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CONSTRUCTION OF SUBTERRANEAN PORTION OF BUILDINGS ON A NATURAL BED

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ABSTRACT: This article is devoted to the state of the art in equipment and techniques for constructing the underground portions of single-story industrial buildings. Attention is given to excavating methods and equipment, assembly of prefabricated foundations, laying of monolithic concrete, etc.

KEY WORDS:

Structural Engineering
Prefabricated Structure
Concrete
Excavating Machinery

This translation was accomplished from a xerox manuscript. The graphics were not reproducible. An attempt to obtain the orignial graphics yielded negative results. Thus, this document was published as is, in order to make it available on a timely basis.

Beginning with this issue of the magazine, the editorial board is introducing a new section, "Advanced Technology and Means of Large-Scale Mechanization." It will be supervised by TsNIIOMTP [Central Scientific Research Institute OMTP], whose specialists will make recommendations for progressive methods of erecting individual structural elements of buildings, based on the application of new means of mechanization. Both the latest series machinery and means of mechanization built by the production and scientific research organizations of the construction ministries and departments will be recommended. The scheme of large-scale mechanization to carry out the entire totality of construction processes of certain specific elements of buildings will be given in the articles when possible.

This section is opened by a series of articles on the construction of the individual structural elements of one-story industrial buildings. It is proposed to publish articles on the installation of the underground portion of such buildings, the supporting frame, protecting and built-in structures, floors, and roofwork. In the future, such cycles of articles will be dedicated to individual structural elements of apartment houses and multistory industrial buildings.

The editorial staff hopes that the publication of the new section will help builders in the solution of one of the important problems of the new five-year plan period - reducing manual labor, and large-scale mechanization of operations.

CONSTRUCTION OF SUBTERRANEAN PORTION OF BUILDINGS ON A NATURAL BED

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Construction of the subterranean portion of buildings on a natural bed includes operations to dig and finish excavations, construct monolithic structures, assemble precast reinforced concrete elements, and carry out waterproofing and earth backing with compacting.

Excavators equipped with a reverse shovel usually dig the foundation trenches and pits. The selection of excavators is determined by the geometric dimensions of the trenches, the soil category and other working conditions at the specific construction site. In those cases when the excavators of several size groups meet these conditions, and when they are all available to the construction organization, the selection of machines should be made by cost and engineering indices taking into consideration the volume of work at the given site. Calculations made by TsNIIOMTP show that it is economical to use excavators of the first and second size groups (bucket capacity 0.15 - 0.25 m^3), which according to their parameters have the possibility of digging trenches of the designed dimensions, for trenches having a volume of no more than 60 m^3. It is more advantageous to dig trenches with a volume of 60 - 400 m^3 using excavators of the third size group (bucket capacity 0.4 m^3). It is most economical to use excavators of the fourth size group (bucket capacity 0.65 m^3) for large-volume operations.

The cited volumes are calculated for average working conditions and can be specified for concrete objects, and can also be determined for other technological processes (digging foundation pits by carrying off the soil with excavators, assembly of prefabricated foundations, laying monolithic concrete and others). The method of such calculations is stated in detail in the brochure "Determination of Areas for the Rational Application of Construction Machinery," which was published by the Central Office of Technical Information of TsNIIOMTP in 1970. It can be obtained at the following address: Moscow, K-12, Kuybyshev Street, house 3/8.

Expenditures of labor on excavation amount to an average of 57 man-hours per 1000 m^2 of one-story industrial buildings. Of this total, approximately half - up to 29 man-hours - is comprised of expenditures of manual labor in grading and finishing foundation pits and trenches.

Dispersed operations to dig tiny trenches for lead-ins of underground communications, areaways, small individual foundations, communication lines pole holes, etc., are currently performed by manual labor. A considerable portion of the diggers is engaged in the so-called "non-volumetric" operationsplaning surfaces, finishing slopes, ditches, etc.

Native Soviet industry and the construction organizations have built a number of specialized machines and devices to mechanize these operations. The subject of this discussion will be several of these machines which have recommended themselves well in practice and ensure a substantial reduction in expenditures of manual labor.

The small E-2516 excavator-grader, manufactured at the Andizhan construction machinery plant (Figure 1), is used successfully to grade and finish foundation pits. The presence of a telescopic arm provides a straight trajectory of bucket motion, thanks to which the machine can grade the bottom and slopes of the foundation pit with high precision. A D-50L engine rated at 55 hp has been installed on the excavator; it has caterpillar drive, and the path of the telescopic arm is 2.75 m. It ensures the following digging radii: without extension - 6.8 m, with extension - 7.8 m, digging depth - 3 and 3.7 m, respectively, digging height - 3.2 and 3.6 m. Speed of the machine is 1.8 km/hr., dimensions are 6 X 2.4 X 2.5 m.

The excavator arm can be raised by 25° and lowered by 45°, can be rotated around the vertical axis of the machine and around its own longitudinal axis. This provides a high maneuverability of the machine. All the working motions of the excavator (including its own travel) are accomplished by hydraulic engines and hydraulic cylinders, which made it possible to considerably reduce the weight of the machine. One of the following interchangeable working parts can be used, depending on the working conditions and the nature of the performed operations: an excavation bucket with a capacity of 0.25 m^3; grading bucket with a capacity of 0.4 m^3; loader bucket with a capacity of 0.4 m^3 and a grading blade 1.8 m wide.

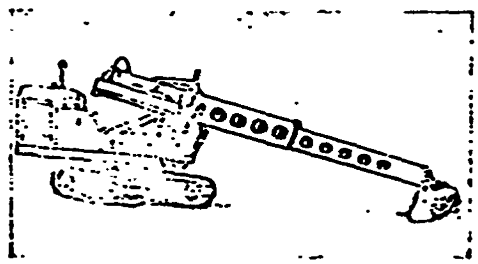

Figure 1. E-2516 excavator-grader.

Excavator-graders of larger standard dimensions have also appeared in recent years at our construction sites: the E-4010 of Soviet manufacture with a bucket having a capacity of 0.4 m^3, and the "Satur" excavator (Czechoslovakia).

Hydraulic pressure grab buckets on a rigid rod are being successfully used to dig foundation pits for individual foundations, to dig local depressions, and to dig wells and deep trenches. They ensure the accuracy of excavation configuration by means of a rigid suspension and a high productivity thanks to an increase in the cutting force developed by the pressure mechanism.

Hydraulically-operated grab buckets are manufactured by the Kiev excavator plant in the series of interchangeable equipment of E-5015 excavators. Constructions of such grab buckets in the series of hydraulic crane installations on T-40 and "Belarus'" tractors, as well as in the series of specialized equipment of the E-302 excavator, have been developed at TsNIIOMTP. Working drawings of these grab buckets are distributed by the Central Office of Technical Information of TsNIIOMTP.

Production tests of a bucket with a reverse shovel on the E-302 excavator with a rectilinear lip having a width of 0.54, 0.8, 1.1 and 1.4 meters (Figure 2) proceeded successfully in 1970. These buckets make it possible to dig trenches that are 0.6, 0.9, 1.2 and 1.5 meters wide (at the bottom), respectively, under the grading mark and do not require additional cleaning of the bottom and slopes. The working drawings of the buckets will be distributed by the Central Office of Technical Information of TsNIIOMTP in 1972.

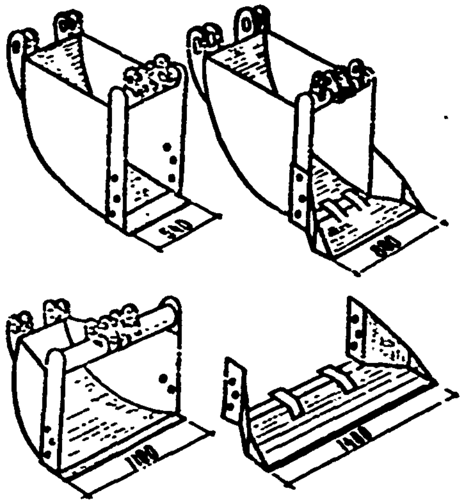

Figure 2. Buckets with rectilinear cutting lip.

Hydraulic and hydraulic spring hammers of various constructions, made as interchangeable equipment for the excavators, have begun to be used in recent years to dig small volumes of frozen ground (in places of communication lead-ins, for example), together with already known equipment. The double-action S-01-82 hydraulic hammer on the E-153 excavator, developed by the VNIIStroydormash [All-Union Scientific Research Institute of Construction and Road Machinery] (Figure 3) can be considered one of the most successful. This hammer develops an impact energy of 300 km-m and an impact frequency of 100-300 per minute; it weighs 670 kg. When working on frozen ground it provides an output of 30-40 m^3/hr. Working drawings of the S-01-82 hydraulic hammer can be obtained from VNIIStroydormash at the following address: Moscow, G 66, 2nd Frunzenskaya Street, 8.

Good results were obtained by using tubular electric heaters (TEN) in the winter to warm the ground. Both deep and surface heating of frozen ground can be accomplished using tubular electric heaters, depending on the working conditions. Detailed data on the use of tubular electric heaters are cited in the brochure "Cyclic Method of Melting Frozen Ground with Tubular Electric Heaters," published by the Central Office of Technical Information of TsNIIOMTP in 1967.

The OMG-70 outfit, consisting of a burner device, which includes a burner, a centrifugal blower and a fuel tank, as well as a series of boxes with air insulation and a heat distribution pipe with two compartments, is being successfully used by a number of construction organizations to thaw the ground when digging trenches. This heat distribution pipe makes it possible to ensure the equal distribution of heat under the boxes and to lower the fuel consumption by two or three times, and also to regulate the temperature under the boxes within the limits of +500 - 600°, which prevents their burning through. The total length of the trench section heated by the boxes is up to 40 m, including a 20-m length of thawed section and a 20-m length of prepared section. Fuel consumption per m^3 of thawed ground is 6-8 kg of kerosine (solar oil) or 9-11 m^3 of gas. Outfit output is 0.3 - 0.5 m^3/hr. Its weight is 1950 kg. Working drawings of the OMG-70 are distributed by the Central Office of Technical Information of TsNIIOMTP.

When mounting prefabricated elements of individual foundations the crane is placed on the bottom of the foundation pit. Such an arrangement makes it possible to get the crane as close as possible to the object being mounted. The lightest mounting means (autocranes, pneumatic wheeled cranes and caterpillar cranes, crane-excavators, etc.) can be used for this purpose. The required parameters of mounting means - hoisting capacity and swinging radius - are determined in each specific case by the maximum weight of the element, the configuration of the foundation and the crane construction.

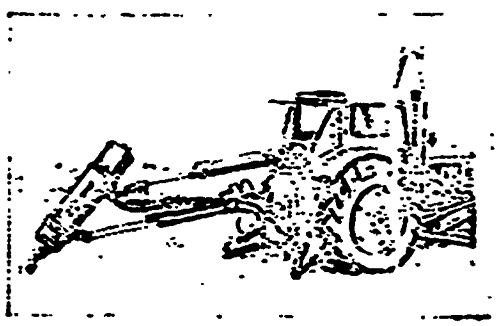

Figure 3. S-01-82 hydraulic hammer on "Belarus'" tractor.

In those cases when it is inadvisable for the crane to travel on the bottom of the foundation pit (supersaturated foundation pits, lack of lanes because of the close spacing of foundations and the large magnitude of the slopes, etc.), operations are conducted from the edge of the foundation pit.

Selection of a scheme is determined by local conditions.

Execution of operations to assemble prefabricated foundations begins with the supply of materials to dig the foundation. A sand foundation is most frequently made 10 - 15cm thick. It is advisable to use a single-rope grab bucket to deliver sand, as well as for earth backing and auxiliary operations (Figure 4). It can be mounted on any erection crane without an additional repassing of cables. Construction of single-rope grab buckets having a different capacity - from 0.5 to 1.0 m^3 - have been developed at the present time. Working drawings of the grab bucket are distributed by the Central Office of Technical Information of TsNIIOMTP.

Investigations conducted at TsNIIOMTP showed, that assembly of prefabricated elements of foundations weighing up to 5 tons with a work volume less than 1300 tons is possible and economically advisable to perform using caterpillar cranes having a hoisting capacity of 10 tons. With a large volume of work, such foundations should be assembled using caterpillar cranes having a hoisting capacity of 16 tons.

It is recommended to assemble elements of foundations weighing 5 - 9 tons with caterpillar cranes having a hoisting capacity of 16 tons or with pneumatic wheeled cranes having a hoisting capacity of 25 tons. It is rational to use pneumatic wheeled cranes having a hoisting capacity of 40 tons to assemble single-unit prefabricated foundations weighing 14-19 tons with a work volume of up to 1700 tons, and it is advisable to use 40-ton caterpillar cranes with a large work volume.

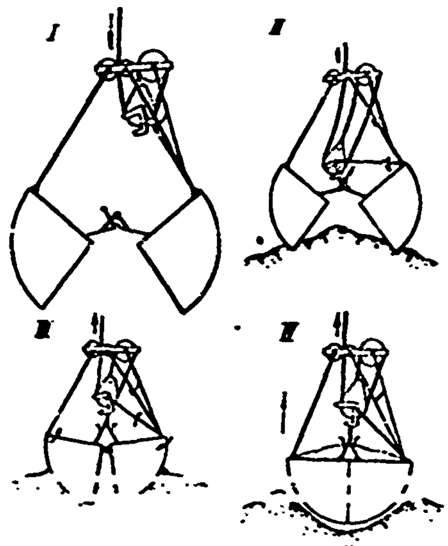

Figure 4. Operational scheme of single-rope grab bucket. I - lowering to ground; II - coupling of the grapple with transverse member; III - grabbing ground; IV - raising of grab bucket.

Expenditures of labor on the installation of prefabricated foundations reach an average of 110 man-hours per 1000 m^2 of one-story industrial buildings. Of this figure, about 77 man-hours (70%) is made up of expenditures of manual labor, primarily of slingers. Work was conducted at TsNIIOMTP to select and perfect hoisting devices in order to reduce these labor expenditures and to increase the reliability of the fastening of loads. Working drawings of unified hoisting devices are distributed by the Central Office of Technical Information of TsNIIOMTP.

The process of constructing monolithic foundations includes the installation of falsework, assembly and installation of reinforced frames, supplying and compacting a concrete mix and treatment of it. Expenditures of labor for the performance of these operations amount to an average of 120 - 125 man-hours, of which 100 - 110 man-hours (83-88%) are made up of manual operations. The largest expenditures of manual labor go to falsework and reinforcement operations. These expenditures are considerably reduced with the use of unified falsework parts and centralized manufacture of reinforced frames, which on the job site are only placed in the falsework.

Three versions of collapsible-adjustable panel forms, metalic, wooden, and combined, have been developed and successfully introduced by TsNIIOMTP in a number of construction organizations. Albums of the working drawings of this falsework are distributed by the Central Office of Technical Information of the TsNIIOMTP. Introduction of falsework parts permits a reduction in the expenditure of labor on falsework operations by a minimum of two times and ensures a substantial saving of lumber.

Reinforcement forming a unified reinforced falsework unit can be installed with centralized manufacture of reinforced frames into falsework units. Such units are assembled by two methods. If the reinforced frames can take temporary loads from the falsework, then the falsework is suspended on such a frame by means of tie rods and bolts. If, on the other hand, the reinforced frames cannot bear the temporary load, then the falsework is assembled into a rigid geometrical, unchanging unit, in which the reinforcement elements are attached in the design position.

Metal welded block forms are manufactured to concrete a large number of foundations of the same type. They are installed by means of a crane and are separated from the concrete by lifting jacks.

Monolithic strip foundations are arranged either in the thrust in the foundation trench, or in the falsework at the work site.

A concrete mix is usually supplied to the falsework of the foundations by the same cranes which are used when carrying out falsework and reinforcement operations. The mix is delivered by a crane bucket with a capacity of 0.3 - 0.8 m^3. Buckets with a capacity of 1.6 - 3 m^3 and a vibrating bucket with a capacity of 1.6 m^3 are used when there are cranes with an increased hoisting capacity. Crane output in the delivery of the concrete mix in buckets amounts to up to 20 m^3 per shift. In cases when a delivery rate of concrete mix of more than 20 m^3 per shift can be ensured according to the conditions for organizing operations, it is advisable to use specialized means of mechanization - concrete placers.

Self-propelled concrete placers are belt transloaders, mounted on the chassis of the base machine - a tractor, excavator, etc., or a special chassis (Figure 5). The fundamental scheme of all concrete placers is identical: the concrete mix from the automatic dumpers is taken to a hoisting vibrating bunker, which feeds the mix onto the belt of the fan conveyor of the supplied mix to the place where it will be laid. The vibrating bunker is equipped with a measuring gate in order to regulate the flow of concrete mix. If the swinging radius of the conveyor is more than 12 m, it is made a component, particularly in the form of a telescopic boom suspended on the turning platform. Machines with a turning platform, which makes it possible to distribute the concrete by area, possess the best cost and engineering data. Telescopic conveyor booms with reverse belt drive are being used in recent constructions of concrete placers, which makes it possible to change the place of the supply of concrete from 3 to 20 m without moving the machine. The technical characteristics of concrete placers manufactured by the construction organizations are given in the table.

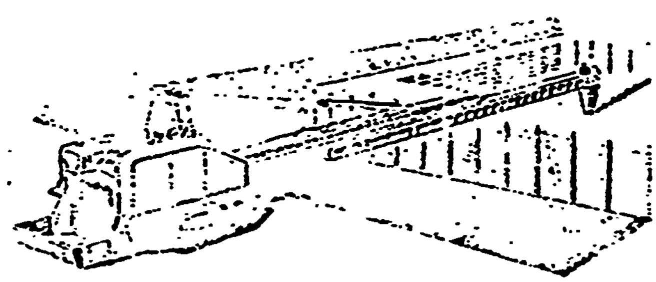

Figure 5. Self-propelled concrete layer.

The use of concrete placers required additional expenditures for mechanization in connection with the use, parallel with the placers, of cranes to supply the falsework and reinforcement. However, these expenditures are compensated by the fact that the high rate of concreting (100 m^3 and more per shift) permits a substantial improvement in the quality of concrete operations and a great increase in their duration.

It is also effective to use vibration equipment when it is necessary to deliver the concrete mix for a distance of more than 20 m on the horizontal. A series of such equipment, consisting of a vibration feeder and vibrating troughs with stock columns was developed in TsNIIOMTP.

Considerable difficulties arose in the practice of building one-story industrial buildings when compacting the ground with earth backing, especially when constructing foundations under floors, blind areas, entrances to shops, etc. ES = 180 and BS = 180 tampers manufactured by the "Bamechanik Halle Ost" enterprise (GDR) can be successfully used for these purposes. These compactors are designed to pack cohesive and non-cohesive soils of small volumes in crowded conditions. The compactors have a gasoline (BS = 180) or electric (ES = 180) engine, a crank gear connecting rod mechanism, a body on spiral springs, vibrates and strikes the surface of the ground, compacting it. The weight of each of the compactors is 180 kg, the impact frequency is 420 per minute, the speed of movement is up to 5 m/min., and output after two passes is 67.5 m^3/hr.

TECHNICAL CHARACTERISTICS OF BELT CONRETE PLACERS

1 Показатель	2 Типы бетоноукладчика								
	3 БУ-1, БУ-2, Кривбасстроймеханизация, Кривой Рог		4 ЭМ-44, СКБ Госстроя УССР, Киев	5 БУМ-1, БУМ-2 Запорожалюминстрой		6 УБ-132, трест № 8.6 Харьков	7 ПУ-1 Башнииспецстрой	8 ПУ, Куйбышевгидрострой	9 БУ-20, ЦНИИОМТП Госстроя СССР
	10 База бетоноукладчика								
	12 Кран БКСМ-14	13 Экскаватор Э-662	11 Трактор						
			14 С-100	15 Т-107 погрузчик	14 С-100	16 Т-75	14 С-100	17 Экскаватор Э-302	18 Специальный гусеничный ход
1	2	3	4	5	6	7	8	9	10
19 Длина стрелы транспортера, м	17	18	16	10	11	12	10	10	30
20 Вылет стрелы, м	14	15	16	10	8	11	10	9	3—[illegible]
21 Угол охвата в плане, град.	150	180	180	20	120	100	140	180	360
22 Угол подъема стрелы, град.	16	12	10	10	20	20	15	15	20—60
23 Площадь охвата, м²	40	40	100	14	14	12	15	20	630
24 Высота зоны охвата, м	4.5	5	5.5	2.3	4	5.5	3	4.5	5
25 Вес машины, т	16	27	23	16	16	13	17	13	12.7

1 - index; 2 - types of concrete placers; 3 - BU-1, BU-2, Krivoy Rog Basin Construction Mechanization, Krivoy Rog; 4 - EM-44, Special Design Office of the State Committee for Construction of the UkSSR, Kiev; 5 - BUM-1, BUM-2, Zaporozh'ye Aluminum Construction; 6 - UB-132, trust No. 8.6, Khar'kov; 7 - BU-1, Bashkir Scientific Research Institute for Special Construction; 8 - PU, Construction Administration of the Kuybyshev Hydroelectric Power Plant; 9 - BU-20, TsNIIOMTP of the State Committee for Construction of the USSR; 10 - base of concrete placer; 11 - tractor; 12 - BKSM-14 crane; 13 - E-662 excavator; 14 - S-100; 15 - T-107 loader; 16 - T-75; 17 - E-302 excavator; 18 - Special caterpillar drive; 19 - length of conveyor boom, m; 20 - boom, m; 21 - angle of contact in plane, degrees; 22 - angle of boom elevation, degrees; 23 - area of contact, m^2; 24 - height of contact zone, m; 25 - weight of machine, tons.

The compactors move during operating, and the operator only holds and guides it by means of a handle. The compactors are equipped with easily mounted metal wheels, providing transportation from one object to another. Interdepartmental tests of these compactors conducted in the USSR showed, that they are capable of compacting cohesive and non-cohesive soils to a depth of 40 cm up to a density of 0.96 - 0.98 of the standard density with an optimum of two passes. According to the decision of the appropriate organizations of the Council for Mutual Economic Aid, these compactors are being delivered from the GDR to all the socialist countries.

New constructions of compactors created at TsNIIOMTP (patent number 162868 "Working Member to a Machine for Compacting Soil with a Regulated Impact Impulse") should be mentioned from the design developments which can be recommended for practical introduction. They differ from the previously known compactors in that there is no rigid kinematic bond in them between the compacting plate and the body. Rotating rollers supported on support shoes are mounted on the eccentric shafts of the compactors. They are attached to the compacting plate, which is joined with the body through spring-actuated rods. Model compactor tests under production conditions showed their high effectiveness and reliability in operation.

This compactor can be made in the form of a suspended plate to an erecting crane or hanging equipment on hydraulically operated excavators. In the latter case the technical characteristics of the compactor on excavators with a bucket capacity of 0.4 - 0.5 m^3 are characterized by the following data: impact energy - 400 kg-m, weight of impact part - 250 kg, maximum number of impacts - 100 per minute, depth of compacting - 70 cm, reaching a soil density after one pass of the working member of 0.98 of the standard density, compacting time - 10 seconds.

Hanging equipment on DT-20 and T-25 tractors, worked out by the Special Design Office of Mosstroy/Moscow State Construction and Installation Trust/ for intra-site loading-unloading and transporting operations, has recommended itself well in practice. This equipment consists of a self-unloading bucket having a capacity of 0.18 m^3, attached behind the tractor, as well as a blade and pitchforks attached to the front part of the machine. Bulk cargoes weighing up to 300 kg and bales weighing up to 200 kg are transloaded and transported by means of these working members. The bucket and pitchforks are loaded by forward and reverse movements of the tractor, respectively. When lifted to a height of up to 0.5 m, the bucket automatically turns to the transport position, and when lowered to the ground it opens. The blade, 1.4 m long and 0.45 m high, was made to turn on a swivel in later models. Working drawings of the equipment are distributed by the Special Design Office of Mosstroy (Moscow, G-64, Nizhne-Susal'nyy Alley, 5).

Water-removal plants on "Belarus" tractors are being successfully used by a number of construction organizations to drain foundation pits, ditches, and sewers. A S-245 pump with an output of 100 m^3/hr. at a suction height of up to 6 m receives rotation from the power take-off shaft of the tractor through a conical reduction gear and pulley. Suction and charging pipes 200 mm in diameter are part of the installation outfit. Working drawings are distributed by the Central Office of Technical Information of TsNIIMTP.

Portable submersible pumps manufactured by the Moscow mechanical plant of the Energomekhanizatsiya trust of Minenergo of the USSR can be recommended for the removal of small volumes of water. Among these are the "GNOM-10" centrifugal pump with an output of 20 m^3/hr. and the MZ-2 screw pump with an output of up to 6 m^3/hr. During operation the pumps are submerged in water and force it into the head connecting pipe.

Introduction of recommendations stated in this article makes it possible, as the calculations conducted at TsNIIMTP showed, to substantially lower the required labor capacity and the length of the erection of the underground part of one-story industrial buildings, and to reduce expenditures of manual labor by 15 - 30 man-hours per 1000 m^2 of production area.