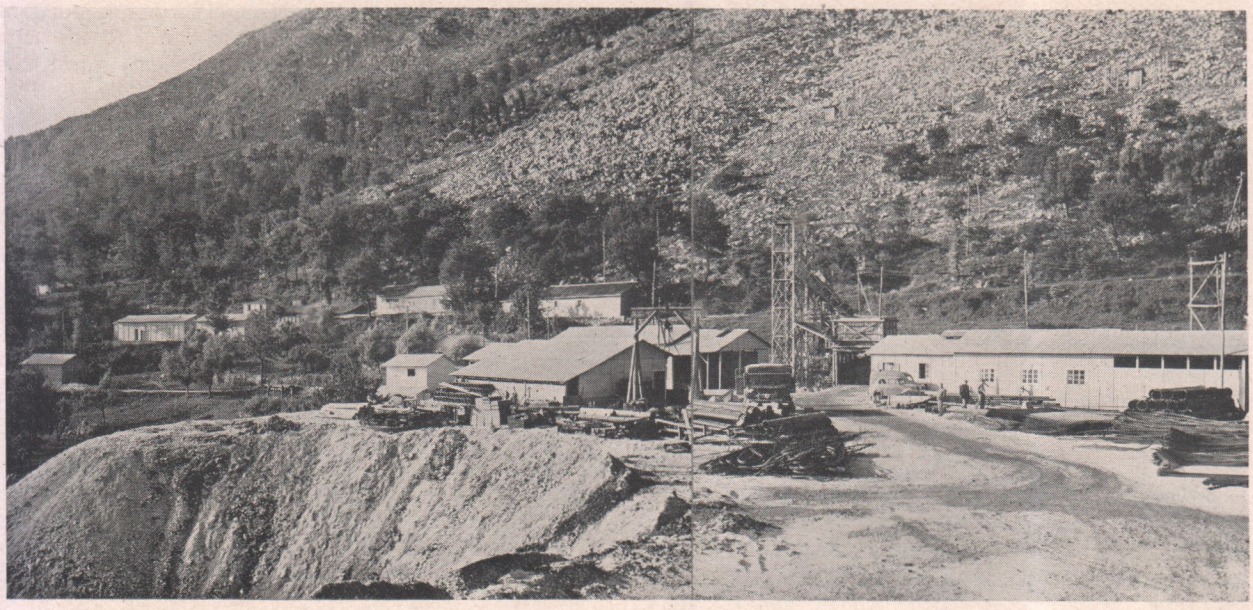


Fig. 1. View of the works at the Venafro end of the tunnel

The Volturno-Garigliano Scheme

Particulars are given of this Italian project, constructed by the Società Meridionale de Elettricità, with special reference to the tunnelling work

BEGUN about one year ago, the construction of Volturno-Garigliano hydro-electric power plant was the result of extensive study by the engineers of the Società Meridionale di Elettricità (S.M.E.) of Naples, who for several years devoted their energies to the complex problems involved. The scheme is now nearing completion and is not only a notable achievement in itself but is one of the greatest importance to Southern Italy as the 131 million kWh per annum of energy that will be produced will make a valuable contribution to the industrialisation of the South.

The Volturno river has a length of 170 km. (105 miles) from its source in the mountains of Meta, in the Molise district, to where it flows into the Gulf of Gaeta. The course of the river, because of its different characteristics, can conveniently be divided into three distinct parts: the first from the source at Cape Volturno to its confluence with the Vandra torrent; the second down to its confluence with the river Calore, which is its most important tributary; and the remainder from the junction with the Calore to the Tirrenian Sea.

The power plants under construction for the S.M.E. are situated on the second portion of the river Volturno, the development of which, however, presented a number of difficult problems. The first part of the river was already developed by the Ente Autonomo de Volturno whose power stations were in operation, while the lower part serves the important function of irrigating the Campania — a fact which has so far

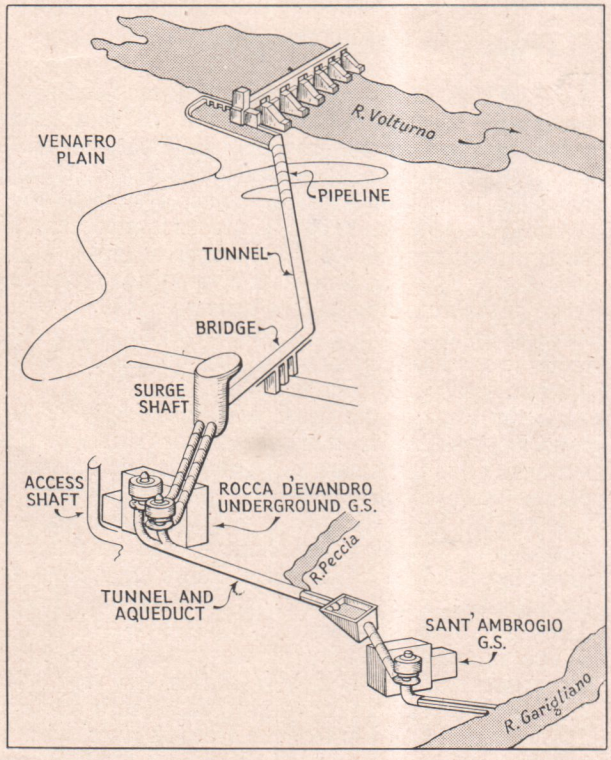


Fig. 2. General outline of the Volturno-Garigliano scheme

inhibited a definite scheme for its utilisation as a source of hydro-electric power.

The middle portion has presented the engineers with two principal difficulties; the first of these is the width of the river below the junction with the Vandra, which would have necessitated a big and expensive dam and intake works; and the second, which is still more important, is the fact that from the natural head at the junction of the Vandra river, which is 236 m. (770 ft.) above sea level, to where it joins with the Calore river at 35 m. (115 ft.) above sea level, there is only a difference of 200 m. (655 ft.) over a distance of 50 km. (30 miles). Further, of this 200 m. (655 ft.) the first 60 m. (197 ft.) is located between two points comparatively near to each other, which, while offering fairly easy utilisation of such a head, would greatly complicate the problem of utilising the remaining downstream course.

Also, the river receives several tributaries which add to the discharge and which proved a deterrent against the possible utilisation, by means of a reservoir, of this central portion of the Volturno river. In fact, every scheme which attempted to utilise the heads and discharge in the middle part of the river were negatived by the extreme lengths necessary for supply channels, which would have been altogether out of proportion to the amount of power that could be produced.

In consideration of these difficulties, the engineers of the S.M.E. have adopted a more convenient, easy and alternative solution by conveying the waters of the Volturno to the nearby Garigliano river and, in this way, utilising the different levels of the two river beds.

In 1950, in accordance with this plan—first proposed by Eng. Giovanni Battista Canevari — the S.M.E. started the construction of two power stations, one at Rocca d'Evandro and the other at S. Ambrogio, combining the waters of the Volturno river with the intake below the junction with the Sava river and discharging them out in the Garigliano river below, where this joins the river Peccia. In this way the difference in height provides a head of 160·40 m. (525 ft.) and gives a water discharge of 13·20 cu. m. per sec. (465 cusecs) at the Rocca d'Evandro power station and 18·0 cu. m. per sec. (635 cusecs) at the S. Ambrogio power station, which will give a total production of 131 million kWh per year.

Details of these two power stations are as follows:

FIRST POWER STATION (ROCCA D'EVANDRO)

Natural head	140·30 m. (460 ft.)
Installed power	2 × 22,000 kVA
Energy production per year	109,000,000 kWh
Delivery tunnel dimensions:	
Circular diameter ...	4·26 m. (14 ft.)
Area	13·86 sq. m. (149 sq. ft.)
Length	14·460 km. (9 miles)
Discharge tunnel:	
Length to the reservoir for the second power station is 5·042 km. (3·14 miles) of which 4·052 km. (2·52 miles) is tunnel and 0·990 km. (0·62 miles) is open channel.	

SECOND POWER STATION (SANT' AMBROGIO)

Head	20·10 m. (66 ft.)
Installed power	7,500 kVA
Energy production per year	22,000,000 kWh

The delivery head consists of the discharge channel of the first power station, which, in open air, has a length of 1,180 m. (3,870 ft.)

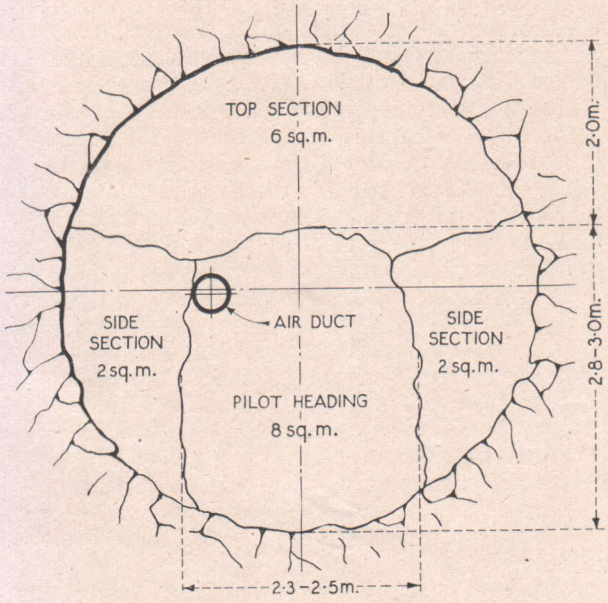
The planning of these power stations was undertaken by Prof. Carlo Drioli, General Director of S.M.E., Prof. Giacomo Baroncini, Director of the Plants, and Eng. Ugo Carotenuto, the Director of Works for the power station.

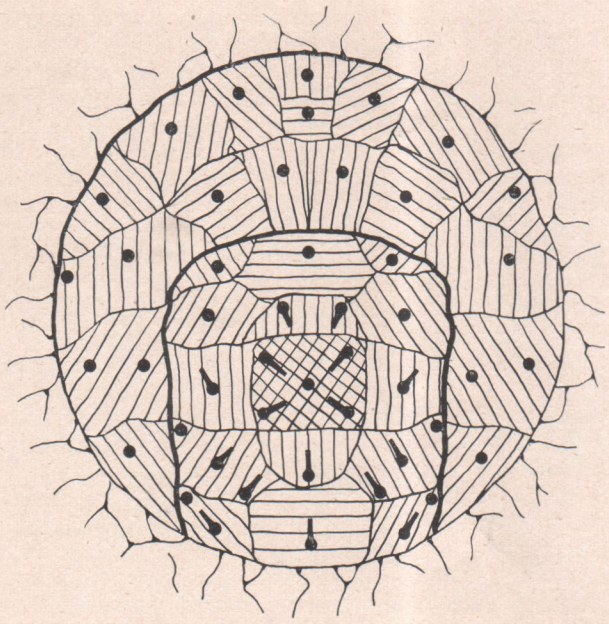
Fig. 3. The camp at Venafro, consisting of prefabricated houses dispersed on the mountainside

Rocca d'Evandro Delivery Tunnel

One of the most interesting aspects of the work for the Volturno - Garigliano power station is the delivery tunnel, which carries the waters from the Volturno, with a head of 140·30 m. (460 ft.) to the Rocca d'Evandro power station. This is essentially a pressure tunnel, of circular section, with an internal diameter of 4·26 m. (14 ft.) and having a length of 14·50 km. (9 miles). The first 5,500 m. (18,000 ft.) cross the plain of Venafro in a pipeline constructed above the plain and under the Volturno-Sulmona railway, the Rio S. Bartolomeo and some smaller roads.

For the succeeding 9 km. (5·6 miles) the tunnel goes through the limestone mountains which divide the Vol-





turno basin from that of the Garigliano. When passing the Casilina highway it is constructed as a reinforced-concrete bridge with five arches of 25 m. (80 ft.) width each.

The contracts for the construction of the tunnels were awarded by S.M.E. to Impresa Angelo Farsura of Milan with Silvio Arrigoni as director of works, and Impresa Nicola Rivelli of Naples with Nicchiarelli as director of works.

In this article we are concerned only with the work carried out by Impresa Farsura in the first part of the tunnel, which conveys the waters from the Volturno to the Garigliano. This work, which has now been completed, has attracted particular interest due to the exceptional results obtained. The tunnel driven by this company has the following data:

Total length (two adits, one with shaft)	5,436 m.	17,800 ft.
Diameter of tunnel:		
Excavation	4·95 m.	16 ft. 3in.
Finished	4·26 m.	14 ft.
Finished area	19 sq. m.	205 sq. ft.

Type of rock: Limestone of extremely variable character.

The work of excavation was started on February 1, 1950, from both ends at Venafro (Pozzo, Rocca Pipirozzi) and Mignano (Cannavinelle), driving in opposite directions on the same axis.

Tunnelling Operations

The tunnel was planned according to the full-face method. However, in order to ascertain the type of rock likely to be encountered, the excavation was

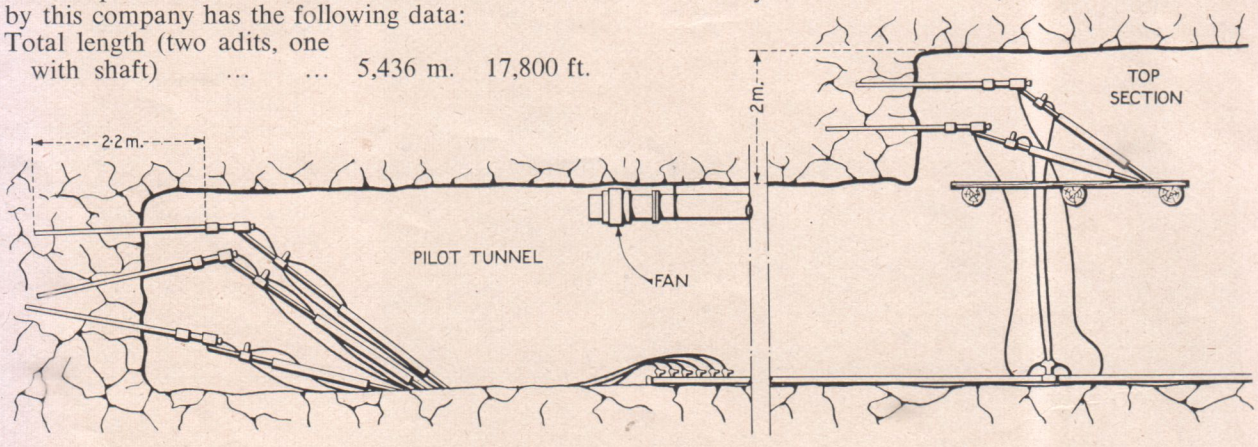


Fig. 4 (top left). Subdivision of the tunnel section for excavation

Fig. 5 (top right). Blasting pattern when using a bottom pilot heading

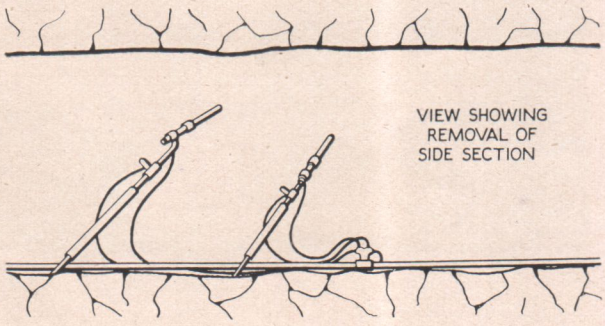


Fig. 6. Disposition of drills in the pilot and main headings

Fig. 7. Three Atlas RH 655W drills at work in the pilot tunnel

Fig. 8. A portion of the Rocca d'Evandro tunnel before being lined

carried out with a pilot tunnel which was kept at the bottom when the rock was hard and firm, but was carried along the top when the nature of the rock required immediate reinforcement. The full-face method was, therefore, generally followed by breaking down the top section in the first case (pilot tunnel at the bottom) and by breaking down the central section in the second case (pilot tunnel in the roof). The pilot tunnel was driven far in advance of the main heading, not in order to secure greater economy or to facilitate the work by dividing it into two sections (it would have been more economical, in fact, to have driven all on the same vertical section) but, on the contrary, mainly to allow a more exact and careful examination of the rock to be made and so adopt the best blasting methods. The pilot tunnel was, therefore, of an exploratory character (see Fig. 6). The excavation at the top and side sections kept pace of course with the pilot tunnel at a suitable distance in the rear.

Fig. 6 also shows the number and position of the rock drills used, all being of Atlas manufacture, viz:

3 type RH-655W, with pushers, in the pilot tunnel.

2 for the roof section.

2 for the side sections.

Seven rock drills were thus simultaneously at work in each heading and each drilled thirty 7-8 ft. deep holes in each shift.

Charging and Blasting

Drilling was conducted on the Swedish double-vee pattern, the firing scheme being shown in Fig. 4. Fig. 5 shows the firing sequence used where the rock was poor and less compact. The quantity of explosive used was 1·5 kg. per cu. m. (2·4 lb. per cu. yard) of rock with a composition of 1·1 kg. G.D.M. and 0·4 kg. Dinamon.

Ventilation

Ventilation of each heading was effected by a 35 h.p. electrically-driven fan for the main circulation of the air, assisted by a compressed-air-driven auxiliary fan for the quick dispersal of the gases after the blasts. This double system of ventilation allowed the workers to go back to work in a very short time—not more than about 8-10 minutes. The ventilation ducting was 400 mm. diameter (15¾ in.) and constructed of steel sheeting for the first 1,500 m. (5,000 ft.) after which canvas-rubber tubing was used for the remaining distance to the face.

Removal of the Spoil

The driving method used made mucking out an easy matter. In fact, as the pilot tunnel was driven far in advance of the top and side sections—about 60 m. (200 ft.)—it was possible for a whole train of 15 cars and a loader to be moved into the pilot tunnel before blasting the top and side sections of the main heading. Mucking out took place in the main tunnel and the pilot tunnel simultaneously, the operation being so timed that the whole train of cars and two loaders moved out together, making way for the two new drilling teams.

Organisation and Analysis of Working Time

For the construction of the part of the tunnel

assigned to the Impresa Farsura, 500 workers were employed. Of these, 60 were used from the approach adit of Magnano and 60 from the approach adit of Venafro. At each adit the workers were divided as follows:—

Pilot tunnel:

1 foreman
4 drillers
1 helper
1 loader driver
1 mechanic

8 for three shifts of 8 hours

Top and side sections:

1 foreman
6 drillers
2 helpers
1 loader driver
1 mechanic

11 for three shifts of 8 hours

When rock was encountered that made reinforcement and timbering necessary (Fig. 10), the drilling team was modified somewhat as follows:—

1 foreman
8 drillers
2 helpers

11 for two shifts of 10 hours

Normally the two approaching gangs worked in shifts of 8 hours with the excavation of two rounds per shift, viz. six rounds in 24 hours. As the advance in each round was about 1·80 m. (5·9 ft.), the average rate of advance in 24 hours was 10—12 m. (33—40 ft.). Consequently the advance from the two adits in 24 hours averaged 20—22 m. (66—72 ft.).

The division of the working time for each shift is given hereunder:—

Advance of loading machine ...	10	minutes
Mucking	90	„
Removal of loading machine ...	5	„
Advance of rock drills	10	„
Drilling	100	„
Charging and blasting	10	„
Ventilation	15	„
Each shift ...	240	minutes

Details of Typical Round in the Pilot Tunnel

Cars loaded (1,200 litres each) (42½ cu. ft.)	15
Number of holes drilled	20—30
Total length of holes drilled	70—75 m. (230—246 ft.)
Explosives used:	
GD1—M	20 kg. (44 lb.)
Dinamon	5 kg. (11 lb.)
Advance obtained	2—2·20 m. (6 ft. 6 in.—7 ft. 3 in.)

Use of Drilling Equipment

All the above details refer to the second part of the tunnelling work, carried out by the Impresa Farsura. The whole work may be divided into two periods,

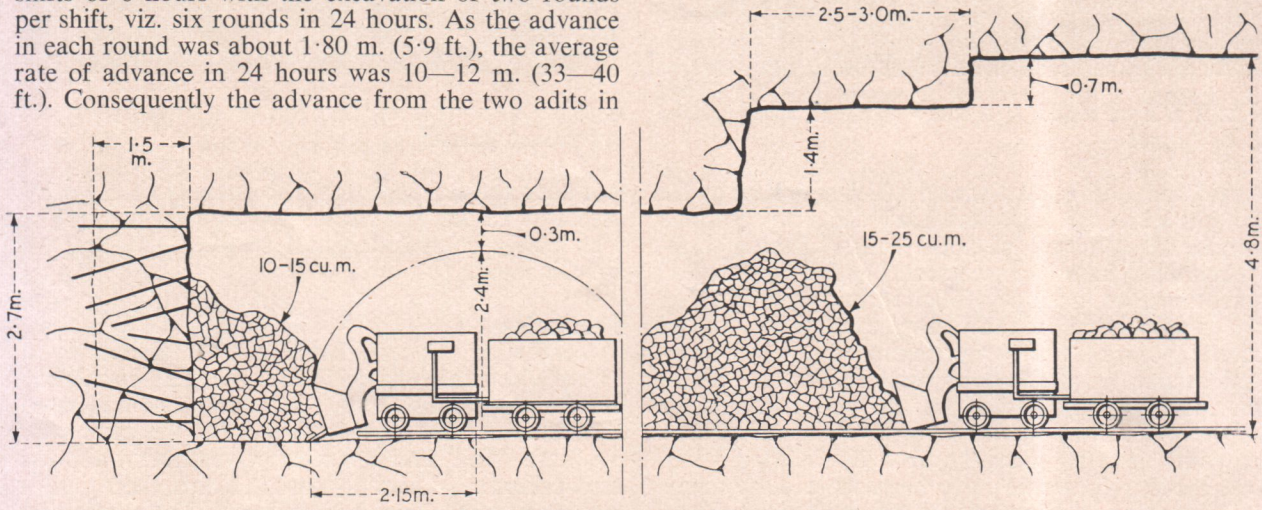


Fig. 9. Mucking out in normal rock using a bottom pilot heading

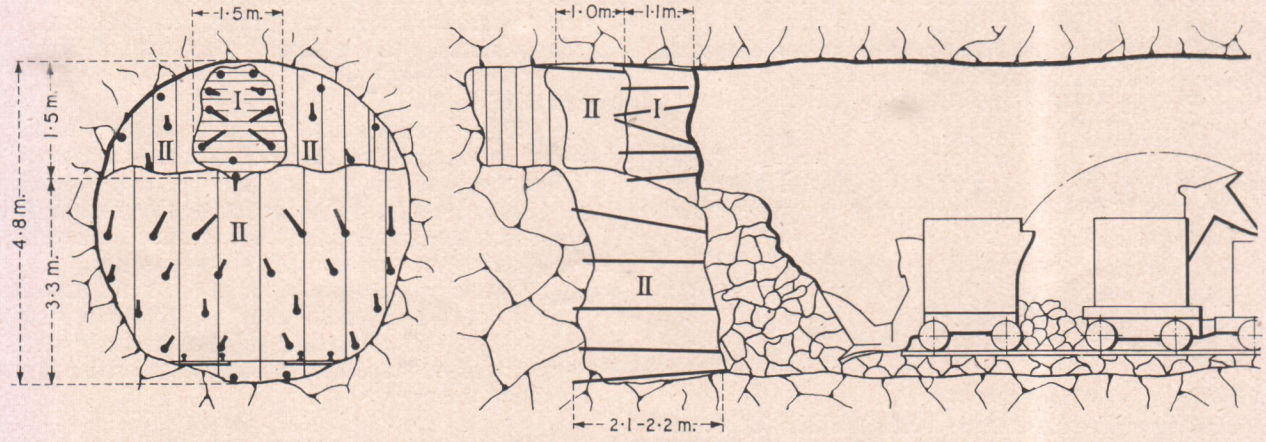


Fig. 10. Blasting pattern and mucking out in weak rock using a pilot heading at the top

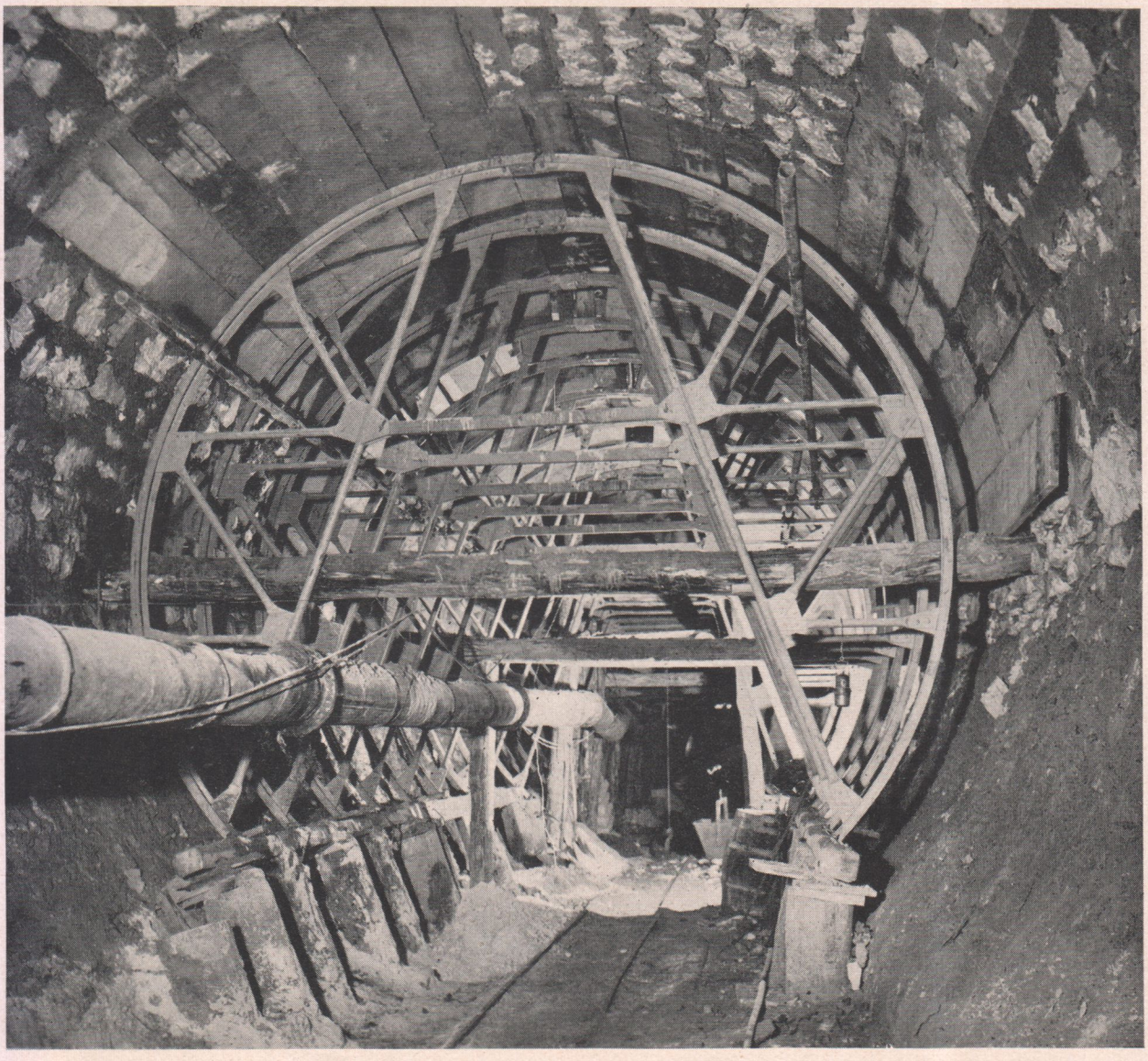


Fig. 11. Shuttering for placing the concrete lining

according to the drilling methods used; the first from February 1 to June 30 and the second from July 1 to December 10, 1950.

Excavation was begun on February 1 from the two adits, Venafro and Mignano, but owing to the necessity to obtain a more rapid rate of advance, the engineers of the Impresa Farsura discontinued the drilling methods and equipment previously used and changed over on July 1, 1950, to the Swedish method. This innovation resulted from a study that the engineers had made in the meantime of a number of tunnelling works in other countries, notably various hydro-electric schemes under construction by Electricité de France, where the Swedish method had been successfully applied for two years or more. So impressed were they with the results they saw that they decided to convert to the same method and equipment without delay. In France this method was based on the use of Atlas light rock drills, type RH-656W, used in conjunction with Sandvik Coromant tungsten-carbide-tipped drill steels and pneumatic pushers. An immediate improvement in the rate of advance resulted even before the miners had time to become conversant with the new technique, but as more experience was gained tunnelling records began to be obtained. One fact alone will be sufficient to indicate the success obtained. The completion of the work was timed for the end of May 1951, but against any original expectation, the work was finished on December, 10, 1950.

An interesting comparison of the footage obtained with and without the new equipment is as follows:—

Heading	Older Equipment	Swedish Method
	In 5 months' work (from Feb. 1 to June 30, 1950)	In 5 months and 10 days' work (from July 1 to December 10, 1950)
Mignano -	800 m. (2,620 ft.)	1,700 m. (5,580 ft.)
Venafro -	420 m. (1,380 ft.)	2,080 m. (6,820 ft.)
Total Advance	1,220 m. (4,000 ft.)	3,780 m. (12,400 ft.)

(Continued on page 236)