Annex I.2

DESALINATION PROCESSES AND TECHNOLOGIES

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I.2.1. BACKGROUND

Desalination has become an important method for improving water quality and supply throughout the world. It has become increasingly important as the world has become aware of unacceptable water quality, inadequate supplies, drought situations, and difficulties with inter-regional water transfers.

Desalination is a process discovered centuries ago, but one which has undergone technology breakthroughs in the past four decades. The significant changes which have taken place are the result of rising population in arid areas with poor water resources other than the ocean, industrial development and population which has outgrown traditional water sources. The arid middle eastern countries have experienced the most pressing need for drinking water, and, aided by the abundance of petro-dollars in the last three decades, has spurred the rapid development of desalination processes, particularly distillation.

In other parts of the world, industrial growth has caused the need for high quality water for industrial processing operations. In addition the resulting wastewater has created a dual need for a cost effective, energy efficient process. The membrane processes filled that need with development of low cost membrane separations which are widely used in Europe, Pacific Rim and the USA.

Another factor spurring the development of desalination processes is newly found knowledge of contaminants in drinking water which are detrimental to human health. For example, chlorinated hydrocarbons such as tri-halomethanes (THMs) are now recognized as carcinogens. Giardia muris and cryptosporidium parvum outbreaks (protozoan organisms) in the USA have caused additional health concerns and renewed energy toward better water treatment processes. The recent development of nanofiltration and ultra low pressure reverse osmosis offers cost efficient methods for removal of these contaminants.

In fast developing urban coastal areas, continued withdrawal of groundwater supplies has resulted in the intrusion of seawater, causing increasing salinity in the groundwater basins. An innovative method is widely used in southern California to deter seawater intrusion. Municipal wastewater is reclaimed utilizing traditional primary and secondary treatment, followed by reverse osmosis and disinfection, then injected into a series of wells along the coast which act as a barrier to intruding seawater. The coastal barriers have been extremely effective.

The thermally driven multi-stage flash evaporation (MSF) process is still the most widely used desalination process. This is particularly true in the middle eastern countries, where petroleum is plentiful. Fast developing as a preferred method are the membrane processes, which are non-thermal, and electrically driven. The processes are more cost effective and utilize electricity from existing power grids. In remote areas, alternative energy sources can be used such as solar or wind energy.

There is a serious interest in the use of nuclear power for desalinating seawater. Led by the IAEA, strong efforts are underway to understand the implications of combining nuclear produced energy with desalination. A study has been made of various desalination processes and reverse osmosis (RO) has been selected as one of the processes with most promise, combining low energy consumption with little possibility of contamination with radioactive water. On the other hand, multi-effect distillation (MED) and MSF depend less on feed water quality and, in the case of poor feedwater quality, RO needs more sophisticated pre-treatment and monitoring.

Today, more than 70% of the world desalination capacity is in the middle eastern countries, with Saudi Arabia having the greatest capacity. MSF comprises most of this sub total. The USA is second in world capacity, but nearly all of the installed capacity is comprised of membrane systems. RO comprises most of this sub total.

I.2.2. CURRENT DESALINATION TECHNOLOGIES

(1) Global perspective

Most of the major commercial desalination plants have been built in the Middle Eastern countries. Of these, the majority are seawater desalination plants with integrated power production and desalination. Some recent large plants have been built combining distillation and RO, to take advantage of the merits of both.

In the Americas, the predominance of desalination activity has been with brackish water plants. Most of them are RO and electrodialysis processes. The state of Florida leads the production of desalinated drinking water with more than 570 000 m^3/day of installed capacity. Nearly all of this capacity is low pressure RO, or nanofiltration, for desalination of brackish water. Few seawater plants have been constructed and few are projected for the future. There is great activity, however, in using membrane processes for reclaiming wastewater for secondary reuse, and a leading edge project in California to re-purify reclaimed effluent for direct placement in a drinking water reservoir.

Japan has played a leading role in the development of membrane processes. Since the demise of the USA government effort they have led the continued development of RO membranes. Many Pacific Rim countries have been active in the design and construction of large plants, many in the middle eastern countries. Korean and Japanese companies have been particularly active. Although several small RO plants have been installed with Japanese nuclear plants, seawater desalination has not been applied on a large scale in Japan. The biggest advances have been in utilization of RO and ion exchange for production of ultra pure water.

The countries of the European Union have played a major role in design and construction of many middle eastern desalination plants, and the only graduate program in desalination in the world was established in Scotland. European countries have been leaders in developing desalination processes for industrial use.

Eastern European countries have been slow to develop desalination expertise, but are actively pursuing use of desalination technology. Their primary thrust has been to utilize the technology to accelerate industrial development.

North African countries have used desalination for decades, but mostly with small plants for arid and remote locations. The popular tourist areas are now beginning to use desalination extensively. A few systems in the 10 000 m^3/d range have been successfully installed. The use of nuclear energy to power RO systems is being actively pursued in a number of countries.

South Africa has been active for many years in desalination technology and has spawned at least one active RO manufacturer.

World-wide installed capacity grew to 18 678 000 m^3/d by the end of 1993 when the last world inventory was conducted [I.2-1] and has grown more than 15% in the past two years. There were never more desalination plants built than in the 1992/93 biennium; it exceeded the previous biennium by 22%. Continued growth equal to or exceeding the growth rate in the last biennium is anticipated. The majority of desalination capacity is still located in Saudi Arabia [I.2-1]:

INSTALLED DESALTING CAPACITY BY COUNTRY

Country	Capacity (m^3/d)	Percent of total (%)
Saudi Arabia	5 020 324	26.9
USA	2 749 816	14.7
United Arab Emirates	2 081 091	11.1
Kuwait	1 523 210	8.2
Libyan Arab Jamahiriya	677 750	3.6

Although distillation processes, primarily MSF have dominated world capacity, RO has grown steadily and now constitutes more than 32% of the installed capacity of land based plants. Saudi Arabia, Kuwait and the United Arab Emirates operate more than 69% of the MSF capacity. The USA has greater RO capacity than any other region, but most of the capacity is for brackish water.

INSTALLED CAPACITY BY PROCESS

Process	Capacity (m^3/d)	Percent of total (%)
Multi-Stage Flash (MSF)	9 633 347	51.5
Reverse Osmosis (RO)	6 100 224	32.7
Electrodialysis (ED)	1 070 005	5.7
Multiple Effect Distillation (MED)	765 143	4.1
Vapor Compression (VC)	686 418	3.7
Membrane Softening (MS)	341 299	1.8
Other	104 811	0.6

Even though MSF continues to command the largest percentage, that percent of total capacity has steadily declined from 1984 when it comprised 67.6% of the total. By comparison, RO has stabilized at 32.7% from 20.0% in 1984. Membrane softening (MS) is a relatively new process, which gained favor in the USA when trihalomethanes (THMs) became recognized as carcinogenic constituents in many drinking water supplies. Although THMs are not well removed with membranes, their precursors are removed very well. The practice is to remove the precursors with membrane softening prior to disinfection. MS is a low pressure RO technology.

(2) Reverse osmosis

When solutions of two differing concentrations are placed on either side of a semi-permeable membrane, water passes through the membrane toward the more concentrated side in an effort to equalize the concentrations. The force created by this water movement is called osmotic pressure. For the purpose of seawater desalination or water cleaning, mechanical force is applied to the more concentrated side with a hydraulic pump. Once the osmotic pressure is overcome, water molecules are transported across the membrane to the side with lower concentrations.

Even though there are several membrane processes including RO, electrodialysis, membrane softening, and electrode ionization, the balance of this report will discuss only RO, since it is the only commercial membrane process capable of desalinating seawater economically.

RO utilizes semi-permeable membranes through which water is forced under hydraulic pressure. Water is transported through the membrane, excluding inorganic ions and most organic molecules. The mechanism for transport is generally recognized to be ion diffusion. Currently two basic membrane types are available:

(a) Asymmetric: cellulose acetate polymers which are inexpensive, but require two passes for seawater to reach potable water quality. Polyamide hollow fibers are more costly, but allow production of potable water quality with a single pass.

(b) Thin film: generally polyamide thin films which are cross linked with underlying porous polymer support. They can obtain potable quality water from seawater with just one pass through the membrane. They are more expensive than cellulose acetate, have better chemical resistance and better salt removal, but tend to foul with biologic matter more easily.

The spiral wound design for membrane elements is a unique design incorporating flat sheet membranes into a compact cylindrical configuration. The membrane packing density is vastly improved over tubular and plate and frame designs.

The hollow fiber design is comprised of millions of small diameter fibers (typically 50~80 microns o.d., 20~40 microns i.d.). Feedwater flows around the outside of the fibers and is forced through the fiber walls to the lumen, which conveys the product to the end plate where it is collected.

Pre-treatment of the feed water prior to the membrane section is an important step in RO. Some typical pre-treatments include:

(a) Removal or minimization of fouling constituents
(b) Acid addition or threshold inhibitor addition for scaling control
(c) Chlorination for biologic micro-organism control (and de-chlorination if chlorine sensitive membranes are used)
(d) Micron cartridge filtration.

The degree of pre-treatment required is dependent on the characteristics of the feedwater, and is greatly affected by the type of intake structure adopted. Since RO requires feedwater with low turbidity and suspended solids, natural seawater wells are preferred. The vast majority of seawater RO systems constructed with seawater well fields for intakes have operated superbly. For these systems, only minimal pre-treatment is required, usually consisting of chemicals addition, and micron filtration.

Where seawater well fields are not possible due to the hydrogeology of the site area, submerged or open seawater intakes may be required. Submerged intakes are more successful than open intakes, but still require more rigorous pre-treatment than seawater wells, due to higher turbidity and abundance of ocean biota. Successful plants have been built using bacteriostat and chemical addition, followed by conservatively designed multi-media filtration (low throughput per square foot) and micron cartridge filtration.

Common siting of a reverse osmosis plant with a nuclear plant suggests that the two plants can share intake and discharge structures. Due to the large volume of water required for nuclear plant cooling, an open intake system would be the least expensive to construct. Unfortunately, many membrane fouling problems have incurred with open seawater intakes. Shallow intakes require extensive pre-treatment which may include coagulation, sedimentation, followed by dual or multi-media filtration, chemical addition and micron cartridge filtration. The solutions have been documented, so the proper pre-treatment can be established, but the cost may exceed other alternatives.

Co-location would allow utilization of available thermal energy to raise the feedwater temperature, which may be attractive in areas where seawater temperature is cold. Higher temperature lowers the operating pressure at constant flux, or results in higher flux at the same pressure. These factors would reduce the operating cost and/or the capital cost. Raising of feedwater temperature must be done judiciously, since elevated temperature also results in higher product water salinity, generally results in more rapid membrane fouling (requiring more frequent cleaning), may cause greater membrane compaction (resulting in lower flux or higher pressure), and may reduce membrane life. The savings in total water cost by elevating temperature from 15~18°C to 30°C is expected to be in the range of 3%.

A factor which has become more prominent in recent years is the disposal of the brine. Even though large plants have been operating for many years with brine disposed to the ocean, there has not been a significant amount of research conducted on the effect on local environment. Recent research efforts have resulted in the development of a computer code which approximates the behavior of the discharge plume under various conditions [I.2-8]. The mixing of RO brine with copious volumes of cooling water discharge minimizes the possibility of high salinity brines reaching the ocean floor, which may cause environmental damage. Research indicates that brines can be safely discharged into the ocean environment, but the design of the discharge line and methodology used is site sensitive. The environmental impact will be an important aspect in the design of future plants.

It is doubtful that a large nuclear plant could be built close to a large urban area. This would necessitate the conveyance of product water for a relatively long distance, incurring the additional cost for piping and pumping. Separately located facilities, on the other hand, would require construction of separate intake and discharge structures. All of the advantages and disadvantages of siting must be weighed to determine the most cost effective solution for a particular site.

RO has become widely used because of its effective removal of dissolved solids (approaching 99.5% removal of sodium chloride), organic contaminants, bacteria, and viruses. The removal efficiency of thin film membranes are stable with time, and membrane life is now about five years. Low corrosion materials can be utilized, and operation takes place at low temperature. One of the features which makes it attractive to operators is its simple operation; the process requires little supervision. With proper design and operation, RO plants can achieve 90~95% plant availability.

The recovery rate of a water treatment process is defined as the volume of product water produced from unit volume of feedwater. For seawater RO, the recovery ranges from 30 to 50%, depending on the salinity of the feedwater and the pressure capability of the membrane used. Since RO is a pressure driven process, the driving force must exceed the osmotic pressure of the solution, which increases with the recovery rate.

The product water achieved by reverse osmosis with a single pass varies with the degree of recovery employed. Quality exceeding WHO standards can be achieved. Due to the characteristic of membranes to remove multivalent ions much better than monovalent ions, remaining ions are nearly all sodium chloride. The result is a negative Langelier Saturation Index (LSI), which is corrosive to distribution piping. Chemicals such as lime are commonly added to increase the LSI to a positive level, before distribution.

With regard to equipment, energy recovery devices have been utilized for more than two decades. The early designs were either not very efficient, or unwieldy to incorporate into systems. Recent products seem to avoid both deficiencies, and the energy consumption for seawater desalination has decreased to a standard of about 4.5 kW(e)·h/m^3. Highly efficient energy recovery systems have successfully operated for six or more years, at about 3.2 kW(e)·h/m^3, but these are not yet suitable for large systems. A new energy recovery pumping system has been recently developed and will begin prototype testing soon. Energy consumption in the range of 2.5 to 3.2 kW(e)·h/m^3 is anticipated.

The desire to minimize brine discharge, which necessarily increases feed pressure required to raise the recovery rate, has induced companies to explore higher operating pressures. Pressures of 8.4 MPa for spiral wound elements and 9.8 MPa for hollow fiber elements are now available for commercial products.

The process has developed steadily, having been commercialized in just the last 30 years. Remarkably, the same cellulose acetate formulations developed in the 1960s are still in use today. The thin film membranes were introduced in the late 1970s and represented a true technology breakthrough. Research and development efforts in the last 20 years have not resulted in signs of any new breakthroughs.

Due to intense competition in the past few years, the cost of RO membranes has been reduced considerably. Recent commercial offerings indicate capital cost as low as US $1000/m^3/d installed capacity and water cost of about US $1.00/m^3 (based on standard basis for costing [I.2-9]. The lower cost of membranes and improved equipment and technology will continue to reduce the cost of desalination with reverse osmosis.

(3) Thermal process

The thermal processes discussed in this section [I.2-9] include those processes which commercially deployed acceptance for seawater desalination, and include:
(a) Multi-Stage Flash Evaporation (MSF)
(b) Multiple Effect Distillation (MED)
(c) Vapor Compression Distillation (VC)

The total dissolved solids (TDS) content of seawater varies considerably depending upon specific site location, and may vary from 15 000 to 50 000 ppm TDS. In addition to this inorganic content, various organic species may be present.

Thermal processes are generally excellent for removing dissolved minerals from water. Typically, a unit in good mechanical condition and operated properly can achieve water quality of less than 1.0 mg/l. The removal of organics, including volatile organics is also good. Although volatile organics can evaporate with the pure water, there is little chance of re-dissolving them in the product water if the venting system in the condensing section is designed and operated properly. The volatile substances are removed from the condensing section with the "sweep" steam, used to ensure that all gases are removed from the unit.

The extent of pre-treatment required for thermal systems varies with the design of the system. For higher temperature operation, more complex pre-treatment is required to prevent scaling and minimize corrosive effects.

PRE-TREATMENT REQUIREMENTS

Process	Operating temperature (°C)	Pre-treatment* requirements
Multi-Stage Flash	88	Polyphosphate
Multi-Stage Flash	113	Acid or polyelectrolyte Degassification Deaeration
Vapor Compression	Ambient	None
Vapor Compression	88	Polyphosphate

*(*Seawater requires chlorination for biological control)*

The recovery rate of thermal processes is dependent upon feedwater quality and operating temperature. The difference between the feedwater temperature and the process operating temperature is the driving force for water production. Thus, as the temperature difference increases, greater recovery rates are possible.

MAXIMUM RECOVERY RATES FOR
THERMAL PROCESSES

Process	Operating temperature (°C)	Maximum recovery (%)
Multi-Stage Flash	88	12
Multi-Stage Flash	113	20
Multiple Effect Distillation	71	30
Multiple Effect Distillation	113	40
Vapor Compression	Ambient	40
Vapor Compression	88	50

The temperature difference driving force is produced by raising the operating temperature, normally by steam. Each process also uses electricity for pumping purposes.

A commonly used term in thermal processing is "performance ratio" which is the quantity of distillate produced for a given quantity of energy consumed in the process. It is determined by considering the efficiency of the heat cycle used to produce process energy. The following table shows process energy, primary energy and equivalent oil use at maximum attainable performance rates.

Thermal desalination plants can benefit from dual purpose arrangements, i.e. plants which produce both electricity and water. Benefits accrue from the allocation of energy and costs to each of the processes and are further increased by a reduction in steam costs.

Reliability is very important to plant owners. Processes that operate at high reliability offer the potentially lowest water costs. All desalting processes have demonstrated plant availabilities of over 85 percent.

ENERGY USE PROJECTIONS - SINGLE PURPOSE PLANTS

Process	Recovery (%)	Process & pump Use	Equivalent fuel oil use (m^3 oil/m^3 water)
Multi-Stage Flash	21	53.7 kW(th)·h/m^3 2.6 kW(e)·h/m^3	6.3×10^{-3}
Multiple Effect Distillation	31	43.0 kW(th)·h/m^3 1.32 kW(e)·h/m^3	4.2×10^{-3}
Vapor Compression	50	15.8 kW(e)·h/m^3	3.6×10^{-3}

Process operational flexibility is also an important factor to allow plants to operate at off-design conditions. Flexible operation is required when there are increases or decreases in water demand, changes in feedwater temperature, and cleaning of process surfaces (e.g. heat exchanger tubing). For small changes, demand can be met from available storage capacity. For large changes, operational changes must be made. This requires changes in maximum operating temperature or mass flow rate through the unit or both simultaneously. The ability of a process to meet changing demands must be accommodated in the plant design. Thermal processes can operate at minimum partial load of 25%.

Thermal processes are designed with different plant configurations, which generally refers to the particular arrangement of the heat exchanger tubing. The common arrangements for multi-stage flash, multiple effect distillation and vapor compression respectively are: once through, recycle, single or multiple decks; horizontal tube, vertical tube, feed forward; mechanical compressor or steam-driven-compressor.

The product from thermal plants is of high quality, with TDS in the 1 ppm range. The resulting Langelier index of about - 8.1 is extremely corrosive, and chemicals (usually lime and caustic) are added before distribution.

As with reverse osmosis, brine disposal is an important consideration. In addition to concentration of naturally occurring components from seawater, heavy metals may be present and higher brine temperature will be experienced. Existing seawater thermal desalination plants return the brine is returned to the ocean.

Although it is difficult to generalize when discussing process costs, one may chose fairly standard conditions used by most technologists [I.2-9] and the following comparisons can be made:

DESALINATION COST COMPARISON
(40 000 m^3/d plant capacity)

Process	Capital cost (US \$/m^3/d)	Water cost (US \$/m^3)	
		Single purpose	Dual purpose
Multi-Stage-Flash	1945	2.2	1.78
Multiple Effect Distillation	1430	1.81	0.95
Reverse Osmosis	1000	0.92	

The key environmental concerns for thermal processes are land use, noise, brine disposal impacts, air quality, and construction impacts; however, amenable solutions for these potential problems can be found for nearly every plant.

I.2.3. FUTURE POTENTIAL OF DESALINATION

There is always the potential of improving desalination technology to make the processes more efficient and more cost effective. There are also new concepts which are being researched today which show promise. Although there have been no major breakthroughs in technology since the discovery of thin film composite membranes in RO, subtle improvements were made with each decade. The evaporation processes have exhibited improvements in materials and scale prevention chemicals to make the processes more reliable and more economic.

(1) Reverse osmosis

The greatest potential for improvement in desalination is with the RO process. There have been great strides made in membrane development in the last 30 years which has resulted in improvement of salt rejection from 85% to 99.5%, and improvement in flux from 0.33 to 0.61 m^3/m^2/d at 5.6 MPa. There are other anticipated improvements:

- Membranes. Bacteria and chlorine resistant membranes for seawater service may be just around the corner. Significant research and development effort continues in this area.

- Membranes. Higher pressure membranes and modules continue to develop. Hollow fiber membranes have already exhibited 9.8 MPa capability and flat sheet spiral wound membranes are now available up to 8.4 MPa. These developments will continue, although there are economic trade-offs between increased recovery and energy consumption.

- New membranes. The attraction of new polymers for desalination will continue. New concepts such as block grafting and surface chemistry may result in an entirely new membrane to augment current products.

- Improved pre-treatment. Increasing emphasis on improved pre-treatment will result in new techniques and improvements in traditional methods. Both microfiltration and ultrafiltration offer this possibility.

- Larger membrane elements. The largest membrane elements to date are 30 cm diameter and 152 cm length. With improvement of pre-treatment methods, longer membrane life, and simplified cleaning methods, the handling factor becomes less important and larger membrane elements are feasible.

- Larger membrane modules. Since RO plants are already fabricated in "trains," the commercial availability of pre-constructed standard train packages is close at hand. Packages of 10 000 m^3/d are being prepared for commercial offering. This should further reduce capital cost.

- Efficient energy recovery. For seawater desalination, the recovery of energy for RO is still a key element in reduction of power consumption and hence, operating cost. Several energy recovery devices of higher efficiency are currently being tested and a promising low energy pump/recovery unit is being developed.

(2) Multi-stage flash evaporation

Much of the improvement of thermal processes has already occurred, but additional improvements are anticipated:

- Increasing maximum operating temperature. This can be accomplished by removing scaling components and/or developing better scale inhibitors. The former is feasible by utilizing nanofiltration to pre-treat seawater, which would remove the hardness components. Although this has not yet been done, the concept is sound and nanofiltration is an accepted technology. Improvement of chemicals is the subject of extensive research. The result would be reduction of heat transfer surface area, decreasing evaporator size, and hence, capital cost.

- Development of new materials. There has been a considerable effort to improve construction materials of both shells and tubes. There will be continued improvement with new high temperature plastics, coatings for steel, concrete, and tube materials. These improvements should reduce both capital and operating cost.

- Increase size of evaporator module. There is movement in this direction toward a "standardized design" of ~90 000 m^3/d.

- Raising operating ratio. Through improved new philosophy regarding proper maintenance and possibly larger capacity storage tanks, a higher operating ratio is possible.

(3) Multiple-effect distillation

- High temperature operation. Operation at higher temperatures in the 130~140°C range is possible through improved pre-treatment and uniform liquid dispersion on the heat transfer surface.

- Improved materials. Although aluminum tubes have now been used for some time, improved materials are needed. The difficulty is in achieving the required heat transfer coefficients while using low cost materials which resist corrosion.

(4) Vapor compression distillation

- Larger compressors. The challenge of building larger compressors for this service with reliability and cost effectiveness continues. This should become a reality in the future, increasing module size and reducing both capital and operating cost.

- Cogeneration plants. The combination of vapor compression units with small scale power generation plants (diesel or gas turbine) should be considered.

(5) Alternative energy sources

In addition to nuclear energy, considerable progress is being made in developing alternative energy sources.

- Fuel cells. Several options are being considered including use of fuel cell waste heat for evaporation, operating electrodialysis with the generated DC power, and operating RO by converting the generated DC to AC power.

- Geothermal. Some geothermal resources are already used as a heat source for heating buildings and are projected for use for pre-heating seawater prior to RO desalination processes.

- Photovoltaics (PV). Several years ago, PV was considered for desalination and several small systems were built. The PV cells are improving considerably, and may now be approaching outputs which make it a viable alternative energy source, particularly when used concurrently with improved membranes, pumping and energy recovery systems.

(6) Environmental considerations

Insufficient resources have been utilized to examine the environmental effects of desalination processes. Some of the ongoing research is directed to solution of the following:

- Mitigating the potentially lethal effect of hypertonic solutions on marine organisms
- Oil contamination countermeasures for seawater plants
- Environmentally suitable intake and discharge systems for seawater plants.

(7) Future research approach

There is much room for continued improvement in desalination processes. It will require concerted focus on these problems to achieve the desired results, rather than the isolated, independent studies common to date. With the diminishing availability of research funds, there are added pressures to consolidate research efforts with co-funding from several entities. Joint funding is an approach already embraced by several research institutes and organizations in the USA.

The National Water Research Institute (NWRI) utilizes private funds to seek matching funds from government agencies, research institutes, and private industry to jointly fund water research projects. It is an institute "without walls." That is, none of the research is conducted within the walls of the institute. In a concerted effort to reduce the cost of research, funds are provided to the principal investigator to conduct the research at his own facility, or one which can be provided for him. The next stage of the development will be establishment of National Centers for Research. Facilities at the centers will be made available for researchers to use, supported by the NWRI. They have been joined by the USA Bureau of Reclamation and the USA Department of the Army in this effort.

The establishment of the Middle East Desalination Research Centre is an example of using funds from several different countries to support water research. The Center will also be one without walls, funding R&D at any of several research laboratories and universities in the Middle East. One of the principal assets of the Center will be a communications network in the Middle East, providing access to shared research results. Several countries have already made funding commitments to this effort, and more are expected. The Center was established by efforts initiated by the Sultanate of Oman within the Multi-lateral Water Resources Committee, Middle East Peace Process.

Continued pooling of resources is encouraged to advance the current state of the art in desalination technology. Although the competitive energies of commerce tend to keep research efforts confined, it is hoped that eventually, combined research programmes among complementary companies will be adopted. There is no question that desalination technology is critical to the continued development in many parts of the world.

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