ADVANCED TECHNOLOGIES AND POWER INSTALLATIONS FOR THERMAL AND ELECTRIC ENERGY GENERATION

6.3. Heat and power supply units of low capacity

6.3.5. Application of gas piston units for thermal and electric power generation

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Nowadays gas reciprocating units (GRUs) are widely used for combined generation of thermal and electrical energy at low-capacity units. GRUs represent internal combustion engines, working on gas. A number of foreign and national manufactures produce GRUs with capacity, changing from several watts to 10 MW with heat utilization for heat-supply needs. A list of the most widespread manufacturers of such small gas-engine power plants is provided below:

Manufacturer (Country)	Capacity, kW
Caterpillar (USA)	70…5900
Cummins (USA)	4,2…2000
Deutz (Germany)	172…3916
FG Wilson (Great Britain)	10…1000
Guascor (Spain)	142…957
Jenbacher (Austria/USA)	312…3041
Rolls-Royce (Great Britain)	2400…8500
Tedom (Czech Republic)	25…5900
Wa r t s i la (Finland)	3888…8730
Waukesha (USA)	75…3250

The main element of such power plant is a gas internal combustion engine which is a drive for the electric generator. Generators can be synchronous or asynchronous. And the synchronous generator can work in an independent mode or in parallel with a power network. The engine and the generator are commonly incorporated into one unit, installed on a base frame. The generated electric current is distributed to a power network.

Thermal energy is generated in the process of cooling of an engine (the primary contour) and utilization of flue gas heat (the secondary contour). The primary contour provides cooling of the engine and heat transfer from the engine to the secondary contour.

Engine is cooled, as a rule, with water. Circulation of liquid in the first contour is provided with pumps. Further, depending on the schemes used by the manufactures, cooling water of the primary contour comes to the water-water heat exchanger and heats water, entering the second contour, and then returns to the pump intake of the primary contour.

The secondary contour is a main thermal contour, intended for heat supply of the consumer. Transfer of thermal capacity from flue gases and from the primary contour directly for heat supply to a consumer is carried out in this contour.

Each similar installation represents a single module or a combination of the modules, equipped with the necessary equipment and greasing, automatic control systems, systems of burn-up and protection.

At operation of common (steam) power plants a considerable quantity of heat is generated due to technology of power generation. Utilization of this heat isn't always possible and its considerable part is discharged into atmosphere through steam condensers, cooling towers, etc. Comparison of specific electric energy production, generated by different units at heat demand, is presented in Tab. 6.14.

Analysis of the provided results shows that steam and gas turbines are efficient for thermal power plants of high capacity, and for thermal power plants of low capacity GRUs appear to be more effective.

Even when electric power capacity makes 1 MW, thermal capacity of such equipment makes around 1 MW yielding high specific power generation at heat demand and sufficiently high electric power generation efficiency η_{el} = 0,38, therefore, thermal power plants of low capacity on the basis of GRUs have the following advantages:

- installation is small-sized, with a factory readiness, can operate in an automatic mode;
- doesn't require significant expenses for installation, can be placed in an easy design, container type compartment;
- sufficient maintenanceability;
- moderate capital costs for construction of a thermal power plant (about 1000 USD for 1 kW of the installed capacity).

Tab. 6.15 presents actual characteristics of Caterpillar GRUs of G3520C type of 2 MW. Analysis of these characteristics shows that providing high economic indicators, these installations have high harmful emissions, it is characteristic for all GRUs. Besides, performance of certain maintenance works is required in process of operation. A list and procedure of maintenance works are summarized in Tabs. 6.16-6.21.

Table 6.14. **Characteristics of different types of power plants**

TPP type	Fuel	Specific unit capacity, MW	Specific unit generation*	Electric efficiency	Efficiency of fuel use, %
Combined heat power plants with steam turbines	All types	0,1...250	0,2… 0,73	0,1...0,38	Up to 90
Combined heat power plants with gas turbines	Gas, gas and turbine fuel	0,25... 300	0,2… 1	0,2...0,46	Up to 85
Combined cycle thermal power plants (with steam and gas turbines)	Gas, gas and turbine fuel	3...800	0,2… 1,2	0,3...0,58	Up to 85
GRU	Gas, diesel	0,05…13	0,3… 1	0,3... 0,4	Up to 90

* The first figure refers to units of lower specific capacity

Table 6.15. **Characteristics of GRU of G3520C type**

Nominal electric capacity at cos*f* = 0,8, kW	2000
Voltage, V	10 500
Natural gas consumption under 100 % load, m^3/h	501
CO content, in conversion to 5 % O_2, mg/m^3	957
NO_x content in conversion to 5 % O_2, mg/m^3	500
Overall sizes, m:	
Length	7,2
Width	1,9
Height	2,3
Weight of dry unit, kg	24 000
Maximum thermal capacity, kW	2144
Temperature at the unit inlet/exhaust, °C	70/90
Exhaust gas temperature at the unit inlet/outlet, °C	460/120
Water flow rate through the heat exchange unit, m^3/h	25,6
Maximum water pressure in the system, MPa	0,6
Overall sizes, m:	
Length	6,2
Width	2,4
Height	3,6

Table 6.16. **Spare parts for TO250 for the generator installation G3516**

Number	Name	Quantity for a unit
CAT NGEO SAE40	Oil for gas engines	80 l
ZR2044	Cooling liquid addition	2
185-4637	Greasing	1
26525	Surface cleaner	1
169-8373	Tank for collection of oil samples	1

Table 6.17. **Spare parts for TO1000 for the generator installation G3516**

Number	Name	Quantity for a unit
CAT NGEO SAE40	Oil for gas engines	416 l
1R-0726	Oil filter	3
9Y-6792	Spark plug sealing	16
185-4002	Dielectric lubrication	3
4W-9725	Sealing	1
4W9765	Sealing	2
125-1372	Gasket	1
135-2651	Gasket	1
033-6031	Rubber ring (breather)	2
185-5346	Greasing	1
24333	Joint filler for screw joint	1
18938	Liquid sealing	1
—	Technical polyethylene, trash bags	1
26525	Surface cleaner	1

Table 6.18. **Spare parts for TO2000 for the generator installation G3516**

Number	Name	Quantity for a unit
8N-6309	Air filter	2
185-5346	Greasing	1
154-9385	Gas filter	1

Table 6.19. **Spare part for TO4000 for the generator installation G3516**

Number	Name	Quantity for a unit
7C-9710	Sealing (bypass)	1
194-8518	Spark plug	16
1U-5353	Technical paper	1
26525	Surface leaner	1
23039	Washing liquid	20 l
4C-5598	Antiwelding greasing	1

Table 6.20. **Spare parts for TO8000 for generator installation G3516**

Num ber	Name	Quantity for a unit
1345958	Sealing	16
26525	Surface cleaner	1
125-0517	Maintenance kit for a transformer	16

Table 6.21. **General schedule of maintenance**

Machine hour	Maintenance			
	1000	2000	4000	8000
1000	X	—	—	—
2000	—	X	—	—
3000	X	—	—	—
4000	—	—	X	—
5000	X	—	—	—
6000	—	X	—	—
7000	X	—	—	—
8000	—	—	—	X

Therefore, in spite of the fact that GRUs have a high automation degree and compact sizes, they require significant operational costs.

Therewith, the characteristics presented above show that low-capacity co-generation thermal power plants on the basis of GRUs are more effective at low thermal loads.

Comparison of different types of installations shows that the most optimal application of steam and gas turbines for low-capacity combined heat and power plants under a base thermal load (here and after a base load means the load which remains all the year round) starts from Q_h = 10 Gcal/h

For lower loads application of low-capacity combined heat and power plants on GRU basis is reasonable in case of appropriate electric power consumption.