

# **OTEC Power Generation Saves Mankind**

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## Introduction

Foodstuffs, water, energy and comfortable living environment are indispensable elements for human beings to sustain modest daily life. In pursuit of better and peaceful life we have been struggling to think of improved means on many fronts and a lot of wonderful inventions have been made. Science and technology have thus been progressed. So is our civilization too.

Today at the beginning of the 21<sup>st</sup> century, however, we are confronting to new problems. They are global warming of the earth, energy crises, population problem, foodstuffs problem and water problem. People call them the 5 major problems in the 21<sup>st</sup> century.

The major cause for global warming is blamed at burning of fossil fuels such as oil, coal and gas in the developed countries since 1850s. Utilization of fossil fuels has spewed huge volume of  $CO_2$  gas into the air. And the overall  $CO_2$  density on the earth has been increasing ever since.

Rising of the sea surface level and irregular climate changes are immediate issues brought on by global warming of the earth. Republic of Palau, Republic of Nauru and Fiji are, among other South Pacific island nations, most severely hit by this dreadful phenomenon. It is our grave concern of today that some of them are already loosing the precious coastlines to the seawater due to the rising of the sea level. Seawater erosion into living houses, mixing of seawater into fresh drinking water, invasion of seawater into farm land are taking place commonly in these countries. And unexpected heavy drought occurs occasionally.

It is well known to us that these man-made misfortunes and irregularities are happening not only in the regions I just mentioned but also in many other parts of the world. But I say that we, the earth fellow, must put the first priority to challenge the problems the South Pacific island nations are facing to. In order to help preserve the beautiful countries in the region and for happiness of wonderful people there we must get together and do utmost efforts to realize commercial OTEC power generation plants.

Among other issues to tackle the global warming problems I have been urging to build OTEC power generation plants in the South Pacific island nations. I am very pleased to address at this Forum the following subjects;

- 1) Temperature distribution of seawater and principle of OTEC technology
- 2) ,High potentials of seawater in relation to OTEC technology,
- 3) History of development of OTEC technology,
- 4) Impact of OTEC power plants,
- 5) The Indian 1000 kW OTEC power plant and India's future trend,
- 6) OTEC technology and multifunctional systems and
- 7) Floor plan to build an OTEC power plant in the South Pacific island countries.

# 2. Temperature distribution and principle of OTEC technology 2 – (A) Temperature distribution of seawater:

Fig. 1, which depicts seawater distribution near Palau, Fiji, Nauru and the nearby region, provides us with the following information.



Fig.1-1 Seawater Temperature in the countries

participating in Pre-World Water Forum in Palau





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participating in Pre-World Water Forum in Palau



From Report on OTEC Site in Palau

Fig.1-4 Seawater temperature in Palau

- Surface seawater (at less than 50m from sea level) is warm at 25 ~ 32. We call seawater with warm temperature "Warm Sea Water".
- (2) Seawater temperature in the depth of 1000m or more is always cold at about 4~5.
  Seawater in the depth of 300 m or more is called "Depth Sea Water". Sea- water in the Depth sea water is referred to "Cold Sea Water".
- (3) We know from the above that there is the temperature difference between warm and cold seawaters is about  $21 \sim 27$ .

## 2 – (B) Principles of OTEC technology

Power generation by OTEC technology is to utilize the temperature difference between warm and cold seawaters. There are 4 different "Cycles" known for this technology, they are

- ① Rankine Cycle
- ② Kalina Cycle
- ③ Uehara Cycle and
- ④ Open Cycle.

Rankine Cycle will be the ideal model for non-professional people to get to know of the basics of OTEC technology, although Uehara Cycle f my own invention can attain the most effective cost performance as compared to the others.

Fig. 2 explains the basic principle of OTEC technology.

As shown, there are 6 major component machines and equipment in an OTEC power plant. They are Evaporator, Turbine, Condenser, Working fluid pump, Warm seawater pump and Cold seawater pump. These are interconnected with each other by pipings.

Evaporator has a lot of thin metal plates installed in it. We fill it with a substance, which evaporates at a fairly low temperature at  $20 \sim 30$ . This substance is referred to Working Fluid. Ammonia NH3 is regarded the most suitable one at the moment. Surface seawater of  $20 \sim 30$  temperature taken up by Warm Seawater Pump will be directed to flow through those thin plates in Evaporator. Then, liquefied ammonia sitting in Evaporator gets heated by warm surface seawater and becomes steamed ammonia.

Ammonia-steam goes into Turbine passing through Evaporator pipes, by which Turbine starts rotating.

Generator coupled to rotating Turbine starts running to generate power.

In the meantime, ammonia-steam which has lost its temperature after doing its business in Turbine is to be drawn into Condenser, which has a similar construction to Evaporator with



Fig. 2 Closed Cycle

# 2 – (C) Now, about Uehara Cycle:

It is theoretically proven that even Rankine Cycle OTEC technology combined with Uehara system can generate power more economically than other power systems like thermal, solar energy and wind power. But I would strongly recommend to go with Uehara Cycle for enhanced economics of power generation.

Rankine Cycle is designed to use pure ammonia as Working Fluid, while it is a Mixed Mediums of ammonia and water that is used in Uehara Cycle. Heat efficiency attainable by Uehara Cycle is higher by 50 ~ 70% than that of Rankine Cycle. This means that, for the same output capacity of OTEC power plant, our method consumes far less, say 70 ~ 100% less, volume of surface and cold seawater as compared to the needs by Rankine Cycle. This influences greatly on economy of OTEC power plant.

The principle of Uehara Cycle is given in Fig. 3.



- Mixed Medium of ammonia and water will be sent first by two working fluid pumps into Re-generator and then further into Evaporator.
- ② Warm seawater pump takes in surface seawater into Evaporator, where liquid portion of ammonia-water gets evaporated and it turns into mixed vapor of ammonia-water. As this mixed vapor is a saturated vapor, it gets separated in Separator into ammonia water and vapor containing ammonia-water. Mixed vapor of ammonia-water goes in Turbine #1 and drives this Turbine to rotate. Part of mixed vapor, which comes out of Turbine #1, will be extracted into Heater and the rest of them is directed into Turbine #2 to drive Generator.
- ③ In the meantime, ammonia water separated in Separator passes through Re-generator and then into Absorber via pressure reducing valve. In Absorber ammonia water absorbs mixed vapor from Turbine #2. Some of mixed vapor which Absorber can't possibly take will be cooled down and condensed by cold seawater to turn into liquid. Working fluid pump takes it into Heater and it is then forwarded again back to Evaporator.
- ④ Repetition of this operation ensures power generation by seawater alone on permanent basis.

# 3. History of development of OTEC technology

The principle of OTEC technology is not of any new invention, but rather very old.

It goes back to 1881, when a French scientist Mr. J.D'Arsonval had announced for the first time in the world history his principle theory of OTEC power generation, The year 1881 enjoyed another epoch making history. A proto-type model of thermal power plant was introduced for the first time in human history. As far as OTEC technology goes, another French scientist Mr. G. Claude had most actively challenged in trying to enhance the technology for commercial use. He had repeated a lot of experiments and tests but no positive results had been obtained. Then, the research study of OTEC technology had gradually come to stop until 1973, largely because of flooding supply of fossil fuel into the market.

But this situation had suddenly and drastically changed in 1973 when soaring price shock of oil was announced. This incident had brought economic confusion to many parts of the world but Japan was hit particularly severely. We refer that year to the year of "oil shock". After the oil shock in 1973, researchers in Japan as well as in the USA started to look into OTEC technology seriously. The USA government at that time had endorsed OTEC study a national project and allotted at one time a budget of US\$10 billion. They had built two pilot plants during that stage of research programs. But today they have scaled down their study programs.

Japanese government had also launched right after the oil shock year a vigorous project titled "Sunshine Project". A number of power generation companies and other institutes had participated in the research studies and several pilot plants had been put up since then. But after some years of hectic studies all of them had retired from the scene, saying they had failed to get persuasive data to go further.

On the contrary to the above, we at Saga University have been conducting strong efforts since the year 1973 without intermission to bring forth OTEC technology applicable for commercial use. We have built so far 11 pilot plants, which are quite essentials for our studies and analysis of all possible aspects. We firmly believe that we have now reached a stage to be able to put our OTEC technology into commercial application.

In the meantime, we have obtained a number of international patents. National Institute of Ocean Technology, Chennai, India, who is the authoritative research center of marine related projects in India, had built a floating type of 1000kw OTEC pilot plant under our technical assistance and cooperation. And as far as I know, planning of OTEC power plant are under way in Republic of

Palau, Cook Islands, Taiwan, the Philippines and others.

# 4. Impact of OTEC power plants

Currently we are all confronting to serious problems such as ;

- (1) environmental problems,
- (2) energy problem,
- (3) population problem,
- (4) foodstuff problem and
- (5) water problem.

These 5 problems are all inter-related each other.

Primary suspect of environmental problems is utilization of fossil fuels such as coal, oil and gas. Burning of fossil fuels spews  $CO_2$  and NOX into the air.  $CO_2$  has triggered the global warming. The worsening global warming causes melting down of glaciers in the Arctic and in turn brings about rising of seawater level. Due to this, flat land area is getting smaller globally, while desert in the USA and China keeps expanding its territory much larger.

Rainfall sprays massive NOX contained in acid rain and damages forests. Forests with damaged tress loose its water holding capacity endorsed to forests. Rained water flows down immediately into rivers and to sea. Water availability on land thus gets smaller and shortages of water and foodstuffs are looming as the serious problems in the 21<sup>st</sup> century. To loose valuable trees and forests means lesser availability of phytoplankton in the sea, which definitely causes reduction of marine life such as fish, shells and algae and seaweed. In other words, food chain on the scale of the plant earth is being threatened now by the global warming.

As such, it is the most important and urgent tasks to solve this environmental problems, which bend over us as a matter of life-or-death in the 21<sup>st</sup> century. Any attempt to solve these critical problems, however, must generate public interest by bringing continued growth of economy. In this sense, I am very much convinced that OTEC power plant has the greatest possibility to attain improvement to the environ mental conditions and also continued economic growth simultaneously.

Now, let us review once again.

#### (1) OTEC technology and environmental problems

Environmental problem is of course directly connected to the other 4 issues and it sits in the center of these issues.

- ① OTEC power plant exhausts far less volume CO<sub>2</sub> as compared to thermal power plant and solar battery method. We have made thorough calculations of exhausted CO<sub>2</sub>. Please refer to table 2 for this information. As is given there, OTEC is categorized the power generation method to exhaust the least minimum CO<sub>2</sub>. Actually it is only 2.4% of thermal power plant operated by LNG. From this, if 10% of the world energy sources are switched to OTEC technology, we can reduce CO<sub>2</sub> emission drastically globally.
- ② Deep cold seawater pumped up into OTEC power plant is rich in nutrition. This nutritious seawater can be sprayed after passing through OTEC system over to surface seawater. This will reduce the density of inorganic carbon substance molten in surface seawater. According to the latest reports, 30µmol CO<sub>2</sub> per 1kg seawater can be drawn into sea from the atmosphere.
- ③ CO<sub>2</sub> exhausted on land can be reduced by drawing it into depth sea water. This means there is another possibility of economic gain by building an OTEC power plant, whereby you could trade the CO<sub>2</sub> emission right with advanced countries who are under the international obligation to reduce CO<sub>2</sub> emission,

#### (2) OTEC technology and energy saving:

- ① There are almost 100 countries in the world who could offer ideal place for OTEC power plant. Within the exclusive economic zone of Japan alone there is a possibility to generate 10<sup>14</sup> kWh OTEC power plant, which is equivalent to 8.6billion tons of oil. If even 1% of this huge energy consumption can be switched to source of OTEC, then we are talking about very bright future surrounding the environmental problems.
- ② The 21<sup>st</sup> century is sometimes referred to the age of hydrogen. OTEC technology provides easy access to make hydrogen from desalinated fresh water using its own electricity. Hydrogen is deemed to be a "future fuel" for internal combustion engines, since it exhausts no toxic substances at all. Most ideal is, however, to produce fuel battery utilizing this hydrogen. Fuel battery shall become definitely a major energy source in the 21<sup>st</sup> century.
- ③ It is known that uranium and lithium are contained richly in deep cold seawater. The technology to extract these substances from seawater are making big progresses. The South Pacific island nations have a great potential to become eligible exporters of such energy,.

## (3) OTEC technology and water problem

Instead of relying on natural rainfall, which is quite often contaminated with toxic substances like NOX, people can now resort to OTEC technology for supply of fresh drinking water. For your guidance, a 100 MW OTEC power plant with Uehara Cycle version with 26 surface seawater and 6 deep cold seawater deals with a flow of 160 tons per second warm seawater and 176 tons cold seawater flow. Abundant volume of fresh water and also mineral water is right there.

# 5. The Indian 1000 kW OTEC plant and India's future trend

As was briefly touched in the Chapter 3 above, Indian government has completed the construction of a floating type OTEC power plant of 1000kw gross output capacity and is now holding the barge at a pier before the hurricane season there passes away. We Saga University had played a good role in this Indian project by rendering our expertise.

Fig. 4 is the picture of this Indian OTEC power plant installed on a barge, which is scheduled to be moored at about 35km off Chennai coast toward Sri Ranka.



Fig.4 The Indian 1000 kW OTEC plant

# 6. OTEC in Palau and its multiple-purpose use plan

In order to combat global warming problems and also to spur their economic development, the Government of Republic of Palau had been keeping an eye on possible introduction of OTEC power plant in their county. Their ultimate goal is said, as far as we are informed, to switch from fossil fuels to seawater for all needs of electricity. To obtain fresh water from seawater is an easy task for OTEC power plant by applying our patented desalination technology.

We are very pleased to announce hereby that we Saga University has, jointly with Xenesys Inc., a Japanese private sector company, signed an agreement with Palauan government on technical collaboration on OTEC technology. In accordance with the said agreement, we have studied basics on temperature distribution of seawater etc. along the coast of Palauan islands and established 7 possible sites for OTEC power plant. Our study indicates that a total of 30MW OTEC power plant at two different sites would be large enough for the time being to cover the total demand of electricity.

I am sincerely wishing that the above plan would be put into practice at the earliest possible date.



Fig.5 Grand Master Plan of OTEC Power Station in Palau

# 7.Conclusion

I may say that OTEC technology is gaining the worldwide attention as one of the most reliable means to give a solution to the 5 major problems in the 21<sup>st</sup> century I mentioned in the beginning. I firmly believe OTEC technology is a good news particularly to countries who are suffering from lack of fresh water and energy. We are ready and happy at any time to exchange views on what we can possibly offer to the needed.