NATURAL TEMPERATURE DIFFERENCES AS AN ENERGY SOURCE

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Summary

Since the birth of the industrial society 150 years ago, the needs for energy began to increase dramatically. Fossil and then nuclear fuels are there to meet the short-term demand but intensive usage of those resources results in questions on the sustainability of the resource and on the irreversible environmental damage. In the long term our solely alternative to energy supply is to rely on solar or/and nuclear. Heat stored in water masses is one form of solar energy available for future development.

1. Introduction

The world ocean is a huge reservoir of solar thermal energy. It is widely distributed around the world and was envisioned more than one hundred years ago as a potential source of energy usable to serve man’s activities. This article is mainly concerned with the thermodynamics and the enabling technologies that permit the extraction of useful work from the thermal energy stored in the body of surface water in tropical ocean (Ocean Thermal Energy Conversion OTEC) and, to a lesser extend, in some large bodies of liquid water in sub-polar regions. Technical and economic issues are analysed, and opposed to anticipated environmental and social benefits that could results from OTEC intensive usage. Recent developments indicate OTEC has the potential to contribute significantly to respond to the world increasing demand for sustainable supply for energy in the near future.

2. Temperature Differences in the Ocean and Between Air and Water.

Earth climate depends essentially on the exchanges of energy between the Earth and the Cosmos with the Sun being the main source of incoming energy. In comparison with the energy received from the Sun the heat generated within the core of the Earth itself, and transmitted to the biosphere through the crust, is negligible.

For the average temperature of the Earth biosphere remains globally constant as it does, at least at the scale of human's lifetime, the Earth irradiates back to space the same amount of energy it received. The two energy fluxes – that incoming from the Sun and that irradiated back by the Earth - do not locally balance and the temperature equilibrium in the Earth biosphere is globally maintained thanks to a complex heat transfer from tropical towards polar regions. Atmospheric winds together with oceanic currents are the vectors of this energy transport of sensible and latent heat. The winds in the atmosphere move warm and humid air, and currents in the ocean moves the ocean warm surface water from the tropical zones towards the poles while cooler air and water masses move from the poles towards the equator. If there was not this large "horizontal" heat transfer, the tropical regions would be much warmer and the Polar Regions much colder than they are. At 40° North latitude, where the North-South fluxes are at their maximum, the total amount of sensible heat flux exported towards the poles by air in the atmosphere is estimated around $2.5x10^{15}$ W. At the same latitude oceanic sensible heat fluxes is estimated about $1x10^{15}$ W and to $2x10^{15}$ W for latent heat flux. These values for natural heat fluxes are to compare to $3x10^{12}$ W for the world electric power plants capacity.

Because of their tremendous importance for the navigators the surface currents and the general surface water motions in the ocean have been intensively observed and mapped for several centuries and are rather well known in comparison with the displacements of water masses bellow the surface that are much more difficult to measure. Surface currents are wind driven. A well-known example of heat transport by surface current from the tropical region towards the northern high latitude is the Gulf Steam that flows from the Gulf of Mexico to Europe. In the depths the density variations caused by the variations of temperature or salinity of water drives the currents. The flow of subsurface water is called the thermohaline circulation. (from ancient Greek words: therme that meant heat, and halos meaning salt).

In natural thermal exchanges between substances at different temperature heat flows from hot to cold. In the North Atlantic, cold Artic air removes heat from the Atlantic Ocean water, increasing its density and causing water to sink in the depths in a huge cataract at a rate of several million cubic meters of water per second. Similar down welling of dense cold water occurs in the Antarctic Ocean. The sinking deep water fills the deep oceanic basins and circulates around the world mixing with other sources of cold deep water at thousands meters depth before up welling in the Pacific and Indian Oceans, in a long process that lasts over hundreds to thousands of years. The general thermohaline circulation pattern has been mapped only recently by oceanographers thanks to the development of sophisticated measuring instruments and powerful modelling techniques. The global flow rate for deep water thermohaline ocean circulation is estimated over $50x10^6$ m^3s^{-1}.

It results from the ocean circulation a rather stable vertical temperature distribution of water in the low latitudes (equatorial and tropical zones) where a vertical temperature gradient greater than 20°C exists between the warm water at the surface and the cold water at few hundreds of meters depth. An other result of the atmospheric and oceanic circulations patterns is the existence of masses of liquid water, i.e. slightly over 0°C, in high latitudes, in the close vicinity of polar air at temperature several tens of degrees below water freezing point.

3. Extracting Work from the Ocean Heat Reservoir

Because of the energy conservation law, in natural thermal exchanges as those concerned with the heat transport from low to high latitudes, the heat lost by air and water flowing out of the tropical region has to equal that gained in the Polar Regions. But flux of thermal energy can also be transformed in mechanical work as man does for example in a steam engine. At the very beginning of the industrial era the burning of wood in a boiler was used to produce the water vapour that powered a piston-type machinery before being sent in the atmosphere to condense at ambient air temperature. This process addressed the feasibility to extract permanent mechanical work from a constant heat flow driven by the temperatures difference that exists between a heat reservoir or “hot source” and a “cold sink”.

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Biographical Sketch

M.Gauthier was born in France in 1935. He holds an Engineer degree from « l’Ecole Nationale Supérieure des Arts et Métiers » (ENSAM, Paris 1957), a Master 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 (1959-1960). In 1961 he joint the « EURATOM - European Community for Atomic Energy - in Brussels. He came to the «CNES » - Centre National d’Etudes Spatiales in 1963 and worked one year for TWR in Redondo Beach California before joining the CNEXO (Centre National pour l’Exploitation des Ocean) 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 head 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 the IFREMER Delegate for the Pacific Region (Nouméa, New-Caledonia, 1990-1994). In 1994 he joint the EuroGOOS Secretariat hosted at the Southamptom Oceanography Centre , UK. He retired from IFREMER in 1998.

He was awarded officer of the French «Ordre National du Mérite » in 1986. He is the acting Chairman of the IOA, International OTEC/DOWA Association, since its creation in 1990.