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RESOURCES

(FOUO 26/79)

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ELECTRIC POWER AND POWER EQUIPMENT

CONJUGATION OF HIGH DAMS WITH CANYON WALLS

Moscow GIDROTEKHNICHESKOYE STROITEL'STVO in Russian No 8, Aug 79 pp 3-6

[Article by A. A. Borovoy, chairman of Soviet National Committee on Large Dams, Mikhaylov, L. P., First Vice-Chairman of SNC, and Moiseyev, I. S., Vice Chairman of SNC]

[Text] The construction of hydroengineering complexes in the USSR is carried out on plains, mountain and foothill rivers, and in various natural conditions. Rivers of the plains are usually navigable and are characterized by uneven runoff with respect to time, considerable flood discharges, and long floodplain and superfloodplain terraces composed to a considerable degree of nonrocky soils (hydroengineering complexes on the Volga, Kama, Don, Ob', and other rivers).

These hydroengineering complexes include earth dams occupying the largest part of the head front and usually constructed by the hydraulic fill method, multispan concrete dams combined, as a rule, with the GES [hydroelectric power station] building, and navigation structures. In some GES (Kamskaya, Plyavin'skaya and others), the presence of a spillway GES made it possible to get rid of a separate concrete dam. Usually the configurations of the main concrete structures are selected in one foundation pit covering the span of a narrow river channel by a rock banket.

In hydroengineering complexes on rivers of the plains, the conjugation with nonrocky banks is usually accomplished by earth dams whose antifiltration devices, as cores, diaphragms or injection screens, are introduced deep into the banks and create single antifiltration contour over the entire head front.

The depression surfaces in the body of the dam lower in time, but some dams have filtration in the bank borders of earth dams above the design assumptions (Tsimlyanskaya, Kakhovskaya and other dams). By constructing discharge wells and washing the ground to the area of the lower pool, the bogging up of the lower pool area and discharge of filtration water into the lower pool were eliminated.

On mountain and foothill rivers, hydroengineering complexes are built with large water reservoirs created by high (up to 325 m) concrete and earth dams. Table 1 gives the characteristics of a number of high-head hydroengineering complexes. Their layout solutions are characterized by a maximal utilization of high-head concrete structures for discharging the water used in construction and operation, as well as for feeding water to the GES power units.

In narrow rocky gorges, fixed and spillway arch dams are usually built.

On wide rivers abounding in water, when the ratio of the valley along the crown of the dam to its height is more than 6-8, when there are considerable flood discharges exceeding 10,000-12,000 m^3/s, and when there are rocky bases, spillway dams are built of concrete as gravity and multiple buttress dams. The head front sections conjugated with the banks are constructed either in the form of fixed concrete dams of short lengths (Ust'-Kamenogorskaya, Krasnoyarskaya dams) or dams of local materials (Bratskaya, Ust'-Ilimskaya, and others). Deep river-bed injection screens and drainages situated within the limits of a valley or a river bed continue as a bank screen.

The construction of rock-and-earth dams in areas of various lengths and heights has expanded considerably (Charvakskaya, Nurekskaya, Rogunskaya, and others). Flood spillways at these complexes are tunnel-shaped (including shaft-shaped) and are used for passing the water used in operation and construction and for channeling water to the GES building. Most hydroengineering complexes with dams of any types have continuous antifiltration and drainage devices along the entire width of the dam and in the bank abutments.

The structures of the Nurekskaya hydroengineering complex include a rock-and-earth dam 300 m high, three construction tunnels at various levels, catastrophic spillways, and pressure-station unit. The head front of the Rogunskaya hydroengineering complex on the Vakhsh River is created by a rock-and-earth dam 325 m high which forms a water reservoir of a useful capacity of 8.6 billion m^3. The complex includes deep water intakes of first and second sections, tunnel-type spillway with deep and surface water intakes, two levels of construction tunnels, and an underground GES building.

Conjugation of High Dams with Canyon Walls. In the presence of local widenings of the span, when weakened geological zones are located at higher levels of bank abutments, and in order to reduce the loads on the base, arch dams are often conjugated with the bank abutments. Cemented and drainage screens are necessarily extended in the direction of the banks.

In order to improve the structural behavior of the abutment receiving the loads from the dam, as well as in order to reduce the hydrostatic and filtration head of water on the base, the abutment is often isolated from the upper pool with a gravity stub-wing, as it was done in the Ingurskaya arch dam. Cemented and drainage screens are continued on the slopes along the foot of the stub-wing.

[redacted]

The Chirkeyskaya arch dam is conjugated with the banks by means of abutments 40 m high 50 m long. In the Sayano-Shushenskaya arch gravity dam, the dam is conjugated with the banks by means of blind concrete sections 246.6 m long at the left bank and 298.5 m long at the right bank. In their lower parts, these sections are concreted tightly to the slopes of the rocky pit, which produces additional thrust into the rock and protects the contact zone of the base against erosion and distruction under the effect of the environment.

In the base of the Ingurskaya dam, 24 large cracks and tectonic disturbances (fractures) were detected at the right bank. The fracture zone in the most stressed zone is filled with concrete, and lower -- with concrete walls with an overall depth of the order of 70 m. Large cracks in the most stressed zone are fixed with concrete by the mining method, and are cemented lower. The remaining cracks in the base of the dam are cemented.

The base of the Sayano-Shushenskaya dam is composed of strong Proterozoic crystalline shist which are not subjected to suffusion. The base has zones of tectonic disturbances which are more permeable to water than the solid mass containing them. The base of the dam has a double antifiltration screen 100 m deep and a vertical-hole drainage 50 m deep.

The canyon in which the Chirkeyskaya arch dam is located is chiefly composed of slanting thin laminated limestone with thin intermediate layers of marl on the left bank broken up by tectonic cracks and edge-repulsion cracks. As a result of cementing, the deformation modulus of the limestone base of the Chirkeyskaya dam was increased 1.59-2.04 times.

The left-bank slope is reinforced on the downstream side of the hollow under the dam with prestressed anchors situated in six levels. A reinforced-concrete retaining wall 43.7 m high was built along the height of the three lower levels on the surface of the slope, and reinforced-concrete beams were placed along the vertical extent of the three upper levels on the surface.

The reinforcement of the left-bank slope by anchoring rather than breaking the slope in order to reduce its steepness produced a saving: in concrete -- 44,000 m^3 and rock excavation -- 180,000 m^3. Moreover, the area above the GES building was reinforced with rod ties installed without preliminary stressing into steeply inclined holes up to 35 m deep. The ties are covered with cement mortar and are sealed in a reinforced concrete plate.

Structures of the Abutments of High Dams. In order to bring the pressure curve closer to the axis of the dam and to reduce the stress in the rock, some arch dams are designed with thicker index contour (Ingurskaya dam).

The most widespread contour is a broken contour of the abutments free from reentrant angles with a polygonal or curvilinear shape in the plane without a sharp point of inflection of the index contour.

[redacted]

Table
Characteristics of High-Head Hydroengineering Complexes

Hydroengineering Complex	Dam Height, m	Rock in Dam Base	Conjugation with Banks	Volume of Main Jobs, thousand m3	
				Concrete	Rock Excavation
Bukhtarminskaya	90	Gabbro	Short blank concrete gravity sections at banks, cementation and drainage screens in base.	1180	--
Bratskaya	126	Diabases	Structural elements of earth dams and drainage devices in their bases.	4858	1090
Krasnoyarskaya	124	Granites	Short blank concrete gravity sections, cementation and drainage screens	5500	1340
Ust'-Ilimskaya	105	Diabases	Earth dams built in bank abutments.	4850	1516
Sayano-Shushenskaya	242	Crystalline Schists	Dam abutments cut deep into the banks. Abutments are of a broken shape, and cut into the banks less at the upper boundary; the dam has a cushioned connection with the foundation.	9720	4351
Chirkeyskaya	232	Fractured Limestone	A thickened part of the foundation along the contour of the dam separated by a perimetrical seam and a plug in the channel part.	1760	2475
Zeyskaya	110	Diorite	No provision for special conjugation structures in the dam. Bank sections of the dam with structural elements are securely extended into the banks.	2369	2043
Nurekskaya	300	Sandstone and siltstone	The core of the dam and the antifiltration screen are extended into the walls of the channel part of the span; the core is conjugated with rock by a concrete plug.	--	--

Table (Cont'd)

Charvakskaya	168	Limestone	The dam core cuts into the walls. The foundation of the dam core contains a cementation tunnel which plays the role of a tooth in conjugation with rock.	594	4126
Kurpsayskaya	113	Sandstone and argillite	Concrete dam cuts into the banks; has cementation and drainage screens. Foundations of bank sections are inclined toward the upper pool.	1142	1171
Ingurskaya	27	Limestone and dolomite	The dam is conjugated with the banks by means of abutments. The thicker foundation part of the dam is separated by a seam from the body of the dam.	4831	6280
Ladzhanurskaya	69	Limestone	Cushioned connection of arches of uniform thickness embedded into foundation. Concrete plug in the depression of the channel.	138	57
Rogunskaya	325	Sandstone and siltstone	Dam core and antifiltration and drainage screens are extended into the banks	1162	4041
Toktogul'skaya	215	Low-carbon fractured limestone	By making the deformation seams monolithic, it was possible to reduce the volume of the dam's cutting-in the banks.	3971	2405

The design solution of the conjugation of the Ingurskaya dam with the base was accomplished in the form of a widened arch separated from the dam by a parametrical arch layer intended for: lowering compression stresses transmitted to the rocky mass; reduction of tensile stresses at the contact of the dam with the rock; acceleration of the closing of the rock surface and protection of the rock from loosening; smoothening of local unevenness of the supporting surface.

The parametric seam is an arc of a circumference selected from the condition of the passage of an equivalent force through it.

At the downstream boundary of the Ingurskaya dam at lower marks in the spots where the dam was insufficiently cut into both banks, the base was reinforced with a concrete plate.

In order to prevent and compensate for the shifting along the break if it occurs, a special design was developed for the part of the Ingurskaya dam above the break in which the height of the dam saddle cut by two systems of smooth seams was increased. This ensured a certain freedom of deformations.

The conjugation of concrete spillway dams with earth dams is usually accomplished in the form of a fixed concrete dam, or by means of a retaining wall, and in some instances, by means of a flexible reinforced concrete core wall within the earth dam. The conjugating concrete and reinforced-conctete honeycombed structures are used in some instances for production needs.

The conjugation of a spillway and a nonoverflow concrete dam is often accomplished in the form of a separate concrete wall which changes into a separate pier in the lower pool.

The spillway dam is separated from the GES building adjoining the dam by a nonoverflow section of the dam or by a separate abutment which continues in the lower pool within the limits of the devices damping the energy of the stream and serving at the same time as a longitudinal cofferdam during construction (Sayano-Shushenskaya GES).

Erection of Structures in Sections. In laying out the structures, the possibility of enlarging them in the future is taken into consideration in many instances. The basic dimensions of the structures are set with consideration for the loads of the first section with checking for the case of enlargement, and only for individual elements of the structures whose enlargement is impossible or is very complicated, the project considers the loads of the second section (screens and cores of dams, head channels, grooved insertion structures, etc). Special attention is given to ensuring interaction between old and new parts of the structures.

Most of the high-head hydroengineering complexes in the USSR are put into operation in consecutive sections, as well as in stages, ensuring the startup head at dams which have not yet been built high enough (Bratskaya, Krasnoyarskaya, Chirkeyskaya, Ingurskaya, and other GES) and making the construction and deformation seams necessarily monolithic.

The gravity dam of the Bratskaya GES was first constructed with a toothed profile which was not sufficiently thick, which made it possible to reduce the startup volume of the concrete cage by 300,000 m^3 for the introduction of the first units of the GES with further cementation of the longitudinal seam. The stressed state of the dam is satisfactory.

Calculations of Strength and Stability. Foundations of structures are calculated according to two groups of limiting states: calculations of the overall structure-foundation stability and the filtration strength of the foundation; calculations of the shifting of structures and local strength of the foundations, as well as the stability of the slopes.

The limiting strength of a rocky foundation is established as a result of studying rock samples in the water-saturated state with and without consideration for cementation.

Calculations of the stability of bank abutments of arch dams are based on the analysis of the shifting stability of calculated rock blocks which could form within the rocky mass in the limiting stressed state characterized by the fact that there takes place the Coulomb criterion over all shift surfaces limiting physically possible calculated blocks. The reserve stability factors, with consideration for a possible degree of error, are taken to be equal to 1.6-1.8 for the main combination of loads and 1.35 for special combinations of influences.

In dams spanning wide areas, the role of the channel part in ensuring the stability of the dam increases, because the value of the shifting load transmitted from the dam to the channel part of the foundation exceeds 30-40%, and in the Sayano-Shushenskaya dam reaches 50%. Calculations of the stability of the foundation of a dam allow for joint work of the channel and the bank parts, proceeding from the functional diagram of the onset of the limiting state which allows for the movement of the dam partly along the concrete-rock contact area and partly with the entrapment of the rocky foundation.

Cutting into Rock. The cubic volumes of rock excavations and the concrete replacing the removed rock reach considerable amounts (Table 2).

Decisions about the removal of weakened rock in local sections of the foundation are made at the present time on the basis of the analysis of the stressed state in the body of the dam and in bank abutments and the stability of the dam with examination of measures increasing the reliability of the structure, such as the lowering of counterpressure, anchoring of sections, cementation of ruptures, construction of underground supporting structures, fixing cracks with concrete, etc. Intensively weathered rock (separable layer) is necessarity removed without blasting.

Table 2

(1) Плотина	(10) Тип	(15) Высота, м	(16) Отношение объемов скалы и бетона, %
Братская (2)	Гравитационная (11)	126	17,8
Усть-Илимская (3)	•	105	14,1
Красноярская (4)	•	124	28,3
Мамаканская (5)	•	58	34,9
Токтогульская (6)	•	215	8,0
Зейская (7)	Массивно-контрфорсная (12)	110	32,6
Ингурская (8)	Арочная (13)	272	48,7
Саяно-Шушенская (9)	Арочно-гравитационная (14)	240	23,8

Key:
1. Dam
2. Bratskaya
3. Ust'-Ilimskaya
4. Krasnoyarskaya
5. Mamakanskaya
6. Toktogul'skaya
7. Zeyskaya
8. Ingurskaya
9. Sayano-Shushenskaya
10. Type
11. Gravity
12. Massive buttress
13. Arch
14. Arch-gravity
15. Height, m
16. Rock-concrete volume ratio, %

The deformability of the foundation must not affect the depth of the embedment of gravity and buttress dams with the exception of the removal of greatly loosened rock zones, as was the case in the construction of the Krasnoyarskaya dam.

Studies have shown that in many instances the strength of the foundation expressed by the shift resistance coefficient varies from 1.0 to 2.8 and, therefore, the requirement about the removal of the entire eroded rock sometimes causes excessive volumes of work. Increased penetrability of the solid rock is not always the reason for the removal of the rock in the foundation of dams, because such foundations are well injected and drain the filtration flow below the screen, reducing the counterpressure. Local sections of rock weakened by caverns or cavern cavities adjoining the foundation pit are cleared down to the healthy rock, as it was done during the construction of the Ingurskaya arch dam.

When dams are built on permafrost ground, the main measures for preserving the filtrational properties of the rock are measures for thawing and injection of the rock mass or, on the contrary, for maintaining the foundation in the frozen state.

The cutting into canyon walls is done in the majority of cases layer by layer by the preliminary splitting-off method with subsequent dumping of the blasted rock down. But at the construction of the rock-earth Nurekskaya dam, in order to save time in individual sections, the cutting-in for the core of the dam was done by the mass caving method, also with preliminary splitting-off of the rock being dumped down. The results of such caving showed a sufficiently good preservation of the rock in the zone adjoining the core.

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PASSAGE OF ICE DURING THE CONSTRUCTION OF SAYANO-SHUSHENSKAYA GES

Moscow GIDROTEKHNICHESKOYE STROITEL'STVO in Russian No 8, Aug 79, pp 25-28

[Article by V. A. Koren'kov, Candidate of Technical Sciences]

[Text] In 1969-1975, during the construction of the Sayano-Shushenskaya GES, the ice was passed through the narrowed channel of the Yenisey River. When the trench of the second section was formed, the passing of the ice in the course of 1976-1978 was accomplished through bottom holes of the first level.

During that period, the Siberian branch of VNIIG [All-Union Scientific Research Institute of Hydraulic Engineering imeni V. Ye. Vedeneyev] conducted field observations of the passage of ice. The results of these observations in combination with the materials on the passage of ice at other hydroengineering complexes of Siberia [1-4] can be used in designing and construction in the future.

By the spring of 1969, an upper earth dam and a crib cap were erected (Figure 1). The height of the dam reached 20 m with a crown mark of 130 m, and the width along the crown was 8-12 m.

In the section adjoining the crib 85 m long, the head slope was reinforced with a riprap layer of up to 2 m.

By the spring of 1969, the crib cap had a height of up to 15 m and was composed of five cribs covered from the head side with metal sheaths 8 mm thick 7 m higher than the mark of 123 m.

On the river side, the foundation of the crib up to the mark of 125 m was reinforced with a riprap 4.5 m wide on the top and with fastened concrete blocks 2 x 1 x 1 m^3 laid along the riprap.

By the spring of 1970, a trench of the first section was formed at the construction site (Figure 2). The dams of the trench were constructed of a gravel and pebble mass with a core of sandy loam [6]. The upper dam and the crib cap were brought to a 135 m mark.

Figure 1. Passage of Ice Through the Narrow Section of the Transit Channel of the Sayano-Shushenskaya GES on May 3, 1970.

Figure 2. Breaking of Ice Fields Druing the Passage of Ice Through the Narrow Section on April 26, 1972.

The longitudinal dam 620 m long with a head slope of 1:2.5 had a riprap along its entire length.

The upper crib cap extending in the direction of the narrowing section for protecting the longitudinal dam against erosion by the stream and the destructive effect of ice. The considerable length of the longitudinal dam made it necessary to build a crib spur 40 x 16 m in plane 20 m high consisting of two cribs covered with rock.

During 1970-1975, the outer contour of the trench of the first section practically did not suffer any substantial changes. The width of narrowing was 130 m or 0.4 of the river's width. Table 1 shows the main characteristics of the conditions of the passage of the ice through the narrowed channel.

Table 1

Main Characteristics of the Conditions of the Passage of the Ice Through the Narrowed Channel at the Construction Site of the Sayano-Shushenskaya GES in 1969-1975

(1) Годы	(2) Сумма* температур воздуха за ноябрь—март, °C	(3) Дата начала пропуска льда	(4) Характеристика льда		(7) Гидравлические характеристики в начале пропуска льда				(12) Продолжительность ледохода, сут	(13) Сток льда, млн. м³	(14) Высота навалов на верховую перемычку, м
			(5) толщина, см	(6) прочность** основной массы льда, тс/м²	(8) уровень верхнего бьефа, м	(9) расход воды, м³/с	(10) перепад уровня между бьефами, м	(11) скорость льда на входе в сужение, м/с			
1969	--74,5	2.V	60-90	20—30	128,4	2700	4,2	2,5—3,0	4	50,0	2-3
1970	--56,6	8.V	50—70	15--20	122,3	750	1,7	0,8—1,0	3	10,0	1,0
1971	--63,2	27.IV	60--100	25--35	126,0	—	1,6	2,5--3,0	8	60,0	6—7
1972	—47,4	26.IV	60—80	20—30	124,2	2240	—	2,0	2	6,5	1—2
1973	--49,4	23.IV	60—90	15—25	123,6	420	—	1,0—1,2	4	8,5	1,0
1974	—51,8	22.IV	60—100	10—15	124,6	1500	2,1	1,3—1,6	7		1—2
1975	--50,3	8.V	50—90	10—15	124,3	1300	—	1,1—1,3	6		1,0

*Norm -- 61.5 degrees C.

**Strength corresponds to the cross-breaking strength ($R_И$) in application to console specimens of ice with a cross section of hxhx3h for a destructive force "downward" (h -- thickness of ice cover)].

Key:
1. Years
2. Sum* of air temperatures for November-March, degrees C
3. Date of the beginning of the passage of ice
4. Ice characteristics
5. Thickness, cm
6. Strength** of the main mass of ice, ton-force/m^2
7. Hydraulic characteristics at the beginning of the passage of ice
8. Level of the upper pool, m
9. Water flow rate, m^3/s
10. Level difference between pools, m
11. Speed of ice at the entrance to the narrowed channel, m/s
12. Length of the ice floating period, days
13. Ice runoff, million m^3
14. Height of ice piles on the upper dam, m

During all those years, field measurements revealed a substantial (up to 50% and more) lowering of the cross-breaking strength of the bulk of ice during spring periods. Three-layered ice was prodominant (snow-type on top, needle-type in the middle, and water-type below). However, during the periods of the passage of the ice, the range of changes in its strength was sufficiently great. The coefficient of the nonuniformity of ice strength (ratio of the strength of the strongest ice to the strength of the bulk of the ice) reached 5. This reflected the difference in the thickness and structure of the ice, the height of snow on the ice, conditions of the location of the sections of ice along the river (characteristics of the banks, peculiarities of the microclimate), etc. During the passage of ice through the narrowed channel at the construction site of the Sayano-Shushenskaya GES, large ice fields came to the site from a section of the river not over 5-6 km long. In upstream sections, the breaking up of ice was accompanied by the formation of ice gorges in which the ice was crushed and melted substantially in some years. On May 8-9, 1970, it was noted that an ice field B=160 m wide, h=0.7 m thick, $R_{И}$ = 0.15 MPa [megapascal], approached the entrance to the narrowed channel at a rate of $v_{Л}$ =1.0 m/s and stopped there for a long period of time.

Thus, according to the conditions of the passage of the ice, the width of the narrowing of 130 m was the minimum permissible width for the spring of 1970.

Difficulties with the passage of large ice fields were also observed in the spring of 1971. In the remaining years, the narrowing had a certain width margin. Observations showed that the outer and height contours of the dams and cribs of the trench of the first section and their structures accepted in the project and carried out performed their functions successfully in suffiently complicated (particularly in the spring periods of 1969-1971) ice conditions.

During all of those years, the formation of motionless accumulations of ice were observed in front of the upper dam. These accumulations protected it against the intensive dynamic influences during the floating of ice.

However, ice piles 7 m high and movement of ice onto the slope of the upper dam were observed. The height of the banks of soil forming during the movement of the ice onto the slope reached 2 m.

By moving the crib cap in the direction of the narrowed channel it was possible to divert the stream with ice in the direction of the left bank and to protect the longitudinal dam against damage by ice.

Large ice fields could not enter the narrowed channel because they were broken under the influence of higher water surface gradients at the inlet section into strips 10-30 m long along the stream.

The passage of crushed ice from the ice gorges through the narrowed channel progressed without difficulties. The force effect of such ice on the structure was smaller than during the passage of ice fields. The depths within the limits of the narrow channel after the erosion of the alluvium in the second year of the passing of ice were greater than 6-8 m. This ensured free passage of multilayered masses of ice from ice gorges within the limits of the structures.

By the spring of 1976, after the formation of the trench of the second section for passing water needed for construction purposes and ice, botton holes of the first level and the spans of the crown situated above the holes were prepared. However, in the spring of 1976, just as in the two subsequent years, the flow of water during the passing of ice was insufficient for complete flooding of the bottom holes 13 m high with a threshold mark of 114 m, and they worked as open spans 5.3 m wide at the inlet separated by 10.8 m thick piers with a flat front side. The passage of relatively large masses of ice with such size of ice-discharge spans was accomplished for the first time in the practice of large-scale hydroengineering construction. Table 2 gives basic information on the conditions of the passing of ice through unflooded bottom holes of the first level at the construction site of the Sayano-Shushenskaya GES during the spring periods of 1976 and 1977. There are a number of common characteristics in the conditions of the passing of ice during the spring periods of 1976-1978 because the lower pool during all these years (just as in the spring periods of 1969-1975) broke up earlier than the upper pool. By the beginning of the passing of ice, ice fields were situated in front of the structures in an area 2-5 km long, and 2-5 km higher were the accumulations of crushed ice from gorges. The passing of the ice was progressing in the conditions of sharp rise in the water discharge and, accordingly, in the levels caused by the passage of waves from the breaking up of ice gorges at the upper sections of the river.

Table 2

Conditions of the Passage of Ice Through the Bottom Holes of the First Level of the Sayano-Shushenskaya GES

Indexes	Years	
	1976	1977
Number of open holes during the passage of ice.	9	9
Number of openings participating in the passage of ice.	8	6
Total width of the ice-passage front, m.	42.4	31.8
Ratio of the total width of the ice-passage front to the river width in front of the structures.	0.12	0.09
Depth of stream in front of holes, m.	11	9
Date of the beginning of ice passage.	4.V	2.V
Speed of ice approach to the structures	3.3	3.1
Highest specific water discharge in the holes during the passage of ice, m^3/s.	40	30
Difference of levels at the structures, m.	4.0	3.7
Thickness of ice, m.	0.9	0.9
Cross-breaking strength of the bulk of the ice, MPa [megapascal].	0.35	0.25
Lengths of ice fields approaching the structures, m.	50-100	50-130
Greatest lengths of blocks of ice floating into holes, m.	10-15	8-10
Greatest specific discharge of ice through the holes, m^2/s.	10	11
Ratio of the specific discharge of ice to the specific discharge of water, %.	25	29
Volume of ice runoff, million m^3.	8.0	7.0

An important problem which the builder encountered in preparing for the passage of ice through the bottom holes was the problem of their icing.

Thus, by the end of February 1976, most of the bottom holes on the side of the upper pool were filled by 30-70% with ice and slush along their vertical extent. On the side of the lower pool, the middle bottom holes were plugged up with ice and slush by 60-80%. This raised the levels in front of the structures during the winter periods and increased the thickness of ice in the vicinity of the structures.

The icing of the holes caused some concern with regard to their operation during the passage of ice. By the ice-floating period of 1976, ice of up to 15 m wide was still frozen solidly in front of the inlet section. During the passage of the ice, the ice was broken in two of these holes. The extreme right-bank hole did not let the ice through, because ice was preserved in the course of the entire ice-floating period within the limits of the hole. For the same reason, holes No 7-9 did not let the ice through during the ice-floating period of 1977.

In the three years of the passing of ice through the bottom holes of the first level under comparable hydraulic conditions, the conditions in the spring of 1976 were most complex. That spring, large ice fields whose bulk was solid ice arrived to the narrowed channel in front of the structures.

At $h=0.8\div1.0$ m, $R_И=0.3$ MPa and a length of ice fields of over 50 m, they were breaking under the influence of the hydraulic drop at the inlet into the narrowed channel into strips of 15-25 m long along the stream.

Ice fields with lengths of up to 60 m, $h=0.8\div1.0$ m and $R_И=0.3\div0.4$ MPa approached the piers without breaking up.

Large blocks of ice coming to the structures could not be thrown down without being crushed. At approach speeds of 3.0-3.5 m/s, blocks of ice collapsed partially at the impact in the zone of contact and in the majority of cases cracked in the longitudinal direction.

The decisive factor facilitating the passage of ice was the submerging of the lower part of blocks of ice after the impact by the oncoming stream (Figure 3). At that time, the ice broke up and entered the spans chiefly in the vertical position. The water levels during the ice floating period reached the marks of 125.5-126.0 m.

The above-mentioned nature of ice movement through the holes is the fundamental difference of the scheme of passing the ice through narrow deep spans with wide separate piers from the schemes of passing the ice through spans of crowns with a low threshold, which ensures different requirements for ice-discharge structures. For the schemes of passing the ice through narrow spans with wide separate piers (ratio of the pier thickness to the width of the span within the limits of 1.5-2.5), the problem of prescribing the width of the spans loses its original value. The problem of ensuring the depths of the stream in the spans of over 10 m for approach speeds of the stream of over 2.5 m/s acquires particular significance.

The high intensity of the arrival of ice to the bottom holes during all those years resulted in the plugging of the upper part of their inlet cross sections by horizontally floating pieces of ice. Under these conditions, there formed

Figure 3. Breaking of Ice Fields During Their Passage Through the Bottom Holes of the First Level on 4 May 1976

Figure 4. Passage of Ice from Ice Gorges Through the Bottom Holes of the First Level at the Sayano-Shushenskaya GES on 2 May 1977

an ice barrier of up to 30 m in length along the stream in front of the structures. When the approach speeds were up to 3-4 m/s, blocks of ice submerged under one another while approaching the ice barriers, and the accumulation of ice did not spread on higher sections of the river.

During the passage of ice through the bottom holes at the construction site of the Sayano-Shushenskaya GES, it was observed that the inlet cross section was plugged up only partially by pieces of ice which were in a vertical position. However, even when the arrival of ice to the structures was relatively high (specific discharge of ice in the holes up to 25-30% of the specific discharge of water), the inlet cross section of the bottom holes were never completely plugged up by ice up to 1 m thick at a cross-breaking strength of up to 0.4 MPa.

This is confirmed by earlier theoretical studies on this problem [5].

The passing of 10-point ice from ice gorges through the bottom holes at the construction site of the Sayano-Shushenskaya GES continued for 1.5-2.0 hours. Two and three-layer accumulations of ice were up to 10 m in size, where 0.6-1.2 m thick with $R_{И}$ =0.4 MPa. Individual strong blocks of ice (h=1.0 m, $R_{И}$ =0.4 MPa) which assumed a horizontal position stopped frequently at the inlet to the holes (Figure 4). Under the effect of the coming masses of ice and the stream, the accumulations of ice at the inlet to the holes were dispersed and moved into the holes chiefly in a vertical position.

The conditions of the passing of the ice through the bottom holes were considerably easier due to the absence of lumber in the accumulations of ice.

Conclusion. During the construction of the Sayano-Shushenskaya GES, the passing of the ice was accomplished in the course of seven years through a narrowed channel 130 m wide, and through the bottom holes of the first level 5.3 m wide in the course of three years. The bottom holes were not flooded during the ice floating period and worked according to the scheme of narrow deep spans with wide separate piers.

It was established by observations that the outer contour and the height of the earth dams and cribs of the trench of the first section and their designs accepted in the project and carried out fulfilled successfully their functions in sufficiently complicated (particularly in the spring periods of 1969-1971) ice conditions.

For the first time in the practice of hydroengineering construction, the passing of comparatively large ice drifts was performed through ice-discharge spans 5.3 m wide. The decisive factor ensuring successful passing of ice under these conditions were the appropriate hydraulic conditions (stream depths of over 9-10 m and approach speeds of over 3 m/s).

Consideration of the experience of the hydroengineering complexes of Siberia built on rivers with heavy floating of ice made it possible to make simple and economical decisions on individual problems (giving up high covering of cribs, use of earth dams, and use of narrow bottom holes of the first section). In the future, when using schemes of passing the ice through narrow bottom holes in more severe climatic conditions, it is necessary to consider the possibility of their substantial icing and intensive ice formation in them in the course of winter periods.

The solution of complex problems of the passing of ice during the construction of hydroengineering complexes in medium and low section of large rivers of Siberia requires further field observations at the hydroengineering complexes under construction and improvement of the calculation and modeling methods of studies.

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10.233
CSO: 1822

ELECTRIC POWER AND POWER EQUIPMENT

NEWS IN CONSTRUCTION AND OPERATION

Moscow GIDROTEKHNICHESKOYE STROITEL'STVO in Russian No 8, Aug 79, pp 55-56

[News items]

[Text] The flood at the Yenisey River started rapidly and unexpectedly. On 17 May, the water flow rate of the Yenisey was 1950 m^3/s, and on 19 May it was 2775 m^3/s.

Two spillway openings of the second level and an open spillway started working. On 21 May, the inflow of water was 5200 m^3/s, on the 22nd -- 6300, and on the 23rd of May 7000 m^3/s. The builders mobilized all available resources, and in an unusually short period of time (before 23 May, instead of 1 June according to plan) erected the first poles along the entire head front up to the design mark. Dam beams were installed in open spillways and gates in the spillway openings according to the design, a large complex of cementation jobs was done, and the bottom openings of the first level were closed.

When the passing of the Yenisey water during the flood period was studied, the aeration of the stream (saturation by air) was not sufficiently taken into consideration. On 22 June, the diversion of aerated streams of water was started through a water-dividing wall, 29th and 28th sections, at a distance of up to 30 m in the direction of the GES building. The available pumps could pump about 8000 m^3 of water in one hour, but it was coming at a rate of about 40,000 m^3. The trench started getting flooded. There was a danger that the first unit put into operation last December might get flooded.

At 10 hours 44 minutes, 23 May, the first unit was stopped, and mass evacuation of the equipment was started. Oil tanks were sealed tightly and all systems were shut. Passages to the turbine and generator well were tightly sealed by electric welding. The hydraulic unit was flooded. The gantry for transporting concrete to the main concrete-laying cranes was put out of commission earlier. Some dam beams in open spillways were raised and blown up, and gates in spillway openings were raised (wherever possible).

The builders of the dam were not at a loss what to do in this very complex situation. They showed self-control, were well organized and persistent. They struggled with the raging elements around the clock. The system of concrete delivery was reexamined. A 150-meter belt conveyor was built from the construction site of the GES to the third poles. The new system was completed in the beginning of June and made it possible to speed up the laying of concrete in the structures of the hydroengineering complex.

The construction of a transportation tunnel for trucks with concrete from the right bank to the dam of the complex is nearing completion.

The water flow rate in the Yenisey is decreasing. Powerful floating pumping stations capable of pumping up to 17,000 m^3 of water from the GES trench in one hour have been assembled. A temporary deviding wall between the trench of the GES building and spillway dam was built. On 12 June, the pumping stations started pumping the water out of the GES trench. Full dam walls were installed at the spillway of the 39th section.

On 19 June, the unit was dried and the installers started restoration jobs. On 21 June, the builders removed mud, oil, and slime from the crater of the second hydraulic unit, and on 22 June, it was delivered for the installation of the generator stator.

From 14 to 21 June, a committee of the USSR Minenergo [Ministry of Power and Electrification] worked at the construction site in order to develop measures ensuring the introduction of two more hydraulic units this year. The implementation of the developed measures makes it possible to ensure the introduction of the second and third units in 1979.

On 22 June, the construction headquarters of the Sayano-Shushenskaya GES confirmed the possibility of the introduction of two additional hydraulic units in 1979.

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On 6 June 1979, a second hydraulic unit started idling at the Kegumskaya GES. After the necessary measurements, the unit will undergo a complex testing.

The concreting of the covering of the volute chamber of the third turbine has been completed.

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At the construction site of the Ingurskaya hydroelectric power station in the Georgian SSR, the installation of the fourth turbine with a capacity of 260,000 kW was started one month ahead of schedule. The laying of concrete into the arch dam is progressing on schedule.

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The first hydraulic turbine of 78,000 kW was put into industrial operation in July at the Nizhnekamskaya GES which has a design capacity of 1,248,000 kW.

The concreting of the volute chamber of the second hydraulic unit has been started. Its turbine is being produced at the LMZ [Leningrad Metal Plant] and will be completed in June. The assembly of large sections of the turbine stator for the hydraulic unit No 3 was done at the erection site. It is planned to complete the assembly in the crater in July 1979.

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All construction jobs for the plant unit at the Yushkoozerskaya GES on the Kem' River have been completed. It is planned to complete the rotor at the LMZ in the third quarter of this year.

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The construction of the Cheboksarskaya GES has entered a new stage. They started receiving hydraulic equipment. It is being manufactured to order of the All-Union Key Construction Project at the enterprises of Leningrad, Novosibirsk, Kakhovka, and many other cities. Stators of the first two turbines have been delivered and their installation was started in the first half of June. The Cheboksarskaya hydroengineering complex is the final stage of the Volga power cascade. When it starts operating, the reconstruction of the great waterway along the entire length of the Volga will be completed.

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The most difficult section at the construction of the Arpa-Sevan tunnel was excavated ahead of schedule at the end of May of this year by the brigade headed by S. Boryan. This made it possible to start its facing with concrete at an accelerated pace. The tunnelers struggled with the elements at a depth of 1.5 kilometers under the alpine Vyrdenisskiy Range. Thermal water, gases, and high temperature made their work difficult. However, their extensive experience and excellent cooperation of all services and subdivisions helped them. Highly productive equipment ensured a rapid pace of tunneling. Less than 300 m are left to complete the construction of the tunnel.

The 48-kilometer Arpa-Sevan underground route will be completed this year. It will change the channel of the Arpa River, directing its water into the Sevan.

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Three billion m^3 of water discharged into the reservoir of the Ust'-Ilimskaya GES during the days of the spring flood. This ensures a stable operating condition of the hydroelectric power station during the summer navigation period and will ensure the possibility of maintaining a high water level for navigation on the Angara River.

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Having covered more than 1000 kilimeters along the Zeya, Amur, and Bureya rivers, river transportation workers delivered cargoes to Talakan for the builders of the Bureyskaya GES for the first time since the beginning of the navigation season. The needs of the new Far Eastern construction site in structures and equipment are growing every month. During the summer and fall, it is necessary to deliver to Talakan twice as many parts of residential homes as last year. The Amur River transportation workers undertook a considerable part of deliveries. Dredging work was done on the 80-kilometer section of the Bureya River, and sandbanks were cleared. During the summer shallow-water period, the water level in the Amur and Zeya rivers will be maintained with the water from the reservoir of the Zeyskaya GES.

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In Dagestan, preparatory work is being done for the construction of the Irganayskaya GES. The cutting of a transportation tunnel through a 4 km-long mountain range has been started.

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Specialists of the Far Eastern branch of the institute "Energoset'proyekt" [All-Union State Planning, Surveying, and Scientific Research Institute of Power Systems and Electric Power Networks] have completed work on the creation of a scheme of external electric power supply of the eastern sector of the Baikal-Amur Railroad whose builders are now completing the construction of the Urgal -- Komsomol'sk-on-the-Amur section this summer, one and a half years ahead of schedule. This scheme is used now for designing 220 kV electric power transmission lines and substations. The members of the branch have delivered blueprints for the electric power transmission lines from the Zeyskaya GES in the direction of Khabarovsk.

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On 3 June, our country celebrated Land Meliorator's Day. Land reclamation has become one of the main trends of the technological progress in our country's agriculture. The scale of the land reclamation construction in our country is larger than anywhere in the world. During the three years of the Tenth Five-Year Plan, 4.6 million hectares of irrigated and drained land was delivered for use, and 23 million hectares of pastures were irrigated. The construction of the Karakum canal in Turkmenistan and of the Kuybyshev irrigation and watering canal in the Volga Region is continuing and the construction of the Kakhovskiy irrigation system is nearing completion. Water management jobs are progressing extensively in all zones of our country.

Land reclamation has been put on an industrial basis. Land reclamation is done not only with the aid of reliable and effective machines, but also the most modern technical equipment. The results of the reclamation work are becoming more and more tangible. Constituting only about 9% of the arable land, the reclaimed land yields almost 29% of agricultural products. The land reclamation workers marked their holiday with new labor successes.

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At the lower reaches of the Amu Darya River, the construction of the Central Asia's largest Tuyamuyunskaya hydroengineering complex is in full swing. This is one of the most crucial periods for the builders: they are preparing to dam this rapid river. The workers of "Tuyamuyungidrostroy" are working at an accelerated pace. Each one of them understands that the completion of the water reservoir will make it possible to reclaim and irrigate 500,000 hectares of new land.

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The salt lake Sasyk in the Black Sea Region will turn into a freshwater lake. The construction of a 14-kilometer canal has been completed. It will connect the banks of the Danube and Sasyk Lake. By the end of this year, the Danube water will start flowing through this canal into the lake. Preparations for this experiment are now under way. Powerful pumps are pumping salt water from the lake at a rate of 25 m^3/s and dump it into the Black Sea.

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ELECTRIC POWER AND POWER EQUIPMENT

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ADVANCED SOLUTIONS IN CONSTRUCTION OF THE VOZEYSKAYA 220 KV SUBSTATION

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 3, 1978 pp 28-32

[Article by engineers A. I. Brenner, T. S. Burukhina, Ya. I. Kogan, L. P. Sidorenko and A. I. Khokhlov]

[Text] Construction of the Vozeyskaya 220 KV substation has been commissioned to the Elektrostroypodstantsii trust to supply electricity to facilities located in the northern part of the Komi ASSR. The area of the substation, which is situated on untillable land to the north of the Pechora railroad station, is free of development and is covered with mixed forests of average density.

The relief of the site is level, with small grades. The southern part has a grade with a difference in absolute elevations of up to 4 m and in the northern part it is to 1.5 m.

The soil conditions of the site are as follows: from the surface and down to a depth of 3 m are a dark-brown peat with average degradation with wood-pulp remains and dusty loams with peat formations in spots, interlayered with sand. The soils show much frost heaving, and they have the following characteristics: γ = 1.9-1.85 ton/m^3; C = 2.8-1.0 kN/m^2; φ = 18-17°; E = 1400-800 kN/m^2. The ground water level is 0.3 m below ground.

The region for construction of the facility is characterized by harsh climatic conditions: the average yearly duration of the frost-free period is 132 days; the average depth of the snow cover is 55-80 cm; the depth to which soil freezes is 208 cm; the normal dynamic wind pressure is 490 N/m^2 and the average annual absolute minimum temperature is -44°; the site is in ice cover Region II.

The design for the substation under examination, which was completed by the North West Department of the Energoset'proyekt Institute, included the following technical decisions: installation of two 220/35/10 KV transformers with a capacity of 40mV·A each with voltage regulators were specified; a circuit for two units with isolating switches and automatic jumper connections from the transformer side was adopted at 220 KV; at 35 KV, a tapped system of busbars (Fig 1, a) was selected.

A decision for the portals to the busbars to be made from precast reinforced concrete components (those for the 220 KV open switchgear unit to be made from centrifuged concrete and those for the 35 KV open switchgear unit to be made from vibrocompacted concrete) was adopted. The supports under the equipment were to be made from precast reinforced concrete USO-5A supports with USO-5A-1 extensions. Their installation in drilled foundation pits with subsequent concreting was specified.

Frame-panel buildings are specified for the substation control point (SCP) and the covered switchgear unit (CSU). There are casing type precast reinforced concrete foundations under the columns. It was proposed that TPSKh panels 300 mm thick and made from claydite concrete be used for the enclosing structures. The buildings have a gable roof made from roll materials with a heater made from foamed concrete with a density of 500 kg/m^3. The proposed dimensions for the buildings are as follows: SCP - 12 x 24 m; CSU - 6 x 24 m.

The erection of production facilities was also specified by the design: an underground oil catch tank with a volume of 85 m^3 made from precast reinforced concrete, a fire tank with a volume of 150 m^3 made from precast reinforced concrete, intrasite roads, oil discharge networks, waterpipe networks and fencing for the substations.

The construction organization was to have erected the substation within 6 months, whereas the normal construction period is 15 months. Having to carry out operations in the harsh natural climatic conditions of the Far North, the isolation of the site from plants and outfitting bases, the lack of roads, as well as the technical decisions which were adopted did not permit the carrying out of the set task.

In connection with this, it was necessary for the trust to develop a comprehensive program for optimizing design decisions based on the adoption of more advanced designs in order to reduce labor costs and construction periods to a minimum. Particular attention was devoted to decreasing the weight and volumes of loads which must be transported over the winter road from the Pechora station in short periods of time, to reducing the typal dimensions of the structures and to insuring maximum completeness of the sets of equipment and structures delivered to the site.

New decisions were developed by the trust as a result of an analysis of the most advanced designs, substation layouts and industrial construction methods.

The 220 KV OSU was made from a portalless design with rigid busbars and anchor fasteners for the 220 KV high-voltage line outlets* The rigid

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*The work "Investigation and development of structural decisions for complete 220 KV transformer substations" from the Gor'kiy Department of the Energoset'proyekt Institute was used in the designing stage.

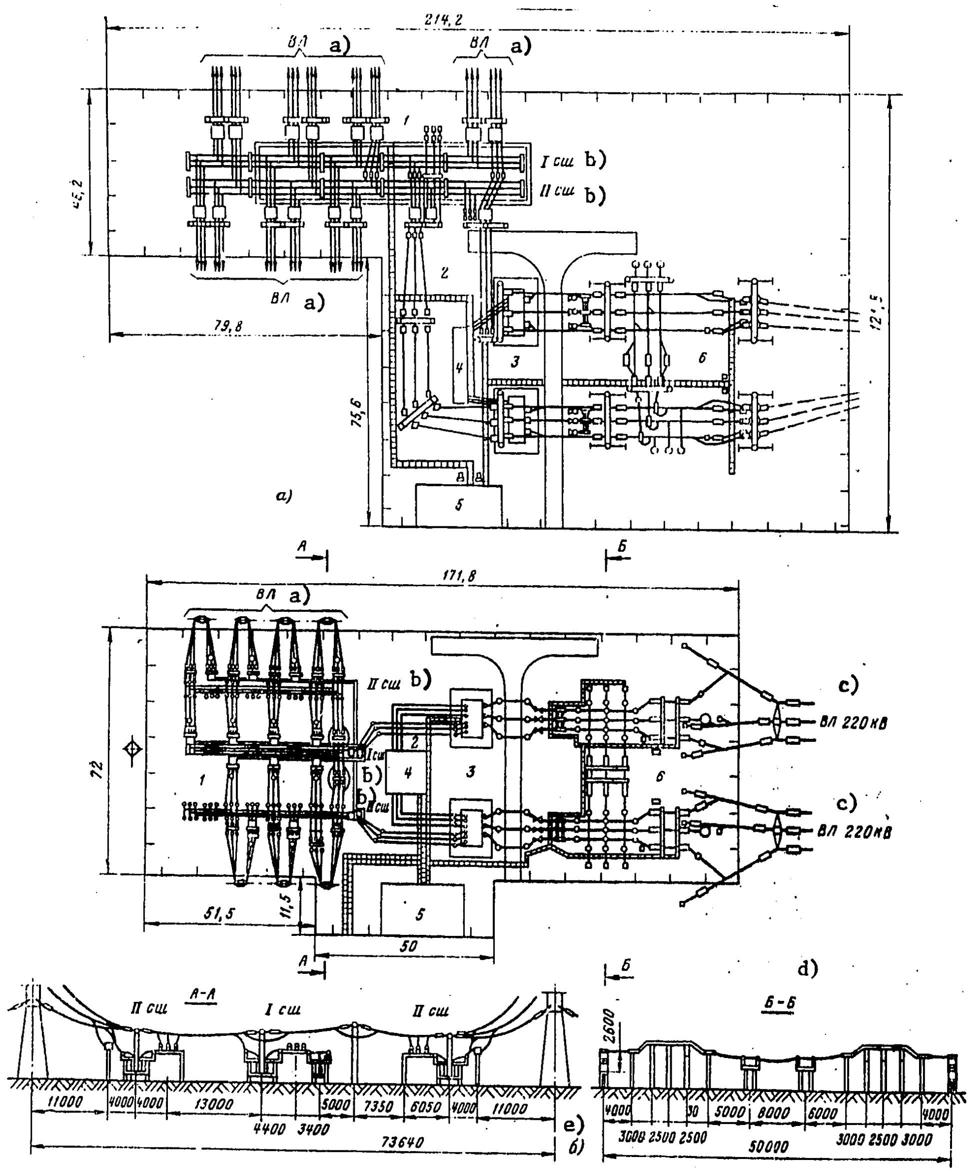

Figure 1. Plan of the Substation

Key:

a. According to the original plan
b. As proposed by the trust:
   1. 35 KV OSU
   2. Flexible connectors
   3. Transformer group
   4. CSU
   5. SCP
   6. 220 KV OSU

a) HV lines
b) Collecting bars
c) 220 KV HV lines
d) B-B
e) b

busbars were designed to be double-decked, made from tubing 64 mm in diameter and 8 m long. The material for the tubing was AV-T-1 alluminum alloy. The busbars on the lower deck have bolt connections, with a span of 16 m, and they rest on insulators (at the 6-meter mark). The rigid busbars were connected with the columns of circuit breakers and isolating switches by a flexible connector. The upper deck of busbars was supported by props (at the 8.2-meter mark) which were resting on the busbars in the lower deck (Fig 1, b). The site for the busbar to cross the road to the transformers is rigid (at the 10-meter mark). This satisfies the over-all dimensions being set by PUE [specifications for setting up electrical installations]. The outlet to the 220 KV HV lines was specified without portals, with the cables being fastened using anchored guy wires (Fig 2).

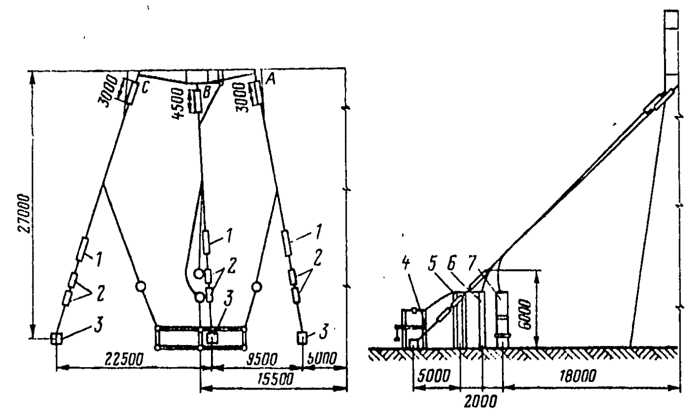

Figure 2. Plan of the 220 KV HV Line Outlets

Key:

1. Insulator chain
2. Turnbuckle
3. Anchor
4. Isolating switch
5. High frequency suppressor
6. Bus support
7. Coupling capacitor

A U-shaped layout for one of the sections was developed for the 35 KV OSU. This arrangement permitted us to use rigid busbar sets and unitized equipment produced by the Kuybyshev plant "Elektroshchit." The rigid busbars of the lower deck (at the 3.2-meter mark) rest on the columns for the units' isolating switches. In those places where insulation of the units was not specified by the layout, the busbars rest on special supports. As is the case in the 220 KV OSU, the upper busbar deck is supported by braces (at the 3.8-meter mark). The outlet to the 35 KV lines was specified without portals, with the cables being fastened to the units.

The rigid busbars used in the 220 KV and 35 KV OSU have a number of advantages: in light of the insignificant sagging of rigid busbars, it became possible to use switchgear designs of minimum height, which, in turn, permitted us to avoid using portals; it was possible to use the simplest support designs because of the absence of constant stresses; the low profile insured good visibility of the busbars and equipment; the support insulators became more accessible for cleaning.

Short, flexible 35 KV couplings fastened to tubular supports were used for the transformer group. The transformer was approached on the 220 KV side on the rigid busbar.

USV-5A supports 6.4 m long were used as supports under the equipment, on the basis of the specific soil conditions, and this permitted us to reduce vertical planning operations significantly. Here, tubular steel supports developed by the trust were used in place of reinforced concrete components necessary for increasing the length of the piles to the rated height. The lower, bearing part of the support consists of a metal plate with rigidity fins (proposed dimensions 200 x 200 mm). The plate was welded to the metal insert of the pile head. The upper part of the column was made to be detachable (proposed dimensions 300 x 300 mm), and it was made from plate steel and had rigidity fins welded to it. The tubular pile may be cut off at the proper place in the upper section to insure the necessary support height when the piles are not driven particularly precisely. After the reference mark had been trued, the upper support section was seated on the pile and welded to its body with rigidity fins.

The decision was used for the first time in construction of the Usinskaya 220 KV substation, thereby reducing the weight and volume of the structures which had to be transported significantly.

The fencing designs for the SCP and CSU buildings, produced by the Energotekhprom enterprise, were executed using folding metal fencing (SZR) with complex panels made from profiled sheet metal and the effective PSB-1 heater. The buildings were mounted on USB-5A piles (the 10 KV CSU). A four-row mounting for the KRU [expansion unknown] distribution heads with two service corridors was developed instead of the customary two-row layout with the aim of making maximum use of the volume of the building. The total area of the building is 12 x 12 m. The cabinets were connected using rigid connectors. The KRU distribution heads were set on metal ceiling beams attached to the USV-5A piles and raised one meter above the level-grading mark. Power and pilot cables were laid along metal shelves attached to the piles in the sub-floor area which was formed. Power cable leads from the CSU were made in two reinforced concrete troughs one meter wide which were on the ground. The ceiling between the KRU distribution heads was made from reinforced concrete slabs (Fig 3, b, b).

The SCP building design was decided upon in much the same way as the 10 KV CSU building, but with an elevated, heated floor. Cable was laid in the control panel area without conduits in this case. A space 325 mm wide was left between the building walls and the reinforced concrete floor slabs. Boxes with three cable racks were hung from the metal parts of the walls over the spaces. The cables were led into the building in reinforced concrete conduits placed under the walls. The cables were drawn from the conduits into the box and laid out along the racks. The cable channel is formed beneath the panels by installing relay and power panels on No 16 channel irons. As a result, the cables were laid in bunches in the space beneath the panels in between the channel bars. The power cables for the panels supplying power for our own needs were brought in from the end of the building to insure the necessary bending radius.

The outer fence for the substation, designed to be made from reinforced concrete columns and foundation slabs with chain-link fillers, was replaced by a column-less chain-link fence 1.8 m high, developed the Long Range Transmissions Department of Energoset'proyekt Institute together with the Elektrostroypodstantsii trust.

The cable was laid in metal conduits attached to the equipment in the open switchgear units.

Specific organizational-technological preparations were carried out taking the design decisions which had been adopted into consideration in order to insure that the equipment for the facility was assembled accurately into sets. After receiving the technical specifications, a group of specialists departed for the construction site to evaluate local conditions. Blueprints, which were coordinated with the planning organization, were drawn up according to the technical decisions which were adopted. A construction organization plan and a plan for complete outfitting of the substation facilities with structural designs and building materials, with their quantities and optimum delivery having been determined, were also drawn up. The peculiarities characteristic of northern conditions were taken into consideration: rehandling of loads, mainly in the wintertime, the impossibility of on-site assembly of structures, etc. A list of the basic operations for the preparatory and the main construction periods, their volumes, total labor costs, requirements for working cadre and equipment were included in the work schedule. Deadlines for finishing construction operations on the facilities and their scheduling for equipment installation were determined using the schedule along with a time schedule.

Power supply for construction was specified by the construction organization plan to be obtained from a portable APEDS-200 power plant. Water supply was also provided for. Organizationally, the complete cycle for erecting the substation was divided into two periods: the preparatory period and the main period. The following types of operations were carried out during the preparatory period: optimization of the design decisions; development of blueprints for the construction and the electrical parts of the substation; complete outfitting of the facilities with sets of designs and materials; organization of the construction base for the substation; moving the construction district; transporting the construction equipment and machinery, housing trailers, materials, structures, etc. to the Pechora station by rail and from there by winter road.

Рис. 3. ЗРУ 10 кВ.
а — общий вид; б — план расположения шкафов КРУ: 1 — шинопровод 10 кВ; 2 — шкаф КРУ.

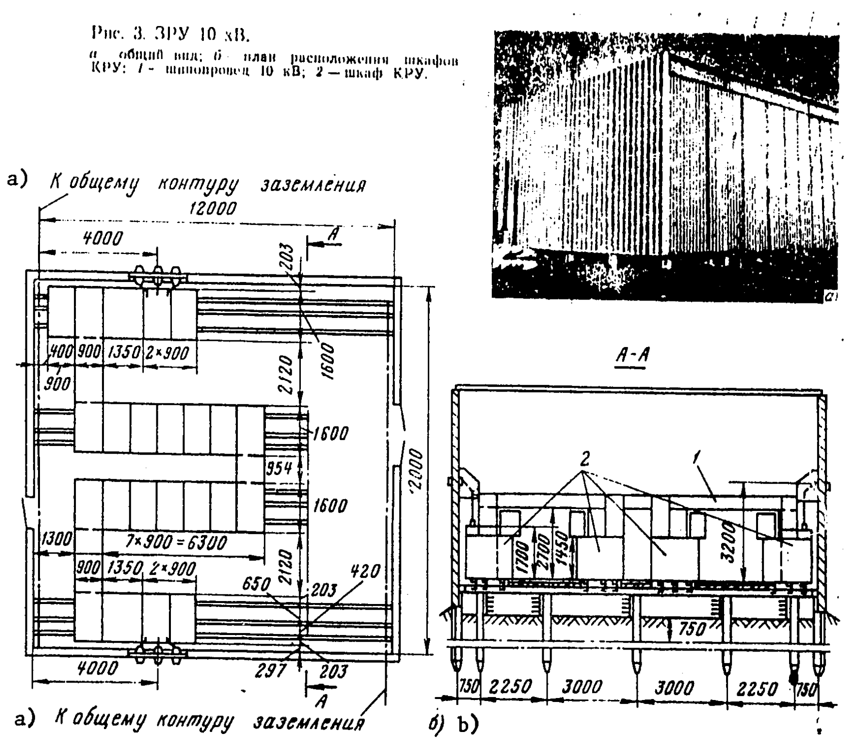

Figure 3. The 10 KV CSU

Key:

- a. General view
- b. Plan for KRU distribution head layout:
- 1. 10 KV busbar conductor
- 2. KRU distribution head
- a) To common ground circuit
- b) b.

Because of the accurate organization of operations by Mechanized Column No 52 and the trust's Production and Industrial Outfitting Administration, all operations included in the preparatory period were carried out by the set deadlines.

In the primary construction period (February-June), the construction and installation operations were carried out. This period began with preparation of the site and driving of the piles. A multi-unit brigade consisting of 20 men did the work. According to the cost-accounting brigade contract which was signed, the brigade took on the obligation to do all the work in 4 months and to have the 220 KV and 35 KV OSGs, the buildings for the SCP and the CSU, the oil flow and waterpipe networks ready for installation, i.e. to perform work for a total of R 387,000. In fact the work was done for R 420,000, the average output per worker in the brigade being R 15,700 (converted to an annual basis). The trust's Production and Industrial Outfitting Administration delivered the necessary materials and structures according to plan, in accordance with the outfitting plan. The metal structure workshop of the Production and Industrial Outfitting Administration's outfitting base produced the tubular columns and supports under the equipment and the metal structures for the floors of the SCP and CSU units. They then dispatched them in complete sets to the construction site.

The following equipment and machinery were used during construction of the facilities: a VVPS-20/11 pile driver, an MRK-750 drilling unit, two K-156 truck cranes, a TK-53 tractor crane, a T-180 bulldozer, an S-100 bulldozer, a GTT Tread-type prime mover, an APEDS-200 portable electrical power plant and GAZ-66, Ural-375, MAZ-543 and MAZ-537 trucks.

The machinery dispatched from mechanized column No 52's base was carefully checked and equipped with spare parts; experienced operators were chosen to work with them.

As a result of efficient organization of the preparatory and main building and installation operations and the practical solution of all questions concerning outfitting of the facilities with materials and designs, and due to the constant assistance on the part of the client (Komienergo) and local party and soviet organizations as well, erection of the substation was completed within the planned deadlines.

Optimization of design decisions permitted us to reduce the consumption of basic materials and, correspondingly, the weight of loads to be transported (by 2.5 times) (Cf. table).

It is necessary to note in particular that the total consumption of precast reinforced concrete was reduced by 65 percent. The insignificant 8 percent increase in metal consumption was caused by the use of collapsible buildings. When constructing similar facilities in the future, metal consumption may be reduced significantly by using rapidly erected buildings made from precast reinforced concrete with a high level of availability from the factory.

The total labor expenditures for construction of the substation were reduced to 1/5 of their former level, significant reduction being achieved

a) Объект подстанции	b) Сборный железобетон, м³	c) Металлопрокат, т	d) Масса перевозимых грузов, т
e) ОПУ	114,65/59	12,35/37,04	281,8/187
f) ЗРУ	163,2/27	13,6/26,54	243,8/89,9
ОРУ 220 кВ g)	207/79,8	30,99/32,89	640,1/156,9
ОРУ 35 кВ h)	120,36/59,6	26,3/27,72	382,8/163,9
i) Трансформаторная группа	122,16/53,76	28,17/19,16	311,1/138,6
j) Ограда подстанции	62,3/—	30,82/9,64	880,9/9,6
k) Итого . .	789,7/279,2	142,3/152,9	1941/746

1) Примечание. В числителе даны показатели по первоначальному проекту, в знаменателе — по переработанному.

Key:

a. Substation facility
b. Precast reinforced concrete, m^3
c. Rolled metal, ton
d. Weight of transported loads, ton
e. SCP
f. CSU
g. 220 KV OSU
h. 35 KV OSU
i. Transformer group
j. Substation fence
k. Totals
l. Note: Values based on the initial design are given in the numerator and those for the re-worked design are in the denominator

due to fabrication of structures at plants and the trust's outfitting bases (buildings with a high degree of factory availability, the 35 KV OSU units, the rigid busbars, cable support conduits under the equipment, etc). The area occupied by the substation was reduced by 27 percent. The economic effect from the use of advanced structural designs at the substation was R 134,000.

The State commission which accepted these facilities recommended that the developments proposed by the trust for erecting similar substations under conditions in the Far North be utilized.

9194
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ELECTRIC POWER AND POWER EQUIPMENT

UDC 621.311.4.001.2

FAST ERECTION OF 35 - 220 KV SUBSTATIONS

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 4, Apr 78 pp 3-4

[Article by G. L. Korobov and I. Sh. Piven', engineers]

[Text] The plan for the further development of power in the 10th Five-Year Plan period calls for building about 9000 35 to 220 kv substations. This mass erection of substations focuses the attention of designers on a constant search for new efficient solutions that would make it possible to reduce sharply construction time, material intensiveness and the cost of the buildings as a whole with maximum industrialization of the construction-installation work.

One of the results of the work of the Northwestern Department of the Energoset'proyekt Institute in this direction was the creation of a series of fast-erection substations (BMP).

The basic difference between the BMP and traditional substations is a new in principle approach to the design solution of individual elements and their mutual layout. This makes it possible to eliminate the use of portals for busing and to reduce to a minimum (and for substations made according to simplified arrangements, practically eliminate) work on erecting foundations for the installation of unit equipment.

The first studies were made on a 110/10 kv single-transformer substation in an arrangement of a unit-line-transformer with an isolating switch, and on a 110/10 kv two-transformer substation in a bridge arrangement with a switch in the cross connection and isolating switches in the transformer circuits.

The high voltage unit equipment is mounted on a common structure supported at one end on the end line pole, installed at the center of the substation and at the other end -- on the 6 to 10 kv RU [Distribution system] (types KRUN or ZRU), or on a mobile UTB [expansion unknown] unit. Thus, the high voltage equipment of each two-transformer substation is located on different sides of the pole perpendicular to the side of the approach of the 110 kv high voltage line; the power transformers are installed on the low voltage RU (RUnn) on the continuation of the unit axes not far from the exterior fence.

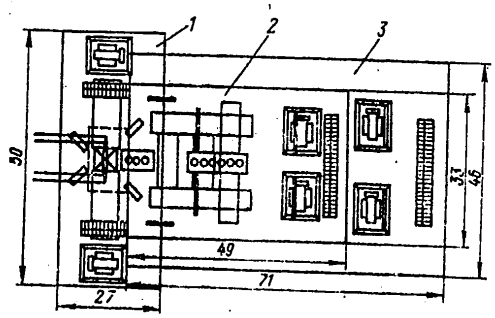

Fig. 2. Sites of various substations (example of a 110 kv substation site at Koltushi).

1. BNP
2. KTPB
3. Typical substation

Table

Indicator	BMP	According to typical design	Savings, %
Area of substation, m^2	1360	3600	62
Total consumption:			
concrete, m^3	87	204.5	57.5
structural steel, tons	12.2	14.7	17
control and power cables, km	2.6	4.4	41
Total cost of construction, 1000 rubles	244.5	331.1	26.2
Including work:			
construction	42.98	94.38	55
installation	40.15	42.12	5
Labor, men-shift	1573	2400	34.5

The Table shows a comparison between BMP and traditional technical-economic indicators (as applied to the 110 kv Koltushi substation).

When necessary, the cross connection equipment between the units is located on the two other sides of the line pole and is installed on individual foundations.

The arrangement of all substation elements adopted provides easy access to and safe servicing of the equipment, including each unit individually (while other units remain in operating condition) using series produced machines.

Detachable links are provided in the enclosure should it be necessary to bring in machines or take out equipment.

Busing of all the ORU [Open distribution system] (with the exception of the sections between unit elements and switches in the cross connections which are made of aluminum pipes) are made mainly with flexible conductors.

Taking into account the arrangement features of a given substation, the RUnn is divided into two parts with the electrical connection between being either flexible cable or bus cross bars.

To locate relay protection apparatus, there is an OPU [expansion unknown] building at the substation made of "sandwich" panels, UTB units and other well-known structures using a great deal of prefabricated material. Cables are laid either in the open or in metal pipes in prefabricated trays.

Since the end pole is located in the center of the substation site and, therefore, all substation elements are located within the protection zone of this pole, special means for lightning protection of the equipment are not required.

The 110/6 kv Koltushi substation is an experimental industrial prototype of the first substation of the BMP series, being built by the Sevzapelektroset'-stroy Trust.

When BMP series production is organized under plant conditions, this effect will be even greater.

It should be noted that the area allotted for the BMP is even smaller than the area occupied by the KTPB (Fig. 2).

In the future, it remains to develop a 35 to 220 kv BMP series using unit and bridge arrangements on the high voltage side with two- and three-winding transformers.

After accumulating sufficient experience on building and operating the BMP prototypes, it is advisable to change over to the manufacture and complete delivery of such substations by corresponding plants.

2291
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ELECTRIC POWER AND POWER EQUIPMENT

UDC 621.311.4. 002 "4"

BUILDING 110 KV SUBSTATIONS ACCORDING TO COMPREHENSIVE DESIGN

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 4, Apr 78 pp 4-7

[Article by G. P. Grosman, engineer]

[Text] Until recently the Energoset'proyekt Institute developed typical comprehensive substation designs for a limited number of arrangements. The basic efforts of the institute were directed to the development of individual structures, units and distribution systems (RU) that make up substations according to typical arrangements. By 1977, unit development spanned the entire range of elements.

At present simplified arrangements of substations are designed basically for 110 kv with ORU (Open distribution systems) of the highest voltage and up to 63 megavolt-ampere transformers. In 1977-1978, about 500 complete substations (single-transformer) will be built for an annual requirement of 1300 units. It will be necessary to build 800 substations on individual projects on the basis of equipment being supplied in bulk. Obviously, the time has come to create comprehensive designs of substations with the most frequently used ORU arrangements.

According to the Energoset'proyekt Institute data for 1974-1975, of the 14 typical ORU 110 kv arrangements, only 5 were used in 6 to 38% of the cases covering 86% of the requirements. The remaining arrangements were used in 1.3 to 2.9% of the cases. Although 2 years of statistical data cannot serve as a basis for introducing radical changes in design technology, however, judging by preliminary analysis, the experience of a typical comprehensive substation design for the most used arrangemonts should justify itself.

Building substations according to typical comprehensive designs provides a uniformity of technical solutions, simplifies them and makesit less expensive to design and build, and eases the supplying of facilities under construction with structures, equipment and materials.

Calculations made show that after the development of a typical comprehensive design, taking into account the most frequently used arrangements, the typicalization percentage will be about 90.

In a typical comprehensive design, previously developed typical designs of units and structures are being used which are being applied at present in concrete designs.

On the basis of design and construction experience in recent years, certain changes were introduced in these units which made it possible to reduce the distances between the circuit breakers in the transformer circuits and eliminate circuit breakers ahead of the isolation switches in the 110 kv transformer circuits etc. (see Fig.)

The design is intended for use in all climatic belts with the exception of northern regions where special equipment is required, as well as high mountain regions. In air-polluted regions, design corrections and the use of stronger insulation are permitted.

A typical comprehensive design was developed for two substation modifications:

with two and three-winding transformers (110/10 and 110/35/10 kv) with a capacity of up to 16 megavolt-amperes with the possibility of replacing them by two 25 megavolt-ampere transformers;

with two transformers with a capacity of up to 46 megavolt-amperes which, if necessary, could be replaced by two 63 megavolt-ampere transformers.

Single-tranformer substations can easily be designed on the basis of the two-transformer design.

Designs are being developed for three versions of the electrical circuits for the 110 kv ORU: two units with isolation switches and a nonautomatic cross connection from the line side; the same with an automatic cross connection from the transformer side; a bridge with a switch in the cross connection and an isolation switch in the transformer circuits.

An arrangement is being adopted for the medium voltage (35 kv) with a one bus system sectionalized by a switch; at a 10(6) kv voltage: a one bus system sectionalized by a switch, two bus systems sectionalized by switches with double reactors at the inputs to the low voltage transformers and two bus systems sectionalized by switches.

In applying a typical design of an RU arrangement to various voltages, the selection made depends upon the type of connection of the substation to the network, the power of the transformers being installed, the magnitude of the short circuit currents, the number of 10 kv bus sections, the number of lines being connected and a number of other factors.

The basic element of a substation is the transformer on which the switching arrangement, the grouping, the structural execution and the operation depend. In this connection, it is especially important to provide a uniform solution for the transformer installation units and their connections to the distribution systems of all voltages which will facilitate raising the

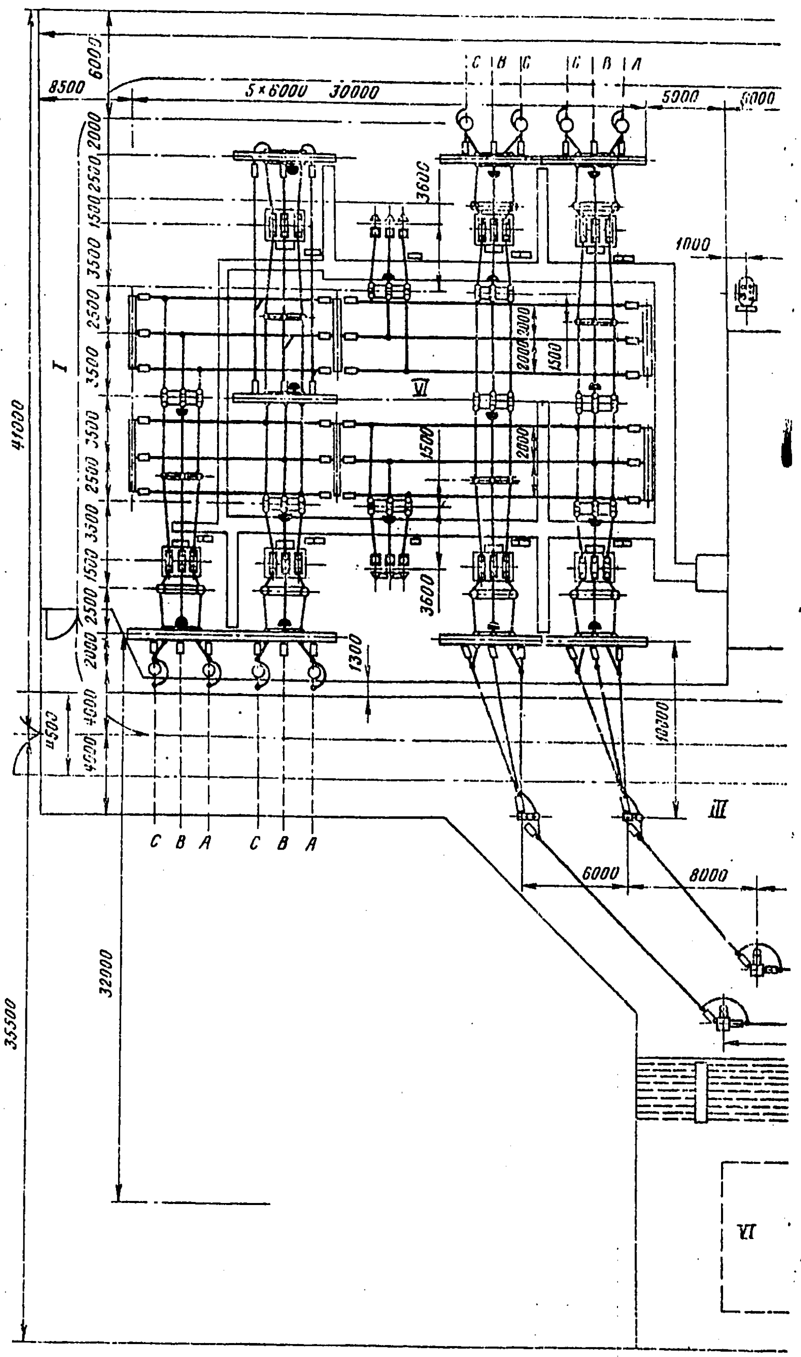

Fig. Version of a 110 kv substation arrangement (left side)

I. Truck passage
II. 110 kv ORU
III. Repair site
IV. 10 kv KRUN
V. OPU
VI. 35 kv ORU

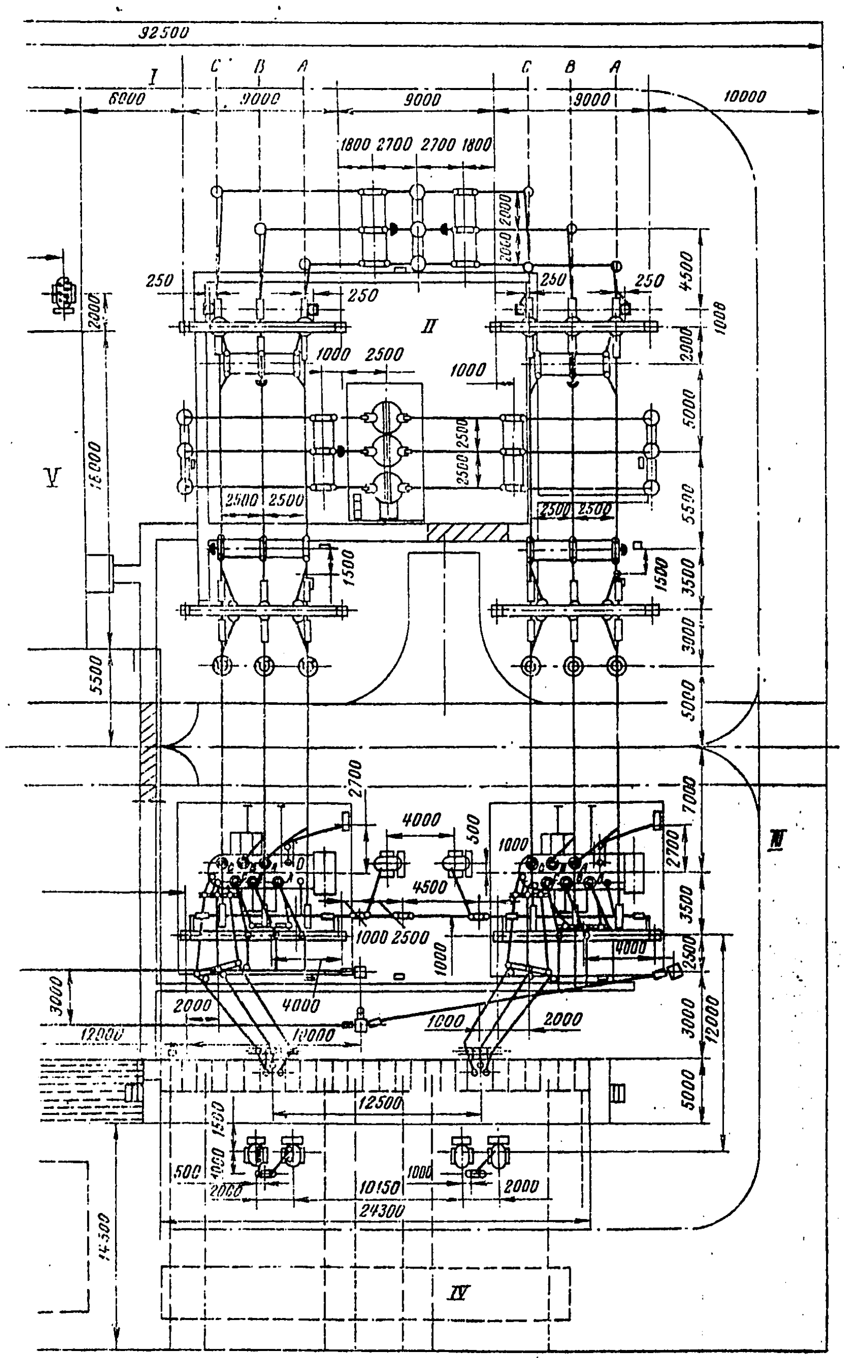

Fig. Version of a 110 kv substation arrangement (right side)
Designations the same as on the left side

industrialization of construction when changing over to fully prefabricated substations.

The typical design which was adopted is an arrangement in which the transformers are installed near the common motor vehicle highway with a flexible 110 kv bus passing through it (it is planned to repair transformers in their places of installation by means of truck cranes).

It is recommended to use truck trailers to deliver the transformers to where they will be installed and to have a siding on which a tractor with a trailer could be accommodated.

All typical arrangements have the same transformer installation units, transportation arrangements and RU for all voltages, lead-outs of cable channels and trays, and design of 10 and 35 kv bus bridges. The arrangements of 110 kv and 35 kv ORU were adopted according to existing typical designs -- flattened type on standardized structures.

The design of the 35 kv bus connectionsbetween the outlets of the transformers and the 35 kv ORU is of considerable importance for locating the 35 and 110 kv ORU as close as possible to the outlet of the 110 and 35 kv lines on the same side. The typical design adopted is an arrangement of conductors in the vertical plane. This makes it possible to reduce the width of the corridor for the 35 kv connections by 8 meters. For a site length of about 90 meters, the area occupied by the substation decreases considerably (by 700 m^2), the length of the 10 kv bus bridges (by 8 meters), the fence (by 16 meters) and the cables between the 110 kv ORU and the 10 kv KRUN [Complete distribution system for outdoor installation] become shorter with a corresponding reduction in the length of the cable trays.

The design uses 10 kv KRUN systems made by the "Elektroshchit" Plant with the cells located in one or two rows, depending upon the number of sections (two or four) and enclosed installation when the building is 9 meters wide. The 10 kv RU arrangements provide for the possibility of building the substation by stages, i.e., put in operation one rowof 10 kv RU with the first transformer.

It is desirable to bring 35 and 110 kv lines out into a common corridor from substations located on the outskirts of populated points or within built-up areas. Sometimes lines are brought out in opposite directions (this version of the arrangement was adopted for the 110 kv KTPB made by the Kuybyshev "Elektroshchit" Plant).

Frequently there arises the necessity for bringing 35 and 110 kv lines out into corridors located at a 90° angle to each other. The design permits the use of any of the indicated solutions, as well as any mutual disposition of 35 and 110 kv ORU.

At substations with three-winding transformers the control, relay protection and automation system apparatus are installed in the OPU building 6 x 13 meters; with a two-winding transformer--in a 6 x 12 meter building.

The disconnection of the 10 kv line switches, equipped with spring drives is done by direct action relays; when electromagnetic drives are used, the solenoid circuits for connecting the switches are fed by BPRU rectifiers. Transformer protection is actuated by the automatic connection of a short-circuit device or by the transmission of a disconnect pulse to the circuit breaker at the feed end.

Experience in operating 110 kv substations with up to 63 megavolt-ampere transformers indicates that it is inadvisable to build stationary fire-fighting systems and emergency oil drains with oil collectors.

A questionnaire conducted by the Energoset'proyekt Institute when collecting proposals for reducing construction costs substantiates the advisability of such a simplification.

One possible version for reducing costs is the construction of a small water drainage network connected to a well with a capacity of about 2 m^3, equipped with a pump that keeps oil collecting pits ready to receive oil. The pump must be blocked automatically when the transformer is damaged. The design described is the first experiment in developing and introducing a comprehensive design for substations that reduces the costs of design and construction, as well as accelerating the putting of the facilities in operation.

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END