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ANALYSIS OF HEAT-COGENERATION TURBINE UNIT OPERATION IN SCHEMES OF PRELIMINARY TREATMENT OF MAKEUP WATER

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The new scheme of preliminary treatment of makeup water of various technological purposes at parallel work of turbine units with heat release to external consumers has been offered. Variants of work of one of the existing and offered schemes are compared and analyzed. Use of the developed scheme in comparison with the existing one allows cutting fuel consumption up to 15...16 % or 31 thousand tons of equivalent fuel per heating season.

Rational use of energy carriers (fuel) is one of the most principle tasks of FEC (fuel and energy complex) enterprises including TS (thermal stations). Fuel factor of FEC consumptions is one of the main constituents of the enterprise supplied product rate (heat and electric energy). The problem of cost cutting (including fuel consumptions) for manufacturing and supplying the product becomes the most urgent problem due to formation of new conditions on the market NOREM (new wholesale electricity and power market).

One of the existing schemes (Scheme № 1) of preparing make up water and heat supply with delivery water to one of the largest operating TPP in Siberia having the open water intake system and vapor supply to industrial consumers without dry return is introduced in Fig. 1. The new scheme (Scheme № 2) is introduced in Fig. 3. Considerable losses of heat carrier (delivery water and vapor of industrial consumers) which should be fulfilled at TPP are typical for this scheme of TPP.

Vapor heat-exchanger apparatuses – 1, 2 (1 – boiler make up heater, 2 – heat network make up heater) are of wide use in the existing schemes, Fig. 1 (Scheme № 1) of heating make up water for chemical cleaning. These heaters are necessary for heating and withstanding the make up water temperature on the required level 26±1 °C. The reduced temperature of make up water is accepted for the examined station and depends on processes carried out in the shop of water chemical purification. River water taken directly from the river bed serves for compensation of working substance leakage. The temperature of water taken from the river depends on a season and falls within the range of +1...+6 °C for the considered heating season of the examined station.

Use of a condenser – 3 of turbine unit operating on degraded vacuum is possible for preliminary heating of make up water taken from the river. The whole required flow of make up water or its part may pass through the condenser – 3. The values of make up water flow passing thought the condenser or round about it as well as the make up water temperature after the condenser – 3 and on by-pass line of the condenser – 3 characterize the make up water temperature before vapor heat exchange devices – 1, 2. The make up water consumption through – 1, 2 and the heating value from temperature before heating units to 26±1 °C forms thermal load of the vapor heat exchange devices. Vapor is supplied to heating units – 1, 2 from the heat-cogeneration turbine unit TU2 (of the type T-25-8,8) having one controlling steam extraction with control range 0,12...0,25 MPa. After heating to the required values the water taken from river for compensation of leakage of various engineering purpose the make up water is sent to the shop of water chemical purification.

The make up water returned from the shop of water chemical purification is warmed to the necessary technological temperature values by the steam TU1 (this aggregate is not shown in the considered schemes, Fig. 1 and 3) and is not examined as it has constant values (thermal load) without influence on operation of the considered schemes. Besides thermal load of heating units – 1, 2 the turbine unit TU2 carries thermal load conditioned by heating the return delivery water carried back from consumers with the temperature $t_{об}$ (temperature of the return delivery water according to the temperature chart of heat release, Fig. 2, Curve – 1) or $t_{об.ф}$ (actual temperature of return delivery water obtained by data processing of the studied station, Fig. 2, Curve – 2 has the value higher than $t_{об}$) to the temperature $t_{о.о.}$ (temperature of the mixture obtained by heating a part of consumption of the returned delivery water in heating units – 5, 6, and their partial bypassing if necessary, Fig. 2, Curve – 3). The use of bypass line – 7 of the heating units is conditioned by the necessity of withstanding temperature of heating water according to the temperature chart in the range of outside air high temperatures.

Besides TU2, the turbine unit TU3 (of the type T-115-8,8) having two steam extractions with the control range of 0,05...0,25 MPa was used for covering the specified thermal loads conditioned by consumption of the carried back returned delivery water $G_{об}$=1028 kg/s. Drain water $G_{к.j}$ of the heating units – 4, 5 is returned to the thermal diagram TA3 and condenser of the heating units – 1, 2 and – 6 to the thermal diagram TA2.

In respect to the studied station the make up water consumptions for heating network amount to 278 kg/s (heating network makeup), for compensation of losses with vapor of industrial extraction and losses in the station cycle 125 kg/s (boiler makeup). All calculations for variable conditions of turbine unit operation [2] by the diagrams of Fig.1 and Fig. 3 were carried out with the condition of working by thermal schedule with minimum ventilating vapor pass in the low pressure part (LPP) of the turbine units TU2 and TU3. Carrying out the calculations the restrictions for TU3 by thermal load in 653 GJ/h, by maximum consumption of delivery water 833 kg/s through the heating units – 4, 5 were accepted; the restrictions were accepted according to the data of manufacturing plant.

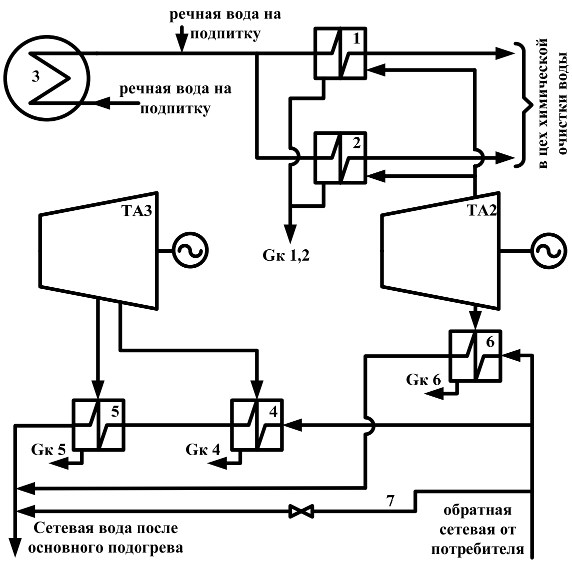

Fig. 1. *Scheme of preliminary water treatment № 1*

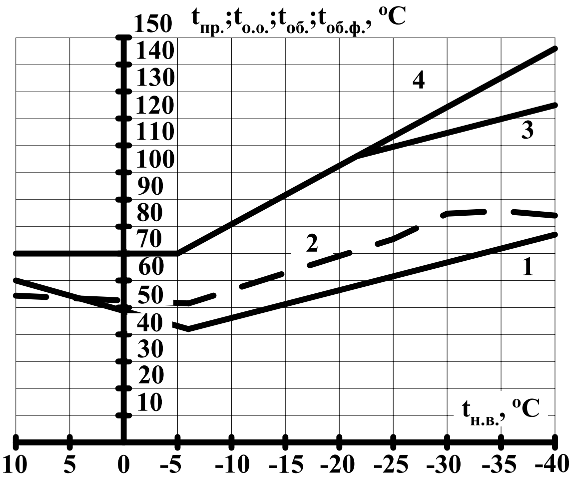

Fig. 2. *Temperature chart of heat release*

Content of the proposed changes consists in substitution of steam heat-exchange devices – 1, 2 by water-to-water heat-exchange devices (WWHD) – 8, 9 (Fig. 3). The notations of the elements in Fig. 3 correspond to the notations of Fig. 1. WWHD for heating makeup water, running to the shop of water chemical purification, to the required values as a heating medium, use the return delivery water supplied to the station from consumers with $t_{об}$ or $t_{об.ф}$. As a result of makeup water heating the return delivery water is cooled up. The cooled up delivery water (the temperature of the return delivery water is lower than the values of temperature chart and if the actual temperature of the return delivery water is higher than the temperature chart then the use of Scheme № 2 in Fig. 3 allows approximating it considerably to the design values) enters the two-step heating of TU3. As a result of redistribution of thermal and electric loads between TU2 and TU3 conditioned by decrease of temperature of the return delivery water entering the heating units – 4, 5 of TU3 (at one and the same carrying capacity of the heating units of TU3 – 4, 5 the temperature decrease of the return delivery water relative to the considered diagram promotes the increase of thermal and as a result the electric load of turbine unit TU3 having a more economic two step scheme of heat release [4], [5]). Lower temperature of the return delivery water at the two step scheme promotes the decrease of pressure in a lower hot water converter – 4 (pressure decrease in a lower heating extraction) that increases electric generation by steam supplied to this heating unit; besides it promotes the decrease of passing vapor $G_{чнд}$ through the fully closed regulating orifice into LPP and condenser. It is appropriate to apply the Scheme № 2 in the whole range of outside air temperature +8...–40 °C Fig. 9.

The result of the proposed changes is the decrease of thermal and electric energy of TU2 (having less economy one-step scheme of heat release in comparison with two-step scheme of heat release of TU3) or its full exclusion from the scheme at sufficiency of the delivered heat from TU3 at high temperature of the outside air. The total electric power generated by turbine units TU2 and TU3 in the diagrams № 2 is higher than at operation by the diagram № 1 at the equal heat release. Change of water consumption by flows, the condenser – 3 and its bypass allow changing thermal load falling to WWHD (maximum thermal load corresponds to full condenser bypass – 3, i.e. the direct water supply to the heating units – 1, 2 or – 8, 9 from river). The higher thermal load of WWHD, the higher the fuel economy by the new scheme.

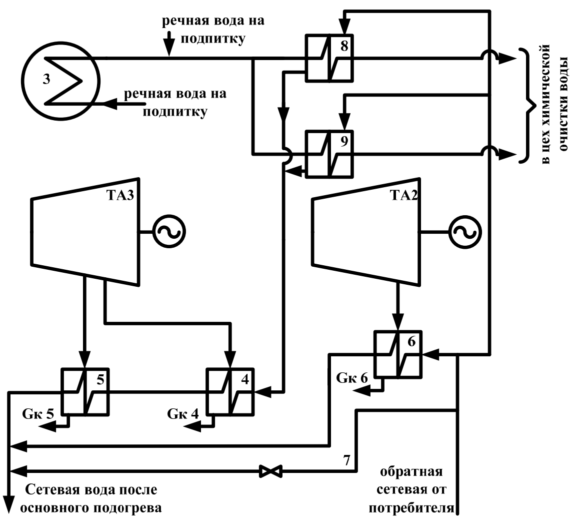

Fig. 3. *Scheme of the preliminary water treatment № 2*

Additionally generated electric power on thermal consumption promotes the displacement of electric energy generation by condensation cycle of the considered station or another source. In order to determine the fuel economy due to additionally generated electric power applying the new Scheme № 2 Fig. 3 the specific fuel consumption of the displaced source of power supply 246 *g.edu.f./(kW·h)* and 550 *g.edu.f./(kW·h)* are accepted. In order to determine the annual fuel saving at use of the proposed Scheme № 2 the calculations on the examined schemes functioning in temperature range from +8 to –40 °C in increments of 5 from 0 °C were carried out. Hourly economy of the equivalent fuel was determined by calculation results for each temperature value $t_{н.в.}$.

According to [1] and average number of standing for each design temperature value for the region of heat station arrangement the annual fuel saving is determined. The curves allowing us to determine the annual fuel saving when using the Scheme № 2 depending on the thermal load value falling to WWHD both for $t_{об}$ (Curve – 2 for the displaceable energy supply source with specific fuel consumption 550 *g.edu.f./(kW·h)* and Curve – 4 for the displaceable energy supply source with specific fuel consumption 246 *g.edu.f./(kW·h)*), and for (Curve – 1 for the displaceable energy supply source with specific energy consumption 550 *g.edu.f./(kW·h)* and Curve – 3 for the displaceable energy supply source with specific energy consumption 246 *g.edu.f./(kW·h)*) are introduced in Fig. 4. In the region limited by the Curves – 2, 4 (Fig. 4), and Curves – 1, 3 (Fig. 4) the annual fuel saving for TPP with specific fuel consumption for electric energy generation in the range of 246...550 *g.edu.f./(kW·h)* may be determined.

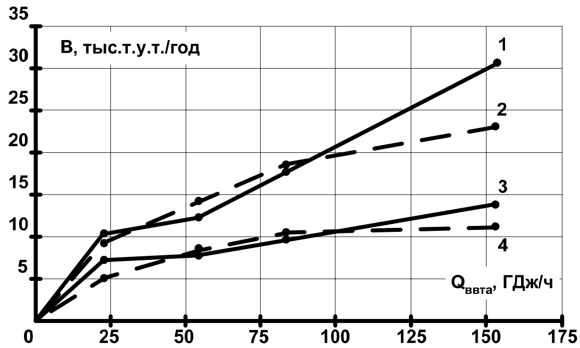

Fig. 4. *Curves of annual fuel saving*

Introduction of the Scheme № 2 promotes:

1) redistribution of loads (thermal, electric) between aggregates operating in parallel, increasing the load of one of them and decreasing the load of the other less saving aggregates. At low thermal loads it allows excluding completely the operation of one of the considered aggregates;
2) pressure decrease in lower heat extractions (at two or more stages of the main heating of makeup water) that promotes the increase of electric energy generation at thermal consumption;
3) decrease of thermal losses in the condenser of turbine unit. Owing to the pressure loss in lower heat extraction at fully closed regulating orifice the vapor passing into LPP and condenser decreases considerably;
4) reduction of specific fuel consumption for generation and delivery of electric energy at support with thermal energy in the required quantity;
5) displacement of condensation generation of electric energy properly at the considered station or in electric power system;
6) exception of the steam heat-exchange devices and pumps transferring the condensed water of heating steam of heating units – 1, 2 (Fig. 1).

The results of operation of aggregates functioning in parallel by the existing studied scheme of heat station (widely used at TPP) and the proposed new scheme of preliminary makeup water treatment at heat release to the consumers for the variant without heating makeup water in the condenser – 3 and with thermal load falling to WWHD $Q_{ввта}$=152 GJ/h depending on the outside air temperature $t_{н.в.}$ are introduced in Fig. 5–9.

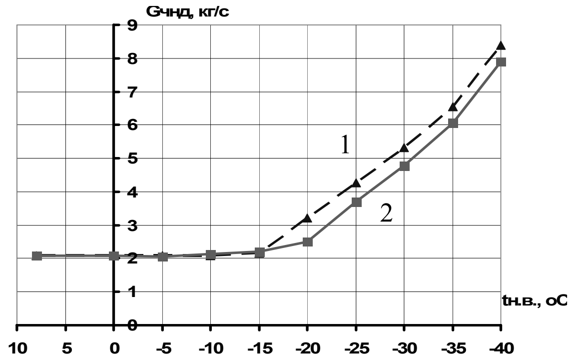

Fig. 5. *Characteristic of steam consumption in LPP of TU3 when using: 1) Scheme № 1; 2) Scheme № 2*

It is seen in Fig. 5 that steam consumption in LPP of TU3 (Curve – 2) when using Scheme № 2 is lower than at use of Scheme № 1 (Curve – 1).

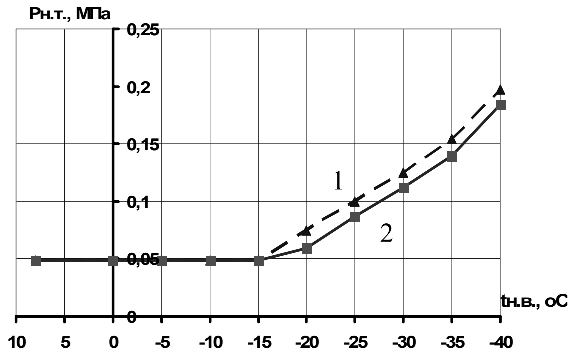

Fig. 6. *Characteristic of pressure $P_{Н.Т.}$ of lower heat extraction of TU3 at use of: 1) Scheme № 1; 2) Scheme № 2*

It is seen in fig. 6 that the pressure of the lower heat extraction of TU3 (Curve – 2) at use of Scheme № 2 is lower than the pressure of lower heat extraction of TU3 at use of Scheme № 1 (Curve – 1).

It is seen in Fig. 8 that total electric power (Curve – 2) generated by the turbine units TU2 and TU3 at use of Scheme № 2 is higher than the total electric power of the turbine units TU2 and TU3 at use of Scheme № 1 (Curve – 1).

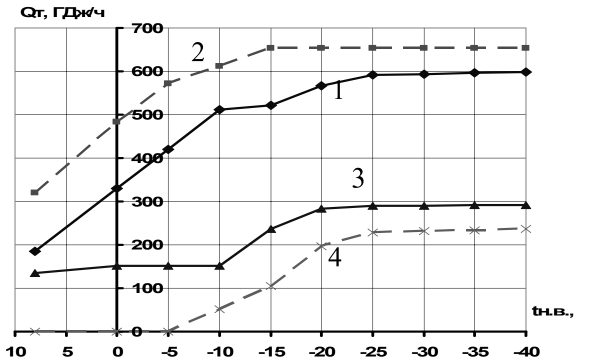

Fig. 7. *Characteristic of the release thermal loads Q_T from TU2 and TU3: 1, 3) turbine units TU3 and TU2, Scheme № 1; 2, 4) turbine units TU3 and TU2, Scheme № 2*

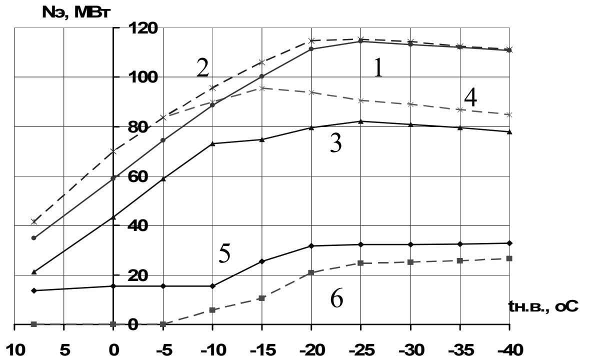

Fig. 8. *Characteristic of electric loads $N_э$ to TU2 and TU3: 1, 2) total load of TU2 and TU3, Schemes № 1 and № 2; 3, 5) load of TU3 and TU2, Schemes № 1; 4, 6) load of TU3 and TU2, Scheme № 2*

As it is seen in Fig. 9 the values of specific fuel consumption for electric energy generation at use of Scheme № 2 in the whole range of outside air temperature is rather lower that at when using Scheme № 1. The abrupt change of the Curve – 1 at the outside air temperature –10 °C is conditioned by inclusion of turbine unit TU2 into the Scheme of heat release.

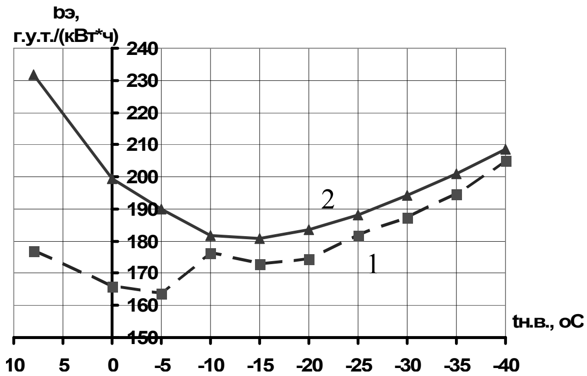

Fig. 9. *Characteristic of average weighted specific fuel consumption $b_э$ by TU2 and TU3 for electric energy generation at use of: 1) Scheme № 2, 2) Scheme № 1*

Conclusion

The new more saving scheme of makeup water preliminary treatment using the heat of the return delivery water was developed for FEC enterprises on the basis of TPP.

Application of the new scheme allows decreasing fuel consumption to 15...16 % or 31 thousand tons of equ. fuel by heating season.

The new scheme promotes the decrease of electric energy cost by reducing specific fuel consumption.

Using the new scheme promotes the improvement of ecological situation against the background of reducing the specific fuel consumption for electric energy generation.

The obtained efficiency data indicate the appropriateness of applying the developed scheme at the FEC enterprises on the basis of TPP and promote further expansion of applying schemes using the return delivery water as a heating medium.

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