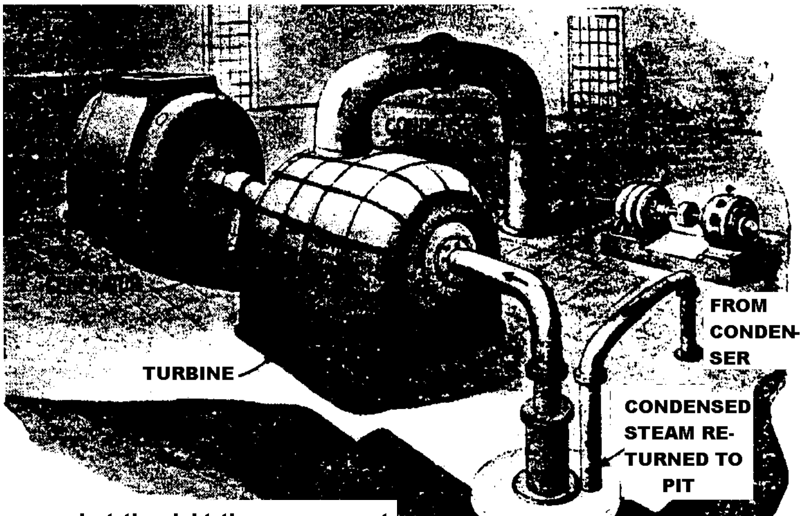
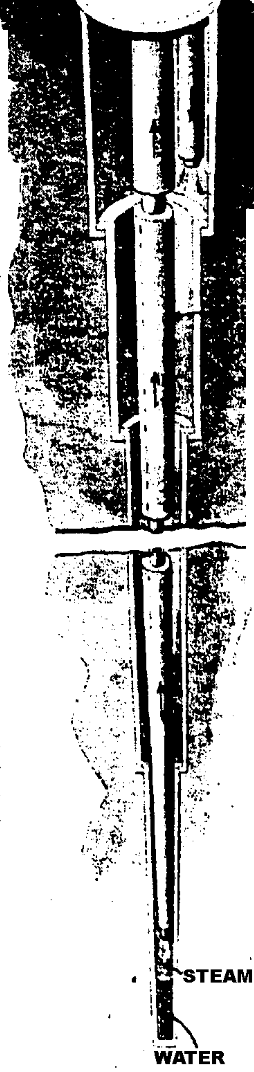
Our Future Motive Power

by Nikola Tesla

In this instructive article, the great scientist and inventor who revolutionized industry and communication with his alternating current motors and distributing system, and opened the way for radio with his high-frequency researches, analyzes the problem of obtaining power to replace our wasted fuel, and indicates the method of tapping the earth's hidden resources which will support the industry of future generations.





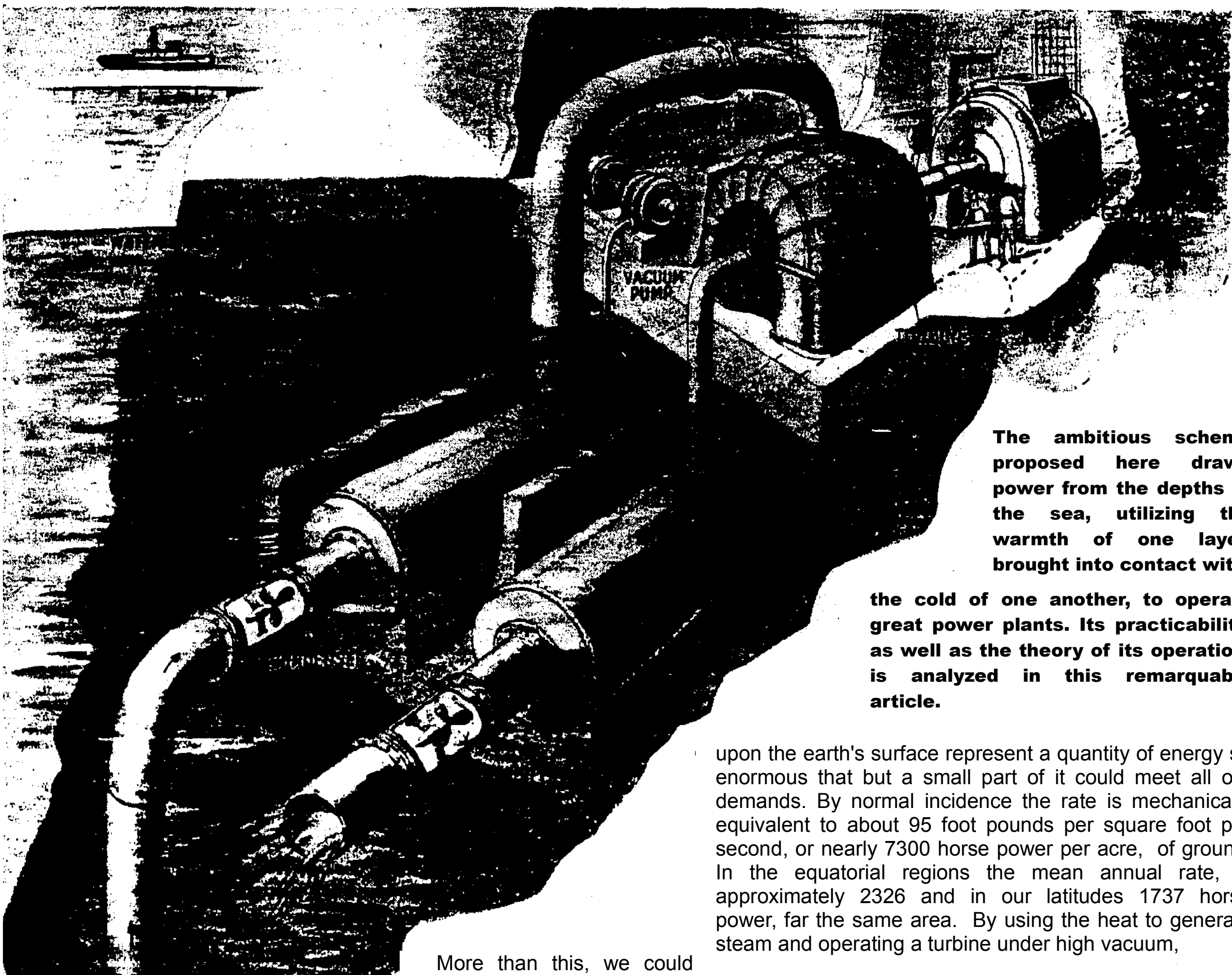
Above and at the right the arrangement of the great terrestrial-heat power plants of the future. Water is circulated to the bottom of the shaft, returning air steam to drive the turbine, and then returned to liquid form in the condenser, in an unending cycle.

Internal heat of the earth is great and, in comparison with the demands than man can make upon it, is pratically inexhaustible: since the heated contents of th earth are six trillions (10^{18}) of tons.

The material as well as intellectual progress of Man is becoming ever more dependent on the natural forces and energies he is putting to his service. While not exactly a true measure of well being and enlightenment, the amount of power used is a reliable indication of the degree of safety, comfort and convenience, without which the human race would he subject to increasing suffering and want and civilization might perish.

Virtually all our energies are derived from the sun, and the greatest triumph we have achieved in the utilization of its undying fire is the harnessing of waterfalls. The by fro-electric process, now universally employed. enables us to obtain as much as eighty-five per cent of the solar energy with machines of elementary simplicity which, by resorting to the latest improvements in the technical arts, might be made capable of enduring for centuries. These advantages are entirely exceptional. very .serious handicaps and great, unavoidable losses confronting us in all other transformations of the forces of nature. It is, therefore, desirable in the interest of the world as a whole, that this precious resource should be exploited to the limit. Judging from the average height of the wetter discharged annually from the clouds, and the mean fall river the aggregate land surface, tile total terrestrial water power may be theoretically estimated at ten billions of horse power. Of course, only a part of that is suited for practical development and relatively little is actually utilized — twenty-five per cent, perhaps, in the most advanced countries, less in others, tend there are some in which not even the ground has teen broken. Great waterfalls exist in many inaccessible regions elf the globe and clew tines are bring discovered, all of which will he eventually harnessed when the wireless transmission of energy is commercialized. there is foundation for hope, however, that our present limitations in the amount of the available power may lie removed in the future. Three-quarters of the earth's surface are covered by the oceans and the rainfall over all this vast area is useless for our purpose. Much thought has been given to artificial production of rain, but none of the means proposed offers the slightest chance of success. Besides, so flip only the precipitation in a limited region wits contemplated, leaving the total quantity of moisture for the entire land unchanged except as modified through the natural tendency of the oceans to divert snore anti snore wetter from the continents. The real and important problem for us to solve is not to bring about precipitation in any chosen locality, but to reverse this natural process, draw the Vapors from the germs and thereby increase, at will, the rainfall on the land. Can this he done?

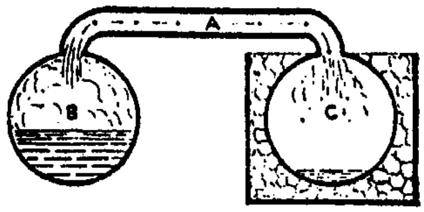
The sun raises the water to a height where it remains in a state of delicate suspension until a disturbance, of relatively insignificant energy, causes condensation at a place where the balance is most easily disturbed. The action, once started, spreads like a conflagration for a vacuum is formed and the air rushing in, being cooled by expansion. enhances further condensation in the surrounding masses of cloud. All life on the globe is absolutely dependent on this gigantic trigger mechanism of nature and my extended observation have shown that the complex effects of lightning ,are in most cities, the chief controlling agents. This theory, formulated by me in 1892, was borne out in some later experiments I made with artificial lightning bolts over 100 feet long, according to which it appears possible, by great power plants suitably distributed and operated at the proper times, to draw unlimited quantities of water from the oceans to the continents. The machines being driven by waterfalls, all the work: would be performed by the sun while we would have merely to release the trigger. In this manner we might obtain sufficient energy from falling water to provide for all our necessities.



The ambitious scheme proposed here draws power from the depths of the sea, utilizing the warmth of one layer, brought into contact with the cold of one another, to operate great power plants. Its practicability, as well as the theory of its operation, is analyzed in this remarquable article.

More than this, we could create new lakes and rivers, induce it luxuriant flora and fauna and convert even the arid sands of deserts into rich, fertile soil.

But the full realization of this idea is very remote. The hard fact is thin unless new resources are opened up, energy derived from fuel will remain our chief reliance. The thermodynamic process is wasteful and barbarous, especially when burning coal, the mining of which, despite of modern improvements, still involves untold hardships and dangers to the unfortunates who are condemned to toil deep in the bowels of the earth. Oil and natural gas are immensely superior in this and other respects and their use is rapidly extending. It is quite evident, though, that this squandering cannot go on indefinitely, for geological investigations prove our fuel stores to he limited. So great hits been the drain on them of late years that the specter of exhaustion is looming up threateningly in the distance, and everywhere the minds of engineers and inventors are bent upon increasing the efficiency of known methods and discovering new sources of power. Nature has provided an abundant supply of energy in various forms which might be economically utilized if proper means and ways can be devised. The sun's rays falling upon the earth's surface represent a quantity of energy so enormous that but a small part of it could meet all our demands. By normal incidence the rate is mechanically equivalent to about 95 foot pounds per square foot per second, or nearly 7300 horse power per acre, of ground. In the equatorial regions the mean annual rate, is approximately 2326 and in our latitudes 1737 horse power, far the same area. By using the heat to generate steam and operating a turbine under high vacuum,



The "cryophros" is well known as a scientific toy, exemplifying also the principle of refrigerating machinery.

probably 200 horsepower per acre could be obtained as net useful power in these parts. This would be very satisfactory were it not for the cost of the apparatus which is greatly increased by the necessity of employing a storage plant sufficient to carry the load almost three-quarters of the time.

The energy of light rays, constituting about 10% of the total radiation. might be captured by a cold and highly efficient process in photo-electric cells which may become on this account, of practical importance in the future. Some progress in this direction has been already achieved. But for the time being it appears from a careful estimate, that solar power derived from radiant heat and light, even in the tropics, offers small opportunities fair practical exploitation. The existing handicaps will be largely removed when the wireless method of power transmission comes into use. Many plants situated in hot zones, could then be operatively connected in a great super-power system to supply energy, at a constant rate, to all points of the globe.

The sun emits, however, a peculiar radiation of great energy which I discovered in 1899. Two years previous I had been engaged in an investigation of radioactivity which led me to the conclusion that the phenomena observed were not due to molecular forces residing In the substances themselves, but were caused by a cosmic ray of extraordinary penetrativeness. That it emanated front the sun was an obvious inference, for although many heavenly bodies are undoubtedly possessed of a similar property, the total radiation which the earth receives from all the suns and stars of the universe is only a little more than one -quarter of one per cent of that it gets from our luminary. Hence, to look for the cosmic ray elsewhere is much like (1) "chercher le midi dans les environs de quatorze heures." My theory was strikingly confirmed when I found that the sun does, indeed, emit a ray marvelous in the inconceivable minuteness of its particles and transcending speed of their motion, vastly exceeding that of light. This ray, by impinging against the cosmic dust generates a secondary radiation, relatively very feeble but fairly penetrative, the intensity of which is, of course, almost the same in all directions. German scientists who investigated it in 1901 assumed that it came from the stars and since that time the fantastic idea has been advanced that it has its origin in new matter constantly created in interstellar space ! ! We may be sure that there is no place in the universe where such a flagrant violation of natural laws, as the flowing of water uphill, is possible. Perhaps, some time in the future when our means of investigation will be immeasurably improved, we may find ways of capturing this force and utilizing it for the attainment of results beyond our present imagining.

The tides are often considered as a source of motive power and not a few engineers have expressed themselves favorably in regard to their use. But as a matter of fact, the energy is, in most places, insignificant, the harnessing of the waterfall over an acre of ground yielding but little more than one horse power. Only in exceptional locations can the power of the tides be profitably developed.

It has been, the dream .of many an inventor to utilize the energy of ocean waves, which is considerable. But although numerous schemes have been advanced and much ingenuity shown in devising the mechanical means, nothing of commercial value has so far resulted and the prospects are, very poor on account of technical difficulties and the erratic character of this power source.

The force of the wind can be much more easily put to our service and has been in practical use since times immemorial. It is invaluable in ship propulsion and the windmill must be seriously regarded as it power generator.

If the cost of this commodity should greatly increase we will be likely to see the countries dotted with these time-honored contrivances.

Unfortunately, the value of all these resources is very much reduced by periodic and casual variations, and we are driven to search for it source of constant twenty-four hour power comparable to that of a waterfall Thus we are led to consider terrestrial heat as a possible fountain of unvarying energy supply.

Terrestrial Energy

It is noteworthy that already in 1832 Lord Kelvin called attention to natural heat as a source of power available to Man. But, contrary to his habit of going to the bottom of every subject of his investigations, he contented himself with the mere suggestion. Later, when the laws of thermo-dynamics became well understood, the prospects of utilizing temperature differences in the ocean, solid earth or the atmosphere, have been often examined. It is well known that there exists, in tropical seas, a difference of 50°F. between the surface water and that three miles Bellow. The temperature of the former, being subject to variations, averages 82°F, while that of the latter is normally at least, at 32°F., or nearly so, as the result of the slow influx of the ice-cold polar stream. In solid land these relations are reversed, the temperature increasing about one degree Fahr. for every 64 feet of descent. Very great differences are also known to exist in the atmosphere, the temperature diminishing with the distance above the earth's surface according tot it complex function.

But while all this was of common

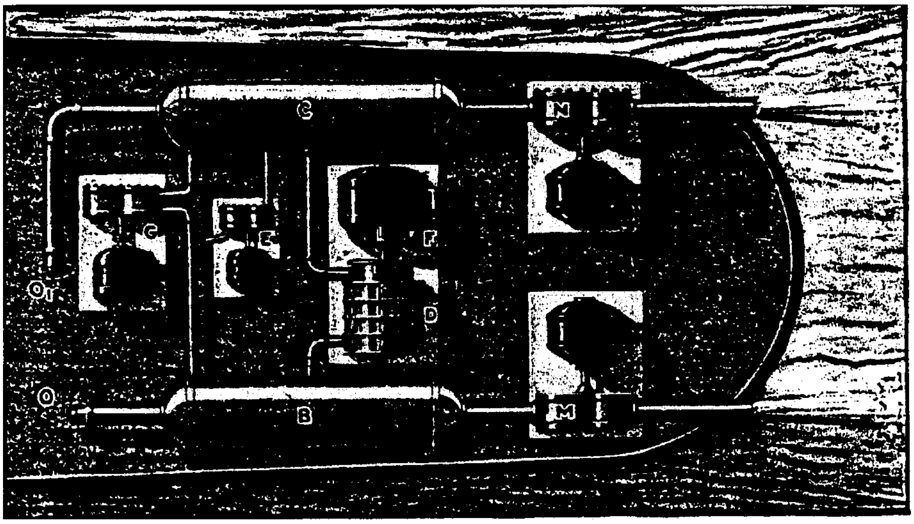


FIG. 1
Design of a vessel to be propelled by energy derived from temperature differences in the water. The symbols designating the operating mechanism are explained in the text.

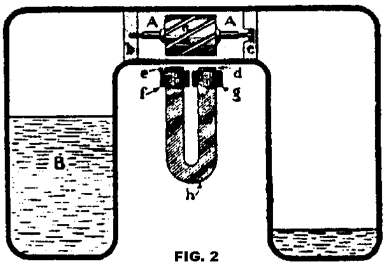


FIG. 2
Fundamental plan of a system whereby the transfer of vapor between two vessels at different temperature drives the armature of an electrical generator.

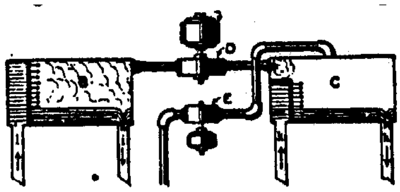


FIG. 3
A more complete sketch of the thermodynamic system, in which the necessary degree of vacuum is produced by the suction pump E.

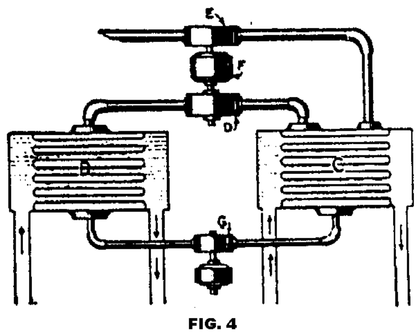


FIG. 4
Here the water, or other fluid operating the turbine D is kept in a closed system, circulating through condensers immersed in water of different temperature

(1) To look for noon around 2 o' clock

knowledge for at least 75 years and the utilization of the heat of the earth for power purposes a subject of speculation, no decided attempt to this end seems to have been made until an American engineer, whose name I have been unable to ascertain, proposed to operate engines by stream generated in high vacuum from the warm surface water and condensed by the cold water pumped from a great depth. A fully and carefully worked out plan of this kind, supported by figures and estimates, was submitted by him to prominent capitalists and business men of New York about 30 years ago. He not only contemplated the production and distribution of power for general use but intended even to propel boats lay energy derived in the same manner, using. preferably. ether an working fluid. On account of his death, or for other reasons, the project was not carried into practice.

Of this I learned much later when I interested in my alternating system Alfred S. Brown; it well known technical expert, called upon to examine the merits of my inventions, and C. F. Peck. a distinguished lawyer, who organized a company for their commercial introduction. These men were among the first approached by the engineer and considered his plan rational in principle. but the pipe lines, pumps, engines, boilers and condensers involved too great an outlay and, besides. a profitable disposal . of the power was difficult and uncertain. My discovery of the rotating magnetic field brought about a change in the situation and in their attitude. They thought that if the energy could be economically transmitted to distant places by my system and the cost of the ocean plant substantially reduced, this inexhaustible source might be successfully exploited. Mr. Peck had influential connection, among them John C. Moore, the founder of the banking house hearing his name. With the. exception of the late .J. P. Morgan, who towered above all the Wall Street people like Samson over the Philistines, Moore was probably the strongest personality. I was given to understand that if I could evolve a plan satisfactory to Mr. Brown and other engineers. all the capital required for an enterprise on a very large scale, as contemplated by them, would be promptly furnished. No encouragement from my associates was needed for determining me to undertake the task, as the idea appeared, at first, wonderfully promising and attractive nithough there was nothing about it fundamentally new.

Undoubtedly, the essential conditions required to operate a steam or other thermodynamic engine could be fulfilled, a considerable temperature difference Being available at all times. No proof had to be furnished that heat would flow from a higher to a lower level and could be transformed into mechanical work. Nor was It necessary to show that the surface water, although much below its normal boiling point of 212°F., can be readily converted into steam by subjecting it to a vacuum which causes ebullition at any temperature however low. It is of common knowledge that, due to this same effect, hence cannot be cooked or eggs hard-boiled on high mountains. Also, for a like reason turbines have been wrecked in steam power plants with the boilers completely shut off. the slightly warm water in the system, of connecting pipes being evaporated under a high vacuum inadvertently applied.

This behavior of water, or liquids In general, was long before beautyfully exemplified In the classical device called "cryophoros" consisting of two communicating and exhausted bulbs partially filled with liquid, which is evaporated in one anti condensed in the other. It was invented by W. H. Wollaston, a great english scientific man and investigator (1766-1828), who first commercialized platinum and was credited by some to have anticipated Faraday to the discovery of electromagnetic rotation. The original Instrument brought out, at the beginning of the nineteenth century had one of the bulbs packed In ice with the result of freezing water in the other. Conformably to the views of that time It was thought that the cold of the lee was carried to the water and so the Greek name, meaning "cold-carrier," was given to the device. But now we know that the process is of opposite character, the freezing being brought about by the transport of the latent treat of evaporation from the warm to the cold bulb. One would naturally infer that the operation would cease as soon as the water is frozen at the surface, but curiously enough the ice itself continues to yield steam and it is only because of this that all of the water is solidified. We may imagine how puzzling this phenomenon appeared more than one century ago!

The ocean plant proposed by the engineer was nothing else but Wollaston's device of huge proportions, adapted for continuous operation and having an engine interposed between the two communicating vessels. In estimating its thermo-dynamic performance the first results I arrived at through the medium of pad and pencil fairly bewildered me. To illustrate by an example, suppose that equal quantities, say, one-half pound of the warm and of the cold water, respectively, at 82° and 32° Fahrenheit, are mixed or put in thermal equilibrium otherwise. The first will then give tip to the second 12.5 heat units, mechanically equivalent to 0.0725 foot pounds--the same energy which would be developed in the fall of one pound from so great an altitude as 0.0725 feet. The dream of my life had been to harness Niagara, but here was a fall sixty times higher and of unlimited volume. To raise the cold water to the surface from any depth whatever, required but a triding effort and as other losses also seemed negligible concluded that if only a small portion of this hypothetical fall could be utilized, one of the greatest problems confronting humanity would be solved for all times to come.

I knew that It was too good to be true, nevertheless I followed this ignis fatuus for years until, little by little; through close reasoning. calculation and experiment. I got the true bearings in the swamp of my ignorance and doubt. Then this scheme of harnessing the ocean revealed itself to my mind as- one of the crudest imaginable. Just to transport a little heat. water has to be pumped and disposed of in quantities so enormous that a large installation of this type would present new problems in engineering. Contrary to the opinion I had previously formed, this involved the expenditure of a great amount of energy. Then I realized that the gases contained in the water can be only partially extracted and have to be continuously removed from the condenser to prevent the rise of back pressure which might reduce the speed and eventually stop the engine.

Furthermore. due to certain conditions. the sleep sea water must enter the pipe warmer than it should conformably to soundings. so that the full temperature difference cannot be obtained. and I discovered other peculiar causes which. after some time. might seriously interfere with the proper functioning of the mechanism. The steam. raised directly from the surface water. is of the poorest quality. mere mist under small pressure, and its consumption per horsepower hour was likely to be twenty times greater than in modern plants. In hydro-electric stations. ad before stated. eighty-five per cent of the energy of falling water way be captured. while in this case hardly more than two-tenths of one per cent of the theoretical fall can be utilized Worst of all, the size and cost of the equipment is utterly out of proportion to the greatest possible returns. Theme and other limitations and difficulties forced themselves upon me in studying the plans as first submitted.

The introduction of my alternating system started a scramble for the most valuable water power sites anal no attempt was made to harness the ocean. But my interest was aroused to such a degree that I continued the work and made a number of improvements which are thought to possess some merit. Satisfied that pipes supported by floats or hung is submarine abysses were Impracticable, I proposed a sloping tunnel, lined with beat insulating cement; affording a smooth and unbroken passage for the sleep sea water. I found ways of simplifying and cheapening the apparatus and making it more effective by reducing the moisture of the steam and otherwise, and these advances may eventually prove of practical value.

To conduce to a more ready understanding of the evolution of the ocean power plait from the cryophoros and of the nature of some of my Improvements, reference may be made to the drawings is which Fig. 1. represents the original device of Wollaston, comprising two highly exhausted- vessels B and C, respectively, the boiler and condenser, connected through a channel A. The first named vessel being partly filled with water or other liquid and the second packed in a freezing mixture, the vacuum causes the water when slightly warmed to boil furiously and the well known effect is observed. As the steam generated In the boiler rushes into the condenser with great speed, it is capable of producing a considerable mechanical effort. The first named vessel being partly filled with water or other liquid and the second packed in a freezing mixture, the vacuum causes the water when slightly warmed to boil furiously and the well known effect is observed. As the steam generated In the boiler rushes into the condenser with great speed, it is capable of producing a considerable mechanical effort.

Fig. 2 illustrates how the thermo-dynamic transformation of energy may be effected to obtain useful external work. This particular arrangement Is chosen in order to dispense with the necessity of a connection to the outside which would call for the employment of a vacuum pump. A. steel armature a, of a diameter nearly equal to that of the channel A, connecting vessels B and C, and shaped like - a fan, is supported in virtually frictionless bearings b and c. of which the latter may be designed for taking up the thrust. Surrounding the armature, or turbine rotor, and in close proximity to the same, are soft-iron projections as d and e, wound with coils f and g and forming part of a permanent magnet h. The rapid rotation of the, armature results in a periodic shifting of magnetic lines from one to the other set of projections, this inducing in the coils currents which may be utilized.

The next step is to adapt the device for continuous operation. This may be done in two ways: by supplying the evaporating anti condensing water directly to the vessels B; and C, or by merely transmitting and abstracting heat through their walls, in which case the working fluid is entirely separated and circulated in it closed circuit.

The first plan is diagrammatically shown in Fig. 3. The vessels B and C are cylinders joined by a turbine D through suitable pipe connections. A suction pump E, constructed for producing a very high vacuum, to attached to the condenser C and may be driven by the turbine through a gear or, as indicated, by an induction motor energized with alternating currents from the dynamo F coupled to the turbine. The water being under atmospheric pressure would flow into the evacuated vessels, at too great a speed occasioning corresponding losses, and for this reason it is necessary to supply and drain it through balancing barometric columns i i and k k of proper height thereby insuring the desired circulation; the direction of which is indicated by arrows. Since the latent heat absorbed in evaporation and set free in condensation is very great, an immense quantity of water must be circulated through the vessels in order to prevent changes of temperature sufficient to seriously reduce the performance of the apparatus. In addition to the devices shown, separators must be employed for extracting gases from the water before its entrance into the boiler and condenser. These cannot be of the effective centrifugal type as they would entail too great a loss energy. The only kind practicable is that used from the earliest beginnings of modern hydraulics, the action of which is based on a slow reversal of direction of flow and accomplishes only partial degasification. It should be noted that the cases, by rapid expansion and attendant cooling, impair greatly the quality of the steam and also, more or less, the vacuum in the vessels. One of my improvements is to supply the water in the form of jets, as represented. which furnish the necessary evaporating and condensing surface while at the same time carrying array gases which would be liberated if the water were admitted as usual.

A careful study of the scheme illustrated in Fig. 3 has satisfied me that it is, for a number of reasons, disadvantageous and less practicable than that shown in Fig. 4. In this instance the vessels B and C are surface condensers of ordinary design but of very great active areas in view of the excessive steam consumption and small differences of temperature applied. They may be of the same size, for although the passage of heat from the hot to the cold water takes place through the steam, the law of mixtures is obeyed, the maximum transfer occurring when the quantities of both are equal. Were it not for that the performance might be appreciably improved by supplying the hot water, which has to pass only through short piper, in greater quantity. The vessels are connected through a turbine D coupled to a generator F, as before, and besides the suction pump E a deep well pump G is employed to force the condensate into the boiler. The water should be sweet and thoroughly degasified yielding steam of good quality and greatly reducing the work of the pumps, and both boiler and condenser should be completely immersed in the circulating media to minimize the heat losses. The important practical advantages of this plan are that any suitable working fluids anti units of very great capacity may be used.

Technical experts who array examine the merits of the ocean power scheme will be apt to dismiss lightly the loss of energy Involved in the propulsion of the hot and cold water which is reality, may be very serious on account of the lift above the mean ocean level. The outlets are unavoidably very large and if their centers are from three to four feet above the mean level to insure normal functioning at high tide the pumping losses will be considerable. Furthermore, the water is subjected to repeated changes in direction and velocity and suffers a frictional loss of head, especially in the long conduit, all of which may be equivalent to an additional life of a few feet, making the total, say, 7 feet. conservatively estimated.

Now, in the Gulf of Mexico, or in Cuban waters, where my associates intended to build plants, the temperature difference between the hot and cold water will be hardly more than 36°F. as an annual .average and with the poor steam obtainable the circulation may be as much as 12 lbs, of each per horse power per second. Consequently, the mechanical work may be estimated at 108 foot pounds per second and this figure must be almost doubled because the over-all efficiency of induction motor-driven pump units, which have to be employed, is not much above fifty per cent, as a rule. Since one horse power is a rate of 550 foot pounds per second this means a loss of about 40 per cent. Besides, the operation of the degasifiers, vacuum and deep well pumps, will consume energy which has to be supplied from the turbo-generator and taken at nearly twice its value for the reason pointed out. All these losses may be reduced in various ways but not to a very great extent, and the example clearly shows the desirability of doing away with them. This argument in applicable, even with greater force, to the cost. of the pumping outfits of which I will endeavor to convey an idea by assuming that a 30.000 horse power plant in installed, requiring not less than 300,000 pounds of hot and of cold water per second. which means. approximately, 4,700 cubic feet of each. As a velocity of 3 feet per second should not be exceeded, two pumps capable of meeting the requirements would have intake and outlet openings of 1800 square feet, with the usual allowances. Evidently such monstrous machines could not be used, for one reason, not to mention others, that the lift would be very great and the loss incurred prohibitive. This brings to light a bad feature of the scheme illustrated in Fig. 3, namely. that it is impracticable to have recourse to very large units and thereby secure the customary advantages. A great number of small units must be of necessity used and it follows that the larger the plant the poorer it will be. Instead of the two pumps each with openings of 1800 square feet. at least one hundred motor driven pumps with orifices of 36 square feet and a corresponding number of boilers and condensers with enormous inlet and outlet pipes would have to be employed, and at a staggering cost.

These and other similar considerations have prompted me to devise the plan schematically shown in Fig. 3 in which I do away entirely with the water pumps by relying wholly on ebb and tide to bring about the required circulation of the heating and cooling media, thus simplifying the plant and obviating great losses and expenditures. The installation comprises two very large basins lined with heat insulating cement designated by H and I and provided with suitable supports for heat-insulating roofs or covers the function of which is to minimize losses by radiation and influx of heat. respectively, from the hot and to the cold water. Each of the basins has a controllable opening, respectively K and L situated close to the bottom, where also the boiler B and condenser C, are located. The latter ate connected through a turbine D coupled to a generator V, constituting a unit of large capacity. As in t0he case before described, a suction pump M and a deep well pump G are provided, driven by induction motors energized from the generator. All this machinery is placed on a common foundation, as indicated. The basins are filled at high tide and the outflow during the period of ebb is controlled do as to secure the best results. Although the power is subject to periodic variations, the plant can be operated satisfactorily without the employment of batteries or other means of storage and thus the cost of this commodity may be greatly reduced.

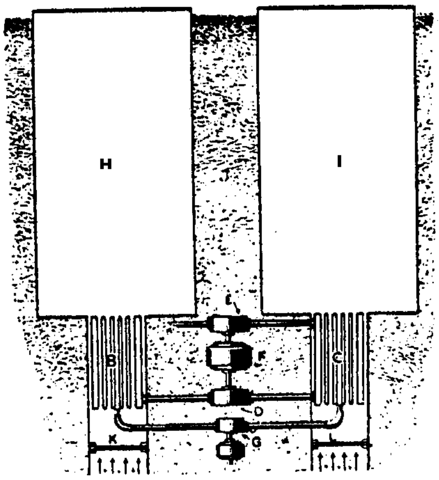


FIG. 5
The basins H and I are filled and emptied by the tide, saving much of the energy otherwise expended in pumping.

Another way of deriving power from the temperature differences in the ocean without the use of water pumps in illustrated In Fig. 8. The apparatus comprises the same; essential parts which have been already described, namely, a tubular boiler B and like condenser C connected through a turbine D driving a generator F, a high vacuum pump B and a small reciprocating deep-well pump G for lifting the condensate from the condenser into the boiler. The latter is supported in the warm surface water by a doating structure carrying all the machinery, while .the former in suspended at a suitable depth in the cold tracer. Both of these parts are arranged with the tubes in vertical position insuring a good circulation of the heating and cooling media. This arrangement is very simple and effective but the raising of the condensate by pump G consumes considerable work. I have designed wirelless power plants on this plan with practical objects in view and they may perhaps find valuable uses in the future.

Fig. 7 represents a partial view of a boat with apparatus for propelling it solely by the heat energy abstracted from the water; I true not informed just how the American engineer intended to propel his vessel and the scheme illustrated is my own. Two rotary pumps M and N are employed to force the warm and cold water, respectively, through the tubes of the boiler B and condenser C. This apparatus is placed slightly below the waterline for minimizing the losses involved in the circulation of the heating and cooling media

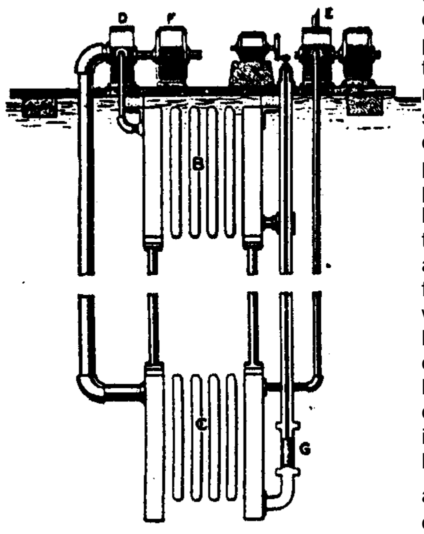


FIG. 6
A floating thermo-electric power plant, in which the condenser C is suspended beneath the boiler B and the condensate circulates vertically.

The pumps are supposed to be driven by induction motors, as illustrated, and are connected to the discharge pipes and other parts in such a tray that the water cannot enter the hold of the vessel. The boiler intake O is near the ocean's surface while that of the condenser is at the requisite depth; a streamline shaped duct O1, open in front, being employed for the purpose. As the temperature of the water diminishes very rapidly through a limited distance from the surface of the ocean, sufficient energy can be abstracted from the water using a duct of fifty feet length to propel the boat by the streams escaping through the discharge pipes. No other means of propulsion is necessary end even the steering can be accomplished by suitably regulating the volume of the two streams discharged astern as shown. The turbine D, generator F, high vacuum pump E, deepwell pump Q and other parts serve the same purposes its before. Some stored energy must be provided to start the vacuum pump and thereby initiate the operation of the apparatus.

The ocean power plan of the illustration on page 27 seems very inviting when considering that the energy obtained in proportionate to the quantity of the water pumped and, therefore, virtually unlimited. But it must be remembered that the true merit of such a scheme can only be measured by the returns. We have still greater and more readily available resources which are unused because they are unprofitable. On closer investigation many discouraging facts are unearthed. The deep sea water is, normally, at a loss temperature but at any time a warm current of water may be produced and render the plant useless. It has been observed that there may be differences of 35° F. or even more In the temperature of water at the same depth. Just as convection currents occur in the air so they may also be produced in the ocean and this is an ever present menace to an undertaking of this kind. It also appears the actually obtainable temperature difference must be always appreciably smaller than might be Inferred from soundings. The raising of the denser water below a certain niveau as into the less dense above it involves a performance of work which must be done by the pump but is not lost an the volume of the water discharged at the top of the deep-sea duct is correspondingly increased. This does not hold true of the water above the niveau and, consequently, the flow into the intake of the duct taken place preponderatingly from above, that is, in the direction of the downward convection current. Owing to this, warm water from above enters the intake thus reducing the temperature difference. Another curious fact cannot be ignored. The sea is densely populated with organisms which are subject to changes caused by age. As they grow older the life stream deposits more and heavier solid matter, they become specifically heavier and sink gradually until finally at great depths life is extinct. It this floating matter could be removed by the pump at a constant rate, as the water, it would give relatively little trouble. But as water is removed the concentration of this matter continuously increases and may become so great as to interfere seriously with the operation of the plant. Impairment of performance. If not interruption; taught also be brought about by rust and deposits in the pipes, loosening of joints and other mishaps and for this reason I consider a tunnel as the practicable means for transporting the cold water.

I have studied this plan of power production from all angles and have devised apparatus for bringing down all losses to what I might call the irreducible minimum and still I find the performance too small to enable successful competition with the present methods.

The utilization of temperature differences in the solid earth prevents several important advantages. It would make it unnecessary to go to the tropics where power is of smaller value. Indeed, the colder the climate the better. A shaft could be stink in the midst of a densely populated district and a great saving effected in the cost of distribution. The shaft would be costly, of course, but the apparatus cheap, simple and efficient. The first drawing, on page 20, illustrates its essential parts comprising a boiler at a great depth, a condenser, cooled by river or other water available, on the ground, a turbine coupled to a generator, and a motor-driven high vacuum pump. The steam or vapor generated in the boiler is conveyed to the turbine and condenser through an insulated central pipe while another smaller pipe, likewise provided with an adiathermanous covering serves to fed the condensate into the boiler by gravity. All that is necessary to open up unlimited resources of power throughout the world is to find some economic and speedy way of sinking deep shafts.

Whether we shall have to rely on power derived from terrestrial heat must be left to the future. If we should exhaust our present resources without opening up new ones, this possibility might arise. Undoubtedly, our stores of coal and oil will be eventually used up and there is not enough water power to supply our needs. The idea of obtaining motive energy from atoms or change of elements is unscientific and illusionary and cannot be condemned too emphatically. The same to true of the scheme of harnessing the energy supposed to be liberated at such temperatures as 40,000,000 degrees C (Centigrade) recently suggested. The fundamental fallacy in all these proposals is that it takes more energy to disintegrate than can be usefully recovered even in an ideal process.

Glaringly fallacious theories are responsible for such chimerical hopes. Probably the worst of these is the electron theory, Of the four or five atomic structures which have been suggested not a single one is possible. Not more than one in a thousand men of science knows that an electron — whatever it be — can only exist in the perfect vacuum of intermolecular and interstellar spaces or highly exhausted tubes and that the nucleus stripped of electrons, is devoid of energy.

It was clear to me many years ago that a new and better source of power had to be discovered to meet the ever increasing demands of mankind. In a lecture delivered before the American Institute of Electrical Engineers at Columbia University May 20, 1891, I said: "We are whirling through endless space with inconceivable speed all around as everything is spinning. everything is moving, everywhere is energy. There must be some way of availing ourselves of this energy more directly. Then, with the light obtained from the medium, with the power derived from it. with every forth of energy obtained without effort, from the store forever inexhaustible. humanity will advance with giant strides."

I have thought and worked with this object in view unremittingly and am glad to say that I have sufficient theoretical and experimental evidence to fill me with hope, not to say confidence, that my efforts of years will be rewarded and that we shall have at our disposal a new source of power, superior even to the hydroelectrlc. which may be obtained by means of simple apparatus everywhere and in almost constant and unlimited amount.

Captions

- Above and at the right, the arrangement of one of the great terrestrial-heat power plants of the future. Water is circulated to the bottom of the shaft, returning as steam to drive the turbine, and then returned to liquid form in the condenser, in an unending cycle.
- Internal heat of the earth is great and in comparison with the demands which man can make upon it. is practically inexhaustible: since the heated contents of the earth are six trillions (10^{18}) of tons.
- The ambitious scheme proposed here draws power from the depths of the sea. utilizing the warmth of one layer, brought into contact with the cold of another. to operate great power plants. Its practicability, as well as the theory of its operation, is analysed in this remarkable article.
- The "cryophoros" is well known as a scientific toy. exemplifying also the principle of refrigerating machinery.
- FIG. 2 — Fundamental plan of a system whereby the transfer of vapor between two vessels at different temperatures drives the armature: of an electrical generator.
- FIG. 3 — A more complete sketch of the thermodynamic system, in which the necessary degree of vacuum is produced by the suction pump E.
- FIG. 4 — Here the water, or other fluid operating the turbine D is kept in a closed system circulating through condensers immersed in water of different temperatures.
- FIG. 5 — The basins H and I are filled and emptied by the tide, sawing much of the energy otherwise expended in pumping.
- FIG. 6 — A floating thermo-electric power plant; in which the condenser C is suspended beneath the boiler B and the condensate circulates vertically.
- FIG. 7 — Design of a vessel to be propelled by energy derived from temperature differences in the water. The symbols designating the operating mechanism are explained in the text.