DESALINIZATION OF WATER

John O'Meara*

There are three principal reasons why I consider it a high privilege to participate in the Third Annual New Mexico Water Conference. First, meetings such as this, are the backbone of water resources development planning. Second, I expect to learn a great deal from your discussions, and third, desalinization, my assigned topic for this Conference, is a subject of world-wide interest and growing promise.

The challenge of providing adequate supplies of water to meet our growing demands is indeed great, but to me, this Conference is witness to the fact that you have long ago firmly resolved not to let the lack of water curtail the future expansion of your population your agriculture and your industry.

By drawing upon your inspiring heritage of water resource development, groups such as this will provide the necessary leadership to meet and answer the challenge.

One answer to that challenge is the coming realization of the ancient dream of man -- fresh water from the sea at a competitive price. Often overlooked, but just as important, and of first interest to this area -- fresh water from the vast reserves of inland brackish water.

For purposes of desalinization, the Office of Saline Water divides water into just two general categories:

Sea water containing 35-40,000 ppm (parts per million), dissolved solids, and brackish water, ranging in dissolved solids content from 1,000 up to 35,000 ppm.

Before we discuss the latest developments in the field of saline water conversion, I believe it would be of general interest to review some of the history of man's effort to freshen the salty seas.

We must realize that all of the world's people live on less than one-quarter of the globe's surface. They are dependent for life entirely on the fresh water upon and beneath the inhabitable land. Man's epic struggle to survice on this planet could be written in terms of his constant concern and need for water.

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Through the ages, natural supplies of water, fluctuating in an erratic manner, have governed the rise and fall of civilizations. Some of the most creative and cooperative ventures in the annals of human advancement were applied to the development of water resources. As a part of his quest for water, man has been trying for along time to change salt water into fresh. Probably a lot longer than most people realize.

Aristotle wrote about it. Caesar was able to obtain fresh water from the sea, and in so doing, frustrate the efforts of his enemies when he was besieged at Alexandria. Francis Bacon discussed it in his book "Sylvia Sylvarum," which was published in 1635. Thomas Jefferson conducted some successful experiments in 1791.

Actually, the distiliation of sea water to obtain fresh water is a technique almost as old as the teakettle. The first practical installations came with the advent of the steamship and its requirement of fresh water for boilers. Today, every large ocean-going vessel has its battery of evaporators.

The first large, land-based plants, those in Curacao and Aruba in the Caribbean Sea, were not built until 30 years ago. On these islands there is very limited rainfall, and the character of the land is such that it retains very little water that can be recovered from the ground by wells. The only alternate source of fresh water is by expensive tanker transport.

The plight of the Virgin Islands gives startling evidence of just how expensive it is to obtain water supplies by this method. To supplement the inadequate supplies of natural water on St. Thomas Island, the public works department has been forced to haul water by barge from the island of Puerto Rico. In 1957 they imported 33 million gallons in this manner at an average cost of $6 a thousand gallons.

During the last war, portable distilling units were developed for the armed services to purify both sea and brackish water into drinkable supplies. These stills had extremely small capacities, and their high cost of water production was of secondary importance. They served their purpose by providing a compact, versatile unit that produced an otherwise unattainable supply of fresh water.

During the early post-war years, scientists and technicians were conducting only sporatic research for a more efficient saline water conversion process than could be accomplished by the then expensive distillation process.

During this same period, from a status of barely casual interest, the increasing demand for fresh water began to occupy public interest.

Even the most amply provided parts of the Nation began to evidence concern.

With our population growing at chain-reaction speed, our industrial community expanding at an unprecedented rate and agricultural interests pressing for more irrigation - all at a time when our natural supplies of water were depressed by widespread drought, the value, perhaps eventually even the necessity, of turning the unlimited supplies of ocean water to productive use became unmistakably clear.

To stimulate the scientific search for such a process, or processes, Congress passed the Saline Water Act in 1952. The first law provided $2-million for a five year period to conduct research and technical development work. It was amended in 1955, by extending the life of the program through 1963 and raising the authorization of $10-million.

In the six short years this program has been in effect, Congress has appropriated a total of only $4,020,000, including the current fiscal year appropriation, the largest yet received - $1,170,000.

This is what has been done.

Our research embraces many fields of science, but it is limited by the fact that there are only two basic ways to obtain fresh water from salt.

1. Take the water out of the salt.

2. Take the salt out of the water.

Within these limitations, however, we have many possibilities.

Where should we begin? How can we best solve this problem? These are questions that faced the newly formed staff of the Office of Saline Water in 1952.

The authorized program was designed to encourage private research and development in this general area and to assist such private effort by means of a program of Federally financed research and development contracts where private activity alone did not seem to be making sufficient progress. Public effort both local and Federal was to be coordinated for the purpose of accelerating research and development.

One of the first policy problems to be worked out was to decide what procedures would be followed in deciding who would receive contracts and at the same time make sure than any money granted is wisely used. The problem was solved by adopting a system that had long been successfully used by the National Science Foundation.

When a research proposal is received by the Office of Saline Water, it is carefully evaluated by the staff. If it carries even the seed of a practical idea, it is submitted to several of the Office's scientific consultants - experts outside the Government - for review. On the basis of the consultants' evaluation, the Office may proceed to negotiate a research contract. Research results are later scrutinized by the Office and its consultants. A favorable report may lead to further research or pilot plant development.

To stimulate interest and to obtain the greatest practicable participation of private knowledge and skill, an active campaign was developed at the outset of the program to bring together all existing and new ideas on conversion methods for research and development, and to enlist the cooperation of engineers, scientists, and organizations in exploring these ideas and methods. A brochure, "Demineralization of Saline Waters," was compiled and distributed, outlining all known phenomena or processes that might be considered for saline water conversion.

The success of this campaign can be accurately evaluated. Over six hundred citizens have submitted ideas and proposals. Many of these suggestions have had great value, resulting in research that is developing entirely new processes.

Not all suggestions received, however, are worthwhile. One man, for example, thought it would be a good idea to tow icebergs from the Arctic to the United States, here to be melted down into fresh water. Another contract seeker built his proposal around a rocket with a nose cone constructed of palladium - a metal, he claimed, which permits only hydrogen to pass through it. Fill the nose cone with oxygen, he suggested, and shoot it into the stratosphere. Since hydrogen is the lightest known element, he reasoned it surely must be in heavy concentration at some great height. As the rocket passes through this concentrated layer of hydrogen, the hydrogen will penetrate the palladium, and when twice as much hydrogen as oxygen is in the nose cone, you will naturally have H_2O - water! Just one final Recover the nose cone.

Early experience in the program indicated the need of developing a formula for determining costs of conversion of saline waters. At the outset of the program, the cost estimates made by advocates of the various processes were analyzed. It was found that few of these estimates, if any, included all actual costs. Further, many such estimates of five or six years ago represented optimistic extension of laboratory results to future large-scale application. Thus, for example, it was estimated that projected largesize distillation plants utilizing processes then in commercial production could convert sea water to fresh water at a cost of $1.25 to $1.50 per thousand gallons of product. Overlooked by some was the fact that such large-scale operation had not been actually accomplished.

In an effort to establish an accurate basis for computing costs, the Office of Saline Water prepared and published a "Standardized Procedure for Estimating Saline Water Conversion Costs." This procedure was designed as a standard to include all factors affecting the cost of the conversion product in order to obtain a reliable figure. To compute water costs under this procedure such items as total plant investment; operating costs, including fuel and chemicals used in the process; supplies and maintenance materials; labor; amortization; taxes; interest; insurance; etc., must all be calculated and itemized.

This procedure has proved invaluable for comparing conversion costs, but its use to a certain degree, penalizes the program, because the cost of water supplied from natural sources is not generally computed so comprehensively. In other words, the Office of Saline Water is quoting actual cost of product water, whereas, in many instances, rates for water supplied from natural sources is an arbitrary figure which does not necessarily reflect total cost. It is common practice to charge off the capital investment of a water supply system against property taxes or other revenue sources. I am not sure just what per cent of the cost of natural water capital investment might be, but I do know in converting sea or brackish water to fresh, the capital investment can amount to as much as 75 per cent of the computed cost.

Even with the standardized procedure, cost computation and comparison continues to be a nagging problem. With most of the land-based distillation plants located in foreign countries, we cannot say with certainty that their published conversion costs are accurate by our standards. The flash distillation plant in Kuwait, for example, is converting fresh water from the salty Persian Gulf, for an announced price of .63 cents per thousand gallons. This cost evaluation was computed by the consulting firm of Ewbanks & Partners, London, England. We don't know if this firm considered all the cost factors listed in our standardized procedure to arrive at this figure. Other unusual circumstances affect this announced price. The plant utilizes the waste gas from the extensive oil fields in Kuwait, so fuel is supplied at no cost. Free land, low cost labor, tax and interest-free operation may also be reflected in the product price. The point is, even if the attractive published price of .63 cents per thousand gallons for this process is accurate, it could not be duplicated here.

Estimating fuel oil at $2.40 per barrel, for example, the cost of conversion for this system would jump to $1.87 per thousand gallons.

On several occasions there have been press reports of new processes for which the inventor claimed a conversion cost of only 15 or 20 cents per 1000 gallons. It is only natural that such claims should receive wide circulation, for such a conversion cost would represent a major scientific breakthrough in the state of the art.

Unfortunately, in checking these proposed processes -- and they have all been only that -- a proposal, we have found they are either based on a set of unreliable critical assumptions, or the claimed price represented only a fraction of the actual conversion cost.

Twenty years ago it cost about $5,00 to distill a thousand gallons of sea water to fresh. In line with the economic trend of the times we could properly expect today's cost to be about $10.00 per thousand gallongs, but progress achieved through research and development is bringing the cost of conversion down.

Some of the latest installations are producing fresh water from the sea for $1.75 per thousand gallons. Moreover, we believe plants may now be designed and actually operate to produce fresh water from the sea for $1.00 per thousand gallons. If our present laboratory results prove out in actual operation, we may soon be able to reduce the conversion cost to 50 or 60 cents a thousand gallons.

I have emphasized cost, because the program has only one goal -- converted water at an economic price. All the problems faced by the Office of Saline Water are either born of, or directly related to, cost factors.

While the air has been full of cost claims and counterclaims, research and development has been progressing at a remarkable rate.

Laboratory and economic study to date has narrowed the field from some twenty phenomena or processes to five broad groups: (1) distillation through artificial heat; (2) solar heat distillation; (3) separation of salt by membrane processes; (4) freezing; and (5) chemical or electrical means of separation, including solvent extraction.

Many people have wondered why we continue research in so many different processes. Why not concentrate all research on just a single system? We are exploring the broad field because, first: we do not know which process will ultimately prove to be the most economical, if indeed it has even yet been conceived; and second, it has been ascertained that the various potential processes must be tailored to suit different conditions of providing fresh water from a variety of saline sources, in different locations, for different uses and in various quantities. Some may be best adapted to supply an individual farmstead or home, others to furnishing millions of gallons per day to a city or an industry.

Improvement of conventional distillation processes, both to reduce their high investment cost by increasing the rate of heat transfer and to reduce the energy cost by diminishing the heat losses, engaged extensive study from the first.

Although there are several different types of distillation equipments and cycles, all are presently subject to the same general limitations - scale depostion and corrosion. Scale forming constituents are precipitated out of solution as evaporator temperatures rise above 160^{b} F. The scale fouls heat transfer surfaces and impedes fluid circulation. The brine is corrosive, necessitating the use of expensive alloys.

A series of research and development studies has been in progress in the fields of heat transfer, scale prevention, and less expensive corrosion resistant materials of construction.

A distillation process using long tube vertical evaporators adapted from time-tested equipment widely used in the chemical industry is now under pilot plant test at Wrightsville Beach, North Carolina. In this cycle sea water is passed through a series of evaporators under progressively reduced pressure. The efficiency and economy of this process depends completely on scale free operation. We believe this can be accomplished through new techniques we are testing in the pilot plant operation.

Another pilot plant, also at Wrightsville Beach, North Carolina is testing a vapor compression process invented by Dr. Kenneth C. D. Hickman of Rochester, New York. This system has an evaporator consisting of a stack of eight discus-shaped copper rotors. Sea water is introduced into the inside of each rotor by stationary nozzles; there reduced pressure causes it to evaporate rapidly. The vapor is compressed and condensed on the outside of the rotors, its latent heat passes through the rotors and in turn aids the vaporization process on the inside surface.

The flash type of distillation process is now receiving increasing commercial application. In this process, warm salt water enters an evaporation chamber in which the pressure has been reduced below the boiling point of the salt water, thereby inducing a portion of liquid to vaporize or flash into steam.

Distillation by means of solar heat has the advantage of eliminating the cost of the fuel energy otherwise required. However, the diffuse nature of solar energy makes necessary the use of large areas for collection. The major problem in solar distillation is reduction of equipment costs. Research on solar stills having that objective and of increasing efficiencies has been carried out by the Office of Saline Water. Both glass and plastics membranes have found application as transarent covers for solar stills, and equipment costs are being reduced.

A comprehensive development program on solar stills through contract with Batelle Memorial Institute of Columbus, Ohio, has been initiated. Several solar stills of improved design are being installed for further testing and development at a seashore test station near Port Orange, Florida. Solar stills have attractive possibilities for areas where solar intensities are high and other conversion methods costly or impracticable.

Salt water separation by freezing has been the subject of a number of experimental researches. The use of freezing has certain inherent advantages such as a lesser tendency toward scaling and corrosion because of the low temperatures involved, and more important, the lower energy required to freeze sea water as compared to the energy required to vaporize or bring it to a boil. A direct freeze-separation process developed by the Carrier Corporation of Syracuse, New York, will soon be ready for pilot plant testing.

All the processes just discussed follow the general process formula of taking the water out of the salt. One group of researchers held to the theory that it would be more efficient to take the salt out of the water since the salt represents only 3½ per cent of raw sea water, and in some brackish water less than one-half of one per cent.

Six years ago this theory was little more than a laboratory phenomenon. Today it is a commercial reality.

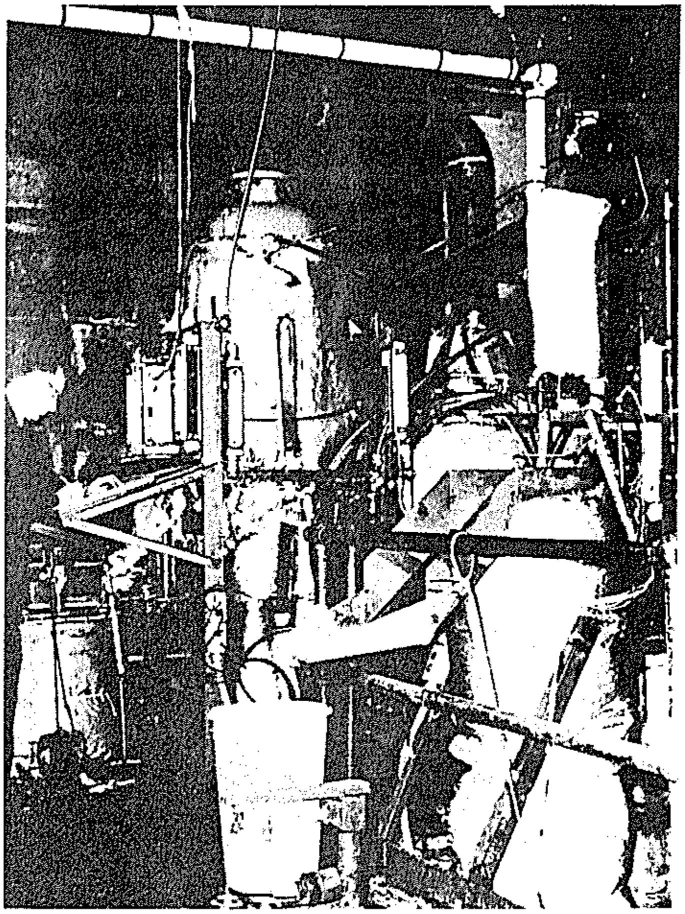
This process, known as electrodialysis, utilizes a combination of electric current and thin membranes of resin or plastic to remove the dissolved solids from the water.

An electrodialysis cell consists of a sandwich of alternating cation permeable and anion permeable membranes. Upon the application of an electric current the positively charged ions, (such as sodium) pass through the cation permeable membranes and negatively charged ions, (such as chloride) move in the opposite direction and pass through the anion permeable membranes. The water in the center chamber of each membrane sandwich is thus depleted of salt while the water passing through the intervening pairs is enriched.

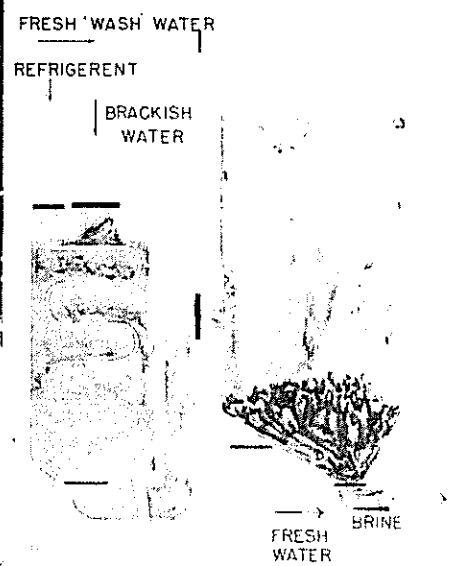
One of the limiting factors in the use of this process has been the membranes themselves. Consequently, during the past few years, considerable research has been aimed at improving the characteristics of those membranes. As a result, greatly improved ion selective membranes have been developed. This process has proved most efficient for the conversion of brackish water.

One of the most advanced electrodialysis processes is that of Ionics, Inc., of Cambridge, Massachusetts, developed through assistance of the Office of Saline Water. More than 20 Ionics production plants are in use having capacities ranging from 500 gallons per day upward, with the largest plant of 86,400 gallons per day in the Middle East at Bahrein.

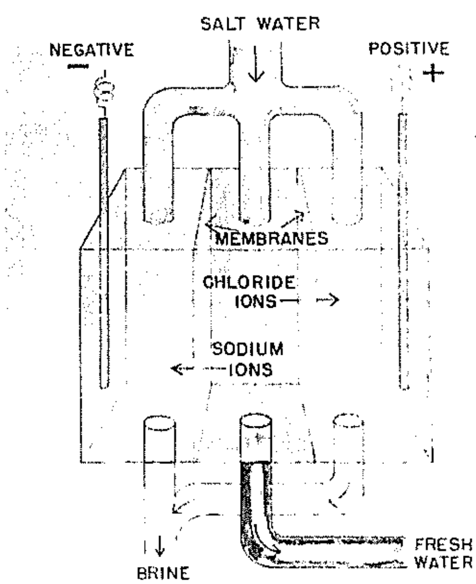
We have expanded our research program to include atomic energy. We have just recently completed a contract study of the applicability of combining nuclear reactors with saline water distillation processes.

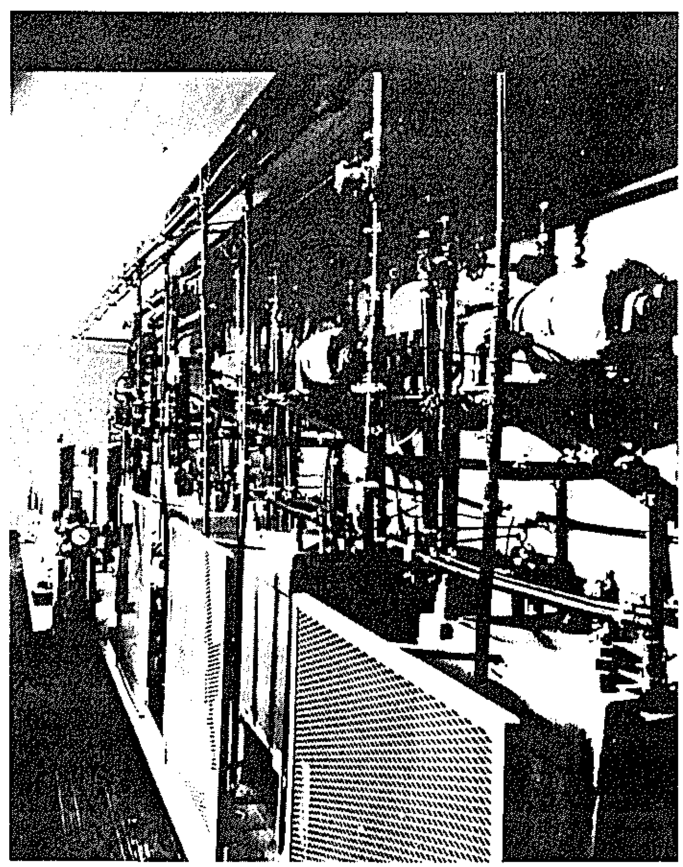


FREEZING



ELECTRIC MEMBRANE





LONG TUBE VERTICAL EVAPORATOR

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NOW UNDER TEST AT
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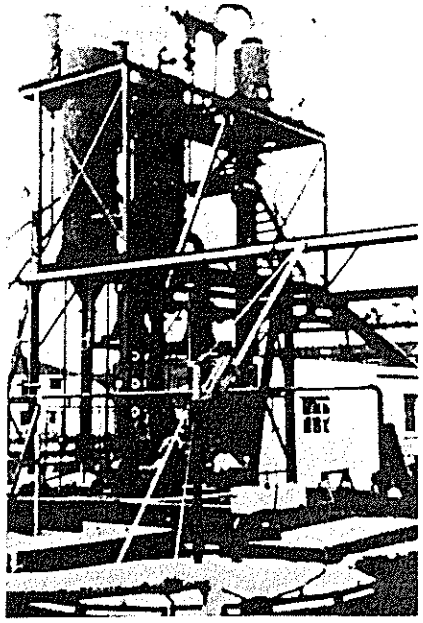
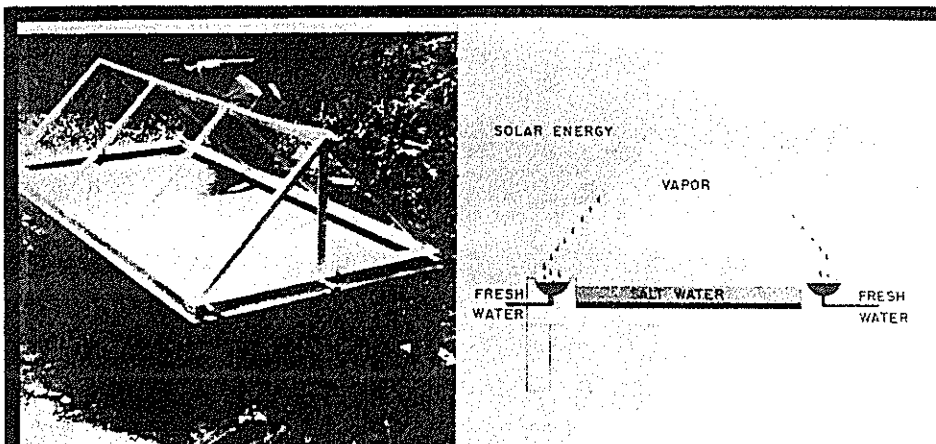
SCALE CAN NOW BE CONTROLLED BY USE OF ACID WITH CORROSION RESISTANT ALLOYS.

DEVELOPING IMPROVED SCALE PREVENTION METHODS TO PERMIT USE OF INEXPENSIVE MILD STEEL





SOLAR STILL

VAPOR COMPRESSION DISTILLATION

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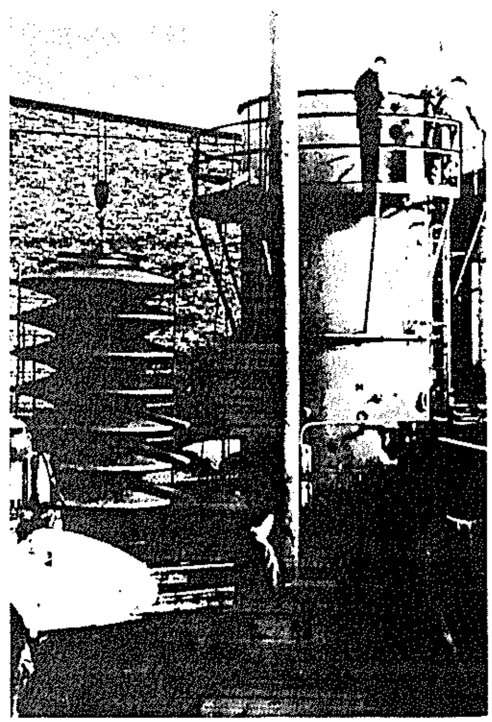
NOW UNDER TEST AND
DEVELOPMENT AT
WRIGHTSVILLE BEACH, N.C.

REQUIRES NO HEAT

ROTATING EVAPORATOR INCREASES PRODUCTION

REDUCES SCALE



A new $98,000 contract co-sponsored by the Office of Saline Water and the State of California has already been negotiated for definitive study of a process reactor-steam plant, in order to estimate costs and establish problem areas for research and development work through pilot plant operation.

We know the conversion of sea water to fresh in great quantities will require the expenditure of a staggering amount of energy - either as thermal energy for distillation or mechanical energy for pumping. The energy requirements are so large, indeed, that it seems unlikely, at least in certain areas, that fossil fuels can supply this energy without seriously affecting the supply-demand balance.

Not only is there a great abundance of nuclear energy, it also has definite potential economic advantages in comparison with other fuels.

We will continue to vigorously pursue our research in the application of nuclear energy as a source of heat for distillation, and at the same time, explore the possibility of adapting its use to the development of other processes.

The Office of Saline Water has negotiated over sixty research and development contracts. Of these: 20 have been with universities and colleges; 30 with research organizations; 10 with industrial concerns; and 3 with government laboratories. These contracts have a value range of $1,000 to $245,000. You might be interested to learn that one of these, a $1,200 contract was with New Mexico Highlands University for a preliminary study of solar energy storage materials. A new $8,000 contract has just recently been signed with Highlands to further develop the original contract studies.

In addition to the research and development contracts, the Office of Saline Water has also entered into five cooperative agreements. One of these is with the State of California. Negotiations are underway for similar agreements with the States of Texas and Florida. Perhaps this group will provide the spark that will bring New Mexico into formal participation in the saline water conversion program. Such participation, as I will point out in a few moments, might have considerable bearing on future developments of the program.

Now, I want to dwell for a moment on the future prospects of the program and, if time permits, I will attempt to answer any questions you may have.

The future is bright.

Plans are now being completed to inaugurate a new and highly important $10-million development program authorized by the 85th Congress. This legislation was introduced by New Mexico's own Senator, Clinton P. Anderson. He was later joined in the sponsorship of this Resolution by Senators Case of South Dakota, Kuechel of California, Wiley of Wisconsin, and Johnson of Texas.

This new legislation authorizes us to design and build not less than five large demonstration plants to test some of the new processes that are being developed.

The Secretary of the Interior, Fred A. Seaton, who, I assure you, has an intense personal interest in this program, will select the first process to be tested on or before March 2, 1959, and the remaining four processes at three-month intervals thereafter.

Three of these processes will be designed to test sea water conversion. One will be located on the west coast, one on the east coast and one on the gulf coast. Two of these plants will have a designed capacity of not less than one million gallons per day.

Two plants will be built to test brackish water conversion processes. One of these plants will be located in the Northern Great Plains and the other in the arid areas of the Southwest. One of these plants will have a designed capacity of not less than two hundred and fifty thousand gallons per day.

The Department is actively seeking State and local financial assistance and cooperation in selecting sites for these plants. Six principal conditions will be considered in reaching a decision on the location, size and type of the five different processes.

These conditions are:

1. The type of process to be demonstrated.

2. Location where water is needed.

3. Availability of the raw produce - saline water.

4. Local factors affecting the plant.

5. The type and extent of local public and private financial support, including the viewpoints of the State or other cooperating agencies.

6. Demonstration value.

A prospectus outlining these six conditions has been prepared and is now available to States or other interested parties. (I have a few copies of this prospectus with me, and will distribute them on a first come--first served basis).

We expect to gain much valuable new knowledge from this program. Knowledge that will bring us much closer to the day we will be able to supply the technological information that will provide fresh water from sea and brackish sources at a competitive price for homes and industry, both here and abroad.

As we continue to make progress in the field of lower cost conversion, the tangible results of potential succes are challenging to imagine: hugh plants rising along the seacoast, capable of producing millions of gallons of fresh water a day; other plants for brackish water inland; providing life-giving liquid to great tracts of now arid wasteland--in America, North Africa, Australia, the Middle East--made to bloom and bring forth a good life and a higher standard of living for men, women, and children around the globe.