THE RANCE TIDAL ENERGY INSTALLATION

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An article on the French tidal energy schemes appeared four years ago (January 1963) in this Review. One of these was planned for the estuary of the Rance, a small coastal river that falls into the Channel between Dinard and Saint-Malo, the other for the extensive sea-area stretching from Mont-Saint-Michel to the Chausey Islands, and from Cancale to Granville. These schemes had been drawn up in the years immediately following the Second World War, at a time when the power-outlook in France seemed somewhat gloomy : demand was increasing continually with no quickly available source in sight. It was, it is true, believed that ultimately nuclear energy might well be applied in industry but the time-lag was over-estimated and, in addition, it was feared that the cost would not be competitive. Tidal energy therefore was hailed as a welcome solution, and it seemed no wild dream to envisage its exploitation over so wide an area as the bay of Mont-Saint-Michel.

It was this that lay behind the Chausey Islands tidal energy scheme. Hitherto hydraulic power had been drawn only from rivers; the sea might raise unexpected problems and it would have been rash to embark on so far-reaching an enterprise without first finding the answer to all the difficulties encountered on a smaller scale. In 1950 the Rance estuary was accordingly chosen as a pilot-scheme, on a power-producing scale of about one-fiftieth. Initial studies were immediately pushed ahead, and building started at the beginning of 1961. Progress was rapid, but so much was involved that it took five years to complete the civil engineering work and another year to finish installing the equipment. Like all great enterprises that do credit to the nation's industry and contribute to the development of its economy, the plant was officially opened by the President of the French Republic on 26 November 1966.

All that has still to be done is to complete the delicate task of bringing into service the 24 turbo-alternators as each is mounted in position. It is anticipated that the plant will be working normally during the third quarter of 1967, very little later than the target date.

When the earlier article appeared, the construction of the dam and plant had not progressed sufficiently for a description of the work to be of much interest. Only a couple of photographs were included, to illustrate the large scale and the difficulties involved. In this article, we shall summarise what has been done and follow this by some observations on present-day ideas on the use of tidal energy.

The construction of the Rance plant (begun, as we said, in 1961) called for a permanent labour force of several hundreds, rising at one period to nearly a thousand.

The sections that were supported on the river banks were completed fairly quickly. On the Dinard side a lock, without which navigation between the sea and the estuary would be impossible, was built on banks that are dry at low water. This was protected by a huge concrete wall which was later incorporated in the actual plant. This work was finished in November 1962. On the other bank, a group of six sluice-ways was built between Pointe de la Briantais and a rocky island (the Chalibert Rock) about 150 metres from the Point. The purpose of these is, at certain periods of the tide, to accelerate the filling or emptying of the basin. The work was carried out on the dry bed of the river, inside a watertight enclosure formed by two coffer-dams running between the Chalibert Rock and the river, and then emptied by pumping. These were constructed from huge cribs of metal sheet-piles, circular in form, with a diameter of 20 metres, which were built *in situ*, one against the other, sunk some distance into the solid earth and filled with sand. The six adjustable gates which can produce a total flow of 10 000 cubic metres per second were brought into service in March 1963 after the removal of the coffer-dams.

The greater part of the retaining dam lies between the lock and the Chalibert Rock and so completes the deep-river work. It is over 500 metres in length, two-thirds of this being the power-plant itself, followed by a stone-bedded fixed dyke; this latter takes the place of a section of the plant that appeared in the initial plan but was later abandoned.

The lay-out and size of the plant resemble those of the big modern low-head hydro-electric plants. The lower part, which is housed-in, is 10 metres below lowest low water and is also the busiest. It contains arranged in parallel 24 double-funnel shaped tunnels designed to concentrate, in either direction, powerful jets of water on the turbines of the bulb-units housed in their central portion, leaving a play of no more than a few millimetres at the most for the rotation of the blades. The turbines, 5.35 metres in diameter and with variable-angle blades, revolve at about 94 r.p.m. and activate alternators with a nominal power of 10 000 kW when contained in an atmosphere at double normal atmospheric pressure. Each group of eight bulb-units is connected to a transformer placed above the tunnels which raises the voltage delivered to 225 000 volts. This can then be fed into the national grid. As in all hydro-electric plants of this type, the upper part contains the handling and control equipment concentrated on a huge control panel. In addition, powerful travelling cranes allow the bulb-units to be withdrawn for maintenance, after cutting off from the flow of water the tunnels in which the units are contained, by closing water-tight valves fitted at each end.

Since the power-plant is an integral part of the dam, its upper part rises a little above the level of the highest high water (this being about 13.5 metres above the lowest low). Thus the concrete walls of the construction are about 26 metres in height, from the foundations of the plant to its top. This top, moreover, carries a wide road which, running over the fixed dyke also and the sluices, cuts down the road distance from Dinard to Saint-Servan from 37 kilometres to 7.

Like the sluices, the fixed dyke and the plant were built on the dry river-bed. This time, however, the work was done inside a huge enclosure nearly 25 acres in area, formed by two large coffer-dams running from the lock to the Chalibert Rock. Here the engineers came up against a special problem quite outside the normal run of difficulties encountered when dealing with a river. The completion of the down-stream coffer-dam had the effect of closing the Rance estuary, in other words of cutting off a flow that with a strong tide can rise to 18 000 cubic metres a second, or about three times that of the Rhone in flood at Avignon.

This dividing coffer-dam was, in principle, to have been built with pile-plank cribs similar to those used for the sluice enclosure, though considerably higher, reaching 26 metres in the deep part of the river. As the work proceeded, however, it gradually narrowed the gap left for the water and in spite of the safety-valve provided by the wide-open sluice-gates, the difference in level between the water upstream and downstream became more pronounced, first on one side and then on the other, as the tide changed. The currents became stronger and threatened the construction and stability of the cribs. Studies, based on a model of the Rance reduced to a scale of 1/150, made it clear that when ten of the cribs were in position, leaving an opening between them of 360 metres, the final closing-up could be effected only by introducing a more elaborate procedure. The method chosen involved the prior installation of 19 "light" support-points; these consisted of long cylinders of reinforced concrete nine metres in diameter. They were made in the port of Saint-Malo and towed, floating, to the working site. There, before being filled with sand, they were lowered vertically into foundations prepared on the bed of the Rance by men working 20 to 25 metres underwater in a large diving caisson. The intervals between the support-points were then filled in, first two by two to keep the gaps divided; then the whole length was covered by curtains of concrete slabs. The new support points so produced served as the foundations for cribs even more massive than the first.

As the number and the width of the gaps in the coffer-dam decreased, so the difference in the water-levels increased, until in the last springtide periods it was over three metres. The flow of water connecting the two levels followed elegant curves along the sides of the concrete cylinders and as the current swept through each gap it set up a seething wash whose boiling foam stretched for several hundred metres. The engineers, however, were not particularly captivated by the beauty of the scene; it represented for them simply one more of the disconcerting aspects of their months old struggle with wind and tide.

It was the wind that most often gave them cause for concern, since in wild northwesterly weather the rocks and islets sheltering the Saint-

Malo roadstead allowed the entry, particularly at high tide, of waves of considerable height which broke against the cribs and threatened to loosen them and so impair the watertightness of the coffer-dam. The tides, again, provided a dramatic episode to mark the closing of the final gaps. Between the periods of slack water, which was the only time the work could be carried out, the currents had become so strong that in a few hours they eroded the rocky bed of the river to a great depth, and it was feared that the support points would be swept away and the cribs would pull out from their seating in the rock. Solutions had to be found with great urgency to meet the nature and the strength of this threat : solutions that were sometimes intricate, sometimes rough and ready, as for example the filling up of a massive erosion that dug out a trench over two metres deep, by rapidly sinking some 50 concrete blocks each weighing several tons.

Finally, after many agonising hours, the sealing-off of the estuary was finished on 20 July 1963, precisely on time. All that then had to be done was to close the sluices and the lock in order completely to shut off the basin from the sea and to build the upstream coffer-dam of the enclosure in calm water. Once the enclosure had been emptied, it was the scene of intense activity devoted to building the power plant and the embankment. Anyone travelling along the downstream coffer-dams at the time of high water could not fail to be impressed by seeing on one side, almost at his feet, the waves beating against the cribs, while in the other direction, 25 or 30 metres lower down, there was an army of tractors and bulldozers at work, and quite close a huge concrete framework rose up almost to his own level, with men busily employed upon it. By the beginning of 1966 the dam could be regarded as finished and the coffer-dams were progressively removed. Only work on the equipment and in clearing up is now going on inside the plant, now largely below water level. One quarter of the groups are at the moment in working order, and have already been used to produce current.

In a few months' time the new electric power station will be completely finished, and after a running-in period it will be able to enter into normal service.

Production will of necessity be intermittent since the turbines can be used during only two periods in each tide. The most favourable corresponds to the emptying of the basin into the sea through the tunnels that hold the bulb-units; this begins about half-way through the outgoing tide and can last almost four hours until slack water on the ebb. The height of fall is relatively large and in consequence production of power is very considerable. In the other period, which begins about two hours before and finishes shortly after high water, it is the sea that, flowing in the opposite direction, raises the upstream level. In this case the difference in level that can be used is not so great. Overall production can be improved by using the bulb-units to raise the level of the basin still higher by pumping water into the sea for some time after high water. The quantity of water so raised to a slightly higher level will later be returned with a sufficiently high head and so, in spite of losses in conversion, will produce more power than is lost by pumping.

Economic considerations must obviously determine the way in which the plant is to be used, within the limits imposed by technical conditions. The principle, accepted after lengthy studies, is based on the use of an electronic ordinator, to be installed at Nantes, which will continuously calculate the cost price of a kilowatt-hour as a function of the demands at that moment, in particular the requirements to be satisfied and the conditions of production of all the country's electrical power stations. This will immediately determine how the tidal energy plant can most advantageously be used at the moment in question.

The great flexibility of production so obtained will help to minimise an inherent disadvantage in electricity, for this cannot be stored and must therefore be used as and when it is produced. In particular, if the tidal phase lends itself to pumping activity at the same time as electricity produced by heat is available (for example on a Sunday afternoon in summer when industrial and lighting requirements are at their lowest) it will be advantageous to increase the volume of water above the dam by pumping even beyond conditions that in other circumstances would not be advisable.

It is anticipated that production will reach and even exceed the 500 000 000 kilowatt-hours expected annually from the plant : in other words, more than one hundredth of hydro-electric production in France. This may not seem a great deal, but it represents the combined consumption of the three towns of Brest, Rennes and Le Mans. Thus, for the first time in the history of the world, blue coal will be used on an industrial scale : and oddly, it will be the Emerald coast that will owe its priority in this respect to the size of its tidal-range.

Now that the Rance tidal-energy installation has been completed, the question of the Chausey Islands enterprise will come up. Although this plant would provide enormous quantities of power, produced with great reliability and with no pollution, these considerations are not in themselves sufficient for the go-ahead. Economics generally has the whip-hand of technology, as we saw in the case of the Rance scheme, and various other factors must come into it, among the chief being competition from other sources of power and their prospects for the future.

It has been estimated that the work involved for the Chausey Islands plant would take about fifteen years, and call for a total expenditure of 20 000 million present-day francs. This cost, acceptable with the present price of power, might well become excessive as a result of the development and improvement of other methods of producing electricity.

Moreover, although in France hydro-electric installation is approaching its end through lack of further suitable sites, the future seems safe enough. Oil-producers are optimistic, for the discovery of deposits of oil and natural gas is keeping pace at present with the increase in consumption, and the experts believe that it will be a long time before this ceases to be so.

Those who pin their faith to atomic energy are equally optimistic : fission-energy, I mean (since in the case of fusion energy, that of the H-bomb, the only one that is practically "clean" as they like to call it, and is almost inexhaustable, its harnessing still remains a distant ideal).

In the case of the former, some unhappy minds may be worried by the large quantities of radio-active waste its use leaves behind — whose disposal is of deep concern to international opinion — and may fear, too, that world reserves of uranium will be squandered pretty quickly, but those who are at present in control of the politics of power production are trusting to new methods that will make it possible greatly to reduce the volume of waste, which can then be neutralised by being buried in deep excavations reserved for that purpose; they believe too that uranium, like oil, exists in much larger quantities than is imagined and that relatively poor ones, still excluded from estimates, might very well be used at a later date.

Thus circumstances hardly favour the construction of the Chausey Islands installation, and it is almost certain that neither our own nor a later century will see it built. Had the decision whether to go ahead even with the Rance scheme been postponed until now, it would probably have been turned down. Already in 1923, in a work on tides and their industrial application, the knowledgeable Ingénieur hydrographe Eugène FICHOT was writing :

" It is most remarkable that of all the forces that Nature has handed over to us in turn, those whose secret she has guarded the most jealously seem at the same time to allow themselves to be harnessed the most readily.

" It was only yesterday that electricity was mastered and already man has no more obedient or adaptable servant. Hardly had we succeeded in controlling explosion, that other untamable force, than straightaway the broken wings of Icarus took on new and undying life. And who can read the secrets waiting for us in intra-atomic energy ?

" On the other hand the ocean has been with us since mankind's infancy, offering us the ceaseless movement of its waters : and yet we have hardly yet succeeded in putting to work this inexhaustible source of energy ready to our hand. "

It is, indeed, a paradox that in his hunt for power man has always turned to primary or secondary sources that are more and more inconspicuous, while the movement of the seas and of the atmosphere make him a wide-open offer of inexhaustible reserves of power. There is, however, an obstacle to the industrial exploitation of these vast resources, and it lies not so much in the irregularity of their manifestations as in their low area-density; this obliges us to tap them over very wide expanses and, in order to do so, to construct vast workings which our age is still nervous of undertaking. However, the abandonment of the ambitious Chausey Islands project should not blind us to the resounding success of the Rance tidal-energy installation. Judging from the interest in the new station shown abroad, it may well, we believe, serve as a prototype for other such plants. Already in France, the Pierre Bénite's low-head plants on the Rhone, and Gerstheim's on the Rhine, have been equipped with powerful bulb-units, of 20 000 and 24 000 kilowatts respectively; and this would never have been considereed had not the special requirements of the Rance plant brought out the advantages accruing from this type of generator.

Thus in the irresistible march of progress every new great undertaking bears fruit in the number of special problems it raises from its conception to its final completion : problems whose solution does not simply affect the cases that brought them light, but also serves to enrich and rejuvenate the great store of techniques available to experts. Moreover human qualities are an essential factor in carrying out large enterprises. The engineers who were the first to build a powerful tidal-energy installation showed their boldness in tackling a new type of work. The carrying out of the detail made constant demands on their ingenuity and energy of spirit. They follow worthily in the footsteps of those who opened the Suez Canal, who built the Eiffel Tower, the liners *Normandie* and *France* and perfected the Caravelle. It is to be hoped that the new great tunnel enterprise linking France and Great Britain will provide one more occasion of making good use of the genius of such designers and builders.

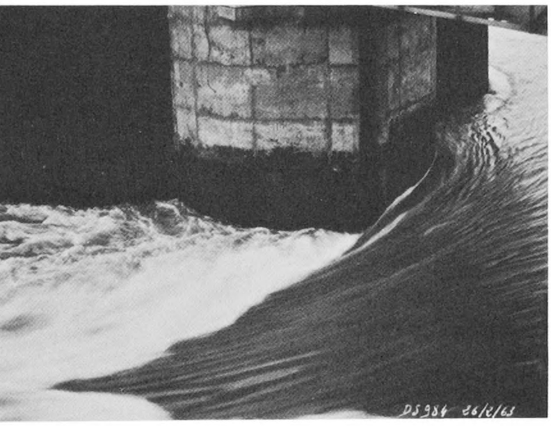

FIG. 1. — 1963, end of February
ing its construction the lower coffer-dam
ders the free flow of the water and produces
fference in the level of the water on either side

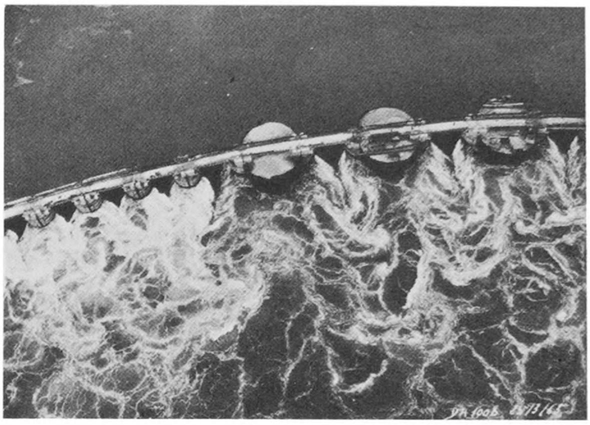

FIG. 2. — 1963, end of March
Another view of the currents flowing through the gaps in the lower coffer-dam

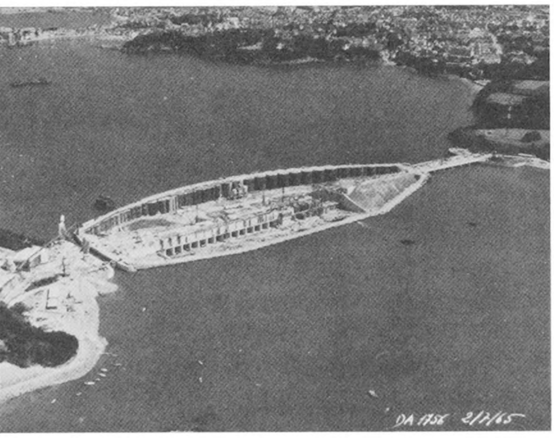

FIG. 3. — 1965, beginning of July
power plant under construction between the
coffer-dams. The 24 concrete tunnels, 10 metres
10 at the intake, for leading the water to the
b-units, are nearing completion, as is the fixed
dyke

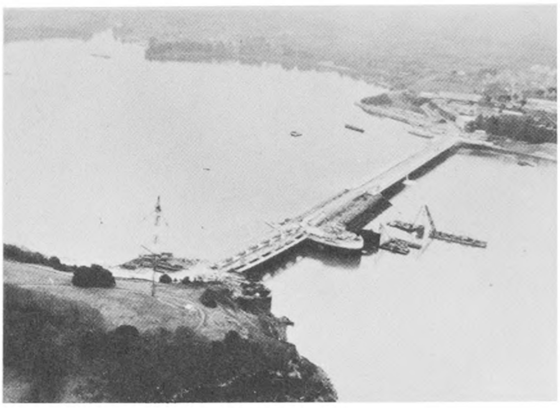

FIG. 4. — 1966, end of December
The dam has been completed and the last sections of the lower coffer-dam are being removed. The view is taken looking towards Dinard, showing in succession the sluice-gates, with the supports of the six valves, the adaptation of the Chalibert Rock, the stone-bedding of the fixed-dyke, the power-plant and the lock, and finally the auxiliary buildings on the left bank of the estuary

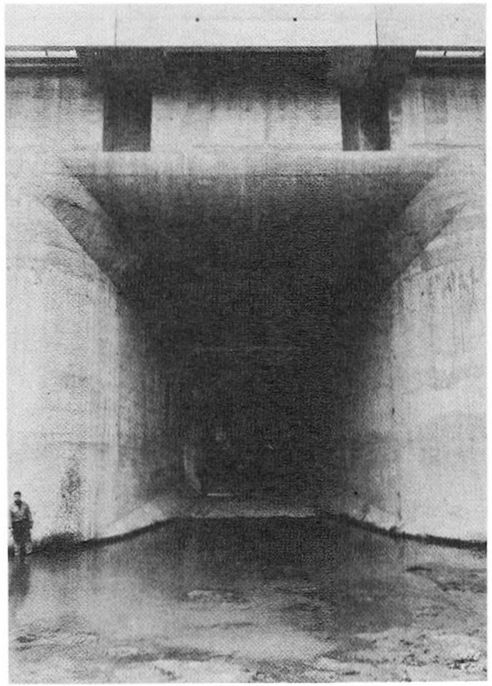

FIG. 5. — 1966, beginning of March
One of the tunnels leading water to the bulb-units. The vanes of a turbine can be seen. View taken over the river bed before flooding

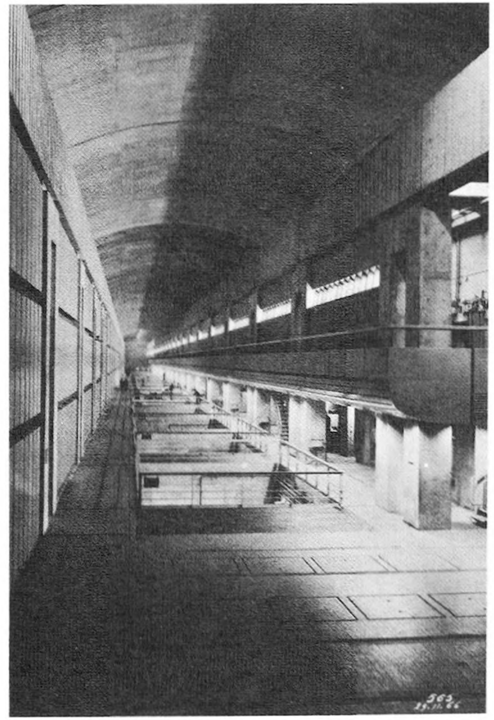

FIG. 6. — 1966, end of November
Interior view of the power-plant. The wide inspection parts of the bulb-units can be seen