Innovative local heat supply stations for industrial buildings

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Abstract. Energy saving effect in heating systems of industrial buildings without 24-hour supervision is reached using the automatic heat management systems. Our paper offers a specific scheme for the automation of a local heat supply station (LHS) with an autonomous heat accumulator and a dual-circuit coolant circuit. The proposed technical solutions can only be effective if the compliance of the thermal resistance of the external enclosing structures of the building to the established requirements is observed.

1. Introduction

It is known that the introduction of innovative technologies in heat supply systems for buildings and industrial structures allows reducing the consumption of thermal energy by an average of 30% during the heating season, both for residential and industrial buildings [1].

The parameters specified in [2] are applicable to both new and existing buildings. They are prerequisite for developing the effective heating system. In particular, the calculation of the building's need for amount of heat carrier is made based on the value of the specific heating characteristics. Subsequently, the agreement is signed between the heat supply organization on one hand and the consumer on the other.

Heating characteristics are not enough to create and maintain comfortable microclimate parameters. To this point the similarity of approaches applicable to all of the building types is limited for the following reasons:

1. Buildings with 24-hour supervision belong to the type of the buildings with an adjustable microclimate with optimized parameters, the values of which correspond to [8].

2. Industrial buildings are classified according to the microclimate parameters of workplaces. Unlike residential buildings, industrial buildings are characterized by significant local heat generation. In this case, it normally refers to the limiting values of the microclimate parameters of the building, established in [3]. "Limit values of microclimate parameters" term is interpreted as the maximum permissible deviation of a parameter from an optimized value.

3. It is important to note that the microclimate parameters during the non-working day [3] are not standardized.

The use of modern heating control systems for industrial buildings in Russia requires a revision of traditional design and operational solutions, which were widely used earlier in the centralized heat points (hereinafter referred to as CHP).
2. Materials and methods

Industrial buildings are the manufacturing enterprises buildings with single-shift or double-shift operation, including technologically compatible engineering systems and communications. The classification of industrial buildings is proposed in [1].

In its vast majority all the buildings overspend the heat energy unnecessarily [5–7], i.e. coolant flow in the heating system has nothing to do with a comfortable temperature inside the building. Often, despite the increase in heat consumption, the temperature regime of a building is far from a human-friendly range of 18-24 °C.

In our opinion, the waste of thermal energy is caused by the mindless following the requirements [2]. The lower temperature limits established in [2] are not less than 15 °C. This requirement applies to residential premises. In case of industrial and administrative premises during the cold period of the year during the off-hours, the permissible air temperature is set between 10 and 12 °C.

However, industrial energy audits demonstrate, that most industrial enterprises prefer not to regulate their own heat supply due to fears of accidents during manual regulation “by eye” at night time, and also due to the misunderstanding of the essence of the automation of this process. Needless to say, the over-expenditure of thermal energy may lead to the increase of costs for thermal energy within the cost of production expenses. You have to either pay extra money, or let it freeze.

The use of automated individual heat points (hereinafter - IHP) allows to partially solve this problem. The ITP connection to the internal heating network circuit of the building is shown in Figure 1. This diagram is dependent on the heating mains of CHP and IHP.

The automatic control system (hereinafter referred to as ACS) of the IHP regulates the coolant flow rate depending on the outdoor temperature (weather compensation), program control of the coolant supply on daily schedules, limiting the maximum and minimum coolant temperature, and ensures secure operation of the heat supply systems.

At the same time, modern IHP ACS have their flaws:

1. The currently popular regulation method of ACS IHP, so-called weather control, based on the deviation from the outside temperature, that, according to [4], does not contribute to a qualitative improvement in the process of heat consumption. With a decrease in the outside air temperature, it is necessary to proportionally increase the coolant flow even when using frequency control of the performance of the CHP pumps.

2. Quite often you have to pay for the entire amount of coolant entering the IHP from a sufficiently remote central heating station or boiler room. The absence of specified rates for heat consumption and coolant transportation, customary for the power supply systems, only aggravates the situation.

3. The actual payment based on the electricity and heat measuring indicators is carried out for the daily volume of coolant supply, which is installed at the IHP input. This volume is determined solely by the characteristics of the coolant coming from an external heat resource, since the regulation of the temperature of the coolant in dependent heating systems is not possible.

Based on the accumulated experience, we propose different a approach for the construction of industrial buildings’ heating points. It is necessary to abandon the "idea" of maintaining the air temperature inside the industrial building during non-working periods of the day.

During the non-working period of the day (it sometimes reaches up to 16 hours), it is possible to reduce the heat load of the building as a function of the minimum allowable water temperature in the heating system. The effect of “thermal inertia” of the heated room is applied here.

Quite naturally, the circulation of cooling water in the heating system should be maintained at the same level. “Thermal inertia” is estimated not by the outdoor temperature, as in weather control, but by the temperature of the water in the return pipe, which according to the accident statistics in heat supply systems cannot be lower than 25-30 °C. This value is 2–3 times lower than the return water temperature at the most “gentle” CHP mode (95/70 or 65/50 graphs). The resulting savings from heat consumption of the building can be increased by the same magnitude.

The essence of such energy saving is the lack of consumption of CHP heat energy during the non-working period of the day. A hydraulic heat tank-accumulator installed as part of the heat point is
applied in such case. Such a heat point will not depend on the coolant temperature in the primary (external to the building) water circuit.

Figure 2 shows the scheme for connecting the heat accumulator to the circulation circuits.

ACS manages the coolant flow in the working and non-working hours of the day based on the modern digital controller indicators and servo drives of coolant flow regulators. The coolant in the external heating network during the non-working period of the day is not received by the system. The following features of the existing schemes determine the innovativeness of their development:

1. LHP is installed according to an independent connection circuit to an external heat network and is supplied with a combined metering station for electrical and thermal energy.

2. The forced circulation of the coolant in the control circuit using circulating pumps is applied. Additionally, electric heating of the water in the hydraulic tank is installed. It is used as a backup measure when the water temperature in the return pipe reaches 20-25 °C.

3. Heat supply to the building is the ‘two-mode’ one. During the working hours, the heat supply from the central heating point is made and the tank-accumulator is filled. During the non-working period of the day only water circulation inside the building is preserved, as the heat supply from the central heating station is not provided.

4. The general level of heating expenses reduction when using LHP reaches 40-60% as compared to the centralized heat supply from the central heating station. Such saving level is achieved by reducing the daily period of heat consumption from the central heating station (at least twice as much), reducing the volume of water circulation, and reducing the amount of electricity consumed by circulation pumps.

LHP hydraulic circuit is shown in Figure 3. The specific feature of the LHP is the heat storage tank and two separate circulation pumps instead of a single dual (as in the heating hubs of large residential buildings). Such hubs have only one input with heat energy metering devices. Structurally, the hub consists of two pipelines connected by a jumper. Before the point where the flows of the supply and return pipelines mix, the ‘shut-off’ valves and a two-way valve with electric actuator for controlling the flow of coolant from the heating network are installed. In the secondary circuit (inside the building), shut-off valves, two circulation pumps for circulating coolant in the heating system and a tank - a hot water accumulator are installed. The controller is also provided (‘control module is shown on the graph). Depending on the outdoor temperature, the weather controller, using a two-way valve in the primary circuit, maintains the temperature of the heating medium supplied to the heating system in accordance with the selected schedule of ambient air temperatures.

Temperature control is based on the comparison of the temperature of the return pipe to the one measured by the outdoor temperature sensor. In the night mode, external heating system does not
produce any heat. Correlation of control actions is made in accordance with the indicators of the coolant temperature sensor in the return pipe and the air temperature in the building. Communication modules are embedded in the electronic controller to provide communication with a computer via LAN or RS232.

The heat node operates in two ‘day’ and ‘night’ modes.

LHP is designed to perform the following functions simultaneously:
- maintaining the set-up pressure (or pressure drop) at the outlet of the group of pumping units;
- controlling the operation of the circulation pumps and switching to the backup pump in case of an accident caused by the manual regulation;
- alternating between connected pumps at the specified intervals to ensure uniform loading of the pumps;

![Figure 3. Hydraulic circuit diagram of an LHP with a tank - heat accumulator.](image)

Thermal insulation of the tank allows to keep the hot water preserved for several hours, possibly even days, so that the heat received in the evening can then be used throughout the night. The design of the internal cavity of the tank does not allow mixing of hot and cold water during the circulation of the coolant.

All of the above components of the LHP are produced locally on an industrial scale by the Russian factories.

In the controller settings, the priority is to maintain the temperature of the coolant in the return pipe of the heating system over the temperature of the surrounding building air.

While developing the concept, we have created mathematical and physical models of the processes pertaining to heating and cooling water in the heating system of the building with a heated area of 1000–3000 m².

The mathematical model is shown in Figure 4, the physical model is shown in Figure 5. Figure 6 shows the characteristics of the heating-cooling cycles obtained on both models for the selected dimensions of the physical model. It is not difficult to notice their convergence applicable in practice.
According to our calculations, the allowed decrease in the temperature of the coolant should not exceed 5 °C per hour during the non-working day period.

Engineering calculation of the heating unit parameters is carried out according to the calculated heat load of the building, its geometrical dimensions and the schedule of temperatures of the supply and return heat transfer pipelines in the heat network or the range of flow rates of the heat transfer medium. Optimization of heating characteristics is carried out on the basis of mathematical modeling.

In the transition from mathematical modeling to real design, it is recommended to use the criteria of the “Reynolds and Prandtl hydrodynamic similarity”, based on the assumption of laminar flow of fluid in pipes.

**Figure 4.** Mathematical model of IHP implemented in the Matlab operating environment.

**Figure 5.** The physical model of ITP implemented at the Department of Electromechanical Systems of the Voronezh State Technical University and Power Supply.
Figure 6. Comparison of the results of mathematical (a) and physical (b) modeling. The abscissa is the time in hours.

3. Results
To date, project proposals have been prepared for the installation of the innovative LHP in the building of “Electrosignal” Joint Stock company (Voronezh) (heated area of 2,450 m²). When installing the LTP, the average annual energy consumption in the building can be reduced from 2 395 Gcal to 1 245 Gcal. Annual cost savings, taking into account the transition to additional power consumption, will amount to 1,215 thousand rubles in 2016 prices. The payback period is about one year.

4. Conclusion
Similar project can be implemented in any industrial enterprise of a city, region or country. In our opinion the short payback period of the proposed design solutions will become attractive for business owners. Whereas the increasing efficiency of heat supply to different buildings and structures will reduce the production costs. This, in its turn, will significantly increase the economic efficiency of the entire enterprise.

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