UDC 658.264

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THEORY OF PULSE CIRCULATION OF THE HEATER IN THE HEAT SUPPLY SYSTEM WITH INDEPENDENT SUBSCRIPTION OF SUBSCRIBERS*

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Statement of the problem. The relevance of the subject is due to the influence of fluctuating flows on the efficiency of the operation of heat and power devices. The known ways of implementing such fluctuations often raise the question of the appropriateness of the effectiveness obtained in comparison with the costs of achieving it. Within the framework of this article, the vibrational circulation of the coolant is proposed to be carried out in a self-sustaining mode according to the principle of a hydraulic ram.

Results. The analysis of the operation of a two-fluid hydraulic ram is performed. The characteristic of pulsed and pulsating vibrational circulation of liquids in its elements is given. The transition to the use of this water-lifting device in a closed system is shown to create pulsed and pulsating circulation of liquids. The scheme of the heat supply system for independent connection of subscribers with pulsed and pulsating circulation of the coolant in its sections is obtained.

Conclusions. The results of the research form a unified view on the method of technical realization of pulsed and pulsating oscillatory circulation of coolants in a self-sustaining mode in separate sections of the heat supply system with independent connection of subscribers. The facts are given that these types of oscillatory motion of the coolant can be used to increase the energy efficiency of heat supply systems.

Keywords: heat supply system, heat network, heat consumption system, heat point, impact unit, impulse circulation of the heat carrier, pulsating circulation of the heat carrier, transformation of the available head.

Introduction. Studies of the influence of oscillating flows on the performance of heat-exchange devices are crucial in this country [1, 4, 29] and abroad [24, 27, 28]. This is primarily due to a great potential of intensification of heat exchange at certain frequencies of speed oscillations of a heat-exchanger in relation to a heat-exchange surface.

* The study is performed as part of the contract № 14. Z56.18.1408-MK (January 17, 2018) "On the Use Conditions of the Grant of the President of the Russian Federation for state support of young Russian scientists — postdoctorates MK-1408.2018.8".

Hence in [3, p. 229] there is data on the possibility of increasing a heat emission for oscillating movement by 2 times. In [22] due to oscillations of elastic shutters in a moving flow, a 134 % increase is recorded.

In order to design oscillations of a heat-carrier, piston pumps [20, p. 24; 30, p. 37—44], membrane blowers [5, p. 41], acoustic [2, p. 17] and vibromechanical [31, p. 364] transformers as well as other mechanisms based on the generation of periodic hydraulic vibration [21] are commonly used. These tools for oscillation circulation of a heat carrier generally operate using an external control that consumes some electrical and (or) mechanical energy. This makes the operation of the systems “a heat exchanger — flow pulser” more challenging and in some cases causes doubts as to whether it is viable to employ the efficiency of a heat-energy setup compared to the costs of oscillation movement of a heat-carrier. In addition, as the results suggest, the potential of oscillations of the speed and pressure of a heat-carrier is not completely utilized.

As part of the current research, it is suggested that an oscillation movement of a heat-carrier in heat energy setups is provided in a self-maintaining mode using the principle of a two-liquid hydraulic ram, i.e. with the generation of impulse and pulsing liquid [8, p. 18]. A system of heat supply [9] with an independent consumer use is chosen to attempt to implement this.

The objective of the paper is to explore impulse and pulsing oscillation circulation of a heat-carrier in a self-maintaining mode for a heat supply system with an independent consumer use due to the principle of a two-liquid hydraulic ram.

In order to achieve this, the following were addressed:

— analysis of the principle of a self-maintaining water-lifting device based on a two-liquid hydraulic ram for identifying the features and character of movement of liquid in its individual constructive elements;

— developing a technical solution for ensuring the operation of a two-liquid hydraulic ram in an isolated hydraulic system;

— developing a schematic solution for integrating a two-liquid hydraulic ram into a heat-supply system with an independent consumer use for impulse and pulsing circulation of a heat-carrier in its individual parts in order to improve its general energetic efficiency;

— protecting the results of intellectual activities obtained as a result of solving the above problems, patents of the Russian Federation for inventions and useful models.

The research is conducted at an educational scientific laboratory “Impulse Heat and Water Supply Systems” Federal State Budget Educational Institution of Higher Education “Mordovia State University Named after N. P. Ogarev" and is an individual project that contains the interpretation of theoretical data on effective use of technologies and tools for organizing impulse movement of a heat-carrier in heat and water supply systems for improving their energy efficiency [12].

1. Analysis of the features of the operation of a self-maintaining water-lifting device based on a two-liquid hydraulic ram. A hydraulic ram as a self-maintaining water-lifting device is widely known as a technological item [19, 25]. It is designed either for one [26] or two non-miscible liquids [16].

Let us look at the principles of the operation of a two-liquid hydraulic ram (Fig. 1) in more detail [13, p. 64].

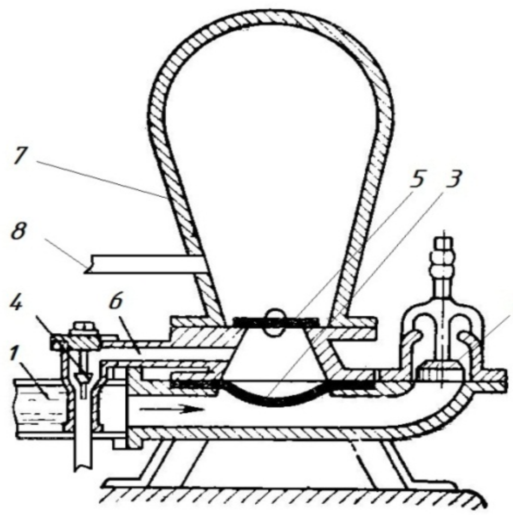

Fig. 1. Two-liquid hydraulic ram:
1 is an alimentary pipe;
2 is a shock valve;
3 is an elastic diaphragm;
4 is a reverse input valve;
5 is a reverse output valve;
6 is an absorbing pipeline;
7 is an air glass;
8 is a pressure pipeline

A working force moves along the alimentary pipe 1 and flows through the open shock valve 2 that is capable of closing automatically under the impact of an established speed of a medium flowing through it and opening under its own weight when its speed is zero. Due to the fact that there is the elastic diaphragm 3 on the same alimentary pipe 1, as the shock valve 2 closes and then opens, it moves up and down respectively. As a result, the reverse input 4 and output valves 5 of a pressure medium will enable it to be fed from the absorbing pipeline 6 into the air glass 7 and then along the pressure pipeline 8 to the user.

The operation of this water-lifting device will proceed in the above manner till there is a working medium fed along the alimentary pipe 1 through the shock valve 2. In individual elements of the two-liquid hydraulic ram there will be impulse and pulsing circulation of liquids.

1. There is impulse circulation in the alimentary pipe 1 with the shock node 2. It is characterized with an accompanying transformation of kinetic energy of flow movement into the

impulse energy of the amount of the movement as well as a hydraulic shock as the flow stops moving and there is some thermal energy emitted. Impulse circulation of liquid in the area of the alimentary pipe 1 to the shock node 2 is due to a positive wave of a hydraulic shock and behind the shock node 2 it is due to its negative wave;

2. Pulsing circulation of liquid occurs in the absorbing 6 and pressure 8 pipelines. It is characterized in relation to a slow change in the speed of a pumping medium in the pumping pipeline 8 with its average value remaining the same. As for the absorbing pipeline 6, the speed of liquid in it will be cyclic and changes fairly slowly from zero to maximum.

In this case pulsing circulation of the pumped liquid is secondary (led) in relation to impulse circulation of the working media. Therefore solving the problem of organizing oscillation circulation of liquid based on the principle of a two-liquid hydraulic ram involves obtaining its impulse supply into an isolated hydraulic system.

2. Technical solution for the operation of a two-liquid hydraulic ram in an isolated hydraulic system. Let us consider whether it is possible for a self-maintaining water-lifting device based on a two-liquid hydraulic ram to operate in an isolated hydraulic system taking into account the coordinates presented in Fig. 2.

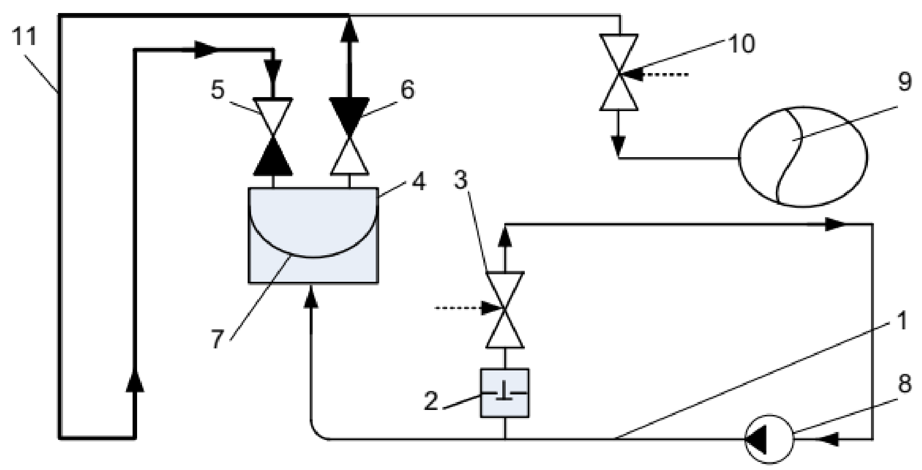

Fig. 2. Principal scheme of organizing impulse and pulsing circulation of liquids in isolated contours:
1 is an alimentary pipe (isolated contour); 2 is a shock valve; 3 is a valve;
4 is an impulse pumper; 5 is a reverse input valve; 6 is a reverse output valve; 7 is a diaphragm;
8 is a pump; 9 is a hydraulic accumulator; 10 is a valve;
11 is an isolated hydraulic contour with pulsing circulation of liquid

This scheme operates in the following way [15]. First an isolated hydraulic contour 11 is filled with a medium of the first type and an isolated contour of the alimentary pipe 1 is filled with a working medium of the second type till the air is completely removed. Using the valve 3 the shock valve 2 is adjusted so that at an established speed at which the working medium of the second type flows through it, it opens automatically. Following preliminary setting using the alimentary pipe 1, the shock valve 2 and valve 3 by means of the pump 8 circulation of the working medium of the second type is organized.

At some point the shock valve 2 closes automatically under the impact of a dynamic pressure of the moving working medium of the second type and causes a hydraulic shock. A positive wave of its distribution will assist the displacement of the diaphragm 7 of the pump 4 over the diaphragm 7 and will pushed out of the reverse output valve 9 and extra valve 10 into a hydraulic accumulator 9. After the shock valve 2 opens automatically under the impact of a negative wave of the hydraulic shock, the diaphragm 7 under excessive pressure generated by the accumulator 9 goes back down in relation to the pump 4. Some of the working medium of the first type comes into the space of the pump 4 over the elastic diaphragm 7 through the reverse input valve 5 from the hydraulic accumulator 9 and in the isolated hydraulic contour 11 will enable its pulsing circulation. After the process repeats itself till there is circulation of the working medium of the second type in the alimentary pipe 1 by means of the pump 8.

The valve 3 is designed for controlling the frequency of the shock valve 2 by means of changing through it the consumption of the working medium of the second type as well as the direction of the diaphragm 7 and consumption of the working medium of the first type in the isolated hydraulic contour 11. The extra valve 10 makes it possible to control an increase in the pressure of an impulse (at the moment of a hydraulic shock) of the working medium of the first type circulating in the isolated hydraulic contour 11.

According to the scheme presented in Fig. 3, at the educational scientific laboratory “Impulse Heat and Water Supply Systems” Federal State Budget Educational Institution of Higher Education “Mordovia State University Named after N.P. Ogarev” an experimental setup was designed. Its fragment with the shock valve and impulse pumper is presented in Fig. 3.

This system is composed of 25 mm polypropylene pipes PP-R and pipeline fittings *G*1/2. The diameter of a conditional passage of a body of the shock valve is 25 mm, a ring gap for flowing of liquid between the body and a shock valve inside it is 2,5 mm. A working diameter of a rubber diaphragm of an impulse pump is 60 mm. The data was collected using a personal computer with the module Zet by *L-Card* and pressure transformers OVEN PD with a current output. A volumetric consumption of liquid was recorded by means of visually mechanical water meters СВК15-3-2И.

Fig. 3. Fragment of the scheme of the experimental setup for organizing impulse and pulsing circulation of liquids in the isolated contours:
1 is a pipeline of the contour of pulsing circulation of liquid; 2 is a shock valve;
3 is a pressure transformer for the contour of pulsing circulation; 4 is a mechanical water meter;
5 is an impulse pumper; 6 is a reverse input valve of a pumped medium;
7 is an automatic air deflector; 8 is a pipeline of impulse circulation of liquid;
9 is a pressure transformer for the contour of impulse circulation; 10 is a tap for a hydraulic accumulator

The efficiency of the suggested technical solution was experimentally evaluated and presented in Fig. 4.

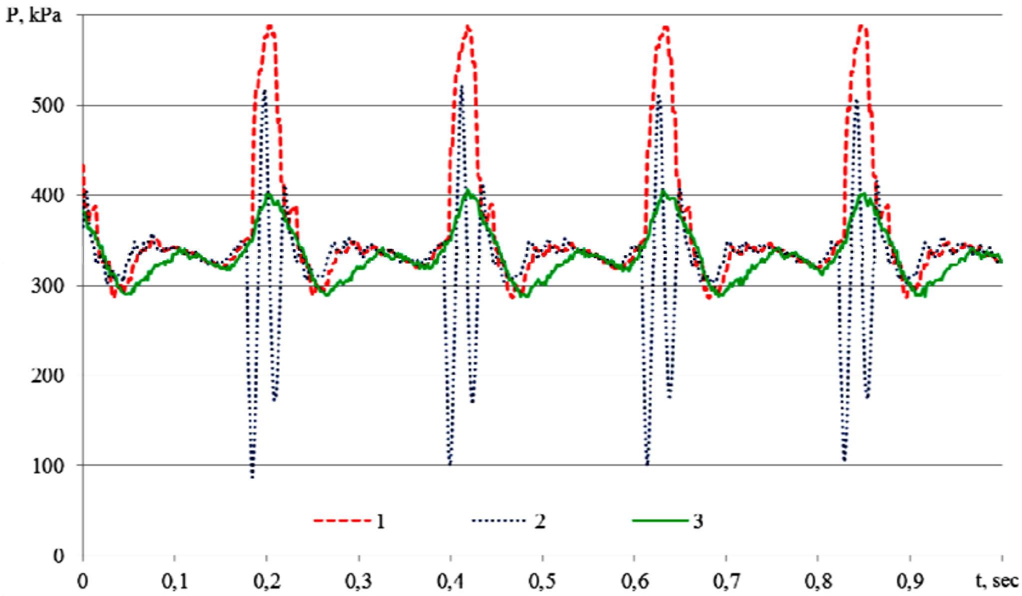

Fig. 4. Graphs of change of pressure in the contours of impulse and pulsing circulation of liquid:
1 in the contour of impulse circulation of liquid in front of the shock node;
2 in the contour of impulse circulation of liquid behind the shock node;
3 in the contour of pulsing circulation of liquid following the impulse pump

As seen in Fig. 4, the system is stable in a self-maintaining mode at the frequency of the closing of the shock valve of 4.58 Hz. The conditions when the dependences were obtained are as follows: a static pressure in the contour of impulse circulation of liquid is 315 KPa; a static pressure in the contour of pulsing circulation of liquid is 332 kPa; the consumption of the working medium through the shock valve 4.14 l/min; pumping consumption generated by the impulse pump is 0.28 l/min.

As seen from Fig. 4, as the shock valve closes in the pipeline area, there is a positive wave of a hydraulic shock of the working medium (the pressure goes up to 600 кPa) and behind the shock valve it is a negative wave (the pressure goes down to 100 kPa). A positive wave of distribution of a hydraulic shock provides displacement of an elastic diaphragm of the impulse pump for pushing out the pressure medium at a maximum pressure in an impulse of 400 kPa. This decrease in the pressure is due to damping of an impulse by compressed air in a hydraulic accumulator (see Fig. 2). At a negative wave of a hydraulic shock liquid from a hydraulic accumulator goes into the contour of pulsing input circulation of an impulse pump as its pressure goes down to 290 kPa.

Graphs in pressure pulsations presented in Fig. 4 allow one to establish the differences of the characteristics of impulse and pulsing flowing of liquid in pipelines. Impulse circulation is characterized with an instant increase in the pressure of the working medium before a closed shock node and conditions for its cavitation behind it. Pulsing circulation of the pressure liquid is smoother in terms of pressure pulsations and more identical to sinusoid given some assumptions.

Considering practical assessment of the performance of the above scheme, it can be assumed that the use of this technical solution allows pulsing circulation of liquid to employ the kinetic energy of liquid of the second type moving impulsively. This can be used for intensifying heat exchange between these two contours by means of a water-to-water heat exchanger [6].

3. System of heat supply for independent users with impulse and pulsing circulation of a heat-carrier. A principal scheme of a heat supply system for independent users with impulse and pulsing circulation of a heat-carrier in its individual areas is presented in Fig. 5.

The system operates in the following way [17]. First it is filled with corresponding types of heat-carriers. Then using a network pump 5 circulation of a high-temperature heat-carrier is performed from the heat source 1 along the supply 2 and reverse 3 pipelines of a heat network through the heat-exchanger 3 of a heat network. As a specified speed of circulation of the high-temperature heat-carrier is achieved through the shock node 9, its passage section closes automatically and a hydraulic shock occurs. A positive wave of its distribution interacting with the elastic diaphragm 11 of the impulse blower 10 causes pulsing circulation of a low-temperature heat-carrier through the reverse input and output 13 valves 12 from one side in relation to the second side of the elastic diaphragm 11 along the distributing 7 and reverse 8 pipelines of the heat use system 6.

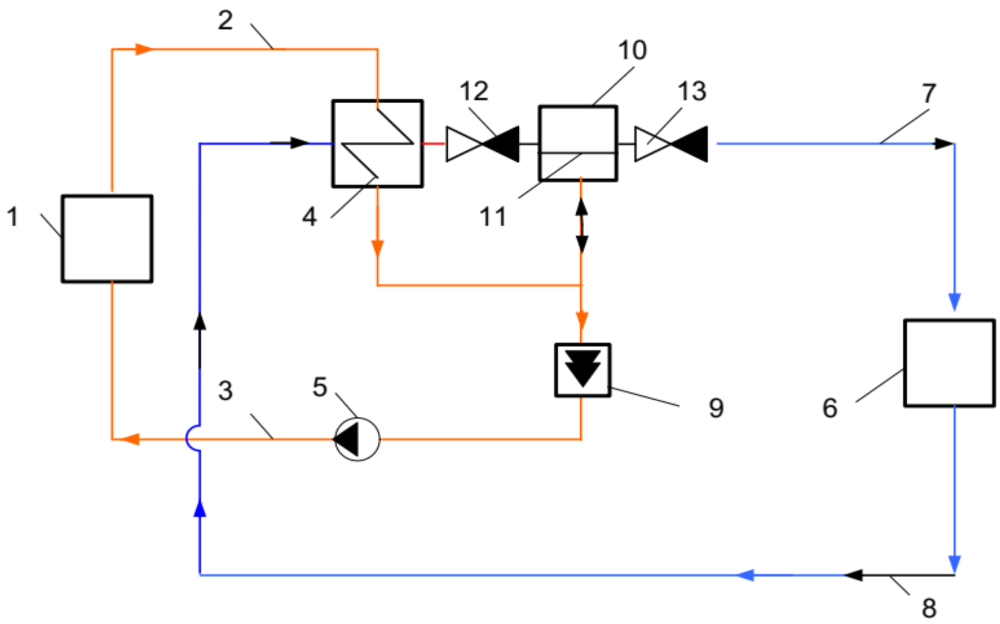

Fig. 5. System of heat supply for independent users with impulse circulation of a heat-carrier in the contour of a heat source and pulsing circulation in the contour of a heat use system:
1 is a heat source; 2, 3 is a supply and reverse pipelines of a heat network;
4 is a heat exchanger; 5 is a pump; 6 is a heat use system;
7, 8 is a supply and reverse pipelines of a heat use system;
9 is a shock node; 10 is an impulse blower; 11 is an elastic diaphragm;
12 is a reverse input valve; 13 is a reverse output valve

At the moment when a positive wave of distribution of a hydraulic shock spends all of its energy, the passage section of the shock node 9 opens automatically. Impulse circulation of the high-temperature heat-carrier in the supply 2 and reverse 3 pipelines of the heat network through the heat source 1 and heat-exchanger 4 by means of the network pump 5 restores and continues till the speed of the high-temperature heat-carrier reaches the value sufficient for automatic closing of the passage section of the shock node 9 again. Then the process repeats in the above sequence till the network pump 5 supplies the high-temperature heat-carrier from the heat soruce 1 to the supply 2 and reverse 3 pipelines of the heat network through the heat exchanger 4 and shock node 9.

Conclusions

1. While investigating the operation of a self-maintaining water-lifting device based on two-liquid hydraulic ram, it can be concluded that its operation is accompanied by the generation of impulse and pulsing oscillation movement of liquid in its individual construction elements. This water-lifting device that was originally used only to supply water in open systems can be employed in an isolated water supply system as well for organizing a self-maintaining impulse and oscillation movement of liquid in individual contours.

2. Integration of the scheme solution of two-liquid hydraulic ram into a heat supply system for independent users allows one to [14]:

— possibly organize impulse circulation of a heat-carrier in a hydraulic contour of a heat source and heat networks;

— possibly transform the pressure from a heat network into that of a certain heat-use system, which allows financial costs for transporting a low-temperature heat-carrier to be reduced or, in some cases, avoided altogether;

— possibly organize pulsing circulation of a heat-carrier in a heat use system.

3. Impulse and pulsing circulation of heat-carrier in different elements of a heat supply system can be used for intensifying heat exchange [7, 23] and perform self-purification from limescale [18].

4. In order to optimize construction elements and parts of a heat supply system, it is possible to locally organize impulse and pulsing circulation of heat-carriers only within heating areas [10]. In order to reduce its metal consumption and mass, technical solutions for heat-exchange devices with an oscillation heat-exchange surface should be employed [11, 32].

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