Annexure –Compilation of all 8 attachments

Attachment No 1/8

OCEAN THERMAL ENERGY CONVERSION (OTEC)

Efforts towards conversion of Ocean Energy for Power generation were initiated several decades back by many nations of the globe and extensively reported over the years and hence not addressed in detail here. Ocean Thermal Energy Conversion System (OTEC) produces Electric Power, utilizing the temperature difference that exists between the upper strata and depth of the ocean. It is assembled in a floating platform and moored at about 1000meter depth.

In OTEC, Ammonia is used as the working fluid, both in the liquid and vapor state, in a closed circuit. Warm saline water from upper strata is used in a Heat exchanger to vaporize the working fluid (ammonia) and generate ammonia vapor which drives a Turbo- Generator (TG) and produces Electricity. The ammonia vapor discharged from the Turbo Generator is condensed in a 'Condenser' as liquid by the cold saline water, taken from ocean depth. The working fluid is stored and cycled in a closed loop.

It is noted that sometimes in 1992, Government of Tamil Nadu entered into a MOU with Sea Solar Corporation of USA for establishing 100 MW OTEC plant in India. But no development program had been undertaken towards implementing this MOU. Further in 1998, Dr A E Muthunayagam initiated the development of an OTEC pilot project in NIOT with a capacity of 1 MW (gross). Regretfully, this pilot project was short closed in 2004 without any successful demonstration of even a single integrated OTEC system. In this circumstances, with no OTEC technology available in India, it necessary that India quickly establishes an operational OTEC plant with 'Technology Transfer' from abroad to achieve our goals with minimum time and expenditure.

In this context, everyone recognizes the gains of ISRO in the 'Liquid Propulsion Systems' development through a 'Technology Transfer' agreement in 1974 under the 'Vikas Project' between SEP, an aerospace company in France and ISRO of GOI. ISRO appointed Dr A E Muthunayagam then as Project Director- Vikas projects. This ISRO-SEP Liquid Propulsion Technology Transfer agreement was the foundation on which liquid rocket engines are designed and developed for almost all Launch vehicle programs of ISRO in the initial years. *Dr A E Muthunayagam hoped that India could leap frog to meet national water needs with a successful Desalination Technology transfer.*

It is observed that Makai Ocean Engineering Company Inc, Hawai, US (MAKAI) is considered as the World Leader in OTEC technology with over four decades of experience in Ocean Technology. In August 2015, MAKAI had commissioned a 100 KW OTEC plant in Hawai and connected it to US grid. This is the first operational OTEC plant in the globe. Details are available in the site www.makai.com. During 2018, Dr A E Muthunayagam approached MAKAI for guidance and help in the development of Offshore systems for Indian Desalination Program. Based on interactions with Makai Ocean Engineering Company of Hawai, USA over a period of time and the understanding reached, a joint venture with MAKAI as Technology Provider was proposed. But it could not be implemented for want of guidance and support from Government and Public sectors.

Attachment No2/8

LOW PRESSURE DISTILLATION FOR DESALINATION

In the 'Low Pressure Distillation (LPD) System for Desalination', the warm saline water from the upper strata of the ocean is injected it into a 'Vaporizer', maintained at a pressure lower than the Saturated Vapor Pressure (SVP), corresponding to the temperature of the injected saline water. Without any external energy addition, the salt free water vapor is generated in the vaporizer which is condensed as 'Desalinated water' in a 'Condenser', also maintained at a low pressure, using the cold water taken from ocean depth, as coolant. The desalinated water produced in the Condenser and the un-evaporated saline water in the Vaporizer, both at low pressure, are discharged to the atmosphere under gravity through two separate barometric seals without use of pumps.

The process of vaporization, the process of condensation and discharge of large volume of water from low pressure environment to atmosphere without pumps through barometric seals are basic principles which are well demonstrated and applied independently. But, a system for desalination, integrating the above three known principles, as evolved, is novel.

As can be subsequently seen, Dr A E Muthuayagam, the founder Vice -Chancellor of Karunya university piloted desalination R&D in the university with sponsored projects from DST, GOI and associated students and faculties. He published two papers in international journals and was granted the Indian Patent No 196396 of 2003 for his work on Low Pressure Distillation (LPD) for Desalination of sea water. He further demonstrated the patent in an experimental desalination at Tuticorin Thermal Power Station on 4th October 2004. He used the warm saline water discharge from the condenser of the thermal power plant as feed water to produce salt free vapour in a low pressure vaporizer and the cold cooling water of the thermal plant from sea as the coolant to condense the salt free vapour as desalinated water in a low pressure fresh water condenser.

In 2005, NIOT adopted the LPD technology and process for desalination and established at Kavaratti a desalination plant of 0.10 MLD capacity and named it as Low Temperature Thermal Desalination (LTTD) plant. It must be noted that LPD and LTTD desalination technologies are the same but for change in the configuration and Engineering to suit the capacity and plant site. If one examines the process of vaporization, it is the low pressure and not temperature which causes vaporization. Hence LPD is a more appropriate name to the desalination system than LTTD.

NIOT has extensively used LTTD concept in their developments over years. Some of the projects reported are listed below:

1. Establishment of LTTD Plants in the islands of UT Lakshadweep - Kavaratti (2005), Minicoy and Agatti (2011), Kalpeni (2020) and Androth, Amini, Chetlat, Kadamat and Kiltan (in Progress)

2. Demonstration of Offshore LTTD plant (1 Million Litres per Day Capacity - 2007) and Preparation of DPR for 10 MLD capacity Plant (2016)-Project abandoned.

3. Demonstration of Condenser Reject Based LTTD Plant in North Chennai Thermal Power Station (1.5 Lakh Litre per Day Capacity - 2009)-Not operational.

4. Establishment of Solar based Multi Effect Distillation Plant in Ramanathapuram (1.4 Lakh Litre Per Day Capacity - 2012) and in Kanyakumari (10,000 Litres per day Capacity 2018)

In addition, OTEC Based Self Powered Desalination Plant at Kavaratti & 2 x 1 MLD Waste heat LTTD plant at Tuticorin Thermal Power Station (TTPS) are under construction. Details not published.

Attachment No 3/8

MOES DESALINATION INITIATIES AND STATUS

With available information in public domain, the following brief is presented.

i) DOD initiated desalination programs in NIOT about two decades back. NIOT successfully established and operated a 0.1MLD desalination plant in 2005 at Kavaratti, and at Minicoy and Agarthi in 2011; subsequently a bit higher capacity desalination plant with the same technology at Kalpeni in 2020. Five more in Anroth, Amini, Chetlat, Kadamat and Kiltan are in progress. Technology is the same for all these plants. Such long delays in implementation of desalination projects by MoES is of concern. For such shore based desalination systems in islands, it appears essential to evolve, develop and commission sustainable Thermodynamic Systems, using the renewable solar energy stored in the ocean.

ii) Seeing the success of Kavaratti desalination plant in 2005, GOI wanted a 10 MLD capacity plant, offshore on priority, for the benefit of coastal community. It was also initially monitored by PMO. NIOT could not implement the project successfully. But NIOT spent about Rs 8.0 crores and got a DPR prepared by M/S L&T in 2016 on a single tender basis (TBC). Subsequently MoES has abandoned the project after spending a few years and few crores of public money. The system configuration with on board DG set for power supply with regular diesel supply from main land for this Offshore system did not appear to be a proper one. MoES could not consider offshore scheme with in situ power generation, because it was from a private agency and not through a tender of MoES. 'GOI rules and procedures' prevailed over 'Performance'. For Offshore desalination system for main land, it appears necessary to develop and commission the Integrated Desalination System, which is offshore, environment friendly, sustainable, does not require any external power supply for its operation by generating all power required for operation in situ from the solar energy stored in the ocean.

iii) In 1998, DOD initiated an Ocean Thermal Energy Conversion (OTEC) project at NIOT with a 1 MW (gross) capacity with Technical assistance from Saga University of Japan. Regretfully, this was not successful. Without change in the scope, the duration of the project was extended with revisions in the budget twice. Unfortunately, it was short closed after about 6 years or so, even without a single integrated system test after spending over Rs 70 crores. Activities of NIOT towards OTEC development are not reported.

A long way appears ahead for MoES to meet the 'Water Needs' of the nation.

Attachment No 4/8

DESALINATION R&D AT 'IIT M' By PROF. A MANI

Solar Multi - Effect Desalination stand-alone system

This principle of desalination involves both flashing and, evaporation and condensation. Basic operating principle of solar multi-effect desalination system is shown in Fig. 1. Solar collector field is used to generate hot water. Vapour is produced by flashing of generated hot water. The flashed vapour becomes the heat input source for the multi-effect evaporator. Sea water is sprayed over the tube in parallel to all effects to generate steam by absorbing latent heat. Steam and condensate is carried to the next stage, till reaches condenser. In the condenser, steam is condensed using intake sea water. This condensed distillate is stored in a tank. In multi-effect desalination system pressure is maintained under vacuum using a mechanical vacuum pump. In this system, vacuum is maintaned using two phase ejector.

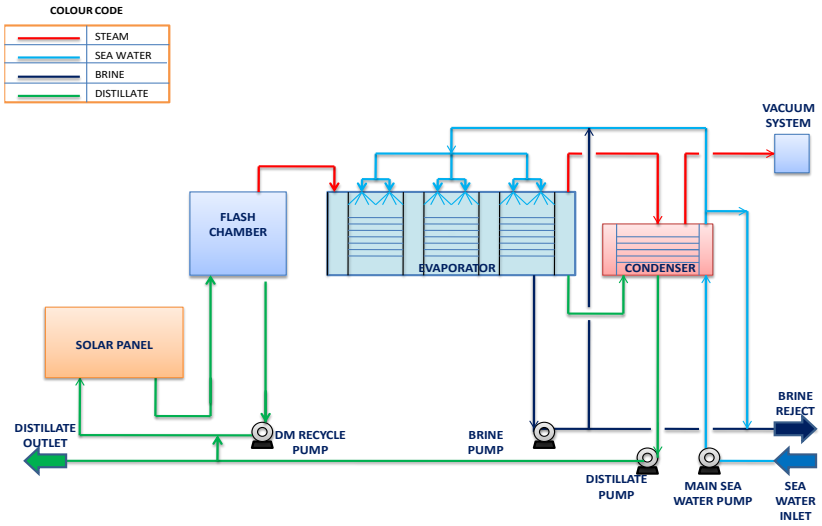


Fig. 1 Schematic diagram of Multi-Effect Solar Desalintion.

Solar Multi-Effect Desalination (MED) system is a stand-alone desalination system operates using solar energy, which is shown in Fig. 2. Solar MED system requires both solar thermal energy and solar photovoltaic electricity for production of potable water. To collect solar thermal energy, 315 numbers of flat plate collectors (2 x 1 m) are used to heat the water to about 70 ^{o}C with a flow rate of 32,000 kg/hr. This heated water is flashed to the flash chamber maintained at 150 mbar. This flashed steam is used as a heating source in the first stage of the multi-effect evaporator. Components of two-phase water ejector is shown in Fig. 3. Sea water is sprayed parallelly to all the effect of the multi-effect evaporator at a rate of 1,170 kg/hr. Steam is produced from the sea water by absorbing latent heat. Steam and condensate are carried to the next stage of the multi-effect evaporator and till it reaches the condenser. Transfer of the steam and condensate is done by manometric effect from one stage to an other stage. In the condenser, sea water at the rate of 27,400 kg/hr is used for condensing incoming steam. This multi-effect evaporator is built with 4 stages to produce 10,000 litres of water per day with a quality below 10 ppm. This solar MED system is powered by using 16 kW solar photovoltaic power plant with half an hour battery backup to meet interruption, if any.

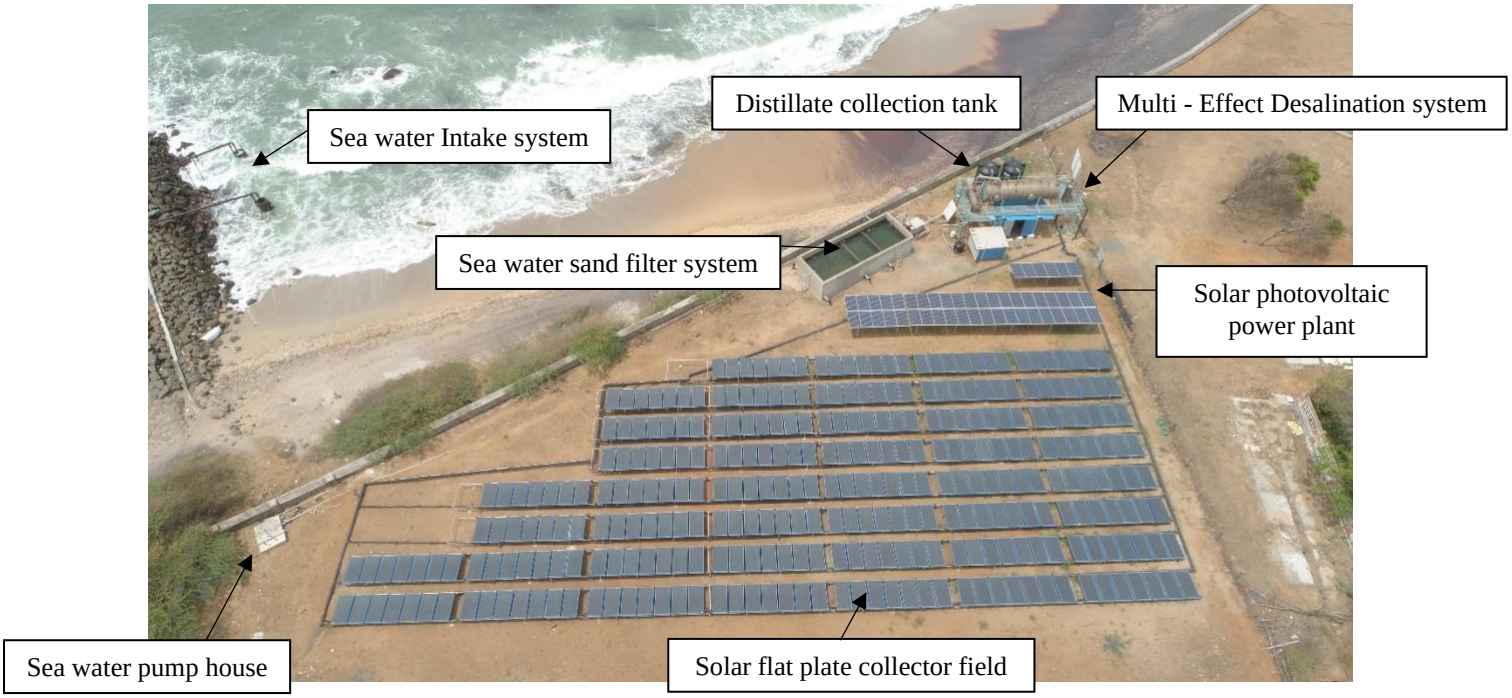


Fig. 2 Pictorial view of Solar Multi-Effect Desalination system.

Solar Multi-Effect Desalination (MED) plant was erected and demonstrated utilising sea water at Vivekananda Kendra, Kanyakumari, which is funded by Ministry of Earth Sciences (MOES), Government of India with a project value of ₹1.36 crores. This plant was commissioned during 2018. Using this system, best quality of water produced is 2 ppm.

Attachment No 5/8

DESALINATION R&D AT KARUNYA INSTITUTE OF TECHNOLOGY & SCIENCE

Dr A E Muthunayagam, Founder Vice Chancellor of Karunya University piloted the Desalination research programs in the university. Two research grants in the area of Desalination under the SERC scheme of DST, GOI was granted to Karunya Institute of Technology & Science, a Deemed University; the first one during 2002 and the other in 2004. The research facilities established under the DST grant for desalination technology studies were utilized by the students and faculties of KITS for Projects, as partial requirements for bachelors, masters and also doctoral programs.

Research Grant by DST, GOI

In June 2002, DST approved the research project titled " **An investigation on the Low Temperature Flash vaporization Process for Desalination"** under the guidance of Dr.A.E.Muthunayagam, Director, Karunya Institute of Technology & Science, Coimbatore. This project was successfully completed

within the sanctioned period of ONE year and a closure report was submitted to DST.

Under this project, a desalination laboratory, shown in the picture below, was established in KITS in 2002 to study the influence of vacuum, temperature, particle size and residence time in vaporizer, etc, on the desalination process. Students and faculties from KITS were conducting experiments in this Laboratory. Some students did their project work in this desalination facility. Some faculties carried out research towards doctoral degree from Anna University in this facility. Apart from presentations in different technical forums, two international publications based on the research at KITS; first one titled "Low temperature flash vaporization for desalination" published in Desalination, Vol 180,2005, pp 25-32 and the second one titled "Modeling and experiments on vaporization of saline water at low temperatures and reduced pressures", published in Applied Thermal Engineering, Vol 25, 2005, pp 941-952.

Based on the results, an Indian Patent No 196396, dated Feb 2003, titled **'A process for System and configuration for desalination of sea water'** was granted to Dr A.E.Muthunayagam.

LABORATORY PLANT AT
Karunya Institute of Technology & Science, Coimbatore.

Further, DST approved in July 2004 a project titled **"Studies on Low Pressure Distillation for Desalination in Thermal Power Stations Using Waste Heat Energy"** from Dr.A.E.Muthunayagam, Karunya Institute of Technology and Science Coimbatore for a duration of 12 month**.** In view of the

advance action taken, immediately after the presentation to the DST expert committee at Roorkee and the cooperation of M/S Koushic Pressure Vessel, M/S AOTS and the Authorities at Tuticorin Thermal Power Station, the Experimental facility was successfully commissioned on 4th October 2004 and experiments were conducted. After the inauguration of the plant, a brief function was organized at TTPS to mark the successful demonstration of a new process for desalination. It was widely covered by the media.

On the 5th of October 2004 the New Indian Express published that a 'New Desalination Technique was tested at Thoothukudi' successfully on a research facility on Monday at TTPS. The Madurai Regional Edition of 'The Hindu' also published on the same day the news with a title 'The Cost effective desalination Technology developed'. In addition, the Science Editor Mr Mohan Sundara Rajan published on 20th October 2004 at Bangalore Science & Technology Edition of Vijay Times, an article titled 'Fresh Water from the Sea- A Rocket Engineer Shows the way' with a brief description of the system. On 15th November the EDUCATIONPLUS edition of 'The Hindu' published an article titled 'Making Fresh water from the Saline cousin', with the picture of the research plant at KITS. There were quite a few articles in the local language also. Some of the paper clippings are given at the end.

The pictures of the Experimental facility at Thermal station and results of initial experiments were presented to DST expert committee during December 2004 who rated the project performance very high and recommended industrial application at the earliest opportunity. The Technology Development Board (TDB) of DST agreed to support the Phase 2 when an operational system shall be established in the Thermal station. Discussions were held with TNEB officials by Dr A E Muthuayagam along with industrial partners (AOTS and Koushic Pressure Vessels Pvt Ltd) and Representatives from TDB of DST. Some understanding was reached to establish a desalination plant at North Chennai Thermal Station but it could not be concluded and established because NIOT offered to TNEB to establish one desalination plant with NIOT financial support.

Four paper clippings are given below

New desalination technique tested in Thoothukudi

By Gladwin Emmanuel

Thoothukudi, Oct 4: A new desalination technique was tested successfully at a research unit that was commissioned in the Thoothukudi Thermal Power Station (TTPS) on Monday.

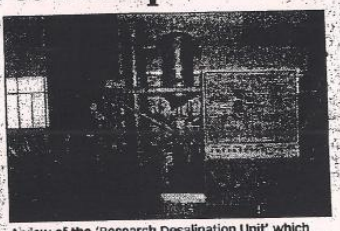
As per the new technique, sea water from upper strata is injected into a vapouriser at low pressure. The vapour so obtained is sent into a condenser, also maintained at low pressure. It is condensed using cold water taken from the lower strata of the ocean.

The man behind this new technology is A E Muthunayagam, former secretary, Department of Ocean Development, Government of India. Muthunayagam, who describes himself as a man obsessed with 'water,' says, "we've made a new beginning with this new technology, which will benefit the society". He has served in the Department of Space Technology, (ISRO, Thiruvananthapuram) for 29 years and is currently Vice-chancellor, Karunya Deemed University Institute of Technology and Sciences, Coimbatore.

"The basic principles which I have adopted for the new technology is based on physics behind boiling", says Muthunayagam. The new system has several merits — it scores over others in maintenance, operation, environmental impact and also in terms of costs, he said.

The research unit has a nominal production capacity of 100 litres fresh water per hour (2,400 litres per day). Muthunayagam prefers to term the new technology as Low Pressure Distillation for Desalination (LPDD).

The desalination systems that are presently operational are grouped as Thermal Systems (Multi Stage Flash MSF, Multi Effect Distillation-MED, Vapour Compression Distillation-VCD) and Membrane Systems (Reverse Osmosis-RO, Electrodialysis-ED). MSF and RO process are the widely-used technologies throughout the world today, contributing to about 86 per cent of the total desalination process. The RO process is in vogue in Gulf countries.



A view of the 'Research Desalination Unit' which was commissioned at the Thoothukudi Thermal Power Station on Monday.

The result of the initial experiments here indicate an excellent performance of the plant and gives confidence for establishing high capacity desalination plants in thermal power stations. Further experiments will be carried out in the coming months to generate design, data, performance evaluation and demonstration to prove the reliability of the plant, said Muthunayagam.

The discussions for setting up this experimental unit at TTPS started about a year back. Muthunayagam recalls he had approached the TNEB and made a presentation. The Department of Science and Technology had sanctioned Rs 22.8 lakh for the project. The unit was put up by Muthunayagam's own company AEM Ocean Technologies and Services Private Limited (AOTS) and Koushic Pressure Vessels Private Limited (KPV), which had done the fabrication for the unit. TTPS offered support for the project.

R Manickavelu, former head of Quality Assurance, LPSC-ISRO, said that the experimental plant commissioned on Monday met all the design specifications and that the quality of the fresh water tested in TTPS laboratory was found suitable for its use.

Muthunayagam said that he is also working on a programme for establishing a desalination complex at sea to produce fresh water and transport it to shore through large floats, low-bottom barges or pipelines, depending on the economy of the operation. For this, he has entered into an MoU with the National Ship Design and Research Centre, Vishakapattinam. "I'm also looking forward to signing an MoU with an American firm", he said.

Coming back to desalination, he said that the TTPS requires 400 tonnes of fresh water daily for each unit — for its boiler feed and other operations.

The total requirement is 2,000 tonnes for the five units here.

"The water that I supply needs some final processing, which the TTPS official say is simple to do", he said, adding that he may put up a pilot plant in TTPS with a capacity of 100 tonnes fresh water a day.

ANNEXURE (1)

Cost-effective desalination strategy developed

By Our Staff Reporter

TIRUNELVELI, OCT. 4. Deviating from the usual thermal and membrane desalination systems, which contribute to about 86 per cent of the total desalination capacity across the globe, the Vice-Chancellor of Karunya Institute of Technology and Sciences (KITS), Coimbatore (Deemed University), A.E. Muthunayagam, has developed a new strategy — 'Low Pressure Distillation for Desalination'.

Dr. Muthunayagam, employing this new, cost-effective technique, has established an experimental desalination plant, with a nominal capacity of producing 100 litres per hour at the Tuticorin Thermal Power Station, which was commissioned today. Modifications and fine-tuning of the instruments would be done to pave way for construction of plants with huge capacity.

The desalination systems across the globe presently function on thermal systems — multi-stage flash (MSF), multi-effect distillation (MED), vapour compression distillation (VCD) — and membrane systems (reverse osmosis-RO) and electro-dialysis (ED). Among these techniques, MSF and RO are widely employed.

In the concept designed by Dr. Muthunayagam, who served for 29 years in the Department of Space as one of the directors and served as Secretary, Department of Ocean Development, Government of India, warm seawater from the upper strata of the sea is injected into the vaporiser kept at low pressure and the water gets vaporised. The vapour is condensed in a condenser, also maintained at low pressure, using cold water taken from the lower strata of the sea. Without using any pump, barometric seals enable to discharge the un-evaporated water from the vaporiser and the fresh water condensate from the condenser, both maintained at low pressure.

The newly-commissioned system effectively reduced the dissolved salts in seawater from 35,000 parts per million to just 20 ppm. "Though this desalinated water can be directly used at the TTPS, we can give final polishing to our product. The fine-tuning of treated water would be going on for the next three-six months," he says.

Dr. Muthunayagam struggled to find a funding agency to construct the technology demonstrator. However, M/s AEM Ocean Technologies and Services Private Limited, Chennai, in which he is a technical director, and M/s Koushic Pressure Vessels Private Limited, Chennai, reached an agreement to construct the demonstrator at the Tuticorin station. The Department of Science and Technology, New Delhi, provided him with Rs. 22.80 lakhs. "The hardware used in this technique is commercially available and has no high technology elements like membranes, fine filters etc. There will not be any mechanical failure of hardware due to high pressure pumping system and vibration as experienced in the reverse osmosis system. Maintenance is practically nil and operations are simple, which do not require highly skilled operators. Unlike the discharges from RO and MSF, the discharge from this process is not pollutants," says Dr. Muthunayagam.

He plans to configure a module with a capacity of 0.25 million litres a day (MLD) and establish operational systems by integrating the required number of autonomous modules without further research and development. "If 10 such modules are integrated on a moored platform on the sea, we can produce 2.50 MLD at a much cheaper cost. We have started negotiations with the National Ship Design and Research Centre, Visakapatnam."

FRESH WATER FROM THE SEA

A rocket engineer shows the way

MOHAN SUNDARA RAJAN

GUEST COLUMN
SPACE MUSINGS

I MET Dr A E Muthunayagam years ago, when he was in charge of ISRO's indigenous cryogenic propulsion technology, which he had formulated. The Indian cryogenic engine (where the propellants remain in liquid form only at very low temperatures) and the stage would soon replace their Russian counterparts in the third stage of the country's rockets designed to launch geosynchronous satellites such as INSAT. He played a key role in developing liquid propulsion engines for our rockets and micro thrusters that stabilise the satellites.

Currently, as the Vice Chancellor of the Karunya Institute of Technology and Science, a deemed university in Coimbatore, (KITS: established by Dr DGS Dhinakaran and Dr Paul Dhinakaran, founders of the Jesus Calls Ministry) Dr Muthunayagam has undertaken a mission to develop and use technologies in an innovative manner for providing socio-economic benefits to people by pooling all the required resources. Accordingly, he has developed a novel technique to desalinate seawater and make fresh water available for use by the industry as well as the public.

The technique, based on his rocket expertise, was developed at KITS with the assistance of a grant from the Department of Science and Technology, Government of India, and an experimental plant was commissioned at the Tuticorin Thermal Power Station in Tamil Nadu earlier this month (October 4). The innovation marks a turning point in the country's technological progress in view of its potential to provide water of good quality from the sea at a very economical price and in an environmentally friendly manner.

The concept underlying the plant is rather simple. Vast quantities of seawater at ambient temperature are taken by thermal power plants for cooling in their operations and discharged into the sea as warm water. At the Tuticorin power plant, the warm water discharged is about 225 million litres per hour. There is a difference of about 10° C between the cool intake from the sea (around 30° C) and the warm water (about 40° C) released into the sea. The desalination technology developed by Dr Muthunayagam, makes use of this temperature difference.

Dr A E Muthunayagam

It is known that water under low pressure will become vapour. Accordingly, warm water is brought into a chamber under low pressure (at 10mm of mercury as against the normal 760mm at sea level) and sprayed by two swirl injectors, designed on the pattern of micro thrusters used in satellites. The resulting water particles become vapour. The entire system is operated under vacuum. The unevaporated water and the fresh water, both at low pressure, are discharged through barometric wells without any pump.

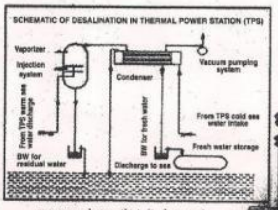
The vapour is then sent to a condenser where cool water from the sea is circulated. As vapour cannot contain salt, pure water comes out and it is collected separately. It has been shown that the fresh water contains dissolved salt of only 20 parts per million (ppm) as against the saline water salt content of 45,000ppm.

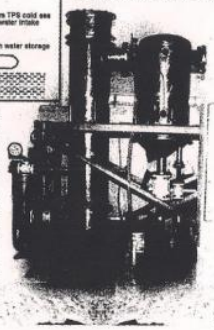
At a yield of just one percent of the waste heat water, about 54 million litres of fresh water per day could be produced at Tuticorin. If the temperature of the warm water is raised to 44° C and that of the cooling water to 28° C, the fresh water production can be doubled to 2 percent. The recycled fresh water from the plant can be used to meet the boiler requirements of the thermal plant itself (it needs 2000 tonnes of desalinated water per day) as well as the needs of the public and industries. Moreover, the marine ecosystem would be safeguarded from the adverse impact of the warm water flow into the sea.

It is pointed out that the desalination technology used in the Station is simple and does not need highly skilled workers. In fact, the experimental plant has been built by a group of industries viz. AEM Ocean Technologies and Services Private Limited and Koushic Pressure Vessels Private Limited with the support of TTPS.

The successful completion of the first phase of the desalination programme shows that it does not need further research and development to design a larger plant. The plant is now producing 100 litres of fresh water per hour. A pilot plant with a 100 tonne a day capacity is being planned.

The cost per litre is estimated to be 10 paise as against one rupee per litre in the conventional desalination plants, using the traditional reverse osmosis technique. A Russian company, which won the global tender floated by the Tamil Nadu government, had offered the conventional technology. The work has not started, as the company has yet to be awarded the tender. Dr Muthunayagam is confident of establishing high-capacity desalination plants in thermal stations in the country.





His colleague, R Manikavel, who was formerly Head of Quality Assurance, Liquid Propulsion Systems Centre of ISRO, points out that the experimental plant meets all design specifications and adds that the data now being generated would be useful in further confirming the reliability of the plant.

Dr Arcot Ramachandran, former Secretary, S&T Department of the Central Government, who has encouraged the indigenous effor says that the system should be give a fair trial, as it addresses the problem of acute water scarcity.

The technique will also be tried in the open sea, some 25 km away from the coast. The desalination plant will be put inside a submersible a few metres below the sea level so as to avoid the motions of the currents. The sea has warm surface water but at a depth of about 1000 metres, the water is cooler by about 20° C, which is ideal for the technique. The fresh water can be stored in floating containers, which can easily be dragged in water to the shore for onward distribution.

The National Ship Design and Research Center, Vishakapatnam, is likely to take up the construction of the submersible. Containers, made of special material to hold fresh water, are available for purchase from foreign sources. Once installed, the low-pressure distillation system can considerably solve the water problem of coastal cities in the country including Chennai.

The good news is that the Tamil Nadu Electricity Board seems willing to welcome the innovation and encourage the installation of high-capacity plants at other thermal plants near the sea. It is the common man's hope that the technological solutions offered by our scientists and engineers would not require any 'desalination' to keep out the murky salts of petty politics.

mohansrajan@hotmail.com

Making freshwater from its saline cousin

Karunya's desalination project

The Vice-Chancellor of Karunya Deemed University, A. E. Muthunayagam, has designed a pioneering system to turn seawater into water vapour, and condense the vapour into freshwater.

CHUGGING OUT of the harbour a little tugboat hauling a large empty bag made of toughened plastic. Some distance from the shore, the boat draws alongside a floating barge with a metallic structure upon it.

This is a desalination plant that has turned seawater into freshwater, and stored it in a large plastic bag that is now almost full.

For a few minutes, the crew on board the tugboat are busy detaching the freshwater bag from the plant and replacing it with the empty bag they have brought with them. After a quick inspection to ensure that the plant is working normally, the crew turn the tugboat towards the shore, drawing the freshwater bag behind them.

Desalination system

This scenario could become commonplace at port cities in the country, if the desalination system based on 'low pressure distillation' is widely adopted for commercial use.

The Vice-Chancellor of Karunya Deemed University, A. E. Muthunayagam, has designed a pioneering system to turn seawater into water vapour, and condense the vapour into freshwater.

To demonstrate that his idea was feasible, Muthunayagam built an experimental plant at Karunya Deemed University in Coimbatore, under a research project sponsored by the Department of Science and Technology (DST).

Saltwater from a tank entered a metallic container called vaporiser, maintained at low pressure by a vacuum pump.

Offshore and onshore

Owing to the low pressure, a portion of the saltwater turned into water vapour and moved into a container called condenser, kept cool by circulating cold water around it.

In the condenser, the water vapour condensed into freshwater, and flowed into a storage receptacle from where it could be periodically removed.

Muthunayagam said that in an offshore unit, warm water from the upper layers of the ocean could be sent into the vaporiser, and cold water from the ocean depths to constantly cool the condenser.

He said that the system could be installed as an onshore unit, to use the warm water discharged into the sea by thermal power stations.

Thermal stations drew water from the sea at about 30 degrees Celsius, and used it for cooling. This raised the temperature of the seawater to 40 degrees Celsius, and it was then allowed to flow back into the sea. In this situation, Muthunayagam planned to use the heated water in the low-pressure vaporiser, and cold seawater in the condenser, which was also maintained at low pressure.

Demonstration unit

Using the Karunya plant, he was able to show that his method of low-pressure distillation was feasible. He demonstrated the system using an experimental desalination plant at the Tuticorin Thermal Power Station last month.

This was in association with M/s AEM Ocean Technologies and Services Pvt. Ltd., and M/s Koushic Pressure Vessels Pvt. Ltd. The plant had a production capacity of 100 litres of freshwater per hour.

All the hardware was commercially available, and there were no high technology elements like membranes and fine filters. Moreover, the operations were very simple and there was no need for highly skilled workers. Above all, it did not harm marine life.

Superior system

Low-pressure distillation required external energy for injecting water into the vaporiser, circulating cooling water around the condenser, and running the vacuum pump. He said that the system was superior to 'reverse osmosis' that required pre-treating the water by filtering it to remove floating substances, and adding chemicals to prevent micro organisms growing on the membrane and damaging it.

When designing the plant, Muthunayagam drew upon knowledge gained in space science as well as ocean development. He said that low-pressure distillation was better than the two major systems of desalination used nowadays.

These were the multi-stage flash system and the reverse osmosis system.

A. A. Michael Raj

Attachment No 6/8

INTERACTION WITH DST, MoES, NITI Aayog, MDWS, GOVERNMENT OF TAMIL NADU

Department of Science & Technology, GOI

The guidance and support which Dr A E Muthunayagam received from Department of Science & Technology, Government of India during the initial days at KITS after his superannuation in 2001 were the nucleus for his desalination developments. Under the SERC scheme of DST, He received his first desalination project during June 2002 titled *" An investigation on the Low Temperature Flash vaporization Process for Desalination"*

Further, he received his second desalination project in July 2004 titled *"Studies on Low Pressure Distillation for Desalination in Thermal Power Stations Using Waste Heat Energy"* Both these projects were successfully completed on time with the active participation of faculties and students of KITS and were well received by DST.

Again in 2013, Dr A E Muthunayagam approached Secretary DST, GOI for guidance and support for a pilot project of 4MLD desalination capacity, integrated with a 1 MW Turbo generator. Secretary DST appreciated they proposal and said that it is impressive and water is the need of the hour. But with the limited finance available to DST and its responsibility to support several research activities all across the nation, DST will not be able to support such a venture, requiring large finance. He also suggested that some method should be evolved to support such a venture. He also suggested that the Government of Tamil Nadu should be approached.

Government of TamilNadu.

In 2014, Dr A E Muthunayagam made a presentation on his integrated desalination concept to Mr Phenendra Reddy IAS, Principal Secretary, Municipal Administration & Water Supply (MAWS) and senior officials of Government of Tamil Nadu. It was well received. Mr Vijayaraj IAS, then MD TWAD was nominated to coordinate and evolve a scheme. In the first meeting MD TWAD informed Dr A E Muthunayagam that the water requirement of Chennai was quite large and suggested that he modifies the proposal to establish an operational system with a desalination capacity of minimum 100 MLD. Accordingly, the proposal was reworked.

In 2015, Dr A E Muthunayagam made another presentation to the same senior Officials of Government of Tamil Nadu to establish a 100 MLD offshore desalination plant off Chennai coast. It was also well received. Chennai Metro Water Supply & Sewage Board (CMWSSB) of GoTN has appreciated the merits and expressed willingness to purchase all desalinated water through a long term Water Purchase Agreement after due process in Government. However, GoTN expressed inability to finance such a program. Regretfully, a source to finance such innovative new initiative on desalination could not be established by Dr A E Muthunayagam, either from Government sector or from private sector.

NITI Aayog.

In 2016, at the invitation of NITI Aayog, Dr A E Muthunayagam presented the same proposal to establish 100 MLD offshore desalination plant off Chennai coast in an inter-ministerial group meeting at NITI Aayog, organized by Dr VK Saraswat, Member Science, NITI Aayog. It was well received and he was asked to submit a proposal to generate a DPR for the project. Accordingly, in September 2016, he submitted a proposal to NITI Aayog

to generate a DPR. Though he had a development plan with details, he could not generate the financial requirements with details to generate the DPR. Hence he proposed a budget in a non-conventional way, to be based on actual expenditure, subject to a ceiling of Rs 500 lakhs with a provision that the budget and expenditure to be monitored and regulated by a high power committee. He also justified this financial requirement by pointing out that MoES had placed a contract with a budget more than Rs 800 lakhs with M/S L&T to generate a DPR for their 10 MLD offshore project on LTTD technology of NIOT. It is pointed out that the power supply for this MoES offshore plant is from an on-board DG set. But the system which he proposed generates all power required for operation in situ from the Solar energy stored in the ocean and no external power supply is required. It is more complex than MoES project. NITI Aayog forwarded his proposal to DST who decided that it should be referred to MoES for consideration. Subsequently, Dr Rajeevan, Secretary MoES informed Dr A E Muthunayagam in his meeting with him on July 2018 that he could not process the proposal because there was no provision in the ministry to support such proposals from industries in private sector. However, during the discussions, Dr Muthunayagam pointed out that in situ power generation is ideal for offshore operations instead of on board DG set which requires regular diesel supply from main land.

Ministry of Drinking Water & Sanitation.

In the middle of 2017, Dr A E MuthunayagamI made the same presentation on 100 MLD offshore desalination project off Chennai coast to Mr Parameswaran Iyer, Secretary, Ministry of Drinking Water & Sanitation (MDWS), GOI and senior officials of the ministry. The secretary appreciated the merits of the proposal, felt that the new concept is worth experimenting and expressed willingness to support it, if approached through a State Government. Also Secretary MDWS informed about the provision for GOI grant up to 50% of such project cost

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Attachment No 7/8

REPORT OF TASK FORCE CONSTITUTED BY MINISTRY OF NEW &RENEWABLE ENERGY ON

(DEVELOPMENT AND DEPLOYMENT OF RENEWABLE ENERGY APPLICATIONS FOR SUPPLY OF CLEAN WATER)

Executive Summary

A task force was constituted by Ministry of New and Renewable Energy vide OM no. F.No.223/3/2021 – Solar R and D dated 28.07.2021 under the Chairmanship of Shri. Dinesh Dayanand Jagdale, Joint Secretary – R&D, MNRE with members from DST, NIOT, Ministry of Jal shakthi, NIWE and NISE.

The task force has studied various technologies for converting saline or waste water to potable water (Desalination), extracting water from nature including humidity in the air etc., using Renewable Energy as a power source. It is noted that the use of renewable energy is yet to mature for commercial scale applications.

Based on the series of discussion and interaction with industry stakeholders, a brief recommendation of the task force is as follows

1. It is proposed to identify an Institutional Mechanism for having a centralized registry / data bank for listing of all the available desalination plants in India along with their power sources (including RE).

2. To propose two categories of projects (i) large scale pilot projects (to find cost per litre) and (ii) community level off grid units (for application in remote areas),

3. To form a joint working group among MDWS, MoES, MNRE along with concerned State Public Health Engineering Department (PHED) for identification of locations for pilot projects on water from atmosphere & Desalination using RE.

4. To propose Joint R&D fund (among MNRE, DDWS & MoES) for promotion of new technologies using RE for Desalination & water from atmosphere. MNRE R&D Institutions will support testing of new technologies with their infrastructure for performance analysis.

5. To invite competitive proposals from industry in collaboration with academia/research institutions that could deliver on a specified user need while pushing the technology envelope and deliverables including the performance and qualification requirements could be clearly spelt out.

6. Support for grant for the industry for transitioning toward renewable energy is important and should be incorporated as per R&D policy of MNRE and DST. A project can be evaluated and funded according to the gap in viability and funding should be in graded manner for prototype/product developmental research and viability gap funding for larger size demonstration projects.

7. MNRE has issued a Framework document on 14th February 2022 focusing promotion of Decentralized Renewable Energy Livelihood application. The Framework covers installation of energy efficient AWG using wind / solar in boats, addressing Fish and Aquaculture domain. This document may be modified incorporating AWG and Desalination using RE addressing monitoring of the products through quality assurance and needed financial incentives for making viability of installation.

8. It is advisable to follow two step approach, i.e. first stage to approve the technology and then implementation in a Pilot Project, while releasing Call for proposal by MNRE, since RE adoption for both Desalination and water from atmosphere is yet to mature.

9. Regions where no water is available and need equipment's like Air to Water Generator needed, viability gap funding becomes more relevant. Such kind of locations can be found out by Ministry of Jal Shakthi by seeking inputs from State Governments, after circulating the Task Force report to them.

10. An Expression of Interest (EOI) may be floated to seek for feasible commercial projects (with low Cost per liter and meeting standards relevant to drinking water quality) on both extraction of water from the atmosphere and also desalination of water and MNRE may formulate schemes for funding RE Components alone for such scaled up commercial projects.

11. In addition, it is proposed for the following funding mechanism

Technology Assessment (Leading to Pilot-Scale Demonstration for technology in the field setting), R&D mode upto Rs 1-1.5cr: This can be for analytical and computational studies, model testing in laboratory or in the field

Convergent Solution (Leading to customized sustainable convergent solutions including techno-socio economic environmental assessment for mounting sustainable solution for a population of approx. 10,000) - **For Projects with Technology Readiness Level (TRL) 7 and above**

Prototype development upto Rs 10cr: Here an actual working prototype with a system for desalination powered by Renewables needs to be implemented at a suitable location. Brackish water as well as seawater desalination could be the intake water. Any combination of desalination technologies and renewables is acceptable. Involvement of industry would be preferred.

Attachment No 8/8
MAKAI-AOTS MOU
To be negotiated and modified for revised scope

MAKAI OCEAN ENGINEERING ISO9001:2015 Certified P.O. Box 1206 Kailua, Hawaii, USA 96734 PH (808) 259-8871 FX (808) 259-8238 info@makai.com **www.makai.com**

24 July 2018

RE: Chennai OTEC/Desalination Plant Memorandum of Understanding

Dear Dr. Muthunayagam,

Makai Ocean Engineering, Inc. (Makai) expresses willingness to participate in the design and construction of an ocean thermal energy conversion (OTEC) power plant used to power a 100,000,000 liter/day (100 MLD) desalination plant off the Chennai coast in India (the Project). The Project consists of an OTEC plant that supplies power, warm seawater, and cold seawater to an integrated thermal desalination system. The desalination system generates fresh water and transmits it to shore.

The parties involved in the Project and their responsibilities are:

- • AEM Ocean Technology & Services PVT LTD (AOTS) – overall lead and executor of the Project. AOTS's responsibilities include the selection and design of a desalination system, coordination of all parties, as well as securing and administrating Project financing.

- • Makai Ocean Engineering, Inc. – technical lead of the offshore platform and OTEC system. Responsibilities include design of the offshore plant and OTEC system and integration of the desalination plant to be designed by others. Makai is not to be an equity partner – all engineering services will be provided on a fee basis.

- • Indian Institute of Technology (IIT) Madras – source of site data and engineering support. Responsibilities include supplying oceanographic, metocean, and bathymetric data as well as supporting the technical design of the offshore platform.

The execution plan for the project is:

1. AOTS raises funding for initial analysis.
2. Makai conducts a scoping study to determine the gross size of system components.
3. The results of the scoping study are used to generate a proposal to create a detailed project report (DPR).
4. AOTS secures funding for preparation of the DPR.
5. Upon funding, AOTS, Makai, and IIT Madras carry out the proposed engineering work and write the DPR.
6. AOTS uses the results of the DPR to secure funding for detailed system engineering.
7. AOTS, Makai, and IIT Madras carry out detailed engineering, producing complete drawings and specifications for the system.
8. AOTS secures funding for system construction.
9. AOTS, Makai, and IIT Madras oversee system construction and installation.
10. System commissioning and operation.

The scope of work to be completed by Makai includes:

- • Preliminary engineering analysis as part of the scoping study.
- • Preparation of the offshore platform and OTEC sections of the DPR proposal.

- • Lead the technical team responsible for the engineering work performed as part of creating the DPR for the offshore platform OTEC system, and interface with desalination plant.
- • Lead the technical team responsible for the detailed engineering design of the offshore platform and OTEC system.
- • Lead the team that acts as the owner's observer during construction and commissioning of the OTEC plant.

Makai looks forward to pursuing this exciting project with AOTS.
Sincerely,
Greg Rocheleau Director of Engineering, Makai Ocean Engineering

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