KROCK DESIGN ASSOCIATES LLC

Dr. Hans Krock, Ph.D., P.E.
President, Krock Design Associates LLC
Member, Energy Harvesting Systems, LLC

After the DOE sponsored development work on OTEC in Hawaii was completed in the mid 1990's , the Department of Ocean Engineering (OE) at the University of Hawaii continued working to further understand the interaction of OTEC and the ocean environment and to explore possible locations where OTEC technology might be applied. Initially, this activity was primarily an academic exercise which included graduate engineering courses, master's thesis, and doctoral dissertations. With time, however, the accumulation of discoveries and successful graduates amounted to significant progress in the effort to develop real OTEC systems. This effort was led by Professor Hans Krock – then Chairman of the re-organized Department of Ocean and Resources Engineering (ORE) and Director of J.K.K. Look Laboratory of Oceanographic Engineering. Graduates from this program now constitute the core of several local ocean related engineering companies (Oceanit, Makai Ocean Engineering, Sea Engineering, Sustainable Design & Consulting, and Honolulu Sea Water Air Conditioning). Others are in significant positions in Taiwan, South Korea, the University of Hawaii, Brazil, Siemens, Intecsea, the City & County of Honolulu, and in the U.S. Navy.

OTEC related contributions by Prof. Krock and his students while in ORE at the University of Hawaii include:

- The basic design for a more efficient and reliable open-cycle OTEC plant with pre-deaeration and re-injection and fresh water production.
- The basic design for a sea water air conditioning (SWAC) system for the Honolulu Convention Center.
- The basic design for a SWAC system for downtown Honolulu.
- The basic design for a SWAC system for Waikiki and the University of Hawaii Manoa combined with cleaning the water in the Ala Wai canal.
- The basic design for an OTEC plant for Diego Garcia.
- The discovery that gases exchange faster in and out of sea water than in and out of fresh water and that the molecular diffusion coefficient for gases (and other non-polar substances) is faster in sea water than in fresh water. This discovery not only makes open-cycle OTEC more efficient and less expensive but also means that the "missing carbon" is not missing but is in the ocean and lowering its pH. Two U.S. patents resulted from this.
- The development of a reliable phytoplankton kinetic model for the tropical ocean as well as measurements of real world eddy diffusivity. These results enable better predictions of the environmental effects of discharging OTEC deep sea water into the photic zone.

- A better understanding of heat exchanger materials, designs, and biofouling control in closed-cycle OTEC systems.
- A better understanding of pure hydrogen production and liquefying systems on a potential OTEC platform.
- A new description of the ocean current structure at different depths and its relationship with the several phases of the solar and lunar tides.
- A better description of the internal wave field off Oahu and off Kona and its relationship to the water quality vertical profile.
- A better understanding of the deployment of and forces on deep water pipes up to a diameter of 2.5 meters.
- Measurement of the dynamics of the mixed water discharge plume from the OTEC-1 ship.
- Measurement of the vertical profile of water quality characteristics at the proposed OTEC site off Kahe on Oahu.
- An evaluation of U.S. Navy installations in the tropical zone for the installation of OTEC facilities.
- Publication of "Ocean Energy Recovery" for the American Society of Civil Engineers (ASCE).

In order to apply these advances to address the energy and water supply problems of tropical island communities, Dr. Krock and some of his former students established an engineering company, Ocean Engineering and Energy Systems Inc. Several additional advances in OTEC technology were made by this engineering company in the course of designing an OTEC facility for the U.S. Navy base on the Indian Ocean Island Diego Garcia, B.I.O.T. these include:

- Adaptation of the Kalina Cycle to OTEC conditions and, thereby, improving significantly on the efficiency of the conventional Rankine cycle that has been used for closed-cycle OTEC to date.
- Partnering with Dr. Alfred Yee to adapt his concrete honeycomb floating platform design to the space requirements of a Kalina Cycle OTEC plant.
- Completion of the environmental statement for the Diego Garcia OTEC project. This statement covered both the short-term and long-term impacts (both positive and negative) of the OTEC plant on the environment. The environmental statement was accepted by the British.
- Completion of the preliminary design study for the Diego Garcia OTEC project, including cost estimates based on direct quotations for all major components such as heat exchangers and turbines.

The Diego Garcia OTEC plant has not been built because private financing arrangements did not come to fruition.

Another significant technical advance for OTEC was made at this time by Dr. Krock with the design and deployment of a deep ocean water supply system for a potable water supply company, Deep Ocean Hawaii. This system is a flexible pipe with the pump at the bottom and is retrievable. This design was awarded a U.S. patent. Additionally, Dr. Krock was instrumental in obtaining FDA approval for use of the deep ocean off Oahu as a potable water supply source.

With all the necessary technology for a reliable and efficient OTEC system in hand, Dr. Hans Krock and Dr. Alfred Yee established Energy Harvesting Systems, LLC (EHS).

EHS has established working relationships with key companies who bring world class capabilities to the production and deployment of commercial scale OTEC platform. Using input from this team, EHS has produced standard designs for 10 to 15MW, 50 to 60MW, and 100 to 125MW OTEC platforms. These designs can be configured to produce a mix of products including base load electrical power, pure desalinated water, and/or pure hydrogen.

Dr. Krock's educational background includes

- Bachelor of Science in Civil Engineering – Arizona State University – 1965 Magna Cum Laude
- Doctor of Philosophy – Environmental Engineering – University of California, Berkeley – 1972

Dr. Krock is a registered Professional Engineer in the State of Hawaii (Civil branch) and was a tenured full Professor in the Department of Engineering at the University of Hawaii.. Dr. Krock has served as chairman of the Department Ocean Engineering and as the Director of the J.K.K. Look Laboratory of Oceanographic Engineering for the University. Dr. Krock now serves as Professor Emeritus at the University of Hawaii in the Ocean & Resources Engineering Department. He is a member of numerous professional and scientific associations.

Dr. Krock has conducted engineering and research projects in Arizona, California, Hawaii, American Samoa, Saipan, Guam, Majuro, Kwajalein, Palau, Pohnpei, Puerto Rico, the Bahamas, South Korea, Roi-Namur, and Germany. His research and professional accomplishments pertaining to OTEC systems applications include, but are not limited to:

- Establishment of water quality standards for the state of Hawaii and for American Samoa (1979)
- Optimization of the design of OTEC systems (1980 – present)
- Determination of gas exchange rates in seawater (1981 – 1993)

A brief listing of OTEC related publications and reports prepared by Dr. Krock follow:

- *Gas Analysis of Water Samples for OTEC Program*, for Westinghouse Electric Corporation and SERI, December, 1981
- *Open OTEC Non-Condensable Gas Exchange Characteristics*, presented at Intersol '85, Montreal, Canada, June, 1985

- *Gas Evolution in Open-Cycle OTEC*, presented at 1986 OMAE Conference in Tokyo, April, 1986
- *Non-Condensable Gas Composition and Out-Gassing Rates in the Open-Cycle OTEC System with Direct-Contact Condensation*, presented at the Internal Conference on Ocean Energy Recover, Honolulu, Hawaii, November 1989
- *De-Aeration and Re-injection of Non-Condensable Gases in Open-Cycle Recovery*, Honolulu, Hawaii, November, 1989
- *Hydrogen Production Using Ocean Thermal Energy Conversion*, presented at the International Hydrogen Conference, Honolulu, Hawaii, September, 1990
- *The Hawaiian International Hydrogen Energy Pilot Project*, presented at the Oceans '91 Conference, Honolulu, Hawaii, October, 1991
- *Coastal Overwash on Kauai: Landfall of Hurricane Iniki*, ASCE Conference of Hurricanes of 1992, Miami, Florida, December, 1993
- *Coastal and Oceanographic Considerations for Hurricane Iniki*, ASCE Conference on Hurricanes of 1992, Miami, Florida, December, 1993
- *The Role of Technology in Ocean Resources Development*, invited paper, presented at the 28th Annual Conference of the Law of the Sea Institute, Honolulu, Hawaii, July, 1994
- *Ocean Thermal Energy Conversion Feasibility Study for the Navy*, Report to US Naval Facilities Engineering Command, Contract No. N47408-94-D-1038, D. O. 0014, University of Hawaii at Manoa, 1996
- *OTEC Power Cycles and Fresh Water Production*, Proceedings of U.S. Navy–Industry Symposium on OTEC, Kailua-Kona, Hawaii, December, 1996
- *OTEC and the Environment*, Proceedings of the U.S. Navy–Industry Symposium on OTEC, Kailua-Kona, Hawaii, December, 1996
- *U.S. Navy-Industry Symposium on OTEC 1996*, Ocean Engineering, University of Hawaii Publication – Editor, Honolulu, Hawaii, 1997
- *Optimize OTEC systems for the Niche Market*, presented at the International OTEC/DOWA Conference, Imari, Japan, November 1999
- *Revisit Ocean Thermal Energy Conversion System*, Mitigation and Adaptation Strategies for Global Change Journal, 8 (2): 157-175, 2003
- *New Systems in Ocean Thermal Energy Conversion*, invited presenter, World Renewable Energy Congress, Aberdeen, Scotland, May, 2005