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Protective Measures for Personnel

by
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In the experimental laboratories and production plants where nuclear fission piles were in operation and where the radioactive materials from such piles were used, the problem of protecting personnel has been enormously magnified by (1) the tremendous increase in the numbers of individuals, (2) the undreamed of radioactivity of the materials to be handled, and (3) the fact that work with these materials will continue for years to come and, therefore, protective measures must be based on the assumption that the individual will be handling radioactive materials throughout his lifetime.

Our present means of therapy of persons who are over-exposed to external radiations or of persons who have dangerous quantities of radioactive materials deposited in their bodies leaves much to be desired. Practically speaking, there is no rational or specific treatment for the disorders induced by these radiations. As a consequence, protection of the worker from these substances is of the utmost importance.

I. General Approach to the Problem.

Protection against external radiation is accomplished by the interposition of sufficient material (gas or solid) between the source and the person to reduce the radiation to less than the maximum permissible level ("tolerance" level).

Protection against radiation originating internally from the deposition of radioactive materials within the body is best accomplished by
preventing their entrance into the body. At the present time no good way exists of hastening the elimination of most of the important radioactive elements once they have been deposited inside the body.

A very important part of the protection problem is the education of the worker in the reasons underlying the necessity for the avoidance of unnecessary or excessive exposure to radiations and radioactive materials. Experience on the project and elsewhere has repeatedly shown that unless the worker is convinced of the fact that radiations do have a biological effect and that the work he is doing involves these damaging rays, the best efforts of the administrative group and of the health protection organization will be largely wasted. In the past, this education has occurred on a rather informal basis. The major responsibility for seeing that all workers with radioactive materials were informed in a general way of the hazards involved rested with the health protection organization.

Another and equally important aspect of the educational activities is the teaching of the techniques developed to minimize the hazards of working with radioactive materials. Up to the present time these techniques have been taught largely by the workers in the various divisions in their individual laboratories. Under these conditions the quality of the training varies widely. In the future, serious consideration must be given to establishing a more formal course of education in both the reasons for, and in the means of, proper handling of radioactive materials.

Ideally, the end result of the training program is a worker who understands, in a more or less detailed fashion, the hazards of radiations and the care that must be taken while working with radioactive elements, who knows the principles underlying the mechanisms of protection, who knows in detail the procedures needed by him for the satisfactory performance of his tasks, and finally who takes nothing for granted. Any job involving radioactive materials
or radiations should be assumed unsafe until proven otherwise. Only by unceasing vigilance on the part of every worker will injuries and fatal accidents attributable to these agents be avoided.

II. Control of External Radiations.

A. Alpha Radiations.

Shielding against alpha particles was relatively simple because of the ease of absorbing them. A few centimeters of air suffices to absorb all of the alpha radiations from known radioisotopes to which research or industrial workers have been exposed. If, for any reason, air shielding was not sufficient, entirely adequate shielding was obtained by interposing a thin layer of almost any substance, even paper, between the source and the worker. Rubber gloves not only stop the alpha rays, but also prevent contamination of the skin.

B. Beta Radiation.

The problem of protection against beta rays can best be approached by considering it under the quantities involved. Any discussion will involve the terms "distant handling" and "remote control" which will be used with special definite meanings. "Distant handling" is used to mean the manipulations of radioactive material with instruments so designed that neither the hands nor any other part of the body comes in contact with the container of the radioactive material. Such operations can be done under direct vision, and no shielding other than distance or partial body is necessary between the operator and the material. In general, "distant handling" equipment is used with radioactive materials which emit beta particles and no gamma rays. The term "remote control" is reserved for describing apparatus and methods which employ solid shielding through which all manipulations are done so that the operator is protected at all times by the interposed shielding. In general,
remote control procedures are used for operations involving large amounts of beta active materials, or any amounts of gamma active materials.

1) Less than 1 Millicurie. In general, adequate protection was provided simply by training the worker in the proper techniques of handling radioactive materials. Speed and precision of handling the container holding the sample were essential in the avoidance of excessive exposure. Radiation exposure studies (Vol. 21 B) have shown that the amount of exposure received in doing a given operation varies widely from operator to operator, and is usually a function of the experience of the operator. As the operation becomes familiar to the worker, less time in contact with the vessel containing the active solutions is needed. As a result, the radiation received diminished markedly.

2) Less than 1 Curie. As the amount of active material increases, speed and precision of manipulation no longer provided adequate protection. Distant handling equipment and partial shielding must also be used. Since the majority of beta particles which come from naturally or artificially radioactive elements have energies well under 4 MEV (million electron volts) maximum or an average of 2 MEV, an absorber providing from 1000 to 2000 mgm. per square centimeter (1 to 2 mm. Pb) will provide ample protection (Vol. 21 B). The biology section of the Health Division of the Metallurgical Laboratory has developed excellent apparatus for the remote handling of the quantities of activity under discussion. A description of the equipment and methods used is presented in Volume 22 B of this report. In general, this group has developed the use of transparent plastics as a radiation shield. Blocks of lucite of sufficient thickness to give protection can be machined into various shapes and sizes to hold the desired equipment. Most of the usual chemical operations have been modified so that they can be carried out in such containers. The use of these devices has materially diminished the risk of
spillage of radioactive materials because the plastic shielded apparatus is mechanically more stable than the unshielded apparatus.

3) More than 1 Curie. In addition to shielding, remote control manipulation was necessary to provide adequate protection. Complete remote control laboratories were necessary when handling several hundred curies of activity (Vol. 9). In addition, certain operations, such as the pipetting of small quantities of very active solutions cannot be safely done except with remote control mechanisms. The biology section has also developed devices for the remote control of this and other procedures (Vol. 22 B). Rubber gloves were worn to diminish the probability of contamination of the skin with radioactive material from the apparatus.

G. Gamma Radiation

Protection against gamma radiation may also be approached by considering the amount of activity to be handled. The energy of the gamma rays must also be considered. Many of the fission products emit gamma rays whose energies range from a few kilovolts to three or four MeV. The very soft gamma ray presented shielding problems somewhat analogous to those raised by beta radiation. If the energy exceeds 40 or 50 kilovolts, measures which are adequate for beta radiation no longer applied.

1) Less than 1 Microcurie. Even with such quantities of radiation, consideration must be given to the possibility of over-exposure. For example, 1 microcurie of radium 1 millimeter from the skin will deliver 6.7 r to the surface of the skin in 8 hours. In other words, the maximum permissible level of exposure (100 mr) is reached in 14 minutes. Thus even when very small amounts of radioactive materials were handled it was considered essential to know the exposure to the individual as accurately as possible. No job was considered safe simply because the amount of radioactive material seemed so small.
2) **Between 1 and 10 Microcuries.** Distant handling was used and shielding was occasionally necessary. The character of the shielding depended upon the energy of the emitted gamma rays and upon the nature of the work. The shield was constructed so as to reduce the intensity of the radiation received by the part of the body closest to the source to less than 12.5 mr per hour, or to less than 100 mr for the operation.

3) **Between 10 Microcuries and 10 Millicuries.** Shielding was almost always necessary to reduce the radiation level of the body to less than 100 mr per 8 hour day. In addition, the radiation levels were such that gross over-exposure to the hands would result from manipulation of unshielded radioactive material. As a result distant handling or remote control was also necessary. For physical experiments, devices which permitted simple procedures to be done with the radioactive substance several feet from the body were sufficient in many circumstances. For chemical experiments, devices were necessary which allowed a wide variety of procedures to be carried on without close contact between any part of the worker's body and the material. Descriptions of the design and use of such implements are given in Volumes 9 and 22 of this report.

4) **Greater than 10 Millicuries.** Shielding was necessary. The amount and kind of shielding material used was largely dictated by the characteristics of the operation and of the radioactive material which was handled. The objective was to reduce the radiation received by any part of the body of any worker to less than 100 milliroentgens per day (12.5 milliroentgens per hour). Many substances have been used as shields on the project. Among the most useful have been lead, concrete and iron. A detailed discussion of the theory and practice of shielding will be found in Volumes 21 A and B.

Use of both distant handling or remote control devices and shielding was mandatory for most if not all operations involving more than 10 millicuries.
In operations involving tens of millicuries, distant handling devices with partial shielding was frequently sufficient. As the amount of activity increased more elaborate distant handling devices and finally remote control systems were necessary. The necessity for protection against scattered (secondary) radiation as well as against the primary beam, must always be born in mind. As a result, when handling quantities greater than approximately 10 curies, complete remote control was necessary regardless of the simplicity or complexity of the operations. The high activity laboratories at Clinton Laboratories (Buildings 706-C and 706-D) and the separations plants at Hanford Engineering Works were designed and constructed so that exceedingly complex chemical processes were carried on without the operator ever seeing the material (Vol. 9).

D. Neutron Radiation.

In general, any source of neutrons is also a source of other radiations. The most prolific sources of neutrons on the Plutonium Project have been the controlled chain reacting units. In designing the shielding for these units the necessity of reducing the neutron radiations to less than the tolerance value had to be taken into account.

Fast neutrons may be absorbed as such by hydrogen nuclei, or may be slowed down by loss of their energy through collisions with nuclei of low atomic numbers and then captured as slow neutrons. The most efficient shields for both capturing and slowing neutrons were made of compounds with a high percentage of hydrogen atoms. Many materials have been used, such as paraffin, masonite, water by itself, and water in building materials. Slow or thermal neutrons are most efficiently absorbed by elements with a high capture cross-section for these neutrons. Cadmium and boron have been extensively used for this purpose. A sheet of cadmium a few millimeters thick will serve
to completely absorb even very high fluxes of slow neutrons. It is however, not necessary to use these materials to provide adequate protection. In pile structures sufficient thicknesses of concrete, mesonite and other materials were provided to reduce the flux of slow neutrons to less than the maximum permissible level of neutrons per square centimeter per second.

It should be emphasized that the preceding discussion of protection against the harmful effects of external radiation is general in nature as it only indicates the character of the measures that were taken. They are similar in nature to those which should be taken by any person working with radioactive materials. The references to the detailed presentation of the measures mentioned here found in other volumes of this report should be read by those contemplating work with radioactive isotopes.

The necessity of obtaining actual determinations of the radiation received by the worker in any given situation is of paramount importance. Such determinations on a continuing basis are an indispensable part of establishing and maintaining proper safeguards for health.

III. Control of Radioactivity Within the Body.

This was best accomplished by the prevention of the entrance of radioactive materials into the body. Any radioactive material that gains entrance to the body by ingestion, inhalation or through the skin is distributed within the body according to the metabolic pattern for the corresponding stable element. Wherever it localizes it radiates the adjoining tissue. Thus, any radioactive material is dangerous because it will continuously irradiate the body from wherever it localizes. The longer the half-life of the radioisotope and the longer it remains fixed in the body, the more hazardous it is. Also, alpha emitting material is more hazardous than beta or gamma ray emitting material because per unit of energy absorbed the alpha rays cause more biological
change. For these reasons plutonium, with an energetic alpha ray, a 24,000
year half-life and an almost permanent fixation in the bone, was the most
hazardous material dealt with on the project. The maximum permissible amount
fixed in the body was calculated to be 1 microgram.

The following discussion is devoted largely to the hazards presented
by the alpha emitting plutonium because methods of protecting against it were
more than sufficient for almost any other element. It is not in any way im-
plied that isotopes emitting beta and gamma rays are innocuous substances.
The precautions needed to protect the worker against their action are in
principle the same.

A. Control of Inhalation.

The prevention or minimizing of the inspiration of radioactive sub-
stances into the lungs can be attained by (1) supplying separate air to work-
er, (2) completely enclosing the radioactive material in an air-tight container;
(3) by filtering the air the worker breathes, or (4) by arranging the direc-
tion of air flow so that the air passes from the worker to the radioactive ma-
terial. As a rule, the first and second methods are the safest ones, but un-
fortunately the most difficult to apply. The third is, in general, unsatis-
factory because of uncertainty regarding the efficiency of the filtering units
and because respirators are extremely uncomfortable to wear. The fourth
method, that of controlling the direction of air flow, has been used most
widely on the project.

1) Separate Air Supply. The air the worker breathed could be con-
trolled by supplying air of known purity to a hood which fits over the head
(Vol. 22 B). The hoods found most useful were made of a light transparent
plastic cylinder, closed at the top with a rubber diaphragm and closed about
the neck by a porous cloth which is adjusted to the neck by a drawstring.
Clean air is supplied by a compressed air system connected to the hood by
means of a flexible tubing. The air pressure inside the hood is greater than that in the room, the air escaping from the hood through the porous cloth about the neck. The first hoods did not have a rubber diaphragm over the top. At Los Alamos it was found that during a sudden deep inspiration, some air was drawn from the room into the hood because the sudden withdrawal of air from the hood caused the pressure to fall below that in the room and the small tubing did not supply air fast enough. When a flexible diaphragm was used the pressure inside the hood did not become less than that in the room.

Face masks covering the entire face were sometimes used instead of head hoods to supply air of known purity to the worker. All face masks are exceedingly uncomfortable for prolonged wearing. They have now been largely replaced by the supplied air hood, where working conditions necessitate this type of protection.

Separate air supply systems were useful, or even indispensable, when routine work was done in rooms where the amount of radioactive material in the air usually exceeded the maximum permissible level for the isotope in question. Hoods and face masks were however clumsy, uncomfortable to wear, and materially reduced the efficiency of the worker. Since the problem of personnel protection could usually be solved by application of alternative methods, it was felt best to use our supply systems only as a temporary measure, pending the installation of adequate facilities. During the war it was sometimes necessary to work for long periods of time under such conditions, because time did not permit the design and installation of equipment which would reduce the amount of radioactive material to less than the maximum permissible level.

All permanent supplied-air systems were furnished with air from a central compressor unit. When such units are to be installed, care must be taken to use other than oil lubricated compressors, as incomplete combustion
of the oil will produce carbon monoxide. As a final precaution installation in the line of carbon monoxide monitors and absorbers is advisable. Several commercial companies can furnish complete supplied air systems which are free from the hazard of carbon monoxide inhalation.

Portable oxygen supply units were available for use with face masks. No group working with radioactive materials should be without this equipment for emergency use. It is indispensable for the protection of workers following major accidents where the air contamination is unknown but probably high.

2) **Separate Sealed Areas.** It was possible to divorce the atmosphere about the radioactive material from the air the worker breathed by the use of so-called "dust boxes". These are closed boxes or cylinders so constructed that the radioactive material can be manipulated in various ways within them. Such devices have been known on the project as dust boxes because they have found their greatest usefulness in the handling of dry materials. The handling of such material was particularly hazardous, especially the transfer of powder from one vessel to another. Should there be an accident involving milligrams or even a few hundred micrograms, the possibility of inhalation of a lethal amount of the radioactive material would exist.

Usually, the dust box was constructed as a closed cylinder 2 to 4 feet in diameter and 2 to 3 feet tall. The lower end of the cylinder was closed by metal, the upper end by glass. The sides of the cylinder were provided with connections for filling the enclosure with air or any desired gas, and with a large double-doored hatch through which material could be introduced or removed. Only one of the doors, either the one to the outside or the one from the hatch to the inside, could be opened at a time. Two closed armholes, provided with long-sleeved rubber gloves, permitted manual manipulation of the specimen when it is an alpha emitting substance.
The dust box has been most useful in handling alpha-active materials. This was so because of the relatively close approximation of the worker to the material intrinsic in the construction and use of such boxes. It should be possible to combine the dust box technique with distant handling of the sample if it becomes desirable to handle dry radioactive materials which emit beta or gamma rays.

3) **Filtering Methods: Respirators.** A third means of preventing the inhalation of radioactive materials was to wear a face mask to which various filtering devices may be attached. The essential element of these devices was filter paper made for this purpose. Where the possibility of exposure to toxic vapor or gases existed activated charcoal was added to the filtering units.

For some time, partial face respirators, covering only the nose and mouth, were used by the workers. As these masks were used it became increasingly evident that the individual variations of profile were such that no one design or even a variety of designs could be expected to fit all individuals on the project. If the adjustment of the mask to the face was not very good, an unknown but substantial part of the air breathed would come around the mask rather than through the filter. This, of course, means that some of the inspired air would contain the toxic substance. In addition, even though an initially good fit was obtained the construction of most of these masks was such that the adjustment was not maintained throughout the period of use. Finally, most of the masks were so uncomfortable because of pressure on the nose or cheeks that the tendency was not to wear them continuously even when the possibility of over-exposure was great.

As a result of the above considerations the recommendation was made that where masks were to be worn they should be full face masks. These masks provided an air-tight closure over the face, minimizing the inhalation of unfiltered air. They had several disadvantages, however. First, the masks be-
came uncomfortable on prolonged wearing, due to the accumulation of perspiration. Second, none of the designs available to use could be worn over all types of eyeglasses. Third, none of the masks available to us were equipped with speaking diaphragms. Full face rubber masks are now being made by a number of industrial concerns. To these may be attached a wide variety of canisters either directly or indirectly by means of a connecting tube.

At the University of Chicago the most satisfactory mask of this type was found to be the U. S. Army assault mask. The filter unit is a small canister approximately 3 inches in diameter and 2 inches thick, which screws onto the side of the neck. It may be obtained in two varieties. One type contains both filter paper and activated charcoal for use against dust and some gases. The other type contains only filter paper and hence is only effective against dust. These masks are more convenient than the usual construction which separates the canister and face piece. In using these masks it should be constantly kept in mind that the canisters, because of their small size, are not effective for long periods of time against gases since the amount of activated charcoal is not great.

The filter paper used in these masks is one which we have been told was developed during the war by the Chemical Warfare Service. Similar papers developed by this branch of the United States Army have been tested. The results are reported in Volume 21 B. The tests show that such papers are extraordinarily effective filters for dust particles of approximately 0.1 micron or greater average diameter.

In closing this discussion on control of the inhalation of radioactive materials by use of respirators it should be emphasized that in our opinion it is not wise to rely upon such devices for permanent control of an atmospheric contaminant. The worker should be asked to do so only if it is impossible to control the hazard adequately by other means. Experience with both scientific
and other personnel, has repeatedly demonstrated that even with supervisors present these devices are frequently left off when they should be worn.

4) **Ventilated Hoods.** A method of protecting the workers which we found most useful was to have the air flow from around the worker into hoods where the hazardous material is being manipulated and out ventilating ducts, preferably after filtration.

The principle of ventilation has been used for many years in industry and in laboratories for the control of noxious gases and dusts. When working with radioactive isotopes it has been found necessary to recommend that all work involving more than a few microcuries be done in ventilated hoods. This has resulted in a high percentage of the laboratory bench space being provided with hoods in the laboratories on the project handling such materials.

The rate of air flow through the hoods was somewhat greater than is customary in the ordinary chemistry laboratory. Experience at the Metallurgical Laboratory has led to the recommendation that under normal working conditions no hood should have an air flow of less than one hundred linear feet per minute. This led to engineering problems of considerable magnitude. In the buildings devoted primarily to the handling of plutonium at the Metallurgical Laboratory the number of hoods, under the above recommendation, resulted in a complete change of air every four minutes in the building as a whole. Since the building contains approximately 200,000 cubic feet of air, fans capable of handling 50,000 cubic feet of air per minute were used. With such a rapid turnover of air, the problem of heating the rooms became very great.

The design and construction of the hoods is very important. Due to the lack of time and personnel, no investigative program leading to the building of hoods of maximum efficiency was undertaken. Such a program seems clearly indicated, for reasons of both protection and economics. It is the
writer's opinion that such a program would yield information in a relatively short time which would materially alter our present hood designs.

It must be emphasized that the problem of safeguarding the worker is not discharged by merely installing the hoods. Some form of routine determination of the functioning of the exhaust system must be made. At the Metallurgical Laboratory, a Taylor Bioanemometer, number 3132, has been used for this purpose. Because of varying size of apertures tested, it is recognized that the testing program is crude and deserves further refinement. However, even with its limitations, routine testing has been a vital part of the overall ventilation program. Experience has shown us that hoods with grossly inadequate air flow or even reversal of air flow may be discovered. The prompt recognition and correction of such conditions is essential. In the future devices for continuously determining the rate of air flow through each hood should be installed.

The determination of the amount of contaminant escaping into the air of the room which may be breathed by the worker is another determination of importance. A number of devices have been developed for these determinations. Most of them now in routine use on the project are based on either the electrostatic precipitation principle, or on the principle of filtration by suitable papers. (See Vol. XXI.) Both principles have given satisfactory results in routine use. An inherent inaccuracy in any known method is that neither gases nor dusts are evenly distributed and therefore the air sample is not necessarily the same as the air breathed by the worker in the same room. Ideally an instrument which would follow the worker and sample the air he breathed should be used. In the absence of such a device, care must be taken to sample air which is probably the most contaminated of all the air which may be breathed.

The problem of contaminating the area surrounding a laboratory by the exhaust air cannot be neglected. If large amounts of radioactive material are
being handled, a major accident might result in the contamination of a large area. Because of this possibility, the discharged air should be passed through equipment which will collect any vapor or dust from it, or the discharged air should be diluted with uncontaminated air to reduce the concentration of contamination to less than the maximum permissible level for the substance involved. This precaution was observed at Hanford in the plutonium processing building. There is no doubt that all new installations designed to handle large amounts of radioactive substances should be equipped with devices for removing any activity from the exhaust air. If this is not possible arrangements insuring adequate dilution of the contaminated air must be provided.

The exhaust ducts, fans and motors may become highly radioactive and therefore maintenance work on them must be done under the supervision and direction of the Health-Physics organization. At Hanford, for example, the fans drawing the air from the chemical cells for disposal through the stacks have become so contaminated that tolerance levels of radiation are found many feet from the fans themselves. The same problem, to a lesser degree, is found in any exhaust system handling radioactive materials.

In general, ventilated hoods have been found in practice to be the most useful of the various methods for the control of radioactive materials in the air. Their use has the advantage of placing a minimum of responsibility on the individual worker. The hoods however, must be closely checked by means of frequent determinations of the air flow through the hoods and of the amount of radioactive material in the air apt to be breathed by the worker. Finally, measures to prevent the discharge of contaminated air must be taken.

B. Control of Ingestion.

Animal experiments have shown that many of the radioactive elements with which we are concerned are very poorly absorbed from the intestinal tract. Studies on plutonium (Vol. 22 B) have shown that in rats, less than $10^{-6}$ of the
amount given is absorbed into the body. Of the fission products, only iodine, cesium, strontium and barium are absorbed to any degree (Vol. 22 B). It has been assumed that the absorption from the human intestinal tract will not differ radically from that of the animals studied. As a result, it is felt that ingestion does not present a problem of the same magnitude as that of inhalation.

Ingestion can occur through drinking or eating from contaminated utensils, through eating food contaminated by contaminated hand, through swallowing contaminants from smoking materials, or by swallowing activity initially deposited in the respiratory tract. Eating or drinking from contaminated vessels can be prevented most readily by prohibiting such activities in any area where radioactive materials are handled. Eating rooms in clean areas were established in most of the sites. It is important to have adequate facilities for the storage and preparation of food in these clean rooms.

Smoking has also been prohibited, after consultation with the workers involved, in places where exceptionally toxic materials are handled. For example, in the plutonium chemical laboratory at the Metallurgical Laboratory, no smoking has been permitted anywhere in the laboratories or offices.

In practice, rubber gloves were worn when working with radioactive materials. These gloves were worn primarily to prevent contaminating the hands with the radioactive materials. Since ingestion of such material may be hazardous and since this may result from transfer from contaminated hands it was of importance to follow the level of contaminations of the skin, particularly the hands. To this end a program of monitoring of the skin and clothes for radioactivity was established at this and other sites (Vol. 21 B). Geiger-Muller beta and gamma counters and proportional alpha counters designed for this purpose are described in Volume 8 B of this report. Using detection instruments of these or similar designs provided adequate means for the detection of radioactivity on the skin.

In addition, however, care must be taken to insure that all poten-
tially exposed workers check their hands before lunch and before leaving at the end of the day. This point was of extreme importance. The finest equipment was valueless unless it was used. Records of the readings obtained in this monitoring program were kept and periodically correlated with other information on the exposure of the person to radioactive materials.

This program in addition to minimizing the chances of ingestion of such substances also give information which enabled us to evaluate the care with which the worker handled such substances, or the conditions under which he was working. If on a given job one worker routinely showed more activity on his hands than did his fellow workers, it could be assumed that he was not as careful as his colleagues. If all workers on a given experiment routinely showed high hand counts, it could be tentatively assumed that the conditions under which they were working were unsatisfactory. Thus, the monitoring of personnel for alpha activity afforded a useful guide to other activities of the radiation protection and health organizations.

C. Control of Entrance Through Skin or Wounds.

Skin. The problem of absorption of radioactive materials through the intact skin was one which gave considerable concern during the early days on the project. Fortunately both experimental and clinical experience has indicated that most, if not all, of the radioactive substances handled on the project were not absorbed through the intact skin under most conditions. An important exception must be made for materials in solution in organic solvents such as ether, chloroform, trichlorethylene, etc. As would be expected, since these materials can be absorbed through the skin, some of the radioactive material can pass through with them. Experiments with ether solutions of uranyl nitrate on mice have shown that this compound can be absorbed through the intact skin (Tannenbaum, Vol. 20 A). Evidence suggestive of absorption of uranium through human skin was obtained in two men who were working with
ether solutions of uranyl nitrate. Their hands were immersed in the solution for many hours each day. The possibility of absorption could be eliminated very simply by wearing gloves which are impervious to the solvent used. In most instances rubber gloves provided adequate protection.

Wounds. Here the problem was much more serious and complex. Absorption of radioactive materials introduced into the body through breaks in the skin may be compared with parenteral injection of these substances. Depending upon the metabolic characteristics of the element or elements in question, they will move from the site of implantation rapidly or slowly. In many instances the movement from the local area to the rest of the body occurs in a matter of minutes or hours. For example, it would easily be possible to introduce a lethal amount of plutonium into the body through a seemingly insignificant break in the skin.

As a result, the Metallurgical Laboratory and other sites on the project required that any lesion or injury, occupational or otherwise, to the skin of persons working in rooms where radioactivity was handled be reported at once to the Health Division. No person with a break in the skin was permitted to work with radioactive materials until the lesion was healed. It was recognized that this rule works a hardship on the planning of the work, but no other equally satisfactory alternative for the protection of the worker has been found.

The importance of the subject is such that an outline of the procedure for handling wounds or lesions potentially contaminated with radioactive materials is given here as well as in Chapter VIII of this volume:

(1) the skin area containing the injury should be placed immediately in a stream of running water and left there for a minimal period of three minutes by the clock. The wound edges should be separated to allow maximal flushing of all wound surfaces. In puncture wounds, where flushing with
water is not efficient, bleeding from the wound should be encouraged by any feasible means.

(2) the Health and Health-Physics Divisions should be notified at once. A member of the Health-Physics Division should go at once to the scene of the accident. He should obtain the circumstances of the accident as exactly as possible, including the kind and amount of radioactive material or materials involved. The apparatus responsible for the wound, and the wound and adjacent skin should be examined to determine the presence or absence of activity. If activity is present, the amount should be estimated. The patient should go or be taken to the place designated by the physician for further treatment.

(3) the physician must evaluate the circumstances of the accident as best he can so that the necessity of further treatment can be determined. Salient facts are the time of injury, the nature of the wound, previous treatment, identity of the contaminant or contaminants, possible amount of contaminant, and results of the estimation of the amount of radioactive material in the wound. Among the therapeutic possibilities are no further treatment, local excision of the wound area, and amputation of the limb (such wounds are usually on an extremity) proximal to the injury. The necessity for delayed treatment will be determined by the results of the estimation of the amount of radioactive material deposited in the body.

IV. Special Factory Problems.

In the developmental stages the University of Chicago and the DuPont Company had numerous subcontracts with industrial companies involving work with uranium. A medical problem of protection was thus created because the subcontractor was not informed as to what material he was being asked to handle or what the dangers were. It is a tribute to the many companies involved that they cooperated so well when frequently the precautions recoc-
mended must have seemed excessive.

In the early phases uranium metal had to be produced in high purity. Then it had to be cast, rolled, pressed, extruded, machined, jacketed and welded. In general the problems posed were similar to those in the laboratories. However, the fact that the worker in the subcontracting company could not be told of the hazards involved made impossible a rational approach to the protection problem from his point of view. Fortunately the major hazard, that of airborne contamination, could be controlled by the installation of adequate ventilating equipment in association with the apparatus which produced the dust or fumes. The principles of ventilation discussed under ventilated hoods applied with equal force to factory conditions, and little difficulty was experienced in providing adequate working conditions from this point of view.

Protection of the skin is fortunately not a difficult problem as uranium in its natural state is, comparatively speaking, not very radioactive. It takes 4 hours of close contact to deliver 100 mr to the skin. Since the length of time of handling the metal could not be predicted, it was recommended that heavy leather gloves be worn by the worker when handling uranium. Such gloves reduced the radiation received by the skin of the hand by 50 per cent. The recommendation was usually followed except by the machinists, who almost to man flatly refused, saying it was impossible to operate a machine tool while wearing gloves. Subsequently, experience at Hanford has shown that it is perfectly possible to do machine work while wearing gloves. There is no good reason why similar work cannot be done under proper conditions in the future.

The point was not pushed because of the urgency of the work, and because it was not felt, in view of the temporary nature of the hazard to the subcontractor's employees, that the hazard was great.
It was strongly urged that the worker wash his hands and face thoroughly after completing work with uranium. This was done to minimize the possibility of ingestion of the metal, and also to reduce the exposure of the skin. In association with this recommendation, eating in the work area was discouraged. If the lunch pail was brought to the work area, the worker was more likely to eat without any prior washing.

The subcontractor was asked to supply shoes, and to supply and launder work clothes and gloves to those employees who were to handle uranium. It was felt that this procedure would minimize the contamination of the worker’s wardrobe and personal belongings with radioactive material.

Uranium fires were not uncommon in the machining establishments until the means of avoiding them was learned. Finely divided uranium metal, such as turnings from a lathe, is pyrophoric and the fire is exceptionally difficult to extinguish. Liberal use of a water soluble-coolant oil while machining prevented overheating of the turnings and consequently reduced the number of lathe fires. In most instances the coolant circulating system had to be rebuilt to provide a flow of several gallons per minute. Also, storage of the turnings was initially accompanied by many spontaneous fires. These finally were prevented by storage of the turnings in water-filled air-tight steel or iron drums.

V. General Measures for the Control of Radiation Hazards.

Several general measures of considerable value have not been discussed in the above sections because they do not readily fit into any one of the topics discussed. Many of these measures are of importance for personnel protection from the general public’s point of view as well as for the individual worker.

A. Provision and Maintenance of Clothing.

Experience on the project has repeatedly shown that workers with
radioactive materials sooner or later contaminate their clothing with these materials. If the worker's own clothing was involved, his home also might become contaminated. Garments worn by persons living in the same quarters as the workers but not associated with the project might also become radioactive through contact, during laundering, or during dry cleaning. Thus the contaminations of the worker's clothes posed potential hazards to the worker, his family, and to the public at large. This potential hazard was minimized by supplying work clothes to most of the persons who worked with radioactive materials. Such clothing was usually washed in special laundries which handle no other material. All garments which showed greater than the permissible radiation level was subjected to special processing. If the radioactivity could not be reduced to less than these levels, the contaminated clothes were discarded. The project established decontamination laundries at the Clinton Laboratories and at the Hanford Engineering Works (Vol. 20 B). The Metallurgical Laboratory sent its contaminated clothing to the laundry at the Clinton Laboratory.

The degree of radioactive contamination and the kind of radiations present was determined before reissuing the laundered clothes. This was done by means of specially constructed proportional alpha counters and Geiger-Muller beta and gamma counters. At the Metallurgical Laboratory all material was monitored before going to the laundry as only the material which showed more activity than was permitted was sent to the special decontamination laundry.

By this program the risk to the worker and to the public has been reduced to a minimum. It was important to remember that other articles worn by the individual must also be carefully and frequently monitored. For example, all masks and rubber gloves must be checked for contamination.
B. Waste Disposal.

The problem of what to do with unwanted radioactive materials has proved to be an extremely vexious one. It was generally agreed that indiscriminate disposal of the material would constitute a serious general health hazard. All sites therefore, established "burial grounds" for the reception of waste radioactive substances and of objects contaminated with above the permissible levels of radioactive materials. The proper conditions for the disposal of such material presents an as yet unsolved problem. For short-lived radioactive elements, burial or storage in a guarded area for a few months or years will allow sufficient time for decay of the activity tolerable levels. The longer lived isotopes, particularly plutonium with a half-life of approximately 24,000 years, present a very different and difficult problem.

Disposal ideally should be done in a way which does not now nor in the future will present a health problem. Up to the time of writing local burial grounds have been used for the long-lived wastes as well as for the short-lived wastes. For the most part the containers, after being placed in the ground, have been broken, allowing the material to run into the soil. Work at the University of California (Vol. 22 B) indicates that the material is adsorbed by the soil very completely. The rate of migration is slow, but finite. The wisdom of this policy has been questioned. Ultimately the material may enter drinking water or be absorbed by plants, thus returning to humans. Among the alternatives suggested are disposal of sealed containers embedded in concrete at sea or burial in a guarded disposal area or area on land, or disposal by dilution in sea water. No final policy has been established as yet. Ultimately, disposal of the more dangerous material may be by way of rockets fired out of the earth's gravitational orbit.

The problem is one of major importance as general contamination of all materials used in civilian life would complicate or imperil many industries.
Tanure made from waste paper contaminated with radioactive elements.

Many of the haz waste had been already had been transported unpacked in cans. The transparency of these cans and their exposures made photographing them difficult. For example, the photographic equipment was specially modified to accommodate the radioactive contamination.
procedures: (1) supplying fresh, uncontaminated air to the worker by a head hood or face mask; (2) completely enclosing the area in which the material was being handled (dust box); (3) wearing a face mask and breathing air through a filter; (4) using ventilated hoods with the air passing from the worker to the radioactive material and thence through a filter to the outside. It was important to periodically monitor the rate of air flow in such regions and to determine the concentration of radioactive material in the air breathed by the worker.

For the most part ingestion of radioactive materials has not presented a serious problem. Fortunately many of the materials handled are very poorly absorbed from the gastro-intestinal tract. It was important, however, to minimize the possibility of ingestion by prohibiting smoking, eating and drinking in work area, and by keeping the hands clean.

The absorption of radioactive materials through breaks in the skin must be prevented. Individuals with breaks in the skin were not permitted to work with radioactive materials until the breaks were healed. Contamination of internal structures through the intact skin did not appear to be very probable except when using solutions of radioactive materials in organic solvents.

Experience has shown that work clothing should be provided to all workers handling radioactive materials. This clothing, if contaminated, should be laundered in special laundries to avoid a public health problem. A program of monitoring the clothing, shoes, masks, and gloves worn by the individual was essential.

Disposal of unwanted radioactive substances has been, and continues to be a major problem.
The problem of protective measures for personnel was increased greatly because of the increase in the number of individuals potentially exposed and in the amount of radioactive materials handled. In general, the solution of the problem of protection lay primarily in the proper training of the worker who was to handle radioactive materials. From a physical point of view, the use of shielding to absorb external radiation and the utilization of measures to prevent internal deposition of radioactive materials were of prime importance.

Protection from contamination of the skin with elements radiating alpha particles was of importance primarily as a means of preventing the ingestion of such radioactive materials. Prevention of irradiation of the skin by beta rays was, and is still, one of the most important problems on the project from the point of view of external radiation. The partial solution of the problem lay in the training of the employees in proper techniques for handling beta-active substances and in the development of suitable devices for distant handling and remote control. Protection against gamma and x-rays depended also on the training of the individuals in the proper techniques for handling such substances, in the use of shielding and in the use of devices for manipulation by remote control. Neutron radiation could be relatively easily controlled by the use of shields composed of compounds containing a high percentage of hydrogen atoms plus a gamma ray shield.

Control of radioactive materials that may get into the body and continue to irradiate the person indefinitely was even more difficult than the control of radiation originating outside of the person. The potential danger to the worker was greatest from the overall point of view from the inhalation of radioactive materials. This hazard could be avoided or minimized by four
APPENDIX I

General Rules and Procedures Concerning Activity Hazards

This document was prepared by the Activity Hazards Committee of the Clinton Laboratory. It is the most recent document compiled by the various units of the Plutonium Project. It is presented essentially in the form in which it was received, with certain minor changes being authorized by Dr. J. E. Wirth.
Section I

Function of the Activity Hazards Committee

The duties of the committee are left entirely to discretion of the Chairman but will, in general, cover formulation of necessary rules and procedures to prevent, as far as possible, injuries from causes directly or indirectly associated with handling and/or exposure to radioactive materials or radiation.

More specifically the present committee proposes:

1. To acquaint personnel, through the Central Safety Committee, with the status of problems concerning protection from the hazards of radioactivity. In this regard potential radiation injuries or accidents will be brought to the attention of the Central Safety Committee.

2. To serve as a nucleus of representative plant personnel which can assist the Medical Division in getting information and formulating general policy relative to activity hazards.

3. To prepare and amend as required the general rules and procedures pertaining to activity hazards.

4. To review the problems incident to established procedures.

5. To serve as an investigating committee for any accidents or injuries arising from radioactivity.

The enforcement of the procedures established is not the responsibility of this committee. It is the responsibility of each individual and/or his direct supervision.
Section II
General Rules and Procedures Concerning Activity Hazards

A. Tolerances (Maximum Permissible Exposure).

B. Radiation Monitoring.
   1. Survey Instruments.
   2. Personnel monitoring Instruments.

C. Protective Clothing and Devices.
   1. Clothing.
   2. Gloves.
   4. Equipment and Fixtures.

D. Eating and Smoking Rules.

E. Contamination of Persons.
   1. Hand and Shoe Contamination - General.
   3. Ingestion, Inhalation, Injection.

F. Contamination of Areas.

G. The Storage, Handling, and Disposal of Radioactive Materials.
   1. Storage and Handling of Plutonium and Similar Hazardous Substances
   2. Disposal of Materials Contaminated with Plutonium or Similar Hazardous Substances.
   3. Storage of Active or Contaminated Materials, (Other than Emitters.)
   5. Disposal of Active Trash, Unwanted Active Materials or Equipment.
   7. Radium Sources.

H. Summary of Responsibilities for the Enforcement of Radiation Rules.
   1. Maximum Permissible Exposure.
   2. Exceeding Tolerances.
   4. Protective Clothing.
   5. Miscellaneous.
A. Tolerance (Maximum Permissible Exposure).

1. The tolerance level for total or limited body exposure is 0.1 rem (roentgen equivalent man) in any 24 hour period and no individual shall knowingly expose himself or cause others to be exposed to greater than this quantity in any 24 hour period. The lowest possible daily total exposure should be striven for in every operation.

The 0.1 rem represents the total additive exposure from the independent components of all radiation involved. The relationship between \( r \) (roentgens)\(^*\), rem (roentgen equivalent man)\(^*\) and rep (roentgen equivalent physical)\(^*\) in accordance with present data are considered as follows:

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>roentgens</th>
<th>rem</th>
<th>rep</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>gamma</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>beta</td>
<td>---</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>fast neutron</td>
<td>---</td>
<td>0.1</td>
<td>0.02</td>
</tr>
<tr>
<td>thermal neutron</td>
<td>---</td>
<td>0.1</td>
<td>0.02 to 0.1</td>
</tr>
<tr>
<td>alpha**</td>
<td>---</td>
<td>0.1</td>
<td>0.01</td>
</tr>
</tbody>
</table>

\(^*\) Considered from the standpoint of internal effect only.

2. The maximum permissible level for plutonium in the atmosphere is tentatively set at \( 5 \times 10^{-10} \ \mu \text{gms/cc} \) (or \( 3 \times 10^{-11} \ \mu \text{c/cc} \)) for an eight hour working day six days per week for a one year period. The object is the prevention of the deposition of a total of more than 1 \( \mu \text{g} \) of plutonium in the body during a person's life. For general safety and convenience other alpha emitters may be considered at the same activity level.

* See Appendix A - Definition of terms.
3. Tolerance levels for beta and gamma emitters.

a. **Air contamination**: The tolerance level for the more hazardous and common beta-gamma radioisotopes (such as iodine, strontium, barium, etc.) is considered to be about $10^{-7}$ /-curies/cc of air. If one takes the overall collection efficiency of the precipitron (operating at 11.5 cu. ft./min) and the counter (Eck and Krebs feeding into a scale of 64) to be $1/8^2$, this would correspond to about 10,000 c/min. for the collected sample (30 minute collection time). Therefore, the general rule is to evacuate an area when the counting rate exceeds 1,000 c/min.

b. **Water contamination**: (The tolerance level in water for these beta-gamma radioisotopes is considered to be about $3 \times 10^{-4}$ /-curies/cc of water. This would correspond to about 1100 d/min/cc (2 \* 150 beta c/min/cc for counters used by the technical division.)

c. **Surface contamination**: (As measured with a "standard" counter or 3-1/4" from a thin-walled Eck and Krebs counter ~.005" thick with ~.5 cm² flat plate area.)

   (1) Maximum permissible reading of clothing, table tops, body, etc. is 500 c/m.
   (2) Maximum permissible reading of hand counter 700 c/m (~100 scaler units.)
   (3) Maximum permissible reading of foot counter 10,000 c/m (~30 scaler units.)
   (4) Maximum permissible reading of GeM probe counter inside 5000 c/m.

B. **Radiation Monitoring**.

1. Instruments to be used for surveys will be specified, distributed, and maintained in calibration by the Health Division. If any specific survey instrument or special monitoring device is required by any research or operating area it may be obtained upon written request to the Health Division (in emergency request by telephone).

* See Appendix B - Description of equipment.
2. Personnel Monitoring Instruments - (Obtainable from H.P. Personnel
monitoring Group).

   a. Two pocket chambers and a film badge meter are to be worn by
everyone who goes within the Restricted Area, except visitors who will wear
a film badge meter. Appropriate procedure under the direction of the Health
Division with cooperation of the guard patrol will insure that the above is
enforced, and that the chambers and film badge meters do not leave the plant.
It is the responsibility of the supervisor to see that meters are worn at all
times by persons in the Restricted Area, or other locations where radioactive
materials are encountered.

   b. Special neutron monitoring films are required for persons working
in the pile building and for persons working elsewhere with neutrons. (For
responsibility, see Section II, part H-3d).

   c. Pocket chambers and film badge meters are not to be tampered with
in any way, and are to be used only for personnel monitoring. If a meter is
accidentally broken or a cap comes off, it should be returned at once to the
point of distribution and a new meter obtained.


   a. The records of exposure as recorded from the above instruments can
be reviewed by the Supervisor or Section Chief. They are available at the
headquarters of the Health-Physics Section.

   b. Notification of a high pocket meter reading confirmed by a high
film badge meter, and notices of high hand or foot counts will be sent to the
responsible supervisor of the person concerned. A sincere attempt to answer
fully the questionnaire shall be made and the form returned to the sender with-
in 48 hours of receipt.

* See Appendix B - Description of equipment.
C. Protective Clothing and Devices.

1. Clothing.
   
   a. It shall be the responsibility of the individual and/or his supervision to see that appropriate protective clothing is worn wherever clothing contamination is probable.

   b. If shoes are confiscated by Health-Physics because of contamination they will be replaced by Clothing Stores with safety shoes. The confiscated shoes should be placed in a paper bag, and sent to the laundry for decontamination or disposal. (See Appendix C-1 "Replacement of Contaminated Shoes").

   c. Contaminated personal clothing shall be enclosed in a paper package marked "contaminated", labeled with the owner's name and badge number, and sent to the laundry for decontamination or disposal. Clean clothing may be obtained on loan, for a period not to exceed one week, from General Stores. The contaminated clothing will be cleaned, if possible, and returned by the laundry. Personal clothing, except shoes, which must be destroyed because of contamination will not be replaced.

   d. Coveralls, laboratory coats or other protective garments worn in the restricted area are not to be worn in the Cafeteria. This applies to all personnel. Protective clothing worn outside the restricted area in connection with work where radioactive contamination is possible shall be governed also by this rule.

2. Gloves.

   a. Suitable gloves shall be worn whenever hand contamination is probable.

   b. Rubber gloves shall be worn when handling open vessels containing more than 10 $\mu$gm of plutonium, when handling equipment suspected of alpha contamination, and preferably when working with quantities of plutonium greater than 1 $\mu$gm. Similar precautions shall be taken with work involving other
alpha emitters, and beta-gamma emitters of comparable hazard.

c. Surgical technique (See Appendix C-2) shall be used when putting on and removing surgical gloves, in order to avoid the possibility of contaminating the inside surfaces.

d. Rubber gloves are to be cleaned, if practical, before removal. All rubber gloves are to be stored and handled so as to prevent contamination of the inside surfaces.

3. Respirators, combat masks and air line hoods.

a. An approved respirator, combat mask or air line hood shall be worn in any location where the concentration of air borne alpha emitters may be greater than $3 \times 10^{-11} \mu C/cc$. Similar precautions shall be taken with air borne $\beta$ and $\gamma$ emitting materials. The air line hoods are available upon request to the Health-Physics Section. The respirators and combat masks are available at Central Stores.

b. It shall be the responsibility of the supervisor of the area using respirators to see that these are not used more than once before being sent to the laundry for inspection and cleaning.

c. It shall be the responsibility of the supervisor of the area using combat masks and air line hoods to notify the area Health-Physics representative after each use.

d. Health-Physics shall be responsible for maintaining combat masks and air line hoods in an adequately uncontaminated and sanitary conditions, and for replacing the filters at suitable intervals.

e. Combat masks and air line hoods (complete sets) shall be monitored and inspected by the laundry, at the request of Health-Physics, after each use and at two month intervals when not in use.
4. **Equipment and Fixtures.**

   a. Hoods in which plutonium is actively handled shall be provided with non-porous, inert floors, such as glass, tile or metal; preferably a stainless steel tray should be used to catch possible spills. All work with plutonium, even dilute tracer solutions, shall be done over such surfaces or over heavy kraft or blotting paper to minimize danger from spills.

   b. Meticulous care should be taken to see that the moving part of open centrifuges are maintained free of contamination. Covers of centrifuges handling active materials must not be open while the motor is in motion.

   c. Equipment and laboratory ware contaminated with plutonium shall be stored in an operating hood or under water until cleaned.

D. **Eating and Smoking Rules.**

   1. Eating, storing or preparation of food in a laboratory or operating rooms where active materials are handled is forbidden. The use of milk bottles or other food containers in handling or storing chemicals is forbidden. Local area rules will make provision for disposition of empty milk and soft drink bottles.

   2. Coveralls, laboratory coats or other protective garments worn in the restricted area are not to be worn in the Cafeteria. This applies to all personnel. Protective clothing worn outside the restricted area in connection with work where radioactive contamination is possible shall be governed also by this rule.

   3. Smoking must be controlled by local area rules.

E. **Contamination of Persons.**

   1. Hand and shoe contamination.

       a. All persons while working with radioactive materials wherein detrimental hand or shoe contamination is possible (as determined by supervision or upon advice of local area Health-Physics representative) are to
(1) Keep the fingernails cut short.
(2) Wash hands thoroughly before eating, smoking or leaving work.
(3) Refrain from smoking.
(4) Waaen rubber gloves if practical before removing them from the hands. (See also Section 6-2).
(5) Utilize available hand and shoe counting facilities as frequently as necessary to insure decontamination. (Adjacent to each counter which is reserved for hand and shoe counting there will be a record sheet on which the individual is to record all counts taken, including high counts and those after washing.

(6) Report to supervision any hand or shoe count which is above the specified limiting value marked on the counting machine. (If the individual, with the aid of his supervisor, is unable to reduce the count below the limiting value listed on the counting machine, Health-Physics or the Medical Department shall be notified as soon as practical, and in all instances before the individual leaves the plant at the end of the shift.)

b. A log of the hand and the shoe counts from each area must be kept by the Health-Physics Section. It shall be available for inspection by the supervisor or his representative.

2. Plutonium contamination of hands.

a. No work with plutonium in any chemical or physical form is ever to be done by a person having a break in his skin below the wrist or with a bandage on his hand. Any person receiving a puncture wound suspected of plutonium contamination shall report to the doctor at the dispensary immediately.

* This rule applies to other radioisotopes which present a similar health hazard (1 mCi Pu \( \leq 1 \times 10^{-7} \) c.).
(See Appendix C-3 "Procedure for immediate care of wounds likely to be contaminated with alpha emitters.") Editor's Note: - See Chapter VIII, this volume.

b. Hands are to be checked at frequent intervals, depending upon location and nature of work; at least twice daily for persons working with milligram quantities (see local area rules).

c. A minimum frequency of hand counts shall be set for each group or area according to the type of work done.

d. All possible contamination should first be removed with soap and water and a brush before using stronger solutions. Frequent washing is recommended during high level plutonium work. (Editor's Note: - See Chapter VIII, this volume for "Procedure for Decontaminating Hands").

e. Solvents - Care must be exercised when using organic solvent to avoid skin contact with plutonium in any form as these solvents may make the skin more permeable to penetration and absorption of plutonium.

3. Ingestion, inhalation, injection.

a. The pipetting of solutions by mouth is forbidden. Glass blowing in laboratories containing active materials should be discouraged.

b. Any person who knowingly swallows, inhales or receives an injection of a radioactive material or who may have been overexposed to radiation from any source is to report to the Medical Department at once. (Editor's Note: - See Chapter VIII, this volume for "Immediate Care of Wounds").

F. Contamination of Areas.

1. All areas in which there is radiation in excess of 12.5 mR/hr shall be either roped off and appropriate signs posted to prevent persons from coming dangerously close to the radiating source, or, where the hazard is of a permanent nature, permanent signs shall be posted, barricades installed and
existing doors locked. Where activity levels are very high a patrol force guard should be posted to prevent accidental overexposure.

2. In general, approval and precautionary measures must be secured from Health-Physics before commencing work in any area where appreciable (> 1/\mu g) plutonium contamination is suspected.

3. No experimental work shall be carried out in an operating area without prior notification and agreement of the operating area head.

4. Experimental work involving especially hazardous levels of activity shall not be undertaken until suitable protective measures have been agreed upon by the section chief or chief supervisor in charge and the Health-Physics section chief.

5. The Health-Physics representative in the area must be notified of any change in procedure which might affect a change in levels of activity in that area.

6. In case of any permanent change of personnel or permanent vacating of quarters it shall be the duty of the individual and his supervisor to see that the area is properly surveyed and if necessary, decontaminated before it is vacated.

7. Areas which formulate special rules pertinent to the area (or room) are requested to send a copy of the rules to the Chairman of the Activity Hazards Committee, to the Health-Physics Section Chief and to the Medical Director, for approval. Such approved rules are to be posted by the area head.

8. Areas or rooms which are to be kept free from contamination are to be posted with signs on all doors warning persons not to enter with contaminated materials or clothing.

9. A hood containing more than 1/\mu g of plutonium\(^{239}\) contamination must

* This rules applied to other radioisotopes which present a similar hazard (1/\mu g \geq 1/16/\mu g).
be clearly marked "high level hood". Hoods so designated shall not be repaired or worked on without approval of Health-Physics, which shall specify protective measures for the personnel involved.

10. Spills and contamination levels.

a. No exposed plutonium is ever "tolerable"; the following are maximum levels which are perhaps unavoidable in some cases.

<table>
<thead>
<tr>
<th>Exposed surfaces, floors, bench tops, etc.</th>
<th>Surface: d/m for 150 sq. cm. (small spots)</th>
<th>Smear: ≤ 2 sq. in. counted in std. chamber</th>
<th>Total γ contamination (LARGE AREA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,000 d/m</td>
<td>0 d/m</td>
<td>14,000 d/m/sq.ft.</td>
</tr>
<tr>
<td>Exposed but protected from handling (rope off, etc.)</td>
<td>10,000 d/m</td>
<td>25 d/m</td>
<td>7,000 d/m/sq.ft.</td>
</tr>
<tr>
<td>Inside poor or intermittently used hood.</td>
<td>30,000 d/m</td>
<td>25 d/m</td>
<td>280,000 d/m/sq.ft.</td>
</tr>
</tbody>
</table>

Inside adequate hood, operating (Upper limit will vary with area rules and hood efficiency)

< A 2 sq. inch paper wiping a total of 12 sq. inches of tested surface.

b. All spills of plutonium must be cleaned up immediately unless inside an adequate hood. Cleaning responsibility shall lie with the operating group in the room and area involved, and they shall check after cleaning to verify that cleaning is thorough. In cases of large spills or in doubt, call Health-Physics.

11. Each Area Head or Section Chief shall be held responsible for maintaining recorded surveys of all radiation hazards in the area. These surveys are to be sent daily to the Health-Physics representative assigned to the areas. The representatives may be found in the following places:

* This rule applies to other radioisotopes which present a similar hazard (1μg ≈ 1/16 μg).
12. The Health Division will be prepared to survey any area on request or will cooperate in making surveys. During the day call the local area representative; at night call the chief Health-Physics surveyor's residence.

13. The Health Division will make independent surveys and pass pertinent information to those responsible for safe conduct of the work.

14. Before entering an area or room to make a survey, the Health-Physics representative will report to the acting Area Head.

G. The storage, handling and disposal of radioactive materials.

1. Storage and handling of plutonium or similar hazardous substances.

   a. Quantities of plutonium greater than 1 mg. shall be securely covered during storage and kept in a hood equipped with doors, or in other spaces specifically accepted by the Health Division Director, or his representative as suitable under the given circumstances. (Such as shelves constructed in an out-pocketing from existing hoods or separate boxes equipped with doors and vented to a proper exhaust.

   b. All transfer of materials between hoods and storage devices must be done in such a manner as to avoid the possibility of spillage or breakage. Double containers to eliminate contamination and breakage danger should be used.

   c. Any work with materials susceptible to atmospheric distribution of plutonium (that is dusting, spillage, vaporizing, effervescence of solution, etc.) shall be done in an "adequate hood".

2. Disposal of materials contaminated with plutonium or similar hazardous substances. All discarded material which has been liable to plutonium contamination is to be buried. Distinctive cans are to be provided, and these handled with proper discretion. If a dust hazard is involved, a Health-
Physics representative shall accompany the can when it is taken to be buried to see that respirators and protective clothing are used when needed. In rooms where large (1 to 2 \( \mu \text{g/m}^2 \)) amounts of plutonium are handled, a small red closed or ventilated can should be provided with a paper lining to receive waste of known contamination, so that the closed paper lining may afford some measure of protection against spread at the time of disposal. (See Appendix C-5 "Procedure for Burial Grounds").

3. Storage of Active or Contaminated Materials (Other than Plutonium and Similar Substances).

a. Storage space for active or contaminated large equipment or material which is to be saved for further use will be provided by the Pile Operating Area. Storage space for contaminated or active glassware, or other small articles, which are to be saved for further use must be provided for by the local area.

b. Contaminated lead bricks from all areas except the pile buildings (unless known to have been activated by neutron bombardment, in which case, see Section G5g) will be stored by the Pile Operating Area Supervisor.

4. Transportation of Active Materials.

a. Off Site Shipments.

(1) No active material or equipment shall be transported into or out of the plant area without written authorization of the Executive Director or his authorized representative.

(2) All radioactive materials being transported into or off the plant shall be surveyed by Health-Physics.

(3) Shipment of radioactive materials to other sites by truck shall follow the procedure outlined in Appendix C-6 "Transfer of Classified Material to U. S. Engineers." The procedure for the receipt of such materials
Sufficient protective means for material shipped by truck or car shall be used to prevent radiation levels greater than 50 mR/hr at the rear wheels of the truck or car and to prevent levels at the truck cab or driver's seat of a car in excess of 100 mR/day for any persons in the car or cab.

In practice there are two forms of shipments:

(a) A shipment of a single container that does not exceed 50 mR/hr on any one surface.

(b) A shipment consisting of more than one container or a shipment of a single container greater than 50 mR/hr.

The Form 203 (see Appendix C-6) accompanying all shipments will be signed by a representative of Health-Physics after he has completed his survey, provided the shipment is in form (a) and radiation levels at the truck cab or for persons in a car are not in excess of 100 mR/24 hour day.

If the radiation levels exceed those given above or if the shipment is in form (b), or if it is possible for the radioactivity to grow during shipment, the Health-Physics Section Chief or the Medical Director shall be notified. In any instance where shipment leaves the plant with radiation levels exceeding those given above, Health-Physics will notify the consignee by teletype or telephone to expect a shipment above usual standards.

(5) When shipments are being transferred under the auspices of and by Army personnel and equipment, the Health-Physics representative will sign Form 201 when radiation levels are below the recommended values given above. Whenever the measured levels exceed the recommended levels given above, all figures obtained for all surfaces of the shipment shall be recorded by the Health-Physics representative on the back of Form 201 and he shall sign
Form 201 signifying that he has made the survey and obtained the figures given on the back of the form.

Clinton Laboratories' personnel will be governed by Rules G-4a(4) and G4a(8) even when acting as an agent or courier for the Army.

(6) If material is shipped in solution, the vessel containing the solution is to be enclosed in a metal container with a sufficient absorbent material to take up all the liquid in case of breakage of the vessel. The container shall be equipped with a gasketed top. The top should be so constructed that the least amount of exposure is received in removing either the top or the solution. No package shall bear contamination on the outside surface above that specified in Section G 10 for alpha emitters and 500 c/m for beta emitters, as determined from smear tests using standard procedures established by the Health-Physics section.

(7) When there are special problems in protection concerning shipment of active materials, the shipper shall contact the Health-Physics section as soon as possible and secure advice in the preparation of a suitable container.

(8) All other Off-Site Shipments.

(a) Courier shipments must be surveyed and considered individually by the Health-Physics Section Chief, the Medical Director, or one of their representatives. In general, the object is to prevent exposure of the courier or contacts to radiation in excess of 100 mr/day and to prevent exposure of shipments of film to more than 10 mr for the entire trip.

(b) Shipments by mail or express shall meet the regulations of the Postal Department or the express company.

b. On Site Shipments or Transfers.

(1) Transportation of active materials within or between buildings on the Plant must proceed in a manner which will cause no overexposure
to any part of the body and will prevent a spill of active solutions. Suitable carrying devices are to be used for such transfers.

(2) The Health-Physics Section shall receive notification of transfer of slugs from the Pile Building. (Editor's change: and shall survey the containers and prescribe safe-handling procedures.)

(3) **Transfer of Samples or other Radioactive Materials from any Building.**

(a) Routine control samples (see local area rules). In general these constitute samples with an activity less than 50 millicuries.

(b) Special samples or other radioactive materials (see local area rules). In general these have an expected activity greater than 50 millicuries. In this case the Health-Physics representative shall be contacted prior to sampling or obtaining the specimen so that he may pass judgment upon the plans for shielding and other protective measures to insure no overexposure to personnel. He will also cooperate in a survey during the sampling or other procedure.

5. **Disposal of Active Trash, Unwanted Active Materials or Equipment.**

a. Two trash cans painted entirely red (both top and can) are to be provided at each desired location, for trash which is contaminated.

b. Only **one** of these two cans should be used at a time and the one in use should be tagged by Supervision of the Area — "Use this Can".

c. It shall be the responsibility of supervision to see that these cans are monitored at sufficiently frequent intervals to prevent active materials from accumulating to such an extent that radiation levels of greater than 12.5 mR/hr. occur.

d. If the activity of a can is greater than 12.5 mR/hr. the Pile Operating Area should be contacted at once in order to have the can taken to
the burial ground for disposition of the trash. (See Appendix C-5 "Procedure for Burial Ground").

e. In ordinary routine collections, Maintenance will provide daily collection sometime during the afternoon. In the morning prior to collection, supervision of the area will see that the can which is to be picked up and emptied is surveyed for radiation activity. If the can and its contents do not exceed 12.5 mR/hr, supervision should tag the can with a label reading "Driver, O. K. To Pick Up." The remaining can should then be tagged "Use This Can."

f. Once a can has been labeled "Driver, O. K. To Pick Up," no more contaminated trash shall be put in that can. When the can has been emptied and returned Maintenance should remove the tag so that it may be held in reserve while the second can is in use.

g. Contaminated lead bricks from the Pile Building will be buried at the burial ground by arrangement through the Pile Area Operating Group (See section C-3(b)).

6. Burial Ground. The burying ground is under the supervision of the Pile Operating Area. (See Appendix C-5 "Procedure for Burial Ground"). All contaminated material and equipment that is to be discarded shall be thrown only in the trenches provided for this purpose.

a. Sufficient earth must cover active materials in a trench to keep the level of radiation at the top of the trench below 12.5 mR/hr.

b. When it is desired to transport especially active materials to the burying ground at times other than on routine collections, transportation facilities will be provided by Maintenance. Arrangements are to be made by calling the burial ground operator. The responsibility for the safe handling of the active materials during transportation and disposal will be assumed by the Pile Operating Area. This responsibility may be specifically taken over
by the local area Health-Physics representative at the request of the Pile Operating Area.

c. It will be the responsibility of the Pile Operating Area to:

(1) See that available trenches are provided and that when covered their locations are marked permanently.

(2) Keep sufficient earth over trash to prevent trash from being blown or floated outside the trench.

(3) Keep an adequate record of all equipment taken to the burial ground for burial or for storage.

d. The burial ground will be periodically surveyed by the Health-Physics Section and any recommendations given to the Pile Operating Area Supervisor.

7. Radium Sources.

a. All radium sources will be in the custody of the Health-Physics Section and will be issued to supervision upon written request.

b. When not in actual use, a radium source is to be kept in the cart or container provided. These carts and containers are not adequate for prolonged storage; when such is desired the source should be returned to the Health-Physics Section.

c. All radium containers should be tagged with the number of the source, and a warning sign, "Ra", "RA-Be", "Po-Be", etc. should be painted on the radium cart.

d. In the event of loss of a radium source, the Health-Physics Section should be notified at once.

e. The Health-Physics Section will periodically check radium sources for radon leaks or other imperfections.

H. Summary of Responsibilities for the Enforcement of Radiation Rules.

1. No individual shall knowingly expose himself or cause others to be
exposed to more than 0.1 rem in any 24 hr. period.

2. In extreme emergencies the acting area head may assume responsibility for a person exceeding 0.1 rem daily exposure provided that:
   a. Insufficient time exists to obtain the services of the Health Division for consultation.
   b. A written report is submitted within 24 hours to the Plant Director and to the Health Division Director, covering the details concerning the necessity for and the amount of the overexposure, and the precautions taken.
   c. The individual or individuals so exposed are sent to the Medical Department as soon after exposure as possible. The Supervisor of each area shall delegate the above authority in his absence.

   a. To see that all persons while working in the restricted area wear meters at all times.
   b. To see that persons working with active materials outside the restricted area wear meters while so engaged.
   c. To request the issuance of permanent meters for employees going into the restricted area on an average of more than 3 days per week. (Address request to Health-Physics Meter group).
   d. To request special neutron monitoring films for persons working in the pile buildings and elsewhere if the persons are liable to exposure to neutrons.
   e. To notify the Health-Physics Meter group of changes in supervision of an employee - since exposure reports are sent to each individual’s supervision.

4. Supervisors Responsibilities re Protective Clothing.
   a. It shall be the responsibility of the individual and/or his supervision to see that appropriate protective clothing is worn wherever clothing
contamination is possible.

b. It shall be the responsibility of the supervisor of the area using respirators to see that these are not used more than once before being sent to the laundry for inspection and cleaning.

c. It shall be the responsibility of the supervisor of the area using combat masks and air line hoods to notify the area Health-Physics representative after each use.

5. Miscellaneous.

a. Supervisors are responsible for maintaining safe radiation levels at the boundaries of their own areas of assigned locations.

b. Each Area Head or Section Chief shall be held responsible for maintaining recorded surveys of all radiation hazards in the area. These surveys are to be sent daily to the Health-Physics representative assigned to the area.

c. In case of any permanent change of personnel or permanent vacating of quarters it shall be the duty of the individual and his supervisor to see that the area is properly surveyed and if necessary, decontaminated before it is vacated.

d. It shall be the responsibility of the supervision of an area to see that the active waste disposal cans are monitored at sufficiently frequent intervals to prevent active materials from accumulating to such an extent that radiation levels of greater than 12.5 mR/hr. occur.

e. The burying ground is under the supervision of the Pile Operating Area. The supervisor shall see that the top of the trench in which trash is thrown does not exceed 12.5 mR/hr. (See also GSC).

f. Responsibilities at time of fire in the Restricted Area and in other areas containing hazardous materials are given in Section VIII. (Edited notes are not produced in this column).
Section III

Classification of Injuries From Overexposure to Radioactivity in Any Form

The nature of operations and experimental work brings up the problem of classification of injuries. It is not altogether comparable to the ordinary occupational disease in that the time relationships for time lost are quite variable. Existing classifications and methods of arriving at the proper classification can however be used.

a. All injuries due to overexposure will be tabulatable except those:

(1) Occurring to Clinton Laboratories' employees off the plant while either visiting or engaged in work for Clinton Laboratories at other locations than the plant (i.e., Chicago, St. Louis, etc.) except when the overexposure has resulted from the direct negligence on the part of the Clinton Laboratories' employees.

(2) Injuries sustained by contractors (or their employees) for whose safety contractual obligations have not been specifically expressed by Clinton Laboratories.

b. Observation or Diagnosis Period. Due to the nature of radiation injuries a period longer than the usual 24-hour observation period may be necessary before physical findings can or cannot be judged to be due to the occupational hazards. The diagnosis period will, therefore, be variable and its length decided in each case by the Medical Department.

If at the end of the diagnosis period the existing condition is found to have been caused or aggravated by employment, then the injury shall be classified as one of the following:

c. Classification of Injuries:

(1) Minor - Minor injuries from overexposure are not envisaged.

(2) Sub-Major - A condition which necessitates the removal of an
employee from his regular duties to one in which no exposure of the type producing his injury is possible, shall be classified as a sub-major injury regardless of the length of time he is away from his normal duties.

(3) **Major** - A condition which is of sufficient severity to cause a man to leave temporarily or permanently the Clinton Laboratories, shall be classified as a major injury, even though he reports to the Medical Department for observation and is maintained on the payroll.

d. Any tabulatable or non-tabulatable injury arising from activity exposure shall be listed on a special list separate from all other plant injuries. These shall not appear on the regular published Safety Department statistics of Plant Injuries.
OUTLINE OF APPENDICES

Appendix A. Definition of Terms

1. rep
2. r
3. rem

Appendix B. Description of Equipment

1. Pocket meter
2. Badge of film meter
3. Neutron film
4. Film rings
5. Dose meters
6. Health-Physics Instruments used at Clinton Laboratories

Appendix C. Letters or names concerning detailed procedures

1. Replacement of contaminated shoes
2. Surgical technic for putting on and/or removing rubber gloves
3. * Procedure for immediate care of wounds likely to be contaminated with alpha emitters. (Plutonium)
4. * Recommended procedure for washing contaminated hands
5. Procedure for Burial Ground
6. Transfer of Classified Material to U. S. Engineers
8. On Site Slug Transfers

* Editor's note: Reproduced in Chapter VIII of this volume.
DEFINITION OF RADIATION TERMS

1. The roentgen (r) is that quantity of X or gamma radiation such that the associated corpuscular emission per 0.0001293 gms. of air produces in air ions carrying 1 esu quantity of electricity of either sign.

2. The roentgen equivalent physical (rep) is that quantity of ionizing radiation which is capable of producing $1.615 \times 10^{12}$ ion pair per gram of tissue or that will suffer an absorption in tissue of 83 ergs per gram.

3. The roentgen equivalent man (rcm) is that quantity of radiation which when absorbed by man produces an effect equivalent to the absorption by man of one roentgen of X or gamma radiation.
APPENDIX B

PERSONNEL MONITORING METERS

(Editor's note: 1 through 5 below are reproduced from the Clinton Laboratory Manual. See Vol. XXI, Health-Physics, for detailed description of these instruments.)

1. The Pocket Meter is a small air ionization chamber or air condenser. It has a full scale reading of 200 mr when charged and read on the minometer in use at Clinton Laboratories. When it is carefully used, it usually gives an error less than 5% of full scale. It is charged at 143 volts and does not give saturation errors unless subjected to extremely high fluxes (of the order of 10 mr/second). It has a bakelite wall thickness of 0.172" and so cannot be used for beta ray measurements if the energy is less than one mev. The minometers are calibrated with 200 KV X-rays so that the pocket meters read low by about 20% for radium gamma rays (1.8 mev). The meters will discharge, giving "false readings" when given extremely rough treatment.

2. The Badge Meter or Film Meter contains an open window and a cadmium shield. A dental size film packet holding two films, one a sensitive (0-5 r) and the other an insensitive film (0-20 r), is placed in this meter by the personnel monitoring girls of the Health-Physics section. The open window may give an indication of the beta exposure but is difficult to interpret an indication of the beta exposure but is difficult to interpret if low energy gamma radiation is mixed with the beta rays because the film is about 20 times more sensitive to low energy X-ray (energy 20 KV) than it is to gamma rays. The readings made behind the cadmium shield are reliable for energies down to about 70 KV.

3. The Neutron Film is contained in a dental film packet and is worn in
<table>
<thead>
<tr>
<th>Performance Considerations</th>
<th>Factors Compared</th>
<th>Poppy</th>
<th>Walkie-Talkie</th>
<th>Preciptron</th>
<th>Zeto</th>
<th>Zeus</th>
<th>Pluto</th>
<th>Lauritten Electrocy</th>
<th>Scanning Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>Not Linear</td>
<td>Linear</td>
<td>Linear</td>
<td>Linear</td>
<td>Linear</td>
<td>~ Linear</td>
<td>~ Linear</td>
<td>Not Linear</td>
<td>Not shed</td>
</tr>
<tr>
<td>Meter Card</td>
<td>Scale: Linear marked with arbitrary numbers</td>
<td>Aural indication only</td>
<td>Linear Register</td>
<td>Counter Geometry known</td>
<td>Scale: Linear marked with arbitrary numbers</td>
<td>Scale: Linear marked with arbitrary numbers</td>
<td>Scale: Linear marked with arbitrary numbers</td>
<td>Scale: Linear marked with arbitrary numbers</td>
<td>Scale: Linear marked with arbitrary numbers</td>
</tr>
<tr>
<td>Readability</td>
<td>Scale: Divisions: Length: 3 in, of arc:</td>
<td>50</td>
<td>3 1/4</td>
<td>50</td>
<td>2 3/4</td>
<td>50</td>
<td>2 3/4</td>
<td>100</td>
<td>Microscope</td>
</tr>
<tr>
<td>Ranges: (Full scales) Units: 100,100,000 e/m</td>
<td>Blocks out above 35 m/hr</td>
<td>10,000 d/sample</td>
<td>6,000-60,000 d/sample</td>
<td>50, 250, 5,000 m/hr</td>
<td>60,000 d/sample</td>
<td>10,000 m/hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Readable increment: (minimum each scale)</td>
<td>20, 200, 2,000 e/m</td>
<td>Aural estimate of more or less by 106</td>
<td>Determined by probable error of counting</td>
<td>250, 2500</td>
<td>2, 8, 150</td>
<td>800</td>
<td>4/sec</td>
<td></td>
<td></td>
</tr>
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</table>

### Usability

<table>
<thead>
<tr>
<th>Radiation (type measurement)</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>α</th>
<th>β</th>
<th>γ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size: (Inches)</td>
<td>10 1/2 x 6 1/2</td>
<td>9 1/2 x 7 1/2</td>
<td>2 3/4 x 3 1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight: (lbs.)</td>
<td>60</td>
<td>10 1/2</td>
<td>7 1/2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Chamber: (High ht.)</td>
<td>1 1/2 x 10 1/2</td>
<td>3 1/2 x 8 1/2</td>
<td>1 3/4 x 13 1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response: (Sec)</td>
<td>5 sec</td>
<td>12 sec</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time: (Sec)</td>
<td>12 sec</td>
<td>24 hrs</td>
<td>7 sec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up time: (Sec)</td>
<td>50 sec</td>
<td>10 sec</td>
<td>60 sec</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Dependability

<table>
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<tr>
<th>Fault readings</th>
<th>High or Low</th>
<th>High or Low</th>
<th>Low</th>
<th>High or Low</th>
<th>High or Low</th>
<th>High or Low</th>
<th>High or Low</th>
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<tbody>
<tr>
<td>Microphonic</td>
<td>Cable, slightly</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Geometric</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Drift: (If Full scale per minute (HSI))</td>
<td>Function of line voltage</td>
<td>0.6%</td>
<td>Function of line voltage</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Hold calibration: (V)</td>
<td>Not calibrated</td>
<td>Fair</td>
<td>Very well</td>
<td>Very well</td>
<td>Well</td>
<td>Very Well</td>
<td></td>
</tr>
<tr>
<td>Amusibility: (V)</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
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### Battery Replacement

<table>
<thead>
<tr>
<th>Tools needed</th>
<th>Screw driver</th>
<th>2 screw drivers and pliers</th>
<th>2 screw driver and pliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time required</td>
<td>6 min</td>
<td>15 min</td>
<td>15 min</td>
</tr>
<tr>
<td>Frequency: (V)</td>
<td>Line powered</td>
<td>Line powered</td>
<td>Year</td>
</tr>
<tr>
<td>Frequency: (V)</td>
<td>Month</td>
<td>Month</td>
<td>Month</td>
</tr>
<tr>
<td>Parts</td>
<td>Special</td>
<td>Special</td>
<td>Special</td>
</tr>
<tr>
<td>Skill required</td>
<td>Insulator</td>
<td>Electronic</td>
<td>Electronic</td>
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<tr>
<td>Features</td>
<td>H.V. adjustment</td>
<td>H.V. adjustment</td>
<td>Fan speed control</td>
</tr>
<tr>
<td>Number of Controls</td>
<td>6</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Handles</td>
<td>No</td>
<td>Shoulder strap</td>
<td>Cart</td>
</tr>
<tr>
<td>Selective Window</td>
<td>Extra</td>
<td>Extra</td>
<td>Counter</td>
</tr>
</tbody>
</table>

### Author's Opinion

1. Response time is the time elapsed after a change of intensity of about 1/2 scale value before indicator approaches closely the new value.
2. Warm-up time is measured from the closing of the switch until the initial transient surge has passed.
3. Slope of zero drift, following initial transient, with respect to time in terms of the full scale mechanical displacement.
4. Change of calibration with time and battery conditions.
5. Instruments not tested to destruction. Subjective opinion listed here.
6. Order of magnitude estimated from survey experience.
# MEASURING INSTRUMENTS

<table>
<thead>
<tr>
<th>Source</th>
<th>Cuttie-Pie</th>
<th>Fish Pole</th>
<th>L &amp; W Electroscope</th>
<th>Vacuum Canes</th>
<th>X-ray Film</th>
<th>Chang &amp; Eng</th>
<th>Virtreesometer</th>
<th>Feinberg</th>
<th>Paint Pail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Linear</td>
<td>Linear</td>
<td>Linear first $^a$</td>
<td>Linear</td>
<td>Exponential</td>
<td>Not quite linear</td>
<td>Not linear</td>
<td>Not linear</td>
<td>Linear $&lt; 1500$ sr/hr</td>
</tr>
<tr>
<td>Scale linear marked with arbitrary numbers</td>
<td>Scale linear marked with arbitrary numbers</td>
<td>Linear scale untrue by 15%</td>
<td>Linear register with GM counter</td>
<td>Photometer scale marked for density values</td>
<td>Linear scale marked with arbitrary numbers</td>
<td>Linear scale marked incorrectly by as much as 50%</td>
<td>Linear scale not correctly marked</td>
<td>Linear scale marked with arbitrary numbers</td>
<td></td>
</tr>
<tr>
<td>40 2</td>
<td>50 2</td>
<td>40 microscope</td>
<td>Register in counting room</td>
<td>Photometer</td>
<td>100 microscope</td>
<td>Irregular</td>
<td>1-1/2</td>
<td>25 2 2 1/2</td>
<td></td>
</tr>
<tr>
<td>30, 30, 2000 m/hr</td>
<td>40,000 m/hr</td>
<td>200, 2000 m/hr</td>
<td>30,000 c/m/sample</td>
<td>---</td>
<td>0.003 to 300 8 hr. tolerance</td>
<td>10 or 200 or 10,000 m/hr</td>
<td>25, 100, 1000 m/hr</td>
<td>20, 200, 2000 m/hr</td>
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<td>1, 10, 100 m/hr</td>
<td>2,000 m/hr</td>
<td>2,000 m/hr</td>
<td>2,000 m/hr</td>
<td>---</td>
<td>determined by probable error of counting</td>
<td>---</td>
<td>10 or 5 or 250 m/hr</td>
<td>1, 4, 10 m/hr</td>
<td>1/2, 5, 50 m/hr</td>
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<tr>
<td>$\beta$ &amp; $\gamma$</td>
<td>$\beta$ &amp; $\gamma$</td>
<td>$\beta$ &amp; $\gamma$</td>
<td>$\beta$ &amp; $\gamma$</td>
<td>$\beta$ &amp; $\gamma$</td>
<td>Past neutrons</td>
<td>$\gamma$ and soft $X$</td>
<td>$\beta$ &amp; $\gamma$</td>
<td>$\gamma$</td>
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<tr>
<td>64x5/3 x 3/4</td>
<td>6x5 3/4 x 3/4</td>
<td>6x3 3/4 x 3/4</td>
<td>6x3 3/4 x 3/4</td>
<td>---</td>
<td>10 x 12</td>
<td>15x15</td>
<td>13x3 3/4x10</td>
<td>13x3 3/4x10</td>
<td>9 dia.x20</td>
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<td>4</td>
<td>5</td>
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<td>$3\frac{1}{2}$ x 6&quot;</td>
<td>$3\frac{1}{2}$ x 6&quot;</td>
<td>$3\frac{1}{2}$ x 6&quot;</td>
<td>$3\frac{1}{2}$ x 6&quot;</td>
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<tr>
<td>10 sec</td>
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<td>30 sec</td>
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</tr>
<tr>
<td>High or low</td>
<td>High or low</td>
<td>High or low</td>
<td>High or low</td>
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\(\text{TABLE X}\)
the badge meter along with the regular beta-gamma film. It is furnished to persons who are known to be exposed to neutrons (see procedure Section II-H. 3.d. for having this film placed regularly in a person's film badge). Fast neutrons produce hydrogen proton recoil tracks in the film. Thermal neutrons produce proton tracks by the reaction \( N(n, p)C \). These proton tracks are counted with the aid of a dark field microscope by the personnel monitoring girls. Fast neutron tolerance is indicated by 21 tracks/50 fields of vision (1 field of vision is \( 1.77 \times 10^{-4} \, \text{cm}^2 \)) and thermal neutron tolerance by 14 tracks/50 fields of vision. The portion of film behind the cadmium is exposed to both fast and thermal neutrons.

4. **The Film Ring** can be used with any of the films described above. They may be obtained by a request to any of the Health-Physics surveyors. They have a very thin ("0.004") beta window and some of them are provided with a cadmium shield.

5. **Dose Meters** may be obtained by a request to any Health-Physics surveyor. They are available in the self-charging type or the externally charged variety. They have ranges up to about 200 mB. Their limitations are essentially the same as those of the Victoreen pocket meters.
Appendix C-1

CONTAMINATED SHOE REPLACEMENT

An employee whose safety shoes or personal shoes have been checked by the Health-Physics Section and found contaminated to an extent requiring confiscation may obtain a free issue of safety shoes to replace them by the following procedures:

Editor's note: The procedures are described in detail in the Clinton Laboratories Manual so that there will be no misunderstanding of the mechanism of obtaining replacement of contaminated shoes. They are local procedures so their reproduction here serves no useful purpose.
Surgical Technic for Putting on and Removing Rubber Gloves

Surgical rubber gloves, used during procedures where hand contamination is probable, should be prepared in advance by powdering the insides and by folding out the wrist portion of the gloves to form a cuff of about two inches.

To put on the gloves the following procedure is advised:

1. The hands are powdered well with talc.

2. The first glove to be donned is grasped at the folded cuff, without touching the exterior of the glove, and pulled onto the fingers and hand, leaving the cuff in the folded position.

3. The second glove is lifted by inserting the fingers of the gloved hand beneath the cuff, and pulling it onto the bare fingers and hand.

4. The cuffs of both gloves are turned back over the wrists, without touching the bare skin.

5. The loose fitting glove fingers are then "worked" into position in the same manner as are cloth gloves.

Removal of the gloves is accomplished in the reverse order, in that the fingers of one gloved hand grasp the beaded rim of the top of the glove of the other hand without touching the inside of the glove, and by traction, invert the glove and pull it off the hand. The index finger of the bared hand is now inserted beneath the beaded rim of the top of the other glove and without contacting the exterior surface of the glove, it is inverted and pulled off the hand.
See Chapter VII of the volume.

of wound licked to be contaminated with plutonium

Recommended Procedure for Immediate Care

Appendix C-3

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Appendix C-4

Recommended Procedure for Washing Contaminated Hands

(See Chapter VIII, this volume)
Appendix C-5

PROCEDURE FOR BURIAL GROUND

A number of persons throughout the laboratories believe it advisable to establish a central control over the burial ground. The reasons for this are:

1. To maintain adequate and permanent records of particularly hazardous materials buried.
2. To provide long range planning of burial ground space and layout of trenches available for emergencies.
3. To see that materials such as plutonium, strontium, and all alpha emitters or other long-life materials are segregated from the routine, mildly contaminated materials.
4. To conserve space where possible and still be consistent with safe practices.

Therefore, this bulletin is to notify you of the following changes in the procedure for burying active trash or unwanted active materials and equipment. (Editor's note: The local rules contain a detailed description of the procedures, reproduction here would serve no useful purpose. Appendices C-6, C-7 and C-8 are local procedures. Their reproduction here would serve no useful purpose.)