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Reviewers:

M. M. Dron’ - Doctor of Technical Sciences, Professor of the Oles Honchar Dnipro National University;

O. I. Nesterenko - Doctor of Physical and Mathematical Sciences, Professor, Head of the Department of Physics of the State Higher Educational Institution “Ukrainian State University of Chemical Technology”

O. M. Vinichenko - Doctor of Economics, Associate Professor, Professor of the Department of Economics of Industry and Organization of Production of the State Higher Education Institution “Ukrainian State University of Chemical Technology”

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The monograph deals comprehensively with the use of renewable energy sources in terms of the introduction of energy-saving technologies, the solution of problems of increasing the reliability of their use, the formation of a system for assessing the development of renewable energy sources in the face of global challenges, etc. These issues are considered in detail in the analysis of the prospects for the use of elements of protection against electrical overload in solar cells, the results of experimental studies of the implementation of such components. The application of heat pump technologies and energy-active converters of solar radiation energy in the field of resource saving is considered. Materials for solving the problems of acoustic impact on the environment in the implementation of energy-saving technologies, etc. are presented in various ways. This monograph is of scientific and practical importance and is intended for masters, postgraduate students of technical and economic specialties, teachers, researchers and managers engaged in energy saving technologies at industrial enterprises and in the housing and communal sector of Ukraine.

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CONTENT

PART 3
SUBSTANTIATION OF THE FURTHER IMPLEMENTATION OF HEAT PUMP AND HEAT STORAGE TECHNOLOGY INTO THE ENERGY OF INDUSTRY AND UTILITIES

V. O. Gabrinets, I. V. Tytarenko, G. L. Gnatiuk

An essential feature of communal household heat consumption is the need to create comfortable conditions for a large number of people. The same applies to people working in industrial enterprises.

Without solving many thermal issues, there can be no question of improving the efficiency and economy of heat and fuel consuming of railway transport facilities. These issues can be solved by modernizing the equipment and using secondary energy resources, timely equipping the depots and repair plants with more modern thermal engineering equipment that provides environmental protection.

Nowadays, the system of central heating, which was considered to be the most reasonable one, is gradually becoming less competitive in comparison with decentralized heat production. This is especially the case with low-density areas, typical of most industrial buildings, where one- or two-story buildings predominate.

Recently, there have been many suggestions for boiler designs that use electricity to produce heat. Among such devices are electric heaters (steam and hot-water) as well as hydrodynamic heaters.

From an energy point of view, electric and hydrodynamic heaters can be assigned to the same class of heaters, namely those that use electricity for their work. The coefficient of conversion of electric energy into thermal energy is quite high (92…95 %). Other advantages of such heaters include some favourable operating performance. Namely: in most cases, they do not require continuous work supervision. In addition, there is no need to build special rooms to house the heat generator. They are characterized by the relative ease of supplying primary energy - electric current, not gas or, especially, fuel oil or solid fuels. Simplicity of productivity regulation and possibility of approach of the heat generator to the consumer; speed of commissioning and some others. But keep in mind that electricity is objectively a cheap fuel. It is itself produced from primary energy sources (coal, gas, nuclear fuel, etc.) at an efficiency of 30…35 %. Therefore, a thorough economic analysis must be made before deciding on the use of electric heaters. And energy audit is required where electric heaters are already used.

The use of electric heating in one form or another can be advantageous when combined with heat storage batteries. In this case, the electric heater should be used mainly at night, when there is a preferential tariff for electricity, and the consumption of the heated coolant occurs at a convenient time for the consumer. Additional costs associated with the implementation of such a system are due to the installation of a multi-tariff electricity meter and a water or other heat storage device. Under such conditions, as the calculations show, the use of electric heating in economic terms approaches the conditions of obtaining heat due to the burning of organic fuel. An additional advantage of such heat supply is its environmental friendliness.

Currently, Ukraine's electricity sector is in a difficult situation. In particular, many issues related to thermal power are related to the rational volumes and structure of electricity production in the United Energy System (UES) of Ukraine. One of the main issues in this process is related to the process of adjusting the daily load schedule (DLS), which is characterized by a large irregularity (see figure).

The following basic methods are used to align the daily load schedule: transfer of energy-intensive enterprises to work at night, creation of hydroelectric power plants (HEPP), daily regulation of power units load, use of reserve capacities at peak and half-time (e.g, gas turbine plants), use of excess electricity for the purposes of electric heating in industry and thermal power engineering [1].

Among these align methods DLS currently the last is the most rational. Therefore, there are encouraging measures for nighttime electricity use in different countries. Exactly such an encouraging measure is a preferential tariff which allows to receive not only significant technical but also considerable national economic effect. Thus, the implementation of electric heating together with the accumulation of heat received at night is appropriate and deserves considerable attention.

Greater effect on the rationalization of the heat supply system of the depot and other enterprises and objects of railway transport, including rolling stock, can be achieved by the widespread introduction of heat pump installations (HPI). This is the most attractive area for energy conservation through the use of low-potential heat from the environment (for example, water of river and lakes, as well as non-freezing soil or exhaust air from the ventilation system and even ambient air), as well as secondary energy and waste heat. But its implementation requires a larger initial investment and can therefore be considered in a more distant perspective, which, among other things, should be worked on today.

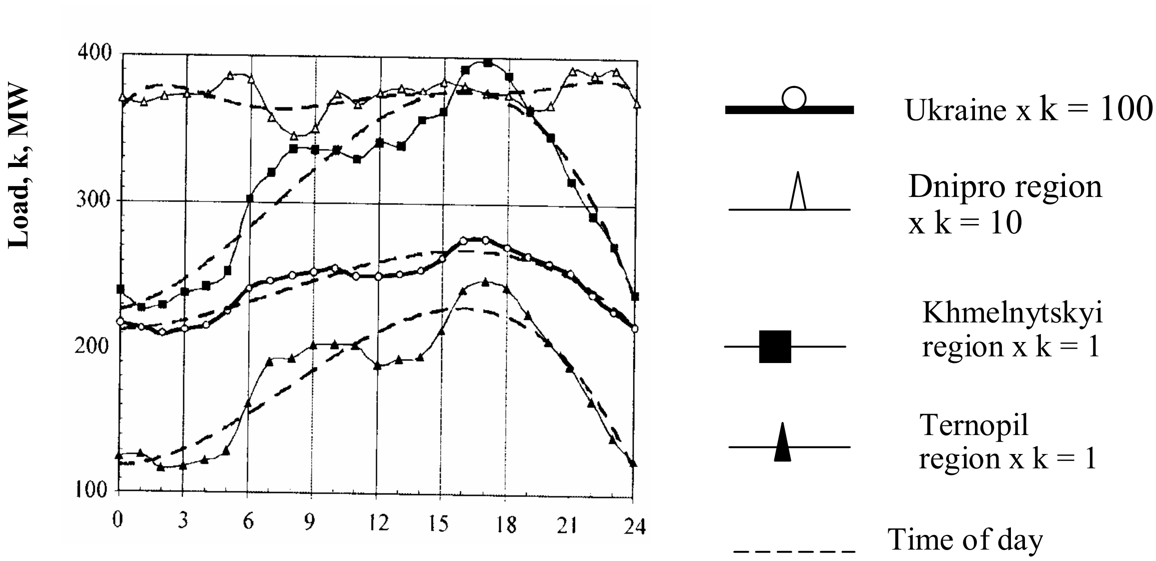


Fig.3.1 - Daily load on winter regime day 2005, MW (x is an indicator of the number to the numerical values of loads along the ordinate axis

Operation of the heat pump working under the scheme "Soil-water"

The pipeline is fitted into the ground. When pumping coolant through it, the latter is heated to the ground temperature. Further, according to the scheme, water enters the heat exchanger and gives all the heat to the internal circuit of the heat pump.

A refrigerant under pressure is pumped into the internal circuit of the heat pump. Freon or its substitutes are used as the refrigerant because freon destroys the ozone layer of the atmosphere and is banned from use in new developments. The refrigerant has a low boiling point and so when the pressure drops sharply in the evaporator, it moves from the liquid state to the gas at low temperature.

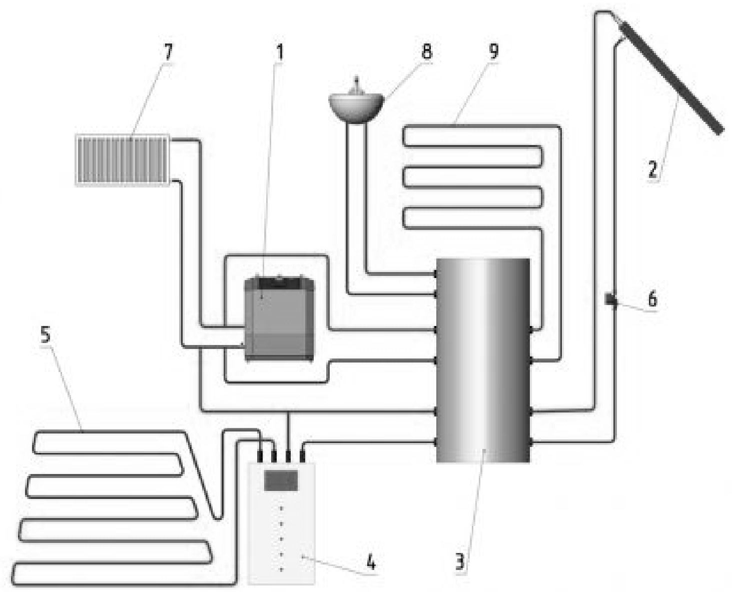
After evaporation, the gaseous refrigerant enters the compressor and is compressed by it. At the same time it warms up, and its pressure increases. The hot refrigerant enters the condenser, where there is a heat exchange between it and the coolant from the return pipeline. Giving its heat, the refrigerant cools and goes into a liquid state. The coolant enters the heating system and cools again, transfers its heat to the room. When the refrigerant passes through the pressure reducing valve, its pressure drops and it again enters the liquid phase. The cycle is then repeated.

In the cold season, the heat pump works as a heater, and in the hot season it can be used to cool the room (while the heat pump does not heat, but cools the coolant -

water. And the cooled water can be used to cool the air in the room).

In the general case, the heat pump is a Carnot machine operating in the opposite direction. The refrigerator pumps the heat from the cooled volume into the ambient air. If to place the refrigerator on the street, then, by extracting heat from the outside air and transferring it inside the house, it is possible in rather simple way to heat the room.

However, as practice shows, a heat pump alone is not enough to supply building with heat and hot water. The scheme of heating and hot water supply of the house, which is optimal according to the authors, is offered.



1 - the heat generator;
2 - solar collector;
3 - indirect heating boiler;
4 - heat pump;
5 - the pipeline in the ground;
6 - flow regulator;
7 - heating radiators;
8 - hot water supply;
9 - "warm floor"

Fig. 3.2 - Scheme of house heating and hot water supply

This scheme involves the simultaneous use of three heat sources. Its main role is the heat generator (1), the heat pump (4) and the solar collector (2), which serve as auxiliary elements and help to reduce the electricity consumption, as a consequence, and increase the efficiency of heating. The simultaneous use of three sources of heat almost completely eliminates the risk of freezing the system.

After all, the probability of failure at the same time and the heat generator, heat pump and solar collector is negligible. The scheme shows two options for room heating: radiators (7) and "warm floor" (9). This does not mean that both options should be used, but merely illustrates the possibility of using both.

Principle of heating scheme operation.

The heat generator (1) supplies the heated water to the boiler (3) and a circuit consisting of heating radiators (7). The boiler also receives a heated coolant from the heat pump (4) and the solar collector (2). Part of the heated by heat pump water is also fed to the inlet of the heat generator. When mixing with the "return" of the heating circuit, it raises its temperature. This contributes to more efficient water heating cavitator of the heat generator. The heated and accumulated water in the boiler is fed to the circuit of the "warm floor" system (9) and the circuit of hot water supply (8).

Considering the wide range of thermal capacities required to satisfy technological and domestic consumers in industry and utilities, as well as the range of heat consumption parameters, it is important to determine the nomenclature of heat generating equipment for energy conservation planning. Of course, the efficiency of this scheme will be different in different latitudes. After all, the solar collector will have the highest efficiency in summer and, of course, in sunny weather. In our latitudes there is no need to heat the premises in summer, so the heat generator can be switched off altogether. And since the summer is hot enough for us and we hardly present our life without air conditioning, the heat pump is supposed to be included in the cooling mode. Naturally, the pipeline going from the heat pump to the boiler will be blocked. Thus, the problem of hot water supply is supposed to be solely with the help of the geliosystem. And only if the geliosystem does not cope with this task, use a heat generator.

As shown in [2], a number of such measures can be implemented through the modernization and improvement of existing heat generating and heat consuming equipment. But now it is necessary to plan and start to introduce deeper structural changes in the energy sector. First of all it concerns the widespread use of secondary energy resources through the implementation of heat pump technology. As sources of low-potential heat, atmospheric air various ventilation emissions, natural water bodies, soil and, above all, wastewater from industrial cooling systems can be used to operate heat pumps. At the same time, the use of heat pump technology in the hot season allows to create comfortable conditions for people, which greatly improves their well-being and increases productivity. At the same time, the use of fixed and heat supply funds during the year significantly improves their efficiency and reduces payback.

The energy efficiency of the heat pump is estimated by the conversion factor ($К_{HP}$), which is equal to the ratio of the heat pump output to the consumed electric power (mainly for the electric drive of the compressor): $К_{нр} = Q_{нр} / N_{ел}$

It should be noted that, by virtue of the thermodynamics laws, the value of $К_{тн}$ is always greater than one, and therefore the amount of thermal energy transmitted to the consumer is greater than the amount of external energy input by the amount of energy selected from a low-potential source. The base value of $К_{тн}$ depends on a number of factors, but always not less than 2…4.

The energy expediency of using heat pumps as heat sources is convincingly proven by the results of a large number of scientific researches and experience of operation of millions of HPPs in industrialized countries of the world [3, 4, 5].

The technical and economic calculations show that the fuel consumption in the heat supply systems on the HPP basis can be reduced in comparison with large heating boilers 1,2...1,8 times; with small boilers and individual heat generators 2...2,6 times, and in comparison with electric heaters without heat accumulators - 3...3,6 times.

The payback period for HPP investments is usually between 2 and 5 years. Payback periods for low-energy waste heat recovery systems may be less than 2 years. For example, investment in the system of providing the optimal temperature and humidity regime in a typical indoor pool, developed by NPP "Insolar" on the HPP basis and heat utilizers of waste air and water flows and implemented in the "Naftovik" basin in Okhtyrka, Sumy region, paid off in 18 months [3]. At the same time it was possible to reduce the peak energy consumption almost 8 times and to exclude the basin from the category of energy-consuming objects.

Unfortunately, today in Ukraine it is difficult to point out any other direction of development of new technology and technology that would be in such striking contradiction, both with its potential capabilities and with the level of development in other countries of the world. If millions and hundreds of thousands of units operate in developed and developing countries, HPPs operate in different functional areas, then in Ukraine there are single installations, created mainly on the basis of refrigeration equipment imported from specialized countries - manufacturers from Western Europe.

The question about the intensive deployment of own production and widespread use of heat pump and heat storage technology on railway transport arises, which is caused by the growing energy crisis in the world and the very limited fuel and energy resources of Ukraine. However, the development of a wide range of HPPs in terms of their heat and cold performance, as well as the parameters of the coolants at the outlet, requires considerable investment, and therefore it is necessary to solve the strategic problem of providing thermal energy to the industry with the minimum possible product range.

The initial data for the analysis and construction of the strategy of modernization of energy supply of the industry is the range of capacities to meet consumers needs of heat and cold, as well as the temperature regimes of heat sources.

The majority of modern HPPs, with a wide range of heat and cold outputs (from several kilowatts to several megawatts), provide a coolant temperature at the exit of the installation from 55^0C to 75^0C. This is due to the fact that they are designed in a single-stage design and use relatively low-temperature refrigerants and their mixtures (operating bodies): R22, R407, R410 with critical temperature ~100^0C. In the railway sector, the heat demand of the heat sources, as mentioned above, provided that the respective systems are decentralized, ranges from a few kilowatts to 1…3 MW. At the same time, the temperature level of the coolant supplied to the heat supply system, and especially of the coolants used in some technological processes, should be higher: up to ~ $130…140^0$C, for example, for wood drying and up to ~ $170…180^0$C for drying of electric machines and devices. As for heating systems, the temperature level of the heat about $75…85^0$C can satisfy new buildings with high requirements for thermal insulation of building enclosures and equipped with systems of heating “warm floor” type. At the same time, existing structures and their heat supply systems are designed for supply to the heating system of the coolant with a temperature of $85…95^0$C, so when supplying the coolant with a lower temperature, there is a need to equip the existing heating systems with additional heating devices. In addition, it should be borne in mind that the climate in Ukraine is slightly cooler than in most countries of Western Europe and America. Therefore, in the north and east, it often involves the provision of heating systems, along with heat pumps, additional heating devices, such as electric or gas heaters (the so-called bivalent circuit), which complicates the system and makes it less efficient.

Taking into account the desirable reduction of the nomenclature of products of heat pump equipment for the purpose of unification of production, we propose to limit in the short term the development of the production of electric heating installations equipped with heat accumulators and multi-tariff electric power meters ranging from three to thirty kilowatts. As for higher capacities, heat pumping installations of appropriate performance, which could function in both heating and cooling modes, should be designed and implemented to meet such needs. At the same time, the installation of heat pumps should be preceded by an energy audit of the enterprise, the purpose of which is to identify the secondary energy resources that are now released into the environment.

An example is the new development of “Ecoterm” - heat pumps, electric heat storage heaters and high-efficiency electric boilers of 300 and 600 kW.

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