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TRANSLATION

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A. N. Kirgintsev, V. M. Sokolov and N. I. Burlakova

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ON THE MECHANISM OF THE PROCESS OF MAGNETICALLY TREATING WATER

By

A. N. Kirgintsev, V. M. Sokolov and N. I. Burlakova

The magnetic method of treating feeder water for steam producing aggregates, discovered in 1945 [1] , acquired broad application over the entire world. The effect of magnetic devices on feed water appears in the fact, that the salts dissolved in the water separate in steam generating aggregates preferably in the form of sludge, and not in form of solid scales. The mechanism of the given phenomenon remains unexplained to this day. In literature [2-6] the points of view on the process of magnetically treating water differ from each other, and still they do not take into consideration the changes in salt compostiion of the water after same has been treated in a magnetic apparatus. Consequently it became logical to seek the cause of the phenomenon in the purely physical effect of the magnetic field on solutions.

In this report we have not made it out business to evaluate the physical view-points [2-6] because the data on [3] indicate substantial iron corrosion characteristics (poles of magnetic devices) in the magnetic field, as result of which a black product - magnetite is formed. On the basis of iron corrosion characteristics in the magnetic field, it was considered advisable to establish what kind and in what amounts of corrosion products are acquired by water and to what extent these products may affect sludge formation.

Experimental part

The experimental water was processed in three electromagnetic devices (devices 1, 2, 3). Devices No. 1 and 2 differ from each other only by field capacities and in the diameters of poles. In apparatus No. 1, the pole diameter equals 10 mm, and in apparatus

No. 2 - 20 mm. Structurally they are identical and represent an assembly of 6 horseshoe shaped electromagnetic (Fig. 1). In the interpolar spaces of these magnets is inserted tube 1 (brass or glass depending upon the experiment). Field intensity in tube 1 is boosted by a steel core 2. The tested water, flowing over tube 1, is subjected to the effect of the magnetic field.

Apparatus No. 3, (Fig. 2) represents a bipolar cylindrical electromagnet, the yoke of which consists of two steel tubes 1 with flanges, interconnected by steel bolts 5. These bolts transmit the magnetic flux, excited by coil 4 wound over a bronze spacer ring 3. In the yoke is situated the core 2, centered by screws 6. The examined water is passed through gap 7 of 1 mm in width and is thus subjected to the effect of the magnetic field. Magnetic field intensity in gap 7 was measured by an induction method [7].

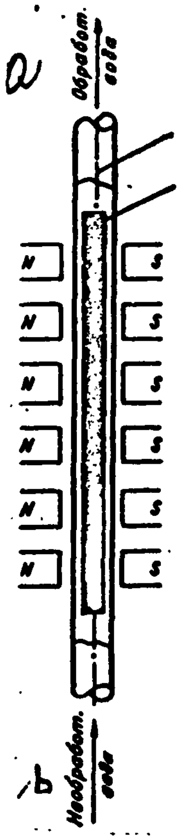

Fig. 1. Electromagnetic apparatus No. 1 and 2. 1-tube; 2-core; a-treated water; b-untreated water.

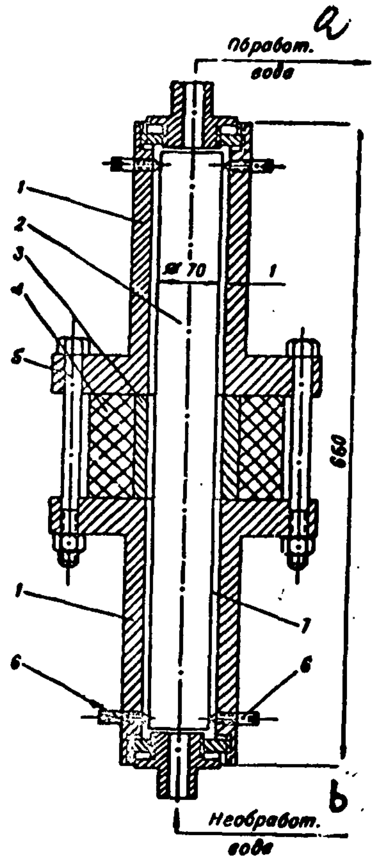

Fig. 2. Bipolar cylindrical electromagnetic apparatus No. 3; 1-yoke; 2-core; 3-coil; 4-spacer ring; 5-clamping bolt; 6-adjustment screw; 7-gap; a-treated water; b-untreated water.

Effect of Magnetic Treating on Distilled Water

Many authors report about an increase in pH of the water as result of its being treated in magnetic devices. In our experiments distilled water was treated in devices No. 2 and 3. after the outcome from which samples were taken under the water, which enabled to avoid volatilization and absorption of gases as well. In the samples was determined the pH value, contents of free CO_2 and O_2. The experimental results are given in tables 1-4. In the corroding apparatus No. 3 the pH of the water rose (Table 1,3) whereby the pH depends upon magnetic field intensity (Table 1). The CO_2 content in processed water remains unchanged (Table 3). Processing of water only by exposure to the magnetic field (water was passed in apparatus No. 2 through glass tube), also does not change the CO_2 content, but the pH also remains unchanged (Table 2). The oxygen content in the water after being processed in device No. 3 decreased. Iron corrosion products in the water should according to the theory of electrochemical corrosion [8] give ions of di-and trivalent iron. Qualitative reactions showed in the presence in water, processed in apparatus No. 3, of divalent iron ions and absence of trivalent iron ions.

Table 1. Dependence of pH of distilled water upon the processing at various magnetic field intensities in the gap of the electromagnetic apparatus No. 3 (pH of initial water 4.2; rate of flow 1.2 cm/sec),

Intensity of constant magnetic field in Oersteds.	420	520	650
pH	5.18	5.47	5.00

Table 2. Behavior of CO_2 and pH in water processed by the magnetic field of apparatus No. 2 (glass tube)

No. of experiments	1	2	3	4	5	6
CO_2 content, mg/l	99	97	96,7	96,2	90	94
pH	4,65	4,65	4,65	4,65	4,65	4,65
Intensity of content magnetic field in Oersted	0	600	1000	1200	1400	1600

Qualitatively divalent iron ions were determined by titration in an acid medium 0,01 N solution of K_2Cr_2O7 with diphenylamine. Total alkalinity aas determined by titration with a 0,01 N HCL solution with methyl orange. For distilled water with pH, equalling 4,30 after treating pH = 4,42 $[Fe^{\cdot\cdot}]$ =12,4 mg/l, total alkalinity – 0,000437 g. eq/l.

Table 3. Behavior of CO_2 and pH under effect of processing in electromagnetic apparatus No. 3

No of experiment	1		2		3	
Nature of water	processed	unprocessed	proc.	unproc.	proc.	unproc.
CO_2 content mg/l	28,9	28,6	29,7	29,5	398	380
pH	5,40	529	5,39	5,27	4,6	4,23

Table 4. Behavior of oxygen under effect of processing water in electromagnetic apparatus No. 3.

Nature of water	Content of oxygen mg/l in experiment			
	1	2	3	4
Unprocessed	3,65	3,05	392	302
Processed	1,55	1,55	2,34	2,52

Corrosion of iron in magnetic field

Corrosion of iron in magnetic field was observed in general outlines by the corrosion of steel poles (Fig. 1 and 2) of apparatus No. 3. These poles as result of corrosion were coated with a black slimy powder which, as shown by X-ray structural analysis, appears to be magnetite which is in perfect conformity with report [3]

Of greatest interest was the establishment of the effect of magnetic field intensity on the formation of $Fe^{\cdot\cdot}$. For this purpose, distilled water with a pH = 4,30 was passed through apparatus No. 3 at a rate of 1.2 cm.sec. The pH was due to previous saturation of the water with carbon dioxide. Only the magnetic field intensity changed. Fig. 3 illustrates the detected dependence. In all these experiments the position of the maximum on curve $[Fe^{\cdot\cdot}]$ - H was reproduced stably, but the value of the maximum changed from experiment to experiment. For this very same distilled water at a field intensity of 650 Oerst. was established the effect of rate on the formation of divalent iron, which is illustrated in Fig. 4.

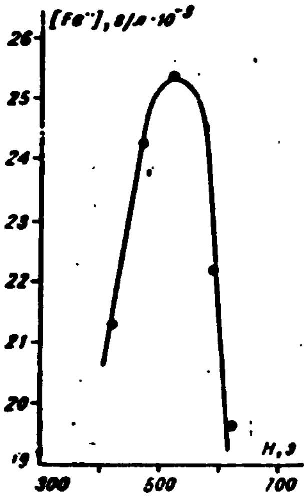

Fig. 3. Dependence of formation of divalent iron ion on magnetic field intensity rate of water flow 1.2 cm/sec

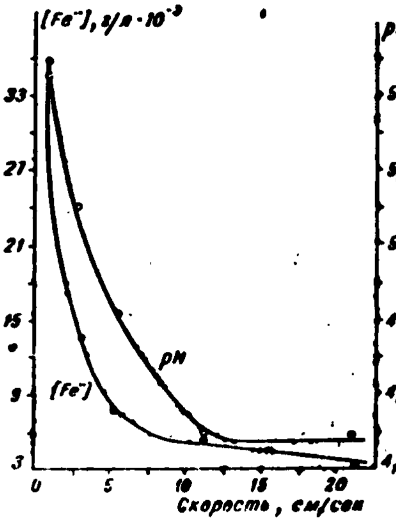

Fig. 4. Dependence of formation of divalent iron ion and pH upon the rate of flow of the water. Initial pH of water 4,2 and magnetic field intensity 650 Oerst.

Simultaneously for these samples was determined the pH value, which, as is evident from Fig. 4, is in perfect conformity with the change in iron content. The formation of a divalent iron ion consumes oxygen, which is confirmed by data of table 4. A calculation will easily show that the decrease in oxygen is in conformity with its consumption for the formation of iron.

Crystallization of dissolved salts

The results of our experiments with the use of apparatus No. 3 are in agreement with literature data, but, besides that, it is established that treated water acquires the ion of divalent iron. Apparatus No. 3 differed from industrial devices only by smaller size of working gap (Fig. 2 and 7). In this connection we assume that waters treated in industrial conditions also acquire $Fe^{\cdot\cdot\cdot}$. Hence comes a principally important conclusion about the effect of $Fe^{\cdot\cdot\cdot}$ on the formation of sludge. For this purpose were made experiments on the crystallisation of dissolved salts during evaporation. The criterion for the evaluation of the crystallisation process was the amount of evaporated water in percentages at the moment of appearance of the first crystals, visible by the naked eye. Selection of that value in the role of criterion is connected with the fact, that crystallization in treated waters takes place with perferable development of the sludge forming process, which indicates a facilitation of seed forming. Consequently salts crystallisation in treated water during evaporation should begin at smaller concentrations of dissolved salts. A majority of natural waters contains calcium sulfate, which appears to be a typical scale former, its solutions are therefore selected as objects of investigation.

Evaporated were samples with $CaSO_4$ content of 0.28 g/l. Some samples of such concentration were prepared by pouring together 1 : 1 of ordinary distilled water and a calcium sulfate solution with a concentration of 0.56 g/l. Other camples were prepared by pouring together 1 : 1 distilled water, after preliminary processing in apparatus No. 3 and having Fe... = 0,0001 g/l, with a calcium sulfate solution with a concentration of 0.56 g.l. In samples prepared by the first method, the first crystals appeared upon evaporation of 65% of water, and in samples, prepared by the second method - during evaporation of 25% of water.

During the evaporation of a solution containing 0.56 g/l $CaSO_4$ the first crystals were formed during the evaporation of 24% of water, and from the calcium sulfate solution of same concentration, but first treated in apparatus No. 3 at a rate of flow of the solution of 20 cm/sec and magnetic field intensity of 650 Oerst., - during the evaporation of 2% of water. Concentration of Fe.. in the treated solution equalled 0,0008 g/l.

Further experiments were carried out with the use of apparatus No. 1. Three types of samples have been prepared but of identical calcium sulfate concentration. Samples of first type were prepared by dissolving calcium sulfate in ordinary distilled water; samples of the second type - by dissolving calcium sulfate in distilled water, having undergone treatment in apparatus No. 1 (Fig. 1) with tube 1 and corroding steel core 2: samples of type three - by dissolving calcium sulfate in distilled water, having undergone treatment in apparatus No 1, but instead of the corroding core was inserted a similar one but protected against corrosion by chrome plating. The first crystals during concentration/evaporation of first, second and third kind of samples were formed upon evaporation of 75, 25% and 75% of water respectively.

Evaluation of experimental results

Known data from literature sources, that in treated waters the pH rises and iron parts of magnetic devices are coated with magnetite, are confirmed by our experiments. In addition, it was established, that in waters, treated in corroding devices, appears a divalent iron ion and the general content of CO_2 remains unchanged, and the O_2 - content decreases. When water was treated under the pure effect of the magnetic field (treatment in noncorroding apparatus) the pH value and CO_2 content have not changed. It was further established, that in samples containing water, processed in a corroding apparatus, the formation of crystal was much sooner, that in samples, containing water, processed under the pure effect of the magnetic field, and in subsequent crystallization of salts took place just as in samples containing only ordinary water.

A rise on pH in treated water is explained in reports [5 and 6] by the rupture of hydrogen bonds under the effect of the magnetic field, but in these very same reports is shown, that the viscosity of the water after treating rises, and the separation of hydrogen bonds decreases the viscosity of the water [9]. In distilled water pH is determined by the CO_2 content, since CO_2 as result of processing remains in solution in unchanged amounts, then the rise in pH, on the basis of our own experiments, would be best explained on account of the appearance of a divalent iron ion. The conformity in the change of iron content and change in pH, which is illustrated in Fig. 4, speaks in favor of such an explanation. It is stated in reports [5 and 6] that the processing with the magnetic field decreases the solubility of gases; but in general the CO_2 in our experiments, has not changed, and the reduction in oxygen content should be put on account of iron corrosion.

Formation on steel components of magnetic devices of a black slimy magnetite powder speaks about the characteristic features of iron corrosion in magnetic field. The fact that such characteristics do exist in indicated in Fig. 3, showing the dependence of corrosion upon magnetic field intensity.

Displacement of salt crystallization in direction of sludge formation is attributed by authors [2-6] to the purely physical effect of the magnetic field on the solution. But experiments on concentration/evaporation of calcium sulfate solutions indicate, that is the water was treated in a corroding device, that salt separation much sooner, even before saturation does take place, e.g. during concentration/evaporation of 2 and 25% water, respectively. In the first case the samples contain Fe.., in the second none. Fe.. is not contained in samples, in which the water was treated in noncorroding devices. Salt crystallization in these samples begins, as in ordinary water water samples, i. e. upon the attainment of natural saturation. It can be assumed on the basis of these facts, that Fe... forms upon heating $FeCO_3$ and serves as seed former during the crystallization of salts in the volume of the solution, especially since iron carbonate has the structure of calcite. The magnitude of ion radii for Fe++, equals 0.8 Å, and for Ca++, it equals 1 Å but it is no hindrance to such a possibility. In boiler waters the basic role is played by the $CaCO_3$-$CaSO_4$-H_2O system. Treated water offers a system $FeCO_3$-$CaCO_3$-$CaSO_4$-H_2O. The values of solubility reproduction of components of these systems equal:

Sample $_{FeCO_3} = 2,5 \cdot 10^{-11}$, Sample $_{CaCO_3} = 4,8 - 9,9 \cdot 10^{-9}$, Sample $_{CaSO_4} = 6,1 \cdot 10^{-5}$.

A comparison of samples for $FeCO_3$ and $CaCo_3$ shows, that from the $FeCO_3$ solution is formed first $CaCO_3$. In favor of sludge forming effect of $FeCO_3$ speaks the separation of salts during its present far from the point of saturation, which may indicate the formation of less soluble mixed crystals of the $FeCO_3$-$CaSO_4$ type.

It is known that treated water preserves the acquired quality for about 24 hrs after which it disappears. This can be explained by oxidation of Fe.. dissolved by oxygen, as result of which is formed Fe (OH_3). It is evident from Fig. 5 that oxidation of divalent iron in open samples is much sooner, than in closed ones, and it is understood herefrom, that preliminary aeration, as is evident from report [3,] should reduce the effect of magnetic treating of water.

Conclusion

1. It was shown, that water, treated in magnetic corrosion type apparatus, acquires a new component - ion of divalent iron, i. e.. It changes its chemical

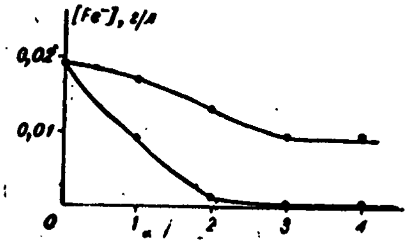

Fig. 5. Kinetics of oxidation of divalent iron ion in open and closed systems. a; time, diurnal periods.

composition.

2. The presence in the water of a divalent iron ion allows to explain the characteristic features of the magnetic water treating method; increase in pH, reduction in oxygen content, increase in sludge formation and preservation of acquired qualities by the treated water.

3. The magnetic field has a substantial effect on the corrosion of iron.

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