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Ocean Thermal Energy Conversion

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Abstract: Ocean Thermal Energy Conversion also known as OTEC, is a system in which differences in ocean temperatures are used to create mechanical energy in the form of turning a turbine in the system. This mechanical energy is then converted into useable electricity which can be put back into the grid. Unlike other systems such as wind, or solar that are also successful in producing a positive net output of power, an OTEC system can be run 24hours a day, all year long as there is always a difference in surface water temperatures v. deeper ocean water temperatures.[1.] In the 1880's after being inspired by an idea Jules Verne wrote about in his novel "Twenty Thousand Leagues Under the Sea", a French researcher named Jacques D'Arsonval developed the concept of OTEC which is being used and improved upon in today's society to help sustain power consumption needs around the globe in a clean energy producing manner.

I. Introduction

As stated by Energy.gov [1.], OTEC is a process called ocean thermal energy conversion that uses heat energy stored in the Earth's oceans to generate electricity.

OTEC is a system that uses warmer surface water and cool deeper ocean water to spin the turbine of a heat engine in order to product useable electricity back to the grid. As mentioned by energy.gov [2.], The Concept of OTEC was pioneered in the 1880's by a French researcher named Jacques Arsene d'Arsonval, and later one of his students named Dr. Georges Claude built the first OTEC plant in Cuba in 1930. After his success with the OTEC system he built in Cuba, he built another larger OTEC system on a 10,000-ton cargo vessel off the coast of Brazil. Unfortunately before the plant could record a positive net power output it was destroyed by storms and waves, however these two men gave rise to the idea and engineering to build OTEC plants which are currently being researched and implemented in today's oceans. With the always increasing need for electricity producing systems like OTEC can help to sustain the energy needed for human consumption. OTEC is also a clean energy producer leaving an almost non-existent carbon footprint in the production method of electricity, further developing clean methods like this is very important as the Earth's atmosphere is continually increasing in CO_2 concentration and we know of course this is not a good thing for the planet.

II. OTEC and how it works.

Ocean Thermal Energy Conversion, also known as OTEC for short, is the use of temperature differences around 20°C-25°C from the warmer surface waters and cooler deeper water to produce electricity. Ocean surface water that is heated by solar energy then stored in the earth's oceans is evaporated and used to spin a turbine in a generator it create power, the cooler ocean water is then used to re-condense the vapor and recycle the warmer working fluid of the system back to the evaporator and through the generator again as shown with the closed cycle OTEC system in Figure 1., below.

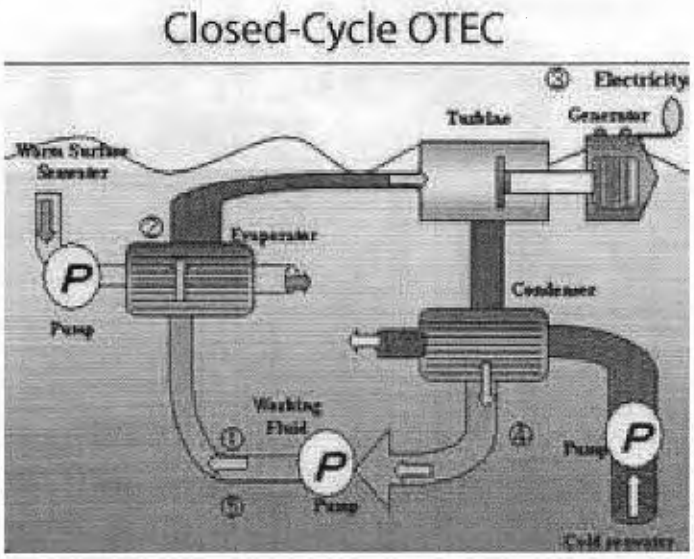

Figure:1 Basic diagram of a closed cycle OTEC system.

There is also an open cycle OTEC plant as well, in which the key difference is the warm working fluid of the system is discharged after condensation rather than being recycled and new warm surface water is pumped to the evaporator. All other aspects of the vapor turning the turbine in the generator and the cooler water re-condensing the

working vapor are common to both OTEC types. Shown below in Figure 2., Is an open cycle OTEC system used to illustrate the subtle differences between open and closed cycles of OTEC plants.

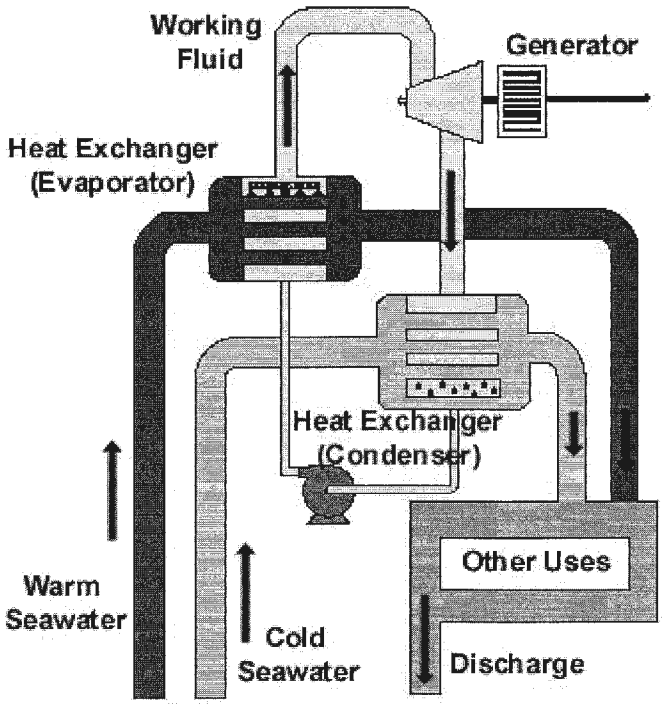

Figure:2 Basic diagram of an open-system OTEC power generating plant

One key fact to note about these OTEC systems is that they are a very clean source in producing electricity as they have virtually no carbon footprint being added to the earth's atmosphere which is an ever growing concern around the world. OTEC systems can also have extremely high efficiencies in converting thermal energy to electricity

considering that the heat used to warm the surface water is free from the solar radiation provided by the Sun.

III. History and Innovation of OTEC

In the 1880's after being inspired by an idea in the novel, "Twenty Thousand Leagues Under the Sea" French researcher/physicist Jacques Arsene d'Arsonval developed the concept of Ocean Thermal Energy Conversion (OTEC) which was later developed on by a student of his named Georges Claude, as stated by Energy.gov [2.], George Claude built the first OTEC system in 1930, The system produced 22 kilowatts of electricity with a low-pressure turbine. The system was built in Cuba for testing after his initial success in Cuba he set out to build a larger OTEC plant off the coast of Brazil on a 10,000-ton cargo vessel. However promising the system was, unfortunately is was destroyed by storms and waves before the system could record a positive net power output. One of the pioneering developments that is being improved upon today was made by Claude in the form of a vapor injector. This idea gave rise to greater efficiencies in the system, as is being used in and improved upon in today's OTEC systems. In 1979, the Natural Energy Laboratory as well as cooperating private-sector partners created the first mini OTEC system to produce a positive net output of power. This system was stationed around 2.4km off the coast of Hawaii. In 1984 another big breakthrough was made in OTEC in the form of a vertical-spout evaporator which converted warm sea water to a low pressure steam show below in Figure 3., This

vertical-spout evaporator helped reach efficiencies as high as 97% which is extremely good in energy conversion ratios.

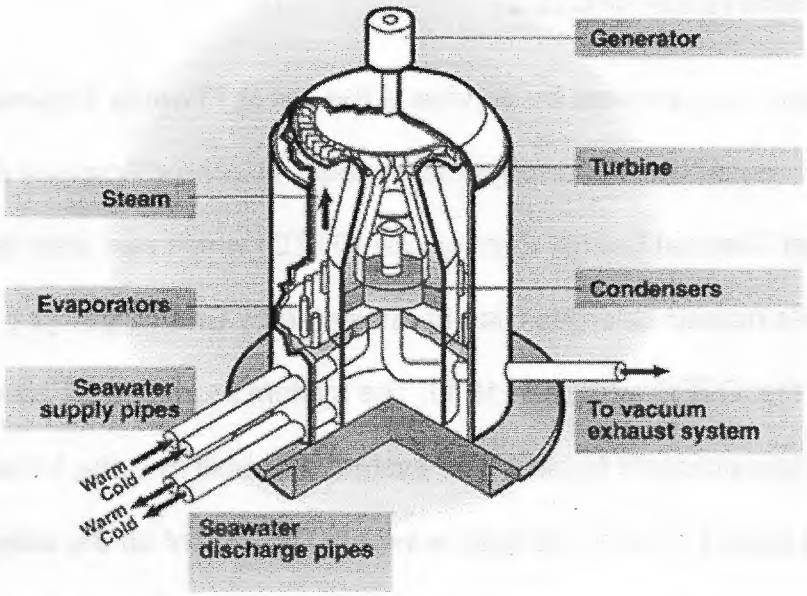

Figure.3 Diagram of a vertical-spout evaporator used in OTEC systems.

Today OTEC systems are being implemented around the globe to help sustain the ever growing needs of electricity, these concepts and innovations need credit where credit is due and that is the two gentlemen Jacques Arsene d'Arsonval, and Dr. Georges Claude how pioneered the concept and engineering for the OTEC systems and concepts.

IV. Practicality of OTEC systems

So far the OTEC systems discussed were generally low in power output, more of prototypes. However there are plans of increasing the scale greatly up to 10Mw-100Mw

OTEC plants as mentioned by OceanEnergy.com [7.], Huge OTEC plants are being planned off the shores of Hawaii and China. However there is a big devil in the detail of successful OTEC plants, which is the cost of install such technology. A commercial size megawatt OTEC plant can cost from 80 to 100 million dollars to build, which in theory would be very nice if it was built and ran efficiently, a system like this could supply large amounts of electricity to support the grid. However there is another major risk in building large scale OTEC systems. Once the system is build it is very much at the mercy of the environment around it which can be unstable to say the least. Storms, waves, and hurricanes can potentially destroy an 80-100 million dollar investment in the blink of an eye. This fact can make investors very skeptical in forking over such large amounts of money for a high-risk system when there are many other safe investments as far as energy conversion goes such as solar or wind power. None the less these systems can be extremely efficient in producing clean energy with efficiencies as high as 97% with proper vertical-spout evaporators and provide power in the megawatt class if implemented.

V. Conclusion/Discussion

OTEC systems are very clean sources of power using the energy from the sun that is being stored in the ocean's water to produce electricity up to even the megawatt size range for commercial applications of the OTEC systems. Not only the electricity produced very clean, it is also extremely high in efficiency up to 97% when using a vertical-spout evaporator in the system. These extremely good facts of very clean and efficient energy produced from the OTEC systems is coupled by a very expensive cost

of instillation ranging up in the 80-100 million dollar range for a megawatt class system. Also there is a very real high risk situation of the OTEC systems being destroyed by unstable weather in the ocean areas where these systems have to be built. The OTEC systems are manly used around the equator meaning that there is high likelihood of hurricanes and violent storms passing through the areas where these systems are to be built which can completely destroy the very expensive OTEC power plant. The high price and high risk of destruction can make it tough to get investors for the projects, however if successfully implemented these OTEC systems can be a great addition to the methods of clean energy production around the world and even in the megawatt size class which is very impressive electricity output especially at such high efficiencies.

References:

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