ENERGY SAVING AT THE HEAT SUPPLY SOURCE USING GAS TURBINE TECHNOLOGIES

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The article deals with heat and power supply systems, which give maximum energy savings and bring profit, include municipal and industrial systems for the joint production of heat and electric energy using gas turbines which are gas turbine *TPP* (*GTU-TPP*). The effective fuel efficiency of such systems reaches 90% and is the highest one among other technologies. In addition to energy saving, the use of gas turbine technologies improves the environment, as emissions of pollutants NO, CO and CO_2 into the atmosphere are significantly reduced due to the fact that the saved fuel isn't burnt in the furnaces of the existing boilers.

Keywords: gas turbines, combined-cycle gas plant (*CCGT*), combustion chamber, steam turbine, condenser, mains water, process water, heated process water, Transonic (*TS*).
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The municipal and industrial systems of the joint production of the heat and the electric energy with the use of gas turbines which are gas-turbine *TPP* (*GTU–TPP*) are related to systems of heat and power supply giving the maximum economy of energy resource and bringing the benefit (Fig.1). The effective fuel efficiency of such systems achieves 90% and is the most one among other technologies.

The advantage of gas-turbine TPP in comparison with existing steam-turbine plants of electric energy and heat production is the fact that in them all energy losses in input and output, in redactor, generator, at costs on auxiliaries is 1% and electric energy costs on operation compressor drive is 5%. The fuel efficiency is 86,1% at joint production of electric energy and heat. The analysis of components in heat cost price from boiler rooms working on nature gas, shows that electric energy price in heat cost price achieves 10% and costs on fuel is within the limit 55%. The heat becomes more expensive at such structure of Russian heat power engineering even at low tariffs on nature gas and its payment is carried out from regional budget.

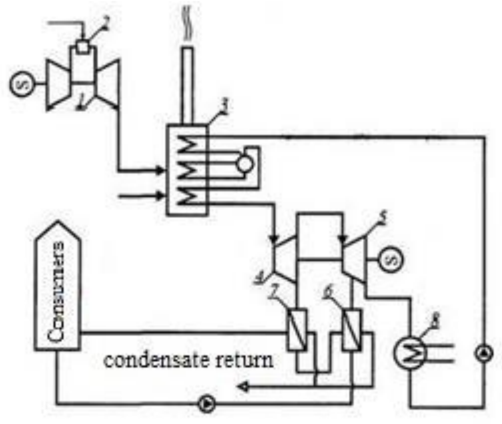

Fig.1. The scheme of steam-gas TPP: 1 is gas-turbine plant; 2 is combustion chamber; 3 is boiler-utilizer; 4 is steam turbine, part of high pressure; 5 is steam turbine, part of low pressure, 6 is means water heater of low pressure, 7 is means water heater of high pressure, 8 is condenser.

The fuel efficiency on electric energy production by steam-gas plant (*SGP*) in comparison with steam-turbine energetic blocks of supercritical pressure is higher on 15-25% and achieves 51-54%. Besides, at its work the emissions into the atmosphere decreases in 3 times and the usage of cooling water decreases in 2 times. The additional equipment of steam-turbine station by gas turbine having the best dynamic characteristics in comparison with steam turbines allows us to increase its maneuvering capabilities because of regulation besides the improvement of thermodynamic indexes of station (increase of power energy manufacture on the base of boiler thermal input).

The analysis of the work supplied by heating boiler-room shows that in autumn-winter period the fuel efficiency is within the limits 81–86% and in non-heating period is within the limits 60%. These are very high indexes of fuel efficiency as in world practices the binary steam-gas plants with fuel efficiency which is equal to 60% are still only in test development stage.

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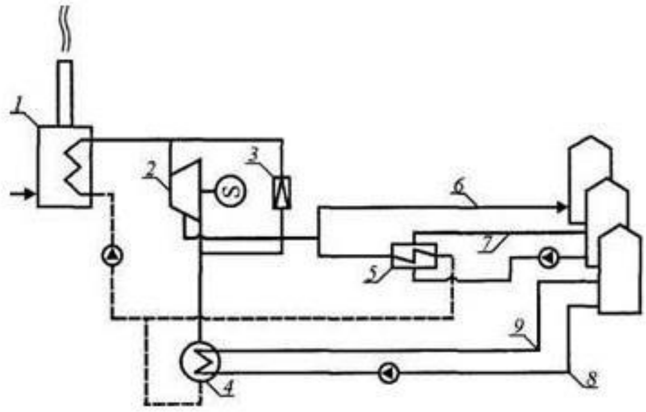

Fig. 2. The principal scheme of supply of heating-manufactural boiler rooms by electro generating plants: 1 is steam boiler; 2 is steam turbine; 3 is reduction cooling plant; 4 is condenser; 5 is means water heat exchanger; 6 is steam on technological wastes; 7 is means water, 8 is process water; 9 is heated process water.

The reconstruction of municipal and manufactural boiler rooms in *GTU–TPP* solves 4 main tasks of energy saving:

- boiler rooms giving to population up to 62% of heat energy transform from electro energy sink into supplier of cheap electro energy in both peak and base modes;
- the fuel specific consumptions on both the electric energy manufacture and heat manufacture decrease;
- heat energy cost price decreases that is very important as the donations can be transformed into investments;
- losses in electrical networks decrease as the local electric energy sources appear in manythousand distant micro-districts of Russian Federation.

The application of transonic device "Transsonic" (*TS*) which is in the possibility use of decrease of velocity of sound in two-phase flows, for example, water–steam, can be the one of the variant of new resource and energy saving technologies on heat source.

The dependence of velocity of sound in homogeneous two-phase mixture from volume phase relation is shown in fig.3:

$$\beta = V_g / (V_g + V_l)$$

where V_g is gas volume of mixture;
$V_g + V_l$ is mixture volume.

The velocity of sound in liquid (for example, in water at usual conditions) achieves almost 1500*m/sec*, in pure gas at the same conditions it is 330*m/sec*. If they are mixed in ratio 1:1 then the velocity of sound in such mixture at the usual conditions will be near 20*m/sec* and it is obvious that velocity of sound is less than the velocity of sound not only in liquid but in gas. Consequently, the homogeneous two-phase medium is more compressible one than the pure gas.

The air-gas channel of *TS* is schematically shown in fig.4, the pressure distribution inside the apparatus is shown in fig.5.

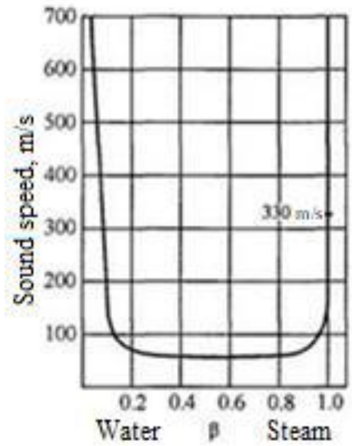

Fig.3. The curve of the dependence of velocity of sound in homogenous two-phase mixture on volume state of phases water–steam.

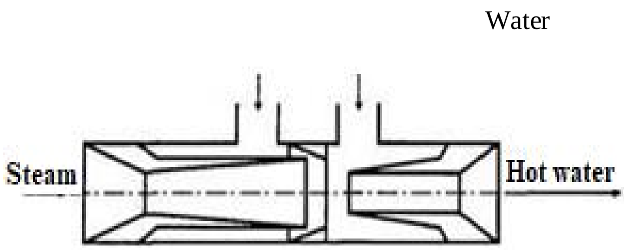

Fig.4. The scheme of air-gas channel of *TS*.

The steam going into apparatus through nozzle mixes with water between cross-sections II and III, then this mixture goes into tubing-casing annulus. The homogeneous two-phase mixture the flow velocity of which is higher than local velocity of sound forms in input into cylindrical channel. The direct transition through velocity of sound in adiabatic channel of uniform cross section is impossible, that's why the compaction jump causing the "collapse" of steam bubbles takes place. The hydrodynamic regime at which the liquid with higher temperature than in input appears in output from apparatus after compression jump is established, if the superheated steam or saturated steam is used as a gas phase.

When after steam mixture with the water, the homogeneous two-phase mixture the velocity of which in input to annual space is equal to 50*m/sec* appears, that is less in many times than velocity of sound in the steam (500*m/sec*) and in liquid (1500*m/sec*), then the velocity of sound in such mixture can decrease up to 5*m/sec* in vacuum band before pressure jump. In this case Mach number $M = w'/a$ presenting itself the ratio of the flow velocity (w) to velocity of sound (a) achieves 10. The intensity of pressure jump (from p_1 up to p_2) is proportional to squared Mach number, i.e. in the given example the pressure after jump can be higher almost in 100 times than it was before and really this ratio can achieve 1000.

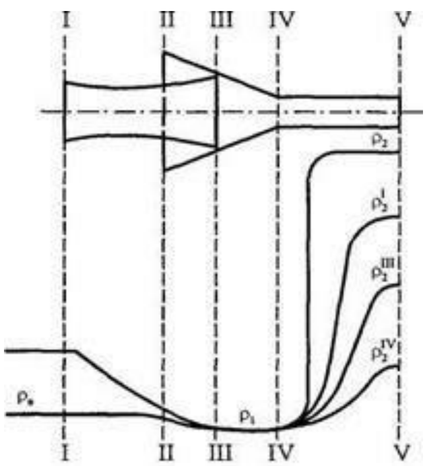

Fig.5. The graphs of pressure distribution inside apparatus.

TS apparatus has the principally another process energetics. In analogous devices the transformation of heat energy into kinetic one and finally into work of supersonic flow (jet trust in flying vehicles, processes in steam and gas turbines, turbo-compressors) takes place in tradition way because of increase of flow velocity (Mach formula numerator) that is accompanied by the big energy losses. $M>1$ value in *TS* is achieved because of the decrease of velocity of sound (denominator in Mach formula) at very insignificant flow velocity, as the energy costs are comparably small ones. The distinguishing character of *TS* in the field of hydrodynamics is the fact that the flow pressure in apparatus output can be higher in many times than the pressure of the water and steam in input into apparatus.

Moreover, *TS* apparatus capacity working as pump doesn't change at the change of the opposite pressure in the mains water in the difference from usual transfer pumps. Due to this fact, *TS* can be effectively used in the capacity of the pump, heater (cooler), dispenser, mixer, pasteurizer and homogenizer in most different fields: power

Taking under consideration the above mentioned one can conclude that the ecology improves at the use

engineering, chemistry, ecology, pharmaceutics and finally in milk and food industries.

Nowadays, "Transsonic" usage is the more spread one in heating systems and hot water supply systems. For example, the block from four *TS* apparatuses the weight of each not more than 50*kg* exchanges the four boilers mass of each is more than 1,5 tones and three mains pumps by the total weight more than 1 ton in the one of Moscow local boiler room. Moreover, one *TS* supply the capacity from 60 up to 260m^2/h, temperature in input is up to 70°*C*, in output up to 145°*C*, the pressure in return line is near 0,4*MPa* and in straight line is up to 1*MPa*.

100% electric energy economy (mains pumps work in emergency and start-up operations), up to 30% of gas can be saved in regime of partial loads, as the *TS* work conditions are the such ones that they principally exclude the overflows in the boiler because of external load imbalance with the source heat power.

In exploitation process the apparatuses are treated the constructive changes. As a result, the apparatuses of new generation presenting themselves the one *T*-branch and having the steam nozzle and confusor in air-gas channel, are proposed. These apparatuses are called "Fisonic". These apparatuses are practically can be built into any existing heat-technological system having the most different values of temperatures and pressure, as the calculation of its air-gas channel can be carried out by individual orders. The apparatuses are projected and prepared in such way that they can stably work in whole range of calculative parameters as heat exchanger and pumpers.

"Fisonic" heat exchanger is the most effective one from the energy and resource saving point of view in comparison with other known heat exchanging apparatuses. Its dimensions and mass is on one order less than other heat exchangers. The length doesn't exceed 400*mm*, the diameter is equal 10*mm*, mass is 52*kg*.

The economic effect of apparatus work is confirmed by the following factors:

- decrease of capital costs in comparison with existing schemes;
- significant decrease of specific costs of electric energy on 1*Gcal* of heat as the necessity in the use of powerful mains pumps is absent;
- decrease of fuel specific consumption on 1*Gcal* of generated heat for heat supply systems because of the higher heat exchange efficiency in the comparison with the traditional heat exchangers;
- decrease of exploitation consumptions as the necessity if heat exchanger repair is absent.

The use of "Fisonic" apparatuses working in "pump–boiler" regime allows us to economize the electric energy, as in this time the mains pumps not work. Their efficiency is 99,7% and real efficiency is < 90%, that's why the steam consumption at "Fisonic" apparatus use decreases on 10% and consequently the fuel consumption decreases. Besides, the exploitation consumptions decrease.

of gas-turbine technologies besides energy saving, as the emissions of N0, CO and CO_2 pollutants into atmosphere significantly decrease because of the fact that the saved fuel isn't burnt in the furnaces of the existing boilers. The use of the "Fisonic" apparatus technologies in boiler room flow diagram instead of heat exchangers is the perspective energy saving direction. The payback period of consumptions on implementation of energy saving "Fisonic" technology is the one heating season in average in the dependence on system type, its heating capacity and other aspects.

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