LEWIS

OTS: 60-41,304

JPRS: 5486

1 September 1960

ULTRASONIC TREATMENT OF WATER

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- USSR -

Distributed by:

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

~~Price: $0.50~~

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
205 EAST 42nd STREET, SUITE 300
NEW YORK 17, N. Y.

JPRS: 5486

CSO: 4711-N

ULTRASONIC TREATMENT OF WATER

[Following is the translation of an article by Engineer L. B. Sigalov entitled "Ul'trazvukovaya obrabotka vody" (English version above), in "Bezopasnost truda v promyshlennosti" (Industrial Safety Measures), No.4, Moscow, April 1960, pages 21-23.]

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 industral 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 elsticity 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 bubblos 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 elastic vibrations of a sonic and ultrasonic range of frequencies, a magnetostriction 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 currant 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.

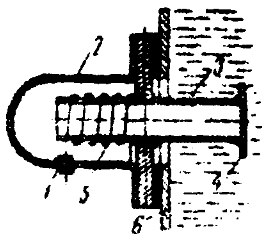

Fig.1. Principles of construction of a mgnetostriction oscillator:
1 - insulated lead-in, 2 - protective cover, 3 - nickel tube, 4 - sound radiating diaphragm, 5 - coil fed by the ultrasonic wave generator, 6 - boiler wall.

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 recieved 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 C_5 is charged by means of the resistance R_4 and the oscillator coil V_0 up to the voltage level of the rectifier. The latter is assembled as a single half-cycle circuit and consists of a transformer TR_1, selenium washers B-1 and a capacitor filter C_1.

[Please, see next page.]

Fig.2. Circuit of ultrasonic instrument IG-58

In its normal condition, the thyratron L_2 does not conduct any current, and the capacitor C_5 remains charged. When the appropriate voltage impulse is fed to the grid of the thyratron L_2, the latter begins to conduct a current, and the capacitor discharges through the coil of the oscillator V_0. In the oscillation contour, that consists of the inductance of the oscillator coil and the capacitor capacitance of capacitor C_5, there appear damped electrical oscillations, the frequency of which is governed by the magnitude of the capacitance of C_5 and that of the inductance of the oscillator coil.

In the absence of grid pulsing in the thyratron, the latter becomes "locked" (does not conduct current),

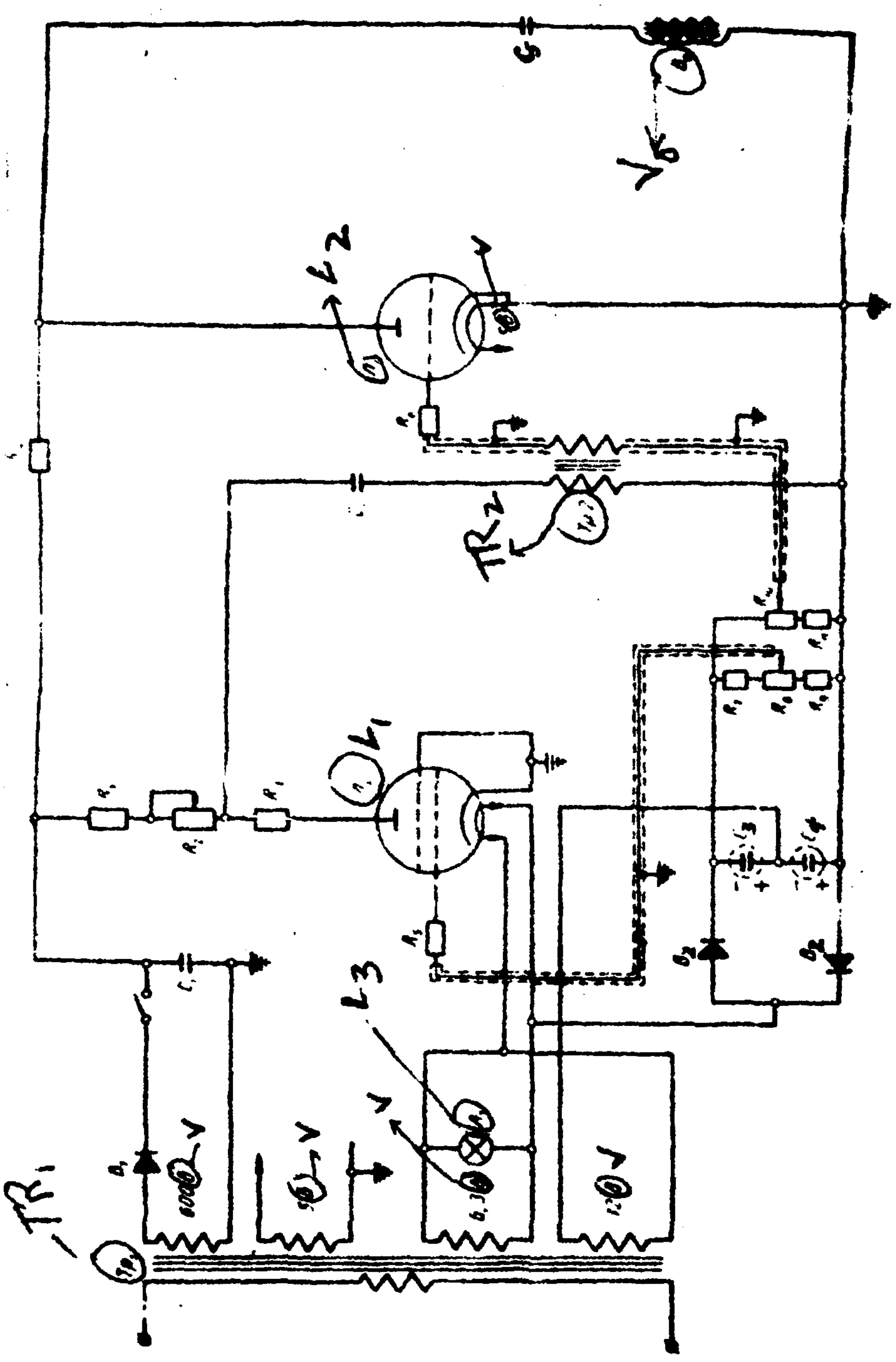

Fig. 2.

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 thyratron L_2. Voltage pulses are created by thyratron 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 correspoding to that which fires the thyratron L_1, capacitor C_2 is discharged through coil 1 of transformer TR_2, the thyratron L_1 and resistance R_3. At the same time, the voltage necessary to fire thyratron L_2 is created in coil 11 of transformer TR_2 connected to the grid of thyratron L_2. The grid bias of thyratron 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 Leningrad Water Transport Institute, a standard barium-type arc gap/RB-280 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 C_3 becomes charged through resistance R_4 and the coil L of the magnetostriction transducer. In the first instant after the connection of the rectifier, the voltage on capacitor C_3 rises from zero to the potential at which discharger RB is fired, after which resistance bewteen discharger electrodes drops sharply due to ionization of the medium. Capacitor C_3 is discharged into the oscillation contour C_4 - L, that consists of the parallel-connected capacitor C_4 and coil of magnetostriction transducer L. In the process of discharge of capacitor C_3, its voltage decreases down to the level at which discharger RB is extinguished. Thereafter capacitor C_3 again becomes charged through resistance R_4 and coil L up to a voltage equal to the ~~img~~ 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

C_4 - L as a result of the discharge of capacitor C_3 induces electric oscillations in the contour having damped characteristics, the frequency of which is determined by the values of the capacitance of C_4 and inductance of L.

The charge resistance R_4 fulfills the following functions: during the charge period of capacitor C_3, 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 shortcircuiting of the rectifier through the discharger. The magnitude of resistance R_4 determines the charge period of the capacitor and, therefore, the number of ignitings of the discharger in a unit of time.

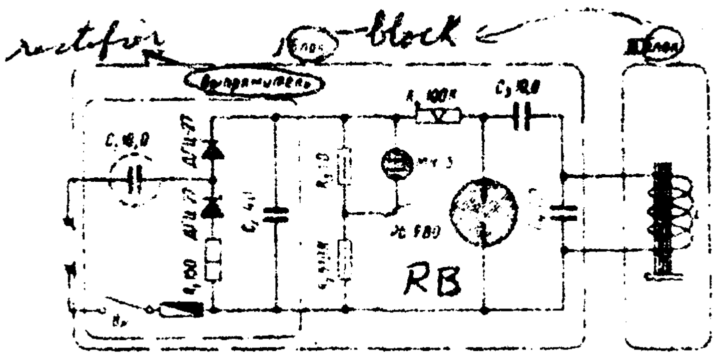

Fig.3. Circuit of ultrasonic instrument IGU-9

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 situated 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 "Promehergo" have shown that ultrasonic treatment of waterconsiderably 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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