

COMBINED PRODUCTION OF HEAT AND ELECTRIC ENERGY**Khikmatov Akobir Bakhodir ugli**

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ABSTRACT:

A comparison is made of the separate and combined methods of production of heat and electricity, some quantitative indicators of the state of the energy sector in Russia are given, and the expediency of constructing mini-thermal power plants instead of existing boiler houses. A scheme of such a mini-CHP with a number of advantages in comparison with analogues is proposed.

Key words: *central heating and power plant, condensing power plant, local stand-alone installation, gas turbine engine, gas piston engine, dispersive steam generator, transonic jet-nozzle apparatus*

INTRODUCTION:

Combined generation of electrical and thermal energy is the most efficient way to save fuel both in housing and communal services and in industry. The traditional separate production of electrical energy by condensing power plants and thermal energy by boiler units is a very inefficient technology. Most of the energy is lost in the form of waste heat.

The overall fuel utilization factor of combined heat and power plants can reach 85–90% [1,180]. Therefore, for many decades, large combined heat and power plants (CHP) were used for the production of electrical energy and central heating.

The use of local off-grid CHP plants can also provide this level of overall efficiency. These installations can be used in cases where the use of centralized thermal power plants is unprofitable. For local systems, there is no need to transmit energy over long distances, since energy is produced at the place of its consumption and losses are minimized.

But at present, in Russia, the combined cycle is implemented practically only at steam turbine combined heat and power plants - CHPPs that generate 55% of the total amount of electricity consumed, which provide only 36% of thermal energy in the country, since the use of such CHPs is possible only in the largest cities, where there is a sufficient density of thermal loads [2, 32]. The rest of the electricity is produced at condensing power plants (CPPs). It follows from here that at the best CPP efficiency of 38-39% and the average efficiency of CPP in Russia of 25% (in the USA - 35%) [2, 32], more than 61% of the heat of the burned fuel of CPP stations is released into the atmosphere through cooling towers. The main part of thermal energy (46%) is produced in boiler houses [2,34], which not only do not generate electricity, but are its largest consumers in the housing and communal services sector.

With the current change in the fuel balance of Russia, 62% of thermal power plants are provided with natural gas [3] (in the first half of the 20th century, the country's energy sector worked exclusively on coal, since natural gas and oil deposits had not yet been discovered, and in the first years of the 21st century, it was revealed that Russia has 42% of predicted resources and 33% of gas reserves of the world for 2.8% of the population and 12.8% of the globe [2]). Consequently, the gigantomania in the energy sector, which historically developed in the first half of the 20th century (only large CHPPs and CPPs, when operating on coal, ensured minimization of specific fuel consumption) has ceased to be economically justified. In the process of servicing residential areas with heat from thermal power plants at a distance of up to 40 km (the stations were built outside settlements for environmental reasons), with a planned level of heat loss of 5%, the latter result in average losses at the level of 15-16% of the transmitted heat energy [2,38]. According to other sources [3], these losses reach 30%. And in this

situation, even the construction of district boiler houses does not provide any advantages compared to domestic boiler houses due to the need for a sufficiently branched heating network with inevitable losses on it and additional costs of electricity for pumping network water.

The presence and constant development in the central European part of Russia of the Unified Gas Supply System inevitably leads engineers to the idea of the expediency of creating another electric generating system parallel to the Unified Energy System, united not by power lines, but by gas pipes (back in 1962, N. I. Sazonov noted that the transmission of gas through gas pipelines is 10-12 times more economical than the transmission of electrical energy through high-voltage power lines). Therefore, gas-fired power plants should be built in areas where heat and electricity are consumed.

The implementation of a combined cycle gas-fired boiler house in each boiler house - the generation of electricity with the utilization of the heat released in this case for the needs of heat supply - solves the problem of both local power supply and heating of the desired object while bringing the efficiency of using the energy potential of the burned fuel to a level of 91- 92%. Fuel is saved, environmental problems are solved, and the reliability of energy supply is increased. At the same time, the country's power-producing capacities that are retired due to physical aging are being replaced. At the same time, the boiler house is transformed into a mini-CHP according to the current terminology [3,45].

In [4], it is reasonably shown that it is much cheaper for the owner to build his own power plant on the basis of a mini-CHP than to pay several times higher tariffs of RAO "UES of Russia" for the consumed electricity. So, in it is stated that the cost of electricity generated at mini-CHPs with turbogenerators NVP "Turbokon" with a unit capacity of 500-600 kW (backpressure turbines) in 2000 was 6 kop./kW, meanwhile, boiler houses in Moscow in the first half of 2001 Mosenergo was paid 45-64 kopecks/kW for electricity. The specific cost of gas-fired power plants with piston engines and a resource of 200 thousand hours is \$250-900 per kW of installed capacity, and the average cost of CHPPs in Russia is \$1,600 per kW of installed capacity [4]. According to data published in the press by a number of engine-building plants in Russia, the unit cost of 1 kW of installed capacity of a thermal power plant based on an internal combustion engine (ICE) ranges from 190 to 500 US dollars; the specific cost of a gas condensing power plant at the end of 2000 was \$860 per kW of installed capacity [4,36]. At the same time, it should be taken into account that Russian power plants purchase gas at domestic prices, which as of January 2008 are about six times lower than the world prices. The skew in the use of natural gas in the country's fuel balance with respect to coal is also due to the fact that coal prices are on average 1.5 times higher than gas prices. According to the energy strategy of Russia until 2020, in the near future the gas-coal price ratio will be at the level of 2/1, which threatens consumers of the country's energy resources with at least a threefold increase in tariffs. And if before 1990 the share of costs for electricity and heat in the total cost of production was 3-7%, then the rise in prices for these resources led to an increase in this share to 45-65% by 1997 [6, 7]. The negative trend is currently aggravated, the growth rate of energy costs is alarmingly high. The only reasonable way out in this situation to solve the problem of ensuring reliable operation of the enterprise at acceptable energy costs is to rely on one's own strength and create a mini-CHP for one's own needs.

A discussion in periodicals on the topic of the preference for using a gas turbine engine (GTE) or an internal combustion engine (ICE) in a mini-CHP as a drive for an electric generator - melting on natural gas - gas-piston engine (GPE), tends towards the use of GPE for a number of indicators. In particular, gas turbine engines require the construction of gas compressor booster stations to increase the gas pressure from 0.3-1.2 MPa of the city gas network to 2.5 MPa at a minimum allowable distance from residential facilities of 500 m; availability of

storage facilities for reserve diesel fuel; new chimney and waste heat boilers due to higher consumption of exhaust gases call. A gas turbine engine is characterized by a high noise level and a three times higher specific output of nitrogen oxides per kilogram of fuel burned; the motor resource of a gas turbine engine of 30-35 thousand hours is always lower than the motor resource of diesel generators (60-120 thousand hours), the value of which for the GPE can be further increased by 1.5-2 times, and the geoactivation of friction units when modifiers are added to the lubricating oil increases the engine life by another several times; in addition, the average efficiency for GTE is 25%, and for GPE - 40%.

Energy supply based on the use of a combined cycle, by analogy with the experience of foreign countries, where each fairly large facility - a shopping center, an entertainment complex, a medical institution - is necessarily equipped with a mini-CHP, is complicated by the inevitable observed unevenness of electricity consumption during the day (morning, noon, evening), as well as depending on the time of year. The production of thermal energy in a mini-CHP is strictly functionally connected with the generation of electricity. Statistical observations show that peak loads on heat supply for heating and ventilation can be 2-2.5 times exceed the demand for electricity, and to make up for the shortage of heat in the energy supply system, it is necessary to provide the appropriate boiler equipment. This situation is critical in the case of developing an energy supply system for an agricultural greenhouse complex, where the tolerances for the temperature of working premises are very strict. Interregional ISPC INTECH together with Samara State Technical University developed a set of equipment for the implementation of a combined cycle of energy supply.

The scheme of combined production of electric and thermal energy is built on the basis of a gas piston engine for the production of electricity, and in ISPC INTECH is working on a further increase in engine life relative to the heat supply system proposed in [2, 44] based on a dispersive steam generator DPG, a TSA transonic jet-injector apparatus and a microprocessor control system. The implementation of the technological process eliminates the need for chemical water treatment, the presence of network pumps, and minimizes the required production space. The efficiency is 89%, the equipment is non-explosive, qualitative and quantitative regulation of the heat supply process is implemented, the effect of self-cleaning of heating mains and thermal appliances during operation is ensured. The cost of electricity - three to four times and heat - at least two times lower in relation to those existing on the market. The disadvantage of the system should include a decrease in efficiency in the summer. The innovations implemented by SPC INTECH mostly relate to the heat supply system. Let's briefly consider some of them.

Heat supply units of MNPTs INTECH are equipped with reagentless water treatment devices (UPOVS-2 OJSC MAKSMIR), which exclude scale formation in the boiler unit due to the effect of magnetic, electric and ultrasonic fields on water [14,65].

Scale formation, as well as corrosion of engineering equipment and communications are among the most urgent problems of thermal power engineering. The formation of a scale layer 1 mm thick on the inner surface of the boiler unit entails an excessive consumption of fuel by 5-8%, and poor-quality water treatment (or its absence) can lead to a decrease in system efficiency by 15-30%.

The MNPC INTECH heat supply installations use a four-chamber magnetic apparatus (UPOVS-2) with a built-in deaeration chamber, which eliminates the need for expensive filters, chemicals, and a deaerator device. Water enters the deaeration chambers, where, under the influence of controlled magnetic, electric fields and ultrasound, O₂ and CO₂ are completely removed from it, the presence of which causes internal corrosion of the system.

The use of four working chambers, through which water passes, makes it possible to influence it for a long time and in a complex way by cumulative fields, as a result of which scale-forming salts turn into fine sludge, which is not deposited on the internal surfaces of power equipment and pipelines and is separated in a dirt trap. Apparatuses for anti-scale treatment of water systems (UPOVS-2) are suitable for the preparation of almost any water with a temperature of up to 115 ° C. Productivity - up to 30 m³ / h, electric power consumption - from 0.3 to 2.2 kWh. The hardness of the source water is 1.5-30 mg equiv./l. The content of iron in the source water is up to 1.5 mg/l.

Dispersion steam generator:

The design of the steam generator is fire-tube. Fuel through the flow sensor enters the block burner. The steam temperature at the outlet of the steam generator is 180-240 °C. Steam pressure - 2-10 at.

The fundamental difference of this apparatus is that it provides heating of water not in a liquid state of aggregation, but in the form of an aerosol (cold water vapor) with a water particle diameter of 10–20 microns [15]. Obtaining aerosols is carried out using ultrasonic dispersers developed by MNPTs INTECH. The aerosol has physical properties similar to superheated steam. The dispersive steam generator thus provides the main requirement - the mutual independence of the steam temperature and pressure.

The aerosol heating rate is much higher than the water heating rate; therefore, the rate of heat removal from the heated surface when it is washed by a finely dispersed aerosol flow is much higher than when the same surface is washed with water. When the aerosol flow rate is close to or equal to the flow rate of hot gases heating the separating surface, the heat transfer coefficient sharply increases.

Consequently, the water aerosol intensively removes heat from the hot flue gases, making it possible to reduce the dimensions of the steam generator. Water aerosol enters the annular space of the steam generator. Heat exchange between hot gases and water aerosol occurs at a much higher rate than between hot gases and a liquid medium. Steam of the required temperature and required pressure is supplied to the load through the outlet pipe. Part of the exhaust gases is fed back to the combustion chamber by means of a steam-gas jet compressor, providing afterburning of combustible components. Therefore, the content of harmful emissions in the exhaust of the steam generator is significantly below the established MPC standards and meets the most stringent requirements of international standards.

The steam generator provides heating of finely dispersed water to the specified parameters (temperature and pressure) with an efficiency of 94%. Specific fuel consumption is 5-8% less than in traditional boiler units of the same capacity. The time for the steam generator to reach the specified mode is several tens of minutes. It is characterized by increased reliability of work. The absence of water in the liquid state of aggregation in the high-temperature zone in the proposed design of the steam generator eliminates the threat of a potential explosion in the event of an accidental ingress of water aerosols into the combustion chamber during cracking of the flame tubes, which is typical for all existing boiler units. The device is insensitive to the content of salts in dispersed water. When water passes through the ultrasonic field of the dispersant, the crystal lattice of salts dissolved in water is destroyed. The amorphous state of salts is temporary (metastable), but the period of the metastable state significantly exceeds the time spent by water aerosols in the hot zone, and salts are not deposited on the hot pipes of the heat exchanger, in heating mains and thermal devices for this reason. The control system provides automatic maintenance of the set steam output parameters. The steam from the steam generator enters the inlet of the steam jet pump-heater (TSA).

Steam-water transonic jet-injector apparatus:

The active component (steam) is supplied to the active nozzle 1 (Fig. 6) [16], the flow part of which is profiled in such a way that complete expansion of the steam and a high rate of its outflow are ensured. The passive component (water) enters through 2 into the receiving chamber, from which, through the annular gap between the outlet section of the active nozzle and the generatrix of the conical nozzle, it is fed into the mixing chamber, where it is mixed with the active component. The annular gap is adjusted so that the flow velocity through it is $50 \div 80$ m/s. A homogeneous two-phase mixture is formed in the mixing chamber. A feature of two-phase media is a significant decrease in the speed of sound relative to the speed of sound in single-phase media. The speed of sound in the liquid phase (water) is 1500 m/s, the speed of sound in steam is 300 m/s, the speed of sound in a mixture (steam with water) is 5 m/s. Thus, the flow velocity in the mixing chamber before entering the cylindrical channel 3 significantly exceeds the local speed of sound. In the cylindrical channel of the mixing chamber, during supersonic flow, shocks occur, which leads to compression of the mixture. In this case, complete condensation of the vapor occurs, accompanied by the cavitation collapse of the compressed vapor bubbles. All steam energy is transferred to water. In the resulting single-phase liquid medium, the speed of sound increases sharply.

The flow velocity in the cylindrical channel turns out to be much lower than the local speed of sound. Direct passage through the sound barrier in an adiabatic channel of constant cross section is impossible.

There is a sharp increase in static pressure. The intensity of the pressure jump is proportional to the square of the Mach number. From the cylindrical channel, the flow enters the diffuser 4, where the flow slows down and the static pressure increases. The static pressure at the outlet of the TCA can reach values that exceed the pressure of the inlet components. The cavitation process in the mixing chamber ensures a constant flow rate. The TCA is a positive displacement pump, a change in the load resistance at the TCA output does not affect the input characteristics of the device. The pressure characteristic TCA ensures the circulation of the coolant flow in the heating network without the use of circulation pumps.

The condensed steam directly transfers all its potential energy to the water, providing water heating. A change in the steam pressure at the TSA inlet leads to a change in the coolant flow rate and its temperature over a wide range. Changing the water pressure at the second inlet of the TSA allows, within certain limits, to change the temperature of the coolant at the outlet of the TSA at a constant flow rate.

Heat supply installations based on TSA were first installed by MNPTs INTECH in 1992 in Kazan. A total of 12 projects were completed. In 1996 and then in 2001, heat supply units were put into operation at the existing steam capacities at the Samara Combine of Ceramic Materials (capacity 5 Gcal/hour) and at the Ural-cement plant in Korkino, Chelyabinsk Region (capacity 30 Gcal/hour). The installations are still working, the reviews are positive everywhere. But those outdated design solutions can no longer be recommended for use, since the modification shown in fig. 7 is the most appropriate.

CONCLUSION

An analysis of the situation with prices for natural gas based on fundamental government decisions [3] demonstrates an inevitable increase in the cost of this energy carrier in the fairly near future. For a potential customer of local energy supply systems, there is still some time left to consider alternative proposals and make a decision on the implementation of one of them. But it should be borne in mind that the supply of time is not unlimited. And if now the financial support requested by energy supply companies as technical conditions for the possibility of connecting to their networks often exceeds the costs of implementing their own local heat supply

and makes up the bulk of the costs of building local heat and power supply, then with a general increase in prices by 2020 d. these costs can increase many times over.

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