ON TECHNICAL POSSIBILITY AND PRACTICAL EXPERIENCE OF ULTRASONIC SCALE PREVENTING DEVICES USE ON BOILERS AND HEAT-EXCHANGERS IN RUSSIA

A.G.Semenov

N.N.Andreev Acoustics Institute
Russian Academy of Sciences4, Shvernik street
Moscow , 117036
Russia

ABSTRACT Scientific foundation for ultrasonic scale preventing devices construction was given in 40^{s} - 50^{s} of this century but their production in former USSR was organized later in 70^{th}. Several different principles of scale preventing is overviewed together with physical principles of ultrasonic method. Practical experience received in USSR in 80^{s} is discussed. Technical decisions and inventions used for construction of the first device UZU-1 produced in Cheboksary plant are enumerated and principles of UZU-2 device are briefly sketched.

1. INTRODUCTION

Problem of scale which is formed on the surfaces of boilers, heat-exchangers and other energetic equipment cause a lot of trouble in practice. Additional energy and fuel losses, demands to clean inner surfaces of equipment each year by special acid solution with stopping boiler for comparatively long period is the price society must pay for natural water use in heat-exchangers. Some estimates say that if scale would not exist, economy of fuel (or additional energy when the same amount of fuel is used) is to be up to 4% - which is very convinceable figure for practical engineer and businessman.

Proposed ways of scale preventing are touched in first paragraph. For the most reliable way to protect equipment using natural water from scale formation is ultrasonics, the next paragraphs are devoted to ultrasonic scale preventing devices and in the first place UZU-1 "Acoustic" and more portable and energy saving UZU-2, produced in Cheboksary according to USSR patents [2]. In 1980 patents on these inventions were taken also in USA, France, Great Britain, Japan, Germany, Finland, Switzerland. Details of experimental data received previously in USSR in that field are also reviewed on the basis of official documents analysed in report [1].

2. METHODS AND MEANS OF SCALE PREVENTING

Traditionally scale omitting regime in heat exchanging utility operation is reached by special salts evacuating chemical treatment of water (H-cationizing, OH-anionizing, osmosis, dailisis and others) or by transforming of weakly soluble salts of water hardness in soluble Na salts (Na-cationizing). Iron salts are extracted as usual on mechanical filters, magnetic filters etc. Such chemical methods are expensive, demand a lot of money and labor on special utility, chemical materials, high qualification of personnel - so they are very weak economically.

In USSR and several other countries special devices providing means of physical treatment of water are developed to prevent scale and deposit formation on heat exchanging surfaces. Best known are two types of devices - for magnetic treatment of water and ultrasonic devices. These types are most effective as well. Magnetic treatment of water are the cheapest way of preparing water for heat exchanging utility. USSR produced devices for that purpose good for water expense from several kilogramms to several tens of thousands ton of water per hour. The problem of this method is absence of serious physical theory of phenomena and correspondingly deficiency of strict recommendations to where and when use magnetic treatment of water. Our experience says that approximately in 50% cases magnetic treatment of water is weakly or even not effective in scale preventing.

Much more interest is drawn in practice to ultrasonic method of scale preventing. Scientific foundations of this method were worked out in 40^{s} - 50^{s}, but wide development became possible only later when corresponding mechanical and electromechanical components for ultrasound emission became available and semiconductor elements were used in electrical circuits. In Russia (USSR) most widely known are ultrasonic device A1-AUN (produced in Rustavy, Georgia) and UZU-1 "Acoustic", UZU-2 (produced in Cheboksary, Russia). Each of these devices has it's own field of use. First one is used in food industry for deposit prevention. In the field of energetics more often are used second two devices. They are installed on boilers, heaters, steam and water boilers, coolers, water-fresheners, steamers, condensers, fuel heaters, economizers and tubes. The circle of utility where ultrasonic devices could be used included also high pressure utility to be controlled by special state control administration. The use of them in our country is permitted officially.

3. PHYSICAL PRINCIPLES OF TECHNOLOGY USED IN ULTRASONIC SCALE PREVENTER

Physical mechanism of scale formation is different on

immobile and vibrating heat exchanging surfaces as well as in free and ultrasonically driven water with some substances dissolved.So it is desireable to construct device producing vibrations in order that acoustical energy could be transmitted from device to every dangerous , from the point of scale formation , part of the boiler.Vibration frequency used must be not too high in order that acoustical energy would not be damped out on the way to distant boiler parts and not too low in order that produced vibration would not meet natural frequencies - resonances of boiler construction. In the last case vibrational field produced would be distributed in the boiler volume not uniformly. Special considerations should also be taken into account to prevent scale formation on inner surface of heat exchanger tubes. For that purpose frequency must be chosen not much higher than or of an order of first vibration resonance frequency of tube crossection to ensure the maximum possible symmetrical radial vibration amplitudes of scale particles on the tube walls.

Something should be added on mechanism of intrinsic processes taking place in water in ultrasonic field. It is clear that in ultrasonic field physico-chemical reaction kinetics changes. Most effective is sound action on hardness of salts which become instable during heating. The main process is very much alike with well known process of crystallisation around some "initial" centers, when in water some small hard particles are added, for instance, of marble or calcium carbonate for increasing the surface of "initializing" centers - added particles. Scale formation takes place not only on the walls but on the particles surface too. So the more there would be such "initial" centers the less scale would be on the walls. Ultrasonic treatment uses fact that in water such centers - little particles are always present. Division of this particles when cavitation bubbles are crushed in the sound field leads to increase of active scale forming surface and evidently to scale preventing on the heat exchanger walls. From the other hand the vicinity of cavitation bubbles will be enriched by salts due to well known diffusion effect in bubble volume. This effect together with comparatively high temperature leads to formation of new "initializing" centers when bubbles are crushed. There is also a row of circumstances related to the fact that ultrasound emission takes place in the vicinity of vibrating heat exchanger surfaces. Then micro flows are formed leading scale particles from surface to the volume of the water and boundary flows turbulization takes place too.Partially crystallization in the water volume is speeded by degasation of water under action of ultrasound. That way concentration of free carbon acid formed by means of thermal destruction of carbonates is decreased. Simultaneously one can expect quite simple processes of ready scale crushing on the walls due to their vibrations. Scale pieces obviously should be evacuated.

Those are qualitatively main physical phenomena responsible for scale formation.

4. PRACTICAL USE OF DEVICES IN HOME ENERGETIC UTILITY

One of the most important parameters used in heat-exchanging utility efficiency estimates , for instance , when scale-preventing devices are used is heat thrust Δt. This value characterizes presumably two stage heater. If in first contour of heating temperature change is Δt_1 and in second - Δt_2 , then taken strictly [6] heat thrust is:

$$\Delta t = (\Delta t_2 - \Delta t_1)/\ln (\Delta t_2/\Delta t_1)$$

But if $\Delta t_2/\Delta t_1$ is less than 1,7 which is real for effective heater [1] , then last formula could be approximated:

$$\Delta t = (\Delta t_2 + \Delta t_1)/2$$

So one could easily understand that the less are temperature losses Δt_1 and Δt_2 in contours , the less is temperature thrust for the system as a whole , which is thus minimum for new or newly cleaned heater when scale is absent at all.

One of documents presented in [1] - shows results of heat thrust comparative control performed to esteem efficiency of scale preventing by means of UZU-1 big (6transducers) scale preventers on huge metallurgy plant boilers. Temperature thrusts observed on the same paralel operating boilers in the end of exploitation season - 20 ^{o}C without scale preventer and 8-10 ^{o}C when scale preventer was installed , it was also noticed that observation of second opened boiler evidenced - mechanical cleaning procedure is now not necessary at all.Approximately the same data - change of heat thrust from 40 ^{o}C before to 10 ^{o}C after installation was observed for other civil boiler. Other document [1] gives affirmative answers to important question formulated for conventional civil boiler working with UZU-2 scale preventing devices installed (boiler was already in exploitation for a year , was not opened as usual and it's inner surfaces were not cleaned before scale preventer being installed) - if scale preventer substantially influence on new scale formation and at the same time destroy old scale formed on boiler walls before as well? It should be noted that according to experience obtained before (on the basis of previous observations of opened boilers) - one year of boilers use formed scale on inner walls of thickness up to 0.5 - 1.5 mm. Scale preventing devices were installed on two

boilers in the middle of operating season for approximately 6 months and were working steady in that period for 1440 and 1488 hours correspondingly. When opened in the end of this period no scale was found on the walls of boilers, but cracked scale was lying on the bottom of collectors - up to 40 and 44 kg and boiler cylinder - up to 35 and 36 kg correspondingly. Cracked scale has thickness from 1.0 to 2.5 mm and dimensions up to 150 sq.cm. Chemical composition of scale includes: Fe-compounds (oxides) - 11%, Ca,Mg-compounds (oxides and carbonates) - 58.9%, other practically insoluble substances - 30.1%. Then boilers were closed and opened next time after year exploitation. No scale was found neither on walls nor, in cracked state, on boiler's bottom. When temperature of boiler walls was measured to be 120 ^{o}C, temperature of magnetostrictive transducers remains not more than 65 ^{o}C which is normal for Ni used in transducers.

Acts of inspection of heat exchanging utility presented in [1] and related to boilers (heat exchangers) of Cheboksary energy plant equipped with UZU-1 scale preventer. It is stated that due to previous experience - one year use leads to approximately 150 - 300 gm/sq.m of scale on heat exchanger tubes (on boilers walls up to 600 gm/sq.m). After installation of ultrasonic device almost no scale on the test boiler tubes and inner surfaces was found, except of some dusty particles which could be easily washed by water.Measurements of scale thickness undertaken additionally show - (1.0-2.0 mm) before and (0.1-0.2) mm after UZU devices installation correspondingly. Several tubes of two boilers compared were crushed and photographed for comparison [1].Next type of evidence presented is protocol of comparison of two methods of scale preventing - chemical and ultrasonic. It is shown that ultrasonic method is the best. Due to it's use the quantity of scale found was decreased from 595.6 g to 13-14 g per square meter of heat exchanging surfaces. From the other hand addition of chemical substances (oxiethyldendyfosphon acid up to 0.8 g/liter) practically don't change scale amount for type of water taken whith quantity of salts in the limits from 270 to 450 mg/liter.Nevertheless , for arbitrary type of water it is still recomended to use these two methods together.Very important positive result confirming scale preventing possibility abroad was obtained after several year experience for Russian boiler DKVp-4-13 closely resembling Korean boiler HWP-40 (nominal productivity about 4 tons of steam per hour, operating pressure 13 kg/sm^{2}).Together with special tests taken in KIST in 1992 it stimulate technology transfer to Korean industry (Sae Bo Industry LTD). It is recommended to use scale preventing devices on new or newly cleaned equipment. Ultrasonic devices slightly change kinetics of physico-chemical processes provocating the scale to form but they do not

change insoluble substances to soluble. There for kind of waste material (slag) could be concentrated in some reserved parts of system, mainly in places with slow flow speed. Anyway means and places for slag withdrawal are necessary. When device is connected and adjusted to standard mains frequency 60 Hz, parameters and characteristics could be slightly changed, but scale preventing possibility remains safe. The level of vibrations are meeting existing standards for energetic utility in USSR. Sound noise levels were experimentally controlled and proven to be very low and meet standards too [1]. Usually, operator on energy plant due to presence of multiple other noise sources does not react to specific whistle noise of transducers. In Russian technical regulating documents quality of effective scale preventing necessary to achieve is two times decreasing intensity of scale formation.In fact , if scale preventer is installed by specialists - professionally , then for used in Russia types of water scale is absent on the walls of definite boiler practically at all.

5.CONCLUSION

Overview of more than ten year experience of ultrasonic scale preventing methods and devices UZU-1 and UZU-2 produced in Russia (Cheboksary) practical use shows:
1. Ultrasonic method of scale preventing is very effective in the field of energetics for different types of water heating equipment.
2. Variety of ultrasonic scale preventing devices are produced in Russia to realize this method.Being produced serially they have legal state approvement to use for home energetic utility.
3. Waterheating energetic utility together with water quality used abroad by main characteristics and parameters are close to utility and water used in Russia. That is why possibility and good perspectives of use scale preventing devices produced in Russia or produced on the same principle in other contries there could be concluded.

REFERENCES

1. A.G.Semenov , E.V.Litvinov and V.A.Morskov, "Practical Experience of Ultrasonic Scale Preventing Devices Use on USSR Boilers and Heat-Exchangers", Technical report of INVAC Corp.LTD, Moscow,1992

2. "Method and Ultrasonic device of cleaning heatexchanging surfaces", USSR patent N 1.058.408, N 1.075.508, N 1.205.383, N 1.189.186

3. S.S.Kutateladze Heat transfer experiment manual (in Russian). Gosenergoizdat, Moscow 1958, p.253.