Designing of the Experimental Models of Multipurpose Water Treatment Plant

A.L. Kartashev, M.A. Kartasheva, E.V. Safonov

***Abstract*–In this paper, development of the experimental model of multipurpose water treatment plant is considered. Construction multipurpose water treatment plant realizes the Ranque-Hilsch effect in a vortex flow.**

***Index Terms*–Water treatment, vortex flow, Ranque-Hilsch vortex effect, construction of plant**.

The experimental models of multipurpose water treatment plant (MWTP) for the generation of steam and creating a flow of coolant used effects arising from vortex flow, including phase transitions, representing the water evaporation process and the condensation of water vapor are designed.

Devices that realize the vortex motion, called differently: centrifugal, cyclone, cyclone-vortex and vortex chamber, vortex tube (Ranque-Hilsh vortex effect), cyclones and hydrocyclones, vortex separators, vortex firing and combustion chamber, etc. [1]. Their common feature is the presence of the working area (typically cylindrical or conical shape) and flow swirl (generally tangential or axial).

The term «vortex chamber» was introduced in the simulation of atmospheric vortices in laboratory conditions. According to the accepted terminology, the vortex chamber – is a device which realize uniform distribution of the medium input chamber periphery and in which a working medium performs rotational-translational move- ment.

Vortex flows of various types with the realization of different physical processes are carried out by a number of technical solutions. For the purposes of the realization of applied research carried out by the technical solutions chosen of MWTP on the basis two technologies using vortex flows of the working fluid: effects Ranque-Hilsh and centrifugal effect.

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The research method of preparation of the boiler and heating water based on the effect of Ranque-Hilsh [2,3], is the primary objective of the project. The research method of preparation of the boiler and heating water, based on centrifugal effect – a secondary objective of the project.

The main application of the MWTP is to provide quality of the water regime of heat supply systems to eliminate scaling processes in hot-water boilers tract and transport pipelines in order to increase efficiency of operation of the main equipment.

There are a variety of designs swirlers [4,5], but in the vortex tubes are used almost exclusively tangential swirls and snail swirls. For such constructions characterized by the formation nearly the swirl the central zone of reverse flows, the diameter of which is about half the diameter of the tube and the length of the intensive swirling flow can reach several tens of the diameter of the tube [4]. The cause of the reverse currents is that as it moves rapidly rotating steam tube along its circumferential (tangential) speed decreases due to the deceleration of the wall and, accordingly, decreases the radial pressure drop. If the speed of forward movement of the rotating gas along the tube is relatively small, i.e., rate of pressure drop at the longitudinal periphery of the tube is insignificant, the rapid decrease in pressure drop along the radial pipes leading to the appearance of the tube axis negative pressure gradient, and which generates a reverse flow. Vortex tubes are a counter flow and direct flow.

For the purposes of the present research uses a counter flow vortex tube realizing Ranque-Hilsh vortex effect. Steam is fed into the vortex tube at a high speed (of the order speed of sound) through the nozzle in the form of snail constructed by Archimedes spiral located at the end of the tube. Hot steam is discharged through the peripheral annular outlet at the opposite end of the tube, and the cold vapor is taken through the central aperture, which is located on the end of the tube near the inlet nozzle (Fig. 1).

As the control valve cover general pressure level in the vortex tube is increased and the flow rate of cold flow through the aperture increases with a corresponding decrease in the hot stream flow. The temperatures of the hot and cold flows are also changed.

Product purpose: experimental models multipurpose water treatment plant (MWTP-1, MWTP-3, MWTP-10) on the basis of the vortex tube designed for experimental studies desalination method of phase transitions in the vortex under high vacuum using effect Ranque-Hilsh.

Parameters, dimensions that characterize the operating conditions of the experimental models (MWTP-1, MWTP-3, MWTP-10) multi-purpose water treatment plant on the basis of the vortex tube are shown in Table 1.

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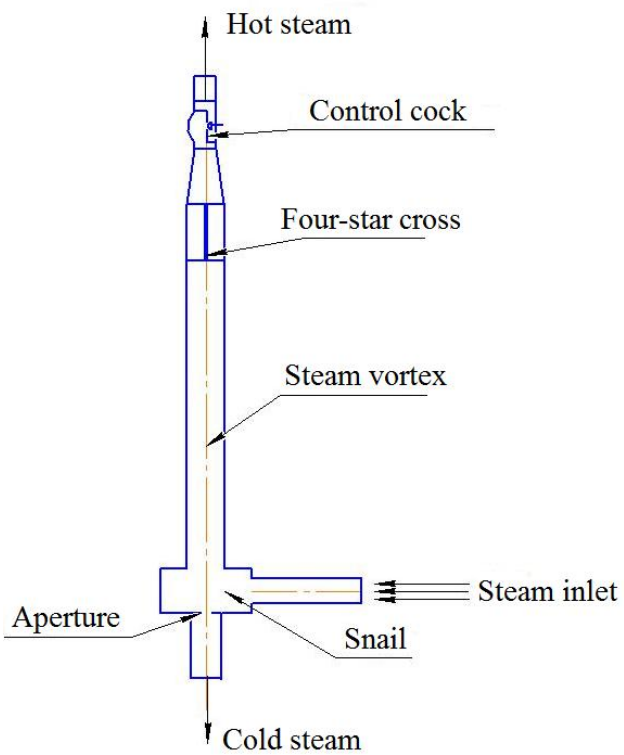

Fig. 1. Scheme of the experimental samples multipurpose water treatment plant on the basis of the vortex tube

Table 1

№	Characteristic	Dimension	MWTP-1	MWTP-3	MWTP-10
1	Water consumption	kg/s	1,1	3,3	11,0
2	Water temperature on inlet	°C	75 - 105	75 - 105	75 - 105
3	Water pressure on inlet	MPa	0,04 - 0,12	0,04 - 0,12	0,04 - 0,12
4	Steam consumption	kg/s	0,28	0,84	2,80
5	Dimensions (length x width x height)	mm	380 x 2574 x 873	380 x 2645 x 968	380 x 3250 x 1150
6	Mass	kg	36	84	97

Performance range of experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant: 0,5÷10,0 m^3/h.
The lineup:
– MWTP-1: 0,5÷1,0 m^3/h;
– MWTP-3: 1,0÷3,0 m^3/h;
– MWTP-10: 3,0÷10,0 m^3/h.

Experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant provides quality indicators of desalinated water is not worse:
– total hardness: less than 1 mg-eq/kg;
– sodium content: 15 mg/kg;
– silicic acid: 15 mg/kg;
– specific conductivity: less than 0,1 mS/cm.

In accordance with the recommendations [6] adjusted for the technical realization capabilities, vortex tube has the following geometrical characteristics:
– to reduce the working area of the vortex tube length to 4 - 9 caliber (diameter tube) inside the central tube at its hot end mounted with four-star cross;
– the relative diameter of aperture of the cold flow d_c/D = 0,5;
– relative flow area of the nozzle inlet $4S_T/(\pi D^2)$ = 0,1;
– using one nozzle having a rectangular cross section, the width b and height h which relate b/h = 2;
– the nozzle is constructed in the form of a snail in a spiral of Archimedes.

General view of the experimental models MWTP-1, MWTP-3, MWTP-10 on the basis of the vortex tube is shown in Fig. 2.

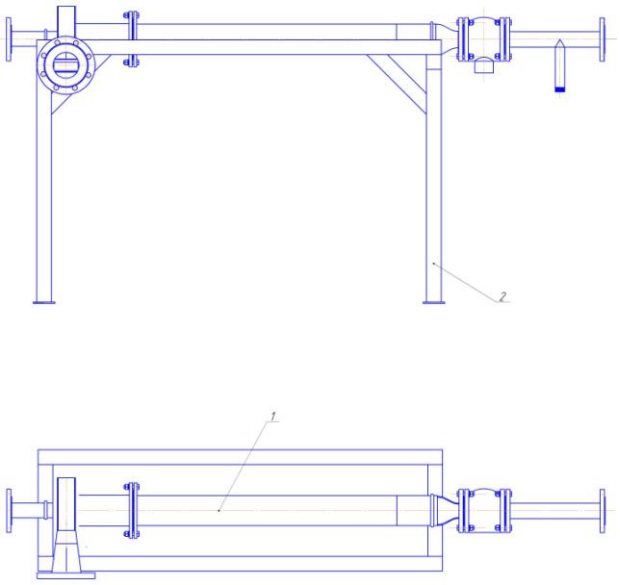

Fig. 2. General view of the experimental models MWTP-1, MWTP-3, MWTP-10 on the basis of the vortex tube

Experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant on the basis of the vortex tube consists of the actual vortex tube and stand. Experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant on the basis of the vortex tube have a similar structure and differ only in size. Next, we consider the construction of an experimental model MWTP-1 multipurpose water treatment plant on the basis of the vortex tube.

Assembly drawing of the vortex tube MWTP-1 is shown in Fig. 3. The vortex tube contains in its construction of three main parts:
– the central tube (position 2);
– input node (position 3);
– the output node (position 4).

Center tube (Fig. 3) of the vortex tube consists of:
– a cylindrical tube, which swirl chamber (position 7).
– conical nozzle with a throttling valve (position 2).

Straightener four-star cross is shown on Fig. 4.

The input unit (Fig. 5) contains in its composition:
– the transition from the circular cross-section to a rectangular cross-section of the nozzle (position 4);
– snail equipped with a tangential nozzle (position 3);
– aperture of «cold» flow with an axial hole with a pipe-bend (position 8).

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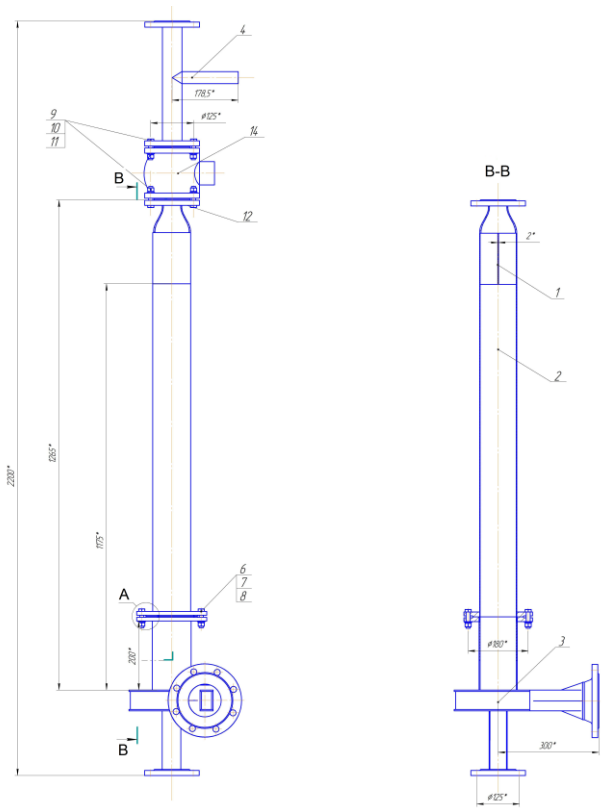

Fig. 3. Assembly drawing of the vortex tube experimental sample MWTP-1 multi-purpose water treatment plant on the basis of the vortex tube

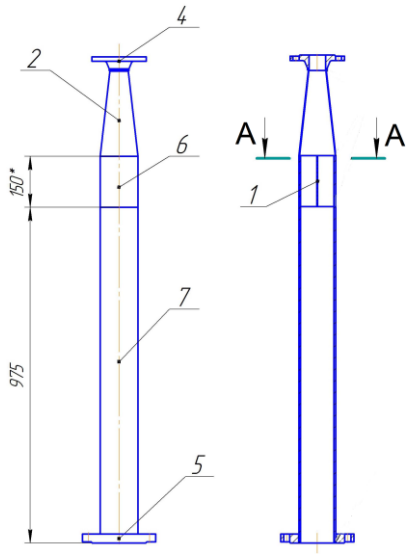

Fig. 3. Central tube of experimental model MWTP-1 of multipurpose water treatment plant on the basis of the vortex tube

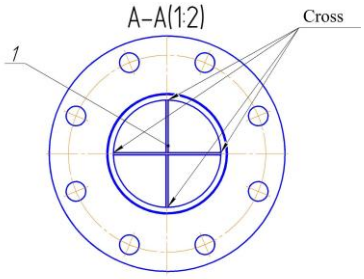

Fig. 4. Scheme of straightener four-star cross

To provide a different performance of the vortex tube, use three sizes of the snail to the MWTP-1, MWTP-3 and MWTP-10:

– MWTP-1 – 90x45 mm;
– MWTP-3 – 150x75 mm;
– MWTP-10 – 280x140 mm.

The output unit contains in its structure connecting elements for connecting the vacuum and circulating circuits of test bench.

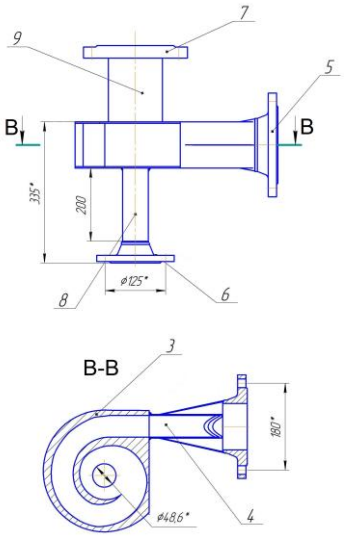

Fig. 5. The input node of the vortex tube of experimental model MWTP-1 of multipurpose water treatment plant on the basis of the vortex tube

Experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant on the basis of a vortex tube made of stainless steel 12X18H10T as the most common and available, in order to avoid corrosion of the system.

Joining the experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant on the basis of a vortex tube to test branch is realize by means of flange connections with bolt fixation.

As a result of this work have been developed the design documents for making the experimental models (MWTP-1, MWTP-3, MWTP-10) of multipurpose water treatment plant on the basis of the vortex tube.

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