SUMMARY REPORT

on the results of testing Hydroflow Industrial (test) units on heat exchangers for cooling the distillate of the Zaporizhzhya Nuclear Power Plant (ZNPP, Ukraine)

The full report can be viewed here

http://elar.tsatu.edu.ua/handle/123456789/11335

Zaporizhzhya Nuclear Power Plant (ZNPP) is Europe's largest nuclear power plant located on the banks of the Dnieper river in Zaporizhzhya Region (Ukraine), consisting of 6 power units with a capacity of **1000** MW each.

Hydroflow Ukraine LLC and SAV KOMPLEKT, together with ICC UKRAINE, was testing two Hydroflow Industrial (test) units installed before condensate coolers on cooling water supply pipes (diameter = 108mm, material steel ST.45.8) during the period of 3 months (December 2019 till March 2020). The temperature of the cooling water at the inlet to the circuit, during the tests, ranged from 12.5° C to 21° C, the temperature of the cooled condensate - from 100° C to 106° C.

The condensate cooler is a tubular heat exchanger made of A35.47/1 stainless steel, comprising 110 tubes with a diameter of 25x2 mm and length of 2490 mm.

The complex deposits, consisting of calcium and magnesium carbonates, silt, sand, rust and biological particles, were formed on the inner surface of the heat exchanger tubes and on the water supply pipe during operation.

Colonies of snails (Melanoides tuberculata) bred on the surface of sediments. As a result, the thermodynamic and hydraulic characteristics of the heat exchanger became worse, and formed hard deposits significantly increased the scope and timing of maintenance work.

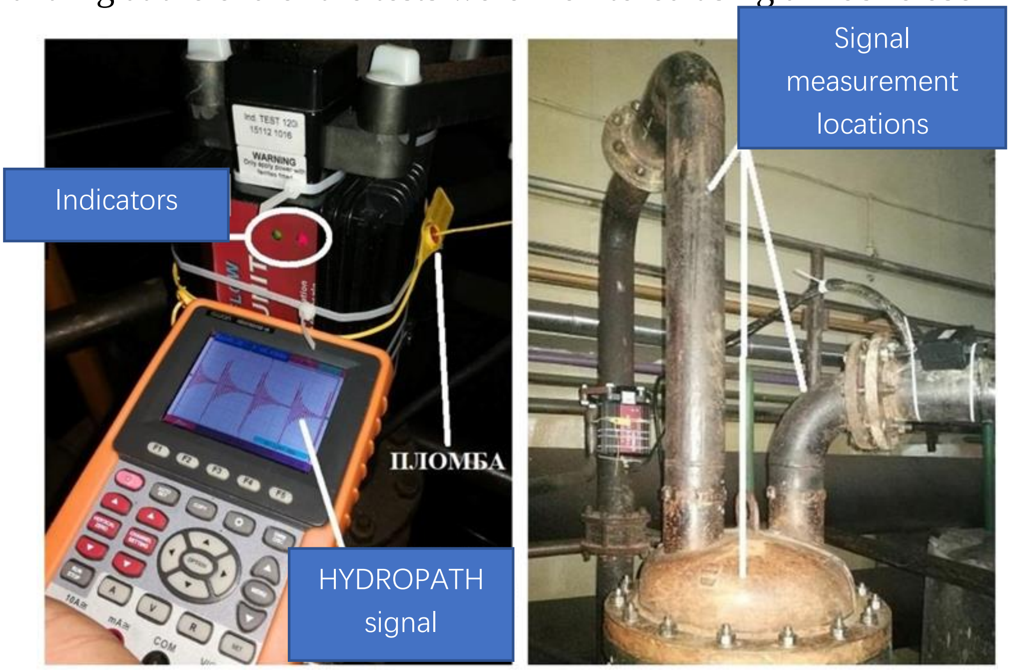
The aim of the test installations was to prove the effective influence of the HYDROPATH signal generated by the Hydroflow Industrial (test) unit on the process of softening and fracturing of deposits on the inner walls of the tubes, as well as preventing the growth of snail colonies

Before the beginning of the test installations both heat exchangers were opened for inspection of their initial condition, application of control "beacons" and selection of control samples of deposits, which were examined in a local certified laboratory.

The condition of the internal surfaces of the heat exchanger tubes was also examined with photo and video fixation using "TESLONG" digital endoscope. Snails Melanoides tuberculata were discovered on silty deposits inside several heat exchange tubes. The tubes were filled with sludge so much that it was impossible to immerse the endoscope probe into them to a depth of more than 0.5 m

The thermal sensors were mounted on the inlet and outlet of the water and condensate cooling circuits to analyze the changes during the testing of the heat engineering parameters. The censors' data were read every two hours and processed according to a special program.

The frequency and waveform during the installation of the Hydroflow Industrial (test) unit and its dismantling at the end of the tests were monitored using a mobile oscilloscope.

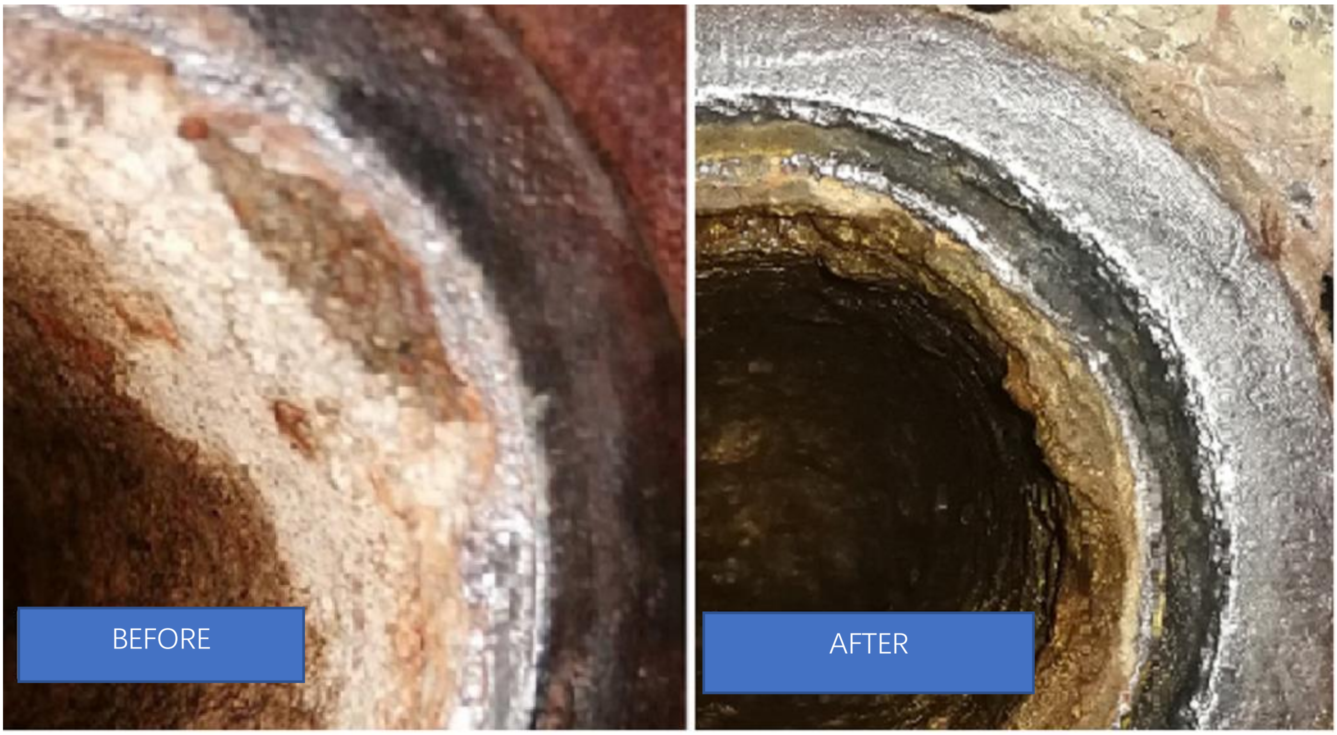


Installation of Hydroflow Industrial (test) unit on a process water supply pipe

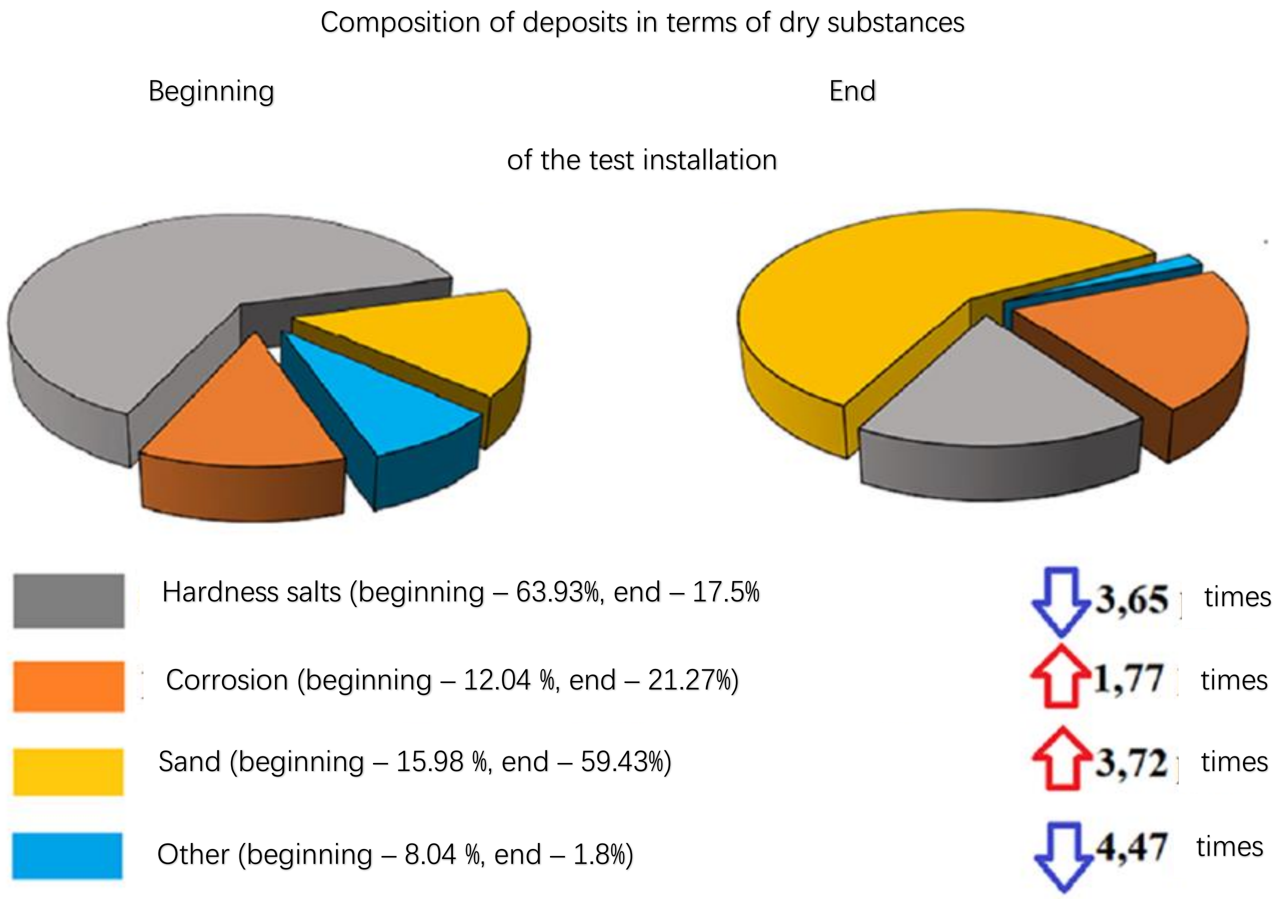
At the end of the test installations the control opening of the heat exchangers with fixation of the current state of the controlled surfaces was made. According to the Test Installation Program test cleaning of some sections of the controlled stainless steel surfaces of the tube plates was performed using a household plastic brush, as well as the test cleaning of inner surfaces of the heat transfer tubes using a plastic and steel wool to a depth of 1-1.5 m.

Using "TESLONG" endoscope the condition of the inner surfaces of the heat exchange tubes and their test treatment areas with the help of a steel wool was examined. Also during the final opening the samples of deposits from inner surfaces were taken and transferred to the laboratory for analysis.

Test installation results:



Comparison of the state of the inner surface of the the industrial water supplying pipe at the beginning and at the end of the test installation



Changes in the structure and chemical composition of deposits on the inner surface of the industrial water supply pipe

Due to the influence of the HYDRPATH signal generated by the Hydroflow Industrial (test) unit it has been conclusively achieved:

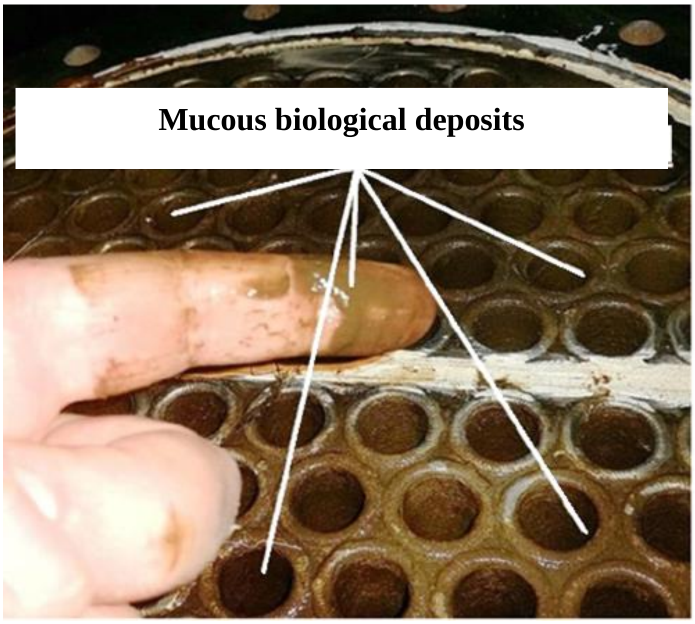
A) On the inlet pipe (Material - ST.45.8)

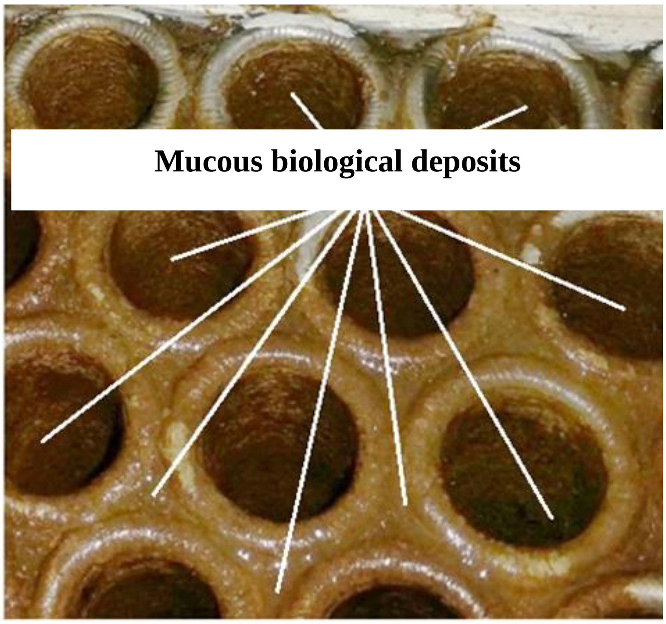
- Extreme (decrease by 3.65 times), confirmed by laboratory analysis, leaching of carbonates from the structure of deposits, a significant increase in brittleness, decrease in hardness and size of very hard complex deposits existed at the beginning of test installation;
- Complete blocking of the formation of new deposits on the applied special "beacons";
- Complete removal of biological deposits, which are the nutrient base for snails;

B) On the surfaces of tube sheets of heat exchangers (Material - stainless steel A35.47/1):

- A significant degree of destruction of existing and the prevention of the formation of new biological deposits;

- The practical possibility of removing, with the help of a household plastic brush, a thin powder layer formed on the surfaces of the “beacons”. This powder layer consists of carbonate microcrystals washed out from complex deposits and has minimal adhesion to stainless metal;





- ***Mucous biological deposits on the tube plate <u>at the beginning of the test installation</u>***

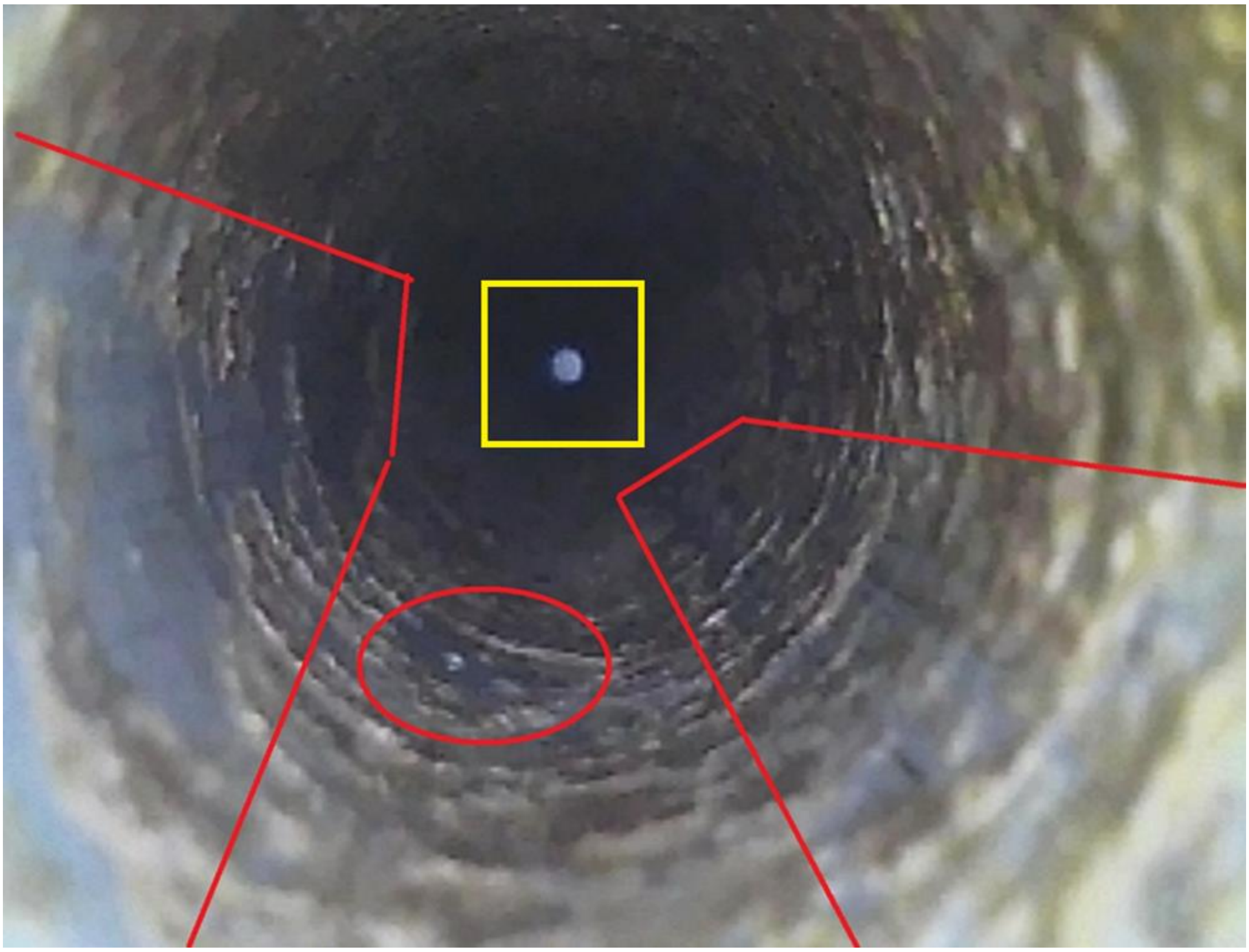
Tube board cleaning using household plastic brush

Cleaned “beacons” on the pipe using household plastic brush

Cleaning the heat exchanger tubes with a steel wool

C) On the surfaces of the heat exchanger tubes of the heat exchanger (Material - stainless steel A35.47 / 1):

- Changing of the structure and softening of the carbonate structures present on the walls of the heat exchanger tubes and evidence of the possibility, in practice, of their removal using a conventional steel wool;
- Blocking the formation of new carbonate deposits on the walls of the tubes;
- Easy removal of silt structures from the walls of the tubes using a conventional plastic brush;
- Complete removal of biological deposits with a characteristic color, mucous texture and putrefactive odor, which were recorded at the beginning of the test installation;



Removing the carbonate layer from the wall of the heat transfer tube using

metal brush. Red sectors - zones of removed sediments, yellow sector - clean section at the end of the tube.

Sampling deposits from the inner surface of the wall of the heat transfer tube

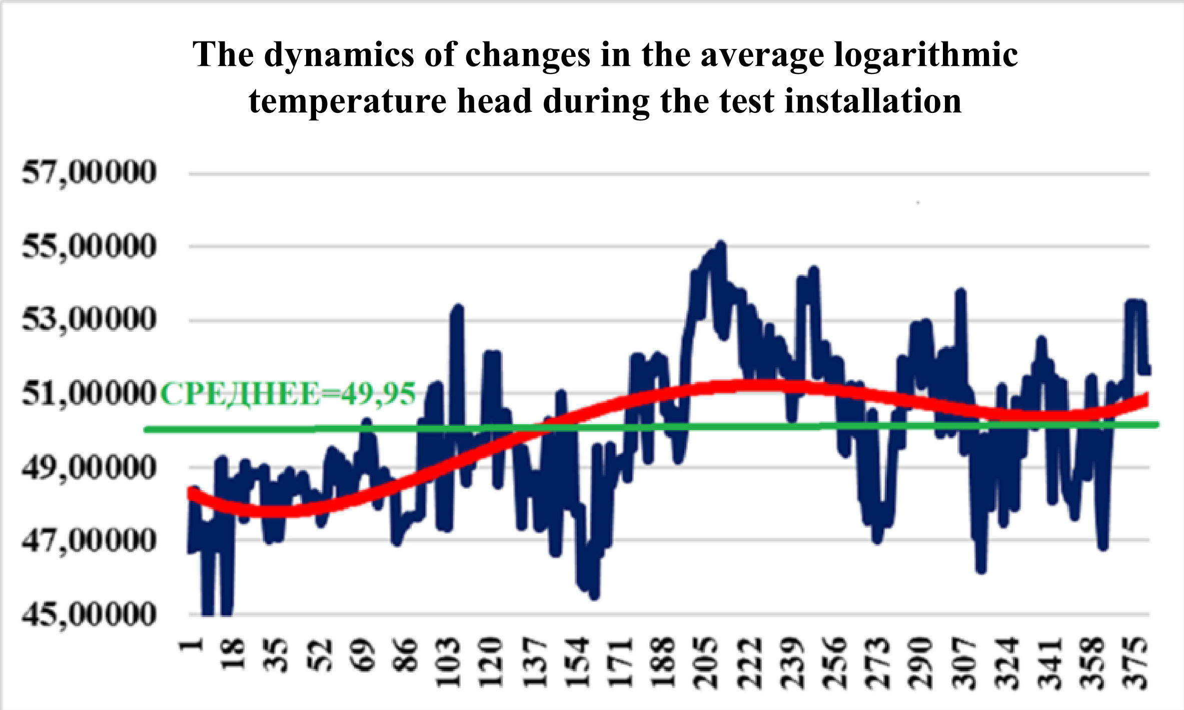
Data processing:

- was regular (every 2 hours) during the entire test period,

- was taken from temperature sensors installed at the inlet and outlet of the heat exchanger circuits,

- recorded a steady increase in the average logarithmic pressure,

- documented the improvement of this generalizing thermodynamic indicator.



All goals set in the Test Installation Program were achieved.

The test installation results allow us to state that Hydroflow units:

- Can be effectively used for long-term use in order to gradually remove and prevent the formation of new complex deposits (including those with a biological component), including a carbonate binder component, without using mechanical or chemical methods of cleaning the inner surfaces of pipes of various diameters in the process both operation and repair work on the power equipment of nuclear power plants and thermal power plants;
- Effectively contribute to improving the operational thermal characteristics of the power equipment of nuclear power plants and thermal power plants, reducing accidents, reducing the frequency, volume and laboriousness of repair work by gradually reducing the thickness and strength of complex deposits on the inner surfaces of pipes of various materials and various diameters of the equipment;
- Allow to fight the fouling of the inner surfaces of the power equipment of nuclear power plants and thermal power plants with various types of mollusks by effectively destroying their food supply - biofilms and other biomaterial.

Additionally, in the process of performing the complex of works at Zaporizhzhya NPP site, our experts conducted the preliminary survey for the technical feasibility of installing Hydroflow units at the following units and assemblies:

- oil-water cooling system of the main block transformer;
- heat exchanger 1ST33W01 of the gas cooling systems ST of generator;
- oil-water cooling system of turbine oil cooler;

- cooling systems for the bearing oil bath and pumping station electric motor of the circulation system spray poolsю

The surveys confirmed the technical feasibility and long-term benefits of installing Hydroflow units at these units and assemblies.

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The authors of the test installations are grateful to Zaporizhzhya NPP team, Mr. Dmitry Sabadin and Mr. Oleg Dudar for their help in resolving organizational issues and for their technical advice.