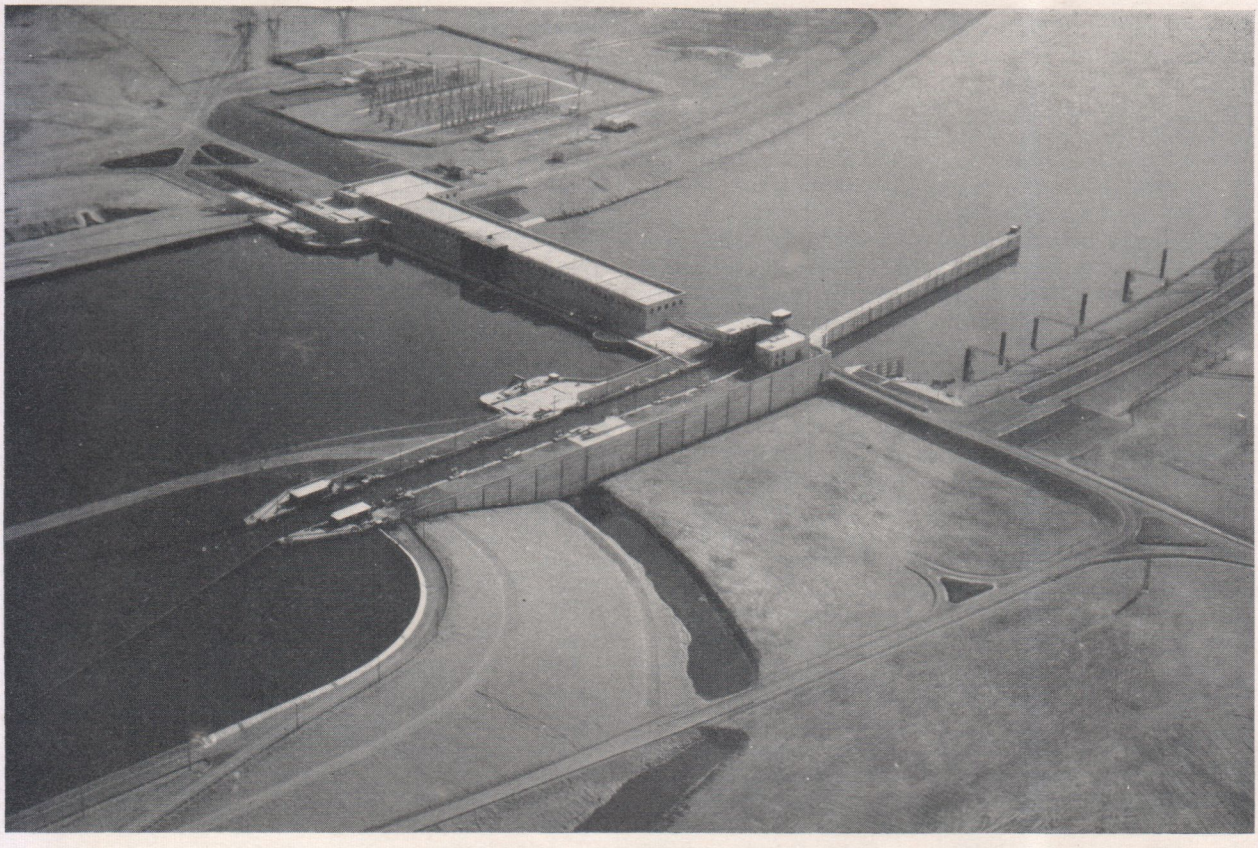


*Fig. 2. An upstream aerial view of Henri Poincaré power station*

# The Rhône Valley

## A description of the multi-purpose development of the Rhône between the Swiss frontier and the Mediterranean with particular reference to current schemes in the middle third of the Lower Rhône

PART ONE

IN this series of articles, we propose to describe the various stages of the vast multi-purpose development of the Rhône valley, with particular reference to the middle third of the lower section of the river. Since time immemorial, the Rhône has been one of the main arteries of communication in France and has also irrigated great areas of semi-arid territory. Although this integrated development has the principal aim of making more power available, improved navigational and irrigation facilities, flood protection and water supply are byproducts of almost equal importance.

For many years past, the production and consumption of electrical energy in France has increased by 8 or 9% per annum, corresponding approximately to a 100% increase every eight years, and it is estimated that, at the current rate of industrial expansion, the demand will be from 102 to 110 milliard kWh by 1966. If this demand is to be satisfied, thermal, nuclear and hydro-electric plant will have to be installed wherever and whenever possible, although the position has been eased by the important discoveries of large reserves of natural gas in south-west France and of oil in the Sahara. Nuclear generation is expected to provide 5 milliard kWh by 1965 and 50 milliard kWh by 1975, but although Electricité de France is now building a nuclear power station at Chinon in the Loire Valley, full-scale and economical nuclear generation is still a matter of probability rather than certainty because so much technical progress still has to be made in this relatively young science. France is not a major exporting country and her prosperity must to some extent depend on limiting imports, not only of raw materials and consumer goods, but also of energy. While research and experience in nuclear engineering continues, all available hydro-electric resources are of prime importance, and the Rhône has thus become one of the keys to the future prosperity of the country.

A complete development of the Rhône entails a river length of 450 km. from the Swiss frontier to the town of Beaucaire some 55 km. from the Mediterranean and will involve a total of 19 separate units, seven of which will be on the Upper Rhône upstream

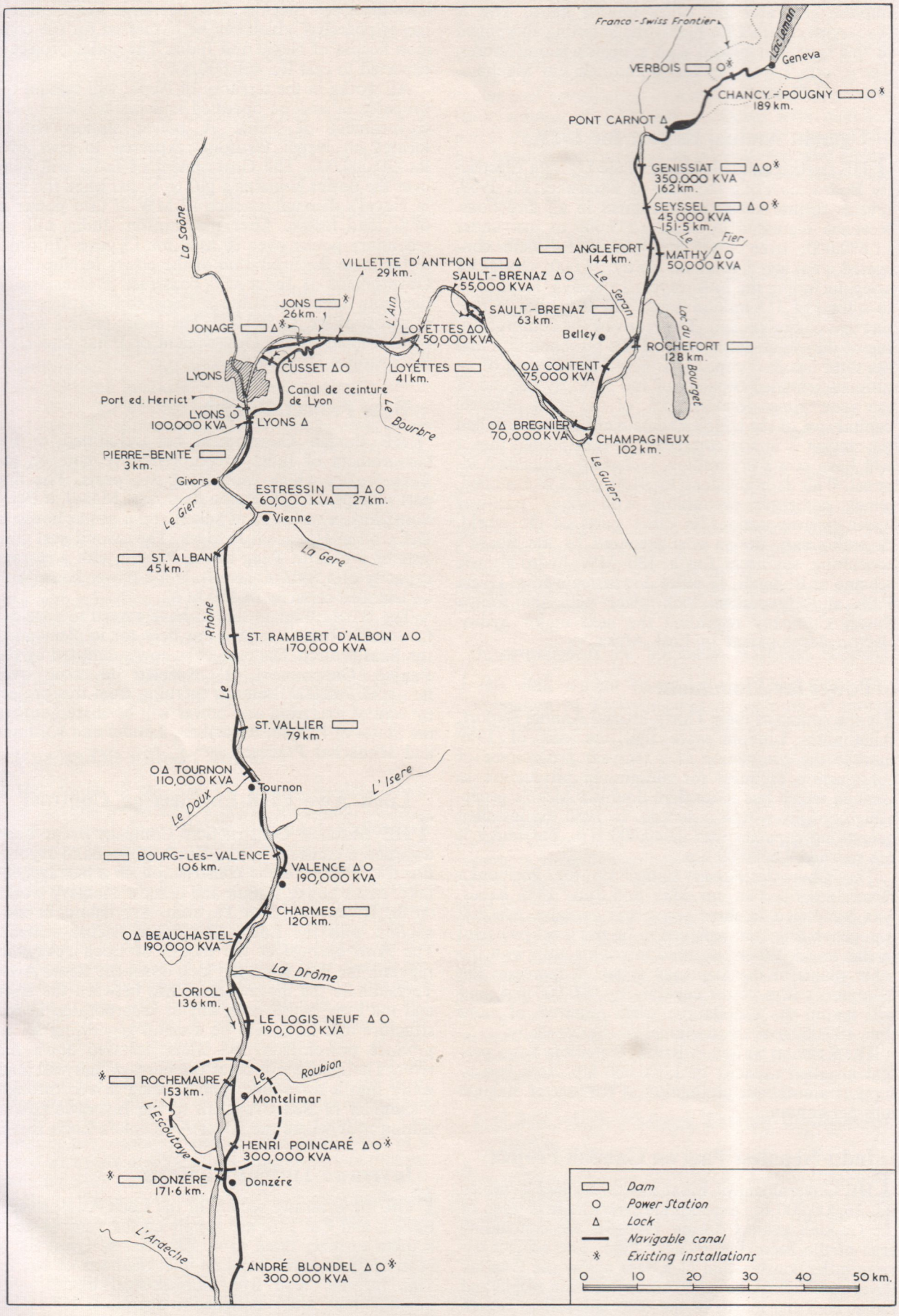



*Fig. 1. Map showing the development of the Rhône from the Swiss border to the Ardeche river*

from Lyon and 12 downstream. Five major developments are either in service or under construction (see Fig. 10) in the central section of the Lower Rhône, which, when completed, will increase the available peak-load power by 250 MW for a 4-hour period. The 19 power stations will have a total capacity of 2,900 MW and will produce 15 milliard kWh. About 40% of the hydro-electric potential is already in service through the completed schemes at Génissiat (see WATER POWER, December, 1952, p. 466) and Seyssel in the upper reaches of the Rhône, and Donzère-Mondragon (see WATER POWER, January, 1953, p. 30) and Montélimar in the middle third.

By an Act of Parliament dated May 27, 1921, the Compagnie Nationale du Rhône (C.N.R.) was entrusted with the development of the Rhône from the three main points of view of power, navigation and agriculture. The company undertook the first step in harnessing the Rhône by building the dam and power station at Génissiat of 420 MW capacity and producing 1,700 million kWh annually, and the Seyssel compensation basin, followed by the Edouard-Herriot docks at Lyon. The C.N.R. then commenced the development of the central section of the Lower Rhône between the confluences of Isère and Ardeche and covering a length of 110 km. between Touron and Mondragon.

The preliminary studies of the central section showed almost immediately that the nature of the terrain and the number of towns and villages in the valley would make it impracticable to build high dams across the valley, because such a solution would have entailed the loss of very large areas of valuable agricultural land and the exodus of many widely distributed centres of population. A possible solution might have been to build a series of dams across the river bed with high retaining walls extending from each dam upstream to form a storage reservoir, but this type of development would have involved enormous expenditure without providing any satisfactory flood control. The final plan adopted provides for interdependent chains of dams, diversion canals and power stations at suitable intervals along the river, and, apart from obvious local differences, all the sections of the Lower Rhône will ultimately resemble each other.

Seasonal regulation of the discharge is difficult, but some control can often be maintained on a weekly or daily basis, particularly in view of the Génissiat installation which can pass 750 cu. m. per sec. at peak periods. It will eventually be possible for the power stations at Seyssel, Chautagne, Belley and Brégnier-Cordon to pass peak discharges of 600 cu. m. per sec.; the peak discharge at Sault-Brénaz will be reduced to 500 cu. m. per sec., but the power station farther downstream will benefit from the additional discharge of the river Ain and will have a maximum flow of 700 cu. m. per sec.

Three power stations, at Pierre-Bénite, Bourg-les-Valence and Vallabrègues, will all have large storage reservoirs, and it is anticipated that the discharge available, reinforced by the former two, will be compensated by the Vallabrègues development when the scheme is finished. However, in the meantime, discharge through the power stations will have to depend on the amount of compensation flow required to maintain normal navigation upstream of undeveloped sections.

*Fig. 3. Upstream view of Donzère power station showing canal lock and tailrace*

Three power stations, at Pierre-Bénite, Bourg-les-Valence and Vallabrègues, will have large storage reservoirs, and it is anticipated that the discharge available, reinforced by the former two, will be compensated by the Vallabrègues development when the scheme is finished. However, in the meantime, discharge through the power stations will have to depend on the amount of compensation flow required to maintain normal navigation upstream of undeveloped sections.

In contrast to the lower part of the river, the Upper Rhône has never been a practicable proposition for vessels of any size, and it will only become navigable when the hydro-electric development of the section between Lyon and the Swiss frontier is further advanced. However, as those who have made the interesting but harassing journey through inland waterways from Le Havre to Port St. Louis will know, a passage up or down the Lower Rhône is not always uneventful. Although navigation is often difficult during long periods in the summer, schemes have to be completed with as little interference to river users as possible. This fact has greatly influenced the programme established for the development south of Lyon, but projects upstream from the city have been undertaken purely from the standpoint of hydro-electric potential. There were a number of reasons for the decision to develop the middle third of the Lower Rhône first. There are shoals and sandbanks throughout the course from Lyon to the Mediterranean, but a more efficient regulation of the discharge from Lake Léman (Lake of Geneva) would alleviate this difficulty in some places, and, in any case, the conditions have been greatly improved by the power stations already in service. The gradient of the Rhône fluctuates considerably, and there is a particularly strong flow in the middle section which makes upstream navigation difficult and occasionally perilous; the power required for propulsion is usually calculated as 1 metric h.p. per ton, but commercial users have been obliged to operate specially built craft which are uneconomical outside this section or on the Saône. It is for this reason that it has been unusual in the past for commercial craft to ply from the Mediterranean up to Chalon-sur-Saône and beyond; thus, with the improvement of the middle section the benefit to navigation will be immediate and the future of transport on the Rhône and Saône assured.

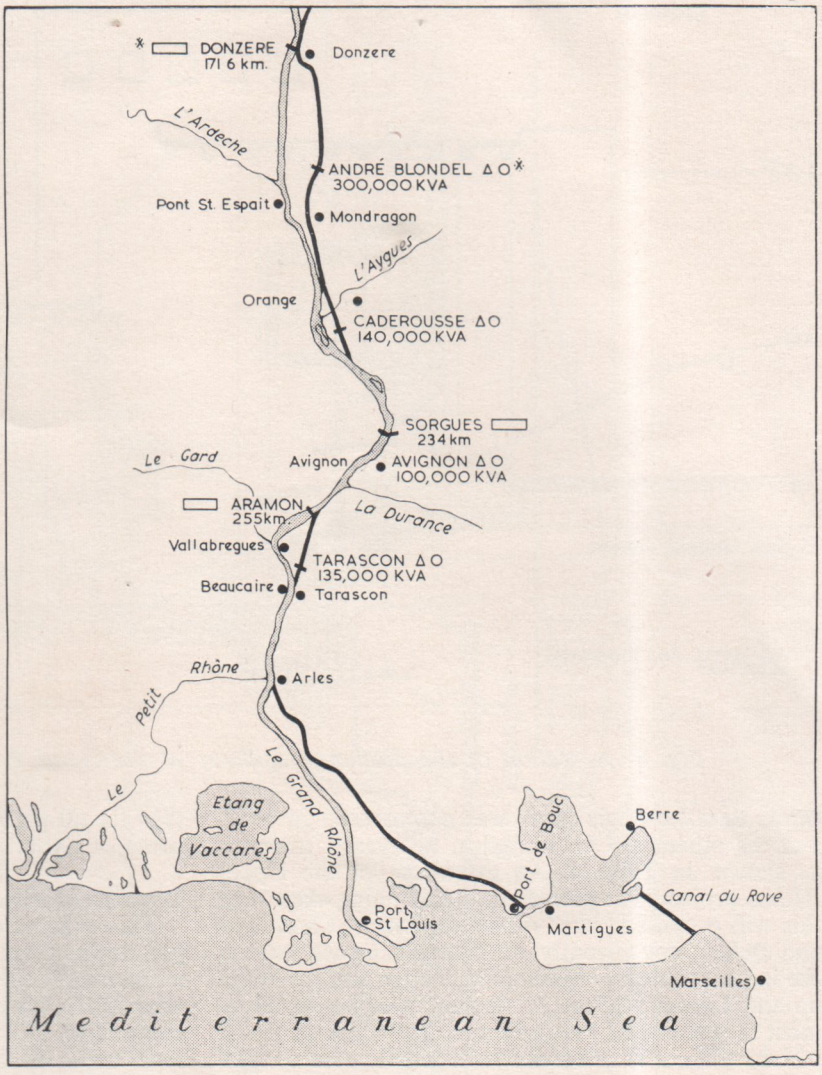



*Fig. 4. Development of the final section of the Rhône*

The Compagnie Nationale du Rhône is following a well-defined programme for the development of the entire Rhône valley; as already mentioned, the Génissiat-Seyssel project was the first major step, because the 420 MW plant is in a key position between the heavily populated Paris region and the south east. The second stage, covering the middle third of the Lower Rhône, is now in the course of development, and the power stations at Donzère and Montélimar are already in service with a total installed capacity of 570 MW. Of the remaining three units in the middle

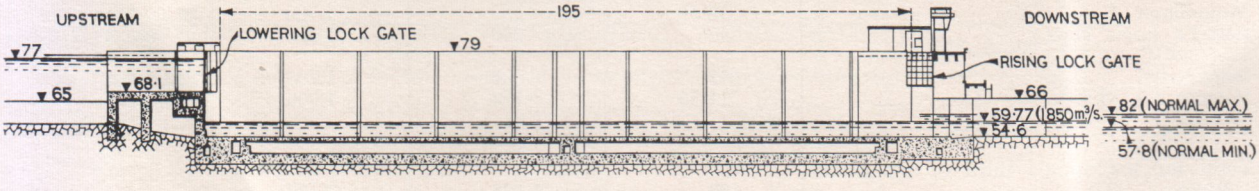



*Fig. 5. A section of the lock at Henri Poincaré station in the Montélimar section*

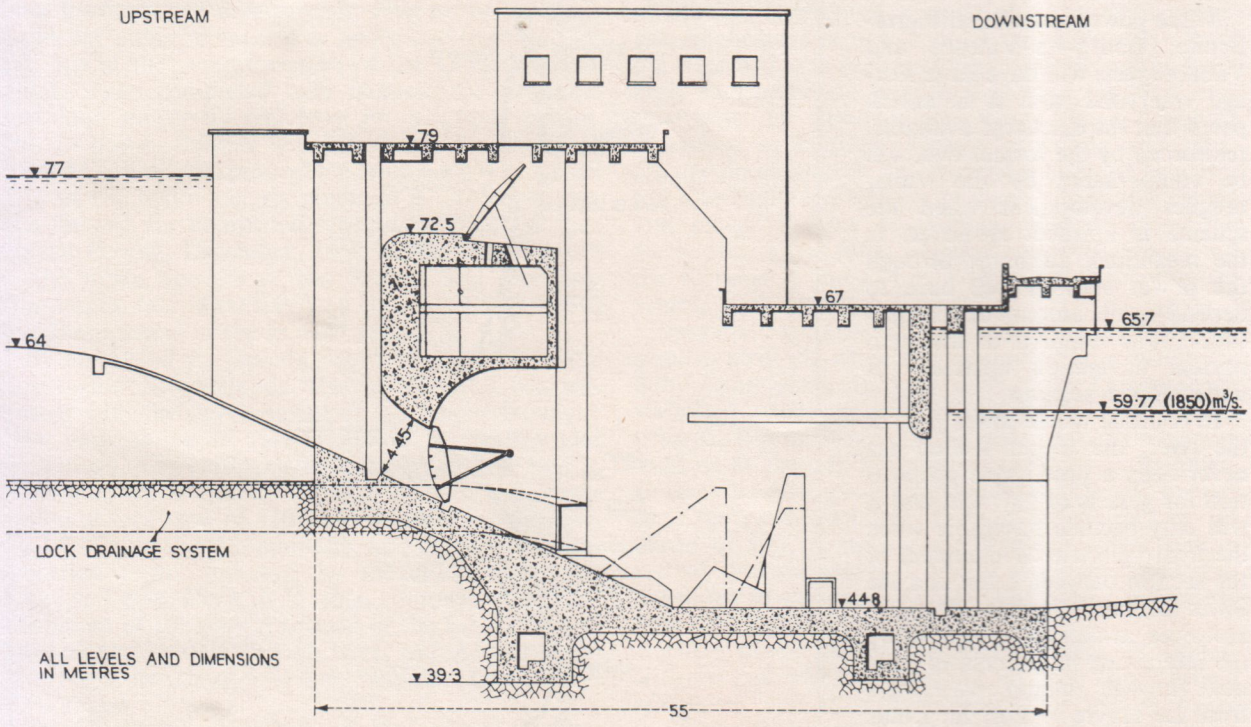



*Fig. 6. A section of the discharge spillway at the Henri Poincaré power station*

third, Baix-Le-Logis Neuf was commenced in 1957, and the others will be started at two-yearly intervals as shown in Table I. An extension of the Upper Rhône project is at present in the planning stage, and this will provide further power stations at Chautagne and Belley; concurrently with these schemes, studies are in progress on projects at St. Vallier and Le Péage on the Lower Rhône. A further complex development is planned at Pierre-Bénite, just south of Lyon, which, when it is in service, will greatly ease congestion in the Saône ports and at the confluence of the Rhône and Saône. Although it was originally intended that this project should be included in the current five-year plan, lack of finance has unfortunately enforced a postponement.

The southernmost development of the central third is Donzère-Mondragon, and has already been described with the André Blondel power station in WATER POWER, January, 1953, p. 30; a brief account may be given here, however. The chain of schemes in each section of the Lower Rhône will be developed from south to north so that Donzère is the first essential link in the middle third and has served as a prototype for all present and future multi-purpose projects south of Lyon.

**Donzère-Mondragon**

This scheme consists of a dam across the Rhône, just downstream of the small town of Donzère and of a historical defile bearing the same name, with an intake on the left-hand side of the river. A 28 km. canal, comprising 17·3 km. of headrace and 10·7 km. of tailrace, bypasses the river over a length of 31 km. The average gross head is 23·4 m. and the net head about 22 m.

The weir has six openings, closed by rubber-sealed tainter gates, the largest of which is 45 m. wide, providing a passage large enough to allow navigation, while the remaining five are each 31·5 m. wide. All the tainter gates are of unusual design and are fitted with a tilting upper leaf having a maximum course of 1·75 m.; the largest unit can be raised 15 m. above the sill. The normal water level at the weir is 58·00, which is 5·6 m. above the former low level for a discharge of 560 cu. m. per sec.; normal flood level is at elevation 56·85, corresponding to a discharge of 3,950

TABLE I

| Name | Height of fall | Installed capacity | Annual power production | |
|---|---|---|---|---|
| | m. | MW | million kWh | |
| Donzère-Mondragon ... ... ... ... | 24 | 300 | 2,000 | In commission |
| Montélimar ... ... ... ... ... | 18·50 | 285 | 1,700 | In commission |
| Baix-Le Logis Neuf ... ... ... ... | 13 | 200 | 1,200 | In course of construction |
| Beauchastel ... ... ... ... ... | 13 | 200 | 1,200 | Projected |
| Valence ... ... ... ... ... ... | 11·50 | 170 | 1,000 | Projected |
| Total for the middle third of the Lower Rhône ... ... ... ... ... | 80 | 1,155 | 7,100 | |

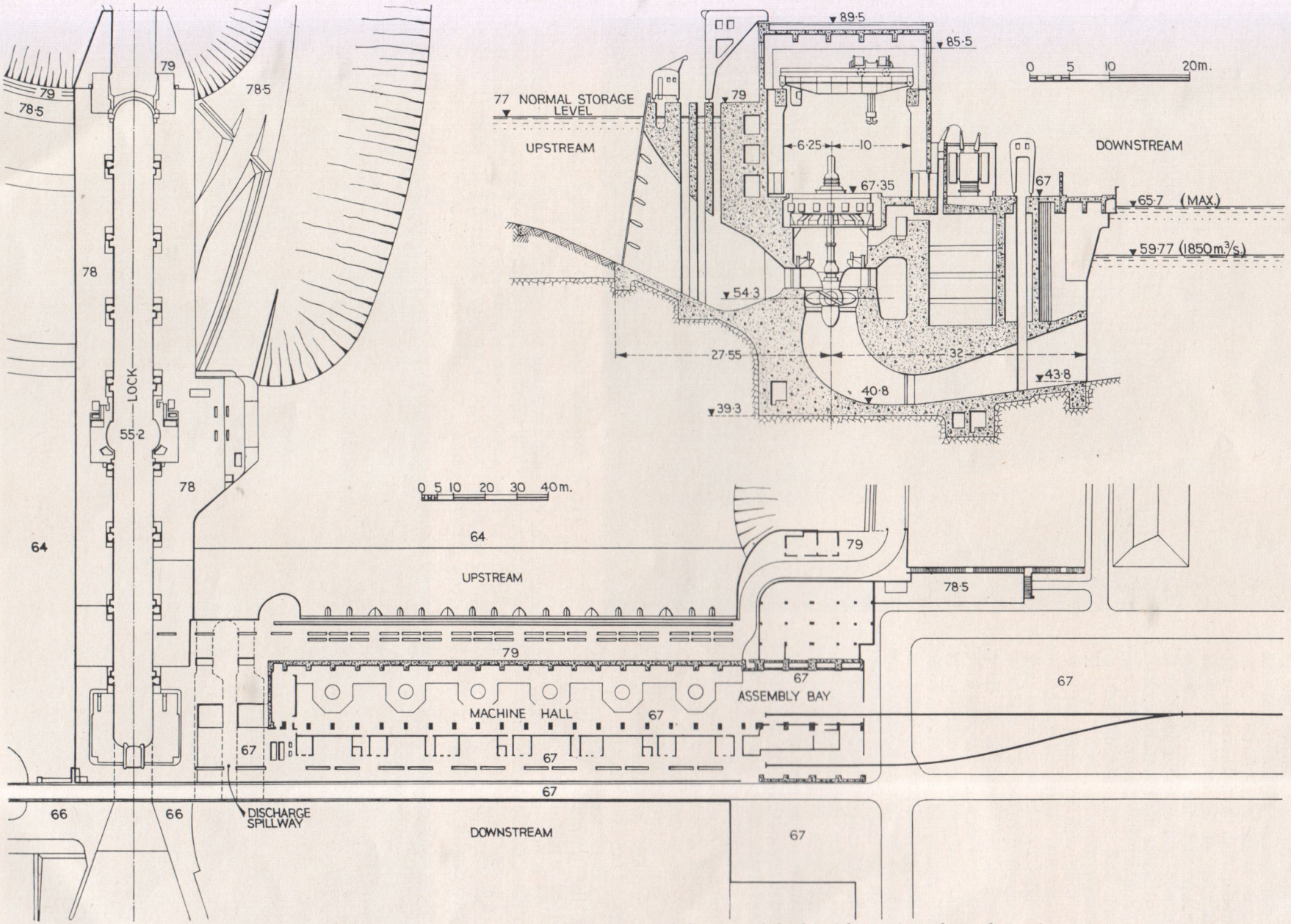



*Fig. 7. Plan of Henri Poincaré station, discharge spillway and lock with section through station*

cu. m. per sec.

The original draft design for the Donzère project placed the power house much farther downstream than it now stands, but, because of exceptionally poor quality rock, the site was subsequently moved upstream to a point where hard sandstone offers a sounder foundation. The machine hall is a spacious and impressive building, 184 m. long, 17 m. wide with the main floor at elevation 41·70 m.; the equipment includes six Kaplan turbines each developing 70,000 h.p. and discharging 255 cu. m. per sec. Each turbine is directly coupled to a 50,000 kW generator operating at 107 r.p.m. At the transformer station, several hundred metres to the west, the voltage is stepped up to 60 kV for use on the Paris-Lyon-Marseilles railway, and to 220 kV for transmission to the French grid.

On the upstream side of the power-station building, an articulated sluice gate of unusual design has been provided for emergency closure. When in the lifted position, this gate lies in a semicircle over the gantry used for moving the gate from one turbine intake to another. It closes by gravity against full pressure, and stoplogs fitting in the steel piling upstream of the trashracks can then be closed under balanced pressure. There is only one emergency sluice gate for the six turbines, this being moved to each turbine as required.

The tainter gates are electrically connected to the turbines and operate synchronously with the opening or closing of the guide vanes. This system prevents the formation of translatory waves at total shutdown, and although the latter has occurred on three occasions in three years, any effect has been short-lived and has in no way interfered with normal navigation.

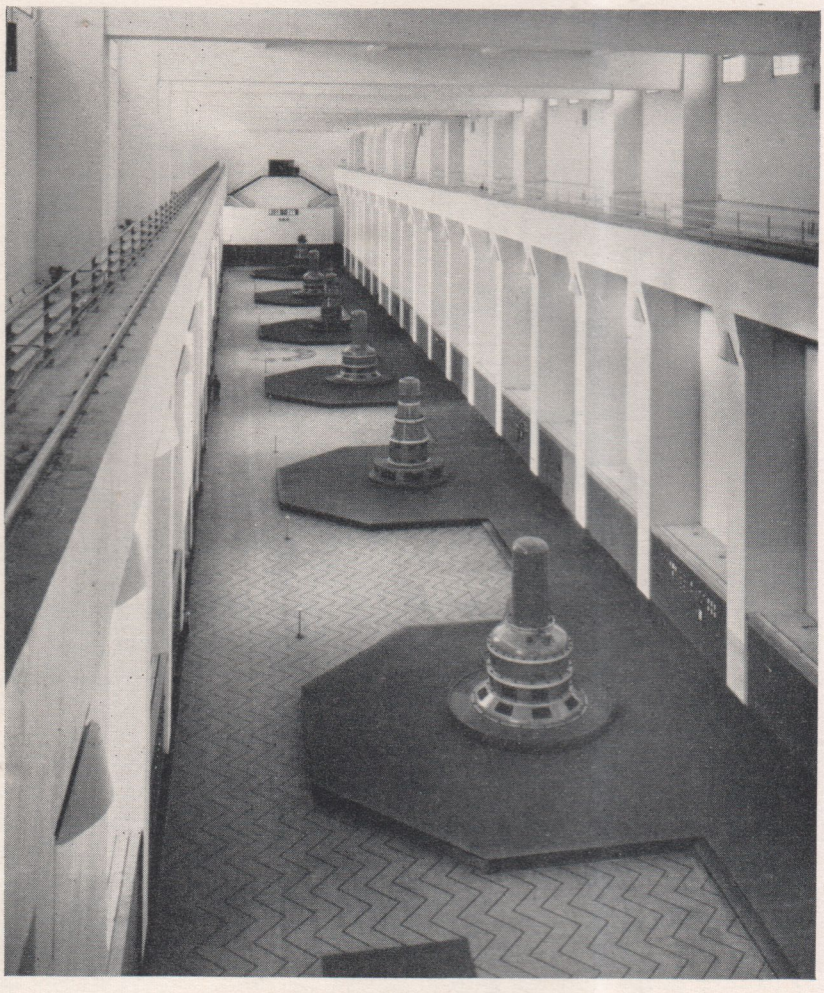


*Fig. 8. Machine hall of Henri Poincaré station*

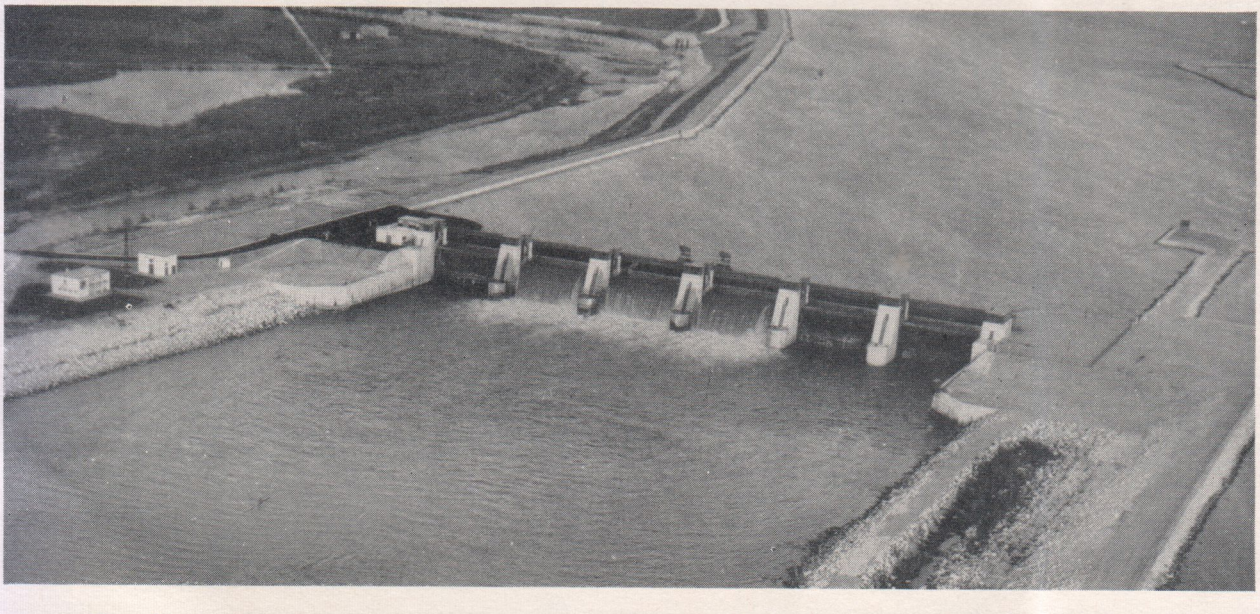


*Fig. 9. The Rochemaure storage dam with the entrance to the diversion canal in the right background*

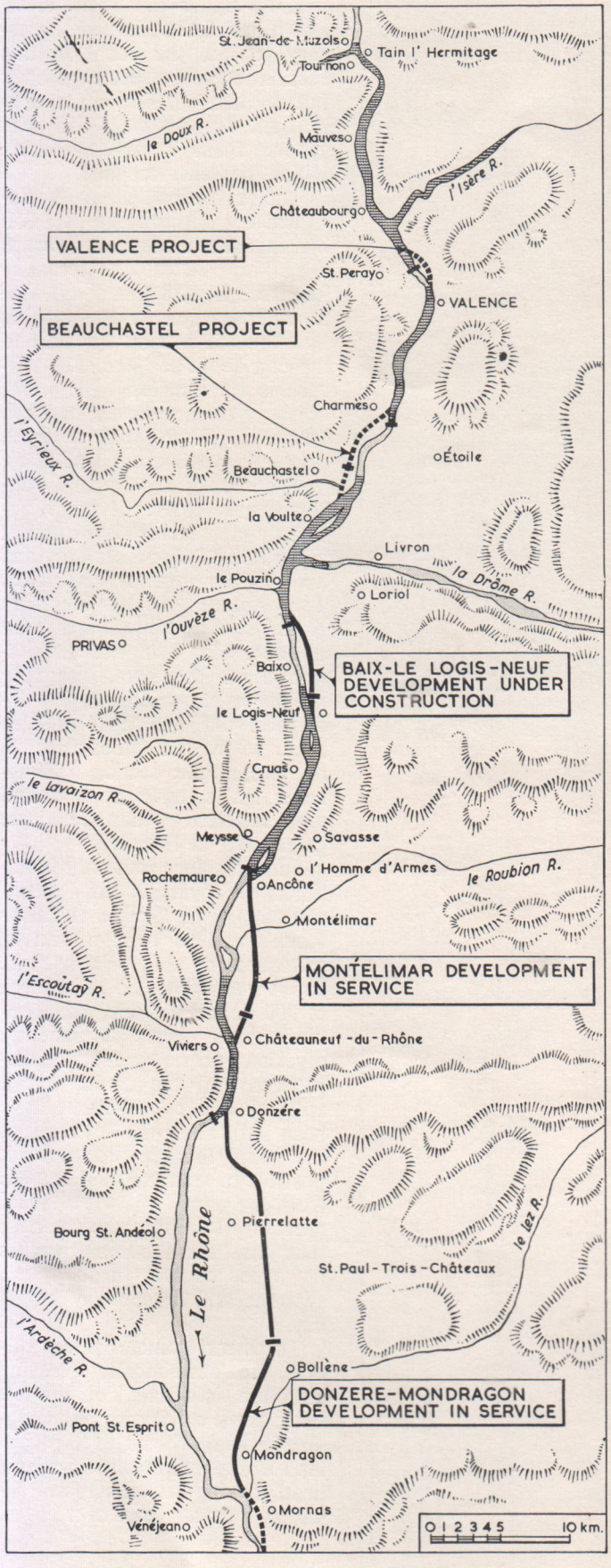



*Fig. 10. Development of the Lower Rhône central section, showing two stations in service, two projected and one under construction*

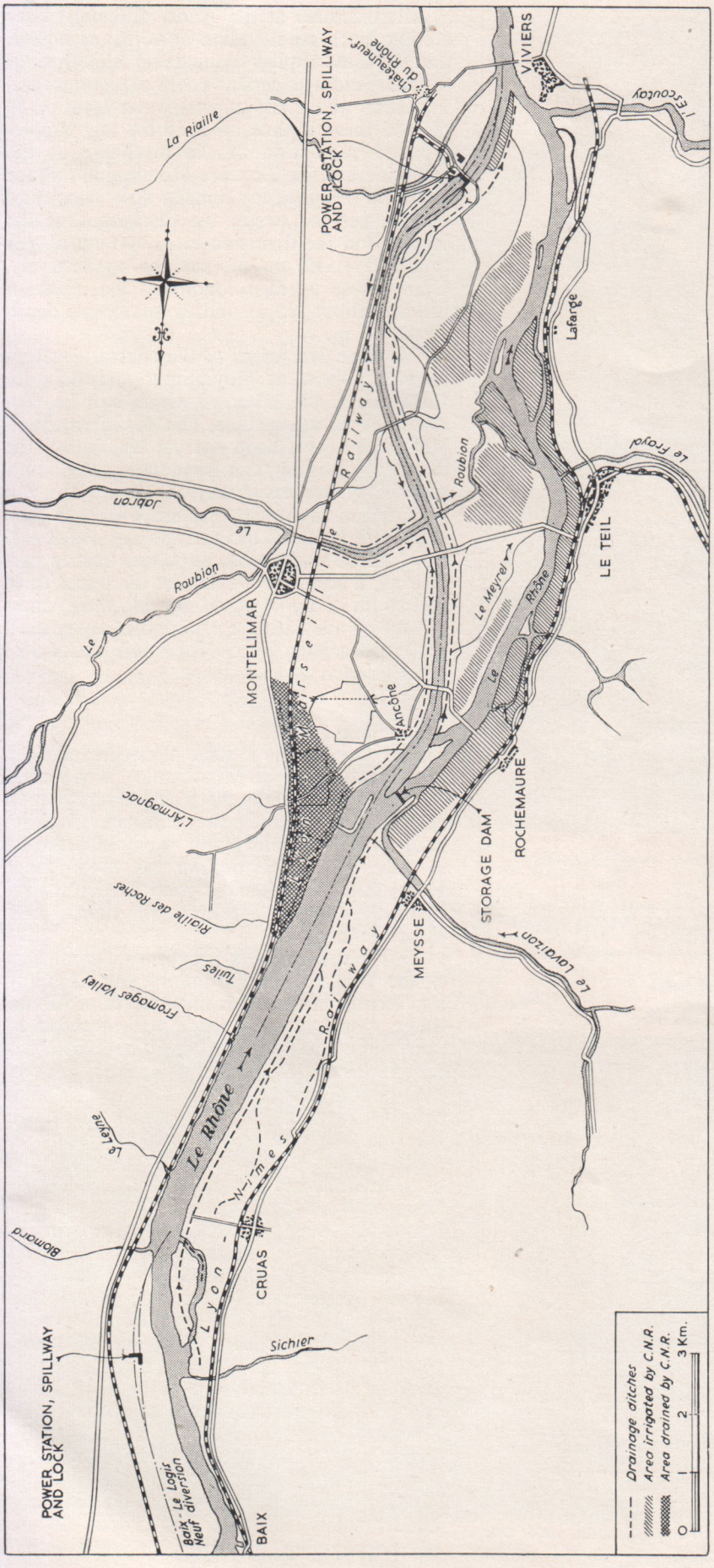
All structures at the André Blondel power station reach an elevation of 60 m. or higher, and the same applies to the dams on both sides of the headrace canal. These structures are, therefore, above the normal water level of 58 m. and there is thus no need for any supplementary regulation of the discharge at the canal intake. The Donzère-Mondragon tailrace has been designed for a mean flow velocity of 1·5 m. per sec. when the discharges of the Rhône and the diversion are 1,590 cu. m. per sec. and 1,530 cu. m. per sec. respectively. Under these average conditions the width of water is about 125 m. and the maximum depth about 12 m.

The next two stages of the central development are those at Montélimar and Baix Le Logis Neuf, the latter of which will be described in the next article. The Beauchastel and Valence projects have not yet begun, but the detailed planning has been completed, and when they are eventually in service the full potential of the middle section will have been exploited. It is still too early to say which section will be undertaken next, but finance permitting, it seems probable that the upper third just south of Lyon would provide the greatest benefit by alleviating congestion at Lyon itself and modernising overworked and out-of-date facilities that already exist.

**Montélimar**

Work on the next stage upstream of Donzère-Mondragon, at Montélimar, began early in 1954 and concerns the Rochemaure dam at Rochemaure and the power station at Châteauneuf-du-Rhône, which first went into service in July, 1957. This station has been named Henri Poincaré, after the great French mathematician, astronomer and physicist, Jules Henri Poincaré.

This development is between the confluence of the Rhône with a tributary, the Escoutay, and Rochemaure, a few miles north of Montélimar. Constructional work was preceded by very thorough geological studies, and it was found that in the defile near the village of l'Homme d'Armes, the river passed over an area of Urgonian limestone, but that fissures in the rock had never become blocked by sediment; as a result, a plain extending 5 km. downstream from the defile up to Montélimar was inundated at every flood discharge. On the left bank, a retaining wall had to be provided to connect the Rochemaure dam to hills just downstream of l'Homme d'Armes and it was feared that the storage reservoir thus formed would cause constant floods over the plain. This difficulty has been overcome by a complicated system of drainage ditches leading back into the Rhône, and these have proved adequate in preventing excess seepage. The diversion canal presented problems of a different nature; the course planned originally passed through sections of hard rock, and a winding path was necessary to avoid them. Unfortunately, the path now crosses an area of poor-quality fissured limestone which




extends under the main river, and it has, therefore, been necessary to line the canal in this section to prevent drainage back into the Rhône. Elsewhere, normal silt deposits carried by the Rhône form a natural lining which prevents seepage.

The diversion canal is designed for a discharge of 1,850 cu. m. per sec. at an average speed of 1·30 m. per sec. The headrace is 11·8 km. long, with a water surface width varying between 155 m. and 200 m. and a mean depth of 10 m. The tailrace is 1·8 km. long, the width at the waterline being between 180 and 220 m. with a depth fluctuating between 5 and 12 m.

The cost of a dam on a run-of-river development must obviously depend on the number and width of the passes provided and on the type of gate used. The price of the gates increases as the square of their span and the cost of a complete installation must, therefore, rise very rapidly as the width of pass increases. At the Rochemaure dam, where the sluices are 26 m. wide, two-section lifting-roller gates have been found more satisfactory than the tainter gates used at Donzère.

Some distance south of Montélimar, the diversion canal cuts a tributary of the Rhône, the river Roubion. This tributary has a catchment of about 600 sq. km. and a maximum flood discharge of 900 cu. m. per sec. The Roubion has been permanently diverted and now normally discharges into the canal, but a spillway and two syphons have been built along the left bank of the canal in order to make it possible to separate the Roubion from the canal when it appears necessary to empty the river. In that case the Roubion regains its true course through the syphons, and the spillway is then dry.

The Henri Poincaré power station, an aesthetically pleasing structure, is situated on the left bank of the canal with the navigable locks on the right. Six Kaplan turbines are installed under a head varying between 10 and 19 m.; at a mean head of 16·5 m.

*Fig. 11. A detailed plan of the Montélimar section in the development of the river Rhône*

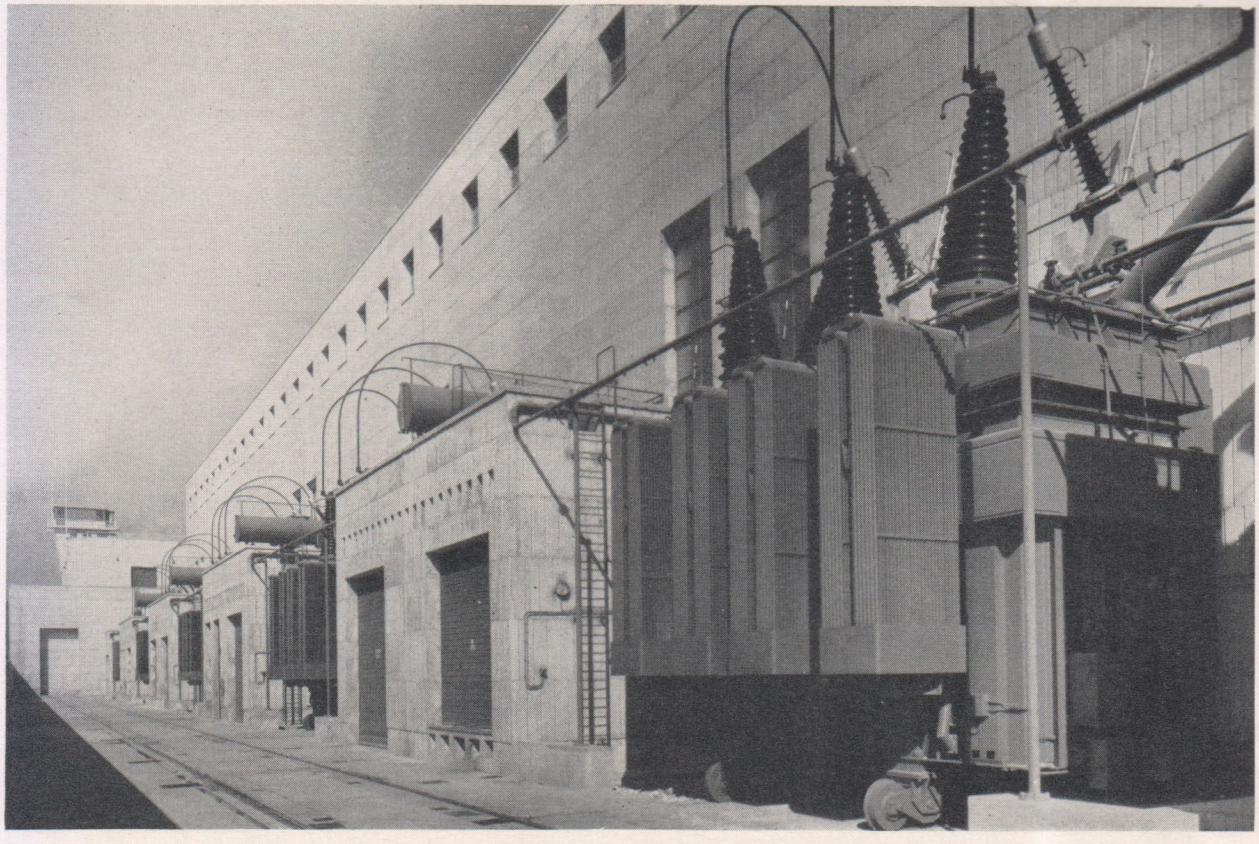


*Fig. 12. A view of the transformers in Henri Poincaré power station*

and a discharge of 315 cu. m. per sec., each unit develops 62,500 h.p. Normal operating speed is 94 r.p.m., and the alternator capacity at this regime is 45 MW and 50 MVA. Three of the units are SFAC-KMW turbines with Schneider-Westinghouse alternators; of the remaining three, two were manufactured by Neyrpic and one by Alsthom-Charmilles, the alternators being by Alsthom in each case. Each of the three thrust bearings in the Alsthom units has 10 bearing pads lubricated at a pressure of 250 kg. per sq. cm. from a central supply tank.

The design of the André Blondel station in the Donzère development precluded any contiguous forebay immediately downstream of the main structure. However, the same has not applied at Montélimar and the transformer bay is thus situated immediately outside the station. Power produced at 10·5 kV is stepped up to 225 kV by 50 MVA three-phase transformers connected by oil-filled cables to a switching station a few hundred metres further south. Average annual output of the Henri Poincaré power station is estimated at 1,670 million kWh, of which approximately 50% is produced during the winter months. The sixth and final unit went into service early in 1959.

In view of previous references in this article to the importance of navigation on the Rhône, a brief description of the lock may be of interest. This structure is 195 m. long and 12 m. wide and closely resembles the St. Pierre lock at Donzère-Mondragon. Although a single lock only has been provided, there is sufficient space for each-way traffic if the need should arise in the future. There are, in fact, only two main differences between the locks at Châteauneuf and St. Pierre, namely the differences in head and in the type of side-walls. At Châteauneuf, the foundation rock was much softer and 25 m. walls were required. The semicircular upstream gate is higher than that installed at St. Pierre due to the wide variations in level, but the downstream structure is identical to its counterpart at Donzère. Both the adduction and drainage systems are of similar design to St. Pierre. However, an economy has been made by fitting square instead of circular aqueducts, and these have been designed so that the rise and fall at maximum head are the same as at Bollène; for these two locks, the speed of intake is thus inversely proportional to the head.

The next article will be devoted to a comparison between the Donzère and Rochemaure dams as well as a description of Baix-Le Logis Neuf, a scheme which in very many respects closely resembles its nearest downstream neighbour, Montélimar.

*(To be continued)*

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**Philplug Stud Bolts.** Expandite Limited, Chase Road, London, N.W.10, have issued a leaflet describing their stud bolts. Tests made in concrete and brickwork have established that the strength of the anchorage exceeds that of the masonry or the shear strength of the bolt. The apparatus to be secured is placed before the bolt is fixed.

**NCK-Rapier Limited.** This firm, of 32 Victoria Street, London, S.W.1, have issued a four-page leaflet about their 205 Skooper which is capable of loading up to 350 tons per hour. A complete specification is given of the machine which has a weight of 16½ tons (16,845 kg.) and has a high gear travelling speed of 2·05 m.p.h. (3·33 km./hr.).