Fig. 10. A recent view of Cambambe dam under construction

The Middle Cuanza Development

An account is given of the construction of the first dam and power station, of 260-MW capacity, at Cambambe on the River Cuanza in Angola. The Middle Cuanza represents one of the major water-power resources of Africa

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PART TWO

THE general construction contract for the Cambambe hydro-electric scheme was awarded, in August 1958, to Sociedade de Empreitadas Moniz da Maia & Vaz Guedes, Ld[a]. and S.A. Conrad Zschokke. Some of the preparatory works—access roads and construction-camp facilities—were awarded to Angola contractors. Among manufacturers of mechanical and electrical equipment the following must be mentioned: for turbines Escher Wyss, S.A., for generators Le Matériel Electrique SW, and for the switchgear and communications equipment Etablissements Merlin et Gérin. The hydraulic equipment for the outlet works, intakes and tailrace tunnels, is being supplied by SOREFAME—Socieda des Reunidas de Fabricações Metálicas, S.A.R.L.

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SONEFE, through its Construction Division, superintends the co-ordination and supervision of the different contracts and the direct execution of some auxiliary works.

Access Roads and Camp Facilities

At the beginning of the works, access to Cambambe was afforded by the old road between Luanda and Nova Lisboa, in long stretches, more a track than a road, and the Luanda railway branch between Zenza do Itombe and the old village of Dondo, 12 km downstream from Cambambe. Now, however, about 220 km of an asphalt-paved road connects Luanda and the access portal to the underground power station in the steep rocky canyon at Cambambe.

The residential zone comprises, besides temporary buildings, a group of permanent quarters connected

Fig. 11. A general view of the crushing, screening and washing plant

Fig. 12. In this photograph can be seen the two sides of the river bend which are connected by the underground power plant below the hill in the centre. The concrete-mixing plant is in the foreground and the dam site on the extreme right

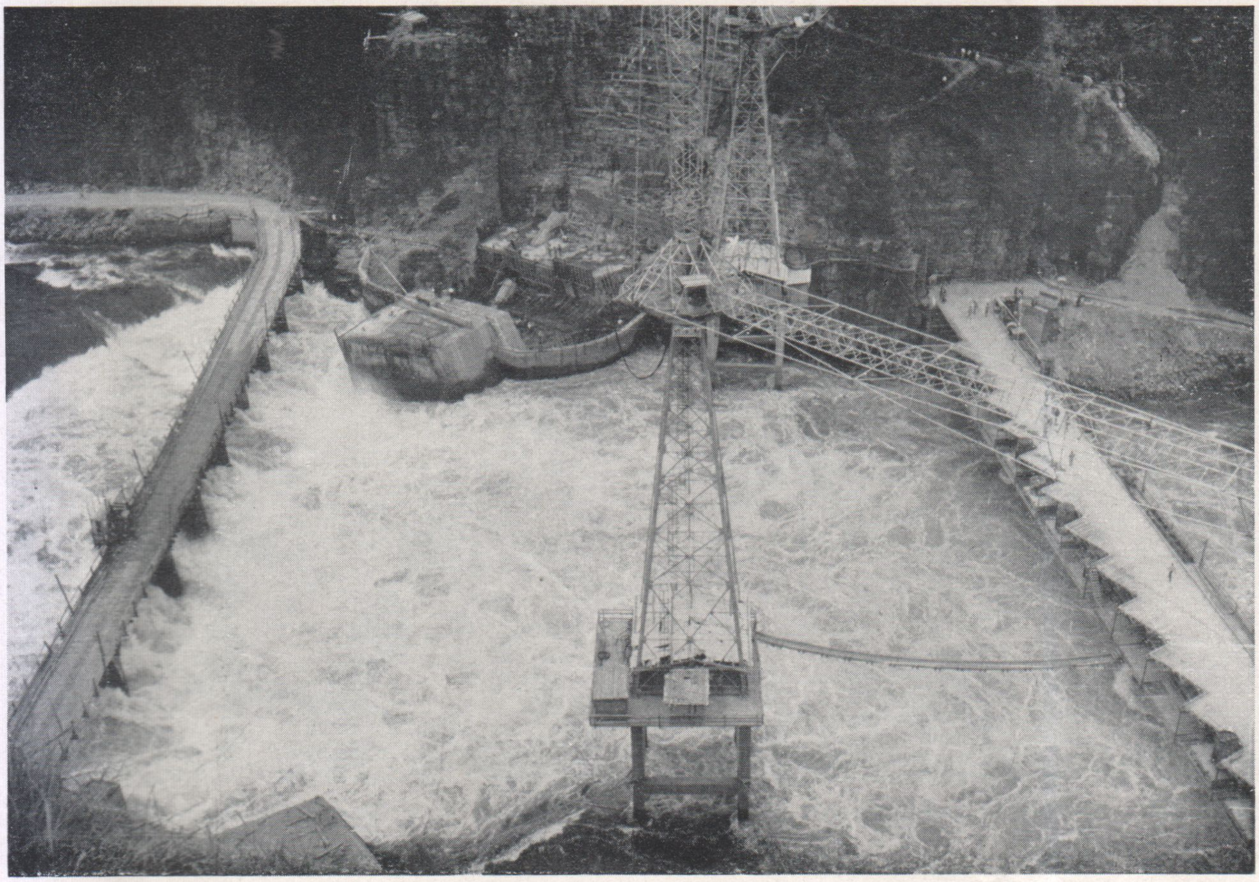


Fig. 13. Concreting the side blocks of the dam during the rainy season

with the hydro-electric development. Almost all temporary camp facilities are demountable aluminium single-storey buildings. Permanent facilities include 29 houses, 1 hotel with 16 rooms, hospital, community hall, stores, school and church.

The hospital possesses a permanent central section, with chemist shop, consulting room, operating theatre, six rooms for patients, and, in temporary buildings, two wards with about 60 beds. The European camp can accommodate 231 families in permanent and temporary houses and about 600 workers in dormitories. Among the community utilities must be mentioned the water-supply system with a filtration plant, an adequate sewage-disposal system, and air-conditioning equipment in houses and dormitories.

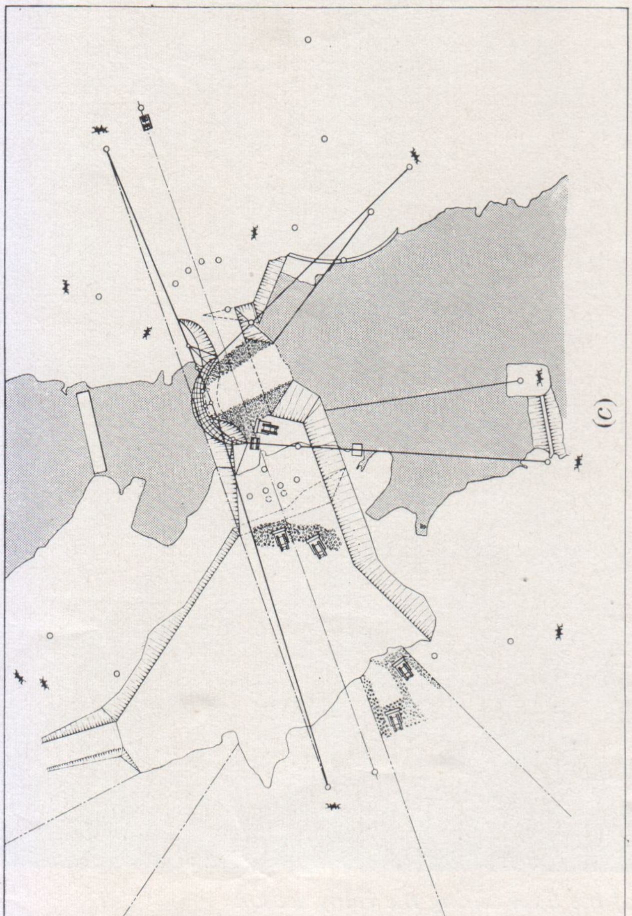
From the beginning of the job, it was very difficult to get the skilled native labourers necessary for the organisation of the working crews; so, in order to prevent serious disruption in the construction schedule, it was necessary to employ European workmen on a higher rate than foreseen and than had been usual before on other jobs in Angola. At the end of 1959, when the hydraulic-circuit tunnels and the power-station cavern were being excavated, and the river-diversion operations were almost at an end, the general contractor's personnel consisted of 500 Europeans and about 900 natives, almost all common labourers.

Equipment

A construction-plant power station was built, equipped with five English Electric 525-kW diesel-generator sets. The compressed-air plant was equipped with Holman compressors, with a total output of 122 m^3/min at 7 kg/cm^2.

The crushing, screening and washing plant (Fig. 11) was designed for an output of 100 tons per hour. Aggregates, divided in to seven sizes, are stored in nine silos with a total capacity of 1,000 m^3, three for sand up to 1·5-mm size and six for coarse aggregates up to 150 mm. Agregate is delivered to the concrete plant by a conveyor with an output of 100 tons per hour. Cement is being supplied by Companhia Secil do Ultramar, from Luanda, and is transported in 5-ton steel containers, by railway as far as Dondo, and by truck in a road haul of 20km to the concrete mixing plant, where the containers are unloaded and the cement conveyed to storage silos or directly to the mixing plant, by a pneumatic conveyor.

The concrete plant (Fig. 12) is equipped with an automatic batching system, with an hourly output of 60 m^3. Materials for batching are stored in eight bin compartments with a capacity of 360 m^3. There are three 1-m^3-capacity concrete mixers of the Winget-Koehring type, and an electro-pneumatic batching system effects the simultaneous weighing of seven aggregates, cement and water, their registration, and the control of the mixing time. Concrete transfer from the mixing plant around the works is made in dumpcrete trucks. Concrete is placed in the dam by four 6-ton 60-m Loro & Parisini derricks, the concrete being dumped from the dumpcretes into buckets on a Bailey service bridge. Forms are built with Angola wood, of good quality, coming



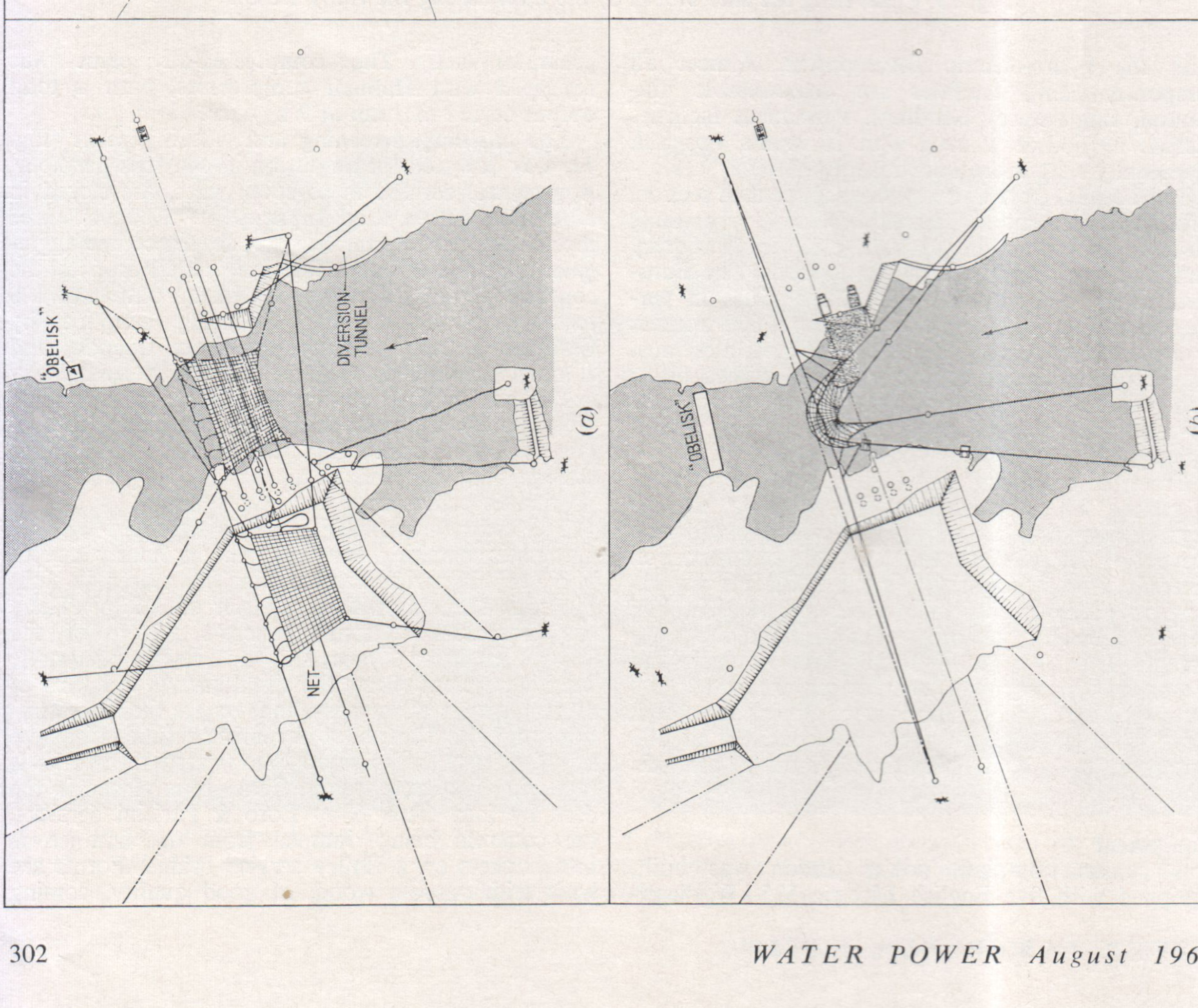


Fig. 14. A series of diagrams showing three successive stages in the operation of diverting the river

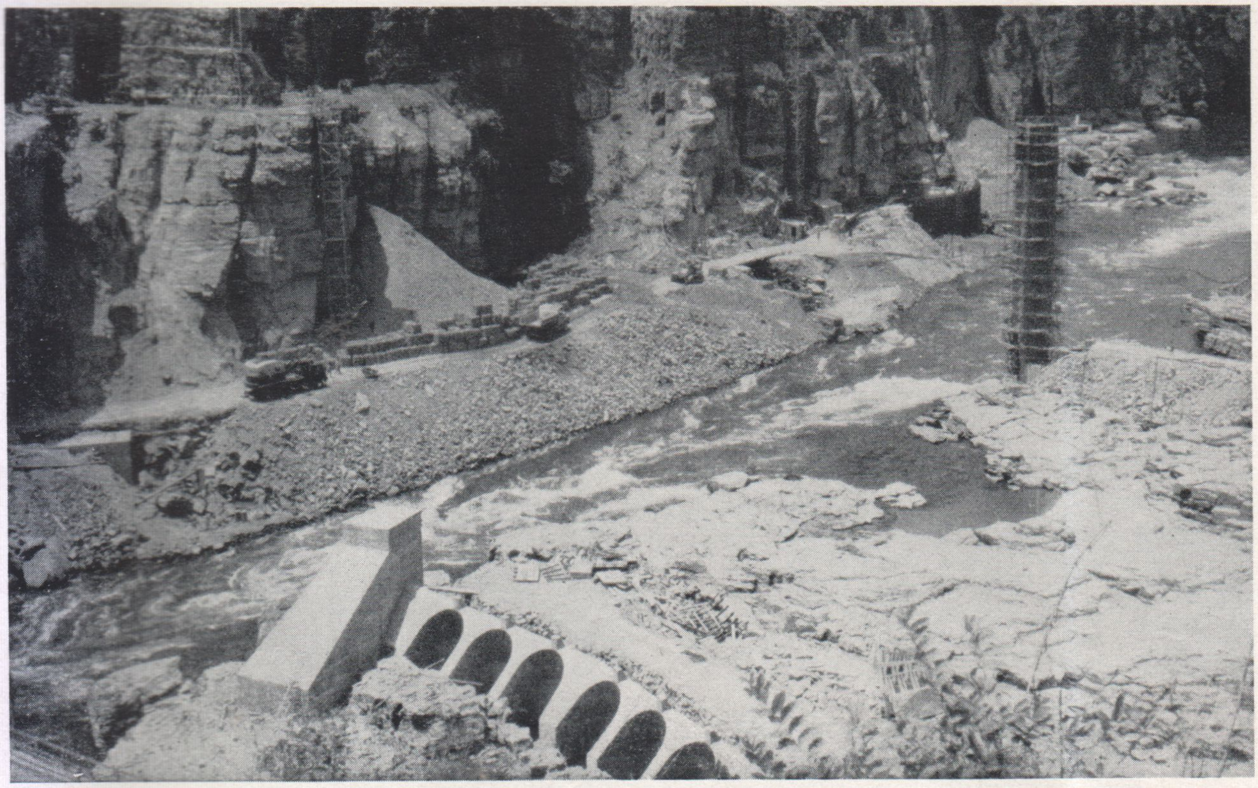


Fig. 15. Preparatory operations for diverting the river. The "obelisk" can be seen standing on the right ready to be thrown across the river

largely from the interior plateau. Tests on concrete for quality control are made at the construction-plant laboratory; cement is sampled and tested by the Engineering Laboratory of Luanda, before leaving the manufacturer's plant.

Excavation, at Cambambe, has been predominantly an underground task. Drilling equipment includes Atlas BBW41 fast drills and Atlas Falcons for shafts and steep-grade tunnel driving. For mucking, two Eimco 21 and six Eimco 105 loaders are employed. Haulage is effected almost entirely by Koehring 4-m^3 dumpers.

Ventilation is carried out by a reversible air system, and safety precautions require a careful inspection of the ambient air for dust and for carbon oxides.

On open-air excavations two Eimco 105 bulldozers, four shovels—two Demag B418, one Lorain L50 and one Ruston Bucyrus 22 RB—partially convertible for clamshell excavation, are employed. Earth and rock are hauled by eight 15-m^3 Krupp trucks.

Repair and servicing of the equipment is carried out in the construction-plant shops, which were also designed to assist in the erection of the power-plant mechanical and electrical equipment. A travelling gantry was installed in the service-plant area specially for assembling and welding the bent steel plates, received from the manufacturer for the pressure-tunnel lining.

Construction Operations

The construction of the cofferdams and the excavation of the diversion tunnel started in September 1958, at the end of the low-water season, in difficult and hazardous competition with rising flood levels, when the contractor had not yet enough men and equipment. Excavation of the diversion tunnel was finished in June 1959, and the last concrete lining was placed at the end of September, two months later than specified in the construction schedule, which called for the complete execution of the river-diversion operations during the low-water season (period from May to October) of 1959.

The irregular shape of the river bed and the high velocity of the water led to a careful model study of the method devised to divert the river. This method, which was ingenious and offered reasonable certainty of success, enabled the closure to be effected more quickly than had been scheduled, and will now be described.

To enable the permanent cofferdam to be built it was decided to construct a temporary rockfill cofferdam a little way upstream, and to reduce the flow sufficiently to enable this cofferdam to be placed, a reinforced-concrete pillar, or "obelisk," seen in Fig. 15, was built on one bank ready to be overturned and dropped across the river.

The rockfill cofferdam was built up on the banks, and to prevent the material forming the centre of the cofferdam from being swept down the river a steel net was constructed on one of the prepared ends of the cofferdam site ready to be drawn into position across the river by winches, as seen in Fig. 14a. An auxiliary drainage gallery was also cut to connect the section of the river bed between the temporary and permanent cofferdams with the diversion tunnel.

The sequence of operations can be followed from the series of drawings, Fig. 14 a.b.c., and the following timetable shows how rapidly the closure was effected.

Fig. 16. Erecting the crane in the underground machine hall

On October 5, 1959, the cofferdam at the entrance to the diversion tunnel was removed, and a flow was established in the tunnel of about 50 m^3/sec.

On October 7 the "obelisk" was tipped into the river and the steel net was drawn across the river and secured. The river flow at the time was 173 m^3/sec, and about 80 m^3/sec was diverted through the tunnel. Rockfill was then dumped into the river upstream of the net (Fig. 14b), and on October 8 at 5.30 p.m., 22 hours after dumping had started, the diversion was accomplished (Fig. 14c). An upstream earth and clay seal was then placed, and by October 12 the leakage had been reduced to 0·5 m^3/sec.

About 12,000 m^3 of rockfill, 1,000 gabions, and 4,000 m^3 of earth and clay were dumped, employing one 1·8-m^3 shovel, four D8 bulldozers, three Eimco 105 loaders, and several trucks and dumpers.

The permanent cofferdam is of concrete and is of mixed construction consisting of a buttress wall, which was previously executed on the broad low left bank, and by a thin arch closing the main river channel (Fig. 1 in Part I). To avoid delaying the construction of the arch, concreting was commenced on the alluvial deposit in a deep cavity in the rocky river bed, and this was afterwards consolidated by grouting. The arch concreting started on October 16 and was finished at the beginning of December, when the river discharge was 360 m^3/sec. During the second fortnight of December, when the river flow exceeded 500 m^3/sec, the diversion tunnel was closed and the river resumed its course through the Cambambe rapids, overtopping the concrete cofferdam.

In the meantime, excavation of the dam-foundation area on the river bed was started, as well as the pier foundations for the service bridge and the supporting structures for the derricks.

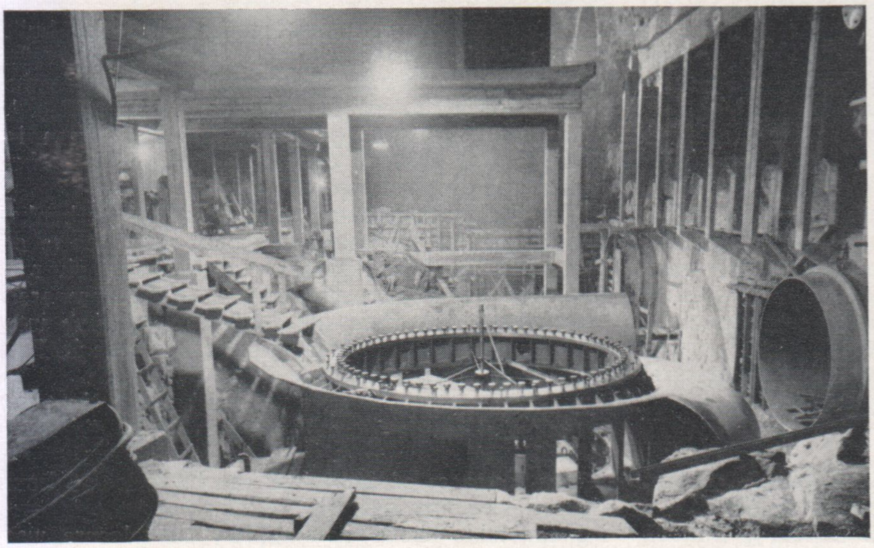


Fig. 17. Assembling one of the turbine spiral casings

After the diversion-tunnel closure the concrete linings in the sides and in the radial-gate section were placed ready for its adaptation as an outlet tunnel. At the end of the rainy season, the tunnel, then in its final form, was used once more for river diversion.

Previously undetected tectonic faults in the structure of the foundation rocks, as referred to in the previous article, determined the necessity for complementary geological investigations before starting concrete work. A great part of the low-flow season was spent on these explorations and the ensuing dis-

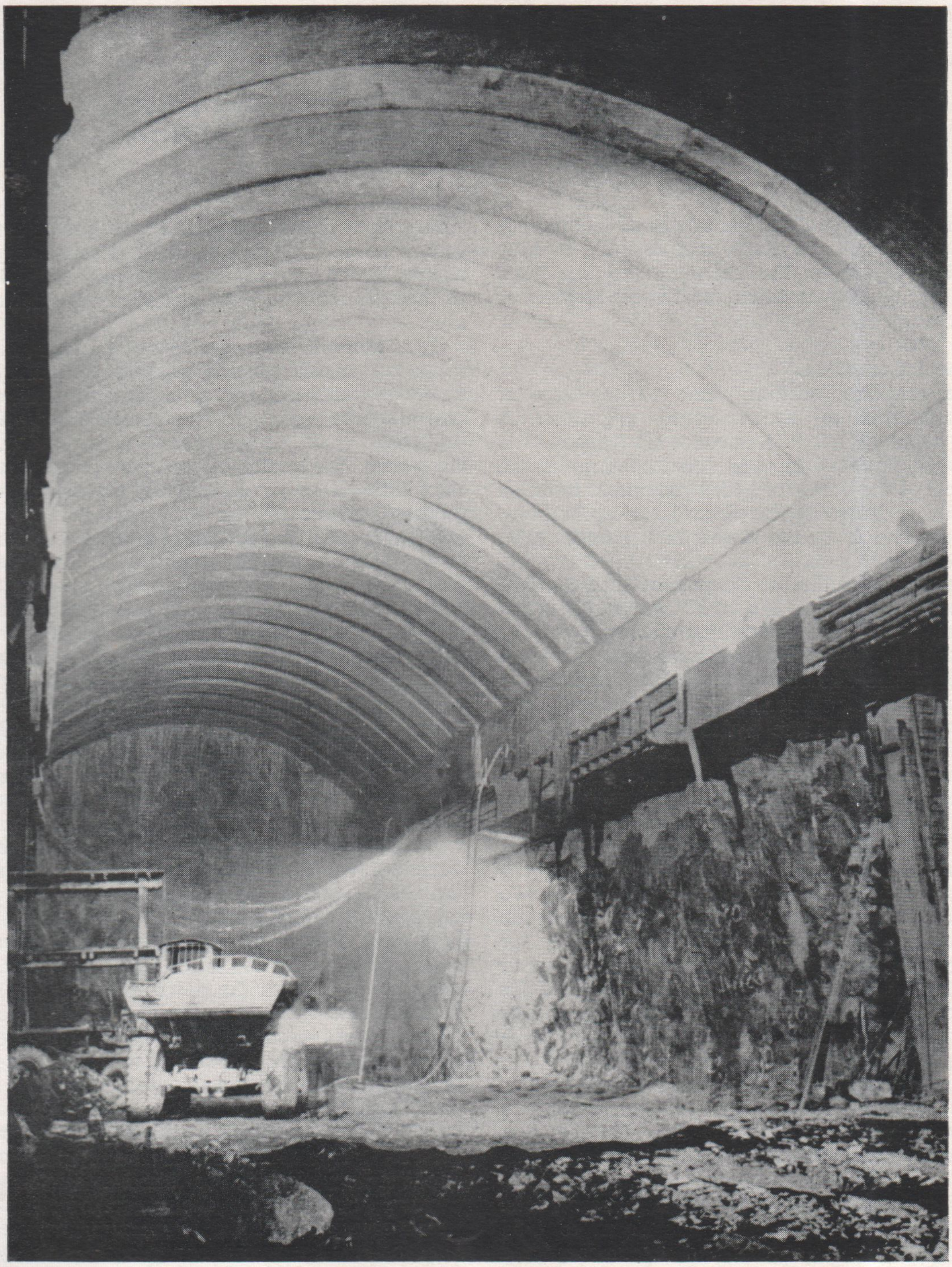


Fig. 18. Cambambe No. 1 machine hall under construction

cussions, so that when the cofferdam was overtopped, at the end of November, the central blocks of the dam were still below the rising flood (Fig. 13). Concreting was resumed on the lateral blocks after faulted areas in the sides of the gorge had been consolidated and the dam design had been revised to obtain greater thickness and better insertion at the abutments; the resulting excess volumes were more than 100% in excavations and 20% in concrete. Concrete placing is now progressing without interruption on all blocks, as the river is now again diverted through the bottom outlet and during its next rainy season will flow through temporary openings left at the base of the dam.

In the underground works, situated mainly in hard granitic rocks, under the sedimentary series—the contact is situated above the roof of the power-station cavern—work proceeded without any difficulty and about 180,000 m^3 was removed (Fig. 18).

Concrete placing and equipment installation is now in progress in the power station (Fig. 16), so that first power production awaits the closure of the dam. This is scheduled for October 1962, after a preliminary experimental period in which the behaviour of the dam foundations will be kept under rigorous control.