ULTRASONIC TREATMENT OF WATER

By L. B. Sigalov

Distributed by:

OFFICE OF TECHNICAL SERVICES
U.S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D.C.

Price: $0.50
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As a result of complex physicochemical processes, the basic of which is the crystallization of matter from oversaturated solutions, the walls of steam boilers in the course of production operations, may become covered with solid incrustations of varying composition and density and with a very low degree of thermal conductivity.

These incrustations have a sharply adverse effect on heat transfer, lower the efficiency of the boiler and, under certain conditions, lead to overheating and the failure of the metal.

To prevent boiler incrustations, many industrial boiler establishments and electric power stations resort to a preliminary treatment of the water in which
this feed water is presoftened in cationite filters.

For low-capacity boiler establishments, however, it is difficult to use this method, because it requires the use of relatively complex and expensive equipment.

In this regard simplified methods of water treatment are of interest, that are accessible for use in low-pressure boilers of low capacity.

These methods include, besides the in-boiler treatment of water, achieved by the addition into the boiler water of precipitating reagents, so-called nonreagent methods recently developed - the magnetic and ultrasonic methods.

A description of the electromagnetic method has been given in the article by M. A. Bitnyi "Installation for electromagnetic treatment of water" ("Industrial Safety Measures", 1959, No. 9).

It is known that elastic waves, the frequency of which exceeds the upper limit of audibility by the human ear (20,000 cps), are named ultrasonic.

Sound waves are capable of being propagated in any elastic medium, whether liquid, solid or gaseous, and the velocity of their propagation is a function of the properties of the medium. Thus, for example, in air at 0° and under normal atmospheric pressure, the velocity of
the sound wave is 332 m/sec. In water it is 1,500 and in steel - 6,100 m/sec. These are average velocities. They may vary depending on the degree of elasticity of the medium, pressure, temperature and other factors.

Ultrasonic short-wave oscillations, in the same manner as light waves, may be propagated in the form of a directed beam, they may be reflected, refracted and focused.

The energy carried in ultrasonic waves, and their properties make possible their use in detecting defects of various materials, in speeding up chemical reactions, in the crushing of materials and for other purposes. In particular, the fact that ultrasound has the property of breaking up solid substances is utilized to prevent the formation of boiler incrustations inside steam boilers and in heat exchange devices.

On the basis of previous investigations it is possible to state that ultrasound has the following effect on materials that form boiler incrustations. Sound waves that in the course of propagation meet crystals or a layer of incrustations, give up to them a portion of their energy, as a result of which these materials start vibrating in unison with the sound waves. In a continuous action of the ultrasonic field on the interface of two phases (crystal -
- liquid), particles of the crystals become detached especially in places where they are attached to the heated surface.

In addition to this, because of the rarefaction that appears in the sound wave, gas bubbles appear in the water (the cavitation phenomenon), and these bubbles burst rapidly producing a hydraulic impact. These phenomena also help to break up the incrustation crystals deposited from the solution.

Thus, the process of steady crystallization of the incrustation salts is being continuously disrupted. The broken up crystals that form in the water are precipitated as a sediment on the bottom of the boiler and are drained off.

In order to produce vibrations of a sonic and ultrasonic range of frequencies, a magnetostriiction oscillator is utilized, the action of which is based on the properties of certain metals (iron, nickel, cobalt and their alloys) to change their geometric dimensions under the action of a magnetic field.

If an alternating current is sent through the coil wound around a nickel rod, the dimensions of the rod will vary periodically due to the alternative magnetizing and demagnetizing effect. The rod will vibrate, causing
Oscillations in the surrounding medium, the frequency of which will be a function of the frequency of the alternating current. When that frequency and that of the oscillator's own vibrations coincide, the amplitude of oscillations will be at its maximum.

Magnetostriction oscillators are constructed in the form of rods, tubes or assemblies of thinplates.

Fig. 1 shows the principles of construction of a magnetostriction oscillator made with a nickel tube. A diaphragm is welded on the portion of the tube that projects into the boiler water. This diaphragm transmits the mechanical oscillations of ultrasonic frequency to the water. At the opposite end of the tube there is a coil, fed by an electric current flowing from an ultrasonic wave generator.

Fig. 1. Principles of construction of a magnetostriction oscillator:
1 - insulated lead-in, 2 - protective cover, 3 - nickel tube, 4 - sound radiating diaphragm, 5 - coil fed by the ultrasonic wave generator, 6 - boiler wall.
At the present time ultrasonic instruments that prevent the forming of boiler incrustations have been developed and tested under industrial conditions for steam boilers of low capacity.

The instrument IG-58, developed by the enterprise "Promenergo", consists of two blocks: a pulse generator, that creates high-frequency electric pulses, and a magnetostriction oscillator, that converts the electric energy received from the generator into mechanical vibrations of ultrasonic frequency.

The technical characteristics of the apparatus are as follows: ultrasonic wave frequency - 28 kc, pulse frequency - up to 10 per second, feed - alternating current of 127 or 220 v, power intake - up to 100 w, length of insulated cable from the generator to the oscillator - up to 20 m.

The ultrasonic generator operates in a pulse regime with impact excitation of the magnetostriction oscillator, and is designed for operations with two oscillators.

Fig. 2 shows the principles of the electrical circuit of the instrument. When it is switched into the general circuit, the capacitor C5 is charged by means of the resistance R4 and the oscillator coil V0 up to the
voltage level of the rectifier. The latter is assembled as a single half-cycle circuit and consists of a transformer T1, selenium washers B-1 and a capacitor filter C1.

[Please, see next page.]

Fig. 2. Circuit of ultrasonic instrument IG-58

In its normal condition, the thyatron L2 does not conduct any current, and the capacitor C5 remains charged. When the appropriate voltage impulse is fed to the grid of the thyatron L2, the latter begins to conduct a current, and the capacitor discharges through the coil of the oscillator V0. In the oscillation contour, that consists of the inductance of the oscillator coil and the capacitor capacitance of capacitor C5, there appear damped electrical oscillations, the frequency of which is governed by the capacitance of C5 and the inductance of the oscillator coil.

In the absence of grid pulsing in the thyatron, the latter becomes "locked" (does not conduct current),
and the capacitor $C_5$ again becomes charged.

Thus, in order to operate the oscillator it is necessary that there be periodic grid pulsing of the thyatron $L_2$. Voltage pulses are created by thyatron $L_1$, that operates in a relaxation regime on the following principle: the capacitor $C_2$ is slowly charged by the basic rectifier $B-1$ through resistances $R_1$ and $R_2$ and the coil of pulse transformer $TR_2$. When the voltage on the capacitor plates reaches a potential corresponding to that which fires the thyatron $L_1$, capacitor $C_2$ is discharged through coil 1 of transformer $TR_2$, the thyatron $L_1$ and resistance $R_3$. At the same time, the voltage necessary to fire thyatron $L_2$ is created in coil 11 of transformer $TR_2$ connected to the grid of thyatron $L_2$. The grid bias of thyatron $L_1$ is ensured by rectifier $B_2$, resistances $R_7$, $R_8$, $R_9$ and capacitors $C_3$ and $C_4$, connected in a doubler circuit.

The number of pulses per second as well as the charging time of capacitor $C_2$ are regulated by means of the alternating resistance $R_2$.

In the instrument IGU-9, developed at the Lenin-grad Water Transport Institute, a standard barium-type arc $RB-280$ gap is utilized as contactor.

The technical characteristics of the instrument
IGU-9 are the following: frequency of ultrasonic oscillations - 40 kc, number of pulses per second - from 2 to 5, feed source (50 cps) - alternating current of 220 v, power intake - up to 16 to 20 w, permissible length of cable from the first to the second blocks - up to 20 m.

Fig. 3 shows the principles of the electric circuit of instrument IGU-9. When the rectifier is connected, capacitor C₃ becomes charged through resistance R₄ and the coil L of the magnetostriction transducer. In the first instant after the connection of the rectifier, the voltage on capacitor C₃ rises from zero to the potential at which discharger RB is fired, after which resistance between discharger electrodes drops sharply due to ionization of the medium. Capacitor C₃ is discharged into the oscillation contour C₄ - L, that consists of the parallel-connected capacitor C₄ and coil of magnetostriction transducer L. In the process of discharge of capacitor C₃, its voltage decreases down to the level at which discharger RB is extinguished. Thereafter capacitor C₃ again becomes charged through resistance R₄ and coil L up to a voltage equal to the igniting potential of discharger RB. The charge and discharge cycle is continuously repeated in the above-described sequence.

The energy received by the oscillation contour
C₄ - L as a result of the discharge of capacitor C₃ induces electric oscillations in the contour having damped characteristics, the frequency of which is determined by the values of the capacitance of C₄ and inductance of L.

The charge resistance R₄ fulfills the following functions: during the charge period of capacitor C₃, it controls the magnitude of the charging current, preventing an overload of the rectifier, and during the period of ignition of the discharger it prevents a short-circuiting of the rectifier through the discharger. The magnitude of resistance R₄ determines the charge period of the capacitor and, therefore, the number of ignitions of the discharger in a unit of time.

![Fig.3. Circuit of ultrasonic instrument IGU-9](image)

All parts of the first and second blocks of the instruments that have been described here are protected by special covers. Electric wiring that connects the two blocks is well insulated. The block-generator is so situat-
ted that the length of the cable from generator to oscillator not exceed 20 m.

The oscillator is affixed directly to the wall, or is connected with it by means of a sound conductor - a steel tube in a water-cooled jacket with two branch pipes for the intake and outflow of the cooling water and a blow-through valve. The installation is grounded for safety.

Tests conducted by the Leningrad Water Transport Institute, the Moscow Institute of Transportation Engineers and the enterprise "Promzhergo" have shown that ultrasonic treatment of water considerably reduces boiler incrustations in low-pressure small capacity boilers and in heat exchangers.

The results obtained prove the need for systematic research to study means of introduction of ultrasonic vibrations into boiler water for boilers of various construction, and for improvement of the instrumentation for ultrasonic water treatment.
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