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THIS IS HOT!

BY ARTHUR C. PARLETT, JR.

The problem of old razor blades is familiar—but the problem of old radioactive isotopes is really a dilly. Where do you throw old isotopes that stay deadly for the next few thousand years? It's a real problem today!

This concerns you.

Atomic power plants are not yet here but they will be soon. The number of nuclear reactors is growing. Because this is so, radiation takes on major importance in your physical environment.

So far the methods developed to keep radiation under control have proven effective; not perfect, they are adequate.

It's a sobering thought to realize that as recently as the middle twenties people deliberately introduced small quantities of radium into their bodies because they wished to enjoy "radiant" health. Many died, horribly, and paid large sums of money for the privilege. In the ignorance of those days—only a little more than twenty years ago—workers in a clock factory employed in painting luminous figures on the dials pointed their brushes by touching them to the lips thereby absorbing infinitesimal

amounts of radium. Some died. And some still live, the radium concentrated in their skeletons still active and inducing sickness, degenerative changes in bones, tumors and cancer. This occurred in the dark ages of our understanding of radiation. Naturally, nothing like that could happen today. Yet—

In 1948, four specially trained scientists, assisting in the Eniwetok peace demonstration, underestimated the danger and exposed their hands to beta radiation. Proper safeguards were provided but these men were in haste.

One recovered completely in fifty days.

Seven months after exposure it was necessary to employ plastic surgery on the hands of the others because unaided nature could not provide a tough enough skin to cover the wounds.

Let there be no mistake: Fa-

miliarity with radiation breeds—respect!

This article has a four-fold purpose:

- (1) To describe how radioactive waste products arise.
- (2) To discuss the nature of radiation and its implications to you.
- (3) To outline the steps now taken to control radiation due to waste products.
- (4) To stimulate thought on better methods of disposal of radioactive waste.

Older readers of Astounding SCIENCE FICTION are urged to refer to the article "Atomic Power Plant" in the February, 1947 issue for an excellent discussion of the basic principles of nuclear reactors, and one possible design of an atomic pile suitable for power generation. For those not already familiar with the operation of a reactor, the following brief outline may be of value.

When an atom fissions, its nucleus splits into two parts. Each part then becomes the nucleus of an atom of another element. The sum of the atomic weights of the generated atoms equals—approximately—the atomic weight of the mother atoms, the difference appearing as energy. Fission is triggered by a neutron entering the nucleus of an uranium atom. Rapidly the uranium atom splits apart and spits out anywhere from one to three neutrons. This is the basis for the chain reaction.

Given proper conditions, these neutrons will enter other uranium

atoms and the process will be repeated. Uncontrolled, we have an atomic bomb wherein the energy release is so fast that temperatures of millions of degrees are reached in millionths of a second. But if the atmosphere of neutrons is controlled by the use of some neutron absorbing, nonfissionable material, the rate of burning can be controlled and atomic fire can be put to useful work—the breeding of new fissionable material, the production of radioactive isotopes for industrial, biological and medical purposes, and the generation of power in form suitable for transmission.

It is not germane to the present discussion to consider in detail the two classes of reactors that are in use at the present time, but mention of the characteristics of each is not out of place. In the homogeneous, or "water-boiler" type exemplified by the Los Alamos reactor, the fissionable material is dispersed uniformly throughout the reactor by making a solution of some soluble salt of enriched uranium. The design is comparatively simple, certainly the construction is more facile than the heterogeneous type discussed below. But as far as the author knows there has been only one such reactor made, and the reason is not hard to find. A homogeneous mixture of natural uranium and graphite, or natural uranium and ordinary water, simply cannot sustain a chain reaction capable of being harnessed. The bombs ex-

ploded over Japan and Bikini were homogeneous reactors, but they employed no moderator and the fissionable material was either U-235 or Pu-239, not natural uranium, nor was any attempt made to control the energy released. If H_2O is used as the moderator, then enriched uranium must be used as the fuel; if natural uranium is the fuel, then D_2O must be the moderator.

The other difficulty connected with the homogeneous type of reactor is the cost of recovery of the valuable products of reaction, which varies directly with the total quantity of material handled. In the homogeneous type of reactor a very large volume of slurry must be handled in order to replace a small percentage of the fuel consumed in the reaction. Furthermore, not only the active portion of the charge to the reactor must be reprocessed, but the diluent as well. Finally, the greater the volume processed the mathematically certain fact is that in absolute terms a greater amount of the sought for materials will be unrecovered, and the waste disposal problems will be that much more important.

On the other hand, the "heterogeneous" type of reactor, typified by Hanford, charges aluminum clad uranium slugs to a lattice of graphite blocks. The holes in the blocks are located on a carefully calculated center-to-center square pitch, and lined with tubes. To make the operation continuous, the slugs of uranium are slowly passed through the tubes,

a spent slug being removed for reprocessing as a fresh slug is charged.

Operation of the reactor produces great quantities of heat which must be removed if the pile is not to melt into shapeless and dangerously radioactive slag. Therefore, some cooling medium is circulated through the annular space between the slugs and the tube wall. At the present time the two media used for this purpose are water and air, both in fantastic quantities, although it is not true, as some of the more naive believe, that the entire volume of the Columbia River is circulated through the Hanford pile. The cooling is done on a once-through and out basis. In the process the coolant is subjected to irradiation by neutron bombardment as it passes through the pile. Contaminated, its impurities made radioactive, can it then be made safe to discharge to the atmosphere or the streams? That is one of the disposal problems.

Here is another. Consider the spent slug being removed from the reactor. Besides uranium, it now contains plutonium, neptunium and various radioactive fission products, e.g., barium and krypton. The slug is removed from the tightly fitting aluminum jacket by chemical means, and the residue is subjected to all the long processes the quantitative analysis student knows so well; fractional precipitation, filtration, washing, reprecipitation, rewashing, et cetera ad nauseam. Once the uranium, plutonium and the fission prod-

ucts have been removed, what are we to do with the waste liquids which necessarily contain some radioactive products?

Accidents must be both guarded against and provided for; they do occur. Suppose an uranium slug should rupture and the uranium and fission products escape into the cooling water and thence into the river. What provisions can be made for such a contingency? Or the even more probable case of spills occurring in a "hot" laboratory may be considered. How is decontamination to be attempted and what shall be done with the waste?

Other than air used as a reactor coolant, which produces significant amounts of argon-41—radioactive—and moderate amounts of carbon-14, probably the most important sources of gaseous waste are chemical separations of fission products from unused uranium and plutonium, and the combustion products resulting from the incineration of radioactive wastes and by-products. It cannot be emphasized too much that radioactivity is not affected by any chemical or physical process; incineration reduces the bulk to be handled but not the radiation to be guarded against. Cases have been noted of radioactive iodine being found in vegetation many miles from the source, carried there by air currents!

At the present time the disposal of solid waste matter is just as troublesome as the other states in which the waste may be. Solid radioactive waste may be exemplified by

such items as contaminated laboratory equipment, valves, motors, piping, and even clothing.

"... The apparent advantages of the compact nuclear fuel... are to a considerable degree offset by the complications... of the disposal of radioactive wastes," says Clark Goodman,* adding in a footnote, "This serious problem has not yet received much attention."

It is possibly superfluous to emphasize the very serious nature of the problem to the readers of a magazine which long ago was printing such stories as Heinlein's unforgettable "Solution Unsatisfactory," and the grim tale of "Tomorrow's Children." Yet it might not be taken amiss if we dwell for a little on the nature of radiation.

Medical history records some nasty passages describing terrible burns and cancerous tissue resulting from the ignorance of the early days of radium and X ray, caused by radiation forces which man did not understand. We seldom hear of these things any more, but it is good to remember that they have happened and that the danger is real, if not imminent. Bear in mind that the total radium supply of the United States is only about thirty ounces, but that in each of our nuclear reactors we have the equivalent of hundreds of tons of radium. Prudence and foresight must mark our way.

*The Science and Engineering of Nuclear Power. Vol. II. Page 291. Addison-Wesley Press, Inc. 1949.

In passing, it might be noticed that one system of classifying radiation subdivides it into two classes, "soft" and "hard." "Soft" radiation is typified by heat and light waves. Some of you photographers may have taken pictures using an electric iron as your source of energy. That was "soft" radiation. It is of no interest to us in connection with this article. What we are concerned with, and what the terms shall always signify in the balance of this piece is "hard" radiation. Equivalent terms are radioactivity, high-energy radiation, atomic energy. It comes from the heart of the atom, originates in the nucleus, and is of two basic and different types, depending upon whether the radioactive atom is a particle emitter, alpha, beta or neutron, or a source of gamma radiation.

As far as effect on living tissue is concerned, it makes little difference which type of radiation is involved. Alpha, beta or neutron particles differ only quantitatively in their ionizing effects from each other and from the X ray type of gamma radiation. What does matter, and matter greatly, is the source of the radiation. Radiation from external sources differs greatly from internal radiation. The former can be directed to specific areas. The effects of the latter depend upon a combination of many factors: (1) The rate of decay of the radioactive material. (2) The amount of such material absorbed. (3) Its quality, i.e., whether it is an alpha, beta, gamma or neutron emitter. (4) How fast the body can get

rid of it. (5) Where in the body it is concentrated.

Fundamentally, the problem consists of this: Ionization of tissue destroys the electrical balance of its components. The molecules, even the component atoms themselves, have their equilibrium upset. They are broken down into charged particles, positive and negative, called ions. It is the nature of an ion to seek its complement: the positive looks for a negative, eagerly searches for means to restore the balance of its electrical forces; and the negative ion will join with any positive ion it encounters. The union need not be a happy one for the body as a whole. New compounds, harmful and even poisonous can form, and the body suffers.

Now, the ionizing effect is a function of rate of radiation, and intensity of the source, and time of exposure. Physicists and biologists have defined two basic terms by which to measure the first two factors, the curie and the roentgen. The curie* is a completely arbitrary unit that defines the number of radioactive atoms that break down in a stated time interval. It is set equal to 3.7×10^{10} disintegrations per sec. This term is a little large for convenient handling, so two smaller units are commonly employed, the millicurie, or 1/1000 curie, and the microcurie or 3.7×10^4 disintegra-

*It is understood that what follows is necessarily something of a simplification. For a brief but enlightening discussion of the curie, and the newer unit, the rutherford (rd), see *The Science and Engineering of Nuclear Power*. Vol. 1, page 22.

tions per second. The specific advantage of having this unit is that it defines very precisely the total quantity of radiating material present. As opposed to the curie, which measures quantity, the Roentgen (r) is an energy term used specifically to measure X ray and gamma radiation. It is defined as 83.8 ergs per gram of dry air. Engineers may find it easier to picture this unit as 3.61×10^{-6} Btu per pound of dry air. To measure the energy of particle radiation a new term is derived—Roentgen Equivalent Physical (rep), which equals 83.8 ergs per gram of tissue. Since the energy loss for an r of gamma radiation in tissue normally will be greater than 83.8 ergs per gram, one r usually does not equal one rep.

It is a curious phenomenon of living beings that the whole is not even the tenth part of the sum of the parts in tolerance for radiation. For example, the LD-50—lethal dosage for fifty percent of an average group—for whole body radiation in man is slightly in excess of 400 r. Yet dosages of 5,000 r are not infrequent in the radiation treatment of skin cancer. The point is that this dosage is concentrated on a small portion of the skin, about one-quarter of a square inch. Parenthetically, something to consider in this connection is the development of a machine capable of irradiating a sharply defined area only 1/25000th of an inch in diameter, soon to be used at the University of Chicago. This is an

area approximately one-tenth the size of the normal somatic cell!

Herein lies the great advantage of a controlled source of external radiation—the possibility of sharply focusing the beam. A less extreme case is the use of X rays in studying certain parts of the body. A series of X rays taken of the kidneys and lower intestines may subject this area to a total dosage of something more than 40 r, yet ill effects from such radiation are rare. This points up another factor—namely that the period of time over which a given dosage is experienced has great influence on its effects on tissue.

As stated, whole body LD-50 for man is somewhat greater than 400 r, yet if this dosage were given in small amounts extending over a year, very little harm could be detected. The body has great powers of recovery.

Many elements enter into the effect of internal radiation upon the system. Once a radioactive substance has been absorbed its effects continue, cumulatively, as long as the substance is active and the body retains it, subject only to the amount—in curies—of the material, the nature of its activity, and whether or not it is concentrated in any particular portion of the body. Iodine, for instance, as is well known, concentrates in the thyroid gland to the extent of seven eighths of the total taken into the body. If the radioactive isotope were so concentrated, the r would be correspondingly localized and intensified. Sodium, on

the other hand, is not specific—as much will be found in one portion of the body as in another.

The effects of an isotope such as nickel, with a half life of thirty-six hours, will be greatly different from those of carbon-14 whose half life is approximately five thousand one hundred years. There are, of course, great differences in the rate of excretion of the different elements: Sodium is excreted almost as fast as it enters, whereas radium will enter and stay from then on, being deposited in the bone structure.

Plutonium, too, enters the bone structure to remain indefinitely, and interfere with the ability of the body to form new blood. It can be detected conveniently only by the methods of urinalysis, and since the amount of plutonium in the urine will rarely be more than 10^{-9} grams per day, regardless of the amount absorbed, the analysis must be very carefully performed.

It is claimed that plutonium is even more dangerous to man than radium. As of today, the most nearly effective treatment developed by the Argonne staff consists in the administration of zirconium. The mechanism is obscure but the result of this treatment is to increase the amounts excreted in the urine. The rate of increase is striking. If zirconium is taken within an hour of the plutonium injection, practically all the plutonium will have been excreted within a matter of minutes. Even should the treatment be delayed for from three days to a week, the use

of zirconium results in a fifty-fold increase in the normal rate of disposal. Even so, it's a long period of recovery from plutonium poisoning, in some cases longer than a lifetime, and the possibilities of stream pollution from this source simply must be eliminated.

Experimental Psychology gives scientific confirmation of a generally known fact: namely, that too much of a good thing is no good, and that intensifying a source of pleasure can transform it into torture. This seems to be a general rule of nature: Nothing too much! Nowhere does this rule hold better than in the use of radioactive isotopes in medicine.

Radioactive iodine, for example, is given in small amounts to patients suffering from Graves disease—exophthalmic goiter—angina pectoris and congestive heart failure. Since it concentrates mainly in the thyroid, Graves disease is treated directly by depressing the activity of the gland; heart conditions are alleviated indirectly because lessening of the thyroid's activity cuts down on the demands on the heart.

Cobalt-60 has many advantages over the use of radium in treatment of cancer, not the least of which is its availability in several more or less pliable forms with varying degrees of activity, and also is being widely used in studies involving nucleic acid metabolism; radiophosphorous finds application in the field of blood disorders, especially leukemia and polycythemia.

But radiation can cause cancer as well as treat it, can cause glandular disturbances as well as relieve them, can bring about blood disorders as well as cure them. Atmospheric and stream pollution became a most important hurdle on the road to the application of the principles of nuclear power.

One danger that was in the foreground of the investigators was the possibility engendered by the tendency of life forms to concentrate scattered elements—the tendency that has caused life to be described as negative entropy. "In the case of stream and river pollution, did a possibility exist that one life form, say algae, would absorb some radioactive material and concentrate it, be absorbed by another life form which would further concentrate the radioactivity, then by another and so on until it would wind up in man? The concept was not farfetched. Remember that iodine in the sea is present in concentrations too low to make direct recovery profitable. Certain types of sea weed, however, perform the extraction readily enough, and concentrate it sufficiently to support a very profitable business. Zirconium is present in sea water in concentrations in the order of 10^{-6} , yet some sea creatures find it indispensable and have no difficulty in obtaining enough for their needs. No, the danger was a definite possibility.

Even now the evidence is not all in. But the indications are that such concentration does not occur. The

first step might, and even the second, but from there on the localization of certain chemicals in certain parts of the organism takes over, and the greatest concentrations appear to be within the bone structure, the nonedible portions of the fish.

It should now be clear that the real problem was not the total elimination of radioactivity from all waste—although that remains the desideratum—but rather the holding of radiation to safe limits beyond the possibility of dangerous reconcentration. The Health Physicists went to work on this problem, and the first item they tackled was, of course, the determination of what "safe limits" meant when expressed as curies and reps.

There are anywhere from six hundred to eight hundred radioisotopes of the elements of the periodic table, each of which has a different level of activity. Some are particle emitters, some are gamma ray radiators, all must be investigated. It's a terrific job these men have done and continue to do against heavy odds and in the face of overwhelming time pressure. The men of the Health Physicist group deserve far more credit than is generally given them.

Working frequently with sparse data, often dealing with mixtures of many different radioactive isotopes, they had the terrible responsibility of setting the limits to radiation levels that could be permitted in the streams, in the atmosphere without danger to you.

For the most part they worked by

extrapolation of known effects produced by X ray and gamma radiation in the biological and medical laboratories. Laboratory animals, white mice and rats, hamsters, guinea pigs, bats—which are mammals, yet their wings are thinner than fine tissue paper and hence permit direct observation of the effect of radiation on blood circulation—were and are being subject to varying amounts and kinds of irradiation. Always, in applying their findings to the human race, the thought was ever uppermost that whatever they found could only be an approximation. Species differ so widely in their tolerance for various forms of radioactivity that extreme care must be exercised in the interpretation of results. Consider, for example, the case of radium poisoning.

The animals tested would appear to the nonspecialist to be far more resistant to the effects of radium inhalation than man. Without the knowledge gained through the painful burns and skin lesions and cancers of the technicians of the early days of radiation study, it would appear that the permissible level for radium could be set far higher than is actually safe. Behind the apparent discrepancy is the curious fact that long periods of time are required for the full effects of radium poisoning to make themselves felt, sometimes decades, and rats and guinea pigs do not have a life span of sufficient length.

But with all that, there is still a great difference in the resistivity of

the various species: The LD-50 for man has already been stated to be slightly greater than 400 r; for the rat the LD-50 lies between 825 and 900 r; whereas for the guinea pig, the LD-50 is only 250 r. So the Health Physicist had to consider variation in tolerance from species to species in setting up his tolerable limits.

Notice also that life is a chain, and that no one can say with confidence that there is any species that does not have some influence upon every other species. The tolerance levels must be so set that not only would man and his domestic animals be unharmed by possible concentrations, but nothing must be done that would upset the balance of Nature.

A realistic approach to the problem also had to concern itself with natural radiation background. All of us are subject to radiation no matter where we live. Our planet is constantly being bombarded with cosmic rays, and certain amounts of gamma and particle radiation are experienced in every locality. The activity level may be low, but it is significant. For instance, in the neighborhood of sea level a person normally receives about 2 to 3 r of radiation in the course of his life; in the neighborhood of Denver the dosage runs somewhat better than 20 r. The criterion to be followed, therefore, was that the amount of radiation contributed to the surroundings be not significantly greater than the

amount of total background radiation.

Limits for discharge to potable water were set at 10^{-5} microcuries per cc.; 10^{-6} microcuries per cc. is the standard permissible limit for air. These limits contain a large safety factor, ranging from 10 to 100.

The normal person can easily withstand a daily amount of irradiation amounting to about 1 r without serious effects. Applying a safety factor of 10, the maximum amount tolerated per employee at any of the atomic centers was set at 0.1 r per day, and this has recently been lowered to 0.3 r per week because some slight enlargement of the ovaries of mice occurred at a daily dosage of 0.5 r per day.

Fundamentally, there are only two possible ways of controlling the amount of radioactivity discharged to nature in the waste products of our nuclear plants. It is a disconcerting fact that radioactivity can only be discharged by time. Man can do nothing to hurry the process. He can do only one of two things: (1) He can dilute and disperse, or, (2) he can confine and control.

It hasn't often been stressed, but the best place to hide a needle is not in a haystack but in a needle factory. Similarly with the dilution of radioactive isotopes; the best diluent is their stable form. A numerical example will make this clear.

Let us assume that the permissible level of radiation for a given isotope is twenty-four microcuries in the organ of maximum concentration, and

that this organ contains four hundred grams of the chemical element. If the two forms of the element are uniformly distributed, then the dilution ratio of 400/24, or 16.7 grams of stable isotope per microcurie of radioisotope would make it impossible for greater than the permissible radiation to take place. If radioactive carbon dioxide is being discharged up a stack, dilution with the stable, ordinary form of this gas is far and away the best method for preventing dangerous concentrations.

When gaseous wastes are vented to the atmosphere without such dilution, the off-gases are very carefully monitored, and meteorological conditions must be such as to insure maximum dilution. The author recently visited Brookhaven to observe their methods of control of atmospheric pollution, since his own industry has somewhat similar problems. He was amazed at the thoroughness of the meteorological group's approach to this problem, and the advances which they have made even over Sutton's* mathematical approach to the problem. Based on their continuing study of atmospheric conditions they have found that it would take a backlog of six or seven days of very adverse weather to force a change in the re-

*"The Theoretical Distribution Of Airborne Pollution From Factory Chimneys" *Quarterly Journal of the Royal Meteorological Society*, V. 73, pp. 426-436, 1947.

"The Problem Of Diffusion In The Lower Atmosphere" *Quarterly Journal of the Royal Meteorological Society*, V. 73, pp. 257-281, 1947.

"A Theory Of Eddy Diffusion In The Atmosphere" *Royal Society of London Proceedings, Series A*, Vol. 135 1932, pp. 143-65.

actor operation schedule. Naturally, the coolant air is filtered both before passing through the pile and after, so that the major radioactive material present in any case is the shortlived radio-argon.

The handling of liquid wastes presents some problems that are unique, and one potentially very important means of removing dangerous contamination from streams.

The chief sources of liquid waste have already been indicated to be cooling water, chemical processing for recovery of fission products and laboratory spills. The aim here is to achieve the proper conditions of dilution so that dispersion becomes permissible. Dilution of the radioactive material is accomplished when possible by simply decay of the isotope in storage. When sufficient half lives have passed, and check with instruments provides assurance that the material has cooled sufficiently, it is simply discharged. When this is not possible, other techniques must be used, one of the most important being the same basic type as is becoming more and more important in the production of industrial water—the use of ion exchange which permits concentration to a volume more suitable for storage. When other types of treatment fail to reduce the activity of the waste to a satisfactory degree, the only remaining solution is to store the material indefinitely. It is readily seen that this is expensive, and better means of disposal are constantly sought.

The cooling water irradiated dur-

ing the operation of the Hanford pile is held in a retention basin under carefully monitored conditions, and not until the level of activity is reduced to permissible limits is the water returned to the Columbia River.

It may be of interest to note that the actual degree of contamination of streams is usually much below the level of activation of the monitoring instruments. In this case, the technique is to obtain a sample of given volume and evaporate this down to a concentration that permits a reading to be taken. When this has been accomplished, the actual activity level in the stream is computed by simple ratio.

Incidentally, although the principle of the Geiger counter and similar instruments is too well known to justify discussion here, it is worth observing that its use is not as simple as one might expect. At Oak Ridge, for instance, they claim that it takes at least a month to learn how to use one properly and to interpret what it says correctly. Monitoring is not a job for the amateur.

Biological treatment of contaminated waters is of increasing interest. This is a treatment borrowed from the sanitary engineer's techniques of treating sewage. It involves the use of activated sludge, i.e., sludge containing aerobic microorganisms which digest the raw sewage. In atomic plant waste disposal, the sludge is made up of a gelatinous mass in which great colo-

nies of bacteria are imbedded. The membranes of the bacteria are greatly swollen by the absorption of water, hence they offer a very large surface area suitable for the capture of radioactive isotopes. As an example of what may be accomplished by this means, research indicates that a two-stage process of this nature will extract ninety-nine percent of plutonium from liquid wastes. The potentialities of this method of treatment are obviously enormous, but as yet they have not been thoroughly explored.

The problems associated with the disposal of the various types of waste are very closely interrelated. In some cases, laboratory equipment may be decontaminated by washing with citric acid, peroxide and/or permanganate. This is obviously not a solution; it is merely a transfer of the problem from one phase to another, where it may be handled by any of the methods outlined above.

The techniques of confinement and control are most generally applicable to solid waste material. If the solid is not itself radioactive but merely contaminated with radioactive materials, the possibility of decontamination exists. Where this is not possible, all that remains is (1) to segregate the waste and let it decay under carefully monitored conditions, or (2), get rid of the material in the safest manner possible.

This last might be achieved by dilution in concrete and burying in the sea, or concentration by evapora-

tion, ion exchange, precipitation, incineration under proper conditions and encasing the residue in some suitable medium and planting deep in the ground under carefully supervised controls.

In a world which will soon see the achievement of the hydrogen bomb, the great concern that exists over a few curies of activity that may arise from operation of the nuclear reactors is somewhat amusing. However, the quickest way to develop neuroses is to start worrying over what may happen. Let it be sufficient to know that the present problem does not present any insuperable difficulties, and that more thought is now being given to the problem than to any similar health contingency.

BIBLIOGRAPHY

Note: The fact there is not very much available in this specific field has encouraged the author to write this paper. Dr. Acbersold told the group at the Seminar on the Disposal of Radioactive Wastes, in January of last year, "If you write a little bit on it, a little bit of knowledge is liable to be an important thing."

GENERAL

- 1.—Cochran, D., and Hansen, C. A. "Some Instrumentation Requirements in an Atomic Power Plant." *Mechanical Engineering*, 71, 10,808. (1949).
- 2.—Davidson, W. F. "Atomic Power and Fuel Supply." *Mechanical Engineering*, 71, 12, 999.
- 3.—"The Science and Engineering of Nuclear Power." Addison-Wesley Press, Inc. Clark Goodman, Editor. Vol. I (1947), Vol. II (1949).

SPECIFIC

- 1.—U. S. Atomic Energy Commission, "Digest of Proceedings, Seminar on the Disposal of Radioactive Wastes," January 24-25, 1949.
- 2.—Isotopes Division Circular B-6. "Interim Recommendations for the Disposal of Radioactive Wastes by Off-Commission Users."
- 3.—United States Atomic Energy Commission. "Atomic Energy and the Life Sciences." United States Government Printing Office: 1949.

Recommendation: Get this volume. It's the biggest value for 45 cents you ever have or ever will see.

SPECIAL

- 1.—"Industrial Uses of Radioactive Materials." A selected Bibliography. Arthur D. Little, Inc., Cambridge 42, Mass. Note: The Arthur D. Little, Inc. has prepared this very useful bibliography for those interested in the applications of radioisotopes to various fields of industry. It is a very excellent reference to have in your library.

THE END