“Water” from the Ocean with OTEC

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“Century of Water” has come. We, human being, are facing some problems caused by human activities, and ‘water’ is one of the most important subject for us in coming era. In the subject, by the way, it should be noted that ‘water’ means not salt water but fresh water.

Everybody knows the earth is called “Water planet” because the existence of water brings particularity of the planet. About 70% of earth’s surface is covered by sea, and 98.5% of water (H_2O) on this planet exists contained in seawater. When sustainable measures to desalinate seawater harmonized with environment will be developed, we will mostly get the solution to the issue of ‘water’.

The Ocean Thermal Energy Conversion (OTEC) is the most expected technology utilizing solar originated natural energy. We will propose to materialize this unique technology combined with seawater desalination employing technique and experience that were developed and accumulated in shipbuilding industry.

Since ocean thermal energy is clean and renewable, and its potential is very huge, a bright future is expected to get infinite “water” harmoniously from the ocean with the OTEC.

Introduction

Energy, water and food are some of the essential requirements for the continuation and evolution of mankind. Presently almost all the energy needs fossil fuels or nuclear power.

The world population is 6.1 billion in 2000, and is still growing explosively. At the same time, energy consumption is also rapidly increasing, as shown in Fig.1. In future economic growth and environmental problems, it is obvious that in the 21st century we should not rely on the current mainstream energy sources such as oil, coal, and uranium for the world energy supply. Thus, we will face an urgent and important problem of developing alternative energy source to replace fossil and nuclear fuel.

For the alternative energy sources, we can think of wind, solar and geothermal power. However, ocean energy should also become an important potential energy source to be developed.

Among the various forms of ocean energy, ocean thermal energy is plentiful and very stable.

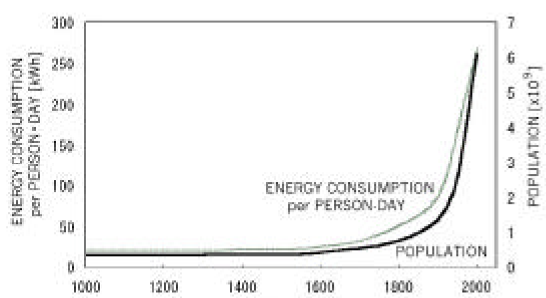

Fig.1. Population and Energy Consumption/Person-Day.

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During the last decade, the technology of OTEC has made a significant progress. It should be emphasized that OTEC technology is applicable to many industrial fields for recovery and saving of energy in lower temperature range and small thermal head.
And it is remarkable that OTEC is suitable to combine with seawater desalination. However, OTEC is beneficial not only to energy and water generation but also to various industrial activities as key technology.

Multiple Industrial Complex with OTEC

In Japan, the research and development for 'Multiple OTEC System' using the potential of Deep Ocean Water (DOW) have been in progress. The image of 'Multi-OTEC' is shown in Fig.2 and typical considerable systems associated with OTEC are described as follows.

1) Desalination

The Saga University has developed a spray-flush type desalination system. With this system around 1% of raw seawater quantity is to be distilled to get fresh water. To combine the OTEC and this desalination system, the capability of desalination is quite huge; i.e. the obtainable distilled water capacity is approx. 10,000 m^3/day with 1MW OTEC, approx. 1,000,000 m^3/day with 100MW OTEC.
It is remarkable that the obtained fresh water can be utilized as resource of hydrogen as described later.
Fig.3 shows the demonstration plant of spray-flush desalination made by Saga University.

2) Mineral Water Production

DOW is rich in minerals. It is possible to produce 'Mineral water' as by-product of the OTEC. Providing with ion-exchanger and mineralizer, a part of desalinated water comes more valuable industrial product. Mineral water is one of most anticipated by-product of OTEC in order to promote a sustainable local industry, particularly for island countries.

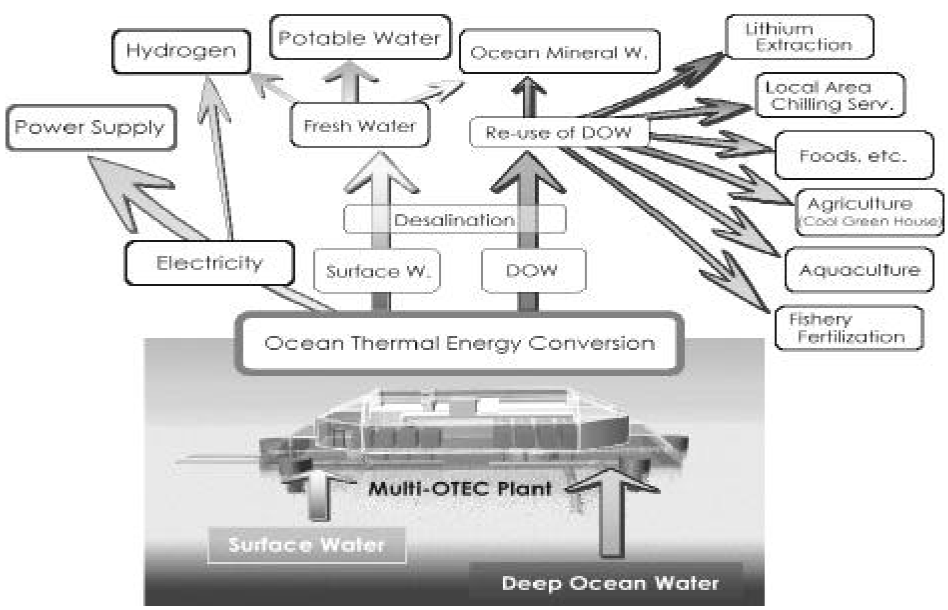

Fig.2. Image of Multiple-OTEC Station.

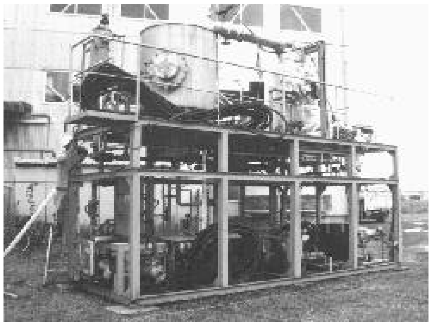

Fig.3. Desalination Plant.

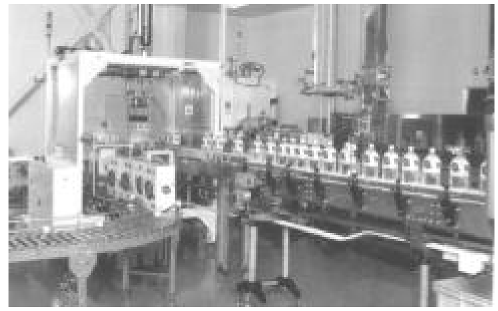

Fig.4. Mineral Water Production.

3) Lithium Extraction

Lithium is the one of important industrial metal in manufacturing of batteries. Extracting chloride-lithium dissolved in seawater is one of considerable method of industrial lithium production. For such lithium extraction from seawater, purity of DOW provides longer cleaning interval of seawater contact surface material polluted with impurity of seawater, because DOW is much purer than seawater at the surface layer. This is an advantage of feasibility from the economical point of view.

4) Air Conditioning

Tropical sea conditions are best for OTEC. In the tropical area there is a need for air conditioning for offices, hotels, etc. For that purpose OTEC is useful. The temperature of depth cold water after utilization for OTEC is still low; e.g. the temperature is to be around 10℃. It is cold enough to use as a chilling heat source of air conditioning. Such air conditioning systems require much less energy than that is needed by ordinary electrical refrigeration method. It means that OTEC requires less electricity than conventional means..

5) Aquaculture

The characteristics of DOW are cold, pure and nutrient rich. These characteristics can be used effectively in aquaculture by getting rapid growth and less disease.

In recent years, another approach has made for fishery fertilization by using nutrient DOW in Japan. Relational inventors are developing an architectural sea area fertilizer unit incorporating OTEC as an energy source of density current generator system.

6) Food, Cosmetics, Medical Science, etc.

Due to surpassing characteristics DOW draws attention in various fields of industry and science. In Japan DOW is utilized for food processing of 'Sake', 'Tofu', etc, and some cosmetics made of DOW are favored by the public.

Effects of DOW attract medical scientist's attention. It has been said that DOW is efficacious against atopic allergy dermatitis. Thalassotharapie, which is a kind of medical treatment for relaxation, is also one of DOW utilization.

OTEC can be used in various applications. .

7) Hydrogen Production

To look a little further future, it should be considered "Offshore Hydrogen Production Platform" with OTEC. This concept provides completely clean hydrogen production by using only natural renewable energy. Considering the tendencies of fuel-cell and micro-gas-turbine, the trend of shifting the basic industrial fuel from fossil to hydrogen would possibly come sooner than expected. As a consequence,, it may be too far in the future that hundreds MW class OTEC for hydrogen generating station will become fundamental energy supplier.

Economical Feasibility of OTEC

It goes without saying that economics is one of the key elements for verification of OTEC power plant. Advanced studies made thus far on thermal cycle and heat exchangers have brought promising results of far improved efficiency of OTEC system as a whole. Although the efficiency of the system itself varies depending upon temperature conditions, the latest heat cycle so called "Uehara cycle" using ammonia/water mixture fluid as working medium can attain a 30~50% higher efficiency as compared to Rankine cycle. Thanks to the highly effective plate heat exchanges newly developed by Saga University, the power consumption of pumps for cold and warm seawater can be lowered to 30~40% of the conventional case. Considering all new achievements, we can easily predict the latest OTEC technology will produce twice as much net power from the same heat source as the conventional OTEC.

In addition to such great improvement of the capability, the reduction of cold depth water quantity with advanced condenser provides smaller sized configuration of piping for DOW riser piping, and thus the economical performance is much improved.

Various accounting models have been applied to determine the cost for the OTEC system. As example of trial calculation, the cost of electricity generated by the OTEC is estimated by NIOT (India), who is now proceeding with an experimental OTEC plant, as shown in Table 1.

According to several accounting models, it has been determined that for a large plant of 50~100MW, the unit cost would be competitive with a coal-fired power station, while for a small plant of 1~5MW the unit cost would be about the same or less than that of a diesel power station.

However OTEC is valuable not only in power generating, but in additional activities. The expected quantities of main by-products of OTEC are shown in Table 2. In case of applying 20m^3/day mineral water production facility with OTEC, for example, total amount of mineral water output is estimated at approx. 600 million JP¥ per year based on unit price of 100 JP¥ per litter and 85% operation rate.

Table 1. Estimation of Unit Cost of Electricity from OTEC Power in India (1999)

Power Output Gross (MW)	1	25	50	100
Power Output Net (MW)	0.617	15.39	30.88	64.23
Heat exchanger cost (Mill.US$)	1.70	44.40	88.22	152.58
Cost of cold w. pipe (Mill.US$)	0.69	1.74	2.67	4.65
Cost of barge (Mill.US$)	0.69	2.33	4.65	9.30
Mooring cost (Mill.US$)	2.09	3.49	4.65	5.81
Turbine + Inst. Cost (Mill.US$)	1.16	17.44	34.48	69.76
Total cost (Mill.US$)	6.42	69.42	134.67	242.10
Cost of electricity (US$/kWh)	0.189	0.082	0.079	0.068

Table 2. Expected Output of By-products.

Gross Power Output (MW)	1	10
Net Power Output (MW)	0.7	7.5
Net Electricity (MWh/year)	4,900	52,500
Up-welled DOW (t/h)	4,700	43,300
Fresh Water (t/h) (*1)	1,100	10,000
Hydrogen (Nm^3/h) (*1)	2,000	22,000
Chloride Lithium (kg/day)	30	260
Mineral Water (bottle/day)(*2)	16,000	150,000

Calculated by Xenesys Inc.

Remarks : *1) All generated electricity to be used for hydrogen production as basis.
*2) 500ml PET bottle equivalent

New Aspects of OTEC Development

One of the major causes for global warming is attributable to heavy dependence upon fossil fuels for electricity. Nevertheless, a number of countries have been relying on diesel generators for their electricity, since they have had no alternative to take up. But now, the story is getting a different turn. Some of island countries in the south Pacific region, whose life is being threatened by rising sea level and exposed to the risk of suffering for lack of surface fresh water, have started to look into the OTEC more seriously than ever. For instance, a technical collaboration agreement was signed in April 2001 by and among the Republic of Palau, Saga University and Xenesys Inc. The President of the Republic of Palau expressed at a news conference his determination to replace their diesel power stations with OTEC power plants combined with desalination system at an earliest possible date.

Positive movement is recognized in Japan, too. Japan is well known as world-leading country in ocean development and shipbuilding industry. In order to realize the OTEC, technologies developed and accumulated in shipbuilding industry are very helpful. Hitachi Zosen Corporation (Hitz), one of historic shipbuilder in Japan and keen on environmental solution fields, has started to develop conceptual design for several OTEC applications with the latest technologies in alliance with Saga University and Xenesys Inc.

For the sake of commercialization of OTEC, research and development programs should be followed up by strategic demonstration and dissemination activities.

Fig.5 shows an illustration of 3~10MW class prototype OTEC barge for demonstration and dissemination. The plant should be built somewhere in an island country in the Pacific Ocean like Palau. This kind of plant is very beneficial for the island nations, since it is to provide not only clean energy and freshwater but also local industries by multiple usage of DOW resource.

Fig.5. Image of Barge Mounted OTEC.

Fig.6 shows an illustration of larger 50~100MW class commercial scale offshore OTEC plant built as a basic energy source. With this kind of offshore plant, the designing of standardized OTEC power station will be worked out for verifying the economic competitiveness in this capacity range.

Fig.6. Image of Large Offshore OTEC.

Needless to say, assessment of environmental conditions by introducing an OTEC power plant is also a part of the majors concerns in executing each of the above steps.

According to the preliminary prediction, in regard to this enterprise, it would be expected that total 1,000MW of Multi-OTEC station would be built in Japan annually in near future. At that time, it means that a new industry having 1.5 trillion JP¥ annual production amount and will employ 10,000 new people.

Forecasting Future

A new era in the technology of OTEC has come. Although the density of the energy is comparatively poor, the ocean provides us a huge amount of thermal energy. Today, the new

OTEC technology makes it possible to extract the energy practically from the ocean. The area suitable for OTEC ranges around the world from the tropics to semi-tropics. An advantage of the OTEC technology should be emphasized on not only its tremendous potential for power generation but also the convenient feature that can disperse the power plant with proper cost of the electricity generation. The cost will become competitive with that of the conventional fossil fuel burning power plants as well as nuclear in the near future.

The desalination technology as by-product of the OTEC can produce a large amount of fresh water from seawater for which the island nations and the other desert countries urgently needed.

Besides, the DOW exhausted from the OTEC plant would contribute to world food security with fishery fertilization.

The OTEC may have a potential to become a powerful solution to three greatest global issues such as 'Energy', 'Water' and 'Food' without harmful influence on irreplaceable earth environment.

In conclusion, the new OTEC and the related technologies would offer the best promise to bring prosperity beyond measures in the 21st century.

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