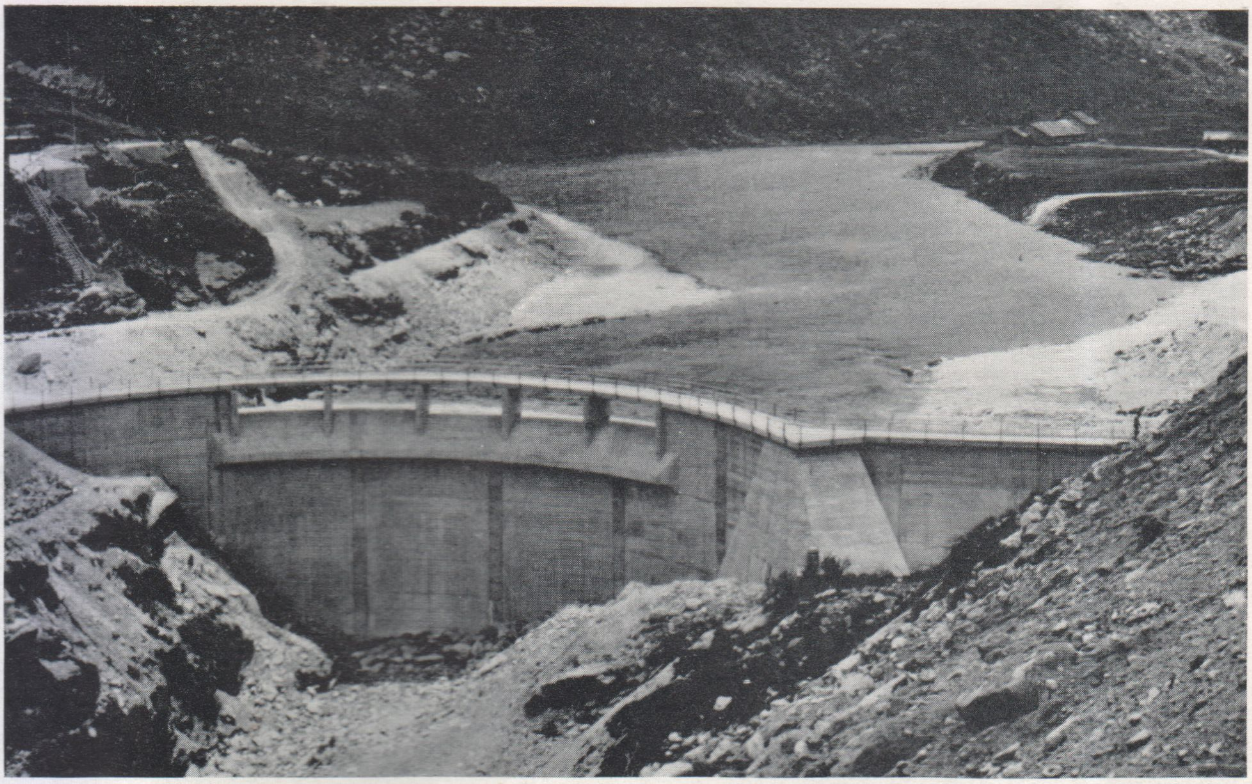


Fig. 9. Preda cylindrical arch dam in the Madris Valley

The Hinterrhein Development

One of the largest schemes in Switzerland is now approaching completion on the Upper Rhine. This article completes the description of the Valle-di-Lei/Ferrera section, which forms the uppermost stage of the scheme

PART TWO

IN our first article we gave a brief outline of this 645-MW scheme in the Grisons Canton of Switzerland, and explained that the development is divided into three stages, with power stations at Ferrera, Bärenburg and Sils respectively. We also described the Valle di Lei dam, on Italian soil, which impounds the head storage for the entire scheme and supplies Ferrera power station. In the present article we propose to consider the remaining works in the Valle-di-Lei/Ferrera stage in greater detail.

Juppa Intake

It will be remembered that in order to supplement the supply to Valle di Lei reservoir the headwaters of the Averserrhein and the Madriserrhein have been diverted. (A map of the scheme was published last month). The intake on the Averserrhein is at Juppa and is depicted in Fig. 12. A fixed weir across the river diverts the flow over a diagonal sill and through a gate into a desilting basin, whence it passes into a tunnel. A scour channel has been formed between the river bed and the desilting chamber. The behaviour of the intake was studied by means of model tests.

An area of unsuitable ground near the intake prevented the main tunnel to the valley of the Madriserrhein from being taken off at this point, so the main tunnel is branched off from the intake tunnel about a quarter of a kilometre downstream. At this point junction is also made with a conduit diverting two right-bank side streams of the Averserrhein.

The main tunnel from this junction point to the Madriserrhein is 5·3 km long and 2·35 m by 2·65 m in section. It has a dip of 0·3% and can carry a flow of 9·2 m^3/sec. Where it emerges into the Madris Valley it gives place to a closed conduit along the hillside, finally reverting to tunnel to enter the Preda reservoir.

Three small side streams flowing into the Madriserrhein—two on the right flank and one on the left —are diverted into Preda reservoir. One of the right-hand intakes leads to a buried conduit which was constructed with the aid of "Ductube" inflatable rubber forms; the concrete was placed round this tube, which was deflated and removed after the concrete had set. The other right-bank tributary falls into a borehole discharging into the tunnel from Juppa. For the left-bank tributary also a "Ductube"-formed buried conduit is used.

Preda Dam and Reservoir

The Preda reservoir serves merely as a collecting pool for the headwaters of the Averserrhein and the Madriserrhein, which are passed without control to the Valle di Lei reservoir. It has a capacity of 270,000 m^3 at a maximum level of 1,948 m.

Preda dam is a cylindrical arch structure secured on the left flank by a gravity abutment beyond which is a gravity wing wall. It is 92 m long at crest and 23 m high above lowest foundation. It is 1·8 m thick down to a level of 1,934·4 m, below which it increases progressively to 2·6 m at the base. Five uncontrolled spillway openings, each 6 m wide, are formed in the crest of the arched section of the dam; two of these openings are at the static retention level of 1,948 m whereas the others are at 1,948·2 m.

The dam, illustrated in Fig. 9, was built in 9-m blocks, openings 1 m wide being left between them. In the spring following completion of concrete placement, these openings were filled in, rubber waterstops being used on both upstream and downstream sides.

All the concrete was placed by pumping, the forms being raised by hand. Cement was used in the proportion of 300 kg/m^3, the aggregate having a maximum size of through 48-mm square-mesh screens.

Civil engineers have to take account of many considerations of amenity, access, and public convenience, but a requirement in the case of Preda dam was new to us; it was that the footway over the dam should be wide enough to allow two cows to pass without becoming wedged.

In the rock in the right bank a bottom-discharge tunnel was cut, together with a gate shaft accommodating two 1·70 m by 2·45 m Buss Limited sliding gates. Special air ducts were run to the gate chamber to prevent excessive suction in the gate control house at the top of the shaft. These gates can be operated either locally or remotely from Ferrera.

In this house are placed indicating and recording instruments for reservoir height and for flow to Valle di Lei, and a totaliser for the Valle di Lei flow. The readings of all these instruments are telerecorded at Ferrera.

In the left bank, immediately upstream of the gravity wing wall, has been constructed the intake to the Valle di Lei tunnel. This intake is uncontrolled but it has a measuring device to which are connected the flow indicator, recorder and totaliser instruments in the gate control house.

The tunnel to Valle di Lei is 4·7 km long and 2·25 m by 2·40 m in cross section, having a dip of 0·3%. It is designed for a flow of 15·3 m^3/sec and normally runs free-flow, but when the Preda reservoir is full it is drowned.

Valle-di-Lei/Ferrera Tunnel and Associated Works

Valle di Lei dam and reservoir were described in our first article, so we pass immediately to consider the tunnel from Valle di Lei to Ferrera and the associated surge chamber, head valve, and pressure shaft.

The tunnel is 6·9 km long, 4·3 m in diameter, has a gradient of 0·3%, and is designed for a flow of 45 m^3/sec. It operates under pressure and has various types of lining according to local conditions. Normal sections in good rock have a light lining of plain concrete; where the rock is crushed the lining is of heavy section, and in the worst areas a thick concrete lining is used together with steel arches placed for protection during the excavation phase and buried in the concrete lining. At one point, where the tunnel passes below the Niemet valley, the rock cover is only 35 m and the water pressure is 13 atm. To meet this condition 185 m of the tunnel was steel lined, with adjoining sections constructed on the Kieser system, using an outer lining of plain concrete and an inner lining of precast segmental concrete blocks which are subsequently prestressed by grouting between the inner and outer linings at a pressure of 20 atm.

The Ferrera surge chamber is of the two-chamber type. An inclined shaft, 12 m long, leads from the tunnel to the lower chamber, which is 9 m in diameter

Fig. 10. Ambach intake in the Avers Valley

Fig. 11. Juppabach intake in the Avers Valley

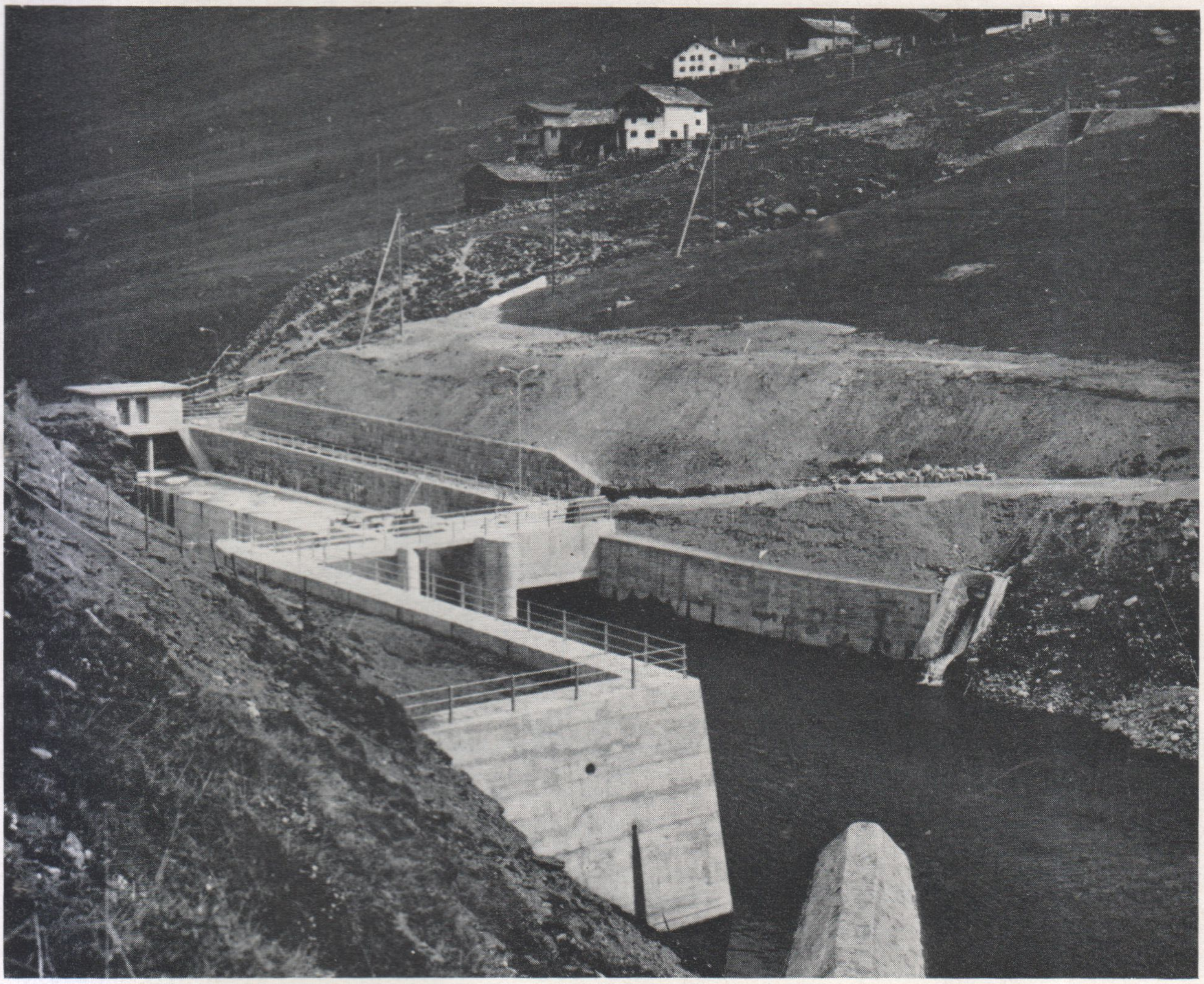


Fig. 12. Juppa weir and intake on the Averserrhein seen from upstream

and 100 m long. A vertical shaft, 4·75 m in diameter and 132·3 m long, rises from the far end of this chamber to the upper chamber, which is 8 m wide, 9 m high, and 60 m long. The Valle di Lei retention level corresponds to a point 5 m below the top of the vertical shaft.

A particularly interesting method of lining was used for the lower chamber, which had to be made absolutely watertight to avoid possible percolation from the chamber to the outside of the pressure-shaft steel lining, which might lead to a build-up of external pressure and buckling of the lining.

First, a circular concrete lining 20 cm thick was placed, after which the rock was grouted to a depth of 2 m, the grout holes being drilled at 2-m centres. The lining concrete had in part to be mixed with a sulphate-resistant portland cement and contained a plasticiser.

The concrete lining was then faced with two layers of bitumen-covered copper sheet. This sheet was of light-gauge metal rolled into a reticulated pattern so that after installation it could accept tension in any direction without rupture, and was covered on both sides with a layer of bitumen. It was delivered in rolls each 67 cm wide and long enough to extend for half a circumference from floor to crown of the chamber. The roll to be laid was placed in a rig and the bitumen coating facing the concrete heated with a gas flame, the roll being traversed gradually upwards and the unrolled sheet pressed by hand firmly against the concrete.

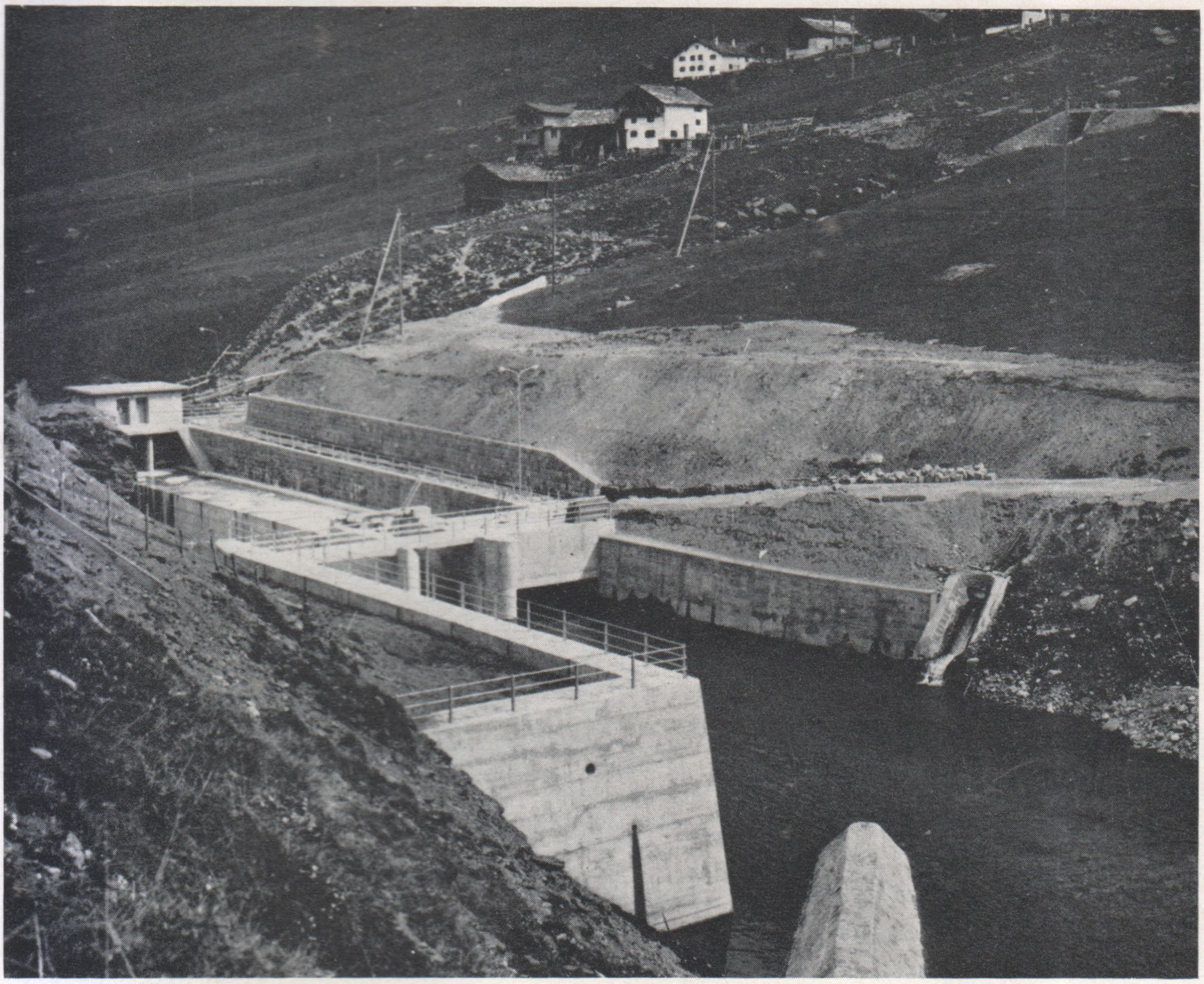
After the two layers of sheet had been placed they were fixed temporarily with 2–3 cm of gunite. Finally an inner concrete lining, 30 cm thick, was placed to support the copper lining firmly against external pressure.

Between the surge chamber and the valve chamber —a length of 73 m—the supply tunnel is steel lined and reduces in diameter from 4·3 to 3 m.

The lining of the pressure shaft was carried out from the valve chamber, and to afford ample working space for this operation the chamber was made 27 m long, 11 m wide, and 16·2 m high. Rock conditions were good, but rockbolts were used for temporary overhead protection against rockfalls.

In the chamber is installed a von Roll butterfly valve 3 m in diameter. It is operated by pressure from a local pumping and storage unit, and can be closed either locally or from Ferrera power station. The closing sequence can also be initiated locally for test purposes, in which case the movement is arrested after the valve plug has rotated through about 3°.

In the upstream wall of the valve chamber there is a winch chamber, in which a 12-ton winch was installed for assembling and for bringing into position



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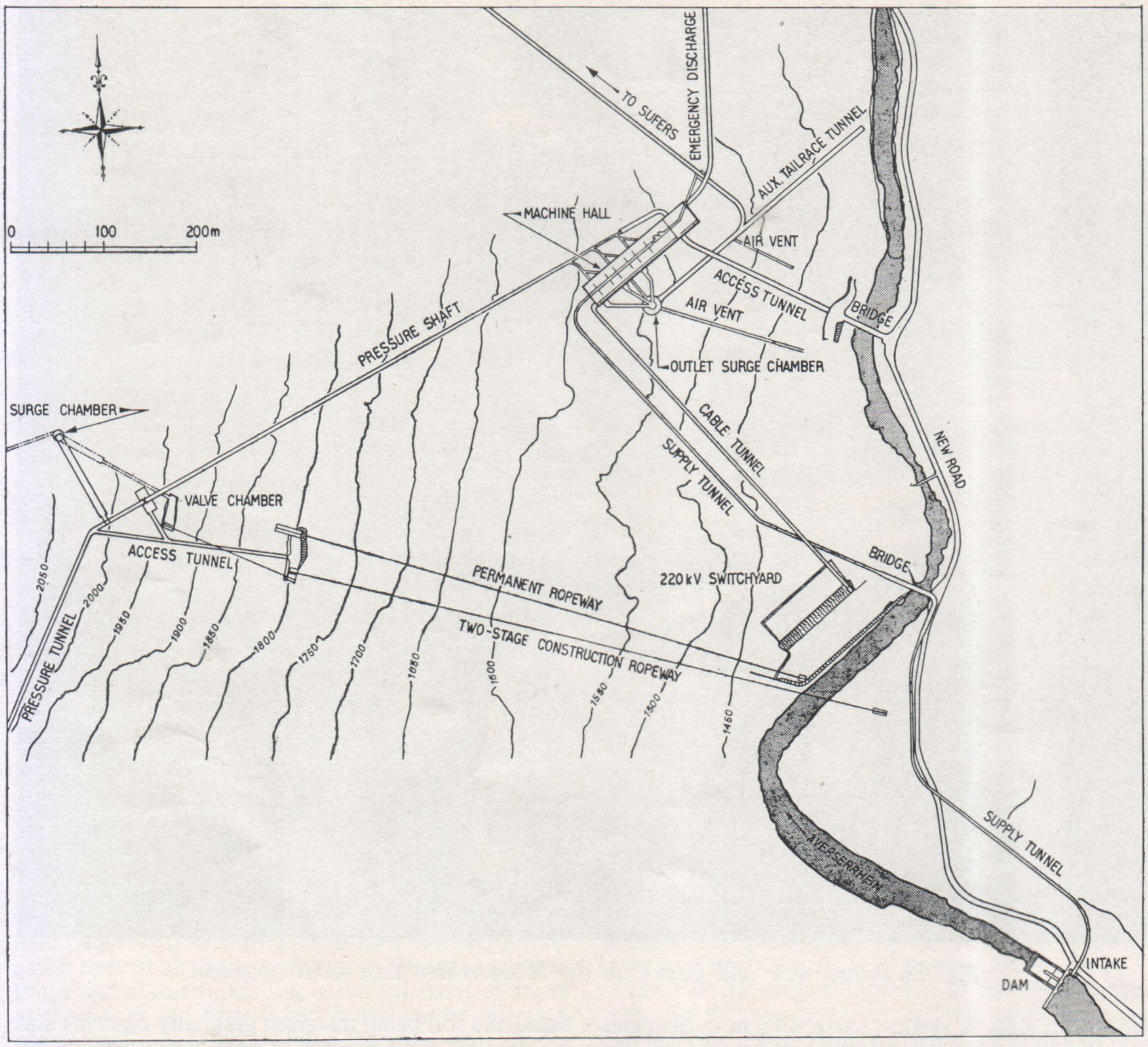

Fig. 13. General plan of Ferrera power station showing the system of tunnels

the pressure shaft lining. Later, this winch was replaced by one of only 3-tons capacity, serving for shaft inspections.

Immediately downstream of the butterfly valve, in the horizontal part of the pipe, is the air-relief valve on the top and a manhole in the bottom. By opening the latter, it is possible to assemble an inspection trolley inside the pipe, and removal of the air valve leaves an aperture through which the winch rope is passed to the trolley. Thus the trolley can be rigged and operated without having to remove and replace a section of pipe—an operation that would take several days.

The surge chambers and the valve chamber are reached by an adit in the mountainside, served by a Bell aerial ropeway, of 8-tons capacity for materials or 3-tons capacity for personnel.

The pressure shaft, which is 638 m long, is set at a gradient of 80% and is 3·3 m in diameter at the top reducing to 3·0 m at the bottom. It has a steel lining ranging in thickness from 19 to 25 mm, which was supplied and erected by Buss AG, Basle.

The distributor, which is laid out to supply three turbines and to receive the discharge from three pumps, was supplied and erected by Sulzer Brothers, Winterthur. The turbine supply pipes are 1,450 mm in diameter and the pump branches 650 mm. It is completely encased in concrete.

Ferrera Machine Hall

Ferrera machine hall is approximately semicircular in cross section and has an excavated length of 142·8 m, a width of 29 m and a height of 25 m. Excavation was commenced by driving the permanent access tunnel, 4·7 m wide by 5·1 m high, carrying it across the site of the machine hall at basement level, and opening up the manifold and the bottom of the pressure shaft. Beforehand a pilot heading and ventilation tunnel had been cut along the level of the machine-hall roof to ascertain the rock conditions. Two tunnels were then driven at basement level along the two sides of the machine hall, and a drift was carried up to the pilot heading at the roof. The roof was then opened out, and as the rock conditions were found to be good the sides were broken down to meet the side tunnels. The entire excavation was then concreted, and finally the heart of rock was taken out.

The somewhat complex system of tunnels associated with Ferrera power station is best followed by referring to Fig. 13, and has been necessitated by the operating requirements. The main turbines—three in number—discharge to a circular surge chamber 20·6 m in diameter and 30·85 m high, from which the tailrace tunnel leads to Sufers reservoir. This tunnel is 4·3 m in diameter, 5·5 km long, and has a dip of 0·11%, the rated flow being 45 m³/sec. Near the machine hall an auxiliary tailrace tunnel returns the turbine discharge to the river in the event of Sufers reservoir being unable to accept it. An emergency tunnel, 4·2 m by 4·2 m, has also been driven from the machine-hall basement to the river to dispose of a flood arising from a valve burst.

Averserrhein Intake

As explained in our first article, the run-off from the Averserrhein catchment below the diversions to Valle di Lei is impounded and can be either pumped up to Valle de Lei reservoir or passed direct to Sufers. Pumping takes place during the spring snowmelt when the Valle di Lei reservoir is being replenished and Ferrera station is not generating. During the winter generation period the run-off is sent to Sufers.

At Innerferrera, a little way upstream from Ferrera station, a reservoir of 230,000 m³ at a retention level of 1,443 m is formed by a concrete dam (Fig. 16) 60 m wide and 28 m high. It is provided with two flap gates controlled by oil-operated rams, and with two bottom openings controlled by radial gates also operated by rams. All these gates were supplied by Wartmann Limited, Brugg. The intake is on the right bank near the dam, and leads to a tunnel 2·6 m in diameter which approximately follows the direction of the public roadway as far as the access bridge to the power station. This bridge is of concrete and forms a closed aqueduct as well as a road bridge. Beyond this bridge the conduit reverts to tunnel and terminates in a circular conduit, 2·2 m in diameter, extending along the machine-hall basement and forming the collector for the main pumps. At the end of this conduit (see Fig. 14) there are connections to two auxiliary pump-turbines—to be described later—and the sump below these machines is connected to the tailrace tunnel to Sufers reservoir.

Mechanical and Electrical Equipment

The main units in Ferrera station are three horizontal-shaft 62·3-MW 750-r.p.m. assemblies, each comprising a Francis turbine, an alternator-motor, and main and pilot exciters. Two of the main units are equipped with a storage pump, coupled by a removable tooth-type clutch.

The castings for the turbine spiral casings, covers, runners, and alternator-rotor spiders were supplied by George Fischer Limited, Schaffhausen, who also provided a spare runner and a spare turbine cover. A photograph of one of the spiral casings is reproduced in Fig. 18.

The turbines were built by a consortium of Escher Wyss and Charmilles, both firms sharing in the design and in the necessary laboratory work. These machines are remarkable because they represent one of the highest-head Francis installations in the world, the gross head being 525 m and the net head 474 m. Each turbine develops 98,100 h.p. at rated full load, with a discharge of 15 m³/sec.

The alternator-motors were supplied by Oerlikon Engineering Co. Ltd., and as alternators are rated at 70 MVA and generate at 10·5 kV.

The main storage pumps are of Escher Wyss manufacture; each absorbs 30,620 h.p. when raising 4·9 m³/sec against a gross head of 397·5 m.

The main transformers are housed in cubicles built against the side wall of the machine hall, and are placed opposite to their respective generating sets. Each set is served by a bank of three single-phase transformers, the bank being rated at

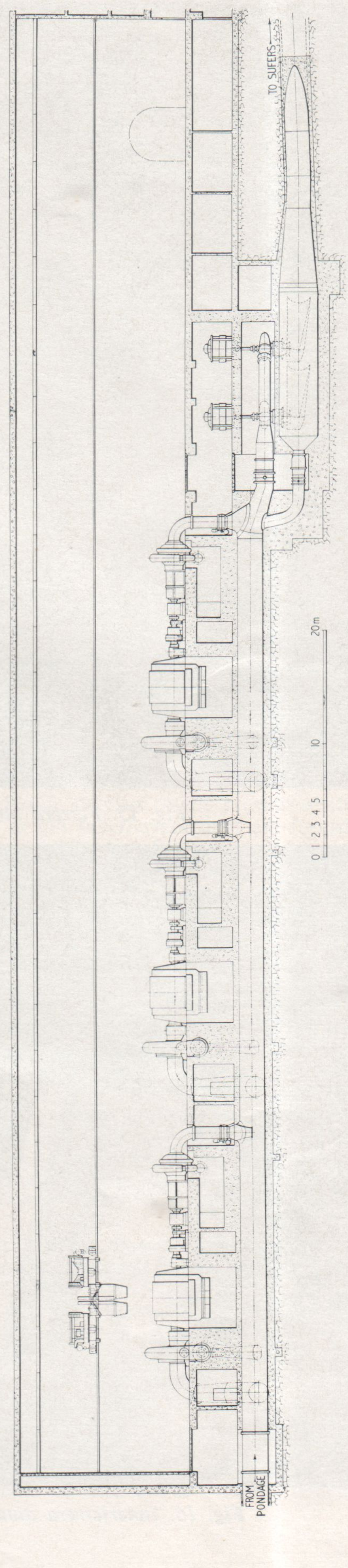

Fig. 14. Longitudinal section through Ferrera power station showing the main pump and booster pump-turbine interconnections

Fig. 15. Ferrera machine-hall cavern in course of excavation

Fig. 16. Innerferrera dam on the Averserrhein in course of construction

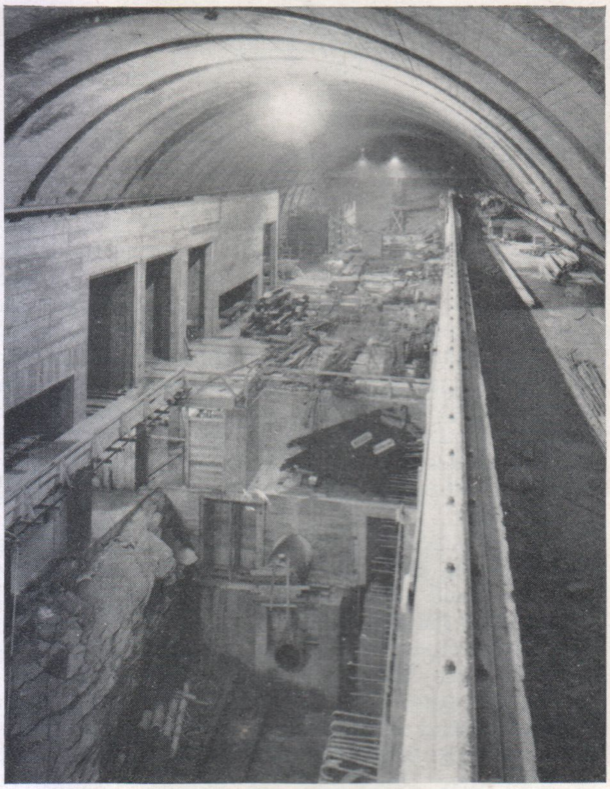

Fig. 17. Ferrera machine hall at a later stage of construction

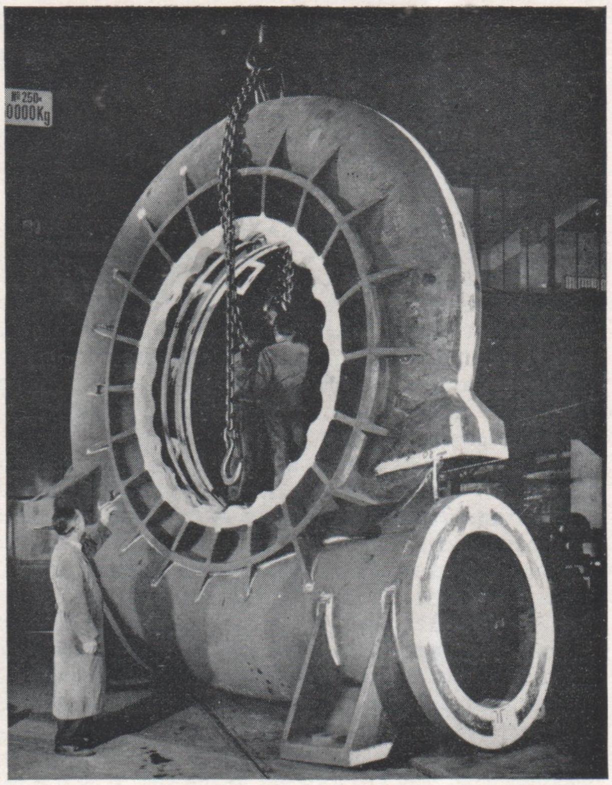

Fig. 18. Fischer turbine spiral casing casting in 2% nickel steel, weight 6·7 tons

70 MVA and stepping up to 225 kV. A tenth single-phase unit is available as a reserve, all units having been supplied by Sécheron.

The main generators are paralleled and switched on the high-voltage side of the transformer banks by circuit breakers in the outdoor switchyard, but they can also be connected to an auxiliary 10·5-kV busbar. The latter also feeds the station services.

Connection between the transformer banks and the switchyard is effected by ten 225-kV oil-filled cables, one of them serving as reserve.

The switchyard is laid out for the eventual adoption of a double-busbar system. Each generator is controlled by an 11,500-MVA Brown Boveri circuit breaker.

We referred a moment ago to two auxiliary pump-turbine units, and their disposition will be seen in Fig. 14. They are vertical machines consisting of Sulzer pump-turbine units coupled to Brown Boveri synchronous-motors / asynchronous-alternators and running at 600 r.p.m. The pump-turbines absorb 2,496 h.p. as pumps, with a discharge of 4 m^3/sec under a head of 41·9 m and deliver 2,000 h.p. as turbines with a flow of 4·2 m^3/sec under a head of 44 m. The electrical machines are rated at 1,800 kVA as alternators and 2,200 kW as motors. They are connected to the 10·5-kV auxiliary busbar through a 10·5/3·3-kV, 5,200-kVA Brown Boveri transformer.

During the snowmelt the flow from the Innerferrera intake is lifted by the main storage pumps to Valle di Lei reservoir. It may also be desired to transfer surplus water from Sufers reservoir, in which event these two auxiliary machines operate as booster pumps to lift the water to the main-pump suction conduit. In winter the flow from the Averserrhein is passed to Sufers reservoir, and these machines then act as turbines to take advantage of the available head at Innerferrera.

A medium-voltage service connection with Bärenburg and power supplies to the pressure-shaft head valve and to the Innerferrera dam are furnished at 16 kV by a 4,000-kVA Sécheron regulating transformer fed from the 10·5-kV auxiliary busbar. When no power is available either from the main generators or from the pump-turbine sets power can be supplied to the valve chamber, the intake, the station services and the village of Innerferrera direct from Bärenburg; Bärenburg power can also be fed back through the 225-kV transformers to drive the pump-turbines as booster pumps.

The station supply at 380 V is derived from the 16-kV system through a 1,000-kVA Sécheron regulating transformer. For emergency use a 550-kVA diesel generating set supplied by Swiss Locomotive and Machine Works, Winterthur, is housed in an exterior building and is connected to the 380-V busbars. It can also be used to operate the pressure-shaft head valve through a 300-kVA transformer stepping up to 16 kV.

The main control room is located at one end of the machine hall, and has been equipped by Electro Tableau, Bienne.

(To be continued)

Allplas Floating Blanket. Lacrinoid Products Limited, Gidea Park, Essex, have published a leaflet describing tests at the National Engineering Laboratory on floating blankets of hollow polypropylene spheres known as Allplas, which were found to reduce water evaporation losses by 83·3% and to reduce the heat input required to maintain a constant temperature by 69·5%.