OCEAN THERMAL ENERGY CONVERSION AND THE UTILIZATION OF DEEP OCEAN WATER

Michel A. P. Gauthier
Acting Chairman of the International Ocean Thermal Energy Conversion (OTEC) and Deep Ocean Water Association (DOWA), Taiwan

Keywords : Ocean, Thermal energy, deep ocean, DOWA

Contents

Summary

Ocean thermal energy conversion (OTEC) is the process in which the solar thermal energy accumulated in the water of the surface layer of the tropical ocean is used to produce useful energy. Warm surface water and cold water pumped from the ocean depth are, respectively, the hot and cold sources of this thermodynamic process. The OTEC principle was described more than a century ago, and several experiments have since demonstrated its feasibility. OTEC is a recruit to the panel of clean and renewable energy resources that are needed to supply the future world demand in primary energy. Results of research on OTEC have revealed that the characteristics of deep ocean water make it an interesting resource not only for energy production but also for producing freshwater, seafood, and other valuable products. This opens new opportunities for OTEC commercial developments and other deep ocean water applications, but implies careful assessment of their environmental issues.

1. Introduction

In the depths of the ocean there exists a huge reservoir of cold water formed by the geography of submerged relief and the natural circulation of water masses. In the tropical region of our planet where this deep ocean water (DOW) is available, just a few hundred meters below the surface, it offers numerous useful applications, especially for production or saving of energy, and the production of freshwater and food. Deep ocean water should be considered a natural resource, still untapped, that could contribute significantly to humanity's sustainable development.

2. Deep Ocean Water (DOW)

The ocean is both a large receiver and a huge reservoir of solar energy. A large share of this energy is stored in the form of heat in the layer of surface water of the oceans and seas in the tropical region. Winds, changes of water density, and rotation of our planet induce forces that generate a general transport of this warm surface ocean water from low to high latitudes. In polar region the warm water transported from tropical regions cools and sinks in the deep oceanic basins. After a long trip in the ocean depths, DOW is slowly forced back to the surface in upwelling regions.

This natural water circulation, which exports heat from tropical regions to the Poles, contributes, as does the circulation of air in the atmosphere, to the thermal regulation of the biosphere. Average vertical profiles of water temperature in tropical regions are shown in Table 1. The value of 4°C at 1000 m depth is typical for DOW temperature profiles.

Depth (m)	**Temperature (°C)**
20	27.2
100	25.3
200	21.4
300	16.1
400	11.1
500	8.0
600	6.5
800	4.9
1000	3.9
1200	3.3

Table 1: Typical average water temperature profile in tropical oceans

During its lengthy voyage in the depths, far from the reach of solar radiation and the influence of photosynthesis, the DOW is enriched with nutrients formed by the transformation into minerals of organic debris falling from upper layers. An example of the vertical distribution of nutrient contents is shown in Table 2.

	Depth		
Parameters	**Surface**	**700 m**	**1000 m**
Density σ_t = 1000(d-1) at atmospheric pressure	23	27.2	27.4
Nitrate (mmol m^{-3})	0.1–1	12–18	25
Phosphate (mmol m^{-3})	0.4–0.5	0.7–2.5	3

Table 2: Typical nutrient contents profile

This description of the ocean circulation that considers only two layers, that is, the surface and the DOW, is oversimplified. Oceanographers consider usually a four-layer transport pattern better to describe thermohaline circulation. A typical water mass stratification in a tropical ocean comprises abyssal water (from ocean floor to 4000 m), deep water (4000 to 1500 m), intermediate water (1500 to 800 m), and upper layer (800 m to surface). Oceanographers identify and track water masses by measuring specific combinations of basic parameters like temperature, salinity, density, oxygen content, and concentration of nutrients and chemicals (greenhouse gases and chemicals like freon, tritium, carbon-14, etc.). Processes described in this article use cold deep ocean water at temperatures ranging from 8–10 °C (for DOWA, e.g. in marine culture) to 6–4 °C (for OTEC).

-
-
-

Bibliography

Avery W. H. and Wu C. (1994). *Renewable Energy from the Ocean; A Guide to OTEC*. Oxford, UK: Oxford University Press. [The most recent book on OTEC history, describing its technical and economic features.]

Claude G. (1935). *Compte rendu de l'Académie des Sciences*. Séance du 18 mars 1935, Tome 200. [It gives Claude's own narration of the *La Tunisie* enterprise and failure.]

Claude G. (1957). *Ma vie et mes inventions*. Librairie Plon. [Includes Claude's narration of his first OTEC experiments.]

Daniel T. H. (1999). The Natural Energy Laboratory of Hawaii Authority: A state sponsored aquaculture and research park. *IOA Newsletter* **1**(1-2). [General presentation of the NELHA facilities and activities.]

Leraand T. K. and Van Ryzin J. C. (1996). Air conditioning with deep sewater: a cost effective alternative for West Beach, Ohahu, Hawaii. *IOA Newsletter* **7**(1), 2-9. [Technical description and cost analysis of DOWA air-conditioning systems for hotels and large buildings.]

Takahashi M. M. (2000). *Deep Ocean Water as our Next Natural Resource*. Trans. K. Kitazawa and P. Snowden. Tokyo: Terra Scientific Publishing Company.

Toyota T. (1999). Present state and prospect of deep seawater application technology in Japan. *Proceedings of the International OTEC/DOWA Conference*, *Imari*, *Japan*, *1999*, p. 23. International OTEC/DOWA Assocoation (IOA) and Saga University. [Most recent overview of DOWA development in Japan.]

Vega L. A. (1994). Pacific International Center for High Technology Research (PICHTR), USA. Economics of ocean thermal energy conversion. IOA Conference, Brighton, UK. pp. 55-59. [Review of production costs for OTEC electricity and co-products.]

Biographical Sketch

Michel Gauthier is Acting Chairman of the International OTEC/DOWA Association. He was born in France in 1935. He holds an Engineer degree from l'Ecole Nationale Supérieure des Arts et Métiers (ENSAM, Paris, 1957), a Masters degree in Mechanical Engineering from the Illinois Institute of Technology (IIT, Chicago, USA, 1958), and a Nuclear Engineering degree from l'Institut National des Sciences et des Techniques Nucléaires (INSTN, Saclay, 1963). He served as an Officer in the French Navy (1958–1960). In 1961 he joint EURATOM (European Community for Atomic Energy) in Brussels, Belgium. He came to the CNES (Centre National d'Etudes Spatiales) in 1963 and worked one year at TWR in Redondo Beach, California, before joining the CNEXO (Centre National pour l'Exploitation des Océans) in 1970. (CNEXO became IFREMER—Institut Français de Recherche pour l'Exploitation de la Mer—in 1984.) In CNEXO/IFREMER he was the head of the Technology and Industrial Department (1970–1975), of the French Deep Sea Mining Project (1976–1979) and of the Tahiti OTEC project

(1982–1986). He served as a consultant for the European Community Marine Sciences and Technology Programme (Brussels, 1987–1990) before becoming IFREMER's Delegate for the Pacific Region (Nouméa, New Caledonia, 1990–1994). In 1994 he joined the EuroGOOS Secretariat hosted at the Southampton Oceanography Centre, UK. He retired from IFREMER in 1998. He was awarded Officer of the French Ordre National du Mérite in 1986.