P a r t 6

# ADVANCED TECHNOLOGIES AND POWER INSTALLATIONS FOR THERMAL AND ELECTRIC ENERGY GENERATION

## 6.3. Heat and power supply units of low capacity

### 6.3.4. Changes in heat load diagrams within a year and their influence on a choice of equipment of small CHPPs

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Statistical processing of change in the average daily ambient air temperature within a year and change in the correspondent heat demand was conducted for preliminary analyses of thermal capacity, ambient air temperatures and assessment of power generation.

Statistical process analyses showed that it is expedient to divide the whole calendar year into several seasons with typical levels of ambient air temperatures, aimed to simplification of calculations:

I — season with maximal winter load with the average daily ambient air temperature $t_{amb.} \leq -20°C$, duration of the period is 172 hours. It is observed, as a rule, in January and February. Average temperature of the whole period is $t_{amb.} = -22°C$;

II —winter period with the average daily temperature of ambient air $t_{amb} = -15°C$, duration of the period is 733 hours. Such temperatures are, as a rule, observed in January, February and at the end of December, temperature range is –20 … –10°C;

III —winter with the average daily temperature of ambient air during the period $t_{amb.} \approx -5°C$, duration of the period is 2128 hours. Such temperatures are observed, as a rule, from November to the second half of March, temperature range of ambient air is 0 to –10°C;

IV —autumn- spring period with the average temperature of ambient air during the period $t_{amb.} = +4°C$; duration of the period is 1877 hours. The second half of April, the whole October refer, as a rule, to this period, temperature range is +8 to 0°C;

V —summer non-heating period, average daily temperature for the whole period is $t_{amb.} > +12°C$. Duration of the period is 2 months (May, September – 1464 hours);

VI—summer non-heating period, average daily temperature for the period $t_{amb.} > +18°C$. Duration of the season is 2016 hours.

Duration of loads during the periods is given in Fig. 6.13. Comparison of results of thermal load calculations, obtained in accordance with Fig. 6.13 and received on the base of statistics, showed that the accuracy is within 2%. Further calculations are based on seasonal average data that significantly simplifies calculations without accuracy losses.

Following from Fig. 6.13, during the heating period power generation units are completely loaded with heat loads and, therefore, are able to generate maximal capacity regardless of variation of hot water load during the day and day of a week. When switching to the non-heating period, power generation equipment starts operating only with a hot water supply load, which, firstly, goes down compared to an average yearly load and, secondary, has significant fluctuations through a day and a week. Decrease in hot water supply load in summer is shown in Fig. 6.13.

Estimated diagram of hot water supply through a summer day of a non-heating period (for the middle European climate zone, Moscow) is shown in Fig. 6.14. These results are obtained, based on statistical processing of hot water load diagrams, provided in [1-3].

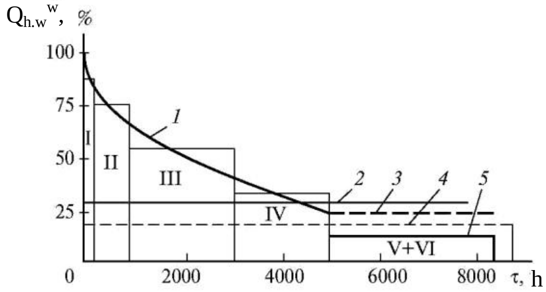


**Fig. 6.13. Heat load change within a year in Moscow:**
*1* —total load of heating, ventilation and hot water supply; *2* — total calculated heat load of hot water supply; *3* — total calculated heat load of hot water supply in summer; *4* — total average yearly load of hot water supply; *5* — total average load of hot water supply in summer

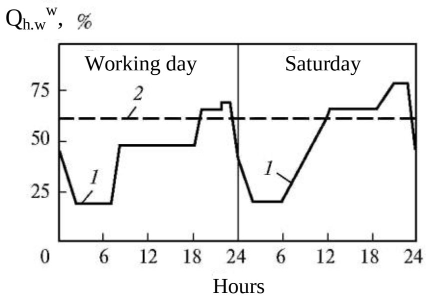


**Fig. 6.14. Change in hot water supply load during a day (summer, middle European climate zone):**
*1* — diagram of hot water supply load change; *2* — total average yearly load of hot water supply

Hot water supply load diagram, presented in Fig. 6.14, shows that hot water supply load decreases at night to approximately 20% of the total calculated load of hot water supply. At that, if only one steam turbine and one steam boiler are installed in the boiler-house to cover the total hot water supply load, then operation according to the thermal load diagram can't be ensured due to technical restrictions, connected with a level of minimal possible load of the boiler and the turbine. Therefore, when choosing power generation equipment for the boiler-house, aimed to cover the total calculated load of hot water supply, there should be installed minimum two units, each of which intended to cover a half of the total calculated load of hot water supply.

In this case in summer one of the units will cover the load and the second will be in a stand-by state or in a planned maintenance, yielding sufficient passing of overnight fall of hot water demand. In order to cover a peak of the diagram a stand-by unit or a water heating boiler will be put into operation.

In case of installation of power generating equipment in the boiler-house to cover a total average annual load of hot water supply, installation of separate units is possible. Thus, in order to pass an overnight fall of hot water demand, the unit capacity does not become less than 40…50% yielding its operation within the whole range of hot water supply load. To cover peak loads, water heating boilers are put into operation, providing an increase in heat supply from the boiler-house.

Types of turbines that can be installed in boiler-houses of different capacities were determined based on hot water supply and thermal capacity of steam turbines. Tab. 6.13 presents some possible options of installation of steam and gas turbines in boiler-houses of different capacity.

Based on variations of hot water heat load, levels of loading of steam and gas turbines were re-estimated under operation in heat load modes in accordance with Fig. 6.14.

Levels of unit loading depend both on hot water supply load and individual characteristics of power generating equipment. Therefore, let's limit our preliminary analyses with consideration of only two types of machines: GT NK-37 and a steam turbine PR-6-3,4/1,0/0,1-1.

Table 6.13**. Possible options of steam and gas turbine installation in boiler-houses**

| Installed capacity of the boiler-house, MW | Heat load of hot water supply, MW | Steam turbine type | Gas turbine type |
|---|---|---|---|
| 10 | 1,55...2,2 | TG-0,6/0,4-K2,8 | — |
| 20 | 3,1...4,4 | TG-0,6/0,4-K2,8 | — |
| 30 | 4,65...6,6 | 2xTG-0,6/0,4-K2,8<br>TG-0,6/0,4-K1,3 | |
| 40 | 6,2...8,8 | TG-1,2/0,4R24/1,2<br>2×TG-0,6/0,4-K2,8 | GTU-2,5P |
| 50 | 7,75...11,0 | TG-1,2/0,4R24/1,2<br>3×TG-0,6/0,4-K2,8 | GTU-2,5P |
| 60 | 9,3...13,2 | R-2,5-3,4/0,3-1<br>2xTG-1,2/0,4R24/1,2 | 2xGTU-2,5P<br>GTU-4P |
| 80 | 12,4... 17,6 | 4xTG-0,6/0,4-K2,8<br>R-2,5-3,4/0,3-1<br>R-2,5-2,1/0,3-1 | Tornado<br>GTU-4P<br>Tornado<br>Tempest |
| 100 | 15,5...22,0 | 2xR-2,5-3,4/0,3-1<br>R2,5-2,1/0,3-1<br>PR-2,5-1,3/0,6/0,1 | 2xGTU-4P<br>2xTornado |
| 120 | 18,6...26,4 | PR-6-3,4/0,5/0,1-1<br>2xR-2,5-3,4/0,3-1 | 2xGTU-4P<br>2xTornado |
| 150 | 23,25...33,0 | PR-6-3,4/0,5/0,1-1<br>PR-6-3,4/1,0/0,1-1 | 2xTornado<br>2xTempest |
| 200 | 31**...** 44 | PR-12-3,4/0,6/0,1 | GTG-16<br>NK-37<br>GTU-25 |