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NEW SOURCES OF ENERGY EXCLUDING SOLAR ENERGY, WIND POWER, AND NATURAL STEAM AND HOT WATER FROM UNDERGROUND SOURCES

(Note by the secretariat)

Document E/CN.14/EP/10 gives the findings of the United Nations Conference on New Sources of Energy, held in August 1961, regarding three of these new sources: solar energy, wind power and natural steam and hot water from underground sources.

Some brief notes on other new sources of energy are given below.

The sources of energy generally regarded as new are (besides solar energy, wind power and natural steam and hot water from underground sources): artificial rain, ocean swell, differences of temperature between the lower layers and the surface of the seas, and tides.

1. Artificial rain

The principle underlying artificial rain consists of causins atmospheric precipitation by seeding certain kinds of clouds, usually with silver iodide or dry ice. This is in fact only an indirect source of energy, generated only where precipitations on a ctachment area increase the volume of water stored in reservoirs.

So much is at stake for the hydroelectric industry and for crops threatened with drought or needing protection against hail that efforts are immediately made to exploit any favourable prospects opened up by this new discovery.

The question has still to be answered, however, whether it can be applied on an industrial scale. Seeding from the ground with silver iodide, either by simply burning impregnated charcoal or by using more sophisticated electric ovens, may probably be carried by upward air currents to considerable heights and may spread quite far, but the actual paths followed have not yet been determined. There can, therefore, be no certainty about the extent to which the substance in fact reaches clouds with temperatures lower than $4^{o}C$ which are apparently the only ones on which silver iodide can act - or whether it is de-activated before reaching them. Meteorological science is apparently not yet in a position to draw conclusions as to the efficacity of the method from direct observation of the effects on clouds.

Hydro-power plant operators and some branches of agriculture take such an interest in the method that they are carrying out silver iodide seeding to try to discover statistically whether there are any effects on precipitation and the rate of flow of rivers. To this end, they are trying to compare precipitation and rate of flow in a target basin at which the seeding is aimed with those in adjacent control basins which are unaffected by the silver iodide (owing, for example, to the direction of the wind) and in which the rates of flow before seeding were approximately identical with those of the target basin. These experiments have been hard to interpret, as have experiments with pulsed seeding, in which periods of emission of the silver iodide were interspaced with equal periods of non-emission in the hope that the intermittence of the seeding would show up on the rain gauges.

Statistical analysis now seems to indicate that the natural irregularity of rainfall is such that even if the silver iodide increased it over all by 5 per cent - and even this increase would be very valuable from an economic point of view - it would take more than fifteen years for the change to be detected.

The tropical zones may perhaps be better suited than the temperate for such attempts to induce rainfall by seeding clouds with silver iodide from the ground, as the air masses are more sharply profiled and are less contaminated by industrial effluvia. In addition, the rains in the tropical zones are mostly connected with local phenomena.

Another method is now emerging as a result of observations on the formation of rain or thunderstorms above fires. The principle is that the combination of air and water vapour above the earth contains a considerable amount of energy derived from the solar energy which brought about evaporation. When the vapour reaches saturation point and condenses, this energy is freed and causes disturbances.

This method has been tried out in equatorial Africa, where clouds have been formed and rainfall induced over bush fires lighted at favourable periods. The experiments performed by Belgian and French physicists using an apparatus consisting of 100 fuel-oil burners, with a thermal output of the order of one million kW, have given conclusive results.

2. Ocean swell

The energy of the ocean swell is the hydraulic energy of waves caused by the action of the wind on a large sea area.

The amount of energy generated is something like 100,000 kWh per running metre and per year in thoroughly exposed places.

The output is, of course, extremely irregular, and at certain times the swell is likely to damage or destroy the installations, so that most of the systems devised by various inventors are not practicable.

The best way to recover the energy is probably to construct, along a shoreline with deep water, a set of dihedra in which the wave rises to a storage reservoir at the peak, whence the water flows back into the sea through a turbine. Experiments with scale models have shown that output can be high if the dimensions of the dihedra are correctly chosen.

Another method proposed consists of using various forms of resonator in order to raise the water level in much the same way, but the installations form veritable breakwaters and, even on shorelines where the natural depth of the water in tideless seas is great, the investment outlay seems prohibitive in comparison with the amount of energy that can be recovered.

3. Difference of temperature between the lower layers and the surface of the sea

The first attempts to exploit the thermal energy of the sea go back about thirty years, when it was shown in France that energy could be produced from a slight difference of temperature between two masses of water; similar experiments were carried out off Cuba some years later.

The collection and conversion into useful energy of the heat stored in sea water are an ingenuous application of the principle by which heat can be converted into mechanical work, given two heat reservoirs at different temperatures. The sea provides enormous reservoirs of this kind; the surface of the water is heated by the sun and, in certain areas, the temperature is high enough in relation to that of the deep water for the temperature gradient to be utilized.

The basic equipment consists of an evaporator, a turbine generator set and a condenser. What happens is as follows: the warm salt water on the surface flows into a low-pressure container, which has been partially evacuated, and some of it vaporizes. The vapour thus produced is "sucked in" by a condenser cooled by water of lower temperature pumped from a deep layer. In passing from the evaporator to the condenser the vapour turns a very low pressure turbine, which in turn operates an electric generator. The entire conversion process depends on the temperature gradient. In order to generate electricity, the difference of temperature between the surface water and the cold water must be about 20°C.; a large volume of water must therefore be pumped from a great depth if a reasonable amount of energy is to be obtained.

The scheme is of little concern to Europe, since the energy in question can in fact be exploited only within an area of the globe bounded by the 25°C surface isotherms, which largely coincide with the tropics. It may, however, be extremely valuable for the countries situated within that area.

The successive setbacks experienced by Georges Claude were all due to the difficulty of piping the cold water up from the great depths. To give an idea of the scale, the first 3,500 kW unit planned for the Abidjan power station requires 5 m^3/sec of water for condensation, which has to be drawn from a depth of 430 m through a pipe 5 km long. It is noteworthy that this flow rate is the same as that which a hydro-power station with a head of about 80 m would need for the same output. This shows that the cost of a pipeline of this kind is not in itself prohibitive.

The problem of laying a pipe in the sea, however, proved very difficult. Georges Claude lost a pipe on two successive occasions while endeavouring to lay it. At the third attempt the pipe was laid, but was very badly damaged and only a few tests of the low-pressure turbine could be carried out, as the cold water flow was inadequate. In another attempt to supply an experimental unit mounted on a freighter by means of a vertical pipe going down to 400 m, he again lost the pipe owing to the swell.

Any practical use of this new form of energy seemed excluded until a reliable method was found to place the deep water feed pipe. Nizery solved the problem by using a pipe rendered less rigid by very strongly reinforced flexible rubber joints, and by employing anti-swell floats which carry the pipe on cables slung from winches, so that the effects of the swell are mitigated. The first experiment, carried out off Brest in 1947, was highly satisfactory: a pipe 150 m long was successfully tried out in a fairly rough sea with waves up to 2 m high.

The problem of how to guide the pipe and lower and raise it in shallow water seemed to have been solved by the anti-swell float, but it remained to be seen whether the apparatus thus developed could be used to place a pipe in position at a considerable depth. Two experiments were carried out at Abidjan. The first was a failure owing to a trivial incident caused by a defect in the equipment. The second trial, however, carried out in spring 1959, was a success: a 100 m long section of a pipe nearly 2 m in diameter was placed in position at a depth of about 300 m, and the operation was carried out during a heavy swell, the trough sometimes reaching 3 m. Before that, no great difficulty had been experienced in joining two lengths of pipe in some 15 m of water with a swell of about 1.5 m. It was thus shown that it was possible, despite quite heavy swells, to place the pipe in position in several sections, connected up in the water. It was also proved experimentally that, by means of hooks attached to it at suitable points, the pipe could be dredged up and moved, if necessary, especially if a mistake occurred in the laying.

The problem which had led to Georges Claude's repeated failures would seem, therefore, to have been solved by the numerous investigations and experiments carried out in the past ten years. It is noteworthy too, that technical progress is contributing more and more to the solution. Frogmen can be of great assistance in manipulating the pipe down to a depth of about 50 m. Undersea television will help considerably in operations at great depths.

(a) The prerequisites are therefore fulfilled for taking the further step of constructing <u>electric power stations</u> of this kind.

From the economic point of view the energy generated constitutes a permanent supply, not only by day and by night but also throughout the seasons, since the temperature of the cold waters at great depth is constant and the temperature of the surface of the sea or lagoons in the equatorial and tropical zones does not vary greatly. The initial outlay for the Abidjan project - the only one which has been fully investigated - is about the same as that for a waterfall producing regulated power.

This method will therefore undoubtedly lead to a new source of energy, but it, too, is subject to geographical limitations; first, it requires warm surface water all the year round, and that is available only in the areas near the equator; and, secondly, it requires a shoreline where the pipe to bring up the deep water will not have to be too long. This calls for either a steeply shelving coast or an underwater estuary of the type which hydrographic research has shown to exist in considerable numbers along many coasts. At Abidjan, for example, it is the presence of an undersea valley known as "the bottomless hole" which enables a pipe 5 km long to tap the water at a depth of 430 m.

There is, it is true, another means of bringing up cold water into the condenser namely mooring of the power station either on the surface or under water - on a kind of boat or submarine. The pipe then goes straight down and its length is reduced to the minimum. Under this system, the power generated is taken to the shore by submarine cable. It has also been suggested that artificial islands might be constructed, perhaps on submarine rock peaks. The islands might be used for other purposes as well as power production; in any case the cold water could be drawn up through a relatively short pipe owing to the steepness of the artificial slopes and the proximity of deep waters. These two latter methods would extend the geographical scope of this source of energy somewhat, as they would not require a steep shore or an undersea estuary.

(b) As has been seen, the primary purpose of using the thermal energy of the seas has been to generate electric power. The method has, however, yet another advantage, which might in many cases prove much more important. <u>Fresh water</u> can be obtained by merely substituting a surface condenser for a jet condenser.

The quantities involved are as follows: given a flow-rate of 1 m^3/sec of cold water drawn from the deep layers of the sea, a flow of warm water about three times as great, and a temperature gradient of about 20°, a power output of 700 kW is obtained and about 1,500 m^3 of fresh water are produced daily. It is worth noting that the ratio between these figures is the same as that between a city's consumption of drinking water and its electric power requirements. Thus, from the point of view of use to man, the two products - water and electric power - obtained in an installation of this kind are of comparable importance. The shortage of water in many tropical regions leads to the conclusion that this type of plant may well be constructed to meet the need for water, both in the first instance and in most instances thereafter.

The cost, estimated at less than US\$ 1.5 per m^3 at the Abidjan plant, is very low for that project as it covers only the special equipment required for producing fresh water; for two other projects it has been calculated that it would be nearly \$6, but in all cases the cost is largely covered by earnings from the sale of electric power. Thus, it would appear that fresh water can be produced by this method more cheaply than by any other at present in use, provided that adequate outlets are found for the electric power generated at the same time. Since electricity rates are high in most areas where there is a water shortage, all the economic prerequisites for setting up a complete plant of this kind will often be present. Where the temperature difference between the surface and the deep water is more than about 14°C, but is not enough for generating electricity - i.e. throughout a much broader climatic zone - the method may be used to produce fresh water alone. However, no attempt has apparently yet been made to compute the cost of fresh water produced in this way. A separate source of power would in any case be required to pump salt water and create a vacuum.

(c) Thirdly, the layout enables the considerable volume of cold water pumped from the ocean depths to be used at the outlet of the plant for refrigeration. Large quantities of fish and plankton for food may also be pumped up with the cold water. Furthermore, after some of the surface water has been evaporated in the power station, the remainder may be diverted into adjacent solar stills, in which the salt, magnesium and other substances contained in sea water are recovered.

These secondary uses should not, however, divert attention from the two essential products obtainable by harnessing the thermal energy of the seas: fresh water and electric power.

5. Tides

The very origin of tidal energy has a special character. Whereas river hydraulics, wind, coal and petroleum all derive from solar radiation, the tides draw their energy from the earth's rotation within the lunar-solar field of gravitation. The kinetic energy thus available is so great that enormous quantities of power may be wasted by friction on the sea coasts or recovered in turbines over long periods (by human standards) without any appreciable lengthening of the day due to retardation of the rate of the earth's rotation.

The tides can be economically utilized, however, only where there is a big rise and fall. The rise and fall depends on local resonance phenomena where the configuration of the coast is suitable. Whereas the tides in mid-ocean rise substantially less than 1 m, spring tides rise some 10 m at a few places where their energy may be profitably harnessed.

From the point of view only of generating power, and leaving aside the question whether it can be marketed, the best places for tidal power plants are apparently:

the Bay of Fundy in Canada,
the south-east coast of Patagonia,
the Severn estuary in England,
Mont St. Michel Bay in France,
Baffin Island,
part of the north coast of Australia,
Korea,
the Gulf of Gambay in India,
the mouth of the Rio Colorado in Mexico.

Not all these places are situated in areas where there is at present any great need for power; some of them, such as the Severn, are near large coal-fields, the output of which, however, is becoming inadequate for the energy requirements of the countries concerned. Others, such as the Bay of Fundy, are close to rivers which can be economically harnessed, and which will be fully exploited sooner or later. In any case, these tides in certain areas add yet another element to the variety of energy resources at man's disposal.

They could be harnessed without awaiting the development of a special technique if they were high enough to make the operation readily competitive with conventional means of power generation. Unfortunately, the mean amplitude is very low. The figures traditionally given to denote the tidal amplitude are those for the mean equinoctial springs. The mean amplitude for all tides is only 70 per cent of the equinoctial spring amplitude, and the mean neap amplitude is no more than 45 per cent. In addition, the difference in level between the basin and the sea when the turbines are working is only a fraction of the difference in level between high and low water. For both these reasons, the turbines would usually be at work with only between one-quarter and one-half of the total amplitude of the mean equinoctial spring tide. At the most suitable places, where the tidal amplitude reaches 12 m, the head ranges from 3 to 6 m during most of the operating period. Hence, tidal plant units are usually slow and expensive.

Moreover, the engineering operations are rendered difficult by the need to work in estuaries where the tide brings in large volumes of water every 12 hours, the amount of which at each spring tide is comparable to the discharge of large rivers in spate.

Lastly, the energy is generated in a lunar-solar cycle ill-suited to human working conditions. The energy recovered is thus very much less valuable than that from a waterfall with a seasonal reserve and is more like that of a fall on a river with an irregular flow.

For all these reasons, it was considered, until recently, that the installation of tidal plants was unduly difficult and expensive.

However, two new developments have now emerged.

First, grid systems have become increasingly powerful, so that larger and larger quantities of intermittent power can be integrated in them. In France, for example, the tidal plant now under construction on the Rance will have an installed capacity of 340,000 kW, which can now be readily integrated into the grid system. The Chausey Islands project will be much larger, with a capacity of nearly 10 million kW, but will not be operational for some twenty years, when the 380,000 V grid will be adequate to integrate 10 million kW into the roughly 50 million kW which France will then require. High-power tidal plants can, therefore, now be planned; and size is one of the prerequisites for profitable operation of this type of installation.

For purposes of random power output, small tidal plants with an installed capacity of from 1,000 to 10,000 kW are not out of the question with a small basin and strong enough tides. Such plants would be of value for the developing regions, but much remains to be done before they become practicable.

Conventional turbines are ill-suited to reversal of the direction of water flow. The planning of a tidal plant equipped with conventional turbines brought about a dilemma: one could either use the simplest form of plant with a barrage across the estuary or bay, as with a river plant, and recover only the energy from the outflow from the basin, but not that from the inflow; or one could construct the plant in such a way that both the incoming sea and the estuary outflow would feed the turbines - and thereby raise the cost considerably. The cases studied have shown that reversible turbines clearly supply the best solution.

Secondly, the Rance project at once disclosed the need for some kind of pump apparatus. The turbine would preferably be not only reversible as regards the direction of the flow but also capable of operating as a pump so as to bring about over-filling of the estuary, or over-draining by lowering the level of the basin below that of low tide, in order to increase the recoverable energy as the water came back in.

The best system appeared to be an axial-flow turbine with a Kaplan wheel, but the fact that the axis was horizontal meant that the water entering or leaving the turbine would have to flow round the alternator, or that the alternator would have to be sunk in a shaft, or enclosed in a bulb completely surrounded by the current. After numerous trials and after some axial units had been built in low-head river plants, it was found that the last-mentioned arrangement was the best. Further work on these bulb units has, moreover, led to the construction of single-block units combining alternator and turbine, the block being placed in position or withdrawn by travelling cranes.

Thus a system has been devised which is considerably superior to that involving conventional units, having the advantages that:

- the turbines can work in both directions and a double action thus obtained without constructing additional barrages and sluices;
- the estuary can be over-filled or over-drained by pumping;
- installed capacity per metre of plant measured along the estuary barrage is increased, since the axial units need less width perpendicularly to the direction of the water flow.

If the plant is equipped with the new type of bulb unit by which the turbines can work in both directions and can act as a pump, a tide can be harnessed by single or by double action as desired, so that power can be generated more often at peak hours. Furthermore, the pumps which can be used or not used at each tide, at will, by providing a good head of water will frequently ensure the availability of power at peak periods - although they will of course have taken current from the grid for pumping at other hours. Theoretically, the plant could even be operated by reference to its safeguard value and always provide power at the peak hour, even though a great deal of energy would have to be expended on pumping and there would be less fuel economy.

In fact, these turbines are so flexible that the optimum output can be selected at each tide, allowing both a considerable saving of fuel and the provision of considerable power at peak times, when this is regarded as justified. The safeguard value of the plant is thereby enhanced, i.e. the possibility, thanks to its presence, of making a given reduction in installed thermal capacity in the face of a particular risk of load-shedding.