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CHEMISTRY AND METALLURGY HEALTH HANDBOOK

OF RADIOACTIVE MATERIALS

August 17, 1945

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CHEMISTRY AND METALLURGY HEALTH HANDBOOK

OF RADIOACTIVE MATERIALS

August 17, 1945

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1. **INTRODUCTION**

The purpose of this Handbook is to apprise workers on the project of the various possible health hazards that arise from nuclear radiations. These hazards are described, and the Health-Safety procedures for dealing with them are outlined. In the interests of compactness the discussion is brief and general. However, it was deemed essential to indicate to the reader the intensive effort being made to eliminate radiation health hazards: hence, the detailed description of monitoring instruments and, as an example, the chemical assay for 49 and Polonium in the urine. For more detailed information on any radiation hazard the worker should consult Dr. Louis Hempelmann. Finally, the worker exposed to nuclear radiations is emphatically urged to follow the two basic rules: (1) know all the possible radiation hazards in a given job, and, (2) see that proper protective procedures are followed in the job.

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PART I. HEALTH PHYSICS

A. General

Nuclear radiations dealt with in large quantities in practice are electrons, alpha particles, gamma rays, and neutrons. Briefly stated, electrons and alpha particles are most harmful, particularly, when the elements from which they are emitted are taken into the body by mouth or by breathing. Inside the body they bombard sensitive tissues directly, whereas from outside they must first traverse air, clothes, and skin before reaching sensitive tissue. Inside the body the proximity to tissue and low rate of elimination make small amounts of radioactive elements very harmful. For example, 0.1 microgram of radium is considered to be the largest amount tolerable in the body. Electron radioactive materials in direct contact with the skin may produce burns of varying degrees depending on the exposure.

The harmful effects of gamma rays and fast neutrons reach all tissues of the body because of their great penetrating power. Their effects are produced by ionization released at all depths below the skin surface. The first reaction will be found in the very radio-sensitive tissues such as the regenerative and blood forming organs. For gamma and fast neutron radiations, the best protection is given by: (a) greatest possible distance from the source, and (b) water, concrete, or lead barrier shields around the source, (the material depends upon the type of radiation).

The common radioactive elements used in large quantities such as Polonium (alpha active), 49 (alpha active), and RaLa (beta, gamma active) are known to get into the air and to spread over surfaces such as tables and floors. Of these, Polonium shows the most striking behavior in that it "creeps" rapidly over surfaces and readily leaves the solid state to float in the air attached to dust particles. The other two elements, 49 and RaLa do not spread as easily as Polonium; for instance, RaLa or 49 solutions must dry along the edges of its container before the dry salt or metal can start floating off into the air. They, nevertheless, get around and as a result the worker must see at all times that the elements are properly confined. All possible free surfaces in the laboratory should be monitored for floating contamination and the air should be changed regularly to prevent contamination from accumulating.

Meaning of "Tolerance" Dose.

The biological or physiological effects that result from exposure to nuclear radiations or X-rays will depend on a considerable number of physical and biological factors. Of most importance among physical factors are: (1) the type of radiation, (2) the spacial distribution and amount of the radiation energy absorbed in the tissues; and (3) the time distribution of the radiation dosage. The biological

factors which influence the response of an organism or a tissue to a fixed set of physical radiation conditions are numerous and are not completely understood. Even under apparently identical physical and biological conditions there is generally a wide spread in the response to radiation of a number of "identical" organisms or tissues. The latter results from what is known as "individual variation" in radiosensitivity.

Accordingly it is quite an involved problem to set "tolerance" doses or dosage rates for all radiation exposure conditions that may be encountered by human beings. By a "tolerance" dosage rate is generally meant that amount of radiation which could be absorbed by the human body per day for an indefinitely long period without producing harmful effects.

"Tolerance" in this sense thus means an upper limit to the radiation energy absorbed per day indefinitely which will be "absolutely safe," i. e. which will produce no observable impairment of any function of a large number of healthy humans. In setting such a "safe tolerance limit" provision is consequently made for extremes in radiosensitivity of individuals and for varied manners of exposure. For an average subject and average exposure conditions there will usually be a certain "safety factor" in the specified safe tolerance limit of dose or dosage rate; i. e. the tolerance value may be consistantly exceeded by a certain factor without evidence of any damage to some individuals. For some individuals and exposure conditions the "safety factor" may be large while in other cases it may be small or zero.

One can thus state that if the average individual stays within the tolerance limits he can be practically certain of suffering no impairment of any of his functions. If he exceeds the tolerance limits one cannot always predict what the results will be. In general, however if the tolerance limits are not greatly exceeded, the individual need not be considered a "dead duck", for in all probability only minor disability may result. This does not mean that tolerance limits are to be taken lightly. It means that if one does not want to gamble with one's health the tolerance limits should not be exceeded.

There are virtually two different protection problems involved depending on whether the radiation concerned, originates at a point that is external or internal to the human body. In both cases the cells concerned are affected by integrated dosage over relatively long periods of time. With external radiation, however, it is possible to remove the source of danger, while with radiation originating from radioactive materials lodged in the body nothing, or at least little, can be done to eliminate the material and the problem is virtually that of avoiding absorption of the substance in the first place. While in the former case, protection methods are in order against the radiation, in the latter case protection is against bodily absorption of the substance itself, in exactly the same manner as against

ordinary chemical poisons.

A distinction should be made between the significance of tolerance values for externally received radiation and for radiation received from internally absorbed radioelements. In the latter case the radiation dosage rate is set mainly by the rate of decay of the radioelement and the rate of its elimination from the tissues involved. Once it is determined that a certain quantity of a radioactive material has been absorbed in certain tissues, the rate at which radiation energy will continue to be released in these tissues is then also practically determined. In this case the "tolerance dosage" (time integral of the dosage rate) is determined by a "tolerance amount" of the radioactive material in the given tissues. In the case of externally received radiation there are infinite variations possible in the time distribution of the dose. As a consequence, a "tolerance amount" of the radiation cannot be quoted but instead, one must state the amount which distributed in time in a certain manner will be tolerated. For example, 0.1 r/day of X-rays received for 10 years will amount to approximately 300 r total, which is considered tolerance when so distributed, but when taken as a single dose of 300 r the amount is considered to be in excess of tolerance.

In quoting the amount of external radiation that may be taken as tolerance, the factor of distribution in time is all important. The "tolerance" value of 0.1 r/day for whole-body human exposure to X-rays and gamma rays is arrived at on the assumption that the subject is liable to be exposed at this rate for the balance of his working life. If the worker is to be exposed only once in his life, a dose of 10r, or possibly more than 100 r, should show no observable effect at all and most likely no appreciable permanent damage. Persons have been given the order of a few hundred roentgens of X-rays total body radiation in a short period (a week or two) and have shown no observable effects either immediate or after months. The amount of whole-body human exposure to X-rays or gamma rays that could be taken for one or two years only, without subsequent exposure, is not known from experience with humans, but animal experimentation leads some to believe the tolerance value under such conditions would be from 0.5r to one r per day. These remarks are not made with the idea of condoning exposures of workers in excess of 0.1 r/day but merely to point out the importance assumed by time distribution of the exposure. "Allowable" or "working" doses of external radiation in excess of the "tolerance" value will be permitted by the Medical Group for special cases when all factors of the time distribution of exposure to the worker are taken into account. The average worker, however, should assume that he may be liable to continued exposure and stay within the tolerance rate of 0.1 r/day.

In the case of absorption of radioactive materials in the body there is no such flexibility in the time distribution of the dosage to the tissues. Once the tolerance amount has been deposited in a tissue, the tissue will eventually receive a tolerance dose (unless, of course, some other normal means is found of eliminating or removing the effects of the radioelement). Consequently, in this case the worker can afford no more accumulation of the material in his tissues once they have

accumulated the tolerance amount. Since tolerance amounts are generally specified at least 100 times below amounts that might prove lethal in a long period of time, no extreme effects are to be expected even in a long time from a small excess over the tolerance amount. This is not intended to make the worker regard the specified tolerance amounts lightly, but merely to assure him that, if in spite of all precautions by himself and safety groups, he should accumulate a small excess over the tolerance amount he will most likely never have evidence of tissue damage. He should, however, make no compromise with safety in any case.

It is not the function of this portion of the discussion to consider the validity of tolerance values. One can say, however, that for materials such as 49, for which there is not a large experience of long-period human exposure, the tolerance amounts are necessarily set with a conservative view, thus affording the possibility of additional safety factor. Lethal and chronic effects of 49 and Po are being studied extensively in animals. The rate of elimination and the manner of deposition of 49 and Po in tissues of humans is also being studied. At some later time the results of experimentation and experience may lead to an upward revision of the specified tolerance amounts. At present it is safe for the worker to proceed with the presently accepted tolerance values, keeping in his favor any safety factors that may result from conservatism in specifying the tolerances.

Some remarks should also be made concerning what is meant by "dose." A distinction should be made between "exposure" and "dose." Exposure connotes the amount to which one is exposed, while dose connotes the amount which one has absorbed. The dose, in terms of energy released in the tissues, is the biologically important factor. Although there is a fixed relationship between exposure and dose (absorption) for any particular set-up, the relationship will vary with conditions. For example, the degree of exposure to 49 may be monitored by the 49 content of the air being breathed, but the "dose" or amount absorbed will depend greatly on the size of the particles on which the 49 is deposited, on the chemical composition, and on the subject. Also the roentgen which is commonly considered a unit of dosage for X-rays and gamma rays is actually a unit of exposure. The roentgen is a unit measured by ionization in air and not in the tissues of the body. It is approximately true for small organisms, however, that an "exposure" of one roentgen of X-rays or gamma rays, over a wide range of energy of the radiations, will produce the same expenditure of energy or "dose" (about 82 ergs) per gram of tissue. In the case of a human, the energy absorbed at all depths in the body will depend on the penetrating power and hence the energy of the radiation; consequently, an exposure to one roentgen of very soft X-rays will not result in as much energy released in all regions of the body as for much harder radiation. The correlation is good enough, however, between the roentgen exposure unit and the average energy released throughout the body, hence dose received, using the average X-rays and gamma rays encountered in practice to make the roentgen synonymous with dose. In the case of 49 and other radioelements which enter the body through breathing,

ingestion, etc., the dose, or amount deposited in the tissues, cannot always be foretold from the exposure, i.e. the amounts monitored in the air, on table tops, on hands, in the nose, etc. The degree of exposure as determined by monitoring can, however, be used as a guide to indicate the possible degree of dosage that may result. When exposure monitoring indicates the possibility of tolerance amounts of absorption, tests are done on the subject's excretions, as will be discussed subsequently, to determine whether a tolerance amount has been accumulated in the body.

PART II. TOXICOLOGY OF RADIOACTIVE MATERIALS

A. 49

This material is highly toxic and must be handled with extreme precaution. Its toxicity is thought to be due entirely to its radioactivity which is principally alpha particle emission. The action of its alpha particles on tissue is identical to that of the alpha particles of radium which have about the same energy. 49 is somewhat less active than radium (15 times) and therefore, less toxic. Furthermore, 49 decays into an element which, for biological purposes, may be considered inactive. This also tends to make 49 less dangerous to the body than radium which forms a chain of radioactive daughter products. These daughter products emit 2.5 alpha particles for every particle emitted by radium nuclei. These dissimilarities between product and radium make 49 approximately fifty times less toxic than radium on the basis of physical factors alone. Difference in metabolism of the two substances, which will be discussed later, indicate that the toxicities are more nearly equal. For safety purposes, 49 may be considered to be approximately as toxic as radium. The situation which we seek to prevent is one comparable to the radium poisonings of the luminous dial painters of the first World War.

The problem of protection of personnel from the hazards of 49 is primarily one of preventing the material from entering the body through any of the usual routes - the lungs, the intestines, or wounds in the skin. Absorption of 49 through the intestional tract is known to be poor. Nevertheless, efforts are made (see Part VI) to eliminate any chance of entrance of material into the body by this means. Absorption of 49 breathed into the lungs represents the most usual method of gradual accumulation of the material in the body. Elaborate precautions are used to protect workers against this hazard. Accidental inoculation of 49 into the body by means of contaminated instruments or objects which pierce the skin is minimized by urging all workers to use great personal care when working with this potentially dangerous material. Should such an accident occur, all personnel should know the best method of treatment of such a wound - namely, immediate washing of the wound by a full stream of tap water, increasing the bleeding of the wound, and reporting to the

Post Hospital within 15 minutes for complete excision of the wound (see Part VI, Section 11 b).

If 49 enters the body in spite of all precautions, it will localize in either the lungs or the bones. Although the lungs have an excellent mechanism for ridding themselves of particulate matter, a small fraction of inhaled dusts and particles can remain in the more remote portions of the lungs. In the case of insoluble salts, these particles may remain in the lung for an indefinitely long period of time. If the compounds are soluble, they may be partially or completely absorbed into the blood stream. 49 which has entered the body in this way or from contaminated wounds is deposited almost completely in the bones. There it forms a very tight chemical combination which, for our purposes, may be considered permanent. In this respect it is unlike radium, a large portion of which is excreted from the bone during the first few months. 49 also tends to be deposited on the surface of the bone in close approximation to the radiosensitive cells of the bone marrow. This unfortunate localization of product in the bone together with the tenacious chemical combination which is formed, make 49 an extremely toxic substance once it enters the bloodstream.

If a toxic amount of 49 enters the body, damage to the lungs or bone marrow may lead to the death of the individual. The toxicity of radioactive materials is unique in that evidence of injuries may not appear for months or even years. Acute injuries could be caused only in case of accident where milligrams of the material enter the body. Delayed effects are more apt to result from the slow accumulation of material (micrograms) over a period of months or years. These latter cases of gradual building-up of product in the body to dangerous levels can be prevented by frequent testing of personnel to determine how much material they contain. Satisfactory tests have been developed (see Part III) and are made regularly on everyone exposed to 49. If these studies indicate that an individual has more than one microgram in his body, he is removed from further contact with the material. It is believed at the present time that 49 in amounts less than one microgram can be tolerated indefinitely by the body without injury of any kind.

B. Polonium

This element is toxic because of its radioactivity. Like 49, it emits principally alpha particles and, therefore, may be considered dangerous only if it enters the body. Since it is many thousand times more radioactive than 49, much smaller amounts of the material are dangerous. This, together with its great tendency to "creep," make it seem much more toxic than 49. In practice, however, polonium is used in much smaller quantities by weight than is 49, though in approximately equal amounts as far as radioactivity. When thought of in terms of the amounts of material used in this laboratory, it is actually somewhat less dangerous than 49 since, 1) it is excreted rather rapidly from the body and, 2) it decays relatively rapidly (140 day half-life) into an inactive daughter element and, 3) it

is not concentrated in any organ in the body. These three facts enable the body to tolerate larger amounts of polonium radioactivity than of 49 or radium.

The problem of protection of personnel in this case is quite similar to that described in the preceding chapter. Strenuous efforts are directed at preventing the material from entering the body. Tests are made frequently to determine exactly how much material is in the body of each worker. Polonium is absorbed from the intestinal tract, from the lungs and possibly even to a slight extent through the intact skin. When it enters the body it is distributed throughout all tissues but is present in greater amounts in the kidney, spleen, and heart. In cases where the body contains toxic amounts of polonium, damage may be expected primarily in these organs.

Except for accidents, the greatest danger from polonium is from chronic exposure where small amounts are absorbed daily in excess of what is lost through excretion and decay. This slow accumulation of material in the body may result in polonium levels which exceed the "safe" amount. It is relatively easy (see Part III) to determine exactly how much polonium is in the body. People who exceed the upper limit of safety (see Part III, Section B), are removed from further exposure.

C. Tuballoy and 25

It has been known for many years that tuballoy is toxic and that a few milligrams injected into a small animal will cause death by kidney damage. The damage to the kidney is caused by chemical action and not by the mildly radioactive properties of the material. In its mode of action, tuballoy resembles the heavy metals (mercury) rather than polonium or 49. Because of its well-known toxicity, the danger to personnel working with tuballoy caused great concern during the early days of the project. Fortunately, biological experiments during the past few years have shown that this danger was greatly exaggerated. This results from the fact that tuballoy is very poorly absorbed from the gastro-intestinal tract and the lungs and presumably not at all through the intact skin. Animals have been fed tuballoy daily in very large amounts for many months with no evidence of bodily damage.

These animal experiments do not enable us to disregard the toxicity of tuballoy but they do indicate that this material is relatively safe to handle. Experience with project workers bears out the fact that with proper precautions (see Health-Safety Rules, Part VI) and frequent testing of individuals for kidney damage, tuballoy can be processed in large amounts without undue danger to personnel. It is very important that the exposed persons cooperate in submitting weekly urine specimens for examination by the Medical Group. By means of weekly urinalysis, kidney damage can be detected in its early stages before severe or irreparable harm has been done.

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Tuballoy and its decay products are highly radioactive; they emit alpha, beta, and gamma radiation. The alpha and gamma radiations are relatively mild and probably not of biological importance. 14 grams of tuballoy are equivalent in alpha activity to 0.1 microgram of radium. [illegible] 25, which is considerably more alpha active than ordinary tuballoy, [illegible] dangerous to personnel primarily because of its chemical properties [illegible] its radioactivity may play a part. The beta radiation from both tuballoy and 25 is of considerable importance in that it may seriously damage the skin. The skin of the hands can tolerate contact with tuballoy metal for two hours a day (0.5 r beta radiation indefinitely) without damage. The tolerance for 25 may be much less than this depending upon how recently it has been separated from its daughter products. If the precautions in the Health Safety Rules (Part VI) are carefully followed, there is no reason to expect skin damage from either of these materials.

PART III. PROCEDURES FOR DETERMINING EXPOSURE OF PERSONNEL

A. Determination of 49 in Urine

1. Collection of Sample: Because of the extreme difficulty of detecting internal contamination with 49, it is necessary to collect a 24 hour sample under very rigorous conditions to prevent contamination of the specimen by the hands. The subject is directed to stay away from the [illegible] area and the S.E.D. barracks during the 48 hour period preceding the [illegible] of collection of the sample to be analyzed. Civilians may remain in their homes during this period if they choose. It is desirable, however, that they leave the site if conveniently possible. Military personnel are requested to spend this period away from the site and are given military subsistance during this time. All persons are asked to wear freshly laundered undergarments during this period and if possible, freshly laundered outer garments. Certainly, no outer garments previously worn in the technical area should be used. The individual is asked to wash his hands frequently during the time away from work.

The subject is asked to report to the Post Hospital at 8:00 o'clock in the morning at the close of this "preliminary" 48 hour period. He is to remain in the hospital room assigned to him for the following [illegible] hours except that he takes his meals in the hospital mess. He is asked to refrain from drinking excessive amounts of beer, coffee, and other beverages during the preliminary period. It is requested also that one drink little no fluid between meals and only one cup or glass of liquid at each meal during the 24 hour period in the hospital. The fluid restriction is requested in an effort to avoid very large urine volumes which make the evaporation procedure extremely difficult and time consuming. The subject is asked to take a shower before putting on hospital clothing. Before showering, the individual empties his bladder and discards the voiding. After showering

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goes to the room assigned for sample collecting, where he remains for the next 24 hours. A hand counter is available in the room and a note is made as to whether or not the individual has activity on his hands. All specimens of urine voided during the 24 hour period are collected in the 2 liter Erlenmeyer flask provided for the purpose. During each voiding the person wears white cotton gloves to prevent epitholial scales from the hands falling into the funnel during the process of urination. These epithelial scales might possibly carry 49 contamination.

On the following morning the subject has breakfast in the hospital mess after which he returns to the room and collects the last voiding of urine at about 8:00 A.M. He then dresses and leaves the hospital, merely leaving his specimen on the table where it was collected. He does not touch or stopper the flask. The sample will be picked up and delivered to the laboratory by some member of the Medical Group.

Rigid adherence to the procedure described above should permit the collection of a 24 hour urine specimen as nearly free from contamination as possible.

2. Method of Determination: The entire 24 hour specimen is evaporated almost to dryness and the residue is wet-ashed, using one addition of concentrated HCl and repeated additions of concentrated HNO_3 and 30 per cent hydrogen peroxide. The ashing is continued until a white solid almost completely free of organic matter remains. The residue is taken up in 2N HCl and a complete hydroxide precipitation carried out. The hydroxide precipitate is dissolved in HCl, and the pH carefully adjusted. The 49, plus 1 mg. of ferric iron as a carrier, is extracted into chloroform after complexing with cupferron. The chloroform is evaporated off and the cupferron residue digested with nitric and perchloric acids. From the perchloric acid solution a lanthanum fluoride precipitation is carried out. The lanthanum fluoride precipitate carrying the 49 is placed on a platinum foil and counted in a proportional counter for a 30 minute period. The results are reported as counts per minute excreted per 24 hours.

Using this procedure, 5-10 counts per minute have been recovered from spiked 1 liter samples of urine with an accuracy of better than 80%.

3. Application and interpretation: Only those people working directly with 49 are to be monitored by this procedure. It is hoped that each individual working with the material can be monitored every two or three months, and those working in unusually hazardous areas, every 30 days. The value for the maximum tolerance dose of 49 has not been established up to the time of this report. Present procedure is to retire anyone showing a persistent excretion of 7 or more counts per minute per 24 hour sample, from further direct contact with the material. All results are reported to the respective group leaders as soon after the completion of the analysis as is conveniently possible. The Group Leader should discuss the results

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with the individual members of his group.

B. Determination of Polonium in Urine

1. Collection of Sample: Because of the possibility of a contamination of the urine samples collected for polonium determination it is suggested that the following plan be used.

On leaving the Technical Area on Saturday night the individual should obtain a specimen bottle and a pair of white cotton gloves from Room U-38. These will be contained in a paper bag. He must not enter the Technical Area again until after the collection of the sample on Monday morning. On Sunday he washes his hands frequently, preferably with abrasive soap. Sunday night he notes the hour at which he discarded the last urine sample. The next morning he showers, puts on the white cotton gloves and collects the first morning voiding before dressing for work. The entire voiding must be collected. He should avoid touching the lid of the bottle at any time. On the label on the bottle he indicates the hour at which a specimen was last discarded and the hour at which the sample was collected, as well as his name. The bottle should be delivered to Room U-38 as the individual comes to work. Under no circumstances should the bottle be taken into a contaminated building. Because of the possibility of the polonium precipitating on the glass, it is requested that the sample be delivered to Room U 38 before nine o'clock Monday morning. All samples are to be collected on Monday morning unless, for some reason a special check must be run during the week.

2. Method of Determination: A measured quantity of urine (50 cc) is acidified with hydrochloric acid and the Po is plated out on a copper disc which is suspended in the acidified urine. The urine is agitated by continued stirring. A proportional counter is used to determine the quantity of Po on the copper disc. The results are calculated to the basis of a 24 hour sample.

When known amounts of Po are added to acidified urine, the recovery by the above method is 80% or greater.

3. Application and Interpretation: At the present time, the [redacted] maximum tolerance dose of polonium is set at that amount which will [redacted] a urinary excretion of 1500 counts/min. (3000 disintegrations per [redacted]ute, when determined by this procedure. The present assumption is that [redacted] individual will be transferred to other work should this tolerance limit be reached.

Only those people working directly with polonium or those involved in accidents with the material are to be monitored. The people working directly with polonium are being checked routinely by this method every week. All results are reported to the respective group leaders as soon after completion of the analysis as is conveniently possible. The group leaders should discuss the results with the

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individual members of their groups.

C. Determination of Albumin in Urine (for evidence of kidney damage caused by tuballoy, 25, and Hg.)

1. Collection of Samples and Methods of Analysis: On Thursday of each week, urine specimen bottles are placed in the washrooms of D-Building, Sigma, and C Shop. All personnel working with tuballoy, 25, and mercury are asked to leave a specimen. These samples are delivered to Q Building for albumin analyses using the Roberts reagent.

2. Interpretation: Results obtained by this method are semi-quantitative only. Tests are rated from 0 to 4 plus. The purpose of the test is to detect faulty kidney function and may be an indication of heavy metal damage. Those individuals showing a consistent albuminuria will be examined further and tuballoy and/or mercury determined in their urine.

D. Determination of Tuballoy and 25 in Urine.

1. Collection of Sample: The first specimen of urine voided in the morning is used for the analysis. When an individual is notified by the Medical Group that he should bring a urine sample for tuballoy analysis, he should report to the first aid station (Room T-13) upon leaving work and obtain a specimen bottle to take home. The bottle will be prepared and ready. The next morning the individual carefully scrubs his hands and collects the first morning voiding before dressing for work. A note should be made on the label of the approximate number of hours the particular sample represents. Care should be exercised in avoiding the handling of the lip of the bottle. On the way to work, the specimen may be left at T-13 where the specimen bottle was obtained.

2. Method of Determination: Aliquots of the urine sample are wet-ashed with concentrated HNO_3 and 30% hydrogen peroxide and taken up in 15 ml. of 6 N HNO_3. The solution is made 0.3N with NH_4NO_3 and the tuballoy extracted with three 10 ml. portions of hexone. The hexone is [redacted] off on the steam bath, the residue ignited gently [redacted] and the carbon from the residue burned off. The pl[redacted] is washed down with HNO_3. Then HNO_3 is evaporated off [redacted] the platinum dish fused with a fusion mixture consisting of [redacted] potassium carbonate, 42.5 g. of sodium carbonate and 2.5 g. of potassium fluoride. After cooling, the fluorescence of the fused mass is compared with that of suitable standards prepared in the same way from known amounts of uranyl nitrate and 2.5 g. of the fusion mixture. The standards and samples are compared in a dark room under a mercury arc light. Results are reported in micrograms excreted per day.

When known amounts of uranium are added to solutions of urine ash, the recovery is 70% or greater.

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3. Application and Interpretation: Only those persons working with tuballoy and 25 who show albuminuria in the regular routine weekly urine analysis should have their urine tested for tuballoy content. The purpose of this test is to determine whether or not the albuminuria is a result of kidney damage by the tuballoy. Persons excreting less than 50 micrograms of uranium per 24 hours are classed as slightly exposed; 50-150, moderately exposed, and over 150, as highly exposed.

PART IV. HEALTH INSTRUMENTS

A. Alpha Survey Meters

1. Pluto

a.) A small, portable, battery operated, two stage amplifier, with linear response, principally used for detection of alpha radiation from plane surfaces (full scale sensitivity, approximately 20,000 to 50,000 c/m, 30% geometry). This meter also responds to beta and gamma radiation, but is relatively insensitive to such radiation because of the small chamber volume and the small ionization produced by beta and gamma rays as compared to alpha.

b.) Not sensitive to counting rates less than 2000 to 5000 c/m. Not to be used where greater than 20% accuracy is needed. Approximate battery life of 75 hours.

c.) These units are available for temporary or permanent loan to laboratory groups.

2. Super Zeuto

a.) Very similar in size and operation to Pluto, but an entirely different circuit (3 stage, D.C. amplifier with negative feedback for faster response). It has two ranges; one, 20,000 to 50,000 c/m full scale (same as Pluto), and two 2,000 to 5,000 c/m full scale.

b.) Not sensitive to counting rates less than 200 to 500 c/m. Not to be used when greater than 10% to 20% accuracy is needed. Approximate battery life of 1000 hours.

c.) These units are available for temporary or permanent loan to laboratory groups.

3. Super Snoop

A mobile, battery operated, alpha survey meter of the proportional counter type. It uses a continuous gas (methane) flow

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counter for the detector. The unit has four ranges, full scale values of 150, 500, 4,000 and 12,000 c/m with non-linear responses. Ear phones are provided for rapid detection of particles of low counting rates. Individual pulses are easily detected.

4. Penny

A mobile, A.C. operated alpha survey meter of the proportional counter type, but differing from the Shoop in that it uses an air-filled counter for a detector. The set has a loudspeaker attachment for audible indication of activity. The unit has a single range 100 to 10,000 c/m full scale (logarithmic response). It is limited in use by the fact that it is necessary to operate on A.C.

5. Portable Alpha Survey Meter

As the name indicates, this meter is completely self-contained (battery operated), and portable. It uses a proportional counter for a detector with sensitivities from 0 - 10,000 c/m. Earphones and counting rate meter are provided for low and high counting rates respectively.

B. Alpha Hand Counters

1. Continuous gas flow type (methane)

Very similar to the Snoop, differing in two ways; one, it is A.C. operated, and two, it is modified for use as a hand counter rather than a survey meter. The sensitive area of the counter is relatively small and necessarily covers only a portion of the hand for a given reading. The unit has a small loud-speaker attachment so that the pulses are audible. The sensitivity is approximately 0-5000 c/m with a non-linear response.

2. Air filled counter type

This unit is a proportional type counter, same as (1) but does not require a continuous gas flow in the counter. The surface area of the counter is such that both sides of one hand can be monitored simultaneously. The full scale sensitivity is approximately 20,000 c/m (25% geometry) with logarithmic response. This type of response makes the reading at low counting rates more accurate when the upper limit is high. A modification of this type is used to monitor alpha contaminated clothing. Both types of hand counters are placed about the various laboratories for the use of all members.

C. Standard Alpha Counter

These units are used for counting nose swipes, hand swipes and other swipe samples. Two models are available; one, the Cyclotron

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Specialized [illegible]

I. Alpha [illegible]

[illegible] the air [illegible] pump and [illegible] to hold a [illegible] counting [illegible] filter p[illegible] standard [illegible] is though[illegible] a critic[illegible] level.

E. Beta and Gamma Survey Meters

1. G. M. Survey Meter

a.) This meter is a portable battery operated beta and gamma detector, manufactured by Hall[illegible] Waters Company. It is composed essentially of three parts. [illegible] a thin walled glass GM tube used as the detector. [illegible] circuit used to supply the high voltage for the GM tube. [illegible] amplifier and integrator [illegible] the pulses from the tube with the level of radiation indicated on a meter. Two ranges are provided, one with a full scale value [illegible] (1.5 of [illegible]), and two, with a full scale value of approximately [illegible] R/hr [illegible] about 10 times normal background. The meter response is slightly non-linear. The battery life for continuous operation is [illegible] 30 hours. During this time the sensitivity decreases approximately [illegible]5%.

b.) A second model, [illegible] similar to a.) is made by the [illegible] Green Instrument Company. This unit has the GM tube mounted on a flexible [illegible] cable. In addition, the sensitivity has a greater range with an upper limit of approximately 20 mr/hr.

c.) These units are available for loan to GM [illegible]

2. L & R Survey Meter

This meter is a small [illegible] electrometer with a quartz fiber electroscope. It contains an internal timing circuit eliminating the use of a stop watch for [illegible] the rate (div/[illegible]). The ranges vary [illegible] approximately [illegible]

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four thin-walled glass G.M. tubes for detectors, an amplifier and a high voltage supply. The G.M. tubes view the clothes from above and below and the amount of contamination is indicated on a counting rate meter.

2. Frisking Meter

This meter is a modification of the Laundry Unit. The modification being the addition of two G.M. tubes, one of which is used as a probe. The other five tubes can be placed in a doorway to monitor personnel passing through. An alarm is sounded if the level of contamination is too high. The probe is used to determine the exact location and amount of contamination on the person upon its detection by the other tubes. The sensitivity of the multiple section (5 tubes) is 500 c/m full scale, and the probe is 4000 c/m full scale.

PART V. MONITORING AND DECONTAMINATION

A. General

The work of this group is primarily that of health and safety, the control and prevention of excessive spreading of contamination due to radioactive elements and compounds, and the instituting and maintaining of safe handling procedures for the benefit of persons exposed to such materials. This is accomplished by a daily check of the rooms or laboratories in which the materials are used, and the issuance of protective clothing specifically designed for the protection of the individuals involved in the handling of radioactive substances. Rooms in which radioactive materials are processed are checked periodically with electronic type of instruments designed for the detection of elements emitting alpha, beta, and gamma radiations. These room checks are not intended to be an exact quantitative radioassay, but are a quick general survey of the degree of contamination that exists, with a reasonable degree of accuracy. This survey "Snoop" method of laboratory check requires a quick, thorough scanning of a laboratory with a quantitative accuracy sufficient to determine the relative degree of contamination and does not hinder the normal operations that are going on in the room.

Decontamination can be effected by scrubbing the contaminated surface with various types of cleaning solutions and drying. The cleaning solutions used will vary with the type of materials and the geometry of the surfaces, as well as with the different radioactive elements and their compounds. The success of a particular decontamination job depends on the accuracy and judgment of the decontaminator. The most suitable types of surfaces for handling these hazardous radiochemicals are, stainless steel, polished glass, polished steel and brass, lucite, and certain plastics in descending order of effectiveness. Wood, cast iron, transite, and painted surfaces are all semi-porous or tend to become so with use and permit the contaminating fluids to soak in and become imbedded below

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surface, in which case decontamination is practically impossible.

A very important result of this periodic room check is the prevention of spreading of radiochemicals. If a solution containing these materials is spilled, the spot formed will at first be wet and localized. However, as the spot dries, the material accumulates on the dust which is always present and is picked up by the air currents, or sticks on the shoes of persons moving about and thus may be transferred throughout an entire building, in which case the material is difficult or impossible to localize and control. To avoid this, any contaminating fluid or solid which is accidentally spilled must be recovered and cleaned up immediately.

The safe handling of radioactive chemicals presents a unique problem. In contrast to most other toxic materials, the substance cannot be rendered inert by ordinary chemical or physical means. If the substance by some means escapes from its controlled containers it should be recovered immediately, or if recovery is impossible, the objects on which the material is spilled must be disposed of by burying as soon as possible.

Another important function of this section is the prevention of body contamination of laboratory technicians working with the "hot" materials. For this purpose protective clothing and equipment such as respirators, coveralls, smocks, caps, rubber gloves, and shoe covers are issued to all exposed persons. These garments are laundered by the Health Instruments Group at necessary periods in order to keep them clean and safe to be worn by the persons needing such equipment. A laundry is maintained by the H. I. Group specifically equipped for this type of cleaning. All clothing leaving this laundry is monitored by instruments and all garments in which the count exceeds safe limits are re-laundered or discarded.

A great deal of study has been made in improving methods of monitoring, and the development of more reliable cleaning agents for removing contaminations. Studies also have been made on the efficiency of the various types of protective equipment, and on improving the effe[illegible] garments.

[illegible] B. [illegible]

Rooms and laboratories in D, D annex, H, Sigma, U, V, and W buildings (RP buildings will be included upon their completion) are monitored daily by "smooping" with the mobile alpha meter (Poppy) or the portable alpha survey meter. Floors, doors, doorknobs, laboratory benches and tables, hoods, outsides of drybenns and other permanent laboratory installations are scanned holding the counter approximately

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one-fourth inch from the surfaces being tested. This requires the services of two men, one to push the instrument through the laboratories and record the counts and the second man to carry the snooper chamber and scan the surfaces under examination. Alpha counts found to be less than 500 c/m (this figure is based upon an average of 150 c/m/in^2) are considered safe and recorded as negligible (certain areas may have special limits set). Alpha counts found to be greater than 500 c/m are considered contaminated or "hot", and marked with suitable markers.

As soon as possible these "hot" spots found should be decontaminated by the laboratory members. Upon completion of decontamination, the H. I. monitor should be called to check the cleaned area (see Part VI, Section 13). Each monitor carries an alpha survey meter and checks the decontaminated area; the count must be below 500 c/m before the decontamination is considered successful. In some cases, the count fails to fall below 500 c/m as recorded on the meter, even after a thorough scrubbing of the area. In these cases, a swipe is made over the surface with a rectangular piece of oil impregnated filter paper and counted separately by holding the swipe against the counter. If no contamination is picked up from the surface, the area is considered impregnated and cannot be cleaned. If necessary these surfaces are replaced or covered with a protective coating of metal or paint. The latter is usually considered unreliable.

Periodic monitoring checks are also carried out on other sundry items such as office desk tops, laboratory glassware, drybox gloves, hood vents, filters from hoods, chairs, coke bottles, and lighting and electrical appliances. The results obtained on these items are recorded and careful control is maintained to keep the alpha contamination within a safe limit, or to effect decontamination if count goes beyond the limit. This safe limit is considered to be 250 c/m or less.

Hand and nose counts have also been instituted to check the amount of contamination which may have been picked up on critical parts of the body. Hand counts are taken by filter paper swipes over the hand, and by the use of hand counters. Nose counts are taken by swabbing the nostrils with a damp filter paper swab. These are counted on the standard alpha counter. Safe counts are considered to be 50 c/m(for 49), 500 c/m (for Po) or less in the nose, and 250 c/m (for 49), 1000 c/m (for Po) or less on the hands. These hand and nose counts have proved to be a reliable check on the amount of contaminating material to which a person is exposed, and serve as a warning to the individual that he must improve his technique and exercise more care in the handling of contaminating materials.

Periodically, changes in monitoring and decontamination procedures may occur. These changes will be indicated to the laboratory members by a suitable memo issued by the H. I. Group.

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PART VI. HEALTH SAFETY RULES

The following list of rules is general in nature, and any exception to it must be by agreement with the group requesting such exception and the authorized representatives of the H. I. and Medical groups.

1. Cleaning rags and other contaminated trash should be disposed of in special trash containers marked with red paint.

2. Booties, coveralls, smocks, surgeon's caps, rubber gloves, and respirators must be worn at all times when working with 49 or Po. Face shields must be worn in all operations involving handling of boiling solutions, or other solutions in which there is any possibility of a spray being formed.

3. Coveralls and respirators must be worn in handling tuballoy or 25 where there is any possibility of either material getting into the air. In machining either of these metals, a solution of water soluble oil must be kept playing on the portion being machined. Direct handling of these metals should be kept at a minimum (see Part II Section C). During operations involving direct handling of these materials for more than one hour per day, thick, protective gloves must be worn.

4. When leaving a building where contaminated operations are carried on; smocks, booties, caps, gloves, and respirators must be removed, (gloves should be left in the working area within the building) Project issued coveralls are not to be worn when leaving the Technical or DP areas or when entering non-contaminated buildings within these areas, except the dispensing sections of K and S stock. Spot checks will be made to see that this rule is followed.

5. All rubber gloves should be washed frequently in the approved manner during long operations and before removing from hands Hands should be carefully washed after removal of gloves and checked under the alpha hand counter.

6. No mouth pipetting shall be done in any operation in which active materials are involved.

7. No material either free or in working containers, and no contaminated objects shall be set on writing desk tops. Exhibition specimens kept in cleaned, closed containers are exempt from this rule.

8. Persons desiring to work with the material in laboratories other than their own, must request permission from the usual occupants before beginning the work.

9. All active dust producing operations must be done in approved dryboxes or sealed vacuum systems.

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10. Fans should be left running in all hoods which contain or have contained active material until they have been checked and decontaminated to the satisfaction of the H. I. Group.

11. a) In case of any spills involving active material, personnel not required for recovery should leave the laboratory immediately and the remaining personnel as soon as possible. All fans not already operating should be turned on before leaving. The H. I. Group should be notified as quickly as possible after any such accidents.

b) In case of an accident in which active material may have been introduced into a wound, the following procedure should be followed:

1. Wash wound immediately with full stream of tap water.
2. Squeeze wound or apply tourniquet to increase bleeding.
3. Report to Post Hospital for treatment of wound as soon as you have changed your contaminated clothes.
4. Inform the receptionist at the Hospital that this is a "Technical Area Emergency"; be careful to confide the nature of the accident only to the doctor in charge
5. Report the accident to both the H.I. and Medical offices after the wound has been treated.

12. No eating, drinking, or smoking will be allowed in rooms so posted. No food or drink is to be kept in laboratory refrigerators.

13. The following M & D procedures are in effect:

a) Daily room surveys are made and all "hot spots" (greater than 500 c/m) will be indicated by a suitable marker.

b) As soon as possible the laboratory personnel should decontaminate the "hot spots" found.

c) Upon the completion of decontamination, if no member of M & D is present, the H. I. Group should be called to monitor the cleaned area in order to determine whether it is below 500 c/m.

d) If any persistent count within a room is 5000 c/m (49, 25, and tuballoy) and 10,000 c/m (Po), or greater, all operation will be stopped within that room until it has been cleaned. The cleaning will be done by the room occupants with the assistance of an H. I. representative, if desired (Section 13c applies after such cleaning).

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Rule 13 does not apply in case of emergency or contaminated accidents. In such cases all M & D services that are necessary and available will be supplied. It should be noted that in the event of serious accidents or spillage the room count is to be assumed to be above 5000 c/m (for 49, 25, and tuballoy), and 10,000 c/m (for Po) or greater, until shown otherwise.

Any questions concerning Health Safety Rules or M & D operations should be discussed with the Medical or H. I. Group.

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II. TABLE OF PRESENT RADIATION LIMITS

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Radiation or Material	Hands c/m	Nose c/m	Body (Surface)	Body (Internal)	Boots c/m	Clothes c/m	Gloves c/m	Respirators c/m	Urine c/m/24hr	Air Tolerance
Alpha (α)	- - - -	- [redacted]	[redacted]	- - - -	- -	- -	- -	- -	- -	- -
Beta (β)	- - - -	[redacted]	[redacted]	- - - -	1.25 mrep/hr	1.25 mrep/hr	1.25 mrep/hr	1.25 mrep/hr	- -	- -
Gamma (γ)	- - - -	- [redacted]	[redacted]	- - - -	1.25 mrep/hr	1.25 mrep/hr	1.25 mrep/hr	1.25 mrep/hr	- -	- -
(Note) 49	250	50	[redacted]	[redacted]	1000	500	250	Total 100(Inside) 200(Outside)	7	(1) 0.0175 c/m/L
(Note) Po	1000	* 500	[redacted]	[redacted]	4000	2000	1000	Total 500(Inside) 1000(Outside)	1500	(1) 0.75c/m/L
(Note) Tu	One hour contact	- - - -	12.5(β) mrep/hr	Very low toxicity by ingestion	Alpha limit same as for 49				See Part III Section D	150μg (2) per cu. ft.
(Note) 25	One hour contact	- - - -	12.5(β) mrep/hr	Very low toxicity by ingestion	Alpha limit same as for 49				See Part III Section D	150μg (2) per cu. ft.
Ra	- - - -	- - - -	12.5(γ) mr/hr	0.1 μg (α)	- -	- -	- -	- -	- -	2.5 x 10^{-8} μg/L (1)

(1) Two year tolerance assuming 100% retention by lungs (actual value depends on fraction retained)
(2) Chemical toxic tolerance
* If both nostril counts are above 50 c/m (49), 500 c/m (Po), the lower value is taken as the high nose count.
** mrep/hr -- milliroentgen equivalent physical per hour (12.5 mrep/hr is tolerance for β and γ, 1.25 mrep/hr for α)

Note: The limits set by the laundry are based on the following figures:

A. 49

1) Boots - 30 c/m/in^2
2) Clothes - 10 c/m/in^2
3) Gloves - 10 c/m/in^2(same as hands)
4) Respirators - 5 c/m/in^2(inside), 10 c/m/in^2(outside)

B. Po limits are, with the exception of respirators, four times those of 49; respirators are five times.

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VIII TABLE OF TYPES OF RADIATION

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Type	Description	Mass gms.	Energy Mev.	Range (Average) Air	Range (Average) Lead	Range (Average) H_2O or Tissue	Velocity cm/sec	Wave-Length A°(10^{-8}cm)	Electric Charge e.s.u.**
Alpha (α)	High Speed He^{++}ion	6.67 x [redacted]	2 to 10	3 to 7cm	0.001 cm	0.01 cm	10^9 to 2.5 x 10^9	- - - - -	9.6 x 10^{-10}
Beta (β)	Electron emitted by nucleus	[redacted] x 10^{-28}	Up to 8	10 ft.	0.1 cm	1 cm	Up to 2.9 x 10^{10}	- - - - -	-4.8 x 10^{-10}
Gamma (γ)	Electro-magnetic radiation emitted by nucleus	[redacted]	.1 to 12	120 ft.	10 cm	100 cm	$3x10^{10}$	10^{-3}-0.1	- - -
Delta (δ)	Secondary radiation from reaction of primary radiation with matter (usually of low intensity)	9.12 x 10^{-28}	Up to 0.005	Up to 0.05 cm	5 x 10^{-6} cm	5 x 10^{-5} cm	Up to 3 x 10^9	- - - - -	-4.8 x 10^{-10}
Neutron (slow) (thermal)	Neutral particle	1.67 x 10^{-24}	Approx. 0.025 x 10^{-6}	600 ft.	Approx. 50 cm	2.9 cm	2.2 x 10^5	- - - -	0
Neutron (fast)	Neutral particle	1.67 x 10^{-24}	0.1 to 10	1500 ft.	Approx. 100 cm	5 cm	$4x10^8$ to $4x10^9$	- - - - -	0
X-ray	Electro-magnetic radiation	- - -	Usually from 10^{-3} to 0.2	100 ft.	1 to 10 cm	10 to 100 cm	$3x10^{10}$	10^2-0.05	- - -

* For gamma rays, X-rays, and neutrons, "Range" means reduction of intensity to about [illegible] by absorption. The inverse square law renders much more reduction in intensity for the greater distances, e. g. for neutrons [illegible] or it is not necessary to be hundreds of feet away from ordinary size sources for health [illegible]

[illegible] of charge * [illegible] coulombs

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