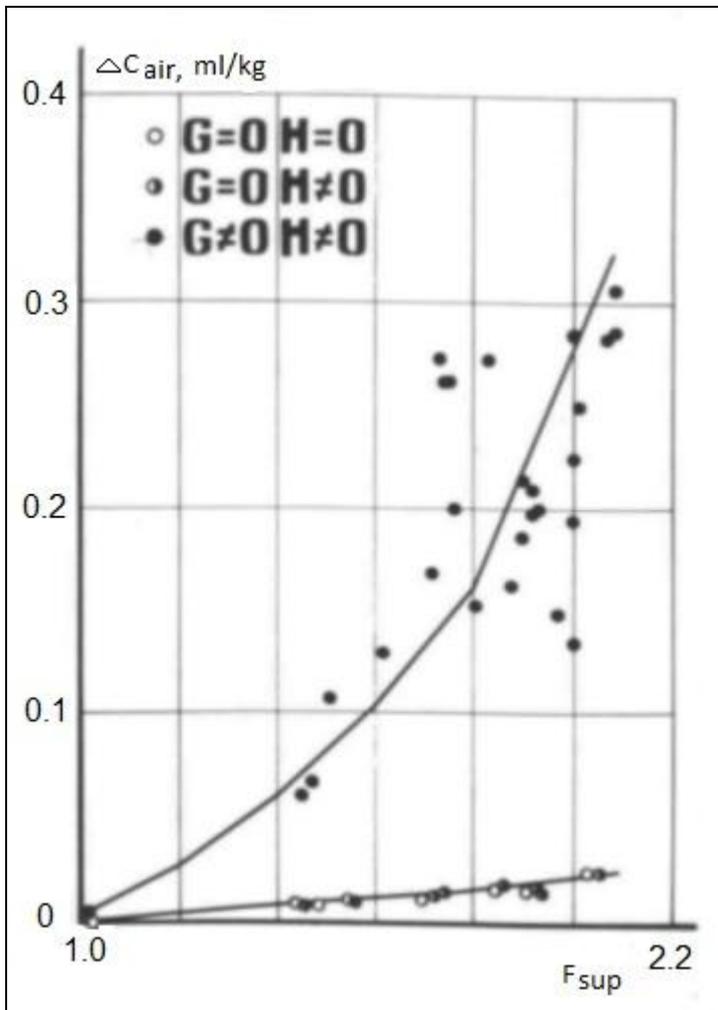


Figure 8. Amount of evolved air ( $\Delta C_{air}$ ) in the magnetic device gap depending on degree of supersaturation ( $F_{sup}$ )

Although, if the magnetic field held a bed of ferromagnetic admixtures ( $G\neq 0$  and  $H\neq 0$ ), the water passing magnetic device became turbid from the smallest air bubbles. The same situation occurred if the water was supersaturated with the salt phase, for example, the main low-temperature scale-forming substance  $CaCO_3$ .

Figure 9 shows a magnetic iron oxide particle taken from the gap of the magnetic device treated water supersaturated with calcium carbonate. These experiments, also proved by industrial ones, enabled us to develop phenomenon of magnetic treatment effect on scale formation and corrosion processes in heat exchange units that result in three well known water treatment technologies:

1. Magnetic filtration (separation)

A magnetic device works as a kind of magnetic filter, retaining in its gap ferromagnetic together with non-ferromagnetic, colloidal, and finely dispersed admixtures of water. At that, saturation process sometimes lasts weeks or months. The case shown on Fig. 6 can be observed only after such period of time. Thus, disagreement between laboratory and industrial data can be explained by the reason that an industrial experiment can last for several weeks, months, years and shows positive result rather than experiment carried out on a laboratory stand within definite time limits. On the other hand, proceeding with pilot plant tests, high-performance devices, and the effect lost because treated water was divided into several parallel streams in the magnetic device and some of them bridged with water impurities, the others operated with increased velocity without filtering water admixtures.

At the same department of MPEI A. M. Voznesenskiaya and B.T. Gusev carried out iron removal experiments thirty years ago. Return condensate from the factories passed through the tanks loaded with ferromagnetic substances, particularly, crushed and sifted iron scale, waste from a steel rolling mill. Additionally, influence of external magnetic field was investigated and it was proved that it increases "iron capacity" of ferromagnetic filter media and reduces residual iron in filtrate. These data was published and forgotten, as befits in Russia. Recently, a German patent on the magnetic filters has appeared based on application of external magnetic field to the ferromagnetic filter bed (for example, steel balls). Now it is used widely to eliminate colloidal and finely dispersed corrosion products. We don't claim that Germans read this article and applied for a patent but just count two time-spaced research events.

## 2. Contact stabilization

A layer or suspension held in the gap of a magnetic device (see Fig. 6) serves to remove partly supersaturation of water with solid or gas phase (a kind of heterogeneous catalysis). This way of scale formation decrease is not new: to control scale formation in a heat exchanger it is installed upstream a filter loaded with crashed marble or with deposits cleaned from the heat exchanger itself. Although, such filter requires being cleaned in time, otherwise, its bed transforms into a monolith, which can be removed only with a rock drill.

## 3. Injection of seed crystals

This method of scale formation control is used widely in thermal water demineralization. Suspension of  $\text{CaCO}_3$  powder in sea water was introduced into the evaporator. At that, a scale formation, that is crystallization of the salts on the heat-exchange surfaces, finds a powerful competitor, sludge formation (crystallization of the same salts on the suspended solid phase). The experiment shows that the seed crystals can be introduced into the water and also appear on ferromagnetic layer held in magnetic device (Fig. 9).

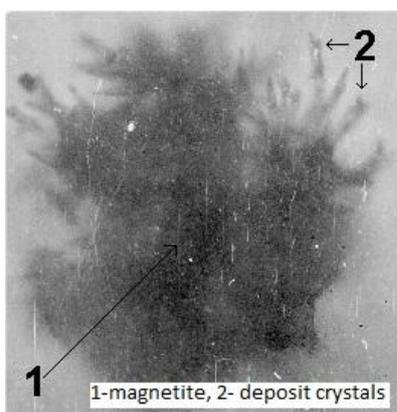


Figure 9. Photograph of a magnetic iron oxide particle with calcium carbonate crystals

Thus, it is arguable that magnetic treatment of the water supersaturated by salt or gas phase containing ferromagnetic admixtures can influence scale formation and corrosion processes in heat exchangers including elimination (dissolving) of existed fouling in the following cases. The deposits formed on heat exchange surface often crack (see Fig.3) due to thermal deformation and vibration of the heat exchange unit. These cracks can disappear under newly formed deposits or alternately, result in cleaning if the degree of primary scale formation is decreased.

Recently some articles appeared [7] in which magnetic treatment is claimed to be observed in water having no ferromagnetic admixtures. The effect can be explained by influence of external magnetic field on colloidal substances which are very unstable. The external magnetic field combining with electrolyte flow can result in coagulation of colloidal particles and creation of additional crystallization grains shifting scale formation from primary to secondary one.

Magnetic water treatment is hard to control and this prevents wide implementation of the method. Formation of seed crystal is uncontrollable process, for example, short-period break and a new start of the heat exchanger leads to disappearance of suspended ferromagnetic layer in the gap of the magnetic device and decrease of its efficiency for a long time.

Magnetic treatment of water is attractive technology by its simplicity and low price. Though modesty be a virtue, yet bashfulness is a vice. So, many of users refused from this technology long ago. Nevertheless, in other places such apparatuses continue to operate keeping the matter unsettled...

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