

particle and water molecule in a gallon of sea water were enlarged to the size of a sand grain having the diameter of a typed period (.), the resulting mass of sand would cover the entire surface of the earth to a depth of more than 800 feet! Items this small are extremely difficult to handle, yet it turns out that scientific techniques can furnish a surprising amount of information about this submicroscopic situation, and research currently under way is continually giving rise to a deeper understanding of actions and interactions which is so needed to generate new ideas.

One example of a desalting method initiated and developed through research activity to the pilot plant phase of development is reverse osmosis. The first discovery was that by applying pressure on a saline solution in contact with a relatively simple polymeric plastic (cellulose acetate), fresh water would pass through the membrane and salt would not. Even though the flux (water flow rate) was approximately a fluid ounce per square foot per day, it was a major scientific achievement. Many detailed studies followed in a search to discover exactly what occurred inside that thin sheet of cellulose acetate to accomplish this separation. As scientists developed a better understanding of this phenomenon, they were able to design and prepare new membranes which provided improved water flow while retaining the salt rejection properties. Membranes are now available with flow rates of 30 gallons per square foot per day and pilot plants to field test this new process are now nearing completion.

One of the many basic problems scientists faced in the development of the reverse osmosis membrane was to determine why or how the membrane permitted the water to pass while rejecting the salt. It could not be simple filtration because the saline and aqueous component particles are too near the same size. It was necessary to study the chemical natures of the membrane polymer, water molecules, and salt ions. From these studies a reasonable qualitative description of how the process works has been evolved and is guiding further investigation as the search for more efficient membranes is continued.

A great many questions about this process remain unanswered: Why does pressure affect water so much more than salt? What is the exact way in which the chemistry and geometry of the polymer determine paths of flow? How can the procedure of preparation and/or the syntheses of new polymeric materials produce more durable membranes? Why is it that some natural membranes can desalinate? What can be done about the membrane-adjacent buildup of salt which interferes with flow? Answers to these and other questions can be expected to come from the perceptive application of modern scientific approaches, and each new answer can improve the potential of the process.

It is readily apparent that saline water conversion, although a technology having operational and historical ties to engineering development, has its roots in basic science.

Freezing processes provide another example of basic research studies being conducted by the Office of Saline Water. It has long been known that when salt water freezes, the ice crystals contain no salt. The freezing temperature is lowered by the salt, and both the temperature change and the amount of heat involved have been understood for many years in terms of classical thermodynamics. Based on this information, engineers have successfully designed freeze-demineralization processes, but inefficiencies still exist which must be reduced in order to decrease the cost of product water. One area in which more fundamental knowledge is needed and is being obtained is to accurately determine what takes place at and near the surfaces of growing ice crystals. We also must understand better how the size and shape of ice crystals are related to nucleation, to rates of cooling, and to the composition of the solution. This is important because a critical step in the process is washing the brine away from the ice, a step which depends strongly on the nature and form of the ice crystals. We also are obtaining new data and information on the mechanisms and kinetics by which heat, water molecules, and ions are transported to and across the boundaries between ice and solution so that these transfer steps can be made fast and efficient. Careful scrutiny of these research areas leads back to still more fundamental questions.

Similar examples could be offered in other research areas and basic research is being sponsored to extend the frontiers of knowledge. In each case, there are good clues to the fundamental questions. The existing evidence is sufficient to provide ample justification for continued effort by experienced scientists and engineers to pursue basic research studies in desalination. Indeed, desalting is a particularly opportune field of research for the very reason that present proc-