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Nuclear Desalination Newsletter

News from the Technical Working Group on Nuclear Desalination
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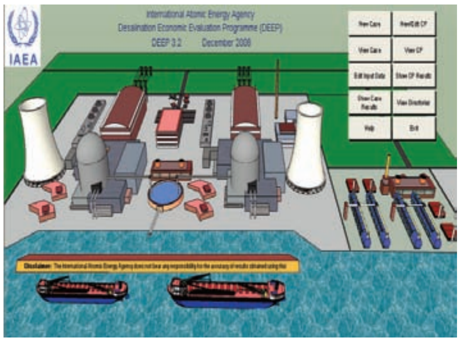
Contents

Review of the IAEA Desalination Economic Evaluation Programme DEEP



The IAEA DEEP software is a powerful tool for comparative economic evaluation of various configurations for desalination plants. DEEP has been used worldwide for the economic evaluation of desalination plants (thermal or electrical) coupled with various energy sources (nuclear, fossil fueled or renewable). Throughout the years, the software was updated constantly. Such updates included the user interface and model structure but not the economic models. Previous continuous development was culminated in the development of the DEEP 3.2 version which has been recently released in 2009.

A newly published paper in the International J. of Desalination presents a step forwards in the continuous effort to maintain high standards and reliability of DEEP. The paper scrutinizes methods used, assumptions made, and constants or default values originally used. The validity of calculations as well as the identification of the most important parameters are presented. Sensitivity analysis is used to identify the most important parameters in the DEEP model.

The review revealed that overall DEEP economic methods and software implementation is still solid for the economic assessment of dual purpose plants. It was found that minor deficiency in DEEP does not affect greatly the results and the overall value of DEEP code. Results derived from DEEP should be used as an additional tool for improving judgment and enhancing the decision-making process. However, users still need to be knowledgeable about DEEP models, its assumptions and the range of applicability of all parameters, and evaluate results based on such knowledge. It should be pointed that improvements based on this review are currently under consideration in the new release of DEEP version. The new version, expected to be released soon, will have some peculiar advantages which will help: a) experts to perform comparative evaluation in an easy, friendly and transparent way, and b) new users to quickly learn the aspects of a desalination plant and their assessment techniques.

Overall, the review proves that both the DEEP economic model and software implementation are solid for economic evaluation of dual purpose plants. Based on results presented and recommendations made, a new version of DEEP is expected to be released in 2010 which will address minor issues and improvements.

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A Word from the Deputy Director General

Seawater desalination is increasingly becoming a vital option for alleviating severe water shortages around the world, and especially in developing countries. Worldwide seawater desalination capacity is expected to increase beyond the current contracted estimate of about 60 million m^3/d. The need for an adequate supply of potable water for growing populations and complex problems is now globally recognized. Desalination using nuclear energy could play a vital role in supplying the much needed potable water for sustainable development and alleviate some of the environment impact of using fossil fuels for desalination.

The IAEA programme on nuclear desalination continues to provide support to Member States through various forums of information exchange, technical cooperation projects, and publications. In the last year, the IAEA launched a new coordinated research programme which aims at investigating new technologies for seawater desalination using nuclear energy; updated and released a new version of the IAEA DEEP software; released a newly developed toolkit on nuclear desalination; and organized (jointly with the International Centre for Theoretical Physics ICTP) a training workshop on Technology and Performance of Desalination Systems.

I am pleased to announce that such support will continue in the forthcoming years in the form of the above mentioned activities as well as of new activities to be implemented in the area of feasibility studies and technical and economic assessment of cogeneration options of nuclear desalination systems including electricity generation and seawater desalination. In addition, the technical working group on nuclear desalination TWG-ND will also continue to provide advice and guidance for implementation of the IAEA's programmatic activities in the area of nuclear desalination.

I am pleased with the release of this issue of the TWG-ND Newsletter highlighting some current activities of the IAEA and from the Member States.

Y.A. Sokolov
IAEA, Deputy Director General

A Word from the Chairman of TWG-ND

Several Member States are taking a step forward in evaluating, planning or starting nuclear desalination projects. Algeria is investigating the option through feasibility studies. A group of the technocrats from Algeria had undergone training in nuclear desalination in India under IAEA technical cooperation program. China has an ambitious plan on nuclear power plants. It is planned to integrate desalination plants to some of the power plants in coastal areas. In Egypt, the construction of El-Dabaa experimental Reverse Osmosis (RO) desalination facility and feasibility study for an electricity/ desalination plant were completed. Nuclear desalination studies in France, is increasingly becoming inter-regional. In India, Nuclear Desalination Demonstration Project was successfully completed. A hybrid desalination plant was integrated to the existing PHWR at Kalpakkam. Japan has rich experience in operating nuclear desalination facilities. In the Republic of Korea, a nuclear desalination unit is in design stage using a cogenerating integral type reactor coupled with a desalination plant. A Nuclear Desalination Demonstration Project utilizing heat from the Karachi Nuclear Power Plant (KANUPP) is being established in Pakistan. In Russia, efforts are continued in developing a floating nuclear power plant for multi-purpose use including desalination. US experience in the field of membrane technologies is utilized in demonstration projects. Member States such as Argentina, Cuba, Indonesia, Kuwait, Libyan Arab Jamahiriya, Morocco, Saudi Arabia, South Africa, Spain etc. are taking active interest in nuclear desalination activities.

Nuclear desalination is becoming increasingly important world-wide. IDA World Congress on Desalination & Water Reuse held in Dubai in November, 2009 included a technical session on 'Alternative Ideas, Innovative Solutions & Nuclear Technologies for Desalination'. A full technical session was dedicated on nuclear desalination in the conference on 'Desalination and Water Purification' at Chennai (India) in March 2010 organized by Indian Desalination Association and Asia Pacific Desalination Association.

IAEA Technical Working Group on Nuclear Desalination is playing its important role by providing guidance on Agency's activities in this field, reviewing progress and exchanging information on the progress on national and international programs. Different research institutions from various Member States are participating in IAEA coordinated research projects which bring together technology users and suppliers for exploring the different possibilities in nuclear desalination concepts.

P. K. Tewari
Chairman, TWG-ND

Recent Activities in Member States

Algeria: The need for fresh water and electricity increases rapidly in Algeria, the Authorities launched a study to assess the potentialities of using nuclear energy for electricity and potable water production. This study, started in 2007 through a technical cooperation project with the IAEA, investigates the option of nuclear desalination with an objective to elaborate a document which will be used to support the government's decision to introduce the nuclear energy in the country. For this purpose, a study of nuclear desalination unit is performed for a potential site: La Macta located in the Western coastal regions of Algeria which is characterized by a very low rainfall rate of 400 mm/year. This study is taken in the national context. Indeed, the energy sources outputs that are candidates in this study are based on the Indicative Program of Electricity Generation developed in Algeria. The definition of nuclear desalination unit capacity is fixed to meet the water demand of the population of this region for a period of 25 years beyond 2025. The cogeneration option is taken into account in this study.

Hamma seawater desalination plant

In this project, three scenarios are proposed for a same period 2020-2030. For the first scenario, 1,000 MW nuclear power reactors are considered. The nuclear reactors selected for the second scenario are of the SMR size. The energy sources candidates for the last scenario have an output corresponding to a strategy option related to fossil energy in Algeria: 400 MW natural gas combined cycle, 100 MW natural gas turbine and 200 MW natural gas turbine.

Results of this project correspond to the economical evaluation of coupling several energy sources: GT-MHR, PBMR, AP1000, PWR900, NGCC400, NGT100 & NGT200 with two desalination processes MED and RO. The results of this study have been presented to the InDA-APDA Conference on Desalination and Water Purification, held in Chennai, India, March 2010.

China: In June this year, it was declared by Liaoning Hongyanhe Nuclear Power Company that the seawater desalination system was officially put into use. This is the first seawater desalination system operating in China's nuclear power plant.

The seawater desalination facility at Hongyanhe station is able to provide 10,080 tonnes of freshwater daily. The SWRO desalination process is used. The freshwater will be used in operating reactors in Hongyanhe nuclear power plant and daily life needs. The system will help address the water resource storage problem at the local condition.

SWRO desalination plant in Hongyanhe nuclear power plant

Liaoning Hongyanhe nuclear power plant is located in northeast of China, which launched the construction in August 2007. The LHNP has four generating units with an annual capacity of one million kilowatts each, and the first unit is expected to go into operation in 2012.

France: NDS has been heavily involved in developing new DEEP models. Current model in DEEP only takes into account very approximately the variation of feed water temperature in the RO process. The new correlations not only permit an accurate treatment of the feedwater temperature but also take into account the variation of important RO performance parameters (feed salinity, feed pressure, specific power consumption etc) which strongly impact the desalted water production and costs.

In its current version, DEEP only calculates power and water costs and does not allow any cash flow analysis. It is for this reason that NDS is also in the process of integrating in DEEP the financial models based on the usual criteria for cash-flow: the net present value, the internal rate of return and the payback period.

India: The nuclear desalination demonstration plant (NDDP) set up by Bhabha Atomic Research Centre (BARC) at Kalpakkam consists of hybrid MSF-RO system of 6300 m^3/d capacity and is coupled to the Madras Atomic Power Station (MAPS). Several firsts were achieved through successful execution of NDDP. It is the largest nuclear desalination plant based on hybrid

A View of Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam

MSF-RO technology using low pressure steam and sea water from nuclear power station. It is the first time that a hybrid nuclear desalination project has been executed coupled to an existing nuclear power station. An intermediate heat exchanger (steam-steam) is incorporated between the nuclear power station and the desalination plant as isolation loop to minimise any possibility of product water contamination. A View of Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam (India) is shown in above Fig.

The hybrid technology has several advantages. It has provision for flexibility, redundancy, usability of warm seawater from the thermal desalination plant as feed to RO, which enhances the productivity and production of two qualities of desalinated water for the best utilization. The other facilities such as, combined post treatment, common seawater intake & brine discharge systems and sharing of manpower & facilities help in reducing the water cost. NDDP consists of a RO section producing 1800 m^3/d potable water along with the MSF plant producing 4500 m^3/d distilled water. The products from MSF & RO can be blended for improving the drinking water quality.

Director General (IAEA) and representatives from IAEA and Member States have visited NDDP at different occasions. A group of technocrats from Algeria were earlier provided training in nuclear desalination for a period ranging from fifteen to sixty days under IAEA Technical Cooperation Program. An engineer from The Syrian Arab Republic was provided one month training in nuclear desalination. NDDP has further enhanced the capability of BARC in desalination field.

Nuclear research reactors produce significant quantities of waste heat. The low temperature (LTE) nuclear desalination plant which was integrated to the nuclear research reactor at Trombay for demonstrating utilization of nuclear waste heat and coupling aspects has completed six years of successful operation. The product is used as make-up water in the reactor.

RO Section of NDDP

To meet the challenges of growing demands of power and water, nuclear plant and desalination system coupled to them would play an important role. It is anticipated that there would be requirement for small, medium and large size desalination plants coupled to nuclear power station in the coastal area governed by the demand with respect to quantity and quality of the desalinated water. Adopting co-generation concept along with hybridization would help in cost effective production of desalinated water.

USA: To the best of Argonne National Lab's (ANL's) knowledge, there are no specific new activities in the area of nuclear desalination for implementation in the USA , other than the on-going desalination activities at the Diablo Canyon NPP. It should be noted, however, that there is an clear increase in the planning and deployment of large seawater desalination facilities along the USA coast (especially in California and Florida). The inactivity on the nuclear desalination front could change rather rapidly with potential future plans to expand nuclear power in the USA (including the commissioning of new plants at or very near to coastal sites). In the meantime Argonne National Laboratory is engaging the IAEA on nuclear desalination issues and stands ready to provide advice and support dependent on available resources to support such activities. ANL is currently participating in a recently launched IAEA CRP on nuclear desalination technology and economic aspects, with specific contribution on a new nuclear desalination economic assessment approach

Report on InDA–APDA Conference on Desalination and Water Purification

A three day conference on 'Desalination and Water Purification' was organized at in Chennai, India in March 2010 under the auspices of Board of Research in Nuclear Sciences (BRNS) in association with Indian Desalination Association (InDA) and Asia Pacific Desalination Association (APDA). The aim was to bring together the stakeholders in desalination & water purification to exchange information, identify the gaps in technology and implementation of related programmes and to assess possible techno-economic solutions to fulfill the societal objective of providing purified water. About 225 delegates from Australia, Austria, Brazil, Germany, India, Israel, Italy, Japan, Singapore, South Africa, Spain, Sweden, USA etc participated in the delibera-

At the inaugural function (from left): Dr. P.K. Tewari Head Desalination Division, Mr. Neil Palmer Vice President Asia Pacific Desalination Association (APDA), Mr. B. Bhattacharjee Hon'ble Member National Disaster Management Authority (Government of India), Ms. Patricia A. Burke Secretary General International Desalination Association (IDA), Mr. S.K. Ghosh Director Chemical Engineering Group (BARC) and Dr. S. Prabhakar Organising Secretary.

tions. Representatives from industries such as Befesa Spain, SWS Italy, Outo Compo Sweden, Gerindtec Germany, Hyflux Singapore, IDE Israel, V.A. Tech Wabag, Ion Exchange (I), ROCHEM (I) and many others took active part in the event.

It was interestingly stated that total water market in India is estimated as US$ 14 billion for municipal, industrial, residential and other requirements. It is growing at a fast rate. Water recovery and reuse is followed in several industries and has successfully demonstrated its usefulness. Industrial water market is about US$ 3.5 billion. Gross wastewater generation is more than 30 000 Million Litres per Day (MLD) at present and estimated to be more than 80 000 MLD by 2050.

An overview on the programme on Desalination in Australia, China, India and Singapore indicated the increasing role of desalination in meeting the public water supply demand. The membrane desalination has been found to be playing a critical role. At the same time, the advantages of implementing thermal desalination systems particularly linked to waste heat sources and nuclear plants have also been highlighted. IAEA's role in nuclear desalination was highlighted. A full technical session was dedicated to nuclear desalination. It included deliberations on techno-economic evaluation, coupling aspects and operating experience.

Recent advances in thermal desalination and membrane technologies were also presented and discussed. Nanotechnology for desalination and water treatment had a good response from South Africa and Brazil besides India. The technology being futuristic in nature, the papers were research oriented, some of them related to preparation of nano-materials and nano-membranes and the remaining on applications for water purification at

laboratory level. Membrane Development session featured papers pertaining to the development of reverse osmosis (RO), nano-filtration (NF), charged and ultrafiltration membranes. It is felt that membrane development is the key to improve economics and eco-friendly separations. The key areas identified include development of nano-composite membranes, antifouling membranes, proton exchange membranes (PEMFC) for fuel cells and bipolar membranes for water salt splitting. The financing and social aspects included informative lectures from IDBI regarding lending for water sector, Inclusive integrated management of local needs through AKRUTI (an experience of BARC), reject management and the challenges in the implementation of safe drinking water programme.

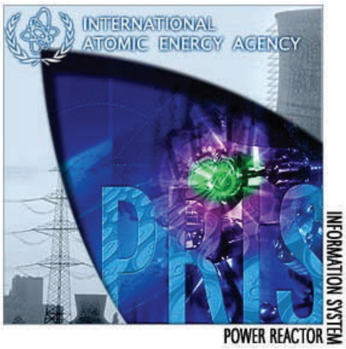
On the last day of the conference, a technical visit was organized to Nuclear Desalination Demonstration Plant (Kalpakkam) and Reverse Osmosis Plant at CPCL (Chennai).

Highlights of IAEA Activities

Updating the Power Reactor Information System (PRIS) with Data on Non-electric Applications of Currently Operating NPP

PRIS is a comprehensive data source on nuclear power reactors in the World. It includes specification and performance history data of operating reactors as well as reactors under construction or reactors being decommissioned. All operating nuclear power plants participate in the PRIS project and provide data regularly.

The monthly production and power losses data are complemented also by information on energy provided for non-electrical applications like district heating, process heat supply and sea water desalination. The set of internationally accepted performance indicators can be used for benchmarking, international comparison or analyzes of nuclear power availability and reliability from reactor specific, national or worldwide perspectives.



PRIS outputs are available in annual publications and on the public PRIS website and through an on-line application. In 2009 the new reporting system PRIS-STATISTICS has been developed. Nowadays entire on-line communication is web-based oriented which makes PRIS globally available. The user friendly interface provides a possibility to easily generate both global and plant specific reports and graphs on nuclear energy status, performance and trends. The system includes also an integrated mapping system.

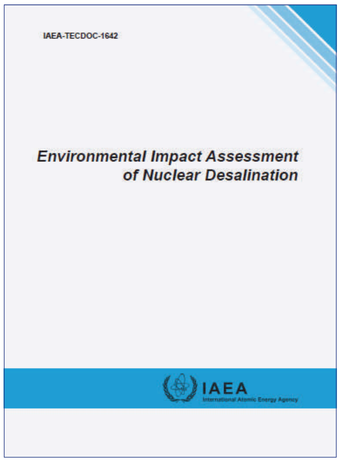
PRIS-STATISTICS supports non-electrical application by providing reports on:

- overview of reactors with different types of non-electrical applications
- nuclear energy utilized for non-electrical applications in individual plants
- electrical equivalent of non-electrical application heat
- percentage of non-electrical to the electrical energy supplied from NPPs

The PRIS website (http://www.iaea.org/pris) provides information for public. It is one of the most frequently IAEA gateways.

Environmental Impact Assessment of Nuclear Desalination

In early 2010, the IAEA published a new IAEA-TECDOC-1642 entitled Environmental Impact Assessment of Nuclear Desalination. The scope of the report is limited mainly to operation related issues related to nuclear desalination and some commissioning issues. Decommissioning of a nuclear desalination plant is considered as an issue concerning more the nuclear power and covered in other publications. Life cycle analyses (LCA) have been limited to LCA values and externalities in order to provide a suitable perspective for the assessment of a nuclear desalination project.



Management of Water Use and Consumption in Water Cooled Nuclear Power

Efficient water use/consumption is very important in several developing countries considering introduction of nuclear power, and in industrialized countries considering expansion of their nuclear power programme. In some countries, the lack of water has even resulted in shortages in electricity generation. Therefore, reducing water use for nuclear power is likely to help developing countries in introducing nuclear power in their energy supply mix.

The efficient management of water use at new nuclear power plants is highly important. Gathering best practices followed on efficient water management and document the approaches. The IAEA has just completed a consultants meeting to finalize the draft document on efficient water use/consumption in water cooled reactors. The document is expected to be published in 2011.

This work is support mainly by an extra budget made available from the USA.

Utilization of Waste Heat from PWRs: Reverse Osmosis with Preheating through the PWR Condenser

Modification of DEEP 3.2 models

Preheating of RO feed-water may increase relative water production – through the increase of permeability with higher temperature - and, in some cases, may even lead to lower costs as a result of higher water production and lower specific consumption (through the decrease of feed pressure as feed-water temperature increases). The phenomenon however is very complex and depends not only on the feed-water temperature but also on the feed-water salinity and the net feed flow. In the actual version of the DEEP code, only a very approximate and simplified correlation is used to take the effect of only the feed temperature on recovery ratio.

This paper describes the essential steps of the research undertaken to elaborate the behavior of important reverse osmosis (RO) parameters as functions of three variables: the feed temperature, the feed salinity and the feed flow. To quantify the combined effect of these variables on RO system performance, nearly 1000 different cases were simulated by the ROSA code. A mathematical treatment of these cases, as indicated in the publication by NISAN et al, then enabled to obtain correlations of the type:

- Recovery ratio = f(feed temperature **x**, feed salinity **e**, feed flow **m**)
- Feed pressure = f(feed temperature **x**, feed salinity **e**, feed flow **m**)
- Feed flow= f(feed temperature **x**, feed salinity **e**,)
- Permeate TDS = f(feed temperature **x**, feed salinity **e**, feed flow **m**)

These correlations were then incorporated into the most recently released version of DEEP: **version 3.2**. Some results obtained from this modified DEEP version are presented and discussed here. The calculations are made in the modified DEEP version with the help of special macros introduced in the DEEP 3.2 template (for the present only the AP600 + RO). The user is allowed two options :1)- calculations with the NDS correlations by choosing the option **NDS** or 2) calculations as before by choosing the option **IAEA**.

Results and discussion

First results, calculated for a 100000 m^3/day RO plant for seawater temperature ranging from 15 to 44°C, are presented in figures 1 and 2. The effect of this variation on the power consumption (figure 1) and water costs (Figure 2) are studied for a feed salinity of 45000 ppm.

Again, figure 2 shows that the effect of increasing the the temperature from 15 to 44°C results in a net decrease of water cost of about 4%. These variations are very case dependent and complex. For given conditions of seawater temperature and salinity the net gain in water costs with preheating may be more than 30% instead of the 4% as shown by the above figure. This was shown in the feasibility study of the EURODESAL project.

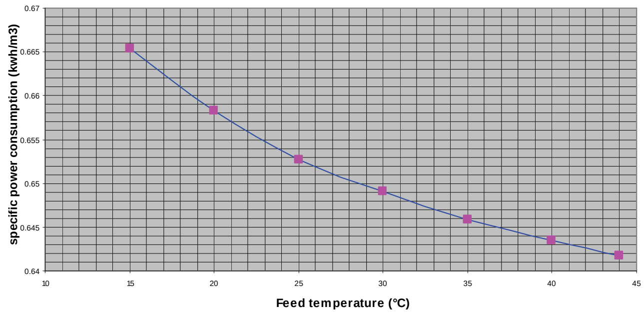


Fig. Influence of feed temperature on specific power consumption

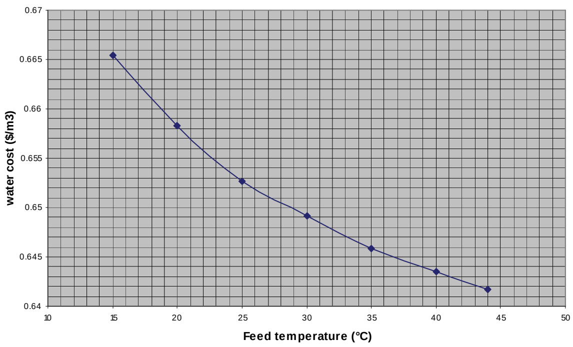


Fig. 2 Influence of feed temperature on water costs

Conclusions

This work was undertaken as part of the first report of the new CRP launched by the IAEA. First results, obtained through the incorporation of new NDS correlations into the recently released version of DEEP (V 3.2), taking into account the simultaneous variations of feed-water temperature, feed flow and feed salinity, confirm the heretofore intuitive conjecture that RO with preheating may lead to significant gains in water costs in specific sites where the available feed water temperatures are lower than 40°C and salinities are within the range 30 000 to 70 000 ppm. In the days to come, the new RO correlations will be incorporated into all available DEEP templates and cases. Experimental verification of the correlations is also foreseen in the context of Indo-French collaboration between the Bhabha Atomic Centre and the CEA.

This article was a contribution by S. Nisan, (NDS international)

List of IAEA Publications on Nuclear Desalination

Environmental Impact Assessment of Nuclear Desalination
(IAEA-TECDOC–1642)

Economics of Nuclear Desalination: New Developments and Site Specific Studies Final Report of a Coordinated Research Project 2002-2006
(IAEA-TECDOC–1561)

Advanced Applications of Water Cooled Nuclear Power Plants
(IAEA-TECDOC–1584)

Status of Nuclear Desalination in IAEA Member States
(IAEA-TECDOC–1524)

Optimization of the Coupling of Nuclear Reactors and Desalination Systems
(IAEA-TECDOC–1444)

Market Potential for Non-electric Applications of Nuclear Energy
(Technical Report Series–410)

Design Concepts of Nuclear Desalination Plants
(IAEA-TECDOC–1326)

Safety Aspects of Nuclear Plants Coupled with Seawater Desalination Units
(IAEA-TECDOC–1235)

Introduction of Nuclear Desalination A Guidebook
(Technical Report Series–400)

Examining the economics of seawater desalination using the DEEP code
(IAEA-ECDOC–1186)

Floating Nuclear Energy Plants for Seawater Desalination
(IAEA-TECDOC–940)

Potential for Nuclear Desalination as a Source of Low Cost Potable Water in North Africa
(IAEA-TECDOC–917)

Use of Nuclear Reactors for Seawater Desalination
(IAEA-TECDOC–574)

Guide to the Costing of Water from Nuclear Desalination Plants
(Technical Report Series–151)

Storage and Transport of Water from Nuclear Desalination Plants
(IAEA-TECDOC–141)

Impressum

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