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TRANSLATIONS ON USSR RESOURCES

(FOUO 15/79)

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CONTENTS PAGE

ELECTRIC POWER AND POWER EQUIPMENT

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DEVELOPMENT AND OPERATING CONDITIONS OF THE HEAT AND ELECTRIC POWER PLANTS IN THE POWER SYSTEM

Moscow TEPLOFIKATSIYA SSSR in Russian 1977 signed to press 5 May 77 pp 25-50

[Article by S. Ya. Belinskiy, Energiya Publishing House, 8,000 copies]

[Text] Initial Period of Development of District Heating (1924-1932)

The development of Soviet power engineering on the scales of the GOELRO Plan created by the initiative of V. I. Lenin was a powerful incentive for the beginning of construction of the heat and electric power plants in our country and the district heating systems connected with them.

During the beginning of the implementation of the GOELRO Plan, some of the first peat-using branches of industry starting restoration after the destruction of the Civil War were the textile, paper and chemical production, and among the cities having the residential buildings with central heating necessary for district heating were the largest cities of the country, primarily Leningrad, Moscow, Khar'kov, Kiev and Rostov.

The basic difficulty when selecting the equipment for the first heat and electric power plants consisted in the absence during that period (in practice to 1929-1930) of a Soviet power machine building base, as a result of which the industrial heat and electric power plants had to be built primarily on the basis of imported equipment, and for a number of municipal heat and electric power plants, it was necessary to be limited to conversion of the condensation turbines to district heating turbines (the third LGES Hydroelectric Power Plant in Leningrad, the VTI Heat and Electric Power Plant in Moscow, and so on). When ordering equipment for the heat and electric power plants, they began with the necessity for operation of these plants (result of the absence of rayon power systems) as isolated plants, but with maximum generation of electric power for heat consumption. The little experience in building turbines with steam taps and condensation and the limited unit power of the turbines of 5000 to 6000 kilowatts resulted in the installation of district heating turbines of 2000 to 4000 kilowatts with counterpressure or worse vacuum at the overwhelming majority of new heat and electric power plants, and for covering peak loads, the purely condensation turbines with the same power.

In practice the implementation of the GOELRO Plan adopted by the 8th All-Russian Congress of Soviets of 22 December 1920 and proposing the construction of 20 thermoelectric power plants with a total installed power of 1110 Mwatts with a maximum power of the thermoelectric power plants of 100 megawatts over a period of 10 years, was completed by 1929.

The first thermoelectric power plant put into operation in accordance with the GOELRO Plan was the Kashirskaya GRES [State Regional Hydroelectric Power Plant] at which two 6000-kilowatt turbines were installed in 1922 for the following parameters: 1.6 MPa (16 kg-force/cm^2) and 350°C. Shortly after this, the Kizelovskaya GRES was introduced at 1.7 MPa (17 kg-force/cm^2) and 375°C with two turbines of 3000 kilowatts each.

In all, by 1925, that is, by the time of the beginning of the development of Soviet district heating in accordance with the GOELRO Plan, new capacity was introduced at the thermoelectric power plants on the order of 80 megawatts with turbines with a unit power of 2.0 to 6.0 Mwatts. From these data it follows that the construction of the heat and electric power plants started at that time with turbines for 1.8-2.2 MPa (18-22 kg-force/cm^2) and 350-375°C with a unit power of 2.0 to 4.0 Mwatts was completely appropriate.

In accordance with the GOELRO Plan, the newly built KES [condensation electric power plants] had to be the base for the birth and subsequent development of the power systems providing for centralization of the electric power supply of the country. Simultaneously, this centralization had to encompass both the previously built electric power plants and, consequently, the power plants operating in industry and in the cities independently of their departmental attachment. This association of previously disconnected electric power plants for operation in a common network led by 1924 to association into integrated electric systems in Moscow (seven electric power plants), Leningrad (five electric power plants, including two industrial ones), in the Donets Basin and other rayons. Both the construction of the rayon condensation electric power plants in accordance with the GOELRO Plan and the formation of the generated electric power systems became subordinate to a united center -- the Glavelektro VSNKh (subsequently reorganized into the Glavenergo NKTP). The summary indexes of the operation of the heat and electric power plants during the initial period of the development of district heating, namely from 1924 to 1932 are expediently considered for two periods: from 1924 to 1928 (that is, before the beginning of implementation of the first five-year plan) and from 1928 to 1932 (that is, during the Ninth Five-Year Plan).

The basic technical characteristics and operating indexes of the heat and electric power plants during these periods are illustrated in Table 1 as applied to the devices, the plans for which provided for them as general-use heat and electric power plants (the so-called rayon [district] TETs [heat and electric power plants]), and the devices designed by the plan for the power supply of the individual enterprises of the given branch of

Table 1

Basic Technical Specifications and Operating Indexes of the Heat and Electric Power Plants in 1928-1932

	(1) Показатели	1928 (2) ТЭЦ общего пользования	1928 (3) ТЭЦ промышленных предприятий	1928 (4) Всего	1932 (2) ТЭЦ общего пользования	1932 (3) ТЭЦ промышленных предприятий	1932 (4) Всего
(5)	Общее число ТЭЦ	2	11	13	7	39	46
(6)	В том числе на параметры:						
(7)	1,3—1,7 МПа (13—17 кгс/см²)	2	5	7	2	6	8
(8)	1,8—2,2 МПа (18—22 кгс/см²)	—	6	6	3	9	12
(9)	2,5—3,5 МПа (25—35 кгс/см²)	—	—	—	1	23	24
(10)	Свыше 3,5 МПа (35 кгс/см²)	—	—	—	1	1	2
(11)	Мощность ТЭЦ, МВт	2,6	44,0	46,6	50,0	340,0	390,0
(12)	Средняя мощность ТЭЦ, МВт	—	4,0	3,5	7,15	8,75	8,4
(13)	Число турбин	2	29	31	15	80	95
(14)	В том числе:						
(15)	с ухудшенным вакуумом	1	5	6	6	6	12
(16)	с противодавлением	—	15	15	4	44	48
(17)	с отбором пара и конденсацией	1	9	10	5	30	35
(18)	Средняя мощность турбин, МВт	—	1,5	1,48	3,3	4,25	4,15
(19)	Установленная тепловая мощность турбин, ГДж/ч (Гкал/ч)	75,42 (18)	2933 (700)	3008,4 (718)	1676 (400)	14 665 (3500)	16 341 (3900)
(20)	Отпуск тепла, млн. ГДж/год (Гкал/год)	0,1676 (0,04)	5,866 (1,4)	6,034 (1,44)	3,77 (0,9)	19,27 (4,6)	23,05 (5,5)
(21)	Отношение годовой выработки электроэнергии к отпуску тепла, кВт·ч/ГДж (кВт·ч/Гкал)	16,7 (70)	28,6 (120)	28,2 (118)	65,8 (276)	80 (335)	78,8 (330)
(22)	Число часов использования установленной электрической мощности	2000	4200	—	4000	4500	—
(23)	Годовая выработка электроэнергии, млн. кВт·ч	1,4	168,0	169,4	240,0	1550,0	1790,0
(24)	Удельный расход условного топлива на выработанную электроэнергию, г/(кВт·ч)	440	340	—	370	400	—

Key:

1. Indexes; 2. general-purpose heat and electric power plant; 3. heat and electric power plant of industrial enterprises; 4. total; 5. Total number of heat and electric power plants; 6. including for the following parameters:; 7. 1.3-1.7 MPa (13-17 kg-force/cm2); 8. 1.8-2.2 MPa (18-22 kg-force/cm2); 9. 2.5-3.5 MPa (25-35 kg-force/cm2); 10. Greater than 3.5 MPa (35 kg-force/cm2); 11. Power of the heat and electric power plants, megawatts; 12. Average power of the heat and electric power plants, megawatts; 13. No of turbines; 14. Including; 15. With worsened vacuum; 16. With counterpressure; 17. With tapping of the steam and condensation; 18. Average turbine power, megawatts; 19. Installed heating capacity of the turbines, gigajoules/hour (gigacalories/hour); 20. Release of heat, million gigajoules/year (gigacalories/hour); 21. Ratio of annual electric power output to heat output; 22. No of hours of use of installed electric power; 23. Annual electric power output, million kilowatt-hours; 24. Specified fuel consumption for generated electric power, grams/(kilowatt-hours)

industry (the heat and electric power plants of industrial enterprises). As follows from Table 1, this type of heat and electric power plant also became the most widespread during this period both with respect to the number of heat and electric power plants (85%) and with respect to power (95% in 1928).

During the first 3 years of district heating (1924-1927) only the third LGES Hydroelectric Power Plant in Leningrad releasing heat in the form of hot water for the communal-domestic purposes basically at the expense of live steam from the boilers, was in operation as a general-use heat and electric power plant.

The work started in 1925 with respect to conversion of the condensation turbines of the third LGES at 680 kilowatts to worse vacuum in practice was completed only in 1927.

The analogous operations in 1928 began to be performed in Moscow with steam feed from the experimental VTI heat and electric power plant (nearest to the plants and the pool) also initially live steam from the boilers, and then by using one of the turbines of the heat and electric power plant, in the structural design of which there turned out to be a suppressed, previously unregulatable steam tap.

Summing up with respect to the purely accidental circumstances (the presence of equipment with little value but suitable for the experiments) the third LGES Hydroelectric Power Plant turned out to be the prototype of the future heating TETs, and the TETs VTI, the industrial-heating TETs. Both of the TETs undoubtedly fit under the definition of the rayon plants, inasmuch as they serve various users.

It turned out to be of essential importance for the next hydroelectric power plant that the work on rebuilding the turbine at the third LGES plant was performed at the Leningrad Metallurgical Plant which, on the basis of this operation accumulated experience in the building of district heating equipment for the heat and electric power plants. The cost benefits from district heating obtained during operation and maintenance of this system turned out to be still more important. An electric power plant with the old worn 680 kilovolt condensation turbine which before rebuilding had a specific provisional fuel consumption with respect to electric power generation of 1046 g/(kilowatt-hour) had a consumption rate after being rebuilt when tested in the district heating mode of 238 g/(kilowatt-hour), and the mean annual specific consumption during the heating season of 1928-1929 was 380 g/(kilowatt-hour). The mean specific fuel consumption with respect to the best condensation electric power plants in 1928 was about 600 grams/(kilowatt-hour) with a calculated consumption of 520 g/(kilowatt-hour). The average consumption with respect to all of the KES [condensation electric power plants] in 1928 was 870 g/(kilowatt-hour).

It is natural that the experience in the operation of a total of two heat and electric power plants with two district heating turbines could not provide a basis for solving the problems with respect to selecting the type of newly manufactured turbines. Under these conditions it was more reliable to generalize the data accumulated at that time on the development of the heat and electric power plants in the industrial enterprises, the number of which for 1928 (see Table 1) had reached 11 with total power of the 29 imported turbines installed at them of about 44 megawatts (the average power of one turbine was about 1500 kilowatts). The greater part of these turbines (66%) were designed for operation by the heating chart (three-fourths of them were counterpressure turbines).

The installed thermal capacity of such heat and electric power plants was about 2933 gigajoules/hour (700 gigacalories/hour), but for a number of reasons no more than 30% of this power was used, as a result of which the maximum operating power of these heat and electric power plants did not exceed 25 megawatts. The annual number of hours of use of the installed capacity was only 3800 (with a defined value of about 6500).

The basic cause of this location of the calculated and operating indexes was lagging of the actual growth of the thermal process loads of the enterprises behind the planned growth which only partially could be compensated for by the generation of electric power in the turbines with steam tapping and condensation as a result of their small number and relatively low capacity (total of about 20% of the total installed capacity).

This worsening of the operating conditions of the heat and electric power plants found reflection in the growth of the specific fuel consumption for the generation of electric power increasing in this case from the designed values of about 240 g/(kilowatt-hour) to 340 g/(kilowatt-hour) (on the average 11 heat and electric power plants in 1928), which still was almost 2.5 times lower than at the rayon condensation electric power plants. Under these conditions the further development of heat and electric power plants based on turbines with counterpressure apparently provided better prospects with respect to fuel savings. For these reasons, for the subsequent development of the district heating and the first five-year plan for the heat and electric power plants of Moscow and Leningrad 12,000 kilowatt counterpressure turbines were ordered from the Leningrad Metallurgical Plant with an analogous increase in power for the turbines of the heat and electric power plants of the industrial enterprises newly ordered for import, for which the same structure of the types of turbines as before 1928 basically was retained (see Table 1).

Along with increasing the unit power of the turbines, the increase in the initial steam parameters for the majority of heat and electric power plants to 2.6-3.5 MPa (26-35 kg-force/cm^2) and for only two of the heat and electric power plants to 6.4 MPa (64 kg-force/cm^2) was essentially new in the 1928-1932 period. In contrast to the KES [condensation electric power plants] the increase in the initial parameters of the heat and electric power plants having turbines with counterpressure in practice did not lead to a reduction in the specific fuel consumption for the generation of electric power, but during this time, the district heating capacity of the heat and electric power plants increased by 1.5-2 times and, consequently, there was a fuel savings.

As is demonstrated in Table 1, the number of general-use heat and electric power plants increased during the first five-year plan to 7 with a total power of 50 megawatts, whereas the number of heat and electric power plants of the industrial enterprises reached 39 with a capacity of 340 megawatts. The development of the general-use heat and electric power plants took place basically at the expense of using turbines with worse vacuum and with tapping of the steam and condensation, that is, the turbines providing for the use of them to cover the electric power load charts independently of the presence of heat consumption. The proportion of these turbines was about 75%. Almost all of the turbines with worse vacuum were obtained as a result of conversion of the purely condensation units.

The specific fuel consumption for the generation of electric power dropped from 440 to 370 g/(kilowatt-hour) as a result of improvement of the initial parameters of steam (which improved the indexes of the turbine with worsened vacuum during operation of these turbines in the condensation mode).

The characteristic feature of the operation of the majority of general-use heat and electric power plants of that period was the fact that the development of the heating networks and the output of heat through them to the residential-communal sector led the thermal capacity of the turbines, as a result of which about 30% of the heat decreased as a result of reduction of live steam from the boilers.

The development of the heat and electric power plants of the industrial enterprises took place on the level of advanced engineering of the time. This is manifested primarily in the improvement of the initial steam parameters. More than 75% of the newly built heat and electric power plants had equipment for parameters of 3.5 MPa (35 kg-force/cm^2) and 400-410°C, whereas the installation of the turbines for 2.2-2.6 MPa (22-26 kg-force/cm^2) and 350-375°C as a result of absence of experience in the manufacture of 16-25 megawatt turbines (and the boilers for them) for higher steam parameters.

For the heat and electric power plants at the Bereznikovskiy Chemical Plant, equipment was installed for 6.0 MPa (60 kg-force/cm2) and 450°C with secondary superheating to 375°C.

As a result of absence of single-shaft turbines with a power of 26 megawatts each with the same initial steam parameters at this heat and electric power plant double-shaft turbines were installed (see Fig 1) with equal

[1]This number includes the five heat and electric power plants transferred from the control of the industrial and communal enterprises to the power systems.

power (12.8 megawatts each) on the upper and lower shafts. The steam for production came from the counterpressure of the turbines of the upper shaft. At this heat and electric power plant, the four-stage regenerative heating of the feed water was used for the first time.

At the heat and electric power plant of the Gor'kiy Automobile Plant, the first district heating turbines in the world were installed with 12 megawatts each and two adjustable steam taps of 0.6 and 0.15 MPa (6 and 1.5 kg-force/cm^2) and condensation. The low pressure parts of these turbines also permitted acceptance of the steam from the side (for example, during the summer exhaust steam from the forging hammers was used by this scheme). The acceptance and the selection of the steam combined in one turbine made it possible to obtain electric power independently of the seasonal heat consumption conditions.

As a result of the introduction of more powerful and economic equipment at the rayon electric power plants, the average specific fuel consumption at these power plants dropped by 90 g/(kilowatt-hours) by 1932, and it was 780 g/(kilowatt-hour), as a result of which the specific fuel economy at the heat and electric power plant was reduced by more than 140 g/(kilowatt-hour). However, altogether as a result of the increase in the heat output from the heat and electric power plants from 6.03 to 23 million gigajoules/year (from $1.44 \cdot 10^6$ to $5.5 \cdot 10^6$ gigacalories/year) and more than doubling of the specific electric power output for the heat consumption, the fuel savings from district heating increased from $100 \cdot 10^3$ to $400 \cdot 10^3$ tons/year (the savings were determined only by the ratio of the condensation electric power plants introduced in accordance with the GOELRO Plan), which corresponds to the specific savings of the provisional fuel at the heat and electric power plants of about 2.08 kg/gigajoule (87 kg/gigacalorie) or about 220 g/(kilowatt-hour) on the average.

In the expired years of the first five-year plan (1931-1932) great progress was made in the development of the rayon central heating. Thus, from the heat and electric power plant built for the Gor'kiy Automobile Plant, continuous central heating was realized for the residences of a population of about 100,000.

In the same period the analogous district heating plans were realized in Kuznetsk, the Lower Tagil and other industrial districts.

Development and Operating Conditions of Heat and Electric Power Plants During the Prewar Period (1933-1940). The fundamentals of the subsequent (after the end of the First Five-Year Plan in 1932) development of district heating began to be developed in 1930 when the problems were resolved of the standardization of the equipment which must be assimilated by the Soviet power machine building plant. The parameters, type and unit power of the district heating turbines were subjected to standardization.

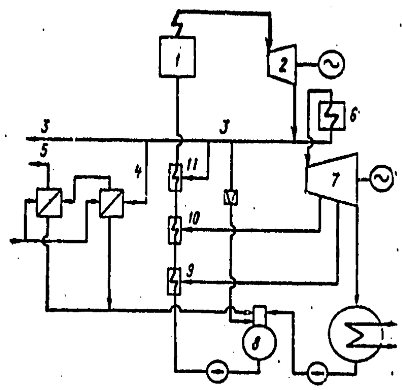

Figure 1. Schematic heating diagram of the Bereznikovskaya heat and electric power plant
1 -- steam boiler at a pressure of 6.0 MPa and a temperature of 450°C; 2 -- preincluded turbine with a power of 12.8 megawatts (upper shaft); 3 -- steam line at a pressure of 1.7 MPa for supplying steam for production, industrial superheating and regeneration; 4 -- steam feed to the two-stage steam conversion unit at pressures of 1.7/0.75 MPa; 5 -- steam line for supplying secondary steam with a pressure of 0.75 MPa for production purposes; 6 -- gas industrial superheating of steam from a temperature of 290 to 375°C; 7 -- condensation turbine with a power of 12.8 megawatts (lower shaft); 8 -- atmospheric deaerator; 9, 10 and 11 -- regeneration system heaters

For standardization with the parameters of the condensation electric power plants, a pressure at the turbines of 2.9 MPa (29 kg-force/cm^2) was selected for the heat and electric power plants insuring sufficient dryness of the steam in the condenser with maximum possible steam superheating temperature for the adopted types of steel at 400°C. For the tapping parameters, two stages were used: for the technological process steam at a pressure of 0.7 ± 0.1 MPa (7 ± 1 kg-force/cm^2) and for heat output by hot water of 0.12-0.2 MPa (1.2-2.0 kg-force/cm^2).

With respect to types of the central heating turbines based on the already existing operating experience of the heat and electric power plants, the decision was made to manufacture basically turbines with tapping of the steam and condensation offering the possibility of developing a rated power independently of the heat load. The greatest complexity arose from the problem of selecting the maximum unit power of the district heating turbines. It was difficult to count on the loads insuring a power of more than 12 to 15 megawatts by the conditions of the concentration of the heating loads based on the heat consumption during this period.

For these reasons, counterpressure turbines of 12 megawatts each (which went into operation in 1933) were already ordered previously for the first heat and electric power plants in Moscow and Leningrad. Inasmuch as by the electric power balance conditions, the power of the generating units was determined as no less than 100 to 150 megawatts, in order to decrease the number of units installed at the heat and electric power plants, a unit turbine power of 25 megawatts equal to the condensation electric power plants was adopted for the district heating turbines of the rayon heat and electric power plants, of which 12 to 14 megawatts were obtained as a result of tapping the steam for district heating, and the remaining power, as a result of regeneration and bypassing steam to the condenser (the so-called attached condensation power).

Summing up, a standard scale of the district heating turbines was adopted for the new heat and electric power plants: 2.5, 4.0, 6.0, 12.0 and 25.0 megawatts, in which the 2.5-12.0 megawatt units were produced both with counterpressure and with steam taps, and the 25 megawatt turbine, either with a 0.12-0.2 MPa (1.2-2.0 kg-force/cm^2) heating tap (AT-25 type) or with 0.7-0.1 MPa (7.0-1 kg-force/cm^2) production tap (type AP-25).

The 25 megawatt turbines were widely used in all of the new rayon heat and electric power plants in Leningrad, Moscow, Khar'kov, Yaroslavl' and other cities.

The summary indexes with respect to the development of the heat and electric power plants by 1940 are presented in Table 2.

In contrast to 1932, the distribution of the heat and electric power plants for general purpose installations and the heat and electric power plants of the industrial enterprises presented in Table 2 was carried out by the departmental attribute. In reality a significant number of heat and electric power plants of the industrial enterprises (having the greatest electric power at that) were in 1940 a source of the district heat supply not only for the communal-domestic purposes, but also production purposes, for example, the Krasnopresnenskaya Heat and Electric Power Plant, Orekhovo-Zuyevskaya, Ivanovskaya, and Kalinin Heat and Electric Power Plants, and so on.

The enlargement of the capacity of the heat and electric power plants was accompanied by increased technical improvements manifested in an increase in the proportion of the turbines on the 2.5-3.5 MPa (25-35 kg-force/cm^2) parameters from 50 to 80%. Beginning in practice with 1935 all of the heat and electric power plants were built for steam parameters (at the turbines) of 2.9 MPa (29 kg-force/cm^2) and 400°C with highly developed recovery. This equipment was manufactured by Soviet plants, and the importation of central heating turbines practically came to a halt by 1935.

Table 2

Basic Technical Specifications and Operating Indexes of the Heat and Electric Power Plants in 1940

Indexes	General-purpose heat and electric power plant	Heat and electric power plant of industrial enterprises	Total
No of heat and electric power plants	40	76	116
Including for the following parameters:			
1.8-2.2 MPa (18-22 kg-force/cm^2)	5	15	20
2.5-3.5 MPa (25-35 kg-force/cm^2)	33	60	93
>3.5 MPa (>35 kg-force/cm^2)	2	1	3
Power of the heat and electric power plants, megawatts	1200	800	2000
Average power of the heat and electric power plants, megawatts	30.0	10.5	17.0
No of turbines:	57	96	153
Including with worsened vacuum	9	5	14
With counterpressure	9	21	30
With tapping of the steam and condensation	39	70	109
Average turbine power, megawatts	2.0	8.3	-
Installed heating capacity of the turbines, gigajoules/hour (gigacalories/hour)	13827 (3300)	23883 (5700)	37710 (9000)
Release of heat, million gigajoules/year (gigacalories/year)	31.4 (7.5)	69.1 (16.5)	100.6 (24.0)
Annual electric power output, million killowatt-hours	6000	4000	-
Specific fuel consumption for the generated electric power, grams/(kilowatt-hours)	495	320	350

Table 3

Basic Indexes of the General-Purpose Heat and Electric Power Plants in 1940

Наименование ТЭЦ (1)	Мощность ТЭЦ, МВт (2)	Максимальная тепловая нагрузка, ГДж/ч (Гкал/ч) (3)	Отношение выработки электроэнергии к отпуску тепла, кВт·ч/ГДж (кВт·ч/Гкал) (4)	Коэффициент полезного действия котельной (брутто), % (5)	Удельный расход топлива на электроэнергию, г/(кВт·ч) (6)
**ТЭЦ А (7)	75	400,2 (117)	453,5 (1900)	79,9	400
ТЭЦ Б (8)	74	293,3 (70)	59,7 (250)*	79,7	220
ТЭЦ В (9)	62	341,5 (81,5)	121,7 (510)	81,0	320
ТЭЦ Г (10)	60	460,9 (110)	329,4 (1380)	76,8	409
ТЭЦ Д (11)	20	326,8 (78)	53,7 (225)*	74,8	240
Типовой проект с турбинами АТ-25 (12)	75	628,5 (150)	101,4 (425)	85,0	300

* Работа по тепловому графику. (13)

Key:

1. Name of heat and electric power plant
2. Power of heat and electric power plant, megawatts
3. Maximum thermal load, gigajoules/hour (gigacalories/hour)
4. Ratio of the electric power output to the heat release, kilowatt-hours/gigajoule (kilowatt-hours/gigacalorie)
5. Boiler efficiency (gross), %
6. Specific fuel consumption for electric power, g/(kilowatt-hour)
7. TETs A
8. TETs B
9. TETs V
10. TETs G
11. TETs D
12. Standard plan with AT-25 turbines
13. *Operation by the heating chart
14. ** [Translator's note]: TETs is the Russian abbreviation for heat and electric power plant; A, B, V, G, D are the first five letters of the Russian alphabet, the equivalent of English A, B, C, D, E]

Table 4

Basic Indexes of the Heat and Electric Power Plants of the Industrial Enterprises in 1940

ТЭЦ заводов (1)	Мощность ТЭЦ, МВт (2)	Максимальная тепловая нагрузка, ГДж/ч (Гкал/ч) (3)	Отношение выработки электроэнергии к отпуску тепла, кВт·ч/Гкал (4)	Удельный расход условного топлива на электроэнергию, г/(кВт·ч) (5)
Металлургического (6)	108	419 (100)	217,2 (910)	403
Химического (7)	84	838 (200)	59,7 (250)*	224
Вагонного (8)	60	628,5 (150)	143,2 (600)	328
Резинового (9)	50	607,5 (145)	86 (360)	296
Автозавода (10)	24	314,3 (75)	74,0 (310)**	216
Тракторного (11)	19	314,3 (75)	110 (460)	360
Типовой проект с турбинами АП-25 (12)	75	963,7 (230)	66,8 (280)	285

(13) * Работа по тепловому графику ТЭЦ высокого давления.
(14) ** Утилизация выхлопного пара молотов.

Key:
1. Plant heat and electric power plant
2. Power of the heat and electric power plant, megawatts
3. Maximum heat load, gigajoules/hour (gigacalories/hour)
4. Ratio of electric power output to the heat release, kilowatt-hours/gigacalorie
5. Specific consumption of provisional fuel for electric power, g/(kilowatt-hour)
6. Metallurgical
7. Chemical
8. Railroad cars
9. Rubber
10. Automobile plant
11. Tractor
12. Standard plan with AP-25 turbines
13. *Operation by the heat chart of a high-pressure heat and electric power plant
14. **Recovery of exhaust steam of the hammers

Two of the most powerful heat and electric power plants (84 and 60 megawatts) were built with steam parameters of 6.0 and 13.0 MPa (60 and 130 kg-force/cm^2).

The total power of the heat and electric power plants with these steam parameters reached 147 megawatts. The highest power (108 megawatts) was established at the heat and electric power plants of the Kuznetsk Metallurgical Plant with turbines of 25 megawatts each (the most powerful condensation electric power plant -- the Zuyevskaya plant -- was 350 megawatts for parameters of 2.9 MPa and 400°C with turbines of 50 and 100 megawatts).

A powerful incentive for the acceleration of the development of the heat and electric power plant and district heating as a whole was the implementation of the well known resolutions of the June Plenum of the Central Committee of the All-Union Communist Party (of Bolsheviks) of 1931. In accordance with these resolutions, by 1935 the construction of heat and electric power plants was being undertaken at accelerated rates: the Kuznetsk, Bereznikovskaya, Yaroslavl', Krivorozhskaya, Lipetsk, Kazan', Krasnozavodsk and many other heat and electric power plants.

The basic operating indexes of the most powerful general-purpose heat and electric power plants are presented in Table 3 (as a supplement to Table 2), and the heat and electric power plants of the industrial enterprises, in Table 4.

The calculated saving of heat was about $2.5 \cdot 10^6$ tons/year. The economic indexes of the heat and electric power plants were lowered not only as a result of the loading with respect to electric power generation but also as a result of the relatively low efficiency of the boiler units. Thus, according to Table 3 the gross efficiency of the boiler rooms during this period did not exceed 80-81% (with a calculated value of about 85%). The cause consisted in the difficulty of assimilation of the burning of low grades of fuel under the high-output units: anthracite dust, brown coal (Moscow and Chelyabinsk), kiesel coal, the waste from the enrichment of mineral coal and also milled peat.

The fuel balance of the heat and electric power plants by 1940 had the following structure: fuel oil 5%, peat 7%, anthracite dust 34%, Moscow coal 17%, Chelyabinsk coal 15%, kiesel coal 6%, Donetsk coal 10%, other 6%.

The loss of efficiency of the heat and electric power plants was also influenced by the unreliability of the initial structural designs of the high-pressure heater of the recovery heating system for the feed water.

The difficulties with loss of condensation at the consumers were initially overcome by installing steam converters (Fig 1), and subsequently they were reduced significantly by the introduction of Na-cation-exchange resin water purifiers almost everywhere and the application of staged evaporation in the steam boiler vessels (author Prof E. I. Romm). Known difficulties were also connected with the release of heat from the heat and electric power plants in the form of hot water. In the first step of building the heating networks, the maximum temperature of the network water was taken as 120-130°C. The maximum pressure of tapping the steam at the standard turbines of the Leningrad Metallurgical Plant and the Kirov Plant was 0.2 MPa (2 kg-force/cm2), which provided for heating the network water to 110-115°C and required the installation of heaters at the heat and electric power plants fed, as a rule, by the reduced steam at 0.6 MPa (6.0 kg-force/ cm^2). The theoretical heating system of the heat and electric power plant providing for the two-stage heating of the network water is illustrated in Fig 2.

The initial structural designs of these peak heaters were insufficiently reliable, which led to underrelease of heat during the cold part of the year as a result of feeding water at reduced temperature to the heating networks.

By the arguments connected with reducing the cost of the heating network and also with the acute shortage of pipe, at a number of the heat and electric power plants the calculated maximum water temperature was increased to 130°C. In addition, the technical economic calculations were used to discover the optimal ratio of the thermal loads of the basic and peak heaters equal to 1:1; here the district heating factor at the heat and electric power plants was 0.5.

The satisfaction of this condition when releasing heat through the pressure-reducing and cooling unit required an increase in power of the installed power steam generators of the heat and electric power plant. However, in practice the possibilities of the installation of such boiler power at the heat and electric power plants were highly limited as a result of which the district heating coefficients of the heat and electric power plants were within the limits of 0.6-0.65, and the maximum temperature of the supplied network water was 115 to 120°C.

The increase in the number of heat and electric power plants built in the large industrial and residential centers (Moscow, Leningrad, Kiev, Khar'kov, and so on) has revealed a trend toward the appearance of two types of heat and electric power plants classified with respect to type of predominant heat load, namely: the heating heat and electric power plants (with the type T turbines) and the industrial heating (with the type P and T turbines).

In the heating heat and electric power plants incomplete loading of the taps was determined by the lag in the construction of the heating network connected basically with the shortage of pipe, and the complete utilization of their electric power reaching 6000-6500 hours per year was connected with the general shortage of electric power.

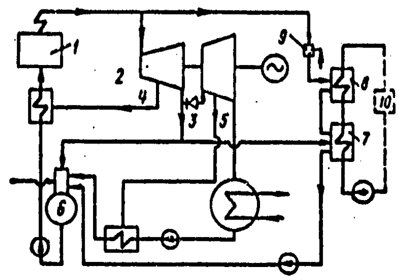

Figure 2. Heating diagram of the thermoelectric power plant with two-stage heating of network water in the base and peak-load heaters
1 -- steam boiler; 2 -- steam turbine with adjustable tapping of the steam and condensation; 3 -- adjustable heat tapping of the steam; 4, 5 -- nonregulatable taps for recovery; 6 -- deaerator; 7 -- basic heater of the network water; 8 -- peak heater of network water; 9 -- pressure-reducing and cooling unit; 10 -- heat users

At the industrial heating heat and electric power plants the low degree of use of the taps was the result, as a rule, of incompatibility of the types and sizes of turbines installed at the heat and electric power plants with the structure of the heat users. The way out of the developed situation was found by creating new types of turbines for these heat and electric power plants with two adjustable steam taps and condensation (PT-turbine).

The basic advantage of these turbines was obtaining the calculated district heating power from them, independently of the load ratio of the P and T taps; here the condensation power was approximately cut in half.

The problem set up by the June Plenum of the Central Committee of the All-Union Communist Party (Bolsheviks) in 1931 for district heating to force the imported high-quality fuel (fuel oil and Donets coal) out of the fuel budget of the cities was carried out successfully. Thus, the heat and electric power plants in Moscow were built for operation on Moscow coal, in Leningrad on peat, in Kiev, Khar'kov, Rostov and Kuybyshev, Saratov and other cities, on anthracite dust. By 1940 about $2.0 \cdot 10^6$ tons of natural fuel (primarily Donets coal and fuel oil) previously burned in the low-economical boiler houses and industrial enterprises, were forced out of the fuel budget of the cities by central heating.

In order to reduce the ash and sulfur dioxide discharge, the plans for all of the coal heat and electric power plants provided for the construction of ash traps which were not always put into operation simultaneously with the beginning of operation of the heat and electric power plants, and the calculated efficiency of the ash trap was not always insured on the operating units.

Heat and Electric Power Plants During World War II and in the Recovery Period (1941-1950). Directly before the ending of the war, three new heat and electric power plants were built at accelerated rates in Moscow, two in Leningrad and also heat and electric power plants in Yaroslavl', Kiev, Kuybyshev, and Orsk, and other cities.

The capture by the enemy of a significant part of the territory of the country during the first 2 years of the war led to the necessity for moving a number of the industrial enterprises and electric power plants to the east. A total of more than 60 electric power plants with a total capacity of 5.8 million kilowatts (including about 1 million kilowatts of power at the heat and electric power plants) were evacuated and temporarily stopped operations. The overwhelming majority of the turbines of the heat and electric power plants were again installed at the enterprises in the cities of the eastern part of the country. In spite of the difficulties of wartime during these years the construction of new heat and electric power plants also continued. Thus, at the beginning of 1942, the Chelyabinsk Heat and Electric Power Plant No 1 was put into operation, and then the Novosibirsk Heat and Electric Power Plant No 3 and the Heat and Electric Power Plant of the Ural Turbine Plant. In subsequent years new heat and electric power plants began operation in Krasnoyarsk, Chelyabinsk, Bogoslovsk and other cities. Overall, by the end of 1944, the release of heat from the heat and electric power plants reached the prewar level.

As the territory of the country was liberated from the fascist invaders, the restoration of the previously dismantled equipment at the heat and electric power plants in Moscow, Leningrad, Khar'kov, Kiev and other cities began. In addition, in 1945 construction of new heat and electric power plants was started using foreign equipment, as a result of which the total power of the heat and electric power plants together with the deliveries of new equipment from Leningrad Metallurgical Plant, the UTMZ Plant and the Bryansk Plant reached 5 million kilowatts by 1950 with a heat release of about 293.3 million gigajoules (70 million gigacalories), which made it possible to obtain a fuel savings of about 7.5 million tons.

In the connection with the organization in 1946 of the Ministry of Electric Power Plants (MES) significant changes took place in the organizational structure of the administration of the heat and electric power plants which, in connection with the significant development of district heating were in the majority converted to district heat supply units. The number of such heat and electric power plants more than doubled inasmuch as by 1950 all of the prewar heat and electric power plants had in practice resumed operations. The heat and electric power plant equipment which had been moved in 1941 to 1942 continued in the majority of cases to operate at new electric power plants in the eastern regions. In addition, a large number of industrial enterprises located outside the areas of operation of electric system in 1946-1950, using foreign equipment, constructed their own heat and electric power plants. Overall the number of heat and electric power plants had increased to 700 by 1950, including 130 heat and electric power plants in the MES [Ministry of Electric Power Plants] system, 100 heat and electric power plants in the form of block stations operatively subordinate to the MES dispatchers and 470 heat and electric power plants of industrial enterprises and cities operating in isolation (Table 5).

The successful use in the eastern parts of the country of the district heating turbines was facilitated to a significant degree by the fact that for the most part these were turbines with steam selection and condensation and the most powerful at that; therefore they could be quite economically used to equip the defense industry with electric power independently of the presence of the thermal load. Under the conditions of an acute shortage of electric power, the broad use of the overload capacity of these turbines was started. This capacity (see Fig 3) was known in prewar time, but in practice was not used, for the specific provisional fuel consumption for the additional condensation power obtained amounted to about 1000 g/(kilowatt-hour).

Table 5

Basic Technical Specifications and Operating Indexes of Heat and Electric Power Plants in 1950

(1) Наименование показателей	ТЭЦ МЭС (2)	Блок ТЭЦ (3)	Прочие ТЭЦ (4)	Всего (5)
(6) Число ТЭЦ	130	100	470	700
(7) Мощность ТЭЦ, МВт	2800	1200	1000	5000
(8) Средняя мощность ТЭЦ, МВт	17,5	12,0	2,2	7,1
(9) Установленная тепловая мощность турбин, ГДж/ч (Гкал/ч)	50 280 (12 000)	41 900 (10 000)	12 570 (3000)	104 750 (25 000)
(10) Годовой отпуск тепла, млн. ГДж (млн. Гкал)	115,2 (27,5)	30,2 (7,2)	117,3 (28,0)	267 (63,7)
(11) Выработка электроэнергии, млрд. кВт·ч/год	18,5	7,2	4,0	29,7
(12) Отношение выработки электроэнергии к отпуску тепла, кВт·ч/ГДж (кВт·ч/Гкал)	134,8 (565)	238,7 (1000)	112,2 (470)	88,3 (370)
(13) Удельный расход условного топлива на выработку электроэнергии, г/(кВт·ч)	548	560	600	—

Key:
1. Name of indexes
2. Heat and electric power plants of the Ministry of Electric Power Plants
3. Heat and electric power plant block
4. Other heat and electric power plants
5. Total
6. No of heat and electric power plants
7. Power of heat and electric power plants, megawatts
8. Average heat and electric power plant power, megawatts
9. Installed thermal power of turbines, gigajoules/hour (gigacalories/hr)
10. Annual release of heat, millions of gigajoules (millions of gigacalories)

[Continued on p 17]

[Key to Table 5, contd]

11. Generation of electric power, billions of kilowatt-hours/year
12. Ratio of the electric power output to the heat release, kilowatt-hour/gigajoules (kilowatt-hour/gigacalorie)
13. Specific provisional fuel consumption for the generation of electric power, g/(kilowatt-hour)

Under wartime conditions, the noneconomicalness of such conditions was put in second place, the more so in that on passage of the electric power load peaks in a number of power systems the dispatchers required operation of even the counterpressure turbines on exhaust (with a power to 12000 kilowatts), which under such operating conditions required still greater fuel consumption.

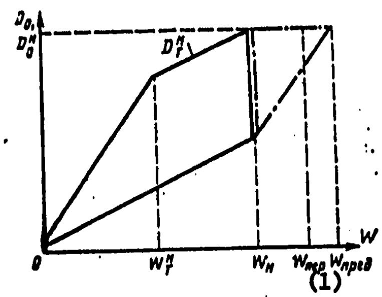

Figure 3. Schematic diagram of turbine operating conditions with regulatable steam tap and condensation

D_0^H is the rated steam consumption by the turbine, tons/hour;

D_T^H is the rated adjustable steam tap, tons/hour;

W_H is the rated turbine power, megawatts; W_T^H is the district heating power of the turbine with rated steam tap, megawatts;

W_{over} is the permitted overload power of the turbine, megawatts;

W_{lim} is the limiting possible overload capacity of the turbine for maximum steam flow rates through the high pressure part and the low pressure part, megawatts; -.-.- — the region of possible overload conditions of the turbine.

Key:

1. $W_{over} W_{lim}$

The overload power of the turbines of the AT-25 and the AP-25 types was brought almost everywhere to 28000-30000 kilowatts, and in certain cases (by the permission of the manufacturing plants) even to 32000 kilowatts with a reduction of the district heating power of the turbines from the calculated value of 60 to 65 to 25-30% (Fig 4).

In order to accelerate the starting of the evacuated turbines in the eastern part of the country at a number of heat and electric power plants (the Krasnogorskaya heat and electric power plant, and so on), direct-flow Ramzin boilers of simplified design were manufactured for them to operate on a pressure of 3.0-3.1 MPa (30-31 kg-force/cm^2)

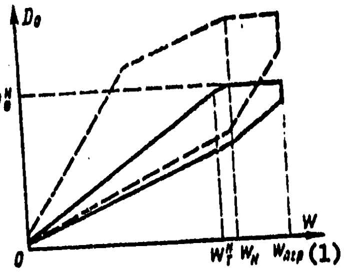

Figure 4. Comparison of the operating diagrams for the AT-25 and VT-25 turbines
_______ -- VT-25 turbine; - - - - - -- AT-25 turbine;
W_H -- rated turbine power, megawatts; W_T^H -- district heating power of the turbine with rated steam tap, megawatts; W_{over} -- permitted overload power, megawatts; D_0^H -- rated steam consumption by the turbine, tons/hour

Key:

1. W_{over}

Incompatibility of the pressure of the tapped steam (especially for the AT-25 turbines) with the needs of the users was eliminated (for fuel savings and to unload the power boilers) by the installation of the jet heat transformers developed at the VTI Institute. Under the conditions of acute metal shortage, mixing heaters were installed in place of the surface heaters for heating the network water at a number of the heat and electric power plants.

During the war years the fuel budget of the heat and electric power plants changed significantly. In place of anthracite dust, Moscow coal and partially peat at the heat and electric power plants they began to burn Ural brown coal and Kuznetsk mineral coal, and the use of kiesel and Ukhta coals was also expanded.

The restoration of the heat output from the turbines of the heat and electric power plants in the areas engulfed in the ore in practice started in 1945 (the heating networks began to release heat in Leningrad, Khar'kov, Kiev and other cities in 1944) and in 1946 a number of heat and electric power plants were also in operation with total electric and thermal power. As the coal extraction was recovered in the Donetsk and Moscow Basins the fuel budget of the heat and electric power plants approached prewar with somewhat greater proportions of coal from the eastern regions.

The restoration of the power of the heat and electric power plants led the restoration of the condensation electric power plants (as a result of the greater degree of destruction of them); therefore the proportion of the generation of electric power with respect to condensation cycle at the heat and electric power plants turned out to be above the prewar level.

As was demonstrated in Table 5, the basic amount of electric power at the heat and electric power plants was generated with a specific provisional fuel consumption to 548 g/(kilowatt-hour), and the appearance of a significant number (more than 170) of isolated low-power heat and electric power plants on foreign low-economy equipment raised this index from 380 g/(kilowatt-hour) -- the level reached in 1940 -- to 560 g/(kilowatt-hour) with a specific consumption at the condensation electric power plants dropping to 645 g/(kilowatt-hour).

The ratio of the electric power output to the heat release (the basic attribute of the growth of the operation of the heat and electric power plants with respect to the condensation cycle) increased from 88.3 kilowatt-hour/gigajoules (370 kilowatt-hour/gigacalorie) in 1940 to 112.2 kilowatt-hour/gigajoule (470 kilowatt-hour/gigacalorie) in 1950.

The created collectives of the power machine building plants of the country worked under stress conditions in the war years on the creation of new, more economical equipment for the condensation electric power plants and the heat and electric power plants. A brilliant result of this work was the manufacture of the VT-25 district heating turbine at the Leningrad Metallurgical Plant in 1948 for initial steam parameters of 9.0 MPa (90 kg-force/cm^2) and 480°C (in subsequent years the steam temperature was increased to 500°C) with adjustable tapping of the steam at 0.12-0.25 MPa (1.5-2.5 kg-force/cm^2). This was the most improved district heating turbine of the time in the entire world. With complete loading of its district heating tap (100 tons/hour) made it possible to reduce the fuel consumption at the heat and electric power plants during operation in the district heating mode to 200 g/(kilowatt-hour) (considering the "attached" condensation power of the total of about 2.5 megawatts instead of 9.0 megawatts on the AT-25 turbine). A comparison of the diagrams of the operating additions of the VT-25 and AT-25 turbines is illustrated in Fig 4.

In 1949 the double-tap turbine type VPT-25-90 was manufactured with industrial tapping of the steam at $1.0^{+0.3}_{-0.2}$ MPa (10^{+3}_{-2} kg-force/cm^2) and with a weighted mean specific electric power generation for heat consumption almost double that for the analogous APT-25-29 turbines.

In subsequent years these turbines began to be series manufactured at three plants, and by 1965 the installation of the turbines operating on lower parameters at the heat and electric power plants ceased.

By 1950 as a result of the preincluded turbines operating on 11.0 MPa (110 kg-force/cm^2) of the Soviet and foreign plants the number of heat and electric power plants with the parameters of 6.0-11.0 MPa (60-110 kg-force/cm^2) increased to 7 with a total power of turbines with such parameters above 500 megwatts, which amounted to about 10% of the total power of the heat and electric power plants.

Technical Progress in the Development of the Heat and Electric Power Plants in 1951-1970. Beginning in 1950 Soviet power engineering entered into the era of intensive growth of operating efficiency of the power supply installations.

In the area of condensation power plants this was manifested in increased initial steam parameters of the turbines initially to 9.0 MPa (90 kg-force/cm^2) with a unit power of each turbine of 100 megawatts. Beginning in 1959, the condensation electric power plants began to assimilate the series 150/160 and 200 megawatt units for superhigh steam parameters of 13.0 MPa (130 kg-force/cm^2) and 565°C with industrial superheating to 565°C, and in 1963, the 300 megawatt units for transcritical steam parameters of 24.0 MPa (240 kg-force/cm^2) and 540/560°C. As a result of adjustment of the operation of these units the specific fuel consumption at the condensation electric power plants quickly began to drop first to 400-440, and then to 346-360 g/(kilowatt-hour) (net). Under the developed conditions at the heat and electric power plants, a set of measures was taken to retain the basic advantages of the district heating units as units insuring fuel economy by comparison with the separate power supply system.

The quantitative and qualitative indexes of the development of district heating during this period were discussed quite completely in the present collection in the article by Ye. I. Borisov and V. P. Korytnikov "Role of District Heating and Power Engineering in the National Economy of the USSR." It must be noted that on the whole district heating encompasses about 50% of the prepared centralized heat consumption, and in individual cities this index increases to 60-65%.

Just as significant progress in the development of district heating has turned out to be attainable in the continuous improvement and application in practice of the developed set of advanced, technically new solutions.

One of the most important measures with respect to improving the operating efficiency of the heat and electric power plants in the power system consisted in equalizing the initial steam parameters at the heat and electric power plantsand condensation electric power plants. The growth of the initial steam parameters of the heat and electric power plants first of all was needed to increase the specific electric power generation at the heat and electric power plants as the basic factor in saving fuel during district heating.

For example, for the heat and electric power plants having a turbine with counterpressure, the specific fuel consumption for the generation of electric power in practice does not depend on the initial pressure. Thus, in particular, for the 26 kg-force/cm^2 (2.6 MPa) turbines at the hydroelectric power plant No 1 of Mosenergo [Moscow Power Administration] and the R-50-130 turbines of the Grozna Heat and Electric Power Plant at 130 kg-force/cm^2 (13.0 MPa) this index is in practice identical, and it amounts to 150 and 160 g of provisional fuel per 1 kilowatt-hour respectively (the difference occurs as a result of the efficiency of the boiler units and the condensate losses). However, the fuel savings per gigacalorie released to the users of the Grozna Heat and Electric Power Plant, if we compare it with the best condensation electric power plant operating with a specific provisional fuel consumption of 335 g/(kilowatt-hour) is almost twice that of the Hydroelectric Power Plant No 1 of Mosenergo.

The improvement of the initial steam parameters for the heat and electric power plant also gives indexes close to the condensation electric power plant (for the same steam parameters) with respect to fuel consumption when operating by the condensation cycle. Nevertheless, the basic condition of efficient operation of the heat and electric power plant remains the requirement of maximum generation of electric power with respect to the district heating cycle, for which prolonged rated load of the taps of the heat and electric power plants for heat release is required.

For the heating heat and electric power plants this growth of electric power generation is possible as a result of attaching the year around hot water supply load and also operation with an optimal district heating coefficient within the limits of 0.5-0.65. The hot water supply loads on the heat and electric power plants during 1950-1953 were relatively low and amounted to no more than 5 to 6% of the heating load. The residential construction started in 1955 on a broad scale made it possible by 1960 to raise the proportion of the hot water supply load to 10-12%, and subsequently to 14-15% (with design calculations for the future to 25%). This proportion of the hot water supply load offers the possibility of increasing the annual number of hours of use of the rated thermal power of the turbine taps from 2200-2500 to 3500-3700 hours and more.

Increasing the maximum network water temperatures from 125-130 to 150°C in practice was completed by 1955 at almost all of the heating networks of the country, and the new types of turbines beginning in 1948 were produced with an upper limit of adjustable tap of 0.25 MPa (absolute) (2.5 kg-force/cm^2). The conversion of the operating conditions of the heat and electric power plants to heat release from the turbines from the alpha heat and electric power plants equal to 0.5 was held up as a result of significant increase in cost for this heat and electric power plant connected with the installation of expensive and at the same time acutely short power steam generators required to feed the steam through the pressure-reducing and cooling units for the peak-load network heaters.

The cardinal solution to this problem came only in 1959 when the peak-load hot water boilers designed by the VTI Institute and the Orgenergostroy Administration appeared in the heat and electric power plants. The mass installation of these boilers for heating network water from 110-115 to

150°C provided almost universal conversion of the heat and electric power plants for operation from the alpha heat and electric power plant equal to 0.4-0.5. With these district heating coefficients and proportion of hot water supply about 10 to 15%, the number of hours of use of the turbine taps increased to 4000-4500 with corresponding reduction in the generation of electric power by the condensation cycle. The application of the peak-load water heating boilers permitted significant decrease in cost of heat and electric power plants as a result of reducing the number of power steam generators. The application of the two-tap VPT-25-90 turbines with the water heating peak-load boilers at the heat and electric power plants with mixed production-heating load sharply reduced the demand for turbines with counterpressure which in practice were not installed at the new heat and electric power plants during the period before 1960 (the small heat and electric power plants of the industrial enterprises with 2.5-4.0 megawatt turbines constituted an exception).

Beginning in 1953-1954, in connection with the increased oil extraction in the Priural'ye [Ural] region, the construction of a number of high-capacity oil refineries was started, for which heat and electric power plants were required with a power of 200-300 megawatts. For these heat and electric power plants, it was expedient to replace the installation of the 25 megawatt turbines by turbines with a unit power of 50-60 megawatts. These double-tap turbines were built in 1956 for a pressure of 9.0 MPa (90 kg-force/cm^2) at the Leningrad Metallurgical Plant and in 1957 at the UTMZ Plant for a pressure of 13.0 MPa (130 kg-force/cm^2). As the technological process heating load increased at these plants and also with an increase in construction of the chemical combines for the production of fertilizer, plastics and artificial fiber having a steam requirement of 600 to 800 tons/hour, the necessity arose for the resumption of the production of counterpressure turbines, but now for higher steam parameters, namely, 13.0 MPa (130 kg-force/cm^2). The production of the counterpressure turbines with a power of 50 megawatts was started at the Leningrad Metallurgical Plant in 1962.

The manufacture of R-50-130 turbines instead of the LMZ VR-25-2 turbines for a pressure of 9.0 MPa (90 kg-force/cm^2) solved three problems simultaneously: 1) an increase in initial steam parameters of 9.0 MPa (90 kg-force/cm^2) to 13.0 MPa (130 kg-force/cm^2), a reduction in the counterpressure parameters from 1.8 to 1.0 MPa (from 18 to 10 kg-force/cm^2), which together offered an increase in specific generation for heat consumption from 38.2 to 50 kilowatt-hour/gigajoule (from 160 to 205 kilowatt-hour/gigacalorie) and 3) an increase in the power of the counterpressure turbines to 50 megawatts, that is, making their power equal to the PT-50 turbines.

The absence of 50 megawatt turbines in the nomenclature of manufactured equipment for the heating heat and electric power plants led to the necessity for the use of the PT type turbines at these heat and electric power plants (for example, Heat and Electric Power Plant No 9, 11, 12, 16, 20 and 22 of Mosenergo, and so on), which increased the proportion of generation of electric power by the condensation cycle at them and also significantly lower the index of specific electric power generation on heat demand.

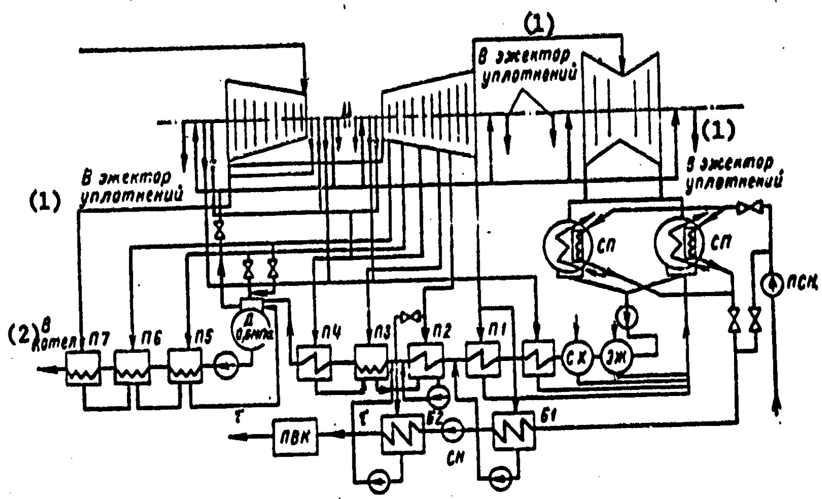

Figure 5. Theoretical heating diagram of the T-100-130 turbine installation
P1-P7 — recovery system heaters; D — deaerator; B1, B2 — network heaters of first and second heating stages: CП — tube bundle in the condenser for heating network water; ПСН — network booster pump; СН — network pump; ПВК — peak-load water heating boiler; τ — network water temperature.

Key:

1. to the seal ejector; 2. to the boiler

In addition, the development of residential construction in the large populated centers (Moscow, Leningrad, Kiev, Minsk and other cities) created the base for the construction of a significant number of heating heat and electric power plants with a capacity of 300-400 megawatts or more. For this purpose, the UTMZ plant developed the plans for the T-50-130 and T-100-130 turbines for purely heating purposes and in 1960, the output of such turbines with 50 megawatt power was started, and in 1962, 100 megawatts.

The theoretical difference in these types of turbines was the application in them of two-stage heating of the network water as a result of lower tapping at 0.05-0.2 MPa (absolute) (0.5-2.0 kg-force/cm2) and upper tapping 0.06-0.25 MPa (absolute) (0.6-2.5 kg-force/cm^2) with a possibility of conversion of the turbines to the operating conditions with counterpressure on condensation of the of the exhaust steam on the special surface (in the network bundle) for heating the network (or makeup) water isolated in the turbine condenser.

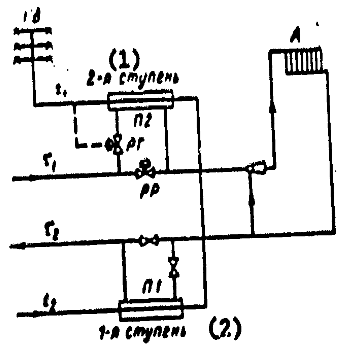

Figure 6. Heating diagram of the water line water of the VTI-Mosenergo
A -- heating system; ГВ -- hot water supply system; П1 and П2 -- tap water heaters; PT -- temperature regulator; PP -- flow rate regulator; t_1 and t_2 -- tap water temperature; τ_1 and τ_2 -- network water temperature

Key:

1. second stage
2. first stage

The goal of lowering the pressure in the heating taps below 0.12 MPa (1.2 kg-force/cm^2) was stated many times for the manufacturing plants when developing the plans for the VT-25 type turbines, and then the VPT-50 turbine, but it was not solved as a result of the danger of sucking air into the low-pressure part through the steam tap fittings. The growth of the culture of manufacturing the fittings and equipment permitted these restrictions to be removed, which offered the possibility of significantly increasing the generation of electric power in the heating demand from 107.4 to 138.5-148 kilowatt-hour/gigajoules (from 450 to 580-620 kilowatt-hour/gigacalorie).

In subsequent years the manufacturing plants permitted the reduction of the absolute pressure in the heating taps to 0.07-0.08 MPa (0.7-0.8 kg-force/cm^2) on the previously manufactured turbines of the VT and VPT types.

The theoretical heating diagram of the heating turbines with two-stage heating of the network water by the tapped steam during preliminary heating in the condenser "bundles" and heating from 115 to 150°C in the peak-load water heating boilers is illustrated in Fig 5.

The most effective was operation of the turbines at the heat and electric power plants to which the thermal networks with the hot water supply users included by the closed heating system for the tap water were connected (see Fig 6). In this system the return water from the heating systems is also cooled and goes to the heat and electric power plant with a temperature of 30-50°C. The combination of the diagrams of the heat and electric power plants with respect to Fig 5 and the heat supply system of the subscribers with respect to Fig 6 offered the possibility of increasing the value of the specific electric power generation to 148 kilowatt-hour/gigajoule (620 kilowatt-hour/gigacalorie) at the heat and electric power plants during the warm days of the heating season inasmuch as subsequently the operation of such turbines with a minimum pressure of the lower tap of 0.03-0.04 MPa (absolute) (0.3-0.4 kg-force/cm^2) was permitted.

In 10 years (from 1950 to 1960) more than 500 turbines were installed at the heat and electric power plants with a pressure of 9.0 MPa (90 kg-force/cm^2) with a total power of about 9 million kilowatts.

As a result of an increase in the initial steam parameters, a reduction in the average specific consumption of provisional fuel from 440-450 to 395 grams/(kilowatt-hour) was achieved for average fuel flow rates at the condensation electric power plant of the same parameters at 437 g/(kilowatt-hour).

The presented indexes for effective operation of the heat and electric power plants were obtained for use coefficients of the thermal power for the production steam taps of 0.60-0.70 and for the heating taps about 0.45. At the heating heat and electric power plants with the VPT-50 turbines, the use of the lower tap heating power was 63% and the upper (peak mode), 12%.

The unit power of the heat and electric power plants in a number of power systems increased from 75-100 to 125-150 megawatts.

With properly selected equipment for the heat supply of the industrial enterprises and the district heating of the cities in a significant number of power systems the average specific fuel consumption with respect to the system was found to be lower than at the best condensation electric power plants for the 9.0 MPa parameters. Thus, in the Bashkirenergo system with a proportion of electric power generation for heat consumption of about 50%, the specific fuel flow rates through the system on the whole was 346 grams/(kilowatt-hour), Sevkavenergo Power Administration 376 g/(kilowatt-hour) and Kuybyshevenergo, 391 g/(kilowatt-hour).

Along with the construction in the power system of the high-power heat and electric power plants in the isolated areas, the construction of the low-power heat and electric power plants using foreign equipment started in the reconstruction period was continued.

The installation of the 50-100 megawatt turbines at the heat and electric power plants with a pressure of 13.0 MPa (130 kg-force/cm^2) started after 1960 had a significant increase in operating efficiency of the heat and electric power plants as a consequence.

By 1970, more than 100 new heat and electric power plants had been built in the system of the USSR Ministry of Power Engineering and more than 600 district heating turbines had been installed. The total power of the district heating turbines increased from 16.6 million kilowatts to 47.0 million kilowatts (including up to 35.0 million kilowatts with respect to the MES system) with an average power of the newly installed turbines of about 60 megawatts.

As a result of the changes taking place during these years in the administrative subordination, the number of general purpose heat and electric power plants in the administration of the Ministry of Power Engineering was 266 by 1970 (out of the total number of heat and electric power plants equal to 943) with installed capacity of 35,900 megawatts with a total power of all of the heat and electric power plants of about 47000 megawatts. The installed capacity of the turbines at a pressure of 13.0 MPa (130 kg-force/cm^2) reached 16.9 million kilowatts by 1970. Exceeding the total power of all of the heat and electric power plants installed by 1960 (16.16 million kilowatts), the turbine power of 9.0 MPa (90 kg-force/cm^2) by 1965 was about 12.0 million kilowatts, and in subsequent years it changed insignificantly as a result of remarking the turbine power. This remarking in 1970 was also performed for certain types of 13.0 MPa (130 kg-force/cm^2) turbines: the turbine power of 50 megawatts was increased to 55 megawatts for the T-50-130 turbines and to 60 megawatts for the PT-50-130-13 turbines (the new designation of the T-50/55-130 and PT-50/60-130 turbines respectively).

The introduction of the higher powered 13.0 MPa (130 kg-force/cm^2) turbines into operation permitted a significant improvement of the quality indexes of the operation of the heat and electric power plants. The consumption of the provisional fuel at the best heat and electric power plants with the T and PT turbines was reduced to 217 grams/(kilowatt-hour) with a specific fuel consumption at the best condensation electric power plants with the same parameters of 367.9 g/(kilowatt-hour), and at the condensation electric power plants with parameters of 24.0 MPa (240 kg-force/cm^2), 362.5 g/(kilowatt-hour).

The proportion of electric power generation for heat consumption in 1970 was on the average about 54%, and the specific generation for heat consumption reduced to the heat of the steam taps, 60 kilowatt-hour/gigajoules (252 kilowatt-hour/gigacalorie). In 1970 the T-50-130 and T-100-130 turbines had the highest value of the mean specific district heating generation of electric power at 438 and 431 kilowatt-hours/gigacalories respectively (with an average tap load with respect to heat of 33 and 43%), and the R-50-130 turbines at the lowest value. With a heat load of about 51.5% they generated a total of 48.7 kilowatt-hour/gigacalories [sic] (204 kilowatt-hour/gigacalorie) with a calculated generation of about 59.7 kilowatt-hour/gigacalorie [sic] (250 kilowatt-hour/gigacalorie).

In spite of the insufficiently high use of the thermal power of the R-50-130 counterpressure turbines (by 1970 more than 40 units had been installed), in accordance with the claims of the planning organizations of the UTMZ in 1969 the manufacture of still more powerful turbines had been started, the operating conditions of which also were insufficiently effective as a result of the low thermal load at the heat and electric power plants.

The fast growth of power and economy of condensation power plant and the heat and electric power plants with a steam pressure of 13.0 MPa (130 kg-force/cm^2) created conditions under which the use in the power systems of the equipment of the heat and electric power plants and the condensation power plants with a pressure of 3.5 MPa (35 kg-force/cm^2) having specific consumptions at the 500-600 g/(kilowatt-hour) level in practice began to lead to significant overconsumption of the fuel. By the initiative of the ORGRES [State Trust for the Organization and Rationalization of Regional Electric Power Plants and Networks] in 1959 at the individual condensation electric power plants and the heat and electric power plants, operations were started with respect to rebuilding the condensation turbines and the turbines with tap and condensation at 2.6-2.9 MPa (26-29 kg-force/cm^2) for operation under district heating conditions with lowered vacuum.

The total power of the condensation turbines rebuilt during the period from 1960 to 1970 into district heating turbines was 2.85 million kilowatts; however, the increase in district heating power was a total of about 1.6 million kilowatts as a result of the reduction of the electric power of the turbines. The total energy characteristic of the rebuilt turbines is presented in Table 6 from which it follows that among the rebuilt turbines it turned out to be possible and expedient to also include the K-50-90 and K-100-90 turbines for pressure of 9.0 MPa (90 kg-force/cm^2) along with the AK-25 and AK-50 turbines with rebuilding of the K-50-90 and the K-100-90 as turbines with counterpressure or with regulatable tap.

Simultaneously condensers of a significant number of the T-25-90 and PT-50-90 turbines were adapted on the basis of the operating experience of the T-50-130 and the T-100-130 turbines for heating the network water with the corresponding worsening of the vacuum but without loss of electric power.

The secondary (after almost a 30-year break) appearance at the heat and electric power plants with a significant number of turbines with worsening of the vacuum did not indicate that the initial failure to use them was erroneous. The unfavorable properties of such turbines for operation in the power systems connected with a reduction in their maneuverability with small heating loads remained unchanged. However, the power of the heat and electric power plants growing during this period in the power systems to 50 million kilowatts permits compensation for this deficiency as a result of operation of the type T and PT units and the KES [condensation electric power plants] superhigh parameters, inasmuch as the proportion of the total power of the rebuilt turbines will be less than 1.5% of the power systems.

Table 6

Rebuilding of the Condensation Turbines into District Heating Turbines

Тип турбин (1)	Начальные параметры (2)			Расход свежего пара, т/ч (3)		Электрическая мощность, МВт (4)		Отбор или противодавление после реконструкции (5)	Удельный расход условного топлива на производство электроэнергии на ТЭС, г/(кВт·ч) (6)	
	(9) МПа	(10) кгс/см²	(11) °C	(7) до реконструкции	(8) после реконструкции	(7) до реконструкции	(8) после реконструкции		(7) до реконструкции	(8) после реконструкции
К-25-20	2,6	26	375	120	165	24	25	(12) Отопительный отбор 100 т/ч	515	300
К 25-20	2,6	26	275	120	130	24	16	Противодавление (13) 0,1—0,2 МПа (1—2 кгс/см²)	515	215
К-25-29	2,9	29	400	122	172	25	25	Отопительный (14) отбор 125 т/ч	480	258
К-50-29	2,9	29	400	232	280	50	23	Отбор 0,7 МПа (15) (7 кгс/см²), 225 т/ч	405	310
К-50-90	9.0	90	500	220	440	50	58	Противодавление (16) 0,8 МПа (8 кгс/см²), 350 т/ч	356	215
К-100-90	9,0	90	500	377	460	100	90	(17) Отбор 0,2 МПа (2 кгс/см²), 200 т/ч	380	268

Key:

1. Type of turbine
2. Initial parameters
3. Consumption of live steam, ton/hr
4. Electric power, megawatts
5. Tapping or counterpressure after rebuilding
6. Specific consumption of provisional fuel for the protection of electric power at the thermoelectric power plants, g/(kilowatt-hour)
7. Before rebuilding
8. After rebuilding
9. MPa
10. kg-force/cm²
11. °C
12. Heating tap 100 ton/hr
13. Counterpressure 0.1-0.2 MPa (1-2 kg-force/cm²)
14. Heating tape 125 ton/hr
15. Tap 0.7 MPa (7 kg-force/cm²), 225 ton/hr
16. Counterpressure 0.8 MPa (8 kg-force/cm²) 350 ton/hr
17. Tap 0.2 MPa (2 kg-force/cm²)200 ton/hr

The unit power of the heating heat and electric power plants reached 650 megawatts by 1970 (Heat and Electric Power Plant No 20 of Mosenergo), and the industrial heating plants, 400 megawatts (Tol'yatti Heat and Electric Plant). The total release of steam at these heat and electric power plants was about 60% of the total released heat, and at individual heat and electric power plants it exceeded 1000 tons/hr.

The condensate loss at a number of the heat and electric power plants was 30-40%. However, the progress made in the field of water preparation at the heat and electric power plants with high and superhigh parameters (the application of chemical desalination) made it possible to release steam at the heat and electric power plants, as a rule, directly from the turbine taps, that is, without installing the steam converters. The unit output capacity of the housings of the steam converters at the heat and electric power plants where they were installed for any reason reached 50 tons/hour.

During operation of the heating heat and electric power plants with turbines adapted for two-stage heating of the network water, contradictions arose between the optimal conditions of such turbines and the operating conditions of thermal networks using the two-stage heating system for the tap water for hot water supply systems. These contradictions consist in the fact that during the nighttime hours in the absence of domestic consumption of heat, the return water temperature in the heating networks increased by 20-30°C and in the cold part of the year at a number of the heat and electric power plants, it rose to 80-90°C (as a result of the "overheating" of the buildings unavoidable in such a system). At the heat and electric power plants this increase in temperature of the return water meant a reduction in the district heating power of the T-50 and the T-100 turbines as a result of forcing the taps by the heat at the peak-load boilers.

Independently of this situation, at the heating heat and electric power plants fully loaded with respect to heat in the power systems of the center and the western part of the country, by request of the dispatchers it was necessary also to lower the electric power of the district heating turbines during the night hours of transmission of the minimum electric loads which also was connected with losses of possible fuel savings as a result of the replacement of the turbine taps by release of heat from the hot water boilers of the heat and electric power plants. This nighttime loading of the heat and electric power plants with respect to heat is connected with losses of 100 tons of fuel per day for each 100 megawatts of power of the district heating turbines. As the experience in the operation and maintenance of the heat and electric power has demonstrated, the least loss in fuel savings from unloading the T-taps during the minimum electric load hours of the power systems came from the heat and electric power plants, the equipment of which included the PT type turbines, inasmuch as during these periods of the day, the release of heat to the heat consumers could be (according to the load conditions of the steam users) switched from the T-taps to the P-taps.

In connection with the requirement of the sanitary inspection agencies for improvement of the cleanness of the air in a number of the heat and electric power plants located directly in the cities, the burning of coal was replaced by using natural gas and fuel oil. The new heat and electric power plants of the large cities -- Moscow, Leningrad, Kiev, and so on -- began to be constructed for operation only on gas and fuel oil. Altogether by 1970, in the fuel balance of the heat and electric power plants the proportion of gas and fuel oil increased from 30% in 1960 to 55%, and with a reduction in the proportion of coal, from 68 to 38%.

At the heat and electric power plants of Moscow with a total electric power of·3.5 million kilowatts and a thermal power of 50,280 gigajoules/hr ($12 \cdot 10^3$ gigacalorie/hr), the proportion of gas and fuel oil in 1970 was 73%, and coal, a total of 27%.

The total savings of fuel at the general purpose heat and electric power plants of Minenergo [the Ministry of Power Engineering] increased from 4 million tons in 1960 to 20.5 million tons in 1970, from which more than 13 million tons (or about 65%) were obtained as a result of the operation of heat and electric power plants having an additional steam pressure on the turbines of more than 3.5 MPa (35 kg-force/cm^2).

Development of the Heat and Electric Power Plants During the Execution of the Ninth Five-Year Plan of Development of the National Economy (1971-1975). By 1975 the power of the heat and electric power plants had increased to 58.5 million kilowatts with an annual heat release of about 3820 million gigajoules (915 million gigacalories), of which 2840 million gigajoules (680 million gigacalories), or about 75%, came from the heat and electric power plants of the Ministry of Power Engineering. The dynamics of the variation of the basis indexes of the development of the heat and electric power plants by 1975 are presented in Table 7.

As follows from this table, during the 1971 to 1975 period, the operating efficiency of the heat and electric power plants increased significantly, and the proportion of the electric power generation at the heat and electric power plants increased by almost 33%. During these years, the equipment of the heating heat and electric power plants included the T-250/300-240 turbines for transcritical steam parameters of 24.0 MPa (240 kg-force/cm^2) and 540°C with the application of industrial superheating, and for industrial heating heat and electric power plants of UTMZ in 1973 the PT-135/165-130 turbine was manufactured for pressure of 13.0 MPa (130 kg-force/cm^2).

By 1975 seven of the T-250/300-240 turbines and three of the PT-135/165-130 turbines had been installed. The theoretical heating diagrams of the T-250/300-240 turbine is presented in Fig 7, and for the PT-135/165-130 turbine, in Fig 8. In addition, as a result of the improved use of the carrying capacity of the high-pressure part and medium pressure part of the 60 and 100 megawatt turbines, remarking of their power was accomplished with an increase in it for the 60 megawatt turbine to 75 megawatts and the 100/105 megawatt turbine to 110/120 megawatts.

The composition of the turbines with respect to the parameters and power at the heat and electric power plants and the Ministry of Power Engineering and the basic operating indexes of them are presented in Table 8.

In accordance with the improvement in structure of the district heating turbines by the initial steam parameters, the proportion of the generation of electric power by the turbines at 13.0 MPa (130 kg-force/cm^2) increased from 41% in 1970 to 54.8% in 1975, and the fuel savings by the turbines in this group, from 6.35 to 9.7 million tons. The total fuel savings from the operation of the heat and electric power plant increased from 20.5 million tons in 1970 to 27.2 million tons in 1975 with a reduction in the specific fuel consumption for the generation of electric power by the 13.0 MPa turbines (130 kg-force/cm^2) from 283.2 to 264 g/(kilowatt-hour).

Table 7

Development of the General Purpose Heat and Electric Power Plants of the Ministry of Power Engineering

	Показатели (1)	1960	1965	1970	1975
(2)	Установленная мощность теплофикационных турбин, млн. кВт	11,4	23,7	36,9	48,1
(3)	Выработка электроэнергии, млрд. кВт·ч/год	65,8	135,0	195,3	248,2
(4)	Доля комбинированной выработки электроэнергии, %	31,5	41,0	54,0	61,7
(5)	Отпуск тепла от ТЭЦ, млн. ГДж/год (Гкал/год)	607,1 (144,9)	1288,4 (307,5)	2125,2 (507,2)	2880,0 (680,2)
(6)	Доля отпуска тепла в горячей воде, %	27,0	34,0	42,0	46,0
(7)	Удельная выработка электроэнергии на тепле из отборов турбин, кВт·ч/ГДж (кВт·ч/Гкал)	40,6 (170)	50,1 (210)	60,1 (252)	69,0 (269)
(8)	Удельный расход условного топлива на отпущенную электроэнергию от ТЭЦ, г/(кВт·ч)	462	397	324	279,4
(9)	То же по КЭС	475	426	388	365,4

Key:

1. Index
2. Installed capacity of the district heating turbines, millions of kilowatts
3. Generation of electric power, millions of kilowatt-hour/year
4. Proportion of combined electric power generation, %
5. Release of heat from the heat and electric power plants, millions of gigajoules/year (gigacalorie/year)
6. Proportion of heat release in hot water, %
7. Specific generation of electric power for heat from the turbine taps, kilowatt-hours/gigajoules (kilowatt-hour/gigacalories)
8. Specific provisional fuel consumption for released electric power from the heat and electric power plants, g/(kilowatt-hour)
9. The same with respect to condensation electric power plants

All in all, the proportion of the total fuel savings from operation of the heat and electric power plants with parameters of 9.0 and 13.0 MPa (90 and 130 kg-force/cm^2) increased from 66% in 1970 to 73% in 1975 with the corresponding reduction of the proportion of the heat and electric power plants of lower parameters.

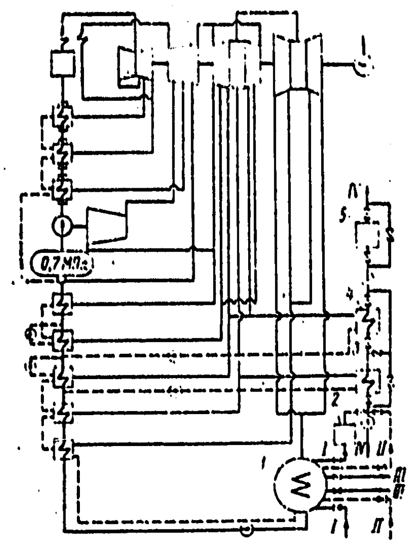

Figure 7. Theoretical heating diagram of the T-250/300-240 turbine
1 -- condenser; 2 -- chemical purification and deaeration of the makeup water; 3 -- first stage network heater; 4 -- second stage network heater; 5 -- peak-load water heating boiler; I -- makeup water of the heating network; II -- return network water; III -- circulating water; IV -- network water

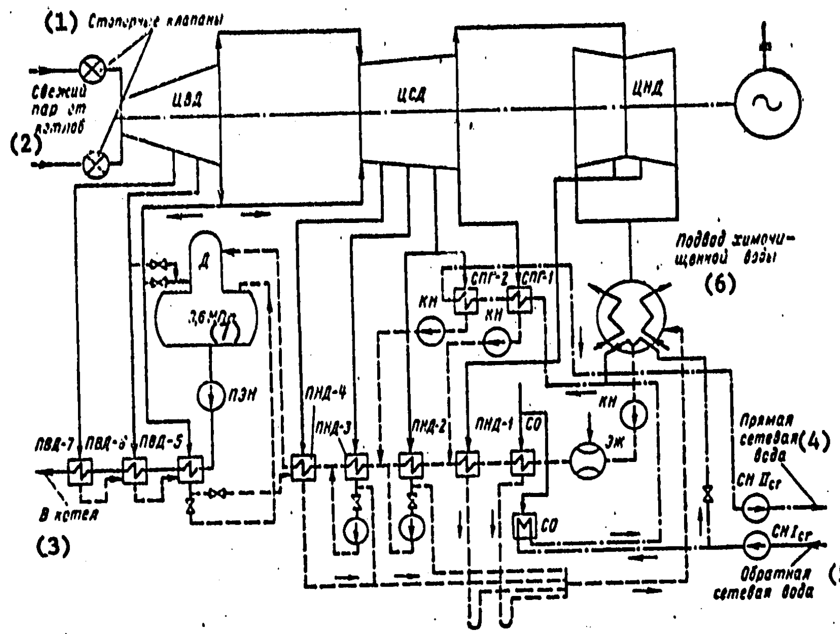

Figure 8. Theoretical heating diagram of the T-135/165-130 turbine installation
ЦВД, ЦСД, ЦНД -- high, medium and low pressure cylinders;
Д -- deaerator; ПЭН -- feed electric pumps;
ПВД and -- high and low pressure heaters;
КН -- condensate pumps; СПГ -- network heaters; СО -- packing and cooling agent; ЭЖ -- ejector; СН -- network pump

Key:
1. Stop valve
2. Live steam from the boilers
3. To the boiler
4. Direct network water
5. Return network water
6. Chemically purified water feed
7. 0.6 MPa

Table 8

Basic Operating Indexes of the General Purpose Heat and Electric Power Plants of the Ministry of Power Engineering

(1) Тип турбин	(2) Год	(3) Число турбин	(4) Суммарная электрическая мощность, 10⁶ кВт	(5) Суммарная тепловая мощность, ГДж/ч (Гкал/ч)	(6) Выработка на тепловом потреблении, %	(7) Удельная выработка электроэнергии на тепловом потреблении, кВт·ч/ГДж (кВт·ч/Гкал): (8) Расчетная	(9) Фактическая	(10) Число часов использования электрической мощности, ч/год	(11) Число часов использования тепловой мощности, ч/год	(12) Средняя нагрузка турбины, МВт	(13) Удельный расход топлива, г/(кВт·ч)
Т-50-130	1965	11	0,6	4273,8 (1020)	29,0		100,5 (421)	5420	1020	40,5	300
	1970	34	1,72	13156,6 (3140)	48,1	131,3 (550)	104,5 (438)	5300	2020	41,0	304
	1974	30	1,97	15 084 (3600)	54,1		116,0 (480,0)	6150	3780	43,0	296
	1975	30	1,97	15 084 (3600)	52,0		113,0 (470)	6100	3980	45,0	302
Т-100-130	1965	13	1,3	8700 (2100)	28,7		101,43 (425)	5400	1970	60,0	300
	1970	47	4,7	31 425 (7500)	48,5	133,7—138,4 (560—580)	102,9 (431)	5650	3760	65,0	281
	1974	80	8,12	52 400 (12 600)	55,7		125,2 (523)	5600	3780	80,0	269
	1975	88	9,0	58 000 (13 900)	56,0		127,0 (529)	5750	3850	82,0	264
ПТ-50/60-130 (14)	1965	72	3,72	40 000 (9500)	30,0		59,43 (249)	6600	—	43,0	400
	1970	118	6,43	66 000 (15800)	41,5	112,2 (470)	64,4 (270)	6400	3800	45,0	331
	1974	134	7,62	33 200 (7940)	49,0		76,0 (317)	5786	3840	46,0	303
	1975	144	8,25	80 000 (19500)	52,0		76,5 (319)	5000	4000	47,0	291
Р-50-130 (15)	1965	24	1,2	10391,2 (2480)	100,0			2580	2560	29,0	—
	1970	63	3,15	27 235 (6500)	100,0	59,7 (250)	48,7 (204)	4600	4600	35,0	166
	1974	70	3,8	63 000 (15000)	100,0		56,0 (231)	4880	5140	30,0	160
	1975	80	4,0	64 500 (15 400)	100,0		57,0 (230)	4950	5100	39,0	160
Р-100-130 (16)	1974	11	0,1	17 900 (4270)	100,0	60,9 (255)	56,7 (237)	3420	3760	66,0	159
	1975	12	1,2	20 100 (4830)	100,0		57,0 (239)	4600	5150	75,0	160
Все турбины на 13,0 МПа (130 кгс/см²) (17)	1970	278	13,9	120 800 (31 000)	51,0	—	66,8 (280)	5700	4000	43,0	290
	1974	361	23,87	236 000 (56 320)	61,0	—	81,0 (339)	5530	4150	47,5	267,5
	1975	384	25,07	253 000 (60 430)	62,2	—	81,5 (390)	5100	4200	—	260
Все турбины на 9,0 МПа (90 кгс/см²) (18)	1974	—	11,1	168 000 (40 025)	59,1	—	66,0 (278)	5700	4100	—	298,6
	1975	—	14,4	181 000 (40 327)	60,3	—	67,0 (280)	5600	4100	—	296,5
Все турбины на 4,5 МПа (45 кгс/см²) и ниже (19)	1974	—	6,54	117 000 (28 000)	65,3	—	40,0 (168)	4650	15 600	—	330,3
	1975	—	6,45	116 700 (27 940)	69,9	—	40,0 (168)	4350	5550	—	313,8
Все ТЭЦ Минэнерго (20)	1974	—	45,41	530 000 (127 000)	60,6	—	66,8 (280)	5210	4160	—	286,5
	1975	—	48,25	550 000 (131 700)	61,7	—	69 (289)	5300	4100	—	279,4

[See key on p 35]

[Key to Table 8, p 34]:

1. Type of turbine
2. Year
3. No of turbines
4. Total electric power, 10^6 kilowatts
5. Total thermal power, gigajoules/hr (gigacalorie/hr)
6. Generation for heat consumption, %
7. Specific generation of electric power for heat consumption, kilowatt-hr /gigajoule (kilowatt-hour/gigacalorie)
8. Calculated
9. Actual
10. No of hours of use of electric power, hours/year
11. No of hours of use of thermal power, hours/year
12. Average turbine load, megawatts
13. Specific fuel consumption, g/(kilowatt-hr)
14. PT-50/60-130
15. R-50-130
16. R-100-130
17. All turbines at 13.0 MPa (130 kg-force/cm^2)
18. All turbines at 9.0 MPa (90 kg-force/cm^2)
19. All turbines at 4.5 MPa (45 kg-force/cm^2) and lower
20. All heat and electric power plants of the Ministry of Power Engineering

Table 9

Basic Operating Indexes of the Minenergo [Ministry of Power Engineering] Heat and Electric Power Plants

(1) Начальное давление пара турбин ТЭЦ	(2) Отпуск электроэнергии, %				(3) Удельный расход условного топлива на отпущенную электроэнергию, г/(кВт·ч)			
	1965	1970	1973	1974	1965	1970	1973	1974
(4) 13,0 МПа (130 кгс/см²)	22,6	41,3	51,0	52,6	338,0	283,2	269,7	267,5
(5) 9,0 МПа (90 кгс/см²)	46,3	36,8	34,0	33,4	366,0	326,1	306,4	299,7
(6) 5,4—7,4 МПа (54—74 кгс/см²)	4,1	2,2	2,1	1,5	362,0	333,0	278,0	270,0
(7) 3,6 МПа (36 кгс/см²)	28,0	19,7	12,9	12,5	494,0	411,0	339,0	333,3
	100,0	100,0	100,0	100,0	397,0*	324,0*	291,3*	286,5*

(8) * Средние значения

Key:

1. Initial steam pressure of the TETs turbines
2. Release of electric power, %
3. Specific consumption of provisional fuel for the released electric power, g/(kilowatt-hr)
4. 13.0 MPa (130 kg-force/cm^2)
5. 9.0 MPa (90 kg-force/cm^2)
6. 5.4-7.4 MPa (54-75 kg-force/cm^2)
7. 3.6 MPa (36 kg-force/cm2)
8. *mean values

More detailed information about the structure of fuel economy at the Minenergo Heat and Electric Power Plants is presented in Table 9. From this table it follows that not only at the heat and electric power plants with high steam parameters but also at those operating with an initial pressure below 4.5 MPa (45 kg-force/cm^2) a significant reduction in the specific fuel consumption for generation of electric power from 411 to 333 g/(kilowatt-hour) respectively was achieved. This reduction in the fuel consumption was reached as a result of the rebuilding of the turbines of these parameters into counterpressure turbines and with worsening of the vacuum. In addition, it must be noted that in essence the rebuilding of these turbines gives relatively small improvement of the indexes of this group of turbines and the operation of all of the heat and electric power plants of the Ministry of Power Engineering as a whole. The dismantling of these turbines with the transfer of their thermal loads to the high-parameter heat and electric power plant can provide additional fuel savings to 2.0-2.5 million tons per year.

From the data presented in Table 7 it follows that as a result of the lag in building the heating networks from the heating heat and electric power plants, the heat release from them gives a total of about 1257 million gigajoules (300 million gigacalories) with an installed capacity of the turbines insuring heat release to 1592.2-1676 million gigajoules (380-400 million gigacalories) per year. If we assume that about 125.7-167.6 million gigajoules (30-40 million gigacalories) must be conserved at the heat and electric power plants in the form of a reserve for subsequent years, the underrelease of heat from the heat and electric power plants in the amount of 209.5-251.4 million gigajoules (50-60 million gigacalories) actually lowers the savings from the district heating by 2.0-2.5 million tons.

The reduction in fuel savings as a result of unloading the turbine taps of the heat and electric power plants during nighttime can be estimated in the amount of about 1 million tons per year.

Thus, as a result of the organizational and the regime measures, the fuel savings achieved by 1975 from the operation of the heat and electric power plants could be increased by more than 10%. The elimination of these deficiencies is one of the basic problems of the development of district heating in the Tenth Five-Year Plan.

With respect to the development of the heat and electric power plants, district heating and centralized heat supply the USSR quantitatively and qualitatively greatly leads the USA and the industrially developed countries of Western Europe.

The beginning of district heating abroad belongs to 1877 (United States of America). By the 1970's there were a total of about 100 heat and electric power plants in operation in the United States (basically at industrial enterprises) and 400 units for centralized heat supply to 300 cities.

The majority of the installations in the cities are the low parameter steam boilers belonging to private companies. The central parts of the capital of the United States, Washington, D. C., are supplied with heat from the government steam boiler. In the largest heating supply system in the United States in New York there are two heat and electric power plants in operation with a total power of 540 megawatts; four counter-pressure turbines of 50 megawatts each at the Waterside Plant and a 340-megawatt condensation turbine with nonadjustable steam tap of 180 ton/hour at the Astoria Plant (for the heat supply of the gas plant).

The total centralized heat released in the United States will reach 1670 million gigajoules (400 million gigacalories) per year; of this about 90% is from industrial heat and electric power plants with an installed capacity of about 10 million kilowatts (basically counterpressure turbines). The most widespread type of heat and electric power plant is basically the block station of up to 100 megawatts at the enterprises of the petrochemical, chemical and paper industry. The power of the heat and electric power plants is determined, as a rule, by the electricity consumption of the enterprises of the block station owners which is the result of the practice in the United States of issuing separate licenses to the district electric power supply and the heat supply. Among the most powerful industrial heat and electric power plants built in the United States in the last 10 to 15 years it is necessary to mention the heat and electric power plants of the Linden Petrochemical Complex with two central heating turbines of 225 megawatts each for 13 MPa (130 kg-force/cm^2) and 535°C with adjustable steam tap and condensation and at the heat and electric power plants of a number of oil refineries at which two to three units are installed each with counterpressure turbines of 50 megawatts each.

In Western Europe the district heating units reached the greatest development in the Federal Republic of Germany where the total power of the heat and electric power plants is about 4.0 million kilowatts and the heat release about 209 million gigajoules/year (50 million gigacalories/year). Among the district heated cities are Hamburg, Munich, and Mannheim, Dusseldorf, and so on, the extent of the heating networks in which is 40 to 80 km with maximum heat release to 628 gigajoules/hour (150 gigacalories/hour). The total number of centralized heat supply units in the Federal Republic of Germany is about 800, and of them about 100 are built as heat and electric power plants with a total heat release to 50,300 gigajoules/hour (12000 gigacalories/hour). The most widespread are the counterpressure turbines of 10-15 megawatts, including the turbines for superhigh and transcritical steam parameters. In contrast to the United States, block heat and electric power plants in the Federal Republic of Germany participate in the covering of the variable part of the electrical chart of the power system for which at the heat and electric power plants in addition to the counterpressure turbines, frequently low-parameter condensation turbines are installed which are included as the second low pressure shafts to the turbines with counterpressure (analogously to the scheme in Fig 1). In order to increase the maneuverability of the heat and electric power plants in recent years, steam and gas units are installed at some of them made up of the 30-40 megawatt gas turbines and the 70-100 megawatt steam turbines and more.

The district heating in Denmark has received broad development in the postwar period where the centralized heat supply units cover more than 40% of the heat consumption of the country, of them about half are the proportion of the heat and electric power plants. A characteristic feature of district heating in Denmark is the district heating of the small settlements from the rayon district condensation electric power plants with heat release from the nonregulatable taps of the condensation turbines. At the heat and electric power plants in Odense and Elsberg, turbines were installed with 131 and 175 megawatts with steam taps and condensation for initial steam parameters of 14.5-17.5 MPa (145-175 kg-force/cm^2). The total heat release from the heat and electric power plants reaches 4.0 million gigajoules/year and approximately the same amount is released by the 420 municipal district boilers.

The fuel and energy crisis started in 1973 in a number of foreign countries led to the fact that the problems of saving fuel and efficient construction of the fuel and energy balance have begun to be included among the primary problems subject to government control.

A comparison of the paths of development of power engineering in the USSR and in the foreign countries encompassed by the fuel crisis permits establishment of the indisputable advantages of the course taken in the USSR toward a comprehensive development of district heating as the basis for the efficient construction of the energy balance of the country with minimum consumption of fuel resources.

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ELECTRIC POWER AND POWER EQUIPMENT

ROLE OF CENTRAL HEATING SYSTEM IN POWER ENGINEERING, NATIONAL ECONOMY

Moscow TEPLOFIKATSIYA SSSR in Russian 1977 pp 7-24

[Article by Ye. I. Borisov of the USSR Ministry of Power and Electrification and V. P. Korytnikov of the All-Union Scientific Research and Design Institute for the Power Industry in the collection of articles edited by S. Ya. Belinskiy and N. K. Gromov "Teplofikatsiya SSSR" (The Development of the Central Heating System of the USSR) Energiya 312 pages]

[Text] In the history of all the generations of mankind the grandiose creative activity of the Leninist Communist Party will always serve as an example of the profound scientific elaboration and practical solution to the fundamental problems of transforming social relationships and satisfying the material and spiritual needs of man. In all stages of communist construction the central concern of the CPSU has been and is the creation of a powerful material and technical base which would be used for a continuous rise in the material and cultural standard of living of the people, for ensuring high development rates of socialist production and improving its economic efficiency, as has been affirmed in the decisions of the 25th CPSU Congress.

In the development of the productive forces a major role is played by power and its most progressive basis, electric power. In 1975, the production of electric power for the nation reached 1,038,000,000 kilowatt hours, and the installed capacity of all the power plants was 218,000,000 kilowatts. A new important goal had been achieved by the Soviet state in creating the material and technical base of communism. There have been major advances both in the area of developing thermal power as well as in the area of hydropower construction. Our nation has built the world's largest hydropower plants with a capacity of 4.2 and 6 million kilowatts. In terms of the per capita production of electric power, the USSR has reached the level of the economically most developed nations of the world.

The thermal power plants comprise the main basis of the nation's power, generating around 87 percent of the total electric power. The achievements of Soviet thermal power are significant.

The largest Krivoy Rog GRES has gone into operation with a capacity of 3 million kilowatts, and new unique thermal power plants are being designed with a unit capacity of 4 and 6.4 million kilowatts. In 1975, there were 132 power units in operation with a capacity of 300 megawatts. Units with a capacity of 500 and 800 megawatts have been developed. The first turbine unit with a capacity of 1,200 megawatts has been developed for installation at the Kostroma GRES. At the Leningrad Atomic Power Plant two units have been put into service with reactors of 1 million kilowatts each.

The central heating system is a most important component in Soviet thermal power. In November 1974, this area of power development marked its 50th anniversary. The elaboration of the scientific and technical bases for the combined production of electric and thermal power, the development of many types of specialized equipment for the TETs and the heat transporting systems, and the solution to numerous scientific, technical and practical problems involved in the building and operation of large central heating systems were an accomplishment of Soviet scientists and engineers. It must be emphasized that the idea of the extensive production of electric and thermal power by the combined method and the centralized power supply from large sources conform fully to the underlying principles of the comprehensive development of the national economy on the basis of electrification. These most important provisions were formulated in Lenin's GOELRO [State Commission for the Electrification of Russia] Plan which established the basic principles for the creation of socialist industry as a foundation for building a communist society.

The CPSU Central Committee and the Soviet government have always given great attention to the development of Soviet power. More than 20 billion rubles were spent in just the Ninth Five-Year Plan for building power plants and electrical and thermal networks. Some two-thirds of the boiler and furnace fuel is consumed for the needs of the nation's electric and thermal power supply. The enormous outlays on the development of the nation's power and fuel supply necessitates the rational utilization of the fuel and energy resources. In solving this problem of great significance is the broad introduction of centralized heat supply and above all the development of central heating from the TETs, as around 40 percent of the boiler and furnace fuel is consumed for heat supply needs.

The operation of the first common-use heat line from the Leningrad Power Plant No 3 (25 November 1924) is considered to be the beginning of the development of central heating in our nation, and this was followed by the experimental TETs of the VTI [All-Union Institute of Heat Engineering] in Moscow (1928). On the basis of this first experience, construction was then started on central heating installations in Rostov, Khar'kov, Kiev, Yaroslavl', Ivanov, Samara, Kazan' and other cities.

Being an important component in thermal power, the central heating system in keeping with its quantitative and qualitative growth has assumed ever greater significance as one of the basic directions in the electrification of the USSR and the rational shaping of the fuel and energy balance. In providing for the generating of electric power in heat consumption with substantially lower specific fuel consumptions in comparison with the KES [condensation type power plant], central heating has stimulated technical progress in heat engineering as a whole. At the same time the advances in improving the technical level in the development of the KES have strengthened the search for methods and means for improving the central heating systems. At the end of the 1920's, extensive scientific research and experimental work was started on a further increase in steam parameters on the basis of two experimental central heating units. A small TETs was built in Moscow and a comparatively large one in Berezhniki with a steam pressure of 6.0 megapascals. At the same time this new direction made headway with great difficulty. The Commission for Central Heating under the Department of Industrial Power of the USSR All-Union Council of People's Commissars as well as the Committee for Central Power of Glavenergo [Main Power Supply Administration] of the People's Commissariat of the Fuel Industry helped greatly in defending this direction. A major contribution to defending the ideas of central heating was made by such Soviet scientists and engineers as L. L. Ginter, V. V. Dmitriyev, Zh. L. Tanner-Tannenbaum, V. M. Chaplin, M. O. Grinberg, A. A. Krauz and others. On 1 January 1931, the total capacity of the central heating units was 210 megawatts, and the length of the common-use heating networks was 45 km with an annual heat output of 6.3 million gigajoules [GJ] (1.5 million gigacalories [Gcal]).

Extensive development of central heating started in the 1930's after the decision of the June (1931) Plenum of the VKP(b) [All-Union Communist Party (Bolshevik)] Central Committee "On the Moscow Municipal Economy and the Development of the Municipal Economy of the Nation" which stated: "The Central Committee feels that in the further plan for the electrification of the nation full consideration should be given to the task of the all-out construction of large TETs."[1]

In 1931, construction was started on the experimental TETs of the VTI with superhigh pressure (13.0 megapascals [Mp], 500°C), and in 1934, a Soviet-built Ramzin design straight-through boiler (the first in world power engineering) was installed at this TETs with a steam productivity of 160/200 tons per hour and parameters of 14.0 Mp and 500°C with intermediate steam superheating.

In the period 1931-1934, the total capacity of the TETs was increased by 660,000 kilowatts (about 20 percent of the total increase in capacity for all power plants) and was 870,000 kilowatts. Heat output increased by 6.5-fold, and the fuel savings due to central heating in 1934 were over 1 million tons. The following plants were built and put into operation:

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[1] "KPSS v Rezolyutsiyakh i Resheniyakh" [The CPSU in Resolutions and Decisions], Vol 4, Moscow, Gospolitizdat, 1970, pp 551-552.

the Kuznetsk TETs with 84 megawatts, the Berezniki TETs with 93 megawatts, the TETs of the Yaroslavl' Combine with 25 megawatts, the Krivoy Rog TETs with 25 megawatts, the Lipetsk TETs with 24 megawatts, the TETs of the Gor'kiy Motor Vehicle Plant with 24 megawatts, the TETs of the Khar'kov Tractor Plant with 15 megawatts, the Lugansk TETs with 16 megawatts, the TETs of Uralmash [Urals Machine Building Plant] with 10 megawatts, the Groznyy TETs with 25 megawatts, the TETs of the VTI with 36 megawatts, the Krasnozavodskaya Station in the city of Khar'kov with 25 megawatts, and the Kazan' TETs with 20 megawatts.

The length of the common-use heat networks had increased up to 200 km.

By this time on the basis of the successes achieved in the industrialization of the nation during the First Five-Year Plan, there was the rapid development of Soviet power machine building.

In 1940, the nation had in operation around 100 TETs with a total capacity of 2,000 megawatts, and the heat production from them was 104.85 million GJ (25 million Gcal), that is it had increased by 17-fold, while the length of the heating networks was 650 km, and the annual fuel savings had reached 2.5 million tons. On the basis of TETs, power supply was also provided for the large industrial centers.

In terms of the total production of electric power (43 billion kilowatt hours) and the capacity of the thermal power plants [TES] (9.6 million kilowatts), the USSR reached second place in Europe. The USSR manufactured the world's first steam turbine with a power of 100 megawatts at 3,000 rpm.

An important feature of prewar Soviet thermal power was that it developed on a basis of chiefly using local low-grade types of fuel such as anthracite culm, brown coal, and peat, and this was of great national economic significance.

During the period of the Great Patriotic War, dependable fuel supply for the power plants was provided on a basis of the local types of fuel. Regardless of the fact that around 60 TES were partially or completely destroyed with a total capacity of around 5 million kilowatts, including many of the TETs, however due to the measures which were undertaken in the nation, by 1945 the capacity of the TES was 9.9 million kilowatts (in 1940, 9.6 million kilowatts). By the beginning of 1951, the capacity of the TES had increased up to 16.39 million kilowatts, and the output of electric power at them in 1950 had reached 78.53 billion kilowatt hours. The share of high pressure units rose from 3 percent in 1940 up to 20 percent in 1950. The total capacity of the central heating units in 1950 was 3.7 million kilowatts, or more than 22 percent of the total capacity of the TES.

By the beginning of the 1950's in the area of electric power production at the TES, the task of increasing electric power output was solved by a further increase in the capacity of the GRES and individual units, as well as a changeover to high and superhigh steam parameters. In 1953, the first thermal power units went into operation with parameters of 17.0 Mp and 550°C with secondary steam superheating. In 1954, there was the beginning of a new stage in the development of Soviet thermal power, as in this year the world's first atomic power plant [AES] went into operation.

In the period 1951-1955, the completion of new capacity and the output of electric power at the TES almost doubled, and the average annual increases were 13.8 percent for capacity and 13.4 percent for the generating of electric power. On the basis of units with a capacity of 50 and 100 megawatts, the unit capacity of the large TES reached 400 megawatts. By the beginning of the Seventh Five-Year Plan (1959-1965) the capacity of the TES was 42.8 million kilowatts, and the output of electric power was 188.8 billion kilowatt hours.

At the same time up to 1961, the basic central heating units serially produced by industry had capacities of 6, 12 and 25 megawatts. The smaller central heating equipment in comparison with the KES led to an excessively high (350-450 rubles per kilowatt hour) cost of an installed kilowatt of power at the TETs, and objectively delayed the development of central heating. Nevertheless, during the period of 1951-1960, the installed capacity of the TETs rose by 12.9 million kilowatts, and was 16.6 million kilowatts, while the proportional amount of the total capacity of the central heating units in the total capacity of the TES increased up to 32 percent.

In 1960, heat production from the TETs was more than 1,130,300,000 GJ (270 million Gcal), or more than 43 percent of the demand for heat of industry and the cities.

Characteristic for the designated decade was a rise in the concentration of the thermal loads in the large cities and industrial centers, and on the basis of this there was predominant development of large regional public TETs the capacity of which in 1960 was around 72 percent of the capacity of all the TETs, and heat production was around 53 percent.

In 1960, the public TETs were connected with consumers by heating networks with a total length of 3,450 km. The share of electric power output by the central heating units of this group of TETs was in the same year 35.5 percent of the total output by all the TES. Some 31.5 percent of the total output by the central heating units was generated in heat consumption.

The following data show the scale of the concentration of heating loads: in 1950, the Moscow TETs produced over 8.38 million GJ (2 million Gcal) of heat, and in 1961, the same heat production was reached also by 13 cities of the European USSR (Leningrad, Kiev, Khar'kov, Yaroslavl' and others) as well as several cities in Siberia and the Urals (Novosibirsk, Krasnoyarsk, Chelyabinsk, Ufa, Perm' and others). Particularly high development rates in the central heating system were reached in the decade from 1960 through 1970, when substantial quantitative and qualitative shifts occurred in the area of central heating. The capacity of the TETs in the nation rose by

2.7-fold and by the end of 1970 had reached 45 million kilowatts, and heat production was 2,933,000,000 GJ (700 million Gcal). The proportional amount of the central heating units (in terms of capacity) with an initial pressure of 13.0 Mp was around 40 percent; 53 percent for those with a unit capacity of 50 megawatts and over, and 54 percent for the share of electric power output from heat producing units. The average weighted specific consumption of conditional fuel units on the generated electric power in 1970 was 309 grams per (kilowatt hour) at the TETs equipped only with central heating units, and 297 grams per (kilowatt hour) at the analogous TETs of the Minenergo [Ministry of Power and Electrification], that is, lower, respectively, by 55 and 67 grams per (kilowatt hour) at the best unit GRES. The dynamics of capacity growth at the TETs and the production of heat from them from 1930 up to the present is shown in Fig. 1.

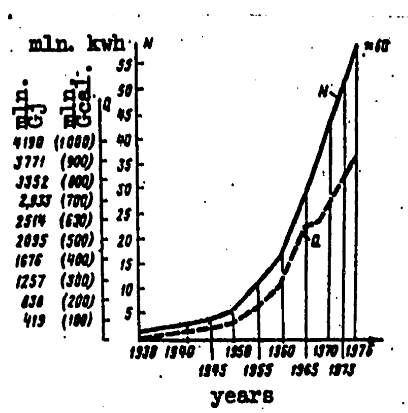

Fig. 1. Growth dynamics for capacity of TETs and heat production from them.

Q--heat production; n--capacity

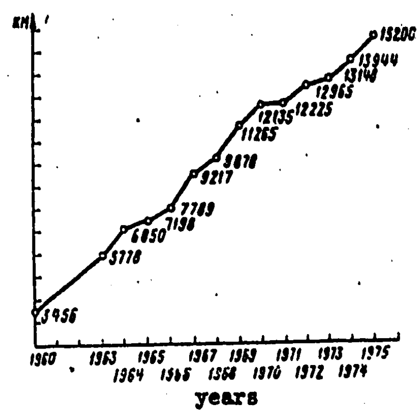

Fig. 2. Length in kilometers of main heating networks of the USSR Minenergo.

From the very outset of its development, the Soviet central heating system has followed an unique path. Hot water (in contrast to the United States and the Western European nations where basically steam is used) has been employed as the heat carrier for heating, ventilating and in certain instances for production needs. In the USSR, for the first time in the world, an open heat supply system with the direct use of system water for domestic hot water supply was developed and widely introduced.

In our nation a skilled school of heating power engineers has developed and this has created the scientific bases of central heating and has ensured its rapid development.

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The Soviet power machine builders have developed highly economic turbines with steam bleeding for two-stage reheating of the system water or make-up water of the heating system. The scientists, designers and workers of all the central heating subdivisions have traveled a difficult path from the production of the first Soviet turbine with a capacity of 12 megawatts in 1931 to the creation of the world's largest central heating turbine unit with a power of 250/300 megawatts with supercritical steam parameters. For the first time the plans of heating TETs were worked out using a new design for the peak water heating boilers with a heat productivity up to 754 Gj per hour (180 Gcal per hour) inclusively.

Our engineers have also developed new designs of heating networks, a method has been proposed for the technical, economic and hydraulic calculations for the heat transport systems, and standards for production designing, the production systems of the TETs and their rational layout have been worked out.

In terms of the development scale of central heating, the USSR holds first place in the world, in significantly outstripping the other developed countries. The development of heat supply from the TETs is closely tied to the possibilities which are provided by the managing of a planned economy under socialism. In this regard in recent times the example of the USSR has been also followed by other socialist countries. Recently in the aim of saving fuel, under the conditions of the growing fuel shortage and increased cost, as well as the developing struggle to purify the atmosphere, the combined system of power supply has also begun to be more widely developed in a number of the capitalist countries. The present state of the central heating system in the USSR can briefly be characterized by the following data.

In 1975, the total capacity of the TETs in the nation was around 60 million kilowatts, and heat production by all the TES was around 3,772,000,000 Gj (900 million Gcal). The length of the heating networks from the TETs of Minenergo was around 15,000 km. The growth dynamics of the length of the main heating networks is given in Fig. 2. The central heating units were around 33 percent of the capacity of the TES of the nation and 27 percent of the capacity of all electric plants. The share of electric power output surpasses these figures due to the higher number of hours of use for the installed electrical capacity of the TETs. In 1975, the TETs provided around 42 percent of the annual heat consumption of all the urban settlements of the nation, and in individual major economic regions the level of central heating was significantly higher than the average, and reached: 63 percent in the East Siberian economic region, 56 percent in the Volga region, and 47 percent in the Urals region.

In 1975, around 60 percent of the electric power of the TETs was generated under heating supply conditions, and this provided a substantial savings of fuel. For the TETs of the Minenergo (the capacity of which is over 80 percent of the total electric capacity of all the TETs), the total fuel savings approached 30 million tons of conditional fuel units. In the last decade there has been a substantial improvement in the structure of the central heating units put into operation, particularly at the TETs of the Minenergo. More than 95 percent of the turbines put into use (in terms of capacity) have steam parameters of 13.0 Mp and higher. Turbines with a capacity of under 50 megawatts with an initial parameter below 9.0 Mp are now being used as an exception only at the TETs being enlarged. There has been an increase in the share of the use of T-type turbines which provide the highest proportional output of electric power from central heating units. The improvement in the structure of the turbines put into use has led to a decline in the specific fuel consumption. In 1975, at the TETs of the Minenergo with units of 13.0 Mp, the proportional consumption of conditional fuel units was around 264 grams per (kilowatt hour). At a number of the TETs, the specific fuel consumptions are 175-180 grams per (kilowatt hour).

As a whole over the last 15 years of the most intensive development of central heating, its national economic effectiveness has been characterized by the data of Tables 1 and 2 as well as Figs. 3 and 4. The total fuel savings during these years was over 270 million tons of conditional fuel units.

Central heating has gained the greatest development in supplying power to industry, where the TETs provide around 50 percent of the industrial consumption of heat. The large enterprises of the most heat-intensive sectors of industry (oil refining, chemical and others) as a rule are supplied with heat from the TETs of Minenergo.

Table 1

Reduction in Specific Fuel Consumption for Public TES

Periods (years)	Reduction of specific fuel consumption, grams/(kilowatt hr)		
	All TES	KES	TETs
1961-1965	468-413 = 55	465-426 = 39	475-397 = 78
1966-1970	413-366 = 47	426-388 = 38	397-324 = 73
1971-1975	366-340 = 26	388-369 = 19	324-282 = 42
1961-1975	468-340 = 128	465-369 = 96	475-282 = 193

As a whole for the nation, for the large cities with predominantly modern development, the central heating level of the housing and utility sector reaches 50-60 percent. For example, in Moscow in 1975, around 70 percent of all users (37,300 buildings) were centrally supplied with heat from the TETs, and heat production from the TETs exceeded 209.5 million GJ (50 million Gcal) a year, and the length of the heating networks from the TETs was 2,150 km. In Leningrad, heat production from the TETs exceeds 62.85 million GJ (15 million Gcal per year), and this supplies 50 percent of the housing and utility consumers.

Table 2

Basic Summary Indicators for the Economic Effectiveness of Central Heating (Public TETs)

Indicators	1961-1965	1966-1970	1971-1975	1961-1975
Increase in TETs capacity, million kilowatts	11.8	13.1	13.2	38.1
Fuel savings, million tons (total)	40.5	92.8	137.5	270.8
Including: By combined output of electric power and heat	36.2	83.6	125	244.8
due to difference in boiler efficiency at TETs and large boiler stations	4.3	9.2	12.5	26.0
Increase in fuel savings	23.7	52.3	44.7	120.7

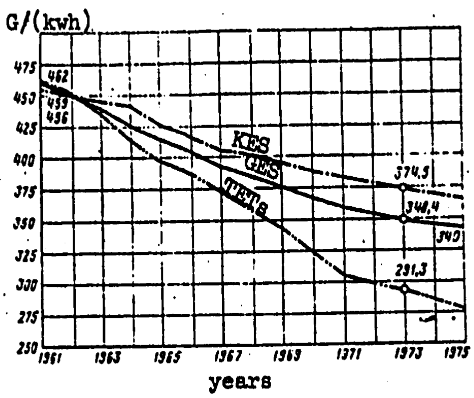

Fig. 3. Dynamics of the decline in the specific consumption of conditional fuel units at the public KES, TETs and TES (KES + TETs).

The new cities which arise around large enterprises and industrial centers are virtually 100 percent supplied with central heat. Nevertheless, at present around two-thirds of the heat consumption of the cities and urban-type settlements is satisfied by small industrial, district and group boiler houses as well as by local heating units (basically furnaces).

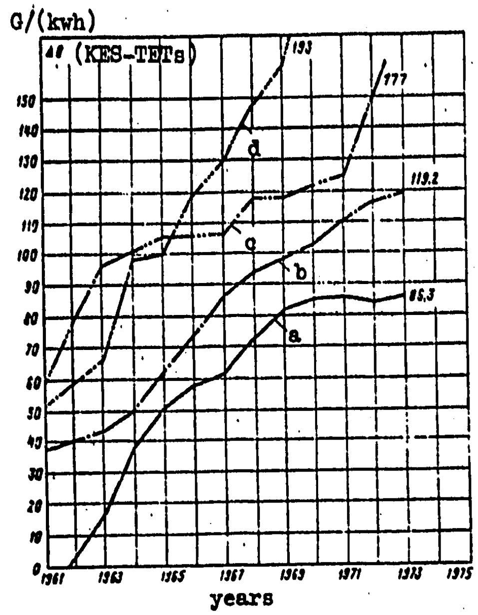

Fig. 4. Difference in specific consumption of conditional fuel units at the KES and TETs in terms of initial steam parameters.

a--pressure of 13.0 Mp and higher; b--pressure of 9.0 Mp; c--pressure from 5.4 to 7.4 Mp; d--pressure of 3.6 Mp and lower.

Central heating and central heat supply have a major role to play in protecting the environment against fuel combustion products and released heat and against pollution of the territory. The total release of harmful matter into the atmosphere is reduced by approximately 15 percent because of central heating and central heat supply.

By using the released heat and by reducing losses from the stack gases, central heating also provides a reduction in heat pollution of the atmosphere by the power plants of Minenergo by approximately 13-15 percent.

From materials of a technical and economic report on the development of Soviet heat supply up to 1980, it follows that from 1970 through 1980, the annual heat consumption of the national economy will arise from 8,908,000,000 Gj (2,126,000,000 Gcal) up to 14,246,000,000 Gj (3.4 billion Gcal), or by 1.6-fold. Also characteristic is an increase in production heat consumption in agriculture by 1.92-fold, with a total increase in rural heat consumption of 1.43-fold. The calculated (maximum-hourly) and annual loads of the cities and urban-type settlements for the USSR are given in Table 3.

Table 3

Heating Loads of Cities and Urban-Type Settlements in the USSR

Consumers	Maximum-Hourly			Annual		
	1970	1975	1980	1970	1975	1980
Cities and urban-type settlements:						
1000 Gj/hr, mil Gj/yr	2,000	2,753	3,453	6,985	9,034	11,564
1000 Gcal/hr, mil Gcal/yr	477	657	824	1,667	2,156	2,760
%	100	138	172	100	129	166
Including:						
Industrial enterprises						
1000 Gj/hr, mil Gj/yr	186	1,747	2,254	4,676	6,117	7,261
1000 Gcal/hr, mil Gcal/yr	283	417	538	1,116	1,460	1,900
%	100	147	190	100	131	170
Housing-utility sector						
1000 Gj/hr, mil Gj/yr	814	1,006	1,198	2,309	2,917	3,603
1000 Gcal/hr, mil Gcal/yr	194	240	286	557	696	860
%	100	124	147	100	126	156

The proportional amount of centralized heat supply for the urban settlements in total heat consumption of the nation is to rise from 77 percent in 1970 to 80 percent by 1980.

The rise in the heat consumption of cities and urban-type settlements up to 1980 is to be accompanied by a further increase in the concentration of the heating loads (Table 4).

The total annual demand for heat by cities and urban-type settlements in terms of the type of heating agents is shown in Table 5.

For production steam bleeding of turbines of the P, PT and R types, the basic bleeding pressure both in the present and over the long run will remain a pressure of 1.3-1.8 Mp; to a lesser degree a steam bleeding pressure of 0.5-1.0 Mp will be required, and approximately 8-10 percent of the produced heat requires a steam bleeding pressure above 1.8 Mp.

The given data on the scale of growth of heat consumption by the national economy show how important is the highly efficient use of the fuel and energy resources.

Table 4

Growth of Concentration of Thermal Loads in Cities in Period of 1970-1980

a) Уровень тепловой нагрузки тыс. ГДж/ч (тыс. Гкал/ч)	1970							
	b) Количество городов		c) Всего по всем городам			d) Средняя нагрузка города		
	e) число	%	f) тыс. ГДж/ч	g) тыс. Гкал/ч	%	h) ГДж/ч	i) Гкал/ч	%
1) Более 41,9 (более 10)	2	1,2	188,6	45,0	13,4	—	—	—
2) От 20,95 до 41,9 (от 5 до 10)	3	1,8	89,3	21,3	6,4	—	—	—
3) От 12,57 до 20,95 (от 3 до 5)	17	10	324,7	77,5	23,8	19106,4	4560	—
4) От 4,19 до 12,57 (от 1 до 3)	66	39	530	126,5	37,6	8045	1920	—
5) От 2,1 до 4,19 (от 0,5 до 1,0)	81	48	276,5	66	19,6	3415	815	—
6) Всего	169	100	1409,1	336,3	100	—	—	—
7) Рост		100	—	—	100	—	—	—
8) В том числе для нагрузок от 2,1 до 12,57 (от 0,5 до 3)	147	87,0	806,6	192,5	57,4	5489	1310	—
7) Рост		100			100			100

continuation of Table 4

a) Уровень тепловой нагрузки тыс. ГДж/ч (тыс. Гкал/ч)	1975							
	b) Количество городов		c) Всего по всем городам			d) Средняя нагрузка города		
	e) число	%	f) тыс. ГДж/ч	g) тыс. Гкал/ч	%	h) ГДж/ч	i) Гкал/ч	%
1) Более 41,9 (более 10)	2	0,8	201,5	48,1	10,7	—	—	—
2) От 20,95 до 41,9 (от 5 до 10)	11	4,6	302,9	71,3	15,8	—	—	—
3) От 12,57 до 20,95 (от 3 до 5)	21	8,9	337,3	80,5	18,0	16047,7	3830	—
4) От 4,19 до 12,57 (от 1 до 3)	94	39,6	716,5	171	38,2	7625,8	1820	—
5) От 2,1 до 4,19 (от 0,5 до 1,0.	109	46,1	325,6	77,7	17,3	2974,9	710	—
6) Всего	237	100	1879,6	448,6	100	—	—	—
7) Рост	—	140	—	—	134	—	—	—
8) В том числе для нагрузок от 2,1 до 12,57 (от 0,5 до 3)	203	85,0	1042	248,7	55,5	5132,7	1225	93,5
7) Рост		138			129			

continuation of Table 4

a) Уровень тепловой нагрузки тыс. ГДж/ч (тыс. Гкал/ч)	1980							
	b) Количество городов		c) Всего по всем городам			d) Средняя нагрузка города		
	e) число	%	f) тыс. ГДж/ч	g) тыс. Гкал/ч	%	h) ГДж/ч	i) Гкал/ч	%
1) Более 41,9 (более 10)	3	1	276,5	66	11,6	—	—	—
2) От 20,95 до 41,9 (от 5 до 10)	17	6	473	113	19,7	—	—	—
3) От 12,57 до 20,95 (от 3 до 5)	29	10	460,9	110	19,1	15838,2	3780	—
4) От 4,19 до 12,57 (от 1 до 3)	123	44	867,3	207	36	7039,2	1680	—
5) От 2,1 до 4,19 (от 0,5 до 1,0)	112	39	331	79	13,7	2953,9	705	—
6) Всего	284	100	2409	575	100	—	—	—
7) Рост	—	168	—	—	171	—	—	—
8) В том числе для нагрузок от 2,1 до 12,57 (от 0,5 до 3)	235	83,0	1198,3	286	50	5111,8	1220	—
7) Рост		153			149			

[Key to Table 4 on preceding page:]

a--Level of heating load 1000 GJ/hr (1000 Gcal/hr); b--Number of cities; c--Total for all cities; d--Average load of city; e--Number; f--1000 GJ/hr; g--1000 Gcal/hr; h--GJ/hr; i--Gcal/hr;

1--More than 41.9 (more than 10); 2--From 20.95 to 41.9 (from 5 to 10); 3--From 12.57 to 20.95 (from 3 to 5); 4--From 4.19 to 12.57 (from 1 to 3); 5--From 2.1 to 4.19 (from 0.5 to 1.0); 6--Total; 7--Growth; 8--Including for loads from 2.1 to 12.57 (from 0.5 to 3).

Table 5

Annual Demand for Heat of Cities and Urban-Type Settlements (by types of heat carriers)

Consumers and Heat Carriers	1970	1975	1980
1. Industry, mil GJ	4,676	6,117	7,961
(mil Gcal)	(1,116)	(1,460)	(1,900)
Steam, mil GJ	3,457	4,249	5,212
(mil Gcal)	(825)	(1,014)	(1,244)
%	71	69	65.5
Hot water, mil GJ	1,219	1,868	2,749
(mil Gcal)	(291)	(446)	(656)
2. Housing-utility sector:			
Hot water, mil GJ	2,309	2,917	3,603
(mil Gcal)	(551)	(696)	(860)
Total for cities and urban-type settlements,			
mil GJ	6,985	9,034	1,564
(mil Gcal)	(1,667)	(2,156)	(2,760)
Steam, %	49.5	47.0	45.0
Hot water, %	50.5	53.0	55.0

Among the basic directions for saving fuel and energy resources and their rational use, the following are envisaged: a) an increase in the combined generating of electric and thermal power at the TETs by increasing their load for the heating schedule; b) the further development of central heating and centralized heat supply of the cities, industrial centers and enterprises on the basis of building TETs and regional boiler houses; c) the elaboration and introduction of new highly economic sources and systems of heat supply for the national economy, including using atomic power for heat supply purposes.

The solution to these problems should consider the reliability of the heat supply systems, the load requirements of the power systems for the TETs with a rise in the uneven electric load schedules and other factors. Consideration of the reciprocal influence of the listed factors in optimizing the development scale of the combined systems and their location considering national economic efficiency require systems analysis in selecting the technical directions.

Even now there is the generally recognized necessity of working out long-range heating supply systems for large cities over the next 10-15 years, while the 5-year stages should be adjusted using systems analysis methods and employing special mathematics and computers. The development of the scientific bases for the systems analysis of the development of heat supply in recent years has been carried out under the leadership of Academician L. A. Melent'yev by the Siberian Power Institute and the VNIPIenergoprom [All-Union Scientific Research and Design Institute for the Power Industry].

One of the important directions for improving the technical and economic indicators of the TETs is the increase in their basic equipment and capacity.

At present the R-100 and T-250 central heating turbines have already been developed and are being produced. Production has started on the PT-135 turbines, and in 1978, series production of the T-175 central heating turbines will begin. The replacement of two PT-60-130/13 turbines with one PT-135/165-130/15 turbine reduces capital investments by 1.5-2 million rubles, and provides a savings of conditional fuel units of around 17,500 tons a year. The use of the T-175/210-130 turbines instead of the T-110/120-130 provides a calculated savings of capital investments of 1.5-2 million rubles per unit, while the specific output of electric power with simultaneous heat production rises by 3 percent, and the specific fuel consumption for the output of electric power under condensation conditions is reduced by 3.5 percent.

During the period of 1976-1980, most characteristic will be heating loads on the order of 6,285-8,380 GJ/hr (1500-2000 Gcal/hr), and these can be best covered by installing the central heating turbines which are being produced or are being readied for production at the TETs.

At the industrial-heating TETs, in the next few years, in a majority of instances it would be advisable to install the PT-135/165-130/15, R-100-130/15 and T-175/210-130 central heating turbines. These turbines are standardized in terms of the high-pressure cylinder and have the same maximum consumption of live steam equal to 760 tons/hr. Here for each turbine two steam generators of 420 tons/hr each are installed. The use at such TETs of one steam generator with a steam productivity of around 800 tons/hr in the place of two generators can provide a savings in capital investments of around 1.0 million rubles per steam generator.

At present TETs with an electric capacity of over 1.5 million kilowatts are already in operation, under construction or being designed in the power systems of Mosenergo [Moscow Regional Administration for the Power System], Lenenergo [Leningrad Regional Administration for the Power System] and Kiyevenergo [Kiev Regional Administration for the Power System] and also for a series of large industrial complexes. Over the long run the number of cities and industrial centers with heating loads over 8,380-10,500 GJ/hr (2,000-2,500 Gcal/hr) will rise.

One of the basic technical directions for improving the efficiency of central heating is the method developed in recent years in the USSR of series construction of the TETs. This method was worked out by the collectives of the VNIPIenergoprom, Orgenergostroy [All-Union Institute for the Planning of Electric Power Projects], Energomontazhproyekt [?All-Union Design Institute for Electrical Installation], the Barnaul and Belgorod boiler plants with the active participation of the construction-installation organizations, the plants and design bureaus for metal structural elements and other organizations. The method is based upon articulating the main building of the TETs into separate construction-production sections consisting either of a "boiler--turbine" block or of a "two boilers--turbine" block with the corresponding auxiliary equipment. As the basic equipment the plans provide for one type of boiler with a productivity of 420/450 tons/hr (for the gas-mazut TETs) and seven types of turbines, that is, all the types presently being produced or readied for production, with the exception of the T-250 turbines. In design terms the sections have been worked out in such a manner that from them it is possible to make up a main building with any combination of the designated equipment and with any sequence of its installation. Particular to the plans are also the broad unification of the auxiliary installations and the use of a sectional principle in the unified auxiliary building (Fig. 5).

There has been a significant reduction in the construction volume of the production buildings, the built-up area and the total areas of the TETs site. The unified auxiliary building (OVK) and the other solutions for the site provide a reduction of 30-35 percent in the build-up area, a reduction of 1.4-1.7-fold for the overall area of the site, a reduction on the average of 22 percent in the construction cubic volume, and the volume of prefabricated reinforced concrete elements is reduced by approximately 30 percent, and the length of the intrasite utility and communications networks is shortened.

The plans provide for the delivery of equipment and structural elements in blocks, the dimensions and weight of which guarantee their transporting by rail. High production efficiency is achieved in carrying out the construction and installation work, and the construction process is turned into a series of installation operations in assembling the TETs from ready-made construction and installation blocks. The calculated rise in labor productivity and the overall reduction in labor expenditures, in observing the design conditions for the organization of construction, are around 40 percent; the reduction in the proportional construction cost is 10-15 percent.

Here there is a significant reduction in the construction time, as the operation of the first unit is possible in 18-21 months after the beginning of the preparatory period and after 12-15 months from the beginning of the basic work at the site. At present, many TETs are being built already under the plans of the TETs-ZIGM [?gas- and mazut-fired TETs] (the Minsk TETs-4, Kaunas, Novo-Sterlitamakskaya, Kuybyshev and others).

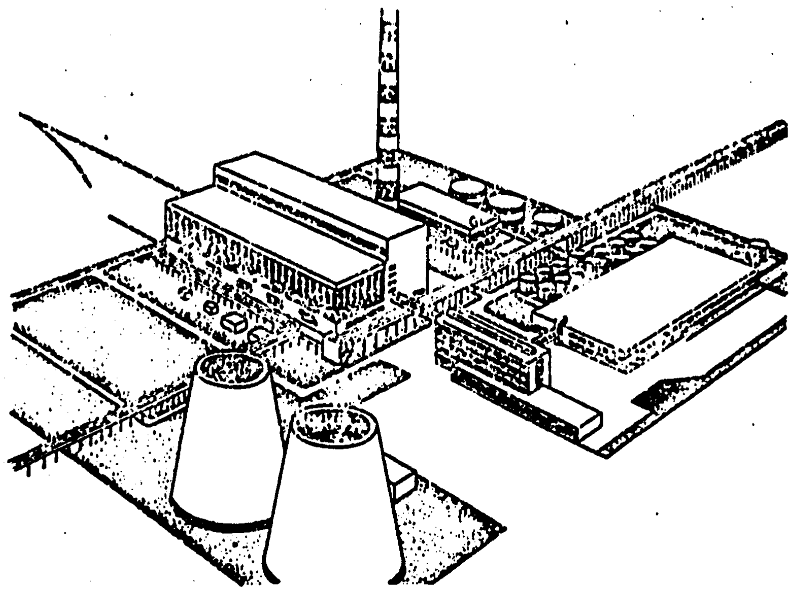

Fig. 5. Overall view of the serially-built gas-mazut TETs (TETs-ZIGM)

At these TETs, 12 units were already put into operation in 1975-1977. The VNIPIenergoprom is working on the series plans for TETs to be operated on solid fuel. These plans provide the possibility of using such fuel both in power as well as peak water heating boilers.

The small-sized boilers of the type installed at the Rostov TETs-2 for 500 tons/hr are also being introduced.

Even with the present development level of central heating, capital investments for building the heating networks reach 50 percent of the capital investments for building the TETs and comprise around 700-800 million rubles a year. The complexity of the heating network systems in large cities is shown in Figs. 6 and 7 [Fig. 7 is not reproduced].

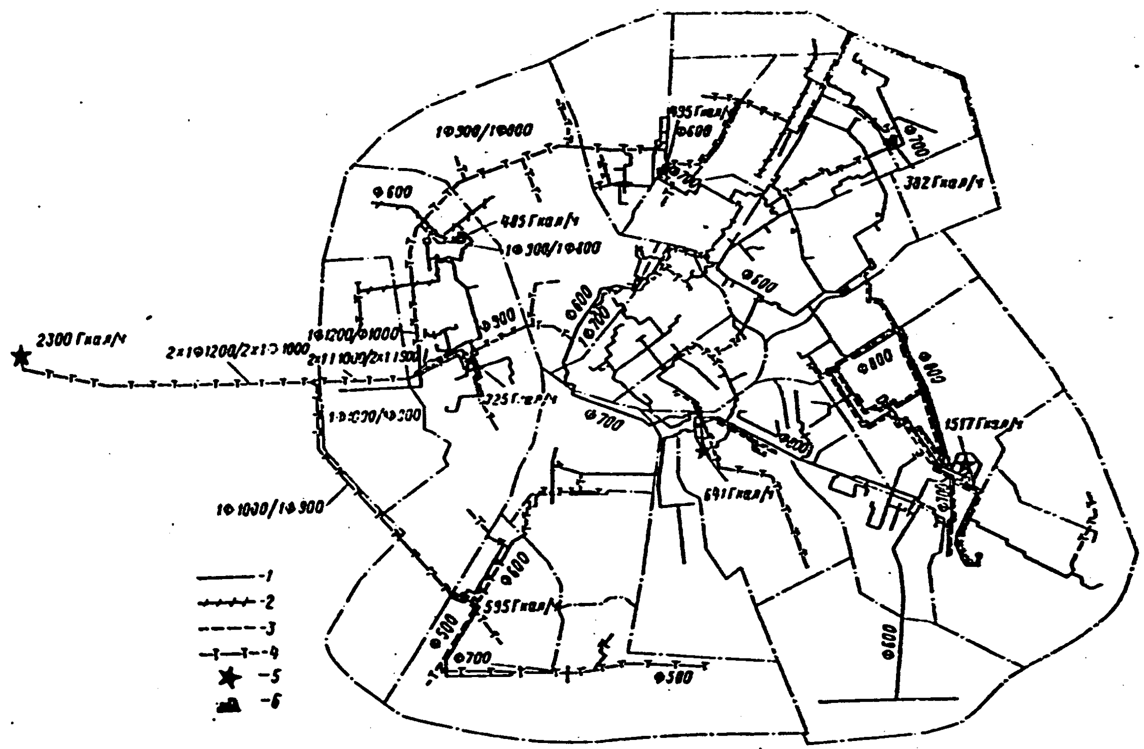

Fig. 6. Diagram of Main City Heating Networks with a Population of About 1 Million Inhabitants

Key: 1--existing water mains; 2, 4--planned water mains; 3--steam lines; 5--TETs 6--regional heating boilers.

The acquired experience shows that the industrialization and mechanization of construction-installation work on the thermal networks to a greater degree is achieved with ditchless laying which allows simultaneously a substantial reduction in material expenditures and initial capital investments by 20-30 percent.

Designs have been developed for ditchless laying in the form of casings from site-cast autoclave reinforced foam concrete, asphalt-perlite and asphalt-haydite applied to the pipe under plant conditions. Work is being done to develop the ditchless laying with covering insulation from self-hardening asphaltites and with insulating from phenol foam plastics, and so forth. However all these designs are still far from the ideal.

It is essential to have a further improvement in the existing designs of the ditchless laying in the aim of a fundamental improvement in their reliability, durability and production efficiency. Moreover, it is also essential to work out new, more advanced designs, particularly for large diameter pipe.

They require a substantial improvement in the structural elements used for underground laying in manned and unmanned channels and for aboveground laying on low and tall supports. It is essential to convert to the use of standard large-dimension elements (from 3 to 6 meters) and work out more advanced designs for preassembled chambers suitable for production in small series as well as preassembled fixed supports.

A rise in the economic efficiency of central heating can be achieved in reducing the calculated expenditures of system water by an optimum rise in the temperature schedules for controlling the production of heat if the heat sources are a significant distance away from the heat consumption areas. Of great significance is the introduction of the open system of heat supply with the single-pipe transporting of heat. The changeover to a single-pipe heat transport through transit heating networks can also being about a significant reduction in capital investments as a whole for the heat transport system. The working out of all these questions can open up new opportunities for organizing the further heat supply of cities from existing GRES.

The VNIPIenergoprom with the participation of the VTI is developing such systems for the heat supply of a number of cities. The operational efficiency of central heating is substantially influenced by the specific output of electric power and the share of electric power output under heat-supplying conditions, and these are growing year by year, however as a whole for the nation they still are far from the optimum level. It is also essential to note a number of other factors which reduce the efficiency use of the existing TETs. The summary data of the VNIPIenergoprom on this question are given in Table 6.

In addition to the factors listed in Table 6, the efficiency of the TETs is also reduced as a consequence of the fact that many heat supply systems are operated with an increased temperature of the return system water and increased consumption of the heat carrier. For eliminating these shortcomings,

Table 6

Underutilization of Heating Capacity of Existing Public TETs by Basic Factors

Name of factor	Number of examined TETs	Planned heating capacity of TETs, Gj/hr (Gcal/hr)	Unutilized thermal capacity, Gj/hr (Gcal/hr)	Under-utilization, %
Lag in development of heat users and incorrectly over-stated planned load	47	167,990 (40,093)	59,740 (14,258)	35.6
Lag in construction of main and distributor heating net-works	32	97,510 (23,272)	40,538 (9,675)	41.5
Absence or shortage of peak thermal capacity	29	73,237 (17,479)	20,530 (4,900)	28
Discrepancy of available capacity of peak water heat-ing boilers to the rated in operating on mazut	25	34,023 (8,120)	3,352-4,190 (800-1000)	10 - 12

there must be the corresponding automatic heat regulators at the consumers, and the manufacturing of these controls has not been organized.

In many instances the restricted use of the steam bleeding from turbines of the industrial-heating TETs has been caused by the incomplete return of the condensate from the industrial enterprises. In approximate terms the re-turn of the condensate to the TETs is 70-75 percent of the technically pos-sible, and even less from the chemical plants. As a whole for the 105 in-vestigated high-pressure TETs, the elimination of the designated factors in the under utilization of thermal capacity in 1980 could provide an annual fuel savings of over 3.9 million tons of conditional fuel units.

By carrying out measures to fully load the take-offs of the existing tur-bines, by disassembling the worn out and obsolete units and by increasing the share of capacity of the central heating turbines with an initial pres-sure of 13.0-24.0 Mp from 40-90 percent and the T-type turbines from 29-60 percent, the average annual specific output of electric power under heat-producing conditions could be increased from 58.5 kilowatt hours/Gj (245 kilowatt hours/Gcal) in 1970 up to 100-107 kilowatt hours/Gj (420-450 kilo-watt hours/Gcal) in the future. This would make it possible to double the fuel savings with the same level of heat production from the TETs.

At present a predominant majority of the TETs is being built under title of the USSR Minenergo and is financed from funds allocated for the development of electric power. A certain number of the TETs for particularly large industrial enterprises and complexes is being financed from funds for the development of the corresponding industrial sectors or with their proportional participation. At the same time many specialized sectorial organizations are working out plans for the creation or development of industrial centers in which proper attention is not being paid to the questions of rational power supply, and particularly heat supply. Thus, in recent years more than 300 plans for industrial centers have been worked out, but only for a few of them are combined power supply systems provided.

It is becoming more and more apparent that without a substantial rise in the maneuverability of the TETs, the covering of the variable portion of the electric load schedules in the European section of the Unified Electric Power System over the long run will be very difficult even with the minimal share of the AES. For this reason important demands are being placed on the maneuvering abilities of the TETs which are to be completed in the near future. The total installed capacity of these TETs should comprise almost one-half the total capacity of all the TES, and more than 40 percent of the capacity of the TES to be completed during this period will go for the Unified Power System. Consequently, at least 40 percent of the electric capacity of the TETs which are to be built should possess rather high maneuverability.

The advantages of the combined production of thermal and electric power are fully present in the use of nuclear fuel, since all the known methods of the industrial conversion of thermal power into electric involve the release of a significant quantity of heat into a cold source. The introduction of nuclear sources into the system of centralized heat supply should be a part of the comprehensive problem of nuclear power. The use of nuclear sources for heat supply, in addition to saving limited fuel resources, also facilitates the problem of protecting the air basin over cities.

The zone of equal economy of the TETs and ATETs [Atomic Heat and Electric Plant] is obtained on a level of a heating load of 6,285 GJ/hr (1,500 Gcal/hr). The optimum unit capacities of reactors of the VVER and VK type for the ATETs correspond to the unit capacities of the reactors for the AES.

The turbogenerators of the ATETs should be designed for economic work under all conditions with a fixed steam consumption corresponding to the rated heat productivity of the reactor. The optimum central heating coefficient can be set within the limits of 0.7-0.8. The relatively small share of the fuel component in the cost of building the ATETs determines the advisability of building large central heating systems for long-distance heat supply with higher values for the direct system water temperatures (210-250°C) in comparison with systems based on organic fuel. At the same time the successes in developing reliable radiation protection systems can create conditions for bringing nuclear sources closer to heat load centers.

In describing the basic technical directions for the development of central heating, we must not overlook the problem of reducing the proportional number of personnel at the TETs and the regional boiler houses. Here the basic ways obviously can be: Simplifying the management structure, increasing the automatic control and monitoring equipment, further increasing the reliability of equipment operation, the quality of installation and repairs, as well as improving the structure and organization of the repair services.

Among the other technical directions, we must also point to the possibility of introducing steam-gas units into central heating. There are also plans for high-temperature heat supply for thermal production processes. These systems have been proposed in the USSR and have been patented in a number of nations.

The given technical directions for the development of central heating show the enormous reserves for improving the heat supply systems.

The forecasts for the basic technical and economic indicators for the development of central heating over the long run have shown that from the technical viewpoint it is feasible to have for all the TETs:

a) A reduction in the proportional capital investments into the TETs by approximately 9-10 percent;

b) A reduction of labor expenditures in building the TETs by 30-37 percent;

c) A reduction in the proportional capital investments in the main heat lines by 15-18 percent and a reduction in labor expenditures by 55-57 percent;

d) A reduction in the overall length of the "design--construction" cycle to the completion of the first unit at the TETs by 37-40 percent;

e) An increase in the proportional output of electric power under heat-supply conditions up to 100-107 kilowatt hours/Gj (420-450 kilowatt hours/Gcal), and the share of total output in heat-supply conditions up to 70-72 percent;

f) A reduction in the specific fuel consumption per kilowatt hour by 10-15 percent and per Gj of heat by 0.7-1.2 percent.

The actual achieving of an improvement in the designated indicators requires purposeful creative efforts both by the designers as well as by the power machine builders, the operators and the construction and installation organizations.

At the same time it is essential to also consider the objective factors which inevitably will influence an increase in the total and proportional capital investments and labor expenditures in building the TETs and heat transporting systems as a consequence of the rise in expenditures on environmental protection measures, the increase in the proportional amount of TETs under construction which will be operated on solid fuel, the complicating of certain types of thermomechanical equipment, and so forth.

By 1980, the centralizing of heat supply for cities from the TETs and large boiler houses can reach approximately 80 percent.

The centralizing of heat supply for agricultural users will also be markedly developed.

In conclusion it is essential to stress that the 50-year experience of the development of central heating in the USSR has fully justified itself, and this progressive method of the combined production of thermal and electric power in the foreseeable future will be one of the basic directions for the development of power in our nation.

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