Using waste heat for heat supply and creating a single steam network with power generation due to pressure differences

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Abstract. In modern economical conditions external heat suppliers often become quite expensive for a consumer enterprise due to their monopoly, so the task of reducing the amount of heat received from them to the minimum, and of using one’s own capabilities to the maximum arises. In this article, using a particular example, the authors considered certain technical characteristics of using waste process heat at the enterprise while transferring the enterprise’s heat supply system to its own heat sources, as well as creation of a single steam network with electricity production due to pressure differences.

1. Introduction
Refusal from an external heat source, or significant change of the heat amount received from it, due to the use of one’s own heat, results in the change of heat supply system topology. It is obvious that the network of pipelines should be aligned with the new mutual arrangement of sources and consumers. Otherwise, throughput with existing network pipes at certain areas may be insufficient to supply consumers with heat completely. According to the terms of reference we studied the resources to transfer the enterprise’s heat system to its own heat sources, refusing from heating the network water in a boiler thermal power plant. Herewith, own heat sources mean the utilization of process heat by the enterprise, and an available boiler room [1–5].

2. Results and discussion

2.1. Analysis of capabilities to use waste heat for heat supply of the enterprise
One of particular tasks was to study the capability to use the waste process heat of workshops for heating these workshops, namely:

– in the amount of 10 Gcal / hr at each input of subscribers 911 and 918 (hereinafter the numbering of subscribers corresponds to the accepted numbering at the enterprise) by heating the return network water at existing costs in the housings, or by installing a special mini-boiler (see figure 1);

– in the amount of 40 Gcal/hr by the mini-boiler scheme with the generation of this heat in the pipeline of the return network water of the united consumer 1015 (see figure 2).
As the study has shown, the heat use of subscribers 911 and 918 is quite possible, taking into account the following heat engineering characteristics of these subscribers.

At a temperature schedule of 150/70 °C the required consumption of the network water of subscribers 911 and 918 amounts to, correspondingly, 114.68 and 115.17 t/hr, and heat supply in the amount of 10 Gcal/hr for each flow results in the return water heating of about 87 °C.

With a calculated pressure at the outlet of these subscribers about 4 at, and the corresponding saturation temperature of 143 °C, heating at 87 °C results in impermissible water boiling during most of the heating season.

Installation of a mini boiler for subscribers 911 and 918, when passing through it 250 t/hr of water, is technically feasible, but hardly appropriate, as the amount of heat consumed by the network depends on the outdoor temperature, and the amount of waste process heat is an independent value. So, during most of the heating season waste-heat recovery is not possible in the network.

The most rational solution of the problem of recovery of this amount of heat is its input to the return network water in the network locations with high consumption. The closest locations to subscribers 911 and 918 are pipelines sections between nodes 4, 5, 6 and 6, 7 (figure 1), in which nominal (at a temperature schedule 150/70 °C) consumption is, correspondingly, 360 t/hr and 262.57 t/hr.
In case of installing a heat exchanger between nodes 4, 5, 6 heating of network water will be just 55.5 °C, and temperature at the output from the heater will not exceed 125.5 °C, which gives the minimum reserve value of about 15 °C before boiling. Herewith, all available heat can be used throughout all heating season.

In a temperature schedule 150/70 °C installation of a heat exchanger at the section between nodes 6 and 7 is practically excluded due to relatively low consumption of the network water and impossibility, in this regard, to prevent its boiling.

![Diagram](image)

**Figure 2.** Section of the heat supply scheme in the area of united consumer 1015.

However, situation can change at a different temperature schedule, and consumption of water will also change. For example, at a temperature schedule 115/70 °C, the consumption of network water through the section between nodes 6 and 7 will become equal to 466.3 t/hr and the value of water heating will reduce to 43 °C.

It is more difficult to organize utilization of 40 Gcal/h in united consumer 1015 (see figure 2).

In addition to inexpediency of using a mini boiler for the above reasons, the solution of this problem is complicated by the necessity of output of 40 Gcal/h by high consumption of water (550 t/h at a temperature schedule 150/70 °C). In the nearest section of a main trunk pipeline the existing consumption 126, 9 t/h is significantly less.
The only possible solution is an artificial increase of water consumption through sections of trunk pipelines of return water, adjacent to the united consumer, with installation of network water heaters on these sections.

The most appropriate solution seems to install heaters on a bypass of the section of the trunk pipeline of return network water between shutoff valves 8 and water discharge to united consumer (1032, 1033, 1037) with overlapping this pipeline with valve 9 and closing valves 10, 11, 12, as figure 2 shows. Thanks to the mentioned overlaps, it is possible to increase the consumption of return network water through the heat exchanger from 140,2 t/h to 905,5 t/h. To increase reliability, it is recommended to install several heaters connected in parallel.

The indicated increase of network water flow rate through separate trunk pipelines will be most likely to result in the necessity of increasing pipes diameters in individual sections.

2.2. On the problem of creating a unified steam network 40 AT at the enterprise, with electricity generation due to pressure differences 40/27/1,2 AT

One of the tasks of creating a unified steam network P-40 was to determine the incut point ROU 40/27 at a specific section with determination of maximum flow rate capability ROU, with steam supply from a thermal power plant, disconnected consumers P-40, and backpressure above ROU 29 at.

When analyzing the distribution of steam consumption set by the terms of reference for steam consumers P-40, we paid attention to a high value of steam consumption through ROU 40/27 (to 135 t/h), which is a tangible potential loss.

The use of a steam turbine instead of ROU could allow taking off power, the maximum value of which is:

\[ N = G \times \Delta h \times \eta = 2925 \text{ kW}; \quad (1) \]

where: \( G = 375 \text{ kg/s (135t/h)} \) is a maximum steam consumption through the turbine;

\( \Delta h = 120 \text{ kJ/kg} \) is a heat drop at the turbine in the modes with the indicated steam consumption for ROU;

\( \eta = 0,65 \) is an overall efficiency of the turbine-generator unit (adopted by analogues).

A finished steam turbine of this or similar power, produced by domestic enterprises for steam parameters ROU 40/27, is not known to the authors. Therefore, with the implementation of the idea of installing a turbine instead of ROU, it seems that difficulties will arise, because it will be necessary to develop a new turbine project, which, of course, will significantly increase the cost of its creation and, despite the obvious economic effect, and taking into account the unstable economic situation in the country, lead to an unacceptable payback period.

Regarding the question of defining a maximum flow rate capacity ROU at pipelines geometry set by the terms of reference, and backpressure above ROU 29 at, in the first place this value depends on the flow rate capacity of throttle control valves used in ROU. In standard ROU, closest in its characteristics to the working conditions in the structure of the set network P-40, a maximum flow rate capacity of throttle control valve 995-150 is

\[ K_{V_{\text{max}}} = 282 \text{ m}^3/\text{h}, \quad (2) \]

which provides a maximum steam consumption under the modes considered:

\[ G = 3.6 \sqrt{\frac{\Delta P \cdot F^2 \cdot 2}{\sum \zeta \cdot v}} = 96 \text{ t/h}, \quad (3) \]

where: \( \Delta P = 12 \text{ kg/cm}^2 \) is a given minimum pressure difference between a source (a thermal power plant) and a consumer (network П-27);
\[ F = 0.07 \text{ m}^2 \] is a pipe cross-sectional area of the given diameter in the considered section; 
\[ v = \text{m}^3/\text{kg}, \] a specific volume of steam at the inlet to the throttle control valve \( ROU \); 
\[ \sum \zeta = \sum \zeta_p + \sum \zeta_{\text{val}} \] is a total coefficient of hydraulic resistance of the route, reduced to \( F = 0.07 \text{ m}^2 \); 
\[ \sum \zeta_p \] is a coefficient of hydraulic resistance of the pipe in section 11; 
\[ \sum \zeta_{\text{val}} \] is a coefficient of hydraulic resistance of the valve; 
\[ K_{V_{\text{max}}} \] is a maximum valve flow rate capacity.

The steam consumption defined above is significantly less than 135 t/h required by the task. However, you should notice that the pressure drop 40/27 given by \( ROU \) is not characteristic of \( ROU \), and it may be provided not by a throttle control valve, but by a usual control one which widens greatly the flow rate capacity of such \( ROU \).

For the considered task we can recommend a two-seat control valve 14c-76-64 Dy400 as a possible way of throttling steam, for it can provide a maximum pass of 180 t/h of steam.

The optimal \( ROU \) inlet point for decreasing hydraulic losses in the section before it must be located directly in point 2.

Regarding the installation of a turbogenerator instead of \( ROU \), we should notice the following. Considering a significant difference in steam parameters from different producers, it is necessary to install a mixing device in point 2 in front of the turbogenerator. After mixing, steam parameters in point 2 will be \( P = 32 \text{ at}, ROU = 411-417 \ ^\circ \text{C} \). For comparison, nominal steam parameters at inlet of serial anti-pressure turbines to average parameters of a similar enterprise are \( P = 3.5 \text{ MPa}, T = 435 \ ^\circ \text{C} \), what follows that with the existing parameters such a turbine will be working under off-design modes at low efficiency. If it is impossible to operate the turbine with such steam parameters, it becomes necessary to redevelop the turbines or develop a new design.

Total steam consumption for a turbine from three producers is 210÷240 t/h. Nominal steam consumption for an anti-pressure turbine with a drop 35/11 \( \text{MPa} \) and power 6 MW is within 90÷100 t/h, i.e. it is possible to install two turbines. During a scheduled repair of one of steam producers, it allows operating one turbine for 100% of power, which is more economical than the operation of one more powerful turbine under partial loads.

In the single steam network scheme \( P-40 \) with two turbines, it seems interesting to install one of the turbines in direct proximity to steam producers of workshop \( AK-72 \) and boiler room k. 1101, which allows avoiding unnecessary heat hydraulic losses, when transporting steam to point 2.

In the single steam network scheme \( P-40 \) with the turbogenerators, it is necessary to provide for the presence of \( ROU \) installed parallel to the turbines, which will provide consumers with reduced pressure steam during planned or emergency shutdowns of the turbines. For this it is possible to use available \( ROU \), and, when it is necessary, to provide for installation of new ones. It seems most convenient to locate \( ROU \) in direct proximity to the turbines. In this case switching the steam supply to consumers from the turbine to \( ROU \) does not influence the working mode of the rest of the reduced pressure network.

The presence of a reduced temperature steam source (ammonia production units) in the network significantly decreases the potential of fresh steam, compared with the turbine. In this regard, it is necessary to consider the option of using higher temperature steam for turbines with working drop 40/12 at, and lower temperature steam should be mixed with turbine exhaust steam to obtain steam of 27 at.

Turbine differential pressure, power and quantity selection should be made, considering reduced pressure steam production needs. For this it is necessary to analyze annual schedules for steam production and consumption \( P-40, P-27 \) and \( P-12 \).

3. **Conclusion**

1. Based on the calculation study, the options for the most rational organization of the use of waste process heat of workshops for the needs of the enterprise’s heat supply with the placement of network water heaters on main pipelines with artificial increase in some cases of network water flow through these heat exchangers are substantiated.
2. When creating a single steam network \( P-40 \) at the enterprise, it seems appropriate:
   – in case of installation of ROU 40/27 instead of the throttle-control valve ROU, to use the two-seat control valve 14s-76-64 Dy400, providing the required consumption of steam;
   – when using a turbogenerator instead of a ROU, to install two turbogenerators in the immediate vicinity of the steam producers, namely: at the AK-72 workshop and boiler room k.1101.

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