International Nuclear Desalination Advisory Group

to the International Atomic Energy Agency

INDAG NEWSLETTER

No.5 – September 2005

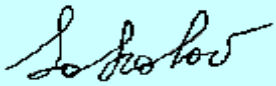
A WORD FROM THE DEPUTY DIRECTOR GENERAL

The nuclear desalination activities in the Member States carried out with the support of the IAEA comprised of establishing nuclear desalination demonstration projects, carrying out techno-economic feasibility studies on the introduction of nuclear power-desalination plants at the specific sites having water scarcity and design and development of small and medium sized reactors for safe and economic production of potable water from seawater.

Two pre-feasibility studies have been completed and the construction of two nuclear desalination demonstration projects have started in the year. The CRPs on nuclear desalination have provided information on optimum coupling of different reactor types with the commercially established desalination processes and their economics. The economic evaluation of nuclear desalination and its competitiveness with conventional desalination have been made by MSs using the Agency's software DEEP. An updated version DEEP-3 has been developed and is scheduled for release in this year.

During the last meeting of INDAG held in July 2004, the members exchanged information on the progress of national and interregional activities in nuclear desalination and reviewed the progress of the Agency's work, as well as activities planned for 2006-2007. INDAG also discussed how the Agency could contribute to facilitating nuclear desalination activities in Member States. INDAG has entered its third term (2005-2008) and the next meeting is planned for February 2006.

I am pleased with the release of the fifth issue of the INDAG Newsletter highlighting the current activities of the Agency and from the Member States.

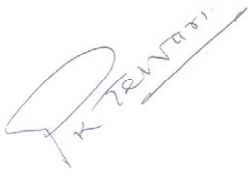


Y.A. Sokolov
Deputy Director General
Department of Nuclear Energy, IAEA

A WORD FROM THE CHAIRMAN

Nuclear desalination has strong potential to emerge as an attractive option for water security as water shortages, unreliable water supplies and poor water quality have in recent years been the major obstacles for sustainable development and poverty alleviation that require urgent attention. Over one billion people in the world lack access to safe drinking water. Water shortages are increasingly limiting development options. About 14.6 million children die yearly because of water shortages or exposure to water related diseases. By 2025, a significant fraction of world population (over 3.5 billion people) will live in areas facing severe water shortages.

It is in this context, the role of INDAG becomes very important. The fifth issue of the INDAG Newsletter includes the contributions from INDAG members in the field of nuclear desalination. The Newsletter brings up to date information regarding INDAG, its activities and recommendations. This issue provides information on the recent activities on nuclear desalination of the Member States. It includes technical articles on 'Nuclear Desalination Activities in China' by Y. Zhang and 'Coupling of MED-TVC with SMART for Nuclear Desalination' by Y. D. Hwang from Republic of Korea. The useful information on major international collaborations and IAEA activities in the field of nuclear desalination has been highlighted.



P.K. Tewari
Chairman, INDAG

INDAG is an Advisory Body to DDG-NE established in 1997.
The next INDAG meeting is planned for February 2006.

Recent Activities in Nuclear Desalination in Member States

ARGENTINA:

Argentina has continued to support the Agency's ongoing programs on nuclear desalination.

With CNEA as the participating institution, Argentina contributes to the CRP 2 and considerable progress has been made on the economical assessment of specific Nuclear Desalination sites, and on the conceptual specification of an optimized co-generation plant. This includes an analysis of the seawater pretreatment (chemical and UF) for an RO-Plant as a site-specific issue.

Supported by the Nuclear Engineering Division of INVAP, the effort on developing safety aspects of Nuclear Desalination has also progressed. The specific engineering work focused on a safety-oriented design of the coupling, based on the use of pressure reversal (on a Heat Exchanger) as a safety feature. This development is cumulative respect to the design of a coupling with water monitoring as a safety feature, presented in INDAG 2004.

CHINA:

The construction of a nuclear desalination demonstration plant (SNDP) with production capacity of 160.000m^3/d in Shandong Peninsula of China was proposed in 2000. The pre-feasibility of SNDP was completed in 2001 and was reviewed and approved by the central government in 2002 and 2003, respectively. The feasibility study started from 2003 March. The SNDP consists of an NHR-200 coupled to a MED process. Two desalination processes were considered and compared in the feasibility study based on the requirement by the central government. One is the high temperature VTE-MED process and the other is MED-TVC process. The feasibility study is expected to be completed in 2005. After assessment of feasibility study it will be decided whether to build the SNDP.

EGYPT:

NPPA is carrying a number of integrated activities and studies to keep a state of readiness for efficient execution of NPP when the decision is taken. Also NPPA is working to complete the necessary infrastructure, including site development, preparation of the required studies and documents as well as manpower development.

With the cooperation of the IAEA, technical and economical feasibility study to use NP for electricity generation and potable water production has been completed. Also, the IAEA is supporting the effort to construct a simulator for ND.

An experimental facility is under construction at the site. The objective of this facility: to obtain real data on preheat-RO technology at the site conditions, which will useful for the future activities.

FRANCE:

CEA, along with its partners CNSTN (The Tunisian National Centre for Nuclear sciences), STEG (The Tunisian utility) and SONEDE (the Tunisian water company), completed the Site-specific study for the La Skhira (The TUNDESAL project) under the bi-lateral agreement between CEA and CNSTN and under the aegis of IAEA's INT/4/134 programme. The results of the study and the final report were presented to the Tunisian authorities on the 14th of March 2005.

CEA also completed the development of the MED plant simulator (carried out under a specific IAEA contract) for the NPPA Egypt. The validation of the simulator results, against an operating MED plant, is actually in progress

Bi-lateral collaboration agreements are currently under negotiation between CEA and BARC (India).

As part of its contribution to the IAEA CRP: "Economic Research on, and Assessment of, Selected Sites and Case Studies", CEA carried out several corrections to the DEEP models and integrated in its version of DEEP, the new correlation for the ROph process, based on physical and mathematical principles.

CEA is developing precise models for the utilisation of waste heat, from the GT-MHR and PBMR type of reactors, coupled to MED plants. These will be incorporated into the next CEA version of DEEP.

INDIA:

BARC (India) is setting up a 6300 m^3/d hybrid MSF-RO Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam. Sea Water Reverse Osmosis (SWRO) section of NDDP has already been completed and commissioned. It is operating successfully as per design intent since 2002. Potable water produced is supplied to nearby areas. MSF is under construction. India has been sharing the NDDP experience with the Member States. A Technical Meeting (TM) on "Integrated Nuclear Desalination Systems" was organized during December 13-16, 2004 in Chennai (India). There were ten participants from Member States of Argentina, China, Egypt, France, India, Indonesia, Israel, Russia and Saudi Arabia. In addition, there were two observers from UAE. A site visit to NDDP (Kalpakkam) was also organized during the meeting.

BARC (India) has an active programme to study the possible utilization of waste heat from the nuclear reactor by coupling low temperature evaporation (LTE) desalination systems for seawater desalination. A 30 m^3/d LTE desalination plant was coupled to CIRUS nuclear reactor utilizing a part of its waste heat for seawater desalination. It was commissioned in the first quarter of 2004 demonstrating the successful utilization of nuclear waste heat for sea water desalination producing high quality desalinated water (8-18 µs/cm conductivity). The plant is operating very well on regular basis providing high quality makeup water for the nuclear reactor (CIRUS). Based on its successful experience, it is proposed to integrate a 500 m^3/d nuclear desalination plant with AHWR for seawater desalination.

The development work done at BARC (India) has generated capability to design, fabricate, commission and operate small and large size nuclear desalination plants for large scale deployment and providing opportunities for the socio-economic development of water scarcity areas and coastal arid zones. The road map includes establishing large size nuclear desalination plants (100-300 MLD) coupled to nuclear power plants in coastal regions for both power and water security.

ISRAEL:

The revised governmental desalination policy is to install seawater desalting plants up to the accumulative capacity of 315 millions m^3/yr within this decade. In addition, quite a few plants of tens of million cubic meter per year capacity from brackish water are already operating, under construction or will be ordered soon. This policy has been determined in view of the existing national

water balance deficit and the growing water demands.

The first part [50%] of the largest plant, SWRO of 100 MCM/Y nominal capacity, located near Ashkelon on the Mediterranean about 60 km south of Tel-Aviv, was commissioned in August 2005. The promised water price at the plant exit is as low as about 50-53 US cents per cubic meter. The required desalted water quality is extremely high - 20 ppm chlorides and low boron content.

Nuclear desalination, however, seems now more remote than ever for Israel. Nevertheless, data and experience – construction as well as O&M - gathered from the Ashkelon and Hadera projects might most probably contribute a lot of information as well as ground for decision making regarding future large nuclear desalination projects.

JAPAN:

Japan has no national projects, international projects and inter-regional projects at the present time. However, Japan has nuclear desalination facilities, which are co-located inside the nuclear power plants, in order to supply the fresh water, which is being used inside the plant. The capabilities of all desalination facilities is not so high, however, those are being operated without any serious troubles now.

R&D of some innovative nuclear technologies are being conducted under the contract with MEXT and METI. These technologies will be incorporated into the future nuclear power plants.

Two kinds of improved RO system, in which the recovery ratio can be increased from 40 % to 60 % have been developed by Toyobo and Toray. One of system with one stage was installed into the desalination plant (50,000ton/day), which was constructed in Fukuoka. Its construction was finished and the test operation by each unit will be started in the near future. Another new technology related to the intake of seawater was also installed into the Fukuoka desalination plant.

KOREA REP OF:

The objectives of Korean programme are mainly to develop an integrated desalination plant with SMART (System-integrated Modular Advanced Reactor) for a dual-purpose application. The programme is being carried out by the Korea Atomic Energy Research Institute (KAERI) as the leading organization with the support of Government and participation of industries. The concept of the SMART desalination plant aims to supply 40,000 tons of fresh water per day and 90 MW of electricity to an area with approximately hundred thousand populations or an industrialized complex. The SMART reactor which is an integral type pressurized water cooled reactor with a rated thermal power of 330 MW is coupled with the Multi-Effect Distillation Thermal Vapor Compression (MED-TVC) process.

Both the conceptual design and basic design of SMART with a desalination system were successfully completed in March of 1999 and in March of 2002, respectively. The construction project of the SMART pilot plant for comprehensive performance verification of SMART reactor and desalination technology is actively in progress. Plant layout and compartment arrangement are completed. Major components such as steam generator, main coolant pump, and control element drive mechanism are being developed and currently performance tests are underway. A series of performance tests and safety tests for SMART reactor systems are in progress at high-temperature high pressure thermal hydraulic test facility at KAERI.

Licensing documents required for construction permit of the SMART pilot plant were submitted to the regulatory body on June 2005. It is expected that the construction of the SMART pilot plant can be started in 2006.

LIBYA:

Libya has seen the desalination of seawater to be one of the major option to augment national efforts for the supply of potable water and decided to conduct certain activities toward capacity building and cost optimization in this field. Among the activities in this direction are:

1. The establishment of a specialized research center to be responsible for research and development in technologies for water desalination and wastewater treatment. A national program to acquire know-how and transfer of technology in the field of seawater desalination industry was initiated in collaboration with some European companies.
2. In the context of exploring the energy alternatives for seawater desalination and supply of electricity, an IAEA supported TC Project, multi-function simulator, was initiated. This will be utilized for educational and training purposes and promoting studies in the field of nuclear desalination.
3. Establishing cooperation with other countries for feasibility study on nuclear desalination for specific site is being considered so as to promote and deepen the technical and economic investigations for the optimum coupling between energy and desalination systems.

MOROCCO:

Morocco adopted specific laws covering all water management aspects, including pricing and environmental issues and creating Basin agencies. In order to address water scarcity in the near term, Water Authorities set up and are implementing the 2005-2025 National Water Plan. Nuclear desalinisation is an option among other options. The Government of Morocco strongly believes that existence of effective regulatory infrastructure is a prerequisite for the development of any promotional nuclear activities. Consequently, it is establishing an adequate and sound legal and institutional legislative and regulatory nuclear framework and is committed to become familiar with all existing and available technologies and expertise in nuclear peaceful activities in general and desalination in particular.

PAKISTAN:

Pakistan has awarded a contract for the manufacturing of MED type plant of 1600 m3/day and the detailed design of Intermediate Coupling Loop is in progress. We have also awarded a contract for the manufacturing of main components of Coupling Loop. Detailed design of sea water supply circuit and power supply circuit is also in progress. Safety analyses and environmental impact reports are also being prepared for submission to the regulatory authorities. Soil investigations at the project site have been completed to start the civil work. Equipment layout is being developed.

RUSSIAN FEDERATION:

The Federal Atomic Energy Agency (ROSATOM) has made a decision to start in 2006 construction of a small floating barge-mounted heat and power co-generation nuclear plant based on state-of-the-art ship propulsion reactor KLT-40C (150 MWt PWR). Financial and technical contribution to the project implementation from international partners is under consideration. It might comprise building of a barge and its subsequent delivery to Russia. Severodvinsk-city (Arkhangelsk Region) in the

Russian North-West is selected as operation site for the first unit. Demonstration of this nuclear technology is thought to allow its larger scale application in remote regions over Russia and abroad for electricity and heat production and also for seawater desalination.

The pre-project work aimed at the assessment of technical characteristics of nuclear desalination systems based on prospective Russian medium-sized (VVER-640, GT-MGR, VBER-300 etc) and small-sized (KLT-40C, RUTA, UNITERM, SVBR-75/100 etc) reactors is under way. An output of these activities is assumed to apply for practical implementation of nuclear desalination. "The Concept of activities in Nuclear Desalination using Russian Reactors" has been developed and is discussed now in the ROSATOM. The document defines short- and medium-term objectives in nuclear desalination.

Russian design and scientific organizations took part in the IAEA CRP-2 on "Economic Research on, and Assessment of, Selected Nuclear Desalination Projects and Case Studies".

SAUDI ARABIA:

Saudi Arabia is the largest desalinated water producer in the world, contributing to 30 percent of global production, according to official statistics. Desalinized water currently constitutes Saudi Arabia's chief source for drinking water. The Saudi government transports its desalinated water via a 2,500 kilometer pipeline network, 21 pumping stations, 131 depots and 10 stations for mixing the desalinated water with underground water.

King Abdulaziz City for Science and Technology has financed a research project in nuclear desalination planning for Saudi Arabia. The outcome of the study showed that nuclear desalination is very promising option, however besides economic issues, safety concerns of water contamination is very important issue need to be investigated for coupled nuclear desalination system

UNITED STATES OF AMERICA:

The U.S. is actively engaged with the IAEA in pursuing interesting and beneficial research projects and ideas in specific filed nuclear desalination and in cogeneration of water and power in general. Argonne National Lab (ANL) is leading this continuous interaction and is participating in several activities in this area. The U.S., for example, is very keen on its continuous contribution to the on-going Coordinated Research Project (CRP) on the evaluation of the economics of site-specific possible future nuclear desalination facilities. In this project, ANL is examining the economic feasibility and considerations of nuclear desalination facilities (with Generation III+ type reactors to begin with) in semi-arid, developed and fast-growing regions in the U.S. (e.g. Texas). Also in the framework of the aforementioned CRP, ANL has taken one of the leading roles in advising the Agency on the upgrade and modernization of the computer software DEEP (Desalination Economic Evaluation Program). ANL is eager to do all it can to see the release of a new fully-operational version of DEEP.

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Nuclear Desalination Activities in China

Y. Zhang, Tsinghua University, People's Republic of China

The construction of a nuclear desalination demonstration plant (SNDP) with production capacity of 160.000m^3/d in Shandong Peninsula of China was proposed in 2000. The pre-feasibility of SNDP was completed in 2001 and was reviewed and approved by the central government in 2002 and 2003, respectively. Hao-Xin Investment Co. is the owner and the Institute of Nuclear and New Energy Technology, Tsinghua University is the engineering contractor. The feasibility study started from 2003 March. The SNDP consists of an NHR-200 coupled to a MED process. The NHR-200 as a nuclear heating reactor with 200 MW capacity is designed with a numbers of advanced features, such as integral arrangement, full natural circulation, self-pressurized, in-vessel CR drive, passive safety systems in order to achieve very high safety margins. Therefore, no off-site emergency actions such as sheltering, evacuation, relocation and decontamination in case of all credible accidents can be achieved. Two desalination processes were considered and compared in the feasibility study based on the requirement by the central government. One is the high temperature VTE-MED process and the other is MED-TVC process. A tower-type arrangement for the VTE-MED is adopted. Two trains of VTE-MED are coupled with NHR-200. Each train consists of 3 towers, in which 7 models of evaporators compose of one effect in parallel and 32 effects of evaporators are vertically arranged and a high GOR of 22 is designed. Four units of MED-TVC process are coupled with NHR-200. Each unit has a desalination capacity of 30,000m^3/day and it is consisted of 14 effects of evaporators. The motive steam from the steam generator is supplied through the thermal vapor compressor (steam ejector) and extracts low-pressure steam from the sixth effect of evaporator. Therefore, a GOR of 15 will be achieved. Now, the investment and economic analysis on the two desalination processes are conducted using Chinese official procedure. The feasibility study is expected to be completed in 2005. After assessment of feasibility study it will be decided whether to build the SNDP. Figure below shows an artist view of the SNDP.

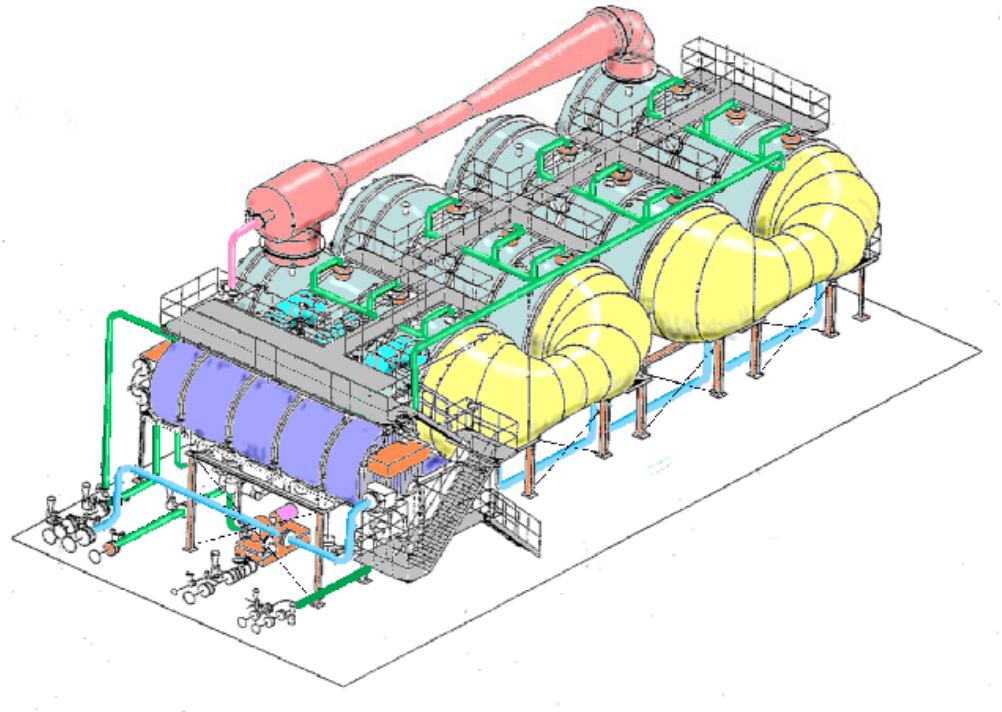
Coupling of MED-TVC with SMART for a Nuclear Desalination

Y. D. Hwang, KAERI, Republic of Korea

The SMART desalination plant has been developed for a target water production capacity of 40.000m^3/day and an electricity generation of about 90MW. The integrated SMART desalination plant consists of four (4) units of a Multi Effect Desalination Process combined with a Thermal-Vapor Compressor (MED-TVC). Each unit is designed with a capacity of 10,000m^3/day, performance ratio of 19.6 and a motive steam to load ratio of one. The thermal vapor compressor was combined with the MED process to improve the energy utilization of the processed steam.

In a nuclear desalination, a radioactive contamination of the product water is the most important issue with respect to the safety and public acceptance. In this regard, the units of the desalination plant are coupled with the SMART power system through an intermediate heat transfer loop. The major function of the intermediate heat transfer loop is to protect the desalination plant from a radioactive contamination and produce a medium pressure motive steam by using the steam extracted from the turbine. Radioactivity monitoring systems were also installed in the water production system and the intermediate loop where the concentration of radioactivity is higher than that in the desalination plant. These systems will provide an enhanced capability for radioactivity detection.

Since the desalination plants are connected thermally with the SMART power system, the transients of the desalination system can directly influence the operation of the SMART plant. The slow transient, such as a gradual reduction in the energy demand of the desalination system can be easily accommodated for by the SMART system through either the load following capability or a cut-back of the energy supply to the desalination system. Thus, only the fast transients induced by the desalination system become important events to be considered for the safety of the SMART desalination plant. For the disturbances of the SMART desalination plant, several events were identified as the potential disturbances imposed by the desalination plant. The impacts of these disturbances on the Design Basis Accidents and Performance Related Basis Events of the SMART plant were evaluated by the conservative bounding approach of the key safety parameters and the results showed no additional safety concerns for the SMART desalination plant.



SMART MED-TVC Desalination Plant

KEY DESIGN PARAMETERS OF THE SMART DESALINATION PLANT

Parameters	Design Values
Primary System	
- Thermal Power of the Core (MWt)	330
- Nominal Pressure in Primary Circuit (MPa)	15.0
- Primary Coolant Temperature (Core Inlet/Outlet, °C)	270/310
- Operating Range of Power Change (%)	20-100 N_{nom}
Secondary System	
- Steam Flow Rate (kg/sec)	152.7
- Steam Pressure/Steam Temperature at Turbine Inlet (MPa/°C) at normal operating condition	3.0/286
- Feedwater Pressure/Temperature (MPa/°C)	5.0/180
Desalination System	MED-TVC
- Plant Capacity	40,000m^3/day (4 x 10,000m^3/day)
- Steam Flow Rate Extracted from Turbine	30.0kg/Sec.
- Steam Pressure/Temperature Extracted from Turbine	0.9Mpa/175.4 °C
- Steam Pressure/Temperature Supplied to TVC	0.8Mpa/170.6 °C

The desalination process employed in the integrated SMART desalination plant is the type of a falling film, with a multi-effect evaporation with horizontal tubes and a steam jet ejector. Each distillation unit has the production capacity of 10,000m^3/day of distilled water at the top brine temperature of 65°C by using seawater supplied at the design temperature of 33°C. Thermal Vapor Compressor was added to the MED process to improve the energy utilization. The addition of the thermal vapor compressor was possible because the steam produced by the steam transformer is a higher temperature and pressure than that required in the evaporator. Thermal vapor compressor enables the low-pressure waste steam to be boosted to a higher pressure effectively, thus reclaiming it's available energy.

The technology used in the SMART desalination plant will be proven through the technology verification program currently underway. The verification program includes the separate effect tests and comprehensive integral test. The advanced design features and the overall performance of the SMART nuclear desalination plant will be demonstrated through the verification program of the SMART plant. The figures below show the main cooling pump and the control element drive developed for the performance/ endurance test of SMART-P

Major International Collaborations completed/ underway

- **Indonesia and Korea, Rep. of**

Korea Atomic Energy Research Institute (KAERI) and National Atomic Energy Agency of Indonesia (BATAN) jointly evaluated economic feasibility of a nuclear desalination plant on Madura Island using SMART. The final drafts of the PFS and the URD were ready for submission to the Government. It envisions the nuclear desalination plant operation in 2018 producing 4000 m^3/d of fresh water.

- **Tunisia and France**

CEA (France) and CNSTN (Tunisia) signed a collaboration agreement on January 15, 2002 for a technical and economic evaluation of Nuclear Desalination for the site of La Skhira. The pre-feasibility report of the TUNDESAL project was completed and sent to the Government.

- **Pakistan**

In proceeding with engineering details of coupling a thermal desalination unit with KANUPP, PAEC received technical assistance through IAEA from international experts including from Argentina and Germany. PAEC has started the construction of the project, which is to be completed in 2006.

- **INNOMED**

France is coordinating the preparation of a follow-up project to EURODESAL, for an ambitious proposal under the International Cooperation with Mediterranean countries (INCO/MED programme) of the 6th Frame Work Programme of the European Commission This project, regrouping 4 partners from the EU (Cyprus, France, Germany, Italy) and three from North Africa (Egypt, Morocco, Tunisia) is designed to propose sustainable solutions based on wastewater recycling and desalination for possible specific sites in the Mediterranean region.

Highlights of on-going and future activities at IAEA (2004/2005)

The results of the CRP on "Optimization of the Coupling of Nuclear Reactors and Desalination Systems" were published as IAEA-TECDOC-1444 (2005)

The CRP on "Economic Research on, and Assessment of, Selected Nuclear Desalination Projects and Case Studies" launched in 2002 has participating institutes from 11 Member States. The third RCM was held in May 2005.The draft of the proposed TECDOC was discussed. The update version of DEEP was presented. The new version DEEP 3 is now ready for release.

INDAG met in July 2004 and presentations of the status of activities in the Member States were made by the members. INDAG reviewed the Agency's current and future activities and made several recommendations. The follow- up actions are being taken up.

IAEA presence at International Conferences

1. Role of Nuclear Desalination in Meeting the Potable Water Needs in Water Scarce Areas in the Next Decades; EuroMed 2004, Marrakech, Morocco (2004)
2. DEEP: A tool for Evaluating Co-generated Power and Desalination Strategies, EuroMed 2004, Marrakech, Morocco (2004)
3. IAEA's Desalination Economic Evaluation Programme (DEEP), MEDRC Workshop on Desalination Costing, Limassol, Cyprus (2004)
4. Status and Prospects of Nuclear Desalination, IDA World Congress, Singapore (2005)
5. Recent Model Development for the Desalination Economic Evaluation Programme DEEP, IDA World Congress, Singapore (2005)

Recent IAEA publications relevant to nuclear desalination[1]

- Optimization of the coupling of nuclear reactors and desalination systems, IAEA-TECDOC-1444, Vienna (2005)
- The IAEA Power reactor information system- PRIS and its extension to non-electrical application, decommissioning and delayed projects information, IAEA-TRS-428, Vienna (2005)
- Innovative small and medium sized reactors: Design features, safety approaches and R&D trends, IAEA TECDOC-1451, Vienna (2005)

[1] **How to get IAEA publications**: Orders and requests for information may be addressed directly to:
Sales and Promotion Unit, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400, Vienna/Austria
E-mail: sales.publications@iaea.org, Web site: http://www.iaea.org.wordatom/Books

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