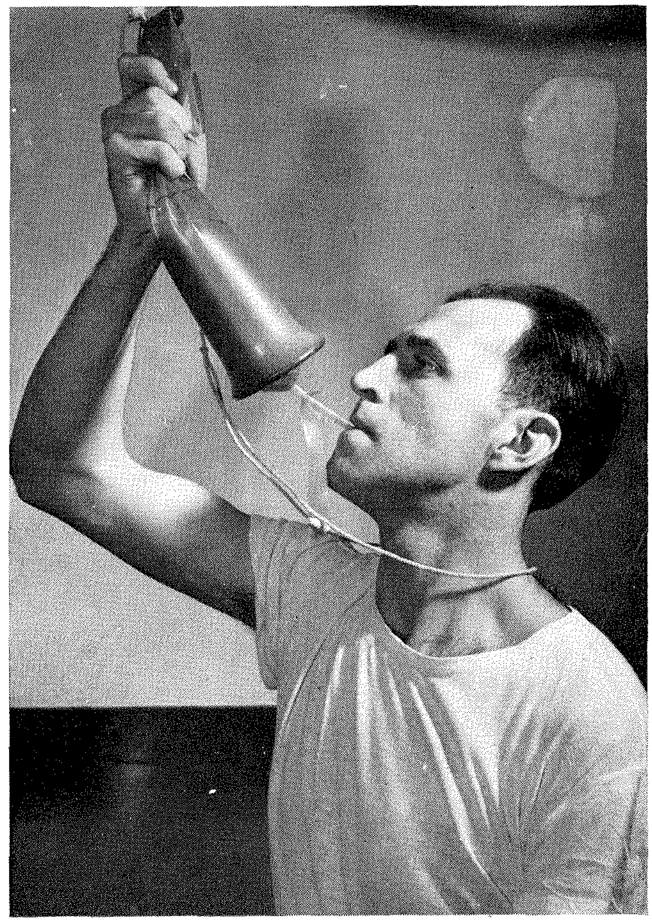
Plastic processing bags, for converting sea water into potable drinking water, became standard life-raft equipment during the war.



Seawater reclamation is just around the corner? Here's the straight story on our chances of getting

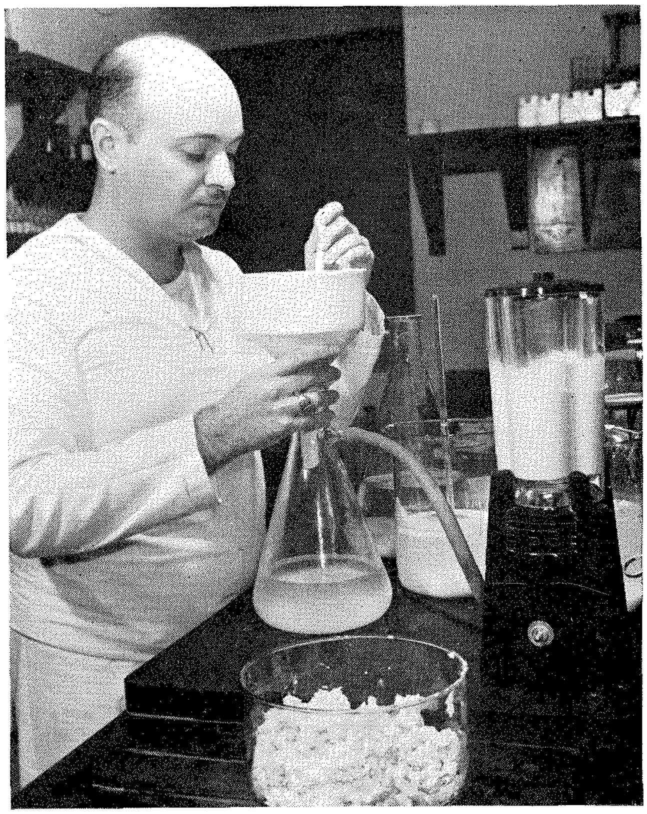
FRESH WATER FROM SALT

by William W. Aultman '27

THERE HAS BEEN A GOOD DEAL of publicity in recent months about the possibility of producing water for agricultural, industrial and domestic purposes from sea water. The publicity has been given added impetus by the severe drought conditions which have prevailed in the Pacific southwest. But what are the facts behind the publicity? A brief summary of some of the factors which affect this problem may help in evaluating the articles which now appear almost weekly.

Where cost is not a consideration it must be admitted that the reclamation of sea water is a possibility. A cost of $5.00 per pint for drinking water produced from sea water by the ion exchange process aboard life rafts was inconsequential when it meant saving men's lives. The entire supply of drinking and cooking water for over 30,000 Army and Navy personnel on Iwo Jima was produced by various types of distillation units, as was the supply aboard many ships and on other Pacific islands. The gallon of fuel that it took to produce from 15 to 85 gallons of potable water from sea water by such distillation equipment was a very small part of the cost of modern warfare, but even that cost was kept at a minimum by limiting the use of such water to 5 to 10 gallons per person per day. This compares with an average use around southern California of over 140 gallons per person per day. But when consideration is given to methods of producing domestic, industrial or agricultural water, cost is a primary factor.

A study made in 1931-32 by the California Division of Water Resources showed that irrigation water in southern California cost from $2.14 to $38.75 per acre foot, depending upon the location and the source of the water. An acre foot of water is that quantity which will cover one acre of area to one-foot depth, which is 325,851 gallons. Domestic water rates may be more than double these irrigation rates, for the distribution of such water to the consumer comprises a large portion of the retail sale price. Continued on page 4



Wartime workers at Naval Medical Research Institute developed method for producing drinking water from sea water.

Production of natural Colorado River Aqueduct water at present costs $12.00 per acre foot or 3.6 cents per 1,000 gallons, exclusive of interest and bond redemption. Ultimately this cost will be reduced to $8.00 per acre foot. At the present time, the approximate total cost of the untreated water, including interest and bond redemption, is about $20.00 per acre foot or six cents per 1,000 gallons. Softening and filtering this supply for domestic use adds another $10.00 per acre foot to the cost, bringing the total cost of treated water at present to about $30.00 per acre foot or nine cents per 1,000 gallons. This is the cost of the water available at relatively high elevations, from which little or no boosting is necessary to get it to the consumer. A sea water supply must be boosted from sea level to the desired elevation of use. In both cases the cost of getting the water to the consumer's tap must be added.

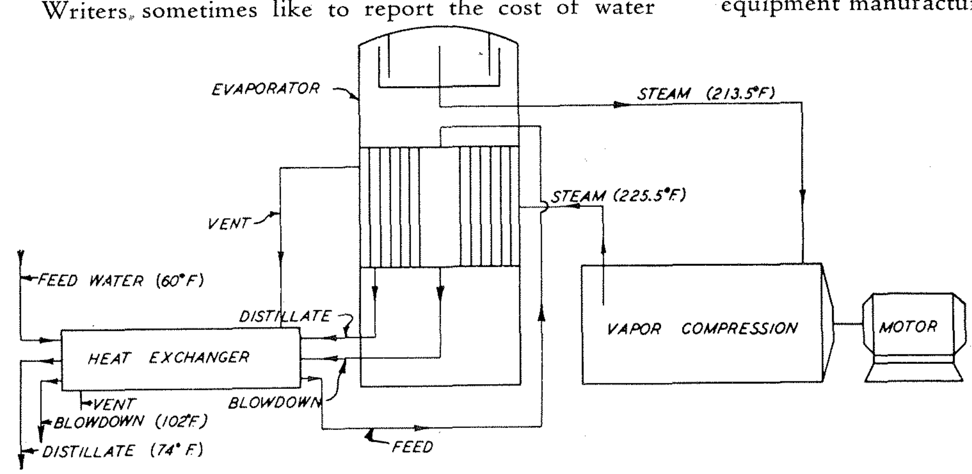
Writers, sometimes like to report the cost of water as so many cents per ton, because, in these terms, it sounds like a lot of water for very little money. A cost of five cents per ton for water is equivalent to $67.80 per acre foot or 20.8 per 1,000 gallons. So water costing five cents per ton is not **cheap** water.

A study of some of the methods which have been suggested for producing fresh water from sea water clearly indicates their economic infeasibility.

The method which presently appears to be the lowest in cost is distillation by multiple-effect evaporators in compression distillation. This type of unit is known as the "Kleinschmidt still", or as a vapor-compression or thermal-compression distillation unit. A good description of this type of equipment is given by Dr. Richard G. Folsom (B.S. '28, M.S. '29, Ph.D. '32) now Professor of Mechanical Engineering at the University of California in Berkeley:

"The compression distillation plant consists of three principal elements—the compressor, evaporator, and heat exchanger. The operation of the unit follows closely that of a normal household refrigerator, except that the latter is a closed system and the former is an open system. In the refrigerator the refrigerant is continuously circulated inside the equipment, where the compressor increases the pressure of the refrigerant and forces it through the system; the heat exchanger removes heat from the refrigerant and transfers it to the outside air, and the evaporator absorbs heat from the box, or area to be refrigerated, and adds it to the refrigerant—which in turn is pumped by the compressor to the heat exchanger, in order to transfer the heat to the outside.

"In the distillation system there is a continuous addition of raw water and a continuous drawing off of brine and pure distilled water. In operation the raw water (sea water) passes through the heat exchanger, where it absorbs heat from the distillate and brine, which in turn is discharged from the system at a temperature slightly above that of the incoming raw water. The hot raw water passes to the evaporator, where it mixes with a relatively large volume of recirculated brine, and heat is added. Steam is then formed at, or slightly above, atmospheric pressure, and is drawn off to the steam compressor, which is similar to an air compressor and raises the steam pressure by about three pounds per square inch and 10°F. The output from the steam compressor passes to the other side of the evaporator, where it is condensed by the removal of heat which is used to create steam from the incoming mixture of raw water and brine. The steam then passes to the heat exchanger, where it is cooled and discharged from the system as the distillate. In the portable equipment manufactured for Army and Navy purposes,



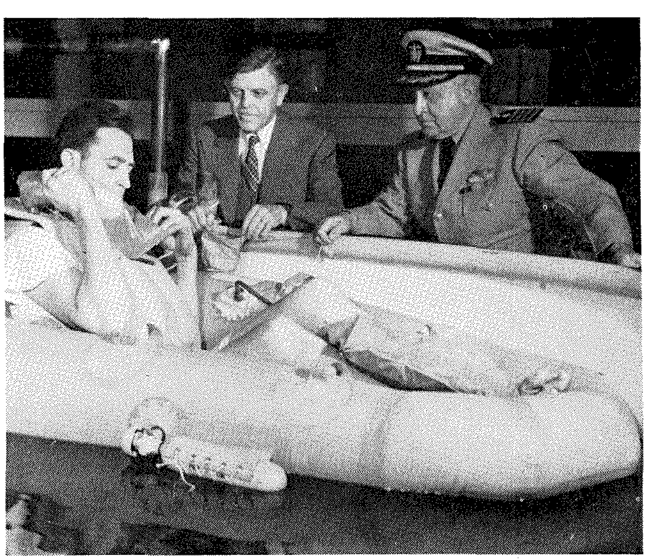
VAPOR-COMPRESSION DISTILLING UNIT: This method of converting sea water into fresh water—described in text above—appears, at present, to be lowest in cost.

the optimum performance appears to be between 175 and 200 pounds of water per pound of fuel, such fuel including the mechanical power to drive the compressor."

One of the major problems in operating vapor-compression distillation units has been the scaling of the evaporator and heat exchangers. As the scale builds up, the efficiency of operation decreases until it is no longer economical to continue the process. Present units have an operating history of about 700 hours before they must be shut down and cleaned. A unit which at the start of operation is able to produce 200 pounds of water per pound of fuel, will produce about 100 pounds of water per pound of fuel by the end of 700 hours of operation. Recent work on this problem for the Army—by Professor W. F. Langelier and his associates of the University of California College of Engineering at Berkeley—appears to have greatly reduced the scaling of the evaporator, so it may be possible to obtain a consistent 200 to 1 fuel efficiency for long periods.

Possible--but practical?

Assuming that a production of 200 pounds of water is obtained from each pound of fuel (192 gallons to 1 gallon), what would such water cost? To produce 1,000,000 gallons of distilled water from sea water would require 5,208 gallons of Diesel oil, or an equivalent amount of mechanical energy. At the lowest quotation presently obtainable for this type of fuel, 9.5 cents per gallon f. o. b. El Segundo, the cost would be $495 per million gallons, or $161 per acre foot of water **for fuel only.** Labor to operate and maintain the stills is estimated to cost from $40 to $200 per acre foot, depending upon the size of the distillation unit obtainable. Allowing for the effect of load factors actually attainable in year-round operation of a water-producing plant, interest, amortization, depreciation, and charges for pumping—since the water is produced at sea level—the total cost will probably be $400 to $500 per acre foot delivered. This is 13 to 17 times the present cost of softened Colorado River water. Distilled water quality is not necessary for a domestic supply, but only 1.4 per cent of sea water could be mixed with distilled water and still maintain the U. S. Public Health Service standard for potable water—500 p. p. m. (parts per million) dissolved solids. This ratio is so small that it would not appreciably affect the cost of producing a potable water from sea water.



Naval Research Institute held wartime demonstrations of sea water conversion in experimental water tank at Bethesda, Md.

To produce 1,000,000 acre feet of potable water a year, the designed capacity of the Colorado River Aqueduct, would require 1,700,000,000 gallons (40,400,000 barrels) of Diesel oil, or its equivalent source of mechanical energy, per year—or about one-quarter of California's total fuel oil production per year. It is entirely possible that larger, more efficient stationary distillation units will be built, but at a water to fuel ratio of 200 to 1 the efficiency of heat recovery is already very high, so it is doubtful if the increase in efficiency could be sufficient to bring the cost of such distilled water within the range of present or future local water production costs.

The immediate question of the layman is, "Why not use atomic power?" Dr. L. A. DuBridge has, I believe, quite adequately answered that in his article on "The Future of Atomic Energy," which appeared in the November 1947 issue of ENGINEERING AND SCIENCE. He says, "I am inclined to believe that 30 to 50 years will elapse before uranium can possibly become a **major** source of power, comparable, say, to present production of electrical energy. And even this assumes that military requirements for plutonium will not take the whole output for the next few years, as they are likely to do. Furthermore, by the time uranium is likely to be a large-scale source of power our power needs will have multiplied so greatly that we will still need full-scale production of coal, oil and other existing fuels."

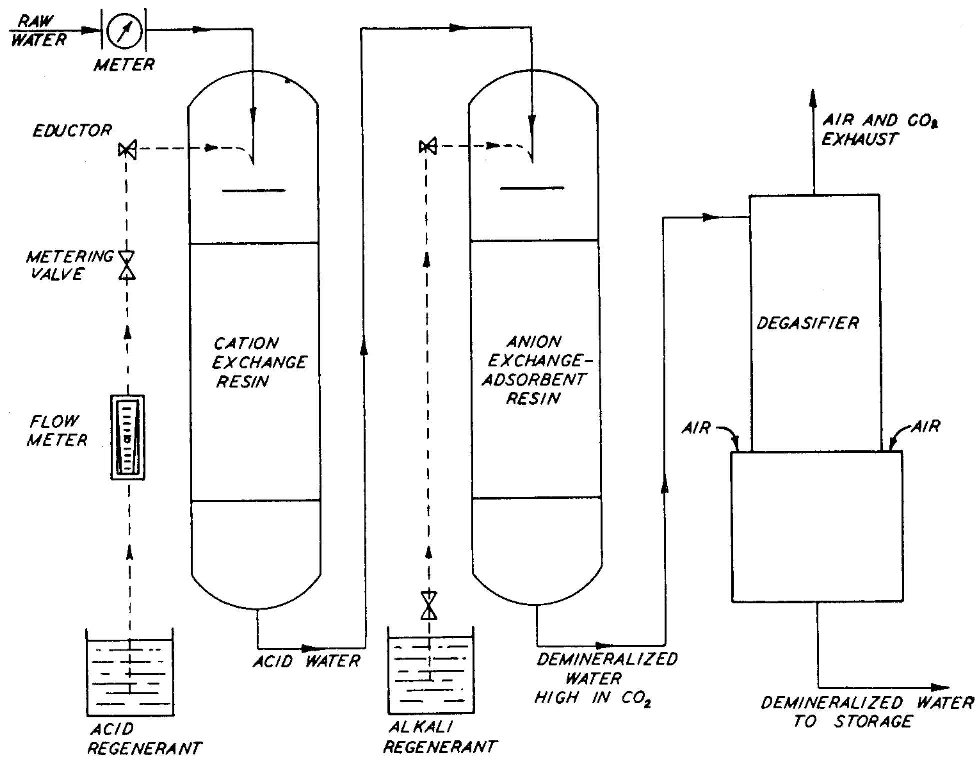
Cheap nuclear fuel?

About the cost of such power when it is available, he says, "Including both plant investment and fuel costs (and neglecting vast development costs) uranium power will certainly cost much more than power from coal . . . . it is hard to see how uranium power can be very cheap . . . . An over-enthusiastic press—and some over-enthusiastic scientists—have created the impression that the **large scale** use of **cheap** nuclear fuel is just around the corner. The sober fact is that uranium 235, while it may be concentrated, it is neither an **abundant** nor a **cheap** source of power. If we use only U-235 there is not enough of it in the world to be very interesting. We must therefore convert U-238 to plutonium, but this is a slow and costly process."

What about other sources of power—from the wind, or the sun, from waves, or tides, or from thermal differences in the ocean? Such energy sources are frequently mentioned in published articles and they sound very alluring to the uninitiated, but many of them have been under investigation for a hundred years, so far without any tangible results. Again quoting Dr. Folsom, in referring to such methods of power production, "Schemes of inventors using these types of energy must be looked at with care."

The development of organic anion and cation exchangers has made possible complete demineralization of water. Their greatest use is in various process industries where the cost of such water treatment is but a small proportion of the total process cost. The cost and the feasibility of demineralization depend upon the salinity of the water before treatment.

There is much publicity in the trade journals about producing water equal in quality to distilled water by such anion and cation demineralization. There is even a statement that this can be done for as little as

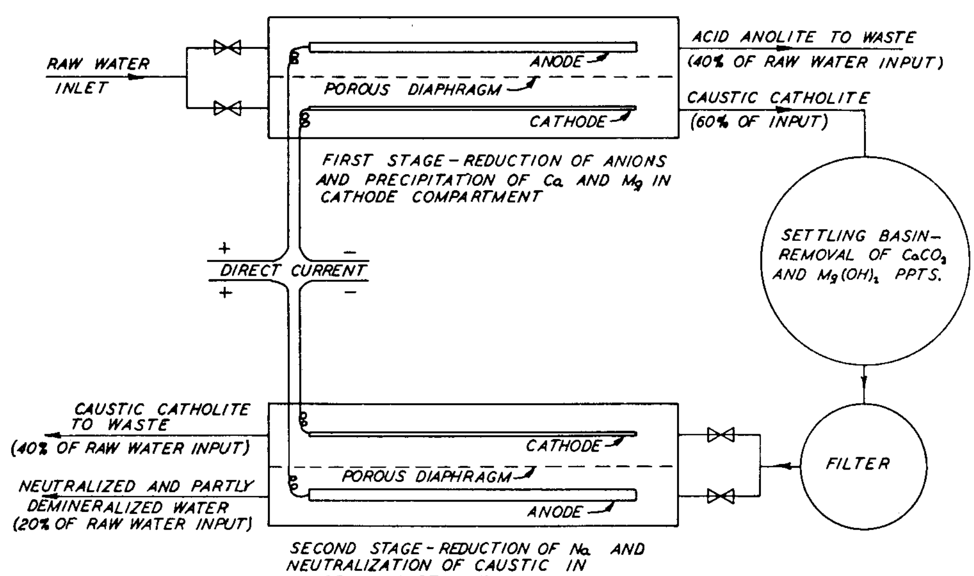


DE-IONIZING SYSTEM UTILIZING ION-EXCHANGE RESINS: Development of organic anion and cation exchangers has made possible complete demineralization of water. But how practical is the process for treating sea water?

26½ cents per 1,000 gallons, or $86.35 per acre foot—but no mention is made of the initial quality of the water being thus demineralized. This process costing 26½ cents per 1,000 gallons will demineralize water containing only about 370 p. p. m. total dissolved solids, a water which is already potable. Sea water contains approximately 36,000 p. p. m. total dissolved solids.

The unit cost of demineralization is directly proportional to the salinity of the water being demineralized. The various manufacturers of anion and cation exchangers report somewhat different efficiencies of ion removal. Assuming what is believed to be a fair average operating efficiency, the cost of the regenerating chemicals (acid and soda ash or caustic soda) required to demineralize sea water at existing chemical prices in southern California would be about $25.00 per 1,000 gallons, or over $8,000 per acre foot. This is the regenerating-chemical cost only and includes nothing for operation, maintenance, depreciation, or interest on the investment. But the factor which completely eliminates this method of producing potable water from sea water is that, when treating sea water, it requires from 20 to 30 times the amount of demineralized water produced, just to wash the regenerating acid and alkali from the demineralizing material.

Another method which has been investigated for producing potable water from sea water is the electrolytic process (below) developed by Robert E. Briggs, Industrial Chemist. This is a modification of the old three-compartment electrolytic method of water treatment. It is a process which has apparent promise in the treatment of industrial and domestic waters, and appears to compete in cost with existing methods of treatment. Studies made by the inventor show that treating sea water requires 180 kilowatt-hours of electrical energy per 1,000 gallons of fresh water produced. With



ELECTROLYTIC SYSTEM FOR PARTIAL DE-MINERALIZATION OF WATER: This process has apparent promise in treatment of industrial and domestic waters. But, for treating sea water, it has serious drawbacks.

power at 5 mills per kilowatt-hour, this would be $0.90 per 1,000 gallons, or $293 per acre foot of water porduced, for power alone. This method would require a water waste of four times the recovery, so 5,000 gallons of water would have to be pumped for each 1,000 gallons of potable water produced. The power required to produce 1,000,000 acre feet of potable water per year by this method would be 58,650,000,000 kilowatt-hours, or 12 times the power output from Hoover Dam.

Several people, in discussing the reclamation of sea water, have pointed out the potential recovery of chemicals from the concentrated salt solutions which would be produced. In attempting to evaluate the profit from the recovery of such chemicals, it would be well to consider the effect that the production of 50 tons of salts from each acre foot of fresh water recovered would have on the present price quotations for those chemicals. Their market value would probably exceed but slightly, if at all, the considerable cost of precipitating such chemicals from the reject brine.

Recently a method was suggested for producing fresh water by freezing sea water. Fresh water can be obtained by this procedure, but again the costs are prohibitive. It is estimated that it would cost at least $1.25 per 1,000 gallons, or $400 per acre foot, to produce water by this method.

From an engineering standpoint there is no question that fresh water can be and is being produced from sea water. But within the forseeable future there appears to be no possibility that it will be economically feasible to turn to the ocean as the source of domestic, agricultural, or industrial water along either coast of the United States. Considerable sums could be spent beneficially in developing existing local supplies by conserving more flood waters, by treating sewage and industrial wastes, and by continuing to develop and protect existing supplies before turning to the ocean as a source of fresh water. Under emergency conditions where relatively small quantities of water are needed, aboard ship, or in such places as the oil fields of Saudi Arabia, the cost of the water produced may not be the determining factor. Sea water reclamation could then be used very satisfactorily.

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Institute to receive Dupont grant

CALTECH HAS BEEN NAMED one of the ten U. S. educational institutions—and the only one west of the Mississippi—to receive a $10,000 grant-in-aid from the DuPont Company for unrestricted use in basic chemical research.

The purpose of the program is to increase the amount of such research, and to insure a steady flow of fundamental knowledge to industry and to the country at large. The first grant will be made for the academic year 1949-50, and if the program proves successful, will be continued for a five-year period.

Other recipients of the DuPont grant are Cornell, Harvard, M.I.T., Ohio State, Princeton, Yale, Illinois, Minnesota, and Wisconsin. The institutions will select the research projects in which the funds will be used, the only stipulation being that they be free from any commercial implications at the time the research work is started.

In announcing the gifts, Crawford H. Greenewalt, president of DuPont, said: "It is well recognized that applied research in industry has been dependent in a large measure upon the fundamental knowledge resulting from the work carried out in the past in universities. Today, however, we see a situation in which such work is at low ebb in European universities, and in which American universities have to some degree turned to remunerative applied research at the expense of the fundamental research which they are so well equipped to carry forward.

"It is the DuPont Company's belief that industry can, both for its own and for the national interest, take a constructive part in making it possible for our institutions of higher learning to reverse this trend away from fundamental research. . . . . The company hopes in this way to contribute something to enable our universities to make further progress in the stockpiling of basic knowledge, which has been recognized as one of the paramount needs of the country for future industrial development and for national health and defense."

In addition, the DuPont Company has renewed its post-graduate fellowship in chemistry at the Institute, and has initiated a corresponding fellowship in physics, available for the first time in the coming academic year.