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講演論文

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NELHAにおける海洋温度差エネルギーの開発

Ocean Thermal Energy Development at NELHA (Natural Energy Laboratory of Hawaii Authority)

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In 1974, The State of Hawaii created the Natural Energy Laboratory (NELHA) to help the State become less dependent on imported fossil fuels, the main source of energy for Hawaii. The project at NELHA on the Kona coast of the Big Island of Hawaii was to research how electricity can be produced by the temperature difference of the warm surface seawater and cold seawater from the deep. That process is called OTEC or Ocean Thermal Energy Conversion (Claude, 1930).

While OTEC was developed in 1881 by a Frenchman named Jacques D'Arsonval it was not until 1979 at NELHA that for the first time in history, OTEC was proven a success with NET power output. This project was a closed cycle OTEC plant performed just off-shore from NELHA on a barge and did 15 kW of NET elec-

Fig. 1.　The Open Cycle OTEC plant at NELHA operated between 1992 and 1998.

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tricity production.

The success of this project led to a phase II project to build an Open Cycle OTEC (Fig. 1) at NELHA which operated from 1992 to 1998 (Vega, 2001).

In 1981, the State of Hawaii installed two pipelines to pump both warm surface water and cold, deep ocean water. Later in 1984, two more pipelines were installed with larger capacity. Then in 2001, to allow for a 1 MW OTEC plant to be built, the State of Hawaii installed two new pipelines of surface and deep seawater at a $25 million cost. These two new pipelines pump 21,000 gallons of seawater per minute using HDPE pipes (140 cm in diameter) where the deep water is being pulled up from 915 meters deep and is 5C in temperature (Toyama, 2010).

More recently, OTEC in Hawaii has enjoyed a resurgence of international interest. Governor Linda Lingle facilitated an agreement between the Taiwan Industrial Technology Research Institute and Lockheed Martin, a major OTEC developer, for a pilot OTEC plant to be operated in Hawaii. This agreement was signed on November 18, 2008 (Office of the Governor, State of Hawaii, website).

In the summer of 2010, a joint US/Japan/Hawaii/Okinawa energy task force identified OTEC as one of several energy projects which will be explored cooperatively. The task force was established as a result of an agreement between President Obama and Prime Minister Hatoyama in 2009 (METI, website). Formal agreements on the collaboration are under discussion.

The US Department of Energy (USDOE) has played a critical role in the development of OTEC technology. The US Navy has also been instrumental in supporting research into OTEC components as well as pilot plant design (Fig. 2). In addition to participating in the projects, named above, from the 1970s into the 1990s,

Fig. 2. The Navy funded heat exchange test tower was completed in 2011 and uses anhydrous ammonia as the working fluid. Up to 4 different heat exchangers can be tested and a possible 100 kw turbine is expected to be installed in the future, pending funding.

USDOE has recently provided financial support for additional critical research into OTEC components and environmental issues. The following research efforts exemplify the renewed attention given to OTEC in Hawaii.

- Makai Ocean Engineering, an Oahu-based consultancy, received an ARRA grant from USDOE to evaluate whether a mist-lift open-cycle process for a large OTEC plant can significantly lower OTEC costs.
- Makai Ocean Engineering developed a model which illustrated the distribution of a warm water plume from an OTEC plant to help understand potential environmental and operational impacts.
- USDOE and the Office of Naval Research awarded contracts to Lockheed Martin to study OTEC life cycle costs and energy potential.
- Lockheed Martin advanced a novel method of cold water pipe fabrication.

NELHA has utilized its seawater pipelines for energy related projects, allowing it to go back to its original intent on developing natural energy and electricity initiatives. A project called "Holaniku at Keahole Point" by NELHA tenant, Keahole Solar Power, LLC uses concentrating solar collectors to focus the sun's heat to create thermal energy generation using an organic rankine cycle generator (Fig. 3). Like OTEC, organic rankine requires a large temperature difference to provide the pressure needed to drive the turbines. Normal locations which do not have access to deep ocean water would need some way to provide cold temperatures, however, the project at NELHA uses existing deep ocean water to create the Delta T needed for efficient power generation. The project is a multi-application facility for power generation, process heat, absorption chilling and even seawater desalination.

One of the most useful ways NELHA and their tenants use the cold temperature of the deep ocean is in heat transfer applications where a heat exchanger (Fig. 4) replaces the traditional refrigerant coolant (Fig. 5) (Syed *et al.*, 1991).

Fig. 3. 1008 solar thermal collectors are tracking the sun where the heat is used for a solar assisted OTEC system using an organic rankine cycle and NELHA's cold deep ocean water.

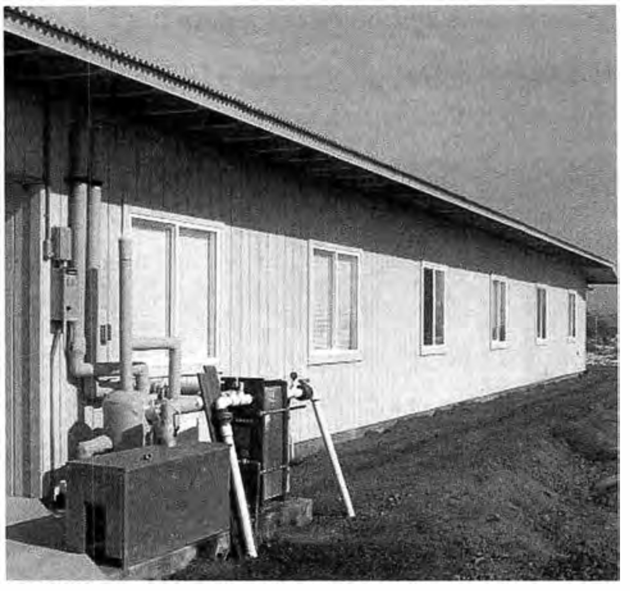

Fig. 4. A typical seawater A/C heat exchanger at a NELHA tenant facility

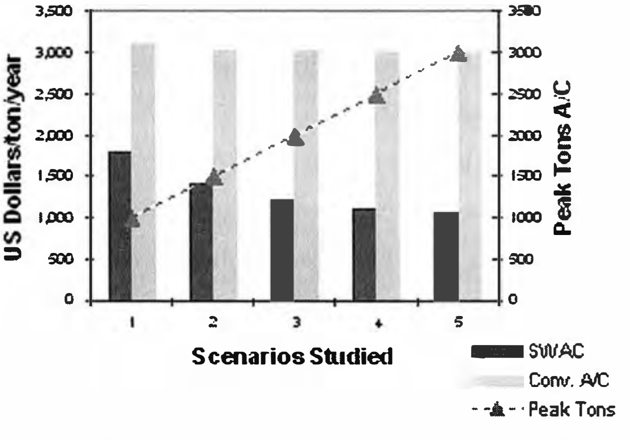

Fig. 5. Cost Comparison of SWAC vs Conventional A/C

This technique allows for an 80% reduction in electrical cooling costs compared with conventional air conditioning (Makai Ocean Engineering website).

To summarize, the combination of cold deep ocean water and warm surface water pumped at NELHA has proven to be a winning combination for economic development in Hawaii. By growing business in sustainable technologies involved with food, water, energy and health, NELHA adds $40+ million (NELHA website) to the States GDP each year while reducing the vulnerability of the island's food and energy security.

References

Claude, G. (1930), Power from the Tropical Seas, Mechanical Engineering, 52, 1039-1044.

Makai Ocean Engineering Website, http://www.makai.com/renewable_energy/swac.htm

Ministry of Economy, Trade and Industry (METI) website, http://www.meti.go.jp/english/policy/energy_environment/global_warming/e20091113a02.html

NELHA website, http://www.nelha.org/about/history.html

Ocean Energy Council Website, http://www.oceanenergycouncil.com / index.php / OTEC-News / HAWAII - GOVERNOR - LINGLE - ANNOUNCES - NEW - OCEAN - THERMAL - ENERGY - PRTNERSHIP.html

Syed, M. A., Nihous, G. C. and Vega, L. A. (1991), Use of Cold Seawater for Air Conditioning, Oceans '91, Honolulu, Hawaii.

Toyama, G. (2010), Deep Ocean Water as Catalyst for Economic Development, Deep Ocean Water Res., 11, 21-23.

Vega, L. A. (2001), Ocean Thermal Energy Conversion Primer, Marine Technology Soc. J., 6(4): 25-35.