ADVANCED TECHNOLOGIES AND POWER INSTALLATIONS FOR THERMAL AND ELECTRIC ENERGY GENERATION

6.2. Gas turbine and combined-cycle units

6.2.2. Combined cycle plants

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Binary CC units, summarized in Tab. 6.8, were designed in Russia during 1990-1995.

Detailed description of CCUs, presented in the table, is provided below.

Combined cycle unit CCU-450T. Northwest thermal power plant, commissioned in 2000 in St.-Petersburg, is the first power plant in Russia, equipped with large combined cycle units of binary type (CCU-450T) with high efficiency, unreachable in steam turbine units. The efficiency of power unit CCU-450T in a condensing mode makes more than 50 %, fuel consumption rate is more than 85 %, and power generation to thermal consumption ratio is more than 1300 kW·h/Gcal. Each of the designed units consists of:

- two gas turbines of "Siemens" V94.2 type, manufactured by JV "Interturbo";
- two HRSG manufactured by JSC "ZiO-Podolsk";
- one steam turbine, manufactured by SC "LMZ";
- four-stage heat supply unit;
- auxiliary equipment and systems.

Table 6.8. **Characteristics of combined cycle units, developed in Russia**

Characteristics	CCU-80	CCU-325	CCU-450T[1]*	CCU-450[2]*
Gas turbine				
Manufacturer	STC “Dvigateli NK”	SIU “Mashproekt”	“Siemens”	“Siemens”
Type	NK-37-1	GTE-110	V94.2	V94.2
Capacity, MW	30	107,5	166	145,8
Quantity	2	2	2	2
Steam turbine				
Manufacturer	Kirov works	SC “LMZ”	SC “LMZ”	SC “LMZ”
Type	T-20	К-110-7,5	T-150-7,5	К-150-7,5
Capacity, MW	20	107,3	114	165,6
Quantity	1	1	1	1
Boiler				
Manufacturer	BZEM[3]*	ZiO[4]*	ZiO	ZiO
Type	Double drum	Double drum	Double drum	Double drum
Quantity	2	2	2	2
Combined cycle unit				
Power capacity, gross, MW	80	322,3	446	457,2
Heat supply, Gcal/h	42	0	350	0
Specific fuel consumption in grams of relative fuel/(kW·h)	252,7	234,26	142	239,9
Efficiency, gross, %	—	52,43	—	51,19
High-pressure steam flow rate at the turbine inlet, t/h	72	297,3	480	470
High-pressure steam after the boiler, MPa	4,0	7,2	8,0	8,0
High-pressure steam temperature after the boiler, °C	430	498	515	515
Low-pressure steam flow at the turbine inlet, t/h	20	73,2	86	61
Low-pressure steam after the boiler, MPa	0,75	0,66	0,65	0,65
Low-pressure steam temperature after the boiler, °C	205	245	205	225
Exhaust gas temperature, °C	125	101	105	101
Implementation year	—	—	2000	—

[1]* t_{amb} = –2,2°C.
[2]* Height above the sea level - 410 m.
[3]* BZEM — Barnaul works for power machine construction.
[4]* ZiO — Podolsk works named after S. Ordjonikidze.

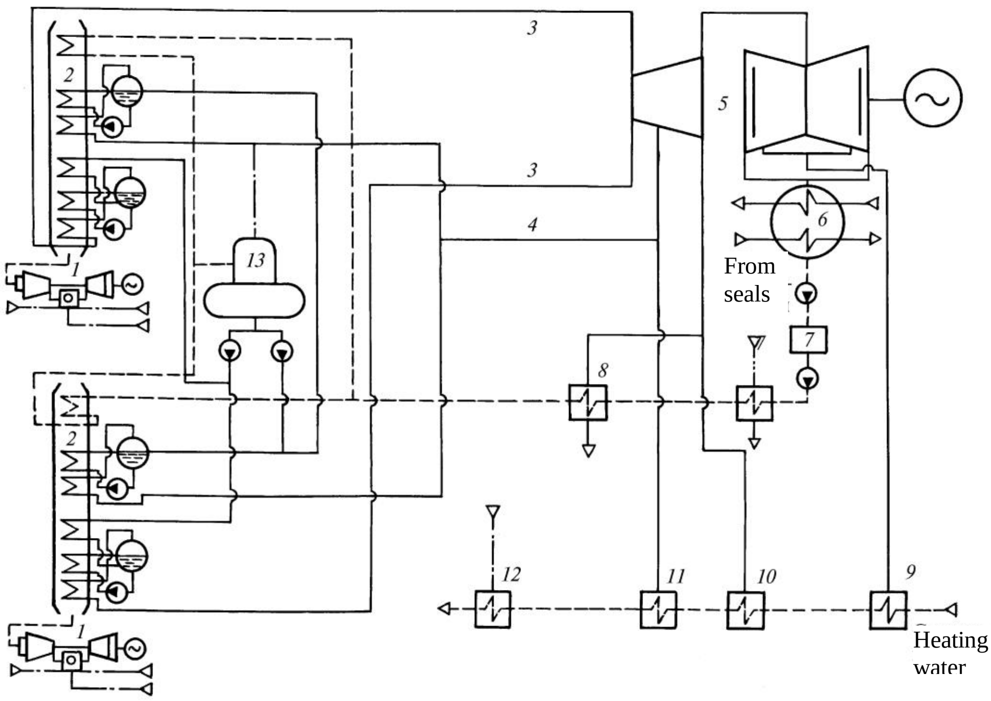

Fig. 6.8. Principal flow diagram of the combined cycle unit CCU-450T:
1 — gas turbine (GT); *2* — Drum double pressure HRSG of P-90 type; *3* —high-pressure pipelines to the steam turbine; *4* — low-pressure pipelines to the steam turbine; *5* — steam turbine; *6* — steam turbine condenser; *7, 8* — low-pressure heaters; *9, 10* — horizontal heaters of the heating water HHWH-1 and HHWH-2; *11, 12* — vertical heaters of the heating water VHWH-3 and VHWH-4; *13* — Deaerator (0,65 MPa)

The principal thermal flow diagram of CCU-450T, designed by VTI for the Northwest combined heat power plant of St.-Petersburg (Fig. 6.8) is the first in a series of unified designs of GTU exhaust heat utilization, implemented at a number of power plants: CCU-450T of Kaliningrad CHPP-2, 27 and 21 of the JSC “Mosenergo”, CCU-325 of Ivanovo SDPP, CCU-39 of Sochi TPP.

Complete GTU V94.2 (manufactured in Russia by OJSC “Power machines” – LMZ branch, under the name of GTE-160) is widely applied in CCUs abroad. A condensing CCU on its base has an efficiency of 51 … 52 %. Each GTU is a single shaft machine, equipped with two outside low toxic combustion chambers, providing NO_x concentration in exhaust gases below 25 million^{-1} (at 15 % O_2 content in exhaust gases). Due to the fact that diesel fuel is provided as an emergency one, water is injected into the combustion chamber for reduction of NO_x emissions.

Electric generator of GTU is cooled by air, which is cooled by condensate in a closed cycle. From the heated condensate the heat is removed by a circulating water in the water-to-water heat exchanger.

Heat-recovery steam generators have a tower configuration of the heating surfaces, made from pipes with lateral spiral finning. GT exhaust gases enter the HRSG from the bottom. Each HRSG includes two steam generation paths — a high-pressure (8,0 MPa) and a low-pressure (0,65 MPa) path, aimed at deep cooling of exhaust gases. The high-pressure path consists of an economizer, a boiler and a steam superheater, a low-pressure path consists of a boiler and a steam superheater. The first on the gas course is a high-pressure path, the second — low-pressure, a gas heater of condensate (GHC) is at the boiler exhaust. To prevent from condensation of steam from the exhaust gases at the last tubes of the gas heater of condensate (GHC), the condensate temperature at the GHC input is maintained below 60°C by recirculation of heated condensate to its input. For additional decrease in exhaust gas temperature, a water-to-water heater is included into the condensate recirculation line. The heater is cooled with the heat supply system make-up.

The steam turbine has two cylinders — a high-pressure turbine (HPT) and a low-pressure turbine (LPT). The high-pressure steam enters the turbine through two units of stop-control valves. Steam is supplied to each valve unit from one boiler. Each steam line can be disconnected from the steam turbine by two main steam valves (MSV-1 and MSV-2). Low-pressure steam is fed directly through a casing of high-pressure cylinder (HPC) between the 16th and 17th stages. A separator for moisture extraction is provided in a receiver between HPC and LPC. The dense rotary diaphragm is applied for effective regulation of heat loading. Its closing provides the minimum leakage of steam into the condenser. The turbine condenser is cooled by circulating water. Its heat is removed to a "wet" cooling tower. The condenser is also equipped with the built in heat exchanger, cooled by the heating system make-up that yields a decrease in heat losses with circulating water.

Power generators of steam and gas turbines are air-cooled.

A heat supply unit includes four stages of heating of the heating water. It consists of two horizontal heating water heaters (HHWH-1 and HHWH-2) and two vertical (VHWH-3 and VHWH-4) heaters. The heaters VHWH-3 and VHWH-4 are thus connected by steam that can be fed from steam turbine extractions and directly from HRSGs. In the last case the steam turbine can be disconnected, thus, the unit has maximal heat load. VHWH-3 and VHWH-4 are connected by heating water so that it is possible to release hot water in two streams with different temperatures.

The condensate-feed cycle includes a unit desalinating installation, a condenser of steam from steam turbine seals, a low-pressure heater, put into operation when in GTU liquid fuel is combusted, a deaerator with the working pressure of 0,65 MPa, condensate and feed pumps.

Start-up- exhaust devices, unit reduction and cooling installation of high pressure and reduction installation of low pressure are provided in the scheme yielding the unit start-ups at various combinations of the working equipment. Beside their direct purpose, they are used to reduce steam parameters at operation of the unit only with VHWH-3 and VNWN-4. When the unit is started-up, steam can be exhausted either to the condenser or the heating system water heater in the presence of heat demand. The last option is preferred as it excludes heat losses at start-ups. Steam turbine start-up is, thus, carried out by gradual steam transfer from the heater of heating water to the steam turbine according to the start-up mode diagram.

Each steam line is equipped with injecting steam coolers in order to prevent from inadmissible temperature of high-pressure steam at a steam turbine inlet (above 545°C) which may occur at high ambient temperatures. The same steam coolers can be used to decrease steam temperature at start-up of the steam turbine.

A combined cycle unit CCU-450T operates in the following modes (ST-steam turbine, HRSG- heat-recovery steam generator, C- condenser, BIH- build-in heater, HSU-heat supply unit, relative heating load is shown in brackets, 100% load is provided at completely closed diaphragm):

2×STU + 2× HRSG + ST +C	Condensation mode
1×GTU + 1× HRSG + ST + C	Condensation mode
2×GTU + 2× HRSG + ST + C + BIH + HSU (100 %)	Heating mode
1×GTU + 1× HRSG + ST + C + BIH + HSU (100 %)	Heating mode
2×GTU + 2× HRSG + ST + C + BIH + HSU (more than 0 — less than 100 %)	Combined modes
1×GTU + 1× HRSG + ST + C + BIH + HSU (more than 0 — less than100 %)	Combined modes
2×GTU + 2× HRSG + HSU	Heating mode
1×GTU + 1× HRSG + HSU	Heating mode

HRSGs and a steam turbine are passive elements of the unit, their steam production and capacity completely depend on a gas turbine operating mode. Every GTU loading can be regulated in two ways: by means of the inlet guide apparatus together with the fuel control valve, and also with the only help of the fuel valve. In the first case the economical efficiency is maximum; a loading range of each GTU is of 100 to approximately 60 %. In the second case GTU can be unloaded to the no-load running at a subsequent efficiency decrease. A basic operating mode of the unit steam part is the sliding pressure mode, where bottom limit is approximately 50 % of the GT loading due to technical restrictions of the HRSG.

Feed water from a deaerator is pumped by three high-pressure feed pumps (one of them is a stand-by pump) and three low-pressure feed pumps (one of them is a stand-by pump) and directed to:

- the low pressure circuit — directly to the steam drum;
- the high-pressure circuit — into the water economizer.

The control feed valve of a high-pressure cycle is installed after the water economizer to prevent from possible water boiling in it and disturbance of hydrodynamics. Steam is generated in the boiler with repeated compulsory circulation of an agent, performed by two circulating pumps (one of them is a backup pump). Diameters of steam drums are substantially larger than for power steam boilers in order to prevent from entering the boiler water to the steam superheater at increase in water level during start-ups. Diameter of a high-pressure drum is 2400 mm, low-pressure drum — 2200 mm. High-pressure drum is manufactured from the special steel with wall thickness of 52 mm in order to prevent from high thermal tension. The low-pressure boiler is also designed with a repeated compulsory circulation.

Saturated steam, leaving a drum, enters the steam superheater, where it’s overheated to the temperature corresponding to the GTU load. Temperature regulation is not provided.

As it has been mentioned before, steam supply from each boiler to the turbine is performed though a separate steam line. When two gas turbines are operating within the 60 … 100 % load range, the high- and low-pressure control valves are completely opened. At loads below 60% of the nominal value, turbine valves keep high pressure of 4,0 MPa and low pressure of 0,45 MPa. Condensate pumps feed the main condensate to the unit desalination installation. Condensate from heaters of the heating system is also supplied there after additional cooling. Unit desalinating installation can be bypassed by the main condensate when its quality is correspondent to the standard. Condensate pumps of the second stage feed condensate to the gas heater of condensate and then to the deaerator. A control valve is installed after each gas heater of condensate before the deaerator in order to prevent from condensate boiling. The control valve keeps pressure in the gas heater of condensate higher than the saturation pressure. To provide the required condensate underheating to a saturation temperature in the deaerator (5 … 10°C) full bypass of the gas condensate heater is provided in unexpected cases.

Thermal flow diagram of CCU-450T is developed yielding any combination of power and heat load within a technical range of power loads and a heat load in a range from its maximum to its full absence (condensation mode). The following specific expenses of a reference fuel for the generated electricity are achieved during the heating period under operation in a heating mode with optimum equipment composition:

External air temperature, °C	—40		—26		—14,7		—2,2		+8	
Heat load, Gcal/h	Above 140	Less 70	Above 130	Less 110	Above 130	Less 100	Above 120	Less 100	Above 160	Less 100
Specific fuel consumption g/(kW·h)	150…160	210	150	180…206	143…148	165…205	140…145	160…185	135…145	154

Combined cycle unit CCU-325. A power unit CCU-325 is a combined cycle unit of a binary type, designed for power generation in a base and semi-peak modes. The primary and reserve fuel is natural gas, emergency — diesel fuel.

The power unit consists of:

• two GT of GTE-110 type, developed by SIU "Mashproekt" (Nikolaev) and manufactured by OJSC "Saturn", with turbine-generators TFG-110-2UZ of JSC “Electrosila” (St.-Petersburg);

• two horizontal HRSGs of P-88 type, OJSC “ZIO” (Podolsk);

• one steam turbine of K-110-6,5 type with a heating system unit OJSC "LMZ" (St.-Petersburg) with turbine- generators TFP-110-2UZ of JSC "Electrosila";

• auxiliary equipment;

• automatic control system.

Total capacity (gross) of the combined cycle units makes 327 MW, efficiency — 51,5 %, at an ambient temperature +15 °C, NO_x concentration in the exhaust gases doesn't exceed 50 mg/m^3 (at 15 % O_2).

Principal flow diagram of CCU-325 is shown in Fig. 6.9.

The gases after performing work in gas turbines enter HRSGs, consisting of two pressure paths, where they are cooled approximately to 100°C, and then the gases are exhausted to the atmosphere through a stack. A gas stop valve is installed after each HRSG. It shuts down when a GT stops and a HRSG is decommissioned into a hot stand-by. A bypass start-up stack is not provided. Condensate from the steam turbine condenser is pumped by condensate pumps to the steam condenser of sealing and then enters the gas heaters of condensate (GHC), installed after each HRSG. After a GHC condensate enters the deaerator. The deaerator is fed by a low-pressure steam. Recirculation pumps return the heated condensate after GHC to the condensate line at the GHC inlet in the volume sufficient to provide a temperature after mixing of more than 60°C. This measure yields to prevent from oxygen corrosion of the inlet pipes. The water-to-water heat exchanger with the individual pump is included into the second recirculation line, parallel to the first line. This heat exchanger is the first stage of water heating before the heat supply system. The heating water is heated by condensate, heated in a GHC. Using of water-to-water heater yields deeper cooling of flue gases. Additional cooling of gases by 10°C allows generation of about 3,5 Gkal/h of heat in each boiler. Control feed valves are installed after the GHC to prevent from condensate boiling in it. Their main purpose is distribution of condensate flow between the boilers in accordance with the heating load of a GT. Besides, at further development they can be used for regulation of water level in the deaerator. Feed water from the deaerator, operating at a pressure of 0,6 … 0,7 MPa, is pumped by electric feed pumps of low pressure directly to the low-pressure drum, and

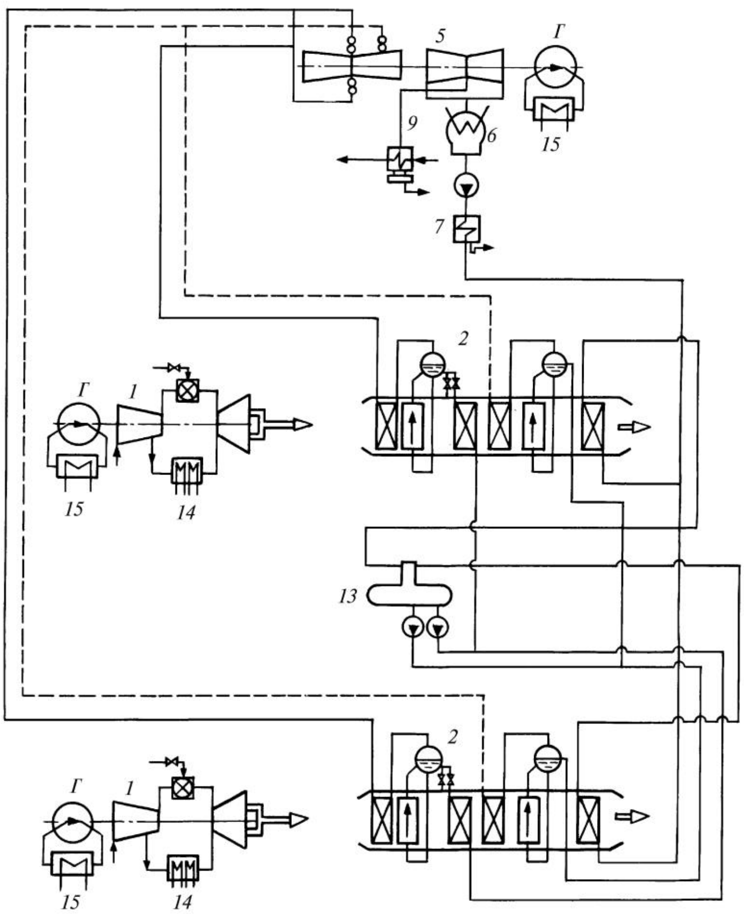

Fig. 6.9. Principal flow diagram CCU-325:
1—13 — the same as in Fig. 6.8; *14* — GT air cooler; *15* — generator air cooler

by high-pressure electric feed pumps - to the economizer of a high-pressure circuit. Control of water level in the drum is provided with the feed valve, installed before it. Water, entering the low-pressure drum, evaporates in the low-pressure boiler, and the generated steam is superheated and directed to an intermediate point of the steam turbine. Some steam, generated in a low-pressure cycle, is supplied to the deaerator without entering the turbine for condensate deaeration. A high-pressure electric feed pump supplies feed water to the high-pressure cycle. Steam, generated in a high-pressure cycle, enters a high-pressure turbine. Both boiler drums are equipped with emergency discharges in case of water level increase above the set level. Besides, periodic blow down is provided from the bottom points of high- and low-pressure boilers. Regulation of low- and high-pressure steam temperature is not provided. Boiler steam lines of high- and low pressure are united with a crosspiece before the steam turbine for uniform supply of steam to the high-pressure turbine at operation with one boiler. High- and low-pressure steam bypasses of the steam turbine are provided for each boiler for independent start-ups of gas turbines with HRSGs and the steam turbine. Each boiler is equipped with a separate rapid action reduction-cooling unit, designed for the nominal steam consumption at operation of the steam turbine with one gas turbine. Low-pressure steam bypasses are equipped only with reduction-cooling valves. Heat supply system of the steam turbine K-110-6,5 consists of one heater of heating water preliminary heated in a water-to-water heat exchanger. Electric generators are cooled by conditioned air cooled with technical water in the water-to-air heat exchanger.

Outside heat exchanger is provided for cooling the air, used for GT blades cooling.

Ventilation of the GT case is performed by air, selected from a complex air cleaning device with the help of smoke exhausters.

Combined cycle unit CCU-80. A power unit CCU-80 is designed for power and heat supply of medium and small towns and settlements, back-up of power supply of responsible objects. The combined cycle unit CCU-80 can be used both in regions distant from power supply systems and newly mastered regions and in large towns for reconstruction of steam turbine TPPs, worked out their resource.

For operation of the combined cycle unit CCU-80, supply of gas with pressure of more than 0,18 MPa and flow rate of 13000 kg/h and water supply with flow rate of 6 m^3/h are required.

The combined cycle unit is designed for operation in base and semi-peak modes. It can be used to cover peak loads if necessary as it possess high maneuverability (start-up time is approximately 12 minutes).

Primary fuel for the combined cycle unit is natural gas. Diesel fuel is provided as a reserve one.

Complete combined cycle unit includes the following equipment:

Basic modules:

- two gas turbine units with engines NK-37-1, electric generators with a rated power of 32 MW and serving systems;
- compressor equipment modules;
- module of the steam-power equipment with a steam condensation turbine and the electric generator of a rated capacity of 20 MW;
- module of a condensate air cooler, including pipelines and feed fittings, distribution and withdrawal of cooling water from a condensate cooler ("dry" cooling tower);
- module of chemical treatment;
- electric and technical systems. Totally 14 containers (modules) are delivered.

Automatic control system of the combined cycle unit

Separately installed equipment:

- two HRSG;
- an air cooler of condensate ("dry" cooling tower);
- two installations for neutralization of nitrogen oxides in exhaust gases (gas purification installation);
- two waste storages - tanks from NO_x neutralization installations;
- air oil cooler of an oil supply system of the steam turbine generator;
- air water cooler of the turbine generator cooling system;
- gas pipes with gate valves and silencers for gas delivery from gas turbines to HRSGs.

Maximum capacity of the combined cycle unit at operation of one GT and a steam cycle makes 32,1 MW (ambient temperature makes 15°C). Capacity of the steam turbine is 8,5 MW in the condensing mode, heat production in a mode with steam bleeds for a heating system makes 24 Gcal/h (heating water temperature 70/118°C) with the turbine capacity of 3,15 MW.

In process of CCU steam circuit operation only for heat generation at the stopped steam turbine, heat supply is provided as follows:

• 60,4 Gcal/h — in case of two gas turbines in operation, flow rate of 1000 m^3/h, water temperatures of 70/130 °C;

• 29,8 Gcal/h — in case of one gas turbine in operation, heating water flow rate of 500 m^3/h, water temperatures of 70/130°C.

Duration of starting-up and loading of the first started-up gas turbine unit makes 12 min, in emergency cases it’s less than 5 minutes.

Duration of HRSG start-up till the full load is not more than 60 minutes.

Duration of the steam turbine start-up, starting at a high pressure of steam 1,2 MPa (abs.), from the cold condition — less than 40 minutes, from the heated-up condition — less than 25 minutes.

Regulation of the combined cycle unit load within the regulated range can be performed without time restrictions by changing the GT load.

Operation of the steam path of the combined cycle unit is provided in the sliding high-pressure mode at a pressure change within the range of 4,0….2,0 MPa (abs.), depending on a load. Low pressure of steam in all modes is maintained constant and equal to 0,75 MPa (abs.).

A fuel gas diesel-compressor, keeping the gas pressure at the engine inlet of about 1,7 MPa, and the starting air electric compressor for start-up the engine from pneumatic starter are provided for the GT start-up operations.

Commissioning of the power plant is carried out by main fuel compressors when there is power in the external power network.

Compressors for starting gas and air are the same for two gas turbines and located in a separate container. Compressors are equipped with service systems, providing their start-up and operation, devices for clearing of supplied gas and air. Receivers and fittings, necessary in starting air system, are located in a separate module.

Exhaust gases after each boiler enter the installation for NO_x neutralization, performed by raw water. NO_x appeared in the GT combustion chamber. Gas cleaning efficiency makes 90 … 95 %. Concentration of nitrogen oxides after the installation is expected to be less than 50 mg/m^3.

The condensate from all apparatuses of the installation is removed to the electric flotation filter. After it the purified water returns to ionizers for its further using in a gas cleaning cycle, and solid wastes are dried up and collected in the bunker, from which at a flow rate of about 3,5 t/day (from two installations) they are transported to two storage-tanks, designed for a three-day collection. Equipment for water treatment and its cleaning after utilization in the installation is located in separate modules.

In CCU-80 all polluted, mineralized and oily waste waters and also operational leakages through equipment connection, collected in a power plant collecting tank, enter thermal treatment unit. Thermal treatment of waste water is not economically proved, but it is almost a unique complex method of waste water utilization for an environmentally-clean technology of power generation. Efficiency of waste water clearing is 96 … 99 %. The thermal treatment principle is based on waste water evaporation in the fire chamber burning natural gas, as well as on concentration of admixtures and separation of solids in the suspension separation unit. 0,1 m^3 of gas is required for evaporation of 1 kg of waste water. The solid phase, collected in the bunker, should be periodically removed from the power plant territory to special storage places.

Two waste water treatment units are provided, one of which is a stand-by.

All thermal treatment units are placed in a separate module.

The basic CCU-80 features are shown below:

Capacity of the power plant (gross/net), MW·h:
In a condensation mode …………………6,84/63,94*
With steam extraction for heating ………58,11/55,21
Heat for central heating, providing a heating temperature of 150/70°C, Gcal/h ………………………40
Efficiency in a condensation mode
(Gross/net), % …………………………47,12/45,08*
Heat utilization ratio
(Gross/net), % ……………………………73,8/71,7*
Nominal generator power, MW:
with a drive from gas turbines …………………….32
with a drive from steam turbines ………………….20

Notes.
1.The characteristics are provided:
at the rated temperature of external air 15°C;
at the rated pressure of external air 0,1013 MPa;
at operation of after burning devices of HRSG.
2.The characteristics marked with * are specified at fuel gas pressure before the CCU-80 of 4,5 MPa.

Combined cycle units of low capacity

On the base of GTUs with capacity below 20 MW there can be created CCUs of small capacity for industrial and municipal needs. Short description of studies, carried out by Russian companies [6], is provided below.

Designs of several combined cycle units, based on AL-31STE engine, described in Tab. 6.9, have been developed by the scientific institute “Teploelectroproekt”.

Shakhtinskaya CHPP was constructed in Rostov region based on a design, developed by a scientific industrial enterprise (SIE) “Energoperspectiva”. Four J-59LZ engines of SIU "Mashproekt" are installed at the thermal power plant. The first two engines of Shakhtinskaya CHPP are equipped with heaters of heating water, the third and the fourth - with HRSGs. A steam turbine is planned for installation at the CHPP. Fuel afterburning before boilers is provided in all options. Design features of the CHPP are presented below:

Installed heat power, MW	63,2
Installed heat capacity, Gcal/h	547,8
Number of hours of the installed electric power use, h	7465
Specific reference fuel consumption, g/(kWt·h)	193,2
Specific capital investments, rub/kW (1991)	2717

Scientific institute "VNIPIenergoprom" designed a combined cycle unit CCU-40 with a capacity of about 40 MW, operating under discharge scheme. The combined cycle unit consists of one gas turbine CCU-16 (SIU "Mashproekt"), a power boiler E-160 (Sibenergomash) and a steam turbine T-25/30.

Features of the thermal power plant on the basis of the CCU-40 are presented below:

Installed heat power, MW	188
Installed heat capacity, Gcal/h	350
Number of hours of the installed electric power use, h	6500
Number of hours of the installed heat power use, h	6500
Fuel (main/reserve)	Gas/oil
Specific reference fuel consumption, g/(kW·h)	290
Specific capital investments, rub/kW (1991)	672,2
Specific manpower, people/MW	1,39

The units described above do not limit the possible combinations of equipment and rated CCU capacities. Almost all design institutes of RAO “UES of Russia”, scientists and manufactures of GTU are working on development of similar units.

Gas turbine combined heat power plants

The simplest combined installation is a GTU-CHPP, representing a combination of a gas turbine and a gas heater of heating water (HSWGH). The first GTU-CHPP of this type was built in 1978 for heat supply of Yakutsk. Four gas turbines of GTE-35 type and three gas turbines of GTE-45 type ("Turboatom") are currently in operation there. Total power capacity makes 300 MW, the maximum heat load supplied by the power plant, makes about 350 Gcal/h.

Gas heaters of heating water are in operation for more than 15 years almost without repairs and have shown high operational and thermal technical characteristics.

Table 6.9. **Design characteristics of some combined cycle units**

Characteristics	CHPP-20 of the JSC “Mosenergo”	Novorossiyskaya CHPP	Kaluzhskaya CHPP (site. 1)	Kaluzhskaya THPP (site. 2)
Installed electric power, MW	162	216	110	92
Installed heat power, Gcal/h	200	144	122	190
Number of hours of the installed electric power use, h	5570	6500	6610	6460
Number of aviation engines	6	8	4	4
Specific reference fuel consumption, g/(kW·h)	204,8	220	218	180
Specific capital costs, rub/kW (1991)	345	472	625	647
Specific manpower, people/MW	116	196	187	187
Specific area of construction, m^2/kWt	—	—	0,386	0,325

Proposals of manufactures of aviation and ship engines on production of low-capacity power gas turbines, as well as design of such turbines by power machinery works have strengthened an interest in construction of GTU-CHPP for replacement, first of all, of regional boiler-houses in small towns, provided with natural gas. This option, eventually, doesn't exclude an application of large gas turbines within GTU-CHPP when a constant large-scaled heat supply is required.

Any gas turbine can be equipped with HSWGH for system water heating, or with HRSG for industrial heat supply.

In addition to the mentioned Yakutskaya SDPP and Shakhtinskaya CHPP being, as a matter of fact, GTU-CHPPs, Dzerzhinskaya SDPP of SC “Nizhnevartovsk” should be also mentioned, where GTU-CHPP with HRSG based on a "Siemens" gas turbine V94.2 is in operation.

Hybrid installations with GTU. The next step in development of combined cycles for thermal engineering is construction of "hybrid" installations (Fig. 6.10). In such installations GTU or CCU is build-up with fuel elements [7].

High temperature fuel elements, operating under 850°C (solid oxide) and 650°C (based on melted carbonates) may serve as a heat source for gas and steam cycles. In the last case it becomes a “triple” system instead of a binary. In process of development of the certain units with capacity of 20 MW, performed is the U.S., the achieved efficiency made about 70% at combustion of natural gas with internal reforming into CO and H_2. Of course, there are possibilities of feeding of fuel elements with synthesis-gas and pure hydrogen, obtained, for example, using oil gasification. In the existing programs there’s a task to increase in future a capacity of hybrid units to 300 MW and higher and their efficiency up to 75% in case of gas combustion and 60% at coal combustion.

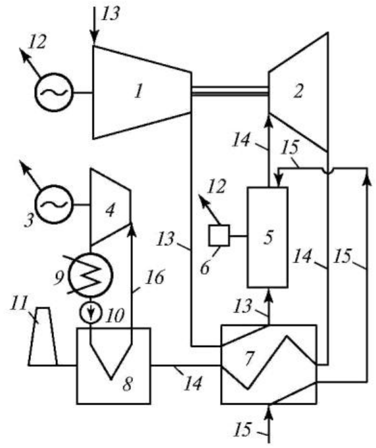

Fig. 6.10. Hybrid power unit:
1 — GT compressor; *2* — gas turbine; *3* — power generator; *4* — steam turbine; *5* — fuel elements; *6* — invertors; *7* — heat exchanger; *8* — HRSG; *9* — condenser; *10* — pump; *11* — stack; *12* — power to the network; *13* — air; *14* — fuel combustion products; *15* — cleaned natural gas; *16* — steam

In the breakthrough project of coal-fired TPP without emissions [8] an efficiency of 70% is mentioned. The difficulties are connected with high price of fuel elements and limited capacity of separate fuel cells, which can be hardly technologically combined in one large installation. Considering this, the first commercial power units with fuel elements will be more likely of a small capacity (from 3…5 to 1100…3000 kW) and intended for independent units of electric and thermal energy generation.