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Atomic Energy Division
Idaho Falls, Idaho

CPP HEALTH PHYSICS MANUAL

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PREFACE

Personnel of the Chemical Processing Plant will be exposed to occupational hazards in addition to those of ordinary chemical industries in the form of radioactive materials. Although the way in which radiation damages living tissue is not entirely known, considerable is known about the effect of radiation on living organisms. It is known that radiation will kill all living cells if applied in sufficient dosage. Also that man is continuously exposed to radiation from cosmic and other sources which has not been proven to be either harmful or useful (from an evolutionary standpoint). We have, then, an unavoidable low level radiation which is part of the environment, as well as a much higher level of radiation which is proven to be harmful. We also have between these levels an exposure which, in spite of admitted variations in effect on different individuals, has not produced detectable changes in large groups. However, the period of time and number of people exposed at this rate are not presently sufficient for most experts in the field to definitely state that the level is absolutely safe. We might expect considerable agreement on a statement that detectable damage during a human lifetime of exposure at this intermediate level is very unlikely and that any damage which should appear would be to particularly susceptable individuals. Hence, based on present knowledge, the nearer the exposure approaches to the background level, the lower the probability of injuries.

Some principles of radiation protection are being presented which allow exposure to approach the background level as near as is practical with the operation involved, yet which never exceed the recommended exposure limits. This does not necessarily guarantee that this level of exposure is harmless. A lifetime of exposure to radiation considerably above background may involve some risk. However, it must be recognized that any human activity involves some risk, so if the risk from radiation exposure does not exceed other risks already present, it should be acceptable to the individuals involved.

Regardless of the detection instruments, alarm devices, rules and procedures, it is obvious that an individual must assume considerable personal responsibility for his own protection from injury by radiation.

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DEFINITION OF RESPONSIBILITY

The General Manager is responsible for the safe operation of the plant. The Health Physics Department has been established to advise the General Manager on precautions necessary to control or avoid hazards resulting from work with radioactive materials. The various departments under the direction of the General Manager will be responsible for safeguarding the health of the individuals under their jurisdiction. These departments will call upon the Health Physics Department for the location, measurement and evaluation of radiation hazards as well as recommendations for their control or elimination. The responsibility for the enforcement of recommended regulations and policies, as approved by the General Manager, shall rest with the supervisors of the various departments or areas. It will be the responsibility of these supervisors to keep the Health Physics Department informed of the nature and extent of the work involved in all operations in order that the necessary information may be accumulated and recommendations prepared. The Health Physics Department in turn will be obligated to inform the various departments of the existence and nature of radiological hazards resulting from work anticipated or in progress.

The Health Physics Department in co-operation with other departments will maintain necessary records and compile such measurements and data required to assure the General Manager that the operations of the plant conform to radiological regulations established by the Atomic Energy Commission and are safe according to American Cyanamid Company standards.

RADIOACTIVITY AND THE UNITS OF RADIATION

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II

RADIOACTIVITY AND THE UNITS OF RADIATION

II: 1

INTRODUCTION

Activities in the field of atomic energy are based primarily upon the principles of atomic physics and chemistry. Within the limitations of this manual, it is impossible to give a self-contained discussion of this field; however, it is felt that a brief survey of the fundamental principles and a statement of terminology might be useful as an introduction.

We now think of all materials as composed of a finite number of materials which are referred to as chemical elements, i.e., hydrogen, carbon, etc. Two or more of these elements may combine to form compounds such as water. They may exist in three physical forms: solid, liquid, or gaseous, and may be associated in various kinds of mixtures. In the light of present knowledge, the chemical elements are described as being made up of extremely minute entities known as atoms. The atoms of any one element are unique in their structure, while all atoms are thought of as being assemblies of three basic structural components called neutrons, protons and electrons. Since these fundamental "building blocks" of nature are so extremely minute, we cannot hope to give them a visual description. We can, however, describe their physical properties. We may, for instance, detect their relative mass or weight and their electrical properties.

The negative unit of electric charge is never found associated with a smaller mass than that of an electron (9.1×10^{-28}gm) and, for most purposes, may be considered identical with the electron. The unit of positive charge may be associated with either a particle of the same mass as the electron, called a positron or positive electron, or it may be associated with a particle of 1840 times this mass, called a proton. A third particle, the neutron, has no electrical charge associated with it, but has a mass very nearly that of the proton. An atom is thought of as an arrangement of these particles resembling our solar system. For an atom of any one element a number of protons and neutrons potentially exist in a region near the center of the system. These particles together are termed the nucleus of the atom. Around the nucleus, arranged in groups or shells, revolve a number of electrons. In any complete atom, there are as many electrons as there are protons in the nucleus so that the net electrical charge of the atom is zero. Any chemical element then is characterized by a particular number of protons in the nucleus of its atoms and a corresponding configuration of electrons around the nucleus. We might immediately ask, however, about the number of neutrons in the nucleus, and how this might change the characteristics of the atom. Since the neutron has no charge and since the chemical behavior of atoms is essentially dependent upon their affinity for one another (electrical in nature), we might conclude that the chemical properties of an atom are not primarily determined by the number of neutrons in the nucleus. Hence, any one chemical element might be made up of atoms with differing numbers of neutrons in their nuclei. Atoms of a given chemical element with specific numbers of neutrons in their nuclei are termed isotopes. It is customary to describe an atom in the following manner: example - ${}_{92}U^{235}$ - the symbol U identifies the atom as the chemical element uranium; the subscript 92 indicates the number of protons in the nucleus and the superscript 235 indicates that it is the <u>isotope</u> with 235 particles in the nucleus (92 protons and 143 neutrons). The atom $_{92}U^{238}$ (92 protons, 146 neutrons) is still the chemical element uranium, but the atom has three more neutrons in its nucleus. These are isotopes of uranium.

We might next observe that any process which alters the quantity of positive charge carried by the nucleus changes the atom from one chemical element to another, since the nuclear charge determines the normal number of electrons. When such a process occurs spontaneously in atoms, it is called natural radioactivity.

RADIOACTIVITY

Radioactivity resulting from the release of atomic energy is essentially like the radioactivity which was discovered in 1897 by Becquerel to occur naturally in compounds of uranium. Independent of external stimulation, they gave off three kinds of radiation which were designated by the first three letters of the Greek alphabet - alpha, beta and gamma (α, β, γ). The alpha rays were found to consist of fast moving particles of mass nearly four times that of a proton and with two units of positive charge. These particles are identical with the nucleus of a helium atom of the same mass. The beta particles were found to consist of high speed electrons or positrons. The gamma rays are of essentially the same nature as visible light or X-rays, consisting of discrete bundles or "quanta" of energy moving with the fundamental velocity of all electromagnetic energy, carrying no electrical charge and without separate identity before emission or after absorption. Furthermore, it was established that all three originated in the nuclei of the uranium or other "radioactive" atoms.

The emission of an alpha particle results in the net loss to the nucleus of two protons and two neutrons, thus leaving the nucleus of a different isotope and element. The emission of a beta particle from a nucleus may result from the transformation of a neutron into a proton, thus producing a nucleus of another element. The emission of a gamma ray, since it carries no charge, is thought of as resulting from the fact that the nucleus previously existed in an "excited" or "unstable" state. By the emission of a photon or quantum whose energy is characteristic of the particular nucleus, a more stable condition may be achieved.

The nucleus of an atom of a radioactive isotope has an inherent instability which might be thought of as a definite probability that it will spontaneously disintegrate in any given time. Furthermore, the number of nuclei disintegrating in any one unit of time depends upon the number of atoms present at that time. In order to obtain a quantity which expresses the rate of decay of a particular isotope, the concept of "half-life" is used. The "half-life" of an isotope refers to the time (in any applicable units) required for half of the atoms initially present to disintegrate. Thus, after one half-life, one half of the original number of atoms still exists. After two half-lives, one quarter of the original number exists, etc. The half-lives of differing types of radioactive transitions may vary from fractions of a millionth of a second to thousands of years. This is usually expressed by $N = N_0 e^{-\gamma t}$ where $\gamma = \frac{.693}{T_{\frac{1}{2}}}$.

The unit of activity or quantity of radioactive samples is highly important in dose determinations and is based on the number of atoms disintegrating per second. Conventionally, this unit is termed the curie. This unit was originally based on the activity of one gram of radium, or upon the activity from radon in equilibrium with one gram of radium. This definition has since been extended and now refers to that quantity of any radioactive material which disintegrates at the rate of 3.7×10^{10} dis/sec. It should be emphasized at this point, however, that failure to distinguish between total ionizing events and total disintegrations, in the case of isotopes that do not have simple decay schemes, has led to confusion and error in the use of the curie. For example, with a radioisotope that emits both a beta and a gamma ray in a single disintegration, if there are internal conversion electrons; that is, if some of the gammas give up their energy to eject K shell electrons from an atom, we have a gamma replaced by an electron: then measurement of the beta particles will lead to a disintegration rate too high. If only the gammas are measured, a disintegration rate too low results. Unless the number of gammas leading to conversion electrons is known, the disintegration rate will not be correct and the amount of the radioactive isotopes expressed in <u>curies</u> will be incorrect. This indicates that the method of decay of any material must be accounted for in the use of the <u>curie</u> as a unit.

A new unit of radioactivity has recently been defined, i.e., the <u>Rutherford</u>, which refers to that quantity of any radioisotope decaying at the rate of 10^6 disintegrations per second.

<u>Interactions of Nuclear Radiations with Matter</u>

Our present interest in radioactive material depends on the damage that results from the passage of nuclear radiation through the human body. While a complete description of the various interactions of different types of radiation with matter is beyond the scope of this manual, it is felt that enough information should be presented to allow an understanding of the basic problems involved and hence aid the reader in grasping the concepts to follow.

The first characteristic of all nuclear radiations to be considered is that they are all emitted with energies which are very large in comparison to those involved in normal chemical phenomena. The unit commonly used as a measure of their energy, the <u>electron volt</u>, is defined as that amount of energy necessary to move an electron through an electrical potential of one volt. This corresponds to the kinetic energy (energy of motion) of a hydrogen atom moving at a velocity of 550 miles a minute. As an example for comparison, four electron volts of energy are liberated when the molecule of oxygen combines with an atom of carbon (as in the burning of fuel) to form a molecule of carbon dioxide. In comparison to these values, alpha particles are emitted with energies ranging from four million to eight million electron volts (Mev). Beta particles have energies up to several Mev and gamma rays emitted from most common transitions range up to about 3 Mev.

Charged particles passing through matter exert electrical forces on electrons and nuclei in their immediate vicinity. This results in such effects as ionization, chemical dissociation of complex organic molecules (within the human body), and local heating or thermal effects which may also cause change. The probability that a particular atom will be ionized depends upon a number of factors, including the length of time during which the force acts. Thus, the number of ions formed per unit length of path increases to a maximum value as the particle is slowed down and then rapidly falls to zero.

The gamma quantum, on the other hand, does not carry an electric charge and generally passes through large numbers of atoms without giving up any of its energy. However, there exists a certain probability per unit length of path that it will give up a large part or all of its energy to some one electron along its path. This probability depends upon its energy, upon the number of electrons per unit of volume, and upon the atomic number (nuclear charge) of the atoms. The electron to which it gives up its energy is ejected from its atom with an initial velocity characteristic of the energy received and proceeds to dissipate its energy in a manner identical with that of a beta particle of the same energy. If the electron does not receive all of the energy of the gamma quantum, the new quantum of lower energy proceeds along a new path with a new probability of interaction with electrons along its path.

While the processes by which alpha and beta particles dissipate their kinetic energy are essentially the same, the larger charge and lower speed of the alpha particle results in the production of a much larger number of interactions per unit length of path. Its larger mass also lowers its probability of being scattered. This results in the fact that nearly all of the particles will penetrate the material to approximately the same depth. In the case of beta particles, they are scattered by atoms quite effectively. This causes much of the energy of these particles to occur at or near the incident surface. In the case of gamma radiation, however, we cannot speak of a finite range, since the probability of the interaction of a quantum of gamma energy is independent of the distance previously traversed. Neglecting scattered radiation, we may discuss the absorption of gamma rays in matter just as we discussed the decay of radioactive material, i.e., if a given thickness of an absorbing material will remove half of the gamma ray quanta from a beam then twice that thickness will remove three-fourths, etc. This is usually expressed by $I = I_0 e^{-ux}$. It should be emphasized, however, that gamma rays do not generally give up all of their energy in one encounter, but may, by means of multiple scattering processes, continue through the absorbing medium attenuated in energy. In any final analysis the absorption of gamma radiation must be considered as a very complicated diffusion problem. For this reason great care must be used in shielding against gamma rays. Not only must attenuation of any direct beam be considered, but also radiation scattered from any material in the vicinity, such as air, floor, walls, etc. Shielding from nuclear radiations is perhaps the chief method of protection against it.

We might summarize the absorption of alpha, beta and gamma radiation by simple illustrations as follows:

1. Alpha particles dissipate their energy very rapidly and will not penetrate an ordinary sheet of paper. They all penetrate absorbers to approximately the same depth.

2. Beta rays dissipate their energy less rapidly than alpha particles and will penetrate several millimeters of aluminum. Beta particles are emitted from nuclei in a continuous energy spectrum from very low to limiting maximum energy. Therefore they appear to be absorbed approximately exponentially by absorbers with only a small fraction penetrating to their maximum range in a forward direction.

3. Gamma rays dissipate their energy even less rapidly than beta particles. They are attenuated exponentially by an absorber and since they can never be completely absorbed, they have no maximum range. Approximately one centimeter of lead is required to reduce 1 Mev gamma rays to one-half their initial intensity.

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UNITS OF RADIATION DOSIMETRY

Any unit of radiation dose must be readily measurable in terms of simple physical quantities with reliable instrumentation. We are, of course, desirous of obtaining information as to the biological damage produced by any given dose of radiation. For this reason we would like to have our units proportional to the biological damage produced. In view of the complexity and present lack of information, it has been impossible to devise a unit which completely fills these requirements. We may, however, readily measure either the energy absorbed from the radiation per unit mass (in electron volts or ergs) or the ionization produced per unit mass in terms of the number of free charges. The unit of charge used is the electrostatic unit (esu). Whichever unit of dose is employed, energy absorbed or ionization, the ionization produced per unit volume is the physical quantity actually measured.

The roentgen is "that quantity of X or gamma radiation such that the associated corpuscular emission per cubic centimeter of air at standard conditions produces in air one electrostatic unit of quantity of electricity of either sign". The roentgen (r) is a unit of radiation exposure and is based on the effect of X or gamma radiation on the air through which it passes and applies only to X or gamma radiation in air. This unit considers the ionization caused by the secondary particles (electrons) ejected from some known volume of air. The roentgen is not a radiation unit: it does not describe directly the number of photons in a beam nor their energy: it merely gives the effect of that radiation in one cc of air; namely, the ionization which it produces. When all of the ions of either sign are counted and found to equal one esu of charge (2 x 10^9 electrons), then one roentgen of radiation has been absorbed in the original cc of air. This in terms of energy absorbed per gm of air is equal to 83.8 ergs.

It is quite important to realize, however, that the energy absorption per unit mass of material is not the same in all substances, but is dependent upon the material and its density. In soft tissue the energy absorbed per gram of tissue per roentgen is approximately 93 ergs, while in bone it is considerably higher. A dose given in roentgens would apply in tissue only if it were measured in tissue. We must next establish the concept of dosage rate. The roentgen is, itself, independent of time, since it refers only to charge produced. Dosage rates are given in roentgens per hour.

Since ionization and, hence, damage in tissue is often produced by radiations other than photons (X or gamma); that is, by betas, alphas, neutrons and protons, there must be a dose unit applicable to corpuscular radiation which will be a measure of the energy absorbed in tissue exposed to these radiations. The roentgen-equivalent-physical, as we shall define it, is that dose of any ionizing radiation which produces energy absorption of 93 ergs per gram of tissue. This corresponds to the energy absorption in soft tissue resulting from a dose of one roentgen. It must be understood, however, that the energy absorbed by tissue exposed to gamma radiation depends on the atomic composition and density of the tissue and definitely upon the energy of the photons, while a rep is always 93 ergs per gram of tissue independent of kind of tissue or the energy and type of the radiation. However, for most purposes it is convenient to regard the r and the rep as equivalent, in that they produce the same physical effect in soft tissue.

The biological evidence indicates that the effects of the various ionizing radiations are not the same and that a different degree of tissue damage can be expected from the absorption of a given quantity of alpha ray energy than from the same quantity of beta-ray energy or neutron energy. The roentgen-equivalent-man (rem) is that dose of any ionizing radiation which delivered to man is biologically equivalent to the dose of one roentgen of X or gamma radiation. The rem is not a measure of energy absorption or of ionization produced in tissue, but is a measure of a quantity of radiation that produces certain biological effects. Extensive experimental studies have been made of the relative biological effectiveness (RBE) of the ionization produced in tissue by the various types of ionizing radiation and an equal amount of tissue ionization due to gamma radiation. These values were obtained by experimentation on animals. The present accepted values of RBE are:

Gamma rays from Ra (0.5 mm Pt)	1
X rays of energy 0.1 to 3.0 Mev	1
Beta rays	1
Protons	10
Alpha particles	20
Fast neutrons	10

In terms of energy:

$$1 \text{ rem} = \frac{93}{\text{RBE}} \text{ ergs/gm tissue} = \frac{\text{rep}}{\text{RBE}}$$

Thus, for alphas, 1 rem : $\frac{93}{20} = 4.65$ ergs/gm tissue = 0.05 rep.

These are often tabulated as follows:

Gamma or X rays	1 r = 1 rep = 1 rem
Beta particles	1 rep = 1 rem
Alpha particles	1 rep = 20 rem

A very useful relationship for determining the dosage rate at one foot from an unshielded source of gamma radiation (point source) is given by $R = 6CE$ where R is the dosage rate at one foot, C is the number of curies of the radioisotope emitting the gamma radiation, and E is the gamma energy per disintegration. This, it must be understood, assumes one quantum of energy E per disintegration (Mev).

To aid in the understanding of this manual and for the general information of those interested, a short list of definitions of terms not already defined is included in the following section.

II: 4

DEFINITIONS OF TERMS

Ampere	Unit of current of electricity. It is equal to one coulomb per second.
Angstrom	A unit of length, one one-hundred-millionth of a centimeter (10^{-8}cm.), convenient for stating the wavelengths of visible and ultraviolet light and of roentgen rays.
Atomic Number	The number of positive charges on the nucleus of an atom.
Atomic Weight	The weight of an atom, the unit being one-sixteenth of the weight of the common oxygen atom.
Binding Energies	The energy which must be introduced into the nucleus or external electron structure of an atom to cause the release of a given nuclear particle or component.
Chain Reaction	A reaction, chemical or nuclear, in which the energy or particles generated by the breakdown of one or more additional atoms or molecules whose reaction in turn causes other atoms or molecules to disintegrate. The term is also used sometimes to designate a spontaneous nuclear reaction in which the product of the first disintegration is also radioactive.
Contamination (Radioactive)	Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm may be in vitiating the validity of an experiment or a procedure, or in actually being a source of danger to personnel.
Critical Mass	The minimum amount of a given fissionable material required for a spontaneous chain reaction. The chain reaction will not run unless more neutrons are being formed than escape through the surface of the system.
Cross-section	Apparent target area of a nucleus which is undergoing bombardment by nuclear particles, judged by the number of successful reactions obtained. As this apparent area involves internal factors which determine whether a reaction occurs or not, it is usually different from reaction to reaction. It is a way of stating the probability that a given nuclear reaction will occur during the bombardment of one substance by particles of one kind or another. (Gamma radiation is considered as discrete bundles of energy.)

Decontamination	Separation of undesirable substances from a desired product; e.g., separation of radioactive fission products from uranium. Also, removal of radioactive materials from surfaces, clothing, etc.
Erg	A unit of work. The amount of work done when a force of one dyne acts through a distance of 1 centimeter.
Fission	The splitting of an atom into two large fragments, in contrast to other nuclear disintegrations where the fragment emitted is an alpha particle or smaller. Fission is known to occur only among the heaviest atoms and in few of those. Splitting of Li^8 into two alpha particles is not called fission. Fission is induced by absorption of a fast or slow neutron, and follows immediately or after a short time with emission of several fast neutrons.
Fission Product	One of the elements produced by fission, usually radioactive.
Ion	An atom or molecule which carries a net electrical charge or a free negative electron.
Ionization Chamber	An enclosure designed to measure the electric conductivity of the enclosed gas when ionized by radiation. It is commonly used for measuring the intensity of gamma rays and other ionizing radiation.
Kev	Kilo electron volts. A convenient energy-unit of one thousand electron volts.
Micro	Prefix meaning one-millionth.
Milli	Prefix meaning one-thousandth.
Molecule	The smallest piece of a substance that can exist independently. May be made up of many atoms of different elements.
Neutrino	An elementary particle, electrically neutral and of negligible mass. Particle postulated in beta-decay theory.
Nucleon	A proton or neutron. The term is convenient when referring to these two types of heavy particles found in the atomic nucleus.
Ohm	A unit of electrical resistance. The international ohm is the resistance, at zero degree C., of a column of mercury of uniform cross-section, having a length of 106.3 cm. and a mass of 14.4521 gm.

Quantum	A definite quantity; in nuclear physics, a quantity of energy. Planck's quantum of constant of action, 6.55×10^{-27} erg-seconds, when multiplied by the frequency of a given radiation (per second) gives the quantity of energy contained in one quantum. One thinks of radiation of a given frequency as a stream of particles or bundles of energy each carrying one quantum of energy.
Radioactive Equilibrium	The state which prevails when the amount of a radioactive isotope stays constant because new atoms are being formed at the same rate at which they disintegrate through radioactive decay.
Z	Symbol commonly used for atomic number.

BIOLOGICAL EFFECTS OF RADIATION

III

III

BIOLOGICAL EFFECTS OF RADIATION

III: 1

EXTERNAL DOSE

Radiation applied externally acts immediately and continuously only while the tissue is exposed. Effects may not appear immediately, the time interval between exposure and effect depending on the dose and the type of tissue.

It has been established that the various parts of the body may be classified as to their sensitivity to radiation. Muscles, heart tissue, and tissue of the central nervous system appear to be the least sensitive, while the blood forming tissue in the bone marrow, lymphoid tissue and tissue of the reproductive system appear to be quite sensitive. In general, the histopathology of radiation indicates that any tissue region where rapid cell reproduction is taking place will be extremely sensitive to radiation. The fetus, in its early stages is quite sensitive to radiation, and for this reason, X-ray therapy or diagnosis during the early periods of pregnancy might be extremely dangerous, and should certainly seem to be unadvisable.

Absolute protection can only be afforded by limiting the amount of radiation reaching the body tissue. However, contrary to a common misconception, tissue does not ordinarily (remote possibility in case of neutron radiation) become radioactive as a result of irradiation. The effect terminates with the exposure or removal of the active material in case of contamination.

Alpha rays with a very few exceptions do not penetrate the horny layer of the skin. Beta rays in the energy range from 1 to

5 Mev penetrate tissue roughly from ½ to 2 cm., while gamma rays and neutrons are not appreciably affected by the skin, but penetrate to the inner tissue.

Radiation doses, which would be fatal if applied to the whole body, may be applied locally to small areas, without producing significant changes, except to the local area. This is the reason that doses as high as 10,000 r can be given to a single tumor. Thus, The time of appearance of symptoms of radiation damage is a function of the total dose received and the time in which the dose was delivered. Symptoms observed, in the order mentioned, might well be reddening of the skin (erythema), congestion of the blood and swelling due to the accumulation of fluid in the lymphatic system, formation of blisters, loss of hair (epilation) and secondary ulcerations. Both non-malignant and malignant tumors have developed. After healing, the skin may ~~show~~ have a thin, ~~atrophied epidermis with a~~ scaly appearance. Tumors have been known to develop many years after the original exposure.

There is ample evidence to show that there are individual differences, ~~even within a species,~~ ~~of~~ in the sensitivity to and effects of radiation on living organisms. The effects are dependent on the amount absorbed, the area exposed and the rate of absorption. Some phenomena such as genetic effects, are apparently independent of the rate of delivery and depend only on the total dosage. Some reports indicate an increased effectiveness with a decrease in the rate of delivery, possibly due to an increased sensitivity as a result of continued irradiation. However, in the majority of cases, the effect of a dose decreases as the rate of exposure decreases. For example, at the accepted rate of 0.3 r/wk, over 600 r would be accumulated in forty years without apparent damage to the body, while this dose to the whole body in one day would most likely be fatal. A logical explanation of this is that if the rate of delivery of the radiation is such that daily recovery cannot keep up with the damage, the resulting effects will become evident.

It is not possible to state the amount of radiation that will produce certain consequences because humans experiments are not feasible and ~~have accepted~~ large acute doses have been the ~~only as the~~ result of accidents. Animal experiments, ~~where the relative sensitivity to humans has been studied~~, have resulted in the following approximate conclusions:

APPROXIMATE EARLY EFFECTS OF WHOLE BODY ACUTE RADIATION

Acute Dose (r)	Probable Effect
0-25	No detectable ~~obvious~~ injury.
25-50	Possible blood changes but no serious injury.
50-100	Blood-cell changes, some injury, no disability.
100-200	Injury, possible disability.
200	Fatal, to 5 per cent.
200-400	Injury and disability certain, death possible.
400	Fatal to 50 per cent.
600	Fatal to 95 per cent.
Over 600	Fatal.

III: 2

INTERNAL DOSE

Presently accepted limits for various isotopes deposited in the body will be stated in a later chapter.

Radioisotopes, when contained inside the body, present greater hazards than when they are limited to external sources, for the following reasons: (1) They irradiate one continuously until they are eliminated. (2) They may or may not be readily eliminated from the body. (3) Sources inside the body are in intimate contact with the body tissue. This enables alpha and low-energy beta radiation (which, because of their limited range in matter, do not present an external hazard) to reach radiosensitive tissue inside the body and to dissipate all their energy in a small volume of tissue. Thus, the energy imparted per unit volume of tissue, which in reality is the only true expression of dosage, might be quite high within a critical body organ. (4) It is extremely difficult to measure the amount and distribution of a radiosotope in the body so that it is usually impossible to assess the hazard completely. Methods of uranalysis have been developed for some isotopes but most of these analyses are very tedious, time consuming and expensive.

In general, the chemical characteristics of the radioactive material which enters the body determine where the material will be deposited. Radioisotopes will follow the same metabolic processes as the naturally occurring stable isotopes of the same elements. Elements not normally present in the body will follow the pattern of those with similar chemical characteristics which are normally present. For example, barium, strontium and radium, which are analogous to calcium, will be deposited in the bone tissues. The hazard from ingested radioactive materials depends on the solubility, chemical properties and physical states, since these determine how much will be absorbed from the gastro-intestinal tract. In order to constitute an internal radiation hazard, the radioactive isotopes must gain access to the circulating blood from which they can be deposited in the bones, liver, spleen, or other organs. Therefore, while the isotopes are in the gastro-intestinal system, the effect of the radiation resembles that of external, rather than internal, radiation. Fortunately, most fission products occur as oxides which are only slightly soluble in body fluids. Cesium, barium and iodine do occur in soluble forms.

Entry of radioactive materials into the body through openings in the skin as wounds where radioactive contamination is possible is particularly important. Various methods of treatment have been recommended, some quite radical. It is believed by many that the treatment should be the same as for any wound contaminated with potentially harmful material, such as toxic substances or bacteria. Good local surgical care seems most important. In emergencies involving interruption of breathing, severe bleeding or shock, it is recommended that they be dealt with first, for obvious reasons. The removal of the radioactive material, even though some may be deposited, can be dealt with when the emergency no longer exists. There is some risk involved, but it is certainly less acute than letting the removal of radioactive materials interfere with the treatment of the situations mentioned. In most cases the probability of radioactive contamination will not be known and most often will not be high.

Inhalation of radioactive materials is always a problem in a plant of this type. Permissible limits of air-borne materials will be stated. Assimilation depends on the chemical characteristic and the size of the particles. The nose will filter out practically all particles greater than 10 microns (10^{-3} cm.) in diameter and about 95% of all particles greater than 5 microns in diameter. The optimum particle size for passage from the alveolar space of the lungs to the blood stream is less than 5 microns. Insoluble particles from one to five microns may reach the lymphatic system.

The biological effectiveness of an isotope is determined by its tendency to concentrate in certain parts of the body from which it may be eliminated either rapidly or slowly. The biological half-life is the period of time during which the amount of the radioisotope deposited in the body is reduced to one-half its initial value. The effective half-life of a given isotope depends on its radioactive half-life which determines its rate of decay, and the biological half-life which is related to the natural rate of excretion from the body. An isotope with a very short radioactive half-life will inevitably have a short effective half-life in the body, but substances with medium or long radioactive half-lives, depending on the tendency to concentrate and the rate of elimination, may have either long or short effective half-lives. Substances with fairly long effective half-lives are internal hazards. For example, plutonium has a long radioactive half-life, is deposited in the bone, and eliminated very slowly, the loss being due almost entirely to radioactive decay; hence, it has a very long effective half-life and is considered an extreme internal hazard. Cesium 237, on the other hand, has an effective half-life of about 15 days in spite of its radioactive half-life of 33 years, due to its rapid elimination from the body.

As in external radiation, reduction in the number of white cells is an early indication of damage. This is caused by damage to the blood-forming tissue, usually by deposition of isotopes in the bone marrow and spleen. Malignant growths may develop in the region where radioactive materials are concentrated.

III: 3

GENETIC EFFECTS

These effects may differ from other changes produced by radiation in that they are believed to be cumulative, to be approximately independent of dosage rate and within limits of the energy of radiation.

According to presently accepted biological theory, living cells contain chromosomes which contain chains of submicroscopic units called genes. Each gene is believed to be associated with a particular physical characteristic. Genes of the germ cells largely determine the characteristics of the offspring.

Individuals with characteristics different from the species occur spontaneously in nature. If these characteristics can be inherited, the phenomena are called mutations. Chromosomal mutations arise from changes in the chromosome structure. Gene mutations are attributed to changes in the genes. The latter are classified as dominent or recessive. Offspring exhibit characteristics associated with the mutated gene if it is received from either parent in the dominent case, but the mutated gene must be available from both parents in the recessive case. A large percentage of mutations are lethal or deleterious, but since most are also recessive, they may go for generations without detection. Although most mutations lead to heredity defects, some changes have been put to man's advantage , as is illustrated by the mold penicillium which manufactures penicillin. The strain largely used at present was selected from a number of radiation induced mutants because it produces a large yield of penicillin.

The male sex chromosome is a special case in which all gene mutations act as if dominant. Some geneticists suggest the possibility, due to the above, of a detectable change in the female-to-male ratio, due to a decreased survival of male children throughout a number of years.

It does not seem possible, on the basis of the limited information available at this time, to draw any definite conclusions concerning the genetic effects in men. On the basis of results obtained with animals, there is slight doubt that radiation induced mutations are possible, but the total exposure required to produce the changes is completely uncertain.

Serious genetic damage to the human race from sublethal doses of radiation is thought to be unlikely. If individuals carrying recessive mutations should increase gradually over a large number of years until they were present in a large proportion of the population, the chances of their being carried by both parents might increase to the point where the effects would become evident.

III: 4

RADIATION SICKNESS

Diagnosis of Radiation Sickness

This is not intended to be a recommended diagnostic procedure but only a summary of conclusions reached as a result of the study of the Japanese atomic casualties.

The white blood cell count is considered to be the most valuable and direct single index of radiation sickness. The white cell count, however, is an indication of radiation sickness when the exposure has been at least moderately severe, possibly 100 to 300 r, although 25 to 100 r of whole body exposure may produce minor blood cell changes. Because of daily variation, unobserved infections and differences in counting techniques, the count of an individual may be appreciably lower than a previously established normal without exposure to radiation. If a group were suspected of exposure to radiation in dangerous amounts, a similar and appreciable white cell reduction in all, with the elimination of the possibility of an epidemic, would be considered positive evidence. If the number of white cells per cubic millimeter of blood falls below 2000, the chances of recovery are not good and if less than 500 will be almost certainly fatal.

Most Japanese cases showed a drop in the number of lymphocytes (white cells formed in lymphatic tissues) soon after exposure. Some cases of increase in total white blood cell count were reported, apparently due to an increase in the number of granulocytes (white cells formed mainly in the bone marrow). However, the increase was followed in a few hours by a sharp decrease. Hence, after the first day there was always a rapid decrease in the total white blood cell count which continued for five or six days. The total had decreased from 4,000 to 10,000 per cubic millimeter to, roughly, 1,000 to 3,000, and in most severe cases to 300 or less before death.

Lymphocytes reached their low point in about a week and, in cases which were in the process of recovery, began to increase. Lymphocytes had shown considerable gain in three weeks and granulocytes were also increasing. Red blood cells often declined during this period.

Since the main function of the leukocytes (white blood cells) is to defend the body against infection and remove injured tissue, their absence increases the susceptability to infection.

There is considerable evidence to indicate that if no drop in the number of lymphocytes is detectable in 72 hours after exposure, the dose has been too small to cause serious illness. The lymphocytes are the first cells to show signs of regeneration if recovery is to take place.

SUMMARY OF CLINICAL SYMPTOMS OF RADIATION SICKNESS

Time After Exposure	Lethal Dose (600 r)	Median Lethal Dose (400 r)	Moderate Dose (300 - 100 r)
First week	Nausea and vomiting after 1-2 hours No Definite Symptoms Diarrhea Vomiting Inflammation of mouth and throat	Nausea and vomiting after 1-2 hours No definite symptoms	No definite symptoms
Second week	Fever Rapid emaciation Death (Mortality probably 100%)	Beginning epilation	
Third week		Loss of appetite and general malaise Fever Severe inflammation of mouth and throat	Epilation Loss of appetite and general malaise Sore throat
Fourth week		Pallor, blood spots under the skin, diarrhea and nosebleeds Rapid emaciation Death (Mortality probably 50 per cent)	Pallor, blood spots under the skin Diarrhea Moderate emaciation Recovery likely unless complicated by poor previous health or superimposed injuries or infections

Pathology of Radiation Sickness

Damage caused by radiation originates in the individual cells, the effects varying with the type of cells. In general, the nuclei of cells are more sensitive to radiation than cytoplasm. Hence, cells containing a high percentage of nuclear material are more sensitive than cells containing a large percentage of cytoplasm. Rapidly multiplying or actively reproducing cells are most sensitive.

The radiosensitivity of various common tissues probably decreases in the following order: lymphoid tissue and bone marrow; epithelial cells (testes and ovaries, salivary glands, skin and mucous membrane); endothelial cells of blood vessels and peritoneum; connective tissue cells; muscle cells; bone cells and nerve cells.

Lymphoid tissue, injured by radiation, tends to swell due to the accumulation of fluid. The throats of many Japanese victims became so ulcerated and infected that breathing and swallowing was difficult. Wasting of the lymph glands, tonsils and lymphoid patches of the intestines was common in Japan.

Most of the constituents of the blood, other than the lymphocytes, are manufactured by the bone marrow. Mature blood cells leave the marrow and go to the blood stream where they remain for variable periods before being destroyed by natural processes. The shorter the life of a particular blood cell, the more quickly it will present evidence of radiation injury by a reduction in the number of cells due to the inability of the marrow to replace the cells. Hence, the red cells which have the longest life are the last to show a reduction. Atrophy of the bone marrow was characteristic of the Japanese cases up to three or four months after exposure.

Post-mortem examination of the blood vessels of the testes showed the most marked changes due to radiation of any vessels of the body. Changes in ovaries were less pronounced. A total body dose of 400 to 600 r is required to sterilize a man, which would be fatal in most cases. Temporary sterility, however, has been known to occur with small doses.

Between the thirteenth and fourteenth day the hair began to fall out in bunches in many Japanese cases. This stopped after one or two weeks and never resulted in permanent baldness. The hair of the head was most sensitive, followed by the armpits, eyebrows and beard.

Swelling and ulceration of the layers of mucous membranes lining the gastro-intestinal tract is common in radiation sickness. The changes resemble those of acute bacillary dysentery.

Treatment of Radiation Sickness

Considerable effort is being made to develop methods of treating individuals so as to lessen the effects of radiation and of aiding recovery from radiation sickness. None of the preventative treatments which have come to our attention are applicable to situations which might be anticipated in our plant. Many of the more complicated treatments are still in the experimental state with animals and have not been tried on humans.

The objectives of treatment of radiation sickness are:

1. To maintain the fluid and salt equilibrium of the body.
2. To control infection.
3. To prevent hemorrhage.
4. To prevent anemia.

Efforts to accomplish these objectives might consist of:

1. Supply the necessary sugars, proteins, vitamins and fluids by intravenous feeding.
2. Control infection by the use of antibiotics.
3. Give whole blood transfusions as required until the bone marrow has had time to regenerate and produce blood cells.
4. Provide immediate hospitalization to insure complete rest, avoidance of chills and fatigue.

PERMISSIBLE RADIATION LEVELS

IV

IV

PERMISSIBLE RADIATION LEVELS

IV: 1

EXTERNAL

Limits

The maximal permissible level for chronic exposure of the total body to penetrating radiation (beta, gamma, X-rays) shall be at the rate of 0.3 rep per week at an effective depth in soft tissue of 5 centimeters, assumed to be the depth of the blood-forming organs. A measured dose not exceeding the rate of 0.3 rep per week in air will be assumed to meet these requirements.

For soft components of radiation (including beta rays with energy less than 2 Mev), an additional rate of 0.2 rep per week, as measured in air, is permissible. The maximal permissible level for chronic exposure to the basal layer of the skin, at a depth corresponding to 7 milligrams per square centimeter, may thus be at the rate of 0.5 rep per week - but with the restriction that the dose at the depth of the blood-forming organs shall not exceed the rate of 0.3 rep per week.

In case of exposures limited to the hands and forearms, the maximal permissible dose shall be 1.5 rep per week, measured in air or at the basal layer of the skin.

Weekly (or bi-weekly) exposure records should be kept of all personnel who are subject to such exposure. For administrative purposes, however, exposure levels may be considered in terms of the average taken over a longer period of time, not to exceed three months. A single week's exposure need not be considered excessive if it is not over twice the permissible level of 0.3 rep per week (or twice the level of

0.5 rep per week under the appropriate conditions), provided the average weekly exposure over three months does not exceed the maximal permissible limit.

Interpretation

Records for cumulative purposes will be based on films only. The films will be interpreted for us by the Health Physics Division of the Atomic Energy Commission, Idaho Directed Operations. They will report beta and gamma readings. The gamma reading will be based on the density behind the cadmium shield and converted to milliroentgens by a radium or equivalent calibration curve. The beta reading will be obtained by subtracting the gamma or shield density from the open window density and reading the remaining density on a beta calibration curve.

We will interpret the permissible limits above as 300 mr on the gamma or shielded part of the film, provided there is no beta reading, or a maximum of 500 mrep beta on the open window part of the film, provided there is no gamma, or 500 mrep of beta plus gamma, provided the gamma does not exceed 300 mr. The maximum hand and forearm exposure will be 1.5 rep per week of gamma, beta, or beta plus gamma.

Additional Limits

The Radiation Protection Committees of the United States, Great Britain and Canada, at a conference in Chalk River, Ontario in September 1949, agreed on the maximum permissible tissue dose levels for external radiation as tabulated below. We will comply with these and their revisions, if any, provided there are no official AEC directives which conflict.

MAXIMUM TISSUE DOSE LIMITS IN "REPS" PER WEEK

Type of Radiation	At Any Point Within the Body	Relative Biological Effectiveness	In the Basal Layer of the Epidermis	
			Exposure of Entire Body	Exposure of Hands Only
X & Gamma	0.3	1	0.5	1.5
Beta	0.3	1	0.5	1.5
Protons	0.03	10	0.05	0.15
Alpha	0.015	20	0.025	0.075
Fast Neutrons	0.03	10	0.05	0.15
Thermal Neutrons	0.06	5	0.1	0.3

IV: 2

INTERNAL

Internal radiation at this time presents a greater Health Physics problem than external radiation because the material irradiates continuously, the biological half-life in many cases is long, the material is in direct contact with the tissue, and accurate methods of measurement of the amount and distribution of various isotopes in the body have not been completely developed.

Radioactive materials enter the body by inhalation, ingestion, absorption through the skin, and by openings in the skin, such as wounds.

Specific procedures will be provided in another section to help lower the probability of material getting into the body.

We will use, unless directed otherwise by AEC-IDO, maximum permissible air and water concentrations based on Harwell and Chalk River conferences as published by the Washington AEC for the information of contractors, as tabulated on the following page.

Isotope	Max. Permissible Body Burden uc	Permissible * Air Conc. uc/cc 168 hrs./wk.	Permissible ** Air Conc. uc/cc 40 hrs./wk.	Permissible *** Water Conc. uc/cc
Ra^{226}	0.1 (bone)	8×10^{-12}	2.1×10^{-11}	4×10^{-8}
Pu^{239}	0.04 (bone)	2×10^{-12}	5.2×10^{-12}	1.5×10^{-6}
$U^{Natural}$		1.7×10^{-11} (25 ug/m^3)	4.5×10^{-11}	
Soluble U^{233}	0.04 (bone)	8×10^{-10}	2.1×10^{-9}	1.6×10^{-4}
Insoluble U^{233}	0.008 (lung)	1.6×10^{-11}	4.2×10^{-11}	
Sol. U^{235} U^{234}	0.04 (bone)	8×10^{-10}	2.1×10^{-9}	1.6×10^{-4}
Insol. U^{235} U^{234}	0.008 (lung)	1.6×10^{-11}	4.2×10^{-11}	
I^{131}	0.3 (body)			
	0.18 (thyroid)	4×10^{-9}	1.1×10^{-8}	3×10^{-5}
H^3 (as HTO)	10^4 (body)	5×10^{-5}	1.3×10^{-4}	0.4
(as HT)		5×10^{-2}	1.3×10^{-1}	
Sr^{90}	1	1×10^{-10}	2.6×10^{-10}	6×10^{-7}
Na^{24}	15			8×10^{-3}
p^{32}	10			3×10^{-4}
C^{14} (as CO_2)	300	1×10^{-6}	2.6×10^{-6}	
S^{35}	200	2×10^{-6}	5.2×10^{-6}	1×10^{-2}
Co^{60}	1	2×10^{-9}	5.2×10^{-9}	1×10^{-5}
A^{41}		1×10^{-6}	2.6×10^{-6}	
Xe^{133}		1×10^{-5}	2.6×10^{-5}	
Xe^{135}		3×10^{-6}	7.9×10^{-6}	
Sr^{89}	2.0			
Th^{234} (UX_1)	0.8			

General permissible concentration of gross fission products in air and water, for use when the particular isotopes are unknown, will be:

Air Concentration	alpha beta-gamma	3×10^{-11} uc/cc 10^{-8} uc/cc
Water Concentration	all	10^{-7} uc/cc

* Air concentrations are calculated on the basis of 168 hours per week exposure with a breathing rate of 1.25×10^6 cc per hour of working time and 0.63×10^6 cc per hour of off-time.

** These concentrations are calculated on the basis of 40 hours per week working time at a breathing rate of 1.25×10^6 cc per hour and negligible exposure during the non-working time.

*** Water concentrations are based on assumption of 1.5 liters per day of intake as liquid and 1.0 liters per day of intake as food.

PERMISSIBLE CONTAMINATION LEVELS

Many installations have set definite limits of contamination for various areas and surfaces. We intend to make a decision in each particular case based on the information available. Factors involved will be:

1. Is the contamination hazardous due to direct radiation?
2. Is it hazardous due to ingestion or inhalation under the circumstances which exist?
3. Can a contaminated area be isolated and allowed to decay without interfering with operation?
4. How can the hazard be eliminated most economically?

Some of the limits which we believe necessary are tabulated on the following page.

Personnel and Clothing (Permissible Contamination Levels)

Surface of Skin or Clothing	Type of Contamination	Maximum Permissible Contamination
Skin - (general body contamination)	All	Any detectable contamination to be reported to Health Physics Field Office.
Skin - hands	Alpha (not readily removable)	Less than 500 d/min. over 100 cm^2 of surface.
	Beta	Permissible level as indicated on hand and foot counter.
Shoes (personal)	Alpha	Less than 500 d/min. over $100cm^2$ of surface.
	Beta, gamma	1000 c/min.* (inside or outside).
Shoes (issue - not to leave plant)	Alpha	500 d/min. ($100cm^2$ of surface area).
	Beta, gamma	10,000 c/min.*(outside) 1,000 c/min.*(inside).
Clothing (personal) levels above which clothing will be impounded.	Alpha	500 d/min. ($100cm^2$ of surface area).
	Beta, gamma	500 c/min.*
Clothing (protective)	Alpha	500 d/min. ($100cm^2$ of surface area)
	Beta, gamma	1000 c/min.*
Iodine Content in Thyroid	I^{131}	Less than 0.18 uc in thyroid.

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* As measured with a standard G-M probe, under the best geometrical arrangements.

Additional Permissible Plant Contamination Levels

	Beta, gamma **	Smear ***	
		c/m ($\beta\gamma$)	c/m (α)
Vendors' containers - food	None detectable	20	10
Materials to AEC shops (NIMCO)	Less than 1 mrep/hr	50	10
Materials leaving controlled area (acid bottles, carboys, gas cyl., etc.)	Less than 0.4 mrep/hr	50	10
Commercial carriers leaving controlled area	ICC regulations	50	10
AEC controlled carriers	ICC regulations	50	10
Radioisotope containers leaving controlled area	ICC regulations	50	10
Salvage material	Less than 0.4 mrep/hr	50	10
Material to stores, glass shop, etc.	None detectable	20	10
Instruments to AEC Health Physics calib.	Less than 0.4 mrep/hr	50	10

** There must be no detectable alpha with such instruments as the Zeuto or Samson.

*** A smear shall be interpreted as wiping 40 sq. in. of surface (4, 10 in. passes) with 2" diameter Whatman 50 filter disc or equivalent and counting at 10% geometry for beta-gamma in a standard mica end-window G-M counter, and 50% geometry for alpha in a parallel plate ion chamber or gas flow proportional counter.

IV: 4

EMERGENCY RADIATION LIMITS

The following three types of emergency and permissible exposure limits are intended to pertain only to situations involving radiation. These are:

1. Acute Situation

   This is intended to mean a situation where holding the whole body exposure to 300 mr/wk of penetrating radiation will seriously interrupt production schedules, result in loss of product, handicap some other urgent operation or similar circumstance.

Radiation (Dose)	Concentration in Water	Concentration in Air
600 mr/wk not to exceed an average of 300 mr/wk over any continuous 3 month period.	Same as routine operation.	Same as routine operation.

2. Emergency

   We interpret this to be a situation where limiting the radiation exposure to 300 mr/wk of whole body penetrating radiation will result in extreme damage to equipment, injury to personnel or large financial loss.

Radiation (Dose) in Roentgen	Concentration in Water uc/cc	Concentration in Air uc/cc
A total of 10 r to those normally exposed to radiation. A total of 25 r to those not exposed to radiation in normal duties.	Beta-gamma 10^{-3}; Alpha 10^{-3} for 10 days immediately after a reaction only.	Beta-gamma 10^{-6}; Alpha 10^{-10} for not greater than 2 days.

3. Emergency Accident (Disaster)

This is interpreted to mean that limiting radiation exposure to routine limits is probably impossible, loss of life and/or complete destruction of the plant is probable. We are referring particularly to a critical reaction within the plant or an attack with atomic weapons.

Radiation (Dose)	Concentration in Water	Concentration in Air
Maximum of 100 r in one day, not greater than 150 r in one week and a 300 r maximum limit for any period.	Same as Emergency.	Same as Emergency.

It is assumed that there will be one man on each shift who will have maximum authority. He will be able to settle controversies immediately and state when and what type of emergency exists. He will be able to command the advice and assistance of all people working in the plant and to delegate authority as he believes best.

It should be recognized that an individual receiving a large radiation dose would be expected to stay away from radiation for long periods. Also that special provisions would have to be made for measuring or estimating large dose rates or total dosage when they are beyond the range of ordinary personnel monitoring equipment. The values for water and air concentrations in the extreme cases are conservative in respect to some authorities, but it is believed that under the worst anticipated conditions the values can be applied without interfering with the progress of most operations. Respiratory protective equipment may be used in concentrations above those mentioned.

WASTE DISPOSAL

V

V

WASTE DISPOSAL

V: 1

RESPONSIBILITY

The Operations Department is responsible for the treatment and control of radioactive wastes at the CPP. The waste disposal section of the Operations Department has one group responsible for the control of liquid waste processing and another responsible for the control of gaseous and particulate process wastes. The Health Physics Department will co-operate in monitoring all wastes leaving the confines of the plant area and will act in an advisory capacity on operations which might result in health hazards.

V: 2

GENERAL PROBLEM

The waste disposal problem arises from the fact that residual wastes from a plant of this nature may be released or discharged to the environment under such conditions as to seriously endanger the health or livelihood of the surrounding population. Nature frequently shows remarkable abilities to concentrate various chemical elements, particularly when they are present in only trace amounts as is the case with many radioisotopes.

Liquid wastes might be discharged into water courses beyond the controlled area of operation and in turn find their way into water and food supplies. Gaseous or particulate air-borne activity discharged from the stack as process wastes not only constitutes an immediate health hazard from the standpoint of inhalation, but also might find its way eventually into food and water supplies, or prove to be damaging to normal commerce. An example of the latter is the potential damage to the products of the film industry which has been clearly demonstrated as a result of A-bomb tests in Alamogordo and Nevada. In the first case, contaminated straw used for making film wrappings had a detrimental effect on the film and in the second case, contaminated process water from a stream had a similar effect. These phenomena lead many well-informed and far-thinking persons to question whether aqueous and air dilution can be depended on to discharge radioactive wastes safely to a drainage system or to the atmosphere.

While it is not generally considered to fall in the class with the disposal of wastes, a general appraisal of the philosophy behind the stringent control of contaminated materials (solids) might be considered at this time. Primarily, the spread of contamination is controlled as much as possible to safeguard the health of the general public, but there are many other considerations which impose more stringent control of contamination on materials leaving the plant than health reasons. Materials such as high pressure gas cylinders, glass or metal reagent containers, wood and metal items, if allowed to move freely through the plant in the course of its operation, would undoubtedly find their way through normal salvage channels to the "melting pot" to be reused in the manufacture of other or similar items. If such materials were to become contaminated with radioactive substances and allowed to return to these channels, eventually all structural materials might become contaminated to a small degree. While this would probably not result in a serious health hazard, there are certain uses of all materials which require that the natural level of radioactive contamination be very low. For example, highly sensitive scientific instruments constructed to measure the presence of radioactive materials could not be made of contaminated material. The photographic industry could not tolerate contaminated materials.

Because of all the reasons mentioned, the recommended permissible levels for waste disposal have been very low. On the other hand, as the long time effects of radioactive materials become known, the present standards may be found unnecessarily severe.

In general, wastes from an operation of this nature fall into three classes: liquids, air-borne gases and solids, and solid wastes or contaminated materials. Each of these must receive specific treatment in a manner which results in efficient plant operation, yet provides reasonable assurance that plant wastes will not prove harmful in any way. Two basic methods for controlling plant wastes are:

1. Concentration and/or storage.
2. Dilution (liquid) or dispersion (air-borne).

The first method is preferred in the case of tremendous quantities of highly dangerous waste materials, but becomes uneconomical for high volume low level wastes. The major portion of the radioactivity in the process wastes at this plant will be stored in concentrated form. This method has been chosen not only because of the potential hazard of these materials, but also because of their potential value. Many uses will undoubtedly be found for both gross fission products and specific separated isotopes. While this is not an immediate possibility, it definitely should be considered, since it might reduce the expense of fuel processing.

LIQUID WASTE CONTROL IN THE CPP

Control of liquid wastes in the CPP will be accomplished by:

1. Concentration and permanent storage of high level wastes in 335,000 gallon underground tanks.
2. Dilution of low level wastes and disposal to the water table via a continuous radioactive monitoring station and a disposal well drilled to a depth of 100 feet below the water table (600 feet total). Discharged wastes will be limited to 10^{-4} uc/cc.

The monitoring station is equipped with a recording weir meter which records the total liquid flow into this station from the laboratory, process building and waste treatment building. A continuous sample of this stream, proportional in value to the flow, will be collected with a "mini-pump" sampler. This sample will be collected and analysed daily for radioactivity.

In addition, a portion of the waste stream will be pumped through a "Hurst Monitor" which will give a continuous reading of activity. The stream measured will not be proportional to the total flow, but the output of the Geiger tube amplifier will be fed to a watt-hour meter along with an output signal from the weir meter. The watt-hour meter will then be calibrated in terms of curies per gallon.

The individual waste streams entering this monitoring station are sufficiently separated at the input to enable spot sampling of each stream. This will help to isolate the source of activity.

Concentration of wastes will be accomplished by means of evaporation systems in the cells of the process plant and/or in a separate building provided for treatment of these wastes. The major source of activity stored in the permanent storage tanks will be the raffinate concentrates containing the gross fission products which are separated from the spent fuel in the extraction columns. After partial concentration in the column cells these wastes will go directly by jet to temporary storage tanks in the waste treatment building. They will eventually end up in the permanent underground tanks unless some use for these wastes can be found.

For convenience the remaining liquid wastes in the plant can be divided into four main systems or streams.

Service Waste System

This consists of wastes from cold area floor drains, cooling water and steam condensates and condensates from evaporators and condensors. Under normal operations all these wastes should be "cold". They are discharged directly to the monitoring station prior to disposal to the water table. Wastes from the service building contain no activity and, although they go to the monitoring station, they are not sampled but go directly to the disposal well.

Cell Floor Drain System

This consists of "cold lab" sinks, emergency showers, floor drains and cell floor drains. Under normal operating conditions these wastes would contain only small quantities of radioactive materials. However, these wastes are held up temporarily in two 4,600 gallon stainless steel tanks in the process plant to permit sampling and analyses for radioactivity. If the activity is found to be high, the contents of these tanks can be pumped to the waste treatment building for concentration and permanent storage. If the activity is sufficiently low the contents will be discharged to the water table via the continuous monitoring station.

Process Equipment Waste System

This consists of wastes from "hot lab" sinks, cell wall drains and filter-aid drains. Wastes from all process equipment and tanks in the cells (exclusive of gross fission product already mentioned) are pumped to these cell wall drains. These wastes may contain considerable quantities of activity. They are held up temporarily in two 4,600 gallon tanks in the process plant and samples will be taken from these tanks to determine the activity. Normally, these wastes will be pumped to the waste treatment building for concentration and permanent storage. If the activity is low they can be discharged to the monitoring station along with the "cold" wastes.

Fuel Storage Building System

Wastes from this area result from contamination of the canal water by the fuel elements. A portion of this activity is removed in a filter system designed primarily to keep the canal basin water free from discoloration by continuous recirculation and filtration. The contents of these filters are dumped periodically into a "filter aid settling manhole" which is essentially a concrete hold-up tank. Solids are permitted to settle out and the supernate is decanted to an open bottom manhole which permits seepage into the ground. Solids will be pumped from the settling manhole periodically and will be treated and stored with other hot wastes. The floor drains, emergency showers and the overflow from the basin (approximately 20 gpm) are all discharged to the open bottom manhole mentioned above via a water drain monitoring manhole.

Samples will be collected routinely from the manhole and the overflow from the canal in order to compute the amount of activity discharged to the soil.

V: 4

AIRBORNE AND GASEOUS WASTE CONTROL IN THE CPP

Permissible limits for activity released to the atmosphere will be determined on the basis of ground level concentrations. The American Cyanamid Company Health Physics Department will be responsible for monitoring these wastes inside the confines of the CPP area and the AEC Health Physics group will be responsible for monitoring outside the confines of this area. Stacks and vents will be monitored periodically to determine the effectiveness and proper operation of installed filter systems.

The various sources of possible airborne activity and their control in the CPP are:

Hood System

The analytical and works laboratory and Cell X contain some 30 hoods connected in banks of four or less to "Cambridge Absolute Filters" (paper filters). Each filter box is followed by a blower which exhausts directly to the atmosphere on the laboratory roof.

Health Physics will check hood face velocities routinely, monitor the filters for activity periodically and sample the discharge ducts when necessary.

Building and Cell Ventilation

Ventilation for the building and cells is supplied from a 135,000 cfm fan system originating in the service building. "Cold" areas (lab, office building and crane bay) are maintained at a positive pressure and are exhausted directly to the roof.

Plant areas and hot areas are maintained at sub-atmospheric pressure so that movement is always from "cold" to "hot" areas. This differential is maintained by two 75 H. P. fans on the negative pressure side, which discharge the "hot" area ventilation directly to the stack.

Cell ventilation enters the cells through the access and operating corridor and leaves by ports in the ventilation tunnel which connects to the main discharge duct leading to the stack. Under normal operating conditions this air should contain little activity and is consequently discharged directly to the stack without filtration.

Sampler Off-Gases

Ventilation supplied to the samplers in the sample corridor is conveyed to a filter and blower room on the southwest corner of the process plant. The air is filtered through Fiberglas filters and is discharged to the ventilation tunnel and hence to the stack by two 2400 cfm blowers.

These filters will be monitored for radiation periodically and samples will be collected from the exhaust duct when indicated.

Process Vessel Off-Gas (Exclusive of Dissolver Off-Gas)

The gases and particulate air-borne activity formed in all process equipment vessels are ventilated by a separate system which is operated at a reduced pressure to prevent escape of radioactivity into the cells. Cells dealing directly with product solution are equipped with an entrainment separator (off-gas knock-down tower) to remove large particulate matter. All ventilation is conveyed to the waste treatment building by means of a 6-inch stainless steel pipe in the ventilation tunnel, where it is filtered through special fiber glass filters and discharged to the stack through two 2400 cfm blowers. These filters are designed to last several years before replacement is necessary.

Dissolver Off-Gases

These gases are released in the dissolver tanks and will contain the major portion of the activity discharged to the atmosphere from this plant. Besides particulates, these gases may contain radioactive iodine, xenon, krypton and argon. Each dissolver is equipped with a reflux condensor and a stainless steel wool knockdown tower to remove condensates and entrained materials. The remaining gases and particulates are conveyed under negative pressure to the waste building via a 3-inch stainless steel pipe in the ventilation tunnel. Present plans are to discharge these gases and particulates directly to the stack without further benefit of filtration or condensation and storage. Without further treatment, effective disposal of these wastes depends on their dispersion in the atmosphere. Much more efficient control would result from the contemplated addition of a filter plant to remove particulate activity and a system for removal of radioactive gases.

Stack

The stack at the CPP is a reinforced concrete structure, 250 feet high, with a minimum inside diameter of 10 feet. The normal quantity of air discharged to the stack will be 150,000 cfm, but the designed capacity is 300,000 cfm at 150° F. Due to possible temperature inversions, the stack is equipped with heaters to supplement the draft. The stack is provided with sampling ports at 50-foot intervals. A water spray system is provided 20 feet above the base of the stack to wash down activity when required.

V: 5

CONTROL OF SOLID WASTES AT THE CPP

The AEC is presently planning to maintain a central burial ground for solid waste disposal. It will be the responsibility of American Cyanamid Company to properly prepare or package, monitor and label all wastes designated for burial ground disposal according to the specific procedure in the procedure section of this manual.

RADIATION EXPECTED IN THE CFP

VI

VI

RADIATION EXPECTED IN THE CPP

VI: 1

RAW MATERIALS - SF BUILDING

Alpha, beta and gamma radiation will be present from raw material to final product. As mentioned previously, alpha radiation is hazardous when inside the body, beta is easily shielded out, so gamma will be most troublesome.

The raw materials will be irradiated enriched uranium alloys of different composition from different reactors. The material will arrive at our plant for temporary storage in the SF Building. The material will be shielded to allow 24 hour per day continuous exposure without exceeding safe limits. The storage area will be shielded by water so that the radiation is only slightly above background. Adequately shielded containers will be provided to move the material from storage to the separation plant. If the whole body were exposed to an unshielded batch of raw material at a distance of a few feet, a fatal dose of radiation could be received in a few seconds. Therefore, extreme precautions must be taken in all operations involving transfer of fuel elements.

VI: 2

PROCESS BUILDING - 601

All cells, with one or two exceptions, will be areas where entrance is absolutely prohibited, except under special conditions requiring radiation surveys and a "special work permit".

The operating gallery and make up area under ordinary conditions will be free from radiation or contamination. "Protective" clothing will be required, however, since it is remotely possible that conditions could change very rapidly and work with active materials in adjacent areas is necessary.

The sampling corridor will be a potential radiation and contamination area where more than normal precautions may be required.

The service corridor, pipe trench and ventilation duct will be radiation and contamination areas where entrance will be by "special work permit" only.

The laboratory (first floor of 602) and the works laboratory (basement of 602) will be potentially contaminated areas with the risk of exposure to direct radiation somewhat less acute than in other areas mentioned.

The waste building will have intense radiation sources under ordinary conditions sufficiently shielded to permit continuous exposure. There will be a contamination and radiation hazard of varying degrees due to unpredicted occurrences.

The cafeteen, maintenance area, communications area, boiler house, locker room and the top floor of Building 602 will be kept free from radiation and contamination. This will require the utmost co-operation in following rules and using "common sense" to prevent the unintentional transfer of active materials to these areas.

RADIATION AND CONTAMINATION PROTECTION AND CONTROL

VII

RADIATION AND CONTAMINATION PROTECTION AND CONTROL

VII: 1

PERSONNEL

Clothing

"Protective" or "anticontamination" clothing will be required in many areas which will be defined under "Specific Procedures" as "Zone Definitions". Past experience has shown that, in spite of all precautions, errors will be made and accidents will occur which will result in the transfer of radioactive material to the individual and his clothing. Clothing is issued to avoid contamination of personal clothing and hence confine radioactive materials to the plant. The plant clothing will be worn only eight hours per day and laundered frequently. This is to shorten the time of exposure to an individual, should he be carrying radioactive materials on his clothing. By shortening the wearing time, the risk of transferring the materials to the inside of the body is lowered. This clothing does not offer any greater shielding qualities than personal clothing, nor is the radioactive material any less likely to stick to it.

Personal clothing is preferable in the cafeteen. However, since it has become customary to have coffee and a snack once or more per day, and shift workers may find it necessary to eat their lunch when time allows, work clothing will be allowed in the cafeteen when it is covered by uncontaminated outer clothing, such as laboratory coats and shoe covers. These will be available at convenient locations.

Suitable gloves should be worn where contamination is possible. Personnel should become familiar with procedures developed to prevent contamination of the hands, the inside of the gloves and surfaces where the gloves are placed after removal from the hands. (See specific procedures)

Eating, Drinking and Smoking

The object in this case is to prevent radioactive materials from getting inside the body where some isotopes are deposited and may continue to irradiate the surrounding tissue indefinitely.

It must be recognized that, regardless of rules and their enforcement, the individual must assume some responsibility to protect himself and help to prevent careless and irresponsible people from endangering themselves and others.

Eating, drinking (except water from fountains) and the preparation or storage of food will be confined to the cafeteen. Those who prefer to bring their own lunch may store it in a place provided and eat it in the cafeteen. This is intended to include candy bars, nuts or other snacks as well as coffee or soft drinks. However, the consumption of these items will be permitted in the immediate vicinity of the vending machines. The danger of food in active areas with possibly contaminated hands is obvious. Soft drinks introduce an additional problem of returnable bottles. If bottles or other returnable food containers were allowed in the work areas, a survey would have to be made of each container to certify that it is free from radioactive materials. It is impossible to make surveys of small containers with sufficient accuracy to guarantee no active materials.

Smoking is prohibited in areas where radioactive material is handled. Smoking is permitted in offices and areas which are contamination free. The responsibility for preventing ingestion of active materials in these cases rests with the supervisors and largely the individual. This does not authorize smoking where it is prevented for other reasons; fire hazard for example.

Personnel Monitoring

A film badge and pocket chamber will be required to enter the main gate (see specific procedures). These should be worn continuously, preferably on the chest, with the "open window" of the film out and the pocket chamber adjacent. Film rings and wrist badges will be available for special jobs where hand and arm exposure would be expected to be greater than body exposure. Dosimeters which can be read by an individual without special equipment will be available for special jobs where varying radiation fields must be entered. Total accumulated exposure and daily exposure records will be available to supervisors and to individuals on the supervisor's recommendation.

Equipment for checking for the presence of radioactive materials in the thyroid and the upper respiratory system will be available in the Health Physics Department.

Samples will be collected for analyses of radioactive materials eliminated in the body fluids or feces. Such analyses will be performed by AEC Health Physics. Need for such sampling will be determined as a result of the investigation of radiation exposure incidents. In addition, a routine periodic urine analysis might be requested of all personnel.

Preventive Personnel Contamination Regulations

1. Hand and Foot Counts

   Hand and foot counts and probe surveys should be made with the appropriate alpha or beta-gamma counter before personnel eat or leave a shift and whenever contamination is possible. Counts above the posted limits should be reported to a Health Physicist who may assist with decontamination and record the incident. (See specific procedure)

2. Pipetting

Pipetting of any solution by mouth is forbidden.

3. Skin Openings

Work with uncovered breaks in the skin is not allowed. The First Aid Department will furnish suitable covers for minor wounds.

4. Wounds

Wounds obtained while working with radioactive materials where contamination is possible should be:

a. Washed with running water immediately (a few seconds is important).

b. Checked by a Health Physicist.

c. Treated by the First Aid or Medical Department.

Treatment of serious bleeding, stoppage of breathing, shock and less serious but dangerous situations should not be delayed for radiation checks. (See specific procedure.)

5. Glassware

Glassware from areas using radioactive materials should not be submitted for repair or glassblowing. If glassblowing is absolutely essential, it should be done only on a special "work permit".

6. Safety Glasses

Safety glasses should be worn in accordance with general industrial practice. Areas requiring safety glasses should be conspicuously posted. Face shields should be available where splattering is possible.

7. Respiratory Protection

Respirators, assault masks, all purpose masks and air or oxygen supplied masks should be available for emergencies. Personnel should be fully instructed in the use of masks, safety showers and fire fighting equipment. (See specific procedure for respiratory protection.)

8. Maintenance

All maintenance in areas where radioactive materials are possible should be done only on a "Special Work Permit". (See specific procedures)

VII: 2

AREA

Labels

Radioactive materials, regardless of their activity, should be conspicuously labeled and stored only in areas distinguished as "Hot" areas. Where a group of samples are stored in a particular area, labeling of the area will be sufficient. New radiation surveys should be made and posted as the conditions change.

Isolated Areas

Areas with radiation fields greater than 7.5 mrep/hr should be isolated by signs and barricades to prevent unintentional entrance.

Centrifuges

Centrifuges should never be operated with covers open. Tubes should be tested with harmless solutions. Contamination and radiation labels should be applied as required. The inside parts of centrifuges are decontaminated with difficulty. Individuals should recall that the one responsible for contamination is also responsible for decontamination.

Hoods

Health Physicists are equipped to test face velocities of hoods. This will be done routinely at specified intervals. A special check should be requested if there is the slightest doubt about operating efficiency.

Procedures should be established by departments using hoods to prevent fans or blowers from being turned off while volatile materials are in the hoods.

Care and judgment must be exercised to prevent the opening of one or more hood windows on a given manifold so as to exceed the fan capacity and hence lower the face velocity on other hoods.

Precautions must be taken to prevent the restriction of the inlet air to rooms so as to limit the face velocity of hoods.

Where hoods with widely different face velocities and total volumes of flow are adjacent, or even in the same room, frequent checks must be made to see that the flow is not in the reverse direction from the low to the high volume hood.

The direction of flow of low velocity hoods is easily changed. A brisk walk past the face will often momentarily reverse the flow of hoods with face velocities of 100 ft/min or less. Natural drafts caused by opening doors to a room will sometimes change low velocity hood flows.

Frequent checks of hood filters should be made for pressure drop and radioactive contamination.

Hoods where liquid spills are possible should have easily decontaminated impervious linings and be covered with absorbent materials to restrict the spread of liquids.

Sinks and Traps

Radioactively contaminated equipment must not be cleaned in sinks connected to the sanitary sewer. Frequent radiation checks will be made of sinks and traps connected to the plant disposal system.

Water Supply

Provisions should be made to prevent radioactive materials from being sucked back or introduced into the water supply. Suitable safety devices should be attached to water lines where there is even a remote chance of material being sucked back due to water failure or shutdown.

Solid Wastes

Radioactively contaminated solid wastes should be placed only in containers labeled for the purpose. An inner paper lining for these containers is preferable. Powders should be placed in containers to prevent escape. A radiation survey and attachment of a proper tag is required at the time the material is collected at a central point for removal to the burial ground. (See specific procedure.)

Equipment Removal

All articles including furniture, mops, brooms, tools, returnable containers, etc., must have a radiation survey and a "removal tag" attached before being removed from a potentially contaminated area. (See specific procedures)

Return of Used Equipment to Stock

Glassware and small expendable items, as a general rule, will not be returned to stock from a "hot" area. Other more expensive or non-expendable items may be returned to stock or removed to "clean" areas when the "removal tag" is attached. (See specific procedures)

Distance and Shielding as Protection Factors

The three fundamental units, distance, mass (shielding) and time are involved in radiation protection just as they are in all phases of our existence. Since it is the responsibility of the individual to keep his exposure to radiation at a minimum at all times, familiarity with these factors would be advisable. As long as it is necessary to work near intense radiation sources, the use of distance as a means of reducing exposure should be used when at all possible. From a point source of radiation, it should be realized that, as one moves away from the source, the intensity of the radiation will be reduced. For such a source the intensity will fall off as the square of the distance, i.e., if the exposure at one foot from the source were 8 mr/hr, then at two feet it would be 2 mr/hr, etc. From an extended source (source having considerable area) the intensity does not fall off as the square of the distance, but more nearly linearly with distance. These so-called geometrical considerations must, of course, be taken into account by the surveyor in making intensity measurements. Any radiation level measurement posted will indicate the distance from the source at which the determination was made.

Appropriate shielding measures, depending upon the nature of the radiation and its intensity, will be taken when it is more convenient or economical than time or distance. The Health Physics Department will be available to advise in the construction of suitable shields to fit a particular problem and to check such shields for effectiveness in a radiation field. Shield parts, such as lead bricks, should be checked for contamination and the "removal tag" procedure followed when the shield is removed from any area.

The time safety factor can be used in many cases by dividing the radiation exposure over an extended period or among a number of persons. As discussed in the section on "Effects of Radiation", the importance of total dose vs. dose rate must be considered in any time division of radiation dosage.

Transfer Within "Hot" Areas

Transfer of materials should be from person to person; never from person to location. Active materials must not be transferred to a laboratory without notification of the person in charge. Samples should be adequately shielded to prevent exposure above allowable limits and the individual making the transfer should understand the hazards and be familiar with the time and distance from the source which are allowable without unnecessary exposure. Solutions should be packed in secondary containers with liquid tight gaskets, or packed with sufficient chemically inert absorbent material to prevent escape of liquid. Recipients of active solutions should refuse to accept them until the chemical composition, kind and intensity of activity are known.

Clean-up

The group and/or the individual responsible for spills of radioactive material is also responsible for clean-up. A Health Physicist should be called to recommend precautions during clean-up, to help locate contaminated areas and to make a final radiation survey.

Radioactive Shipments by Public Carrier

The Interstate Commerce Commission publishes complex regulations governing shipment by all methods of public transportation. Individuals packaging materials for shipment should consult these regulations, copies of which are available in the Health Physics Department. The radiation readings stated on the labels must be made by a Health Physicist and a record made of the materials, radiation readings, etc. Radiation readings on courier shipments must also have Health Physics approval. (See specific procedures)

INSTRUMENTS

VIII

VIII

INSTRUMENTS

VIII: 1

INTRODUCTION

It is the purpose of this chapter to describe, in general terms, the various instruments which are in use by the Health Physics Department. The particular application of each instrument will be outlined and some limitations discussed. Detailed discussion of the theory responsible for the operation of each instrument will not be included, since it is available in the scientific literature in many forms.

Instruments which will indicate the presence of nuclear radiations might be placed in two general classifications:

1. Those which integrate or sum over a large number of individual processes taking place in the indicating medium and give either an accumulative or instantaneous average indication of such radiations.
2. Those which register the presence of individual particles or quanta through their interactions with matter in a sensitive volume.

Examples of the first group would include certain types of ionization chambers, photographic emulsions (density measurements), and colorimetric dosimeters, while in the second class would fall Geiger-Mueller tubes, proportional ion chambers, scintillation counters, etc. Some instruments in use are sensitive to only specific types of radiation while others may be adapted to the detection of several different types. The sensitivity for a particular type of radiation varies considerably for different instruments.

The proper use of detection instruments in a Health Physics program requires not only that their operation be understood, but primarily that the results obtained be interpreted correctly. In order to make such an interpretation, the characteristics of a particular instrument must be thoroughly understood.

VIII: 2

PERSONNEL MONITORING INSTRUMENTS

Pocket Ionization Chambers

Pocket ionization chambers or "pencil meters" are almost universally used by Commission contractors as a reliable means of measuring accumulative gamma ray exposure of personnel. These chambers are in effect pencil shaped air condensers. The outer cylinder consists of a tenite wall molded around a carbon saturated conducting paper tube. Through the center of the chamber, forming the other electrode, runs an insulated graphite coated aluminum rod. This rod extends through the end of the chamber and is covered by an aluminum cap which serves as a contact for charging and reading the residual charge on the chamber after exposure to radiation. The chamber is initially charged to 150 volts and will discharge approximately 75 volts upon exposure to 190 mr of gamma radiation (medium energy range). The chamber, in its present form, is mechanically rugged and not seriously subject to discharge due to accidental jarring. Although the chamber primarily is considered as a detector of gamma radiation, it will give some indication of beta radiation above 0.7 Mev. The total range of the normal pocket chamber is from 0 to 300 mr. The results obtained from these chambers are independent of the energy of the gamma radiation above 300 Kev., but in the energy region from 40 to 250 Kev., they may give readings as much as 5 times too high. This effect results from the use of materials of high atomic number in construction of the meters.

Film Badge

The sensitivity of the photographic emulsion to ionizing radiation permits its use as a personnel monitoring device. The so-called "Film Badge", in the form commonly used, has an open window section and a section covered by a shield of cadmium, and contains a film packet (Du Pont 552). The film packet consists of a sensitive and an insensitive sheet of film; the sensitive sheet covering a range from 20 mr to 20 r and the insensitive from 50 mr to 40 r of gamma radiation. The 1mm cadmium shield is included to stop most beta radiation and extremely low energy gamma radiation. The open window section of the film is sensitive to that beta radiation which penetrates the paper wrapping and its sensitivity to betas is calibrated against the betas emitted by normal uranium in equilibrium with UX_1. The shielded portion of the film is considered as an indicator of the exposure to penetrating gamma radiation and is calibrated against the gamma rays of radium and its products.

The degree of "blackening" produced in the developed film will depend not only upon the total quantity of radiation but upon the energy of the radiation. The energy sensitivity of the film is such that the shielded portion will yield readings independent of energy above 150 Kev. Below 150 Kev., the sensitivity rises to a peak at about 90 Kev., and then falls off sharply due to losses in the cadmium shield. Readings in this region may be as much as two times too high (film calibrated against Ra). The unshielded portion of the film can only be used as a general indicator of the superficial body dose of beta and/or soft gamma radiation.

Special film emulsions and techniques are also available which will give an indication of the exposure of the body to fast or slow neutrons.

Film Rings and Wrist Badges

When work to be performed is such that exposure to the hands and forearms is quite probable, plastic finger rings or wrist badges can be provided which are assembled and interpreted in a manner similar to the film badge. These devices may be used to indicate surface exposure to either beta or gamma radiation on any particular portion of the body.

Colorimetric Dosimeters

This class of indicators relies upon the photochemical reactions which take place when certain chemicals are subjected to ionizing radiation. Certain of these reactions yield products which act upon dyes to change their color. One such device consists of small glass vials filled with mixtures of alcohol, free chloroform and brome-creosol purple, an indicator dye used in colorimetric pH determination. When chloroform is subjected to ionizing radiation hydrochloric acid is formed. As the pH of the solution passes a certain value the color of the dye changes from purple to yellow. The pH of the initial solution is adjusted by adding quantities of sodium hydroxide so that the indicator will change color at a dose of 1 r, 10 r, or more. Such devices would prove quite useful as indicators of total exposure in case of disaster.

Pocket Dosimeter

The pocket dosimeter is very similar in its characteristics to the pocket chamber, but is constructed in such a manner as to allow the user to read his total exposure to gamma radiation by observing an internal scale. The instrument is very similar in appearance to the pocket chamber, but contains a fiber electroscope to indicate the condition of charge on the instrument. It may be read by holding it up to the light and observing the position of the fiber on a transparent scale through a lens system. The usual range of this instrument is from 0 to 200 mr, although higher ranges are available. In general, this class of instrument is more fragile than the pocket chamber and should be handled with care. In reading the instrument the fiber should always be oriented in the vertical position in order to obtain consistent results. This instrument is very useful in high levels of activity because of the self-reading feature. It is also available with boron coated chambers to indicate personnel exposure to thermal neutrons.

Bell Pocket Alarm Meter

This meter is a small, pocket sized integrating ion chamber which gives an audible warning to the wearer when a predetermined dose of gamma radiation is received. The average battery life is approximately 200 hours of continuous operation. This instrument would be most applicable for work in high radiation levels for limiting working time, etc. The simplicity of its construction makes it a very sturdy and reliable instrument for certain purposes.

VIII: 3

PORTABLE SURVEY INSTRUMENTS

Lauritsen Fiber Electroscope

The principle of an electroscope relies on the attraction or repulsion of materials charged with positive or negative electricity. A quartz fiber, insulated from its surroundings, is charged with a battery voltage. Electrostatic forces will cause the fiber to bend or otherwise deviate from its original position. The degree of bending or deformation will be proportional to the charge on the fiber at any time. Ionizing radiation interacting with the air and surroundings of the fiber will cause it to lose its charge at a rate proportional to the amount of radiation entering the chamber per unit time. The position of the fiber, and hence an indication of the amount of radiation received by the chamber, is determined by looking through an eyepiece at its image as seen against an illuminated transparent scale. This instrument may be used to measure total integrated dose or as a rate meter by observing the time required for the fiber to move a given number of divisions across the scale.

The Lauritsen instruments have an aluminum ion chamber coated with aquadag and enclosed in a wooden box. A door is provided which is normally closed for calibration and gamma ray measurement. It serves the purpose of shielding against soft gamma and beta radiation and serves to bring gamma radiation in equilibrium with secondary betas produced in the surroundings. This instrument is most generally used to obtain quantitative dose measurements in the range up to one roentgen per hour. It is quite sensitive and reliable for this use. The instrument does not have uniform sensitivity for low energy gamma rays, due to the fact that the chamber is constructed of aluminum. Photoelectrons produced in the aluminum result in a reading which is too high as in the case of the film and pocket meters.

Cutie Pie

By far the most popular portable survey instrument in use is the "Cutie Pie". It is shaped like a pistol and has a cylindrical ionization chamber made of low Z material. The instrument measures gamma radiation in r or mr per hour, relatively independent of the energy of the gamma radiation. Some installations prefer to use an expendable conducting paper shell, rather than one made of bakelite. Such an arrangement permits measurement of the surface body exposure to beta and secondary electron radiation. Most "hard shell" Cutie Pie instruments have a thin window on the end of the ionization chamber so that qualitative measurement can be made of any beta radiation present. In its usual form the instrument has three or four scale ranges to allow dose measurements from 5 mr per hr to 5 or 10 r per hr. The meter circuit is essentially a Wheatstone bridge with the plate resistance of a triode vacuum tube in one section of the bridge.

The Cutie Pie is an extremely reliable and rugged instrument and gives excellent service over long periods of time without losing its calibration.

Fish Pole Probe

A modification of the Cutie Pie meter is useful in making measurements of very high radiation fields. The circuitry is the same as that of the Cutie Pie with the exception of the resistor values to allow higher ranges. The ionization chamber and vacuum tube are located on the end of an extension rod with the meter and switches mounted on the handle section. The characteristics of this instrument are identical with that of the Cutie Pie except that generally it will allow measurement of radiation dose rates up to 100 r per hr. Another type of gamma probe survey meter will be in use which utilizes flourescent material in conjunction with a photomultiplier tube to detect gamma radiation. These flourescent materials "glow" in the presence of radiation, giving off an amount of light proportional to the intensity of the radiation. The phototube and associated circuity produce a reading on an ammeter which is proportional to the amount of incident radiation. The detector is mounted on the end of a long probe and ranges of 0.3, 3, 30, 300, and 3000 r/hr are provided. The detector is quite fragile and subject to shock. Caution should be exercised in its use. Above all, the phototube should never be exposed to room light with the high voltage turned on.

Zeuto

This instrument is very similar in principle to the Cutie Pie in that it applies the balanced Wheatstone bridge circuit. The form of this instrument in general use contains a rectangular graphite coated ionization chamber with a stretched nylon window. This thin window allows the instrument to be adapted primarily to alpha and low energy beta measurements. It is provided with two scale ranges of 0 to 4,000 and 0 to 40,000 alpha disintegrations per minute when calibrated against the alphas of plutonium. Of course it must be recalled in the use of this instrument that it is sensitive to gamma radiation and beta particles as well as alphas. In general, it is used for semi-quantitative alpha survey work. One major defect of all ion chamber instruments for alpha measurements is the variation in counting efficiency over various parts of the window.

Near the edges of the chamber the efficiency may fall off to as low as 40%. The Zeuto has a switch position for setting the zero meter deflection. Normally a warm-up time of 3 to 5 minutes should be observed prior to zero adjust or general use.

<u>June</u>

This instrument is very similar in design to the Zeuto but is somewhat more versatile. The bottom of the chamber is covered with a rubber hydrochloride screen to allow alpha measurements, but in addition, sliding screens of cellulose acetate and aluminum may be inserted over the thin window. The plastic screen effectively stops all alpha particles and leaves the instrument sensitive to only beta particles and gamma radiation. The second window of aluminum leaves the instrument essentially only sensitive to gamma radiation. The instrument is not a quantitative instrument but may be used very effectively to estimate the quantity and type of any particular source of activity. Three scale ranges are provided: 0-50 mr, 0-500 mr, 0-5000 mr per hr for gamma radiation and will give an indication of alphas up to 3 million d/m. Another model is manufactured with a maximum gamma range of 25 r/hr.

<u>Geiger-Muller Counters</u>

Perhaps the most widely publicized detector of nuclear radiations, this device has found extensive use in research laboratories. Since the principles of the operation of these tubes is discussed quite adequately in the literature, no attempt will be made here to supplement this information, other than to point out that, as opposed to most ion chambers, the G-M tube registers the detection of a gamma ray or ionizing particle as a single event. A distinct voltage pulse is obtained at the output of the tube for each event. These pulses may be registered individually through the use of electronic scaling circuits or an average count rate may be obtained by a summing or integration scheme. The G-M tube takes on many forms, some with extremely thin windows which are quite effective as quantitative detectors of beta radiation, while others have glass or metal walls and are sensitive mainly to gamma radiation. Ordinarily these tubes are quite useful for the detection of gamma radiation in a semi-quantitative manner. They are generally limited by the fact that their operating characteristics are subject to change with time. In the presence of high radiation fields they may jam and usually give no indication of radiation at all. The expected lifetime of the so-called "self-quenching variety of tube is around 10^9 counts. They may become sensitive to visible light under certain conditions and are generally quite temperature sensitive. The counting efficiency of these tubes is quite energy sensitive and for this reason any calibration would be useless if the energy of the radiation to be detected were not known. In general, the detection efficiency for <u>beta particles</u> may run up to 100% (this does not include geometry and is quite sensitive to beta energy). With the exception of extremely soft gamma radiation, efficiencies for <u>gamma rays</u> (normal glass walled tubes) are in the neighborhood of 0.1 to 2% depending upon the energy of the radiation. Despite all of these limitations, the portable G-M survey meter is quite useful as a general detector of low level beta and gamma radiation. In its normal form a glass-walled G-M tube is mounted on a short flexible cable and provided with a metal shield which may be opened or closed to exclude beta radiation. It has three scale ranges: 0-600, 0-6,000 and 0-60,000 c/min beta-gamma or as calibrated against the gamma rays of radium, 0-0.2 mr/hr, 0-2 mr/hr and 0-20 mr/hr.

Proportional Counters

When ion chambers are constructed and operated in a special manner, the voltage pulse obtained at the output of the chamber will be proportional to the ionization produced by a given particle in the chamber. In general, the pulses produced by alpha particles are somewhat larger than those resulting from the detection of beta particles or gamma radiation. By descriminating against all pulses below a given size, such a chamber will respond only to alpha radiation. This principle has been applied to the construction of portable and semi-portable alpha survey meters. One such instrument, known as Poppy, applies its output to a loud speaker that gives a popping sound each time the proportional counter discharges. The chamber voltage can be adjusted so that it will count both alpha and beta radiation. Various probes may be supplied with this instrument ranging from very small chambers to large flat plate chambers for hand counting. Stationary gas-flow proportional chambers find general use in routine alpha sample counting. As a class, the operating characteristics of these instruments are fairly stable, although the voltage adjustment on many of the chambers is quite critical. Utmost care should be exercised in the prevention of contamination of all alpha instruments since a low background is essential to insure that the instrument is in proper operating condition.

VIII: 4

MONITORING INSTRUMENTS

Monitron

The monitron is an integrating ionization chamber instrument which is generally located at positions within the plant where direct radiation might be expected. The chamber detects beta and gamma radiation in the range from 0 to 125 mr/hr. An audible alarm is sounded and a red light flashes at 7.5 mr/hr or 125 mr/hr, depending upon the sensitivity settings which are high and low respectively. These instruments will be located within the cells to give a continuous record of radiation levels in specific locations by applying the output to a moving tape recorder. A few monitrons will be available in mobile form so they may be set up at the scene of temporary work likely to produce high radiation fields.

Proteximeter

The proteximeter is a portable direct beta-gamma integrating ion chamber designed to measure accumulated radiation dose. It is normally used to supplement dosimeters and pocket chambers when the radiation is likely to be variable. It will indicate when a certain dose has been accumulated, regardless of the intensity at a given moment. The normal range of these instruments is from 0 - 200 mr.

Frisker or Octupus

The frisker normally consists of several G-M tubes placed around the perimeter of a doorway to detect beta or gamma radiation. They are set to alarm at slightly above background and serve as a warning that persons passing through the doorway might be carrying radioactive material. Further checks with other instruments are required to locate and measure the intensity and nature of the radiation.

Hand and Foot Counter - Beta-Gamma (See Specific Procedure)

These consist of several G-M tubes shielded from background radiation and arranged so as to detect radioactive materials on the hands and shoes of personnel. The allowable limits of radiation, as indicated by calibration with sources of known intensity will normally be posted near the instrument in terms of register counts. There are six G-M tubes, one on each side of both hands and one for each foot. The output of these tubes is fed to electronic scales of 8 for the four tubes in the hand holes and one scale of 16 for the foot tubes. To use the instrument a person steps up on the platform and places his hands in the two pigeon holes. The weight of the body operates microswitches which set the counters into operation. After a preset time the instrument cuts off automatically and indicates the level of contamination by the readings of the five registers.

Constant Air Monitor - CAM (See Specific Procedure)

This is a mobile apparatus designed to continuously monitor room air for radioactive materials. It consists of a pump which causes air to flow through a cylinder of filter paper surrounding a G-M tube. The tube and filter are shielded from background radiation by a lead shield. A permanent record is obtained by an Esterline Angus recording milliammeter. A three position switch in the count rate meter circuit provides full scale deflection of the recorder for 2,000, 10,000 and 20,000 counts per minute. The instrument is calibrated with the beta radiation of normal uranium. A line representing the slope of the curve caused by the accumulation of air-borne radioactive materials at a rate equivalent to the allowable limit is drawn on the glass cover of the recorder for comparison to the recorder line. When the count rate reaches the maximum on any one scale the instrument automatically switches to the next higher scale. On the intermediate scale a yellow light is turned on, while on the high scale a bell sounds and a red light is turned on.

Filtron (See Specific Procedure)

The filtron collects particulate air-borne activity on a cylindrical filter paper in the same manner as the CAM. The air is pulled through the filter paper at a known rate for a measured time. The filter paper is then removed and counted in special alpha or beta-gamma counting chambers and the concentration of radioactive materials in the air computed. The apparatus is mounted on a two wheel truck which allows it to be moved from place to place.

Hudson Sampler (See Specific Procedure)

This sampler pulls air through a 1 1/8" filter disk mounted in a suitable holder by means of a small electric compressor as commonly used in commercial paint sprayers. The disk may be counted in standard alpha or beta-gamma counters and the concentration of air-borne activity computed. This instrument is portable, weighing only about five pounds complete.

Precipitron (See Specific Procedure)

The precipitron is an air sampler which pulls a known volume of air through a cylindrical chamber in which is produced a corona discharge. As a result of this discharge the particulate activity becomes charged and is drawn to the walls of the chamber. This chamber wall is lined with a thin aluminum foil which can be removed and counted in special counters and the concentration of air-borne particulate activity computed.

To summarize this discussion of field and stationary instruments, the following might be of some use to the field surveyor:

> If an instrument is available that has been calibrated, then it must be used properly in order to allow proper interpretation of the data. Improper use is certainly as bad as improper calibration. Although it would be difficult to give exact rules governing the use of all instruments, certain general considerations are given below:
>
> 1. Allow proper warm up time.
> 2. Check zero setting.
> 3. Determine the type of radiation being measured.
> 4. Never touch any sensitivity adjustment except during calibration.
> 5. Determine the distance from any point source of radiation to the point of measurement.
> 6. Know the limitations of the instrument in use.
>
> In surveying, three things might be of interest: location and identification of a source, dosage rate at a particular point, or total dose received by persons at that point. For the first purpose one might use a portable ion chamber instrument (Juno) which discriminates between alpha, beta, and gamma radiation by means of windows. For the second purpose one could use an instrument such as the Cutie Pie. For the third purpose film or pocket dosimeters might be used.

PROCEDURES

IX

IX

PROCEDURES

IX: 1

PROCEDURE FOR CPP PERSONNEL METERS PROGRAM

Preparation of Badges and Meters

AEC Health Physics will prepare and deliver to our guard gate the proper number of badges and meters for all CPP needs. They will be notified of the number of badges and meters, which we believe necessary for a week's work, sufficiently in advance to allow preparation and delivery. Badges will be identified by number and this number will be X-rayed on the film. The same series of numbers will be returned or replaced each week for CPP use. One charged pocket meter will be supplied with each badge.

Assignment of Badges and Numbers

Prior to the receipt of the badges the first two columns of "Film Report" form IDO #17 (copies of all forms included after procedure) will be filled out by American Cyanamid Company. Permanent employees will be assigned a permanent badge number at the time of employment and will keep this number as long as they continue to work for American Cyanamid Company. In case of termination, this number will not be used again unless the individual is rehired.

The above form (badge number and name) will be available to AEC at the time the weekly supply of badges is delivered by AEC. AEC will place the badges in the rack according to the badge number order appearing on this form. The extra supply of meters for visitors and non-routine use will be placed in a separate rack according to badge number. One pocket meter will be placed in the rack next to each film badge.

American Cyanamid Company will request additional film badges and pocket chambers on form IHP-19 "Badge and Pencil Request".

Distribution of Meters

Permanent employees will select their own meters from the appropriate space in the meter rack as they enter the main guard gate. If a meter is missing, the guard will issue a meter from the extra supply and fill out an "Issue and Record Slip" (AED-IF 14) for Health Physics records. The guard will place this slip in the proper space on the meter rack and a duplicate will be placed alphabetically in a special receptacle. The receptacle will be emptied weekly by AEC and slips forwarded to American Cyanamid Company. At the end of the week (or daily) this information will be transferred by AEC to the weekly "Film Report" with the appropriate notations in the remarks column.

Visitor and non-routine badges or other special film monitoring devices will be issued in the same manner as above on "Issue and Record Slips."

This information will also be transferred to the weekly form as above. Visitors and non-routine users will use the same badge during a "badge week" unless the results are requested for some reason before the end of the week. Pocket meters worn by these individuals provide the basis for investigations or exposure control.

Use

One film badge and one pocket meter will be issued and worn by all persons entering the main CPP guard gate. Badges must be worn on the chest, outside of all clothing, with the clip side in and pocket meters should be worn as close to the film badge as possible. Contamination on a badge or a damaged badge should be reported to the Health Physics Department. A record of the action will be made on the issue and record slip. Film badges will be pulled and processed during the week, only for the following reasons:

1. Pocket meter off scale.
2. Exceeding AEC daily limit.
3. Contaminated badge.
4. Damaged badge.
5. Special request for results.

A record of this action will be made by AEC on Form AED #21 "Daily Pocket Chamber Report" at the time the pocket chambers are read. An "Issue and Record Slip" will also be filled out, if necessary. Results will be reported during the week and on the "Film Report" at the end of the week.

Collection

Each person leaving the CPP area will be required to turn in his film badge and pocket meter at the main guard gate.

Pocket meters will be read daily by AEC. Results will be reported by AEC on the "Daily Pocket Chamber Report". Pulled badges and missing badges or pocket chambers will be reported on this form in the remarks column. AEC will retain a copy of this completed form for their records and one copy will be forwarded to the American Cyanamid Company.

At the end of the "badge week" AEC will pick up the badges at our main guard house. The information on the "Issue and Record Slips", and the remarks on the "Daily Pocket Chamber Reports" will be transferred to the weekly "Film Report". The "Film Report" will then contain the badge number, name and remarks for all film badge activities in the Chemical Processing Plant for an entire week. The remarks column will indicate the type of film device used and the application. Specific remarks will include statements such as visitor, ring film, wristbadge, contamination, damaged badge, not used, missing, misplaced, lost, pulled because of high pocket meter or special request.

A new film badge will be back in the rack before the above shift returns for work on the following day. This can be done conveniently by replacing the pulled set by a duplicate set. However, it may be possible for AEC to return the original badge before the shift gets back (16 hours).

Developing, Reading and Interpretation of Results

AEC will perform all of the above functions. We will have no direct control or responsibility for this phase of personnel monitoring except to submit a known standard occasionally as a check.

However, we will require that the shielded portion of the film badge be reported as gamma radiation based on a Ra or Co calibration. The open window reading will be differentiated between beta and gamma exposure. This interpretation will be obtained by subtracting the shielded density from the open window density and reporting the difference as beta from a beta calibration curve. Correct for Cd and Al losses, if necessary.

Reporting Results and Record Keeping

After developing and reading the films, AEC will fill out the remaining parts of the weekly "Film Report". Non-routine results reported during the week will be included on this form at the end of the week. Processing irregulatities such as damaged or lost in process, X-ray failed, exposure to light, etc., will be reported in the remarks column. AEC will retain one copy of the above and return one to ACCO. This system will provide the AEC and CPP with identical records. AEC and ACCO can either keep or transfer these records of exposure to their files as each desires.

The CPP plans to transfer the results from the "Film Report" and the "Daily Pocket Chamber Report" to form HP-4 (individual exposure record). These will be kept in a Cardineer file. The last column in form HP-4 provides space for recording events and records such as urine and blood analysis, medical examinations and any other information relative to radiation exposure. The results are arranged so they can be summed up in three months. This is the period required by AEC for an average exposure of 300 mrep/week. The total exposure will be carried over onto the first line of the next three month period to provide a continuous record of total accumulated exposure.

Exposure Investigations

All formal investigations will be based on film results only. Two copies of the "Health Physics Exposure Questionnaire" AED #22 will be completed when film results indicate:

1. Whole body gamma radiation of 300 mr per week or greater.

2. Whole body exposure of less than 300 mr per week but a beta plus gamma total of 500 mrep/week or greater.

3. Hand and forearm exposure of 1.5 rep per week of beta or gamma or the sum of beta and gamma.

Whole body exposure will be assumed when radiation is received to any portion of the body other than the hands or forearms.

Informal or formal investigations may be made for other reasons at the discretion of the Health Physics Department. Reported high exposures approaching but not exceeding the above limits will be considered cause for investigation.

The "Health Physics Exposure Questionnaire" will be initiated by the Health Physics Department and completed by the Health Physics field representative in co-operation with the supervisor of the department involved. A copy will be placed in the individual's exposure file and a copy forwarded to the supervisor.

IHP-11 rev. (10-15-51)

FILM REPORT

Plant ____________________ Week Beginning ______________

Badge No.	NAME	REMARKS	Density		Exposure		
			O.W.	Shield	Beta	Gamma	Total

IHP-19

BADGE AND PENCIL REQUEST

Area ____________

Date ____________

To:

AEC Health Physics Division
Personnel Metering Branch

Please issue a ☐ Temporary, ☐ Permanent Health Badge and Pencils for
(check one)

______________________________ beginning ____________. He will be assigned to
Name Firm Payroll # date

________ shift.

Signed ______________________________
Health Physics Representative

Note:

Temporary badges are removed from service as of 12:01 A. M. each Sunday.

PERSONNEL MONITORING ISSUE & RECORD SLIP

NAME ______________________________

COMPANY ______________________________

DATE ______________________ BY ______________

New Badge No. ____________ Old Badge No. ____________

Pocket Meter Yes ________ No ________

Other Device ____________ Number ____________

Reason ______________________________

____

Remarks ______________________________

____

ED-IF 14 3.000 4-52

DAILY POCKET CHAMBER REPORT

Plant__________________________ Date________________________

Badge No.	NAME	RESULTS	REMARKS

AED Dupl # 21 500 11/8/51

NAME ______________________ YEAR 19 ________ NO. ____________

WEEK BEGIN	S	M	T	W	TH	F	S	P. C. TOTAL	FILM BADGE BETA	FILM BADGE GAMMA	FILM BADGE TOTAL	REMARKS OR REFERENCE
TOTAL CARRIED OVER												
						← GRAND TOTAL						

H. P. 4

GOF 2752 PTD. IN U. S. A. 1-52

DIEBOLD CARDINEER FORM 37365A 15A

NAME ______________________ YEAR 19 ________ NO. ____________

WEEK BEGIN	S	M	T	W	TH	F	S	P. C. TOTAL	FILM BADGE BETA	FILM BADGE GAMMA	FILM BADGE TOTAL	REMARKS OR REFERENCE
						GRAND TOTAL →						

NAME ______________________________ YEAR 19 __________ NO. ______________

								P.C.	FILM BADGE			REMARKS OR REFERENCE
WEEK BEGIN	S	M	T	W	TH	F	S	TOTAL	BETA	GAMMA	TOTAL	
TOTAL CARRIED OVER —	— — —	— — —	— — —	— — —	— — —	— — —	— — —					
					← GRAND TOTAL							

H. P. 4

DIEBOLD CARDINEER FORM 373658 (54)

NAME ______________________________ YEAR 19 __________ NO. ______________

								P.C.	FILM BADGE			REMARKS OR REFERENCE
WEEK BEGIN	S	M	T	W	TH	F	S	TOTAL	BETA	GAMMA	TOTAL	
TOTAL CARRIED OVER —	— — —	— — —	— — —	— — —	— — —	— — —	— — —					
					← GRAND TOTAL							

HP-7 (10-9-51)

STRICTLY PRIVATE
Health Physics Exposure Questionnaire

Name of Employee ______________________ Badge No. __________ Date __________

Dept. ______________________ Supv. in Charge __________________

EXPOSURE REPORT

Coincident with the above date the items checked and noted below indicate a possible exposure or an incomplete record concerning the above named employee:

1. Pocket and/or Film Meter Record

	METERS	SUN.	MON.	TUE.	WED.	THUR.	FRI.	SAT.	TOTALS	REMARKS
Last Week Begin.	Pocket Meters									
	Film Meters	B G	B G	B G	B G	B G	B G	B G	B G	
This Week Begin.	Pocket Meters									
	Film Meters	B G	B G	B G	B G	B G	B G	B G	B G	

2. Special Meters or Contamination

INVESTIGATION

3. Cause and Details of above report

4. Recommendation of Health Physics Surveyor and/or Supervisor.

Investigated by ____________________ Date __________ Noted by ______________
Health Physics — Employee's Supv.

FURTHER ACTION

Noted: ____________________ Date __________

AED Dupl #22 400 11/14/51

STRICTLY PRIVATE

PROCEDURE AND POLICIES FOR THE USE OF "PROTECTIVE" CLOTHING

The term "protective" clothing should not be thought of as implying that this class of clothing offers any special shielding against radiation. The major purpose of this clothing is to prevent contamination of personal clothing while in the presence of radioactive materials. It offers no more shielding or protection from contamination than any other type of clothing. However, the "protective" clothing will confine contamination to the CPP. By shortening the time the clothing is worn, the probability of damage by ingestion or direct radiation will be lowered.

1. "Protective" clothing will be provided for authorized personnel and the wearing of these articles will be governed by the zoning and regulations listed below. It shall be the responsibility of the individual and/or his supervisor to see that this clothing is worn when required.

The CPP will be divided into zones as follows:

A. "Protective" clothing or personal clothing covered by suitable "protective" clothing for visitors will be worn in the following areas:

    1. Operating gallery
    2. Make-up area
    3. Access corridor
    4. Sampling corridor
    5. Laboratory area (first floor building 602)
    6. Works laboratory
    7. Waste building
    8. SF building (for those handling active materials)

B. "Protective" clothing and a special work permit stating additional precautions is required for entry to these areas.

    1. All cells except K (solvent recovery) and X (decontamination). Extra precautions will be routine in the latter.
    2. Pipe trench and deep pit tanks
    3. Ventilation duct
    4. Service corridor

3. Persons entering "clean" areas must change or cover "protective" clothing with contamination free garments. Examples of such areas are: cafeteen, maintenance area, boiler house, product storage area, or second floor offices. The status of any of these areas may change at any time as required to fulfill the obligation to provide reasonably safe working conditions.

4. "Protective" clothing in the following forms will be provided to authorized personnel: coveralls, shoe covers, gloves, technician's uniforms (for women) and caps. For special jobs rubber boots, rubbers, rubber gloves and respiratory protective equipment are available.

5. Each individual, upon the written recommendation of his supervisor, will be issued a sufficient number of sets of clothing to be assured that a clean set is always available. Clothing shall be changed daily or monitored for contamination. Clean clothing will be available from the clothing issue room adjacent to the locker rooms. Each individual's clothing will be identified by a number.

6. Clothing will be replaced only on written recommendation of the supervisor and each individual will have to account for clothing to be replaced. The laundry will be expected to notify the clothing clerk of any clothing removed from service due to wear or contamination.

7. Receptacles will be provided in locker rooms for the collection of clothing to be laundered. It will be the responsibility of the clothing clerk to transport the hampers to the monitoring station.

8. Clothing will be monitored by the Health Physics Department, separated into contaminated and non-contaminated groups and suitably tagged.

9. After clothing has been monitored, the clothing clerk will prepare clothing for pickup by the AEC and will maintain such laundry records as might be required.

IX: 3

PROCEDURE FOR THE REPLACEMENT OF CONTAMINATED PERSONAL PROPERTY

1. When an individual's personal clothing or other personal property, which is legitimately inside the CPP, or at any other location while the individual is at work, becomes contaminated with radioactive materials to such an extent that a health hazard is created, and the clothing is impounded, the individual shall be reimbursed for the value of the articles.

2. Measurements of the degree of contamination shall be made by a member of the Health Physics Department who will accept articles to be impounded, issue a receipt (form HP-8, shown on following page) and, when necessary, procure outer clothing to be worn home. The company will not be obligated to provide clothing other than coveralls marked with the identifying symbol or whatever footwear is available, and these on a loan basis only. The footwear now known to be available will consist of shower sandals or rubber boots.

3. The director of the department, or one to whom he delegrates the authority, will be required to provide a memorandum to the Accounting Department stating that the individual is eligible for reimbursement and that the contamination was not the result of personal negligence. The amount of the reimbursement will be the replacement cost of a duplicate article or equivalent.

4. The limits which will determine replacement shall be:

Alpha - 500 d/min/100cm^2

Beta-Gamma - 1000 c/min as measured with a Geiger-Muller tube of the type commonly used on probes with the best possible geometry.

5. Articles will be allowed a 30 day "cooling" period before reimbursement to allow radioactive decay to lower the value to allowable limits. Any other methods available will be used to remove contamination before a check is issued for reimbursement.

HP-8 (11-1-51)

RECEIPT FOR CONTAMINATED ITEMS

Description ______________________________

Received from ______________________ Date ____________

Type of Contamination ______________________________

____

Intensity ______________________________

____

____

Action ______________________________

____

____

Remarks ______________________________

____

____

H. P. Surveyor ____________________

PROCEDURE FOR USE OF RESPIRATORY PROTECTIVE EQUIPMENT

Approved respiratory protective equipment shall be worn in any location where air-borne activity may be present, according to the following procedure:

1. Wear filter type respirator when air-borne activity exceeds 10^{-11} uc/cc for alpha and 10^{-8} for beta-gamma. This use is subject to the determination by air sampling of the fact that such a concentration will exist throughout the working period.
2. Wear army assault-type mask when air-borne activity exceeds the above limits by a factor of ten. This type of mask is more reliable, fits the face better and consequently insures against failure due to air by-passing the filter cannister.
3. Wear positive air-supply masks when air-borne activity exceeds 10^{-8} uc/cc for alpha or 10^{-5} uc/cc beta-gamma. The upper limits of the positive supply masks is governed by external exposure levels.
4. Return the above respiratory equipment to the Health Physics shift office following each use for decontamination and sterilization before reuse.
5. Equipment will be stored under non-contaminated and sanitary condition and filters will be replaced at suitable intervals.

RECOMMENDED PROCEDURE FOR WASHING CONTAMINATED HANDS

1. Wash thoroughly for two to three minutes with a small quantity of industrial hand cleanser (as provided in dispensers), using a sufficient amount of tepid (not hot) water to maintain a thin paste, and rub the paste over the entire surface of the hands and fingers. Rinse off completely with water and repeat the process several times.

2. If the above procedure is not enough to remove all dirt and contamination, the hands should then be scrubbed for a period of a few minutes with liquid or cake soap and a hand brush, being sure to brush the entire surface of the hands, especially around the nails and between the fingers. Light pressure should be exerted on the brush - do not press so hard that the bristles are bent out of shape. A convenient routine is to start by scrubbing one thumb, being sure to brush all surfaces, proceed to the space between the thumb and index finger and similarly to each finger and the webs between the fingers. Attention should be given to the palm and back of the hand and finally additional scrubbing of the nails and cuticles before proceeding in an exact manner with the other hand.

3. Lanolin or lanolin containing creams may be used after washing to soften the hands and prevent chapping.

4. Should the procedures listed above fail to remove contamination, chelating or complexing agents such as Versene may be applied to the skin, followed by a thorough rinse with water.

5. Should all these measures fail to reduce the contamination to acceptable levels, consult the Health Physics field representative.

PROCEDURE FOR THE CARE OF WOUNDS LIKELY TO BE CONTAMINATED

Minor wounds may be considered as those which can be adequately handled by a First Aid Station. Major wounds require the attention of a physician.

A. Minor Wounds

1. Place the wound under running tap water immediately.
2. Continue to wash the wound area for several minutes using soap, a scrub brush and a large volume of water.
3. Report to the Medical Department as soon as possible.
4. Save the object causing the wound so an estimate of its contamination can be made.
5. The Health Physics Department will conduct a contamination survey of the wound area after thorough washing. If there is a residual contamination more stringent measures may be applied for cleaning the wound.

B. Major Wounds

1. Place the wound under running tap water immediately after the accident, if at all possible.
2. Have an associate call the Medical Department immediately and keep some sort of tourniquet proximal to the wound. The pressure of the tourniquet will depend upon the amount of hemorrhage. Venous return flow is to be stopped in all cases when possible, but arterial flow should be stopped only in case of severe hemorrhage.
3. Care of the wound after the initial washing should be under the supervision of the Medical Department. Health Physics will monitor the wound and determine extent of contamination, if any.

SURGICAL TECHNIQUE FOR PUTTING ON AND REMOVING RUBBER GLOVES

When rubber surgical gloves are used where hand contamination is possible, they should be prepared and put on in the following manner in order to avoid transfer of the contamination from the outside surface to the inside surface of the gloves or to the hands.

Put on gloves as follows:

1. Powder the insides of the gloves and fold out the wrist portion of the gloves to form a cuff of about two inches.
2. Powder the hands with talc.
3. Grasp the folded cuff of the first glove without touching the exterior of the glove and pull it onto the fingers and hand, leaving the cuff in the folded position.
4. Lift the second glove by inserting the fingers of the gloved hand beneath the cuff and pull it onto the bare fingers and hand.
5. Turn the cuffs of both gloves back over the wrists, without allowing the skin to be touched by the outside of the glove.
6. Work the glove fingers into position in the same manner as cloth gloves.

Remove gloves as follows:

1. Wash hands before removing gloves.
2. Grasp the beaded rim of one glove with the fingers of the gloved hand without touching the inside of the glove and pull the glove off inside out.
3. Insert the index finger of the bare hand beneath the beaded rim of the other glove and pull the glove off without touching the contaminated outside surface.

When this procedure is carefully followed, contaminated surgical gloves may be used several times.

PROCEDURE FOR CALIBRATION AND USE OF BETA-GAMMA HAND AND FOOT COUNTERS

These instruments consist of geiger tubes shielded from background radiation and arranged in a manner which permits convenient detection of contamination on the hands and shoes. Five of these instruments will be placed in appropriate and convenient locations throughout the plant. These should be used to check contamination on the hands and/or feet before eating or smoking, when changing shift, after handling radioactive materials, or at any other time when contamination is believed likely.

Calibration

Calibration and posting of the permissible levels (register counts) on the blackboard above the instrument will be the responsibility of the Health Physics surveyors. The following procedure will be followed daily to obtain the permissible levels.

1. Obtain the average background for each register and post this value in the corresponding spaces on the blackboard (hands and feet).

2. Place the standard hand calibrating source in the hand ports, determine the average count for each corresponding component of the hands and post these figures on the blackboard as the "permissible hand counts". The activity of the standard calibration source will be related to the permissible level of 1500 mrep/week to the hands.

3. Place the standard foot calibrating source in one shoe pocket and determine the average count. Repeat this procedure for the other shoe pocket and post the average of these two readings on the blackboard as the "permissible shoe count". The activity of the standard calibrating source will be related to the permissible shoe contamination limits specified in the chapter on radiation limits.

4. Replace paper sacks in hand ports and the paper in the shoe pockets once a week or at any other time when background counts from one register differ significantly from those of the previous day.

5. Refer any other work necessary to keep the counters in operation to the Maintenance Department.

Use of Hand and Foot Counters by Personnel

Personnel should check their clothing for contamination with the beta-gamma scanning probe which is located on the scaler cart next to each hand and foot counter. These should be used on the hands and feet before using the hand and foot counter if high contamination is expected.

1. Wash hands before using counter.
2. Remove wrist watch if it has a luminous dial.
3. Step in foot pockets and <u>immediately</u> place hands in hand checking pockets. Make sure fingers of both hands are fully extended to assure the best counting efficiency.
4. Remain in this position until the yellow "timed-out" light glows indicating the end of the count.

   Note: Continuous flicker of the neon lights at the left of the registers indicates a count that is higher than can be accurately recorded by the registers.

5. Re-wash the hands using soap and a scrub brush if the count on any one hand register is above the permissible count posted on the blackboard.
6. Report to the Health Physics field office or notify your supervisor if any one hand count cannot be reduced below the permissible level after several repeated soapings and scrubbings.
7. Report to Health Physics field office if the count on the foot register is above the permissible level posted on the blackboard.

PROCEDURE FOR USE OF THE WORK PERMIT

"Work Permit" form AED-IF1 (shown on the following page) is required for all maintenance work in areas where radiation or contamination is possible.

Departmental supervision, in agreement with the maintenance and other departments involved, shall schedule the work to be performed, initiate the work permit, describe the work to be done, indicate the location in the plant, and supply recommended protective equipment.

They shall review the proposed work with the Health Physics shift personnel, who will perform the necessary survey, establish working time limits, specify types of monitoring required, and recommend additional precautions necessary.

The completed form (bearing the signature of a Health Physicist and/or the Safety Department representative) will be presented to the maintenance supervisor before the work is started. He will comply with the recommendations stated on the form and display the form on a clip board in or near the work area.

Upon completion of any activity covered by a "Work Permit", it will be the responsibility of maintenance supervision to request a survey of the area, all personnel, clothing, tools or equipment to be removed from the job.

Tools, clothing or equipment found to be contaminated will be impounded by Health Physics and a "Receipt for Contaminated Items" issued. These items will be sent to the Operating Department for decontamination prior to release. Local measures for decontamination may be taken under the supervision of the Operating Department or the Health Physics Department.

When the work is completed or the permit surrendered at the end of a shift, the maintenance supervisor will return all copies of the "Work Permit" to the area supervisor.

The area supervisor will check to see that all instructions have been followed. If the job is satisfactorily completed he will sign the "Work Permit" and distribute the copies to the departments represented.

Maintenance infers electrical instrument, technical, or other service personnel directly connected with the execution of the particular job. At the end of one shift, a new "Work Permit" is required if the work is to be carried over to the oncoming shift, unless prior approval is valid for a longer period. If any change in conditions develops during the course of work, supervision present shall remove the workmen until the job can be reanalyzed.

AMERICAN *Cyanamid* COMPANY

ATOMIC ENERGY DIVISION
IDAHO FALLS, IDAHO

WORK PERMIT

(To be Retained and Displayed at the Site of Maintenance Work)

Issued to................................Badge................Department................

Good for................Shift................, 19........, only. Building Number................

Issuing Division................................Work Order No................

Description of Work and Location................................

....

GENERAL HAZARDS AND CONTROLS

	Initial Yes	No
1. Have connections been blanked off?........		
2. Have fuses been removed?........ NOTE: Safety locks on push buttons not sufficient........		
3. Have safety tags been attached?........		
4. Was equipment cleaned with Water........? Steam........?........		
5. Has equipment been ventilated?........		
. Has inflammable gas test been made?........		
7. Is gas or air mask necessary for entering tank?........ If gas, what type of canister........?........		
8. Are there any special precautions to be observed as to ground connections, protective clothing, etc. (Use reverse side for instructions.)		
9. Is the adjacent equipment safe?........		
10. Can sparks ignite material in vicinity or on lower floors or levels?........		
11. IS IT SAFE TO DO THIS WORK?........		

I have checked and approved of this permit for WORKING ONLY.

....
Operating Supv. or Engineer

I have personally inspected and approve of this permit for WELDING—BURNING—HOT WORK ONLY.

....
Operating Mgr., Supt. or Engr.

RADIATION HAZARDS

Survey Readings	Recommended Working Time

Instrument................Time................

Protective Clothing and Equipment Recommended

Type Gloves................Shoecovers................

Cap................Clothing................

Respirator................Type................

Special Meters................

Special Instructions................

....

....

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....
Health Physics Division

....
(If Operating Supervisor is relieved, new Supervisor shall sign his approval above.)

Work (has) (has not) been completed, and this Permit is being surrendered at .... A.M. P.M.

Remarks:................................

....

Maintenance Supervisor

....

Return of Work Permit Acknowledged................................
Area Supervisor

AED-IF 1 1-15-52

PROCEDURE FOR THE TRANSFER OF MATERIALS AND EQUIPMENT WITHIN THE CPP AREA

Transportation of active materials or contaminated equipment within a specific area or between areas in the plant must proceed in a manner which will cause no unnecessary exposure to personnel and will prevent contamination of "clean areas".

1. The supervisor in charge of the area from which any material or equipment is to be transferred will be responsible for requesting a Health Physics survey to determine the presence of contamination.
2. The supervisor will initiate a "Request for Removal" tag (form AED 1, shown on the next page). This will include a description of the item, its location, destination, and the name of the person requesting the move.
3. The Health Physics Department will perform a survey of the article and recommend procedures to be followed.
4. The supervisor in charge of the area to which the article is being transferred will not accept the article unless the tag is attached.
5. Contaminated materials will not be returned to stock.
6. All glassware to be sent to the glass shop must be contamination free, and the tag should so indicate. Special cases will be handled by the use of a "Work Permit".

REQUEST FOR REMOVAL

Of

From

To

Requested by

Date

Area Supervisor

Contamination

Remarks

H. P. Date

AED 1 11-51 500

PROCEDURE FOR THE DISPOSAL OF CONTAMINATED TRASH, EQUIPMENT OR MATERIALS. (SOLID WASTES)

1. Properly identified metal cans will be provided at desired locations throughout the plant for the disposal of contaminated trash and materials. Within the laboratories, step-on waste containers will be provided for such materials.

2. It shall be the responsibility of supervision to see that cans are monitored at frequent intervals to prevent active materials from accumulating in hazardous quantities.

3. The Health Physics Department will recommend that cans reading 7.5 mr/hr or greater be removed or isolated by tags and/or barricades.

4. Janitors will remove materials in untagged cans to the loading dock at specified intervals. They will handle material in tagged cans using precautions recommended verbally by the Health Physicist.

5. The Health Physics Department will make a daily survey of material to be removed from the loading dock by AEC and attach tags indicating handling precautions. Cans without tags will not be removed.

6. Materials which are an extreme radiation hazard will be moved only on a special work permit. These will be transported to the burial ground by American Cyanamid Company personnel using precautions recommended by the Health Physics Department.

PROCEDURE FOR HANDLING SHIPMENTS OF RADIOACTIVE MATERIALS

General

Radioactive materials offered for transportation present a wide variety of problems in packaging, labeling, handling and storage. The potential hazards in transporting these materials were recognized long ago and, as a result, methods and regulations for controlling these hazards have been developed and enacted as law. The Interstate Commerce Commission publishes and enforces these regulations for all methods of public transportation and for all organizations engaged in interstate or foreign commerce (common carriers). It is the duty of each shipper to make the prescribed regulations effective and to thoroughly instruct employees in relation thereto. Shipments that do not comply with these regulations must not be offered for transportation. Copies of these regulations are available in the Health Physics Department.

All radioactive shipments to or from destinations outside the CPP will be monitored by Health Physics Department. The consignor or consignee shall request the survey. Form IDO #16 "Radioactive Shipment Monitoring Record" will be completed by the Health Physicist in triplicate; one copy to the man in charge of the vehicle (outgoing only), one to the consignor or consignee and one to the Health Physics Department file. The Health Physicist will not sign for outgoing shipments which violate ICC regulations. He will inform the consignor of the particular violation and offer suggestions for correction.

Shipments of radioactive materials by the AEC, or under its direction or supervision, which are escorted by personnel designated by the AEC, are specifically authorized and are exempt from ICC regulations. The full responsibility for carrying out the intent of the regulations and for protecting other personnel and shipments of undeveloped film rests with this escort. This type of shipment from or to the CPP will be handled as special cases by the Health Physics Department.

Shipments of radioactive materials are also exempt from prescribed packaging, marking and labeling requirements provided they fulfill certain conditions specified by the ICC. Two of these are:

1. "The package must contain not more than 0.1 mc of Ra or Po, or that amount of Sr-89, Sr-90 or Ba 140 which disintegrates at a rate of more than 5×10^6 atoms per second or that amount of any other radioactive substance which disintegrates at a rate of more than 50×10^6 atoms per second."

2. "The package must be such that no significant alpha, beta or neutron radiation is emitted from the exterior of the package and the gamma radiation at any surface of the package must be less than 10 mr for 24 hours."

In accordance with AEC usage and recommendations we shall interpret "significant" as:

1. Alpha - More than 500 alpha d/m/100 cm^2 (as measured by Victoreen 256 or equivalent instrument).
2. Beta - More than 0.1 mrep/hr at surface of package (contamination) as measured by a G-M type instrument at the nearest point of approach.
3. Smear - Less than 50 beta-gamma c/m and less than 10 alpha c/m. This shall be register counts at about a 10% geometry for beta-gamma and about a 50% geometry for alpha.

We shall use this interpretation for all cases of surface contamination on radioactive shipments or vehicles.

Special Fuel Shipments

Only HEW fuel shipments have been received. This procedure applies specifically to these shipments and generally to others anticipated. New procedures will be developed when required.

Hanford material arrives in a Garrett Freight Lines special trailer with an AEC escort. Each shipment contains two 10-ton carriers per trailer. Carriers are returned in the same manner as soon as the fuel is removed except that they return without an AEC escort (common carrier).

Incoming Carrier and Vehicle

1. Health Physics will be notified of the time of arrival of shipments by the S. F. Accountability Department.
2. Health Physics will monitor the truck and casks and complete form IDO #16 "Radioactive Shipment Monitoring Record" in duplicate. All radiation and contamination readings and remarks concerning the incoming shipment will be entered on this form as required.
3. Radiation readings and comments regarding the conditions of the shipment will be reported to the production supervisor verbally and working time limits recommended if necessary.
4. The receiving station on the loading dock will be covered with absorbing paper and the cask will be lifted to this point.
5. A radiation survey and smears will be made while the bolts are being removed from the top of the cask. A minimum of one smear on top and one on the side of each cask will be taken.

6. Health Physics will monitor the operation of removing the drain plugs from the side of the cask to avoid contamination from escaping gases or liquids.

7. The liquid contents of the casks will be emptied into a pail and radiation readings from this pail will be taken to detect any unusual activity. Samples of the water will be sent for analysis if necessary and the bucket of water will be dumped into the filter aid settling manhole.

8. Radiation checks shall be made as the cask is lowered into the canal, when the top is removed and when the fuel is emptied.

9. When the cask is removed from the canal it will be washed down with a hose and water and permitted to drain over the canal until it has stopped dripping. The contents of the cask should also be drained into the canal with a siphon.

Outgoing Carrier and Vehicle

1. Upon removal from the canal the cask will be returned to the loading dock and uncontaminated absorbent paper will be placed on the floor if necessary. The cask must be wiped dry with rags before radiation measurements can be made.

2. The Health Physicist will again survey the cask and a minimum of two smears will be taken. If radiation and contamination readings are above those specified for exempt* shipments by ICC regulations, the surveyor will notify the production supervisor and he will take necessary steps for decontamination.

3. A survey of the bed of the vehicle will also be made and decontamination recommended (if needed) in order to comply with ICC regulations.

4. After final decontamination the Health Physics surveyor will complete the <u>outgoing</u> "Radioactive Shipment Monitoring Record" in triplicate. He will write the following statement on the bottom of the form: "This vehicle has been cleaned in accordance with paragraph 74.566 (d) of tariff #8 publishing ICC regulations." He will sign in the space provided. The surveyor shall be prepared to issue a written statement to interested parties, indicating that the cask is exempt from prescribed packing, marking and labeling requirements for shipment by public carrier.

5. Two copies of the above form will be given to the AEC courier (one for the vehicle driver and one for AEC). One copy will be retained by the surveyor for the Health Physics Department file.

* Should it be impractical to decontaminate the inside of the carrier to the 5 x 10^7 d/s level, an agreement should be reached between the Production Division, the Health Physics Department and the AEC on the necessary formalities for shipping the carrier. The shipment could be classified and returned as a radioactive shipment, provided the package and truck were properly labeled and identified according to ICC regulations for radioactive shipments. This might involve a higher return shipping rate than if the container were returned as empty.

HP-5 (10/9/51)

RADIOACTIVE SHIPMENT MONITORING RECORD

Date of Survey__________ Incoming__________ Outgoing__________

Shipment Details

Material__________

Type of Package or Load__________

Approximate Size__________

From:__________

To:__________

Via:__________

Radiation Monitoring (Mr/hr)

TRUCK (No.)		PACKAGE	
Cab		Max. Rad.	
Tailgate		At (Distance)	
R. R. Wheel		From (Center or Surface)	
L. R. Wheel		Max. Rad. (At one Meter)	
Inst. Used		Inst. Used	

Contamination

Evidence__________

Measured by Instrument__________

Smears Counted__________

Remarks (Damage to Package, Violation of ICC Regulations, Labels, Possible Over-exposure to Areas or Person, etc.)

____
(Signature)

IDO Dupl #16 100 10/11/51

PROCEDURE FOR OPERATION AND CALIBRATION OF CONSTANT AIR MONITOR

The CAM is a radioactive monitoring instrument which records the magnitude of the air-borne activity in an area and gives visual and aural warning when permissible concentrations may be exceeded. This is accomplished by collecting the activity on a filter paper and measuring this activity with a G-M tube. The signal from the tube is fed to a count rate meter and an Esterline Angus strip chart recorder. The count rate meter gives an indication of the quantity of activity on the paper at any time. The slope of the trace on the Esterline Angus recorder gives an indication of the concentration of activity in the atmosphere (slope proportional to concentration) as well as the total activity on the filter.

The count rate meter and recorder are provided with three sensitivity scales: 0 to 2,000, 0 to 10,000 and 0 to 20,000 c/m. The instrument is normally operated on the 0 to 2,000 c/m scale. If the total airborne activity collected on the filter exceeds this value the instrument automatically changes to the next higher scale and a yellow warning light glows. If the instrument goes off scale on the 0 to 10,000 c/m scale, the instrument automatically changes to the 0 to 20,000 c/m scale, a red light glows and a bell rings. The instrument returns to normal operation when the radiation is removed. The bell can be turned off if desired.

The filter will be replaced by the Health Physics Department once every 24 hours or whenever the activity is sufficient to cause a change to the 20,000 c/m scale. Once a week, or at any time following repairs or adjustments, the CAM will be calibrated in accordance with the procedure listed below. The standard calibrating source is made of uranium oxide. Its activity is equivalent to the activity that the filter paper would collect in 30 minutes if the concentration of activity in the air were at the permissible level of 10^{-8} uc/cc. The trace of this activity would be represented on the strip chart by a uniform sloping line extending from the background count to the final count in 30 minutes. By using the standard, a family of lines with similar slope can be drawn on the glass door of the recorder to give an indication of air concentration when the CAM is in normal operation. The activity of the source is determined by taking into account the pumping rate (5 cfm), filter collection efficiency and the geometry of the G-M tube (17.6%).

CALIBRATION:

1. Manually switch the count-rate meter to the 10X scale.
2. Remove the alarm connector relay and replace with a dummy plug provided.
3. Shut off the pump, remove the counter assembly from the lead pig, and remove the filter paper from the holder.

4. Replace the counter assembly in the lead pig and note the background recorded on the Esterline-Angus recorder.

5. Remove the counter assembly, place the calibration source in the slots where the filter paper normally fits and replace the assembly in the pig.

6. Note the recording of the Esterline-Angus and subtract the background.

7. Multiply the result by the correction factor listed on the source. This factor accounts for the factors mentioned above in the text.

8. Add the background reading to this sum.

9. Mark the recorder tape at a reading corresponding to the sum obtained above (8).

10. Place another mark on the tape indicating the background reading at a position representing a time 30 minutes earlier than the recorded point above (9). Draw a straight line between these two points.

11. Close the glass door and, using a china marking pencil, draw a family of lines on the door, parallel to the line on the strip chart.

12. Remove the source from the assembly, place a clean filter paper on the holder and turn on the pump.

13. Slowly place the assembly in the lead pig. If the filter is properly mounted and sealed with the rubber seals provided, a change of the sound of the pump will result. Proper sealing is necessary to prevent contamination of the G-M tube and assembly.

14. Remove the dummy plug and replace the alarm relay connector.

15. Manually switch the count-rate meter back to the "Voltage" position.

PROCEDURE FOR THE USE AND CALIBRATION OF THE MONITRON

The monitron is a radiation monitoring instrument used to record background radiation in work areas. There will be approximately twenty-five monitrons of various types distributed throughout the CPP. Some of these instruments will be operated as semi-portable radiation monitors while others will relay a continuous indication of the radiation level in the various areas and cells to the operating gallery. All of these instruments give a visual indication of the radiation level on a milliammeter located on the front panel. They also contain an alarm system which may be adjusted to operate visual or audible alarm devices at a preset radiation level.

The sensitivity switch, located on the panel, has three positions: zero, low and high. When the switch is on the high sensitivity position a full scale deflection of the ammeter indicates 25 mr/hr. Normally, the instrument is set to alarm when the radiation intensity reaches 7.5 mr/hr. The alarms can be turned off, but the panel meter continues to indicate the radiation level. On the low sensitivity position, full-scale deflection is 125 mr/hr and a light on the front of the instrument glows continuously. In the "zero" position each sensitivity range may be checked and adjusted to give no meter deflection in the absence of a radiation field.

CALIBRATION (10 mg Ra source)

1. Check the zero of the instrument on the "zero" position for each range.

2. Check the instrument for contamination.

3. Check for proper co-ordination between the milliammeter reading and the remote tape recorder reading.

4. With the instrument on, allowing suitable warm up period, connect the preamplifier into the connector at the rear of the chassis for each channel to be used.

5. Turn the "channel switch" to the on position.

6. Turn the "sensitivity switch" to the zero position.

7. Adjust the "zero set potentiometer" (on panel) until the milliammeter reads zero.

8. Turn the "sensitivity switch" to the "low" position, place the chamber in a 25 mr/hr field and adjust the "low sensitivity potentiometer" (on panel) until the meter reads 0.20 x full scale.

9. With the "sensitivity switch" on the high position, adjust the "high sensitivity potentiometer" (on panel) until the meter reads full scale.

10. Adjust the "Alarm Relay potentiometer" (under alarm lights) so that the alarm will be activated at 7.5 mr/hr (approximately 0.33 x full scale).

IX: 15

PROCEDURE FOR SAMPLING AIR-BORNE ACTIVITY WITH "HUDSON SAMPLER"

This instrument is a portable dust sampler designed for taking "breathing zone" and general air spot samples of dust laden air. The pump is capable of drawing air through a 1 1/8" diameter Whatman #41 filter paper at a rate of flow which can be measured and controlled between 12 and 30 liters per minute. The radioactivity collected on the filter paper can then be counted in standard counting room equipment and the concentration of radioactivity in the dust can be computed in uc/cc.

Collection Procedure for Surveyor

1. Connect the power cord on the sampler to the 110 volt AC outlet and place a 1 1/8" Whatman filter paper disc into the filter holder with tweezers. (Screw the sampling head parts together firmly to prevent air leakage.)

2. Simultaneously turn on the pump switch and start a stop watch to time the duration of the sampling period.

3. Immediately adjust the rotometer to the desired air flow rate with the knurled screw adjustment provided.

4. Turn off the pump and the stop watch when the desired sampling time has elapsed and remove the filter paper with tweezers.

5. Record the sample collection data on the Health Physics "Sample Record" Form IDO #20 (attached) in triplicate. The data should include a sample identification number, a description of the sample conditions and location, the flow rate, the collection time interval and the type of analysis required (alpha and/or beta-gamma).

6. The surveyor should retain the last copy of the above form for his records and send the remaining two copies and the sample to the counting room for analysis.

CPP SAMPLE RECORD

Type of Sample ____________________

Collected by ____________________

Date Submitted ____________________

Analyzed by ____________________

Method of Determination ____________________

Date Reported ____________________

Sample No.	Date	Hour	Sample Description	Sampling Data			Analyze For	Quantity	Total Count	Count time	Bkgd C/M	Counts perMin.	Results
				Rate	Time	Quantity							

[illegible] 500 11/8/51

PROCEDURE FOR SAMPLING WITH FILTRON

The filtron is a semi-portable instrument designed for collecting airborne activity (solids) on a filter paper. It consists of an electric motor and blower unit (air mover), a preset timer, a filter paper holder which is a perforated metal cylinder 1½" in diameter by 8" long, and a sampling head to hold the cylinder in place. Air is pulled through the filter paper at a rate of 5 cfm for a measured time interval. The filter paper and holder are removable and must be counted in special alpha or beta-gamma counting equipment. The concentration of radioactive materials in the air can then be computed in uc/cc.

1. Cut the filter paper to the proper size (4½" by 8") and insert inside the perforated metal holder. (Use Hollingsworth and Vose Spec. #70 paper.) A supply of these units is usually prepared in advance and may be obtained in the counting room.

2. Insert the above unit into the filter head making sure that the wire fastener snaps into place in the slots on the holder.

3. Plug the filtron power cord into a 110 volt AC outlet, start sampling by turning on the blower switch and setting the timer for the desired sampling time interval.

4. Remove the filter unit (paper and holder) from the filter head when the motor stops.

5. Record the sampling collection data on the "Sample Record" form in triplicate. The data should include a sample identification number, a description of the sampling conditions and location, the flow rate (5 cfm), the collection time interval, and the type of analysis desired (alpha and/or beta-gamma).

6. The surveyor should retain the last copy of the above form for his records and send the remaining two copies and the sample to the counting room for analysis.

IX: 17

PROCEDURE FOR USE OF THE ELECTROSTATIC SAMPLER

The MSA Electrostatic Sampler is a portable instrument used for collecting air-borne activity (solids) on an aluminum foil. It consists of a high voltage supply, an ionizing and sample collecting chamber, and a motor and blower unit for pulling air through the chamber. An electrostatic field is maintained across the air stream by a metal electrode running axially through the center of the chamber. When the voltage applied to the center electrode is sufficient to cause a corona discharge, the particles in the air stream become charged. These ionized particles are attracted to the walls of the chamber by the electrostatic field and are deposited on a thin aluminum foil lining. The foil is removable and must be counted in special alpha and beta-gamma counting equipment to determine the concentration of radioactivity in the air (uc/cc).

WARNING - The sampler should never be used in combustible or explosive atmospheres.

1. Select a suitable sampling point. The retractable stand is secured to the case and extended to a convenient height. Remove a central electrode from the sampling tube kit and push it all the way onto the plug in the sampling head.

2. Remove a sampling tube from the kit and remove the plastic caps from each end. Prepare the aluminum foil lining by cutting the foil to the proper size ($7\frac{1}{2}$" x $4\frac{1}{2}$") and form it around the outside circumference of the tube and smooth it carefully. Slide the thin aluminum cylinder from the outside of the sampling tube and place it carefully inside the tube, being sure that the ends of the liner and tube are mated. Fasten the liner to the tube with Scotch tape. (Use hard surface aluminum foil 2 mil thick.)

3. Insert the above unit into the collar around the central electrode by pushing (not turning) until it is firmly seated. Make sure the electrode is properly centered.

4. Place the completed sampling and blower unit onto the retractable stand.

5. Plug the high voltage and motor-blower connectors into the power-pack unit and turn down securely. Plug the electrical supply cord into a 110 volt AC-60 cycle outlet. Make sure the ground clamp is fastened to a grounded pipe, electrical conduit or other good ground.

6. Turn both the power switch and the switch on the blower unit to the "On" position. The light on the power-pack should now glow. Turn the high voltage control up until arcing is produced; then back the control knob down until no arcing occurs. Immediately begin timing the sample.

The operating voltage should be at least 11.5 KV if atmospheric conditions permit. (The flow rate is 3 cfm provided the voltage is maintained between 105 and 120, with 60 cycle frequency.)

7. After desired sampling time, turn all switches off. Either wait 60 seconds or discharge the central electrode by shorting it to the chamber wall with an insulated screw driver. Remove the sample holder and foil liner as a unit and replace the plastic covers on the ends.

8. Record the sampling collection data on the "Sample Record Form" in triplicate. The data should include a sample identification number, a description of the sample conditions and location, the flow rate, the collection time interval, and the type of analysis desired (alpha and/or beta-gamma). The surveyor should retain the last copy for his record and send the remaining two copies and the sample to the counting room for analysis.

PROCEDURE FOR COUNTING AND INTERPRETATION OF DUST SAMPLES

1. Alpha Check the counter operation with a plutonium alpha standard and run a background count if this has not already been done. Kelley-Koett parallel plate counters or Nuclear Measurements Corporation gas flow (argon) proportional counters may be used for disk samples. Special ORNL alpha counters are used for cylindrical samples.

   Beta-Gamma Check the counter operation with a National Bureau of Standards radium D and E beta-standard and run a background count. Any standard beta-gamma end window counter with shelves arranged in a lead shield can be used for counting of disk samples. The second shelf (10% geometry) should always be used unless the activity is too high to count. Special ORNL beta-gamma counters are used for cylindrical samples.

2. Place filter paper samples in the counting chamber or on the shelf (use tweezers for disk samples) and count the sample until the desired statistical accuracy is obtained. A total count of at least 500 counts will give a probable error of approximately ± 3%.

3. For long-lived activity, repeat counts at periodic intervals as indicated in specific instructions below in (7).

4. Determine the total number of counts by multiplying the scaling factor by the number of register counts recorded and add to this the number of scaler interpolation factors indicated by glowing lights (correct for coincidence if necessary).

5. Record the background count, the total count, and the counting time interval on the "Sample Record" form containing the collection data on the sample being analyzed.

6. Divide the total count by the counting time interval, subtract the background from this value and record this figure as counts per minute on the "Sample Record" form.

7. From the above data, interpret, compute and report results in the last column of the "Sample Record" form as follows:

General Formula

$$uc/cc = \frac{c/m}{S \times G \times A} \times \frac{1}{R \times T \times E \times K}$$

S = Sensitivity or detection efficiency of counter.

= 1 (Assume 100% for alpha and beta).

G = Geometry of counter (including backscatter).

= 0.52 for alpha counter (disk).

= 0.50 for alpha counter (cylinders).

= 0.10 for beta-gamma counter (disk).

= 0.21 for beta-gamma counter (cylinder).

A = Self-absorption factor for activity in filter paper.

= 0.70 for alpha (30% loss).

= 1.0 for beta (assume no loss).

R = Sampling flow rate in cubic centimeters/minute.

T = Sampling time interval in minutes.

E = Efficiency of filter paper for particle collection.

= 1 (assume 100% collection for all filter paper).

K = Constant to convert d/m/cc to uc/cc.

$= 3.7 \times 10^{10} \times 60 \times 10^{-6} = 2.22 \times 10^{6}$.

For Immediate Alpha Count (Count Sample When Received)

$$uc/cc\ (Disk) = \frac{c/m}{1 \times 0.52 \times 0.70 \times R \times T \times 1 \times 2.22 \times 10^{6}}$$

$$= \frac{c/m \times 1.238 \times 10^{-6}}{R \times T}$$

$$uc/cc\ (Cylinders) = \frac{c/m}{1 \times 0.50 \times 0.70 \times R \times T \times 1 \times 2.22 \times 10^{6}}$$

$$= \frac{c/m \times 1.29 \times 10^{-6}}{R \times T}$$

For Long-Lived Alpha Count

Take a count (C_1) at time (t_1) at least four hours after the sample has been collected to permit radon products to decay. Take another count (C_2) at time (t_2) at least 16 hours after the first count was taken. Substitute these values in the following equation.

$$C_{LL} = \frac{C_2 - C_1 e^{-0.0655(t_2 - t_1)}}{1 - e^{-0.0655(t_2 - t_1)}}$$

C_{LL} is the long-lived alpha activity in counts per minute and the value in uc/cc can be obtained as above.

For Immediate Beta Count (Count Sample When Received)

$$\text{uc/cc (Disk)} = \frac{c/m}{1 \times 0.10 \times 1 \times R \times T \times 1 \times 2.22 \times 10^6}$$

$$= \frac{c/m \times 4.5 \times 10^{-6}}{R \times T}$$

$$\text{uc/cc (Cylinder)} = \frac{c/m}{1 \times 0.21 \times 1 \times R \times T \times 1 \times 2.22 \times 10^6}$$

$$= \frac{c/m \times 2.15 \times 10^6}{R \times T}$$

For Long-Lived Beta Count

Take a count (C_1) at time (t_1) when the sample is received. Take a second count (C_2) at time (t_2) at least 20 hours after the first count was made.

Substitute these values in the formula stated above for long-lived activity. The value C_{LL} obtained is the long-lived beta count in c/m and the activity in uc/cc can be obtained by substituting in the general formula stated above.

For Decay Curves (Half-Life) and Absorption Curves (Energy)

To obtain decay curves take a series of counts at periodic intervals and plot the counts per minute against time on semi-log paper (time as abscissa on linear scale). Determine the half-life by observing the time required for the activity to decrease to one-half its initial value.

To obtain an absorption curve, take a series of counts with increasing thicknesses of absorbers interposed between the sample and detector. Plot the counts per minute obtained against the corresponding thickness of absorber (mg/cm^2) on semi-log paper (mg/cm^2) as abscissa on the linear scale).

The maximum energy of the beta particles can be determined from this absorption curve. The corresponding beta energy can then be obtained from range-energy tables.

PROCEDURE FOR COLLECTION AND INTERPRETATION OF SMEARS

The smear is used primarily to determine whether the activity on a surface is easily removable.

1. The smear shall be defined as having wiped 40 sq. in. of surface, with at least four ten-inch passes, with a 2" diameter Whatman 50 filter disk.
2. Record the collection data on the "Sample Record Form" in triplicate. The data should include a smear identification number, a description of the surface and location, and the type of analysis desired (alpha and/or beta-gamma). The surveyor will retain one copy of the record and send the remaining two and the smear to the counting room.
3. Smears shall be counted for beta-gamma contamination with a standard mica window G-M tube at 10% geometry.
4. Smears shall be counted for alpha activity in a parallel plate ion chamber or a gas flow proportional counter at 50% geometry.
5. Results will be reported in counts per minute.

PROCEDURE FOR THE TRANSFER OF PORTABLE INSTRUMENTS FOR AEC CALIBRATION OR REPAIR

All portable Health Physics instruments (AEC loans) in the CPP will be maintained in proper working order and calibrated by the AEC Health Physics Department. AEC will provide pick-up and delivery service from and to the CPP portal building on scheduled days.

1. Pick up the instruments at the main CPP portal.
2. Sign the AEC hand receipt for all instruments received and identified by name and number on the hand receipt. Retain one copy for the American Cyanamid Company Health Physics instrument loan file.
3. Transport the instruments to the Health Physics field office and make out an "Instrument Inventory" card for each instrument. Information on the card should include the name of the instrument, the identifying number, its location in the plant and the person to whom it was loaned, if any.
4. Check instruments for proper operation and distribute them to the various laboratory areas and to convenient locations within the process area for the use of operating personnel.
5. Check instruments for proper operation and calibration at convenient intervals during the week. This can be assigned or scheduled on shifts.
6. Collect (in field office) ionization type instruments at least once every two weeks and all G-M type instruments once every three weeks and prepare them for return to AEC. Make a record of the action on the "Instrument Inventory" card.
7. Notify AEC of instruments requiring service and replacement and deliver them to the main portal for AEC pick-up, repair and calibration. Have the AEC representative countersign the hand receipt mentioned above and file it in the inactive file. Only those instruments for which replacements are received will be released.

PROCEDURE GOVERNING THE USE OF THE SHIFT LOG BOOK

A log book will be maintained by shift personnel in order to provide a running record of the activities of the Health Physics field personnel. This record allows oncoming shift personnel to keep abreast of activities which occurred on previous shifts. It also records all action taken, should questions arise at a later date. The log entries will include the following information in the order shown:

1. Date and location of survey or event.
2. Person requesting survey.
3. Name of surveyor.
4. Type of survey.
5. Instruments used.
6. Brief discussion of problem and action taken.

A log book will also be maintained in the counting room. Verbal as well as written attention shall be called to on-coming shift personnel regarding data being collected on long-lived counts, decay curves, etc.