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TRANSLATIONS ON USSR RESOURCES
(FOUO 14/79)

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ELECTRIC POWER AND POWER EQUIPMENT

UDC 621.165

K-1200-240-3 STEAM TURBINE--A NEW PHASE IN DEVELOPMENT OF SOVIET TURBINE CONSTRUCTION

Moscow ENERGOMASHINOSTROYENIYE in Russian No 2,Feb 79 pp 2-6

[Article by Director General of the Production Association of Turbine Construction, Leningrad Metals Plant, G. A. Shinshov, engineers A. P. Ogurtsov, P. V. Kruglov, V. K. Ryzhkov, S. N. Antonov, V. V. Merkulov, N. N. Berunov, V. M. Anfimov, I. I. Pichugin, V. N. Khokhulin]

[Text] The main area of scientific and technical progress in thermal power engineering is the farthest concentration of the electric power production by consolidation of the electric power plants with installation of powerful, highly economical condensation power units at them. In order to ensure high operating reliability of the units with high unit power, high requirements are imposed not only on the completed structural designs of the equipment, but also the quality of their plant manufacture and installation.

The successful assimilation of production and introduction of the series of 300, 500 and 800 megawatt turbines into operation on transcritical steam parameters was a prerequisite of creating the largest power unit with 1200 megawatt capacity.

The indicated requirements were used as the basis for the entire organizational and process complex with respect to the preparation of production and the manufacture of the powerful K-1200-240-3 Soviet steam turbine designed for installation at the Kostromskaya State Regional Hydroelectric Power Plant and manufactured at the turbine construction production association Leningrad Métals Plant.

The K-1200-240-3 turbine which was built considering the latest achievements of science and engineering is a new high-quality phase in the development of Soviet power engineering, the base for creating an entire series of high-power turbines operating both on organic and on nuclear fuel.

As a result of use of new structural solutions in the turbine design, it was necessary to develop theoretically new technological processes, raise the technical level and the level of production equipment. The list of planned and manufactured special equipment reckons more than 7,000 names.

The long cycle and large volume of expenditures on the technological preparation of the production facility and the manufacture of the turbine gave rise to special requirements on the organization of the economic planning and financial activities of the association enterprises and proper organization of the placement of the cooperative suppliers. Tens of enterprises and scientific research institutes of the country participated in building the turbine.

The K-1200-240-3 type turbine is a single-shaft, five-cylinder unit made up of a high-pressure cylinder, a double-flow medium pressure cylinder and three low-pressure double-flow cylinders.

The turbine is designed for operation at an initial steam pressure of 23.5 MPa (240 kg-force/cm^2) and a temperature of 813° K (540° C). It has one intermediate steam superheating to a temperature of 813° K (540° C); the pressure in the concentrator under normal conditions is 3.58 kPa (0.039 kg-force/cm^2) at a cooling water temperature of 285° k (12° C). For a rated turbine power of 1200 Mwatts, provision was made for the possibility of obtaining a peak load as a result of switching off the high-pressure heaters and also the capacity over a long period of time to develop a power of 1400 megawatts. The total length of the turbine without the generator was 47.9 meters, with the generator it was 71.8 meters. The total mass of the turbine was about 1900 tons (without the condenser, auxiliary equipment and pipelines).

The main structural peculiarities of the turbine are the following: a new design for the low-pressure cylinder with a unique exhaust in which a rotor is used made of titanium alloy 1200 mm long; the welded structure of the low-pressure rotor weighs 80 tons and is used for the first time in practice at the plant; the structure of the last stage diaphragms with the intra-channel moisture separation; the placement of the bearing elements of the rotors in the remote bearing housings installed directly on the foundation, and so on. With respect to technical-economic indexes, the K-1200-240-3 turbine is superior to the earlier produced turbines.

The turbine installation with the K-1200-240-3 turbine has lower specific area at the electric power plant and specific turbine and generator length which significantly reduces the cost of capital construction of the original hydroelectric power plant. In addition, this turbine has minimun operating expenses and provides the user with significant cost savings from using it instead of the K-800-240-2 turbine.

The levels of economical operation of the assemblies of the powerful turbine installations and the admissible stresses in their elements have reached such a high value that further increase in them is possible only with careful structural reworking of these units considering the operating experience, a large volume of scientific research work and improvement of the quality of manufacturing them. In order to create advanced high-quality designs, improved materials and technological processes are required.

Let us discuss in more detail some of the structural peculiarities of the K-1200-240-3 steam turbine and the problems which must be solved when manufacturing it.

The high and medium pressure parts are structurally analogous to the corresponding parts of the high-pressure cylinder and the medium pressure cylinder of the K-800-240-2 turbine, but the high pressure rotor of the K-1200-240-3 turbine has increased diameter with respect to the base of the vanes, which offered the possibility of reducing the number of stages of the rotor and raising its critical rpm. This has made it possible to improve the structural design of the cylinder housing and improve the handling capabilities of the turbine which has ensured satisfaction of the requirements of the power system--the necessary daily unloading to the turbine to 60 percent and weekly shutdown of it for weekends. In addition, increasing the rigidity of the high-pressure rotor significantly increases the threshold power of the turbine and is one of the main factors in preventing low-pressure vibration of the drive shaft.

As the high-pressure and medium-pressure rotor material, we selected the R2M steel developed by the plant and finding broad application for the last 20 years in manufacturing the rotors of all of the powerful steam turbines. The studies performed at the plant and the large amount of practical experience of the UZTM turbine plant with respect to the assimilation and production of large forgings made from this type of steel have demonstrated that the R2M steel has good technological nature, it permits us to obtain large high-quality forgings and ensures the required level of mechanical properties.

As a result of the large dimensions and mass of the high-pressure and medium-pressure rotors of the K-1200-240-3 turbine measures are required of the metallurgical industry which will ensure quality and uniformity of the properties with respect to the entire volume of forgings. The heat treatment improved for this purpose was made up of the first normalization matched with cooling after forging and the final heat treatment--water and oil quenching. In addition to the complete complex of tests and the quality control, in accordance with the technical conditions, additional tests were run on samples of the core metal and also for rotors made of a special ring located in the center of the forging.

For the first time in Soviet turbine building practice, a new dovetail connection of the stepped fork type was used for the rotors of the high-pressure and medium-pressure cylinders operating in the high-temperature zone, for the traditional T-type structure did not satisfy the strength conditions for stages of this power. The transition to the new type of dovetail joint with new dimensional network ensuring guaranteed clearances in the connection required the development of a new process for machining the rotors and the creation of special process equipment.

In order to make several thousand holes 15 and 18 mm in diameter for the installation of pins in the discs of the all-forged high and medium-pressure rotors, a special lathe-based drill was built. Carbon drilling heads of two types were designed and manufactured for preliminary drilling of the holes in the rotor and for final machining of the openings after blading equipped with special drills, reams and countersinks.

The high and medium-pressure direct-flow sections were designed considering the application of the gas dynamically machined stages, the characteristics and efficiency of which are defined by computer and they are checked out by model testing in the plant laboratory. In order to ensure high economy and improve the vibration reliability of the blading of the medium-pressure cylinder, a new profile was developed and investigated in detail for the stators.

In order to ensure economicalness, the rotors of all stages of the turbine have a shroud; on the blades of the high and medium-pressure cylinders and the last three stages of the low-pressure cylinder the shroud webs are made as a unit whole with the profile section.

The machining of the working part of the high and medium-pressure blades, the fillets of the shank and webs of the shroud was realized on milling machines with digital control. The software in the development of the control programs was executed with the active participation of the plant--the VTUZ under the production association of turbine building "Leningrad Metals Plant."

For the first time in the plant practice in order to ensure the required vibration and strength characteristics the rotors of all stages of the high-pressure cylinder and six stages of each flow of the medium-pressure cylinder were connected by welding along the shroud and the shank sections into packets. The complication consisted in the fact that the blade materials are 15Kh11MF and 18KH11MNFB steel that is difficult to weld; the working parts of the blade are made finished size before welding, and they have surface roughness of class 9. The welding process must ensure high-quality fusion along the shroud and shank section with minimum deformations, maintenance of the purity of the surface of the working part of the blade.

The UL-118 electron beam welder was used by the Electric Welding Institute imeni Ye. O. Paton of the Ukrainian SSR Academy of Sciences. Its original design made it possible significantly to reduce the total time for creating a vacuum in the chamber as a result of simultaneous loading of eight packets into the chamber and welding the shroud and shank seams located in different planes by three electron-beam guns. The welding of the packets of all 20 stages was accomplished by two types of universal attachments.

The results of the studies demonstrated that during electron beam welding it is possible to do away with preliminary and accompanying heating, which are mandatory when welding the given steel by other methods. This has made it possible to select the welding procedure for the shank part of the blades as counterwelds ensuring minimum residual deformations. A characteristic feature of the procedure consists in the fact that the first seam is welded about 40 percent of the thickness of the shank section, and then a second weld from the opposite side is done to 65 percent of the thickness, overlapping the first by 4 to 5 mm.

A specialized section with the UL-118 device also includes a special heating furnace with controlable shielding atmosphere which will make it possible to maintain the finish of the working part of the vanes during heat treatment.

The diaphragms of the high-pressure and medium-pressure cylinders are made welded with milled solid stators and shroud bands. The requirements of high reliability have given rise to an increase in the moment of resistance of the stators, the shanks and the rims operating in the high-pressure zone and also, the use of high-temperature steel obtained by the method of electroslag remelting. Increased accuracy of manufacturing the welded grates was achieved as a result of using a new technological process for punching the shaped holes in the shroud bands bent along the radius on the EM-12 device designed by the VPTIenergomash Institute and operating in the automatic cycle.

An important measure ensuring operating reliability and improving the strength of the responsible parts of the turbines is the use of billets obtained by refining melting techniques, in particular, the method of electroslag remelting. This method ensures a higher degree of purity of the metal, high uniformity of the structure and properties with respect to the billet cross-section, and improvement of the ductility characteristics. The application of electroslag remelting for the rotor vanes made of 20Kh13, 15Kh11MF and EP291 steel ensured that billets would be obtained free of typical defects in the form of hair cracks essentially lowering the fatigue strength of the rotor blades.

An ingot made of 15Kh1M1F steel manufactured by this method was used as the initial billet for the welded-forged valve housing of the automatic high-pressure gate. With a high level of mechanical properties of the forging, the electroslag remelted metal is characterized by high uniformity and isotropicity of the mechanical characteristics, low sulfur content and low content of nonmetallic inclusions.

A deficiency of the application of ASR steel for housing parts is the fact that the initial billets are obtained in the form of large cubic or cylindrical bars. Thus, for a finished part for the steam intake of the K-1200-240-3 turbine weighing 3 tons, the forged billet will weigh 12 tons.

The use of the method of electroslag smelting (ESS) made it possible to obtain a high-quality billet and lower the consumption of metal.

The 15Kh1M1FL steel traditionally used for the forgings of the housing parts of the high-pressure and medium-pressure cylinder is characterized by sufficient stability of the structure and properties under the prolonged effect of operating temperatures to 843° K (570°C). However, the increase in turbine power requires constant improvement of the metallurgical process in all phases.

The improvement of the billet quality is promoted by measures of a structural nature, defined orientation and direction of pouring within the cross-sections of the part and also proper resolution of the contradictory requirements of the structural elements and casting technology.

The housings of the outer and inner high-pressure and medium-pressure cylinders were cast from steel made in the basic open-hearth furnace at the traditional supplier plants. The studies demonstrated the advantage of forced cooling of the ingots in special chambers by comparison with blowing with compressed air from three sides. The dispersion of the mechanical properties of the metal and the forgings decreased significantly.

The machining of the high-pressure and medium-pressure cylinders was carried out on the basis of the developed technological processes. The preliminary machining of the planes of the horizontal slit was carried out on the four-spindle planomilling machine, and the finish machining, on the planar with finish passes using special broad cutting tools. For broaching the cylinders, a special KU-64 model vertical lathe was used. The housing of the outer high-pressure cylinder and exhaust sections of the medium-pressure cylinder were broached on the all-purpose vertical lathes as a result of the large dimensions.

The low-pressure cylinder is unique with respect to its structural and technological solutions. The creation of the last stage with a rotor blade 1200 mm long and an end area of the exhaust of 11.3 m^2 required the performance of a large volume of scientific research and planning and design work. During the design process, the direct-flow section was worked out in order to optimize the gas dynamic characteristics and select an efficient form of meridional outline. The application of the axiradial diverging diffuser and separation of the exhaust flows from the upper and lower halfs of the exhaust sections developed by the turbine construction production association of "Leningrad Metals Plant" jointly with Moscow Power Engineering Institute made it possible to reduce the magnitude of the losses in the exhaust line of the turbine by comparison with the K-800-240-3 turbine.

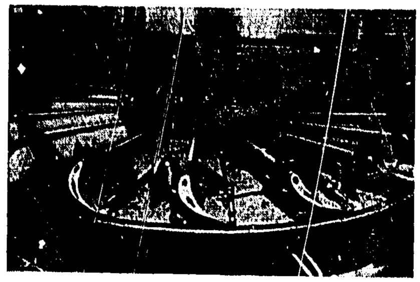

Figure 1. Machining the stators of the fifth stage with internal moisture separation.

Figure 1 shows the processing of the stators of the fifth stage with intra-channel moisture separation. The testing of the correctness of the solutions was realized on the experimental steam turbines of the NPO Association of the TsKTI Institute imeni I. I. Polzunov by investigation of models on a 1:3 scale. The tests were run in a wide range of variation of the volumetric steam consumption and make it possible to determine the level of economicalness of the stages, the compartments and the entire direct-flow section as a whole and also the structure of the flow in the control cross-sections of the direct-flow section.

The vibration test demonstrated the pressure of sufficient reserves of resonance frequencies from the perturbing forces at operating rpm and the relatively low stress level under transient conditions.

The operation of the direct-flow part of the low-pressure cylinder was checked on the ETPN-2 experimental steam turbine specially built by the plant with a compartment made up of the last four stages to a natural number. The program for the experimental work included the dynamic and gas dynamic studies, obtaining the integral characteristics of the compartment, including in the no-load conditions and under small loads and also checking of the corrosion resistance of the input edges of the last stage.

The last stage of the rotor vanes 1200 mm long was made of TC-5 titanium steel (Figure 2) for the experience in operating the blades up to 960 mm long made of titanium steel demonstrated satisfactory results.

The high cost and great labor consumption of machining the titanium alloys required the development and investigation of new methods of machining, including electrochemical machining of the stampings in order to remove the excessive machining allowance, the circular milling on the machine tools of the ST-215 type, grinding and polishing of the disc at reduced rpm in several passes with the application of diamond pastes. Special methods of quality control on the surface layer have been developed.

The rotor blades of the fourth and fifth stages are joined along the periphery using a shaped tooth made in the shroud web for preventing the blades from turning. This connection reduced the number of wire couplings in the profile section.

Figure 2. Stator of the fifth stage of low-pressure rotor.

The machining with respect to the shroud of a complete set of rotor blades for each stage was carried out together with a special attachment which made it possible to perform all of the fitting operations to basic assembly.

For the first time the plant used the Christmas type dovetail connection with edge winding, the optimal design of which was determined by experimental studies of its static and fatigue strength. This type of joint simplifies assembly under the electric power plant conditions, it provides for railroad transportation of the low-pressure rotors. Figure 3 shows the blading of the low pressure rotor. For machining of the shaped grooves in the rotors under the shanks of the blades, a heavy 1A671P14F1 lathe was used equipped with two movable milling stocks, dividers and other devices.

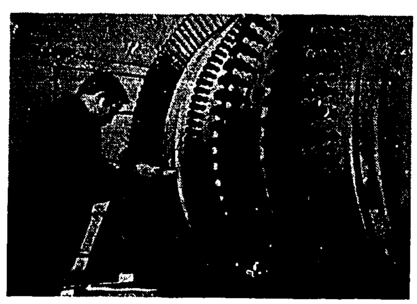

Figure 3. Blading of the low-pressure rotor of the K-1200-240-3 turbine.

In order to reduce the cycle for manufacturing the rotors, the grooves are partially cut at the production association "Khar'kov Turbine Plant" imeni S. M. Kirov.

The application of intrachannel, two-chamber separation of moisture in the diaphragm of the last stage of the system is an active method of protecting the rotor blades of erosion wear. This system is made up of a number of slits about 1 mm wide executed on the input section and the inside surface of the blade profile and also holes in the blades, the body and the rim through which the drop and film moisture are discharged to be tapped for regeneration and the condenser. The technological process of protecting the entrance edges of the rotor blades of the last stage has also been developed.

The many years of experience of the plant with respect to the manufacture of welded diaphragms has made it possible to use new theoretical solutions created on the basis of them in the new turbine along with the old structural-technological flow charts checked out in practice. Instead of the traditional cast iron diaphragms for the low-pressure cylinder in the K-1200-240-3 turbine steel diaphragms are used. This has made it possible to increase their reliability, the possibility of organization of the interchannel separation of the moisture and also it has ensured further application of the low-pressure cylinder in turbines operating on nuclear fuel.

The manufacture of the diaphragm of the last stage not having an analog in Soviet turbine construction presented special difficulties. The mass of one half of the diaphragm in the billet was 6.4 tons with an outside diameter of the diaphragm of about 5 meters and height of the steam channel of 1200 mm. The characteristic features of the special design of the diaphragm also includes the high precision of its manufacture, the use of high-chrome steel requiring special welding procedures. Slits were cut in the guide vanes by the method of electroerasive machining. The machining of the shaped part of the vane, the mass of which was 80 kg, and the dimension along the chord more than 300 mm, was carried out on a modified planar from the basic machine shop.

All of the structural welds were made using high-nickel electrodes which made it possible to do away with the complex high-temperature heating in the welding process and direct heat treatment after welding. This offers the possibility not only of achieving improvement of the quality of the welds as a result of introducing a number of welding procedures aimed at decreasing the welding strains and stresses but also improvement of the conditions of labor of the welders.

When creating welded diaphragms for the K-1200-240-3 turbine, more than 200 technological equipment units were designed and introduced in the assembly-welding cycle alone. A significant role in the machining of the structural elements, the technological process and the assimilation of the production was played by the manufacture of diaphragms for the ETPN-2 experimental natural turbine which made it possible to cut the basic production cycle for the diaphragms in half.

It is necessary to note the special role of welding production in the manufacture of the K-1200-24-3 turbine. The specific weight of the welded structural elements was 75 percent with respect to the total weight of the turbine by comparison with 52 percent for the series-manufactured turbines. One of the significant problems solved in the turbine production process was the creation of the welded low-pressure rotors. This work was participated in by the leading institutes of the country: the NPO TsNIITmash, the Institute of Electric Welding imeni Ye. O. Paton of the Ukrainian SSR Academy of Sciences, the NPO TsKTI imeni I. I. Polzunov, VPTItyazhmash and also the production association Izhorskiy Zavod imeni A. A. Zhdanov and the turbine building production association Khar'kov Turbine Plant imeni S. M. Kirov.

For the first time in its practice, the plant did away with the traditionally used and technologically assimilated design of the low-pressure rotor with adapter discs. When using blades 1200 mm long, even those made of titanium alloy, the stress level in the discs reaches its limiting value for the assimilated type of steel. As a result, it was necessary to develop a welding element for the rotor with forged discs without the central openings. The complexity of the problem consisted in the existence of a higher stress level in the rotors in the K-1200-240-3 turbine determined by the large size of the rotor and its high rpm. The requirements of sufficient strength combined with increased ductility, high resistance to brittle rupture and good weldability were imposed on the material of the initial billets for the welded rotor. As a result of the scientific research work performed by the scientific and production association of the TsNIITmash Institute and the production association Izhorskiy Plant imeni A. A. Zhdanov, a new type of steel was developed which has high mechanical and good technological properties. In order to ensure high quality of the metal and the required level of the entire set of necessary properties, the method of electroslag remelting was used, a theoretical process was developed for assembly and welding of the rotors, methods of monitoring the welds and the heat treatment conditions of the welded billet were found. The generalization of the results of testing the experimental and regular forgings, investigation of the construction strength of the elements of the welded rotor, analysis of the reliability of the welded joint considering the resistance to crack development and also the calculations performed by the method of finite elements by the KISI program on the BESM-6 computer illustrated a sufficient level of margin of strength, reliability of the selected structural design and the type of steel used.

For assembly and welding of the rotors, the specialists of the NPO Association of the TsNIITmash and the VPTItyazhmash institutes have designed a complex nonstandard piece of equipment: a unit for building up a soft interlayer on the discs and the shanks of the rotors, a stand for general assembly and welding and a portal device. The production association for turbine building Khar'kov Turbine Plant imeni S. M. Kirov and the experimental plants of the NPO TsNIITmash and NPO TsKTI imeni I. I. Polzunov participated in the manufacture of this equipment along with the turbine building production association Leningrad Metals Plant. The equipment for automated argon arc welding and welding under a flux layer, and the required heating units were designed and manufactured by the NPO TsNIITmash and the Institute of Electric Welding imeni Ye. O. Paton fo the Ukrainian SSR Academy of Sciences.

The final stage in the entire set of operations with respect to the assimilation of the process of manufacturing the welded rotors was the assembly and welding of a full-scale model. The high-quality execution of the welding operations was ensured by the following monitoring operations: broad utilization of ultrasonic defectoscopy; radiometric monitoring and gamma-examination, visual inspection of the outside appearance of the weld and, in part, the inside fusion of the edges of the root of the welded joint; automatic recording and analysis of all of the argon arc welding parameters, thickening of the outside surfaces of the welds and soft buildup.

The developed procedure for the metrologic measurements when assembling the rotor and monitoring its distortion during the welding process made it possible to reduce the residual deformations to a minimum. The performance of all of the welding operations and the turning of the rotors on a lathe, the mass of which in the billet amounted to more than 80 tons was accomplished at the Khar'kov Turbine Building Plant imeni S. M. Kirov with the direct participation of the specialists of the turbine building production association Leningrad Metals Plant, the NPO TsNIITmash Institute and the Institute of Electric Welding imeni Ye. O. Paton of the Ukrainian SSR Academy of Sciences.

The final step in the manufacture of the K-1200-240-3 turbines was the assembly and testing on a new assembly test station. The presence of two specially designed semigantry cranes with a capacity of up to 5 tons each made it possible to unload the basic crane equipment during the operations with respect to alignment of the parts of the direct-flow sections. The turbine was installed on supports specially mounted on a supporting floor. The cylinder and bearing housings and the parts of the direct-flow sections were aligned with the application of optical monitoring means with high precision to exclude errors in measuring the coordinates of the control holes.

The technological process of assembly and alignment of the turbine was developed with the participation of the PTI Energomontazhproyekt Institute, and it was based on the possible repetition of assembly in installing the equipment under the conditions of electric power plants and to reduce the duration and cost of the installation operations. Here the structural solution of the turbine with the supports for the low-pressure rotors directly on the foundation is highly efficient. This opens up the possibility for the organization of a broad front of preparation and installation operations.

For correction of the developed general assembly process, a broad program was carried out for natural measurements of the stability of the position of the supporting floor and the housing parts during assembly of the turbine, the determination of the actual rigidity of the medium-pressure and low-pressure cylinders, the positions of the centers of the control openings in the housing parts and the static bending of the low-pressure rotor.

Tests were run on the plant test units to determine the fitness of the heavy duty bearings, dynamic tests were run on the rotors in the range of 0-30300 rpm. The turbine underwent control testing under operation on a barring gear, and the hydraulic lift for the rotors was checked out and developed.

Summing up the results of the work done, it is necessary to note that the K-1200-240-3 steam turbine is a new step in the development of Soviet turbine making. As a result of the large volume of design and scientific research work, a qualitatively new type of superpowerful steam turbine was built in the single-shaft execution. It is the base for the further development of power engineering and the development of powerful energy equipment operating both on organic and on nuclear fuel. The uniqueness of the structural and process solutions and absence of analogs required the development of new technological methods and means of production. The created base and the acquired production experience are a guarantee of the successful implementation of the program of scientific and technical progress in power machine building.

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ELECTRIC POWER AND POWER EQUIPMENT

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STATE SYMBOL OF QUALITY FOR HYDRAULIC TURBINE EQUIPMENT

Moscow ENERGOMASHINOSTROYENIYE in Russian No 2,Feb 79 p 22

[Article by engineers M. I. Gal'perin and M. A. Tsvetkov]

[Text] The State Commission has recertified the turbines delivered by the production association of the Leningrad Metals Plant for the Ust'-Ilim Hydroelectric Power Plant and the electrohydraulic regulators of the EGR and EGRK type for the subsequent period awarding a higher quality category. Just as all the preceding units, the last unit of the first phase of the Ust'-Ilim Hydroelectric Power Plant--the third phase of the Angar Cascade--was accepted for operation on 22 October 1977 with an excellent rating. The power of the 15 units of the first stage is 3,675 megawatts.

The unit includes the vertical radial-axial turbine with a rotor diameter of 5.5 meters directly connected to the umbrella type generator. With the same diameter of the rotor, the installed power of the turbine at the Ust'-Ilim Hydroelectric Power Plant is 245 megawatts with a calculated head of 85.5 meters, which is 13 percent higher than the power of the turbines from the Bratsk Hydroelectric Power Plant with a calculated head of 96 meters.

The second phase of the Ust'-Ilim Hydroelectric Power Plant, which is the last of the three units, must be put into operation in 1980. Starting them up will make it possible to increase the efficiency of the use of the flux energy, it will expand the possibility of the participation of the hydroelectric power plant in covering the peak part of the electric load chart.

The turbines of the Ust'-Ilim Hydroelectric Power Plant are distinguished advantageously by the carefully developed flow cycle, the manufacture of the rotor in a welded design with blades stamped from sheet stainless rolled products. This rotor design and manufacturing process have made it possible to obtain more precision built blades identical in size and shape and to correctly place them for assembly and welding of the rotor as a whole.

The selected direct flow channel and the material used made it possible to reduce the cavitation erosion to a minimum. It is necessary to note that for the first time with a rotor diameter of the turbine equal to 5.5 meters, the possibility was found for manufacturing an umbrella type generator with the thrust bearing on the support located on the top of the turbine. This was achieved as a result of using the guide bearing of the segment type turbine with water lubrication which is more compact that the annular one, and is more convenient to maintain and repair. Accordingly, on the majority of the newly built turbines provision is made for a guide bearing of this structural design. These bearings have been used to replace the guide bearings previously installed on the other operating hydroelectric power plants with segments in liquid oil lubrication filled with babbit metal.

At the present time the cost of electric power generated by the units of the Ust'-Ilim Hydroelectric Power Plant is the lowest in the country. With completion of the construction of the Ust'-Ilim Hydroelectric Power Plant, the projects have been widely developed for the construction of the fourth stage of the Angar Cascade--the Bogucharnskaya Hydroelectric Power Plant. The production association of the Leningrad Metals Plant has also been charged with the building of the turbine equipment for this hydroelectric power plant.

The production association of the Leningrad Metals Plant is a unique enterprise in our country, producing electrohydraulic regulators of the EGR and EGRK type. For the first time these regulators have been awarded the high quality category in 1969, and then they were recertified in 1972 and 197[illegible].

All of the turbines built by Soviet hydraulic turbine building associations and plants for Soviet and foreign hydroelectric power plants are equipped with these regulators.

In connection with the ever increasing unit power of the units, the growth of installed power of the individual hydroelectric power plants and the more rigid requirement on operation of the units in the powerful power systems, the requirements on quality of electric power are also rising, and the satisfaction of these requirements is ensured primarily by the machinery, units and equipment of the monitoring and control system. The production association of Leningrad Metals Plant is working continuously on improvement of the regulators, making them correspond to the modern requirements on such equipment.

The awarding of the state symbol of quality to the hydroelectric turbine equipment produced by the production association of Leningrad Metals Plant is an incentive for the work of the entire collective of the association.

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ELECTRIC POWER AND POWER EQUIPMENT

UDC 621.165

IMPROVEMENT OF STEAM TURBINES BUILT BY KHAR'KOV TURBINE PLANT IMENI S. M. KIROV

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[Text] The development of steam turbine making at the Kharkov Turbine Plant imeni S. M. Kirov is characterized by significant growth of unit powers, improvement of the structural elements and improvement of the technical-economic indexes of the manufactured turbines for electric power plants on organic fuel and for nuclear power plants [1-6].

In the last 20 years the unit power of the turbines for electric power plants (Figure 1) operating on organic fuel increased by five times. The power built up at still faster rates for nuclear power plants. In 11 years, beginning in 1966, the unit power of the turbines manufactured by the plant for the nuclear power plants increased by 15 times, and at the present time it has reached 1000 megawatts. The creation of turbine with a 1000 megawatt unit power has become possible as a result of the mastery by the plant of the production of 1500 rpm turbines. The first two 1500 rpm turbines with a power of 500 megawatts of the K-500-60/1500 type manufactured in 1976 are being built to be started up at the Novovoronezhsk Nuclear Power Plant. The turbine with a power of 1000 megawatts, type K-1000/60/1500 is in the production stage. Still higher powered turbines are being developed.

At the present time the plant collective is preparing for the production of turbines with a unit power of 750 megawatts for operation at 3000 rpm in the unit with the RBMK-1500 type reactor. This unit power for high rpm turbines of the nuclear power plants with operating exhaust and vacuum of 0.035-0.04 absolute atmospheres is the maximum.

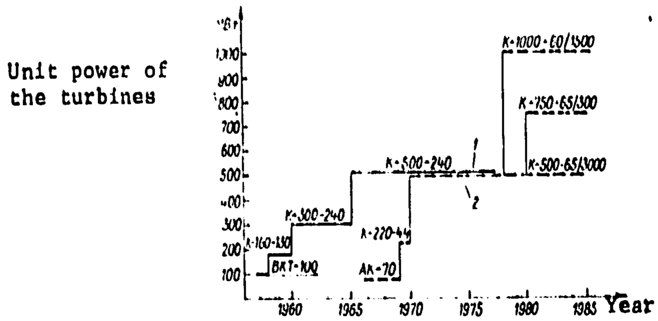

Figure 1. Growth of the unit power of the turbines at the Khar'kov Turbine Plant imeni S. M. Kirov: 1--For electric power plants operating on organic fuels; 2--For electric power plants operating on nuclear fuel.

One of the basic goals of the plant collective is to improve the quality of the manufactured turbines. This problem is being solved with respect to the following basic areas: expansion and improvement of the production-technological base of the plant; comprehensive use of the design experience, the manufacture and installation and prolonged operation of the turbines of earlier production, broad unitization of the assemblies and parts; the use of the results of the experimental research work of the laboratory base of the plant and other scientific research collectives.

As a result of the work done jointly with the collectives of the electric power plants in practice all of the steam turbines manufactured by the plant have received the State Symbol of Quality.

In recent years significant expansion and improvement of the production-technological base of the plant has taken place. The shops equipped with unique metal working equipment, special devices for welding large low-pressure cylinder rotors, and so on have been put into operation.

At the plant special attention has been given to the qualitative changes in the structure of the process equipment fleet. For the manufacture of heavy welded rotors a new section has been built, including the set of welding units, heating furnaces and metal working machine tools. The lathe for turning rotors weighing up to 200 tons has now been installed. Large closed sections have been built for the machining of the housings of the high and medium pressure cylinders and the housings of the low-pressure cylinder. As a rule, all of the special equipment manufactured by the technical specifications of the plant has increased precision and is outfitted with digital program control. The equipment for the production of turbine blades has been essentially renewed. The replacement of the universal milling machines with new five-spindle copying milling machines has, along with reducing the labor consumption, improved the equality of the manufactured guide and rotor vanes. A special section with precision equipment has been set up to build the regulation parts and assemblies.

The plant collective jointly with the branch institutes, the adjustment and research organizations is working constantly on improving the reliability of the produced equipment. This factor has acquired especially important significance for modern large turbines having large dimensions and operating in the modular systems.

The overwhelming majority of the turbines of the Khar'kov Turbine Building Plant imeni S. M. Kirov satisfy the norms adopted for these machines with regards to service life and operating time between repairs. The VKT-100 K-160-130 (PVK-150) turbines are operating fail-safe at the electric power plants. Many of them have significantly increased the calculated operating reserve--100,000 hours. The first models of the K-300-240 turbounit today have operated up to 80,000 hours. As a result of the operating experience, the studies and the adjustment of the turbines, constant work on improving the operating conditions and the structural design of the equipment elements, it has been possible to achieve high reliability index of the 300 megawatt units. The availability factor for these turbines in 1976 was 99.4 percent, and the average work time per failure for the entire fleet of K-300-240 turbines of the Khar'kov Turbine Building Plant imeni S. M. Kirov corresponds to 4200 hours. The availability factor for the K-500-240-2 turbine at the Troitskaya State Regional Hydroelectric Power Plant was 100 percent in 1976, and use coefficient of the installed power during operation of the unit was 101 percent.

The turbines for the K-220-44 and the K-500-65/3000 nuclear power plants which are at the present time the core of nuclear power engineering in our country are operating with high technical-economic indexes. The K-500-65/3000 turbines, the pilot models of which were installed at the Leningrad Nuclear Power Plant have operated under full load in practice since first being started up. The use coefficients of the calendar time during the first years of operation reached 70 to 78 percent, which exceeds the world level of reliability of the operation of units of this power. The experience in operating the K-500-65/3000 turbines has made it possible to create still more powerful units of the K-750-65/3000 type.

In recent years the plant has done intense work to improve the repair suitability of the manufactured turbines. As a result of exclusion of the operations with respect to dismantling the receivers, the standardized low-pressure cylinder developed for the 3000 rpm turbines with side steam feed makes it possible to lower the labor consumption of repairs. A number of measures have been introduced to decrease the expenditures of labor on opening and repairing the bearings, the steam distribution units and the direct-flow sections.

As a result of intense work to improve the economicalness of the K-300-240 turbines and to realize the accumulated experience in the studies and structural improvements in the turbines of other types and sizes, the thermal economy of the units has been brought to the guaranteed values. Therefore the actual specific heat consumption to generate electric power for the K-300-240-2 turbine units is 7702 kilojoules/kilowatt (1840 kcal/kilowatt-hour). The same index for the K-500-240-2 turbine recalculated for the parameters of the K-300-240-2 turbine was according to the ORGRES data 7673 kilojoules/kilowatt (1833 kcal/kilowatt-hour), in spite of the fact that at the time of the thermal testing the turbine unit had worked about 8000 hours and had 90 startups and shutdowns. As a result of the tests, reserves were discovered for further improvement of the economicalness of the K-500-240-2 turbounit estimated at no less than 1 percent. The realization of these reserves will be realized in the structural design of the K-500-240-3 turbounit, the design of which was started by the plant.

The tests run on the K-220-44 and K-220-44-2 turbines and also the K-500-65/3000 turbines at the Soviet and foreign electric power plants demonstrated that with respect to level of economicalness, these turbounits are among the most improved in world power engineering. This has become possible as a result of the introduction of the results of the latest studies in the field of profiling and aerodynamics of the direct flow sections, especially the low-potential section of the turbine into the design of the turbine units and the application of advanced designs with respect to layout and process conditions. The introduction of a modern experimental laboratory base at the plant cooperation with the adjustment and scientific research organizations will permit guaranteeing a high level of thermal economy of the turbines manufactured by the plant.

Improvement of the Structural Designs of the High-Speed Turbines for Electric Power Plants Operating on Organic and Nuclear Fuel

The development of structural designs for high speed turbines for electric power plants operating on organic and nuclear fuel is characterized by systematic development of the assemblies and parts, improvement of their quality, reliability, economy, technological and operating equalities. A great deal of attention has been given to improving the structural designs of the low-pressure cylinders, the proportion of which is a significant part in the turbines for electric power plants operating on organic fuel and it increases to 70 percent in the turbines at the nuclear power plants.

It is possible to consider the application of the following among the structural peculiarities of the high-speed turbines of the Khar'kov Turbine Building Plant imeni S. M. Kirov: double-walled construction of the housing of all cylinders; welded diaphragms made from carbon steel rolled products, and in the high temperature or high-humidity zones, alloyed steel; rigid welded and forged rotors of the low-pressure cylinders having high reliability; joining of all of the rotors of the turbine and the generator with rigid couplings; protective antierosion surfacing of the parts and the systems for removing moisture from the direct-flow section in the zones with high moisture content; transverse two-way condensers.

In the turbines previously made by the plant operating at 3000 rpm, the low-pressure cylinders with built-in supports for the rotors and housings were used in which the forces from atmospheric pressure and also from the frame of the diaphragms and the rotor are taken by a system of mutually perpendicular baffles. Depending on the type and size of the turbine, these low-pressure cylinders have insignificant differences with respect to number of taps, method of tapping, structural design of the seam intake and the direct-flow section with the same theoretical structural design and dimensions. All of this has led to a reduction in production efficiency, for in practice each turbine had a low-pressure cylinder differing from the low-cylinders of other turbines.

The problem of improving the technological nature and improving the production efficiency was solved by the plant by creating a standardized low-pressure cylinder suitable for all of the high-rpm turbines manufactured by the plant. This cylinder was developed and has been used for the first time in the five-cylinder K-750-65/3000 turbine with four low-pressure cylinders. The exhaust pipe of this cylinder is a "honeycomb" design with improved aerodynamic qualities and dimensions as in the existing unmodified design. The loss coefficient of the connection according to the results of blowing down the models at the Khar'kov Turbine Building Plant imeni S. M. Kirov and at the TsKTI Institute imeni I. I. Polzunov is less than 1. The structural design was borrowed from the Leningrad Metals Plant imeni 22nd Congress of the CPSU and provides for separate tapping of the seam after the last stage from the upper and lower halves of the housing with respect to individual compartments. By comparison with the previous low-pressure cylinders of the series turbines, the peripheral rim of the direct-flow section has been improved in the vicinity of the last stage. For the standardized low-pressure cylinder, side feed of the steam was used with the steam inlet located below the horizontal slit. The steam intake lines 1200 mm in diameter are connected on installation to the steam intake lines of the housing of the low-pressure cylinder by welding. The adopted structural design of the steam inlet assembly improves the repairability of the turbine, for it does not require disconnection of it when dismantling the low-pressure cylinder. The steam inlet to the frame of the low-pressure cylinder is made with installation of the guide ribs in the feed cavity; the location of the ribs is accomplished considering the aerodynamic studies of the model. The two-flow section of the low-pressure cylinder has not undergone any special changes by comparison with the low-pressure cylinder of the K-500-240-2 turbine. It has five stages each in each flow and the rotor blades of the last stage are 1030 mm long with all-milled shrouds.

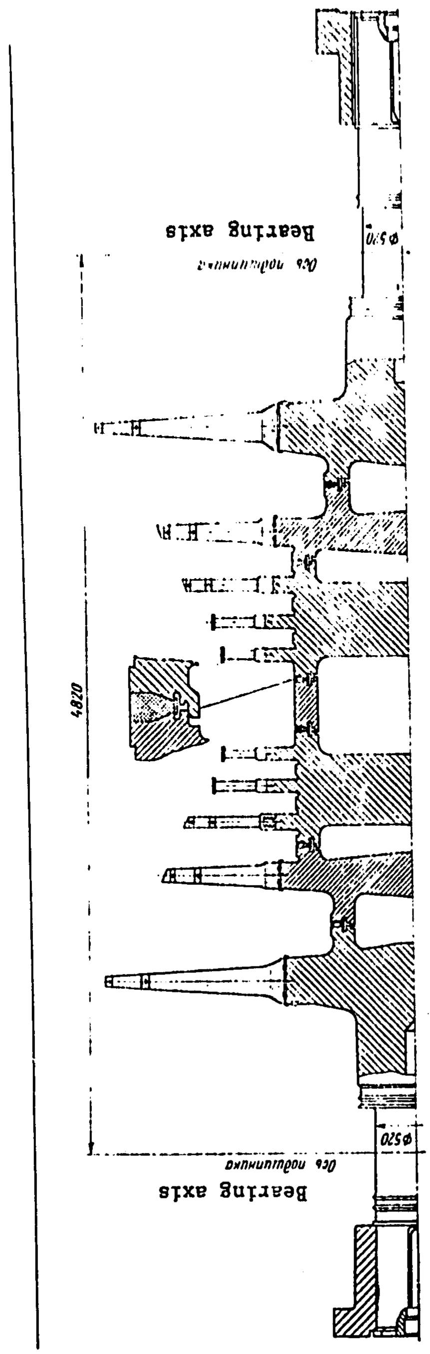

Figure 2. Rotor of the low-pressure cylinder of the welded and forged design for high-speed turbines

On the basis of the performed calculations with respect to optimization of the thermal system considering the different types and sizes of turbines, the optimal separating pressure (P_{sep} = 5 absolute atmospheres) and number of taps were adopted. From each low-pressure cylinder, three taps were made after the first, second and fourth stages. In the exhaust line of the housing a system is provided for cooling it by injection of the condensate during operation of the turbine at idle. In order to prevent cooling of the outside surface of the rim when the moisture hits, it is shielded by thin steel sheets with a clearance of 8-10 mm. This design protects the rim from deformations and opening of the flanges of the horizontal split joint which promotes improvement of the economy of the low-pressure cylinder.

It is possible to expect further improvement of the production efficiency, a decrease in labor consumption and metal consumption of this assembly on making the transition to the structural design of a rod type low-pressure cylinder with built-in supports, the development of which is underway at the plant at the present time.

As has been pointed out, a characteristic feature of the turbines of the Khar'kov Turbine Building Plant imeni S. M. Kirov is broad application of the welded rotors of the low-pressure cylinder. This type of rotor was used for the first time in the PVK-150 turbine, the pilot model of which was manufactured in 1958. During the 20 year period the plant accumulated a great deal of experience in the design, manufacture, operation and maintenance of welded rotors which have recommended themselves well as a highly reliable element of the unit.

At the present time all of the low-pressure cylinders of the high-speed turbines built by the Khar'kov Turbine Building Plant imeni S. M. Kirov have welded rotors. The rotor of the low-pressure cylinder of the series turbines (Figure 2) is welded from seven parts. Six of the annular welds with packing rings joining the rotor elements have identical separation.

The discs of the first to the fifth stages are made without central openings; the last two discs are made in the form of bodies of equal resistance. The disc of the fifth stage is forged together with the shank. In the existing structural designs, the rotor is made with adaptive half couplings. In the future consideration is being given to the transition to a structural design will all-forged half couplings. A great deal of attention is being given to improving the blading of the turbines, improvement of their reliability and economy. On many types of turbines the structural design of the blades of the last stage of the low-pressure cylinder 1030-mm long with all-milled shroud has been developed and introduced.

When creating the structural designs for the turbines for nuclear power plants, K-220-44, K-500-65/3000, K-750-65/3000, broad use was made of a great deal of the operating experience of the wet-steam turbines, especially with respect to improving the erosion strength of the elements of the direct flow section. In these turbines provision is made for the removal of part of the moisture to the regenerative taps and through the openings drilled in the frames of the diaphragms. Provision was also made for the peripheral removal of moisture from each stage through the "trap chambers" above the rotor blades. On the rotor blades with an angle $\beta_1 > 90°$, in order to improve the moisture separation part of the shroud was cut off, as a result of which the intake edges of the blades were opened. The input slit of the trap was located opposite the cut in the turbine stator. The axial dimensions of the slit are selected in such a way as to ensure minimum exhaust of the gas phase and prevent return of moisture to the direct-flow section.

In the low-pressure cylinder stages and in the last stages of the high-pressure cylinder, the peripheral cross-sections of which are made with large entrance angles ($\beta_1 > 90°$), the exit edges of the rotor blades open. Considering that in the next to the last stage of the low-pressure cylinder the rotor blades have sharply variable cross-sections with respect to height and that the peripheral moisture removal after them is inefficient, the diaphragm of the last stage is made with intrechannel moisture separation. In these diaphragms the guide blades, the rim and the body of the diaphragm are hollow. The steam and water mixture is removed to the blade cavity and then drained into the condenser.

All of the rotor and guide blades of the turbines at the nuclear power plants are made from chromium-containing steel which is resistant to erosion wear. On the rotor blades of the two last stages of the low-pressure cylinder, in addition, the input edges are also hardened. In order to prevent erosion, the elements of the stators of the high and low pressure cylinders, including the diaphragm, are made of chromium-containing steel. Surfacing of the bearing surfaces and the split joints of the elements of the stator of the high-pressure cylinder in the dense steam zone by erosion-resistant steel is also used. As the experience in long term operation has demonstrated, the methods of active and passive protection for the turbines of nuclear power plants are highly efficient and ensure reliable operation of the direct-flow section of the turbines.

Slow-Speed Turbines--New Area of Development

A great deal of experience with respect to the creation of powerful saturated steam turbines operating at 3000 rpm has naturally given rise to the preference for the structural designs of many of the elements also for low-speed units. These elements include the high and low pressure rotors, welded and rigid; bearings; and automatic barring gear; welded stainless steel diaphragms; devices to protect the seats and slit joints of the housing parts by surfacing or finishing with stainless steel.

However, a large number of elements of slow-speed turbines could not be obtained by a proportional increase in size. The dimensions of many of the parts of the high-speed turbines (for example, the exhaust lines) are the maximum for transportation by rail; a proportional increase in all of the dimensions would lead to extraordinarily heavy elements. Thus, for example, on doubling the exhaust area, the weight of the low-pressure cylinder would approximately triple; with an increase in linear dimensions it is more difficult to ensure rigidity of the structural elements sufficient for reliable alignment of the turbine considering the increase in mass of the turbine and the condensers themselves. In addition, with an increase in overall dimensions, the deformations caused by atmospheric pressure and nonuniform heating increase; the sharply increasing dimensions of the condensers complicate the building of a foundation corresponding to the static and dynamic strength requirements and rigidity; a number of the problems arise also when designing the condenser itself.

The most important problem for the creation of the slow-speed turbines is the development of a structural design for the low-pressure cylinder ensuring its rigidity and reliable alignment. In the K-500-60/1500 turbine, the low-pressure cylinder with side location of the condensers is used for the first time in Soviet practice. The turbine does not have a rigid coupling to the condensers, which lends stability to the vertical loading on the turbine foundation and independence of the deformations of the low-pressure cylinder housing with respect to the vacuum in the condenser and the degree to which it is filled with water. Earthquake proofness of the turbine has been improved.

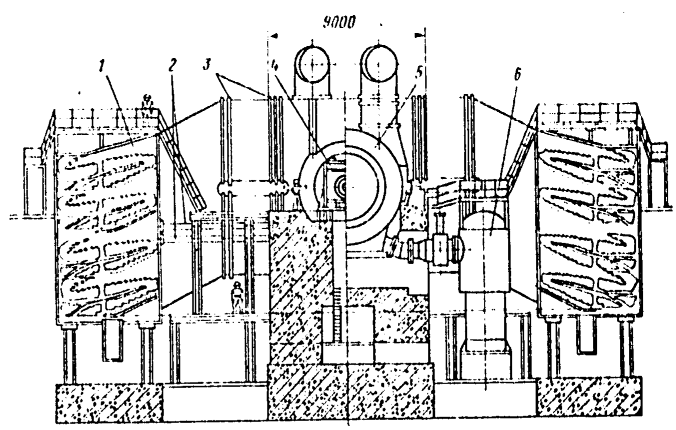

Figure 3. Transverse section of a turbine with side condensers: 1--Condenser; 2--Flexible supports, 3--Compensators, 4--Bearing housing; 5--Housing of the low-pressure cylinder; 6--Feed water heater.

The condenser is supported on individual foundations independently of the turbine. The unbalanced horizontal forces arising from the effect of atmospheric pressure on the outside vertical walls of the condensers are taken by the groups of flexible supports transferring this force to the foundation of the turbine. The housing (frame) of the low-pressure cylinder is made single-wall, which ensures the simplest connection of the receivers and the turbines for tapping the steam, it improves the thermal insulation, it lowers the metal consumption and labor consumption in the manufacturing process. The supports of the bearings and the housing of the low-pressure cylinder are installed directly on the foundation. Inasmuch as the exhaust lines suspended on the housing and elastically connected to the end seals fastened to the bearing supports do not participate in the alignment of the unit, the alignment is not disturbed on variation of the vacuum or heating of the connecting lines.

The condensers are installed with respect to the turbine (Figure 3) somewhat lower than in the known analogous foreign designs. The separation of the condensers with respect to height into two levels permits the energy consumption for driving the circulating pumps to be reduced to the level corresponding to the shaft condensers having lower altitude of the turbine system and it also ensures the possibility of operation with half of the condenser disconnected.

In all there are five (one horizontal and four vertical) unwelded vacuum split joints. The vertical split joints are made so as to ensure simplicity of fitting. For this purpose, flexible elements are installed on both sides of each split joint. The horizontal split is approximately one and a half times smaller than in the case of basement condenser. The increase in the total extent of the split joint which is 35 percent longer than in the case of the basement condenser, is compensated for to a significant degree as a result of this. It is necessary to note that the length of the vacuum split joints of the K-500-60/1500 turbine with side condensers is 17 percent less than in the K-500-65/3000 turbine.

The stand seals and rigid foundation permit checking of the density of the condenser, the housing of the low-pressure cylinder and the greater part of the vacuum split joints by filling the total steam space, the connecting lines and exhaust lines and the housing of the low-pressure cylinder with water. The rigidity of the lines is sufficient to avoid extraordinary deformations.

In the concrete foundation under the turbine a tunnel is made in which the oil lines and electric lines for the devices installed in the bearing supports are laid. The aerodynamic studies performed at the TsKTI Institute imeni I. I. Polzunov and at the Khar'kov Turbine Building Plant imeni S. M. Kirov demonstrated that in the case of side placement of the condensers, the peripheral nonuniformity of the steam flow parameters after the last stage is reduced, which promotes an increase in the operating reliability of the blades; in addition, in the exhaust lines it is possible to recover about 30 percent of the output energy of the steam from the last stage. The exhaust in two directions permit a decrease in overall dimensions of the line and depth of the pipe bundle of the condenser at the same speeds.

On the basis of the primary structural designs adopted for the K-500-60/1500 turbine, a turbine of the K-1000-60/1500 type made up of the high-pressure cylinder, the medium-pressure cylinder and three low-pressure cylinders has been designed and manufactured by the plant. All of the cylinders of this turbine are made two-flow and their through-flow sections are analogous to the flow sections of the corresponding compartments of the K-500-60/1500 turbine.

A version of the turbine without the medium-pressure cylinder has also been developed (see Figure 4). The turbine is made in accordance with the following layout: high-pressure cylinder plus three low-pressure cylinders. The diameter of the pipes feeding the steam to the low-pressure cylinder is 1200 mm instead of 2000 mm in the version with the medium-pressure cylinder. Even with side placement of the condensers this makes it possible to feed the steam to the low-pressure cylinder through the lower part of the housing. In the given version of the structural design, the repair and maintenance conditions have been improved while retaining the basic advantages of the turbines with side exhaust (relative compactness and technological nature of the housings of the low-pressure cylinder, the reliability of the alignment, high aerodynamic characteristics of the exhaust line). Design developments are being worked on for the individual assemblies of the low-speed turbines: the last stages and the low-pressure cylinders which will permit further increase in unit power.

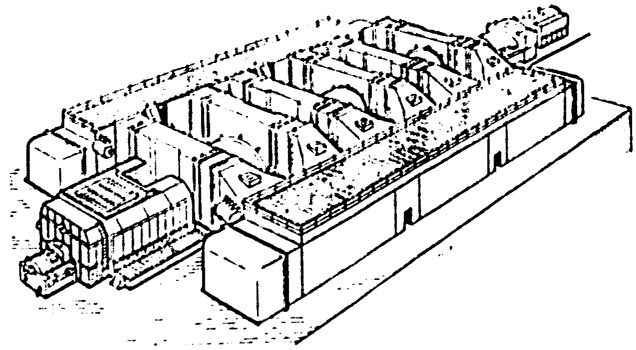

Figure 4. One thousand megawatt turbine operating at 1500 rpm without a medium-pressure cylinder with side condensers.

Turbine Exhaust

The size of the exhaust area is determined by the average diameter D_{ave} and the length of the rotor blade of the last stage. The relation of these two parameters is the most important characteristic which to a great extent determines the structural design of the low-pressure part of the turbine. In the last 20 years a trend has been observed toward an increase in the exhaust areas caused by an increase in length of the active part of the blades of the last stages of the turbine. The lengths of these blades are 660, 740, 780, 852, 960 and 1000 mm (at the Leningrad Metals Plant imeni 22 Congress of the CPSU, a titanium blade with an active section 1200 mm long is in the checkout stage).

When building the last stages it is necessary to solve the problems connected with the problems of gas dynamics and strength, manufacturing technology and metallurgy.

Lowering the turbine power leads to a significant change in the volumetric consumption of the working medium at the exit from the rotor of the last stage. It also changes on variation of the pressure in the condenser. The variability of the flow rate is connected with the variations of the following: the thermal gradient per stage; the degree of reactivity and the reactivity gradient with respect to radius; u/c_0 (where u is the angular velocity, c_0 is the total flow velocity), and consequently, with the variations of the magnitude and direction of the exit velocity and also the nature of its distribution with respect to radius.

With a decrease in the flow rate, the indicated peculiarities lead, if special measures are not take, to a fast decrease in the degree of reactivity in the root zone and, as a consequence, to the appearance of negative values of it, as a result of which increased energy losses are observed in this zone, compounding the losses of stability of motion and separation of the flow both on the rim at the root and on the back edges of the profiles.

The last stage is also characterized by a significant angle of rise of the outside meridional rim. This fact can lead to additional losses connected with flow around the profiles over oblique surfaces in the layer of variable thickness and with certain other factors, as a result of which separation of the flow from the outside meridional boundary and the edge of the profile takes place easily. The growth of the slope angles of the meridional rims and the M numbers (where M is the Mach number) at the exit from the stator leads to significant growth of the gradient of the degree of reactivity with respect to radius differing significantly from that calculated without consideration of these factors.

The enumerated deficiencies are to one degree or another characteristic of the stages manufactured previously (before the 1970's). The deficiencies connected with the operation of the last stages under reduced conditions and at idle can to a significant degree be explained by the random flow processes which have already been mentioned.

The Khar'kov Turbine Building Plant imeni S. M. Kirov began the design of the last two stages several years ago, one of which with a length of the rotor blade of 1030 mm was designed for a number of 3000-rpm turbines, including the turbines of the nuclear power plants, and the other, with a length of the active part of the rotor blade of 1450 mm, for the 1500-rpm turbines installed at the nuclear power plant. This does not exclude the possibility of using it for turbines operating on organic fuel. The principles permitting us to obtain improved characteristics were used in the designs for the new stages. The basic relations of the geometric parameters and the shapes of the structural elements ensuring operating reliability were selected in accordance with these principles. The effect of the various parameters on the characteristics of the stage was tested in numerous experiments.

At the present time one of these stages has undergone operating testing for 25,000 hours; the other has gone through a cycle of comprehensive studies as a result of which it was discovered that the principles used in the design ensure more stable operation in the partial regimes and an increase in efficiency of the stage by 2.5 percent by comparison with the old designs. The plant is continuing its projects aimed at creating new prospective designs for the last stages.

Reduction of Labor Consumption and Metal Consumption

One of the areas of improvement of the elements of the turbines with large unit power and improvement of the production efficiency is a reduction of the labor consumption and metal consumption. Until recently the structural designs of some of the large turbine assemblies and parts were created by established traditional forms and were not supported by the corresponding strength calculations which frequently led to inefficient use of the mechanical properties of the metal and to the application of imperfect structural forms. In realizing the problem of improving the production efficiency, the designers, the efficiency experts and the inventors at the plant are doing a great deal of work on improving the structural designs in the direction of reducing their mass and labor consumption and also improving other indexes. In particular, the assemblies of the compensation units, the reducers and the housings of the low-pressure cylinders have been subjected to careful analysis.

The strength calculations of the supports installed under the condenser springs have made it possible to produce a lighter design and significantly reduce their mass. The analysis and corresponding calculation of the housing strength of the condenser have made it possible to change its design and do away with the heavy (from 10 to 30 tons depending on the type of turbine) supporting frames welded to the bottom of the housing on installation. According to plan, the supporting frames were provided for transfer of forces from the 24 springs (6 at each corner of the condenser) to the bottom of the condenser, and they also served as a base for assembly of the portable parts of the condenser during installation, the analysis of the structural design demonstrated that the application of the frames is not necessary, and the transfer of forces from the springs to the tube panels of the condenser can be realized through two beams welded to the bottom of the condenser. At the support point of the springs the beams are made more rigid by stiffening ribs. The developed design with two longitudinal beams instead of the previously used frames satisfies the strength conditions and makes it possible to reduce the metal consumption (from 9 to 29 tons) and the labor consumption of each condenser.

The reducers connecting the lower halves of the exhaust lines of the housings of the low pressure cylinders to the condensers are box structures made of sheet rolled products 16 mm thick with overall dimensions of approximately 7x9 meters a height from 2 to 5 meters, depending on the type and size of the turbine. The initial structural design of the reducers provided for taking the atmospheric pressure forces by the inside ribbing of the walls and the installation of a three-dimensional system of supporting rods made of round rolled products 45 mm in diameter. The reducers of two adjacent cylinders are connected by two bypasses from the condition of the possibility of disconnecting one of the condensers for cleaning. The unbalanced force appearing as a result of this from the atmospheric pressure on each reducer is neutralized as follows: openings are cut in the walls of the reducer opposite to the bypasses which are equal with respect to dimensions to the cross-section of the bypasses. The supporting plates installed inside the reducer opposite the openings in the bypasses are connected to the wall along the outline of the lens compensators. The bearing plates of the adjacent two reducers are connected through the bypass by the spatial system of rods.

The peculiarities of the structural design of these reducers can also include the fact that each reducer, from the condition of transporting it by rail, is split into two parts which are welded together on installation. The deficiencies of the design of the investigated reducers can include the following: large metal consumption and labor consumption caused by the presence of the three-dimensional rod system for taking the atmospheric pressure and neutralizing the imbalanced forces; the necessity for welding a large number of rods of the two halves of the reducer under installation conditions; additional consumption of from 2 to 5 tons of shaped rolled products (channels No 20) for adding rigidity to the parts of the reducer during transportation of them; worsening of the aerodynamic qualities of the reducers as a result of complicating them with the rod system; increasing the transport expenditures.

The new developed "panel" structural design of the reducers (Figure 5) permits elimination of the enumerated deficiences of this unit. A newly designed reducer is made up of four wall panels one ribbed on the inside with channels 7. The reducer is transported by individual panels welded to each other on installation. The correspondence of the geometric dimensions of the reducer 2 to the drawings and ensurance of these dimensions on installation is achieved by marking the reducer at the plant. For this purpose, on each panel small flanges are provided which are matched and drilled out on assembly with the flanges of the adjacent panel. On the horizontal plane in the middle of the reducer under installation conditions a number of tubular braces 8 are welded on which, jointly with the stiffening ribs of the panels, take the atmospheric pressure. The tapping lines are fastened to these braces. In connection with the transportation of the reducers in individual panels, there is no necessity for transport stiffeners. The absence of the three-dimensional system of rods in the new design permits improvement of the aerodynamic qualities of the reducers. The unequalized forces of the reducers are taken by the rigid braces 6 installed between the water chambers 5 of the condensers and the transverse pins of the fixed points of the low-pressure cylinder.

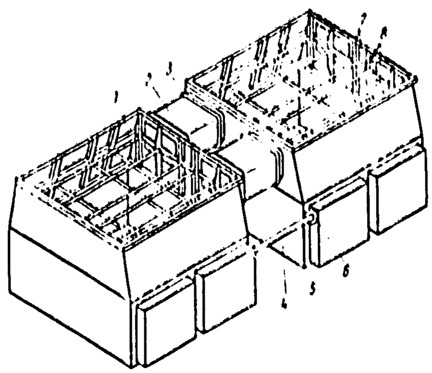

Figure 5. Reducer of the panel designed condenser: 1--Panel wall; 2--Bypass; 3--Compensator; 4--Condenser; 5--Water chambers of the condensers; 6--Braces between the water chambers of the condensers; 7--Stiffening channels of the panels; 8--Tubular braces.

The application of the new design of reducers has made it possible to obtain savings of about 28 tons of rolled products on one K-220-44 turbine and to decrease the labor consumption by approximately 900 standard hours. The panel type reducers will be introduced on all turbines manufactured by the plant. As a result of the work done to improve the structural design of the turbine elements in 1977 alone, it was possible to reduce the labor consumption of production by 62,000 hours and decrease the metal consumption by more than 420 tons.

Conclusions

1. On the basis of using the long-term operating experience of the first generation 300 megawatt turbines, the assimilation of new procedures for thermal and strength calculations with broad utilization of computers, joint work with the KhPI, TsKTI imeni I. I. Polzunov, VTI, NEI and other institutes, the Khar'kov Turbine Building Plant imeni S. M. Kirov has built modern steam turbines with high unit power of 500 to 1000 megawatts for ordinary and nuclear power plants.

2. The improvement of the elements of the steam turbines with high unit power has also been promoted by the organization of a new laboratory base and broad utilization of the results of the scientific research work in the new structural designs.

3. A new area created at the plant--the slow-speed turbine construction--is opening up new possibilities in the area of increasing the unit power of the turbines for the nuclear power plants and improvement of their thermal economy.

4. The steam turbines manufactured by the Khar'kov Turbine Construction Plant imeni S. M. Kirov are distinguished by high reliability, and they have good technical-economic indexes, which is promoting their broad utilization not only in our country but also in many foreign countries.

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ELECTRIC POWER AND POWER EQUIPMENT

CREATION OF A ONE THOUSAND MEGAWATT STEAM AND GAS UNIT WITH GASIFICATION OF SOLID FUEL UNDER PRESSURE

Moscow ENERGOMASHINOSTROYENIYE in Russian No 2,Feb 79 p 46

[Unsigned article]

[Text] At the joint meeting of the gas turbine and compressor sections, steam boilers and steam turbines a study is being made of the proposals of the scientific production association of the TsKTI Institute imeni I. I. Polzunov, the production association Krasnyy Kotel'shchik and the production association for turbine building Leningrad Metals Plant for the creation of a 1000 megawatt steam and gas unit with gasification of solid fuel under pressure, a report was heard from the scientific and production association of the TsKTI imeni I. I. Polzunov and the VNIPIenergoprom Institute of the USSR Ministry of Power Engineering on the technical-economic substantiation of the creation of such a unit, and a proposal was presented by the production association for turbine building Khar'kov Turbine Plant imeni S. M. Kirov on the acceleration of the creation of such units by operating the pilot units with gas turbine assemblies executed on the basis of the GT-45-850 with an increase in their power to 90-100 megawatts, in the steam and gas unit with gas generators, an increase in the initial gas temperature of 920° C and also an increase in output capacity and air pressure in the compressor.

It is proposed that the 1000 megawatt industrial power unit be built as part of the gas generators with an output capacity with respect to solid fuel of about 60 tons/hour with systems to remove sulfur and dust from the low-calorie gas, the high-head steam generators with a steam output for one vessel of about 660 tons/hour with steam parameters of 140 kg-force/cm^2, 515/151° C, two gas turbine units with a useful power of 160-190 megawatts each at gas temperature in front of the turbine of 950-1100° C with an air flow rate through the compressor of 500 kg/sec and an 800 megawatt steam turbine. The specific flow rate of the fuel with respect to the electric power generated is 284-278 g of provisional fuels/kilowatt-hour for operation on Kuznetsk coal. The gas generators are provided with steam and air blowing.

According to the preliminary runs, the creation and the outfitting of the modern steam power units with these steam and gas units can lead to fuel savings of 30 g of provisional fuel/kilowatt-hour, a reduction in capital expenditures by 12 rubles/kilowatt, metal savings for manufacture of the equipment of about 20 kg/kilowatt, a decrease in the content of harmful impurities in the combustion products by 75 percent, including the following: 90 percent with respect to sulfur oxides, 50 percent with respect to nitrogen oxides.

The demonstration unit of this type with a power 170 megawatts is known in world practice. It is in operation at the Kellerman Thermal Electric Power Plant in Lunen (Federal Republic of Germany). Since 1972 the specific capital expenditures on this unit have amounted to about 75 percent of the expenditures for a steam power plant of equal power. Installations with a unit capacity of 500 and 800 megawatts are being designed in the Federal Republic of Germany.

The scientific and technical council recommends approval and continuation of work on building the 1000 megawatt steam and gas unit with gasification of solid fuel under pressure.

In the resolutions of the sections of the scientific and technical council it was noted that the greatest difficulty comes from building the gas generators with a solid fuel rate of 60 tons/hour with gas purification systems which must be provided by the Ministry of Power Machine Building using the organizations of the Ministry of the Coal Industry, the Ministry of Chemical Machine Building, the Ministry of the Petroleum Industry, the Ministry of the Petrochemical Industry, the USSR Ministry of Petroleum, and so on. In connection with the fact that the power gas generator includes steam boiler elements, the head organization for building gas generators has recommended that the Krasnyy Kotel'shchik Production Association be established as the head organization for building gas generators and that the scientific direction be turned over the NPO TsKTI imeni I. I. Polzunov.

In order to accelerate the completion of the gas generators with the gas purification system, it is recommended that full scale modules of the gas generators be developed within the experimental industrial steam and gas units with standard power equipment: the T-180-130 steam turbine--the production association for turbine construction, Leningrad Metals Plant, the gas turbine equipment based on the GT-45-850--the production association for turbine construction Khar'kov Turbine Plant imeni S. M. Kirov and the high-head steam generator based on the VPG-600-545/545 modules developed for the Surgutskaya State Regional Hydroelectric Power Plant. Other versions must also be developed.

It is recommended that the power equipment standardized with the equipment designed or delivered to the thermal electric power plants and nuclear power plants be included in the pilot units for the steam and gas installations.

Considering the possible increase in gas temperature ahead of the turbines to more than 1200° C in the future, it is recommended that work be continued to find radical layouts and areas of application of the steam and gas units with exhaust heat boilers and solid fuel generation under pressure.

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ECONOMICS TRAINING FOR POWER WORKERS

Moscow PROMYSHLENNAYA ENERGETIKA in Russian No 4, Apr 79 pp 2-3

/Article by engineers V. S. Zemskov, P. I. Lartsin, V. A. Ravvin: "The Economics Training of Power Workers at the Chelyabinsk Electrometallurgical Combine"/

/Text/ An economics education is conducive to the development of the consciousness and activeness of workers, their communist attitude toward labor, and helps to increase labor productivity and work quality. At the Chelyabinsk Electrometallurgical Combine much attention has always been devoted to the economics training of the workers. The economics sections are components of the training programs of workers of power engineering specialties at the personnel training shop and of the programs for the improvement of the skills of workers and engineering and technical personnel at the technical training division.

The questions of economics training underwent particular development after the issuing of the CC CPSU decree, "On Improving the Economics Training of Workers." A long-range plan of economics training for the 10th Five-Year Plan was drafted, in conformity with which during the new academic year classes at the schools of communist labor and at economics schools were begun, some of the workers are studying the syllabus of the new course "Advanced Know-How of Increasing Production Efficiency and Work Quality."

The methodologically correct conducting of classes and the provision of the educational process with teaching equipment are of great importance in increasing the qualitative level of studies. For the propaganda workers of schools three-day seminars (with leave from work) are being held, at which themes of syllabuses and methods of studying them are given. The monthly information bulletin of the technical and economic indicators of the combine and its shops is used extensively in the classes. Colorful tables, which reflect the fulfillment of the production plan, the dynamics of the increase of labor productivity and the average wage, the data on the use of electricity and others, are being compiled to help the managers of the schools. In the plant office of economics training the propaganda workers receive skilled consultations on questions of teaching methods. At the end of the academic year conferences of the managers of schools are held, at which the results are discussed and recommendations for the next year are elaborated.

The plan of work of the council for economics training called for the holding of methods seminars and open classes, as well as an account of the individual managers on the progress of economics training in the shops. During this academic year, for the purpose of intensifying the practical direction of economics training, particular attention is being devoted to the study of advanced production know-how, the drive for economy and thrift and the increase of work quality.

In the power engineering shops and subdivisions skilled engineering and technical personnel--the chiefs and deputy chiefs of the shops, the managers of the sections and power engineering services of the technological shops, the best power engineering foremen--have been appointed propaganda workers. They conduct the economics training in close contact with the practical work of the students, help them in the economic substantiation of the socialist obligations.

The majority of students of the schools of communist labor and the economics schools have assumed and are successfully fulfilling the socialist obligations on the early fulfillment of the assignments of the 10th Five-Year Plan.

As a result of the close cooperation of the managers and students of the schools at the combine a number of measures have been adopted, which are aimed at the improvement of the technical and economic indicators of production, the increase of the reliability of operation of the power equipment, the economy and rational use of power resources. Thus, the development of the operating conditions of the compensators of the reactive capacities at the electric plants was carried out, which made it possible to increase the level and decrease the fluctuations of the voltage in the power supply systems of the heavy-duty ferroalloy furnaces, to increase their productivity and to reduce the specific expenditures of electric power.

The workers of the shop of instrumentation and automation developed and introduced a plan of the summation and remote-control transmission of the values of the active and reactive capacity, which is being consumed by the combine. This enables the operations control service of the shop of the networks and substations not only to monitor, but also to regulate the schedule of consumption of electricity.

The modernization of one of the ferroalloy furnaces with the adoption in it of a longitudinal capacity compensator, was carried out by the efforts of many subdivisions of the power engineering service, which increased the power factor of the furnace from 0.8 to 0.94 and the effective power by 35 percent and considerably increased the productivity. In the power engineering shop proposals on increasing the use of secondary power resources have been implemented for a number of years.

The adoption of the indicated and many other measures to a great extent was conducive to the fact that in 1978 as compared with 1977 at the operating capacities of the combine the production of ferroalloys increased by 7,950 tons and of electrode products by 550 tons, 29 million kWh of electric power were saved, about 62 percent of the consumed thermal power was generated by recovery boilers, 33 percent of the power fuel was replaced by blast furnace gas from the ferroalloy furnaces which were covered with crowns (previously it was burned in the air).

The extensive scope of the economics and technical training makes it possible to hope for the further successful introduction of advanced technical decisions in the power engineering system. The development of the combined roasting of the ore-lime mixture and its feeding in hot form into the ferroalloy furnace, the elaboration and introduction for the first time in the sector of measures on evaporative cooling at the smelting furnaces, the development of heavy-duty ferroalloy furnaces with the deep lead-in of 110 kV and longitudinal capacity compensation are the primary tasks in this direction.

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ENERGY CONSERVATION

CONFERENCE ON USE OF PRIMARY, SECONDARY POWER RESOURCES

Moscow PROMYSHLENNAYA ENERGETIKA in Russian No 4, Apr 79 pp 59-60

/Article by B. A. Konstantinov: "Questions of the Co-utilization of Primary and Secondary Power Resources at the Ninth International Conference on Industrial Power Engineering"/

/Text/ The co-utilization of primary and secondary power resources plays an important role in industrial power engineering. This theme was examined in detail in the second section of the Ninth International Conference on Industrial Power Engineering, which was held in September 1978. In all 200 specialists took part in the work of the section. Fourteen reports from the CEMA countries were presented, which examined the questions:

the cogeneration of electric and heat--the priority direction for meeting the demands of industry for electric power and heat (a report from Romania);

the influence of the criteria of reliability on the selection of the schedules for separating the industrial load from the power system of thermal electric power stations (Romania);

the analysis of the status and prospects of development in Hungary of the cogeneration of electric power in the case of the centralized heat supply of industrial projects (Hungary);

the use of secondary power resources in the GDR (GDR);

the choice of the means of generating thermal power for enterprises of the chemical industry (Poland);

the determination of the specific consumption of power and the optimization of comprehensive generation (Romania);

economic and mathematical modeling of the fuel and power balance for comprehensive systems, which utilize various sources of power (Romania);

the potentials and limits of the cogeneration of heat and electric power in industry (GDR);

the utilization of the main directions of the use of TETs's for municipal and industrial heat supply (GDR);

the analysis of the supervision of thermal power stations and the consumption of thermal power in the industrial, housing and municipal services of the Western Slovak area (CSSR);

chemical enterprises as power engineering subsystems of central heating, which use secondary power reserves with a higher level of recovery of power (Romania);

the study of the power management at a large urban industrial complex (Romania);

the improvement of the efficiency of stations equipped with condensing turbines and with a take-off for central heating in the form of hot water (Romania);

the power technology aspects in hydrolytic units (Romania).

The statistical data contained in the reports attest to the rapid development and increase of the economic indicators of TETs's. Thus, as a result of the development of TETs's in Romania the economy of conventional fuel was 2.7 million tons as compared with the separate generation of heat and electric power, and 78 percent of the economy falls to industrial central heating.

In the reports of the representatives of Hungary and the CSSR the tendency for the urban consumption of heat to increase in the past decade in cities with industrial complexes was noted. In the reports of the GDR much importance was attached to the maximum technical and economic conditions which can be placed at the basis of the realization of industrial TETs's. The importance of the type and cost of fuel in the evaluation of the feasibility of realizing industrial TETs's was stressed in the reports of the specialists from Hungary, the GDR and Romania. Under the conditions of Romania the question of the operation of TETs's in the future on lignites of local origin is being raised.

In the report of Poland it was demonstrated that the increase of the cost of fuel makes the realization of TETs's profitable even under the unfavorable conditions of the consumption of heat, while in the report of the GDR it was noted that with the increase of the expenditures on the extraction of primary power sources the limits of the profitability of TETs's are continuing to decrease. An analysis of the criteria of selection of the parameters of the fresh steam, the number of boilers of TETs's, as well as the distribution of the load according to the main and peak schedules was given in the reports of Romania and Poland.

In a number of reports it was stressed that the chemical industry is one of the main consumers of power and a source of secondary power resources. In connection with this the report of Romania indicated the main directions for making the appropriate analysis when solving questions of the use of residual fuel gases, secondary resources of the production of ammonia and calcium carbide, the heat of condensate and secondary steam from industrial units. The reports mentioned chemical, petrochemical and metallurgical units, at which primary and secondary power resources are being used completely.

In the discussion 11 participants spoke. The advantages and drawbacks of the operation of TETs's and the improvement of the methodology of optimizing TETs's with the use of mathematical models and computers were noted. The need to consolidate the cooperation among the CEMA countries in respect to research, designing and the further complete utilization of primary and secondary power resources in industry was emphasized.

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