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ENERGY

(FOUO 27/80)

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ELECTRIC POWER

UDC(622.323+622.324):621.313(075)

DESIGNING ELECTRICAL EQUIPMENT FOR THE OIL, GAS INDUSTRY

Moscow ELEKTROOBORUDOVANIYE NEFTYANOY I GAZOVOY PROMYSHLENNOSTI. UCHEBNIK DLYA VUZOV. IZD. 2-e, PERERAB. I DOP. (Electrical Equipment for the Oil and Gas Industry. Textbook for VUZ. 2nd revised and expanded edition) in Russian 1980, p 2, 475-478

[Annotation and table of contents from book by S.G. Blanter and I.I. Sud, Nedra, 478 pages]

[Excerpts] The book is a textbook for "Electrical Equipment" courses for students of petroleum VUZ and departments offering instruction in the fields of "Technology and Full Mechanization for Working Oil and Gas Deposits," "Drilling Oil and Gas Wells," "Design and Operation of Oil and Gas Pipelines, Gas Storage Tanks and BulkOil Plants," and "Construction of Oil and Gas Pipelines, Gas Storage Tanks and Bulk Oil Plants," as well as in the course "Compressor and Pump Installation Drive" for the field of "Machinery and Equipment for the Oil and Gas Fields." Its contents is in accordance with programs for these courses confirmed by the USSR Ministry of Higher and Secondary Specialized Education.

The book may also be used as a guide by engineers and technical workers engaged in the design and operation of electrical equipment for the oil and gas industry. In it power supply and electrical power equipment for drilling rigs, recovery and industrial oil preparation facilities, oil field compressor and pumping stations, mainline oil and gas pipelines and machinery for laying mainline pipelines are examined. Questions of electric lighting for oil and gas fields, operation of electrical equipment, accident prevention and electric power conservation are set forth.

In the present second edition of the book (the 1st edition was in 1971), the material is updated in accordance with new technical decisions for facilities and electrical equipment and advanced engineering achievements which have appeared since the publication of the first edition of the book.

27 tables, 200 illustrations, 17 titles in the bibliography.

REVIEWER. Department of General and Specialized Electrical Engineering, Groznyy Petroleum Institute.

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ELECTRIC POWER

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HIGH-SPEED CONSTRUCTION OF THE KURPSAYSKAYA GES

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 10, Oct 80 pp 2-8

/Article by Engineer V. S. Shangin: "High-Speed Construction of the Kurpsayskaya GES"/

/Text/ /FROM THE EDITORS. The brief time periods for the erection of the Kurpsayskaya Hydroelectric Power Station with its high concrete dam and excellent quality of construction work have evoked considerable interest. The set of articles published below illuminates the most important construction, organizational, and engineering solutions which have been adopted in the process of designing and building this station in the Naryn Cascade.*/ /in italics/

The Kurpsayskaya GES (Fig. 1), now under construction in Kirghizia is the fourth hydroelectric power station on the Naryn River and the third (of the proposed five) in the Lower Naryn Cascade.

The principal technical and economic indicators of this hydraulic development are cited below:

Rated capacity of the GES, in MW (megawatts)	800
Number of units	4
Capacity of the reservoir, in millions of cu. m	370
Including the following regulated amount	35
Design (calculated) pressure head, in meters	91.5
Design (calculated) discharge of the GES, in cu. m per sec.	972

* This set of articles about experience gained in building the Kurpsayskaya GES utilizes photographs by Ye. Kuluzayev.

Height of the dam, in meters	115
Total volume of concrete, in millions of cu. m	1
Average annual production of electric power, in billions of kW-hrs. (kilowatt-hours)	2.63
Estimated construction cost, in millions of rubles	193
Including the following for SMR (Construction and Installation Work)	151
Production cost of electric power, in kopecks per kW-hr.	0.13
Time required for return of investment on this hydraulic development	Less than one year

The introduction of the first two units of the Kurpsayskaya GES are scheduled to take place in 1981, and that of the remaining two units--in 1982, while the planned deadline for completing construction occurs in 1983.

The site of the Kurpsayskaya GES, situated at a distance of 40 km (lower along the river's course) from the Toktogul'skaya GES, is typically mountainous. The width of the gorge cut by the water amounts to 40--50 meters, while at the point of the dam's crest it is approximately 360 meters. The average incline (declivity) of the riverbed is about 0.003. Passing alongside of the gorge is the Frunze--Osh Highway, which falls within the zone of reservoir flooding.

The region where this hydraulic development is located, including the reservoir, is characterized by heterogeneous, extremely complex tectonic structures and engineering-geological conditions. This explains the presence of large discontinuous dislocations in the immediate vicinity of the hydraulic development, as well as a regional thalasso-Fergana depth fracture, occurring at a distance of 60-65 km north of the hydraulic development; this has undergone rejuvenation at all stages of tectogenesis, including those of the present day.

The basic structures of this hydraulic development are situated in a single structural tectonic block; in accordance with the data of the Institute of Earth Physics (IFZ) of the USSR Academy of Sciences, a maximum possible earthquake intensity of nine points has been adopted into the design of these structures.

The basic rocks are interstratified sandstones and argillites, whose layers intersect the valley almost perpendicularly with respect to the upper head at an angle of 50--65°. The proportion of sandstones herein comprises 70--75 percent, while that of argillites amounts to 25--30 percent. With respect to thickness, the sandstones are subdivided into thin-layered (with a stratum thickness of less than 0.1 m), medium-layered (0.1--0.6 m) and thick-layered (more than 0.6 m). The argillites have a thin-layered structure. Quaternary deposits have an insignificant distribution here. Within the riverbed the thickness of alluvial deposits does not exceed 1--2 m. The following shift characteristics of the foundation rocks have been adopted in the design: $tg\varphi=0.9$ and $S=0.3$ MPa (megapascals).

The climate of the Naryn River Basin is continental. With an average annual air temperature of +13.8°C, the minimum observed in January is -30°C, and a maximum in July of +44°C. Moreover, the winter period is characterized by frequent strong winds, the velocity of which reaches 35 meters per second. Frosts may be observed in October (-10°C) and April (-4°C). The average annual amount of precipitation comes to 378 mm. The fluctuation of water levels in the river amounts to 12--16 m.

The Toktogul'skaya GES, which is located higher on the course of the river, has completely regulated the flow of the Naryn River; in designing the Kurpsayskaya GES this has allowed a substantial reduction to be made in the design construction discharge, and it has been adopted as equal to 1,100 cu. m per sec. (in 1966 it amounted to 2,880, and in 1969 it was 2,640 cu. m per second). After the construction of the Toktogul'skaya GES there was also a principal change in the river's temperature cycle; practically no ice and slush phenomena are now observed.

The basic structures of the Kurpsayskaya GES (Fig. 2) include the following: a concrete gravity dam, a GES building attached to the dam, an interior water spillway in the body of the dam, a surface water spillway, an ORU (open distributive apparatus) of 220 kV (kilovolts) and one of 110 kV.

The concrete gravity dam has a triangular cross-section; the upper pressure-head edge is vertical, while the lower edge has a foundation of 0.7 for the riverbed sections and 0.75--0.8 for the side sections. Within the dam a sectional cut has been provided; herein the design of the intersectional seam provides for the possibility of the joint operation of the sections under load. With its length along the crest of 364 m the dam is divided into 13 sections as follows: four riverbed sections with turbine water conduits and nine bank sections. The width of the sections varies from 19.5 to 30 m. In the sections with a width of 30 m along the upper and lower edges further joint incisions are made to a depth of 5 m. Within the body of the dam provisions have been made to install a system of rooms, stairwells, freight openings, as well as elevators, service areas and so forth (Fig. 3).

The construction of the body of the dam has been planned with a zonal distribution of concrete: the interior zone is made of non-frost-resistant M 150 concrete, the exterior underwater zone--of M 250 concrete, and the exterior surface zone--of M 300 concrete. Provisions have been made to carry out anti-filtration (well drainage) and reinforcement (cementation) measures.

The dam includes a water intake 43 meters high, situated in its four riverbed sections; the lower edges of these sections have turbine water conduits seven meters in diameter, which extend beyond the limits of the dam's cross-section.

The open-type GES building with its single-series units is directly attached to the dam in its riverbed section. The turbine equipment is being supplied by the Turbine Plant PO (Production Association) (from the city of Kharkov), and the generators from the Sibelektrotyazhmash Plant (from the city of Novosibirsk).

The structures for absorbing construction outlays are traditional for an analogous grouping of a hydraulic development under mountain conditions: a by-pass tunnel, an upper cofferdam up to 40 m in height, and a lower cofferdam approximately 18 m in height.

The deep interior water spillway, consisting of a single-aperture rectangular pipe with a cross-section of 5X7 m and equipped with working segmental and repair flat gates, located in one of the right-bank sections of the dam. During the period of reservoir flooding it will be used to pass water through into the tailrace. Within the GES building a spillway is made in the form of an elbow, and beyond the station the elbow makes a transition to a terminal section with a lateral overflow.

In building the Kurpsayskaya GES a complex of progressive engineering technical and organizational economic solutions was adopted; their realization created the prerequisites for carrying out under complex mountain conditions this high-speed construction in order to put into operation hydraulic units with capacities of 200 MW (megawatts) within a single five-year period after the start of construction. Let's enumerate just the principal solutions here.

1. The beginning of the basic operations on the Kurpsayskaya hydraulic development was coordinated (albeit with a certain delay) with the final phase of these operations at the Toktogul'skaya GES. Thus, they managed to create favorable conditions for the effective use in the construction of the Kurpsayskaya GES of the existing groups of highly skilled workers and ITR (engineering and technical personnel).

2. In order to erect the Kurpsayskaya GES, use has been made of the chief production bases (the concrete plant, the gravel-grading system, the reinforced-concrete product construction yard, the transfer center, and so forth) which were built in their time for the construction of the Toktogul'skaya GES.

By the time construction began on the Kurpsayskaya GES in 1976 the facilities of the production base of Naryngidroenergostroy had been mainly shifted to two areas (to the city of Kara-kul' and the village of Shamaldy-Say) and guaranteed the repair of the construction equipment and motor transport, the production of commercial concrete and aggregates for it, structural components made of precast reinforced concrete, the necessary output of wooden items etc. Moreover, there existed a well-developed transfer base and warehouse system of the UPTK (Production-Technological Administration for Equipment Outfitting); all construction and installation organizations also maintained their own systems. But directly in the region where the hydraulic development is being built there is only a minimum number of enterprises which, as regards their technical purposes, cannot be separated from the construction site (Fig. 4).

3. The presence in the city of Kara-Kul' of a well-laid-out residential settlement with all the necessary social and cultural facilities has made it possible to completely avoid residential and civil construction at the site of the Kurpsayskaya GES; it has adopted and carried out a scheme for supplying the workers, the ITR and the office employees at the construction site.

4. In developing structural components for the hydraulic development's principal structures attempts have been made at insuring a high degree of technology in their erection as well as a decrease in the labor consumption of the operations. Furthermore, thanks to the close interrelationship between the builders and planners, already during the construction process additional corrective measures were adopted, directed at reducing the physical volumes of work necessary for the most rapid possible start-up of the first few units.

In order to curtail the duration of the preparatory period, Naryngidrostroy, together with the planners, carefully and thoroughly analyzed the following questions:

the possibilities of curtailing maximum amounts of work needed to be carried out prior to the start of concrete laying in the principal structures and the maximum combination of separate types of operations during this period;

determining the minimum necessary list of temporary buildings and structures which had to be built at the construction site of the Kurpsayskaya GES (including those prior to the beginning of concrete laying);

the acceptability of the existing plan solutions for the hydraulic development's individual elements from the viewpoint of their fastest possible realization, as well as the presence of the necessary material and technical resources.

With this same goal in mind a number of effective measures have been implemented on this construction project:

the replacement of the open segment of the Frunze--Osh road running along the left bank above the hydraulic development by a tunnel made it possible to combine in time work on building the road and the dam;

the replacement of the right-bank transport tunnel by an open section of the road solved the problem of allowing transit transport through, and it insured the necessary rapid pace of excavating the foundation pit of the principal structures;

organizing the area of the pioneer period in direct proximity to the place where the main operations were being carried out permitted a considerable curtailment of the time periods required for putting into operation such extremely important facilities as the compressor, the water-collecting basin, dining-room etc., as well as to reduce expenditures for erecting communications and insuring the necessary increase in the pace of operations;

a change in the construction of the upper cofferdam insured the erection of its principal part prior to switching over discharges into the tunnel and the required allowances during the growing season, and it also considerably simplified the transport scheme at the lower levels of the pit during the period when its excavation was being completed and concrete-laying operations were beginning;

a change in the scheme of the water supply of the construction sites made it possible to avoid building a complicated cluster of water-collecting structures, laying main water lines of as much as 10 km in length, including one along the rocky cliff over which the above-mentioned Frunze-Osh Highway passes;

a reduction of the design construction discharge from 1800 to 1100 cu. m per sec.;

the complete avoidance of building housing facilities in the region of the Kurpsayskaya GES made it possible not to divert labor and material resources, equipment, etc. from the main operations.

Directly on the construction site of the Kurpsayskaya hydraulic network work began on putting up the section of the 110-kV (kilovolt) VL (overhead line) which passes through the gorge along the operational Frunze-Osh Highway and is situated above the future structures and construction sites. For this purpose it was necessary to install 15 metal poles (supports) on the rocky "crests" of cliffs which were accessible only to mountain-climbers; materials and structural components from the assimilated levels were delivered to a height of as much as 300 m sometimes by hand, sometimes by utilizing helicopters. The total length of the raised section amounted to approximately five km. At the same time a 110/6-kV substation was built in order to insure electric-power operations and to solve the problem of high-frequency communications between the Kurpsayskaya GES site, the city of Kara-Kul' and the settlement of Shamaldy-Say.

From the very beginning of production operations there arose the extremely acute problem of insuring the reliability of the transport ties with the left-bank site, necessary for transferring the earth-moving equipment and working the soil under the hydraulic development's principal structures. Before the completion of the permanent bridge across the Naryn River, which was put into operation in 1980 and became part of the section of the Frunze-Osh Highway taken out of the flood zone, use was made for these purposes of a temporary bridge, erected by the bridge-builders of the USSR Ministry of Transport Construction.

In May 1977 the rock drillers of the Kirghiz Special Administration of the Gidrospetsstroy All-Union Association completed work on the approach passage and began cutting through the construction tunnel. In accordance with the plan, this tunnel has a length of 634 m, designed to pass through discharges of as much as 1100 cu. m per sec., and it was supposed to have a reinforced-concrete facing along its entire length. However, upon the initiative of the builders, the facing was revised and was replaced along most of the tunnel's length by a jacketing of sprayed concrete. This made it possible to reduce the amount of concrete work by 8,000 cu. m, outlays of reinforcement by 350 tons and forms by more than 7,000 sq. m.

But the main effect derived from introducing this progressive jacketing consisted in curtailing the length of time required to erect the facility. Thus, work on building the tunnel was completed in one year, and on 10 May 1978 the riverbed of the Naryn River in the line of direction of the Kurpsayskaya GES was shut off.

In accordance with irrigation requirements, within 20 days after the shutoff a discharge was needed through the hydraulic development's line of direction amounting to 800 cu. m per sec. For this purpose it was necessary to erect an upper cofferdam more than 40 m high. In accordance with the initial plan, the cofferdam (with a total fill of 220,000 cu. m) was supposed to be made of rock-fill with a core of clay-loam. The material for erecting this cofferdam was supposed to be delivered from three independent quarries at hauling distances of 10--50 km. To implement this solution, even in case of suspending the pit excavation (because of a transport shortage) would have required 3--4 months.

The workers' planning section of Gidroproyekt's SAO (Central Asian Division), upon a proposal by the construction division developed within a very brief period of time a new design for a cofferdam which could be built within the required deadline at a considerable reduction in cost. Moreover, maximum and successful use was made of local conditions: the cofferdam's line of direction was arranged along the axis of the previously built, temporary bridge with concrete abutments and joining walls; the main part of the antifiltration facing took the form of a concrete wall between abutments on a cleaned rock foundation; directly in the riverbed section provision was made for a fill made with a natural gravel-sand mixture, to be injected subsequently with a clay-cement grouting solution. By the growing season of 1979 the cofferdam being erected was built up further, and this insured the passage of the required amounts from the reservoir of the Toktogul'skaya GES.

Despite considerable pressure head, the filtration discharge through the upper cofferdam after the first stage of the cementation curtain was completed did not exceed 100 l/s (liters per second).

At the same time that the tunnel was being built work was begun on excavating the foundation pit of the principal structures, the site of the ORU (open distributive apparatus), and other facilities. The complex topographical conditions and the virtual impracticability of arranging transport routes to a whole number of intermediate points brought about the need for a differentiated approach to the solution of this problem.

In the first place, as we have already noted, there was a careful and thorough analysis of the possibility of reducing the volume of work, especially at the upper levels, which are difficult of access. The decision not to use cable cranes enabled us to cut out the excavation of 350,000 cu. m of rocky cliffs above the dam's foundation pit, the heighth of whose slopes reached 60 m, and to reduce the total length of time taken by these operations by at least six months. There was an extremely substantial reduction in the amounts of rock excavation in the dam's foundation pit by means of reducing the depth of the cut and removing only the eroded surface zones with cracks which had filled in with suspended loamy material which did not lend itself to cementation. Moreover, the thickness of the layer being removed at times did not exceed 3--5 m. Also reviewed and adopted were a number of other proposals, likewise aimed at reducing the work volumes and curtailing the construction time periods. As a result, the total amount of earthmoving and rock excavation work carried out with regard to the principal structures came to approximately 1.2 million cu. m, while the heighth of the foundation pit's slopes is about 130 m.

The earthmoving work was carried out by EKG-4.6 excavators along with the use of BelAZ-540 and KrAZ-256 dump trucks. The principal amount of these operations was completed over a 1.5-year period ending in December 1978. Among the schemes utilized for excavating the foundation pit, the following deserve special mention:

1. On the right bank between points 105.0 and 50.0 m it was practically impossible to complete the transport levels. In order to arrange the foundation pit within these points, it was decided to carry out an excavation by means of a single explosion, and for this purpose they provided a set-up at the 76.0-m point of a contour tunnel with a cross-section of 6--8 sq. m and a length of 80 m. Drilling out the massive rock was carried out from above as well as from the tunnel itself. Special attention was paid here to drilling holes for contour blasting, spaced at intervals of 0.8--1 m. Inasmuch as the slopes of the foundation pit amounted to 1 : 1 on an average, for the purpose of carrying out bulk loading after blasting at the lowest possible points, the two lower tiers of excavation between points 30.0--50.0 m were removed first. This made it possible to utilize the two most convenient lower transport levels for excavating earth after mass blasting. The blasting of this section of the foundation pit was completed within two months after the Naryn River was cut off.

2. On the left bank the dam's foundation pit was inaccessible to machines at height of more than 100 m. The upper part of the foundation pit to a heighth of about 40 m was excavated from modest-sized areas (created by the small borehole method), using NKR-100 machines. Processing the blasted earth was carried out by GMN-250 hydraulic monitors (excavators). In accordance with a specially developed plan regarding the bulk load which was being formed from the blasted and excavated earth, two D-271 bulldozers and an SBU-2M drilling rig were hoisted by traction to a height of 60 m. Further excavation of the earth to existing transport levels was carried out with the aid of these machines and hydraulic monitors at a step height of 2.5--3 m.

3. The excavation of the foundation pit's lower tier was completed without maintaining a protective layer or the small borehole drilling of the final 1.5--2 m, as provided for in the plan. Such a decision was preceded by tests and full-scale research carried out directly in the foundation pit. Under the specific conditions of building the Kurpsayskaya GES the possibility of avoiding the installation of a protective layer was guaranteed by drilling the main boreholes 0.5 m higher than the plan outline, by reducing the diameter of the boreholes, and by increasing the density of boreholes to 2 × 2.5 m. In order to clean up the foundation after the excavation of the earth, bulldozers were used, equipped with special ripper-blades, as well as hydraulic monitors and mounted shafts.

In December 1978 the earth and rock excavations in the dam foundation pit were completely finished; on 26 December the first cubic meter of concrete was laid into its foundation.

The avoidance of building a complex for grading gravel and a concrete system in the region of the Kurpsayskaya GES, despite the considerable distance needed to transport the concrete mix (40 km), insured from the first few months on that the concrete would be laid at a smooth rate and that it would be of the required good quality. In 1979 some 250,000 cu. m of concrete was laid into the foundation section; moreover, beginning in March, the average monthly pace amounted to 23,800 cu. m (with a low of 17,200 and a high of 29,700 cu. m). Here again we should mention the high technology in the design of this hydraulic development's principal structure--the dam, thanks to which as early as the first year of its construction the labor productivity was greater than during the years of mass concrete laying in building the dam of the Toktogul'skaya GES. In separate months of 1979 output per man-day exceeded seven cu. m (these calculations made use of a method analogous to those employed in the construction of the Toktogul'skaya and Chirkeyskaya GES's).

In accordance with the start-up scheme, by the time the first unit is started up the dam should be built up to a heighth of 75 m and 680,000 cu. m of concrete should be laid into the basic structures. As of 1 July 1980, approximately 450,000 cu. m of this amount had been laid.

At the beginning of 1980 the work front was prepared for installing the insertion parts of the turbine stator and the spiral chamber of Unit No. 1; in June the basic operations were completed on the deep interior spillway, and work had begun on installing the columns and sub-crane beams of the powerhouse (machine room).

In conclusion, it should be mentioned that the experience we have gained in building the KurpsayskayaGES has already convincingly demonstrated the genuine possibility of putting high-capacity hydro units into operation within the course of a single five-year period from the time operations are started. The principal prerequisites for this are as follows:

a sharp reduction in the length of time required for the preparatory period;

maximum utilization of the existing experience gained in erecting analogous structures;

high technology of the structural components of the hydraulic development's principal and auxiliary structures, guaranteeing the required labor productivity and high-quality workmanship.

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EFFICIENT LINING COMPONENTS ON BOILERS WITH GAS-TIGHT SHIELDS

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 10, Oct 80 pp 28-32

/Article by Engineer Yu. S. Tsarikov: "Efficient Lining Components on Boilers with Gas-Tight Shields"/

/Text/ The lining of boilers with gas-tight, all-welded shields made of finned tubes possesses essential advantages over the lining of boilers with smooth-tube shields. In such boilers the lining fulfills the function of merely a thermal isolation of the radiating surfaces whose temperature does not exceed 600°C. At the present time boilers of both the single-pass type as well as the drum-type boilers with gas-tight shields are being turned out by the Red Boilermaker Production Association (TKZ) [Taganrog Boiler Plant and the Barnaul Boiler Plant (BKZ). The plant designs provide the following for the lining components of these boilers: the base layer uses insulation made of inlaid products--perlite, vulcanite, and calcareous-siliceous panels (IKP) and sprayed with asbestos-perlite and asbestos compounds; for the coating layers plaster is used with fiberglass glued on an epoxy base or thin-sheet steel.

The USSR Ministry of Power and Electrification has accumulated considerable experience in manufacturing the above-mentioned linings at assembly areas and at installation sites. In a number of instances, when there is a lack of the materials provided for by the plan, their quality is poor, or there is insufficient time for installation, upon agreement with representatives of the electric power stations and boiler plants, lining components have been made which are not in the plan. At the present, therefore, electric power stations now have about 12 types of linings in operation.

In connection with the above, the need has arisen to determine the qualitative and technical characteristics of these components, to compare them, and to develop the necessary recommendations on the basis of this. Thermal tests of the linings are being systematically conducted by the quality-control service of the special administrations of the Soyuzenergozashchit VO (All-Union Association) and the Soyuztekhenergo PO (Production Association) (in conjunction with representatives of the electric power stations) in accordance with the requirements of the "Instructions on Testing Thermal Insulation in Electric Power Stations." For this purpose use is made of the ITP-6 thermal-flow measuring instruments of the Institute of Technical Thermal Physics of the Ukrainian SSR Academy of Sciences. When necessary, the measurements are double-checked by the flat thermometers designed by the Teploproyekt VNIPI (All-Union Scientific Research and Design Institute). The temperature on the surface is measured by semi-conductor heat sensors of the TP-3 type and surface thermocouples, while the distribution of temperatures throughout the thickness of the layer is determined with the aid of chromel-cupriliferous and chromel-aluminiferous thermocouples.

The methodology for processing the data received is based upon the indicator of the component's thermal conductivity at an average operating temperature. It characterizes not only the material and the manufacturing quality of the lining, but it also takes into consideration to a certain degree the influence on it of thermal-conductive metallic and other inclusions. The reliability of this indicator of thermal conductivity is guaranteed by the large number of test measurements carried out. These tests have enabled us to make a comparison between the design values of the thermal conductivity of the lining components and the measurements obtained in the process. At the present time, in calculating the thickness of a lining we proceed from the reference values for the thermal conductivity of the materials which are included in its design. The thickness of a lining layer which is manifested as the result of calculation is being increased somewhat, and it is being accepted (in the case of all kinds of materials) as equal to 160 and 210 mm for the TKZ and BKZ boilers respectively. In connection with the absence in the literature of the design values for thermal conductivity of combined components (those made of various materials and products), an attempt has been made to determine them on the basis of data obtained as the result of tests; for this purpose the data were grouped by types of materials and methods of carrying out the operations.

Examined below are the most efficient lining components.

Sprayed lining (insulation). /in boldface/ Spraying asbestos and asbestos-perlite masses is a reliable method for obtaining seamless lining components. In recent years such components have been widely adopted on BKZ and TKZ boilers. The spraying is carried out on mounted equipment (BKZ) and partially at assembly areas (TKZ). As the spraying material use is made of Grades-III, V, and VI asbestos, puffed-up perlite, vulcanite, and other binders--acrylic resin (Plexiglass), an aluminum chromophosphate solution, and cement. Spraying a lining, in accordance with the requirements of the instruction now in effect /1/, must be carried out using Grade-III asbestos. However, this instruction /1/ contains a stipulation concerning the possibility (as an exception) of utilizing a mixture consisting of 50% Grade-III asbestos and 50% Grade-V asbestos. In practice, because of a shortage of Grade-III asbestos, this ratio has recently been altered in favor of increasing the proportion of Grade-V asbestos, and even Grade-VI asbestos is being used.

Everywhere attempts are being made with regard to the possibility of using non-asbestos compounds. At the Kuybyshevskaya TETs (Heat and Electric Power Station) and the VAZ (Volga Automotive Plant) TETs the lining and the insulation of the corners of the furnace (fire box), the drums, and the gas-conduit ducts have been made as an experiment with a compound based on granules of mineral wool with an additive of Grade-V asbestos and a binder of acrylic resin. At the Maryyskaya GRES (State Regional Electric Power Station) the spraying of a lining of a cold hopper (funnel) of one of the boilers has been done using IKI (calcareous-siliceous) granules. Widespread use is now being made of ready-made dried asbestos-perlite mixes produced by the Dmitrovskiy Thermal Insulation Products Plant and consisting of Grade-V (or VI) asbestos and puffed-up perlite in a ratio of 2 : 1.

Test data on sprayed linings are cited in Table 1.

The material is usually sprayed on cold heating surfaces, though in some cases it has been done on heated ones (Minskaya TETs-4). There is some experience in spraying at below-freezing temperatures; nephelinic antipyrine, which is recommended by the technical specifications as a coagulant of acrylic resin when spraying on a cold surface, is not always used. Furthermore, the lack of ready-made mixes with antipyrine and the existing technology of spraying do not permit us to make a confident judgement about the effect of nephelinic antipyrine on the quality of a finished component. There is an opinionthat in the spraying process a considerable portion of the dust-type coagulant is blown away by the air stream. This opinion needs to be checked out. In processing the test results run on existing operational boilers, indicators of component thermal conductivity have been obtained which differ substantially from the design indicators adopted in accordance with data in instructions and literature from the sources -- the ZiO [possibly the Podol'sk Machinery Plant imeni Ordzhonikidze], the TsETI [Central Electrical and Heat Engineering Institute for Structural Components imeni Kucherenko]: for a lining made of Grade III asbestos $\lambda = 0.071 \pm 0.00013 t_{cp}$ and made of Grade V asbestos $\lambda = 0.125 \pm 0.00008 t_{cp}$.

The discrepancy between the actual and the design values of thermal conductivity [3] can be demonstrated by making a calculation of the thickness of the lining layer of a BKZ 420-140 boiler, proceeding from a normative level of heat losses of 349 Watts per sq. m and a lining surface temperature of 55°C and a shield surface temperature of 345°C. The design value of the lining component's thermal conductivity, i. e., of a component made of Grades-III and V asbestos, under these conditions is equal to 0.097 and 0.141 Watts/(m . K) respectively. The thicknesses of the lining layer are as follows:

$$\delta_{III} = 0.097\ (345-55)/349 = 80\ \text{mm};$$

$$\delta_{V} = 0.141\ (345-55)/349 = 114\ \text{mm}.$$

It is obvious that with such a thickness of the lining components it is impossible to insure a normative level of heat losses and temperature.

Table 1

Electric Power Station	Type and Station No. of Boiler	Thickness of Lining, in mm	Temperature of Surface, in °C	Density of Heat Flow, in Watts/m^2
Grade-III Asbestos, Perlite Sand, Acrylic Resin				
Kuybyshevskaya TETs	BKZ 420-140 NGM, No. 1*	190	45	170
	BKZ 420-140 NGM, No. 2	217	43	224
Bobruyskaya TETs-2	BKZ 420-140 NGM, No. 5	140	70	
		170	40	280
Mix of Grades-III and V Asbestos (with a ratio of 1 ; 1), Acrylic Resin				
Dzhambulskaya GRES	TGME-206, No. 4	163	49	255
Novokrutskaya TETs	BKZ 420-140 NGM, No. 1	195	39	253
Karaginskaya TETs-3	BKZ 420-140, No. 1	200	35	252
Grade-V Asbestos, Acrylic Resin				
Novosibirskaya TETs	BKZ 320-140, No. 9	190	50	299
Novosibirskaya TETs-3	BKZ 320-140, No. 12	190	50	350
Chitinskaya GRES	BKZ 320-100, No. 12	180	51	320
Dzhambulskaya TETs	ETA 30/40, No. 1	113	32	350
Mix of Grades-V and VI Asbestos (with a ratio of 1 : 1), Cement Mortar				
Kamchatskaya TETs-1	BKZ 120-100 GM, No. 7	190	59	450
Mix of Mineral-Wool Granules (80%), Grade-V Asbestos (15%), Perlite Powder (5%), Acrylic Resin				
Kuybyshevskaya TETs	BKZ 420-140 NGM, No. 1	190	45	280

* Data from Soyuztekhenergo PO (Production Association)

Table 1 (Continued)

Thermal Conductivity of Component, in Watts/(m · K)		Length of Time in Operation, in hours
Design	Test Measurement	
0.097	0.112	--
0.097	0.166	8986
--	--	1000
0.097	0.16	9260
--	0.142	1064
--	0.163	5252
--	0.167	--
0.141	0.2	40975
0.141	0.23	29628
0.141	0.213	--
0.141	0.187	1800
--	0.287	6562
--	0.184	20,000

Testifying to this is the operating experience of the BKZ 420-140 NGM No. 5 boiler of the Bobruyskaya TETs-2, which had a lining thickness of 140 mm. After its start-up the need arose to spray on an additional layer of insulation with a thickness of 20-30 mm.

It should be noted that the indicators of the insulation being sprayed, in particular density and thermal conductivity, depend, to a great extent, on a number of objective factors such as the type of installation and the degree of asbestos swelling furnished by it, the air pressure and outflow velocity of the air mixture, the amount and density of the binder, the distance of the nozzle from the surface being sprayed (it should amount to between 400 and 700 mm). The operator's experience is also quite important. The ratio between the density of the layer and the velocity of the air mixture's outflow as well as its saturation has been confirmed by the results of an experiment which was conducted at the Dzhambulskaya GRES. The scheme of the unit for spraying insulation (Fig. 1) included a cyclone centrifuge (separator) (Fig. 2), which permitted the excess dust-removed air to be discharged through a pistol-type atomizer. The density of the test samples was lowered, according to the data of the construction laboratory of the Dzhambulskaya GRES Special Administration by an average of 20 kg per cu. m. The use of such a method of spraying with a discharge of excess air also permitted dustiness to be averted.

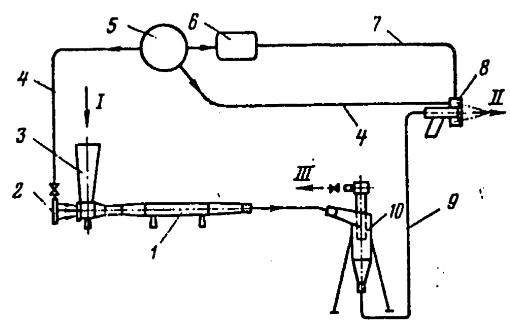

Figure 1. Schematic of Test Installation for Spraying Insulation

Key:

1. Ejection machine
2. Air collector for feeding air
3. Receiving bunker (hopper)
4. Air hose
5. Compressor receiver
6. Tank for binding mortar
7. Hose for feeding mortar to pistol-type atomizer
8. Pistol-type atomizer
9. Material hose for enriched air mixture
10. Cyclone centrifuge (separator)

I Air mixture feeding

II Discharge of atomized air mixture

III Discharge of excess air

In view of the shortage of Grade-III asbestos, a study was made of the possibility of using Grade-V asbestos for spraying insulation. Grade-V asbestos has shorter fibers than Grade-III asbestos. In spraying, therefore, it requires an increased discharge of binder and creates a denser mass of fibers, possessing less elasticity. As a result of such a subjective factor as the operator's attempt to reduce dustiness in the work zone, there is an excess moisture in the mixture. In the case where acrylic resin is used as the binder the excess moisture in the mixture does not cause any significant reduction in the lining's thermal conductivity. When the lining layer is heated up, the moisture contained within the acrylic resin evaporates, and the material becomes porous. Design calculation and experience have demonstrated the possibility of using Grade-V asbestos for spraying with a layer thickness of 210--220 mm. This thickness is sufficient to insure a normative level of heat losses and temperature at the insulation surface (See Table 1).

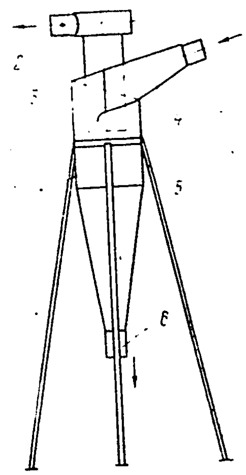

Figure 2. Cyclone Centrifuge (Separator)

Key:

1. Housing (Casing)
2. Nozzle (Outlet) for discharging excess air
3. Discharge regulator
4. Nozzle for feeding air mixture
5. Supporting structure
6. Nozzle for discharging enriched air mixture

Linings made of panel-formed products. [in boldface] The traditional block-inlaid material for BKZ boilers consists of vulcanite panels(plates). Recently calcareous-siliceous panels (IKP) have been used for lining BKZ boilers installed at electric power stations in the European part of the USSR and TKZ boilers installed at TES's in other regions. According to the plant designs, the following thicknesses have been provided for the linings made of IKP: in the TKZ boilers 160 mm (105+5+50, where 105 and 50 are the thicknesses of the IKP, and 5 is the thickness of the mastic layer), in the BKZ boilers 210 mm (105×2). Despite the lack of IKP with a thickness of 50 mm in production, corrective adjustments in the working drawings of the TKZ's have not been made up to now, and this has led to various difficulties. In installing these panels, it is necessary to replace the existing ones with materials having equal values. For example, at the TGMP-204 boilers No. 5, 6, and 7 of the Zaporozhskaya GRES it was agreed upon with the manufacturing plant to replace IKP panels 50 mm thick with perlite ones.

Other TES's have selected materials with suitable thicknesses. For lining these same types of boilers at the Uglegorskaya GRES as a first layer they used perlite and perlite-phosphogel panels whose thickness has not always corresponded to the needs. Hence, the layer thickness of such a lining amounted to 160--195 mm. At the TGME-206 No. 1 boiler of the Pechorskaya GRES, for the same reason and because of a lack of suitable products, perlite-phosphogel panels 90 mm thick had to be cut in such a way that their thickness amounted to 50 mm, and this led to considerable waste.

The results of tests run on lining components made of panel-type products are cited in Table 2.

It is obvious from Table 2 that the linings of the TGMP-204 boilers at the Uglegorskaya GRES have the highest indicators. This may be explained by the fortuitous selection of materials for the component (the first, "hot" layer was made of products with a lower linear shrinkage coefficient than that possessed by IKP--perlite and perlite-phosphogel panels, which guaranteed less openings of the seams /joints/, and the second layer was made of IKP), as well as by exceptionally careful execution of work in the assembly area.

The TKZ boiler laboratory followed up on the lining of this same No. 5 boiler at the Zaporozhskaya GRES. In the report on the tests it was noted that in certain spots the temperature of the facing sheets reached 71° C. Unsatisfactory work on the lining component of this boiler is the explanation for the shrinkages in the IKP layer, which reached 2 percent (according to the engineering specifications) or 20 mm per meter. When the covering layer was removed, gaps (breaks) were revealed between the panels (of as much as 15--20 mm). Inasmuch as the first layer was made of sovelite /?/ panels, their increased hermetic quality (6 times greater than perlite panels and 12 times greater than IKP panels) caused a high temperature to occur in the zone where the IKP had been installed and, consequently, an increased shrinkage in the latter.

Laboratory tests run by Sibtekhenergo have established that IKP shrinkage amounts to 1.47--4.2 percent at a temperature of 600° C. Also included among the shortcomings of IKI are their high hygroscopicity and density under moist conditions. In the design calculations of the installed loads the density of the products is usually taken as equal to 225 kg (kilograms) per cu. m (in accordance with the engineering specifications). However, at times pressed IKP are delivered to the installation areas with a density of 350 and 450 kg per cu. m, inasmuch as the hygroscopicity of the calcareous-siliceous products is very high, their moisture upon delivery according to the engineering specifications may comprise 70 percent, and the actual density of the IKP may exceed the design calculated amount by a factor of 4 or 5. At the Cheboksarskaya TETs-2, when the lining IKP of the boiler unit were being hoisted up, they fell, since this unit's lining components had been kept in the construction yard for three months without being covered up. Tests which were conducted on samples of the lining panels in connection with this accident showed that their density amounted to 396--672 kg per cu. m, and their water absorption, when immersed in water for

Table 2

Electric Power Station	Type and Station No. of Boiler	Thickness of Lining, in mm	Temperature of Surface, in °C	Density of Heat Flow, in Watts/m^2
	Sovelite Mark-400 Panels			
Kamchatskaya TETs	BKZ 120-100 GM, No. 1	230	55	455
	BKZ 120-100 GM, No. 6	230	60	550
Vladivostokskaya TETs	BKZ 210-140	200	37	[illegible]19
Karagandinskaya TETs	BKZ 420, No. 1	220	45	460
	Vulcanite Mark-400 Panels			
Yuzhnosakhalinskaya TETs	BKZ 320-140, No. 1	235	35	245
	Calcareous-Siliceous Panels			
Karagandinskaya TETs-3	BKZ 420-140, No. 1	210	40	290
Kirishskaya GRES	TGMP-324, No. 4	210	43	272
	TGMP-324, No. 5	210	48	305
Perlite Mark-350, Perlite-Phosphogel ("Hot-Layer"), and IKP Panels				
Uglegorskaya GRES	TGMP-204, No. 5	170	60	223
	TGMP-204, No. 7	185	71	210
Severodvinskaya TETs	TGME-464, No. 1*	160	50	310
	TGME-464, No. 1	170	45	210
Sovelite Mark-400 ("Hot-Layer") and IKP Panels				
Zaporozhskaya GRES	TGMP-204, No. 5	160	61	350
	IKP and Perlite-Phosphogel Panels			
Pechorskaya GRES	TGME-206, No. 1**	160	30	160

* Data supplied by Soyuztekhenergo PO (Production Organization)

** Data derived from individual measurements with partial boiler loading

Table 2 (Continued)

Thermal Conductivity of Component, in Watts/ (m . K)		Length of Time in Operation, in hours
Design	Test Measurement	
0.091	0.395	59,217
0.091	0.486	12,744
0.091	0.226	20,130
0.09	0.368	--
0.094	0.186	600
0.098	0.207	--
0.12	0.160	--
0.12	0.184	25,079
--	0.112	8,814
--	0.114	--
--	0.174	--
--	0.123	--
--	0.161	--
--	0.085	150

30 minutes reached as high as 144 percent. For the exact same reason at the Reftinskaya GRES the shield unit of a P-57 boiler, lined with panels from TsKBenergo (Central Power Design Bureau), and fell, while it was being hoisted up.

Combination-type linings made of block-inlaid products, IKP, and sprayed materials (Table 3)./in boldface/ In order to reduce the influence of IKP's shrinkage phenomena and lack of compaction between panels to the level of heat losses, a combination-type of lining has been utilized in a number of boilers upon agreement with the plants concerned. On the BGZ 420-140 NGM Nos. 1 and 2 boilers of the Kaunasskaya and Minskaya TETs's, in accordance with the plan, the first layer has been applied consisting of IKP with a thickness of 105 mm, and the second layer--consisting of an asbestos-sprayed layer of material 100 mm thick. A lining of analogous components has been used on these same types of boilers at the Petrozavodskaya TETs, except that instead of IKP, vulcanite panels were utilized in the first layer. Thermal testing confirmed the high efficiency of the component which had been selected.

Table 3

Electric Power Station	Type and Station No. of Boiler	Thickness of Lining, in mm	Temperature of Surface, in °C	Density of Heat Flow, in Watts/m²
	IKP and Spraying			
Kaunasskaya TETs	BKZ 420-140 NGM, No. 1	212	42	290
	BKZ 420-140 NGM, No. 2	216	46	244
Minsskaya TETs-4	BKZ 420-140 NGM, No. 1	200	39	215
	BKZ 420-140 NGM, No. 2	202	42	220
	Vulcanite and Spraying			
Petrozavodskaya TETs	BKZ 420-140 NGM, No. 1	200	35	210
	Mineral-Wool Mats and Spraying			
Ufimskaya TETs-5	BKZ 420-140 NGM, No. 1	195	45	254
	BKZ 420-140 NGM, No. 1*	190	48	140
Petrozavodskaya TETs	BKZ 420-140 NGM, No. 1	200	45	315
	IKP and Mineral-Wool Mats			
Pechorskaya GRES	TGMP-206, No. 1	160	30	160
	TGMP-206, No. 1**	170	30	140
Mazheykyayskaya TETs	TGME-464, No. 1	160	38	180
	Finnish "Rock Wool"			
Svetogorskiy TsBK TETs	SRK, No. 1	200	36	60
	Kaolin Wool			
Khar'kovskaya TETs-5	TGME-464, No. 1	160	50	120
Uglegorskaya GRES	TGMP-204, No. 6	180	40	150

* Data supplied by Soyuzenergo PO (Production Association)

** Triple-layered component: mats, IKP, and mats

Table 3 (Continued)

Thermal Conductivity of Component, (Test Measurement), in Watts/ (m . K)	Length of Time in Operation, in hours
0.210	6,960
0.174	1,440
0.146	--
0.152	--
0.14	2,056
0.162	5,838
0.112	12,000
0.157	2,056
0.084	150
0.078	150
0.096	200
0.057	16,390
0.0675	1,000
0.073	3,000

Linings made of mineral-wool mats and sprayed materials. /in boldface/ At the Ufimskaya TETs-5 a boiler lining was made of a layer of mineral-wool sewn mats with a thickness of 70 mm within a lining made of steel mesh, installed at a distance of 100--300 mm from each other, and a layer of sprayed asbestos material 100 mm thick, which also filled in the spaces between the mats. This component worked reliably for more than two years. Thermal tests which were run by the Soyuzenergozashchita VO (All-Union Association) and the Soyuztekhenergo PO (Production Association) at various times and after the boiler had been operating for various numbers of hours, confirmed the high operational indicators of such a lining. Analogous components were placed on the boiler of the Petrozavodskaya TETs.

Linings made of block-inlaid products and mineral-wool mats. /in boldface/ In order to verify the possibilities for eliminating wet processes on the TGME-206 No. 1 boiler of the Pechorskaya GRES lining components of two types were installed, retaining the planned layer thickness as follows: one of the IKP and the mineral-wool mats were given layer thicknesses of 105 and 80 mm respectively; the other was made of a layer of mineral-wool mats, IKP, and a second layer of mats (the thickness of the mat layers was 40 mm each, and that of the IKP was 105mm). Observations on the data derived from these components allow us to make preliminary conclusions about their rather high efficiency and reliability. The TGME-464 boiler of the Mazheykyayskaya TETs was given a lining with a thickness of 160 mm on all the shield heating surfaces, made of IKP (hot layer) and mineral-wool sewn mats. In carrying out the second type of boiler lining at the Pechorskaya GRES and the Mazheykyayskaya TETs a levelling mastic layer was not applied between the tubes.

Also checked out was the possibility of lining boilers with gas-tight shields made of mineral-wool products, which would allow us to obtain seamless industrial components and ensure their reliable use over the course of a prolonged period of time. With this goal in mind, the No. 3 boiler of the Minskaya TETs was furnished with a lining component on one section of the shield, made of mineral-wool mats. Tests which were run on this section demonstrated that at a layer thickness of 200 mm the density of the heat flow amounted to 145 Watts per sq. m, while the temperature of the lining surface was 42°C; the thermal conductivity of the lining was 0.099 Watts/ (m·K). A followup study was also made on the condition of a similar lining in the Finnish soda-regenerating boiler with a steam productivity of 90 tons per hour (P=3.9 MPa/megapascals/) at the TETs of the Svetogorskiy TsBK, which went into operation in 1976 and which by the time of the tests had been operating for 16,390 hours. The lining components of this boiler are made of a carpet-like matting of "rock wool" (basalt diabase), threaded on pin-hooks 6 mm in diameter. With a thickness of 200 mm this lining had a thermal conductivity of 0.057 Watts /(m·K), the density of the heat flow amounted to 60 Watts/m^2, and the temperature of the lining surface was 36°C.

Recently, increasingly wider acceptance has been gained by lining components made of high-temperature fibrous materials--basalt fiber and kaolin wool. VNIPI (All-Union Scientific Research and Design Institute) Teploproyekt, on the basis of results of researching the properties of various fibrous materials/4/, recommended for use in the designs of thermal insulation the following optimum densities: mineral-wool 150--160 kg per cu. m, wool made of super-thin fiberglass 90, wool made of basalt super-thin fiber (BSTV)100, and highly aluminous wool 200 kg per cu. m.

In order to make an experimental industrial verification of the possibility of utilizing basalt super-thin fiber and kaolin wool in lining components, the TGMP-204 Nos. 6 and 7 boilers of the Uglegorskaya GRES were furnished with test sections of a lining made of rolled VGR-130 kaolin wool and BSTV of varying density. Tests which were conducted for 3,500 hours after these sections were installed and subsequent observations of them over the course of 6,000 hours demonstrated the high reliability and economical nature of these lining components (Table 4). Moreover, it was established that the best indicators were achieved by utilizing BSTV with a density of 90--97 kg per cu. m. At the present time the TGM-1202 boiler of the Kostromskaya GRES has been furnished with lining components made of a layer of basalt fiber with a thickness of 160 mm, as provided for in the plan for IKP.

Table 4

Indicator	Basalt Super-Thin Fiber, with Density in kg/m^3							Kaolin Wool VGR-130 with a density of 210 kg/m^3
	41	54	65	75	81*	90	97	
Lining Thickness, in mm	185	190	185	190	120	185	190	135--140
Average Layer Temperature, in °C	242	250	245	240	322	240	237	316
Thermal Conductivity, in Watts/(m . K): by measurements	0.07--0.082	0.069	0.058	0.064	0.071	0.052--0.064	0.052--0.057	0.071
by the data of VNIPI Teploproyekt	0.084	0.074	0.067	0.064	0.072	0.058	0.056	0.079

* Basalt super-thin fiber with a density of 81 kg/m^3 and VGR-130 kaolin wool were utilized as the first layer of a combination-type component; the second layer was made of mineral-wool mats withathickness of 70 and 50 mm respectively.

For the purpose of economizing, the coefficient of installation compaction of plant-manufactured mats made of BSTV has been accepted as equal to 3.5, and this insures their density at 81 kg/m^3, or 13 kg per sq. m of surface. For this purpose, mats were laid down in a layer 560 mm high and then compacted from above by a metallic frame to a thickness of 160 mm. At the planned heighth the frame is affixed by a wire "moustache," welded to the pins. The possibility of making a lining out of VGR-130 kaolin wool for the TGME No. 1 boiler of the Khar'kovskaya TETs-5 was agreed upon with the TKZ, but because of organizational reasons it replaced the planned lining made of IKP only on the bottom shields and the lower shield of the transfer gas conduit. Rolls made of kaolin wool were also placed on the pins and tightened by the frame. Thereby a compaction coefficient of 1.5 was insured, and this allowed a layer compaction of 210 kg/m^3 to be achieved.

However, taking into consideration the high cost of basalt and kaolin fiber, we should probably use combination-type components with the second layer made of cheap mineral-wool products.

Conclusions

1. For lining the gas-tight shields of boilers being produced by the TKZ and the BKZ, a layer thickness of a lining made of block-inlaid form of thermal insulation products (except for those made of sovelite) equal to 160 mm is sufficient to guarantee a normative level of heat losses.

The principal factor determining the level of heat losses under stable, equal conditions is the hermetic quality of the lining layers.

2. A combination-type lining made of block-inlaid products, mineral-wool mats, and sprayed materials in various combinations successfully combines the stable thermo-physical properties of rigid-form products with the properties of mineral-wool items and a sprayed layer. This makes it possible to form a seamless, elastic component.

The efficiency of using this type of component on BKZ boilers can be increased if the BKZ, like the TKZ, permits lining operations to be carried out in assembly (prefabrication) areas.

3. The thermo-physical properties of sprayed insulation made of Grade-V asbestos fully meet the requirements for heat insulation materials for the high-temperature surfaces of electric-power engineering equipment.

4. Linings made of fibrous materials (mineral-wool, basalt, kaolin, and others) are the most effective of all those being made at the present time. The use of basalt and kaolin fibers for linings permits us to reduce the thickness of the lining components, the outlay of materials, and the weight of a boiler unit.

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ELECTRIC POWER

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NEW GROUPING SOLUTIONS FOR THE TPP-312A BOILER

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 10, Oct 80 pp 33-37

/Article by Engineer A. G. Isarev and Candidate of Technical Sciences A. G. Kravets: "New Grouping Solutions for the TPP-312A Boiler"/

/Text/ At the Zuyevskaya GRES-2, which is under construction in the Donbass according to a plan of the Khar'kov Division of Teploelektroproyekt, provisions have been made to install eight power units having a capacity of 300 MW (megawatts) each with TPP-312A boilers produced by the Krasnyy kotel'shchik (Red Boilermaker) PO (Production Association). These boilers have been designed to operate on GSSh coal dust; their steam capacity (boiler rating) is 1,000 tons per hour each.

Such boilers were also installed at the Ladyzhinskaya, Zaporozhskaya, and Uglegorskaya GRES's. Their auxiliary equipment is the same, but their grouping solutions vary slightly. This is connected with the fact that the boiler groupings at the Zaporozhskaya and Uglegorskaya GRES's were optimized on the basis of an analysis of the plan solutions for the main power unit of the Ladyzhinskaya GRES and a study of the experience gained in constructing it.

Proposals for optimizing the boiler groupings were implemented to the maximum degree on the first stage of the Zaporozhskaya GRES; this permitted us to curtail metal outlays for manufacturing dust-gas-air conduits (flues) and their supporting structures, to simplify the scheme of dust-gas-air conduits and, at the same time, to increase their reliability, to introduce a highly efficient mechanization scheme, and, thanks to this, to reduce installation time periods and labor outlays.

The experience gained in building and operating the TPP-312A boilers at the Zaporozhskaya GRES confirmed the advantages of the improved grouping, and the latter was utilized by the general planner and the plant manufacturer for the boilers of the Zuyevskaya GRES-2 with minor changes. Thus, because of the soil characteristics at the GRES site, the general planner adopted a basement-less grouping for the equipment of the powerhouse (machine room), and this led to a raising of the operational grade level of the turbine unit (to 12.6 m, instead of the 9.6 m used at the other three electric power stations mentioned above). In order to create a common operational level, as well as to eliminate the differences between the levels of the condensation floor of the powerhouse and the ash floor of the boiler section, the boilers were installed on reinforced-concrete subcolumns at a height of 3 meters. The profile of the site also caused a difference of 1.2 m between the grade levels of the boiler ash floor and the open area of the regenerative air heaters (RVP) and the electrostatic precipitators.

These changes in the boiler grouping were reflected only in the vertical dimensions of the individual circuits of the dust-gas-air conduits; but the arrangement of the auxiliary equipment and the layout of the dust-gas-air conduits at the Zuyevskaya and Zaporozhskaya GRES's are the same.

The boiler section of the main building of the Zuyevskaya GRES-2 has floor-plan dimensions of 45X48 m, and its height to the lower girder zone amounts to 61.07 m.

Hot air is fed to the burners (the front and back walls of the furnace have four burners each) through a double tier of air conduits, two of which are situated below the operational grade level, while the other two are located above it. Also extended under this level are the primary air conduits, gas conduits for admixing inert gasses to the dust system and a suction circuit from the slag shafts. The smoke suction tubes for recirculating the smoke gasses of the GD-20-500U are located along both sides of the convection shaft, while the TsN-15 cyclones (separators) are placed behind it at the 35.0-m grade level.

The RVP-98 regenerative air heaters were installed on reinforced-concrete footings (the upper footing grade level is 13.75 m), the VDN-32B draft fans were installed perpendicular to the wall on the G row of the main building, and the CO-110 heating elements were placed under the RVP.

The hot air conduits from the RVP are introduced into the boiler section at grade levels 8.6; 22.1 (air conduits for the secondary air) and 8.0 m (for the primary air); a baffle was placed between the RVP. The gas conduits from the bunkers of the convective shaft (in the form of two inclined boxes) upon coming out of the boiler unit are joined at first in order to insure the intermixing of gasses, and then they are branched into the air heaters. In the area where the RVP are located the gas-air conduits are fastened to metallic structural components.

In order to repair the RVP, the draft fans, and the gas-air conduits, a semi-gantry crane has been provided, which travels along tracks extended on the columns of the main building and the supporting structural elements of the RVP.

The grouping solutions for the TPP-312A boilers of the Zuyevskaya GRES-2, as developed by the Kharkov Division of the Teploelektroproyekt Institute and the Red Boilermaker PO (Fig. 1), were thoroughly analyzed by the Kharkov Branch of the Energomontazhproyekt Institute prior to executing the working drawings

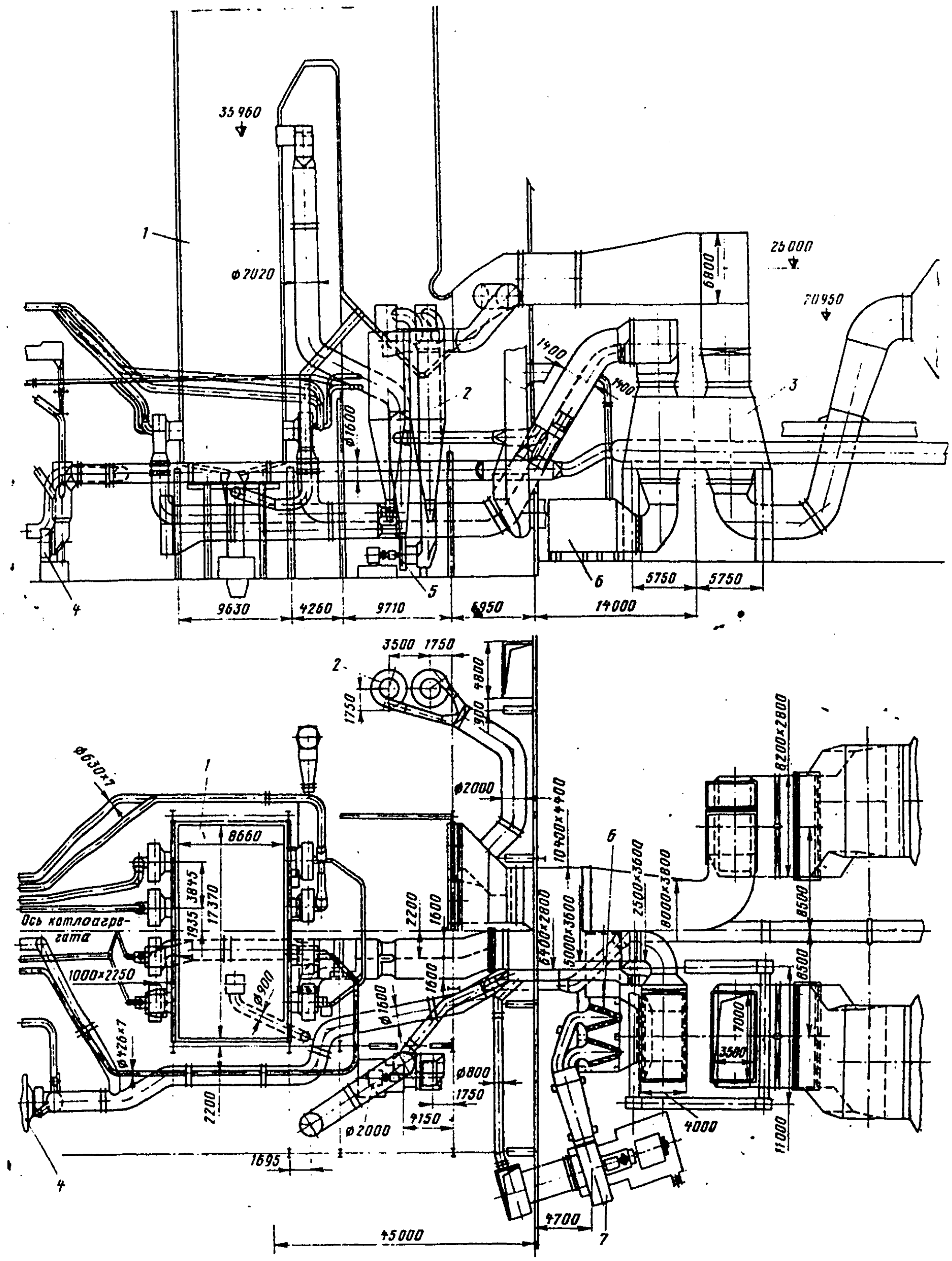
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Figure 1. Initial Boiler Grouping

Key:
1. TPP-312A boiler
2. Cyclone (separator) ash-collector of recirculating smoke-gas circuit
3. Regenerative air heater
4. Coal-pulverizing mill
5. Flue-gas pump for recirculating smoke gases
6. Electrical engineering heating element
7. VDN-32B draft fan

of the dust-gas-air conduits. As a result of this analysis additional possibilities were sought to perfect boiler grouping, insuring a reduction of capital and labor expenditures in building a GRES, improving the conditions of boiler operations, increasing their installation technology and ease of repairs, as well as reducing the expenditure of electric power for the station's own requirements. Technical solutions for optimizing boiler groupings were worked out by a group of specialists at the Kharkov Branch of the Energomontazhproyekt Institute and the Zuyevskaya GRES-2. After review by the Donbassenergo PEO (Planning and Economic Section), Soyuztekhenergo PO, the Red Boilermaker PO, Glavteploenergomontazh, the Teploelektroproyekt Institute, the Glavenergoremont TsKB (Central Design Bureau), and the Soyuzenergozashchita VO (All-Union Association), they were approved by the USSR Ministry of Power and Electrification. Based on these solutions, the Kharkov Branch of Energomontazhproyekt, in conjunction with the Red Boilermaker PO, developed a new boiler grouping (Fig. 2) and adjusted the engineering specifications for the auxiliary equipment, while the Kharkov Division of the Teploelektroproyekt Institute introduced the necessary changes in the plan for the GRES.

One of the unsatisfactory solutions in the initial grouping was the placement of the electrical engineering heating elements directly under the RVP nozzles, which did not allow mechanized equipment to be used in repairing and replacing the heating elements and shut-off valves, which were located in the flow zone of aggressive washing waters.

In the new grouping these heating elements have been brought out from under the RVP footings and placed to the side of the boiler section, which eliminates the possibility of the washing waters falling on the heating units and the shut-off valves. Thanks to the placement of the heating elements in the operating zone of the semi-gantry crane, installation and repair work has been simplified, and supplementary hoisting apparatus is not required. The baffle between the groups of heating elements insures the possibility that both air heaters may operate when one of the fans is shut off. The draft fans are installed not parallel to the axis of the boiler, as they were in the initial grouping, but at an angle to it; this is caused by the structure and the reciprocal placement of the boiler footings, the RVP and fans, as well as by the need to insure an even supply of air and an increase in the relative length of the defuser behind the fan for lowering the circuit's resistance. Also reduced is the aerodynamic resistance of the cold-air

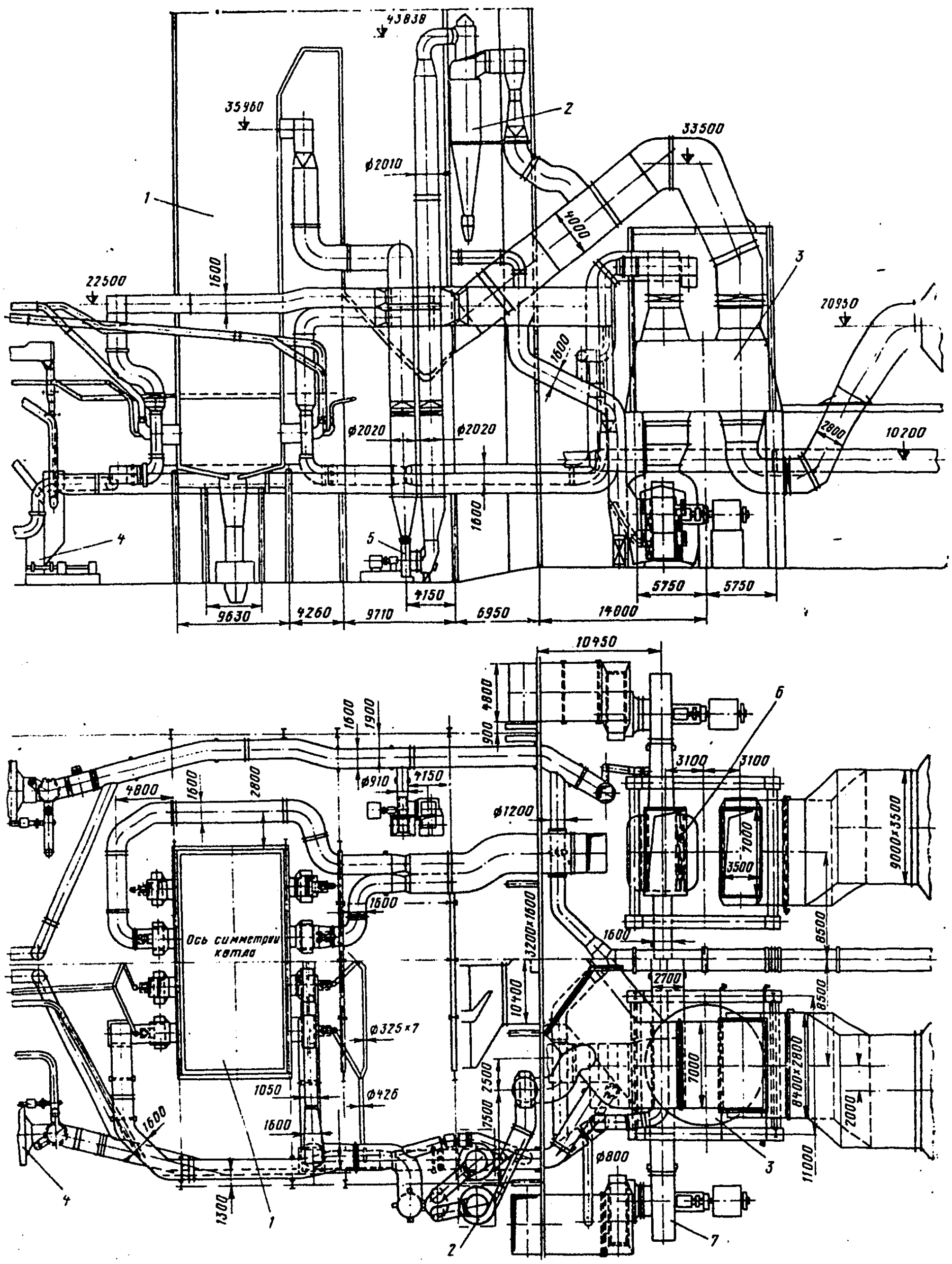
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Figure 2. New Boiler Grouping
(with positions the same as in Figure 1)

suction section of the air conduit by means of installing a pocket chamber in the boiler unit and eliminating two bends in the section of the air conduit before it reaches the fan.

Removing the heating units from under the air heaters permitted a reduction in the height of the RVP footings by 5.8 m and, because of this, a reduction of the outlays required to build them. It also allowed us to substantially improve the gas-air-conduit circuits outside of the boiler section and to simplify the design of the supporting structural components. The gas-conduit loop passes from the bunkers from the boiler's convective shaft to the RVP in the common chamber (box) on a horizontal plane, and it branches out only alongside of the entrance nozzles of the RVP. In comparison with the initial grouping, this solution has the following advantages: a better intermixing of the gases in the common chamber is assured; design of the gas-conduit supporting structural components is simplified; there is an improvement in the conditions for installation and repairs; there is a possibility for lowering the height of the semi-gantry crane for servicing the RVP and the draft fans; there is also an improvement in the external appearance of the electric power station's main building.

In the new grouping the cross-section of the gas conduit is reduced, and this decreases the expenditure of metal and thermal insulation materials. It also assures the gas velocities necessary to avoid falling ash when the boiler is operating under low operating loads. Moreover, the circuit's aerodynamic resistance is not increased.

The hot-air conduits from both RVP are joined (as a result of which there is no further need to install a baffle between the RVP) and are led into the boiler unit in the form of a common inclined chamber (Fig. 3). This chamber is divided by internal partitions into eight channels in accordance with the dust-gas-air conduit scheme.

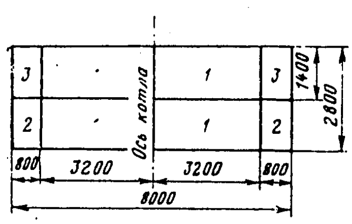

Figure 3. Common Hot-Air Chamber

Key:

1. Channel of secondary air to the burners (with Venturi tubes)
2. Channel of primary air to the dust system (with Venturi tubes)
3. Channel for recirculating hot air into the suction shaft and admixtures into compacting the smoke-gas recirculation circuit

In the area of the boiler the air conduits are at first fed to the burners along the axis of the power unit in two branches (each of which is divided by internal partitions into four channels with a cross-section of 1.4X1.6 m with Venturi tubes), and then, after the air has been fed back to the rear burners,--by two chambers with dividing partitions to the front burners.

Under the boiler air conduits are placed in a horizontal plane; they are suspended from the metal structural components of the convective shaft frame and the furnace door, and they do not interfere with the haulage of the slag-shaft transporters, nor with access to the hatches for removing slag from the tap holes. Air is fed to all the burners from below, and for this reason the chamber's four burners, which were previously aimed upwards, have been turned around.

The use of a single-eared circuit of chambers for feeding hot air to the burners, along with reducing the expenditure of metal and thermal insulation materials, insures a reduction of the circuit's aerodynamic resistance, improvement in the conditions of carrying out repair operations thanks to a freeing up of the zones around the boiler, a reduction of heat releases above the operating level, and a simplification of the supporting structural components. The positioning of the shut-off and regulating valves on the same level as the burners allows their servicing to be facilitated. The length of the primary air conduits has also been reduced, and their configuration has been improved.

In addition to improving the gas-air conduit circuit, the new grouping provides for a reduction in the number and type size of their valves alongside the RVP. Only valves with a cross-section of 2.8X4 m are used in the feed and exhaust gas-air conduits.

The boiler's dust system was not subjected to any substantial changes. In optimizing the grouping a provision was made only to increase the cross-section of the air conduit feeding hot air to the mill fan and laying through a new loop of dust conduits to the rear burners. The first of these changes (it was introduced at the request of the Donbassenergo PEO /Planning and Economic Section/, based on experience in operating boilers at the Uglegorskaya GRES) was brought about by the fact that because of the air conduit's insufficient cross-section, a portion of the air necessary for transporting the dust when the mill was not in operation had to be forced through it, and this increases the danger of igniting the dust in the drum and excludes the possibility of carrying out repair operations.

Changing the air-conduit circuit feeding hot air to the burners allowed us to position the dust conduits near the main back burners and the jet burners ranged directly along the side walls of the furnace. In comparison with the initial grouping, this solution has the following advantages:

the length of the dust conduits is reduced (by 13--15 m), and, inasmuch as this section determines the fan pressure necessary to transport the dust, there is a reduction in the expenditure of electric power for the station's own needs;

repair operations are simplified both for the dust conduits and for the boiler unit as a whole;

there is a decrease in the outlay of metal for manufacturing the dust conduits and their supporting structural components.

The smoke-gas recirculation loop has undergone substantial changes. The new air-conduit circuit for hot air has allowed the shifting of the cyclones down below and a considerable lessening of the recirculation loop's aerodynamic resistance thanks to a reduction in the number of bends and in the extent of the gas conduits. The sorting of the gases is accomplished directly from the bunkers (previously they had been sorted from the gas conduit outside of the boiler unit), which, in addition to improving the recirculation loop's aerodynamics, also guarantees that the boiler unit's wall guard structures will have a simplified design. However, in connection with the fact that the general planner in the adjusted working drawings has not fully realized the advantages of the new grouping, the cyclones have been installed not at the service grade level, but at a point 6 m higher. Besides the basic dust-gas-air conduits listed above, auxiliary loops have also been improved.

The basic data testifying to the advantages of the new boiler grouping of the Zuyevskaya GRES-2, as compared to the initial grouping, are cited in the table shown below.

Equipment	Weight, in tons	Aerodynamic Resistance of Loop, in MPa	Reduction of Design Drive Capacity, in kW
Air conduits	305/228	0.0038/0.0036	71
Gas conduits from the boiler to the electrostatic precipitators	262/218	0.0018/0.0017	32
Recirculating smoke-gas conduits	104/78	0.0035/0.0029	112
Dust conduits to burners	115/90	0.0038/0.0029	105
Exhaust loop from the tap holes	14/8	---	---
Metal structures in the RVP area	215/133	---	---

Table (Continued)

Totals . . .	1015/755	---	---

Note: The numerator shows the indicators of the initial grouping, while the denominator shows the indicators of the new grouping.

According to the data of organizations which have conducted thermal-installation and thermal-insulation operations during the construction of these same kinds of electric-power units at the Uglegorskaya and Zaporozhskaya GRES's and who will carry them out at the Zuyevskaya GRES-2, the reduction in the work volumes and the increase in the grouping's technology will allow them to lower labor outlays for the installation of each boiler by almost 2,500 man-days, to curtail the installation time periods and raise the safety level of operations.

We should also anticipate a substantial reduction in labor outlays and in the time periods needed to carry out repair work with regard to both the dust-gas-air conduits and the boiler unit as a whole, improvement in access to the places where the operations are carried out, and a reduction in the clogging of the boiler section and the RVP zone with dust-gas-air conduits.

Optimization of the boiler grouping will allow us to improve the conditions of its use. Thanks to the change in the dust-gas-air conduit circuit and the dimensions of the safety-enclosure surfaces, heat releases will be reduced in the boiler section, especially at the operational level, and working conditions for the operating personnel will be improved. Furthermore, as a result of the reduction of the insulated surfaces of the boiler's dust-gas-air conduits the amount of thermal insulation operations will be curtailed by 410 cu. m. For each operating power unit the yearly savings in electric power for the station's own needs will comprise about two million kW-hrs.

It should be noted that in developing the new grouping for the boilers of the Zuyevskaya GRES-2 it was impossible to fully utilize all the possibilities for its optimization, inasmuch as the general planner had already completed the basic amount of the plan documents, and the individual structural components were still in the manufacturing stage. However, even under these conditions successful technical solutions were found which conditioned the efficiency of introducing the new boiler grouping.

Improving the grouping of the TPP-312A boiler once again confirms the feasibility and efficiency of the joint work of the planning, operational, and specialized organizations, along with the plants manufacturing the equipment, taking part in the planning and the building of an electric power station. Such a method of operation ought to become mandatory at the present time, when questions of reducing the time periods required for construction, insuring savings in capital and labor expenditures, deficit materials, and electric power, as well as improving the conditions of utilizing electrical engineering facilities, are particularly urgent.

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CUTTING LABOR COSTS IN OVERHEAD ELECTRIC-POWER TRANSMISSION LINE CONSTRUCTION

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/Article by Engineers Yu. V. Bushuyev, V. A. Druzhkov, G. N. Elenbogen: "Several Ways to Cut Labor Expenditures in Constructing Overhead 1150-kV Electric-Power Transmission Lines"/

/Text/ The need to transmit the large capacities of the Ekibastuz and Kansk-Achinsk energy complexes and the Surgutskaya GRES to the country's industrial regions has required the creation of electric-power transmission lines with new voltage classes, in particular, 1150-kV overhead lines.

During the 11th Five-Year-Plan the volume of construction and installation operations in building the 1150-kV overhead lines should comprise 15%, earthmoving operations 10%, installation of precast reinforced concrete 15%, steel structural components 20%, conductors (wires) and cables 20% of the yearly amounts of the respective types of operations in building 35-kV overhead lines and higher.

In order to carry out this program within the established time periods, an approach is necessary which is new in principle, based on a progressive organization of production, rationalization of planning and technical solutions, as well as a widespread use of the achievements of Soviet and foreign science and technology. Such a complex problem must be solved by the joint efforts of organizations and enterprises taking part in building the 1150-kV overhead lines. Moreover, it is necessary to insure coordination and the centralized administration of the entire complex of operations with regard to creating such unique facilities of Soviet electric-power engineering.

In connection with this, the Orgenergostroy Institute has developed a comprehensive technological targetted program entitled "Organizing the Construction of 1150-kV Electric-Power Transmission Lines," in the implementation of which the following are taking part: the Kuybyshev (the leading developer), Leningrad and Novosibirsk branches of the institute, Glavvostokelektroset'stroy, enterprises of Glavenergostroymekhanizatsiya, The Soyuzelektroset'izolyatsiya VPO (All-Union Production Association), the Energostroytrud Center, the VNIIPANKh GA [expansion unknown], the SibNIIE (Siberian Scientific Research Institute for Electrical Engineering) and others.

Positive experience has also been accumulated in cooperation with the general planner of the first 1150-kV electric-power transmission lines--the Long-Distance Transmission Division of the Energoset'proyekt Institute. In particular, taking into consideration the technical schemes which have been worked out for the footings and poles, a check-up has been carried out on the latter for the additional stresses which arise during the installation of poles, conductor and cable; an engineering plan has been worked out for the Ekibastuz--Kokchetav 1150-kV electric-power transmission line and others.

Analysis of the technology of the plan solutions. /in boldface/ The principal difference between the projected structural components for the first 1150-kV overhead lines and the analogous structural components of 500-kV and 750-kV overhead lines is the considerable increase in weight and size.

As footings for the poles of the 1150-kV overhead lines the following precast reinforced-concrete elements have been proposed: sub-footings and anchor slabs, analogous to the mass-produced, standardized structural components of overhead-line footings. However, the dimensions which have been adopted for the sub-footings have led to a situation whereby the amount of earth handled by the excavators has sharply increased. Thus, the volume of the pit under the footing of an anchor-corner hole in certain soil categories amounts to 7000 cu. m. The weight of individual footing elements exceeds the hoisting capacity of the cranes now existing in the electric-network organizations.

The anchor-corner poles of the 1150-kV overhead lines are analogous to the triple-support free-standing poles of the 500-kV and 750-kV overhead lines. However, increasing the base of the pole supports, particularly in conjunction with block-supports 5 and 7 meters in height, has complicated their assembly. There has been a considerable increase in the volumes of operations with regard to assembling pole units at heights of more than 10 m.

Intermediate poles of 1150-kV overhead lines on braces resting on a single point. /in boldface/ Two types of such poles have been developed: POT (Triangular Intermediate Pole) and POG (Horizontal Intermediate Pole)(Fig. 1), which differ in the arrangement of the conductors (for the POT--triangular, and for the POG--horizontal).

Increasing the sizes and weight of the intermediate poles, taking into consideration their geometrical shape, has brought about a raising in the center of gravity to a height of as much as 31 m (Table 1).

The designs of all the 1150-kV overhead-line poles are of the bolt type, made of low-alloy steel and St3-type steel, zinc-plated.

Comparative indicators for the 1150-kV overhead-line poles and analogous structural elements of the 500-kV and 750-kV overhead lines are cited in Table 2.

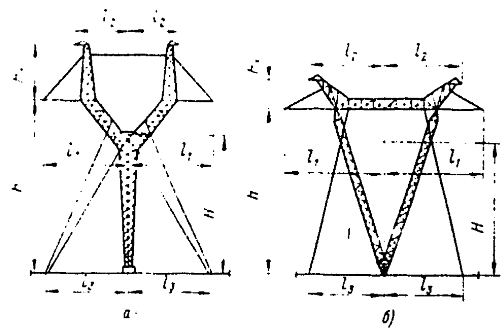

Figure 1. Intermediate 1150-kV Overhead-Line Poles
(a) POT type (b) POG type

Table 1

Type of pole	Dimensions of Pole (Fig. 1), in mm					Weight of Pole, in t	Position of Center of Gravity H, m
	h	l_1	h_1	l_2	l_3		
POT--	40,000	20,200	13,000	12,250	21,000	18.3	30.8
POT 1-1	40,000	20,200	13,000	12,250	27,200	11.9	31
POT-15	40,000	24,200	6,000	17,500	19,500	19.9	30.2
POG-20	37,000	23,000	6,000	17,500	17,500	17.8	28.1
POG 1150 -1	40,000	24,200	6,000	17,500	19,500	21.2	30.8

Table 2

Voltage, in kV	Type of Pole	Weight of Pole, in t	No. of Bolts per pole	Estimated labor consumption per installed km of line, in %
500	PB-1 U2+5	6.6 21.4	1480 3070	100

Table 2 (Continued)

750	Nabla US750-1+5	12 42.1	2100 4100	140
1150	POG-15 U1150+5	19.9 51	3200 4900	260

The design of the Ekibastuz--Kokchetav phase of the 1150-kV overhead line has been accepted as a bundle of eight AS (Automatic Synchronization) 330/43 conductors; two AS 70/72 conductors each are used as lightning-protective cables. Thus, each pole has 28 conductors and cables suspended from it. The tension strands are quadruple-circuit, supporting--single-circuit and V-shaped--from PS-300 and PS-400 insulators. The length of an intermediate-pole strand is 11 m.

With the existing technology for building 35--750-kV overhead lines, 48.5 percent of all types of operations /1/ are carried out manually, while 51.5 percent are accomplished by mechanical means. With regard to each type of operation, the proportion of outlays for manual labor is characterized by the following indicators: assembly of steel poles 73.1 percent, installation of conductors and cables 67.3 percent, construction of footings under steel poles 42.1 percent, and setting up steel poles 24.3 percent. Herein only at the two most labor-consuming types of operations (the assembly of steel poles and the installation of conductors and cables) does the amount of manual operations comprise 60 percent of the total outlays of manual labor.

Analysis of the design solutions adopted at the present time for 1150-kV overhead lines, taking the traditional technology into consideration, indicates that the level of manual labor in building these electric-power transmission lines will be higher than the indicators cited for the 35--750-kV overhead lines by an average of 15 percent. The distribution of labor outlays by types of operations for 500-, 750- and 1150-kV overhead lines are cited in Table 3 (actual labor outlays are given for the 500- and 750-kV overhead lines, while estimated labor outlays are given for the 1150-kV overhead lines).

In comparison with the 500-kV overhead lines, the estimated labor outlays per km of the 1150-kV overhead lines show an increase in earthmoving operations by a factor of 1.6; installing footings--1.6, assembling poles--2.6; setting up poles--1.9; installing conductors and cables--2.8; loading and unloading and other operations--1.8. Total labor outlays show an increase by a factor of 2.2.

The solution to the problem of reducing labor outlays, and particularly those of manual labor, in building 1150-kV overhead lines lies in rationalizing traditional technology as well as in working out designs which are new in principle, along with mechanized means and technical processes.

Table 3

Voltage of O.H. Line, in kV	Distribution of Labor Outlays by Types of Operations, in %					
	Earthmoving	Installing Footings	Assembling Poles	Setting Up Poles	Installing Conductors and Cables	Loading, Unloading, etc.
500	11.8	7.6	23.6	12.2	21.1	23.7
750	8.8	6	30.1	10.8	21.8	22.5
1150	8.5	5.5	32	10.2	25.5	18.3

Based on the results of an analysis of the projected structural components of the 1150-kV overhead lines, as well as of the construction technology now existing in the electric network along with the status of the means of mechanization and transportation, the Orgenergostroy Institute has outlined the following basic principles for planning the organization of construction production:

increasing the technology of the structural components;

building facilities by means of technical flow lines, based on the specialization of the production units of trusts (sections, mechanized columns), for the basic types of construction and installation operations;

comprehensive mechanization of operations, based on the use of efficient means of mechanization and transportation;

transferring labor-consuming processes and those which depend on weather and climatic conditions to stationary, highly mechanized areas, assembly and preparatory sections;

mastering technological processes which are new in principle.

Organization of construction. /in boldface/ Building 1150-kV overhead lines is characterized by the following traits: considerable volumes of operations, great length of the lines (routes), a minimum amount of type sizes of the structural components to be used, and a limited number of plant-suppliers. These characteristics predetermine the necessity and feasibility of organizing construction by the flow (assembly-line) method.

In the authors' opinion, in working out an organizational structure for assembly-line-type construction, it is necessary to guarantee a functional division of the production units. Moreover, top priority must be given to solving the problem of filling out complete production-technology sets for the construction of 1150-kV overhead lines. With this goal in mind, the construction and installation trust must include the creation of an Administration for Equipment Outfitting (UPTK), which will insure that orders are received on time to obtain the material and technical resources for technically complete sets; the organization of a base warehouse system; the preliminary preparation of structural components (enlarged assembly of steel intermediate pole sections, making stays, braces, and rigging, enlarged assembly of insulator strands, sorting drums with conductors and lightning-protective cables, carrying out the cutting of U-shaped bolts, waterproofing footings); as well as conducting loading and unloading and transport operations.

The efficiency of assembly-line-type construction is determined by the level of technical specialization, consolidation and functional duration of the assembly lines. Three variants are possible in organizing assembly lines (flow lines): I--specialized brigades (within a construction supervisor's section); II--specialized sections (within a mechanized column); III--specialized mechanized columns (within a construction-and-installation trust). A comparison of these variants shows that the efficiency of assembly lines increases as they become consolidated. Thus, the reduction in the number of workers when utilizing variant III amounts to 7 percent in comparison with variant II and 11 percent in comparison with variant I.

The Institute has worked out a structural scheme for organizing assembly-line construction of 1150-kV overhead lines for a construction-and-installation trust with an annual volume of SMR (construction and installation operations) of about 40 million rubles (Fig. 2).

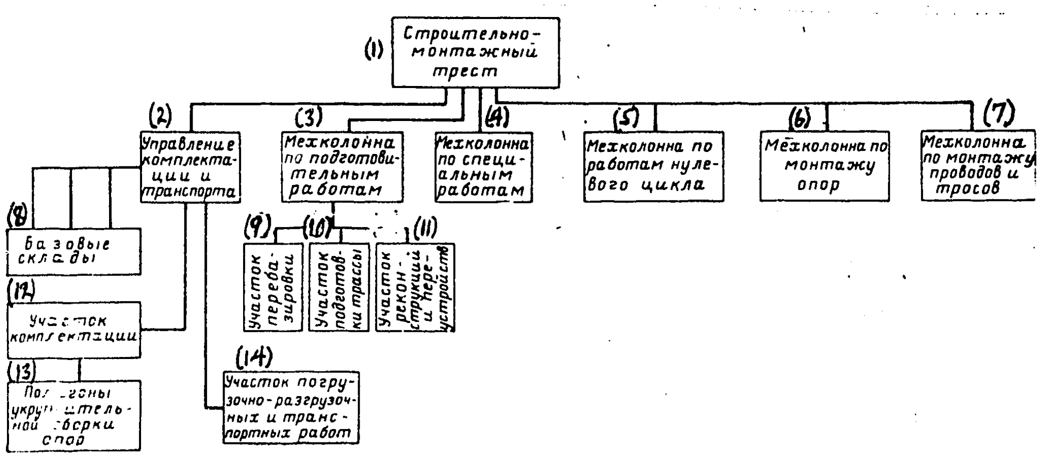

Figure 2. Structural Scheme for Organizing Assembly-Line Construction of 1150-kV Overhead Lines

Key:

1. Construction-and-installation trust
2. Administration for filling out sets and transportation
3. Mechanized column for preparatory operations
4. Mechanized column for special operations
5. Mechanized column for zero-cycle operations
6. Mechanized column for installing poles
7. Mechanized column for installing conductors and cables
8. Base warehouses
9. Section for shifting base
10. Section for preparing route (right-of-way)
11. Section for reconstruction and rearrangement
12. Section for filling out sets
13. Construction areas for consolidated assembly of poles
14. Section for loading and unloading and transport operations

Introduction of the scheme presented here will allow the following: to free up the basic production units from carrying out auxiliary, transportation, and other subordinate operations;

to carry out consolidated assembly of poles, waterproofing of footings, consolidated assembly of insulator strands, cutting U-shaped and anchor bolts, repairing structural components, etc. not on the route but under the stationary conditions of a specialized construction yard, section, or area; insuring centralized repair and technical servicing of the machinery; to put an efficient dispatching communications system into good order; to guarantee an increase in labor productivity and rapid rates of construction; to raise the coefficient of utilizing machinery and to insure the comprehensive mechanization of the principal types of construction and installation operations.

Cyclograms have been worked out for the construction of 1150-kV overhead lines, as well as traffic schedules for the specialized mechanized columns within the construction-and-installation trust (Fig. 3).

In working out the cyclogram, the following factors were taken into consideration: the optimum composition of the brigades, selected on the basis of the technical schemes of operations; the monthly output of the brigades, determined on the basis of the physical labor productivity with regard to the individual types of operations; the number of brigades insuring an even and precise rhythm of assembly-line construction; technical placements by types of operations; distribution of capital investments by years, proceeding from the conditions of the maximum (even) load of the specialized mechanized columns for the construction period.

Cyclograms and schedules have been made for an amount of operations in building 1150-kV overhead lines for a length of 500 km. Moreover, the

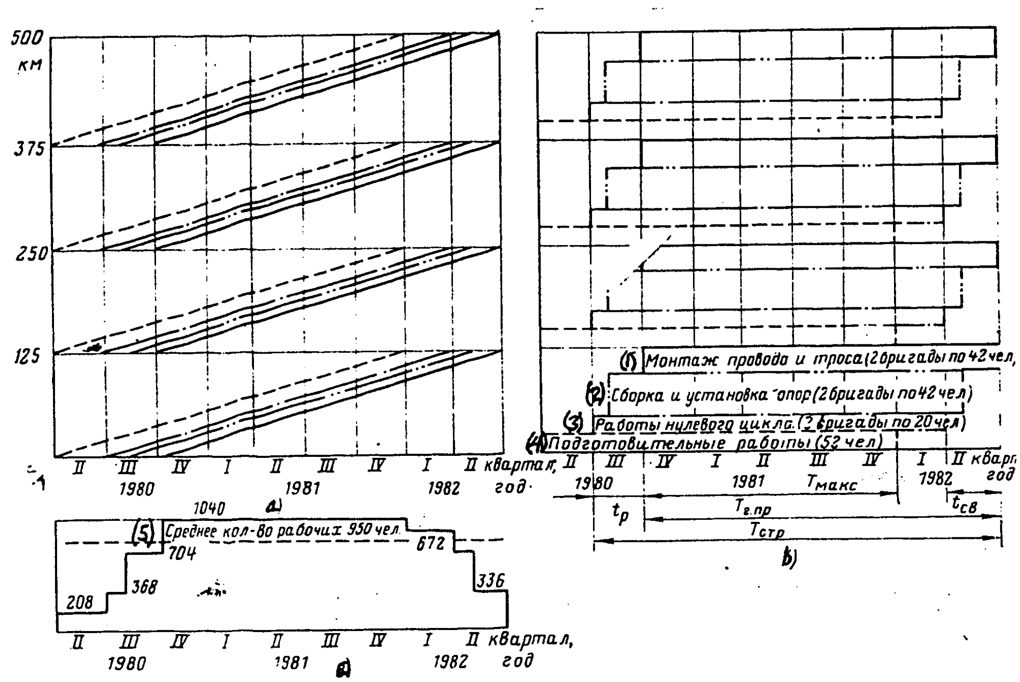

Figure 3. Cyclogram of the Construction (a) and Traffic Schedule of Specialized Mechanized Columns (b) and Manpower (c) Used on 1150-kV Overhead Lines

Key:

1. Installation of conductor and cables (2 brigades of 42 men each)
2. Assembly and set-up of poles (2 brigades of 42 men each)
3. Zero-cycle operations (2 brigades of 20 men each)
4. Preparatory operations (52 men)
5. Average number of workers (950 men)

_ _ _ _ _ _ Preparatory operations; _ _ . _ _ Zero-cycle operations

_ _ . . _ _ Assembly and set-up of poles; _ _ _ Installation of conductors and cables;

t_p Time for developing specialized assembly lines; $t_{cв}$ Time for curtailing specialized assembly lines;

$t_{макс}$ Time of maximum operational stress; $t_{г.пр}$ Time of producing finished work

$t_{стр}$ Length of time required for construction capital investments are distributed in the following manner: during the first year of construction, 11.4 million rubles; during the second year, 31.9 million rubles, and for the third year (first two quarters), 12.7 million rubles. The length encompassed by an overhead section with the volume of work appropriate for the year's program of a specialized mechanized column is accepted as equal to 125 km.

Calculations have shown that in using specialized mechanized columns to build overhead lines productivity in the individual types of operations increases by 16--20 percent. Moreover, the necessary reduction is achieved in the number of workers as well as the number of machines (Table 4).

Table 4

Indicator	Traditional Organizational Structure	Assembly-Line Method of Operational Organization	Savings
Labor outlays, in thou. man-days	663.7	557.9	105.8
Average number of workers	1171	950	221
Number of construction machines	244	211	33

Proposals for raising the technical level of structural components and for improving the technology of 1150-kV overhead-line construction. /in boldface/ The use of technical structural components which meet the requirements of the optimal processes for their manufacture, transportation schemes and installation methods comprises one of the ways to reduce labor outlays. As was noted, the utilization of the accepted components for the 1150-kV overhead lines does not solve the problem of reducing labor outlays, and especially those of manual labor. It should also be noted that these structural components do not satisfy the requirements for saving outlays on building materials nor for those on transportation expenditures. The deficiencies noted pertain primarily to precast reinforced concrete footings.

In the authors' opinion, subsequent plans for the footings of 1150-kV overhead-line poles to be installed in rocky soils should make use of the special embedments in the form a cluster of thin cement anchor-piles which have been developed by the Energoset'proyekt Institute. Such footings can be made by a mechanical method, utilizing mortar-mixing units with forced feeding of the mortar(grouting) into the holes. When an overhead line passes over relatively weak and water-saturated soils, we should examine the possibility of installing footings made of reinforced-concrete piles.

In soils with improved mechanical characteristics it is feasible to install V-shaped footings. The use of V-shaped footings and mechanical methods of operation in installing them allows us to avoid excavating the soil and compacting the backfill on individual sections of the overhead line.

In building 1150-kV overhead lines there are also prospects for utilizing screw-pile footings, particularly in water-saturated soils. Experience in utilizing screw-piles with reinforced-concrete shafts on the individual picket-points of the 750-kV Konakovskaya GRES--Moscow overhead line has shown that their construction requires 80% less reinforced concrete and 4% less steel than in building precast reinforced-concrete sub-footings. Herein the labor outlays are reduced by 75%, while the cost of operations is reduced by 40%. Moreover, the utilization of these footings allows us to practically avoid earthmoving operations, as well as operations with regard to installing pole groundings [2]. In order to introduce screw piles on a widespread basis, it is necessary to develop a special vehicle for sinking them (based on a self-powered machine). Such a vehicle must have a high roadability, a rather low proportionate load on the soil (the presently existing machines, based on the KrAz-type trailer-truck, do not meet the above-mentioned requirements), and at the same time sufficient speed to avoid the necessity of using trailers to haul it.

Abandoning the embedded precast reinforced-concrete footings, which have been accepted for all soil conditions, and the adoption of a differentiated approach to using new structural components will make it possible, in combination with a mechanized technology, to reduce total labor outlays on a zero cycle by an average of 25--30%.

Technical practice has shown that in creating new structural components for the 1150-kV overhead line, it is necessary to take the following conditions into consideration: the technical and economic basis of the structural components for which new mechanized means need to be developed;

the possibility for a consolidated assembly of bolt-type structural components of poles at construction yards or plants;

the maximum and comprehensive utilization of helicopter equipment, primarily where the route passes through difficult conditions (high mountains or swamps);

the use of new and progressive materials, designs and complexes;

the use in the structural components of technical assemblies (permanent hinge joints, rigging-reinforcement assemblies, suspension lines for laminated units, etc).

Carrying out the conditions enumerated above is only possible with joint operations by the planners and engineers, and this should be begun in the early stages of planning a 1150-kV overhead line (for example, at the stage of technical and economic groundwork).

It should be particularly emphasized that such a joint operation must certainly be carried out for planning overhead lines whose routes pass through difficult conditions.

Mechanization of operations. /in boldface/ The Orgenergostroy Institute is devoting particular attention to the problems of raising the level of mechanization of construction and installation operations on 1150-kV overhead lines. The motor pool and supply of machinery now existing in electric-network organizations does not guarantee an increase in the efficiency of carrying out operations to install planned structural components whose weight and dimensions are considerable. Thus, in order to install footings, we must use K-162 and MKP-25 cranes instead of the most widespread TK-53 and T-75 cranes. The task of setting up intermediate poles cannot be efficiently solved without utilizing special cranes with a large hoisting capacity.

Up-to-date methods of installing conductors also require renovation of the machinery products list. This will allow us to introduce the following more progressive methods: laminating conductors under tension and a continuous technical cable, stringing conductors and lightning-protective cables without letting them sag to the ground, combining conductors by using break energy, etc.

The transportation of structural components is a complex task. It should be noted that a specialization of transport means is necessary for hauling reinforced-concrete sub-footings, consolidated sections of intermediate steel poles and drums with conductor and cable. Hauling the remaining items (reinforced-concrete flat structural elements, metal in cases, strands of insulators, and circuit armatures) is furnished by the existing transport means listed in the electric-network trusts (panel trucks with high roadability, logging trucks and other trucks used in building 500--750-kV overhead lines). The solutions adopted by the institute with regard to mechanizing operations for the construction of 1150-kV overhead lines provide both for the widespread utilization of vehicles and machines in regular production by Soviet industry and which are being used in other ministries and departments, and the creation of new special means of mechanization and transportation (for example, the KVL-12A installation crane with a hoisting capacity of 12 t, the TKB-3 crane for assembling bolt-type poles, a set of vehicles for erecting conductors under tension, etc).

The use of these recommended means of mechanization instead of the traditional ones, in conjunction with improved techniques in conducting operations, will allow us to reduce the total labor outlays in building 1150-kV overhead lines by 30%.

Assembly of poles. /in boldface/ In the assembly of steel bolt-type intermediate poles on braces (stays), supplied to the route in individual elements, the principal thrust in reducing labor outlays and the level of manual labor is the widespread utilization of mechanized construction yards along the route for preparatory consolidation of the pole sections.

The Kuybyshev branch of the institute has developed a standard mechanized construction yard for the consolidated assembly of bolt-type steel-pole sections, using electro-telphers with a hoisting capacity of one ton (Fig. 4) or gantry cranes with a hoisting capacity of five tons.

A distinguishing characteristic of this construction yard with an electro-telpher is the possibility of increasing its productivity, since it is composed of single-type technical sections.

When climatic conditions are unfavorable on an overhead-line route, such a construction yard can be enclosed, utilizing steel or reinforced-concrete sections of buildings which can be rapidly erected. In its enclosed variant this construction yard comprises a two-span building made of folding-type sections created by the Energotekhprom enterprise.

The introduction of such an enclosed standard construction yard for the preparatory assembly of poles will allow us to make more rational use of hoisting apparatus, as well as to bring the organization of work sites as close as possible to plant conditions (to reduce the influence of weather conditions, to improve lighting, tool storage, and to utilize additional means of mechanization, as well as to organize work in two or three shifts).

The preparatory consolidation of sections at the construction yard and completing the pole assembly at the stake-point, as compared to assembling the poles from the individual elements at the stake-point, allows us to guarantee a growth of labor productivity in the assembly process by 30%. In overhead-line construction as a whole, taking into consideration the other types of operations, labor productivity increases by 10% while the level of manual labor is reduced from 73% to 40%.

A more significant reduction in labor outlays and the level of manual labor may be attained by organizing the plant manufacture of intermediate steel poles on braces and supplying them in sections. Carrying out such a measure will also allow us to find an easier solution to the problem of the overall supply of structural components to the route and, furthermore, to cut down on the metal losses in building 1150-kV overhead lines.

There are several progressive variants of plant manufacture and supply of steel intermediate poles: welded large sections; large sections, assembled at the plant from welded or bolted flat sections; and flat sections (welded or bolted).

As the results of studies have shown [3], the consolidated assembly of poles on the overhead-line route, made of large sections manufactured at the plant, in comparison with the preparatory consolidation of sections at mechanized

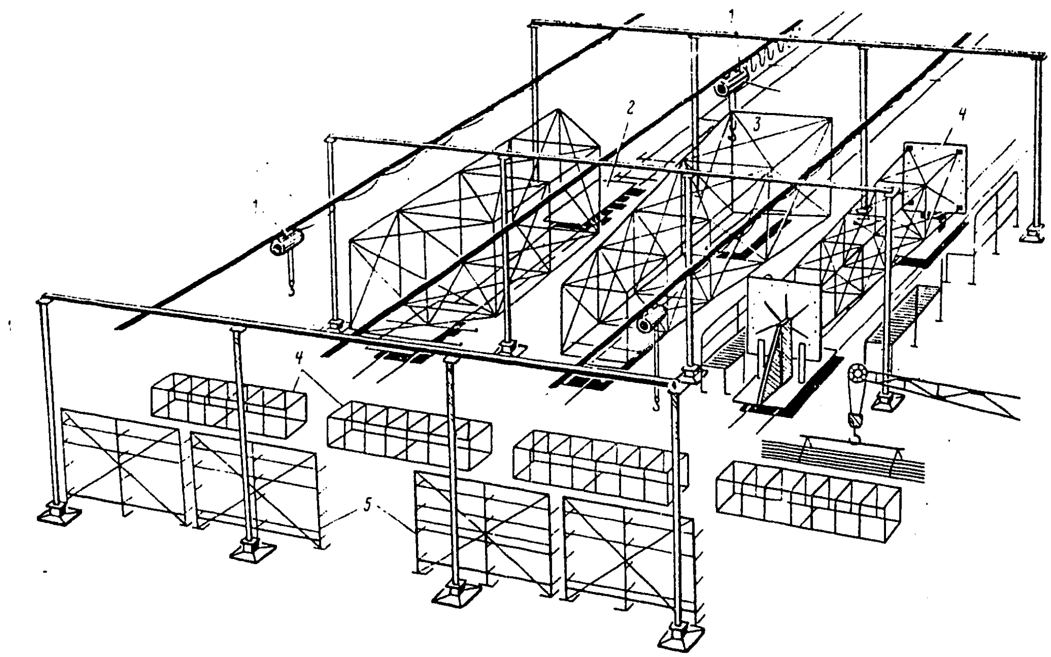

Figure 4. Construction Yard for Consolidated Assembly of Poles for 1150-kV Overhead Lines

Key:

1. Telpher with a hoisting capacity of one ton
2. Conductor (jig)
3. Roller conveyor (table)
4. Tilter
5. Rack (stand)

construction yards and final assembly on the route, allows labor productivity to be increased in the process of pole assembly by 270 percent, and with regard to overhead lines as a whole (taking other types of operations into consideration) by at least 23 percent.

A less efficient measure is to organize the manufacture of the individual flat sections (bolted or welded) at the plants. In this case, according to a preliminary estimate, labor productivity for overhead lines as a whole increases by 15 percent.

The results of computing the savings in labor outlays per km of 500--1150-kV overhead line under normal construction conditions, when the assembly of intermediate pole sections with the braces occurs at a construction yard and when they are manufactured at a plant, are cited in Table 5. When the overhead line passes through a forested or swampy locale, the savings in labor outlays increase to 10 percent and 15 percent respectively.

Table 5

Voltage of Overhead Line, in kV	Estimated Savings in Labor Outlays per km of Overhead Line, in Man-Days		
	Using Mechanized Construction Yard for Assembling Sections from Individual Elements	Manufactured at a Plant: Large Sections	Manufactured at a Plant: Flat Sections
500	20	60	30
750	30	85	45
1150	50	120	60

Depending on the conditions through which the overhead-line route passes, the assembly of the anchor-corners of free-standing poles is carried out in accordance with one of three technical schemes.

In mountainous and swampy regions the pole base stands, support props and supplementary stands are assembled at a consolidated-assembly site (first scheme). Herein the stand sections the geometrical dimensions of whose bases are greater than their height are mounted in a vertical position from the standard work areas. In order to strengthen the zones of the intermediate sections and the support props in the vertical position, standard stamped conductors (jigs) are employed. The area is serviced by TK-53 and T-75 cranes, a lever-type derrick, a compressor with a set of pneumatic nut drills, and a mobile light tower. MI-6 or MI-10K helicopters may be utilized to deliver the pole sections to the picket-stakes and to install them.

Under plain-type conditions, where cranes may be used having greater hoisting capacity (MKP-25, K-255 and MKT-6-45), poles are mounted by the method of augmenting the consolidated sections (second scheme).

The technology of carrying out operations in accordance with the third scheme is traditional. In this case the pole stands are assembled entirely on the ground and are lifted into a vertical position by means of a hinge-joint with the aid of an installation boom or crane with traction from a tractor or a truck.

Setting up poles. /in boldface/ In examining a number of schemes for setting up intermediate poles, including those previously utilized by the electric-network trusts for the 750-kV Konakovskaya GRES--Leningrad Overhead Line and the development of new schemes using a falling installation boom, the conclusion was drawn that the schemes to lift poles by the slewing method is not rational for the POG and POT type poles, even if certain improvements were to be made in them. Utilization of these schemes does not allow a reduction in the labor outlays, and especially not in the outlays of manual labor, since it requires a considerable amount of supplementary operations to be carried out. Furthermore, in this case the process of controlling the pole lifting becomes more complicated, and hence its reliability is decreased.

In order to set up intermediate poles of 1150-kV overhead lines, it is feasible to utilize the method of lifting the poles "in suspension" with the aid of two trailer-type hoists having a hoisting capacity of 12 tons each and a hoisting height of 32 meters, being developed by the Kuybyshev branch of the institute. Such hoists may also be used to set up anchor-corner and free-standing intermediate poles in conjunction with tractor traction.

The Orgenergostroy Institute has also proposed a scheme for hoisting intermediate poles of 1150-kV overhead lines, using two pneumatic-tired cranes with load-hoisting capacities of 40 tons each, and now in serial production by Soviet industry (Fig. 5).

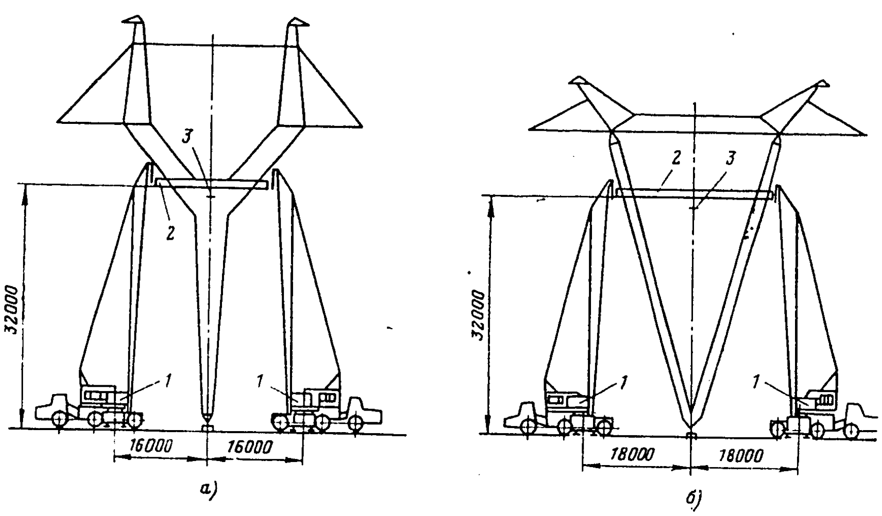

Figure 5. Scheme for Hoisting Intermediate Poles of 1150-kV Overhead Lines POT Type (a) and POT Type (b) with the Aid of Two Pneumatic-Tired Cranes with Hoisting Capacities of 40 Tons Each

Key:
1. Pneumatic-tired crane; 2. Installation crosspiece;
3. Position of center of gravity

Installation of conductors. [in boldface] In building 1150-kV overhead lines the labor outlays for installing 24 conductors, using the traditional technology, are estimated to comprise 25.5 percent of the total labor outlays. Moreover, in comparison with 500-kV overhead lines, the labor outlays for carrying out this type of operation increases by a factor of 2.8. Therefore, the Orgenergostroy Institute has developed new technical solutions for installing conductors.

In order to suspend the conductors, it is proposed to use installation double-roll units, fastened on terminal boats [?]. The clamp assembly which has been developed allows the unit to be easily mounted and dismounted. The advantage of the method under examination is the possibility of carrying out at the same time as the suspension the lamination of the conductors within the terminal clamps of the supporting strand. Moreover, in this case, in order to restring the conductors, they do not have to be lowered to the ground. With the introduction of such a method of installation labor outlays are reduced by 15 percent.

In order to combine conductors, the Kuybyshev branch of the institute, in conjunction with the SibNIIE, has proposed the use of break (explosion) energy . At the present time positive experience has been gained in using this method for the simultaneous combination of eight conductors. Combining conductors by the use of the break-energy method, in comparison with the pressing method allows a considerable reduction in labor outlays and an increase in labor productivity [4].

The Kuybyshev branch has also proposed a method of laminating conductors with the aid of a continuous technical cable. It insures the simultaneous lamination of two-phase conductors, which is particularly efficient for installation under difficult, complex conditions of a route's passage and in transient situations.

The method of installing conductors with a preliminary marking (measuring) off has good future prospects. In order to introduce this method it is necessary to create a number of special attachments and instruments.

In installing conductors by the proposed method the following technical operations are carried out: measuring out conductors in accordance with tables of installation lengths included in the overhead-line plan; measurements of the actual distances in the spans; office processing of the measurements with adjustments made in the planned installation lengths of the conductors in the spans; lamination, combination, and reinforcement of the conductors in the supporting terminal-clamps of the strands or attachment to the tension strands, setting up distance tie beams and hoisting them onto the poles.

Table 6

Proposed Solution	Technical Processes	Required Machinery and Attachments	Reduction of Labor Outlays per 100 km of O.H. Line, in Man-Day %
Footings made of thin cement piles with anchor clamps	Boring a hole, installing the thin cement piles	BTS-2 boring vehicle; trailer mortar-mixing unit; TK-53 crane	278/52 (for anchor-corner poles); 1600/38 (for intermediate poles)
Consolidated assembly of intermediate poles in a construction yard	Assembly of sections on tilter-stands and conductors with the aid of nut drills	Set of non-standardized and telpher equipment; TK-53 crane; mobile power plant	10800/30
Setting up intermediate poles, using two cranes (hoists) "in suspension"	Setting up cranes (hoists), fastening poles to cranes (hoists), hoisting and setting up poles	Two MKT-6-45 cranes (hoists); T-130 tractor with winch (jack)	3300/62
Installing conductors with the aid of two-roll units	Lamination, sighting, restringing conductors without lowering to the ground	Two lamination trucks for 4 conductors; T-130 tractor with winch; two telescoping VRT-34 towers; TK-53 crane	9900/27
Combining conductors, using break energy	Preparation, installation of break joints, installation of break circuit, pressing	Special vehicle for transporting and preparing break joints, two VT-26 towers	735/55

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In comparison with the traditional methods, the proposed technology allows us to eliminate such operations as suspending the conductors in laminated apparatus, sighting and restringing conductors with lowering to the ground, as a result of which labor outlays and manual-labor outlays are reduced by more than 50 percent, while there is also a considerable increase in operational safety.

It should be noted that the introduction of the latter method will facilitate the solution of the problem of installing conductors not only on the 1150-kV overhead linesbut also on 500-kV, 750-kV, and 1500-kV overhead lines.

Utilization of helicopters. /in boldface/ The Orgenergostroy Institute has carried out preliminary work on the technology of building 1150-kV overhead lines with the aid of helicopters. Results of cooperation with the VNIIPANKh GA [expansion unknown] have already made it possible to put into operational plans the conduct of transport and a complex of installation operations with the aid of helicopters.

An analysis of indicators of the estimated reduction of labor outlays for the basic types of operations involved in building the 1150-kV overhead lines, to be carried out using the new technical and design solutions which have been developed and proposed for introduction, as compared with the indicators achieved by using the traditional technology and designs, are cited in Table 6.

As the results of calculations have shown, the introduction of the design and technical solutions proposed by the Orgenergostroy Institute will permit us to cut down labor outlays in building 1150-kV overhead lines by an average of 25 percent.

However, it should be emphasized once more that in order to successfully implement what has been outlined here, it is necessary that all operations connected with the creation of electric transmissions with the new voltage classes be carried out in accordance with a unified and comprehensive targeted program, where the central place must be assigned to the problems of developing new designs and technology. Moreover, the joint development of the designs and technology for building very high voltage transmission lines must begin with the initial stages of planning these lines. And, of course, particular attention must be paid to the development and serial production of special means of mechanization, organization of assembly-line type of construction and precise specialization according to kinds of operations by the subdivisions engaged in building electric-network facilities.

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RESEARCH ON STRUCTURAL COMPONENTS OF AN AES REACTOR SECTION

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 10, Oct 80 pp 53-57

[Article by Candidate of Technical Sciences G. E. Shablinskiy and Engineer A. V. Gordeyev: "Dynamic Studies of Structural Components of an AES Reactor Section"]

[Text] The structural components of an AES (nuclear power station) constitute complex spatial structures which are affected by various types of static and dynamic loads, conditioned by the operation of turbine units, gas blowers, pumps, etc. Another urgent problem is the dynamic interaction between the heat carrier and the heat-protection element, the facing and the individual structural assemblies of the reactor housing (casing).

A substantial influence on the reinforced-concrete housing of a nuclear reactor is exerted by the dynamic loads which come into being during the process of its preliminary pressurization (tensioning). These loads may determine the preliminary tensioning of cable strength and, as a result, the metal consumption and economy of the design.

A necessay condition for evaluating the safety of an AES is also the protection against random (accidental) dynamic loads, for example, those arising as a result of a crash by an airplane or other objects.

The development of theoretical and experimental methods for researching the dynamic problems which must be solved in planning an AES is a necessary condition for successfully carrying out the tasks set by the Party in the field of nuclear power engineering.

Over the course of a number of years work has been done at the MISI (Moscow Structural Engineering Institute imeni V. V. Kuybyshev) on developing experimental and theoretical methods for researching the pressurized (stressed) state of an AES's structural components [1, 2]. The fragment method of calculation is utilized in the theoretical studies. In the equations of the static and geometrical conjugation of the individual fragments the influence of local effects is taken into consideration. The design schematic must correctly reflect the operation of the actual structural component and its behavior characteristics under the assigned loads.

In order to select the design schematics correctly, to verify the results obtained by using them, and, in a number of instances, to make an experimental study of the structural component whose theoretical designs are linked with great difficulties, experimental research is necessary.

In the process of developing research methods for studying the pressurized state of AES structural components, the authors have created new equipment which permits an increase in the precision of the studies being carried out. Examined below are the results of model dynamic tests run on AES structural components, the characteristics of the experimental methodology and of the equipment which was developed.

As is known, at model structure scales of 1 : 50--1 : 200 the operational-frequency range of a vibration stand (platform) necessary to simulate the spectrum of seismic vibrations must consist of approximately 40--500 hertz (cycles per second). The existing electrodynamic-type vibrators meet this requirement. However, in dynamic studies the model being tested must be subjected to the effect of vibrations within assigned amplitudes, frequencies, and directions. Because of the rise of resonance vibrations within the ordinary support systems of vibration stands, it is particularly difficult to fulfill this condition. In order to create a vibration-stand support which would guarantee the required direction of vibrations with the least possible losses for friction and an elastic resistance with the minimum (no more than 10--12 percent) of lateral shifting, the authors conducted special studies and proposed the design of a hydrostatic support for the vibration stand.

The principal difference between the indicated structural component (Fig. 1,a) and the known ones is the presence of a scheme for automatically stabilizing the platform along the coordinate axes. The adopted schematic allows us to execute independent, assigned shifts (displacements) of the platform along each of its axes under minimum resistance with the aid of a system of hydrodynamic suspension, which comprises an operating chamber 1, an inlet valve or jet (nozzle) 3, and an outlet valve or aperture 4 between the support and the platform 2.

The liquid entering into the operating chamber through the jet and flowing out through the aperture is under a set pressure P, which depends on the size of the aperture (the largerthe aperture, the less is the pressure and vice versa). Altering the model in the direction of opening the aperture wider leads to a decrease in its width and an increase in pressure. A stabilizing influence is exerted on the system by the throughput section of the jet being greater and the width of the aperture N being wider. The presurre being transmitted to the model by the liquid which is in the operating chamber is equalized by the external pressure of the air F as a result of a vacuum being created under the model in a special chamber. The combination of pressures P and F prevents the emergence of conditions which would cause a change in the dimensions of the aperture, and this causes a stabilization of the platform's vibrations. Change the section D of the jet allows us to create forced vibrations of the model in the direction of the aperture in accordance with the booster scheme.

Such a design for a hydrostatic support is also used to create vertical vibrations. This is achieved by setting up controllable jets, which regulate the pressure in the chamber and, therefore, the aperture opening N as well. Fig. 1,b shows the schematic of a three-component vibration stand. The vertically occurring vibrations of the vibration-table-plate 2 are created by changing the pressure in chambers 1 with the aid of a controllable jet 3, the size of whose opening is changed by a needle gate (valve) 4, connected with a small-capacity electrodynamic vibrator 5. In this schematic the inertia-less force F is created with the aid of a vacuum chamber located between the vibration table and the base of the stand. The vibration table's horizontal vibrations are provided by an electrodynamic-type heavy-duty vibrator; instead of this, however, use may be made of analogous supports to those described, with controllable jets turned to a 90° angle. The schematic of the vibration stand presented in Fig. 1,b allows us, thanks to the independence of the pressure controls in each chamber, to obtain torsional (relative to the vertical axis) vibrations of the vibration table simultaneously with horizontal and vertical vibrations.

The laboratory of the resistance of materials department of the MISI imeni V. V. Kuybyshev has made a vibration stand with hydrostatic supports in accordance with the working principle described above. This vibration stand has three pressure chambers, situated around the periphery, and one vacuum chamber in the center of the vibration table. The vibration table consists of a circular steel plate 600 mm in diameter and 12 mm thick. The pressure and vacuum chambers are fastened onto a steel disc which is mounted on six, steel, T-section supports, embedded in a massive, reinforced-concrete base. The height of the supports guarantees the possibility of leading pipelines (tubing) to the pressure chambers from the oil pump and to the exhaust chamber (vacuum space) from the vacuum pump. The oil which flows out through the circular apertures of the pressure chamber when the stand is in operation at first flows into the oil collector, and then through a hose into the oil pump's tank. The vibrations of the vibration table are created by the VEDS-200 vibrator by means of a special linking clutch.

The vibration-stand tests indicated a good stabilization of vibrations within the frequency range of 10--400 hertz. Ancillary (lateral, vertical) vibrations in this range (in amplitude) did not exceed 10 percentof the basic horizontal variations. At a frequency of approximately 400 hertz resonance vibrations arose in the steel vibration-table-plate, caused by the first current of its flexural (bending) vibrations. It is obvious that, in case of necessity, this upper limit could be raised substantially further by increasing the plate's rigidity by means of installing rigid fins (edges).

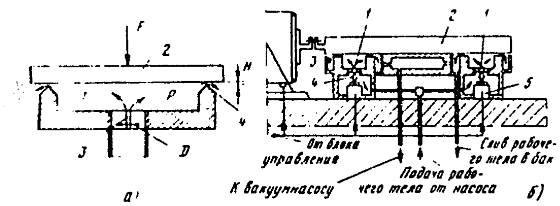

Figure 1. Schematics of a Hydrostatic Support (a) and a Three-Component Vibration Stand (b)

Its is a well-known fact that the similarity theory of solid deformable bodies is based on the equality of the respective natural-sized and model deformations ($\varepsilon_H = \varepsilon_M$). In order to fulfill this condition in carrying out studies on the earthquake-resistance of structures with small-scale models, using low-capacity, high-frequency vibration stands, the models should be made of special materials with a lowered modulus of elasticity ($E_H : E_M = 10 \div 500$) and an increased average density ($\gamma_M : \gamma_H \approx 1 \div 3$). In a number of instances, particularly when the basic purpose of the research is to study a structure's dynamic characteristics, the following may be used as model materials: acrylic resin (plexiglass), epoxy resin, and gypsum (plaster of Paris). In those cases where we need to study the seismic stress and the behavior of a structural component at a limiting point, model materials are used which are more complex in their composition, including lead dust, shot, rubber dust and ground limestone [1].

A vibration stand with the design described above was used to conduct tests on a model of the reactor section of an AES building with a VVER (water-moderated water-cooled reactor)-1000 in a scale of 1 : 200, made of acrylic resin (E_M = 5200 MPa, γ_M = 1.2 g per sq. m), as well as a model of the base (footing) of a K-220-44--TVV-220-2 turbine unit, made of gypsum (E_M = 2850 MPa, γ_M = 0.86 g per cu. cm).

The design of the reactor section of the AES building (Fig. 2a) comprises a three-dimensional structure, including a protective shell (shield), a vault roof, and the following components situated within it: the reactor shaft, footings, and a system of auxiliary structures (walls, columns, and roofs), placed on the base foundation around the shell and around the reactor shaft within it.

The foundation of the turbine unit (Fig. 2,b) represents the structural design of a three-dimensional frame system.

In the tests which were conducted on the design of the reactor section of an AES building the frequencies and forms of its own vibrations were

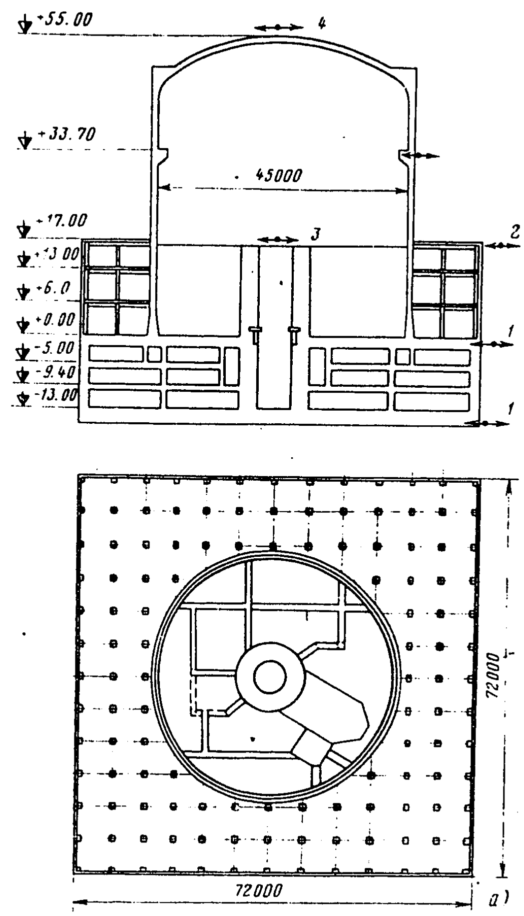

Figure 2, a Design of Reactor Section of an AES Building with Schematic of Measurement Points

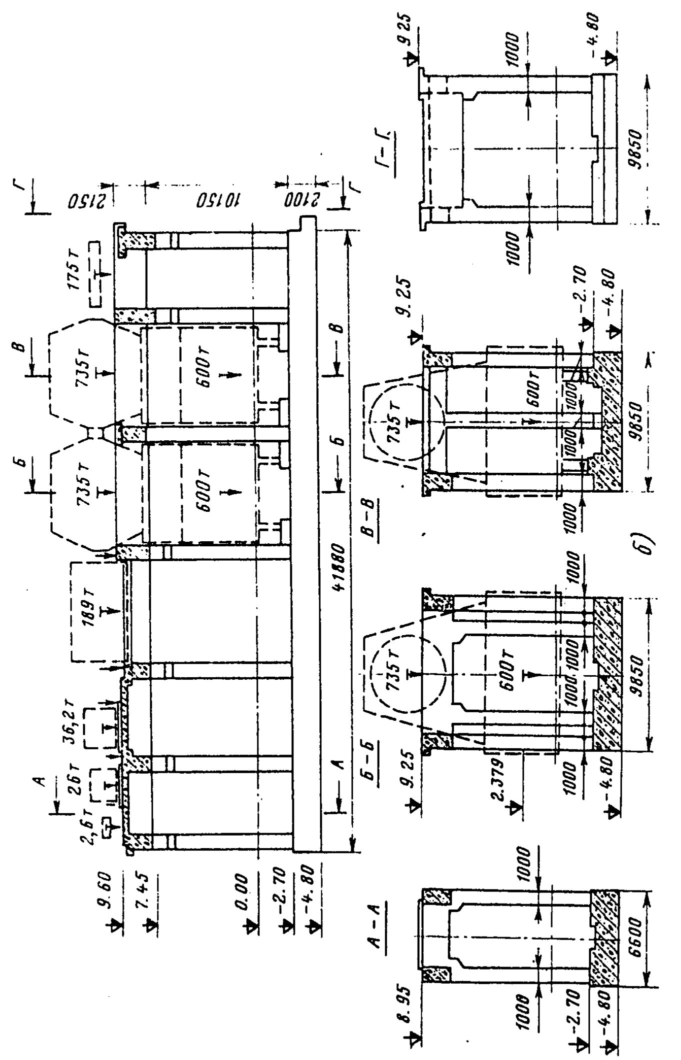

Figure 2, b Design of a Turbine-Unit Foundation Base within the Reactor Section of an AES Building determined, as well as the amplitude-frequency characteristics (AChKh) of its individual points. Inasmuch as the structure under study is a complex three-dimensional structural component, consisting of inter-related plates (partitions and roofs) and stands (columns), its AChKh has a multiplicity of resonance peaks, caused by these elements' becoming resonant in turn.

In the tests AChKh of the structure were studied ranging from 0.4 to 18 hz. (hertz) (here and further on all data are cited as converted to natural-size structures), which is completely sufficient for evaluating its reaction to seismic influences. Most characteristic are the AChKh (Fig. 3, a) determining the vibrations of the top of the footing section (at the zero mark [grade level])and the top of the protective shell (shield) (at the 55.0-m mark) in relation to the footing sole (bottom). The first two resonance peaks correspond to the cantilever vibrations of the entire structure as a unified whole. The basis of this cantilever design consists of the protective shell (the highest and relatively least rigid element) on an elastic foundation (the footing section) with the adjacent rigidities and masses (the ancillary structures, reactor, and steam generators). The first resonance peak (f_1 = 1.9 hz.) corresponds to the first cantilever form of vibrations, and the following one (f_2 = 3.5 hz.)--to the second one (Fig. 4). It should be noted that if the first tone of the vibrations are characterized primarily by shift deformations of the entire structure as a whole (the graph of the distribution of accelerations along the high points is almost a straight line), the second tone is characterized by flexural-shift deformations with a relatively bending at the place of a substantial change in the structure's rigidity along its height (see the graph for f_2 = 3.5 hz., Fig. 4). Thus, the footing section in this case moves practically like a rigid body. Then there is a weak deformation in the lower third of the shell (from the zero mark to the 17.0-m mark), the rigidity of which has been increased by means of installing internal partitions (baffles). But the greatest deformations arise in the middle third of the protective shell (between the 17.0-m and 33.8-m mark)--its most flexible part, since above it the rigidity is again increased by means of widening the structural component for the installation of the sub-crane beam and the juncture of the vertical cylinder with the vaulted roof.

The amplitude-frequency characteristics of 3 and 4 (see Fig. 3, b), which are situated almost on one mark (grade level), reflect the nature of the vibrations of the auxiliary structures and the reactor shaft. In the section of the resonance curve with a frequency of 0.4--5.7 hz. the vibrations of these points are practically the same. At frequencies of more than 6 hz. the structural components of the reactor shaft vibrate, so to speak, independently. Moreover, the resonance curve of the shaft passes considerably below the resonance curve of the auxiliary structures. The rigidity of the reactor shaft, with its reinforcing partitions carrying out the function of rigid fins is higher than that of the auxiliary structures. The shaft's own vibration frequencies are higher than 13 hz., whereas in the auxiliary structures the first resonance peak arises at the frequency of 8 hz., and the next three high resonance peaks in succession are 12, 13.5, and 14.5

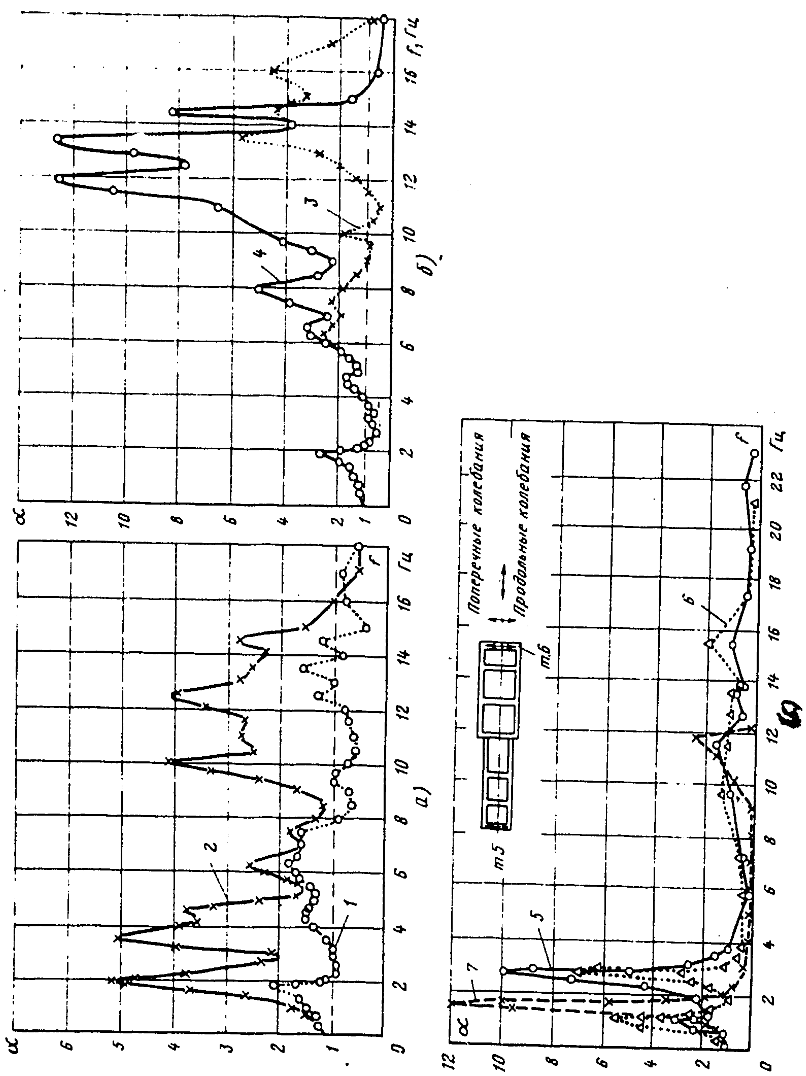

Figure 3. Amplitude-Frequency Characteristics of Various Points in the Reactor Section (a, b) and the Footing (Base) of the Turbine Unit (c)

Key to Figure 3:

1. Top of footing section
2. Top of protective shell
3. Reactor shaft
4. Auxiliary structures (17.0-m mark)

5, 6. Lateral vibrations

7. Longitudinal vibrations at the level of the upper frame's axis

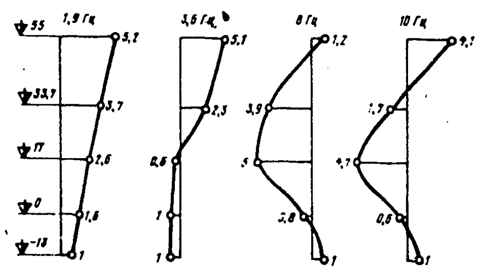

Figure 4. Graphs of Velocity Distribution along the Structure's Height (Its Axis)

hz. The high level of AChKh at frequencies above 10 hz. is caused by the general resonance background, arising from the vibrations simultaneously from several elements of the structure, with a predominance of vibrations from any one of them.

The graphs of the distribution of vibration velocities along the height of the structure for several resonance peaks are represented in Fig. 4. The first two graphs have already been characterized above. The graphs constructed for f_3 = 8 and f_4 = 10 hz. correspond to the third form of flexural vibrations (two units in height). They differ only in the nature of the distribution of velocities by height. Thus, the maximum velocities appear at the 17.0-m mark. The results of studying the structure's vibration have shown that the maximum accelerations at this mark are linked with the coincidence between the inherent flexural frequencies of the shell and the inherent frequencies of the auxiliary structures. Moreover, in the auxiliary structures they are determined by the presence of the roof. In the floor plan each such roof consists of a square slab measuring 72 × 72 m with a large opening in the center (47.5 m in diameter), reinforced by columns on the floor, installed at intervals of 6 m, and by walls (shells) around the edges. During the vibrations of such a plate (slab) in its flat plane the columns play the role of hinge-joint fastenings (their rigidity in a horizontal direction is insignificant), while the side walls play the role of rigid fins. As a result of the general resonance of the roof slabs of the auxiliary structures and the shell, the structure as a whole is affected by the vibration of the complex, three-dimensional form.

In order to evaluate the earthquake-resistance of the turbine-unit footing, to determine its dynamic characteristics (frequencies and forms of its inherent vibrations) and the nature of the distribution of the accelerated velocities between the individual points, depending on the frequency of the forced vibrations, our research included an extremely detailed study of the footing's vibration in the section of the spectrum (range) which is characteristic of seismic activities. The equipment installed in the upper frame of the footing simulated the special loads placed on the model in accordance with the mass of the individual units. Herein the sizes of the loads were selected so as to insure a position of the equipment's centers of gravity which would be similar to those in nature.

All tests on the footing were conducted for dynamic effects directed along (longitudinal) and across (lateral) the turbine unit's axis.*

Most dangerous for the operation of the turbine unit are the footing's lateral vibrations, since they may lead to a destruction of the coaxiality of the machine's individual parts (Fig. 3, c). As may be seen from the ACh Kh graph presented here, the determining influence on the formation of seismic loads will be had by the first two tones of the inherent vibrations ($f_1 = 1.1$ and $f_2 = 2.8$ hz.); moreover, the second tone provides the most dynamic coefficients (up to $\alpha = 10$). In the remaining section of the AChKh (to the right of $f = 4$ hz.) the dynamic coefficients are basically less than the unit and do not exceed $\alpha = 2$ for the individual points.

The nature of the distribution of accelerations (in the form of dynamic coefficients) along the axis of the footing's upper frame for the first two resonance frequencies and for $f_3 = 12.7$ hz. indicates (Fig. 5) that the nonsymmetricality of the footing design itself (in a lateral direction) and the placement on it of a mass of equipment along the longitudinal axis causes the appearance of torsional vibrations.

The first two graphs reflect the nature of the torsional vibrations in the upper frame relative to certain centers of gravity located on the longitudinal axis. For the first form of vibrations ($f_1 = 1.1$ hz.) this center of torsion is situated to the left, while the maximum amplitudes take place to the right in the section with greater masses (turbines and condensors). The second form of vibrations ($f_2 = 2.8$ hz.) characterizes the maximum amplitudes of the section with less masses (see Fig. 5), whereas the center of torsion has shifted to the right. Obviously this testifies to the subsequent entry into resonance of individual parts of the structural component: at first, the sections with lateral frames bearing the turbines (more flexible), and then the sections with lateral frames bearing the generator and

* In the lateral direction measurements were conducted at 7 points of the upper frame along the axes of the lateral frames; in the longitudinal--also at the upper-frame level along the footing's axis and the axes of the longitudinal frames.

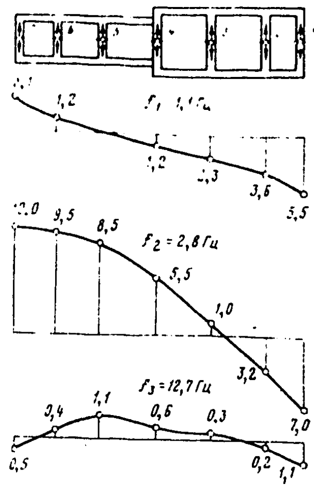

Figure 5. Graphs of Lateral Vibrations of a Footing's Upper Frame

auxiliary equipment (more rigid).

The third graph (Fig. 5) for f_3 = 12.7 hz. characterizes the distribution of accelerations for one of the highest **flexural forms of the inherent** vibrations of the footing's upper frame.

Thus, as follows from the graphs (Fig. 3, c and 4), the greatest values of the dynamic coefficients correspond to the second tone of the vibrations (f_2 = 2.8 hz.). Moreover, if we consider that the maximum accelerations within seismic vibrations are characteristic of the frequency range 3--5 hz, then the second tone of the vibrations will obviously be the determining factor in forming the seismic loads on the footing in a lateral direction. Study of the footing's vibrations in a longitudinal direction has shown that in this case the footing component behaves as a single-mass elastic system; the frequency of its inherent vibrations amounts to 1.4 hz. (Fig. 3, c). Thus, it may be assumed that the dynamic rigidity of the footing in both longitudinal and lateral directions is approximately the same. Furthermore, as a result of the slower damping of the longitudinal vibrations, there occurs an increase by approximately 20% in the dynamic coefficient (as compared to the maximum for lateral vibrations).

Conclusions

1. Study of the vibrations of the reactor section of an AES building have shown that the two lowest tones of the inherent vibrations ($f_1 = 1.9$; $f_2 \doteq 3.5$ hz.) are determined by the flexural-shift deformations of the entire

structure as a unified whole. At frequencies of more than 6 hz. the dynamic operation of the structure will be determined by the inherent vibrations of the elements comprising it (shells, roof slabs, walls). Herein the forms of vibrations of the entire structure have a complex, three-dimensional nature.

2. The design of the turbine-unit footing studied here is sufficiently flexible (with a vibration period of $T_1 \approx 1$ c), possessing approximately the same dynamic rigidity in its longitudinal and lateral directions. The dynamic operation of the footing in its lateral direction is conditioned by the torsional vibrations of the upper frame; herein the determining role in the formation of the seismic load will be played by the second tone of the vibrations (f_2 = 2.8 hz.; α = 10).

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PLANNING AND STUDYING UNDERGROUND FUEL-DELIVERY TUNNELS

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 10, Oct 80 pp 57-60

/Article by Candidate of Technical Sciences V. I. Stepanov and Engineer V. G. Novikov and V. L. Pavlov: "Planning Underground Fuel-Delivery Tunnels and Studying Their Operation"/

/Text/ The Ural Division of the VGPI (All-Union State Planning Institute) Teploelektroproyekt (UralTEP) has developed fuel-delivery, arch-type trestles (scaffold bridges), made of structural steel with mineral-wool heat insulation. The design of these trestles contain practically no protruding elements on which dust may be deposited and this significantly improves the conditions for utilizing them. At the same time underground fuel-delivery tunnels, whose operating conditions are considerably worse than those in above-ground galleries (in connection with the difficulty of arranging transfers by conveyors and the presence of props (posts) within the central passage), are being made, as before, of VKT 3.5-3 rectangular elements. The constructional deficiencies of such tunnels, it should be noted, also include a large amount of work on integrating the hinge-type joints, the monolithic sections, and placing concrete in the floors, difficulties in manufacturing structural components at plants, as well as the complexity of making the transition junction from the rectangular, underground structural components to the arch-type, above-ground ones.

Taking this into consideration, in planning the fuel-delivery structures for the Reftinskaya, Troitskaya and other GRES's, the UralTEP specialists developed and introduced a design for precast, arch-type, underground tunnels, made of reinforced concrete. The arch-type tunnel (Fig. 1) consists of a support slab and two semi-vaults, connected in a "keystone," as well as a hinge-joint with the support slab. Lengthwise the elements are connected with the aid of welding the embedded parts. With regard to its interior outline the tunnel consists of a vault with a radius of 4100 mm. In choosing the sections of its elements and the type of reinforcement, consideration was given to the possibility of using them for the building of the rotary gravity dumps with disk-toothed crushers at the grade level where the underground tunnel comes out--13.8 m.

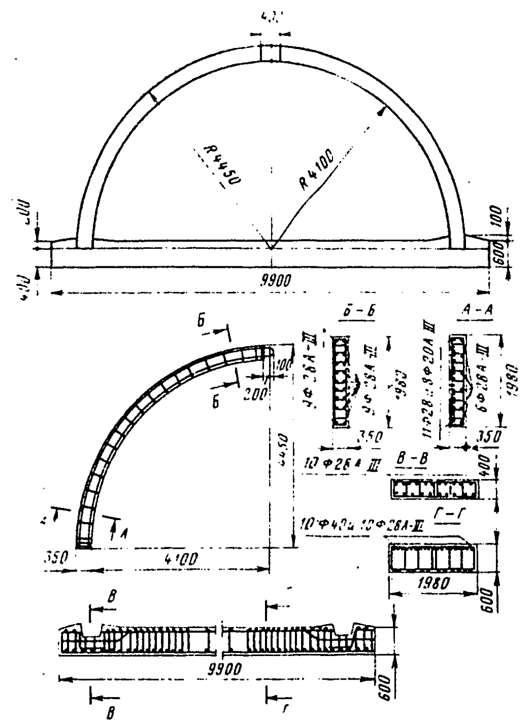

Figure 1. Cross-Section and Reinforcement Schematics of Structural Components of Underground, Fuel-Delivery Tunnels

In order to determine the strength characteristics of the vault structure, a test model was made and tests were run on it. In contrast to the plan solution for the vault, the test model had a width of 1000 mm (instead of 1980 mm) and an outline in the form of a broken circle, consisting of 12 straight-line sections (instead of a circular form).

In order to concrete the semi-vaults, metallic and wooden forms were made with removable sides. The semi-vaults were concreted, and the forms were set aside. The reinforcement and the concreting of the support slab were carried out in the operational position.

The test model was assembled in the following manner; first, the support slab was placed on a sand base, a special apparatus was installed on it in order to support the semi-vault in the plan position, and then the semi-vaults were erected, their position was adjusted and checked, and the joints in the "keystone" and "heels" were integrated. The data on the compression strength of the concrete in these elements of the vault, as well as the integrated concrete are cited in Table 1.

Table 1

Element	Temporary Resistance to Compression, in MPa	Actual Modulus of Elasticity of Concrete, in MPa
Semi-vault I	54	23,500
Semi-vault II	56.8	19,860
Key joint	43	23,800
Support slab	45.3	30,100

Notes: 1. Flan concrete mark M400
2. Concrete mix (composition) (outlay per cu. m): M400 cement--560 kg, granite crushed stone, ranging in size (coarseness) up to 40 mm--1250 kg, granite sand--340 kg.

The test model of the vault was tested with three combinations of stress (loads); moreover, in all cases the distributed load was replaced by a concentrated one. The first combination of loads included within itself loads from the soil, ground water and rolling stock (Fig. 2). In the second

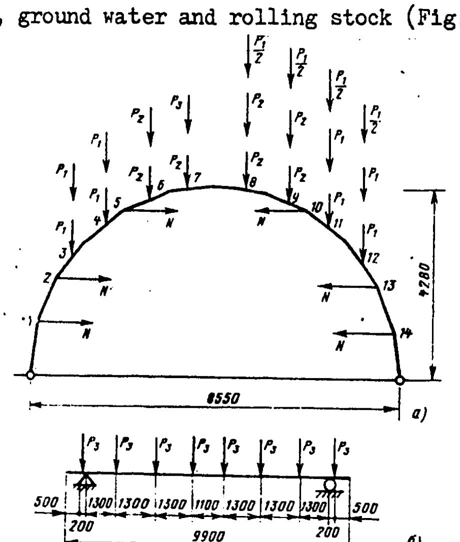

Figure 2. Schematics of Loading in Testing Vault (a) and Support Slab (b)

combination the vault was loaded only with vertical elements from the first loading, while in the third loading a one-sided loading of the vault was conducted with a vertical load (Table 2). The vertical load P on the vault was created with the aid of 16 DG-50 pushing hydraulic jacks, while the horizontal load N utilized three DGS-63 pulling hydraulic jacks.

Deformations and shifts of the vault during the test process were measured by indicators ($1 \cdot 10^{-2}$ mm) and by deflectometers ($1 \cdot 10^{-1}$, $1 \cdot 10^{-2}$ mm), while stresses in its operational reinforcement were measured by resistance strain gages (tensometers).

Table 2

Load (Stress)	Designation	Combination		
		I	II	III
Vertical	P_1	300/360	300/360	150/180
	P_2	326/390	326/390	--
	ΣP	2500/3000	2500/300	600/720
Horizontal	N	236/280	--	--
	ΣN	1410/1680	--	--

Note: The numerator gives the normative load (in kH), while the denominator gives the design (estimated) load.

During the first loading of the vault the test load was gradually brought up to the normative value. Herein vertical shifts in the keystone joint comprised 3.79 mm, and horizontal shifts 0.22 mm. The maximum stress in the operational reinforcement was equal to 78 MPa. Under normative load the vault held out for 17 hours; in this case the increase in deformations in not a single one of the vault's cross-sections exceeded 0.3 mm, i. e., the structure operated in an elastic stage. The vault's remaining deformations after unloading did not exceed 10 percent of the full deformations under normative loading.

The results of repeated loading of the vault up to the normative load were practically indistinguishable from the results of the first loading.

In the design (estimated) loading the vertical shifts in the keystone joint amounted to 4.74, while the horizontal shifts amounted to 1.7 mm. The stress (tension) in the vault's operational reinforcement reached 100 MPa.

The first cracks in the vault in the zone where the maximum moment was acting under the conditions of ΣP = 4130 kH, ΣN = 1320 kH.

Fig. 3, a depicts a graph of the dependency of the vault's vertical shifts in the keystone joint on the load (in comparison with the design curves for two-hinged and hingeless vaults). It may be seen from the graph that the curve. of the vault shifts, constructed in accordance with the test data, practically coincide with the curve constructed in accordance with the design data, obtained for a hingeless vault. This is probably explained by the fact that under the given combination of loads the junction connecting the vault with the support slab operates rigidly.

In testing the vault the test load brought to Σ P = 4820 kH, Σ N = 2720 kH, exceeded the design load by a factor of 1.61. At this stage signs of the vault's destruction were not revealed. In analyzing the dependence of the vertical shifts on the load (Fig. 3, a), exceeding the design load, we observe the maintenance of the proportions between the shifts and the loads, i.e., even beyond the limits of the design load the structure operates in an elastic manner. The maximum stresses in the reinforcement under controlled-destruction loading did not exceed 150 MPa. After unloading the residual deformations were insignificant, and this confirms the conclusion regarding the elastic operation of the vault even under controlled-destruction loading.

In tests made using the second combination without adding horizontal loads the loading of the vault was also conducted in stages. Under a load of Σ P = 2000 kH in the zone of the keystone joint cracks began to appear, and under Σ P = 2500 kH the width of their opening reached 0.4 mm.

Fig. 3, b presents graphs of the changes in vertical shifts in the keystone joint depending on the vertical load obtained by the test method and determined by the design for hingeless and two-hinged vaults. From a comparison of the design of the test data it may be seen that under this loading the vault operates as a two-hinged unit.

Thus, depending on the type of loading the assembly which joins the vault with the lower slab may operate both as a rigid and as a hinged joint. So, when the vault is loaded only by a vertical load (ΣP = 3000 kH) the shifts in the keystone joint amount to 18.7 mm, while the tension stresses in the operational reinforcement reach 222 MPa, whereas when the vault is loaded with loads corresponding to operational ones (Σ P = 3000 kH, Σ N = 1680 kH), these same indicators do not exceed 4.7 mm and 100 MPa respectively.

Under a vertical load of Σ P = 3900 kH we observed the appearance of new cracks and the widening of existing ones, as well as an increase in the deformations and shifts. However, we did not note any clear signs of the vault's destruction...

The last loading of the vault was carried out in order to determine the moment and character of destruction under a one-sided loading (the third combination). The loading was carried out in stages, and at a load of ΣP = 1200 kH, which exceeded the design load by a factor of 1.66,

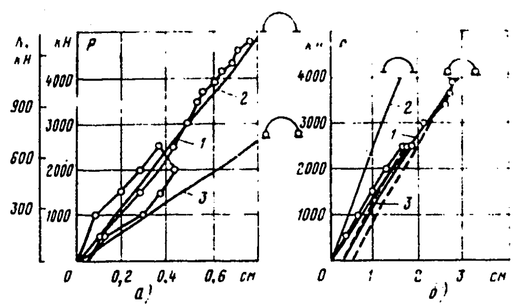

Figure 3. Vertical Shifts in the Keystone Joint when the Vault is Loaded with the First (a) and Second (b) Combination of Loads

Key:
1. Test curves (loading--unloading--loading)
2, 3 Design curves for hingeless and two-hinged vaults respectively

destruction of the vault occurred along an inclined section at a distance of approximately 1/3 of the semi-vault from the keystone joint (Fig. 4, a).

The support slab was tested in an inverted position (with the bottom up) for a combination of loads creating a maximum span moment. A load in the form of concentrated forces was created with the aid of DG-50 pushing hydraulic jacks.

Under a load comprising 57 percent of the normative load cracks were revealed in the central part of the span with a width of as much as 0.1 mm. Under the normative load ($\Sigma P = 936$ kH) the flexure of the slab in the middle of the span amounted to 24.6 mm, the maximum stress in the longitudinal reinforcement did not exceed 190 MPa, and the width of the crack opening attained 0.3 mm. Under the normative load the slab held up for 16 hours; in this case, the increase in flexure amounted to 0.73 mm; the residual deformations of the slab after unloading did not exceed 5 percent of the full deformations. The results of repeated loading of the slab to the normative load were practically no different from the results of the first loading.

At a load of $\Sigma P = 1290$ kH (a design load of $\Sigma P = 1120$ kH) there appeared in the support zone of the slab an oblique crack with an opening width of 0.2 mm, while at a load exceeding the design load by a factor of 1.49 destruction of this zone occurred along an oblique section (Fig. 4, b). Since the slab's support zone was destroyed under loading which was less than the contolled-destruction loading, it was decided to conduct a test

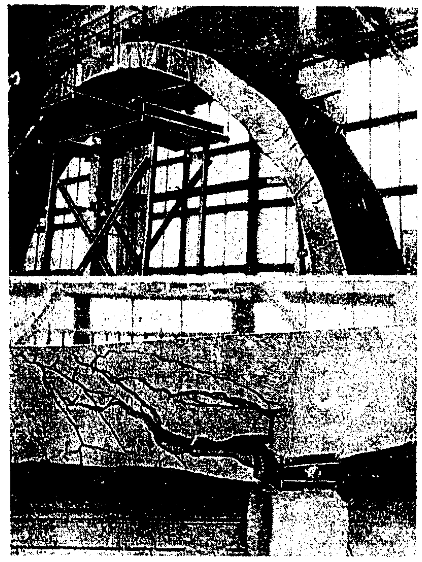

Figure 4. Destruction of Reinforced-Concrete Elements:

a--Vault along an oblique section

b--Support zone of slab

of the targeted support zone for lateral strength. For this purpose, a load was selected in accordance with the flexural moment in the support zone. The second support section was destroyed under a load of Σ P = 1500 kH (with a support reaction of 112.5 kH), which exceeded the design load by approximately a factor of 2. Inasmuch as the destruction of one of the support sections of the slab, as was noted already, occurred under a load which was less than the controlled-destruction load, the reinforcement in the working draft for the support sections of the slab was strengthened.

Serial manufacture of precast reinforced-concrete elements for underground, fuel-delivery, arch-type tunnels has been mastered by the Berezovsk Structural Components Plant.

Based on the results of the tests which were conducted, as well as the industrial introduction of structural components at the Reftinskaya GRES, proposals were worked out in the UralTEP, directed at reducing material consumption of the vault elements and the support slab, as well as the cost of the structural components. In this connection, the following provisions were made:

To reduce the thickness of the vault from 350 to 300 mm;

To make holes with a diameter up to 400 mm in the support slab in order to reduce its weight and lower the consumption of concrete;

To utilize elements of the vault and support slabs with two or three type sizes of reinforcement, depending on the operative load (depth at which the tunnel is located).

However, the implementation of these proposals depends primarily on the construction industry's enterprises which are presently carrying out the regular delivery of tunnel structural components to many facilities (the Ekibastuzskaya and Gusinoozerskaya GRES's etc.), and the transition to the use of improved structural components is linked with a certain adjustment in the sizes of metal forms and a change in the technology of manufacturing of structural components.

New economic solutions are being taken into consideration in developing a standardized plan for the structural components of underground, fuel-delivery tunnels.

Table 3 cites the technical and economic indicators of several variants of underground, fuel-delivery tunnels, determined in accordance with the requirements of Instruction SN 423-71.

The decisive indicators for introducing arch-type, underground tunnels at the Reftinskaya GRES were the assurances with their use of a reduction in labor outlays at the construction site (by almost 22%) and a considerable improvement in operating conditions (a reduction in operating outlays by 37%), although with regard to the cost of construction and outlay of materials the arch-type tunnels yield to the tunnels made of VKT 3.5-3 elements.

The standardized arch-type, fuel-delivery tunnel which is being developed is superior with regard to all indicators to the standardized tunnel made of VKT 3.5-3 elements. Therefore, industry must make the fastest possible transition to the production of the tunnel structural components which have been improved in accordance with the proposals of UralTEP.

Based on the positive results from introducing at the Reftinskaya GRES, the fuel-delivery structural components developed by UralTEP have been used since 1978 at many electric-power engineering construction sites, and in 1979 they were included in the catalog of precast reinforced-concrete structural components for thermoelectric-power stations.

Table 3

Indicator	Tunnel made of VKT 3.5-3 elements	Arch-type Tunnel	
		Introduced at Reftinskaya GRES	Standardized
Outlay of reinforced-concrete, and concrete, in cu. m	10.8	12.5	9.9
Including:			
precast reinforced concrete	6.5	10.6	8
monolithic reinforced concrete	2.2	0.5	0.5
monolithic concrete	2.1	1.4	1.4
Outlay, in kg:			
reinforcement	1747.6	1815.9	1393.3
embedded parts	77.7	175.2	175.2
Labor expenditures for manufacture of precast reinforced concrete structural components, in man-days	141.4	131.2	120
Including:			
in the plant	58.1	66.2	56.8
at the construction site	83.3	65	63.2
Cost of structural component "on the job", in rubles	1485	1723	1359
Operating expenditures, in rubles	374	231	231
Cited specific capital investments, in rubles	127	168	129
Coventionally-constant applied outlays, in rubles	32	27	27
Greater expense for operations in wintertime, in rubles	92	75	75
Cited outlays, in rubles (and %)	2100 (100)	2224 (105)	1821 (86)

Conclusions

1. The tests which were run on the structural elements of underground, fuel-delivery tunnels have shown their adequate strength, rigidity, and resistance to cracking.

2. The introduction of standardized, arch-type, fuel-delivery tunnels will allow us to reduce the outlay of materials by 9 percent, labor outlays in the construction site by 25 percent, and to lower the cost of 1 m of tunnel by 289 rubles.

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DRILLING OIL AND GAS WELLS

Moscow BURENIYE NEFTYANYKH I GAZOVYKH SKVAZHIN in Russian 1980 pp 2, 333-334

[Annotation and Table of Contents from the book "Bureniye neftyanykh i gazovykh skvazhin," Izdatel'stvo Nedra]

[Text] The physicomehcanical properties of rock are considered briefly in the textbook. Drilling rigs are described. Drilling of oil and gas wells is considered in detail. A great deal of attention is devoted to flushing out wells: to flushing agents and preparation and cleaning of drilling muds. Data are presented on prevention and control of absorption and collapse of rock. Techniques of strengthening beds and the corresponding equipment and tools are described.

Intended for students of petroleum technical schools.

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HANDBOOK ON DRILLING MUDS

Moscow SPRAVOCHNIK PO BUROVYM RASTVORAM in Russian 1979 pp 2, 213-215

[Annotation and Table of Contents from the book "Spravochnik po burovym rastvoram," Izdatel'stvo Nedra]

[Text] The required data on the chemical reagents, cements, clays, muds and other materials are outlined briefly in the handbook. Convenient methods of quality control and presented. The most widely used and most promising flushing and cementing muds are described. Classification of most chemical reagents and cements and different additives with indication of the composition and behavior under different geological and technical conditions is outlined.

The handbook is intended for specialists of the oil and gas industry.

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Novosibirsk TEKTONIKA SIBIRI in Russian Vol 9, 1980 pp 152-153

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