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PRESTRESSED CONCRETE PRESSURE CONDUITS FOR ADDUCTIONS OF DRINK AND INDUSTRIAL WATER[1]

by

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The steady [illegible] of population, [illegible] of new residential districts in the urban centers, the more and more intensified agricultural production through irrigation as well as the rapid increase of the industrial output are all developments which could not be achieved without water, the element on which the very existence of man, of plants and of all industrial activities hangs; hence when planning such works, we must from the very beginning be preoccupied with the adequate means to provide for the necessary water supply.

Most frequently water is not to be found in the proximity, but must be transported from the source to the consumer over long distances - sometimes over tens or hundreds of kilometres. From the economic standpoint the water transport over such long distances makes necessary the utilization of pressure conduits.

Not long ago water feed conduits for working pressure over 2-3 atm were made in many countries of cast iron or steel pressure pipes.

In order to spare steel, some conduits for working pressures between 1-4 atm were made of welded sheets 2-3 mm thick, embedded in reinforced concrete cast at the building yard. Such a solution required however large quantities of steel, a great amount of manpower and was very costly.

Recently a whole range of new materials, amont which asbestos-cement, plastics and prestressed concrete have been used to fabricate water feed conduits.

Plastic conduits are generally limited to small diameters (till 150 mm), reaching only in special cases 400 mm. Asbestos-cement conduits are also usually limited to maximum diameters of 600 mm. Reinforced and prestressed concrete complete the range of materials which are used as substitutes for metal; conduits of more than 400 mm diameter, up to 2000 mm and even more, are generally fabricated from this material.

Due to several important technical and economical advantages by comparison with the metal tubes they are replacing, the production of prestressed concrete tubes has known a large development in Romania. Among these advantages the following are to be mentioned:

Sparing of metal

By using prestressed concrete, 1 ton of steel or 2.5 tons of cast iron are spared for each m^3 prestressed concrete.

Cutting of cost price

In Romania the cost price of prestressed concrete conduits is approximately 50% less than the cost price of cast iron conduits, respectively 20% less than that of steel conduits.

<u>A better behaviour in case the admissible pressures are exceeded</u>

By comparison with tubes from reinforced concrete, steel or cast iorn, the prestressed concrete tubes are no destroyed when accidentally submitted to pressures above the expected ones. If such pressures occur, the prestressed concrete tubes fissurate but the fissures close themselves under the prestressing effect as soon as the water returns to the normal pressure. This process doesn't occur with reinforced concrete, steel or cast iron pipes, which are irremediably damaged if submitted to abnormal pressures.

Among other advantages of prestressed concrete conduits the following must also be mentioned:

- a rapid mounting, for which very simple means are needed; no welding, isolation or cathodic protection are necessary as in the case of metal conduits;
- a longer durability - the service life of a prestressed concrete conduit is estimated at about 100 years, compared with only 25 years for a steel conduit;
- almost no maintenance is required;
- the taste of water is not altered.

The prestressed concrete tubes are produced in specialised plants where modern equipment and operating processes are in use. In the last ten years the production of prestressed concrete pressure tubes has largely developed in Romania, what made possible the successful supply of towns, of he industry and of the griculturel irrigation networks with the required quantities of water. The eight plants now under exploitation in our country are currently producing centrifugated precompressed concrete tubes, of which the main characteristics are given in the following table:

characteristics	u/m	Rating inner diameter, mm				
		400	500	600	800	1000
TUBE						
■ outer diameter of the tube	mm	490	590	690	910	1130
■ outer diameter of the muffle	mm	618	718	818	1058	1304
■ real lenght of the tube	mm	5145	5145	5145	5175	5175
■ length of the muffle	mm	598	578	598	640	700
■ mass	Kg.	875	1060	1267	2070	3085
■ total concrete volume	m³	0,332	0,429	0,567	0,831	1,235
RUBBER GASKET						
■ inner diameter	mm	456	546	637	837	1038
■ section diameter	mm	20	20	20	20	20

The first prestressed concrete tube plant came into function in Romania in 1960 under the Swedish patent "Premo". By experiments and research works carried out in the laboratories of our Research Institutes the types of the tubes being produced as well as the initially adopted technology have been ameliorated.

In view of the above mentioned advantages the production of prestressed concrete pressure tubes has steadily increased in Romania and presently the functioning plants totalise a yearly output of some 800 km, what ranges Romania among the biggest producers of such tubes.

The quality control in the producing plants is very strict, the technical conditions being very severe. A 600 ∅ mm tube with the wall only 30 mm thick must be perfectly waterproof when undergoing a hydraulic pressure test at 25 atm.

The pressure pipes fabricated in the Romanian plants are characterized also by some important economical advantages, especially by a small expenditure of materials. In the following table technical data (with reference to steel and concrete) are given, for a 5,0 m tube, with a service pressure of 15 atm and a 3,0 m height of the embankment above the upper generating line.

∅ mm	Total weight of the tube	SBP Steel	concrete thickness, mm	
			core of the tube	protection coat
600	1.250	51	30	15
800	2.050	89	40	15
1.000	3.050	145	50	15

The operating process used by the precast concrete plant "Progresul" in Bucharest for the production of prestressed pressure tubes will now be presented. The plant will be visited on March the 29th.

The main materials used for the fabrication of prestressed tubes are: sand, gravel, cement and high quality SBP steel wire. The aggregates, transported from the quarries in tipping waggons, are first discharged in a reception bunker, from which through a system of conveying belts they are deposited under the form of dumps surmounted by a trestle.

From the dumps the aggregates are taken by other conveying belts to a drying station where they are passed through dry rotary kilns. Afterwards they are uplifted by means of an inclined elevator to the level of the sorting station of the concrete central station, where they are sorted in 5 different fractions.

The cement arrives at the plant in tank-waggons with pneumatic discharge and is discharged in silo from which it is afterwards transported bya mixed pneumatic and mechanic system to the bunkers of the concrete central station.

A selfpropelled dosimeter picks the different sorts of aggregates as well as the cement, from the bunkers, weighing them precisely. The cement and the aggregates are then discharged in mixers where they undergo a forced mixing, the water dosage being precisely made by automatic dosimeters. When the mixing is finished, the concrete is evacuated directly in the distributing bunker which feeds the centrifuge (Pos.1).

The high strength steel wire (fracture strength up to 18,000 kg/cm^2) used for reinforcing the tubes is processed in the plant, by means of winding and braiding machines, in the adequate manner to permit its use by special equipment which execute the longitudinal and transversal reinforcing of the tubes (pos. 5a, b).

The fabrication process begins at the longitudinal reinforcing machine which threads longitudinally two braided wires of 1,5 gauge on a metal tube, the so called "spool-tube"; this tube has at each end a ring with several mandrels. The machine has a mobile carriage which, by its to and fro movement threads the wire longitudinally on the "spool-tube", bending it ove the mandrels of the two rings at the ends of the metal tube (pos.5 c).

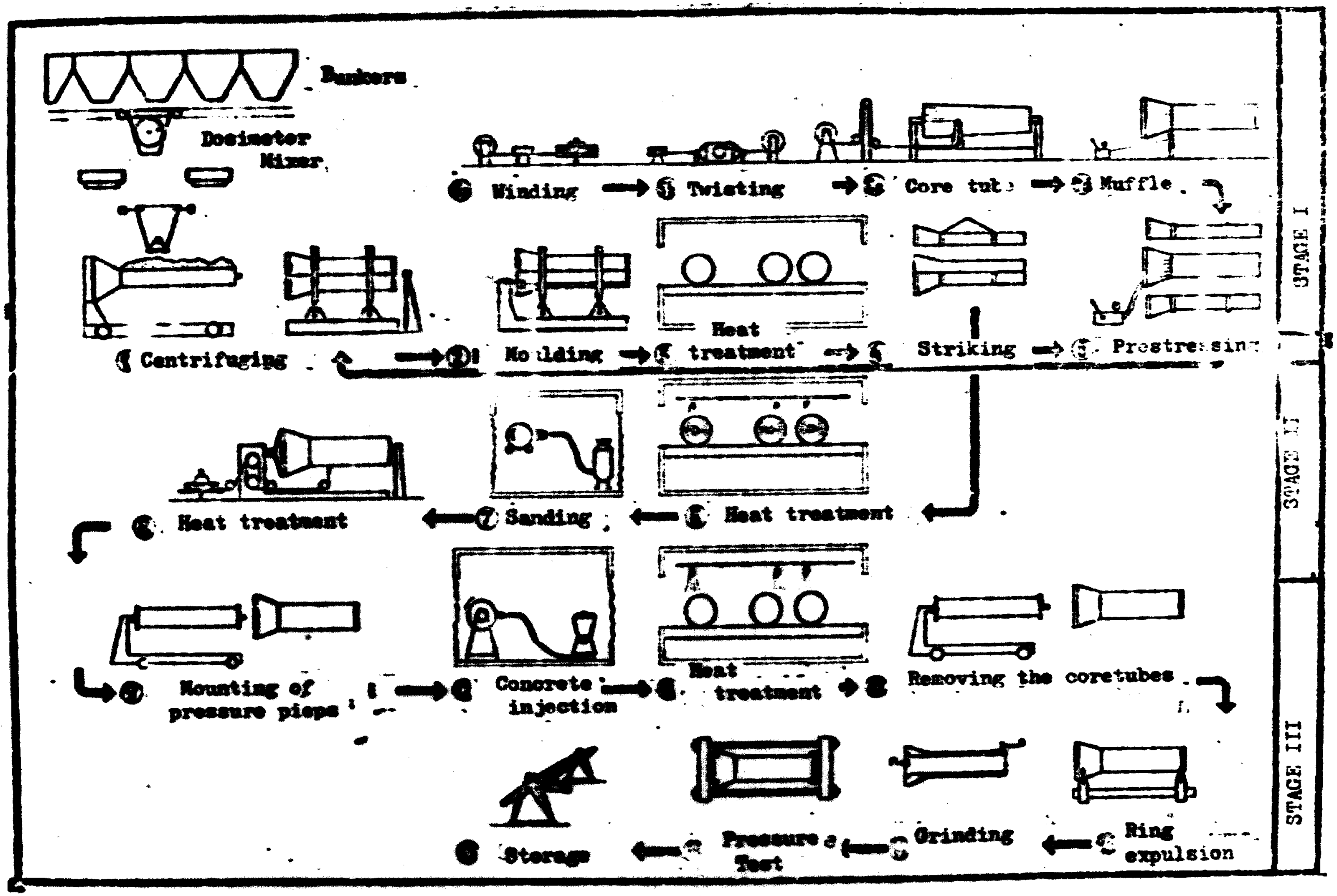
The final tensioning of the longitudinal reinforcement is executed directly on the very robust metal mould consisting of two equal halves rigidly joined together by bolts (pos.5).

The ready made mould is then laid on the centrifuge (pos.1) as described above, while, after being prepared in the mixers, the concrete is discharged in a mobile bunker which moves longitudinally and which distributes it in a partitioned feeder mounted on a self-propelled carriage. The concrete is equally distributed in the compartments of the feeder.

While the mould rotates at a low speed, the feed trough is introduced in the mould and the concrete is emptied in it; the feed trough moves then out the mould and the centrifuge begins to rotate the mould at a higher speed.

The centrifugation itself lasts from 15 to 20 minutes. During this operation a considerable amount of water is eliminated from the concrete on the inner surface of the pipe, due to the centrifugal force. An

FLOW SHEET FOR THE FABRICATION OF PREMO PRESTRESSED CONCRETE TUBES



adequate compaction and a substantial reduction of the factor water - cement is so obtained.

When the centrifugation is terminated, the mould is transferred to a heat treatment chamber (pos.3)

In this chamber the heat treatment is carried out by spraying the tube inside with hot water (50°C) about 8 hours long. During this time the concrete reaches a sufficient strength to resist the longitudinal precompression effort occuring at striking. After an 8 hours heat treatment the minimal admissible strength at striking is 300 kg/cm^2. To obtain such strength, high quality cements with initial high strength are used. During the heat treatment the moulds are transferred to the steaming chambers by means of mechanical devices, so that the workers don't need to enter spaces with a high temperature atmosphere.

When the heat treatment is finished the tubes are evacuated from the steaming chambers with the aid of mechanical devices which also take out of the moulds the core tubes (pos.4).

After striking the core tubes are undergoing a new heat treatment, in another chamber where they remain 24 hours long, during which time they are sprayed inside and outside with hot water (50°C). During this heat treatment the strength of the concrete in the core tube is continually increased, reaching at the end the value of about 500 kg/cm^2; this strength is necessary to take over the efforts occuring during the transversal reinforcing. These efforts are generally the maximal efforts the tubes undergo during the whole fabrication process as well as while in service in the conduits.

By means of a transversal reinforcing machine a turn of wire is wound under tension on the outer side of the core tubes, which results in a transversal precompression of the core tubes. By using wires of different gauges as well as different distances between the turns, tubes adequate for pressures and applications ranging between 4 and 30 atm are to be obtained (pos.8).

The reinforced core tubes are then transferred to a platform where metal pipes - the so-called pressure pipes - are introduced inside them.

The tubes are maintained under pressure before applying the injected concrete coating; simultaneously a careful tightness control of the core tubes is carried out.

The protection of the transversal reinforcement, consisting of a 15 mm thick injected concrete coating, is applied in a separated room which does not belong to the rest of the plant (pos. 10).

After the concrete injection is finished, the tubes are transferred in a third heat treatment chamber, where they are sprayed 24 hours long with hot water (40-50°C), by means of showers. When the injected concrete has hardened, the tubes are taken out of this third chamber by a mechanized device, the pressure cores are dismantled and the water in the inner of the tubes is evacuated (pos.12).

The next operation consists in the detachment of the two rings with mandrels at the ends of the tubes, by cutting the longitudinal reinforcing wires. The operation is executed with a machine equipped with two carriages on which cutting abrasive discs are rotating (pos.13).

The last operation of the fabrication process is carried out with a grinding machine; by means of pneumatic grinders, the inner dimension of the coupling and the outer dimension of the heads of the tubes are adjusted as to comply with the admissible tolerance limits which guarantee the tightness when fitting the tubes in a conduit (pos.14). The dimensions are measured with special gauges the precision of which is ± 1 mm.

After the fabrication process is ended the tubes undergo a pressure test, under conditions similar to t ose prevailing in the conduit. Each tube is mounted on a stand for hydraulic pressure testing. The inner pressure is maintained by applying metal caps with rubber gaskets at both ends of the tube. The test is carried out at a pressure approximately 5 atm higher than the service pressure to which the tubes will be submitted when fitted in the conduit (pos.15).

Besides this usual test, other tests of efforts on the generating line are periodically carried out with the aid of a special equipment. These tests are performed on 1 m long sections and the sections generally resist to loads of approximately 30 tons on the linear metre.

Long term tests are also carried out on a conduct mounted in a special test stand from precompressed concrete. These tests are made in order to verify the tightness of the tubes and of the joint in the long run.

After undergoing the above mentioned tests, the tubes are stacked in storage by diameters and pressures. While in storage they are sprayed with water 7 days long. The storage has a portal crane of 20 m span with two cantilever of 6 m each and with a load lifting capacity up to 5 tons (pos.16).

Generally the tubes are transported to the building yard by means of railway waggons or of high capacity trailers.

They are loaded with the aid of the portal crane directly on the waggons, where they are laid down on wooden supports in two or three superposed levels. Each tube delivered by the plant is marked with the main characteristics, and is accompanied by a certificate of quality.

At the building yard an intermediary storage provided with mechanized discharge equipment is set up, where the tubes are stacked in the same conditions as at the plant.

A special care must be given to the discharge and handling of the tubes, to avoid shocks which could lead to fissuring. Degraded tubes are the source of considerable trouble on the yards, because the faults can be detected only when the pressure test in the conduit is carried out, generally on each kilometre of a mounted conduit.

From the intermediary storage the tubes are charged on platform trailers and transported to the mounting place. If the ground is troubled the transport is carried out on sledges towed by caterpillar tractors.

The tubes are laid down along the ditch where they are suspended with cables, lifted with a crane and finally let down in the ditch, near the end of the conduit. Each tube is tied at both ends with cables at which jacks are attached, to make possible the execution of joinings.

After the rubber gasket is applied near its extremity, the tube is brought near the end of the conduit, a space of about 5 mm remaining free (fig. 2). The rubber gasket is rolled so as to reach the free space between two adjoining tubes: one of the tubes is then pressed into the other by means of the cables at which jacks are attached. Meanwhile the rubber gasket rolls inside the joining, by applying a strong pressure.

If the lay-out of the conduit changes its direction, deviations up to 2°30' are admissible. This amounts to a displacement of about 20 cm with regard to the axis of the former mounted tube, the measurement being made at the end of the deviated tube.

The earth filling under the tube is carried out in two stages. In the first one, which is carried out before the pressure test, the filling up around the tube is executed, the coupling remaining partially free, so that eventual water leakages at the gasket can be detected.

In the second stage the filling is carried out up to the ground level.

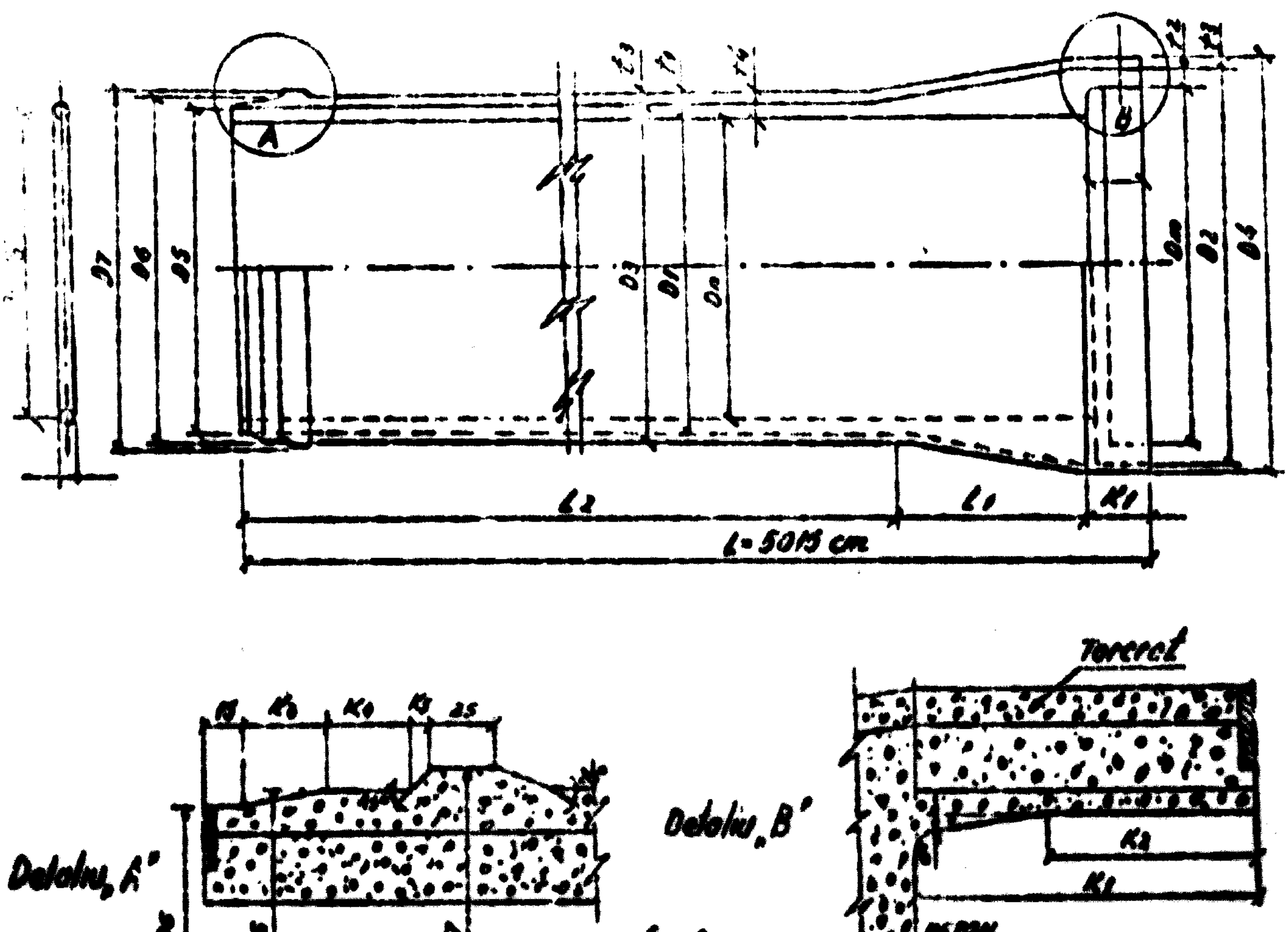

A
B
D7
D6
D5
D3
D1
Dm
D2
D4
L2
L1
K1
L = 5013 cm
Torcret
Detaliu „A"
Detaliu „B"
K2
K1
D6
D7

fig. 1

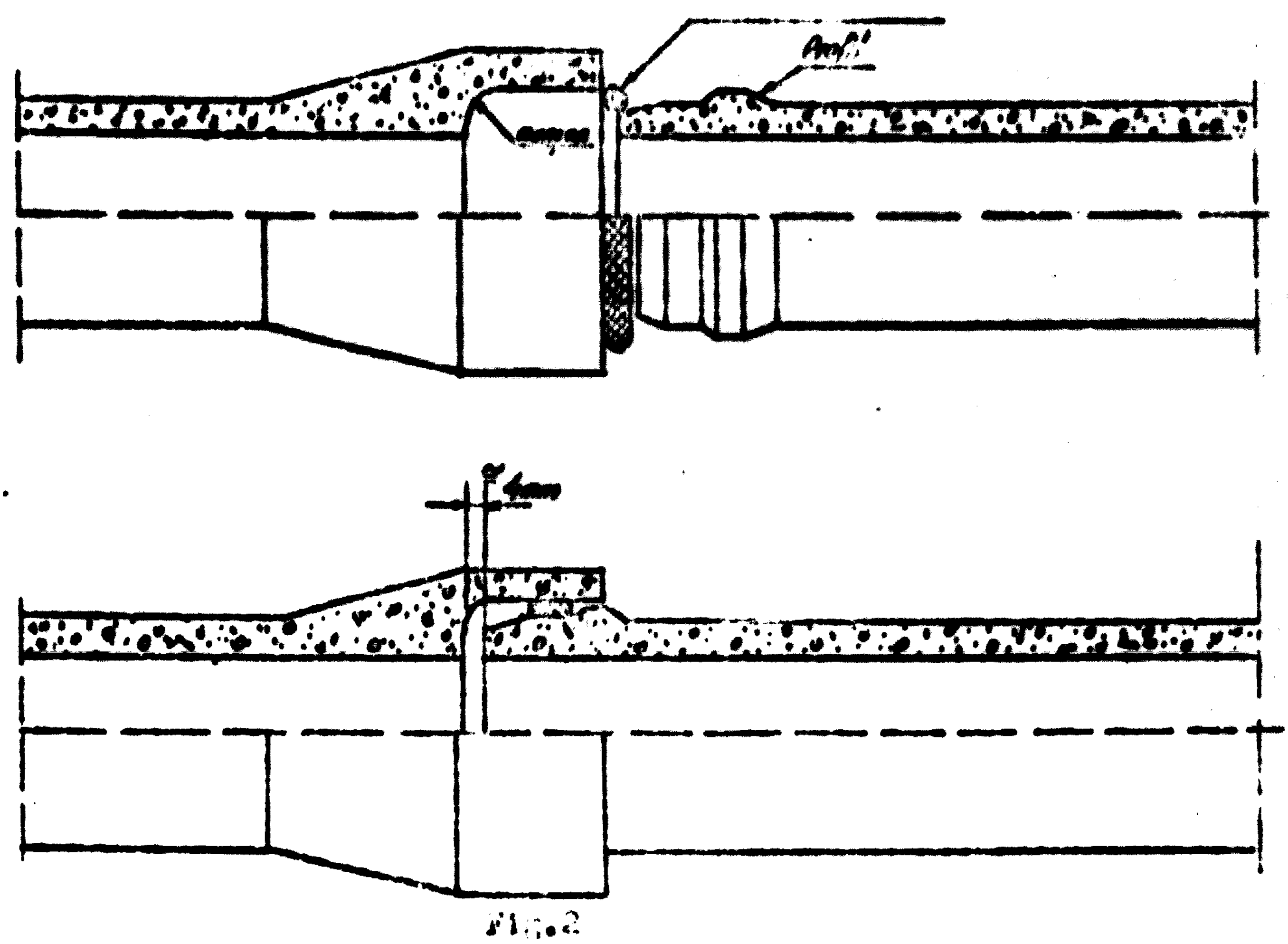

4mm

Fig. 2

The mounting of the tubes is a very simple and a very productive operation. A working team of 9 men can mount daily about 30 tubes, which amounts to an average of 150 linear metres of conduits.

Before being put into service, the conduit undergoes some tightness hydraulic tests, in order to verify if the mounting has been carried out in adequate conditions (the tightness of the joinings is verified) and if the tubes were not deteriorated during their transportation and handling.

The following two tests are carried out:

a) A test on a single section

b) A test on several sections.

By the test on a single section each tube and each joining are separately verified, while by test on several sections the joinings between them are verified.

The testing section is generally of about 1-2 kilometres long.

At the ends of the sections terminal anchorage blocks from concrete or wood are provided for, to take over the pushing efforts in the conduit.

Before filling the tested section with water, its ends are shut with special steel covers which rest on the terminal wall of the ditch or on the concrete block, which must be dimensioned adequately for the testing pressure in the conduit.

The water pressure is gradually raised in the conduit to the maximum stipulated value, while verifying the tightness of the joinings between the tubes. (fig.4).

If during the service some severe damage is detected, the damaged tube must be replaced without delay.

This tube is first to be broken on a 20 cm long section by means of special grinders or of steel picks. The damaged section must be then removed and replaced by a section of the same length, on which a steel sleeve with two flanges with rubber gaskets and binding bolts has been previously mounted. The new section is joined with the adjoining tube by the usual mounting procedure. (fig.3).

The steel sleeve is then displaced in the axis of the free space to obtain the continuity of the conduit. By tightening the binding bolts of the flanges the rubber gaskets are pressed, so that the joining between the sleeve and the tube becomes waterproof.

By means of some special steel or cast iron components, ramifications, curves, reductions as well as the mounting of valves are possible in prestressed concrete conduits.

Up to the present about 3500 kilometres of conduits from prestressed concrete pressure tubes have been executed for feeding water to towns, industrial centers as well as for irrigating agricultural lands. Among the most important works, the following conduits for supplying water for some great centers can be mentioned:

The feed conduit of Craiova, 120 km long, 10 atm pressure, Ø 1000 mm.

The feed conduit of the industrial combine group Slobosia, which consists of two 60 km long conduits, Ø 1000 mm, service pressure 10 atm.

The feed conduit of Iassy, 100 km long, Ø 1000 mm, service pressure 10 atm.

The feed conduit of Budapest, 10 km long, Ø 1000 mm.

Due to the described fabrication process as well as to the quality of the materials, during the twelve years period since the prestressed concrete pressure conduits have been utilised no accidents have occured either in Romania or in the other countries where tubes have been exported.

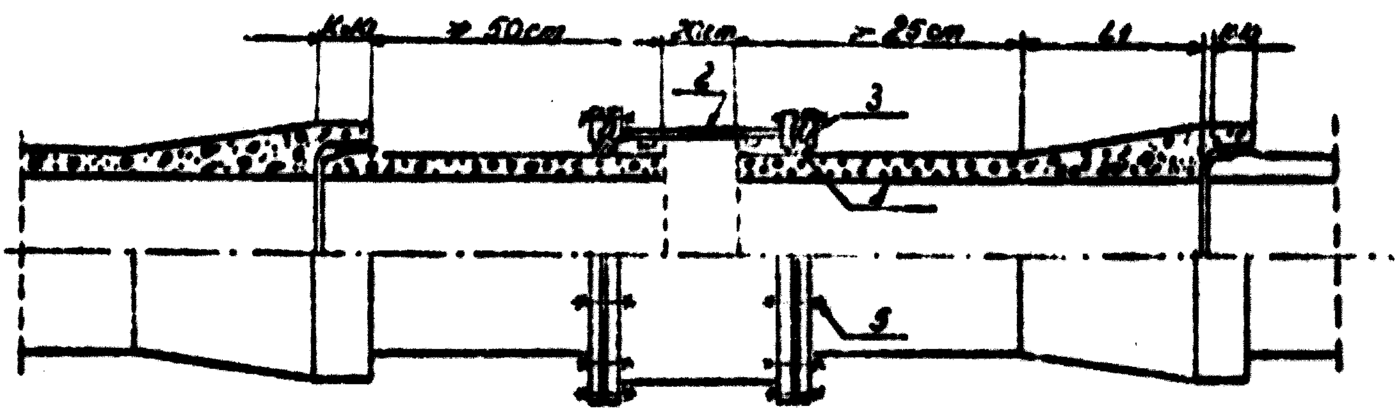


fig.3

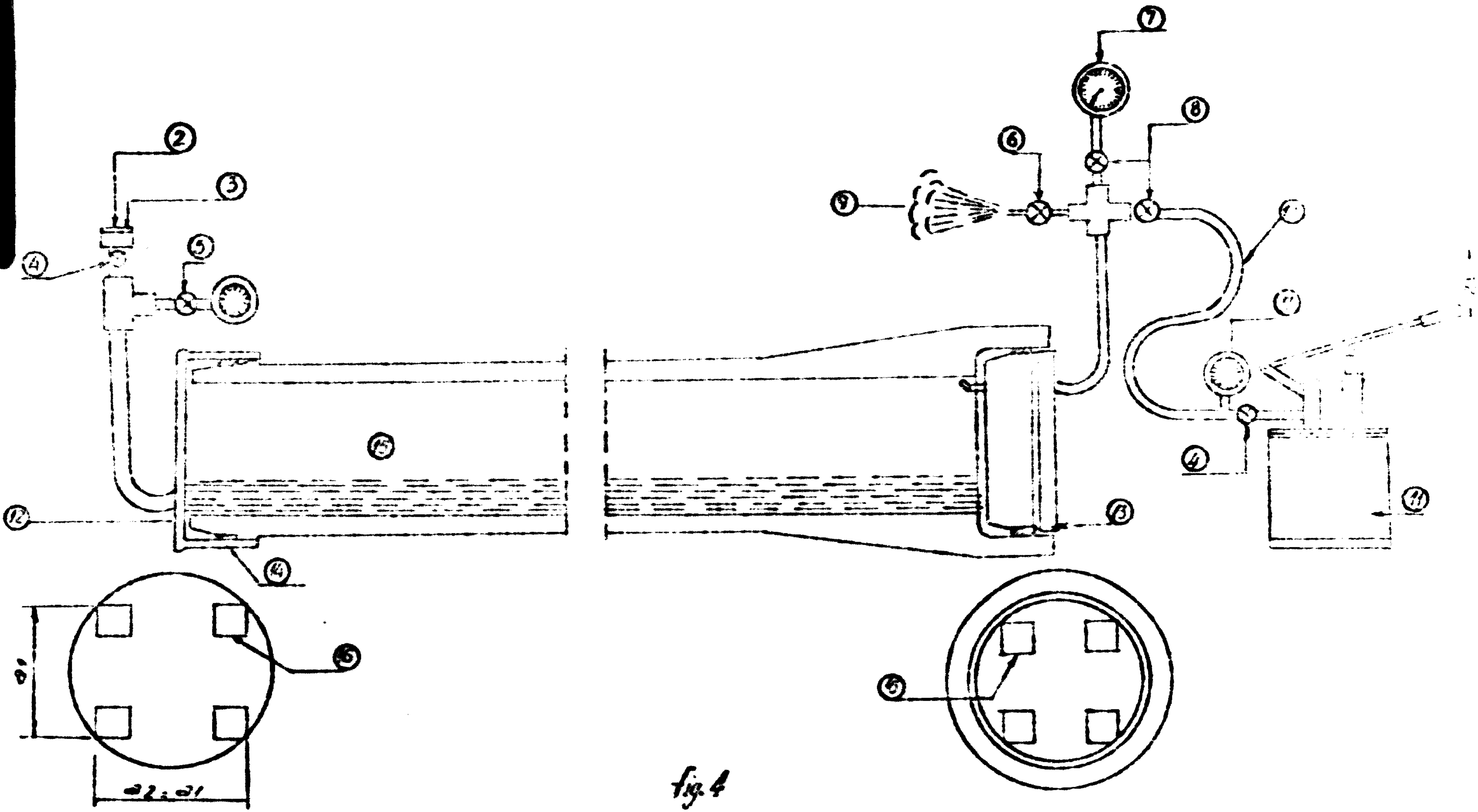


fig. 4

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