OPTIMIZATION OF SMALL POWER UTILITIES WITH GAS GENERATION OF BIOMASS AND SOLID FUELS

Potapov V.N., Ph.D. in technical sciences, assistant professor,
Kostyunin V.V., engineer, developer of gas generators
Yekaterinburg

Commercial generation of combustible gases from organic raw materials at power utilities – thermal power plants (TPPs), boilers, combined heat and power plants (CHP plants) – is highly complicated with problem of cleaning the gas produced from resins and ash, and it has too low reliability of the production and purification of gas to work for electricity market. It is impossible to apply gas to the economical internal combustion engines (ICEs) and gas turbine plants (GTPs) without expensive and complicated in operation gas purification. For thorough cleaning of the gas produced, it must be cool in the heat exchangers, which are polluted with resins and ash, and therefore, requires to be stopped for cleaning and repair. Otherwise, operation of power generators on TPPs and CHP plants with ICEs and GTPs for electricity market is impossible. Complex gas purification will increase the cost of their own needs of TPPs, and their net efficiency may be lower than net efficiency of the new European steam turbine TPPs, which have already reached 45-47% in different coals. Therefore, we believe that in fact, gas generation from local fuels, biomass and waste is more profitable than commercial quality solid fuels by feeding the produced gas to the self-boilers of small energy consumers without highly complicated and expensive thorough purification of gas before its combustion.

Our experience of designing of gas generators and their following adaptation to operating conditions showed commercial border for introduction of gas generation in different tasks of the production of combustible gases. Let us emphasize, in our opinion, 4 commercially attractive schemes of connection of gas generation to existing units for receiving of the power energy of two kinds of small enterprises consumers in residential places. Fig. 1 demonstrates simple and inexpensive schemes. The direct input of the generating gas without cleaning and cooling to a furnace of the water heating boiler or steam generator is realized in them. It is environmentally and economically advantageous to feed it to boiler furnaces that burn expensive coals with low efficiency. These boilers have been originally simple devices for cleaning the flue gases before the chimney.

The scheme a) in Fig. 1 demonstrates direct gas combustion in the furnace of the water heating boiler, and the scheme b) demonstrates, in our opinion, the most economically effective scheme of TPPs or CHP plants with a steam turbine without condenser. These turbines are called in the Russian practice as turbines with backpressure or worsened vacuum. They exclude all major losses of TPPs – heat losses in the turbine condenser. And even in such schemes, it is advisable to use low and medium pressure turbines and to apply steam from the exhaust for heating or industrial needs. In such conditions, the heat of the exhaust turbine is an internal and external commercial product for the plant. In the ideal case, we assume that the boiler burner should include the gas generator in itself making with it a single technical device – a burner with complete or partial gasification of fuels (biomass) in the burner. We have created some samples of this class of devices and tested them on models with burning.

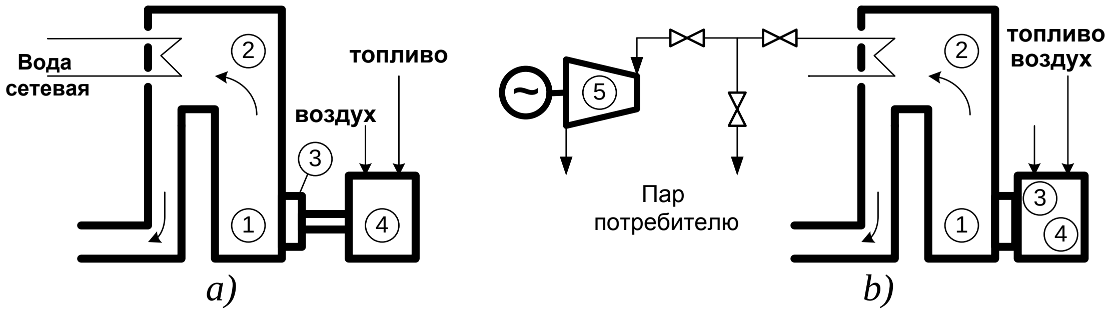

Fig 1. A scheme for direct combustion the gas generated in the water heating boilers (a) and steam generators (b) with supplying of steam to generate power electricity:

1 – a furnace; 2 – a boiler; 3 – a burner; 4 – a gas generator; 5 – a steam turbine.

Вода сетевая = delivery water
Воздух = air
Топливо = fuel
Пар потребителю = steam to the consumer

The schemes proposed by us (Fig. 1) provide for the supplying of a gas with moderate temperatures of generating that is equal to 600-900 °C with the combustion heat of from 1100 to 2000 kkal/m^3 into the furnace. It is attractive if we implement a gas generation in the burner. Generation of two types of secondary energy will be lower as of the cost of fuel and reduce of CO_2 emissions, and the turbine part will be cheaper and more reliable than that one of conventional condensing TPPs with high and supercritical pressures. In the illustrated scheme b), electricity generation will be also cheaper at thermal consumption. Burning of all resins of the gas generation with the gas itself is an important advantage of schemes in Figure 1. These schemes have the fuel energy recovery efficiency by 2-3% higher than many schemes of the TPPs with gas generation. The schemes on Fig. 1 were proposed by us in 2004 for sawdust gasification and combustion heat recovery. For one of the devices, we check the gasification of carbon from the fuel ash. The scheme a) with the substitution of all or part of a fuel with artificial gas is especially attractive for boilers burning expensive fuel without electricity generation. In this case, the heat recovery efficiency of the entire plant can be increased from 40-60% to 82-85% by introducing gas generation from biomass, peat or local fuels in some boilers.

It is always attractive for heating of isolated places and small enterprises. However, we should consider the different schemes of preparation of gas to burning. Our experience has shown that they can determine the commercial feasibility of gas generation. In small facilities, it is advantageous to produce a gas from combustible waste, biomass, peat, or mixtures thereof with coal. For this purpose, vortex gas generators of new type, which have been created by us since 2004, are well suited. Three units with thermal power of 2.5-5 MW have been already in operation or under commissioning.

Our reactors implement flame treatment of raw materials in 3-4 processing stages in a vertical or horizontal vortex, in which we form stages of the O_2 deficit. In our first modification, fuel gasification occurred without strict separation on pyrolysis and gasification, when in the first two stages, the O_2 deficit was maintained at 82-85% and 70-73%. And deep conversion of heavy resins was reached at temperatures above 650-850 °C. Later, we realized our scheme of conversion of water vapor and combustion products in the first chamber at the O_2 deficit up to 87-90%. Then generation of the gas and part of the carbon ash and the conversion of the heaviest resins was completed in the other two chambers at the O_2 deficit consistently from 80-85% to 70-73%. And by this fact, we increased by 2-2.5 times the thermal power of one of the reactors with access to the mode of self-stabilization of the whole process.

To reduce the cost of the gas valves and to increase the reliability of its work, we have found compromise of the level of temperature reduction of the gas to supply it to the boiler and to increase the flexibility of operation of a small enterprise heating scheme. We shared the whole heat made in the reactor into 2 streams. We allot a part of the whole gasification heat (up to 10-12%) and the subsequent burning of the produced gas in the furnace behind the reactor by heating the water. Then we allot this heated water on the accumulation to a special tank for the possible use of this heat in the heating and ventilation system of the enterprise (Fig. 2).

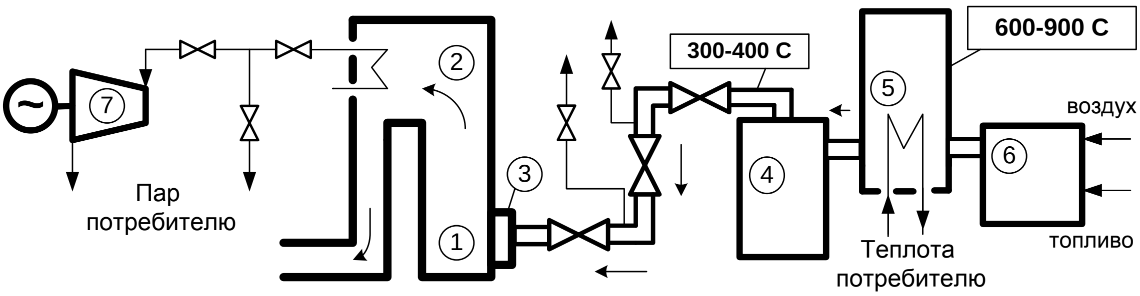

Fig. 2. A scheme of partially cooling and purification of the fuel gas:

1 – a furnace; 2 – a boiler; 3 – a burner; 4 – an ash collector; 5 – a gas cooler.

Воздух = air
Топливо = fuel
Пар потребителю = steam to the consumer
Теплота потребителю = heat to the consumer

The scheme was developed by us in 2010 and with some changes introduced at a grain processing factory where it has been operating since 2011. Its main advantage is heat saving with hot water supply from the tank-accumulator in briefly stops of the reactor or boiler. Another advantage of the scheme is cooling of the gas to an intermediate temperature – to 200-400 °C for the present. In gas generation of biomass at low ash (sawdust and husk with ash content of 1-6%), we equip the boiler with cheap gas valves as required by Russian standards of safety combustible gas supply, as if the gas was natural, with all valves and simple ash treatment. We must note that neither GTP nor even ICE should be generally installed at this type of enterprises if steam turbines with heating industrial steam extraction have been already operating on them, and best of all, steam turbines with poor vacuum or backpressure should be installed.

Such proposed and implemented by us selection (Fig. 2) of the part of the gas heat behind the gas generator we recommend to be further converted to the new concept of TPP operated on local fuels, biomass or waste (Fig. 3). Its principal difference lies in the fact that all or part of the heat from the tank-accumulator can be discharged to a small electric power generation to the electric generator driven by the Stirling engine. These engines operate with high efficiency from the heat source starting from high temperatures (500-600 °C) and can select the heat from the stream of the partially cooled gas, and the others – from the heating agent with a temperature only 100-150 °C naturally having a small thermal efficiency. In the first case, the efficiency of the Stirling actuator may be higher than in many ICE and the Rankin cycles, and even higher than the efficiency of GTP. In the second case, the efficiency of power generation can occur when the raw materials for gasification is much cheaper than energy fuel buying from the commercial market for combustion in a boiler.

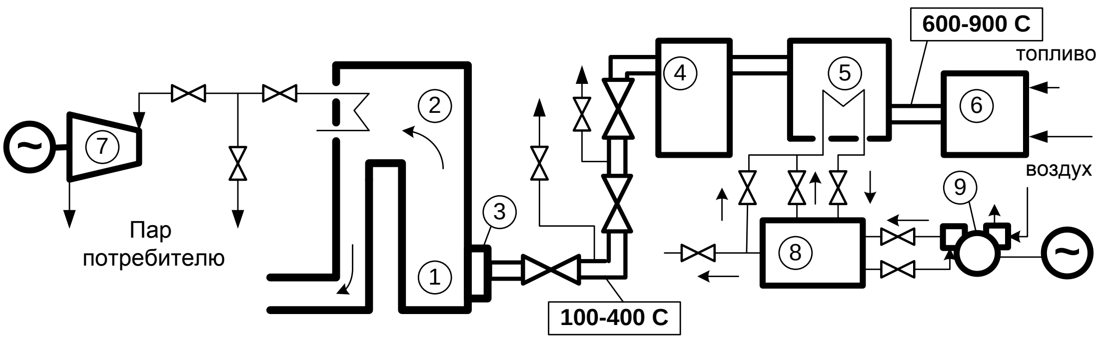

Fig. 3. A new type of TPP with production of energy of two kinds

1 – a furnace; 2 – a boiler; 3 – a burner; 4 – an ash collector; 5 – a gas cooler; 6 – a gas generator; 7 – a steam turbine without condenser; 8 – a tank-accumulator of heat; 9 – the Stirling engine with an electric generator.

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In this scheme (Fig. 3), the cooling of the gas behind the reactor can be increased down to 60-80 °C. But even in this case, in inevitable decreasing of the efficiency of the Stirling engine used, the CHP scheme (Fig. 3) may be profitable if organic waste, recycling and export of which are associated with significant costs for business owners, are gasified. Our assessment calculations for one of such real power plants without steam turbines showed that cost savings from waste gasification with the rejection of their disposal in a particular case may be 2-3 times higher than cost saving by replacement of the part of the natural gas purchased by the owners of the plant for the same boiler of the factory boilerhouse with the same producer gas. Naturally, the partially cooled producer gas with a temperature of 300-400 °C is fed into the boiler after cleaning from ash. It is most advantageous to feed the same gas from waste for incineration to the coal-fired boilers, at least for the replacement of the solid fuel purchased in the market when the boiler of a boilerhouse or a small CHP plant have been already equipped with purification system of flue gases from the boiler ash. In this case, it is no need to equip the gas generator with an additional ash collector with pre-cooling of the gas.

A steam from the boiler with low or medium pressure is most advantageous to feed to a steam turbine without condenser. This ensures maximum efficiency of applying of heat in fuel combustion in our flowsheet (Fig. 3) of both a producer gas from waste and fuels supplied from markets. At that, the heating load can be removed not only from the exhaust turbines, but also from the tank-accumulator of the hot water. Instead of water, the accumulation of heat in the tank-accumulator is performed by a mixture of oil, molten salt or other heat-carrying agent with higher capacity (of 300-600 °C) which is required for driving of the Stirling engine with a higher efficiency.

A particular advantage of the proposed heating power plant (Fig. 3) is to maintain power generation and heat within the range of 5-15% of the nominal value regardless of the mode of operation of the gas generator and associated with it boiler and steam turbine, as well as GTP or ICE. This, according to our estimates in a small plant, will provide power supply for all or part of its own needs depending on the power of the Stirling engine in periods ranging from several hours to a day when stopping both the gas generator and boiler for repair or preventive measure.

The proposed by us scheme (Fig. 3) eliminates a major systemic defect of conventional type of the power industry operated on fossil organic fuels. The scheme of CHP (Fig. 3) breaks into significant intervals the rigid connection between the burning of fuels, steam generation and electricity production on its heat with energy consumption to temporarily satisfy the own needs. That is, generation of electric power will be provided at necessary stopping of any basic equipment of the TPP flowsheet.