Health Hazards in Radiation Work

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THE CONNOTATION of the term *radiation hazard,* which has become common in the last decade, is limited almost entirely to dangers associated with ionizing radiations, and it is with this restricted concept of radiation hazards that the present discussion is concerned. Accordingly, the term *radiation,* unless obviously used in its broader sense, implies ionizing radiation. It is well to reflect in passing, however, that along with ionizing radiations one should also class as hazardous certain other radiations which, having been known much longer, have grown familiar and are generally considered to present no threat to man's well being. Radiant energy in the form of heat and light has definite biological effects, not all of which are either harmless or clearly understood. The disastrous effects of an increase in the sun's temperature beyond the relatively narrow range that is tolerable have received their share of speculative attention. Of more immediate importance is the possibility that as the result of exposure to excessive heat one may suffer severe or fatal burns. The effect of overexposure to sunshine is of no less significance, for there is unequivocal evidence that in addition to producing painful sunburn and even immediate death, such overexposure can induce skin cancer under certain conditions. On a purely statistical basis, the possibility that an individual will incur damage as a result of overexposure to radiation is very much greater in these latter instances than in the case of ionizing radiations.

The fact that ionizing radiations could produce injury first came directly to the attention of the medical profession when persons working with radiation began to develop definite abnormalities which could not be attributed clearly to other causes. The first examples of such abnormalities were noted within the year following Roentgen's original discovery of x-rays. It was observed, for example, that severe skin reactions and temporary or permanent baldness sometimes appeared after exposure to the rays. By the beginning of 1897, at least 23 cases of skin lesions from overexposure to x-rays had been reported in the literature, and the effects of the radiation on deeper tissues were becoming apparent. In July 1897, a note in a British publication, *Methodist Times* (*13*), referring to roentgen ray experiments on plants, included the prophetic comment, "It is of great importance that we should ascertain exactly what is the influence of these rays on living things, both plant and animals, for no doubt grave considerations of health are involved."

Types of Injurious Radiations

Before proceeding with a consideration of safety standards in radiation work, it is well to review briefly the nature of the radiations that constitute hazards. At the outset, it should be emphasized that all types of ionizing radiations produce similar biological effects —namely, cell destruction of some degree. Biologically speaking, x-rays, gamma rays, alpha and beta particles, and neutrons differ for the most part only in the distribution and the magnitude of the destruction produced.

X-rays are probably the most familiar of the ionizing radiations, and their use for diagnostic and therapeutic purposes is widespread. The properties of x-rays are very similar to those of visible light except that the wavelength is much shorter, so that x-rays penetrate many objects opaque to visible light. The use of x-rays in hospitals and industries constitutes the chief hazard from this type of radiation.

Protection in modern hospital radiology departments is as a rule entirely adequate to insure the safety of personnel responsible for routine diagnostic and therapeutic work. Obviously this is true only if there are no flagrant violations of accepted technique. In institutions equipped with very high voltage x-ray machines, the problems are increased considerably because of the greater penetrating power of the beam. In some cases, these high voltage machines have had to be housed entirely separately in order to avoid radiating the occupants of near-by rooms. Fluoroscopists may receive excessive irradiation, especially of the hands, which customarily enter the x-ray beam to palpate or manipulate the organs being examined. Leaded gloves and aprons afford good protection; however, the fingers of radiologists and others who have occasion to utilize the technique of fluoroscopy repeatedly over a period of years are likely to show some signs of radiation injury, as evidenced by changes in finger ridge detail.

Gamma rays are similar to x-rays, except that they have shorter wavelengths and are more penetrating. Formerly, these rays were observed only in association with the naturally occurring radioactive elements, of which radium is perhaps the best-known example. Now, however, they are also produced by high voltage x-ray machines, accelerators, and chain-reacting piles. Many of the more commonly employed artificially radioactive elements are also gamma-emitters. Potential exposure to gamma radiation is therefore widespread; however, the continuing use of radium in medicine still constitutes an important hazard.

The other ionizing radiations are particulate in nature and in this respect differ from x-rays and gamma rays. The particles of alpha rays are doubly charged helium atoms. These rays are strongly ionizing but only slightly penetrating. Once in the tissues, the radiations are highly effective in producing damage. Because of their poor powers of penetration, however, the slightest barrier will protect a worker from alpha rays. Certain isotopes of all elements heavier than lead are alpha-emitters. Of these, radium and its disintegration products and plutonium and polonium are probably the most commonly encountered, and the possibility that these may gain access to the body by ingestion, inhalation, or through an open wound constitutes the main hazard in this instance. After an alpha-emitting isotope has gained access to the body, a certain proportion of the element is more or less permanently deposited in some tissues, notably bone.

In the case of radium, for example, although the initial elimination following ingestion is rapid, permanent retention in humans has been found to vary between 0.1 percent and 10 percent of the intake, with an average of about 2 percent (*2*). In four human cases of chronic radium poisoning, the coefficients of elimination were found to be from 0.002 percent to 0.005 percent per day, a rate which would require approximately 45 years for the elimination of half the fixed radium present in the body—provided, of course, no further radium intake occurred (*3, 10, 11*). In such instances, the tissues are subjected to constant and highly damaging irradiation. The fact that there is often no efficient method for hastening the removal of deposited isotopes from the body enhances the significance of internal contamination in any work with radioactive isotopes.

Radiologists and technicians who work with radium also run the risk of overexposure to external gamma radiation. As in fluoroscopy, the hands usually receive the greatest dose; however, the total body irradiation is by no means negligible (*12*).

The particles of beta rays are electrons. They have greater penetrating power, but produce less ionization than alpha radiation. Almost all radioactive isotopes are beta-emitters and constitute one of the chief sources of potential exposure. Beta radiation also originates from the various accelerators, but the possibility of direct exposure in such instances is very slight. The prolific production of radioactive isotopes by the chain-reacting pile has made isotopes relatively easily available to many interested groups and the hazards associated with production, transportation, and utilization, as well as disposal of waste products, have increased proportionately. By strict regulation of shipping procedures and by limiting the distribution of isotopes to those institutions which have adequately trained personnel and monitoring equipment, it is hoped that the beta radiation hazard, despite its potential magnitude, will in reality remain small.

The seriousness of the hazard encountered in work involving any type of radioactive isotope is dependent in part on the half-life of the isotope under consideration. Other factors being equal, the longer the half-life, the greater the hazard. This relationship arises from the manner in which the customary unit for measuring radioactivity is defined, i.e., the *curie,* which is that amount of material undergoing the same number of disintegrations per second as a standard preparation of radium. The present value of the curie is 3.61×10^{10} disintegrations per second. Radioactive decay is a first-order process; hence the total quantity of radioactive element corresponding to a specified fraction of a curie increases directly with the half-life, as does the mean duration of potential exposure to the radiations given off. In the case of C^{14}, for example, the estimated half-life of approximately 6,000 years makes work with this isotope more hazardous than would be expected on the basis of the weak beta radiation given off during decay.

Neutrons are uncharged particles which have a mass approximately equal to that of the hydrogen atom. They are produced when atomic nuclei are disrupted by bombardment with alpha particles, protons, deuterons, electrons, neutrons, or gamma rays. By virtue of their zero charge, neutrons have great penetrating power. Formerly the chief neutron hazard was associated with the operation of cyclotrons and to a lesser extent with investigations utilizing such neutron sources as radium-beryllium mixtures. The chain-reacting pile is now an important source of potential neutron exposure, and the prevention of such exposure was an important consideration in designing appropriate protection. It is to be expected that neutron hazards will continue to increase with the constantly growing interest in both the theoretical and applied aspects of nuclear physics, and the associated construction of more and bigger and better particle accelerators in universities and research institutions. Impaired vision as a result of work with neutrons has become of particular interest recently, since several nuclear physicists have developed cataracts (*1*). The production of cataracts by neutron irradiation has also been observed in experimental animals (*6*). All available evidence indicates that gross overexposure is necessary to produce this effect.

Recognizing the Hazard

Since the mere existence of hazards is not a legitimate barrier to progress in any field, the alternative of minimizing the dangers associated with hazardous work had to be accepted and developed. This has involved both the development of criteria for safe working conditions and the establishment and maintenance of such conditions.

The evolution of criteria of safe working conditions is an interesting story. In spite of the early observations that certain adverse effects might follow exposure to x-rays, the obvious implication that harmful effects might result from working with the radiation was not immediately recognized, and many pioneers in radiology suffered severe injuries before the existence of the hazard was acknowledged. This was particularly true of the hands as reflected in the high incidence of cancer of the hands among early roentgenologists.

Utilization of x-rays to treat cancers and other conditions made it possible to study changes in relatively large numbers of persons under fairly well-controlled conditions, and it was soon observed that the radiation was beneficial to the patient only insofar as it was detrimental to the abnormal tissue. In the early days, the problem of therapy was complicated by the fact that there was no convenient or widely accepted method of measuring the dosage administered. The first patients were also treated without benefit of the years of accumulated statistics which now constitute an important tool of the radiation therapist. As a result of these factors, many patients received x-ray doses considerably in excess of the therapeutic amount, and showed clear evidence of damage to normal tissues as well as, in many instances, a marked generalized adverse response to the treatment. Since these early days there has been progressive improvement in the measurement of radiation dosage, and today the techniques are quite satisfactory for therapeutic purposes.

The harmful effects of radiations from radium were not recognized so promptly as in the case of x-rays, and Madame Curie herself died as a result of radium poisoning in 1934 (*4*). This was 32 years after the original purification of radium chloride, and approximately 35 years after the discovery of polonium. The classical tragedy of radium poisoning among radium dial painters in New Jersey during the 1920's clearly established the position of radium poisoning as an important industrial health hazard. In this instance, the workers, mostly young women, ingested highly toxic amounts of radium as a result of the practice of pointing their paint brushes with their lips. The development of severe fatal anemia or bone cancer several years after the exposure was supposed to have ceased demonstrated a major difference between prolonged exposure to small amounts of radiation and prolonged exposure to many other toxic substances (*8*).

Once the hazardous nature of the early radiation work was clearly recognized, evidence of radiation damage was deliberately sought in occupations involving potential exposure to ionizing radiations. In the late 1930's, the increased incidence of chronic lung diseases, including cancer of the lung, among miners in the Joachimsthal uranium mines received considerable attention and was eventually found to be directly related to the radiation received (*9*). A great deal of attention also came to be focused on changes induced in radiologists and others by the small amounts of radiation which they received repeatedly during the course of their work.

Accumulated observations clearly indicated that any effect radiation had on normal tissues was essentially harmful, and that radiation produced more or less damage, depending on the ability of the tissue under consideration to withstand the initial insult and subsequently to repair itself by normal processes. There have been several flurries of interest over the so-called stimulating effects of radiation, but these have invariably turned out to be misinterpretations, usually of recovery phases following radiation damage. Inestimable harm has resulted from ignorant exploitation of the supposedly stimulating effects of radiation. The sale of water containing radioactive material and the therapeutic use of x-rays and radioactive substances by untrained persons have been responsible for many serious or fatal radiation injuries.

As already indicated, much of the data originally used in estimating a safe dose was obtained from patients receiving radiation therapy, and from routine observations on radiologists and technicians. In the case of the latter group, the method of determining the safe dose often consisted of determining how much radiation was received per day under conditions where precautions were considered to be adequate. That daily dose was then considered to be safe if, after a relatively long period of time, there were no observable signs of injury in persons so exposed. There are several difficulties inherent in such a procedure, most of which are readily apparent. First, unless the observations designed to detect injury cover many organ systems, there is a good possibility that existing damage will not be detected because it is not sought in the right manner, or is not considered at all. This difficulty encompasses almost all of the latent changes which may follow prolonged or frequent exposures to very small doses of radiation. Further, as it became apparent that lower and lower doses could produce definite changes, it became equally apparent that there was no justification for risking the health of personnel on the assumption that absence of observed changes implied the absence of injury.

The growing recognition of the harmful effects of radiation on normal tissues resulted in studies designed to determine how much radiation could be received without incurring detectable damage. This amount has come to be known as the tolerance dose. Although there are many differences of opinion as to the exact interpretation of the term, the concept of a tolerance dose is concerned chiefly with repeated exposures to small amounts of radiation over a long period of time. The basis for determining the tolerance dose did not change materially for many years, and most revisions in safety standards consisted of successive reductions in previously accepted permissible exposure levels. Neutron tolerances, for the most part, have been based on the relative effectiveness of neutrons and x-rays or gamma rays in producing certain biological effects. In the case of radium the permissible exposure level (i.e., the permissible amount of radium deposited in the body) was established on the basis of cases of radium intoxication in industry. Gradually, however, a more conservative attitude has been adopted. The issue is no longer how much radiation may be received without apparent ill effects, but how little radiation an organism may receive and still show definite changes, either immediately or remotely.

Recent revisions of tolerance doses have been based largely on the results of long term animal experiments designed to provide detailed information relative to the damage produced by prolonged exposures near the tolerance range. Tolerance levels that have been established for the various isotopes have been determined by similar experiments, taking into account the importance of the metabolism of the substances in question, aside from their radioactivity.

It is clear, after reviewing the development of the present concept of safe working conditions, that one of the great obstacles was the failure to consider the possible existence of radiation hazards. But now, the evaluation of such hazards is one of the most important aspects of health protection in radiation work.

Effects on the Worker

The determination of safe working conditions in any specific instance requires information in three separate categories: namely, information relative to the types and intensities of radiations involved, a knowledge of the nature of the exposures, and an appreciation of the biological effects of these radiations. The various kinds of radiation and the more common instances in which they may be encountered have already been discussed briefly. The intensities of radiation vary greatly, depending upon the nature of the work, and must be determined by careful measurements in each situation. To this end, considerable effort has been expended since the discovery of x-rays and radioactivity, and the development of improved instruments and films for the quantitative estimation of radiation has become an increasingly important aspect of health protection. As a result of the advances in this field, satisfactory quantitative estimation of radiation is now possible in most instances. It is desirable, however, that the physical monitoring devices be more sensitive than any radiation-sensitive process in human physiology, and this has not been achieved in all cases.

Exact determination of the type and intensity of radiation encountered in a given instance is often difficult or impossible because of the mixture of radiations present. This is especially true in the case of cyclotrons and other accelerators, and the chain-reacting piles. Further complications occur in certain of these because the relative proportions of the radiations vary and are not always predictable. These uncertainties render the interpretation of the biological effects which follow exposure to such radiation extremely tenuous and make the definition of safe working conditions somewhat arbitrary, with the result that poor agreement often exists relative to the permissible exposure.

With regard to the nature of the exposure, it has already been pointed out that frequently repeated exposures to relatively low doses constitute the greatest hazard in contemporary radiation work. The problem of a limited number of exposures to relatively large doses of radiation is of more immediate concern in the case of patients receiving radiation therapy or individuals exposed to radiation from military explosions; however, the possibility of occasional accidental gross overexposure in experimental work cannot be entirely overlooked. The health protection program in the various atomic energy installations has been successful to a degree almost totally unprecedented, and there have been remarkably few instances of definite overexposure. A recent official tally indicates that only fifteen such incidents have occurred in the six years since the program was undertaken. Only two of the injuries were fatal, and eleven of the remaining thirteen individuals involved either were unhurt or apparently recovered completely.

An appreciation of the biological effects of radiation plays an extremely important role both in the recognition of radiation hazards and in the definition of safe working conditions. Despite the fact that details of the biological effects have not yet been completely unraveled, certain general aspects of these effects are now well recognized. Studies on animals deliberately exposed to radiation indicate that all tissues do not respond similarly to a given amount of radiation. This variation includes the amount of radiation which the various tissues can withstand without detectable damage, the rate at which they appear to respond to doses which produce damage, and the rate and extent of recovery from damage. Cell division in the skin of the mouse, for example, can be entirely inhibited for a short period following exposure to 35 roentgen units of x-rays, whereas cell division in the adrenal gland of the same animal is only 50 percent inhibited by the same exposure (*14*). Skin, white blood cells, bone marrow, reproductive cells, and the cells lining the intestine have long been known to respond readily to relatively small doses of radiation. Adult red blood cells, bone, and nerves, on the other hand, tend to be more or less resistant. Further differences in the susceptibility to radiation damage can be demonstrated in cells of slightly different lineage within a given tissue, as well as among various constituents of individual cells. In experimental animals it is possible to observe all tissues for gross, microscopic, and chemical changes after irradiation. In man it has been necessary to rely on less comprehensive studies in determining the relative radiation sensitivity of various tissues.

A fortunate circumstance exists in the fact that the blood cells and the tissues from which they originate are among the most radiosensitive of all tissues, both in man and in animals. Blood can also be obtained easily and frequently, with a minimum of inconvenience and no danger to the individual. For these reasons, hematological changes have come to be regarded as one of the important methods of detecting radiation damage, and as more detailed studies are undertaken it appears that hematological changes may be far more sensitive indicators of radiation damage than was formerly supposed on the basis of purely routine observations. In the case of the mixture of radiations originating from the cyclotron, for example, it is possible under certain conditions to observe definite indications of a response on the part of the white blood cells in instances where the radiation received is well within the accepted limit according to routine monitoring devices. Blood findings are particularly important in total body irradiation. When exposure is limited to a single part, as for example the hand, a generalized response may not be elicited and the value of hematological examinations is probably limited. Studies of changes in finger ridge detail, however, are of considerable importance in such cases.

In addition to indicating variability in the response of the several tissues to irradiation, animal experiments also indicate that under certain conditions there may be delayed manifestations of damage from a long series of frequent exposures. Specifically, these late results are premature aging, the indication of tumors, decreased fertility, and genetic changes, as well as the previously mentioned induction of cataracts. These effects have all been observed in animals following continued exposures at levels corresponding to doses somewhat above the accepted safe tolerances for man. The induction of tumors and cataracts, however, are the only delayed effects, that have been observed in man, and these appear to follow only relatively gross overexposures. There is a great deal of speculation and equivocation relative to the possibility that decreased fertility and genetic changes will be observed in man after a sufficient number of years or after a sufficient number of generations, as the case may be. In the absence of sufficient data on humans, however, it has been necessary to rely entirely on the results of animal experiments in predicting the occurrence of such changes. On the basis of experimental evidence it appears, in general, that the greater the exposure, the greater will be the number of gametes with altered genes or chromosomes. Many authorities feel that *any* amount of ionizing radiation may produce hereditable changes and that in any individual the effects are cumulative, not only throughout the life of the individual but throughout the entire life of the germ plasm (*5*). Mutations induced by exposure to ionizing radiation are thought to be of the same type as those which occur naturally, and either chromosome or gene mutations may occur. Most mutations are recessive and their effects on subsequent generations are deleterious, resulting in developmental anomalies, marked interference with early development so that the embryo does not survive, or a decreased fertility. In general, gene mutations tend to produce anatomical and physiological anomalies, whereas chromosome mutations tend to manifest themselves as decreased fertility. In either case, large numbers of the population must be affected if the induced changes are to be significant in subsequent generations.

Not all the experimental evidence supports the postulate that extremely low doses of radiation increase the incidence of mutations. In a recent extensive investigation of several years' duration, various species of animals were exposed daily to radiation in amounts near the tolerance range. Breeding experiments were carried out as a part of the study and the incidence of mutations was found not to be increased above the normal, even though other harmful effects were produced in these groups (*7*).

It has been suggested that even if a slight increase in the production of mutations should occur as the result of exposure, the end result would be altered by such factors as a tendency towards decreased fertility in the offspring of irradiated parents and the tendency for many mutations to be lethal or to shorten the life span and reproductive period of the individual. In other words, natural selection would tend to be against mutants. The possibility that irradiation might occasionally induce the reversal of a previous mutation has also been considered as a mechanism for minimizing the genetic effects of radiation.

The interesting controversy relative to the ability of prolonged exposure to small doses of radiation to induce changes is far from a satisfactory settlement, and the possibility that radiation-induced genetic changes may occur in radiation workers continues to be an important consideration in defining safe levels of exposure.

The limitations of experimental studies utilizing animals can never be entirely removed, even with perfectly accurate measurements, for man is not exactly comparable in anatomy or physiology to any of the experimental animals. The contributions from animal experiments, however, have been extremely important, and the data so obtained have done much to light the way towards an understanding of the biological effects of radiation, without which adequate protection of individuals working with ionizing radiations would have been almost impossible. If the antivivisectionists were to have their way, all of the information now available would be based on human misfortune—even, no doubt, involving some of them. It is doubtful, however, that even an antivivisectionist could suppose that information obtained under such unfortunate and poorly controlled conditions would be very useful to the problem at hand.

Safety Measures

Since it is impossible to obtain all the information necessary to define absolutely safe conditions for man, the accepted standards at any given time will be in the nature of approximations, and it is to be expected that revisions will be repeatedly proposed. The uncertainty involved in designing safety standards, however, has been offset to a large extent by the general attitude of conservatism regarding health aspects of radiation work, and the excellent health records of the many groups working with powerful sources of radiation during the war years prove that it is entirely possible to minimize radiation hazards if sufficient effort is made.

In order to achieve conditions where hazards are minimal, it is necessary not only to recognize the hazards and define safe working conditions, but also to maintain these conditions. The latter point is critically important, and it involves training personnel in the necessary techniques, as well as educating them or at least impressing them with the importance of the imposed regulations. It is also necessary to provide adequate physical facilities for protection and monitoring, and to enforce the necessary regulations. The philosophy concerning work with ionizing radiations should in many ways be similar to that concerning work with disease-producing bacteria and viruses. In both cases, the agent in question is harmless until it invades the privacy of the individual, and the basic rule governing protective techniques is to keep the agents rigidly confined to their own environments. In radiation work, this involves keeping a certain amount of distance between the worker and the source of radiation. This distance must be large relative to the ability of the specific radiations in question to traverse it; however, it may be physically great or small, depending upon the medium of which it is constituted. In most cases the physical distance can be shortened by interposing between the source and the individual a substance which readily absorbs the radiation. This procedure, known as shielding, is one of the most important methods of providing physical protection.

No amount of shielding, however, can replace the individual worker's constant vigilance, for it is only by virtue of individual reliability in this respect that hazards can be kept at a minimum. To this end it is vitally important that, regardless of formal education, the individual be well schooled in the techniques of whatever operations he performs, and that he realize the importance of observing the rules and regulations which apply to his own sphere of activity. In some instances the highly trained professional personnel concerned with research in nuclear physics and radiation chemistry did their initial work prior to the accumulaton of knowledge pertaining to the health hazards involved. In other cases investigators have not kept informed about the biological effects of radiation. Having suffered no apparent harm, they tend to be lax in the personal application of health safety regulations and may be as much in need of education as the most unschooled worker.

Because health hazards in radiation work have been kept so low, the medical profession in general has not been confronted to any great extent with the problem of treating radiation injuries. This lack of experience does not represent any sizable addition to the radiation health hazard, however, for although the biological effects of exposure to radiation may be complex, they are not unique. Treatment will generally be an issue only in fairly gross overexposures, which constitute but a single aspect of the over-all problem. It is generally agreed that there is not, nor is there likely to be, any single specific remedy for radiation injury, to correspond, for example, to penicillin for some infections.

The physiological phenomena following total body exposure consist of a complicated sequence of changes which are more or less interrelated and interdependent. Not all of these are well understood. Treatment may be expected to modify the immediate outcome of radiation injury insofar as it can modify the more devastating changes. Some of these, such as burns, dehydration, anemia, and the diffuse infections which follow marked decreases in the number of white blood cells, can be treated by well-known and accepted methods. Treatment for other aspects of severe radiation injury, where the nature of the basic abnormality is more obscure, is the subject of a great deal of research being carried on at the present time. For example, the problem of treatment of the marked bleeding tendency which develops as a result of single gross overexposures is being approached from many diverse directions by various investigators. In all instances, treatment is aimed toward supporting life and bolstering the body's defenses until natural reparative processes can become active, and it is fair to say that the over-all prospect of treating the more immediate manifestations of acute radiation injury is by no means hopeless. In the case of protracted exposures to doses near the tolerance level, the main considerations are somewhat different. Because of the preponderance of latent changes at these levels of exposure, the problem of treatment is almost entirely one of prevention. This, as has been shown, is entirely feasible. As more adequate treatment of acute radiation injury is developed, the relative importance of latent changes in those instances, too, may increase markedly, and those latent effects which had previously been observed only in experimental animals might become the most commonly observed effects of acute radiation injury in man.

Radiation has gained a permanent foothold in modern science and industry, and society is presently struggling to learn to live with it. Health protection of radiation workers has been remarkably successful in atomic energy installations. It has been possible, for the most part, to keep exposures not only at tolerance levels but considerably below them, and the general health of the workers has been better than that in most other industries. The attitude of alarm which has been so commonly associated with the idea of radiation work can safely be discarded, provided it is replaced by one of healthy respect for protective rules. It remains to be seen whether or not the knowledge, skill, and caution thus far accumulated will be applied on a wider scale now that work with radiation is becoming increasingly common throughout this country and the world.

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