KAY-RAY•INC.

INDUSTRIAL PROCESS CONTROL EQUIPMENT

INSTALLATION and NUCLEAR RADIATION SAFETY COURSE

SPRING '85

LIST OF ILLUSTRATIONS

Figure		Page
6- 1	Periodic Chart of the Elements	6- 1
6- 2	Source Collimation	6- 3
6- 3	Radiation Level of Source Strength	6- 4
6- 4	Un-Shielded Source	6- 5
6- 5	Calculation of Radiation Level	6- 6
6- 6	Cesium-137 Source Capsule (1 to 10 Ci)	6- 8
6- 7	Cesium-137 Source Capsule (less than 1 Ci)	6- 9
6- 8	Code of Federal Regulations, Part 19	6-11
6- 9	Code of Federal Regulations, Part 20	6-15
6-10	Code of Federal Regulations, Part 30	6-37
6-11	Code of Federal Regulations, Part 31	6-51
6-12	Code of Federal Regulations, Part 107	6-57

TABLE OF CONTENTS

SECTION 1

BASIC PRINCIPLES OF NUCLEAR PHYSICS

1.0.0 BASIC PRINCIPLES OF NUCLEAR PHYSICS

Outline:

1. Vocabulary
2. The Structure of Matter and the Atom
3. Symbols and Nomenclature
4. Atomic Mass Units (amu)
5. Radioactivity
6. Interaction with Matter
7. Particulate or Corpuscular Ionization
8. Electromagnetic Ionization
9. The Electromagnetic Spectrum
10. Transmutation or Disintegration
11. The Neutron

1.0.1 Vocabulary

Alpha Particle	Gamma Ray
Atom	Ion
Atomic Mass Unit	Ionization
Beta Particle	Mass Defect
Binding Energy	Molecule
Curie	Neutron
Electron	Proton
Element	Radioactivity

1.0.2 The Structure of Matter and the Atom

The study of radioactivity involves the movement of atomic particles as well as the transformation of the atom's nucleus. A review of the structure of the atom is appropriate to introduce the study of radioactivity.

1.0.2 The Structure of Matter and the Atom - Cont'd.

Modern science has clarified some of the earlier theories with definitions:

A. An atom is defined as the smallest particle of an element which is capable of entering into a chemical reaction. (Atom - Greek word meaning not capable of being divided further, i.e., indivisible.)

B. A molecule is defined as the smallest quantity of a substance which can exist by itself and retain all the properties of that substance. (Molecule - Greek word meaning a small mass, atoms joined together in groups.)

C. An element is defined as a pure substance, consisting of atoms of the same atomic number, which cannot be decomposed by ordinary chemical means, i.e., Au, Cu, O, etc.

D. Atoms of different elements can come together to form molecules of compounds, i.e., H_2O.

The major subatomic particles that compose an atom are protons, neutrons, and electrons.

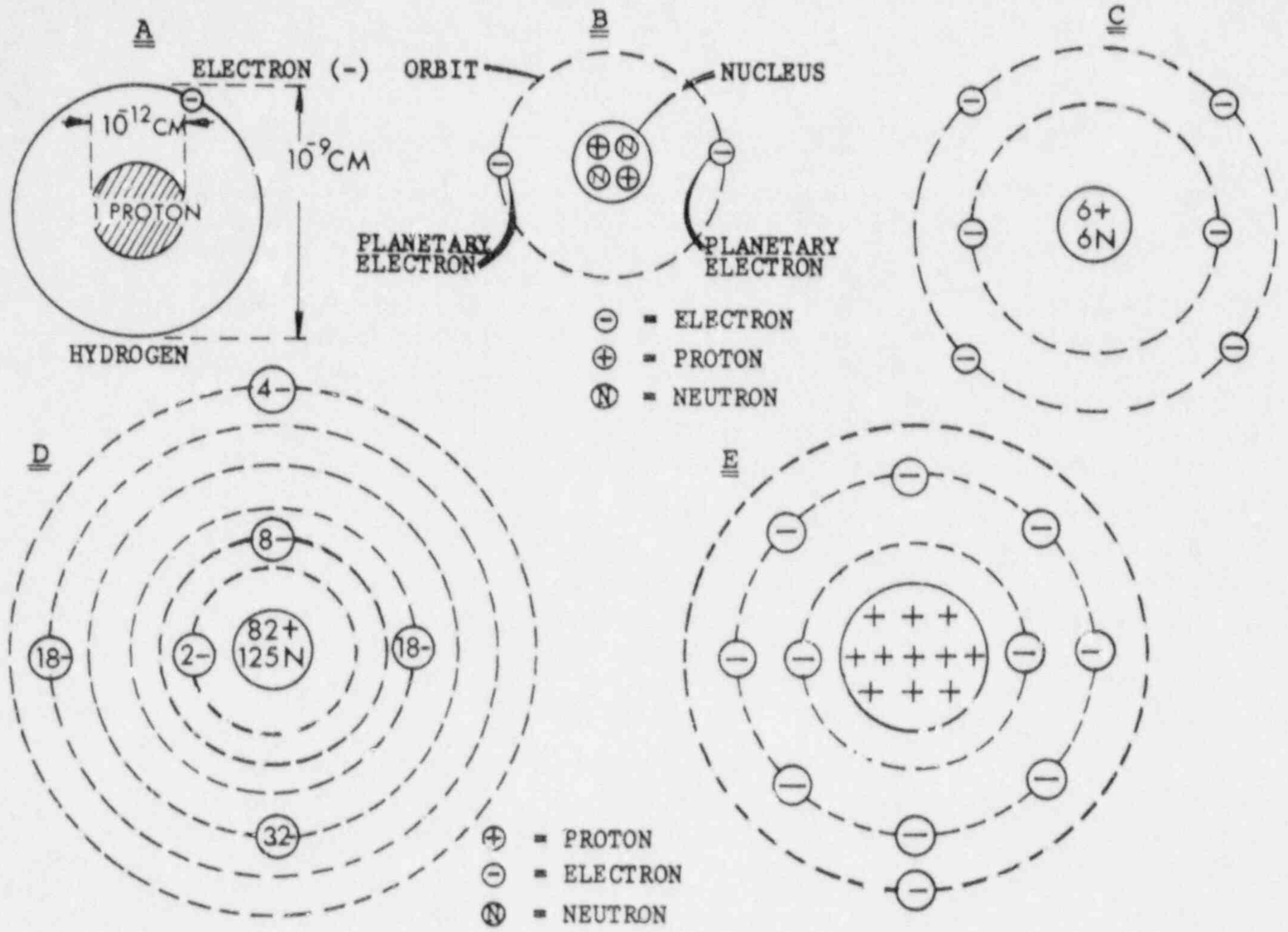
A. Protons have a positive charge, electrons have a negative charge, and neutrons are electrically neutral.

B. The atom consists of a nucleus, composed of protons and perhaps neutrons surrounded by orbiting or planetary electrons (Figure 1-1, A and B).

C. The mass of an electron (9.1×10^{-31} kg.) is 1/1835 of a proton (1.6725×10^{-27} kg.) The neutron has approximately the same mass of the proton. Most of the mass of an atom is in the nucleus.

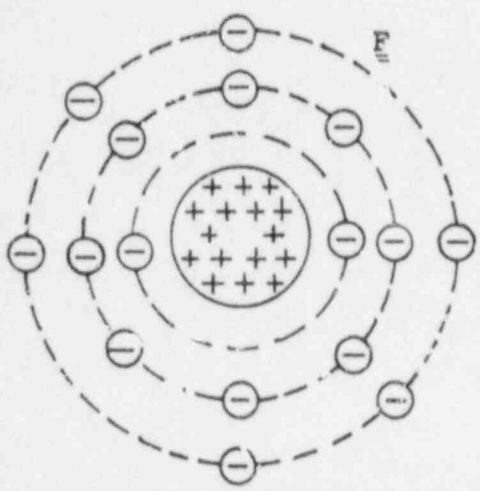
A stable atom has the same number of protons and orbital electrons.

A. When the number of protons and orbital electrons is not equal, the atom is said to be unstable, and is called an ion. (Ion - Greek word meaning traveler.)



— TABLE OF INERT GASES —

Atomic number	Inert gas	Symbol	Electrons in each shell				
			Inner shell 1	Next outer shell 2	Shell 3	Shell 4	Shell 5
2	Helium	He	2				
10	Neon	Ne	2	8			
18	Argon	A	2	8	8		
36	Krypton	Kr	2	8	8	18	
54	Xenon	Xe	2	8	8	18	18



An insulator (sulfur)

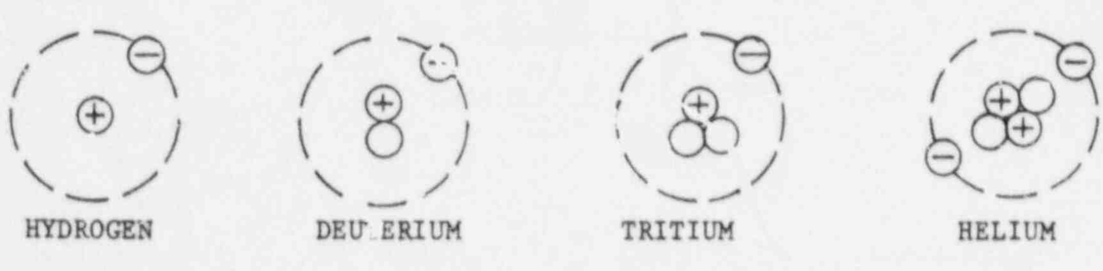


FIGURE 1-1

1.0.2 The Structure of Matter and the Atom - Cont'd.

B. When the number of electrons is greater, the atom is negatively charged, or a negative ion. When the number of protons is greater, the atom is positively charged, or a positive ion.

1.0.3 Symbols and Nomenclature

The representation of elements is in the form $_ZX^A$.

A. "X" is the chemical symbol, i.e., C - Carbon, Cl - Chlorine, O - Oxygen, etc.

B. "Z" indicates the number of protons in the nucleus and is called the atomic number, i.e., $_6C$ - Carbon has 6 protons in the nucleus.

C. "A" represents the total number of protons and neutrons in the nucleus, and is called atomic mass: $_6C^{12}$ - Carbon has 6 protons and 6 neutrons in the nucleus, with an atomic mass of 12 (Figure 1-1, C).

D. The number of neutrons is equal to the atomic mass (A) - atomic number (Z), i.e., $_6C^{12}$ - 12-6=6, 6 neutrons in the nucleus.

1.0.4 Atomic Mass Units (amu)

The masses of elementary particles are frequently expressed in terms of mass units instead of kilograms. Formerly, physicists defined the mass unit as one-sixteenth the mass of oxygen-16, while chemists defined it as one-sixteenth the mass of the natural form of oxygen, which includes small amounts of oxygen-17 and oxygen-18.

In 1963 it was agreed that the atomic mass unit (amu) should be defined as one-twelfth the mass of the carbon-12 atom, i.e C-12 atom equals 12 amu.

Mass defect and binding energy:

A. One amu = 1.66043×10^{-24} gm (Mass)
= 931.7 MeV (million electron volts)

1.0.4 Atomic Mass Units (amu) - Cont'd.

B. The mass of subatomic particles has been determined relative to carbon-12:

a. Proton mass equals 1.00727 amu.

b. Neutron mass equals 1.00867 amu.

c. Electron mass equals 0.00055 amu.

C. Adding up the mass of the particles for $_9F^{19}$ would be:

9 protons x 1.00727	=	9.06543
10 neutrons x 1.00867	=	10.0867
9 electrons x 0.00055	=	0.00495
Total calculated mass	=	19.15708

The charter value for $_9F^{19}$ is 19.00. The difference is 0.15708 and is called the mass defect per atom.

D. When an atom is formed from nucleons, a loss of mass occurs which is related to energy being used by the atom. (Einstein's equation $E = mc^2$)

a. The energy being used during formation of the atom is the total binding energy.

b. The electron volt (eV) is the unit of energy used to define binding energy.

c. The range of energies available from practical radionuclides is a few KeV to 3 MeV. Four of these, and their corresponding gamma ray energies are:

Am^{241} = .060 MeV
Cs^{137} = 0.662 MeV
Co^{60} = 1.25 MeV (1.17 and 1.33 MeV)
Ra^{226} = 1.488 MeV

d. If the total binding energy per atom is divided by the number of nucleons, the binding energy per nucleon is obtained:

For $_9F^{19}$ the binding energy per nucleon is 7.7 MeV.
One amu = 931.7 MeV.
Mass defect for $_9F^{19}$ = .15708 amu.
Binding energy per atom = 931.7 x .15708 = 146.35 MeV.
Binding energy per nucleon = 146.35 ÷ 19 = 7.7 MeV.

Therefore, it would require 7.7 MeV to remove one proton or one neutron from the nucleus of $_9F^{19}$ atom.

1.0.5 Radioactivity

In principle, protons and neutrons can be brought together in a great many combinations to form atomic nuclei. The nuclei representing the majority of these combinations, however, do not exist; even if they could be created, they would decay too quickly to be observed directly. Altogether some 8,000 nuclei are thought to be capable of surviving long enough so that they can be said to exist. Of these, about 300 are stable indefinitely, and are therefore by far the most common nuclei in nature. Another 1,600 nuclei are known that are not stable but decay by the various processes grouped under the term radioactivity.

Atoms undergoing spontaneous nuclear transformation emit radiation of four distinct types and in two distinct forms (Figure 1-2):

A. Alpha particles (helium nuclei).

B. Beta particles (electrons or positrons).

C. Neutron (present in all atomic nuclei except hydrogen).

D. Gamma rays (high frequency electromagnetic radiation) = photons = bundles of energy.

E. X-ray electron produced.

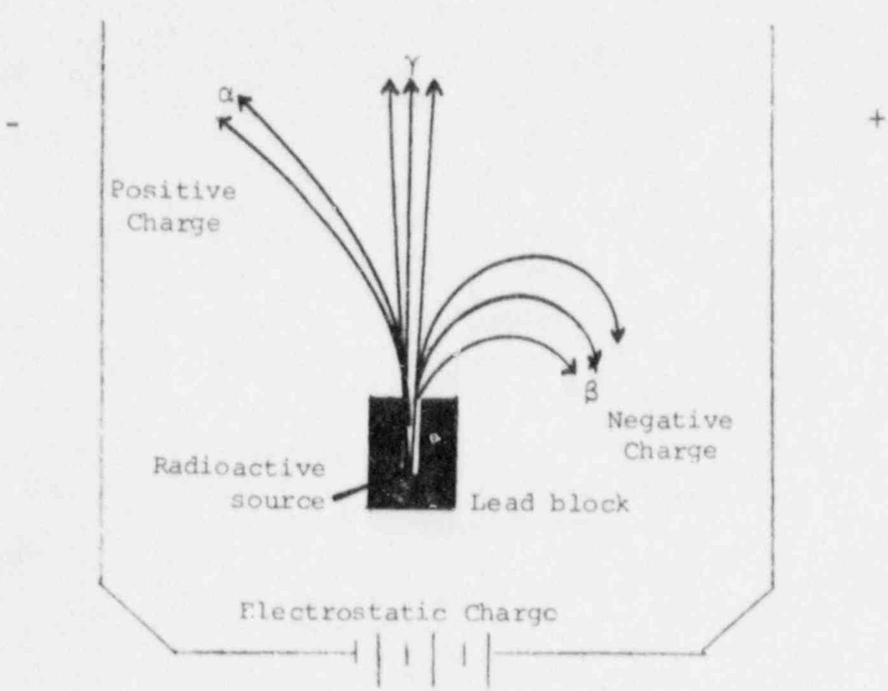


FIGURE 1-2

1.0.5 Radioactivity - Cont'd.

The three types of radioactive emissions from a source are called alpha, beta, and gamma. If a magnetic field is perpendicular to the plane of the paper, the alpha and beta are bent in opposite directions, showing that they have opposite charges (Figure 1-2).

A. Alpha particles are composed of two neutrons and two protons.

   a. The alpha particle has a nuclear mass of four amu and a nuclear charge of +2.

   b. It penetrates 2.5 to 9 cm (0.9 to 3.5 inches) of air; loses kinetic energy; can no longer ionize.

B. Beta particles include electrons or positrons emitted from an excited nucleus.

   a. They have a nuclear charge of ±1. During transmutation in the nucleus, a neutron ejects a (-) beta particle and becomes a proton.

   b. It travels 100 times further through air than alpha particles (8.2 to 29.5 feet).

C. Gamma radiation is emitted as bundles of energy called photons and is a form of electromagnetic radiation similar to X-ray. Gamma ray emission results from energy level transitions within a nucleus.

D. The average range in air of the three types of radiation varies from about five centimeters for alpha to five meters for beta and several hundred meters for gamma.

E. Radioactivity is measured in terms of the rate at which a quantity of the radionuclide is transformed from the parent nuclide to the daughter nuclide.

F. The number of disintegrations occurring in a unit of time is called the "activity" of the nuclide of a specific nuclide-considered "quantity".

G. The "curie" is the unit for activity and is defined as 3.7×10^{10} disintegrations per second.

1.0.5 Radioactivity - Cont'd.

H. The curie defines a number of disintegrations per unit time and not related emissions, which may be alpha, beta, or gamma (not X because X is gamma produced by electron impact only.) One curie of radium does not provide the same radioactive emission as one curie of some other radioactive material, although both will have the same number of disintegrations per second. The curie does not define the nature of the radiation, it simply gives the number of disintegrations per second. It is a measure of the activity of a radioactive source.

1.0.6 Interaction with Matter

When radiation travels through matter, it can disturb the balance of the atomic structure through which it moves. The irradiated material can be either excited or ionized. The electrons of the irradiated atom are moved to orbits of higher energy within the atom. The excited state is unstable, and the atom may regain its more normal (ground) state by the emission of radiation.

When the orbital electrons of the irradiated atom are knocked completely out of the atom, this produces an ionized atom, one with a net positive charge.

Ionization is usually measured in terms of ion pairs produced. The number of ion pairs produced by radiation per unit length of travel in a given medium is defined as specific ionization.

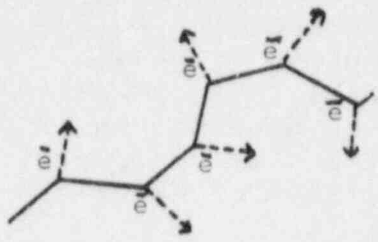
1.0.7 Particulate or Corpuscular Ionization

A. Of all common forms of particulate radiation, the alpha particle has the highest specific ionization. This is due to its double positive charge, large mass, and relatively slow velocity.

ALPHA PARTICLE

1.0.7 Particulate or Corpuscular Ionization - Cont'd.

B. Since beta particles have the same negative charge and mass as electrons, they repel electrons from atomic orbits. Beta particles possess 1/100 of the specific ionization of alpha particles.



BETA PARTICLE

The beta electron also can interact with an atomic nucleus, the beta electron is slowed, and the electron emits radiation known as bremsstrahlung (braking radiation) which is X-ray radiation.

C. Neutrons seldom cause ionization directly. Ions are formed as a result of radiation that is emanated during a reaction between a neutron and an atomic nucleus. Neutrons are absorbed by a material in two more or less distinct stages.

First, the high energy neutrons passing through the material are slowed by collision with the nuclei. Since the probability of absorption of neutrons by most materials is virtually zero at high energies, it is only when the neutrons have reached low energies that the second stage, capture of the neutrons, can take place.

Once the neutron has been slowed, it will be quickly captured before it has a chance to diffuse much further because of the large capture probability for most elements at low energy. Thus the actual penetration properties of the neutrons are really dependent upon the behavior of the fast neutrons, and once a neutron has been slowed, it can essentially be considered as removed from the beam. Neutrons captured by material will, in most cases, result in the emission of high energy secondary gamma rays.

1.0.8 Electromagnetic Ionization

Gamma rays are electromagnetic, have no mass and no charge. The gamma ray has approximately 1/10,000 of the ionizing ability of the alpha particle. Interaction is in three ways (Figure 1-3):

A. The photoelectric effect occurs when the entire energy of a gamma photon is transferred to an orbital electron of an atom. If this energy equals or exceeds the binding energy of the electron to that atom, the electron is ejected from the atom. If the energy imparted to the electron is sufficient, it too can cause ionization.

B. The Compton effect occurs when the gamma photon imparts only part of its energy to an electron which then becomes a free electron and produces ionization. Through a series of such actions, the gamma photon gives up energy until it undergoes photoelectric absorption.

C. Pair production occurs when a gamma photon of energy equal to or greater than 1.02 MeV penetrates close to a nucleus. The gamma photon is converted into an electron and positron that combine with other similar particles and annihilate releasing energy in the form of two X-rays.

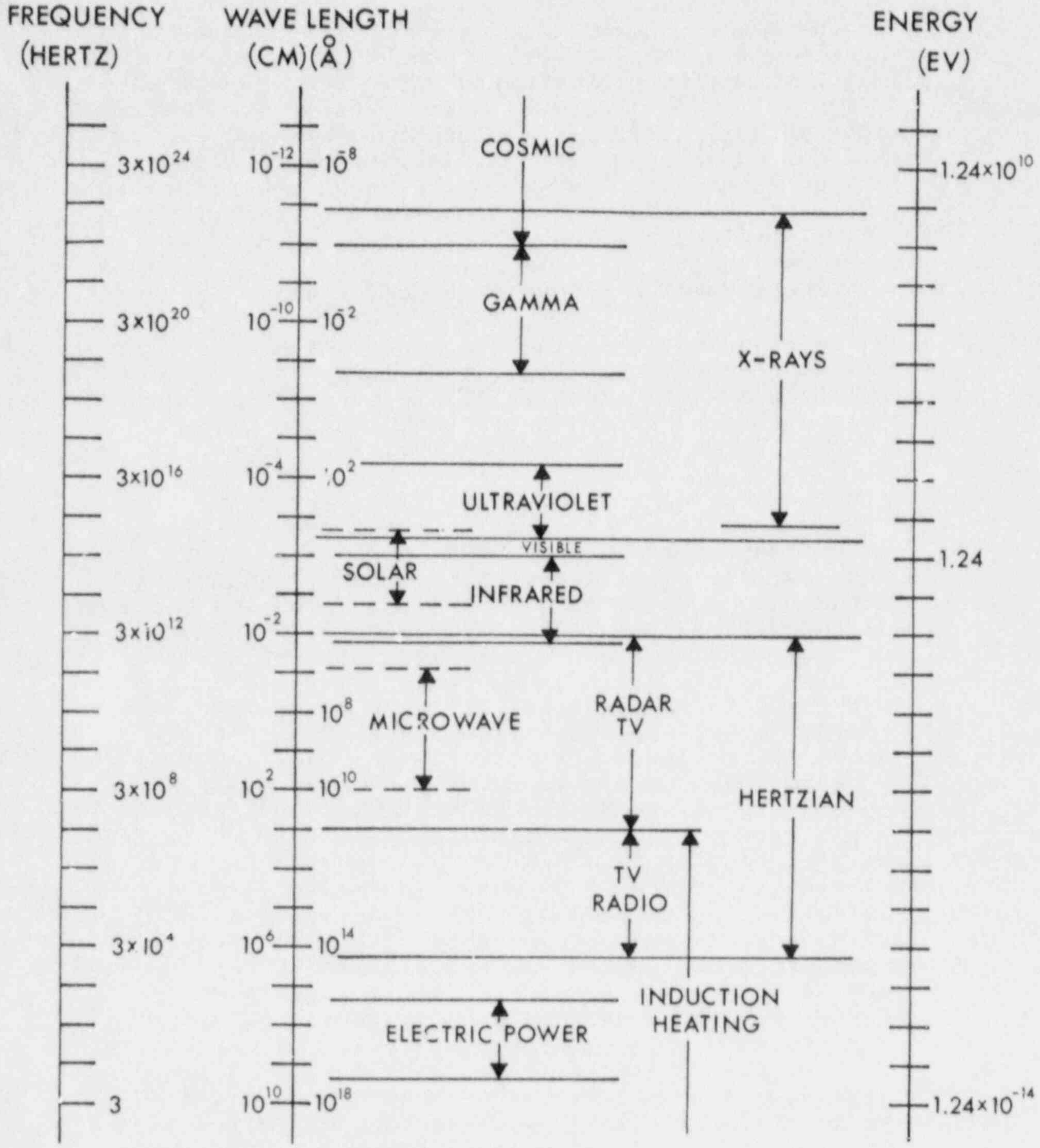
RELATIVE SPECIFIC IONIZATION TABLE

If	Alpha (α)	= 1.0
Then	Beta (β)	= 1/100
And	Gamma (γ)	= 1/10,000
If	Gamma (γ)	= 1.0
Then	Beta (β)	= 100
And	Alpha (α)	= 10,000

FIGURE 1-3

1.0.9 The Electromagnetic Spectrum

Any electromagnetic radiation can be described by three properties: 1) its wavelength, 2) its frequency, 3) the energy per photon of radiation.



THE ELECTROMAGNETIC SPECTRUM

FIGURE 1-4

1.0.9 The Electromagnetic Spectrum - Cont'd.

Because of the enormous range of the electromagnetic spectrum, a variety of units has been found useful in measuring wavelength. In the radio region, the meter or centimeter is the usual unit. The centimeter is inconveniently large in the domain of X-rays and gamma rays, where the Angstrom (A) is customarily used: $1A = 10^{-8}$ cm $= 10^{-10}$ m. Electromagnetic waves cover a wide range of wavelengths from electric and radio waves, with a wavelength of many meters, up to the extremely short wavelength found in cosmic rays, some of which may have energies of billions of electron volts (Figure 1-4).

Figure 1-4 shows the wide range of radiation and its various wavelengths, frequencies, and photon energies. It should be noted that this is a continuous spectrum; there are no sharp boundaries between the various regions; some of the regions overlap.

It should be emphasized that there is no difference between X-rays and gamma rays; they occupy the same energy range, and an X-ray photon having a particular energy would be indistinguishable from a gamma ray photon of the same energy. The two names are the results of the origins of the photons: the term X-ray refers to the photon produced as a result of electrons and atomic interaction; the term gamma ray is applied to photons which originate within the nucleus of the atom by natural radioactivity.

Gamma rays are pure electromagnetic radiation and do not contribute to the transmutation of elements, as do both alpha and beta emissions.

Irradiation of food. In the food industry, radiation may be used in three ways: (1) To prevent sprouting of root crops, such as potatoes; (2) to eliminate insects from grain before storage; and (3) to preserve food by inhibiting or destroying bacteria and other microorganisms. The amount of radiation required for each of these effects differs greatly. A dose of 1000 to 4000 rads is highly effective as a sprout inhibitor when applied to onions or potatoes. Grains and cereal can be disinfested of insects at 20,000 to 50,000 rads, and at 50,000 rads it is possible to sterilize the larvae of insects that lodge inside fruits.

1.0.9 The Electromagnetic Spectrum - Cont'd.

Pasteurization doses, generally in the range from 200,000 to 500,000 rads, will prolong shelf life or storage time. For example, the refrigerated storage life of fresh fish can be extended up to 30 days by such doses. Much higher doses, between 2 and 4.5 million rads are required for "sterilization" of foods for long-time storage without refrigeration. Bacon and other pork products, chicken, and beef can be prepackaged and irradiated at 4.5 million rads. These meats are reported to be well preserved (but not particularly palatable) after a year's storage at room temperature following the treatment.

There are, however, problems associated with food sterilization that have not yet been solved. Chemical changes may be produced in foods which can result in unpleasant flavors, loss of color, or change in texture. For example, lemons become spongy and dairy products develop an odor. The latter is probably from peroxides formed in the milk and butterfat. Cheese is reported to become rancid faster after treatment. The vitamin content of some foods may also be decreased.

1.1.0 Transmutation or Disintegration

As shown in Figure 1-5, radioactivity may result in the transmutation of elements from parent to daughter nuclide. Most natural radioactive elements emit either alpha or beta rays, although few emit both. Gamma rays may or may not accompany the alpha or beta emission.

The rate at which one element changes into another is obviously an important characteristic of the material and is described in terms of either half-life or decay constant.

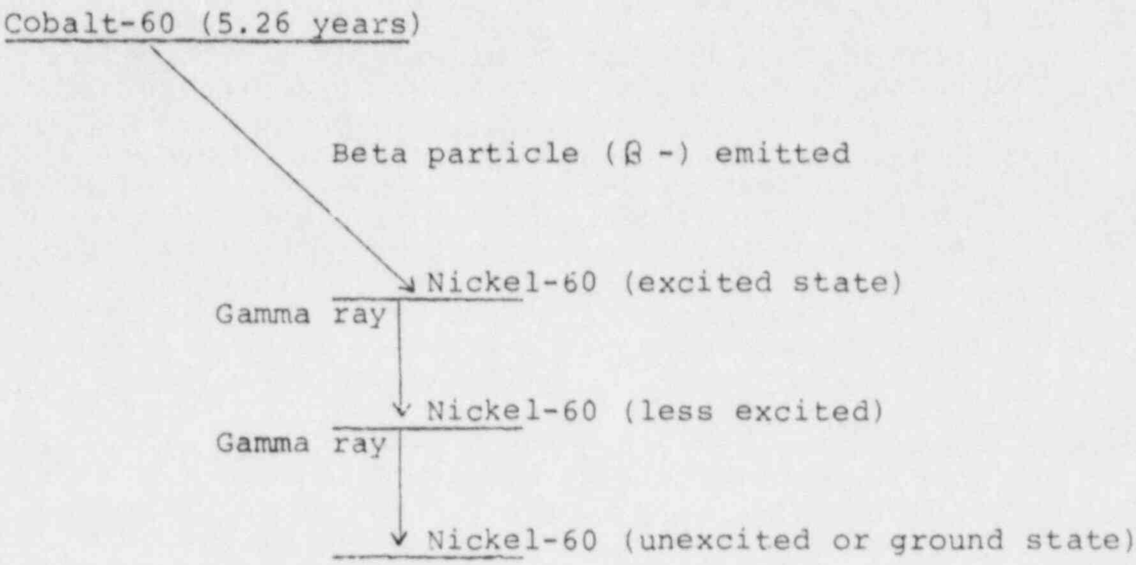


FIGURE 1-5

1.1.1 The Neutron

High-energy neutrons are another type of radiation that has not yet been discussed.

The neutron is an elementary particle (component of an atom) that has about the same mass as that of a proton, but no charge. Lord Rutherford first predicted the existence of a neutron in 1920. Neutrons can be produced by bombarding light elements with alpha particles.

The most intense neutron fluxes are produced by nuclear reactors, or piles. Next come neutrons produced by various accelerator-induced nuclear reactions. Cyclotrons can produce intense beams of high-energy particles, but these have a considerable energy spread, and are accompanied by strong gamma radiation. Thus cyclotron neutrons are far from monoenergetic and are contaminated with gamma rays.

Low-intensity sources suitable for many purposes are made by mixing a radioactive nuclide with a suitable target material. Low Z elements, usually beryllium, are favored targets since they have a low potential barrier.

^{226}Ra-Be, ^{210}Po, and ^{239}Pu are sources for neutron production. To most fully utilize the short-range alpha particles, finely powdered beryllium must be intimately mixed with the active material. Compressed discs may have a yield of 1 neutron for each 2500 alpha particles.

1.1.1 The Neutron - Cont'd.

A Po-Be source has the advantage of a low gamma-ray contamination, but decays with the relatively short half life of ^{210}Pa. A Ra-Be source is relatively constant, but has a strong gamma emission. Pu-Be sources combine the best features of the previous two but are limited in output by the low specific activity of ^{239}Pu.

Neutrons cannot be accelerated like charged particles, but a beam of high-energy neutrons can be degraded by collision processes to very low energies. Neutrons can be classified into various energy ranges (whose boundaries are rather indistinct).

High-energy neutrons are usually considered to have energies greater than 10 MeV. Fast neutrons will range from 10 keV to 10 MeV. Intermediate neutrons range from 100 eV to 10 keV and slow neutrons go down to 0.030 eV. Neutrons just above 1 eV are sometimes called epithermals.

When neutrons lose energy by collision without absorption they will slow until their mean kinetic energy is equal to the mean thermal energy of the sorrounding atoms. The neutrons are then said to be thermal and, by kinetic theory, have $E = (1/2)\ kT$.

Neutrons moving through matter behave differently from charged particles, and their behavior depends strongly on their energy. When the neutron has an energy of 20 Mev or more it is capable of disrupting a struck nucleus with the ejection of a number of particles.

The neutron source most commonly used is a chemical mixture of americium 241 and beryllium. The americium decays and emits large quantities of alpha particles. Alpha particles are double ionized helium nuclei, consisting of two protons and two neutrons. These alpha particles then collide with the intermixed beryllium causing the beryllium to emit medium energy neutrons. The neutron source has a half life of 458 years, and a neutron flux density of 10 million neutrons per second.

The principle mechanism by which the neutron loses energy, is elastic scattering. In an elastic scatter the neutron collides with a formation nucleus, but no energy is internally transferred to the nucleus. The only energy transferred is the kinetic energy (motion) given the struck nucleus.

1.1.1 The Neutron - Cont'd.

An elastic scattering analogy has often been made using the collision between a marble and a billiard ball. The marble (neutron) bounces off the billiard ball (nucleus) transferring only a small amount of its energy in the process.

A noteable exception to this analogy is the element hydrogen because it has a mass approximately equal to the mass of the incident neutron. For neutron-hydrogen elastic collisions, a more reasonable analogy would be the collision of two marbles. When hydrogen is the struck nucleus, the maximum energy loss, is 100%. Of course, not all neutrons will lose this maximum amount of energy. On the average, neutrons will lose about 50% of their energy in each elastic scatter with hydrogen. The probability, or cross section, for elastic scatter is appreciable for hydrogen, across a very broad neutron energy range. It therefore follows that once neutrons pass below the threshold for inelastic scatter, the presence of hydrogen dominates the neutron slowing down process.

The most important absorption process which terminates the lives of most source neutrons is the thermal neutron capture reaction. Principles of this reaction are discussed below. The neutrons are eventually slowed down to an average energy, and most have undergone many collisions and have been reduced to about one millionth of one percent of their original energy. The thermal neutrons continue to elastically scatter off of the nuclei and diffuse, with as many neutrons gaining kinetic energy as those losing energy to these nuclei. Eventually each is captured by one of the nuclei, leaving the nucleus in an excited state. This excited nucleus, in most cases, almost instantaneously emits "capture" gamma radiation, the energy of which is indicative of the capturing nucleus. The cross sections for thermal neutron capture, are very strongly dependent on the nucleus involved. A chlorine nucleus, for example, is more than 100,000 times as likely to capture a thermal neutron as an oxygen nucleus.

In the process of being slowed down to thermal energy and then diffusing, the neutrons tend to move farther from the source with each collision. Since neutrons lose much more energy in collisions with hydrogen than in collisions with other elements, it takes fewer collisions in highly hydrogeneous formations to slow the neutrons down than in non-hydrogeneous formations. The net result of these effects is that the thermal neutron and the secondary thermal neutron capture gamma ray distribution are formed closer to the source in products containing higher concentrations of hydrogen.

1.1.1 The Neutron - Cont'd.

Stated alternatively, at a point sufficiently removed from the source, products or air with decreased hydrogen content have increased concentrations of thermal neutron, capture gamma rays, and epithermal neutrons (those slowed down almost to thermal energy, yet energetic enough to avoid capture).

Neutrons seldom cause ionization directly. Ions are formed as a result of radiation that is emanated during a reaction between a neutron and an atomic nucleus. Neutrons are absorbed by a material in two more or less distinct stages. First, the high-energy neutrons passing through the material are slowed down by collision with the nuclei. Since the probability of absorption of neutrons by most materials are virtually zero at high energies, it is only when the neutrons have reached low energies that the second stage, capture of the neutrons, can take place. Once the neutron has been slowed down, it will be quickly captured before it has a chance to diffuse much farther because of the large capture probability for most elements at low energy. Thus, the actual penetration properties of the neutrons are really dependent on the behavior of the fast neutrons, and once a neutron has been slowed down, it can essentially be considered as removed from the beam. Neutrons captured by material will, in most cases, result in the emission of high-energy secondary gamma rays.

Nuclear Reactors

A nuclear reactor or pile contains both readily fissionable ^{235}U and the more abundant isotope, ^{238}U. Slugs of the uranium fuel elements are separated by a moderator, usually pure carbon in the form of graphite stringers, or deuterium, as heavy water. The function of the moderator is to slow down, or thermalize, without capture, the fast neutrons produced by ^{235}U fission.

A nuclear reactor, like a fission bomb, is an essentially unstable device. Fortunately, a small fraction of the neutrons emitted are delayed sufficiently to permit the introduction of mechanically operated control devices. These control rods consist of an element such as cadmium or boron with a high cross section for thermal neutron capture. In normal reactor operation these control rods are adjusted so that exactly one neutron per fission will be available to initiate another fission.

1.1.1 The Neutron - Cont'd.

A variety of reactor designs is available for special applications. For biomedical purposes a reactor may have a large thermal column, a relatively large volume consisting only of graphite moderator. Any neutrons entering this volume will be thermalized before reaching the center of it. Animals or other test objects can then be introduced into the center of the thermal column, where they will be exposed to the thermal-neutron flux and gamma radiation produced by the fission process and the decay of the fission products.

Large quantities of heat are generated by the fission process; it is usually removed by air or water cooling. In a power reactor, steam may be generated and delivered to turbines or other prime movers. The efficiency of heat engines goes up with the operating temperature and reactor cooling water may be replaced by a liquid metal. Even at the best efficiency attained, however, nuclear energy cannot at present compete economically with fossil fuels in the United States.

Artificial Radioisotope Production

The high neutron fluxes available in nuclear reactors permit the large-scale production of radioactive isotopes. Stable elements placed in the thermal column may absorb neutrons. In most cases the product nuclide is radioactive.

Neutron Therapy

As the physical properties of neutrons became known it was natural to hope that their unique properties would be of value in radiation therapy. Dr. R.S. Stone, the first to use cyclotron neutrons in a group of cancer patients, used a Victoreen 100 thimble chamber and called its readings "n units" instead of roentgens. The results of animal experiments and theoretical considerations suggested that 1 n unit was equivalent to 2.5 R and treatment was given accordingly. The neoplactic tissue responded to neutrons as to other forms of penetrating radiation, but delayed, untoward reactions ensued and the overall results were not encouraging.

Technical advances in the techniques of neutron measurement continued, and in 1952 a detailed analysis of the problem was reported. Unfortunately, the RBE of neutrons depends upon the size of the animal being irradiated, as well as upon the characteristics of the neutron beam and the effect being measured.

1.1.1 The Neutron - Cont'd.

Because of this complication, extrapolation of values from small animals to man is uncertain. It should be pointed out that pure neutron irradiations cannot be achieved. Radiative capture reactions are inevitable in any tissue, so any neutron flux will be accompanied by an appreciable gamma-ray component.

Some unfortunate human overexposures have emphasized the outstanding ability of neutrons to produce lens opacities.

A new approach to the therapeutic use of neutrons is yet to be evaluated. In this technique an element with a high capture cross section is administered in a form expected to concentrate in malignant tissue. A subsequent slow neutron irradiation should release charged particles to produce localized tissue destruction.

SECTION 2

DETECTION OF RADIATION

2.0.0 DETECTION OF RADIATION

Outline:

1. Vocabulary
2. Basic Detector Circuits
3. Ionization Chambers
4. Proportional Detectors
5. Geiger-Mueller Detectors
6. Scintillation Detectors
7. Neutron Detection

2.0.1 Vocabulary

Biological Effects	Ionization
Calorimetry	Luminescence
	Photography

Since we cannot see a moving subatomic particle, it must "do" something before we know it is there. Radiation energy can be measured only by some effect caused by the radiation. These effects include:

A. Photography - blackening of film; historically significant (how radioactivity was discovered), covered in Section 3: "Dosimetry - Personnel Monitoring".

B. Ionization - the most common technique; based on the ion chamber; most effective for alpha; least effective for gamma; relative ionization effectiveness, based on gamma = 1, is:

10,000 = Alpha
100 = Beta
1 = Gamma

2.0.1 Vocabulary - Cont'd.

C. Luminescence - the second most common technique. The florescent effect is the basis of the scintillation counter; zinc sulfide or organic crystal is flourescent when struck by alpha, beta, or gamma rays of sufficient energy. Thermoluminescent Dosimeters (TLD) will be covered in Section 3: "Dosimetry - Personnel Monitoring".

D. Calorimetry - any energy can be measured by its effect of raising the temperature of the body that absorbs that energy. Calorimetry is the most direct but most difficult of measurement techniques because even large doses of radiation produce only small temperature rises.

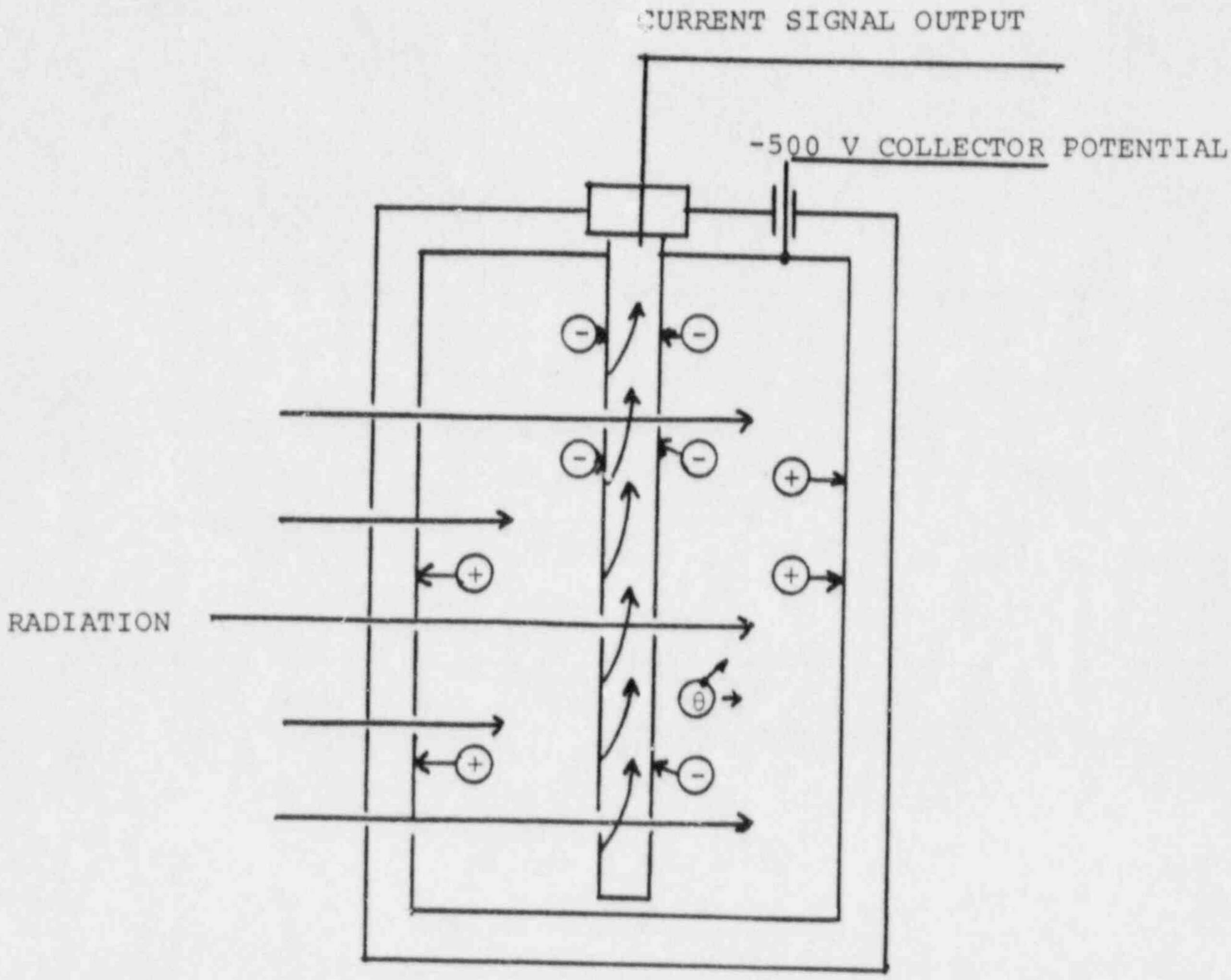
E. Biological Effects - the destruction of or damage to living tissue (bacteria, fruit-fly eggs) is still used as a crude indicator of radiation.

2.0.2 Basic Detector Circuits

A. When a potential difference exists across two parallel plates and ionization occurs between them, the ions travel to the terminal having an opposite charge. Collection of the charge particles at the plates produces a flow of current through a load resistor and produces a voltage signal across that resistor.

B. As shown in Figure 2-1, the circuit can be used either as a charge detector or as a current detector. In the former case, a capacitor across the electrodes is charged by the ions in the chamber; this charge is then measured. In the latter case, a resistor is used instead of the capacitor, and the current resulting from ions in the chamber is measured. The totalized charge on the capacitor is a measurement of dose intensity. Measurement of current is a measure of dose intensity rate.

C. The parallel plates, together with the load resistor, cause a resistance capacitance (RC) voltage pulse.



Gas atoms are ionized by radiation. The resulting current is directly related to the strength of radiation.

FIGURE 2-1

2.0.2 Basic Detector Circuits - Cont'd.

a. Amplification in a detector is called gas amplification. Because of their size and complexity, standard air chambers are not used.

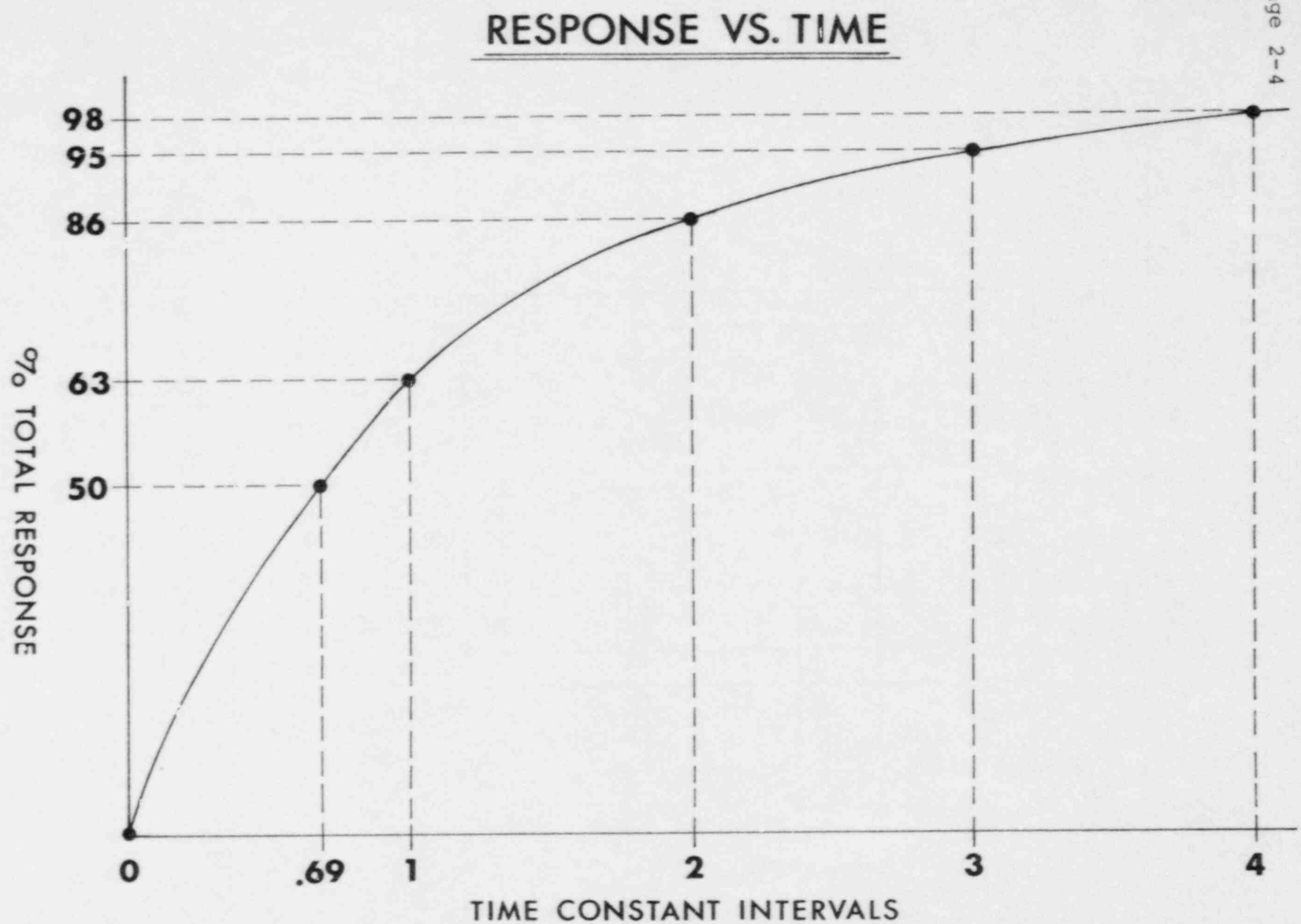

RESPONSE VS. TIME
98
95
86
63
50
% TOTAL RESPONSE
0
.69
1
2
3
4
TIME CONSTANT INTERVALS

FIGURE 2-2

2.0.2 Basic Detector Circuits - Cont'd.

b. Gas amplification factor (A) is equal to the number of electrons collected, divided by the number of primary ionizations. The chamber shown in Figure 2-1 is simply an enclosed volume of gas with a collecting electrode mounted on an insulator. When a high voltage is applied to this electrode, ions formed in the gaseous volume by radiation will be attracted to the electrode.

D. Detector tubes have a very small diameter central wire.

a. Strengthening of the electric field near the central wire aids the avalanche effect.

b. An instrument using .001 inch central wire has most of the avalanche effect occurring within .0005 inch of the wire.

E. As detector voltage increases, avalanche electrons obtain enough energy to penetrate outer electron shells and excite inner shell electrons.

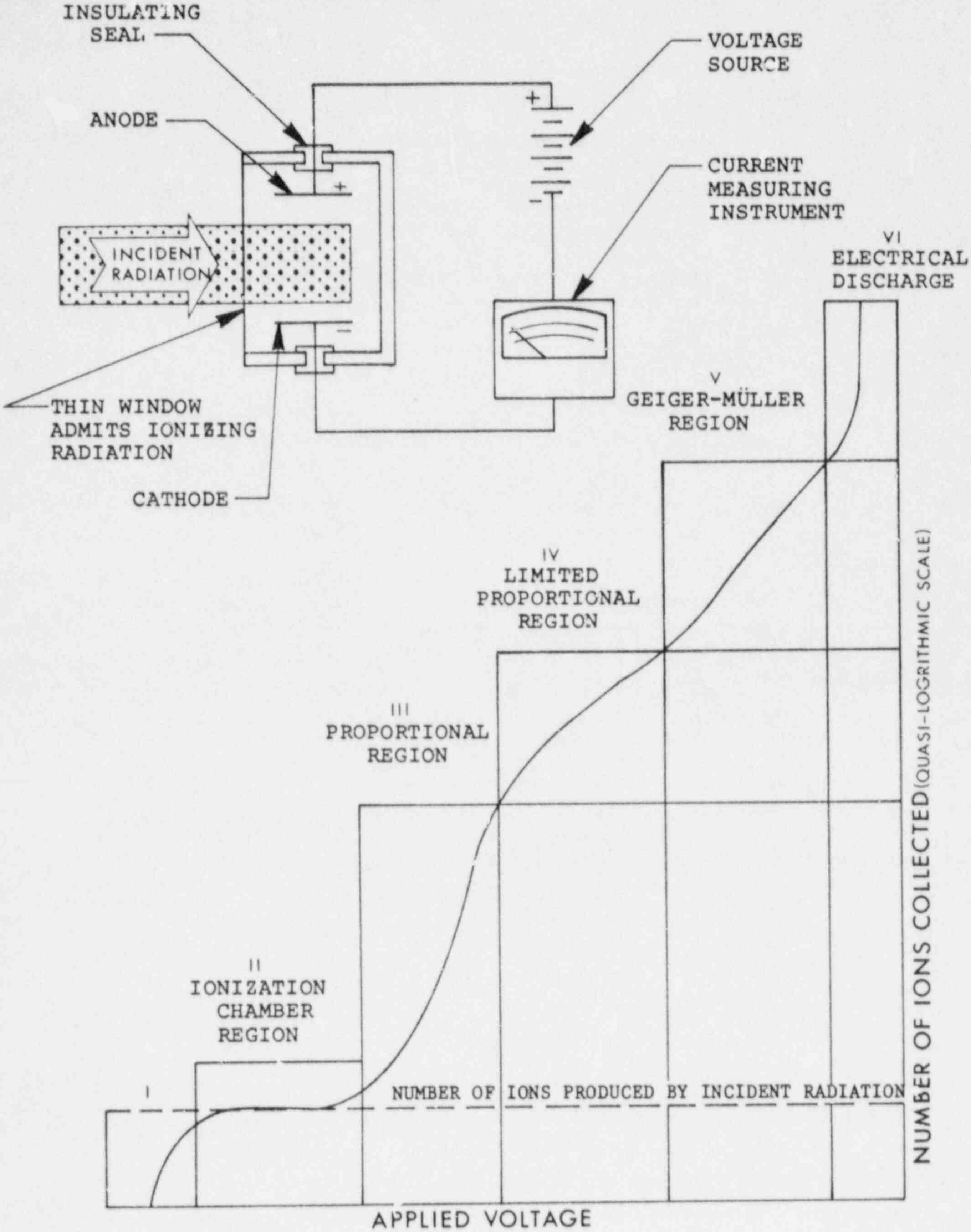
a. When an inner shell electron is excited so that it can escape from the atom, an outer shell electron will fall from its orbit to fill the vacancy.

b. This results in the emission of an X-ray which, in turn, causes ionization by interaction with other atoms.

c. When inner shell electrons are excited, they also yield X-ray upon de-excitation.

F. Incoming radiation ionizes gas in the gas-filled tube. The ions produced are collected at the electrodes. A negative ion collected on the anode causes the meter to deflect (Figure 2-3).

G. In region I some ions recombine. As the voltage increases, the drift velocity of ions increases and recombination decreases. At saturation voltage, or the end of region I, the recombination is at a minimum.



PRINCIPLES OF GAS ION COLLECTION

FIGURE 2-3

2.0.2 Basic Detector Circuits - Cont'd.

H. Region II is called the ionization region and extends over a few hundred volts. In this region, all ion pairs are collected. The voltage range is normally about 100 to 300 volts.

I. Region III is the proportional region. Here the primary ions acquire enough energy from the voltage to cause secondary ionization (gas amplification) and increase the charge collected. The secondary ionization may cause further ionization. In this region there is a linear relationship between number of ion pairs collected and voltage.

J. In region IV no linear relationship exists between ions collected and primary ions. An avalanche of ions starts and increases as voltage increases.

K. In region V there is a complete discharge in the vicinity of the central wire. This region is called the Geiger-Müller (G-M) region. The complete discharge is independent of the initial ionizing radiation and an avalanche of electrons develops all over the central wire and in the gas. The beginning of the Geiger-Muller region, or region V, is called the threshold voltage. Here the number of ion pairs levels off and remains relatively independent of the applied voltage. This leveling-off is called the Geiger plateau.

L. The plateau extends over a region of 200 to 300 volts; the threshold is normally about 1000 volts. The operating voltage of the tube is normally about 1200 volts. It should be remembered that the ionization in this region is independent of the nature and energy of the original radiation. An increase in voltage about the G-M region produces a continuous discharge in the tube and will very quickly destroy the tube.

M. The different methods of detecting radiation (ion chambers, G-M counters, etc.) depend upon the varying behavior of the ions produced by radiation in their passage through the tube. Thus, one type

2.0.2 Basic Detector Circuits - Cont'd.

of detector may have advantages over another in certain applications (i.e., proportional counters as neutron counters, Geiger tubes for small specific ionization).

N. Alpha particles are detectable in all three useable regions, but the proportional is preferred.

O. Beta pulses become detectable at the higher voltages of the proportional regions.

P. Gamma pulses are detectable only in the G-M region and give the same pulse height as alpha and beta particles since any ionization in the chamber will completely saturate the tube.

2.0.3 Ionization Chambers

A. An ion chamber can be used as either a pulse or a rate type detector.

a. In pulse operation, the output of the chamber is indicated as a series of signals (usually voltage) separated in time.

b. In rate operation, no attempt is made to resolve individual action. Instead, the output is the time average of many interactions.

B. Measuring the output current of the ion chamber is an example of a mean level system. When the total dose measured is averaged over the time interval of measurement, the electrostatic or self-reading pocket dosimeter (covered in Section 3: "Dosimetry - Personnel Monitoring") becomes an example of a mean-level type ionization detector.

C. Operating voltage varies with detector geometry and sensing gas and is generally below 500 volts. Pulse width ranges from 10 to 50 microseconds. If there is a pulse width of 5 microseconds and the radiation particles enter more rapidly than one every 5 microseconds, the instrument will not give a proper indication of the pulse rate. The pulses pile up and look like a single pulse to the instrument.

2.0.3 Ionization Chambers - Cont'd.

D. With an integrating ion chamber, the pulse width is purposely increased by several magnitudes. The pulses keep adding up until a point is reached where the stream of ions keep the pulse level constant. To evaluate the reading, the current through the load resistor is measured.

E. The integrating ion chamber will indicate dose rate directly for beta and gamma, giving an indication of the number of particles per unit of time.

2.0.4 Proportional Detectors

A. Gas amplification occurs in the proportional region giving a large pulse.

B. This instrument has a recovery time (pulse width) in the vicinity of 10^{-4} seconds. Typical operating voltage ranges from 300 to 2600 volts. The gas amplification factor is between 10^2 and 10^4.

C. Voltage is plotted against meter readings to pick a good operating level for a specific instrument in a like manner.

a. A radioactive source is placed under the probe; the high voltage is adjusted and readings at various voltages are recorded on graph paper.

b. A curve is produced that will define a small plateau. This plateau will vary from tens of volts to a few hundreds of volts wide.

c. The instrument voltage is adjusted for the middle of the plateau, so that variations in the detector voltage will give no change in the counts indicated.

d. The lower third portion of the plateau is used when high energy beta may be encountered.

2.0.5 Geiger-Müller Detectors

The Geiger-Müller (G-M) counter has been the most widely used detector. It has been popular because: 1) it is highly sensitive to even the smallest radiation, 2) it

2.0.5 Geiger-Müller Detectors - Cont'd.

can be used with many different types of radiation, 3) it has a very high voltage pulse output, 4) its cost is reasonable.

A. The G-M detector is frequently used as a pulse-type detector. G-M detectors have a gas amplification factor of approximately 10^8.

B. The voltage pulse height across the load resistor will be the same for any volume or number of ionizations. Therefore, the reading obtained is approximately the same as a dose rate. The time required for an avalanche to go from initial ionization to final collection is about 10^{-7} seconds. A period of 10^{-2} seconds is required for the positive ions to travel to the cathode and be neutralized. This produces a positive ion sheath that will be moving to the outer wall after the electrons have been collected.

C. Additional electrons will not be able to penetrate the positive ion sheath until the sheath is a certain distance from the anode. This distance is called the critical radius. The time it takes a positive ion sheath to move to the critical radius is known as dead time.

D. The time required for a positive ion sheath to move from the critical radius to the cathode wall is called recovery time.

E. Radiation will not be detected if it enters the probe during dead time. Radiation entering the probe during recovery time will be detected, but will produce a smaller pulse than normal. If a G-M detector is used in a very high radiation field, only one pulse would be recorded between successive dead times. Due to an intense radiation field, the tube may not be able to recover at all, producing a zero reading on the meter.

F. When a positive ion sheath is neutralized at the cathode, X-rays are released which are of sufficient energy to cause ionization.

G. If an instrument were allowed to retrigger once a pulse was formed, it would retrigger indefinitely.

2.0.5 Geiger-Muller Detectors - Cont'd.

H. Quenching is the term applied to measures that prevent retriggering. Quenching may be provided by: 1) lowering the tube voltage for a few microseconds (external quenching), 2) introducing an organic gas into the tube, 3) introducing a halogen gas. External quenching is very seldom used. The + ions transfer their energy to quench gas molecules and when the gas molecules reach the cathode, they dissociate rather than produce an electron.

Alcohol quenched tubes have a lifetime of about 10^{10} events, while halogen ions recombine thereby extending the lifetime of the tube almost indefinitely. The gas is generally about 90 percent argon at a total pressure of 10 cm Hg.

2.0.6 Scintillation Detectors

A. Certain crystalline solids and organic liquids will absorb energy from radiation and emit a photon pulse of light in the visible or ultraviolet region.

B. Approximately one-half of the energy absorbed will be emitted in the form of light.

C. A typical crystal has a de-excitation time of 10^{-8} seconds which gives a counting rate of 10^{10} pulses per second.

D. Addition of certain materials to the scintillating phosphors allows better efficiency. This is known as activation.

E. When organic liquids are used, the de-excitation time is relatively short in comparison to inorganic liquids. More interaction from gamma is encountered with organic liquids due to photoelectric effect.

F. Liquid scintillators allow a sample to be placed within the liquid so that energy given off in any direction can be detected.

2.0.6 Scintillation Detectors - Cont'd.

G. The photomultiplier tube has a photocathode similar to a photocell (Figure 2-4).

a. The photocathode is followed by a dynode which is positive in relation to the photocathode.

b. Electrons given off from the photocathods are attracted to the dynode. Each electron striking the dynode causes several electrons to be given off.

c. A second dynode will be more positive in relation to the first.

d. The electrons freed will be accelerated to the second dynode. Each electron will, in turn, release several other electrons.

e. All of the electrons are finally collected at the end of the photomultiplier tube. This can be seen as a voltage pulse and the instrument counts the pulse rate.

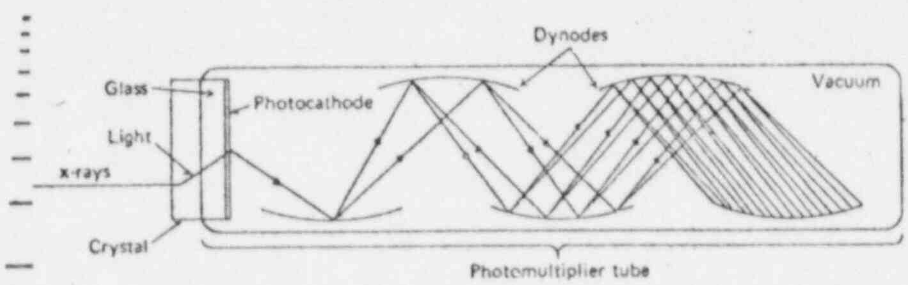


FIGURE 2-4

2.0.7 Neutron Detection

A. Methods of detection vary according to neutron energy. Slow neutrons are detected by nuclear reactions with either boron-10 or with material which has a high cross-section for fission with low neutron energies.

a. The boron chamber consists of a small cylinder containing BF_3 gas or boron-10 in solid form.

b. This detector functions as a proportional counter to detect the alpha particles released from the $^{10}_{5}B$ (n, →a) $^{7}_{3}$ Li reaction.

2.0.7 Neutron Detection - Cont'd.

B. Fission chambers are constructed similarly to boron chambers.

a. For slow neutron detection, enriched U^{235} is used to line the chamber wall.

b. For detecting fast neutrons, the chamber is lined with U^{238}.

c. Pulse counting ion chambers or proportional detectors are used with fission chambers.

C. Scintillation detectors are also used for neutron detection.

a. The energy of the neutrons detected is a function of the scintillation crystal used.

b. The crystal is impregnated with a material which gives off ionizing radiation when bombarded by neutrons.

c. The crystal may be either solid or liquid in form.

D. A neutron chamber's effectiveness is increased when it is surrounded by a moderator.

a. To discriminate neutrons with different energies, the moderator is surrounded with a material such a cadmium, which captures thermal and slow neutrons.

b. Slow or fast neutrons can be detected by using a moderator with a cadmium shield in conjunction with the boron chamber.

SECTION 3

DOSIMETRY - PERSONNEL MONITORING

3.0.0 DOSIMETRY - PERSONNEL MONITORING

This section will give background information on Dosimetry procedures, Dosimetry devices, and hazard control.

Outline:

1. Determination of Exposure
2. Film Dosimeters
3. Criticality Dosimeters
4. Thermoluminescent Dosimeters (TLD)
5. Self-Reading Pocket Dosimeters
6. Exposure Control

3.0.1 Determination of Exposure

A. Gamma exposures are determined primarily through the use of film packets which are exchanged periodically or when personnel exit from possible exposure areas. Other dosimeters include pocket ionization chambers, thermoluminescent dosimeters, and, rarely, chemical dosimeters.

B. Beta exposures are usually evaluated through the use of a film badge covered with various filters which categorize the energies of the incident radiation. Gamma exposure densities are subtracted from the beta plus gamma exposure densities to calculate the beta dose.

C. Neutron film packets are used by persons working in the vicinity of nuclear reactors or neutron sources. Thermal neutron pocket chambers are issued in some areas.

D. Radiation dose caused by internal deposition of radionuclides is determined through biological analysis or by whole body counting techniques.

E. Records are maintained of measured radiation doses both for exposure control and for legal purposes.

F. The standard man is used to establish permissible internal deposition guides.

3.0.1 Determination of Exposure - Cont'd.

G. In emergency situations, appropriate dosimetric devices may not be available and dose estimates may have to be made for individuals and/or the population from exposure measurements.

3.0.2 Film Dosimeters

A. A film badge packet is used to determine external radiation exposure. The developed film is both a measuring device and a permanent legal record.

   a. The film packet consists of one or more dosimetry films similar to dental X-ray film.

   b. The type or number of film used is dependent upon the range desired.

B. Gamma photons react with the filtering material to produce secondary electrons which affect the film emulsions, just as light photons cause changes in film emulsion.

C. The filter material is selected and used in the particular quantity necessary to assure uniform film emulsion exposure response over the usual wide gamma energy range.

D. Calibration of gamma film packets is performed by exposing representative film from each batch to known amounts of radiation, by using a calibrated gamma radiation source.

   a. Films which are not exposed to the radiation of interest are also included in the calibration procedure as control film.

   b. After development, the density of the control film is set at zero on a densitometer.

   c. Densities of the exposed film are measured in net optical density (NOD) units. Known radiation exposure versus NOD is plotted on a calibration graph for each batch of film. These curves are used to determine radiation exposures received by personnel wearing film from the same batch.

3.0.2 Film Dosimeters - Cont'd.

E. Processing of film includes developing, rinsing, fixing, washing, and drying.

   a. Both unexposed control film and exposed film standards are processed with each group of personnel film to assure that background radiation densities (base fog) and calibration standard densities are correct after the film processing.

F. Films exhibiting unusual densities are examined to assure that the exposures are valid and not caused by such things as heat, light, and pressure damage.

G. Beta exposures are usually determined with the same film used for gamma exposure.

   a. Since beta will not penetrate appreciable thicknesses of material, the beta detection area of the film should not be covered with thick material.

   b. The density contributed by any gamma exposure should be subtracted from the beta plus gamma density to determine beta exposure.

   c. Calibration for beta exposure densities is performed similarly to gamma exposure by the more uniform beta density and dose response.

H. Measurements of small neutron exposures are complicated because neutron reactions vary with energy.

   a. Elastic collision of a fast neutron with a hydrogen atom in special film emulsions causes a proton recoil ionization track which can be observed microscopically. Tracks per unit and area per unit resulting doses can then be extrapolated.

   b. These special film emulsions, when exposed to other radiations, may exhibit sufficient density to obscure the proton recoil tracks. Therefore, the film is usually shielded with copper and lead to decrease densities caused

3.0.2 Film Dosimeters - Cont'd.

by other radiation and increase film efficiency for fast neutron radiation detection. The special emulsions used in neutron monitoring film depend only on highly hydrogenous materials surrounding the film to produce tracks from protons released as secondary radiation.

c. Thermal neutron exposures are sometimes measured by using cadmium filters over gamma film by comparison with an area which is not shielded with Cd.

d. Also used are thermal neutron pocket chambers.

3.0.3 Criticality Dosimeters

A. In areas of possible criticality accidents, methods for measuring very large radiation exposures must be provided. It is important to determine the neutron energy spectrum which existed during a criticality accident. This is usually accomplished by using several different elements which have high cross sections for neutron capture at different neutron energies. Common elements used in such criticality dosimeters are gold, sulfur, copper, silver, and indium.

B. The chemical elements in the bodies of personnel exposed to large amounts of neutron radiation may be used to estimate exposure by neutron activation analysis. Blood and hair analyses are most commonly used.

C. High gamma radiation doses can result from a criticality accident, and be above the range of gamma film measurement limits. Glass rod dosimetry is used for this purpose.

3.0.4 Thermoluminescent Dosimeters (TLD)

A. TLD have resulted from recent developments in solid state physics.

3.0.4 Thermoluminescent Dosimeters (TLD) - Cont'd.

a. Examples of materials used are LiF, CaF_2, Li_2, B_4O_7, $CaSO_4$ having impurities such as Mn or Dy added as activators.

b. Incident radiation causes orbital electrons to be raised to higher energy levels. Readout is performed by heating and measuring the light photons released which are proportional to the amount of incident radiation.

B. Advantages of TLD over film:

a. May be used in many forms, i.e., powder, extruded shapes, impregnated into holding materials such as Teflon.

b. TLD's can detect gamma, beta, and slow neutrons.

c. Relatively insensitive to environmental aging caused by heat, light, and moisture.

d. Long "shelf life".

e. Capable of recording into the kiloroentgen range.

3.0.5 Self-Reading Pocket Dosimeters

A. For immediate indication of dose received by exposed personnel, self-reading pocket dosimeters are used (Figure 3-1).

a. A self-reading pocket dosimeter consists of a small air-filled chamber in which a quartz fiber electrometer is suspended. A small microscope and a graduated scale across which the shadow of the quartz fiber moves, indicates the applied dose.

b. The design and operation of a self-reading dosimeter utilizes the principle of discharging a pair of oppositely charged surfaces when the air between them is exposed to ionizing radiation.

3.0.5 Self-Reading Pocket Dosimeters - Cont'd.

c. The migration of the negative particles to the electrometer reduces the positive charge between the frame and quartz fiber of the electrometer permitting the fiber to move closer to the frame which, in turn, causes the shadow of the fiber to move across the calibrated scale.

d. Self-reading pocket dosimeters are available in many ranges of gamma doses from 0 to 200 mR to 0 to 1000 R. Appropriate scale markings are provided with each dose range.

e. The dosimeter charger is a small battery operated power supply designed to impress a DC voltage on a charging electrode of a dosimeter. Pressing the dosimeter into the well serves two purposes:

1) with a slight amount of pressure, the switch is activated which turns on a light in the charger so that the shadow of the fiber of the electrometer may be seen.

2) with increased pressure, the charging switch is also closed in the dosimeter so that an electrical connection is made between the charging circuit and the electrode.

f. While holding the dosimeter firmly in the well, an adjusting knob is rotated until the hairline is on zero. It may be necessary to attempt the charging procedure several times to accomplish a zero setting when the dosimeter is removed from the charging well; however, it is not necessary to have an exactly zeroed setting since the exposure obtained can be determined by subtracting the initial reading from the final reading.

g. Self-reading dosimeters should be worn on the upper front part of the body:

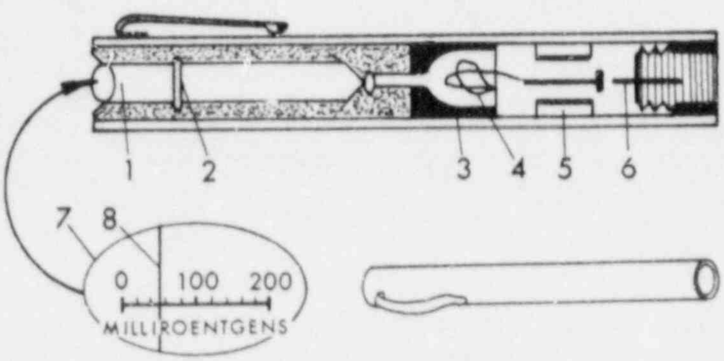
1) generally two are worn at the same time, one of higher range than the other.

3.0.5 Self-Reading Pocket Dosimeters - Cont'd.

2) this serves two purposes: each dosimeter is a check against the other; by wearing dosimeters of different ranges, the total possible range covered is increased.

h. Self-reading dosimeters are quite rugged and durable. However, they can be affected by shock if they are dropped.

1) the gamma dosimeter is insensitive to beta and neutron radiations. Therefore, total dose estimates must consider the dosimeter measurements and also measurements taken with beta radiation sensitive portable dose rate instruments.



POCKET DOSIMETER

Pocket dosimeter, direct-reading type:

1. Microscope
2. Scale
3. Ionization Chamber
4. Quartz-Fiber Electrometer
5. Capacitor
6. Charging Switch
7. Enlarged View of Scale
8. Fiber Indicator

FIGURE 3-1

3.0.6 Exposure Control

A. Monitoring of radiation exposure areas with portable dose rate instrumentation allows prediction of exposures that will be received by personnel working in the areas.

B. Self-reading pocket dosimeters should be worn by personnel who expect to receive exposures. In this way, accumulated exposures can be obtained while they are being received and personnel can leave exposure areas when they reach any established exposure limit.

C. Since gamma film packets are considered as a legal exposure record, it is necessary for the results of film processing to be transmitted to the control location as rapidly as possible when exposures are of a magnitude that could cause personnel to exceed established exposure guides.

D. Personnel dosimetry is valuable as an exposure control mechanism and has an equally valuable function in the measurement and documentation of exposures which have been received by personnel. Dosimetry is an aid to exposure control, but it is secondary to sound exposure preventive measures.

SECTION 4

RADIATION SAFETY

4.0.0 RADIATION SAFETY

Outline:

1. Vocabulary
2. Introduction
3. Radiation Dose Limits
4. Additional Precautions
5. Basic Nuclear Phenomena
6. Effects of Radiation
7. Field Intensity Calculation

4.0.1 Vocabulary

Curie

Dose

Dose Rate

Half Life

Half Value Layer

Linear Ion Density or Specific Ionization

Rad

Rem

Roentgen (R)

4.0.2 Introduction

A. The best way to avoid becomming a weekend traffic statistic is to stay off the highways. With radiation too, the best policy is avoidance. Radiation energy is harmful to the human body when absorbed at an excessive rate. For example, a glowing incandescent lamp cannot be held in the hand without severe discomfort or a painful burn resulting. The hand can be held close to the lamp for seconds, at a few inches for a few hours, or several feet away continuously. By use of an insulating jacket about the lamp or with an insulated glove, the lamp could be held indefinitely without discomfort or injury.

4.0.2 Introduction - Cont'd.

B. Radioactive energy and radiation is analogous to light energy and radiation with a radioactive source taking the place of the incandescent lamp. Permissible human exposure to radioactive sources is dependent upon:

a. The number of millicuries of radioactive material in the source (similar to wattage rating of lamp).

b. Distance from the source.

c. Time or duration of exposure.

d. Amount of absorber between source and body.

e. Amount and portion of the body receiving the radiation.

f. Age of person.

g. Type of radiation.

C. The term "milliroentgen per hour", abbreviated mr/hr, is a measure of the radiation field intensity in air. When radiation is absorbed by the body, the term "rem" or "millirem" (0.001 rem, abbreviated mrem) is used. This distinction is necessary because not all radiation affects the body in the same manner. For gamma radiation, the millirem is equal to the milliroentgen.

4.0.3 Radiation Dose Limits

The Nuclear Regulatory Commission limits the amount of radiation which a person could receive to 1.25 rem per calendar quarter (20.101a). This is an average of about 100 mrem per week.

A. The 1.25 rem per calendar quarter limitation is a dose at which there is no known possibility of injury. However, since the use of gamma radiation is relatively new, the history of injury is not complete. Thus, it is wise to receive as little radiation as possible.

RADIATION PROTECTION GUIDES

Type of Exposure	Condition	Dose (rem)
Radiation worker:		
(a) Whole body, head and trunk, active blood-forming organs, gonads, or lens of eye	Accumulated dose 13 weeks	5 times number of years beyond age 18 1.25
(b) Skin of whole body and thyroid	Year 13 weeks	30 7.5
(c) Hands and forearms, feet and ankles	Year 13 weeks	75 18.75
Population:		
(a) Individual	Year	0.5 (whole body)
(b) Average	30 years	5 (gonads)

NOTE: See FRC Report No. 1, May 1960, for details.

FIGURE 4-1

NATURAL BACKGROUND RADIATION

Type	Source	Dose rate mrad/year	Varies with
External	Cosmic rays	30 - 60	Latitude & altitude
	Soil potassium-40 thorium, uranium	30 - 100	Location (mineral deposits), dwelling (least in tents, greatest in stone buildings)
Internal	Thorium, uranium and daughters	40 - 400	Location & water supply
	Potassium-40	20	Not very variable
	Carbon-14	2	Not very variable
	Tritium	2	Not very variable
TOTAL		100 - 600	

FIGURE 4-2

4.0.3 Radiation Dose Limits - Cont'd.

B. To guard against possible over-exposure and to maintain a record of personnel routinely exposed to radiation, the NRC requires personnel monitoring of persons who are exposed to a radiation field greater than 100 mr/hr (20.202b3).

C. Personnel monitoring devices, such as film badges or dosimeters, are required when personnel can receive a dose in excess of 312 mrem per quarter (20.202a1). For persons under 18 years of age, the dose is 5% of adult dosage per quarter. (20.202a2).

D. When personnel monitoring is required, a record must be kept showing the dose received. When records are kept, and if the employee requests it, the employer must furnish a written report of radiation exposure annually (19.13b) and upon termination of employment (19.13c).

E. For all Kay-Ray installations, the source is contained in a lead-filled source holder with an OFF (store) and an ON (measure) position. When the source holder is mounted on the pipe or vessel and turned to the ON position, the pipe walls and the mounting brackets absorb most of the radiation. The maximum allowed field intensity is 5 mr/hr at a distance of 12 inches from any surface of the gauge (20.204a).

F. Long experience with hundreds of gauges where the source is contained in a source holder, indicates that the dose received by the operators, maintenance personnel, and supervisors is less than an average of 0.2 mrem per week. Thus, for gauges where the source is contained in a source holder, it is usually unnecessary to provide any personnel with monitors. Since monitors are not required, obviously no written records must be kept.

G. Although the rad is a most useful unit, it is found that in biological systems, the degree of damage produced by a given dose depends upon many factors including the type of radiation and how the radiation is distributed. To take this difference into account when adding the absorbed dose of different radiation, we must multiply the absorbed dose of each type of radiation by a quality factor (QF)

4.0.3 Radiation Dose Limits - Cont'd.

which reflects the ability of the particular type of radiation to cause damage. The quantity obtained when the absorbed dose in rads is multiplied by a quality factor is known as the dose equivalent, or rem (rems = rads x Quality Factor).

a. Quality Factor Values:

Gamma rays from radium in equilibrium (0.5 mm) platinum filter	1
X-rays	1
Beta rays and electrons; >0.03 MeV	1
Beta rays and electrons; <0.03 MeV	1.7
Thermal or slow neutrons	3
Fast neutrons	10
Protons	10
Alpha rays	10
Heavy ions	20

4.0.4 Additional Precautions

A. A radiation protection program has two facets: the continuous protection evaluation of exposure and the reduction of exposure by any applicable control measure. The fact that all exposures are maintained below maximum permissible levels is an indication that the control procedures are working, but since any unnecessary exposure is unwise, the possibility of maintaining values as low as possible should continuously be kept in mind.

B. Additional precautions are required when a gauge is used on a vessel large enough to permit entry of personnel. With the source holder in the open position, the radiation field intensity inside the

4.0.4 Additional Precautions - Cont'd.

vessel can be high. A procedure must be established so that personnel cannot enter the vessel until the source holder is in the closed position or the source is removed from the source well. The use of padlocks on all man-way and access port covers is acceptable. The key or combination for the lock should be kept by the person responsible for radiation safety (20.203c2).

4.0.5 Basic Nuclear Phenomena

Radiation definition: the emission or propagation of energy through space or material. In nuclear radiation, this energy is caused by the rearrangement of protons and neutrons within the nuclei of stable atoms. Radiation is present everywhere: in the air (cosmic radiation), X-ray at the dentist's office (20 mrem for each dental X-ray taken), and from your own television set at home (1 mrem for each hour viewed from black and white, 2 mrem for each hour viewed from color), even people packed in a crowd (2 mrem per year).

A. Radiation vs Time.

B. Radiation vs Decay or Disintegration. Common modes of decay:

  a. Alpha particles.

  b. Beta particles.

  c. Gamma emissions.

  d. Spontaneous fission.

  Review paragraph 1.1.0. See Figure 4-4.

C. Time required for product to decay to one-half of its value (half life of material = $T_{1/2}$).

  a. Radium-226 = 1,602 years.

  b. Cesium-137 = 30 years.

  c. AmBe-241 = 450 years.

  d. Cobalt-60 = 5.26 years.

  Example: A 100 mCi Cesium-137 source today will become a 50 mCi Cesium-137 source in 30 years.

D. Radiation vs Shielding. The following table summarizes the shielding materials which should be used with each type of source material.

4.0.5. Basic Nuclear Phenomena - Cont'd.

Type of Source	Shielding Material
Neutron	Between 15 to 30 cm of water, wax, or polyethylene followed by 1 mm cadmium sheet or 1 cm of boron. When boron is used it is normal to mix boric oxide into the wax or water.
Gamma, bremsstrahlung	Lead. The thickness of lead depends upon how active the source is and the energy of the radiation emitted by the source.
Electron capture and B+ sources	These are best regarded as gamma sources.
B- sources	Usually 1 cm of Perspex is used as the shield followed by 1 mm of lead. The lead is used to shield the bremsstrahlung emitted as the beta particle is slowed. For low-activity sources, where little bremsstrahlung is produced, the lead may not be required.

E. Alpha particles are so easily stopped that they never present a shielding problem. A thin piece of paper is sufficient to stop most alpha particles. Because of their short range, alpha particles cannot penetrate the dead layer of skin surrounding the body, although they would enter the eyes. It is the very short-range particles which make sealed sources the least hazardous to handle. If an alpha source is more than 5 cm from the body, the alpha particles will be stopped before they reach the body.

F. Beta particles are more penetrating than alpha particles. Beta particles will not be stopped by normal clothing, nor will they be stopped by the dead layer of skin surrounding the body. They can penetrate up to 3 meters of air. Hence, shielding must be used with beta sources. When a beta particle is slowed, it emits bremsstrahlung and since the production of bremsstrahlung is much reduced in

4.0.5. Basic Nuclear Phenomena - Cont'd.

materials of low mass numbers, it is customary to use Perspex or aluminum when shielding beta sources; 1 cm of material is sufficient. If necessary, this can also be clad with thin lead (1 mm) to shield the bremsstrahlung.

G. It is a fact that beta sources are easily shielded and that at a distance in air greater than 3 meters, the beta particles will not reach the individual. That makes sealed sources less hazardous to handle than gamma sources.

H. Gamma sources are shielded using lead. The thickness of lead required depends on both the energy of the gamma radiation emitted by the source and on the activity of the source. For highly active sources emitting high energy gamma rays, as much as 20 cm of lead may be required.

It is the difficulty in shielding gamma sources which makes them the most hazardous to handle. We cannot rely on small amounts of air between us and the source or on our clothing to shield us.

I. The shielding used with B+ sources or electron capture sources is the same as for gamma sources.

J. Half-value thickness is that thickness of a material necessary to reduce incident radiation by 50%.

Examples are:	Cs 137	Co 60
Water (H^2O)	3.9	5.88 inches
Refractory	1.77	2.60
Aluminum	1.5	3.1
Steel	0.6	0.87
Copper	0.65	0.83
Lead	0.25	0.49

(Also see Figure 6-4: Un-Shielded Source in Air)

K. Neutron, like gamma rays, has a very long path in air and thus shielding is required, however, lead is not used as the shielding material. In this case, shielding is usually wax or polyethylene followed by a layer of boron of about 1 cm thickness, or a cadmium sheet 1 mm thick. Sometimes the boron and wax are mixed to form a borated wax mixture. Water or oil itself forms an effective neutron shield especially if it has boron dissolved in it. The thickness of the wax or polyethylene depends upon the neutron energy, but it is usually about 15 to 30 cm thick.

4.0.6. Effects of Radiation

A. The effects of radiation are based largely on the ionization produced when the energy of the radiation is absorbed in matter. While the physical, and even some of the biological, effects are understood, many of the biological mechanisms and the ultimate radiation damage in humans are not.

B. The physical effects result of ionization is merely a conversion of the radiation energy into another form of energy within the absorber. This energy is usually heat on the atomic scale. The biological effects of radiation are considered here only in sufficient detail to be of assistance in the problems of radiation protection.

C. X-rays or gamma rays, because of their penetrating nature, may dissipate only a fraction of their energy in passing through the body. Radioisotopes, in contrast, may present a further hazard when the material is taken into the body and irradiates the tissues or organs internally. The most serious effect from this standpoint are produced by the alpha emitters. They are particularly marked because alpha emitters outside the body expend their energy either in the clothing or in the dead cells of the epidermis and the emitters cannot penetrate to the living cells.

Once they are taken into the body, this same property of short range and high specific ionization increases their relative effect considerably. Alpha emitters in a small section of tissue will irradiate that small section very heavily.

D. Beta emitters can be both an internal and an external hazard. The range of most external beta radiation is great enough that the outer tissues, at least, will be penetrated. The most common external effects have been radiation burns and malignancies of the skin. Internally they may produce a considerable effect. Their specific ionization is high, although not as high as that for alpha.

E. Most of the heavy metals tend to be deposited in the bone structure. Other common sites of deposition are the lungs and lymph nodes for inhaled particles, and specific organs for certain isotopes such as the thyroid for iodine and the spleen for iron.

4.0.6. Effects of Radiation - Cont'd.

F. The greatest hazard from both alpha and beta emitters is when they are inhaled or ingested. The greatest hazard from gamma e[illegible]ers is ionizing radiation (Figure 4-3).

4.0.7. Field Intensity Calculation

The best way for determining the radiation field intensity is by measurement with a survey meter. However, the field intensity can be calculated fairly accurately.

A. The radiation field intensity can be calculated from:

$$D = \frac{K\ mCi}{(d)^2} \times 1000$$

D = dose rate, mr/hr
mCi = millicurie value of source
d= distance to source in inches
K= constant: 1.3 for Radium
0.505 for Cs^{137}
2.0 for Co^{60}

B. Suppose that for a certain installation, the estimated exposure time to the unshielded source is ten minutes at an average body-to-source distance of 20 inches. The source is 10 millicuries of Cs^{137}. The dose rate for this example would be:

$$\text{Dose rate} = \frac{0.505 \times 10}{(20)^2} \times 1000$$

$$= \frac{5.05}{400} \times 1000$$

and the dosage received would be:

$$\text{Total dose} = 12.6 \times \frac{10}{60} = 2.1 \text{ mrem}$$

4.0.7. Field Intensity Calculation - Cont'd.

Neutron Field Calculation

Neutrons are emitted in omni-directional patterns (360°). Thus, if the distance from the source is known, it can be used as the radius of a sphere.

Dose rates for neutrons are expressed in mrem/hr. This rate is derived from the number of neutrons/sec/cm^2 striking a surface at a given distance from the source. The N.R.C. Reg's. (20.3 Para.19,C4) lists the quantity of neutrons/sec/cm^2 to equal a rem at a specific neutron energy.

NRC 20.3 Para.19,C4

Neutron Flux Dose Equivalents

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm^2)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm^2 per sec).
Thermal	970×10^6	670
0.001	720×10^6	500
0.005	830×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

Neutron Flux:

Number of neutrons/sec emitted by a source.

Example: 500 mCi $AmBe^{241}$ source with 4 Mev equals 1.38×10^6 neutrons/per sec.

Calculation of the number of neutrons/sec/cm^2 at a given distance is achieved by dividing the total neutrons emitted by the total number of cm^2 on the sphere's surface area. The distance from the source at which this information is needed and used is the radius. For Kay-Ray neutron level 7100B, this distance is 9 inches in the store position.

4.0.7. Field Intensity Calculation - Cont'd.

A. Formula

$$N/SEC/CM^2 \text{ at "R" Distance} = \frac{N/SEC}{CM^2}$$

Where: "R" = Desired Distance, for field present.

$$CM^2 = 4\pi R^2$$

B. Given: Kay-Ray 7100B, the source in store position, capsule of $AmBe^{241}$ located 9" or 22.86 cm from surface of neutron sensor.

C. Using formula, solve for number of cm^2 at the desired measurement point first.

I.E.

$$4\pi R^2 = 4x3.14x22.86^2$$

$$= 12.57x522.58$$

$$= 6568.83(cm^2)$$

D. To find $neutron/sec/cm^2$ for 500 mCi $AmBe^{241}$.

Divide: $1.38x10^6$ = 210.083 $N/SEC/CM^2$ @ 9" (or 22.86 cm)

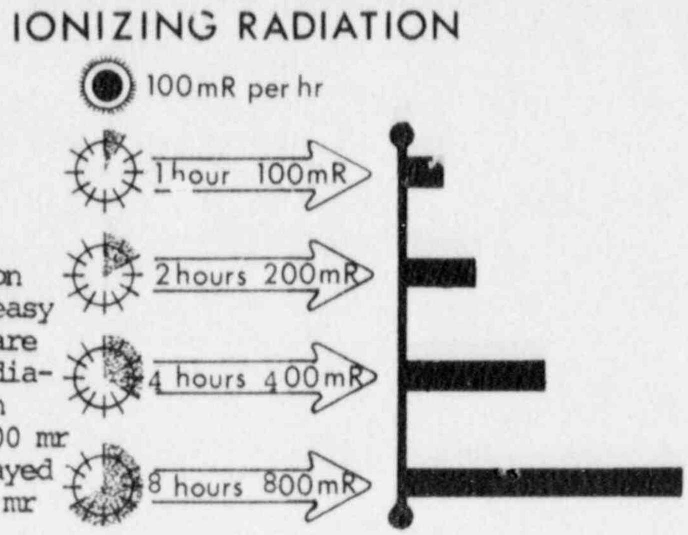
E. From NRC part 20.3 Para. 19, C4, Use the closest Mev value to obtain the average flux to deliver 100 mr in 40 hrs. (5 Mev = $26x10^6$ = 18 flux)

I.E. $\frac{210.083}{18}$ = 11.67 flux

mr/hr @ 9" = $11.67 \times \frac{100}{40}$

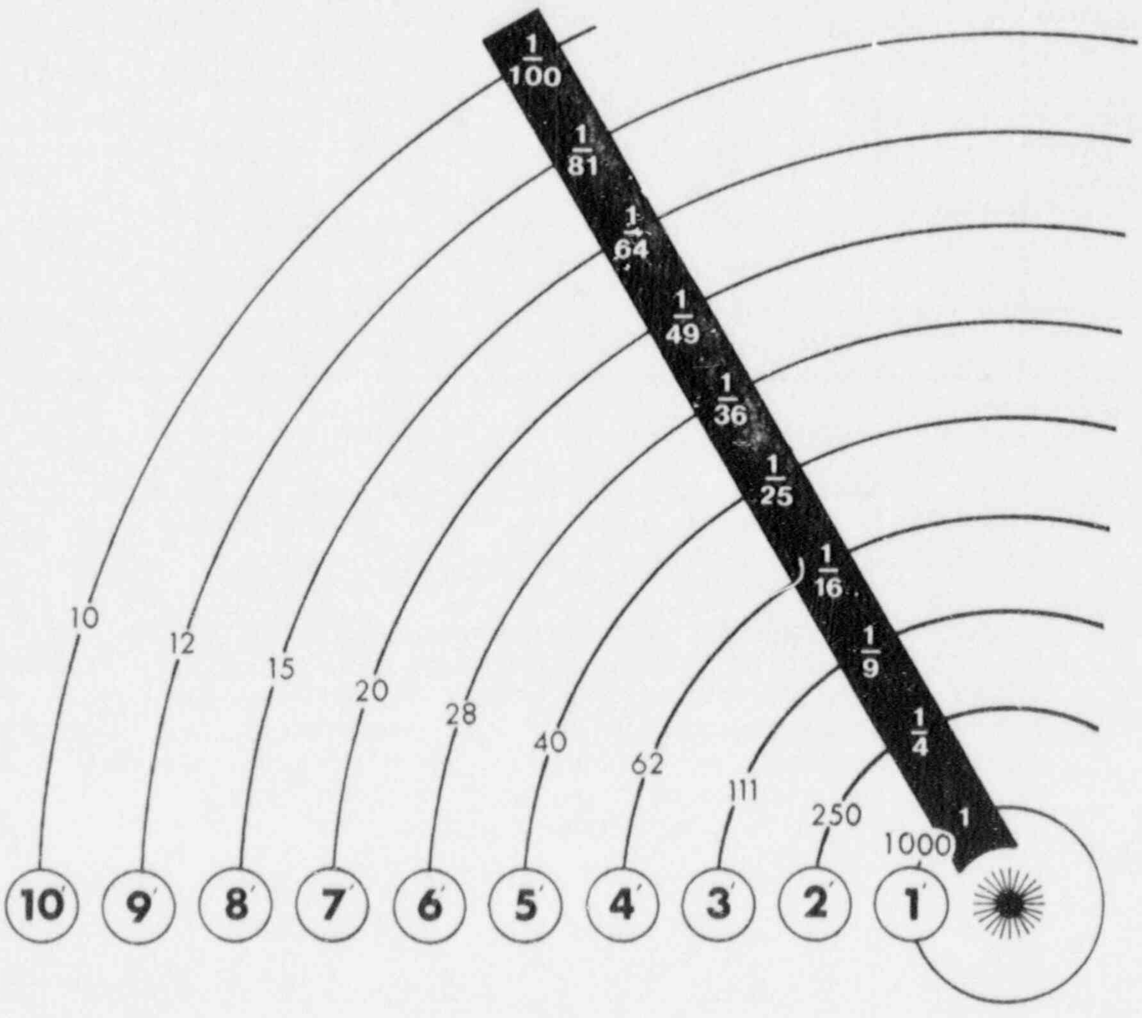
= 11.67 x 2.5

= 29.18 mr/hr @ 9"



The effect of time on radiation exposure is easy to understand. If we are in an area when the radiation is 100 mR/hr, then in 1 hr we would get 100 mr (millirems). If we stayed 2 hr, we would get 200 mr and so on.

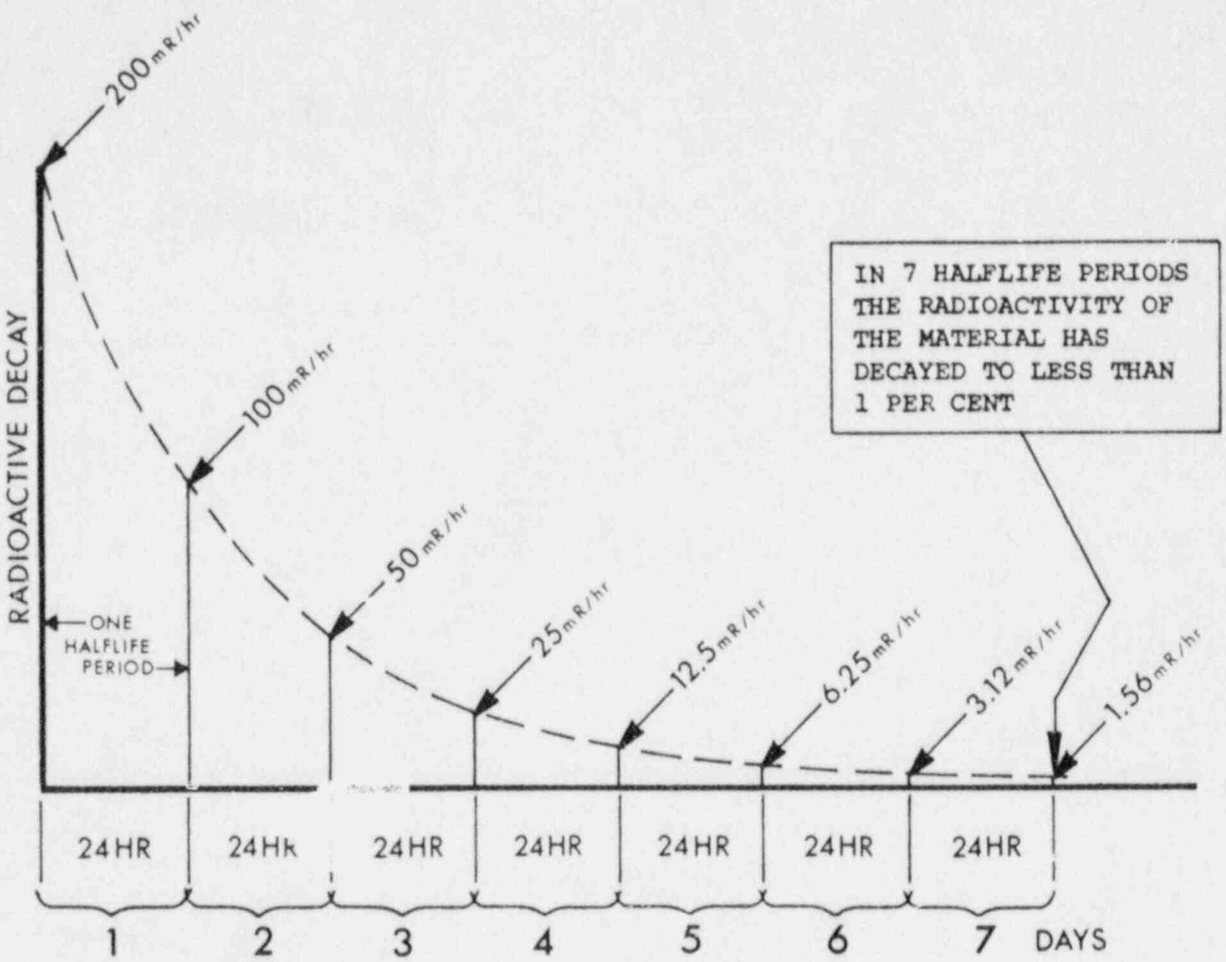
From U.S. Atomic Energy Commission; "Living with Radiation, Part 1 - Fundamentals."



The effect of distance on radiation exposure follows the inverse-square law - the intensity of the radiation falls off by the square of the distance from the source. If we had a point source of radiation giving 1000 units of penetrating external radiation at 1 ft, we would receive only one-fourth as much, or $(\frac{1}{2})^2$, if we double our distance to 2 ft. If we triple the distance, we reduce the dose to one-ninth, or $(1/3)^2$.

From U.S. Atomic Energy Commission, "Living with Radiation, Part 1 - Fundamentals."

FIGURE 4-3



Decay of a radioactive material with a 24-hr half-life. If a contaminant has a short half-life, it is sometimes simpler to allow the area to remain idle until the radioactivity has died off by the natural process of the passage of sufficient half-lives. If, for example, the reading was 100 mR/hr in a room contaminated with a 24-hr half-life gamma emitter, in 24 hr the reading would be down to 50 mR/hr; in another 24 hr, it would be down to 25 mR/hr; and so on, as illustrated here.

From U.S. Atomic Energy Commission,
"Living with Radiation, Part 1 - Fundamentals."

FIGURE 4-4

SPECIFIC ACTIVITY TABLE

Radionuclide	Half-Life	Curies per gram	Radionuclide	Half-Life	Curies per gram
Hydrogen-3	12.3 yr.	9.64×10^{3}	Molybdenum-99	67 hr.	4.72×10^{5}
Carbon-14	5730 yr.	4.46	Technetium-99	6.0 hr.	5.28×10^{6}
Nitrogen-16	7.2 sec.	9.79×10^{10}	Ruthenium-106	367 dy.	3.36×10^{3}
Sodium-22	2.60 hr.	6.25×10^{3}	Iodine-125	60 dy.	1.74×10^{4}
Sodium-24	15.0 hr.	8.71×10^{6}	Iodine-130	12.4 hr.	1.94×10^{6}
Phosphorus-32	14.3 dy.	2.85×10^{5}	Iodine-131	8.05 dy.	1.24×10^{5}
Sulfur-35	88 dy.	4.24×10^{4}	Barium-133	7.2 yr.	374
Chlorine-36	3.1×10^{5} yr.	3.21×10^{-2}	Cesium-134	2.05 yr.	1.30×10^{3}
Argon-41	1.83 hr.	4.18×10^{7}	Cesium-137	30.0 yr.	87.0
Potassium-42	12.4 hr.	6.02×10^{6}	Barium-140	12.8 dy.	7.29×10^{4}
Calcium-45	165 dy.	1.76×10^{4}	Lanthanum-140	40.22 hr.	5.57×10^{5}
Chromium-51	27.8 dy.	9.21×10^{4}	Cerium-141	33 dy.	2.81×10^{4}
Manganese-54	303 dy.	7.98×10^{3}	Cerium-144	284 dy.	3.19×10^{3}
Iron-55	2.6 yr.	2.50×10^{3}	Praseodymium-144	17.3 mon.	7.55×10^{7}
Manganese-56	2.576 hr.	2.17×10^{7}	Promethium-147	2.62 yr.	929
Cobalt-57	270 dy.	8.48×10^{3}	Tantalum-182	115 dy.	6.24×10^{3}
Iron-59	45 dy.	4.92×10^{4}	Tungsten-185	75 dy.	9.41×10^{3}
Nickel-59	8.10 yr.	7.58×10^{-2}	Iridium-192	74.2 dy.	9.17×10^{3}
Cobalt-60	5.26 yr.	1.13×10^{3}	Gold-198	64.8 hr.	2.44×10^{5}
Nickel-63	92 yr.	61.7	Gold-199	75.6 hr.	2.08×10^{5}
Copper-64	12.8 hr.	3.83×10^{6}	Mercury-203	46.9 dy.	1.37×10^{4}
Zinc-65	245 dy.	8.20×10^{3}	Thallium-204	3.8 yr.	462
Gallium-72	14.1 hr.	3.09×10^{6}	Polonium-210	138.4 dy.	4.49×10^{3}
Arsenic-76	26.5 hr.	1.56×10^{6}	Polonium-212	304 ns.	1.75×10^{17}
Bromine-82	35.34 hr.	1.08×10^{6}	Radium-226	1602 yr.	0.988
Rubidium-86	18.66 dy.	8.14×10^{4}	Thorium-232	1.41×10^{10} yr.	1.09×10^{-7}
Strontium-89	52 dy.	2.82×10^{4}	Uranium-233	1.62×10^{5} yr.	9.48×10^{-3}
Strontium-90	28.1 yr.	141	Thorium-2[illegible]	24.1 dy.	2.32×10^{4}
Yttrium-90	64 hr.	5.44×10^{5}	Uranium-234	7.1×10^{8} y	2.14×10^{-6}
Yttrium-91	58.8 dy.	2.44×10^{4}	Uranium-238	4.51×10^{9} yr.	3.33×10^{-7}
			Plutonium-239	2.44×10^{4} yr.	6.13×10^{-2}

FIGURE 4-5

DECAY TABLE

CESIUM-137 Years	CESIUM-137 Percent of Radiation	COBALT-60 Years	COBALT-60 Percent of Radiation
0	100.00	0	100.00
1	97.72	1	87.61
2	95.49	2	76.76
3	93.30	3	67.25
4	91.17	4	58.92
5	89.09	5	51.62
6	87.06	6	45.22
7	85.07	7	39.62
8	83.13	8	34.71
9	81.23	9	30.41
10	79.37	10	26.65
11	77.56	11	23.34
12	75.79	12	20.45
13	74.06	13	17.92
14	72.37	14	15.70
15	70.71	15	13.75
16	69.10		
17	67.52		
18	65.98		
19	64.47		
20	63.00		
21	61.56		
22	60.16		
23	58.78		
24	57.44		
25	56.13		
26	54.85		
27	53.59		
28	52.37		
29	51.17		
30	50.00		

FIGURE 4-6

Expected Effects of Acute Whole-body Radiation Doses

Acute dose (r)	Probable Effect
0-50	No obvious effect, except possibly minor blood changes.
80-120	Vomiting and nausea for about 1 day in 5-10% of exposed personnel. Fatigue but no serious disability.
130-170	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25% of personnel. No deaths anticipated.
180-220	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50% of personnel. No deaths anticipated.
270-330	Vomiting and nausea in nearly all personnel on first day, followed by other symptoms of radiation sickness. About 20% deaths within 2-6 weeks after exposure; survivors convalescent for about 3 months.
400-500	Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness. About 50% deaths within 1 month; survivors convalescent for about 6 months.
550-750	Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100% deaths; few survivors convalescent for about 6 months.
1000	Vomiting and nausea in all personnel with 1-2 hours. Probably no survivors from radiation sickness.
5000	Incapacitation almost immediately. All personnel will be fatalities within 1 week.

Dose (within a factor of 2 or 3)	Effects and Conditions
100,000 r	Spastic seizures; death within seconds; sperm motility stopped.
10,000 r	Disruption of central nervous system function; death within minutes or hours.
1,000 r	Necrosis of progenitive tissues; 100 percent death in 30 to 60 days.
100 r	Mild irradiation sickness in part of the organism; no deaths.
10 r	Few or no detectable effects.
10 r/day	Debilitation in 3 to 6 weeks; death in 3 to 6 months (projected from animal data).
1 r/day	Debilitation in 3 to 6 months, death in 3 to 6 years (projected from animal data).
0.1 r/day	Permissible dose range 1930–50.
0.01 r/day	Permissible dose range 1957.
0.001 r/day	Natural radiation.

FIGURE 4-8

SECTION 5

INSTRUCTIONS FOR BY-PRODUCT LICENSING

5.0.0 INSTRUCTIONS FOR BY-PRODUCT LICENSING

Outline:

1. Introduction
2. NRC Regulations Outline
3. General License Instruction Plate
4. Form NRC-313
5. Guide for Preparing a By-Product License
6. Procedure for Wiping Source Holders (Licensed Personnel Only)
7. Emergency Procedure to be Followed After Damage to Kay-Ray Source Holders
8. Customer Return Procedure
9. Licensing Officials in Agreement States

5.0.1 Introduction

A. Most radioactive material used in gauging devices is regulated by the U. S. Nuclear Regulatory Commission. The NRC issues licenses to users and manufacturers of gauging devices utilizing radioactive materials and inspects sites where materials are being used to determine that the material is being handled properly, safely, and in compliance with the terms of the license.

B. The NRC has issued rules on: 1) the licensing of radioactive materials and devices (10 CFR Part 30), and 2) radiation safety (10 CFR Part 20). A copy of these regulations is located in Section 5. Also, a brief outline of the regulations is given in this section.

C. During 1962 the NRC began entering into agreements with individual states to transfer regulatory authority to them. Known as Agreement States, their regulations closely parallel those of the NRC and are essentially identical except that the Agreement States usually regulate the use of all radiation-producing devices. Thus, the attached NRC regulations are generally applicable.

5.0.2 NRC Regulations Outline

A copy of Title 10 Code of Federal Regulations, Parts 19, 20, 30, and 31, is located in Section 6. This should be read thoroughly to become familiar with the laws governing the use of radioactive materials. Some of the more important regulations are given below. The CFR paragraph numbers are shown in parentheses.

A. The "Individual User" listed on the "Application for By-Product Material License" (NRC-313) is responsible for the source. If this person is transferred or is changed to a position where he is no longer responsible for the source, the license must be amended prior to the assignment of the new "User" (30.32, 30.33, 30.34, 30.38).

B. Use of the source is usually licensed for a particular plant site. If the source is transferred to a different plant site, the license must be amended prior to the transfer (30.34c, 30.38).

C. A record of the initial radiation survey must be kept for reference (20.401b).

D. A record of the periodic leak test must be maintained.

E. A label must be attached to the source holder, or source well, stating the type and quantity of radioactive material and the date of manufacture. The label must bear the conventional radiation symbol (20.203).

F. The area in the vicinity of the source must be posted with a radiation warning sign if the radiation field is greater than 5 mR/hr at a distance of 12 inches from the surface of the gauge (20.203, 20.204a).

G. Personnel monitoring is required when personnel are apt to receive a dose in excess of 312 mrem per quarter, or when they enter a radiation field greater than 100 mR/hr (20.202).

H. Disposal of nuclear sources must be by transfer to an authorized recipient (20.301a). Also see "Customer Return Procedure" (Section 5.0.8).

5.0.2 NRC Regulations Outline - Cont'd.

I. The Regional Operations Office of the NRC must be notified of any incident, such as fire or explosion, which involves the radioactive material used in the gauge (20.403). Kay-Ray, Inc. should also be notified.

J. If personnel monitoring is required (20.202a), a record of the radiation exposure must be kept on NRC-5 (20.401a, c) and, if the employee requests it, written notification must be given annually or upon termination of employment (10.13, 20.406, 20.404).

K. If a person receives more than 1.25 rem per calendar quarter, notification must be made in writing both to that person and the NRC (20.405).

L. A "Restricted Area" is defined in Parts 19.3 and 20.3; the permissible exposure to individuals in a restricted area is given in Part 20.101. An "Unrestricted Area" is defined in Parts 19.3 and 20.3; the permissible level of radiation in an unrestricted area is given in Part 20.105.

M. Any area where an individual, if continuously present, can receive a dose in excess of 2 mrem in any one hour or where he can receive more than 100 mrem in seven consecutive days, must be treated as a restricted area and access thereto must be under the control of the licensee.

N. Employees working in or frequenting a restricted area must be advised of the restriction by posting of Form NRC-3 (19.11, 20.203). The NRC regulations state that this form must be posted so that employees can "observe copy on the way to or from their place of employment" in the restricted area. Thus NRC-3 could be posted at or near the entry into the restricted area. If personnel do not work in or frequent a restricted area, Form NRC-3 need not be posted.

5.0.3 General License Instruction Plate

1. "The receipt, possession, use, and transfer of this device are subject to a general license or the equivalent and the regulations of the U.S. NRC or a State with which the NRC has entered into an agreement for the exercise of regulatory authority.

2. "Abandonment or disposal prohibited unless transferred to persons specifically licensed by NRC or an Agreement State.

3. "Operation prohibited if there is indication of failure of, or damage to containment of radioactive material.

4. "Installation, dismantling, relocation, repair, or testing shall be performed by persons specifically licensed by NRC or an Agreement State.

5. "Device shall be tested for leakage of radioactive material and proper functioning of the ON-OFF mechanism and indicator, if any. This testing shall not exceed an interval of 3 years.

6. "If there is any indication of failure of, or damage to, this source housing or shutter mechanism or if loss or theft of this device is discovered or if this device is transferred, operation should be suspended, if applicable, and Kay-Ray, Inc. should be notified immediately for corrective action."

TITLE GENERAL LICENSE INSTRUCTION PLATE				KAY-RAY INC. Arlington Heights, Illinois USA
SCALE: FULL				
TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONAL: ±1/64 DECIMAL: ±.005 ANGULAR: ±30 MIN.				DWN BY BENDLER — DATE 12-20-74
NO.	REVISIONS	DATE	APP.	APP. BY [illegible] — DATE 12/30/74
1	[illegible]	[illegible]		DWG. NO. 620-000202
2	DWG NO. WAS PB-202	[illegible]	[illegible]	
3				
4				

5.0.4 Form NRC-313

Form NRC-313 (I)
(3-80)
10 CFR 30

U.S. NUCLEAR REGULATORY COMMISSION

Form Approved by GAO
B-180225(RO579)

INSTRUCTIONS FOR PREPARATION OF APPLICATION FOR BYPRODUCT MATERIAL LICENSE

FORM NRC-313 (I)

GENERAL INFORMATION

An applicant for a "Byproduct Material (Radioisotopes) License," should complete Form NRC-313 (I) in detail and submit in duplicate to the U.S. Nuclear Regulatory Commission. The applicant should endeavor to cover his entire radioistope program with one application, if possible. However, separate applications should be submitted for gamma irradiators. Applications for medical uses should be submitted on Form NRC-313 (M) and applications for use of sealed sources in radiography should be submitted on Form NRC-313R. Supplemental sheets may be appended when necessary to provide complete information. *Item 18 must be completed on all applications. Submission of an incomplete application will often result in a delay in issuance of the license because of the correspondence necessary to obtain information requested on the application.*

NOTE. –When the application includes one of the special uses listed below, the applicant should request the appropriate pamphlet which provides additional instructions:

1. Industrial Radiography–"Licensing Requirements for Industrial Radiography" (use application Form NRC-313R for Radiography);
2. Laboratory and Industrial Uses of Small Quantities–"Guide for Preparation of Applications for Laboratory and Industrial Uses of Small Quantities of Byproduct Material."
3. Broad License (research and development)–"Licensing Guide for Type-A Licenses of Broad Scope for Research and Development;"
4. Licensing Guides for the performance of well logging operations.
5. Licensing guide for the use of sealed sources in portable and semiportable gauging devices.

The Commission charges fees for filing of applications for licenses as specified in Section 170.12, Title 10, Code of Federal Regulations, Part 170. The applicant should refer to Section 170.31, *Schedule of fees for materials licenses,* to determine what fee should accompany the application. No action can be taken on applications until fees are paid. Checks or money orders should be made payable to the U.S. Nuclear Regulatory Commission.

Two copies of the completed Form NRC-313 (I) and two copies of each attachment thereto, should be sent to the Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. One copy should be retained for the applicant's file. Applications may also be filed in person at the Commission's office at 1717 H Street, N.W., Washington, D.C. or at 7915 Eastern Avenue, Silver Spring, Maryland.

EXPLANATION OF FORM NRC-313 (I)

Form NRC-313 (I) is designed for use in supplying information on programs of varying complexity. The applicant should provide complete information on his proposed program for the possession and use of licensed material. For those items that do not apply, indicate as N.A. (not applicable).

Item No.

1. Self-explanatory
2. The "applicant" is the organization or persons legally responsible for possession and use of the licensed materials specified in the application.
3. Self-explanatory
4. Self-explanatory
5. The actual sites of use should be listed as indicated. Permanent facilities such as field offices for portable gauges or devices should be identified in Item 5 by Street, Address, City and State. Temporary field locations of use should be specified as "temporary job sites of the applicant" and list the States throughout which the temporary job sites will be located. Attach additional properly keyed sheet if more space is needed.
6. Self-explanatory
7. The "Radiation Protection Officer" is the named individual who is expected to coordinate the safe use of the licensed material specified in the application and who will ensure compliance with the applicable parts of Title 10, Code of Federal Regulations.

5.0.4 Form NRC-313 - Cont'd.

8. List by name each radioisotope to be possessed and used under the license. Example:

A	B
(1) Iodine-131	(1) Iodide
(2) Iodine-131	(2) Iodinated Human Serum Albumin
(3) Krypton-85	(3) Gas
(4) Cesium-137	(4) Sealed Source

C	D
(1) Not Applicable	(1) 10 millicuries
(2) N. A.	(2) 1 millicurie
(3) N. A.	(3) 1 millicurie
(4) Iso. Corp Model Z-78	(4) 2 source of 150 millicuries each

Attach additional properly keyed sheets if more space is needed.

8.E State the use of each licensed material listed in 8.A, B, C, and D.

9. Description of containers and/or devices in which sealed sources listed in Item 8 will be stored or used. Example:

A	B
(1) #4 – Source housing	Iso. Corp

C
Model Z-278

10-18 Self-explanatory. (For those items that do not apply, indicate as N.A. (not applicable).

PRIVACY ACT STATEMENT

Pursuant to 5 U.S.C. 552a(e)(3), enacted into law by section 3 of the Privacy Act of 1974 (Public Law 93-579), the following statement is furnished to individuals who supply information to the Nuclear Regulatory Commission on Forms NRC-313M, NRC-313a, NRC-313I, or NRC-313R. This information is maintained in a system of records designated as NRC-3 and described at 40 Federal Register 45334 (October 1, 1975).

1. AUTHORITY Sections 81 and 161(b) of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2111 and 2201(b)).

2. PRINCIPAL PURPOSE(S) The information is evaluated by the NRC staff pursuant to the criteria set forth in 10 CFR Parts 30-36 to determine whether the application meets the requirements of the Atomic Energy Act of 1954, as amended, and the Commission's regulations, for the issuance of a byproduct material license or amendment thereof.

3. ROUTINE USES The information may be used: (a) to provide records to State health departments for their information and use; and (b) to provide information to Federal, State, and local health officials and other persons in the event of incident of exposure, for their information, investigation, and protection of the public health and safety. The information may also be disclosed to appropriate Federal, State and local agencies in the event that the information indicates a violation or potential violation of law and in the course of an administrative or judicial proceeding. In addition, this information may be transferred to an appropriate Federal, State, or local agency to the extent relevant and necessary for a NRC decision or to an appropriate Federal agency to the extent relevant and necessary for that agency's decision about you. A copy of the license issued will routinely be placed in the NRC's Public Document Room, 1717 H Street, N. W., Washington, D.C.

4. WHETHER DISCLOSURE IS MANDATORY OR VOLUNTARY AND EFFECT ON INDIVIDUAL OF NOT PROVIDING INFORMATION Disclosure of the requested information is voluntary. If the request information is not furnished, however, the application for byproduct material license, or amendment thereof, will not be processed.

5. SYSTEM MANAGER(S) AND ADDRESS Director, Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

5.0.4 Form NRC-313 - Cont'd.

FORM NRC-313 I (3-80) 10 CFR 30 — U.S. NUCLEAR REGULATORY COMMISSION

APPLICATION FOR BYPRODUCT MATERIAL LICENSE
INDUSTRIAL

See attached instructions for details.

Completed applications are filed in duplicate with the Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety, and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555 or applications may be filed in person at the Commission's office at 1717 H Street, NW, Washington, D. C. or 7915 Eastern Avenue, Silver Spring, Maryland.

1. APPLICATION FOR: *(Check and/or complete as appropriate)*
   - a. NEW LICENSE
   - b. AMENDMENT TO: LICENSE NUMBER
   - c. RENEWAL OF: LICENSE NUMBER

2. APPLICANT'S NAME *(Institution, firm, person, etc.)*

   TELEPHONE NUMBER: AREA CODE – NUMBER EXTENSION

3. NAME AND TITLE OF PERSON TO BE CONTACTED REGARDING THIS APPLICATION

   TELEPHONE NUMBER: AREA CODE – NUMBER EXTENSION

4. APPLICANT'S MAILING ADDRESS *(Include Zip Code)* *(Address to which NRC correspondence, notices, bulletins, etc., should be sent.)*

5. STREET ADDRESS WHERE LICENSED MATERIAL WILL BE USED *(Include Zip Code)*

(IF MORE SPACE IS NEEDED FOR ANY ITEM, USE ADDITIONAL PROPERLY KEYED PAGES.)

6. INDIVIDUAL(S) WHO WILL USE OR DIRECTLY SUPERVISE THE USE OF LICENSED MATERIAL *(See Items 16 and 17 for required training and experience of each individual named below)*

FULL NAME	TITLE
a.	
b.	
c.	

7. RADIATION PROTECTION OFFICER

Attach a resume of person's training and experience as outlined in Items 16 and 17 and describe his responsibilities under Item 15.

8. LICENSED MATERIAL

LINE NO.	ELEMENT AND MASS NUMBER A	CHEMICAL AND/OR PHYSICAL FORM B	NAME OF MANUFACTURER AND MODEL NUMBER *(If Sealed Source)* C	MAXIMUM NUMBER OF MILLICURIES AND/OR SEALED SOURCES AND MAXIMUM ACTIVITY PER SOURCE WHICH WILL BE POSSESSED AT ANY ONE TIME D
(1)				
(2)				
(3)				
(4)				

	DESCRIBE USE OF LICENSED MATERIAL E
(1)	
(2)	
(3)	
(4)	

5.0.4 Form NRC-313 - Cont'd.

9. STORAGE OF SEALED SOURCES

LINE NO.	CONTAINER AND/OR DEVICE IN WHICH EACH SEALED SOURCE WILL BE STORED OR USED. A.	NAME OF MANUFACTURER B.	MODEL NUMBER C.
(1)			
(2)			
(3)			
(4)			

10. RADIATION DETECTION INSTRUMENTS

LINE NO.	TYPE OF INSTRUMENT A	MANUFACTURER'S NAME B	MODEL NUMBER C	NUMBER AVAILABLE D	RADIATION DETECTED *(alpha, beta, gamma, neutron)* E	SENSITIVITY RANGE *(milliroentgens/hour or counts/minute)* F
(1)						
(2)						
(3)						
(4)						

11. CALIBRATION OF INSTRUMENTS LISTED IN ITEM 10

☐ a. CALIBRATED BY SERVICE COMPANY

NAME, ADDRESS, AND FREQUENCY

☐ b. CALIBRATED BY APPLICANT

Attach a separate sheet describing method, frequency and standards used for calibrating instruments.

12. PERSONNEL MONITORING DEVICES

TYPE *(Check and/or complete as appropriate.)* A	SUPPLIER *(Service Company)* B	EXCHANGE FREQUENCY C
☐ (1) FILM BADGE ☐ (2) THERMOLUMINESCENCE DOSIMETER *(TLD)* ☐ (3) OTHER *(Specify)*: ____________		☐ MONTHLY ☐ QUARTERLY ☐ OTHER *(Specify)*: ____________

13. FACILITIES AND EQUIPMENT (Check were appropriate and attach annotated sketch(es) and description(s).

☐ a. LABORATORY FACILITIES, PLANT FACILITIES, FUME HOODS *(Include filtration, if any)*, ETC.

☐ b. STORAGE FACILITIES, CONTAINERS, SPECIAL SHIELDING *(fixed and/or temporary)*, ETC.

☐ c. REMOTE HANDLING TOOLS OR EQUIPMENT, ETC.

☐ d. RESPIRATORY PROTECTIVE EQUIPMENT, ETC.

14. WASTE DISPOSAL

a. NAME OF COMMERCIAL WASTE DISPOSAL SERVICE EMPLOYED

b. IF COMMERCIAL WASTE DISPOSAL SERVICE IS NOT EMPLOYED, SUBMIT A DETAILED DESCRIPTION OF METHODS WHICH WILL BE USED FOR DISPOSING OF RADIOACTIVE WASTES AND ESTIMATES OF THE TYPE AND AMOUNT OF ACTIVITY INVOLVED. IF THE APPLICATION IS FOR SEALED SOURCES AND DEVICES AND THEY WILL BE RETURNED TO THE MANUFACTURER, SO STATE.

5.0.4 Form NRC-313 - Cont'd.

INFORMATION REQUIRED FOR ITEMS 15, 16 AND 17

Describe in detail the information required for Items 15, 16 and 17. Begin each item on a separate page and key to the application as follows:

15. RADIATION PROTECTION PROGRAM. Describe the radiation protection program as appropriate for the material to be used including the duties and responsibilities of the Radiation Protection Officer, control measures, bioassay procedures *(if needed)*, day-to-day general safety instruction to be followed, etc. If the application is for sealed source's also submit leak testing procedures, or if leak testing will be performed using a leak test kit, specify manufacturer and model number of the leak test kit.

16. FORMAL TRAINING IN RADIATION SAFETY. Attach a resume for each individual named in Items 6 and 7. Describe individual's formal training in the following areas where applicable. Include the name of person or institution providing the training, duration of training, when training was received, etc.

    a. Principles and practices of radiation protection.

    b. Radioactivity measurement standardization and monitoring techniques and instruments.

    c. Mathematics and calculations basic to the use and measurement of radioactivity.

    d. Biological effects of radiation.

17. EXPERIENCE. Attach a resume for each individual named in Items 6 and 7. Describe individual's work experience with radiation, including where experience was obtained. Work experience or on-the-job training should be commensurate with the proposed use. Include list of radioisotopes and maximum activity of each used.

18. CERTIFICATE

(This item must be completed by applicant)

The applicant and any official executing this certificate on behalf of the applicant named in Item 2, certify that this application is prepared in conformity with Title 10, Code of Federal Regulations, Part 30, and that all information contained herein, including any supplements attached hereto, is true and correct to the best of our knowledge and belief.

WARNING.–18 U.S.C., Section 1001; Act of June 25, 1948; 62 Stat. 749; makes it a criminal offense to make a willfully false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

a. LICENSE FEE REQUIRED *(See Section 170.31, 10 CFR 170)*	b. CERTIFYING OFFICIAL *(Signature)*
	c. NAME *(Type or print)*
(1) LICENSE FEE CATEGORY:	d. TITLE
(2) LICENSE FEE ENCLOSED: $	e. DATE

5.0.5 Guide for Preparing a By-Product License

The following is a guide for the user of nuclear instrumentation. This guide was prepared by the Nuclear Regulatory Commission, Division of Fuel Cycle and Material Safety, Material Licensing Branch, Washington in March of 1980. It attempts to inform the user as to requirements for possession and/or maintenance of equipment containing a sealed source.

Introduction: This guide describes the information needed to evaluate applications for specific licenses for receipt, possession, and use of sealed sources containing by-product material in nonportable gauging devices, i.e., gauges mounted in "fixed" locations, for measurement and/or control of material density, flow, level, thickness, weight, etc. In addition to the contents of this guide, applicants should refer to the requirements in the Commission's regulations listed below. The applicant should carefully read the regulations. This guide is not a substitute for an understanding of the regulations.

A. 10 CFR Part 19, "Notices, Instructions, and Reports to Workers; Inspections".

B. 10 CFR Part 20, "Standards for Protection Against Radiation".

C. 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of By-Product Material".

D. 10 CFR Part 170, "Fees for Facilities and Materials Licenses, and Other Regulatory Services Under the Atomic Energy Act of 1954, as Amended".

Fees: The applicant should refer to 10 CFR Part 170, Section 170.31 "Schedule of Fees for Materials Licenses and Other Regulatory Services", to determine the amount of the fees which must accompany the application. No action will be taken on applications filed without the proper fee. Checks should be made payable to the U. S. Nuclear Regulatory Commission.

Filing an Application: Two copies of Form NRC-313 should be submitted in accordance with the instructions on the form and should provide, as a minimum, the information described in this guide. Since licensees are required to comply with Commission rules and regulations, license conditions, and the content of the submitted application, we suggest that the applicant prepare and retain one copy for reference. Space on the form is limited; additional information should be provided on attachments to each copy of the form. Attachments should clearly reference the applicable items on the form for which additional information is being provided.

5.0.5 Guide for Preparing a By-Product License - Cont'd.

Applications should contain sufficient information to enable the Commission to have a clear understanding of the activities to be performed by the applicant. Submittal of insufficient information will result in delays in issuance of the license. Applications should be mailed to:

Nuclear Regulatory Commission
Division of Fuel Cycle and Material Safety
Material Licensing Branch
Washington, D.C. 20555

Except for Item 1, which is self-explanatory, the following provides a discussion of the minimum information needed for each item on Form NRC-313.

Items 2, 3, 4, and 5 - Applicant, Mailing Address, and Locations of Use: The applicant, corporation, or other legal entity should be specified by name in Item 2 and mailing address in Item 4. The name and telephone number of the individual who should be contacted concerning the application should be provided in Item 3. Individuals should be designated as the applicant only if they are acting in a private capacity and the use of by-product material is not connected with their employment with a corporation or other legal entity.

The actual location(s) where the by-product material in sealed sources, source holders, gauges, etc., will be possessed, stored, and/or used should be specified in Item 5. Such location(s) should be clearly identified by road or street name, number, city, and state. A Post Office box number should not appear in Item 5.

Item 6 - Individual Users: The name of the individual(s) who will use (operate) and/or supervise the use of the devices listed in the application must be listed in Item 6. An adequate number of trained users should be listed to provide for continuity of operations. Normally, an individual user should be physically present when the devices are in use.

Item 7 - Radiation Protection Officer: Normally, it is not necessary for users of nonportable gauging devices to designate a radiation protection officer unless there are multiple users and gauges within the plant or facility. However, the applicant should list the name in Item 7 of an individual user, supervisor, foreman, or other designated individual who has been assigned responsibilities for determining that:

A. All by-product materials, sealed sources, and devices in use and/or in the possession of the applicant are limited to those listed in the license and are being used for the purposes specified in the license.

B. Only those individuals authorized by the license use or supervise use of the devices.

5.0.5 Guide for Preparing a By-Product License - Cont'd.

C. Periodic leak tests of the sealed sources are conducted as required by the license.

D. The established "lock-out" procedures are followed during maintenance or repairs on or around the pipes, tanks, vessels, conveyors, etc., to prevent individuals from entering the radiation beams. (As shown in Item 15 of this guide, "lock-out" procedures must be described in the application for certain types of devices.)

Item 8 - By-Product Material, Forms, and Uses: Each radioisotope to be used should be specified in Item 8.A; Item 8.B should show that the by-product material to be possessed and used is in the form of sealed source(s). The name of the manufacturer and model number of the sealed source should be shown in Item 8.C, and the total activity, in millicuries, in the sealed source should be provided in Item 8.D. Item 8.E should specify the manufacturer and model number of each gauge, source holder, or device in which the by-product material and sealed source described in Items 8.A through 8.D will be used. In addition, Item 8.E should describe the purpose for which the device will be used. Some examples of the kinds of information to be provided in Item 8 are as follows:

8.A	8.B	8.C	8.D	8.E
Cesium-137	Sealed sources	XYZ, Inc. Model XYZ-1	Not to exceed 100 milli-curies per source	For use in an ABC Company Model 22 source holder to control level of coke in hoppers.
Cobalt-60	Sealed sources	Mesa Verde Inc. Model A-34	Not to exceed 1500 milli-curries per source	For use in Grand Mesa Inc. Model 3201 source hold-ers to control level of molten glass in furnace.
Cobalt-60	Sealed sources	Rio Grande Inc. Model RG-1	Not to exceed 500 milli-curies per source	For use in Ojeto Inc. Model X-12 holders for den-sity control of concrete-sand mixture in mixer.

Item 9 - Storage of Sealed Sources: Since sealed sources are normally removed from gauging devices by the manufacturer or supplier of the devices, it is only necessary to reference Item 8 in Item 9.A of the application for information regarding storage devices, i.e., storage in the gauging devices only. Applicants who will remove or relocate gauging devices (refer to Specific Authorizations in this guide) should describe storage devices (if any) and storage areas (refer to Item 13 - Facilities and Equipment, in this guide).

5.0.5 Guide for Preparing a By-Product License - Cont'd.

Items 10 and 11 - Radiation Detection Instruments: For routine use of devices, radiation survey and measuring instruments are not normally required. Applicants who will perform other activities which require the use of radiation detection instruments should provide the applicable information described in Specific Authorizations of this guide.

Item 12 - Personnel Monitoring: For routine use of devices, the use of personnel monitoring devices (film badges or thermoluminescent dosimeters) are not normally required. Applicants who want to perform non-routine activities which will require the use of personnel monitoring devices should provide the name of the supplier of the monitoring devices and the frequency of exchange for processing by the supplier. For guidance concerning personnel monitoring requirements, the applicant should refer to 10 CFR Part 20, Section 20.202.

Item 13 - Facilities and Equipment: The applicant should provide a description of the equipment and facilities to utilize the devices containing the by-product material. A simple annotated sketch or drawing showing where each device is installed and the location of adjacent ladders, aisles, or work areas employees will occupy should be provided.

Item 14 - Waste Disposal: The applicant should describe the disposal method for sealed sources containing by-product material when use of the devices containing the by-product material is discontinued. If the supplier will remove the devices and sealed sources from the applicant's facility for disposal, this should be so stated in the application. If persons or a company other than the supplier will remove the devices and sealed sources from the applicant's facility for return to the supplier or transfer to an authorized recipient, the number of the NRC or Agreement State license which authorizes removal and disposal of the applicant's sealed sources should be provided.

If the applicant will remove devices containing sealed sources for return to the manufacturer or for transfer to another authorized person for disposal, this should be stated in the application. Specific Authorizations, Paragraph A, of this guide specifies the additional information which should be provided in the application for authorization to perform this operation.

Item 15 - Radiation Protection Program: For routine use of devices, the applicant should provide the following information:

A. The name of the company or person who will conduct servicing operations involving installations, relocations, removals, initial radiation surveys, maintenance, repairs, and removal of the devices containing licensed material and installation, replacement, and disposal of sealed sources containing licensed material used in the devices. If any of these operations will be performed by someone other than the supplier of the device, the applicant should provide the name and the number of the NRC or Agreement State license which authorizes performance of these operations. Applicants who request authorization to perform any of the above servicing operations should provide the information described in Specific Authorizations, Paragraph A,

5.0.5 Guide for Preparing a By-Product License - Cont'd.

B. A description of how access to the devices containing by-product material will be controlled (barriers, warning signs, remote or inaccessible locations, control by individual users, etc.)

C. For use of a device where it is possible for a major portion of an individual's body to receive exposure to the radiation beam from the device, a description of "lock-out" procedures, (i.e., procedures for preventing employees from entering the radiation beam during maintenance, repairs, or other work on or around the bin, tank, hopper, pipe, etc., on which the device is mounted) should be submitted. If the device shutter or switch is locked, bolted, "tagged-off", etc. until the work is completed, the applicant should describe this and provide the name of the individual(s) responsible for enforcing this procedure.

D. The procedures for leak testing of the sealed sources. If the supplier of the devices containing the sealed sources will perform leak tests of the sealed source in the applicant's facility, it is only necessary for the applicant to state this and to specify the frequency of the leak tests. If the applicant plans to use a leak test kit, the name of the supplier and the model number of the leak test kit should be specified. Applicants who will perform their own leak tests (collect the leak test wipes and analyze the wipes), should provide the information described in Specific Authorizations, Paragraph B, of this guide.

The required frequencies for leak testing of sealed sources in non-portable devices range from three months for alpha-emitting by-product material to six months for beta-gamma emitters. Some sealed source/device combinations containing beta-gamma emitters have leak test frequencies not to exceed three years. Information concerning sealed sources and devices which have three year leak test frequencies may be obtained from suppliers and/or manufacturers. Unless a specific request for the three year leak test frequency is included in the application, a six-month frequency will be specified in licenses.

Items 16 and 17 - Qualifications of Individual Users: The training and/or experience of each individual named in Item 6 of the application must be commensurate with the requested use and should be described in attachments for Items 16 and 17. For routine use of devices containing sealed sources, the training provided by the manufacturers at the time of installation is sufficient to qualify individual users. Training for non-routine operations (installation, re-location, removal from service, etc.) or training provided by someone other than the device manufacturer must be described in detail and submitted as an attachment to the application. As a minimum, the following information should be submitted:

5.0.5 Guide for Preparing a By-Product License - Cont'd.

A. The names and qualifications of the instructors.

B. An outline of the training program.

C. The duration of the training program.

D. The method for determining trainee competency.

Item 18 - Certification: The application should be signed and dated by an official representative of the applicant, i.e., the Plant Manager, Department or Division Head, Safety Supervisor, etc., to certify that the application contains information which is true and correct to the best of the applicant's knowledge and belief. Applications which are unsigned will be returned for proper signature.

Amendment of Licenses: Applications for amendment of existing licenses may be filed in the same manner as initial applications or may be filed in letter form. The application should clearly identify the license to be amended by license number and specify the exact nature of the requested changes to the license. Additional supporting information, as necessary, should be provided.

Renewal of Licenses: Applications for renewal of licenses filed at least thirty (30) days prior to the expiration date shown in the license remain in effect until final action has been completed on the application. Applications filed after the expiration date are considered to be new applications. Applicants needing additional time to prepare renewal applications should submit written requests for extension of the license expiration date.

Renewal applications should contain complete and up-to-date information concerning the applicant's activities to be conducted under the license. General references to previously submitted information (i.e., see previous applications, see previous amendment, etc.) or submittal of copies of the current license are not acceptable. Form NRC-313 should be completed in its entirety and documents submitted with the application should describe the applicant's current program.

Applicants may reference previous applications and/or documents in renewal applications provided these are clearly identified by date. Where portions of previously submitted applications and/or documents will be referenced in the renewal application, these should be clearly identified by date, attachment number, section number, and page number.

Specific Authorizations: This section describes the information applicants must provide in applications to the Commission for specific authorizations to perform any of the following operations:

A. Servicing operations on devices containing by-product materials.

B. Leak testing of sealed sources except by means of leak test kits.

C. Calibration of radiation survey and measuring instruments.

5.0.5 Guide for Preparing a By-Product License - Cont'd.

Each of these are discussed, in order, in the following:

A. Servicing Operations: Applicants who want to perform operations on devices involving installation, relocation, maintenance, repair, removal for disposal, performance of radiation surveys following installation, etc., should provide the following information:

a. The specific device(s) on which the operations are to be performed.

b. A description of each specific operation to be performed.

c. The step-by-step procedures to be followed in performing each operation including a description of the radiation safety procedures which will be followed.

d. The name of each individual who will perform the services.

e. An outline of the training received by each individual who will perform the operation. This training should include instructions in the performance of each specific operation, the step-by-step procedures to be followed, radiation safety and the use of radiation survey instruments, "lock-out" procedures, i.e., procedures for securing the device shutters and/or switches in the closed or shielded position, and, if applicable, personnel monitoring requirements.

f. A description of the qualifications of the individual(s) who provided the training in servicing of devices.

g. If operations are performed which require radiation surveys (i.e., installations or removals), a description should be provided to show the locations of the radiation measurements and the kinds of records to be maintained of the results.

B. Leak Testing of Sealed Sources: Applicants who want to perform leak tests of sealed sources, i.e., collect the wipe tests and analyze the results, should provide the following information:

a. The name and qualifications of each individual who will perform the leak tests.

b. Procedures and materials to be used in collecting test samples.

c. The type, manufacturer's name, model number, and radiation detection and measurement characteristics of the instrument to be used for assay of test samples.

d. Instrument calibration procedures, including the name of the manufacturer and model number of each standard source to be used, the nuclide and quantity of radioactive material in each standard source, the step-by-step calibration procedures to be followed, and the name and the experience and training of each

5.0.5 <u>Guide for Preparing a By-Product License</u> - Cont'd.

individual who will perform the calibrations. In providing information concerning the standard sources used in calibrations, applicants should provide information concerning the accuracy of each source used. Each source should be, as a minimum, ±5 percent of the stated value and traceable to a primary standard, such as that maintained by the National Bureau of Standards.

e. The method, including a sample calculation, used to convert instrument readings to units of activity, i.e., microcuries.

C. Radiation Survey Instruments: If the applicant will perform activities requiring the use of radiation survey instruments, each instrument should be described. The manufacturer's name, model number, and the range of each instrument should be provided. If the applicant will perform calibrations of the radiation survey instruments, the following information should be provided.

a. The manufacturer and model number of each radiation source to be used.

b. The nuclide and quantity of radioactive material contained in each source.

c. The accuracy of the source(s). The traceability of the source to a primary standard should be provided.

d. The step-by-step procedures, including associated radiation safety procedures.

e. The name and the experience and training in instrument calibrations for each person who will perform the calibrations.

If the applicant intends to contract out the calibration of instruments, the name, address, and license number of the firm should be specified together with the frequency of calibration for each type of instrument.

An adequate calibration of survey instruments usually cannot be performed with the built-in check sources. Electronic calibrations that do not involve a source of radiation also are not adequate to determine the proper functioning and response of all components of an instrument. Daily or other frequent checks of survey instruments should be supplemented <u>every six months with a two-point calibration on each scale of each instrument with the two points separated by at least fifty percent of the scale</u>. Survey instruments should also be calibrated following repair. <u>A survey instrument may be considered properly calibrated when the instrument readings are within ± ten percent of the calculated or known values for each point checked</u>. Readings within ± twenty percent are acceptable if a calibration chart or graph is prepared and attached to the instrument.

5.0.6 Procedure for Wiping Source Holders (Licensed Personnel Only)

A. Following the instructions of the Model A source wipe kit, prepare the cotton swab for testing.

B. Take cotton swab and wipe around all weldments of the source holder, source shutter, position handle, and all other corners and edges of the device.

C. Record the information requested on the back of the source wipe kit.

D. Return source wipe kit to Kay-Ray, Inc. If mailed, survey wipe test kit envelope. Radiation level must not exceed 0.5 mR/hr. If excessive radiation is present, contact Kay-Ray, Inc. at 312-259-5600.

E. Kay-Ray will process the source wipe kit upon receipt.

F. Wipe Test Certificate will be forwarded to the customer for his records.

KAY-RAY INC.
INDUSTRIAL PROCESS CONTROL EQUIPMENT

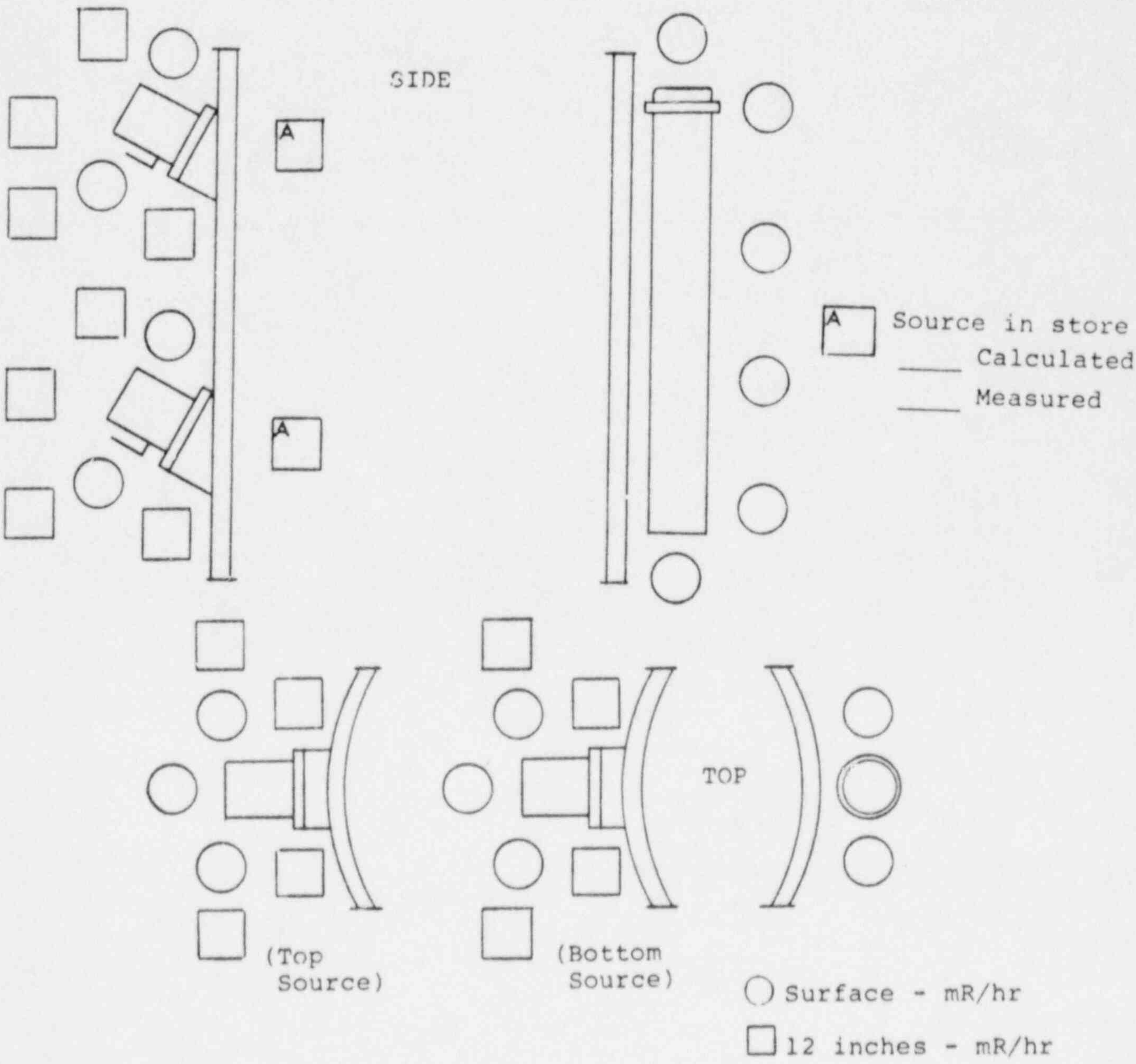
516 West Campus Drive, Arlington Heights, Illinois 60004
Phone: (312)259-5600 Cable Address: KAY-RAY Telex 281-085

RADIATION SURVEY
CONTINUOUS LEVEL

User ______________________ Kay-Ray No. __________

Location ______________________ Date __________

Source in measure unless stated otherwise.



Performed by ______________

FIGURE 5-1

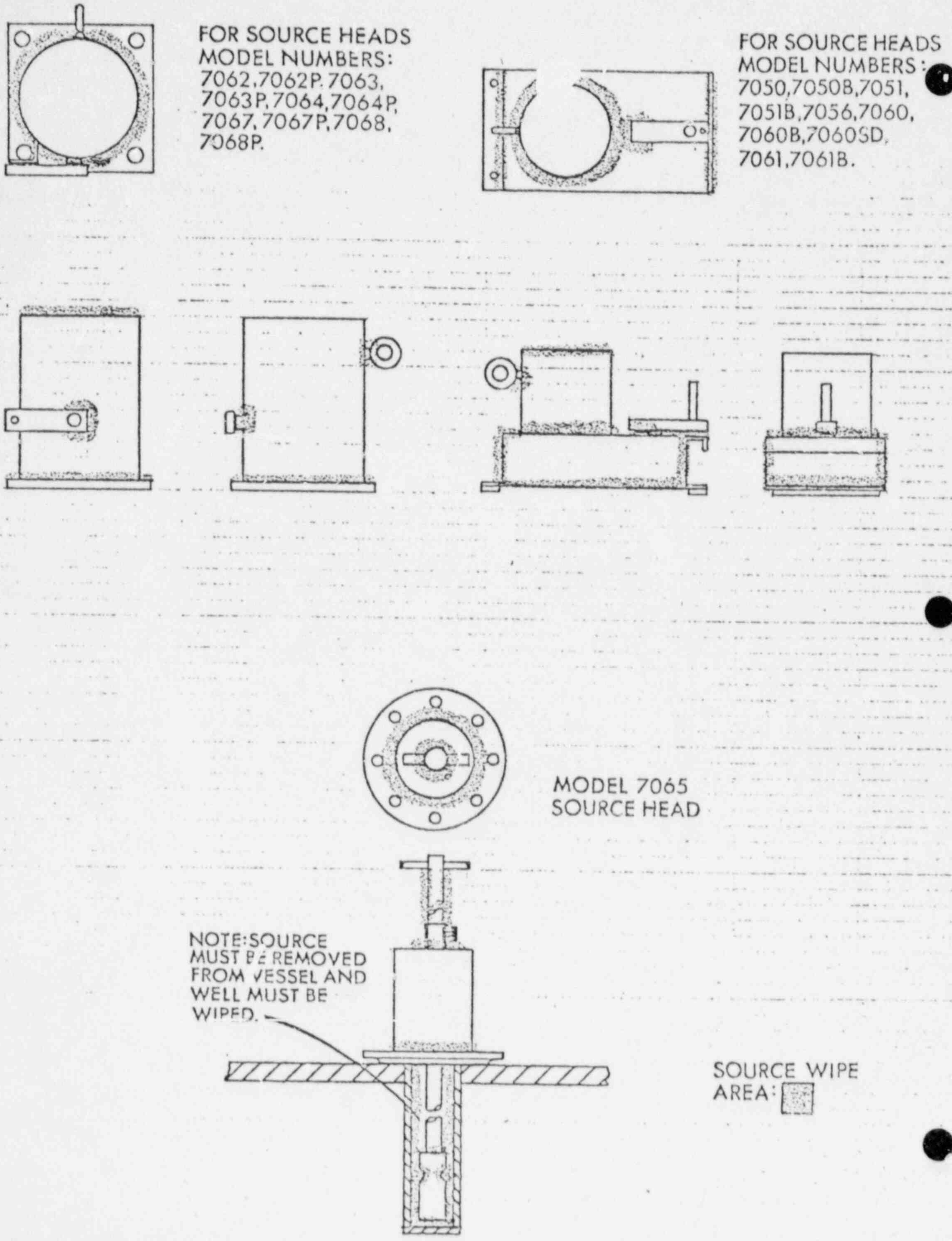

FOR SOURCE HEADS
MODEL NUMBERS:
7062,7062P,7063,
7063P,7064,7064P,
7067,7067P,7068,
7068P.
FOR SOURCE HEADS
MODEL NUMBERS:
7050,7050B,7051,
7051B,7056,7060,
7060B,7060SD,
7061,7061B.
MODEL 7065
SOURCE HEAD
NOTE: SOURCE
MUST BE REMOVED
FROM VESSEL AND
WELL MUST BE
WIPED.
SOURCE WIPE
AREA:

FIGURE 5-2

KAY-RAY®INC.
INDUSTRIAL PROCESS CONTROL EQUIPMENT
516 West Campus Drive, Arlington Heights, Illinois 60004
Phone (312)259-5600 Cable Address KAYRAY Telex 28-2536

LEAK TEST CERTIFICATE

To:

Date:

Ref:

KR Job No:

This certifies that the source(s) listed below have been leak tested according to prevailing NRC standards, and radioactive contamination found to be less than .005µCi

Please retain this certificate for your files.

CERTIFICATION:

By: ____________________

Title: ____________________

Date: ____________________

****

Leak Test Serial No.	Source Holder Manufacturer	Source Holder Model No.	Source Holder Serial No.	Activity (mCi)	Date	By

FIGURE 5-3

5.0.7 Emergency Procedure to be Followed After Damage to Kay-Ray Source Holders

A. This procedure applies to all instances where damage is incurred by the source holder due to such action as fire, etc.

B. Immediately rope off the area around the source holder to a radius of 30 feet in diameter.

C. Inform plant radiation safety officer, or person responsible for use of the source, as to the situation.

D. Inform, by phone or telegram, the proper regional NRC office of the accident.

E. Notify Kay-Ray, Inc., 312-259-5600, if their assistance is required.

F. Limit access to source head until a radiation survey and source wipe can be performed by qualified personnel or a representative of Kay-Ray, Inc.

5.0.8 Customer Return Procedure

The following procedure must be used in returning equipment with radioactive material. However, this procedure cannot be followed unless specifically authorized by the user's specific license. The user's license must state that removal of the source head is permitted. Kay-Ray personnel are licensed to perform this function.

A. No material is to be returned without prior authorization from Kay-Ray, Inc.

B. Material must be packaged properly to insure against damage.

C. All material returned must have a packing slip stating original purchase order number and the reason for the return.

D. Material is to be shipped prepaid to:

KAY-RAY, INC.
506 West Campus Drive
Arlington Heights, Illinois 60004
Attn: Service Department

E. Shipper will construct the crate so as to limit radiation level on outside surface to 50 mR/hr or less.

F. Crate must bear radioactive labels on two opposite sides of the crate showing appropriate radiation class (Figures 5-5, 5-6, and 5-7). Labels are available from Kay-Ray, Inc. upon request.

G. Contents, number of millicuries or curies, and transportation index must be filled in prior to shipment. Transportation Index is measured radiation level in mR/hr at one meter (39") from surface of source head.

H. Bill of Lading must describe material (Figure 5-4).

Original-Not Negotiable **Straight Bill of Lading** Short Form Shipper's No.____________

* ____ Carrier's No.__________

(Name of Carrier)

RECEIVED, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading,

at * ____________________ 19____ From ____________________

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, ... applicable motor carrier classification or tariff if this is a motor carrier shipment.

Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, including those on the back thereof, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

Consigned to KAY-RAY, INC., 506 W. Campus Drive, Arlington Heights, Illinois 60004

(Mail or street address of consignee—For purposes of notification only.)

Destination Arlington Heights State IL Zip 60004 County Cook Delivery Address ☆ 506 W. Campus Dr.

(☆ To be filled in only when shipper desires and governing tariffs provide for delivery thereat.)

Route ____________________

Delivering Carrier ____________________ Car or Vehicle Initials ____________ No. ________

No. Packages	HM	Kind of Packaging, Description of Articles, Special Marks and Exceptions	*Weight (Subject to Correction)	Class or Rate	Check Column
C #	XXX	Radioactive material, special form, n.o.s.; UN 2974, Fissile Exempt;	---		
		ISOTOPE: __________; Group III, special form; ACTIVITY: (# of mCi or Ci); one carton; CATEGORY: II YELLOW or III YELLOW LABELS; Transport Index: __________			
NO. PD.		SHIPPER MUST COMPLETE SECTIONS WHERE ASTERISK'S ARE NOTE: CANNOT COMBINE CARTONS ON ONE LINE- DOCUMENT MUST BE SIGNED AND DATED. ALL SHIPMENTS MUST BE PREPAID.			

Subject to Section 7 of conditions, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement: The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

(Signature of Consignor)

If charges are to be prepaid, write or stamp here: "To be Prepaid."

Received $____ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per ____ (The signature here acknowledges only the amount prepaid.)

Charges advanced:

$____

* ____

* ____________ Shipper, Per ______________________ Agent, Per ______________________

Permanent post-office address of shipper ______________________

Wilson Jones Company

1179

NOTE: Do not combine cartons on one line.

*Shipper must fill in or sign.

FIGURE 5-4

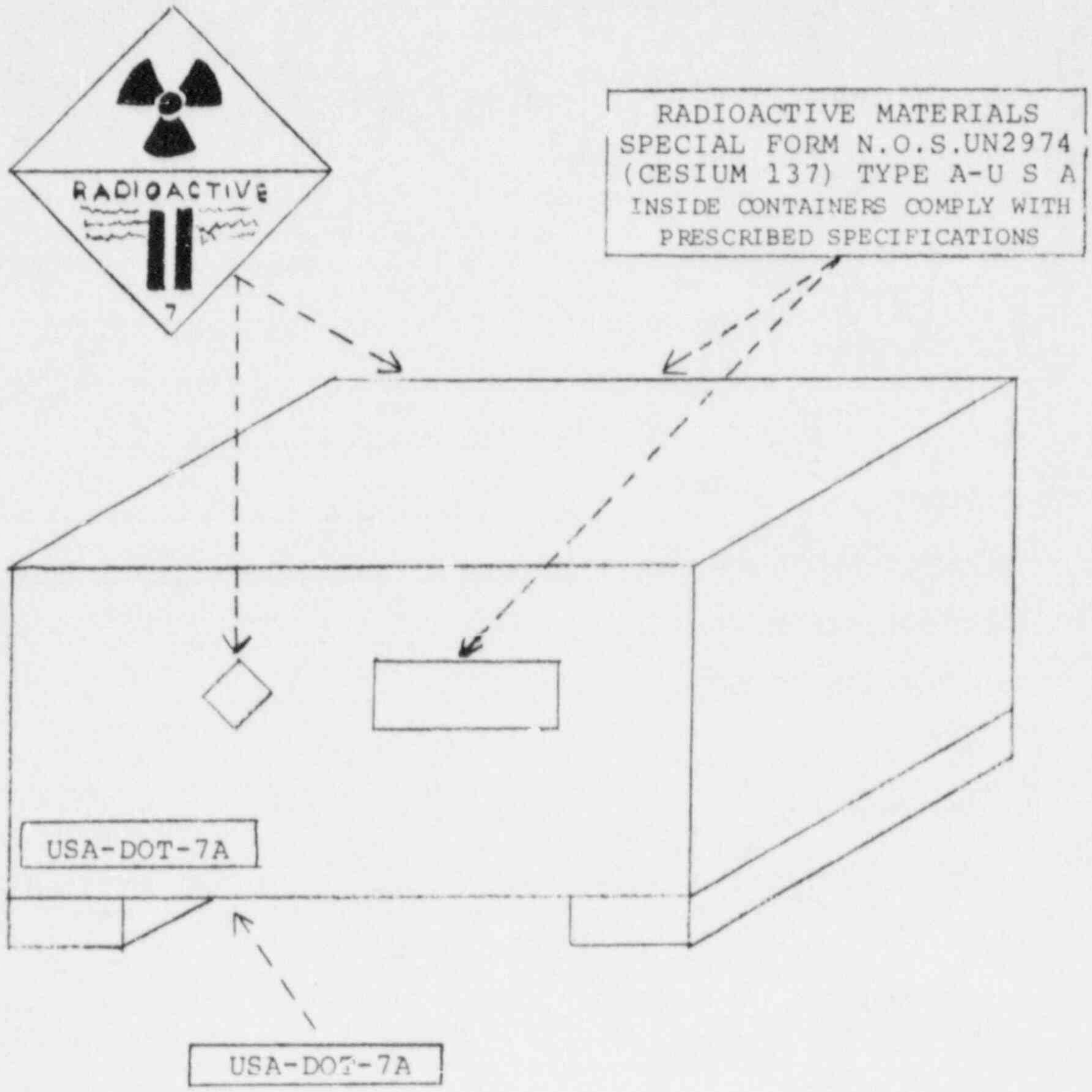
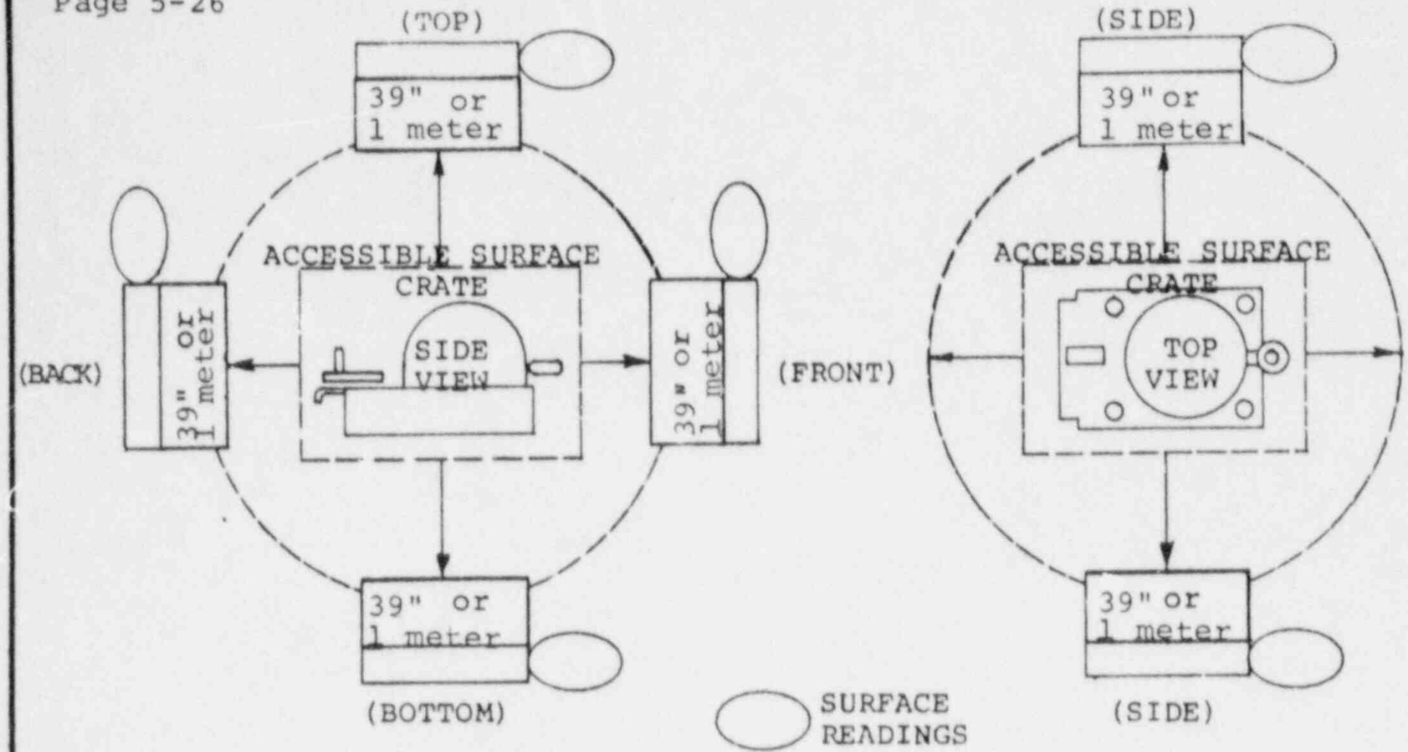

RADIOACTIVE
II
7
RADIOACTIVE MATERIALS
SPECIAL FORM N.O.S.UN2974
(CESIUM 137) TYPE A-U S A
INSIDE CONTAINERS COMPLY WITH
PRESCRIBED SPECIFICATIONS
USA-DOT-7A
USA-DOT-7A

FIGURE 5-5



CUSTOMER NAME: ______________________

SOURCE MODEL NUMBER: ______________________

SOURCE SERIAL NUMBER: ______________________

TESTED AND APPROVED BY: ______________________

DATE: ____________ KR: ______________________

RADIONUCLIDE: ____________ ACTIVITY: ____________

COMMENTS: ______________________

DOSE RATE LIMITS

LABEL RADIOACTIVE	AT 39" OR 1 METER FROM EXTERNAL SURFACE	ANY ACCESSIBLE POINT ON SURFACE
"WHITE I"	0	0.5 MR/HR
"YELLOW II"	1.0 MR/HR	50 MR/HR
"YELLOW III"	10 MR/HR	200 MR/HR

TITLE: RADIATION SURVEY WORK SHEET FOR RETURNED GOODS

TOLERANCES UNLESS OTHERWISE SHOWN
FRACTIONAL = ± 1/64
ANGULAR = ± 30 MIN.
.00 = ±.010 / .000 = ±.005

KAY-RAY® INC.
INDUSTRIAL PROCESS CONTROL EQUIPMENT

NO.	REVISION DESCRIPTION	EMCO	APPR.	DATE
2	REVISED & REDRAWN	1346	SFG	10-10-79

SCALE: ⊣⊢ INCHES(METRIC)

DWN: Kenneth L. Ferguson DATE: 10-10-79

APP: C. B. Green DATE: 10/10/79

DWG. NO. 974-000101 REV. 2

RADIOACTIVE MATERIAL PACKAGES LABEL CRITERIA
49 CFR Transportation 172.403
DOSE RATE LIMITS

LABEL	AT ANY POINT ON ACCESSIBLE SURFACE OF SOURCE HOUSING	AT 1 METER OR 39" FROM EXTERNAL SURFACE OF SOURCE HOUSING (TRANSPORT INDEX)
"RADIOACTIVE-WHITE I"	0.5 mR/hr	0
"RADIOACTIVE-YELLOW II"	50 mR/hr	1.0 mR/hr
"RADIOACTIVE-YELLOW III"*	200 mR/hr	10 mR/hr

*Requires vehicle placarding

T.I. is the highest field present at any measured point 1 meter or 39" from surface of source housing.

Radioactive - White I

Background - White

Radioactive - Yellow II

Upper Half - Bright Yellow
Lower Half - White

Radioactive - Yellow III*

Upper Half - Bright Yellow
Lower Half - White

CERTIFICATION OF TRAINING

Name:

Company:

The above named individual has successfully completed the INSTALLATION AND NUCLEAR RADIATION SAFETY course offered by Kay-Ray, Inc., consisting of the following curriculum:

- Principles and practices of radiation protection
- Monitoring radiation levels using Geiger counters
- Radiation exposure limits
- Radiation areas defined
- Calculating radiation levels from known gamma source size and distances
- Calculating dose rates of typical installation
- Leak testing Kay-Ray source housings
- Safety practices required for the use and handling of Kay-Ray source housings
- Installation of source housings demonstration and Hands-On installation

This training course consists of formal discussions, practical applications, leak testing, specific installation discussions, and hands-on installation completion with related forms for record keeping.

Certified on equipment
model

Instructor:
Date:

FIGURE 5-8

AGREEMENT STATE PROGRAM

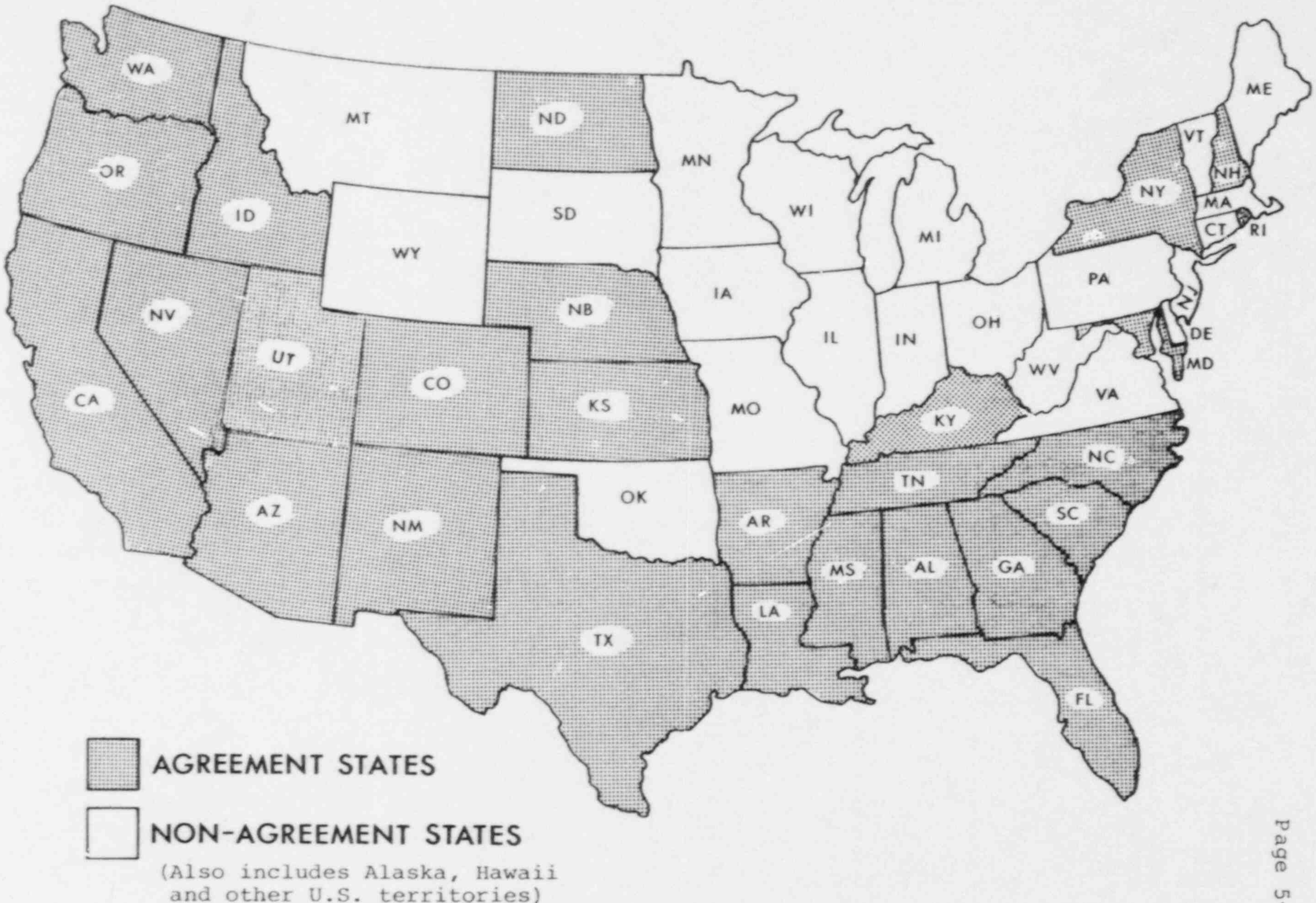


FIGURE 5-9

5.0.9. LICENSING OFFICIALS IN AGREEMENT STATES

ALABAMA
Mr. Kirk Whatley
Director of Radioactive Materials Licensing
Bureau of Radiological Health
Room 510, State Office Building
Montgomery, Alabama 36130
(205)261-5315

ARIZONA
Mr. Charles F. Tedford, Director
Arizona Radiation Regulatory Agency
925 South 52nd Street, Suite 2
Tempe, Arizona 85281
(602)255-4845

ARKANSAS
Mr. Mark Smith, Chief
Licensing & Environmental Surveillance Section
Radiological Health Section
Division of Radiation Control and Emergency Management Programs
Arkansas Department of Health
4815 W. Markham Street
Little Rock, Arkansas 72201
(501)661-2000

CALIFORNIA
Mr. Joseph O. Ward, Chief
Department of Health Services
Radiological Health Branch
714/744 P. Street
Sacramento, California 95814
(916)445-0931
(916)322-2073 (Mr. Ward)

COLORADO
Mr. Albert J. Hazle, Director
Division of Radiation Control
Office of Health Protection
Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220
(303)320-8333, Ext. 6246

FLORIDA
Mr. Paul E. Shuler, Jr.
Public Health Physicist Manager
Radioactive Materials Section
Office of Radiation Control
State of Florida Department of Health and Rehabilitative Services
1317 Winewood Blvd.
Tallahassee, Florida 32301
(904)487-1004

GEORGIA
Carol Connell, Chief
Radioactive Materials Unit
Radiological Health Section
Georgia Dept. of Human Resources
GMHI-Room 425 South
1256 Briarcliff Road N.E.
Atlanta, Georgia 30306-2694
(404)894-5795

IDAHO
Mr. Robert D. Funderburg, Manager
IDHW-Division of Environment
Radiation Control Section
450 W. State
Statehouse
Boise, Idaho 83720
(208)334-4107

KANSAS
Mr. Gerald W. Allen, Director
Kansas Department of Health and Environment
Bureau of Air Quality and Radiation Control
Forbes Field, Bldg. 321
Topeka, Kansas 66620
(913)862-9360, Ext. 284

KENTUCKY
E. Edsel Moore, Manager
Radiation and Product Safety Branch
Dept. for Health Services
Cabinet for Human Resources
275 East Main Street
Frankfort, Kentucky 40621
(502)564-3700

LOUISIANA
Mr. William H. Spell, Administrator
Nuclear Energy Division
Office of Environmental Affairs
P.O. Box 14690
Baton Rouge, Louisiana 70898
(504)925-4518

MARYLAND
Mr. Robert E. Corcoran, Chief
Division of Radiation Control
Dept. of Health and Mental Hygiene
201 West Preston Street
Baltimore, Maryland 21201
(301)383-2744 or 2735

5.0.9. LICENSING OFFICIALS IN AGREEMENT STATES - Cont'd.

MISSISSIPPI
Mr. Eddie S. Fuente, Director
Division of Radiological Health
State Board of Health
P.O. Box 1700
Jackson, Mississippi 39215-1700
(601)354-6657 or 6670

NEBRASKA
Mr. Ellis Simmons, Director
Division of Radiological Health
State Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, Nebraska 68509
(402)471-2168

NEVADA
Mr. John Vaden, Supervisor
Radiological Health Section
Nevada Division of Health
505 E. King Street
Carson City, Nevada 89710
(702)885-4750

NEW HAMPSHIRE
Ms. Diane Tefft, Manager
Radiological Health Program
State of New Hampshire
Department of Health and Welfare
Division of Public Health Services
Health and Welfare Building
Hazen Drive
Concord, New Hampshire 03301
(603)271-4588

NEW MEXICO
Mr. Benito Garcia, Acting Bureau Chief
Radiation Protection Bureau
Environmental Improvement Division
P.O. Box 968 - Crown Building
Santa Fe, New Mexico 87503
(505)984-0020

NEW YORK
Mr. Jay Dunkelburger, Director
Bureau of Nuclear Operations
New York State Energy Office
2 Empire State Plaza, Agency 2
Albany, New York 12223
(518)474-2190

NORTH CAROLINA
Mr. Cecil B. Brown, Head
Radioactive Materials Branch
Radiation Protection Services
Department of Human Resources
Division of Facility Services
Box 12200
Raleigh, North Carolina 27605-2200
(919)733-4283

NORTH DAKOTA
Mr. Dana Mount, Director
Division of Environmental Engineering
Radiation Control Program
State Department of Health
1200 Missouri Avenue
Bismarck, North Dakota 58501
(701)224-2348

OREGON
Mr. Ray D. Price, Manager
Radiation Control Section
Division of Health
Department of Human Resources
1400 S.W. 5th Avenue
Portland, Oregon 97201
(503)229-5797

RHODE ISLAND
Mr. James E. Hickey, Chief
Division of Occupational Health and
Radiation Control
Rhode Island Department of Health
Cannon Building
75 Davis Street
Providence, Rhode Island 02908
(401)277-2438

SOUTH CAROLINA
Mr. Heyward Shealy, Chief
Bureau of Radiological Health
South Carolina State Department of
Health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201
(803)758-5548

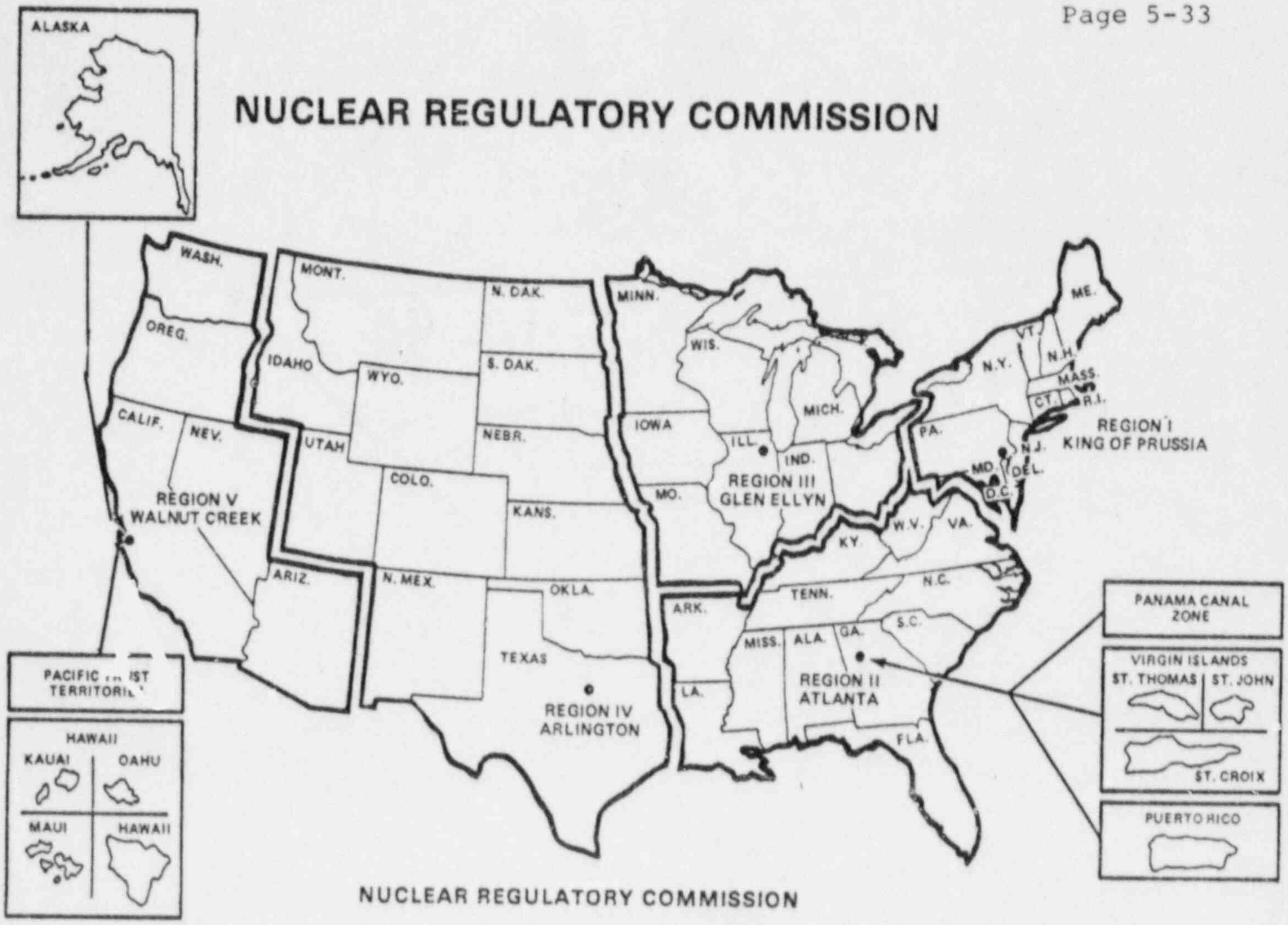
TENNESSEE
Mr. Michael Mobley, Director
Division of Radiological Health
Department of Public Health
C2-212 Cordell Hull State Office Building
Nashville, Tennessee 37219-5404
(615)741-7812

5.0.9. LICENSING OFFICIALS IN AGREEMENT STATES - Cont'd.

TEXAS
Mr. Joe Klinger, Administrator
Industrial Operations Branch
Bureau of Radiation Control
Texas Department of Health
1100 West 49th Street
Austin, Texas 78758
(512)835-7000

UTAH
Bureau of Radiation Control
P.O. Box 2500
150 West North Temple
Salt Lake City, Utah 84110
(801)533-6734
Mr. Arnold J. Peart, Health Physicist
(Administrator has not been named yet)

WASHINGTON
Mr. Gary Robertson, Manager
Radiation Control Section
DSHS Health Services Division
Mail Stop LF-13
Olympia, Washington 98504
(206)753-3351



NUCLEAR REGULATORY COMMISSION

REGION I

Mr. John Glenn, Director
Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pennsylvania 19406
215-337-5000

REGION II

Mr. James P. O'Reilly, Director
Nuclear Regulatory Commission
101 Marietta Street NW
Atlanta, Georgia 30303
404-221-4503

REGION III

Mr. James G. Keppler, Director
Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, Illinois 60137
312-790-5500

REGION IV

Mr. Karl V. Seyfrit, Director
Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 1000
Arlington, Texas 76011
817-334-2841

REGION V

Mr. Robert H. Engelken, Director
Nuclear Regulatory Commission
1990 North California Blvd.
Walnut Creek, California 94596
415-943-3700

FIGURE 5-10


RADIOACTIVE II
CONTENTS
ACTIVITY
TRANSPORT INDEX
7


RADIOACTIVE III
CONTENTS
ACTIVITY
TRANSPORT INDEX
7

SECTION 6

MISCELLANEOUS SAFETY AIDS AND INFORMATION

Periodic Chart of the Elements

FIGURE 6-1

THE SYMBOL. Shown in the middle of each block directly below the name of the element. The color used indicates the physical state of the element under ordinary conditions: black for solids, green for liquids and blue for gases.

THE ATOMIC WEIGHT. Directly below the symbol for each element the atomic weight is shown in black. The values are taken from the official Report on Atomic Weights Cf. J. Amer. Chem. Soc. 84, 4193 (1976). For elements not listed in the Report the mass number of the longest lived isotope is shown in brackets.

THE ATOMIC NUMBER. Shown in red in the upper left hand corner.

ELECTRONIC CONFIGURATION. Shown at the upper right as a group of black numerals. When read downward they indicate the number of electrons normally found in successive energy levels.

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	NOBLE GASES
1	1 H 1.0079																	2 He 4.00260
2	3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.998403	10 Ne 20.179
3	11 Na 22.98977	12 Mg 24.305											13 Al 26.98154	14 Si 28.0855	15 P 30.97376	16 S 32.06	17 Cl 35.453	18 Ar 39.948
4	19 K 39.0983	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.90	23 V 50.9414	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.70	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc (97)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.4	47 Ag 107.868	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.30
6	55 Cs 132.9054	56 Ba 137.33	57 *La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.9665	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0254	89 **Ac (227)	104 † (260)	105 † (260)													

† The International Union for Pure and Applied Chemistry has not adopted official names or symbols for these elements.

* Lanthanide Series	58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 Pm (147)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9304	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.97
** Actinide Series	90 Th 232.0381	91 Pa 231.0359	92 U 238.029	93 Np 237.0482	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

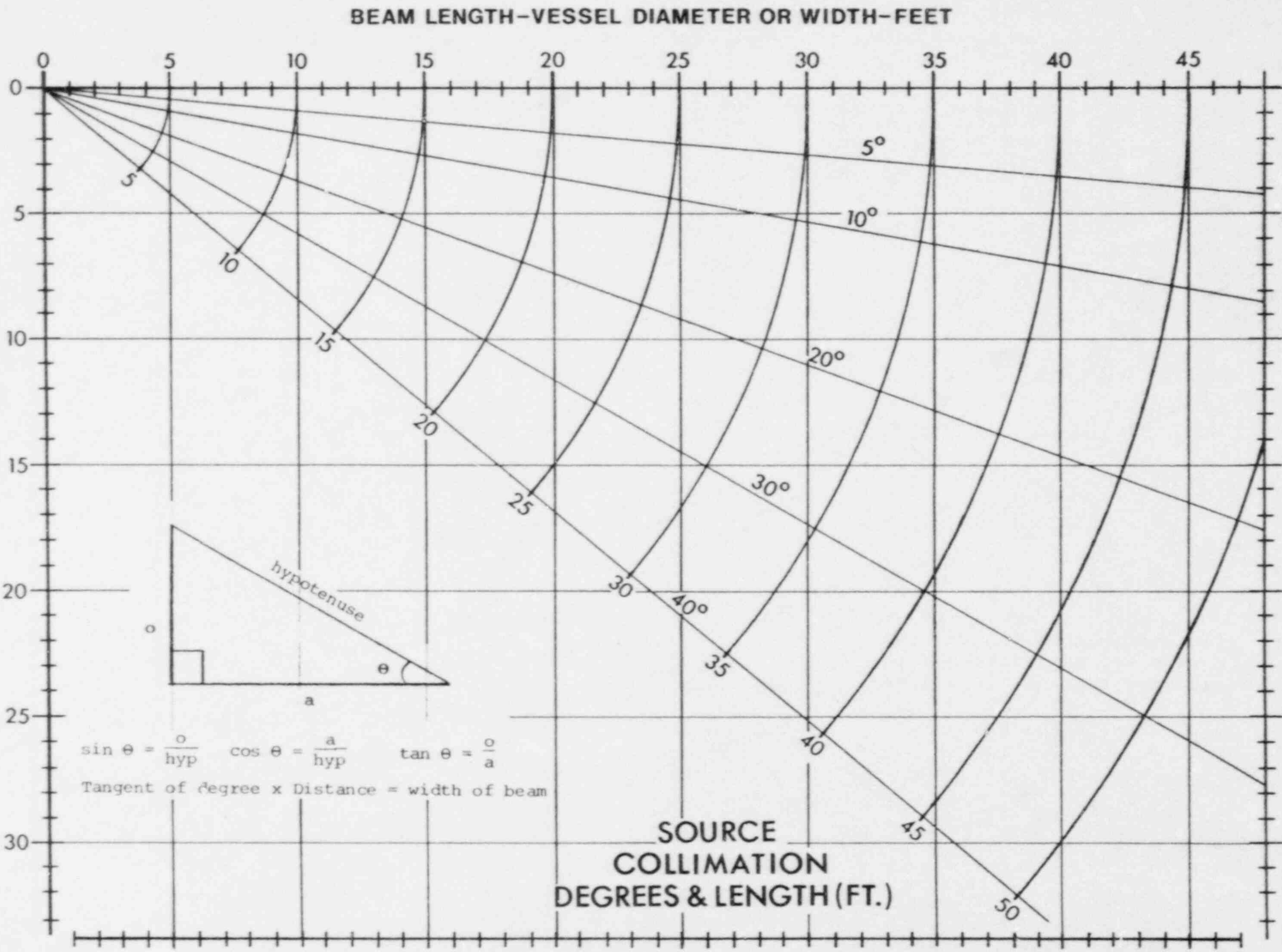
Cat. No. S45520

PHYSICAL PROPERTIES OF COMMON METALS & ALLOYS

Metal or Alloy	Density at 20°C (grams per cm^3)	Specific Heat at 20°C	Melting Point Centigrade	Coefficient Linear Expansion at 20°C (per C° x 10^{-6})	Resistivity at 20°C (micro-ohms per cm)
Aluminum	2.7	0.21	659	26	2.82
Brass	8.6	0.092	900	19	7
Cadmium	8.65	.055	321	28.8	7.62
Chromel 180	8.95	.092	1100	16.1	29.8
Copper	8.9	0.091	1083	17	1.72
German Silver	8.4	0.094	1100	18.4	33
Gold	19.3	.031	1063	14.3	2.44
Iron	7.8	0.115	1535	11	10
Lead	11.3	0.031	327	29	22
Magnesium	1.74	.245	651	26.0	4.6
Manganin	8.4	—	910	18.7	44.0
Nichrome Alloy	8.2	—	1500	13.7	100
Platinum	21.4	.032	1755	8.8	10.0
Silver	10.5	0.056	960	18.8	1.59
Steel	7.8	0.107	1510	12.0	10-70
Tungsten	18.7	.034	3400	4.3	5.5
Zinc	7.1	0.092	419	26.3	5.8

PHYSICAL PROPERTIES OF COMMON LIQUIDS

Liquid	Density at 20°C (grams per ml)	Specific Heat 15°C (cal/g-C°)	Boiling Point at 760mm Hg (°C)	Coefficient of Volume Expansion at 20°C (per C° x 10^{-3})	Index of Refraction for Sodium Light
Acetic Acid	1.05	.468	118.1	1.071	1.37
Acetone	.7908	0.52	56.2	1.49	1.36
Alcohol, Ethyl	.789	0.56	78.5	1.12	1.36
Alcohol, Methyl	.793	0.59	64.96	1.20	1.33
Alcohol, N-Propyl	.7796	.586	97.2	.956	1.39
Aniline	1.022	.488	184.4	.858	1.58
Benzene	.879	.406	80.1	1.24	1.50
Carbon Disulfide	1.263	—	45.0	1.15	1.63
Carbon Tetrachloride	1.595	0.20	76.8	1.24	1.4664
Chloroform	1.50	.234	61.3	1.27	1.4433
Ether, Diethyl	.714	0.54	34.6	1.66	1.35
Glycerol	1.26	0.56	290	0.51	1.47
Mercury	13.6	0.033	357	0.182	1.62
Toluene	.867	.395	110.6	1.099	1.4961



BEAM LENGTH-VESSEL DIAMETER OR WIDTH-FEET
5°
10°
20°
30°
40°
hypotenuse
o
a
θ
sin θ = o/hyp cos θ = a/hyp tan θ = o/a
Tangent of degree x Distance = width of beam
SOURCE
COLLIMATION
DEGREES & LENGTH (FT.)

FIGURE 6-2

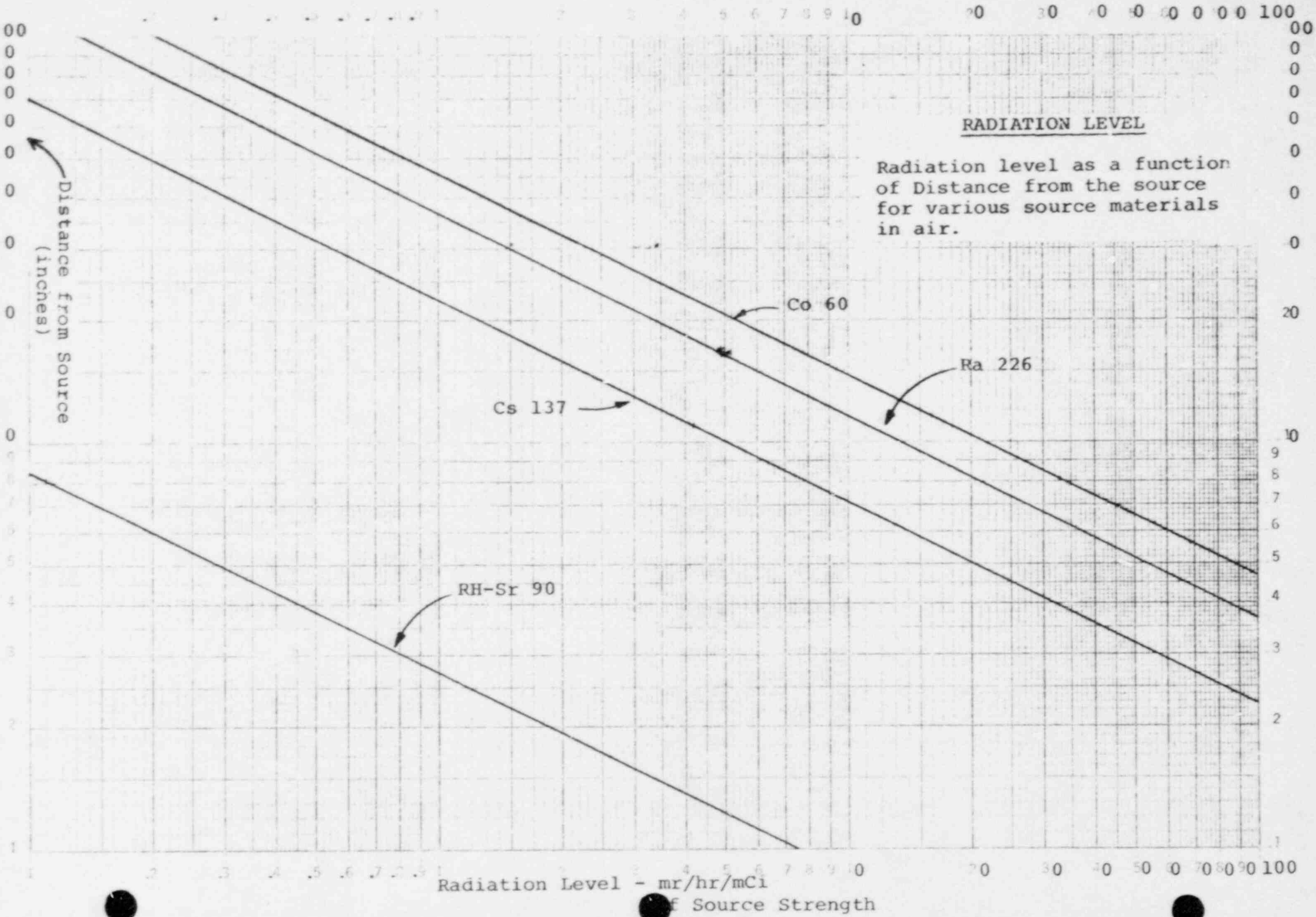

RADIATION LEVEL
Radiation level as a function of Distance from the source for various source materials in air.
Co 60
Ra 226
Cs 137
RH-Sr 90
Distance from Source (inches)
Radiation Level - mr/hr/mCi
Source Strength

FIGURE 6-3

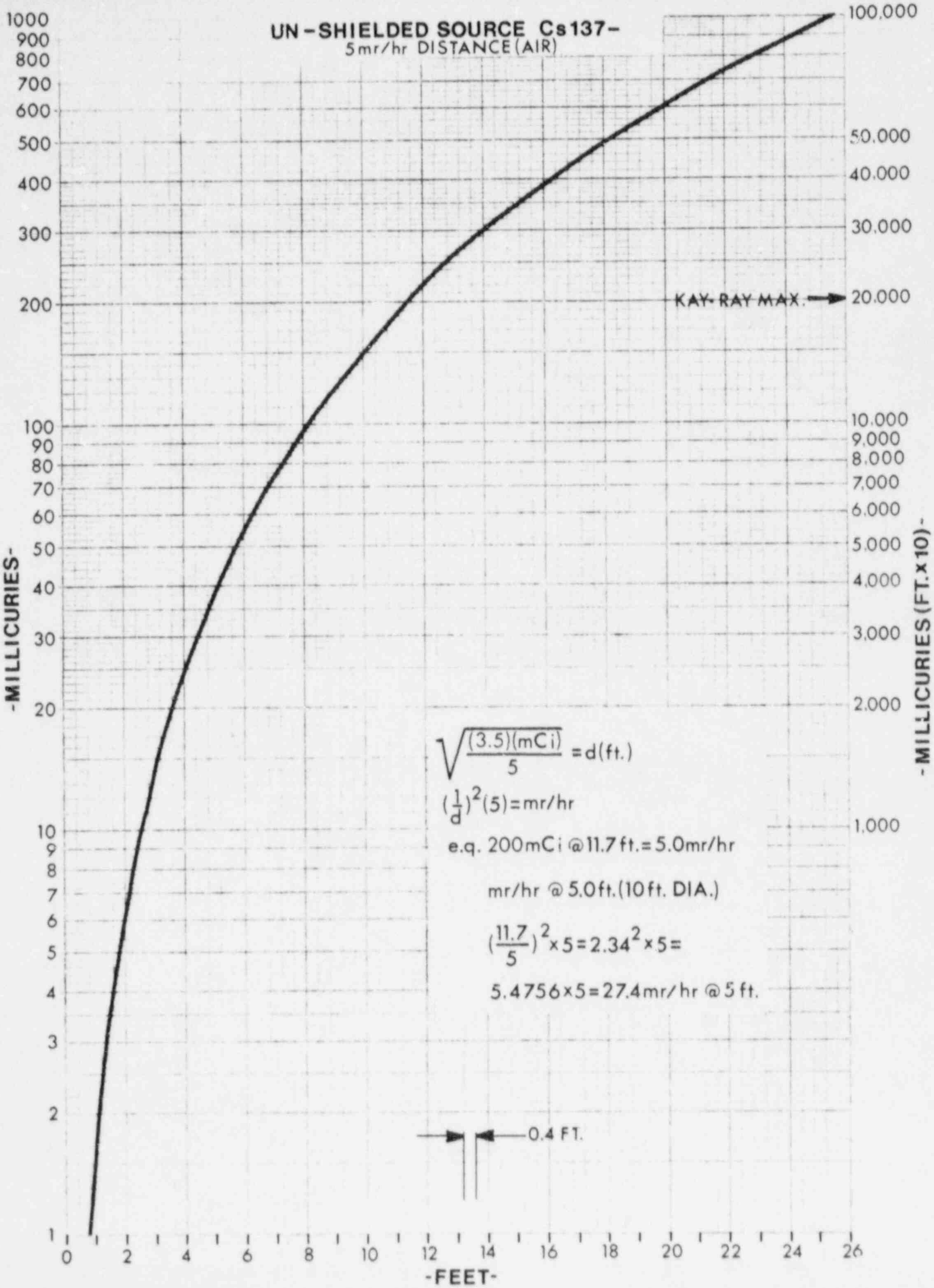

UN-SHIELDED SOURCE Cs137-
5mr/hr DISTANCE(AIR)
KAY-RAY MAX.
√((3.5)(mCi)/5) = d(ft.)
(1/d)²(5) = mr/hr
e.q. 200mCi @11.7ft.=5.0mr/hr
mr/hr @ 5.0ft.(10ft. DIA.)
(11.7/5)² × 5 = 2.34² × 5 =
5.4756×5=27.4mr/hr @5ft.
0.4 FT.
-MILLICURIES-
-MILLICURIES (FT.x10)-
-FEET-
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
100,000
50,000
40,000
30,000
20,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2
4
6
8
10
12
14
16
18
20
22
24
26

FIGURE 6-4

CALCULATION OF RADIATION LEVEL

Inside vessel with source closed

$$MR/HR = \frac{K\ (X^2)}{(X + D)^2} \times \text{source size (mci)} \times .001 \div RR$$

K - from chart
X - from chart
D - distance in feet
RR - reduction ratio of the wall thickness

$$RR = 2^{(\frac{1}{2}v)}$$

SOURCE HOLDERS

	X	K
7050B	.65	20
7051B	.65	20
7062	.375	1000
7063	.520	50
7064	.70	20
7067	.89	2
7080	.583	150

Example: 7062 with 50 mCi Cs^{137}, wall thickness ¼" steel, surface of source 2" from outside wall.

Calculate: Radiation inside vessel at 1.25 feet from inside surface.

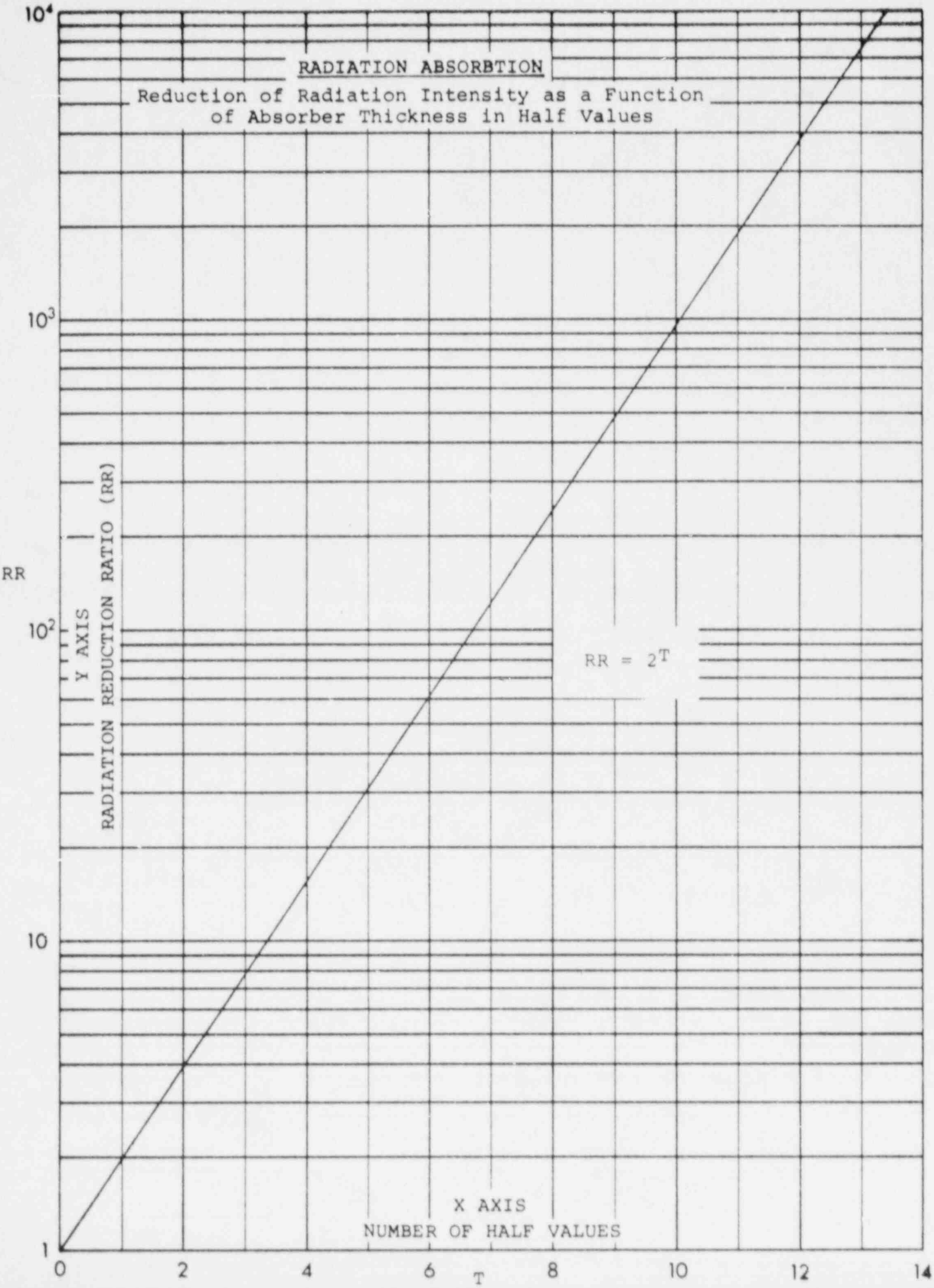
$$\frac{1000 \times .375^2}{(.375 + \frac{17.25}{12})^2} \times 50 \times .001 = 2.14$$

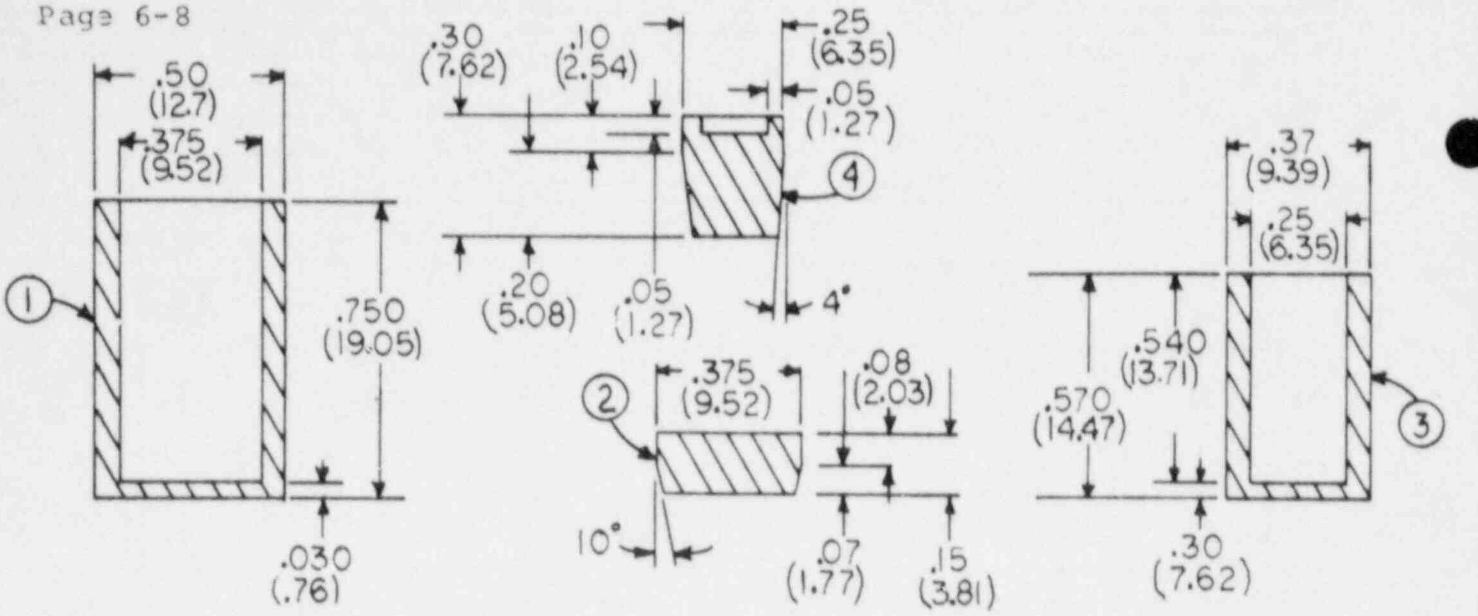
$.25 \text{ steel} = \frac{.25}{.6} = .416$ ½ values $\qquad 2^{.416} = 1.334$ RR

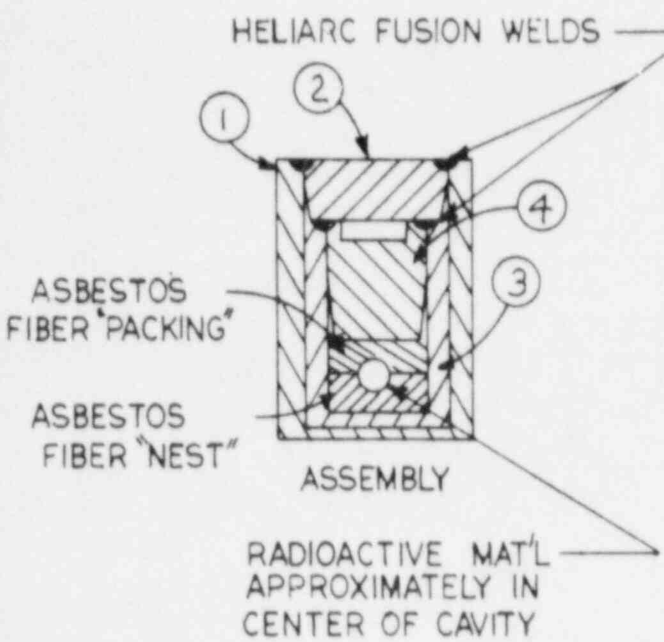
$$\frac{2.14}{1.334} = 1.604 \text{ MR/HR}$$

FIGURE 6-5

FIGURE 1


RADIATION ABSORBTION
Reduction of Radiation Intensity as a Function of Absorber Thickness in Half Values
$RR = 2^T$
RR
Y AXIS
RADIATION REDUCTION RATIO (RR)
X AXIS
NUMBER OF HALF VALUES
T
10^4
10^3
10^2
10
1
0
2
4
6
8
10
12
14





NOTES:

1. Items 1 and 3 to be mated to each other to limit lateral movement to .005 in. max.

2. Asbestos fiber fill to be used as a means of eliminating the movement of source material within the capsule.

3. Item 2 to be pressed in place sufficient to remove linear movement between items 1 and 3.

4. Capsule (Iteml) to be engraved with isotope, activity, model no., serial no., and date.

5. After welding perform liquid nitrogen leak test on inner & outer capsule welds.

6. After welding outer capsule perform seven (7) day wipe test.

7. Leak test certificate to be supplied with each source.

8. Amount of activity must be as specified ±10%.

TITLE SOURCE (CESIUM) CS-137 FOR SOURCES OF ONE TO TEN CURIES

SCALE 2:1

TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONAL:
DECIMAL: ANGULAR:

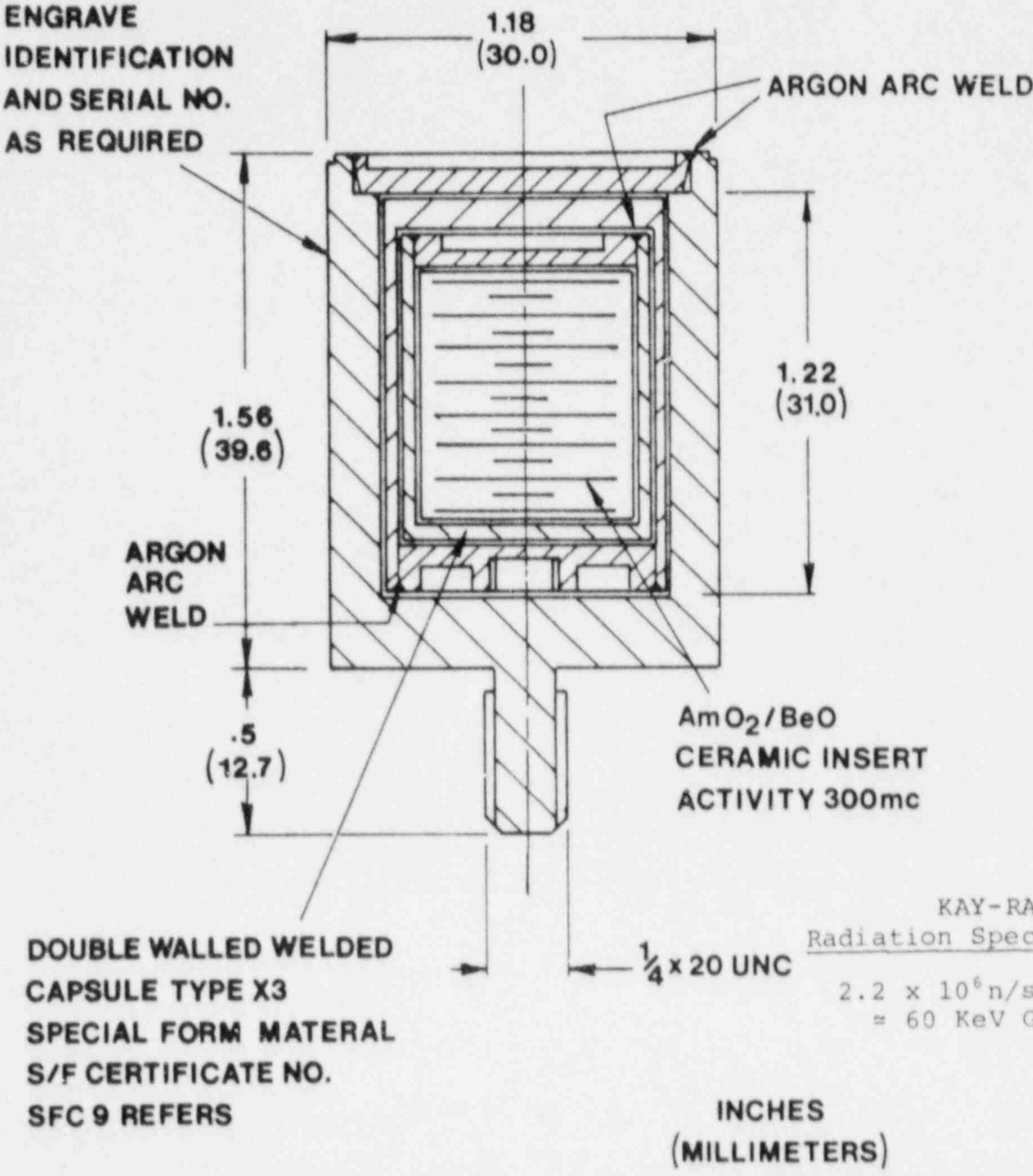
NO.	REVISIONS	DATE	APP.
1	REDRAWN - SEE HIST. (SAME #)	6/76	RWL
2			
3			
4			

KAY-RAY INC.
Arlington Heights, Illinois USA

DWN. BY MENCIS DATE 7/22/75
APP. BY BENDLER DATE 3/24/76

DWG. NO. 625-000102

MATERIAL: 3/16" STAINLESS STEEL



KAY-RAY
Radiation Specification

2.2×10^6 n/sec./Ci
≈ 60 KeV Gamma

AmBe 241 300mc CERAMIC SOURCE				KAY-RAY INC. Arlington Heights, Illinois USA
SCALE 2:1				
TOLERANCES UNLESS OTHERWISE SHOWN				
NO.	REVISIONS	DATE	APP.	DWN. BY T. Corning — DATE 4-2-76
1	DWG. # WAS 690-000201	5/76	RWL	APP. BY [illegible signature] — DATE 4/3/76
				DWG. NO. 690-000104

FIGURE 6-7

UNITED STATES NUCLEAR REGULATORY COMMISSION

RULES and REGULATIONS

TITLE 10, CHAPTER 1, CODE OF FEDERAL REGULATIONS—ENERGY

PART 19 NOTICES, INSTRUCTIONS, AND REPORTS TO WORKERS; INSPECTIONS

AUTHORITY: Secs. 53, 63, 81, 103, 104, 161, Pub. L. 83-703, 68 Stat. 930, 933, 935, 936, 937, 948, as amended (42 U.S.C. 2073, 2093, 2111, 2133, 2134, 2201); Sec. 401, Pub. L. 93-438, 88 stat. 1254 (42 U.S.C. 5891)

§ 19.1 Purpose.

The regulations in this part establish requirements for notices, instructions, and reports by licensees to individuals participating in licensed activities, and options available to such individuals in connection with Commission inspections of licensees to ascertain compliance with the provisions of the Atomic Energy Act of 1954, as amended, Title II of the Energy Reorganization Act of 1974, and regulations, orders, and licenses thereunder regarding radiological working conditions.

§ 19.2 Scope.

The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed by the Nuclear Regulatory Commission pursuant to the regulations in Parts 30 through 35, 40, or 70 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter.

§ 19.3 Definitions.

As used in this part:

(a) "Act" means the Atomic Energy Act of 1954, (68 Stat. 919) including any amendments thereto;

(b) "Commission" means the United States Nuclear Regulatory Commission;

(c) "Worker" means an individual engaged in activities licensed by the Commission and controlled by a licensee, but does not include the licensee.

(d) "License" means a license issued under the regulations in Parts 30 through 35, 40, or 70 of this chapter, including licenses to operate a production or utilization facility pursuant to Part 50 of this chapter. "Licensee" means the holder of such a license.

(e) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

§ 19.4 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 19.5 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Director, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street, NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

§ 19.11 Posting of notices to workers.

(a) Each licensee shall post current copies of the following documents: (1) The regulations in this part and in Part 20 of this chapter; (2) the license, license conditions, or documents incorporated into a license by reference, and amendments thereto; (3) the operating procedures applicable to licensed activities; (4) any notice of violation involving radiological working conditions, proposed imposition of civil penalty, or order issued pursuant to Subpart B of Part 2 of this chapter, and any response from the licensee.

(b) If posting of a document specified in paragraph (a) (1), (2) or (3) of this section is not practicable, the licensee may post a notice which describes the document and states where it may be examined.

(c) Form NRC-3, "Notice to Employees", shall be posted by each licensee wherever individuals work in or frequent any portion of a restricted area.

NOTE: Copies of Form NRC-3 may be obtained by writing to the Director of the appropriate U.S. Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix "D", Part 20 of this chapter, or the Director, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555

(d) Documents, notices, or forms posted pursuant to this section shall appear in a sufficient number of places to permit individuals engaged in licensed activities to observe them on the way to or from any particular licensed activity location to which the document applies, shall be conspicuous, and shall be replaced if defaced or altered.

(e) Commission documents posted pursuant to paragraph (a)(4) of this section shall be posted within 2 working days after receipt of the documents from the Commission; the licensee's response, if any, shall be posted within 2 working days after dispatch by the licensee. Such documents shall remain posted for a minimum of 5 working days or until action correcting the violation has been completed, whichever is later.

§ 19.12 Instructions to workers.

All individuals working in or frequenting any portion of a restricted area shall be kept informed of the storage, transfer, or use of radioactive materials or of radiation in such portions of the restricted area; shall be instructed in the health protection problems associated with exposure to such radioactive materials or radiation, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed; shall be instructed in, and instructed to observe, to the extent within the worker's control, the applicable provisions of Commission regulations

FIGURE 6-8

and licenses for the protection of personnel from exposures to radiation or radioactive materials occurring in such areas; shall be instructed of their responsibility to report promptly to the licensee any condition which may lead to or cause a violation of Commission regulations and licenses or unnecessary exposure to radiation or to radioactive material; shall be instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or radioactive material; and shall be advised as to the radiation exposure reports which workers may request pursuant to § 19.13. The extent of these instructions shall be commensurate with potential radiological health protection problems in the restricted area.

§ 19.13 Notifications and reports to individuals.

(a) Radiation exposure data for an individual, and the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body of an individual, shall be reported to the individual as specified in this section. The information reported shall include data and results obtained pursuant to Commission regulations, orders or license conditions, as shown in records maintained by the licensee pursuant to Commission regulations. Each notification and report shall: be in writing; include appropriate identifying data such as the name of the licensee, the name of the individual, the individual's social security number; include the individual's exposure information; and contain the following statement:

38 FR 22217

> This report is furnished to you under the provisions of the Nuclear Regulatory Commission regulation 10 CFR Part 19. You should preserve this report for further reference.

(b) At the request of any worker, each licensee shall advise such worker annually of the worker's exposure to radiation or radioactive material as shown in records maintained by the licensee pursuant to § 20.401(a) and (c).

(c) At the request of a worker formerly engaged in licensed activities controlled by the licensee, each licensee shall furnish to the worker a report of the worker's exposure to radiation or radioactive material. Such report shall be furnished within 30 days from the time the request is made, or within 30 days after the exposure of the individual has been determined by the licensee, whichever is later; shall cover, within the period of time specified in the request, each calendar quarter in which the worker's activities involved exposure to radiation from radioactive materials licensed by the Commission; and shall include the dates and locations of licensed activities in which the worker participated during this period.

(d) When a licensee is required pursuant to § 20.405 or § 20.408 of this chapter to report to the Commission any exposure of an individual to radiation or radioactive material the licensee shall also provide the individual a report on his exposure data included therein. Such report shall be transmitted at a time not later than the transmittal to the Commission.

(e) At the request of a worker who is terminating employment in a given calendar quarter with the licensee in work involving radiation dose, or of a worker who, while employed by another person, is terminating assignment to work involving radiation dose in the licensee's facility in that calendar quarter, each licensee shall provide to each such worker, or to the worker's designee, at termination, a written report regarding the radiation dose received by that worker from operations of the licensee during that specifically identified calendar quarter or fraction thereof, or provide a written estimate of that dose if the finally determined personnel monitoring results are not available at that time. Estimated doses shall be clearly indicated as such.

44 FR 32352

§ 19.14 Presence of representatives of licensees and workers during inspections.

(a) Each licensee shall afford to the Commission at all reasonable times opportunity to inspect materials, activities, facilities, premises, and records pursuant to the regulations in this chapter.

(b) During an inspection, Commission inspectors may consult privately with workers as specified in § 19.15. The licensee or licensee's representative may accompany Commission inspectors during other phases of an inspection.

38 FR 22217

(c) If, at the time of inspection, an individual has been authorized by the workers to represent them during Commission inspections, the licensee shall notify the inspectors of such authorization and shall give the workers' representative an opportunity to accompany the inspectors during the inspection of physical working conditions.

(d) Each workers' representative shall be routinely engaged in licensed activities under control of the licensee and shall have received instructions as specified in § 19.12.

(e) Different representatives of licensees and workers may accompany the inspectors during different phases of an inspection if there is no resulting interference with the conduct of the inspection. However, only one workers' representative at a time may accompany the inspectors.

(f) With the approval of the licensee and the workers' representative an individual who is not routinely engaged in licensed activities under control of the license, for example, a consultant to the licensee or to the workers' representative, shall be afforded the opportunity to accompany Commission inspectors during the inspection of physical working conditions.

(g) Notwithstanding the other provisions of this section, Commission inspectors are authorized to refuse to permit accompaniment by any individual who deliberately interferes with a fair and orderly inspection. With regard to areas containing information classified by an agency of the U.S. Government in the interest of national security, an individual who accompanies an inspector may have access to such information only if authorized to do so. With regard to any area containing proprietary information, the workers' representative for that area shall be an individual previously authorized by the licensee to enter that area.

§ 19.15 Consultation with workers during inspections.

(a) Commission inspectors may consult privately with workers concerning matters of occupational radiation protection and other matters related to applicable provisions of Commission regulations and licenses to the extent the inspectors deem necessary for the conduct of an effective and thorough inspection.

(b) During the course of an inspection any worker may bring privately to the attention of the inspectors, either orally or in writing, any past or present condition which he has reason to believe may have contributed to or caused any violation of the act, the regulations in this chapter, or license condition, or any unnecessary exposure of an individual to radiation from licensed radioactive material under the licensee's control. Any such notice in writing shall comply with the requirements of § 19.16(a).

(c) The provisions of paragraph (b) of this section shall not be interpreted as authorization to disregard instructions pursuant to § 19.12.

38 FR 22217

§ 19.16 Requests by workers for inspections.

(a) Any worker or representative of workers who believes that a violation of the Act, the regulations in this chapter, or license conditions exists or has occurred in license activities with regard to radiological working conditions in which the worker is engaged, may request an inspection by giving notice of the alleged violation to the Director of Inspection and Enforcement, to the Director of the appropriate Commission Regional Office, or to Commission inspectors. Any such notice shall be in writing, shall set forth the specific grounds for the notice, and shall be signed by the worker or representative of workers. A copy shall be provided the licensee by the Director of Inspection and Enforcement, Regional Office Director, or the inspector no later than at the time of inspection except that, upon the request of the worker giving such notice, his name and the name of individuals referred to therein shall not appear in such copy or on any record published, released, or made available by the Commission, except for good cause shown.

(b) If, upon receipt of such notice, the Director of Inspection and Enforcement or Regional Office Director determines that the complaint meets the requirements set forth in paragraph (a) of this section, and that there are reasonable grounds to believe that the alleged violation exists or has occurred, he shall cause an inspection to be made as soon as practicable, to determine if such alleged violation exists or has occurred. Inspections pur-

suant to this section need not be limited to matters referred to in the complaint.

(c) No licensee shall discharge or in any manner discriminate against any worker because such worker has filed any complaint or instituted or caused to be instituted any proceeding under the regulations in this chapter or has testified or is about to testify in any such proceeding or because of the exercise by such worker on behalf of himself or others of any option afforded by this part.

§ 19.17 Inspections not warranted; informal review.

(a) If the Director of Inspection and Enforcement or of the appropriate Regional Office determines, with respect to a complaint under § 19.16, that an inspection is not warranted because there are no reasonable grounds to believe that a violation exists or has occurred, he shall notify the complainant in writing of such determination. The complainant may obtain review of such determination by submitting a written statement of position with the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, who will provide the licensee with a copy of such statement by certified mail, excluding, at the request of the complainant, the name of the complainant. The licensee may submit an opposing written statement of position with the Executive Director for Operations who will provide the complainant with a copy of such statement by certified mail. Upon the request of the complainant, the Executive Director for Operations or his designee may hold an informal conference in which the complainant and the licensee may orally present their views. An informal conference may also be held at the request of the licensee, but disclosure of the identity of the complainant will be made only following receipt of written authorization from the complainant. After considering all written and oral views presented, the Executive Director for Operations shall affirm, modify, or reverse the determination of the Director of Inspection and Enforcement or of the appropriate Regional Office and furnish the complainant and the licensee a written notification of his decision and the reason therefor.

(b) If the Director of Inspection and Enforcement or of the appropriate Regional Office determines that an inspection is not warranted because the requirements of § 19.16(a) have not been met, he shall notify the complainant in writing of such determination. Such determination shall be without prejudice to the filing of a new complaint meeting the requirements of § 19.16(a).

38 FR 22217

§ 19.30 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Act or Title II of the Energy Reorganization Act of 1974 or any regulation or order issued thereunder.

40 FR 8774

A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of section 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act or any rule, regulation, or order issued thereunder, or any term, condition or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and upon conviction, may be punished by fine or imprisonment or both, as provided by law.

38 FR 22217

§ 19.31 Application for exemptions.

The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 19.32 Discrimination prohibited.

No person shall on the ground of sex be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity licensed by the Nuclear Regulatory Commission. This provision will be enforced through agency provisions and rules similar to those already established, with respect to racial and other discrimination, under title VI of the Civil Rights Act of 1964. This remedy is not exclusive, however, and will not prejudice or cut off any other legal remedies available to a discriminatee.

40 FR 8774

UNITED STATES NUCLEAR REGULATORY COMMISSION

RULES and REGULATIONS

TITLE 10, CHAPTER 1, CODE OF FEDERAL REGULATIONS – ENERGY

PART 20 STANDARDS FOR PROTECTION AGAINST RADIATION

AUTHORITY: The provisions of this Part 20 issued under secs. 53, 63, 65, 81, 103, 104, 161, 68 Stat. 930, 933, 935, 936, 937, 948, as amended; 42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201. For the purposes of sec. 223, 68 Stat. 958, as amended, 42 U.S.C. 2273, §§ 20.401-20.409, issued under sec. 161 o., 68 Stat. 950, as amended; 42 U.S.C. 2201 (o). Secs. 202, 206, Pub. L. 93-438, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846).

§ 20.1 Purpose.

40 FR 8774

(a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Nuclear Regulatory Commission and are issued pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974.

44 FR 32352

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that the total dose to an individual (including exposures to licensed and unlicensed radioactive material and to other unlicensed sources of radiation, whether in the possession of the licensee or any other person, but not including exposures to radiation from natural background sources or medical diagnosis and therapy) does not exceed the standards of radiation protection prescribed in the regulations in this part.

40 FR 58847

(c) In accordance with recommendations of the Federal Radiation Council, approved by the President, persons engaged in activities under licenses issued by the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 should, in addition to complying with the requirements set forth in this part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable. The term "as low as is reasonably achievable" means as low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.

40 FR 8774

§ 20.2 Scope.

The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed pursuant to the regulations in Parts 30 through 35, 40, or 70 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter.

§ 20.3 Definitions.

(a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

40 FR 42587

(4) "Calendar quarter" means not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January and subsequent calendar quarters shall be such that no day is included in more than one calendar quarter or omitted from inclusion within a calendar quarter. No licensee shall change the method observed by him of determining calendar quarters except at the beginning of a calendar year.

(5) "Commission" means the Nuclear Regulatory Commission or its duly authorized representatives;

FIGURE 6-9

(6) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(7) "Individual" means any human being;

(8) "Licensed material" means source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

(9) "License" means a license issued under the regulations in Part 30, 40, or 70 of this chapter. "Licensee" means the holder of such license;

(10) "Occupational dose" includes exposure of an individual to radiation (i) in a restricted area; or (ii) in the course of employment in which the individual's duties involve exposure to radiation; provided, that "occupational dose" shall not be deemed to include any exposure of an individual to radiation for the purpose of medical diagnosis or medical therapy of such individual.

(11) "Person" means (i) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Administration (except that the Administration shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244)), any State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing.

(12) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(13) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

(14) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

(15) "Source material" means (i) uranium or thorium, or any combination thereof, in any physical or chemical form; or (ii) ores which contain by weight one-twentieth of one percent (0.05%) or more of a. uranium, b. thorium or c. any combination thereof. Source material does not include special nuclear material.

(16) "Special nuclear material" means (i) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (ii) any material artificially enriched by any of the foregoing but does not include source material;

(17) "Unrestricted area" means any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

(18) "Department" means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c) and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93–438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565 at 577–578, 42 U.S.C. 7151).

(19) "Termination" means the end of employment with the licensee or, in the case of individuals not employed by the licensee, the end of a work assignment in the licensee's restricted areas in a given calendar quarter, without expectation or specific scheduling of reentry into the licensee's restricted areas during the remainder of that calendar quarter.

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;

(4) "Survey" defined in § 20.201;

(5) Units of measurement of dose (rad, rem) defined in § 20.4;

(6) Units of measurement of radioactivity defined in § 20.5.

§ 20.4 Units of radiation dose.

(a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad) = 0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem) = 0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X– or gamma radiation;

(2) A dose of 1 rad due to X–, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subparagraph (3) of this paragraph, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² per sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(d) For determining exposures to X or gamma rays up to 3 Mev, the dose limits specified in §§ 20.101 to 20.104, inclusive, may be assumed to be equivalent to the "air dose". For the purpose of this part "air dose" means that the dose is measured by a properly calibrated appropriate instrument in air at or near the body surface in the region of highest dosage rate.

[38 FR 29314]

§ 20.5 Units of radioactivity.

(a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie=3.7×10^{10} disintegrations per second (dps)=2.2×10^{12} disintegrations per minute (dpm). Commonly used submultiples of the curie are the millicurie and the microcurie:

(1) One millicurie (mCi)[1]=0.001 curie (Ci)[1]=3.7×10^{7} dps.

(2) One microcurie (μCi)[1]=0.000001 curie=3.7×10^{4} dps.

(b) [Deleted 40 FR 50704.]

(c) [Deleted 39 FR 23990.]

[25 FR 10914]

§ 20.6 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

[40 FR 8774]

§ 20.7 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

[44 FR 32352]

§ 20.101 Radiation dose standards for individuals in restricted areas.

(a) In accordance with the provisions of § 20.102(a), and except as provided in paragraph (b) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from radioactive material and other sources of radiation a total occupational dose in excess of the standards specified in the following table:

[25 FR 10914]

	Rems per calendar quarter
1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1¼
2. Hands and forearms; feet and ankles	18¾
3. Skin of whole body	7½

[44 FR 32352]

(b) A licensee may permit an individual in a restricted area to receive a total occupational dose to the whole body greater than that permitted under paragraph (a) of this section, provided:

(1) During any calendar quarter the total occupational dose to the whole body shall not exceed 3 rems; and

[25 FR 10914]

(2) The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed 5 (N−18) rems where "N" equals the individual's age in years at his last birthday; and

(3) The licensee has determined the individual's accumulated occupational dose to the whole body on Form NRC-4, or on a clear and legible record containing all the information required in that form, and has otherwise complied with the requirements of § 20.102. As used in paragraph (b), "Dose to the whole body" shall be deemed to include any dose to the whole body, gonads, active blood-forming organs, head and trunk, or lens of eye.

[44 FR 32352]

§ 20.102 Determination of prior dose.

(a) Each licensee shall require any individual, prior to first entry of the individual into the licensee's restricted area during each employment or work assignment under such circumstances that the individual will receive or is likely to receive in any period of one calendar quarter an occupational dose in excess of 25 percent of the applicable standards specified in § 20.101(a) and § 20.104(a), to disclose in a written, signed statement, either (1) that the individual had no prior occupational dose during the current calendar quarter, or (2) the nature and amount of any occupational dose which the individual may have received during that specifically identified current calendar quarter from sources of radiation possessed or controlled by other persons. Each licensee shall maintain records of such statements until the Commission authorizes their disposition.

(b) Before permitting, pursuant to § 20.101(b), any individual in a restricted area to receive an occupational radiation dose in excess of the standards specified in § 20.101(a), each licensee shall:

[25 FR 10914]

(1) Obtain a certificate on Form NRC-4, or on a clear and legible record containing all the information required in that form, signed by the individual showing each period of time after the individual attained the age of 18 in which the individual received an occupational dose of radiation; and

(2) Calculate on Form NRC-4 in accordance with the instructions appearing therein, or on a clear and legible record containing all the information required in that form, the previously accumulated occupational dose received by the individual and the additional dose allowed for that individual under § 20.101(b).

[25 FR 10914]

(c)(1) In the preparation of Form NRC-4, or a clear and legible record containing all the information required in that form, the licensee shall make a reasonable effort to obtain reports of the individual's previously accumulated occupational dose. For each period for which the licensee obtains such reports, the licensee shall use the dose shown in the report in preparing the form. In any case where a licensee is unable to obtain reports of the individual's occupational dose for a previous complete calendar quarter, it shall be assumed that the individual has received the occupational dose specified in whichever of the following columns apply:

[25 FR 10914]

Part of body	Column 1 Assumed exposure in rems for calendar quarters prior to Jan. 1, 1961	Column 2 Assumed exposure in rems for calendar quarters beginning on or after Jan. 1, 1961
Whole body, gonads, active blood-forming organs, head and trunk, lens of eye	3¾	1¼

[41 FR 18300]

(2) The licensee shall retain and preserve records used in preparing Form NRC-4 until the Commission authorizes their disposition.

[25 FR 10914]

(d) If calculation of the individual's accumulated occupational dose for all periods prior to January 1, 1961 yields a result higher than the applicable accumulated dose value for the individual as of that date, as specified in paragraph (b) of § 20.101, the excess may be disregarded.

[41 FR 52300]

§ 20.103 Exposure of individuals to concentrations of radioactive materials in air in restricted areas.

(a)(1) No licensee shall possess, use, or transfer licensed material in such a manner as to permit any individual in a restricted area to inhale a quantity of radioactive material in any period of one calendar quarter greater than the quantity which would result from inhalation for 40 hours per week for 13 weeks at uniform concentrations of radioactive material in air specified in Appendix B, Table I, Column 1.[2,3] If the radioactive material is of such form that intake by absorption through the skin is likely, individual exposures to radioactive material shall be controlled so that the uptake of radioactive material by any organ from either inhalation or absorption or both routes of intake[4] in any calendar quarter does not exceed that which would result from inhaling such radioactive material for 40 hours per week for 13 weeks at uniform concentrations specified in Appendix B, Table I, Column 1.

[1] Wherever possible, the appropriate unit should be written out as "curie(s)," "millicurie(s)," or "microcurie(s)," and the abbreviations should not be used.

** Amended 36 FR 1466.

43 FR 29270

[1] Since the concentration specified for tritium oxide vapor assumes equal intakes by skin absorption and inhalation, the total intake permitted is twice that which would result from inhalation alone at the concentration specified for H^3 S in Appendix B, Table I, Column 1 for 40 hours per week for 13 weeks.

[2] For radon-222, the limiting quantity is that inhaled in a period of one calendar year. For radioactive materials designated "Sub" in the "Isotope" column of the table, the concentration value specified is based upon exposure to the material as an external radiation source. Individual exposures to these materials may be accounted for as part of the limitation on individual dose in § 20.101. These nuclides shall be subject to the precautionary procedures required by § 20.103(b)(1).

[3] Multiply the concentration values specified in appendix B, table I, column 1, by 6.3×10^{8} ml to obtain the quarterly quantity limit. Multiply the concentration value specified in appendix B, table I, column 1, by 2.5×10^{9} ml to obtain the annual quantity limit for Rn-222.

Footnotes 4 and 5 on page 20-4.

(2) No licensee shall possess, use, or transfer mixtures of U-234, U-235, and U-238 in soluble form in such a manner as to permit any individual in a restricted area to inhale a quantity of such material in excess of the intake limits specified in Appendix B, Table I, Column 1 of this part. If such soluble uranium is of a form such that absorption through the skin is likely, individual exposures to such material shall be controlled so that the uptake of such material by any organ from either inhalation or absorption or both routes of intake[4] does not exceed that which would result from inhaling such material at the limits specified in Appendix B, Table I, Column 1 and footnote 4 thereto.

(41 FR 52300) (3) For purposes of determining compliance with the requirements of this section the licensee shall use suitable measurements of concentrations of radioactive materials in air for detecting and evaluating airborne radioactivity in restricted areas and in addition, as appropriate, shall use measurements of radioactivity in the body, measurements of radioactivity excreted from the body, or any combination of such measurements as may be necessary for timely detection and assessment of individual intakes of radioactivity by exposed individuals. It is assumed that an individual inhales radioactive material at the airborne concentration in which he is present unless he uses respiratory protective equipment pursuant to paragraph (c) of this section. When assessment[5] of a particular individual's intake of radioactive material is necessary, intakes less than those which would result from inhalation for 2 hours in any one day or for 10 hours in any one week at uniform concentrations specified in Appendix B, Table I, Column 1 need not be included in such assessment, provided that for any assessment in excess of these amounts the entire amount is included.

(b)(1) The licensee shall, as a precautionary procedure, use process or other engineering controls, to the extent practicable, to limit concentrations of radioactive materials in air to levels below those which delimit an airborne radioactivity area as defined in § 20.203(d)(1)(ii).

(2) When it is impracticable to apply process or other engineering controls to limit concentrations of radioactive material in air below those defined in § 20.203(d)(1)(ii), other precautionary procedures, such as increased surveillance, limitation of working times, or provision of respiratory protective equipment, shall be used to maintain intake of radioactive material by any individual within any period of seven consecutive days as far below that intake of radioactive material which would result from inhalation of such material for 40 hours at the uniform concentrations specified in Appendix B, Table I, Column 1 as is reasonably achievable. Whenever the intake of radioactive material by any individual exceeds this 40-hour control measure, the licensee shall make such evaluations and take such actions as are necessary to assure against recurrence. The licensee shall maintain records of such occurrences, evaluations, and actions taken in a clear and readily identifiable form suitable for summary review and evaluation.

(41 FR 52300) (c) When respiratory protective equipment is used to limit the inhalation of airborne radioactive material pursuant to paragraph (b)(2) of this section, the licensee may make allowance for such use in estimating exposures of individuals to such materials provided that such equipment is used as stipulated in Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection."[6]

(d) Notwithstanding the provisions of paragraphs (b) and (c) of this section, the Commission may impose further restrictions:

(1) On the extent to which a licensee may make allowance for use of respirators in lieu of provision of process, containment, ventilation, or other engineering controls, if application of such controls is found to be practicable; and

(2) As might be necessary to assure that the respiratory protective program of the licensee is adequate in limiting exposures of personnel to airborne radioactive materials.

(e) The licensee shall notify, in writing, the Director of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D at least 30 days before the date that respiratory protective equipment is first used under the provisions of this section.

(f) A licensee who was authorized to make allowance for use of respiratory protective equipment prior to December 29, 1976 shall bring his respiratory protective program into conformance with the requirements of paragraph (c) of this section within one year of that date, and is exempt from the requirement of paragraph (e) of this section.

§ 20.104 Exposure of minors.

(25 FR 10914) (a) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area who is under 18 years of age, to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in the table in paragraph (a) of § 20.101.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area, who is under 18 years of age to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

(41 FR 52300) (c) The provisions of §§ 20.103(b)(2) and 20.103(c) shall apply to exposures subject to paragraph (b) of this section except that the references in §§ 20.103(b)(2) and 20.103(c) to Appendix B, Table I, Column 1 shall be deemed to be references to Appendix B, Table II, Column 1.

§ 20.105 Permissible levels of radiation in unrestricted areas.

(25 FR 10914) (a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

§ 20.106 Radioactivity in effluents to unrestricted areas.

(29 FR 14434) (a) A licensee shall not possess, use, or transfer licensed material so as to release to an unrestricted area radioactive material in concentrations which exceed

---

[4] Significant intake by ingestion or injection is presumed to occur only as a result of circumstances such as accident, inadvertence, poor procedure, or similar special conditions. Such intakes must be evaluated and accounted for by techniques and procedures as may be appropriate to the circumstances of the occurrence. Exposures so evaluated shall be included in determining whether the limitation on individual exposures in § 20.103(a)(1) has been exceeded.

[5] Regulatory guidance on assessment of individual intakes of radioactive material is given in Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program," single copies of which are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

[6] This incorporation by reference provision was approved by the Director of the Federal Register on October 19, 1976. Single copies of Regulatory Guide 8.15 are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

the limits specified in Appendix "B", Table II of this part, except as authorized pursuant to § 20.302 or paragraph (b) of this section. For purposes of this section concentrations may be averaged over a period not greater than one year.

(b) An application for a license or amendment may include proposed limits higher than those specified in paragraph (a) of this section. The Commission will approve the proposed limits if the applicant demonstrates:

(1) That the applicant has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted areas; and

(2) That it is not likely that radioactive material discharged in the effluent would result in the exposure of an individual to concentrations of radioactive material in air or water exceeding the limits specified in Appendix "B", Table II of this part.

(c) An application for higher limits pursuant to paragraph (b) of this section shall include information demonstrating that the applicant has made a reasonable effort to minimize the radioactivity discharged in effluents to unrestricted areas, and shall include, as pertinent:

(1) Information as to flow rates, total volume of effluent, peak concentration of each radionuclide in the effluent, and concentration of each radionuclide in the effluent averaged over a period of one year at the point where the effluent leaves a stack, tube, pipe, or similar conduit;

29 FR 14434

(2) A description of the properties of the effluents, including:

(i) chemical composition;

(ii) physical characteristics, including suspended solids content in liquid effluents, and nature of gas or aerosol for air effluents;

(iii) the hydrogen ion concentrations (pH) of liquid effluents; and

(iv) the size range of particulates in effluents released into air.

(3) A description of the anticipated human occupancy in the unrestricted area where the highest concentration of radioactive material from the effluent is expected, and, in the case of a river or stream, a description of water uses downstream from the point of release of the effluent.

(4) Information as to the highest concentration of each radionuclide in an unrestricted area, including anticipated concentrations averaged over a period of one year:

(i) In air at any point of human occupancy; or

(ii) In water at points of use downstream from the point of release of the effluent.

(5) The background concentration of radionuclides in the receiving river or stream prior to the release of liquid effluent.

(6) A description of the environmental monitoring equipment, including sensitivity of the system, and procedures and calculations to determine concentrations of radionuclides in the unrestricted area and possible reconcentrations of radionuclides.

(7) A description of the waste treatment facilities and procedures used to reduce the concentration of radionuclides in effluents prior to their release.

(d) For the purposes of this section the concentration limits in Appendix "B", Table II of this part shall apply at the boundary of the restricted area. The concentration of radioactive material discharged through a stack, pipe or similar conduit may be determined with respect to the point where the material leaves the conduit. If the conduit discharges within the restricted area, the concentration at the boundary may be determined by applying appropriate factors for dilution, dispersion, or decay between the point of discharge and the boundary.

29 FR 14434

(e) In addition to limiting concentrations in effluent streams, the Commission may limit quantities of radioactive materials released in air or water during a specified period of time if it appears that the daily intake of radioactive material from air, water, or food by a suitable sample of an exposed population group, averaged over a period not exceeding one year, would otherwise exceed the daily intake resulting from continuous exposure to air or water containing one-third the concentration of radioactive materials specified in Appendix "B", Table II of this part.

(f) The provisions of this section do not apply to disposal of radioactive material into sanitary sewerage systems, which is governed by § 20.303.

§ 20.107 Medical diagnosis and therapy.

Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.108 Orders requiring furnishing of bio-assay services.

Where necessary or desirable in order to aid in determining the extent of an individual's exposure to concentrations of radioactive material, the Commission may incorporate appropriate provisions in any license, directing the licensee to make available to the individual appropriate bio-assay services and to furnish a copy of the reports of such services to the Commission.

25 FR 10914

Precautionary Procedures

§ 20.201 Surveys.

(a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

(b) Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part.

§ 20.202 Personnel monitoring.

(a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 25 percent of the applicable value specified in paragraph (a) of § 20.101.

(2) Each individual under 18 years of age who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 5 percent of the applicable value specified in paragraph (a) of § 20.101.

(3) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment" means devices designed to be worn or carried by an individual for the purpose of measuring the dose received (e. g., film badges, pocket chambers, pocket dosimeters, film rings, etc.);

25 FR 10914

(2) "Radiation area" means any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirems;

(3) "High radiation area" means any area, accessible to personnel, in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

35 FR 5033

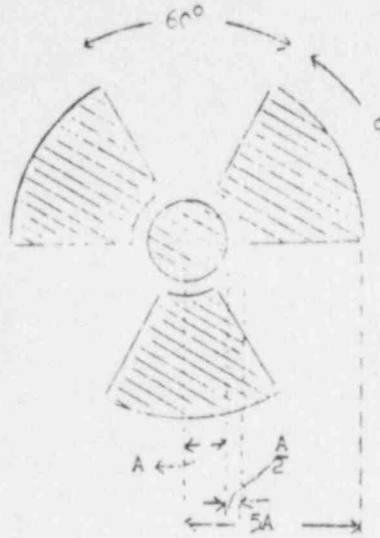
§ 20.203 Caution signs, labels, signals, and controls.

(a) *General.* (1) Except as otherwise authorized by the Commission, symbols prescribed by this section shall use the conventional radiation caution colors (magenta or purple on yellow background). The symbol prescribed by this section is the conventional three-bladed design:

PART 20 • STANDARDS FOR PROTECTION AGAINST RADIATION

RADIATION SYMBOL

1 Cross-hatched area is to be magenta or purple.
2 Background is to be yellow.



(2) In addition to the contents of signs and labels prescribed in this section, licensees may provide on or near such signs and labels any additional information which may be appropriate in aiding individuals to minimize exposure to radiation or to radioactive material.

(b) *Radiation areas.* Each radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]
RADIATION AREA

(c) *High radiation areas.* (1) Each high radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]
HIGH RADIATION AREA

35 FR 5033

(2) Each entrance or access point to a high radiation area shall be:

(i) Equipped with a control device which shall cause the level of radiation to be reduced below that at which an individual might receive a dose of 100 millirems in 1 hour upon entry into the area; or

(ii) Equipped with a control device which shall energize a conspicuous visible or audible alarm signal in such a manner that the individual entering the high radiation area and the licensee or a supervisor of the activity are made aware of the entry; or

(iii) Maintained locked except during periods when access to the area is required, with positive control over each individual entry.

(3) The controls required by subparagraph (2) of this paragraph shall be established in such a way that no individual will be prevented from leaving a high radiation area.

(4) In the case of a high radiation area established for a period of 30 days or less, direct surveillance to prevent unauthorized entry may be substituted for the controls required by subparagraph (2) of this paragraph.

35 FR 5033

(5) Any licensee, or applicant for a license, may apply to the Commission for approval of methods not included in subparagraphs (2) and (4) of this paragraph for controlling access to high radiation areas. The Commission will approve the proposed alternatives if the licensee or applicant demonstrates that the alternative methods of control will prevent unauthorized entry into a high radiation area, and that the requirement of subparagraph (3) of this paragraph is met.

42 FR 64619

(6) Each area in which there may exist radiation levels in excess of 500 rems in one hour at one meter from a sealed radio-active source[2] that is used to irradiate materials shall:[3]

(i) Have each entrance or access point equipped with entry control devices which shall function automatically to prevent any individual from inadvertently entering the area when such radiation levels exist; permit deliberate entry into the area only after a control device is actuated that shall cause the radiation level within the area, from the sealed source, to be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and prevent operation of the source if the source would produce radiation levels in the area that could result in a dose to an individual in excess of 100 mrem in one hour. The entry control devices required by this paragraph (c)(6) shall be established in such a way that no individual will be prevented from leaving the area.

(ii) Be equipped with additional control devices such that upon failure of the entry control devices to function as required by paragraph (c)(6)(i) of this section the radiation level within the area, from the sealed source, shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make an individual attempting to enter the area aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of such failure of the entry control devices.

42 FR 64619

(iii) Be equipped with control devices such that upon failure or removal of physical radiation barriers other than the source's shielded storage container the radiation level from the source shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make potentially affected individuals aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of the failure or removal of the physical barrier. When the shield for the stored source is a liquid, means shall be provided to monitor the integrity of the shield and to signal, automatically, loss of adequate shielding. Physical radiation barriers that comprise permanent structural components, such as walls, that have no credible probability of failure or removal in ordinary circumstances need not meet the requirements of this paragraph (c)(6)(iii).

(iv) Be equipped with devices that will automatically generate visible and audible alarm signals to alert personnel in the area before the source can be put into operation and in sufficient time for any individual in the area to operate a clearly identified control device which shall be installed in the area and which can prevent the source from being put into operation.

(v) Be controlled by use of such administrative procedures* and such devices as are necessary to assure that the area is cleared of personnel prior to each use of the source preceding which use it might have been possible for an individual to have entered the area.

(vi) Be checked by a physical radiation measurement to assure that prior to the first individual's entry into the area after any use of the source the radiation level from the source in the area is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(vii) Have entry control devices required in paragraph (c)(6)(i) of this section which have been tested for proper functioning prior to initial operation with such source of radiation on any day that operations are not uninterruptedly continued from the previous day or before resuming operations after any unintended interruption, and for which records are kept of the dates, times, and results of such tests of func-

---

[1] Or "Danger".

[2] This paragraph (c)(6) does not apply to radioactive sources that are used in teletherapy, in radiography, or in completely self-shielded irradiators in which the source is both stored and operated within the same shielding radiation barrier and, in the designed configuration of the irradiator, is always physically inaccessible to any individual and cannot create high levels of radiation in an area that is accessible to any individual. This paragraph (c)(6) also does not apply to sources from which the radiation is incidental to some other use nor to nuclear reactor generated radiation other than radiation from byproduct, source, or special nuclear materials that are used in sealed sources in non-self-shielded irradiators.

[3] These requirements apply after Mar. 14, 1978. Each person licensed to conduct activities to which this paragraph (c)(6) applies and who is not in compliance with the provisions of this paragraph on Mar. 14, 1978, shal file with the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, on or before June 14, 1978, information describing in detail the actions taken or to be taken to achieve compliance with this paragraph by Dec. 14, 1978, and may continue activities in conformance with present license conditions and the provisions of the previously effective § 20.203 until such compliance is achieved. For such persons compliance must be achieved not later than Dec. 14, 1978.

‡ Amended 43 FR 2167.

* Amended.

tion. No operations other than those necessary to place the source in safe condition or to effect repairs on controls shall be conducted with such source unless control devices are functioning properly. The licensee shall submit an acceptable schedule for more complete periodic tests of the entry control and warning systems to be established and adhered to as a condition of the license.

(viii) Have those entry and exit portals that are used in transporting materials to and from the irradiation area, and that are not intended for use by individuals, controlled by such devices and administrative procedures as are necessary to physically protect and warn against inadvertent entry by any individual through such portals. Exit portals for processed materials shall be equipped to detect and signal the presence of loose radiation sources that are carried toward such an exit and to automatically prevent such loose sources from being carried out of the area.

(7) Licensees with, or applicants for, licenses for radiation sources that are within the purview of paragraph (c)(6) of this section, and that must be used in a variety of positions or in peculiar locations, such as open fields or forests, that make it impracticable to comply with certain requirements of paragraph (c)(6) of this section, such as those for the automatic control of radiation levels, may apply to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, for approval, prior to use of safety measures that are alternative to those specified* in paragraph (c)(6) of this section, and that will provide at least an equivalent degree of personnel protection in the use of such sources. At least one of the alternative measures must include an entry-preventing interlock control based on a physical measurement of radiation that assures the absence of high radiation levels before an individual can gain access to an area where such sources are used.

42 FR 54619

(d) *Airborne radioactivity areas.* (1) As used in the regulations in this part, "airborne radioactivity area" means (i) any room, enclosure, or operating area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations in excess of the amounts specified in Appendix B, Table I, Column 1 of this part; or (ii) any room, enclosure, or operating area in which airborne radioactive material composed wholly or partly of licensed material exists in concentrations which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B, Table I, Column 1 of this part.

(2) Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

AIRBORNE RADIOACTIVITY AREA

(e) *Additional requirements.* (1) Each area or room in which licensed material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding 10 times the quantity of such material specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

RADIOACTIVE MATERIAL(S)

(2) Each area or room in which natural uranium or thorium is used or stored in an amount exceeding one-hundred times the quantity specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

RADIOACTIVE MATERIAL(S)

(f) *Containers.* (1) Except as provided in subparagraph (3) of this paragraph, each container of licensed material shall bear a durable, clearly visible label identifying the radioactive contents.

(2) A label required pursuant to subparagraph (1) of this paragraph shall bear the radiation caution symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL". It shall also provide sufficient information[1] to permit individuals handling or using the containers, or working in the vicinity thereof, to take precautions to avoid or minimize exposures.

(3) Notwithstanding the provisions of subparagraph (1) of this paragraph, labeling is not required:

(i) For containers that do not contain licensed materials in quantities greater than the applicable quantities listed in Appendix C of this part.

(ii) For containers containing only natural uranium or thorium in quantities no greater than 10 times the applicable quantities listed in Appendix C of this part.

(iii) For containers that do not contain licensed materials in concentrations greater than the applicable concentrations listed in Column 2, Table I, Appendix B of this part.

(iv) For containers when they are attended by an individual who takes the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established by the regulations in this part.

(v) For containers when they are in transport and packaged and labeled in accordance with regulations of the * Department of Transportation.

31 FR 10514

(vi) For containers which are accessible[2] only to individuals authorized to handle or use them, or to work in the vicinity thereof, provided that the contents are identified to such individuals by a readily available written record.

(vii) For manufacturing or process equipment, such as nuclear reactors, reactor components, piping, and tanks.

(4) Each licensee shall, prior to disposal of an empty uncontaminated container to unrestricted areas, remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

43 FR 22171

[1] Or Danger

*Amended.

[1] As appropriate, the information will include radiation levels, kinds of material, estimate of activity, date for which activity is estimated, mass enrichment, etc.

[2] For example, containers in locations such as water-filled canals, storage vaults, or hot cells.

* Amended 34 FR 19546.

§ 20.204 Same: exceptions.

Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

(b) Rooms or other areas in hospitals are not required to be posted with caution signs, and control of entrance or access thereto pursuant to § 20.203(c) is not required, because of the presence of patients containing byproduct material provided that there are personnel in attendance who will take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits established in the regulations in this part.

(c) Caution signs are not required to be posted at areas or rooms containing radioactive materials for periods of less than eight hours provided that (1) the materials are constantly attended during such periods by an individual who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations in this part and; (2) such area or room is subject to the licensee's control.

(d) A room or other area is not required to be posted with a caution sign, and control is not required for each entrance or access point to a room or other area which is a high radiation area solely because of the presence of radioactive materials prepared for transport and packaged and labeled in accordance with regulations of the Department of Transportation.

§ 20.205 Procedures for picking up, receiving, and opening packages.

(a)(1) Each licensee who expects to receive a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section shall:

(i) If the package is to be delivered to the licensee's facility by the carrier, make arrangements to receive the package when it is offered for delivery by the carrier; or

(ii) If the package is to be picked up by the licensee at the carrier's terminal, make arrangements to receive notification from the carrier of the arrival of the package, at the time of arrival.

(2) Each licensee who picks up a package of radioactive material from a carrier's terminal shall pick up the package expeditiously upon receipt of notification from the carrier of its arrival.

(b)(1) Each licensee, upon receipt of a package of radioactive material, shall monitor the external surfaces of the package for radioactive contamination caused by leakage of the radioactive contents, except:

(i) Packages containing no more than the exempt quantity specified in the table in this paragraph;

(ii) Packages containing no more than 10 millicuries of radioactive material consisting solely of tritium, carbon-14, sulfur-35, or iodine-125;

(iii) Packages containing only radioactive material as gases or in special form;

(iv) Packages containing only radioactive material in other than liquid form (including Mo-99/Tc-99m generators) and not exceeding the Type A quantity limit specified in the table in this paragraph; and

(v) Packages containing only radionuclides with half-lives of less than 30 days and a total quantity of no more than 100 millicuries.

The monitoring shall be performed as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or eighteen hours if received after normal working hours.

(2) If removable radioactive contamination in excess of 0.01 microcuries (22,000 disintegrations per minute) per 100 square centimeters of package surface is found on the external surfaces of the package, the licensee shall immediately notify the final delivering carrier and, by telephone and telegraph, mailgram, or facsimile,† the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office shown in Appendix D.

TABLE OF EXEMPT AND TYPE A QUANTITIES

Transport group[1]	Exempt quantity limit (in millicuries)	Type A quantity limit (in curies)
I	.01	0.001
II	0.1	0.050
III	1	3
IV	1	20
V	1	20
VI	1	1000
VII	25,000	1000
Special Form	1	20

(c)(1) Each licensee, upon receipt of a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section, other than those transported by exclusive use vehicle, shall monitor the radiation levels external to the package. The package shall be monitored as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or 18 hours if received after normal working hours.

(2) If radiation levels are found on the external surface of the package in excess of 200 millirem per hour, or at three feet from the external surface of the package in excess of 10 millirem per hour, the licensee shall immediately notify by telephone and telegraph, mailgram, or facsimile, the director of the appropriate NRC Regional Office listed in Appendix D, and the final delivering carrier.

(d) Each licensee shall establish and maintain procedures for safely opening packages in which licensed material is received, and shall assure that such procedures are followed and that due consideration is given to special instructions for the type of package being opened.

§ 20.206 Instruction of personnel.

Instructions required for individuals working in or frequenting any portion of a restricted area are specified in § 19.12 of this chapter.

[1] The definitions of "transport group" and "special form" are specified in § 71.4 of this chapter.

†Amended 41 FR 16445.

40 FR 26679 **§ 20.207 Storage and control of licensed materials in unrestricted areas.**

(a) Licensed materials stored in an unrestricted area shall be secured from unauthorized removal from the place of storage.

(b) Licensed materials in an unrestricted area and not in storage shall be tended under the constant surveillance and immediate control of the licensee.

WASTE DISPOSAL

25 FR 10914 **§ 20.301 General requirement.**

No licensee shall dispose of licensed material except:

(a) By transfer to an authorized recipient as provided in the regulations in Part 30, 40, or 70 of this chapter, whichever may be applicable; or

(b) As authorized pursuant to § 20.302; or

45 FR 71761 (c) As provided in § 20.303, applicable to the disposal of licensed material by release into sanitary sewerage systems, or in § 20.106 (Radioactivity in effluents to unrestricted areas).

25 FR 10914 **§ 20.302 Method for obtaining approval of proposed disposal procedures.**

*(a) Any licensee or applicant for a license may apply to the Commission for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations in this chapter. Each application should include a description of the licensed material and any other radioactive material involved, including the quantities and kinds of such material and the levels of radioactivity involved, and the proposed manner and conditions of disposal. The application should also include an analysis and evaluation of pertinent information as to the nature of the environment, including topographical, geological, meteorological, and hydrological characteristics; usage of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures.

26 FR 352 *(b) The Commission will not approve any application for a license to receive licensed material from other persons for disposal on land not owned by the Federal government or by a State government.

36 FR 23138 (c) The Commission will not approve any application for a license for disposal of licensed material at sea unless the applicant shows that sea disposal offers less harm to man or the environment than other practical alternative methods of disposal.

25 FR 10914 **§ 20.303 Disposal by release into sanitary sewerage systems.**

No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of subparagraphs (1) or (2) of this paragraph:

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

25 FR 10914 (d) The gross quantity of licensed and other radioactive material released into the sewerage system by the licensee does not exceed one curie per year.

Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.305 Treatment or disposal by incineration.

No licensee shall treat or dispose of licensed material by incineration except as specifically approved by the Commission pursuant to §§ 20.106(b) and 20.302.

RECORDS, REPORTS, AND NOTIFICATION

§ 20.401 Records of surveys, radiation monitoring, and disposal.

(a) Each licensee shall maintain records showing the radiation exposures of all individuals for whom personnel monitoring is required under § 20.202 of the regulations in this part. Such records shall be kept on Form NRC-5, in accordance with the instructions contained in that form or on clear and legible records containing all the information required by Form NRC-5. The doses entered on the forms or records shall be for periods of time not exceeding one calendar quarter.

45 FR 71761 (b) Each licensee shall maintain records in the same units used in this part, showing the results of surveys required by § 20.301(b), monitoring required by §§ 20.205(b) and 20.205(c), and disposals made under §§ 20.302, 20.303 and deleted § 20.304.[1]

41 FR 18300 (c)(1) Records of individual exposure to radiation and to radioactive material which must be maintained pursuant to the provisions of paragraph (a) of this section and records of bioassays, including results of whole body counting examinations, made pursuant to § 20.108, shall be preserved until the Commission authorizes disposition.

(2) Records of the results of surveys and monitoring which must be maintained pursuant to paragraph (b) of this section shall be preserved for two years after completion of the survey except that the following records shall be maintained until the Commission authorizes their disposition: (i) records of the results of surveys to determine compliance with § 20.103(a); (ii) in the absence of personnel monitoring data, records of the results of surveys to determine external radiation dose; and (iii) records of the results of surveys used to evaluate the release of radioactive effluents to the environment.

45 FR 71761 (3) Records of disposal of licensed material made pursuant to §§ 20.302, 20.303, and deleted § 20.304[1] are to be maintained until the Commission authorizes their disposition.

41 FR 18300 (4) Records which must be maintained pursuant to this part may be the original or a reproduced copy or microform if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by Commission regulations.

(5) If there is a conflict between the Commission's regulations in this part, license condition, or technical specification, or other written Commission approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part for such records shall apply unless the Commission pursuant to § 20.501, has granted a specific exemption from the record retention requirements specified in the regulations in this part.

34 FR 7500 **§ 20.402 Reports of theft or loss of licensed material.**

(a) Each licensee shall report by telephone† to the Director of the appropriate Nuclear Regulatory Commission of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D, immediately after its occurrence becomes known to the licensee, any loss or theft of licensed material in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

41 FR 16445 (b) Each licensee who is required to make a report pursuant to paragraph (a) of this section shall, within thirty (30) days after he learns of the loss or theft, make a report in writing to the appropriate NRC Regional Office listed in Appen-

*Redesignated 36 FR 23138.

[1] Section 20.304 provided for burial of small quantities of licensed materials in soil. Notice of its deletion appears in the Federal Register of October 30, 1980 (45 FR ——).

† Amended 42 FR 43965.

dix D with copies to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, setting forth the following information:

(1) A description of the licensed material involved, including kind, quantity, chemical, and physical form;

(2) A description of the circumstances under which the loss or theft occurred;

(3) A statement of disposition or probable disposition of the licensed material involved;

(4) Radiation exposures to individuals, circumstances under which the exposures occurred, and the extent of possible hazard to persons in unrestricted areas;

(5) Actions which have been taken, or will be taken, to recover the material; and

(6) Procedures or measures which have been or will be adopted to prevent a recurrence of the loss or theft of licensed material.

(c) Subsequent to filing the written report the licensee shall also report any substantive additional information on the loss or theft which becomes available to the licensee, within 30 days after he learns of such information.

(d) Any report filed with the Commission pursuant to this section shall be so prepared that names of individuals who may have received exposure to radiation are stated in a separate part of the report.

34 FR 7500

§ 20.403 Notifications of incidents.

(a) *Immediate notification.* Each licensee shall immediately notify by telephone and telegraph, mailgram, or facsimile, the Director of the appropriate NRC Regional Office listed in Appendix D of any incident involving byproduct, source, or special nuclear material possessed by him and which may have caused or threatens to cause:

41 FR 16446

(1) Exposure of the whole body of any individual to 25 rems or more of radiation; exposure of the skin of the whole body of any individual of 150 rems or more of radiation; or exposure of the feet, ankles, hands or forearms of any individual to 375 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 5,000 times the limits specified for such materials in Appendix B, Table II; or

(3) A loss of one working week or more of the operation of any facilities affected; or

(4) Damage to property in excess of $200,000. ‡

27 FR 5906

(b) *Twenty-four hour notification.* Each licensee shall within 24 hours notify by telephone and telegraph, mailgram, or facsimile, the Director of the appropriate NRC Regional Office listed in Appendix D of any incident involving licensed material possessed by him and which may have caused or threatens to cause:

41 FR 16446

(1) Exposure of the whole body of any individual to 5 rems or more of radiation; exposure of the skin of the whole body of any individual to 30 rems or more of radiation; or exposure of the feet, ankles, hands, or forearms to 75 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix B, Table II; or

(3) A loss of one day or more of the operation of any facilities affected; or

(4) Damage to property in excess of $2,000. ‡

27 FR 5906

(c) Any report filed with the Commission pursuant to this section shall be prepared so that names of individuals who have received exposure to radiation will be stated in a separate part of the report.

28 FR 6822

(d) For nuclear power reactors licensed under § 50.21 or § 50.22, the incidents included in paragraph (a) and paragraph (b) in this section shall in addition be reported pursuant to § 50.72.

45 FR 13434

‡Amended 42 FR 43965.

*Correction

§ 20.404 [Deleted 38 FR 22220.]

42 FR 20138

§ 20.405 Reports of overexposures and excessive levels and concentrations.

(a) In addition to any notification required by § 20.403, each licensee shall make a report in writing within 30 days to the appropriate NRC Regional Office listed in Appendix D with a copy to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, of:

41 FR 52300

(1) each exposure of an individual to radiation in excess of the applicable limits in §§ 20.101 or 20.104 (a) or the license; (2) each exposure of an individual to radioactive material in excess of the applicable limits in §§ 20.103(a)(1), 20.103(a)(2), 20.104(b) or the license; (3) levels of radiation or concentrations of radioactive material in a restricted area in excess of any other applicable limit in the license; (4) any incident for which notification is required by § 20.403; and (5) levels of radiation or concentrations of radioactive material (whether or not involving excessive exposure of any individual) in an unrestricted area in excess of ten times any applicable limit set forth in this part or in the license. Each report required under this paragraph shall describe the extent of exposure of individuals** to radiation or to radioactive material, including estimates of each individual's exposure as required by paragraph (b) of this section; levels of radiation and concentrations of radioactive material involved; the cause of the exposure, levels or concentrations; and corrective steps taken or planned to assure against a recurrence.

35 FR 15087

(b) Any report filed with the Commission pursuant to this section shall include for each individual exposed the name, social security number, and date of birth; and an estimate of the individual's exposure. The report shall be prepared so that this information is stated in a separate part of the report.

(c) [Deleted 38 FR 22220.]

§ 20.406 [Deleted 38 FR 22220.]

43 FR 44827

§ 20.407 Personnel monitoring reports.

Each person described in § 20.408 of this part shall, within the first quarter of each calendar year, submit to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, the reports specified in paragraphs (a) and (b) of this section covering the preceding calendar year.[1] All other persons specifically licensed by the Commission shall, within the first quarter of calendar years 1979 and 1980, submit to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, the reports specified in paragraphs (a) and (b) of this section covering the preceding calendar years 1978 and 1979.[2]

(a) A report of either (1) the total number of individuals for whom personnel monitoring was required under §§ 20.202(a) or 34.33(a) of this chapter during the calendar year; or (2) the total number of individuals for whom personnel monitoring was provided during the calendar year: *Provided, however*, That such total includes at least the number of individuals required to be reported under paragraph (a)(1) of this section. The report shall indicate whether it is submitted in accordance with paragraph (a)(1) or (a)(2) of this section. If personnel monitoring was not required to be provided to any individual by the licensee under §§ 20.202(a) or 34.33(a) of this chapter during the calendar year, the licensee shall submit a negative report indicating that such personnel monitoring was not required.

(b) A statistical summary report of the personnel monitoring information recorded by the licensee for individuals for whom personnel monitoring was either required or provided, as described in paragraph (a) of this section, indicating the number of individuals whose total whole body exposure recorded during the previous calendar year was in each of the following estimated exposure ranges:

Estimated whole body exposure range (rems)[1]	Number of individuals in each range
No measurable exposure	
Measurable exposure less than 0.1	
0.1 to 0.25	
0.25 to 0.5	
0.5 to 0.75	
0.75 to 1	
1 to 2	
2 to 3	
3 to 4	
4 to 5	
5 to 6	
6 to 7	
7 to 8	
8 to 9	
9 to 10	
10 to 11	
11 to 12	
12+	

[1] Individual values exactly equal to the values separating exposure ranges shall be reported in the higher range.

The low exposure range data are required in order to obtain better information about the exposures actually recorded. This section does not require improved measurements.

§ 20.408 Reports of personnel monitoring on termination of employment or work.

(a) This section applies to each person licensed by the Commission to:

(1) Operate a nuclear reactor designed to produce electrical or heat energy pursuant to § 50.21(b) or § 50.22 of this chapter or a testing facility as defined in § 50.2(r) of this chapter;

(2) Possess or use byproduct material for purposes of radiography pursuant to Parts 30 and 34 of this chapter;

(3) Process or use at any one time, for purposes of fuel processing, fabrication, or reprocessing, special nuclear material in a qantity exceeding 5,000 grams of contained uranium-235, uranium-233, or plutonium or any combination thereof pursuant to Part 70 of this chapter; or

(4) Possess or use at any one time, for processing or manufacturing for distribution pursuant to part 30, 32, or 33 of this chapter, byproduct material in quantities exceeding any one of the following quantities:

[1] A licensee whose license expires or terminates prior to, or on the last day of the calendar year, shall submit reports at the expiration or termination of the license, covering that part of the year during which the license was in effect.

[2] The Commission will evaluate the data obtained for 1978 and 1979 pursuant to this paragraph, and the benefits derived therefrom and may take action, including publication of notice of proposed rulemaking, to extend or otherwise modify this reporting requirement.

‡ Amended 42 FR 43965.

** Amended 43 FR 29270.

Radionuclide [1]	Quantity in curies
Cesium-137	1
Cobalt-60	1
Gold-198	100
Iodine-131	1
Iridium-192	10
Krypton-85	1,000
Promethium-147	10
Technetium-99m	1,000

[1] The Commission may require, as a license condition, or by rule, regulation or order pursuant to § 20.502, reports from licensees who are licensed to use radionuclides not on this list, in quantities sufficient to cause comparable radiation levels.

(b) When an individual terminates employment with a licensee described in paragraph (a) of this section, or an individual assigned to work in such a licensee's facility but not employed by the licensee, completes the work assignment in the licensee's facility, the licensee shall furnish to the Director of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, a report of the individual's exposures to radiation and radioactive material, incurred during the period of employment or work assignment in the licensee's facility, containing information recorded by the licensee pursuant to §§ 20.401(a) and 20.108. Such report shall be furnished within 30 days after the exposure of the individual has been determined by the licensee or 90 days after the date of termination of employment or work assignment, whichever is earlier.

43 FR 44827

§ 20.409 Notifications and reports to individuals.

(a) Requirements for notifications and reports to individuals of exposure to radiation or radioactive material are specified in § 19.13 of this chapter.

(b) When a licensee is required pursuant to §§ 20.405 or 20.408 to report to the Commission any exposure of an individual to radiation or radioactive material, the licensee shall also notify the individual. Such notice shall be transmitted at a time not later than the transmittal to the Commission, and shall comply with the provisions of § 19.13(a) of this chapter.

38 FR 22220

Exceptions and Additional Requirements

§ 20.501 Applications for exemptions.

The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

25 FR 10914

§ 20.502 Additional requirements.

The Commission may, by rule, regulation, or order, impose upon any licensee such requirements, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

25 FR 10914

§ 20.601 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of section 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

40 FR 8774

APPENDIX A [Reserved]

NOTE—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0043), (R0044), and (R0084).

APPENDIX B

Concentrations in Air and Water Above Natural Background

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		* I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony (51)	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub[2]	6×10^{-3}		1×10^{-4}	
	A 41	Sub	2×10^{-6}		4×10^{-8}	
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	* S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		* I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}		1×10^{-6}	
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-2}	1×10^{-7}	9×10^{-4}
	Cs 134m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-8}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	8×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-8}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		* I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2 = 9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2 = 13 yrs)	I	2×10^{-8}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-3}		4×10^{-5}	
Indium (49)	In 113m	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In 114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	In 115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-8}	3×10^{-3}	1×10^{-9}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Iodine (53)	I 134	I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	4×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}		1×10^{-7}	
	Kr 85	Sub	1×10^{-5}		3×10^{-7}	
	Kr 87	Sub	1×10^{-6}		2×10^{-8}	
	Kr 88	Sub	1×10^{-6}		2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	* S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-2}	3×10^{-8}	2×10^{-3}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41)	Nb 93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
*	Pt 193	S	1×10^{-6}	3×10^{-2}	4×10^{-8}	9×10^{-4}
		I	3×10^{-7}	5×10^{-2}	1×10^{-8}	2×10^{-3}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-4}
		I	4×10^{-8}	4×10^{-2}	1×10^{-9}	1×10^{-3}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope[1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Plutonium (94)	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-5}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}
Potassium (19)	K 42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}		1×10^{-8}	
	Rn 222[3]	...	... 3×10^{-8}		3×10^{-9}	
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)	Isotope[1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium (34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
		I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta 182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Technetium (43)		Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
			I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
		Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
		Tc 97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
		Tc 97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
		Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
			I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
		Tc 99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
			I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)		Te 125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		Te 127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
			I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
		Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Te 129m	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
			I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}
		Te 129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
			I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
		Te 131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
			I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)		Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)		Tl 200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
		Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-5}
Thorium (90)	*	Th 227	S	3×10^{-10}	5×10^{-4}	1×10^{-11}	2×10^{-5}
			I	2×10^{-10}	5×10^{-4}	6×10^{-12}	2×10^{-5}
		Th 228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
			I	6×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		Th 230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
			I	1×10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	*	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Th 232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
			I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}
	v*	Th natural	S	6×10^{-11}	6×10^{-5}	2×10^{-12}	2×10^{-6}
			I	6×10^{-11}	6×10^{-4}	2×10^{-12}	2×10^{-5}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See footnotes on page 20-18)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Thorium (90)		Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
			I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)		Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
			I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)		Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
			I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
		Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
			I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)		W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
		W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)		U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
			I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
		U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
			I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
		U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 234	S[4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 235	S[4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
		U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	**	U 238	S[4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
		U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	**	U-natural	S[4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)		V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
			I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)		Xe 131m	Sub	2×10^{-5}		4×10^{-7}	
		Xe 133	Sub	1×10^{-5}		3×10^{-7}	
		Xe 133m	Sub	1×10^{-5}		3×10^{-7}	
		Xe 135	Sub	4×10^{-6}		1×10^{-7}	
Ytterbium (70)		Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)		Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
			I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
		Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
			I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
		Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
			I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
			I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

Element (atomic number)	Isotope [1]		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}		3×10^{-8}	
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.			3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.			6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-8}

25 FR 10914

[illegible]

40 FR 50704

[3] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 x 10 MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

39 FR 23990

‡4. For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight (enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-3} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$SA = 3.6\times10^{-7}$ curies/gram U   U-depleted

$SA = (0.4 + 0.38\,E + 0.0034\,E^2)\,10^{-6}$ $E \geq 0.72$

where E is the percentage by weight of U-235, expressed as percent.

*Amended 37 FR 23319.

**Amended 39 FR 23990; footnote redesignated 40 FR 50704.

***Amended 40 FR 50704.

†Amended 38 FR 29314.

‡Amended 39 FR 25463; redesignated 40 FR 50704.

NOTE TO APPENDIX B

25 FR 10914

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\frac{C_C}{MPC_C}\leq 1$$

30 FR 15801

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—6×10^{-13}
b. For purposes of Table I, Col. 2—4×10^{-7}
c. For purposes of Table II, Col. 1—2×10^{-14}
d. For purposes of Table II, Col. 2—3×10^{-8}

26 FR 11046

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

30 FR 15801

c. Element (atomic number) and isotope	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131, (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	....	9×10^{-5}	....	3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129, (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	....	6×10^{-5}	....	2×10^{-6}
If it is known that Sr 90, I 129, (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present	....	2×10^{-4}	....	6×10^{-6}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present	....	3×10^{-4}	....	1×10^{-5}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	3×10^{-9}	....	1×10^{-10}	....
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present	3×10^{-10}	....	1×10^{-11}	....
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}	....	1×10^{-12}	....
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present	3×10^{-12}	....	1×10^{-13}	....

40 FR 50704

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

39 FR 23990

a. For purposes of Table I, Col. 1—1×10^{-10} μCi/ml gross alpha activity; or 5×10^{-11} μCi/ml natural uranium; or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} μCi/ml gross alpha activity; or 2×10^{-12} μCi/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

26 FR 11046

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Appendix B (MPC_A) does not exceed 1/10 (i.e. $\frac{C_A}{MPC_A}\leq\frac{1}{10}$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1/4 (i.e. $\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\cdots\cdots\leq 1/4$).

APPENDIX C

Material	Microcuries
Americium-241	.01
Antimony-122	100
Antimony-124	10
Antimony-125	10
Arsenic-73	100
Arsenic-74	10
Arsenic-76	10
Arsenic-77	100
Barium-131	10
*Barium-133	10
Barium-140	10
Bismuth-210	1
Bromine-82	10
Cadmium-109	10
Cadmium-115m	10
Cadmium-115	100
Calcium-45	10
Calcium-47	10
Carbon-14	100
Cerium-141	100
Cerium-143	100
Cerium-144	1
Cesium-131	1,000
Cesium-134m	100
Cesium-134	1
Cesium-135	10
Cesium-136	10
Cesium-137	10
Chlorine-36	10
Chlorine-38	10
Chromium-51	1,000
Cobalt-58m	10
Cobalt-58	10
Cobalt-60	1
Copper-64	100
Dysprosium-165	10
Dysprosium-166	100
Erbium-169	100
Erbium-171	100
Europium-152 9.2 h	100
Europium-152 13 yr	1
Europium-154	1
Europium-155	10
Fluorine-18	1,000
Gadolinium-153	10
Gadolinium-159	100
Gallium-72	10
Germanium-71	100
Gold-198	100
Gold-199	100
Hafnium-181	10
Holmium-166	100
Hydrogen-3	1,000
Indium-113m	100
Indium-114m	10
Indium-115m	100
Indium-115	10
Iodine-125	1
Iodine-126	1
Iodine-129	0.1
Iodine-131	1
Iodine-132	10
Iodine-133	1
Iodine-134	10
Iodine-135	10
Iridium-192	10
Iridium-194	100
Iron-55	100
Iron-59	10
Krypton-85	100
Krypton-87	10
Lanthanum-140	10
Lutetium-177	100
Manganese-52	10
Manganese-54	10
Manganese-56	10
Mercury-197m	100
Mercury-197	100
Mercury-203	10
Molybdenum-99	100
Neodymium-147	100
Neodymium-149	100
Nickel-59	100
Nickel-63	10
Nickel-65	100
Niobium-93m	10
Niobium-95	10
Niobium-97	10
Osmium-185	10
Osmium-191m*	100
Osmium-191	100
Osmium-193	100
Palladium-103	100
Palladium-109	100
Phosphorus-32	10
Platinum-191	100
Platinum-193m	100
Platinum-193	100
Platinum-197m	100
Platinum-197	100
Plutonium-239	.01
Polonium-210	0.1
Potassium-42	10
Praseodymium-142	100
Praseodymium-143	100
Promethium-147	10
Promethium-149	10
Radium-226	.01
Rhenium-186	100
Rhenium-188	100
Rhodium-103m	100
Rhodium-105	100
Rubidium-86	10
Rubidium-87	10
Ruthenium-97	100
Ruthenium-103	10
Ruthenium-105	10
Ruthenium-106	1
Samarium-151	10
Samarium-153	100
Scandium-46	10
Scandium-47	100
Scandium-48	10
Selenium-75	10
Silicon-31	100
Silver-105	10
Silver-110m	1
Silver-111	100
Sodium-24	10
Strontium-85	10
Strontium-89	1
Strontium-90	0.1
Strontium-91	10
Strontium-92	10
Sulphur-35	100
Tantalum-182	10
Technetium-96	10
Technetium-97m	100
Technetium-97	100
Technetium-99m	100
Technetium-99	10
Tellurium-125m	10
Tellurium-127m	10
Tellurium-127	100
Tellurium-129m	10
Tellurium-129	100
Tellurium-131m	10
Tellurium-132	10
Terbium-160	10
Thallium-200	100
Thallium-201	100
Thallium-202	100
Thallium-204	10
**Thorium (natural)[1]	100
Thulium-170	10
Thulium-171	10
Tin-113	10
Tin-125	10
Tungsten-181	10
Tungsten-185	10
Tungsten-187	100
**Uranium (natural)[2]	100
Uranium-233	.01
Uranium-234 Uranium-235	.01
Vanadium-48	10
Xenon-131m	1,000
Xenon-133	100
Xenon-135	100
Ytterbium-175	100
Yttrium-90	10
Yttrium-91	10
Yttrium-92	100
Yttrium-93	100
Zinc-65	10
Zinc-69m	100
Zinc-69	1,000
Zirconium-93	10
Zirconium-95	10
Zirconium-97	10
Any alpha emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	.01
Any radionuclide other than alpha emitting radionuclides, not listed above or mixtures of beta emitters of unknown composition	1

35 FR 6425

Note.—For purposes of § 20.303, where there is involved a combination of isotopes in known amounts, the limit for the combination should be derived as follows: Determine, for each isotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific isotope when not in combination. The sum of such ratios for all the isotopes in the combination may not exceed "1" (i.e., "unity").

45 FR 71761

[1] Based on alpha disintegration rate of Th-232, Th-230 and their daughter products.

[2] Based on alpha disintegration rate of U-238, U-234, and U-235.

* Amended 36 FR 16898.

** Amended 39 FR 23990.

Appendix D

UNITED STATES NUCLEAR REGULATORY COMMISSION

INSPECTION AND ENFORCEMENT REGIONAL OFFICES

Region	Address	Telephone	
		Daytime	Nights and Holidays
I Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont	Region I, USNRC Office of Inspection and Enforcement 631 Park Avenue King of Prussia, Pa. 19406	‡ (215) 337-5000	‡ (215) 337-5000
II Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, *** Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia	† Region II, USNRC Office of Inspection and Enforcement 101 Marietta Street Suite 3100 Atlanta, Georgia 30303	* (404) 221-4503	* (404) 221-4503
III Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin	Region III, USNRC Office of Inspection and Enforcement 799 Roosevelt Road Glen Ellyn, Ill. 60137	** (312) 932-2500	** (312) 932-2500
IV Arkansas, Colorado, Idaho, Kansas, Louisiana, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming	Region IV, USNRC Office of Inspection and Enforcement 611 Ryan Plaza Drive Suite 1000 Arlington, Texas 76012	(817) 334-2841	(817) 334-2841
V Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, and U.S. territories and possessions in the Pacific	Region V, USNRC Office of Inspection and Enforcement 1990 N. California Blvd. Suite 202 Walnut Creek, Calif. 94596	** (415) 943-3700	** (415) 943-3700

40 FR 42557

*Amended 41 FR 55851.

†Amended 43 FR 32741.

‡ Amended 43 FR 52201.

** Amended 44 FR 63515.

*** Amended 45 FR 18905

UNITED STATES NUCLEAR REGULATORY COMMISSION

RULES and REGULATIONS

TITLE 10, CHAPTER 1, CODE OF FEDERAL REGULATIONS – ENERGY

PART 30

RULES OF GENERAL APPLICABILITY TO DOMESTIC LICENSING OF BYPRODUCT MATERIAL ★★

GENERAL PROVISIONS

EXEMPTIONS

LICENSES

RECORDS, INSPECTIONS, TESTS, PROCEDURES, AND REPORTS†

† Amended 37 FR 9207.
‡ Added 37 FR 9207.

ENFORCEMENT

SCHEDULES

AUTHORITY: Secs. 81, 82, 161, 182, 183, 68 Stat. 935, 948, 953, 954, as amended (42 U.S.C. 2111, 2112, 2201, 2232, 2233); secs. 202, 206, 88 Stat. 1244, 1246 (42 U.S.C. 5842 and 5846).

Section 30.34(b) also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), § 30.34(c) issued under sec. 161b., 68 Stat. 948 (42 U.S.C. 2201 (b)) and §§ 30.51 and 30.52 issued under sec. 161, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

40 FR 8774

§ 30.1 Purpose and Scope.

This part prescribes rules applicable to all persons in the United States governing domestic** licensing of byproduct material under the Atomic Energy Act of 1954, as amended (68 Stat. 919), and under Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242), and exemptions from the domestic** licensing requirements permitted by section 81 of the Act.

30 FR 8185

§ 30.2 Resolution of conflict.

The requirements of this part are in addition to, and not in substitution for, other requirements of this chapter. In any conflict between the requirements in this part and a specific requirement in another part of the regulations in this chapter, the specific requirement governs.

** Amended 43 FR 6915.

30 FR 8185

§ 30.3 Activities requiring license.

Except for persons exempt as provided in this part and Part 150 of this chapter, no person shall manufacture, produce, transfer, receive, acquire, own, possess, or use,** byproduct material except as authorized in a specific or general license issued pursuant to the regulations in this chapter.

§ 30.4 Definitions.

As used in this part and Parts 31-35** of this chapter:

(a) "Act" means the Atomic Energy Act of 1954, (68 Stat. 919)* including any amendments thereto;

43 FR 14199

(a-1) "Department" and "Department of Energy" means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95-91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c) and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93-438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95-91, 91 Stat. 565 at 577-578, 42 U.S.C. 7151).

30 FR 8185

(b) Terms defined in section 11 of the Act shall have the same meaning when used in the regulations in this part and Parts 31-35** to the extent such terms are not specifically defined in this part.

* Amended 36 FR 1466.

FIGURE 6-10

40 FR 8774 (c) "Agreement State" means any state with which the Atomic Energy Commission or the Nuclear Regulatory Commission has entered into an effective agreement under subsection 274b. of the Act. "Non-Agreement State" means any other State;

30 FR 8185 (d) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

(e) "Commission" means the Nuclear Regulatory Commission and its duly authorized representatives;

(f) "Curie" means that amount of radioactive material which disintegrates at the rate of 37 billion atoms per second;

(g) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(h) "Human use" means the internal or external administration of byproduct material, or the radiation therefrom, to human beings;

(i) "License" except where otherwise specified means a license for byproduct material issued pursuant to the regulations in this part and Parts 31-35† of this chapter;

38 FR 29314 (j)(1) "Microcurie" means that amount of radioactive material which disintegrates at the rate of 37 thousand atoms per second;

(2) "Millicurie" means that amount of radioactive material which disintegrates at the rate of 37 million atoms per second;

40 FR 8774 (k) "Person" means (1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department** , except that the Department** shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244),[5] any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing;

30 FR 8185 (l) "Physician" means an individual licensed by a State or territory of the United States, the District of Columbia or the Commonwealth of Puerto Rico to dispense drugs in the practice of medicine;

(m) "Production facility" means production facility as defined in the regulations contained in Part 50 of this chapter;

(n) "Radiographer" means any individual who performs or who, in attendance at the site where the sealed source or sources are being used, personally supervises radiographic operations and who is responsible to the licensee for assuring compliance with the requirements of the Commission's regulations and the conditions of the license;

(o) "Radiographer's assistant" means any individual who, under the personal supervision of a radiographer, uses radiographic exposure devices, sealed sources or related handling tools, or radiation* survey instruments in radiography;

(p) "Radiography" means the examination of the structure of materials by nondestructive methods, utilizing sealed sources of byproduct materials;

(q) "Research and development" means (1) theoretical analysis, exploration, or experimentation; or (2) the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes. "Research and development" as used in this part and Parts 31-35† does not include the internal or external administration of byproduct material, or the radiation therefrom, to human beings;

30 FR 8185 (r) "Sealed source" means any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material;

(s) "Source material" means source material as defined in the regulations contained in Part 40 of this chapter;

(t) "Special nuclear material" means special nuclear material as defined in the regulations contained in Part 70 of this chapter;

45 FR 18905 (u) "United States", when used in a geographical sense, includes Puerto Rico and all territories and possessions of the United States;

(v) "Utilization facility" means a utilization facility as defined in the regulations contained in Part 50 of this chapter;

37 FR 5745 (w) "Commencement of construction" means any clearing of land, excavation, or other substantial action that would adversely affect the natural environment of a site but does not include changes desirable for the temporary use of the land for public recreational uses, necessary borings to determine site characteristics or other preconstruction monitoring to establish background information related to the suitability of a site or to the protection of environmental values.

§ 30.5 Interpretations.

30 FR 8185 Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part and Parts 31-35† by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 30.6 Communications.

Except where otherwise specified, all communications and reports concerning

---

[5] The ** Department facilities and activities identified in section 202 are:

(1) Demonstration Liquid Metal Fast Breeder reactors when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

(2) Other demonstration nuclear reactors, except those in existence on January 19, 1975, when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

(3) Facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from licensed activities.

(4) Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive waste generated by the ** Department, which are not used for, or are part of, research and development activities.

† Amended 43 FR 6915.

* Amended 36 FR 1466.

** Amended 45 FR 14199

the regulations in this part and Parts 31-35† and applications filed under them, should be addressed to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C., 20555. Communications, reports and applications may be delivered in person at the Commission's offices at 1717 H Street N.W., Washington, D.C., or **7920 Norfolk Avenue, Bethesda, Md.

EXEMPTIONS

§ 30.11 Specific exemptions.

(a) The Commission may, upon application of any interested person or upon its own initiative, grant such exemptions from the requirements of the regulations in this part and Parts 31-35† of this chapter as it determines are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest.

30.11(b) [Deleted 45 FR 65521

§ 30.12 Persons using byproduct material under certain *** Department of Energy Nuclear Regulatory Commission contracts.

Except to the extent that *** Department facilities or activities of the types subject to licensing pursuant to section 202 of the Energy Reorganization Act of 1974 are involved, any prime contractor of the *** Department is exempt from the requirements for a license set forth in sections 81 and 82 of the Act and from the regulations in this part to the extent that such contractor, under his prime contract with the *** Department manufactures, produces, transfers, receives, acquires, owns, possesses, or uses† byproduct material for: (a) the performance of work for the *** Department at a United States Government-owned or controlled site, including the transportation of byproduct material to or from such site and the performance of contract services during temporary interruptions of such transportation; (b) research in, or development, manufacture, storage, testing or transportation of, atomic weapons or components thereof; or (c) the use or operation of nuclear reactors or other nuclear devices in a United States Government-owned vehicle or vessel. In addition to the foregoing exemptions and subject to the requirement for licensing of *** Department facilities and activities pursuant to section 202 of the Energy Reorganization Act of 1974, any prime contractor or subcontractor of the *** Department or the Commission is exempt from the requirements for a license set forth in sections 81 and 82 of the Act and from the regulations in this part to the extent that such prime contractor or subcontractor manufactures, produces, transfers, receives, acquires, owns, possesses, or uses† byproduct material under his prime contract or subcontract when the Commission determines that the exemption of the prime contractor or subcontractor is authorized by law; and that, under the terms of the contract or subcontract, there is adequate assurance that the work thereunder can be accomplished without undue risk to the public health and safety.

§ 30.13 Carriers.

Common and contract carriers, freight forwarders, warehousemen, and the U.S. Postal Service are exempt from the regulations in this part and Parts 31-35† of this chapter and the requirements for a license set forth in section 81 of the Act to the extent that they transport or store byproduct material in the regular course of carriage for another or storage incident thereto.

§ 30.14 Exempt concentrations.

(a) Except as provided in paragraphs (c) and (d) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in this part and Parts 31-35† of this chapter to the extent that such person receives, possesses, uses, transfers, owns or acquires products or materials containing byproduct material in concentrations not in excess of those listed in § 30.70.

(b) This section shall not be deemed to authorize the import of byproduct material or products containing byproduct material.

(c) A manufacturer, processor, or producer of a product or material in an Agreement State is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in this part and Parts 31, 32, 33, and 34,† to the extent that he transfers byproduct material contained in a product or material in concentrations not in excess of those specified in § 30.70 and introduced into the product or material by a licensee holding a specific license issued by an Agreement State, the Commission, or the Atomic Energy Commission expressly authorizing such introduction. This exemption does not apply to the transfer of byproduct material contained in any food, beverage, cosmetic, drug, or other commodity or product designed for ingestion or inhalation by or application to, a human being.

(d) No person may introduce byproduct material into a product or material knowing or having reason to believe that it will be transferred to persons exempt under this section or equivalent regulations of an Agreement State, except in accordance with a license issued pursuant to § 32.11 of this chapter or the general license provided in § 150.20 of Part 150.

§ 30.15 Certain items containing byproduct material.

(a) Except for persons who apply byproduct material to, or persons who incorporate byproduct material into, the following products, or persons who initially transfer† for sale or distribution the following products containing byproduct material, any person is exempt from the requirements for a license set

† Amended 43 FR 6915.
** Amended 34 FR 19546.
*** Amended 45 FR14199

34 FR 6651

forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires the following products:

32 FR 13920

(1) Timepieces or hands or dials containing not more than the following specified quantities of byproduct material and not exceeding the following specified levels of radiation:

(i) 25 millicuries of tritium per timepiece,

(ii) 5 millicuries of tritium per hand,

(iii) 15 millicuries of tritium per dial (bezels when used shall be considered as part of the dial),

(iv) 100 microcuries of promethium-147 per watch or 200 microcuries of promethium-147 per any other timepiece,

(v) 20 microcuries of promethium-147 per watch hand or 40 microcuries of promethium-147 per other timepiece hand,

(vi) 60 microcuries of promethium-147 per watch dial or 120 microcuries of promethium-147 per other timepiece dial (bezels when used shall be considered as part of the dial),

(vii) The levels of radiation from hands and dials containing promethium-147 will not exceed, when measured through 50 milligrams per square centimeter of absorber:

(*a*) For wrist watches, 0.1 millirad per hour at 10 centimeters from any surface,

(*b*) For pocket watches, 0.1 millirad per hour at 1 centimeter from any surface,

(*c*) For any other timepiece, 0.2 millirad per hour at 10 centimeters from any surface.

31 FR 5315

(2) Lock illuminators containing not more than 15 millicuries of tritum or not more than 2 millicuries of promethium-147 installed in automobile locks. The levels of radiation from each lock illuminator containing promethium-147 will not exceed 1 millirad per hour at 1 centimeter from any surface when measured through 50 milligrams per square centimeter of absorber.

(3) Balances of precision containing not more than 1 millicurie of tritium per balance or not more than 0.5 millicurie of tritum per balance part.

(4) Automobile shift quadrants containing not more than 25 millicuries of tritium.

32 FR 785

(5) Marine compasses containing not more than 750 millicuries of tritium gas and other marine navigational instruments containing not more than 250 millicuries of tritium gas.

31 FR 5315

(6) Thermostat dials and pointers containing not more than 25 millicuries of tritium per thermostat.

(7) [Deleted 34 FR 6651.]

35 FR 8820

(8) Electron tubes: *Provided*, That each tube does not contain more than one of the following specified quantities of byproduct material:

(i) 150 millicuries of tritium per microwave receiver protector tube or 10 millicuries of tritium per any other electron tube;

34 FR 6651

(ii) 1 microcurie of cobalt-60;

(iii) 5 microcuries of nickel-63;

(iv) 30 microcuries of krypton-85;

(v) 5 microcuries of cesium-137;

(vi) 30 microcuries of promethium-147;

And provided further, That the levels of radiation from each electron tube containing byproduct material do not exceed 1 millirad per hour at 1 centimeter from any surface when measured through 7 milligrams per square centimeter of absorber.[3]

35 FR 6425

(9) Ionizing radiation measuring instruments containing, for purposes of internal calibration or standardization, a source of byproduct material not exceeding the applicable quantity set forth in § 30.71, Schedule B.

43 FR 2386

(10) Spark gap irradiators containing not more than 1 microcurie of cobalt-60 per spark gap irradiator for use in electrically ignited fuel oil burners having a firing rate of at least 3 gallons per hour (11.4 liters per hour).

(b) Any person who desires to apply byproduct material to, or to incorporate byproduct material into, the products exempted in paragraph (a) of this section, or who desires to initially transfer* for sale or distribution such products containing byproduct material, should apply for a specific license pursuant to § 32.14 of this chapter, which license states that the product may be distributed by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section.

32 FR 4241

§ 30.16 Resins containing scandium-46 and designed for sand-consolidation in oil wells.

Any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires synthetic plastic resins containing scandium-46 which are designed for sand-consolidation in oil wells, and which have been manufactured or initially transferred* for sale or distribution, in accordance with a specific license issued pursuant to § 32.17 of this chapter or equivalent regulations of an Agreement State. The exemption in this section does not authorize the manufacture or initial transfer for sale or distribution* of any resins containing scandium-46.

36 FR 16898

§ 30.18 Exempt quantities.

(a) Except as provided in paragraphs (c) and (d) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 30-34 of this chapter to the extent that such person receives, possesses, uses, transfers, owns, or acquires byproduct material in individual quantities each of which does not exceed the applicable quantity set forth in § 30.71, Schedule B.

(b) Any person who possesses byproduct material received or acquired prior to September 25, 1971, under the general license then provided in § 31.4 of this chapter is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 30-34 of this chapter to the extent that such person possesses, uses, transfers, or owns such byproduct material.

(c) This section does not authorize for purposes of commercial distribution* the production, packaging, repackaging, or transfer* of byproduct material, or the incorporation of byproduct material into products intended for commercial distribution.

(d) No person may, for purposes of commercial distribution,* transfer byproduct material in the individual quantities set forth in § 30.71 Schedule

* Amended 43 FR 6915.

[3] For purposes of this subparagraph "electron tubes" include spark gap tubes, power tubes, gas tubes including glow lamps, receiving tubes, microwave tubes, indicator tubes, pickup tubes, radiation detection tubes, and any other completely sealed tube that is designed to conduct or control electrical currents.

36 FR 16898

B, knowing or having reason to believe that such quantities of byproduct material will be transferred to persons exempt under this section or equivalent regulations of an Agreement State, except in accordance with a license issued under § 32.18 of this chapter, which license states that the byproduct material may be transferred by the licensee to persons exempt under this section or the equivalent regulations of an Agreement State.

34 FR 9025

§ 30.19 Self-luminous products containing tritium, krypton-85, or promethium-147.

(a) Except for persons who manufacture, process, produce, or initially transfer for sale or distribution* self-luminous products containing tritium, krypton-85, or promethium-147,* and except as provided in paragraph (c) of this section, any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires tritium, krypton-85, or promethium-147 in self-luminous products manufactured, processed, produced, or initially* transferred in accordance with a specific license issued pursuant to § 32.22 of this chapter, which license authorizes the initial* transfer of the product for use under this section.

(b) Any person who desires to manufacture, process, or produce self-luminous products containing tritium, krypton-85, or promethium-147, or to transfer* such products for use pursuant to paragraph (a) of this section, should apply for a license pursuant to § 32.22 of this chapter, which license states that the product may be transferred by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section or equivalent regulations of an Agreement State.

(c) The exemption in paragraph (a) of this section does not apply to tritium, krypton-85, or promethium-147 used in products primarily for frivolous purposes or in toys or adornments.

34 FR 6653

§ 30.20 Gas and aerosol detectors containing byproduct material.

(a) Except for persons who manufacture, process, produce, or initially transfer for sale or distribution* gas and aerosol detectors containing byproduct material,* any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires byproduct material in gas and aerosol detectors designed to protect life or property from fires and airborne hazards, and manufactured, processed, produced, or initially* transferred in accordance with a specific license issued pursuant to § 32.26 of this chapter, which license authorizes the initial* transfer of the product for use under this section.

(b) Any person who desires to manufacture, process, or produce gas and aerosol detectors containing byproduct material, or to initially* transfer such products for use pursuant to paragraph (a) of this section, should apply for a license pursuant to § 32.26 of this chapter, which license states that the product may be initially* transferred by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section or equivalent regulations of an Agreement State.

LICENSES

30 FR 8185

§ 30.31 Types of licenses.

Licenses for byproduct material are of two types: General and specific. Specific licenses are issued to named persons upon applications filed pursuant to the regulations in this part and Parts 32-35.* General licenses are effective without the filing of applications with the Commission or the issuance of licensing documents to particular persons.

40 FR 50703

§ 30.32 Application for specific licenses.

(a) Applications for specific licenses should be filed in duplicate on Form NRC-313, "Application for Byproduct Material License," with the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

40 FR 8774

Applications may be filed in person at the Commission's offices at 1717 H Street, N.W., Washington, D.C., or 7920 Norfolk Avenue, Bethesda, Maryland. Information contained in previous applications, statements, or reports filed with the Commission or the Atomic Energy Commission may be incorporated by reference, provided that such references are clear and specific.

30 FR 8185

(b) The Commission may at any time after the filing of the original application, and before the expiration of the license, require further statements in order to enable the Commission to determine whether the application should be granted or denied or whether a license, should be modified or revoked.

(c) Each application shall be signed by the applicant or licensee or a person duly authorized to act for and on his behalf.

(d) An application for license filed pursuant to the regulations in this part and Parts 32-35* will be considered also as an application for licenses authorizing other activities for which licenses are required by the Act, provided that the application specifies the additional activities for which licenses are requested and complies with regulations of the Commission as to applications for such licenses.

36 FR 145

(e) Each application for a byproduct material license, other than a license exempted from Part 170 of this chapter, shall be accompanied by the fee prescribed in § 170.31 of this chapter. No fee will be required to accompany an application for renewal or amendment of a license, except as provided in § 170.31 of this chapter.

37 FR 5745

(f) An application for a license to receive and possess byproduct material for commercial waste disposal by land burial or for the conduct of any other activity which the Commission determines will significantly affect the quality of the environment shall be filed at least 9 months prior to commencement of construction of the plant or facility in which the activity will be conducted and shall be accompanied by any Environmental Report required pursuant to Part 51** of this chapter.

30 FR 8185

§ 30.33 General requirements for issuance of specific licenses.

(a) An application for a specific license will be approved if:

(1) The application is for a purpose authorized by the Act;

(2) The applicant's proposed equipment and facilities are adequate to protect health and minimize danger to life or property;

(3) The applicant is qualified by training and experience to use the material for the purpose requested in such

* Amended 43 FR 6915.

** Amended 39 FR 26279.

30 FR 8185

manner as to protect health and minimize danger to life or property;

(4) The applicant satisfies any special requirements contained in Parts 32-35;* and

45 FR 65521

(5) In the case of an application for a license to receive and possess byproduct material for commercial waste disposal by land burial or for the conduct of any other activity which the Commission determines will significantly affect the quality of the environment, the Director of Nuclear Material Safety and Safeguards or his designee, before commencement of construction of the plant or facility in which the activity will be conducted, on the basis of information filed and evaluations made pursuant to Part 51 of this chapter, has concluded, after weighing the environmental, economic, technical, and other benefits against environmental costs and considering available alternatives, that the action called for is the issuance of the proposed license, with any appropriate conditions to protect environmental values. Commencement of construction prior to such conclusion shall be grounds for denial of a license to receive and possess byproduct material in such plant or facility. As used in this paragraph the term "commencement of construction" means any clearing of land, excavation, or other substantial action that would adversely affect the environment of a site. The term does not mean site exploration, necessary roads for site exploration, borings to determine foundation conditions, or other preconstruction monitoring or testing to establish background information related to the suitability of the site or the protection of environmental values.

(b) Upon a determination that an application meets the requirements of the Act, and the regulations of the Commission, the Commission will issue a specific license authorizing the possession and use of byproduct material (Form NRC-374, "Byproduct Material License").

§ 30.34 **Terms and conditions of licenses.**

(a) Each license issued pursuant to the regulations in this part and the regulations in Parts 31-35* shall be subject to all the provisions of the Act, now or hereafter in effect, and to all valid rules, regulations and orders of the Commission.

(b) No license issued or granted pursuant to the regulations in this part and Parts 31-35,* nor any right under a license shall be transferred, assigned or in any manner disposed of, either voluntarily or involuntarily, directly or indirectly, through transfer of control of any license to any person, unless the Commission shall, after securing full information, find that the transfer is in accordance with the provisions of the Act and shall give its consent in writing.

(c) Each person licensed by the Commission pursuant to the regulations in this part and Parts 31-35* shall confine his possession and use of the byproduct material to the locations and purposes authorized in the license. Except as otherwise provided in the license, a license issued pursuant to the regulations in this part and Parts 31-35* of this chapter shall carry with it the right to receive, acquire, own, and possess,* byproduct material. Preparation for shipment and transport of byproduct material shall be in accordance with the provisions of Part 71 of this chapter.

(d) Each license issued pursuant to the regulations in this part and Parts 31-35* shall be deemed to contain the provisions set forth in section 183b.-d., inclusive, of the Act, whether or not these provisions are expressly set forth in the license.

(e) The Commission may incorporate, in any license issued pursuant to the regulations in this part and Parts 31-35,* at the time of issuance, or thereafter by appropriate rule, regulation or order, such additional requirements and conditions with respect to the licensee's receipt, possession, use and transfer of byproduct material as it deems appropriate or necessary in order to:

(1) Promote the common defense and security;

(2) Protect health or to minimize danger to life or property;

(3) Protect restric[illegible];

(4) Require suc[illegible] and the keeping of such record[illegible]nd to provide for such inspections of activities under the license as may be necessary or appropriate to effectuate the purposes of the Act and regulations thereunder.

(f) Each licensee shall notify the Commission in writing when the licensee decides to permanently discontinue all activities involving materials authorized under the license. This notification requirement applies to all specific licenses issued under this Part and Parts 32 through 35 of this chapter.

(g) Each licensee preparing technetium-99m radiopharmaceuticals from molybdenum-99/technetium-99m generators shall test the generator eluates for molybdenum-99 breakthrough in accordance with § 35.14(b)(4) (i) thru (iv).

§ 30.35 [Deleted 40 FR 8774.]

§ 30.36 **Expiration of licenses.**

Except as provided in § 30.37(b), each specific license shall expire at the end of the day, in the month and year stated therein.

§ 30.37 **Applications for renewal of licenses.**

(a) Applications for renewal of a specific license shall be filed in accordance with § 30.32.

(b) In any case in which a licensee, not less than thirty (30) days prior to the expiration of his existing license, has filed an application in proper form for renewal or for a new license, such existing license shall not expire until the application has been finally determined by the Commission.

§ 30.38 **Applications for amendment of licenses.**

Applications for amendment of a license shall be filed in accordance with § 30.32 and shall specify the respects in which the licensee desires his license to be amended and the grounds for such amendment.

§ 30.39 **Commission action on applications to renew or amend.**

In considering an application by a licensee to renew or amend his license the Commission will apply the applicable criteria set forth in § 30.33 and Parts 32-35* of this chapter.

§ 30.41 **Transfer of byproduct material.**

(a) No licensee shall transfer byproduct material except as authorized pursuant to this section.

(b) Except as otherwise provided in his license and subject to the provisions of paragraphs (c) and (d) of this section, any licensee may transfer byproduct material:

(1) To the Administration;

(2) To the agency in any Agreement State which regulates radioactive material pursuant to an agreement under section 274 of the Act;

(3) To any person exempt from the licensing requirements of the Act and regulations in this part, to the extent permitted under such exemption;

(4) To any person in an Agreement State, subject to the jurisdiction of that State, who has been exempted from the

---
* Amended 43 FR 6915.
** Amended 39 FR 26279.

licensing requirements and regulations of that State, to the extent permitted under such exemption;

(5) To any person authorized to receive such byproduct material under terms of a specific license or a general license or their equivalents issued by the Atomic Energy Commission, the Commission, or an Agreement State; or

(6) To a person abroad pursuant to an export license issued under Part 110 of this chapter;

(7) ‡ As otherwise authorized by the Commission in writing.

(c) Before transferring byproduct material to a specific licensee of the Commission or an Agreement State or to a general licensee who is required to register with the Commission or with an Agreement State prior to receipt of the byproduct material, the licensee transferring the material shall verify that the transferee's license authorizes the receipt of the type, form, and quantity of byproduct material to be transferred.

(d) The following methods for the verification required by paragraph (c) of this section are acceptable:

(1) The transferor may have in his possession, and read, a current copy of the transferee's specific license or registration certificate;

(2) The transferor may have in his possession a written certification by the transferee that he is authorized by license or registration certificate to receive the type, form, and quantity of byproduct material to be transferred, specifying the license or registration certificate number, issuing agency and expiration date;

(3) For emergency shipments the transferor may accept oral certification by the transferee that he is authorized by license or registration certificate to receive the type, form, and quantity of byproduct material to be transferred, specifying the license or registration certificate number, issuing agency and expiration date: *Provided*, That the oral certification is confirmed in writing within 10 days.

(4) The transferor may obtain other sources of information compiled by a reporting service from official records of the Commission or the licensing agency of an Agreement State as to the identity of licensees and the scope and expiration dates of licenses and registration; or

(5) When none of the methods of verification described in paragraphs (d)(1) to (4) of this section are readily available or when a transferor desires to verify that information received by one of such methods is correct or up-to-date, the transferor may obtain and record confirmation from the Commission or the licensing agency of an Agreement State that the transferee is licensed to receive the byproduct material.

RECORDS, INSPECTIONS, TESTS, PROCEDURES, AND REPORTS†

§ 30.51 Records.

(a) Each person who receives byproduct material pursuant to a license issued pursuant to the regulations in this part and Parts 31-35* shall keep records showing the receipt, transfer,* and disposal of such byproduct material.

(b) Records which are required by the regulations in this part and Parts 31-35* or by license condition shall be maintained for the period specified by the appropriate regulation or license condition. If a retention period is not otherwise specified by regulation or license condition, such records shall be maintained until the Commission authorizes their disposition.

(c)(1) Records of receipt of byproduct material which must be maintained pursuant to paragraph (a) of this section shall be maintained as long as the licensee retains possession of the byproduct material and for two years following transfer,* or disposal of the byproduct material. (2) [Deleted 43 FR 6915.] (3) Records of transfer of byproduct material shall be maintained by the licensee who transferred the material for five years after such transfer. (4) Records of disposal of byproduct material shall be maintained in accordance with § 20.401 (c) of this chapter.

(d)(1) Records which must be maintained pursuant to this part and Parts 31-35* may be the original or a reproduced copy of microform if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by Commission regulations.

(2) If there is a conflict between the Commission's regulations in this part and Parts 31-35,* license condition, or other written Commission approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part and Parts 31-35* for such records shall apply unless the Commission, pursuant to § 30.11, has granted a specific exemption from the record retention requirements specified in the regulations in this part or Parts 31-35.*

§ 30.52 Inspections.

(a) Each licensee shall afford to the Commission at all reasonable times opportunity to inspect byproduct material and the premises and facilities wherein byproduct material is used or stored.

(b) Each licensee shall make available to the Commission for inspection, upon reasonable notice, records kept by him pursuant to the regulations in this chapter.

§ 30.53 Tests.

Each licensee shall perform, or permit the Commission to perform, such tests as the Commission deems appropriate or necessary for the administration of the regulations in this part and Parts 31-35,* including tests of:

(a) Byproduct material;

(b) Facilities wherein byproduct material is utilized or stored;

(c) Radiation detection and monitoring instruments; and

(d) Other equipment and devices used in connection with the utilization or storage of byproduct material.

§ 30.54 Control and accounting procedures for tritium.

(a) Except as specified in paragraph (b) of this section, each licensee who is authorized to possess at any one time and location more than 10,000 curies of tritium shall establish and maintain written material control and accounting procedures that are sufficient to enable the licensee to account for the tritium in his possession under specific license.

The written material control and accounting procedures shall be maintained as long as the licensee retains possession of the tritium and for two years following transfer* of the tritium.

(b) Written material control and accounting procedures are not required for (1) tritium produced or possessed within a production or utilization facility inci-

† Amended 37 FR 9207.

‡ Redesignated 43 FR 6915.

* Amended 43 FR 6915.

dental to the operation of the facility; and * (2) tritium contained in spent fuel, other than tritium intentionally produced in or recovered from a production or utilization facility for any subsequent use.* (3) [Deleted 43 FR 6915.] (4) [Deleted 43 FR 6915.]

§ 30.55 Tritium reports.

37 FR 9207

(a) Except as specified in paragraph (d) of this section, each licensee who transfers or receives at any one time 1,000 curies or more of tritium shall complete and distribute a Nuclear Material Transaction** Report on Form NRC-741, in accordance with the printed instructions for completing the form. Each licensee who transfers such material shall submit a completed copy of Form NRC-741 to the Commission and three copies to the receiver of the material promptly after the transfer takes place. Each licensee who receives such material shall submit a completed copy of Form NRC-741 to the Commission and to the shipper of the material within ten (10) days after the material is received. The Commission's copies of the report shall be submitted to the U.S. Energy Research and Development Administration, Post Office Box E, Oak Ridge, Tennessee 37830, and shall include the Reporting Identification Symbol (RIS) assigned by the Commission to the licensee.

40 FR 8774

(b) Except as specified in paragraph (d) and (e) of this section, each licensee who is authorized to possess at any one time and location more than 10,000 curies of tritium shall submit to the Commission within thirty (30) days after March 31 and September 30† of each year a statement of his tritium inventory to the nearest hundredth of a gram calculated at 10,000 curies per gram.

37 FR 9207

The reports shall be submitted to the U.S. Energy Research and Development Administration, Post Office Box E, Oak Ridge, Tennessee 37830, and shall include the Reporting Identification Symbol (RIS) assigned by the Commission to the licensee.

41 FR 16445

(c) Except as specified in paragraph (d) of this section, each licensee who is authorized to possess* tritium shall report promptly to the appropriate NRC Regional Office listed in Appendix D of Part 20 of this chapter by telephone and telegraph, mailgram, or facsimile any incident in which an attempt has been made or is believed to have been made to commit a theft or unlawful diversion of more than 10 curies of such material at any one time or more than 100 curies of such material in any one calendar year. The initial report shall be followed within a period of fifteen (15) days by a written report submitted to the appropriate NRC Regional Office which sets forth the details of the incident and its consequences. Copies of such written report shall be sent to the Director of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

40 FR 8774

Subsequent to the submission of the written report required by this paragraph, the licensee shall promptly inform the Office of Inspection and Enforcement by means of a written report of any substantive additional information, which becomes available to the licensee, concerning an attempted or apparent theft or unlawful diversion of tritium.

37 FR 9207

(d) The reports described in this section are not required for tritium possessed pursuant to a general license provided in Part 31 of this chapter or for tritium contained in spent fuel.

(e) The reports described in paragraph (b) of this section are not required for (1) tritium produced or possessed within a production or utilization facility incidental to the operation of the facility, other than tritium intentionally produced by or recovered from a production or utilization facility for any subsequent use.* (2) [Deleted 43 FR 6915.] (3) [Deleted 43 FR 6915.]

ENFORCEMENT

30 FR 8185

§ 30.61 Modification and revocation of licenses.

(a) The terms and conditions of each license issued pursuant to the regulations in this part and Parts 31-35* shall be subject to amendment, revision or modification by reason of amendments to the Act, or by reason of rules, regulations and orders issued in accordance with the terms of the Act.

(b) Any license may be revoked, suspended or modified, in whole or in part, for any material false statement in the application or any statement of fact required under section 182 of the Act, or because of conditions revealed by such application or statement of fact or any report, record or inspection or other means which would warrant the Commission to refuse to grant a license on an original application, or for violation of, or failure to observe any of the terms and provisions of the Act or of any rule, regulation or order of the Commission.

(c) Except in cases of willfulness or those in which the public health, interest or safety requires otherwise, no license shall be modified, suspended or revoked unless, prior to the institution of proceedings therefor, facts or conduct which may warrent such action shall have been called to the attention of the licensee in writing and the licensee shall have been accorded an opportunity to demonstrate or achieve compliance with all lawful requirements.

40 FR 8774

§ 30.62 Right to cause the withholding or recall of byproduct materials.

30 FR 8185

The Commission may cause the withholding or recall of byproduct material from any licensee who is not equipped to observe or fails to observe such safety standards to protect health as may be established by the Commission, or who uses such materials in violation of law or regulation of the Commission, or in a manner other than as disclosed in the application therefor or approved by the Commission.

40 FR 8774

§ 30.63 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of sections 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

---

† Amended 42 FR 33265.

* Amended 43 FR 6915.

** Amended 38 FR 2330.

SCHEDULES

§ 30.70 Schedule A—Exempt concentrations.

30 FR 8185

Element (atomic number)	Isotope	Column I Gas concentration µCi/ml[1] †	Column II Liquid and solid concentration µCi/ml[2] †
Antimony (51)	Sb 122	-----	3×10^{-4}
	Sb 124	-----	2×10^{-4}
	Sb 125	-----	1×10^{-3}
Argon (18)	A 37	1×10^{-3}	-----
	A 41	4×10^{-7}	-----
Arsenic (33)	As 73	-----	5×10^{-3}
	As 74	-----	5×10^{-4}
	As 76	-----	2×10^{-4}
	As 77	-----	8×10^{-4}
Barium (56)	Ba 131	-----	2×10^{-3}
	Ba 140	-----	3×10^{-4}
Beryllium (4)	Be 7	-----	2×10^{-2}
Bismuth (83)	Bi 206	-----	4×10^{-4}
Bromine (35)	Br 82	4×10^{-7}	3×10^{-3}
Cadmium (48)	Cd 109	-----	2×10^{-3}
	Cd 115m	-----	3×10^{-4}
	Cd 115	-----	3×10^{-4}
Calcium (20)	Ca 45	-----	9×10^{-5}
	Ca 47	-----	5×10^{-4}
Carbon (6)	C 14	1×10^{-6}	8×10^{-3}
Cerium (58)	Ce 141	-----	9×10^{-4}
	Ce 143	-----	4×10^{-4}
	Ce 144	-----	1×10^{-4}
Cesium (55)	Cs 131	-----	2×10^{-2}
	Cs 134m	-----	6×10^{-2}
	Cs 134	-----	9×10^{-5}
Chlorine (17)	Cl 38	9×10^{-7}	4×10^{-3}
Chromium (24)	Cr 51	-----	2×10^{-2}
Cobalt (27)	Co 57	-----	5×10^{-3}
	Co 58	-----	1×10^{-3}
	Co 60	-----	5×10^{-4}
Copper (29)	Cu 64	-----	3×10^{-3}
Dysprosium (66)	Dy 165	-----	4×10^{-3}
	Dy 166	-----	4×10^{-4}
Erbium (68)	Er 169	-----	9×10^{-4}
	Er 171	-----	1×10^{-3}
Europium (63)	Eu 152 (T/2=9.2 Hrs)	-----	6×10^{-4}
	Eu 155	-----	2×10^{-3}
Fluorine (9)	F 18	2×10^{-6}	8×10^{-3}
Gadolinium (64)	Gd 153	-----	2×10^{-3}
	Gd 159	-----	8×10^{-4}
Gallium (31)	Ga 72	-----	4×10^{-4}
Germanium (32)	Ge 71	-----	2×10^{-2}
Gold (79)	Au 196	-----	2×10^{-3}
	Au 198	-----	5×10^{-4}
	Au 199	-----	2×10^{-3}

[1] Values are given only for those materials normally used as gases.

[2] µCi/gm for solids.

† Amended 38 FR 29314.

30 FR 8185

Element (atomic number)	Isotope	Column I Gas concentration µCi/ml[1] †	Column II Liquid and solid concentration µCi/ml[2] †
Hafnium (72)	Hf 181	-----	7×10^{-4}
Hydrogen (1)	H 3	5×10^{-6}	3×10^{-2}
Indium (49)	In 113m	-----	1×10^{-2}
	In 114m	-----	2×10^{-4}
Iodine (53)	I 126	3×10^{-9}	2×10^{-5}
	I 131	3×10^{-9}	2×10^{-5}
	I 132	8×10^{-8}	6×10^{-4}
	I 133	1×10^{-8}	7×10^{-5}
	I 134	2×10^{-7}	1×10^{-3}
Iridium (77)	Ir 190	-----	2×10^{-3}
	Ir 192	-----	4×10^{-4}
	Ir 194	-----	3×10^{-4}
Iron (26)	Fe 55	-----	8×10^{-3}
	Fe 59	-----	6×10^{-4}
Krypton (36)	Kr 85m	1×10^{-6}	-----
	Kr 85	3×10^{-6}	-----
Lanthanum (57)	La 140	-----	2×10^{-4}
Lead (82)	Pb 203	-----	4×10^{-3}
Lutetium (71)	Lu 177	-----	1×10^{-3}
Manganese (25)	Mn 52	-----	3×10^{-4}
	Mn 54	-----	1×10^{-3}
	Mn 56	-----	1×10^{-3}
Mercury (80)	Hg 197m	-----	2×10^{-3}
	Hg 197	-----	3×10^{-3}
	Hg 203	-----	2×10^{-4}
Molybdenum (42)	Mo 99	-----	2×10^{-3}
Neodymium (60)	Nd 147	-----	6×10^{-4}
	Nd 149	-----	3×10^{-3}
Nickel (28)	Ni 65	-----	1×10^{-3}
Niobium (Columbium) (41)	Nb 95	-----	1×10^{-3}
	Nb 97	-----	9×10^{-3}
Osmium (76)	Os 185	-----	7×10^{-4}
	Os 191m	-----	3×10^{-2}
	Os 191	-----	2×10^{-3}
	Os 193	-----	6×10^{-4}
Palladium (46)	Pd 103	-----	3×10^{-3}
	Pd 109	-----	9×10^{-4}
Phosphorus (15)	P 32	-----	2×10^{-4}
Platinum (78)	Pt 191	-----	1×10^{-3}
	Pt 193m	-----	1×10^{-2}
	Pt 197m	-----	1×10^{-2}
	Pt 197	-----	1×10^{-3}
Potassium (19)	K 42	-----	3×10^{-3}
Praseodymium (59)	Pr 142	-----	3×10^{-4}
	Pr 143	-----	5×10^{-4}
Promethium (61)	Pm 147	-----	2×10^{-3}
	Pm 149	-----	4×10^{-4}
Rhenium (75)	Re 183	-----	6×10^{-3}
	Re 186	-----	9×10^{-4}
	Re 188	-----	6×10^{-4}

Element (atomic number)	Isotope	Column I Gas concentration μCi/ml[1] +	Column II Liquid and solid concentration μCi/ml[2] +
Rhodium (45) ---	Rh 103m	-----	1×10^{-1}
	Rh 105	-----	1×10^{-3}
Rubidium (37) ---	Rb 86	-----	7×10^{-4}
Ruthenium (44) ---	Ru 97	-----	4×10^{-3}
	Ru 103	-----	8×10^{-4}
	Ru 105	-----	1×10^{-3}
	Ru 106	-----	1×10^{-4}
Samarium (62) ---	Sm 153	-----	8×10^{-4}
Scandium (21) ---	Sc 46	-----	4×10^{-4}
	Sc 47	-----	9×10^{-4}
	Sc 48	-----	3×10^{-4}
Selenium (34) ---	Se 75	-----	3×10^{-3}
Silicon (14) ----	Si 31	-----	9×10^{-3}
Silver (47) ----	Ag 105	-----	1×10^{-3}
	Ag 110m	-----	3×10^{-4}
	Ag 111	-----	4×10^{-4}
Sodium (11) ----	Na 24	-----	2×10^{-3}
Strontium (38) ---	Sr 85*	-----	1×10^{-3}
	Sr 89	-----	1×10^{-4}
	Sr 91	-----	7×10^{-4}
	Sr 92	-----	7×10^{-4}
Sulfur (16) -----	S 35	9×10^{-8}	6×10^{-4}
Tantalum (73) ---	Ta 182	-----	4×10^{-4}
Technetium (43) --	Tc 96m	-----	1×10^{-1}
	Tc 96	-----	1×10^{-3}
Tellurium (52) ---	Te 125m	-----	2×10^{-3}
	Te 127m	-----	6×10^{-4}
	Te 127	-----	3×10^{-3}
	Te 129m	-----	3×10^{-4}
	Te 131m	-----	6×10^{-4}
	Te 132	-----	3×10^{-4}
Terbium (65) ----	Tb 160	-----	4×10^{-4}
Thallium (81) ----	Tl 200	-----	4×10^{-3}
	Tl 201	-----	3×10^{-3}
	Tl 202	-----	1×10^{-3}
	Tl 204	-----	1×10^{-3}
Thulium (69) ----	Tm 170	-----	5×10^{-4}
	Tm 171	-----	5×10^{-3}
Tin (50) -------	Sn 113	-----	9×10^{-4}
	Sn 125	-----	2×10^{-4}
Tungsten (Wolfram) (74) -----	W 181	-----	4×10^{-3}
	W 187	-----	7×10^{-4}
Vanadium (23) ---	V 48	-----	3×10^{-4}
Xenon (54) -----	Xe 131m	4×10^{-6}	-----
	Xe 133	3×10^{-6}	-----
	Xe 135	1×10^{-6}	-----
Ytterbium (70) ---	Yb 175	-----	1×10^{-3}
Yttrium (39) ----	Y 90	-----	2×10^{-4}
	Y 91m	-----	3×10^{-2}
	Y 91	-----	3×10^{-4}
	Y 92	-----	6×10^{-4}
	Y 93	-----	3×10^{-4}
Zinc (30) ------	Zn 65	-----	1×10^{-3}
	Zn 69m	-----	7×10^{-4}
	Zn 69	-----	2×10^{-2}
Zirconium (40) ---	Zr 95	-----	6×10^{-4}
	Zr 97	-----	2×10^{-4}
Beta and/or gamma emitting byproduct material not listed above with half-life less than 3 years	--------	1×10^{-10}	1×10^{-6}

30 FR 8185

[1] Values are given only for those materials normally used as gases.

[2] μCi/gm for solids.

+ Amended 38 FR 29314.

NOTE 1: Many radioisotopes disintegrate into isotopes which are also radioactive. In expressing the concentrations in Schedule A, the activity stated is that of the parent isotope and takes into account the daughters.

NOTE 2: For purposes of § 30.14 where there is involved a combination of isotopes, the limit for the combination should be derived as follows:

Determine for each isotope in the product the ratio between the concentration present in the product and the exempt concentration established in Schedule A for the specific isotope when not in combination. The sum of such ratios may not exceed "1" (i.e., unity).

Example:

$$\frac{\text{Concentration of Isotope A in Product 1}}{\text{Exempt concentration of Isotope A}} + \frac{\text{Concentration of Isotope B in Product}}{\text{Exempt concentration of Isotope B}} \leqq 1$$

§ 30.71 Schedule B.

Byproduct material	*Microcuries*
Antimony 122 (Sb 122)	100
Antimony 124 (Sb 124)	10
Antimony 125 (Sb 125)	10
Arsenic 73 (As 73)	100
Arsenic 74 (As 74)	10
Arsenic 76 (As 76)	10
Arsenic 77 (As 77)	100
Barium 131 (Ba 131)	10
**Barium 133 (Ba 133)	10
Barium 140 (Ba 140)	10
Bismuth 210 (Bi 210)	1
Bromine 82 (Br 82)	10
Cadmium 109 (Cd 109)	10
Cadmium 115m (Cd 115m)	10
Cadmium 115 (Cd 115)	100
Calcium 45 (Ca 45)	10
Calcium 47 (Ca 47)	10
Carbon 14 (C 14)	100
Cerium 141 (Ce 141)	100
Cerium 143 (Ce 143)	100
Cerium 144 (Ce 144)	1
Cesium 131 (Cs 131)	1,000

35 FR 6425

** Added 36 FR 16898.

* Added 35 FR 3982.

Byproduct material	Microcuries
Cesium 134m (Cs 134m)	100
Cesium 134 (Cs 134)	1
Cesium 135 (Cs 135)	10
Cesium 136 (Cs 136)	10
Cesium 137 (Cs 137)	10
Chlorine 36 (Cl 36)	10
Chlorine 38 (Cl 38)	10
Chromium 51 (Cr 51)	1,000
Cobalt 58m (Co 58m)	10
Cobalt 58 (Co 58)	10
Cobalt 60 (Co 60)	1
Copper 64 (Cu 64)	100
Dysprosium 165 (Dy 165)	10
Dysprosium 166 (Dy 166)	100
Erbium 169 (Er 169)	100
Erbium 171 (Er 171)	100
Europium 152 9.2h (Eu 152 9.2h)	100
Europium 152 13 yr (Eu 152 13 yr)	1
Europium 154 (Eu 154)	1
Europium 155 (Eu 155)	10
Fluorine 18 (F 18)	1,000
Gadolinium 153 (Gd 153)	10
Gadolinium 159 (Gd 159)	100
Gallium 72 (Ga 72)	10
Germanium 71 (Ge 71)	100
Gold 198 (Au 198)	100
Gold 199 (Au 199)	100
Hafnium 181 (Hf 181)	10
Holmium 166 (Ho 166)	100
Hydrogen 3 (H 3)	1,000
Indium 113m (In 113m)	100
Indium 114m (In 114m)	10
Indium 115m (In 115m)	100
Indium 115 (In 115)	10
Iodine 125 (I 125)	1
Iodine 126 (I 126)	1
Iodine 129 (I 129)	0.1
Iodine 131 (I 131)	1
Iodine 132 (I 132)	10
Iodine 133 (I 133)	1
Iodine 134 (I 134)	10
Iodine 135 (I 135)	10
Iridium 192 (Ir 192)	10
Iridium 194 (Ir 194)	100
Iron 55 (Fe 55)	100
Iron 59 (Fe 59)	10
Krypton 85 (Kr 85)	100
Krypton 87 (Kr 87)	10
Lanthanum 140 (La 140)	10
Lutetium 177 (Lu 177)	100
Manganese 52 (Mn 52)	10
Manganese 54 (Mn 54)	10
Manganese 56 (Mn 56)	10
Mercury 197m (Hg 197m)	100
Mercury 197 (Hg 197)	100
Mercury 203 (Hg 203)	10
Molybdenum 99 (Mo 99)	100
Neodymium 147 (Nd 147)	100
Neodymium 149 (Nd 149)	100
Nickel 59 (Ni 59)	100
Nickel 63 (Ni 63)	10
Nickel 65 (Ni 65)	100
Niobium 93m (Nb 93m)	10
Niobium 95 (Nb 95)	10
Niobium 97 (Nb 97)	10
Osmium 185 (Os 185)	10
Osmium 191m (Os 191m)	100
Osmium 191 (Os 191)	100
Osmium 193 (Os 193)	100
Palladium 103 (Pd 103)	100
Palladium 109 (Pd 109)	100
Phosphorous 32 (P 32)	10
Platinum 191 (Pt 191)	100
Platinum 193m (Pt 193m)	100
Platinum 193 (Pt 193)	100
Platinum 197m (Pt 197m)	100
Platinum 197 (Pt 197)	100
Polonium 210 (Po 210)	0.1
Potassium 42 (K 42)	10
Praseodymium 142 (Pr 142)	100
Praseodymium 143 (Pr 143)	100
Promethium 147 (Pm 147)	10
Promethium 149 (Pm 149)	10
Rhenium 186 (Re 186)	100
Rhenium 188 (Re 188)	100
Rhodium 103m (Rh 103m)	100
Rhodium 105 (Rh 105)	100
Rubidium 86 (Rb 86)	10
Rubidium 87 (Rb 87)	10
Ruthenium 97 (Ru 97)	100
Ruthenium 103 (Ru 103)	10
Ruthenium 105 (Ru 105)	10
Ruthenium 106 (Ru 106)	1
Samarium 151 (Sm 151)	10
Samarium 153 (Sm 153)	100
Scandium 46 (Sc 46)	10
Scandium 47 (Sc 47)	100
Scandium 48 (Sc 48)	10
Selenium 75 (Se 75)	10
Silicon 31 (Si 31)	100
Silver 105 (Ag 105)	10
Silver 110m (Ag 110m)	1
Silver 111 (Ag 111)	100
Sodium 24 (Na 24)	10
Strontium 85 (Sr 85)	10
Strontium 89 (Sr 89)	1
Strontium 90 (Sr 90)	0.1
Strontium 91 (Sr 91)	10
Strontium 92 (Sr 92)	10
Sulfur 35 (S 35)	100
Tantalum 182 (Ta 182)	10
Technetium 96 (Tc 96)	10
Technetium 97m (Tc 97m)	100
Technetium 97 (Tc 97)	100
Technetium 99m (Tc 99m)	100
Technetium 99 (Tc 99)	10
Tellurium 125m (Te 125m)	10
Tellurium 127m (Te 127m)	10
Tellurium 127 (Te 127)	100
Tellurium 129m (Te 129m)	10
Tellurium 129 (Te 129)	100
Tellurium 131m (Te 131m)	10
Tellurium 132 (Te 132)	10
Terbium 160 (Tb 160)	10
Thallium 200 (Tl 200)	100
Thallium 201 (Tl 201)	100
Thallium 202 (Tl 202)	100
Thallium 204 (Tl 204)	10
Thulium 170 (Tm 170)	10
Thulium 171 (Tm 171)	10
Tin 113 (Sn 113)	10
Tin 125 (Sn 125)	10
Tungsten 181 (W 181)	10
Tungsten 185 (W 185)	10
Tungsten 187 (W 187)	100
Vanadium 48 (V 48)	10
Xenon 131m (Xe 131m)	1,000
Xenon 133 (Xe 133)	100
Xenon 135 (Xe 135)	100
Ytterbium 175 (Yb 175)	100
Yttrium 90 (Y 90)	10
Yttrium 91 (Y 91)	10
Yttrium 92 (Y 92)	100
Yttrium 93 (Y 93)	100
Zinc 65 (Zn 65)	10
Zinc 69m (Zn 69m)	100
Zinc 69 (Zn 69)	1,000
Zirconium 93 (Zr 93)	10
Zirconium 95 (Zr 95)	10
Zirconium 97 (Zr 97)	10
Any byproduct material not listed above other than alpha emitting byproduct material	0.1

35 FR 6425

35 FR 6425

35 FR 6425

NOTE.—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0079), (R0089), and (R0173).

PART 31 GENERAL DOMESTIC LICENSES FOR BYPRODUCT MATERIAL†

35 FR 6425

§ 31.1 Purpose and scope.

This part establishes general licenses for the possession and use of byproduct material contained in certain items and a general license for ownership of byproduct material. Part 30 of this chapter also contains provisions applicable to the subject matter of this part.

38 FR 22220

§ 31.2 Terms and conditions.

(a) The general licenses provided in this part are subject to the provision of §§ 30.14(d), 30.34(a) to (e), *30.41, 30.51 to 30.63 and Parts 19, 20, and 21† of this chapter[1] unless indicated otherwise in the language of the general license.

30 FR 8185

§ 31.3 Certain devices and equipment.

A general license is hereby issued to transfer receive, acquire, own, possess and use byproduct material incorporated in the following devices or equipment which have been manufactured, tested and labeled by the manufacturer in accordance with the specifications contained in a specific license issued to him by the Commission.

(a) *Static elimination device.* Devices designed for use as static eliminators which contain, as a sealed source or sources, byproduct material consisting of a total of not more than 500 microcuries of polonium-210 per device.

(b) [Deleted 34 FR 6651.]

(c) [Deleted 35 FR 3982.]

(d) *Ion generating tube.* Devices designed for ionization of air which contain, as a sealed source or sources, byproduct material consisting of a total of not more than 500 microcuries of polonium-210 per device or of a total of not more than 50 millicuries of hydrogen-3 (tritium) per device.

§ 31.4 [Deleted 36 FR 16898.]

39 FR 43531

§ 31.5 Certain measuring, gauging or controlling devices.[2]

(a) A general license is hereby issued to commercial and industrial firms and research, educational and medical institutions, individuals in the conduct of their business, and Federal, State or local government agencies to acquire, receive, possess, use or transfer, in accordance with the provisions of paragraphs (b), (c) and (d) of this section, byproduct material contained in devices designed and manufactured for the purpose of detecting, measuring, gauging or controlling thickness, density, level, interface location, radiation, leakage, or qualitative or quantitative chemical composition, or for producing light or an ionized atmosphere.

(b) The general license in paragraph (a) of this section applies only to byproduct material contained in devices which have been manufactured or initially transferred† and labeled in accordance with the specifications contained in a specific license issued pursuant to § 32.51 of this chapter or in accordance with the specifications contained in a specific license issued by an Agreement State which authorizes distribution of the devices to persons generally licensed by the Agreement State.

39 FR 43531

(c) Any person who acquires, receives, possesses, uses or transfers byproduct material in a device pursuant to the general license in paragraph (a) of this section:

(1) Shall assure that all labels affixed to the device at the time of receipt and bearing a statement that removal of the label is prohibited are maintained thereon and shall comply with all instructions and precautions provided by such labels;

(2) Shall assure that the device is tested for leakage of radioactive material and proper operation of the on-off mechanism and indicator, if any, at no longer than six-month intervals or at such other intervals as are specified in the label; however:

(i) devices containing only krypton need not be tested for leakage of radioactive material, and

(ii) devices containing only tritium or not more than 100 microcuries of other beta and/or gamma emitting material or

---

[1] Attention is directed particularly to the provisions of the regulations in Part 20 of this chapter which relate to the labeling of containers.

* Amended 38 FR 33968.

† Amended 43 FR 6915.

[2] Persons possessing byproduct material in devices under the general license in § 31.5 before Jan. 15, 1975 may continue to possess, use or transfer that material in accordance with the requirements of § 31.5 in effect on Jan. 14, 1975.

FIGURE 6-11

10 microcuries of alpha emitting material and devices held in storage in the original shipping container prior to initial installation need not be tested for any purpose;

39 FR 43531

(3) Shall assure that the tests required by paragraph (c)(2) of this section and other testing, installation, servicing, and removal from installation involving the radioactive materials, its shielding or containment, are performed:

(i) in accordance with the instructions provided by the labels; or

(ii) by a person holding a specific license pursuant to Parts 30 and 32 of this chapter or from an Agreement State to perform such activities;

(4) Shall maintain records showing compliance with the requirements of paragraphs (c)(2) and (c)(3) of this section. The records shall show the results of tests. The records also shall show the dates of performance of, and the names of persons performing, testing, installation, servicing, and removal from installation concerning the radioactive material, its shielding or containment.

41 FR 18300

Records of tests for leakage of radioactive material required by paragraph (c)(2) of this section shall be maintained for one year after the next required leak test is performed or until the sealed source is transferred or disposed of. Records of tests of the on-off mechanism and indicator, required by paragraph (c)(2) of this section, shall be maintained for one year after the next required test of the on-off mechanism and indicator is performed or until the sealed source is transferred or disposed of. Records which are required by paragraph (c)(3) of this section shall be maintained for a period of two years from the date of the recorded event or until the device is transferred or disposed of.

39 FR 43531

(5) Upon the occurrence of a failure of or damage to, or any indication of a possible failure of or damage to, the shielding of the radioactive material or the on-off mechanism or indicator, or upon the detection of 0.005 microcurie or more removable radioactive material, shall immediately suspend operation of the device until it has been repaired by the manufacturer or other person holding a specific license pursuant to Parts 30 and 32 of this chapter or from an Agreement State to repair such devices, or disposed of by transfer to a person authorized by a specific license to receive the byproduct material contained in the device and, within 30 days, furnish to the Director of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D of Part 20 of this chapter, a report containing a brief description of the event and the remedial action taken;

(6) Shall not abandon the device containing byproduct material;

(7) Shall not export the device containing byproduct material except in accordance with Part 110 of this chapter;†

39 FR 43531

(8) Except as provided in paragraph (c)(9) of this section, shall transfer or dispose of the device containing byproduct material only by transfer to a person holding a specific license pursuant to Parts 30 and 32 of this chapter or from an Agreement State, to receive the device and within 30 days after transfer of a device to a specific licensee shall furnish to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, a report containing identification of the device by manufacturer's name and model number and the name and address of the person receiving the device. No report is required if the device is transferred to the specific licensee in order to obtain a replacement device;

(9) Shall transfer the device to another general licensee only:

(i) Where the device remains in use at a particular location. In such case the transferor shall give the transferee a copy of this section and any safety documents identified in the label of the device and within 30 days of the transfer, report to the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, the manufacturer's name and model number of device transferred, the name and address of the transferee, and the name and/or position of an individual who may constitute a point of contact between the Commission and the transferee; or

(ii) Where the device is held in storage in the original shipping container at its intended location of use prior to initial use by a general licensee.

(10) Shall comply with the provisions of §§ 20.402 and 20.403 of this chapter for reporting radiation incidents, theft or loss of licensed material, but shall be exempt from the other requirements of Parts 19, 20, and 21* of this chapter.

* Amended 42 FR 28891.

† Amended 43 FR 6915.

(d) The general license in paragraph (a) of this section does not authorize the manufacture or import of devices containing byproduct material.

30 FR 8185

§ 31.6 General license to install devices generally licensed in § 31.5.

Any person who holds a specific license issued by an Agreement State authorizing the holder to manufacture, install or service a device described in § 31.5 within such Agreement State is hereby granted a general license to install and service such device in any non-Agreement State: *Provided*, That:

(a) [Deleted 39 FR 43531.]

(b) The device has been manufactured, labeled, installed, and serviced in accordance with applicable provisions of the specific license issued to such person by the Agreement State.

30 FR 10947

(c) Such person assures that any labels required to be affixed to the device under regulations of the Agreement State which licensed manufacture of the device bear a statement that removal of the label is prohibited.

(d) [Deleted 39 FR 43531.]

§ 31.7 Luminous safety devices for use in aircraft.

33 FR 6462

(a) A general license is hereby issued to own, receive, acquire, possess, and use tritium or promethium-147 contained in luminous safety devices for use in aircraft, provided each device contains not more than 10 curies of tritium or 300 millicuries of promethium-147 and that each device has been manuactured, assembled or initially transferred† in accordance with a license issued under the provisions of § 32.53 of this chapter or manufactured or assembled in accordance with a specific license issued by an Agreement State which authorizes manufacture or assembly of the device for distribution to persons generally licensed by the Agreement State.

30 FR 8185

(b) Persons who own, receive, acquire, possess or use luminous safety devices pursuant to the general license in this section are exempt from the requirements of Parts 19, 20, and 21* of this chapter, except that they shall comply with the provisions of §§ 20.402 and 20.403 of this chapter.

(c) This general license does not authorize the manufacture, assembly, repair or import of luminous safety devices containing tritium or promethium-147.

(d) This general license does not authorize the export of luminous safety devices containing tritium or promethium-147.†

(e) This general license does not authorize the ownership, receipt, acquisition, possession or use of promethium-147 contained in instrument dials.

§ 31.8 Americium-241 in the form of calibration or reference sources.

(a) A general license is hereby issued to those persons listed below to own, receive, acquire, possess, use and transfer, in accordance with the provisions of paragraphs (b) and (c) of this section, americium-241 in the form of calibration or reference sources:

(1) Any person in a non-Agreement State who holds a specific license issued pursuant to this chapter which authorizes him to receive, possess, use and transfer byproduct material, source material, or special nuclear material; and

(2) Any Government agency, as defined in § 30.4(g) of this chapter, which holds a specific license issued pursuant to this chapter which authorizes it to receive, possess, use and transfer byproduct material, source material, or special nuclear material.

30 FR 8185

(b) The general license in paragraph (a) of this section applies only to calibration or reference sources which have been manufactured or initially transferred† in accordance with the specifications contained in a specific license issued† pursuant to § 32.57 of this chapter or in accordance with the specifications contained in a specific license issued to the manufacturer by an Agreement State which authorizes manufacture of the sources for distribution to persons generally licensed by the Agreement State.

(c) The general license in paragraph (a) of this section is subject to the provisions of §§ 30.14(d), 30.34 (a) to (e), and 30.51 to 30.63 of this chapter, and to the provisions of Parts 19, 20, and 21* of this chapter. In addition, persons who own, receive, acquire, possess, use and transfer one or more calibration or reference sources pursuant to this general license:

(1) Shall not possess at any one time, at any one location of storage or use, more than 5 microcuries of americium-241 in such sources;

(2) Shall not receive, possess, use or transfer such source unless the source, or the storage container, bears a label which includes the following statement or a substantially similar statement which contains the information called for in the following statement:**

The receipt, possession, use and transfer of this source, Model ______, Serial No. _____, are subject to a general license and the regulations of the United States Nuclear Regulatory Commission or of a State with which the Commission has entered into an agreement for the exercise of regulatory authority. Do not remove this label.

CAUTION – RADIOACTIVE MATERIAL – THIS SOURCE CONTAINS AMERICIUM-241. DO NOT TOUCH RADIOACTIVE PORTION OF THIS SOURCE.

____
(Name of manufacturer or initial transferor†)

(3) Shall not transfer, abandon, or dispose of such source except by transfer to a person authorized by a license pursuant to this chapter or from an Agreement State to receive the source.

30 FR 8185

(4) Shall store such source, except when the source is being used, in a closed container adequately designed and constructed to contain americium-241 which might otherwise escape during storage.

(5) Shall not use such source for any purpose other than the calibration of radiation detectors or the standardization of other sources.

(d) This general license does not authorize the manufacture or import of calibration or reference sources containing americium-241.

38 FR 22220

(e) This general license does not authorize the export of calibration or reference sources containing americium-241.

§ 31.9 General license to own byproduct material.

30 FR 9904

A general license is hereby issued to own byproduct material without regard to quantity. Notwithstanding any other provision of this chapter, a general licensee under this paragraph is not authorized to manufacture, produce, transfer, receive, possess, use, import or export byproduct material, except as authorized in a specific license.

§ 31.10 General license for strontium-90 in ice detection devices.

(a) A general license is hereby issued to own, receive, acquire, possess, use, and transfer strontium-90 contained in ice detection devices, provided each device contains not more than fifty microcuries of strontium-90 and each device has been manufactured or initially transferred† in accordance with the specifications contained in a license issued pursuant to § 32.61 of this chapter or in accordance with the specifications contained in a specific license issued to the manufacturer by an Agreement State which authorizes manufacture of the ice detection devices for distribution to persons generally licensed by the Agreement State.

(b) Persons who own, receive, acquire, possess, use, or transfer strontium-90 contained in ice detection devices pursuant to the general license in paragraph (a) of this section:

30 FR 9904

(1) Shall, upon occurrence of visually observable damage, such as a bend or crack or discoloration from overheating, to the device, discontinue use of the device until it has been inspected, tested for leakage and repaired by a person holding a specific license pursuant to Parts 30 and 32 of this chapter or from an Agreement State to manufacture or service such devices; or shall dispose of the device pursuant to the provisions of § 20.301 of this chapter;

(2) Shall assure that all labels affixed to the device at the time of receipt, and which bear a statement which prohibits removal of the labels, are maintained thereon;

(3) Are exempt from the requirements of Parts 19, 20, and 21* of this chapter except that such persons shall comply with the provisions of §§ 20.301, 20.402, and 20.403 of this chapter.

(c) This general license does not authorize the manufacture, assembly, disassembly, repair, or import of strontium-90 in ice detection devices.

§ 31.11 General license for use of byproduct material for certain in vitro clinical or laboratory testing.

44 FR 50324

(a) A general license is hereby issued to any physician, veterinarian in the practice of veterinary medicine, clinical laboratory or hospital to receive, acquire, possess, transfer, or use, for any of the following stated tests, in accordance with the provisions of paragraphs (b), (c), (d), (e), and (f) of this section, the following byproduct materials in prepackaged units:

* Amended 42 FR 28891.

† Amended 43 FR 6915.

**Sources generally licensed under this section prior to January 19, 1975, may bear labels authorized by the regulations in effect on January 1, 1975.

33 FR 16553

paragraphs (b), (c), (d), (e), and (f) of this section, the following byproduct materials in prepackaged units:

(1) Iodine-125, in units not exceeding 10 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings or animals.

(2) Iodine-131, in units not exceeding 10 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings or animals.

38 FR 34110

(3) Carbon-14, in units not exceeding 10 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings or animals.

39 FR 26143

(4) Hydrogen-3 (tritium), in units not exceeding 50 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings or animals.

(5) Iron-59, in units not exceeding 20 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings, or animals.

42 FR 21604

(6) Selenium-75, in units not exceeding 10 microcuries each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human being or animals.

42 FR 26986

(7) Mock Iodine-125 reference or calibration sources, in units not exceeding 0.05 microcurie of iodine-129 and 0.005 microcurie of americium-241 each for use in in vitro clinical or laboratory tests not involving internal or external administration of byproduct material, or the radiation therefrom, to human beings or animals.

39 FR 26143

(b) No person shall receive, acquire, possess, use, or transfer byproduct material pursuant to the general license established by paragraph (a) of this section until he has filed form NRC-483, "Registration Certificate-In Vitro Testing with Byproduct Material Under General License," with the Director† of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, and received from the Commission a validated copy of Form NRC-483 with registration number assigned or until he has been authorized pursuant to § 35.14 (c) of this chapter to use byproduct material under the general license in this § 31.11.

33 FR 16553

The registrant shall furnish on Form NRC-483 the following information and such other information as may be required by that form:

(1) Name and address of the registrant:

(2) The location of use; and

(3) A statement that the registrant has appropriate radiation measuring instruments to carry out in vitro clinical or laboratory tests with byproduct materials as authorized under the general license in paragraph (a) of this section, and that such tests will be performed only by personnel competent in the use of such instruments and in the handling of the byproduct materials.

42 FR 21604

(c) A person who receives, acquires, possesses, or uses byproduct material pursuant to the general license established by paragraph (a) of this section shall comply with the following:

(1) The general licensee shall not possess at any one time, pursuant to the general license in paragraph (a) of this section, at any one location of storage or use, a total amount of iodine-125, iodine-131, selenium-75, and/or iron-59 in excess of 200 microcuries.

33 FR 16553

(2) The general licensee shall store the byproduct material, until used, in the original shipping container or in a container providing equivalent radiation protection.

(3) The general licensee shall use the byproduct material only for the uses authorized by paragraph (a) of this section.

(4) The general licensee shall not transfer the byproduct material except by transfer to a person authorized to receive it by a license pursuant to this chapter or from an Agreement State, nor transfer the byproduct material in any manner other than in the unopened, labeled shipping container as received from the supplier.

42 FR 26986

(5) The general licensee shall dispose of the Mock Iodine-125 reference or calibration sources described in paragraph (a) (7) of this section as required by § 20.301 of this chapter.

44 FR 50324

(d) The general licensee shall not receive, acquire, possess, or use byproduct material pursuant to paragraph (a) of this section:

42 FR 26986

(1) Except as prepackaged units which are labeled in accordance with the provisions of a specific license issued under the provisions of § 32.71 of this chapter or in accordance with the provisions of a specific license issued by an Agreement State that authorizes manufacture and distribution of iodine-125, iodine-131, carbon-14, hydrogen-3 (tritium), selenium-75, iron-59, or Mock Iodine-125 for distribution to persons generally licensed by the Agreement State.

44 FR 50324

(2) Unless the following statement, or a substantially similar statement which contains the information called for in the following statement, appears on a label affixed to each prepackaged unit or appears in a leaflet or brochure which accompanies the package: [1]

This radioactive material may be received, acquired, possessed, and used only by physicians, veterinarians in the practice of veterinary medicine, clinical laboratories or hospitals and only for in vitro clinical or laboratory tests not involving internal or external administration of the material, or the radiation therefrom, to human beings or animals. Its receipt, acquisition, possession, use, and transfer are subject to the regulations and a general license of the U.S. Nuclear Regulatory Commission or of a State with which the Commission has entered into an agreement for the exercise of regulatory authority.

____

(Name of Manufacturer)

† Amended 41 FR 16445

[1] Labels authorized by the regulations in effect on September 28, 1979, may be used until one year from September 28, 1979.

33 FR 16552

(e) The registrant possessing or using byproduct materials under the general license of paragraph (a) of this section shall report in writing to the Director of Nuclear Material Safety and Safeguards any changes in the information furnished by him in the "Registration Certificate—In Vitro Testing With Byproduct Material Under General License," Form NRC-483. The report shall be furnished within 30 days after the effective date of such change.

42 FR 26986

(f) Any person using byproduct material pursuant to the general license of paragraph (a) of this section is exempt from the requirements of Parts 19, 20, and 21‡ of this chapter with respect to byproduct materials covered by that general license, except that such persons using the Mock Iodine-125 described in paragraph (a) (7) of this section shall comply with the provisions of §§ 20.301, 20.402, and 20.403 of this chapter.

§ 31.100 [Deleted 36 FR 16898.]

NOTE.—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0088), (R0160).

‡ Amended 43 FR 28891.

UNITED STATES NUCLEAR REGULATORY COMMISSION

RULES and REGULATIONS

TITLE 10, CHAPTER 1, CODE OF FEDERAL REGULATIONS – ENERGY

PART 170

FEES FOR FACILITIES AND MATERIALS LICENSES AND OTHER REGULATORY SERVICES UNDER THE ATOMIC ENERGY ACT OF 1954, AS AMENDED★

GENERAL PROVISIONS

SCHEDULE OF FEES

ENFORCEMENT

AUTHORITY: The provisions of this Part 170 issued under sec. 501, 65 Stat. 290; 31 U.S.C. 483a; sec. 161, 68 Stat. 948, 42 U.S.C. 2201; Sec. 201(f), Pub. L. 93-438, 88 Stat. 1243; 42 U.S.C. 5841.

GENERAL PROVISIONS

§ 170.1 Purpose.

The regulations in this part set out fees charged for licensing services rendered by the Nuclear Regulatory Commission, as authorized under Title V of the Independent Offices Appropriation Act of 1952 (65 Stat. 290; 31 U.S.C. 483a) and provisions regarding their payment.

§ 170.2 Scope.

43 FR 7210

Except for persons who apply for or hold the permits, licenses, or approvals exempted in § 170.11, the regulations in this part apply to a person who is an applicant for, or holder of, a specific byproduct material license issued pursuant to Parts 30 and 32-35 of this chapter, a specific source material license issued pursuant to Part 40 of this chapter, a specific special nuclear material license issued pursuant to Part 70 of this chapter, a specific approval of spent fuel casks and shipping containers issued pursuant to Part 71 of this chapter, a specific request for approval of sealed sources and devices containing byproduct material, source material, or special nuclear material, or a production or utilization facility construction permit and operating license issued pursuant to Part 50 of this chapter, to routine safety and safeguards inspections of a licensed person, to a person who applies for approval of a reference standardized design of a nuclear steam supply system or balance of plant, for review of a facility site prior to the submission of an application for a construction permit, for review of a standardized spent fuel facility design, and for a special project review which the Commission completes or makes whether or not in conjunction with a license application on file or which may be filed.

43 FR 7210

§ 170.3 Definitions.

33 FR 10923

As used in this part:

(a) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material.

(b) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government.

(c) "Materials license" means a byproduct material license issued pursuant to Part 30 of this chapter, or a source material license issued pursuant to Part 40 of this chapter, or a special nuclear material license issued pursuant to Part 70 of this chapter.

(d) "Nuclear reactor" means an apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-supporting chain reaction.

(e) "Other production or utilization facility" means a facility other than a nuclear reactor licensed by the Commission under the authority of section 103 or 104 of the Atomic Energy Act of 1954, as amended (the Act), and pursuant to the provisions of Part 50 of this chapter.

33 FR 10923

(f) "Power reactor" means a nuclear reactor designed to produce electrical or heat energy licensed by the Commission under the authority of section 103 or subsection 104b of the Act and pursuant to the provisions of §§ 50.21(b) or 50.22 of this chapter.

(g) "Production facility" means:

(1) Any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233; or

(2) Any facility designed or used for the separation of the isotopes of uranium or the isotopes of plutonium, except laboratory scale facilities designed or used for experimental or analytical purposes only; or

40 FR 8774

(3) Any facility designed or used for the processing of irradiated materials containing special nuclear material, except:

(i) laboratory scale facilities designed or used for experimental or analytical purposes;

(ii) facilities in which the only special nuclear materials contained in the irradiated material to be processed are uranium enriched in the isotope U^{235} and plutonium produced by the irradiation, if the material processed contains not more than 10^{-6} grams of plutonium per gram of U^{235} and has fission product activity not in excess of 0.25 millicurie of fission products per gram of U^{235}; and

(iii) facilities in which processing is conducted pursuant to a license issued under Parts 30 and 70 of this chapter, or equivalent regulations of an Agreement State, for the receipt, possession, use, and transfer of irradiated special nuclear material, which authorizes the processing of the irradiated material on a batch basis for the separation of selected fis-

*Amended 43 FR 7210.

FIGURE 6-12

[40 FR 8774] sion products and limits the process batch to not more than 100 grams of uranium enriched in the isotope 235 and nto more than 15 grams of any other special nuclear material.

[33 FR 10923] (h) "Research reactor" means a nuclear reactor licensed by the Commission under the authority of subsection 104c of the Act and pursuant to the provisions of § 50.21(c) of this chapter for operation at a thermal power level of 10 megawatts or less, and which is not a testing facility as defined by paragraph (m) of this section.

(i) "Sealed source" means any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material.

(j) "Source material" means:

(1) Uranium or thorium, or any combination thereof, in any physical or chemical form; or

(2) Ores which contain by weight one-twentieth of one percent (0.05%) or more of (i) uranium, (ii) thorium, or (iii) any combination thereof. Source material does not include special nuclear material.

(k) "Special nuclear material" means:

(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material but does not include source material; or

(2) any material artificially enriched by any of the foregoing, but does not include source material.

[38 FR 30251] (l) "Manufacturing license" means a license pursuant to Appendix M of Part 50 of this chapter to manufacture a nuclear power reactor(s) to be operated at sites not identified in the license application.

[33 FR 11587] (m) "Testing facility" means a nuclear reactor licensed by the Commission under the authority of subsection 104c of the Act and pursuant to the provisions of § 50.21(c) of this chapter for operation at:

(1) A thermal power level in excess of 10 megawatts; or

(2) A thermal power level in excess of 1 megawatt, if the reactor is to contain:

(i) A circulating loop through the core in which the applicant proposes to conduct fuel experiments; or

(ii) A liquid fuel loading; or

(iii) An experimental facility in the core in excess of 16 square inches in cross-section.

(n) "Utilization facility" means any nuclear reactor other than one designed or used primarily for the formation of plutonium or U^{233} and any other equipment or device determined by rule of the Commission to be a utilization facility within the purview of subsection 11cc of the Act.

(o) [Deleted 43 FR 7210.]

[36 FR 145] (p) "Human use" means the internal or external administration of byproduct, source, or special nuclear material, or the radiation therefrom, to human beings.

[43 FR 7210] (q) "Nuclear Steam Supply System" consists of the reactor core, reactor coolant system, and related auxiliary systems including the emergency core cooling system; decay heat removal system; and chemical volume and control system.

(r) "Balance of plant" consists of the remaining systems, components, and structures that comprise a complete nuclear power plant and are not included in the nuclear steam supply system.

(s) "Special projects" means those projects submitted to the Commission for review and for which specific fees are not prescribed in this chapter. Examples of special projects include, but are not limited to, topical reports, early site reviews, waste solidification facilities, fuel reprocessing facilities, and amendment or renewal of standardized reference design approvals.

(t) "Routine inspection" means an inspection performed at frequencies or during a certain period of time prescribed by the Commission for purposes of reviewing a licensee's authorized activities to assure that they are being conducted in accordance with regulatory or statutory requirements and that associated facilities and equipment are being operated in a safe manner.

(u) "Duplicate unit" means one of a limited number of the same kind of units which are to be constructed within a limited time span and subject to review at the same time by the staff.

(v) "Replicate unit" means a unit based on the reuse of a plant design, previously reviewed and approved for construction by the same utility or by another utility as part of another construction permit application.

(w) "Reference systems concept" means a concept that involves the review of an entire facility design or major fraction of a facility design outside of the context of a license application. The standard design would be referenced in subsequent license applications.

(x) "Advanced reactor" means any nuclear reactor concept other than light water reactors and high temperature gas cooled reactors.

[33 FR 11587]

§ 170.4 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

[40 FR 8774]

§ 170.5 Communications.

All communications concerning the regulations in this part should be addressed to the Executive Director for Operation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications may be delivered in person at the Commission's offices at 1717 H Street NW, Washington, DC on or at 7920 Norfolk Ave., Bethesda, MD

[33 FR 11587]

§ 170.11 Exemptions.

[43 FR 7210] (a) No application fees, license fees, amendment fees, renewal fees, approval fees, or inspection fees shall be required for:

[33 FR 11587] (1) A license authorizing the export only of a production or utilization facility.

(2) A license authorizing the export only or import only of byproduct material, source material or special nuclear material.

(3) A license authorizing the receipt, ownership, possession, use or production of byproduct material, source material, or special nuclear material incidental to the operation of a production or utilization facility licensed under Part 50 of this chapter, including a license under Part 70 of this chapter, authorizing possession and storage only of special nuclear material at the site of a nuclear reactor for use as fuel in operation of the nuclear reactor or at the site of a spent fuel processing plant for processing at the plant.

(4) A construction permit or license applied for by, or issued to, a nonprofit educational institution for a production facility or utilization facility, other than a power reactor, to be used for teaching, training, or medical purposes, or for byproduct material, source material, or special nuclear material to be used for teaching, training, or medical purposes, or in connection with a facility, other than a power reactor, used for teaching, training, or medical purposes.

[37 FR 24028] (5) A construction permit or license applied for by, or issued to, a Government agency, except for a utilization facility designed to produce electrical or heat energy pursuant to section 103 or 104b of the Atomic Energy Act of 1954, as amended.

(6) [Deleted 38 FR 18443.]

(7) [Deleted 38 FR 18443.]

28 FR 145

(8) A license authorizing the use of source material as shielding only in devices and containers, provided, however, that all other licensed byproduct material, source material, or special nuclear material in the device or container will be subject to the fees prescribed in § 170.31.

43 FR 7210

(9) A license for possession and use of byproduct material, source material, or special nuclear material applied for by, or issued to, an agency of a State or any political subdivision thereof, except for licenses which authorize distribution of byproduct material, source material, or special nuclear material, or products containing byproduct material, source material, or special nuclear material, or licenses authorizing services to any person other than an agency or political subdivision of the State.

45 FR 50705

(10) Activities of the Commission undertaken, pursuant to Part 75 of this chapter, solely for the purpose of implementation of the US/IAEA Safeguards Agreement.

36 FR 18173 — 43 FR 7210

(b) (1) The Commission may, upon application by an interested person, or upon its own initiative, grant such exemptions from the requirements of this part as it determines are authorized by law and are otherwise in the public interest. (2) Applications for exemption under this paragraph may include activities such as, but not limited to, the use of licensed materials for educational or noncommercial public displays or scientific collections. (3) [Deleted 43 FR 7210.]

43 FR 7210

§ 170.12 Payment of fees.

(a) *Application Fees.* Each application for which a fee is prescribed shall be accompanied by a remittance in the full amount of the fee. No application will be accepted for filing or processed prior to payment of the full amount specified. Applications for which no remittance is received may be returned to the applicant. All application fees will be charged irrespective of the Commission's disposition of the application or a withdrawal of the application.

(b) *License Fees.* Fees for construction permits, operating licenses, manufacturing licenses, and materials licenses, are payable upon notification by the Commission when the review of the project is completed.

(c) *Amendment Fees.* The appropriate amendment fee shall accompany the application for amendment when filed with the Commission. Where applicable, the applicant shall provide a proposed determination of the amendment class and state the basis therefor as part of the amendment request and shall remit the fee corresponding to this determination with the application for amendment. The Commission will examine the amendment fee and will, where applicable, refund any overcharges or bill the applicant for the additional amendment fee.

(d) *Renewal Fees.* The appropriate renewal fee shall accompany the renewal application when filed with the Commission.

(e) *Approval Fees.* Fees for spent fuel cask and shipping container approvals, standardized spent fuel facility design approvals, and construction approvals are payable upon notification by the Commission when the review of the project is completed. Fees for facility reference standardized design approvals will be paid in five (5) installments based on payment of 20 percent of the approval fee (see footnote 3 § 170.21) as each of the first five (5) units of the approved design are referenced in an application(s) filed by a utility or utilities.

(f) *Special Project Fees.* Fees for special projects are payable upon notification by the Commission when the review of the project is completed.

(g) *Inspection Fees.* Inspection fees are payable upon notification by the Commission.

(h) *Method of Payment.* Fee payments shall be by check, draft, or money order made payable to the U.S. Nuclear Regulatory Commission.

43 FR 7210

§ 170.21 Schedule of fees for production and utilization facilities, review of reference standardized designs, and special projects.

(a) Applicants for construction permits, manufacturing licenses, operating licenses, and approvals of reference standardized facilities designs, shall pay the fees set forth in the table below.

(b) Applicants for special project reviews shall pay fees as separately determined by the Commission.

SCHEDULE OF FACILITY FEES

Facility categories	Types of fees	Fee [1]
A. Power reactors		
1. Custom [1]	Application—Construction permit	$125,000
	Construction permit—First unit	944,000
	Construction permit—Concurrent unit [2]	174,000
	Operating license—First unit	1,024,500
	Operating license—Concurrent unit [2]	302,800
2. Standardized design—duplicate unit [3]	Application—Construction permit	125,000
	Construction permit—First unit	944,000
	Construction permit—Concurrent unit [2]	174,000
	Construction permit—First identical unit additional site(s)	757,100
	Operating license—First unit	1,024,500
	Operating license—Concurrent unit [2]	300,200
	Operating license—First identical unit additional site(s)	712,000
3. Standardized design—replicate unit [3]	Application—Construction permit	125,000
	Construction permit—First unit	811,600
	Construction permit—Concurrent unit [2]	164,200
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	914,400
	Operating license—Concurrent unit [2]	293,900
	Operating license—First identical unit additional site(s)	691,500
4. Standardized design—Reference systems concept [3]		
a. Utility referencing a standarized nuclear steam supply system and custom balance of plant for both CP and OL stages	Application—Construction permit	125,000
	Construction permit—First unit	853,600
	Construction permit—Concurrent unit [2]	162,500
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	934,100
	Operating license—Concurrent unit [2]	292,100
	Operating license—First identical unit additional site(s)	669,200
b. Utility referencing a standardized nuclear steam supply system and standardized balance of plant for both the CP and OL stages	Application—Construction permit	125,000
	Construction permit—First unit	721,800
	Construction permit—Concurrent unit [2]	162,500
	Construction permit—First identical unit additional site(s)	725,900
	Operating license—First unit	829,100
	Operating license—Concurrent unit [2]	292,100
	Operating license—First identical unit additional site(s)	669,200
5. Manufacturing license concept [3].		
a. Vendor—review of preliminary design.	Application	125,000
	Manufacturing license	1,477,500
b. Vendor—review of final design.	Final design amendment	448,100
c. Utility referencing a manufacturing license.	Application—Construction permit	125,000
	Construction permit—First unit	730,000
	Construction permit—Concurrent unit [2]	61,500
	Operating license—First unit	1,001,200
	Operating license—Concurrent unit [2]	221,000
6. Advanced reactors [1]	Application—Construction permit	125,000
	Construction permit	1,781,000
	Operating license	1,954,900
B. Standard reference design review [3]		
1. Vendor—Standardized nuclear steam supply system.		

(Continued)

(Continued)

SCHEDULE OF FACILITY FEES

Facility categories	Types of fees	Fee [1]
a. Review of preliminary reference design.	Application	50,000
	Approval	412,100
b. Review of final reference design.	Application	50,000
	Approval	483,400
2. Architect-engineer—Standardized balance of plant:		
a. Review of preliminary reference design.	Application	50,000
	Approval	412,100
b. Review of final reference design.	Application	50,000
	Approval	501,200
C. Test facility: [3]	Application—Construction permit	5,000
	Construction permit	67,200
	Operating license	100,300
D. Research reactor: [3]	Application—Construction permit	5,000
	Construction permit	34,900
	Operating license	55,000
E. Uranium enrichment plants: [3]	Application—Construction permit	125,000
	Construction permit	388,400
	Operating license	457,200
F. Special projects and reviews [4]		

[1] Where a partial fee for a power reactor operating license has been paid prior to the effective date of this amendment, the amount paid shall be deducted from the fee prescribed by this amendment and the difference will be due when the operating license for 100 pct power is issued.

[2] *Concurrent unit.* A concurrent unit is defined as a power reactor of the same design at a single power station that was subject to concurrent licensing review.

[3] When review of the permit, license, approval, or amendment is complete, the expenditures for professional manpower and appropriate support services will be determined and the resultant fee assessed, but in no event will the fee exceed that shown in the schedule of facility fees. When one application for a preliminary design approval or final design approval contains more than one design, the additional approvals are subject to a maximum fee which is the sum of the application fee and approval fee.

[4] Charge will be separately determined by the Commission taking into account the professional manpower required to conduct the review multiplied by the applicable cost per man-year, plus any appropriate support services costs incurred. Where a fee has been paid for a facility early site review, the charge will be deducted from the fee for a construction permit issued for that site. A separate charge will not be assessed for a site review where the person requesting the review has an application for a construction permit on file for the same site, except where the application is withdrawn by the applicant or denied by the Commission. The maximum fee for review of a topical report shall not exceed $20,000.

43 FR 7210

§ 170.22 Schedule of fees for facility license amendments.

SCHEDULE OF AMENDMENT FEES FOR REACTOR FACILITY PERMITS, LICENSES, AND OTHER APPROVALS REQUIRED BY THE LICENSE OR COMMISSION REGULATIONS

Class of Amendment [1]	Fee [2]	
	Power reactors	Test and research reactors
CLASS I: Amendments that are a duplicate of an amendment for a second essentially identical unit at the same site, where both proposed amendments are received, processed, and issued at the same time	$400	
CLASS II: Amendments that are pro forma, administrative in nature, or have no safety or environmental significance	1,200	$600
CLASS III: Amendments, exemptions, or required approvals that involve a single environmental, safety, or other issue, have acceptability for the issue clearly identified by an NRC position, or are deemed not to involve a significant hazards consideration	4,000	2,000
CLASS IV: Amendments, exemptions, or required approvals that involve a complex issue or more than one environmental, safety, or other issue, or several changes of the class III type incorporated into the proposed amendment, or involve a significant hazards consideration, or require an extensive environmental impact appraisal, or result from dismantling or license termination orders	12,300	6,000
CLASS V: Amendments, exemptions, or required approvals that require evaluation of several complex issues, or involve review by the ACRS, or require an environmental impact statement	25,800	12,000
CLASS VI: Amendments, exemptions, or required approvals that require evaluation of a new Safety Analysis Report and rewrite of the facility license (including technical specifications), such as may be required for a license renewal	45,900	20,000

[1] At the time the application is filed, the licensee or applicant shall provide a proposed determination of amendment class and state the basis therefor as part of the amendment or modification request and shall remit the fee corresponding to this determination. The Commission will evaluate the proposed amendment class determination and inform the licensee or applicant if reclassification is required. Reclassification that changes the class of amendment will result in the refund of over-charges to the licensee or applicant or billing the licensee or applicant for additional fees.

[2] License amendments or approvals resulting from Commission Orders issued pursuant to 10 CFR 2.204, and amendments resulting in an initial increase in power to 100 percent of the initial design power level are not subject to these fees, except as provided in footnote 1 to § 170.21. Class I, II, or III amendments which result from a written Commission request for the application may be exempt from fees when the amendment is to simplify or clarify license or technical specifications; the amendment has only minor safety significance, and is issued for the convenience of the Commission.

§ 170.23 Schedule of fees for routine health, safety and environmental inspections of facilities.

SCHEDULE OF FACILITY ROUTINE HEALTH, SAFETY AND ENVIRONMENTAL INSPECTION FEES [1]

Category	Fee [1]	Maximum frequency [2]
(1) Power reactor:		
First unit	$75,700 per year	Continuous.
Additional units at same site [3]	$60,400 per year	Do.
(2) Test reactor	$4,500 per inspection	2 per year.
(3) Research reactor	$4,200 per inspection	1 every 2 years.
(4) Other production or utilization facility [4]	$42,100 per year	Continuous.
(5) Production or utilization facility licensed for possession but not operation.	$650 per year	1 per year.

[1] Routine inspections are safety, environmental, and health physics inspections performed at specified frequencies for purposes of reviewing a licensed program to assure that the authorized activities are being conducted in accordance with the Atomic Energy Act of 1954, as amended, Commission regulations, and the terms and conditions of the license.

[2] The frequency shown in the schedule is the maximum number of routine inspections for which a fee will be assessed.

[3] A reduced fee will be charged when the inspection of an additional unit at the same site is conducted concurrently with the first unit.

[4] Fee is applicable for a fuel reprocessing facility and for a uranium enrichment facility.

§ 170.24 Schedule of fees for routine safeguards inspections of facilities

SCHEDULE OF FACILITY ROUTINE SAFEGUARDS INSPECTION FEES

Category	Fee	Maximum frequency [1]
(1) Power reactor:		
First unit	$11,800 per year	2 per year.
Additional unit at same site [2]	$9,500 per year	Do.
(2) Test reactor (fuel of high strategic importance)	$6,500 per inspection	1 per year.
(3) Research reactor (fuel of moderate strategic importance).	$1,300 per inspection	1 every 2 years.
(4) Other production or utilization facility [3]	$38,700 per year	3 per year.

[1] The frequency shown in the schedule is the maximum number of safeguards inspections for which a fee will be assessed. Power reactors and other production and utilization facilities will be assessed the yearly inspection fee shown in the above table.

[2] A reduced fee will be charged when the inspection of additional unit(s) at the same site is conducted concurrently with the first unit.

[3] Fee is applicable for a fuel reprocessing facility and for a uranium enrichment facility.

43 FR 7210

§ 170.31 Schedule of fees for materials licenses and other regulatory services.

Applicants for materials licenses and other regulatory services and holders of materials licenses shall pay the following fees.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES

Category of materials licenses	Type of fee [1]	Fee
1. Special nuclear material: [2]		
A. Licenses for possession and use of 5 kg or more of contained uranium 235 in uranium enriched to 20 pct or more, or 2 kg or more of uranium 233, for fuel processing and fabrication. [3]	Application	$14,000
	New license	122,600
	Renewal	76,800
	Amendment: [4]	
	Major—Safety and environmental	34,600
	Major—Safeguards	8,300
	Minor—Safety and environmental	1,400
	Minor—Safeguards	3,500
	Administrative	150
B. Licenses for possession and use of 5 kg or more of contained uranium 235 in uranium enriched to less than 20 pct, for fuel processing and fabrication. [3]	Application	12,000
	New license	112,800
	Renewal	71,900
	Amendment: [4]	
	Major—Safety and environmental	34,600
	Major—Safeguards	6,900
	Minor—Safety and environmental	1,400
	Minor—Safeguards	3,500
	Administrative	150
C. Licenses for possession and use of 2 kg or more of plutonium for fuel processing and fabrication. [3]	Application for construction approval	50,000
	Construction approval	480,300
	License fee	241,600
	Renewal	170,800
	Amendment: [4]	
	Major—Safety and environmental	75,000
	Major—Safeguards	13,800
	Minor—Safety and environmental	1,400
	Minor—Safeguards	6,200
	Administrative	150

See footnotes at end of table.

43 FR 7210

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
D. Licenses for possession and use of 5 kg or more of contained uranium 235 in unsealed form, or 2 kg or more of uranium 233 in unsealed form for activities other than fuel processing and fabrication.	Application	3,000
	New license	31,600
	Renewal	18,000
	Amendment:	
	Safety and environmental	1,400
	Safeguards	2,800
	Administrative	150
E. Licenses for possession and use of quantities of plutonium of 2 kg or more in unsealed form for activities other than fuel processing and fabrication.	Application	6,000
	New license	56,300
	Renewal	38,100
	Amendment:	
	Safety and environmental	1,400
	Safeguards	6,900
	Administrative	150
F. Licenses for possession and use of 200 g but less than 2 kg of plutonium in unsealed form.	Application	5,000
	New license	42,100
	Renewal	29,800
	Amendment:	
	Safety and environmental	1,400
	Safeguards	4,800
	Administrative	150
G. Licenses for possession and use of 350 g but less than 5 kg of contained uranium 235 in unsealed form, or 200 g but less than 2 kg of uranium 233 in unsealed form.	Application	2,000
	New license	18,800
	Renewal	11,100
	Amendment:	
	Safety and environmental	1,400
	Safeguards	2,800
	Administrative	150
H. Licenses for receipt and storage of spent fuel: (1) License application for a storage facility of custom design requiring a full design review:		
(a) Storage facility to be located at a new site.	Application	$35,000
	New license	290,000
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	25,000
	New license	209,300
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(2) License application for a storage facility which references an approved standardized design:		
(a) Storage facility to be located at a new site.	Application	25,000
	New license	236,600
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	15,000
	New license	130,000
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(3) License application for a storage facility of duplicate design—design which is identical to a previously licensed detail design:		
(a) Storage facility to be located at a new site.	Application	15,000
	New license	159,200
	Renewal	32,000
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
(b) Storage facility to be located at the site of an existing nuclear facility.	Application	10,000
	New License	73,500
	Renewal	32,000

See footnotes at end of table.

43 FR 7210

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
	Amendment:	
	Major—Safety and environmental	88,500
	Major—Safeguards	6,200
	Minor—Safety and environmental	3,500
	Minor—Safeguards	3,500
	Administrative	150
I. Licenses for possession and use of special nuclear material in sealed sources contained in devices used in industrial measuring systems.	Application—New license	110
	Renewal	110
	Amendment	40
J. All other special nuclear material licenses, except licenses authorizing special nuclear material in unsealed form in combination that would constitute a critical quantity as defined in § 150.11 of Part 150 which shall pay the same rate as Category 1G and special nuclear material for use in power generation which shall pay the fee in Category 10.	Application—New license	460
	Renewal	460
	Amendment	110
2. Source material:		
A. Licenses for possession and use of source material in milling operations, except in in situ leaching and heap-leaching operations.	Application	11,000
	New license	96,700
	Renewal	100,800
	Amendment:	
	Major—Safety and environmental	20,800
	Minor—Safety and environmental	3,500
	Administrative	150
B. Licenses for processing and recovery of source material in in situ leaching operations or heap-leaching operations.	Production scale activity:	
	Application	7,000
	New license	59,500
	Research and development scale activity:	
	Application	2,000
	New license	21,800
	Renewal	17,300
	Amendment:	
	Major—Safety and environmental	4,200
	Minor—Safety and environmental	760
	Administrative	150
C. Licenses for refining uranium mill concentrates to uranium hexafluoride.	Application	11,000
	New license	96,700
	Renewal	45,800
	Amendment:	
	Major—Safety and environmental	20,800
	Minor—Safety and environmental	3,500
	Administrative	150
D. All other source material licenses	Application—New license	140
	Renewal	70
	Amendment	40
3. Byproduct material:		
A. Licenses for possession and use of byproduct material issued pursuant to Parts 30 and 33 of this chapter for processing or manufacturing of items containing byproduct material for commercial distribution, except byproduct material for use in power generation which shall pay the fee in category 10.	Application—New license	460
	Renewal	460
	Amendment	110
B. Licenses issued pursuant to § 32.72 of this chapter authorizing the processing or manufacture and distribution of radiopharmaceuticals containing byproduct material.	Application—New license	190
	Renewal	150
	Amendment	40
C. Licenses for byproduct material issued pursuant to Part 34 of this chapter for industrial radiography operations performed in shielded radiography installation(s) or permanently designated area(s) at the address(es) listed in the license.	Application—New license	190
	Renewal	150
	Amendment	40
D. Licenses for byproduct material issued pursuant to Part 34 of this chapter for industrial radiography operations performed in a shielded radiography installation(s) and at multiple temporary locations at the address(es) shown in the licenses or at temporary jobsites of the licensee in the field.	Application—New license	460
	Renewal	460
	Amendment	110
E. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is not removed from its shield (self-shielded units).	Application—New license	190
	Renewal	150
	Amendment	40
F. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is exposed for irradiation purposes.	Application—New license	460
	Renewal	460
	Amendment	110

See footnotes at end of table.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee	Fee
G. Licenses issued pursuant to Subpart B of Part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons generally licensed under Parts 31 or 35 of this chapter, except specific licenses authorizing redistribution of items which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons generally licensed under Parts 31 or 35 of this chapter.	Application—New license	950
	Renewal	570
	Amendment	230
H. Licenses issued pursuant to Subpart A of Part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons exempt from the licensing requirements of Part 30 of this chapter, except: (1) §§ 32.11 and 32.18 of this chapter, (2) specific licenses authorizing redistribution of items and quantities which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons exempt from the licensing requirements of Part 30 of this chapter, and (3) specific licenses which authorize distribution of timepieces, hands, and dials.	Application—New license	950
	Renewal	570
	Amendment	230
I. Licenses issued pursuant to § 32.18 of this chapter to distribute quantities of byproduct material to persons exempt from the licensing requirements of Part 30 of this chapter.	Application—New license	190
	Renewal	150
	Amendment	40
J. Licenses issued pursuant to § 32.14 of this chapter to distribute timepieces, hands, and dials containing hydrogen 3 or promethium 147 to persons exempt from the licensing requirements of Part 30 of this chapter.	Application—New license	190
	Renewal	150
	Amendment	40
K. Licenses for possession and use of byproduct material for research and development, except those licenses covered by categories 3A or 3B, and licenses covered by categories 7B or 7C authorizing medical research.	Application—New license	190
	Renewal	150
	Amendment	40
L. All other specific byproduct material licenses, except those in categories 4A through 10A.	Application—New license	110
	Renewal	110
	Amendment	40
4. Waste disposal:		
A. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material, from other persons for the purpose of commercial disposal by land or sea burial by the licensee.	Application	32,000
	New license	291,100
	Renewal	98,500
	Amendment:	
	Major-Safety and environmental	197,700
	Minor—Safety and environmental	690
	Administrative	150
B. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material from other persons for the purpose of packaging the material. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	Application—New license	1,100
	Renewal	570
	Amendment:	
	Safety and environmental	570
	Administrative	150
C. Licenses specifically authorizing the receipt of prepackaged waste byproduct material, source material, or special nuclear material from other persons. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	Application—New license	190
	Renewal	150
	Amendment	40
5. Well logging and well surveys and tracer studies: A. Licenses for possession and use of special nuclear material and/or byproduct material for well logging, well surveys, and tracer studies.	Application—New license	480
	Renewal	480
	Amendment	110
6. Nuclear laundries: A. Licenses for commercial collection and laundry of items contaminated with byproduct material, source material, or special nuclear material.	Application—New license	480
	Renewal	480
	Amendment	110

See footnotes at end of table.

43 FR 7210

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee [1]	Fee
7. Human use of byproduct material, source material, or special nuclear material:		
A. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter for human use of byproduct material, source material, or special nuclear material in sealed sources contained in teletherapy devices.	Application—New license	300
	Renewal	270
	Amendment	40
B. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter to medical institutions, or two or more physicians on a single license, for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	Application—New license	190
	Renewal	150
	Amendment	40
C. Licenses issued pursuant to Parts 30, 40, and 70 of this chapter to an individual physician for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	Application—New license	190
	Renewal	150
	Amendment	40
8. Civil defense: A. Licenses for possession and use of byproduct material, source material, or special nuclear material for civil defense activities.	Application—New license	190
	Renewal	150
	Amendment	40
9. Device, product, or sealed source safety evaluation:		
A. Safety evaluation of devices or products containing byproduct material, source material, or special nuclear material, except reactor fuel devices and devices or products distributed to general licensees or persons exempt from the requirements for a license pursuant to Parts 30, 40, and 70 of this chapter.	Application—Evaluation	570
B. Safety evaluation of sealed sources containing byproduct material, source material, or special nuclear material, except: (1) Reactor fuel, (2) sealed sources distributed to general licensees or persons exempt from the requirements for a license pursuant to Parts 30, 40, and 70 of this chapter, and (3) power sources covered by category 10.	do	110
10. Power source: A. Licenses for the manufacture and distribution of encapsulated byproduct material or special nuclear material wherein the decay energy of said material is used as a source of power, except reactor fuel.	Application—New license	1,900
	Renewal	460
	Amendment	460
11. Transportation of radioactive material:		
A. Evaluation of spent fuel cask for greater than 20 kW decay heat.	Application	8,000
	Approval [3]	75,100
	Amendments: [3]	
	Major [3]	6,900
	Minor [3]	3,500
	Administrative	150
	Renewal	150
B. Evaluation of spent fuel cask for less than 20 kW decay heat; air shipping package for plutonium; high-level waste casks; and packages containing radioactive material greater than 2,000 times the type A quantity. [2]	Application	7,000
	Approval [3]	62,200
	Amendments: [3]	
	Major [3]	5,500
	Minor [3]	2,800
	Administrative	150
	Renewal	150
C. Evaluation of fissile packages containing greater than type A quantities of radioactive material; packages containing radioactive material less than 2,000 times the type A quantity [2]	Application	1,000
	Approval [3]	12,800
	Amendments: [3]	
	Major [3]	3,500
	Minor	690
	Administrative	150
	Renewal	150
D. Evaluation of fissile packages containing less than type A quantities of radioactive material; packages containing radioactive material less than 200 times the type A quantity. [2]	Application	700
	Approval [3]	6,200
	Amendments: [3]	
	Major [3]	1,400
	Minor	350
	Administrative	150
	Renewal	150
E. Evaluation of packages containing radioactive material less than 20 times the type A quantity. [2]	Application	200
	Approval [3]	1,200
	Amendments: [3]	
	Major	350
	Minor	150
	Renewal	150

43 FR 7210

See footnotes at end of table.

SCHEDULE OF FEES FOR MATERIALS LICENSES AND OTHER REGULATORY SERVICES—Continued

Category of materials licenses	Type of fee[1]	Fee
12. Review of standardized spent fuel facility design.[5]	Application	12,000
	Approval[4]	107,200
13. Special projects[8]		

[1] *Types of fees.* Separate charges as shown in the schedule will be assessed for applications for new licenses and approvals, issuance of new licenses and approvals, and amendments and renewals to existing licenses and approvals. The following guidelines apply to these charges:

(a) *Application fees.* Applications for materials licenses and approvals shall be accompanied by the prescribed application fee for each category, except that applications for licenses covering more than one fee category of special nuclear material (excluding category 1H) to be used at the same location, shall be accompanied by the prescribed application fee for the highest fee category. Where a license or approval has expired, the full application fee for each category shall be due, except for licenses covering more than one fee category of special nuclear material (excluding category 1H) for use at the same location, in which case the application fee for the highest category would apply.

(b) *License/approval fees.* New licenses and approvals issued in fee categories 1A through 1H, 2A, 2B, 2C, 4A, 11A through 11E, and category 12, shall pay the license or approval fee for each category, as determined by the Commission when the review of the application or project is completed (see footnote 4), except that a license covering more than one fee category of special nuclear material in categories 1A through 1G shall pay a license fee for the highest fee category assigned to the license.

(c) *Renewal fees.* Applications for renewal of materials licenses and approvals shall be accompanied by the prescribed fee for each category, except that applications for renewal covering more than one fee category of special nuclear material (excluding category 1H) to be used at the same location, shall be accompanied by the prescribed renewal fee for the highest fee category. When the review of an application for renewal is complete for licenses in fee categories 1A through 1H, 2A, 2B, 2C, and 4A, the Commission will examine the renewal fee in accordance with footnote 4, and will refund any overcharges of the renewal fee, if applicable.

(d) *Amendment fees.* Applications for amendments shall be accompanied by the prescribed amendment fee(s). At the time an application for amendment is filed for licenses and approvals in fee categories 1A through 1H, 2A, 2B, 2C, 4A, 11A, 11B, 11C, 11D, and 11E, the licensee or applicant shall provide an initial determination of the amendment class and state the basis therefor as part of the amendment or approval request, and shall remit the fee corresponding to that determination; however, when review of the amendment or approval is complete, the Commission will examine the amendment fee in accordance with footnote 4, if applicable, and will refund any overcharges to the licensee or applicant, or bill the licensee or applicant for the additional amendment fee. Amendments which result from written NRC requests may be exempted from these fees at the discretion of the Commission when the amendment is issued for the convenience of the NRC.

An application for amendment to a license or approval classified in more than one fee category shall be accompanied by the prescribed amendment fee for the category affected by the amendment, unless the amendment is applicable to two or more fee categories, in which case the amendment fee for the highest fee category would apply. An application for amendment to a materials license or approval that would place the license or approval in a higher fee category or add a new category shall be accompanied by the prescribed application fee for the new category, except for applications for amendments increasing the scope of a licensed program from fee categories 1F to 1E, 1G to 1D, 3C to 3D, and 7C to 7B, in which cases the amendment fee for the higher fee category would apply. An application for amendment reducing the scope of a licensee's program shall pay the amendment fee of the fee category assigned to the license at the time the application is filed. Applications to terminate licenses shall not be subject to fees.

43 FR 7210

[2] Licensees paying fees under categories 1A through 1H are not subject to fees under categories 1I and 1J for sealed sources authorized in the same license. Applicants for new licenses or renewal of existing licenses that cover both byproduct material and special nuclear material in sealed sources for use in gauging devices will pay the appropriate application or renewal fee for fee category 1I only.

[3] A major amendment is defined as one requiring evaluation of many aspects of licensed activities where the proposed action could present a potential risk to the public's health and safety. A minor amendment is defined as one where safety, environmental, or safeguards considerations may be easily resolved. An administrative amendment is defined as an amendment that is proforma, routine in nature, or has no safety, environmental, or safeguards significance.

[4] When the review of an application is complete, the expenditures for professional manpower and appropriate support services will be determined and the resultant fee assessed, but in no event will the fee exceed that shown in the schedule of fees for materials licenses and other regulatory services. All administrative amendments are based on fixed charges.

[5] Fees would be applicable only in those instances where a site safety and environmental review has been performed and documented by the Commission for the site at which the storage facility is to be located.

[6] Fee is applicable to a license authorizing either production scale activity or research and development scale activity.

[7] A type A quantity is defined in § 71.4(q) of 10 CFR Part 71.

[8] Charge will be separately determined by the Commission taking into account the professional manpower required to conduct the review multiplied by the applicable cost per man-year, plus any appropriate support services costs incurred.

§ 170.32 Schedule of fees for health and safety, and safeguards inspections for materials licenses.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
1. Special nuclear material:			
A. Licenses for possession and use of five (5) kg or more of contained uranium 235 in uranium enriched to 20 pct or more, or two (2) kg or more of uranium 233, for fuel processing and fabrication.	Health and safety	$5,300	3 per year.
	Safeguards	10,300	Do.
B. licenses for possession and use of five (5) kg or more of contained uranium 235 in uranium enriched to	Health and safety	5,300	Do.
	Safeguards	10,300	1 per year.

See footnote at end of table.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[1]	Maximum frequency[1]
less than 20 pct. for fuel processing and fabrication.			
C. Licenses for possession and use of two (2) kg or more of plutonium for fuel processing and fabrication.	Health and safety	4,800	4 per year
	Safeguards	11,700	3 per year.
D. Licenses for possession and use of five (5) kg or more of contained uranium 235 in unsealed form, or two (2) kg or more of uranium 233 in unsealed form for activities other than fuel processing and fabrication.	Health and safety	4,900	1 per year.
	Safeguards	7,600	2 per year.
E. Licenses for possession and use of quantities of plutonium of two (2) kg or more in unsealed form for activities other than fuel processing and fabrication.	Health and safety	780	1 per year.
	Safeguards	5,400	2 per year.
F. Licenses for possession and use of 200 g but less than two (2) kg of plutonium in unsealed form.	Health and safety	780	1 per year.
	Safeguards	2,300	Do.
G. Licenses for possession and use of 350 g but less than five (5) kg of contained uranium 235 in unsealed form, or 200 g but less than two (2) kg of uranium 233 in unsealed form.	Health and safety	780	1 every 2 years.
	Safeguards	4,000	1 per year.
H. Licenses for receipt and storage of spent fuel:			
(1) License application for a storage facility of custom design requiring a full design review:			
(a) Storage facility to be located at a new site.	Health and safety	780	Do.
	Safeguards	2,900	2 per year.
(b) Storage facility to be located at the site of an existing nuclear facility.	Health and safety	780	1 per year.
	Safeguards	2,900	2 per year.
(2) License application for a storage facility which references an approved standardized design:			
(a) Storage facility to be located at a new site.	Health and safety	780	1 per year.
	Safeguards	2,900	2 per year.
(b) Storage facility to be located at the site of an existing nucle(facility.	Health and safety	780	1 per year.
	Safeguards	2,900	2 per year.
(3) License application for a stora, facility of duplicate design—design which is identical to a previously licensed detail design:			
(a) Storage facility to be located at a new site.	Health and safety	780	1 per year.
	Safeguards	2,900	2 per year.
(b) Storage facility to be located at the site of an existing nuclear facility.	Health and safety	780	1 per year.
	Safeguards	2,900	2 per year.
I. Licenses for possession and use of special nuclear material in sealed sources contained in devices used in industrial measuring systems.	Health and safety	330	1 every 5 years.
J. All other special nuclear material licenses, except licenses authorizing special nuclear material in unsealed form in combination that would constitute a critical quantity as defined in § 150.11 of part 150 which shall pay the same rate as category 1G and special nuclear material for use in power generation which shall pay the fee in category 10.	do	780	1 per year.
2. Source material:			
A. Licenses for possession and use of source material in milling operations, except in in-situ leaching and heap-leaching operations.	do	1,800	Do.
B. Licenses for processing and recovery of source material in in-situ leaching operations or heap-leaching operations.	do	1,800	Do.
C. Licenses for refining uranium mill concentrates to uranium hexafluoride.	do	1,800	Do.
D. All other source material licenses	do	480	1 every 2 years.
3. Byproduct material:			
A. Licenses for possession and use of byproduct material issued pursuant to parts 30 and 33 of this chapter for processing or manufacturing of items containing byproduct material for commercial distribution, except byproduct material for use in power generation which shall pay the fee in Category 10[6].	Health & Safety[4]:		
	Large program	1,600	1 per year.
	Small program	780	Do.
B. Licenses issued pursuant to § 32.72 of this chapter authorizing the processing or manufacture and distri-	Health & Safety	650	1 every 3 years.

See footnote at end of table.

43 FR 7210

43 FR 7210

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES--Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
bution of radio-pharmaceuticals containing byproduct material			
C. Licenses for byproduct material issued pursuant to part 34 of this chapter for industrial radiography operations performed in a shielded radiography installation(s) or permanently designated area(s) at the address(es) listed in the license[4].	do	730	1 per year.
D. Licenses for byproduct material issued pursuant to part 34 of this chapter for industrial radiography operations performed in a shielded radiograph installation(s) and at multiple temporary locations at the address(es) shown in the license or at temporary jobsites of the licensee in the field[4].	do	980	Do.
E. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is not removed from its shield (Self-shielded units).	do	390	1 every 5 years.
F. Licenses for possession and use of byproduct material in sealed sources for irradiation of materials where the source is exposed for irradiation purposes.	Health and safety	390	1 every 3 years.
G. Licenses issued pursuant to Subpart B of part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons generally licensed under parts 31 or 35 of this chapter, except specific licenses authorizing redistribution of items which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons generally licensed under parts 31 or 35 of this chapter.	do	390	Do.
H. Licenses issued pursuant to Subpart A of part 32 of this chapter to distribute items containing byproduct material or quantities of byproduct material to persons exempt from the licensing requirements of part 30 of this chapter, except (1) §§ 32.11 and 32.18 of this chapter, (2) specific licenses authorizing redistribution of items and quantities which have been manufactured or imported under a specific license and licensed by the Commission for distribution to persons exempt from the licensing requirements of part 30 of this chapter, and (3) specific licenses which authorize distribution of timepieces, hands and dials.	do	390	Do.
I. Licenses issued pursuant to § 32.18 of this chapter to distribute quantities of byproduct material to persons exempt from the licensing requirements of part 30 of this chapter.	do	390	Do.
J. Licenses issued pursuant to § 32.14 of this chapter to distribute timepieces, hands, and dials, containing hydrogen 3 or promethium 147 to persons exempt from the licensing requirements of part 30 of this chapter.	do	390	Do.
K. Licenses for possession and use of byproduct material for research and development, except those licenses covered by categories 3A or 3B, and licenses covered by categories 7B or 7C authorizing medical research.	do	390	Do.
L. All other specific byproduct material licenses, except those in categories 4A through 10A.	do	390	1 every 5 years.
4. Waste disposal:			
A. Licenses specifically authorizing the receipt of waste byproduct material, source material, or special nuclear material, from other persons for the purpose of commercial disposal by land or sea burial by the licensee.	do	980	1 per year.
B. Licenses specifically authorizing the receipt of waste byproduct ma-	Health & Safety	650	1 every 3 years.

See footnotes at end of table.

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
terial, source material, or special nuclear material, from other persons for the purpose of packaging the material. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.			
C. Licenses specifically authorizing the receipt of prepackaged waste byproduct material, source material, or special nuclear material, from other persons. The licensee will dispose of the material by transfer to another person authorized to receive or dispose of the material.	do	650	Do.
5. Well logging and well surveys and tracer studies:			
A. Licenses for possession and use of special nuclear material and/or byproduct material for well logging, well surveys, and tracer studies.	do	520	Do.
6. Nuclear laundries:			
A. Licenses for commercial collection and laundry of items contaminated with byproduct material, source material, or special nuclear material.	do	590	Do.
7. Human use of byproduct material, source material, or special nuclear material:			
A. Licenses issued pursuant to parts 30, 40, and 70 of this chapter for human use of byproduct material, source material, or special nuclear material in sealed sources contained in teletherapy devices.	do	460	1 every 2 years.
B. Licenses issued pursuant to parts 30, 40, and 70 of this chapter to medical institutions, or two or more physicians on a single license, for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	do	460	1 every 3 years.
C. Licenses issued pursuant to parts 30, 40, and 70 of this chapter to an individual physician for human use of byproduct material, source material, or special nuclear material, except licenses in category 7A.	do	330	Do.
8. Civil defense:			
A. Licenses for possession and use of byproduct material, source material, or special nuclear material for civil defense activities.	do	700	1 every 10 years.
9. Device, product, or sealed source safety evaluation:			
A. Safety evaluation of devices or products containing byproduct material, source material, or special nuclear material, except reactor fuel devices and devices or products distributed to general licensees or persons exempt from the requirements for a license pursuant to parts 30, 40, and 70 of this chapter.	Not applicable		No inspections conducted.
B. Safety evaluation of sealed sources containing byproduct material, source material, or special nuclear material, except (1) reactor fuel, (2) sealed sources distributed to general licensees or persons exempt from the requirements for a license pursuant to parts 30, 40, and 70 of this chapter, and (3) power sources covered by category 10.	Not applicable		No inspections conducted.
10. Power source:			
A. Licenses for the manufacture and distribution of encapsulated byproduct material or special nuclear material wherein the decay energy of said material is used as a source of power, except reactor fuel.	Health and safety	780	1 per year.
11. Transportation of radioactive material:			
A. Evaluation of spent fuel cask for greater than 20 kW decay heat.	Not applicable		No inspections conducted.
B. Evaluation of spent fuel cask for less than 20 kW decay heat, air shipping package for plutonium; high-level waste casks; and packages containing radioactive material	do		Do.

See footnotes at end of table.

43 FR 7210

SCHEDULE OF MATERIALS LICENSE INSPECTION FEES—Continued

Category of materials licenses	Type of fee[1]	Fee[2]	Maximum frequency[3]
greater than 2,000 times the type A quantity.			
C. Evaluation of fissile packages containing greater than type A quantities of radioactive material; packages containing radioactive material less than 2,000 times the type A quantity.	do		Do.
D. Evaluation of fissile packages containing less than type A quantities of radioactive material; packages containing radioactive material less than 200 times the type A quantity.	do		Do.
E. Evaluation of packages containing radioactive material less than 20 times the type A quantity.	do		Do.
12. Review of standardized spent fuel facility design.	do		Do.

[1] *Types of Fees*—Separate charges as shown in this schedule will be assessed for each routine inspection which is performed.

[2] Inspection fees are due upon receipt of notice from the Commission. The inspection fee for licenses covering more than one fee category will be charged only for the highest fee category assigned the license, if the inspection of the entire license is done at the same time. Where a licensee holds more than one materials license at a single location, a fee equal to the highest fee category covered by the licenses will be assessed, if the inspections are conducted at the same time.

[3] The frequency shown in the schedule is the maximum number of each type of inspection for which a fee will be assessed.

[4] Where a license authorizes shielded radiographic installations or manufacturing installations at more than one address, a separate fee will be assessed for inspection of each location, provided, however, that if the multiple installations are inspected during a single visit a single inspection fee will be assessed.

[5] For inspection purposes, large and small programs in Category 3A are defined as follows: A. *Large Programs*—Those licensees handling or processing loose or unsealed material for the manufacture of tagged compounds or products such as sealed sources and distribution of same to others. *Small Programs*—Those licensees who are processors of "finished products," such as previously tagged compounds and sealed sources for introduction into products or repackaging for sale to others.

43 FR 7210

§ 170.41 Failure by applicant or licensee to pay prescribed fees.

In any case where the Commission finds that an applicant or a licensee has failed to pay a prescribed fee required in this part, the Commission will not process any application and may suspend or revoke any license or approval involved or may issue an order with respect to licensed activities as the Commission determines to be appropriate or necessary in order to carry out the provisions of this part, Parts 30, 40, 50, 70, and 71 of this chapter, and of the Act.

SECTION 7

GLOSSARY – ADDENDA

GLOSSARY

A

Absorbed Dose:

When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit mass of irradiated material is called the absorbed dose, and is measured in rems and rads.

Absorber:

Any material that absorbs or diminishes the intensity of ionizing radiation. Materials, like boron, hafnium, and steel, absorb gamma rays and neutrons in reactor shields. A thin sheet of paper or metal will absorb or attenuate alpha particles, and all except the most energetic beta particles.

Absorbtion:

The process by which radiation imparts some or all of its energy to any material through which it passes.

Absorption:

The process by which the number of particles or photons entering a body of matter is reduced by interaction of the particles or radiation with the matter. Similarly, the reduction of the energy of a particle while traversing a body. This term is sometimes erroneously used for capture.

Absorption Coefficient:

Fractional decrease in the intensity of a beam of X-ray or gamma radiation per unit thickness (linear absorption coefficient), per unit mass (mass absorption coefficient) or per atom (atomic absorption coefficient) of absorber, due to deposition of energy in the absorber. The total absorption coefficient is the sum of individual energy absorption processes (Compton effect, photoelectric effect, and pair production).

Compton Absorption Coefficient:

That fractional decrease in the energy of a beam of X-ray or gamma radiation due to the deposition of the energy to electrons produced by Compton effect in an absorber.

Linear Absorption Coefficient:

A factor expressing the fraction of a beam of X-ray or gamma radiation absorbed in unit thickness of material. In the expression $I = I_0 e^{-\mu x}$, I_0 is the initial intensity, I the intensity of the beam after passage through a thickness of the material x, and μ is the linear absorption coefficient.

Mass Absorption Coefficient:
The linear absorption coefficient per cm divided by the density of the absorber in grams per cubic cm. It is frequencly expressed as μ/ρ where μ is the linear absorption coefficient and ρ is the absorber density.

Accelerator:
A device for increasing the velocity and energy of charged elementary particles, for example, electrons or protons, through application of electrical and/or magnetic forces. Accelerators have made particles move at velocities approaching the speed of light.

Actinide Series:
The series of elements beginning with actinium, Element No. 89, and continuing through lawrencium, Element No. 103, which together occupy one position in the Periodic Table. The series includes uranium, Element No. 92, and all the man-made transuranic elements. Also referred to as the "Actinides".

Actinium Series (Sequence):
The series of nuclides resulting from the radioactive decay of uranium-235. Many man-made nuclides decay into this sequence. The end product of this sequence in nature is lead-207.

Activation:
The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles. Also called radioactivation.

Activity:
The number of nuclear transformations occurring in a given quantity of material per unit time. (See Curie)

Aftercooling:
The cooling of a reactor after it has been shut down.

Afterheat:
The heat produced by the continuing decay of radioactive atoms in a reactor after fission has stopped. Most of the afterheat is due to the radioactive decay of fission products.

Air Sampling:
The collection and analysis of samples of air to measure its radioactivity or to detect the presence of radioactive substances.

Alpha Particle:

A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, being stopped by a sheet of paper. It is not dangerous to plants, animals, or man unless the alpha emitting substance has entered the body. (Symbol α)

Alpha Ray:

A stream of alpha particles. Loosely, a synonym for alpha particle.

Amplification:

As related to radiation detection instruments, the process (gas, electronic, or both) by which ionization effects are magnified to a degree suitable for their measurement.

Angstrom:

One angstrom unit equals 10^{-8} cm. (Symbol Å)

Annihilation (Electron):

An interaction between a positive and a negative electron in which they both disappear, their energy, including rest energy, being converted into electromagnetic radiation (called annihilation radiation).

Anode:

Positive electrode to which negative ions are attracted.

Antimatter:

Matter in which the ordinary nuclear particles (neutrons, protons, electrons, etc.) are conceived of as being replaced by their corresponding antiparticles (antineutrons, antiprotons, etc.) Normal matter and antimatter would mutually annihilate each other upon contact, being converted totally into energy.

Atom:

A particle of matter indivisible by chemical means. It is the fundamental building block of the chemical elements. The elements, such as iron, lead, and sulfur, differ from each other because they contain different kinds of atoms. There are about six sextillion (6 followed by 21 zeros, or 6×10^{21}) atoms in an ordinary drop of water. According to present-day theory, an atom contains a dense inner core (the nucleus) and a much less dense outer domain consisting of electrons in motion around the nucleus. Atoms are electrically neutral.

Atom Smasher:
An accelerator.

Atomic Battery:
A radioisotopic generator.

Atomic Clock:
A device that uses the extremely fast vibrations of molecules or atomic nuclei to measure time. These vibrations remain constant with time, consequently short intervals can be measured with much higher precision than by mechanical or electrical clocks.

Atomic Energy:
Nuclear energy.

Atomic Mass:
Represents the total number of protons and neutrons in the nucleus. The mass of a neutral atom of a nuclide, usually expressed in terms of "atomic mass units". (Symbol A)

Atomic Mass Unit:
One-twelfth the mass of one neutral atom of carbon-12. Equivalent to 1.6604×10^{-24} gm. (Symbol amu)

Atomic Number:
The number of protons in the nucleus of a netrual atom of a nuclide. The "effective atomic number" is calculated from the composition and atomic numbers of a compound or mixture. An element of this atomic number would interact with protons in the same way as the compound of mixture. (Symbol Z)

Atomic Reactor:
A nuclear reactor.

Atomic Weight:
The mass of an atom relative to other atoms. The atomic weight of any element is approximately equal to the total number of protons and neutrons in its nucleus. (See Atomic Mass)

Attenuation:
The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Attenuation Coefficient, Pair Production:
That fractional decrease in the intensity of a beam of ionizing radiation due to pair production in a medium through which it passes.

Attenuation Factor:
A measure of the opacity of a layer of material for radiation traversing it. The ratio of the incident intensity to the transmitted intensity. It is equal to I_0/I, where I_0 and I are the intensities of the incident and emergent radiation respectively. In the usual sense of exponential absorption ($I = I_0e^{-\mu x}$), the attenuation factor is $e^{-\mu x}$, where x is the thickness of the material and μ the absorption coefficient.

Autoradiograph:
A photographic record of radiation from radioactive material in an object, made by placing the object very close to a photographic film or emulsion. The process is called autoradiography. It is used, for instance, to locate radioactive atoms or tracers in metallic or biological samples.

Avalanche:
The multiplicative process in which a single charged particle accelerated by a strong electric field produces additional charged particles through collision with neutral gas molecules. This cumulative increase of ions is also known as "Townsend ionization" or "Townsend avalanche".

Average Life (Mean Life):
The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half-life.

Avogadro's Number (Avogadro Constant):
Number of atoms in a gram; atomic weight of any element; also the number of molecules in a gram molecular weight of any substance. It is numerically equal to 6.023×10^{23} on the unified mass scale. (Symbol N_A)

B

Background:
Background radiation.

Background Radiation:
The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of men and animals. It is also called natural radiation. The term may also mean radiation that is unrelated to a specific experiment.

Backscatter:
When radiation of any kind strikes matter (gas, liquid, or solid) some of it may be reflected or scattered back in the general direction of the source. An understanding or exact measurement of the amount of backscatter is important when beta particles are being counted in an ionization chamber of industrial thickness gauges.

Barricade Shield:
A type of movable shield for protection from radiation.

Barrier Shield:
A wall or enclosure shielding the operator from an area where radioactive material is being used or processed. Barriers of radiation-absorbing material, such as lead, concrete, and plaster, used to reduce radiation exposure.

Baryon:
One of a class of heavy elementary particles that includes hyperons, neutrons, and protons

Beam:
A unidirectional or approximately unidirectional flow of electromagnetic radiation or of particles.

Useful Beam (Radiology):
Radiation which passes through the aperture, cone, or other collimating device of the source housing. Sometimes called "primary beam".

Beam Hole:
An opening through a reactor shield and, generally, through the reactor reflector which permits a beam of radioactive particles or radiation to be used for experiments outside the reactor.

Beta Particle:
An elementary particle emitted from a nucleus during radioactive decay with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal. (Symbol β)

Bev:
Symbol for one billion (10^9) electron volts. Also written BeV.

Binding Energy:
The binding energy of a nucleus is the minimum energy required to dissociate it into its component neutrons and protons. Neutron or proton binding energies are those required to remove a neutron or proton respectively from a nucleus. Electron binding energy is that required to remove an electron from an atom or a molecule.

Biological Dose:
The radiation dose absorbed in biological material; measured in rems.

Biological Half-Life:
The time required for a biological system, such as a man or an animal, to eliminate, by natural processes, half the amount of a substance (such as a radioactive material) that has entered it.

Biological Shield:
A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level that is safe for human beings.

Body Burden:
The amount of radioactive material present in the body of a man or an animal.

Boiling Water Reactor:
A reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be used directly to drive a turbine.

Bone Seeker:
A radioisotope that tends to accumulate in the bones when it is introduced into the body. An example is strontium-90, which behaves chemically like calcium.

Breeder Reactor:
A reactor that produces fissionable fuel as well as consuming it, especially one that creates more than it consumes. The new fissionable material is created by capture in fertile materials of neutrons from fission. The process by which this occurs is known as breeding.

Bremsstrahlung:
Electromagnetic radiation emitted (as photons) when a fast-moving particle (usually an electron) loses energy upon being accelerated and deflected by the electric field surrounding a positively charged atomic nucleus. X-rays produced in ordinary X-ray machines are bremsstrahlung.

Bubble Chamber:
A device used for detection and study of elementary particles and nuclear reactions. Charged particles from an accelerator are introduced into a superheated liquid, each forming a trail of bubbles along its path. The trails are photographed and by studying the photograph scientists can identify the particles and analyze the nuclear events in which they originate.

Burnup:
A measure of reactor fuel consumption. It can be expressed as: 1) the percentage of fuel atoms that have undergone fission, or 2) the amount of energy produced per unit weight of fuel in the reactor.

By-Product Material:
Any radioactive material (except source material or fissionable material) obtained during the production or use of source material or fissionable material. It includes fission products and many other radioisotopes produced in nuclear reactors.

C

Capture:
A process in which an atomic or nuclear system acquires an additional particle; for example, the capture of electrons by positive ions, or the capture of electrons or neutrons by nuclei.

Capture, Radiative:
The process by which a nucleus captures an incident particle and loses its excitation energy immediately by the emission of gamma radiation.

Carrier:
A stable isotope, or a normal element, to which radioactive atoms of the same element can be added to obtain a quantity of radioactive mixture sufficient for handling, or to produce a radioactive mixture that will undergo the same chemical or biological reaction as the stable isotope. A substance in a weighable amount which, when associated with a trace of another substance, will carry the trace through a chemical, physical, or biological process.

Cascade:
A connected arrangement of units of equipment for separation of isotopes. A single device or process usually can produce only a small amount of isotopic separation, but if a number of these are connected, the effect can be multiplied and a significant amount of separation achieved. An example is a cascade of barriers for the gaseous diffusion process.

Cathode:
Negative electrode to which positron ions are attracted.

Cathode Rays:
A stream of electrons emitted by the cathode, or negative electrode, of a gas discharge tube or by a hot filament in a vacuum tube, such as a television tube.

Cell, Biological:
The fundamental unit of structure and function in organisms.

Cells, Somatic:
Body cells, usually with two sets of chromosomes, as opposed to germ cells, which have only one set.

Chain Reaction:
A reaction that stimulates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions releasing additional neutrons. These in turn can be absorbed by other fissionable nuclei releasing still more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption in non-fissioning material or by escape from the system.

Chamber, Cloud:
A device for observing the paths of ionizing particles. It is based on the principle that supersaturated vapor condenses more readily on ions than on neutral molecules.

Chamber, Ionization:
An instrument designed to measure a quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Air-Wall Ionization Chamber:
Ionization chamber in which the materials of the wall and electrodes are so selected as to produce ionization essentially equivalent to that in a free air ionization chamber. This is possible only over limited ranges of photon energies. Such a chamber is more appropriately termed an "air-equivalent ionization chamber".

Thimble Ionization Chamber:
A small cylindrical or pherical ionization chamber, usually with walls of organic material.

Tissue-Equivalent Ionization Chamber:
An ionization chamber in which the material of the walls, electrodes, and gas are so selected as to produce ionization essentially equivalent to that characteristic of the tissue under consideration. In some cases, it is sufficient to have only tissue equivalent walls, and the gas may be air, provided the air volume is negligible. The essential point in this case is that the contribution to the ionization in the air, made by ionizing particles originating in the air, is negligible compared to that produced by ionizing particles characteristic of the wall material.

Chamber, Pocket:
A small, pocket-sized ionization chamber used for monitoring radiation exposure of personnel. Before use, it is given a charge and the amount of discharge is a measure of the radiation exposure.

Charged Particle:
An ion. An elementary particle that carries a positive or negative electric charge.

Chemical Dosimeter:
A detector for indirect measurement of radiation by indicating the extent to which the radiation causes a definite chemical change to take place.

Circuit, Integrating:
An electronic circuit which records the total number of ions or events collected for a given time from which an average value for the number of ions or events per unit time can be found.

Cladding:
The outer jacket of nuclear fuel elements. It prevents corrosion of the fuel and the release of fission products into the coolant.

Cloud Chamber:
A device in which the tracks of charged atomic particles, such as cosmic rays or accelerator beams, are displayed. It consists of a glass-walled chamber filled with a supersaturated vapor, such as wet air. When charged particles pass through the chamber, they trigger a process of condensation and produce a track of tiny liquid droplets much like the vapor trail of a jet plane. This track permits scientists to study the particles' motions and interactions.

Coffin:
A heavily shielded shipping cask for spent (used) fuel elements. Some coffins weigh as much as 75 tons.

Coincidence:
The occurrence of counts in two or more detectors simultaneously or within an assignable time interval.

Accidental, Chance, or Random Coincidence:
One that is due to the accidental occurrence of unrelated counts in the separate detectors.

Anticoincidence:
The occurrence of a count in a specified detector unaccompanied simultaneously or within an assignable time interval by a count in other specified detectors.

Delayed Coincidence:
The occurrence of a count in one detector at a short, but measurable, time after a count in another detector. The two counts are due to a genetically related occurrence such as successive events in the same nucleus.

True Coincidence:
One that is due to the incidence of a single particle or of several genetically related particles.

Coincidence Counting:
A method for detecting or identifying radioactive materials and for calibrating their disintegration rates by counting two or more characteristic radiation events (such as gamma ray emissions) which occur together or in a specific time relationship to each other. This method is important in activation analysis, medical scanning, cosmic ray studies, and low-level measurements.

Collimator:
A device for confining the elements of a beam within an assigned solid angle.

Collision:
A close approach of two or more particles, photons, atoms, or nuclei, during which such quantities as energy, momentum, and charge may be exchanged.

Compton Effect:
Elastic scattering of photons (X-rays or gamma rays) by electrons. In each such process, the electron gains energy and recoils, and the photon loses energy. This is one of three ways photons lose energy upon interacting with matter and is the usual method with photons of intermediate energy and materials of low atomic number.

Condenser R-Meter:
An instrument consisting of an "air-wall" ionization chamber together with auxiliary equipment for charging and measuring its voltage. It is used in an integrating instrument for measuring the exposure of X-ray or gamma radiation in roentgens. (See Chamber, Ionization.)

Containment:
The provision of a gas-tight shell or other enclosure around a reactor to confine fission products that otherwise might be released to the atmosphere in the event of an accident.

Containment Vessel:
The receptacle principally relied upon to retain radioactive material during transport.

Contamination:
An impurity which pollutes or adulterates another substance. In radiological safety, contamination refers to the radioactive materials which are the sources of ionizing radiation.

Controlled Area:
Any area to which access is controlled by the user for purposes of radiation safety pursuant to the provisions of the regulations. Airborne radioactivity areas, high-radiation areas, and radiation areas shall be considered controlled areas. Controlled areas shall not include any areas used as residential quarters.

Controlled Thermonuclear Reaction:
Controlled fusion that is produced under research conditions, or for production of useful power.

Coolant:
A substance circulated through a nuclear reactor to remove or transfer heat. Common coolants are water, air, carbon dioxide, liquid sodium, and sodium-potassium alloy (NaK).

Core:
The central portion of a nuclear reactor containing the fuel elements and usually the moderator, but not the reflector.

Cosmic Rays:
Radiation of many sorts, but mostly atomic nuclei (protons) with very high energies, originating outside the earth's atmosphere. Cosmic radiation is part of the natural background radiation. Some cosmic rays are more energetic than any man-made forms of radiation.

Coulomb:
Unit of electrical charge in the MKSA system of units. A quantity of charge equal to one ampere second.

Count (Radiation Measurements):
The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total number registered in a given period of time. The term often is erroneously used to designate a disintegration, ionizing event, or voltage pulse.

Count, Spurious:
In a radiation counting device, a count caused by any agency other than radiation.

Counter:
A general designation applied to radiation detection instruments or survey meters that detect and measure radiation in terms of individual ionizations, displaying them either as the accumulated total or their rate of occurrence.

Counter, Geiger-Mueller:
Highly sensitive, gas-filled radiation measuring device. It operates at voltages sufficiently high to produce avalanche ionization.

Counter, Proportional:
Gas-filled radiation detection device. The pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

Counter, Scintillation:
The combination of phosphor, photomultiplier tube, and associated circuits for counting light emissions produced in the phosphors.

Counting, Coincidence:
A technique in which particular types of events are distinguished from background events by coincidence circuits which register coincidences caused by the type of events under consideration.

Counting Ratemeter:
An instrument which gives a continuous indication of the average rate of ionizing events.

Critical:
Capable of sustaining a chain reaction.

Critical Mass:
The smallest mass of fissionable material that will support a self-sustaining chain reaction under stated conditions.

Criticality:
The state of a nuclear reactor when it is sustaining a chain reaction.

Cross-Section:
A measure of the probability that a nuclear reaction will occur. Usually measured in barns, it is the apparent (or effective) area presented by a target nucleus (or particle) to an oncoming particle or other nuclear radiation, such as a photon of gamma radiation. (Symbol σ sigma)

Curie:
The basic unit to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of one gram of radium. A curie is also a quantity of any nuclide having one curie of radioactivity. (Abbreviated Ci)

Microcurie:
One one-millionth of a curie (3.7×10^4 disintegrations per second). (Abbreviated μCi)

Millicurie:
One one-thousandth of a curie (3.7×10^7 disintegrations per second). (Abbreviated mCi)

Picocurie:
One one-millionth of a microcurie (3.7×10^{-2} disintegrations per second or 2.22 disintegrations per minute). (Abbreviated pCi; replaces the term μμc)

Cyclotron:
A particle accelerator in which charged particles receive repeated synchronized accelerations by electrical fields as the particles spiral outward from their source. The particles are kept in the spiral by a powerful magnetic field.

D

Daughter:
A nuclide formed by the radioactive decay of another nuclide, which in this context is called the parent.

Decay Chain:
A radioactive series.

Decay Constant:
The fraction of the number of atoms of a radioactive nuclide which decays in unit time. (Symbol λ) (See Disintegration Constant.)

Decay Curve:
A curve showing the relative amount of radioactive substance remaining after any time interval. (See Disintegration Constant.)

Decay Heat:
The heat produced by the decay of radioactive nuclides.

Decay Product:
A nuclide resulting from the radioactive disintegration of a radionuclide, formed either directly or as the result of successive transformations in a radioactive series. A decay product may be either radioactive or stable.

Decay, Radioactive:
The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in a decrease, with time, of the number of the original radioactive atoms in a sample. It involves the emission from the nucleus of alpha particles, beta particles (or electrons), or gamma rays; or the nuclear capture or ejection of orbital electrons; or fission. Also called radioactive disintegration.

Decontamination:
The removal of radioactive contaminants from surfaces or equipment, as by cleaning and washing with chemicals.

Delta Ray:
Instrument utilizing a photocell to determine the degree of darkening of developed photographic film.

Densitometer:
Instrument utilizing a photocell to determine the degree of darkening of developed photographic film.

Density, Photographic:
Used to denote the degree of darkening of photographic film. Logarithm of opacity is the reciprocal of transmission. Transmission is the ratio of transmitted-to-incident intensity.

Depleted Uranium:
Uranium having a smaller percentage of uranium-235 than the 0.7% found in natural uranium. It is obtained from the spent (used) fuel elements or as byproduct tails, or residues, or uranium isotope separation.

Depletion:
Reduction of the concentration of one or more specified isotopes in a material or in one of its constituents.

Detector, Radiation:
Any device for converting radiant energy to a form more suitable for observation. An instrument used to determine the presence, and sometimes the amount, of radiation.

Deuterium:
An isotope of hydrogen whose nucleus contains one neutron and one proton and is therefore about twice as heavy as the nucleus of normal hydrogen, which is only a single proton. Deuterium is often referred to as heavy hydrogen; it occurs in nature as one atom to 6500 atoms of normal hydrogen. It is non-radioactive. (Symbol H or D)

Deuteron:
The nucleus of deuterium. It contains one proton and one neutron.

Device, Nuclear:
A nuclear explosive used for peaceful purposes, tests, or experiments. The term is used to distinguish these explosives from nuclear weapons, which are packaged units ready for transportation or use by military forces.

Discriminator:
An electronic circuit which selects signal pulses according to their pulse height of voltage. It is used to delete extraneous radiation counts or background radiation, or as the basis for energy spectrum analysis.

Disintegration Constant:
The fraction of the number of atoms of a radioactive nuclide which decays in unit time; λ in the equation $N = N_0e-\lambda t$, where N_0 is the initial number of atoms present, and N is the number of atoms present after some time, t.

Disintegration, Nuclear:
A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

Disintegration, Radioactive:
Equivalent to radioactive decay.

Distribution Factor:
A term used to express the modification of the effect of radiation in a biological system attributable to the non-uniform distribution of an internally deposited isotope, such as radium's being concentrated in bones.

Dose:
A general form denoting the quantity of radiation or energy absorbed. For special purposes, it must be appropriately qualified. If unqualified, it refers to absorbed dose.

Absorbed Dose:
The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad equals 100 ergs per gram. (See Rad.)

Cumulative Dose (Radiation):
The total dose resulting from repeated exposures to radiation.

Depth Dose:
The radiation dose delivered at a particular depth beneath the surface of the body. It is usually expressed as a percentage of surface dose.

Dose Equivalent (DE):
A quantity used in radiation protection. It expresses all radiations on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)

Dose, Fractionation:
A method of administering radiation in which relatively small doses are given daily or at longer intervals.

Dose, Protraction:
A method of administering radiation by delivering it continuously over a relatively long period at a low dose rate.

Dose Rate:
The radiation dose delivered per unit time and measured, for instance, in rems per hour.

Exit Dose:
Dose of radiation at surface of body opposite that upon which the beam is incident.

Maximum Permissible Dose Equivalent (MPD):
The greatest dose equivalent that a person or specified part thereof shall be allowed to receive in a given period of time.

Median Lethal Dose (MLD):
Dose of radiation required to kill, within a specified period, fifty percent of the individuals in a large group of animals or organisms. Also called the LD_{50}.

Percentage Depth Dose:
Dose of radiation delivered at a specified depth in tissue, expressed as a percentage of the skin dose.

Permissible Dose:
The dose of radiation which may be received by an individual within a specified period with the expectation of no significantly harmful results.

Threshold Dose:
The minimum absorbed dose that will produce a detectable degree of any given effect.

Tissue Dose:
Absorbed dose received by tissue in the region of interest; expressed in rads. (See Dose; also Rad.)

Dose Meter, Integrating:
Ionization chamber and measuring system designed for determining total radiation administered during an exposure. In medical radiology, the chamber is usually designed to be placed on the patient's skin. A device may be included to terminate the exposure when it has reached a desired value.

Dose Ratemeter:
Any instrument which measures radiation dose rate.

Dosimeter:
An instrument that detects and measures accumulated radiation exposure. In common usage, a pencil-sized ionization chamber with a self-reading electrometer used for personnel monitoring.

Dosimetry, Photographic:
Determination of cumulative radiation dose with photographic film and density measurement.

E

Electrode:
A conductor used to establish electrical contact with a nonmetallic part of a circuit.

Electromagnetic Radiation:
Radiation consisting of associated and interacting electric and magnetic waves that travel at the speed of light. Examples: light, radio waves, gamma rays, X-rays. All can be transmitted through a vacuum.

Electrometer:
Electrostatic instrument for measuring the difference in potential between two points. Used to measure change of electric potential of charged electrodes resulting from ionization produced by radiation.

Electromotive Force:
Potential difference across electrodes tending to produce an electric current.

Electron:
A stable elementary particle having an electric charge equal to $\pm$ 1.60210 x 10^{-19} C. and a rest mass equal to 9.1091 x 10^{-31} kg.

Secondary Electron:
An electron ejected from an atom, molecule, or surface as the result of an interaction with a charged particle or photon.

Valence Electron:
An electron which is gained, lost, or shared in a chemical reaction.

Electron Capture:
A mode of radioactive decay of a nuclide in which an orbital electron is captured by and merges with the nucleus, thus forming a new nuclide with the mass number unchanged but the atomic number decreased by one. (Abbreviated EC) (See K-Capture.)

Electron Volt:
The amount of kinetic energy gained by an electron when it is accelerated through an electric potential difference of one volt. It is equivalent to 1.603 x 10^{-12} erg. It is a unit of energy, or work, not of voltage. (Abbreviated ev or eV)

Electroscope:
An instrument for detecting the presence of electric charges by the deflection of charged bodies.

Electrostatic Field:
The region surrounding an electric charge in which another electric charge experiences a force.

Electrostatic Unit of Charge:
See Statcoulomb.

Element:
One of the 103 known chemical substances that cannot be divided into simpler substances by chemical means. A substance whose atoms all have the same atomic number.

Elementary Particles:
The simplest particles of matter and radiation. Most are short lived and do not exist under normal conditions (exceptions are electrons, neutrons, protons, and neutrinos). Originally this term was applied to any particle that could not be subdivided, or to constituents of atoms. Now it is applied to nucleons (protons and neutrons), electrons, mesons, muons, baryons, strange particles, and the antiparticles of each of these, and to photons, but not to alpha particles or deuterons. Also called fundamental particles.

Energy:
Capacity for doing work. "Potential energy" is the energy inherent in a mass because of its spatial relation to other masses. "Kinetic energy" is the energy possessed by a mass because of its motion; MKSA units: $kg\text{-}m^2/sec^2$ or joules.

Binding Energy:
The energy represented by the difference in mass between the sum of the component parts and the actual mass of the nucleus.

Excitation Energy:
The energy required to change a system from its ground state to an excited state. Each different state has a different excitation energy.

Ionization Energy:
The average energy lost by ionizing radiation in producing an ion pair in a gas. For air, it is about 33.73 eV.

Radiant Energy:
The energy of electromagnetic radiation, such as radio waves, visible light, X-ray and gamma rays.

Reaction Energy, Nuclear:
In the disintegration of a nucleus, it is equal to the sum of the kinetic or radiant energies of the reactants minus the sum of the kinetic or radiant energies of the products. If any product of a specified reaction is in an excited nuclear state, the energy of subsequently emitted gamma radiation is not included in the sum. The "ground state nuclear reaction energy" is the reaction energy when all reactant and product nuclei are in their ground states. (Symbol Q_0)

Energy Flux Density (Energy Fluence Rate):
The sum of the energies, exclusive of rest energies, of all particles passing through a unit cross-sectional area per unit time. (Energy fluence per unit of time.)

Enriched Material:
Material in which the percentage of a given isotope present in a material has been artificially increased, so that it is higher than the percentage of that isotope naturally found in the material. Enriched uranium contains more of the fissionable isotope uranium-235 than the naturally occurring percentage (0.7%). (See Isotopic Enrichment.)

Enrichment:
Isotopic enrichment.

Epidermis:
The outermost layer of cells of the skin.

Epilation (Depilation):
The temporary or permanent removal or loss of hair.

Epithermal Neutron:
An intermediate neutron.

Erg:
A unit of work done by a force of one dyne acting through a distance of one cm. Unit of energy which can exert a force of one dyne through a distance of one cm; cgs units: dyne-cm or $gm\text{-}cm^2/sec^2$.

Error, Statistical:
Errors in counting due to the random time distributions of disintegrations.

Excess Reactivity:
More reactivity than that needed to achieve criticality. Excess reactivity is built into a reactor (by using extra fuel) in order to compensate for fuel burnup and the accumulation of fission product poisons during operation.

Excited State:
The state of a molecule, atom, electron, or nucleus when it possesses more than its normal energy. Excess nuclear energy is often released as a gamma ray. Excess molecular energy may appear as fluorescense or heat.

Excursion:
A sudden, very rapid rise in the power level of a reactor caused by supercriticality. Excursions are usually quickly suppressed by the negative temperature coefficient of the reactor and/or by automatic control rods.

Exposure:
A measure of the ionization produced in air by X-ray or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.

Acute Exposure:
Radiation exposure of short duration.

Chronic Exposure:
Radiation exposure of long duration by fractionation or protraction. (See Dose, Fractionation; also Dose, Protraction.)

F

Fallout:
Radioactive debris from a nuclear detonation, which is airborne or has been deposited on the earth. Special forms of fallout are "dry fallout", "rainout", and "snowout".

Fast Breeder Reactor:
A reactor that operates with fast neutrons and produces more fissionable material than it consumes.

Fast Neutron:
A neutron with energy greater than approximately 100,000 electron volts.

Fast Reactor:
A reactor in which the fission chain reaction is sustained primarily by fast neutrons rather than by thermal or intermediate neutrons. Fast reactors contain little or no moderator to slow down the neutrons from the speeds at which they are ejected from fissioning nuclei.

Feed Materials:
Refined uranium or thorium metal or their pure compounds in a form suitable for use in nuclear reactor fuel elements or as feed for uranium enrichment processes.

Fertile Material:
A material, not itself fissionable by thermal neutrons, which can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials: uranium-238 and throium-232. When these fertile materials capture neutrons, they are partially converted into fissile plutonium-239 and uranium-233, respectively.

Film Badge:
A light-tight package of photographic film worn like a badge by workers in nuclear industry or research, used to measure possible exposure to ionizing radiation. The absorbed dose can be calculated by the degree of film darkening caused by the irradiation.

Film Ring:
A film badge in the form of a finger ring.

Filter (Radiology):
Primary: A sheet of material, usually metal, placed in a beam of radiation to absorb preferentially the less penetrating components. Secondary: A sheet of material of low atomic number (relative to the primary filter) placed in the filtered beam of radiation to remove characteristic radiation produced by the primary filter.

Fireball:
The luminous ball of hot gases that forms a few millionths of a second after a nuclear explosion.

Fissile Material:
While sometimes used as a synonym for fissionable material, this term has also acquired a more restricted meaning, namely, any material fissionable by neutrons of all energies, including, and especially, thermal (slow) neutrons as well as fast neutrons; for example, uranium-235 and plutonium-239.

Fission:
The splitting of a heavy nucleus into two or more parts (which are nuclei of lighter elements), accompanied by the release of a relatively large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but usually is caused by nuclear absorption of gamma rays, neutrons, or particles.

Fission Fragments:
The two nuclei which are formed by the fission of a nucleus. Also referred to as primary fission products. They are of medium atomic weight and are radioactive.

Fission Products:
The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay.

Fission Yield:
The amount of energy released by fission in a thermonuclear (fusion) explosion as distinct from that released by fusion. Also, the amount (percentage) of a given nuclide produced by fission.

Fissionable Material:
Commonly used as a synonym for fissile material. The meaning of this term also has been extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean fuel.

Fluence:
The number of particles passing through a unit cross-sectional area.

Fluorescence:
Many substances can absorb energy (as from X-rays, ultraviolet light, or radioactive particles) and immediately emit this energy as an electromagnetic photon, often of visible light. This emission is fluorescence. The emitting substances are said to be fluorescent.

Fluorescent Screen:
A sheet of material coated with a substance (such as calcium tungstate or zinc sulfide) which will emit visible light when irradiated with ionizing radiation.

Fluorography (Photofluorography):
Photography of an image produced on a fluorescent screen by X-ray or gamma radiation.

Fluoroscope:
A fluorescent screen, suitably mounted with respect to an X-ray tube for ease of observation and protection, used for indirect visualization (by X-rays) of internal organs in the body or internal structures in apparatus or in masses of material.

Flux Density (Fluence Rate):
The number of particles passing through a unit cross-sectional area per unit of time. (Fluence per unit of time.)

Flux, Neutron:
A term used to express the intensity of neutron radiation. The number of neutrons passing through a unit area in unit time. For neutrons of a given energy, the product of neutron density with speed.

Focal Spot (X-rays);
The part of the target of the X-ray tube struck by the main electron stream.

Food Chain:
The pathways by which any material (such as radioactive material from fallout) passes from the first absorbing organism through plants and animals to man.

Frequency:
Number of cycles, revolutions, or vibrations completed in a unit of time. (See Hertz.)

Fuel:
Fissionable material used or usable to produce energy in a reactor. Also applied to a mixture, such as natural uranium, in which only part of the atoms are readily fissionable, if the mixture can be made to sustain a chain reaction.

Fuel Cycle:
The series of steps involved in supplying fuel for nuclear power reactors. It includes mining, refining, the original fabrication of fuel elements, their use in a reactor, chemical processing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material, and refabrication into new fuel elements.

Fuel Elements:
A rod, tube, plate, or other mechanical shape or form into which nuclear fuel is fabricated for use in a reactor.

Fuel Reprocessing:
The processing of reactor fuel to recover the unused fissionable material.

Fusion:
The formation of a heavier nucleus from two or more lighter ones (such as hydrogen isotopes) with the resultant release of energy.

G

Gamma Radiation:
Electromagnetic quanta of wavelengths less than ultraviolet, traveling with the speed of light, and conveying energy proportional to its frequency (range of energy from 10 KeV to 9 MeV).

Gamma Rays:
High energy, short wavelength electromagnetic radiation. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials such as lead or depleted uranium. Gamma rays are essentially similar to X-rays, but are usually more energetic and are nuclear in origin. (Symbol γ)

Gas Amplification:
As applied to gas ionization radiation detecting instruments, the ratio of the charge collected to the charge produced by the initial ionizing event.

Gas Cooled Reactor:
A nuclear reactor in which a gas is the coolant.

Gaseous Diffusion:
A method of isotopic separation based on the fact that gas atoms or molecules with different masses will diffuse through a porous barrier (or membrane) at different rates. The method is used by the NRC to separate uranium-235 from uranium-238. It requires large gaseous diffusion plants and enormous amounts of electric power.

Gauging:
The measurement of the thickness, density, or quantity of material by the amount of radiation it absorbs. This is the most common use of radioactive isotopes in industry.

Geiger-Mueller Counter (Geiger-Muller Tube):
A radiation detection and measuring instrument. It consists of a gas-filled (Geiger-Muller) tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation. It is also often known as a Geiger counter.

Geiger Region:
In an ionization radiation detector, the operating voltage interval in which the charge collected per ionizing event is essentially independent of the number of primary ions produced in the initial ionizing event.

Geiger Threshold:
The lowest voltage applied to a counter tube for which the number of pulses produced in the counter tube is essentially the same, regardless of a limited voltage increase.

Gene:
The fundamental unit of inheritance which determines and controls hereditarily transmissible characteristics. Genes are arranged linearly at definite loci on chromosomes.

Generation Time:
The mean time for the neutrons produced by one fission to produce fissions again in a chain reaction.

Genetic Effect of Radiation:
Inheritable change, chiefly mutations produced by the absorption of ionizing radiation. On the basis of present knowledge, these effects are purely additive; there is no recovery.

Genetics:
The branch of biology dealing with the phenomena of heredity and variation.

Geometry:
The spatial configuration, pattern, or relationship of components in an experiment or apparatus. In reactor technology, the term refers to the shape and size of fuel elements, moderator and reflector and their location with respect to each other. In nuclear physics, it refers to the arrangement of source and detecting equipment. In counting and scanning, the term commonly indicates the percentage of the radiation leaving a sample which reaches the sensitive volume of a counter.

Geometry Factor:
The fraction of the total solid angle about the source of radiation that is subtended by the face of the sensitive volume of a detector.

Germ Cells:
The cells of an organism whose function is reproduction.

Glory Hole:
A beam hole.

Glove Box:
A sealed box in which workers, using gloves attached to and passing through openings in the box, can handle radioactive materials safely from the outside.

Gonad:
A gamete-producing organ in animals; testis or ovary.

Gram-Rad:
The unit of integral dose equal to 100 ergs.

Graphite:
A form of carbon in which the atoms are hexagonally arranged in planes. Commonly used for moderators because it can be made in compact, fairly strong blocks, easily machined to close tolerances, and because the prolonged baking at high temperatures used in its manufacture helps eliminate impurities that might absorb neutrons.

Green Salt:
Uranium tetrafluoride.

Grenz Rays:
X-rays produced at voltages of 5 to 20 kVp, intended primarily for surface therapy.

Ground State:
The state of a nucleus, atom, or molecule at its lowest energy. All other states are "excited".

H

Half-Life, Biological:
The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination. Approximately the same for both stable and radioactive isotopes of a particular element.

Half-Life, Effective:
The time required for a radionuclide contained in a biological system, such as a man or an animal, to reduce its activity by half as a combined result of radioactive decay and biological elimination.

Half-Life, Radioactive:
The time required for a radioactive substance to lose fifty percent of its activity by decay. Each radionuclide has a unique half-life.

Half Thickness:
The thickness of any given absorber that will reduce the intensity of a beam of radiation to one-half its initial value.

Half Time:
See Residence Time.

Half Value Layer (Half Thickness):
The thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the exposure rate by one-half. (Abbreviated HVL)

Hand and Foot Counter:
A monitoring device arranged to give a rapid radiation survey of hands and feet of persons working with radioactive material to detect radioactive contamination.

Hardness, X-ray:
A relative specification of the quality of penetrating power of X-rays. In general, the shorter the wavelength, the harder the radiation.

Health Physics:
The science concerned with recognition, evaluation, and control of health hazards from ionizing radiation.

Health, Radiological:
The art and science of protecting human beings from injury by radiation and promoting better health through beneficial applications of radiation.

Heat Exchanger:
Any device that transfers heat from one fluid (liquid or gas) to another or to the enrivonment.

Heat Sink:
Anything that absorbs heat; usually part of the environment such as the air, rivers, or outer space.

Heavy Hydrogen:
Deuterium.

Heavy Water:
Water containing significantly more than the natural proportion (one in 6500) of heavy hydrogen (deuterium) atoms to ordinary hydrogen atoms. Heavy water is used as a moderator in some reactors because it slows down neutrons effectively and also has a low cross-section for absorption of neutrons.

Heavy Water Moderated Reactor:
A reactor that uses heavy water as its moderator. Heavy water is an excellent moderator and thus permits the use of inexpensive natural (unenriched) uranium as a fuel.

Heredity:
Transmission of characteristics and traits from parent to offspring.

Hertz:
The unit of frequency equal to one cycle per second.

High Radiation Area:
Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive, in any one hour, a dose in excess of 100 millirem (one-tenth of a Rem).

Hyperon:
One of a class of short-lived elementary particles with a mass greater than that of a proton and less than that of a deuteron. All hyperons are unstable and yield a nucleon as a decay product.

I

Immunity:
The power which a living organism possesses to resist and overcome infection.

Implant, Radiology:
Encapsulated radioactive material embedded in a tissue for therapy. It may be permanent (seed) or temporary (needle).

Induced Radioactivity:
Radioactivity that is created when substances are bombarded with neutrons, as from a nuclear explosion, or in a reactor, or with charged particles produced by accelerators.

Inelastic Scattering:
See Scattering.

Initial Nuclear Radiation:
Radiation emitted from the fireball of a nuclear explosion during the first minute (an arbitrary time interval) after detonation.

In-Pile:
A term used to designate experiments or equipment inside a reactor.

Integrated Neutron Flux:
Flux multiplied by time, usually expressed as nvt, when n = the number of neutrons per cubic centimeter, v = their velocity in centimeters per second, and t = time in seconds.

Intensity:
The energy or the number of photons or particles of any radiation incident upon a unit area or flowing through a unit of solid material per unit of time. In connection with radioactivity, the number of atoms disintegrating per unit of time.

Interlock:
A device, usually electrical and/or mechanical, to prevent activation of a control until a preliminary condition has been met, or to prevent hazardous operations. Its purpose usually is safety.

Intermediate (Epithermal) Neutron:
A neutron having energy greater than that of a thermal neutron but less than that of a fast neutron. The range is generally considered to be between about 0.5 and 100,000 electron volts.

Intermediate (Epithermal) Reactor:
A reactor in which the chain reaction is sustained mainly by intermediate neutrons.

Interstitial Implants:
Solid or encapsulated radiation sources, made in the form of seeds, wires, or other shapes to be inserted directly into tissue that is to be irradiated.

Ion:
An atom or molecule that has lost or gained one or more electrons and therefore has an electrical charge, either negative or positive.

Ion Engine:
An engine which provides thrust by expelling accelerated or high velocity ions. Ion engines using energy provided by nuclear reactors are proposed for space vehicles.

Ion Exchange:
A chemical process involving the reversible interchange of various ions between a solution and a solid material, usually a plastic or a resin. It is used to separate and purify chemicals, such as fission products, rare earths, etc. in solutions.

Ion Pair:
A closely associated positive ion and negative ion (usually an electron) having charges of the same magnitude and formed from a neutral atom or molecule by radiation.

Ionization:
The process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, chemical reactions, or nuclear radiations can cause ionization.

Primary Ionization:
1) In collision theory, the ionization produced by the primary particles as contrasted to the "total ionization" which includes the "secondary ionization" produced by delta rays. 2) In counter tubes, total ionization produced by incident radiation without gas amplification.

Secondary Ionization:
Ionization produced by delta rays.

Specific Ionization:
Number of ion pairs per unit length of path of ionizing radiation in a medium, e.g., per cm of air or per micron of tissue.

Total Ionization:
The total electric charge of one sign on the icns produced by radiation in the process of losing its kinetic energy. For a given gas, the total ionization is closely proportional to the initial ionization and is nearly independent of the nature of the ionizing radiation. It is frequently used as a measure of radiation energy.

Ionization Chamber:
An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber making the gas a conductor of the electricity.

Ionization Density:
Number of ion pairs per unit volume.

Ionization Path (Track):
The trail of ion pairs produced by an ionizing radiation in its passage through matter.

Ionizing Event:
Any occurrence of a process in which an ion or group of ions is produced.

Ionizing Radiation:
Any radiation displacing electrons from atoms or molecules, thereby producing ions.

Irradiation:
Exposure to radiation, as in a nuclear reactor.

Isobar:
One of two or more nuclides having about the same atomic mass but different atomic numbers, hence different chemical properties.

Isodose Chart:
Chart showing the distribution of radiation in a medium by means of lines or surfaces drawn through points receiving equal doses. Isodose charts have been determined for beams of X-rays traversing the body and for working areas where X-rays or radioactive nuclides are employed.

Isodose Curves:
Curves or lines drawn to connect points where identical amounts of radiant energy reach a specific depth.

Isointensity Contours:
Imaginary lines on the surface of the ground or water, or lines drawn on a map joining points in a radiation field which have the same radiation intensity at a given time.

Isomer:
One of two or more nuclides with the same number of neutrons and protons in their nuclei, but with different energies. A nuclide in the excited state and a similar nuclide in the ground state are isomers.

Isotone:
One of several nuclides having the same number of neutrons but a different number of protons in their nuclei. Example: potassium-39 ($^{39}_{19}K_{20}$) and calcium-40 ($^{40}_{20}Ca_{20}$) are isotones.

Isotope:
One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. An equivalent statement is that the nuclei of isotopes have the same number of protons but different numbers of neutrons. Thus $^{12}_{6}C$, $^{13}_{6}C$, and $^{14}_{6}C$ are isotopes of the element carbon, the subscripts denoting their common atomic numbers, the superscripts denoting the differing mass numbers, or approximate atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.

Isotope Separation:
The process of separating isotopes from one another, or changing their relative abundances, as by gaseous diffusion or electromagnetic separation. All systems are based on the mass differences of the isotopes. Isotope separation is a step in the isotopic enrichment process.

Isotopic Enrichment:
A process by which the relative abundances of the isotopes of a given element are altered, thus producing a form of the element which has been enriched in one particular isotope. Example: enriching natural uranium in the uranium-235 isotope.

J

Joule:
The unit for work and energy, equal to one newton expended along a distance of one meter (1J = 1N x 1m).

K

K-Capture:
The capture by an atomic nucleus of an orbital electron from the first (innermost) orbit or shell, or K-shell surrounding the nucleus.

K-Meson:
See Kaon.

Kaon:
An elementary particle (contraction of K-meson). A heavy meson with a mass about 970 times that of an electron.

Kilo:
A prefix that multiplies a basic unit by 1000.

Kilo Electron Volt:
One thousand electron volts; 10^3 eV. (Abbreviated KeV)

Kiloton Energy:
The energy of a nuclear explosion which is equivalent to that of an explosion of 1000 tons of TNT.

Kilovolt:
A unit of electrical potential difference, equal to 1000 volts. (Abbreviated kV)

Kinetic Energy:
Energy due to motion.

L

LD_{50} (Live/Die 50%):
Possible terminal radiation dose. (See Dose, Median Lethal Dose - MLD.)

Label:
See Tracer, Isotopic.

Lag Time:
The time between the occurrence of the primary ionizing event and the occurrence of the count.

Lanthanide Series:
The series of elements beginning with lanthanum, Element No. 57, and continuing through lutetium, Element No. 71, which together occupy one position in the Periodic Table of the Elements. These are the "rare earths", which all have chemical properties similar to lanthanum. They are also called the "lanthanides".

Latent Period:
The period or state of seeming inactivity between the time of exposure of tissue to an injurious agent and response.

Lattice:
An orderly array or pattern of nuclear fuel elements and moderator in a reactor or critical assembly. Also, the arrangement of atoms in a crystal.

Lead Equivalent:
The thickness of lead affording the same attenuation, under conditions, as the material in question.

Leakage:
In nuclear engineering, the escape of neutrons from a reactor core. Leakage lowers a reactor's reactivity.

Lepton:
One of a class of light elementary particles (having small mass). Specifically, an electron, a positron, a neutrino, an antineutrino, a muon, or an antimuon.

Lesion:
A hurt, wound, or local degeneration.

Lethal Dose:
A dose of ionizing radiation sufficient to cause death. Median lethal dose (MLD or LD_{50}) is the dose required to kill within a specified period of time (usually thirty days) half of the individuals in a large group of organisms similarly exposed. The $LD_{50}/30$ for man is about 400 to 450 roentgens.

Leukemia:
A disease in which there is great overproduction of white blood cells, or a relative overproduction of immature white cells, and great enlargement of the spleen. The disease is variable, at times running a more chronic course in adults than in children.

License:
A license issued under state or federal regulations. A licensee is the holder of such a license.

Licensed Material:
Source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or specific license issued by the state or the Nuclear Regulatory Commission pursuant to applicable regulations.

Light Hydrogen:
Ordinary hydrogen.

Light Water:
Ordinary water (H_2O) as distinguished from heavy water (D_2O).

Linac:
Short for linear accelerator.

Linear Accelerator:
A long straight tube (or series of tubes) in which charged particles (ordinarily electrons or protons) gain in energy by the action of oscillating electromagnetic fields.

Linear Energy Transfer:
A measure of the ability of biological material to absorb ionizing radiation; the radiation energy lost per unit length of path through a biological material. In general, the higher the LET value, the greater the relative biological effectiveness of the radiation in that material. (Acronym LET)

Load Factor:
The ratio of average load carried by an electric power plant or system during a specific period to its peak load during that period.

Loop:
A closed circuit of pipe in which materials and components may be placed to test them under different conditions of temperature, irradiation, etc. If part of the loop and contents are placed in a reactor, it is called an in-pile loop.

Low Level Analysis (Low Level Counting):
A procedure to measure the radioactive content of materials with very low levels of activity, using sensitive detecting instruments and with good shielding to eliminate the effects of background radiation and cosmic rays.

Luminescence:
Emission of light produced by the action of biological or chemical processes or by radiation, or by any other cause except high temperature (which produces incandescence).

M

Magnetic Bottle:
A magnetic field used to confine or contain a plasma in controlled fusion (thermonuclear) experiments.

Magnetic Mirror:
A magnetic field used in controlled fusion experiments to reflect charged particles back into the central region of a magnetic bottle.

Manipulators:
Mechanical devices used for safe handling of radioactive materials. Frequently they are remotely operated from behind a protective shield.

Mass:
The material equivalent of energy, different from weight in that it neither increases nor decreases with gravitational force.

Relativistic Mass:
The increased mass associated with a particle when its velocity is increased. The increase in mass becomes appreciable only at velocities approaching the velocity of light, 3×10^{10} cm/sec.

Mass Defect:
The difference between the atomic mass and the mass number of a nuclide.

Mass Energy Equation (Mass Energy Equivalence):
The statement developed by Albert Einstein, German-born American physicist, that "the mass of a body is a measure of its energy content" as an extension of his 1905 Special Theory of Relativity. The statement was subsequently verified experimentally by measurements of mass and energy in nuclear reactions. The equation, usually given as $E = mc^2$, shows that when the energy of a body changes by an amount, E, (no matter what form the energy takes), the mass, m, of the body will change by an amount equal to E/c^2 (The factor c^2, the square of the speed of light in a vacuum, may be regarded as the conversion factor relating units of mass and energy.) This equation predicted the possibility of releasing enormous amounts of energy by the conversion of mass to energy. It is also called the Einstein equation.

Mass Number:
The sum of the neutrons and protons in a nucleus. It is the nearest whole number to an atom's weight. For instance, the mass number of uranium-235 is 235. (Symbol A)

Mass Spectrograph and Mass Spectrometer:
Two related devices for detecting and analyzing isotopes. They separate nuclei that have different charge-to-mass ratios by passing the nuclei through electrical and magnetic fields.

Matter:
The substance of which a physical object is composed. All materials in the universe have the same inner nature, that is, they are composed of atoms, arranged in different (and often complex) ways; the specific atoms and the specific arrangements identify the various materials.

Maximum Credible Accident:
The most serious accident that can reasonably be imagined from any adverse combination of equipment malfunction, operating errors, and other foreseeable causes. The term is used to analyze the safety characteristics of a reactor. Reactors are designed to be safe even if a maximum credible accident should occur.

Maximum Permissible Concentration (MPC):
The amount of radioactive material in air, water, or food which might be expected to result in a maximum permissible dose to persons consuming them at a standard rate of intake. An obsolescent term.

Maximum Permissible Dose (Maximum Permissible Exposure):
That dose of ionizing radiation established by competent authorities as an amount below which there is no reasonable expectation of risk to human health, and which at the same time is somewhat below the lowest level at which a definite hazard is believed to exist. An obsolescent term.

Maximum Permissible Level (MPL):
The greatest quantity of surface contamination or external radiation permitted in a given circumstance.

Mean Free Path:
The average distance traveled by a particle, atom, or molecule between collisions or interactions.

Mean Life:
The average time during which an atom, an excited nucleus, a radionuclide, or a particle exists in a particular form.

Mega:
A prefix that multiplies a basic unit by one million.

Mega Electron Volt:
One million electron volts, 10^6 eV. (Abbreviated MeV)

Momentum:
The product of the mass of a body and its velocity; MKSA units, kg-m/sec.

Monitor:
An instrument that measures the level of ionizing radiation in an area.

Monitoring:
Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region.

Area Monitoring:
Routine monitoring of the radiation level or contamination of a particular area, building, room, or equipment. Some laboratories or operations distinguish between routine monitoring and survey activities.

Personnel Monitoring:
Monitoring any part of an individual, his breath, or excretions, or any part of his clothing.

Multiplication Factor (Constant):
The ratio of the number of neutrons present in a reactor in any one neutron generation to that in the immediately preceding generation. Criticality is achieved when this ratio is equal to one. The "infinite" multiplication factor is the ratio in a theoretical system from which there is no leakage, that is, a reactor of infinite size. For an actual reactor (from which leakage does occur), the term "effective multiplication factor" which is the ratio based on neutrons available after leakage, is commonly used.

Muon:
An elementary particle, classed as a lepton (not as a meson) with 207 times the mass of an electron. It may have a single positive or negative charge. (Contraction of mu-meson)

Mutation:
Alteration of the usual hereditary pattern, usually sudden.

N

NRC:
Nuclear Regulatory Commission, formerly AEC, Atomic Energy Commission.

Megaton Energy:
The energy of a nuclear explosion which is equivalent to that of an explosion of one million tons (or 1000 kilotons) of TNT.

Megawatt Day Per Ton:
A unit used for expressing the burnup of fuel in a reactor. Specifically, the number of megawatt days of heat output per metric ton of fuel in the reactor.

Meson:
One of a class of medium mass, short lived elementary particles with a mass between that of the electron and that of the proton.

Metabolism:
The sum of all physical and chemical processes by which living organized substance is produced and maintained and by which energy is made available for the uses of the organism.

Metastable State:
An excited nuclear state having a half-life long enough to be observed.

Micro:
Prefix that divides a basic unit by one million. (Symbol μ)

Micron:
A unit of length equal to 10^{-6} meters.

Mil:
A unit of length equal to one one-thousandth of an inch.

Milli:
Prefix that divides a basic unit by one thousand. (Symbol m)

Milliroentgen:
A submultiple of the roentgen, equal to one one-thousandth of a roentgen. (Abbreviated mR)

Moderator:
A material, such as ordinary water, heavy water, or graphite, used in a reactor to slow down high-velocity neutrons, thus increasing the liklihood of further fission.

Molecular Weight:
The sum of the atomic weights of all the atoms in a molecule.

Molecule:
A group of atoms held together by chemical forces. The atoms in the molecule may be identical, as in H_2, S_2, and S_8, or different, as in H_2O and CO_2. A molecule is the smallest unit of matter which can exist by itself and retain all of its chemical properties.

N-Unit:
That quantity of neutron radiation measured in a condenser R-meter that will produce the same amount of ionization as one roentgen of X-ray.

Nano:
Prefix that divides a basic unit by one billion, 10^{-9}. (Symbol η)

Natural Circulation Reactor:
A reactor in which the coolant (usually water) is made to circulate without pumping, that is, by natural convection resulting from the different densities of its cold and reactor heated portions.

Natural Radiation (Natural Radioactivity):
Background radiation.

Natural Uranium:
Uranium as found in nature containing 0.7% of ^{235}U, 99.3% of ^{238}U, and a trace of ^{234}U. It is also called normal uranium.

Neoplasm:
A new growth of cells which is more or less unrestrained and not governed by the usual limitations of normal reproduction. Benign: some degree of growth restraint and no spread to distant parts. Malignant: growth invades tissues or spreads to distant parts, or both.

Neptunium Series (Sequence):
The series of nuclides resulting from the radioactive decay of the man-made nuclide, neptunium-237. Many other man-made nuclides decay into this sequence. The end product of the series is stable bismuth-209, which is the only nuclide in the series that occurs in nature.

Neutrino:
An electrically neutral elementary particle with a negligible mass. It interacts very weakly with matter and hence is difficult to detect. It is produced in many nuclear reactions, for example, in beta decay, and has high penetrating power. Neutrinos from the sun usually pass right through the earth. (Symbol nu)

Neutron:
An uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen. A free neutron is unstable and decays with a half-life of about 13 minutes into an electron, proton, and neutrino. Neutrons sustain the fission chain reaction in a nuclear reactor.

Neutron Capture:
The process in which an atomic nucleus absorbs or captures a neutron. The probability that a given material will capture neutrons is measured by its neutron capture cross-section, which depends on the energy of the neutrons and on the nature of the material.

Neutron Density:
The number of neutrons per cubic centimeter in the core of a reactor.

Neutron Economy:
The degree to which neutrons in a reactor are used for desired ends instead of being lost by leakage or non-productive absorption. The ends may include propagation of the chain reaction, converting fertile to fissionable material, producing isotopes, or research.

Neutron Radiation:
A neutron is a chargless particle of mass similar to that of the hydrogen ion. Fast neutrons convey energy from their source by virtue of the velocity at which their mass travels. Slow neutrons may be termed thermal neutrons when their kinetic energy is equivalent to that of the thermal motion of the atoms among which they diffuse. Thermal neutrons do not convey significant energy from their origin, but are capable of releasing energy as a consequence of the transmutation which occurs when they are captured by absorber nuclei.

Newton:
The unit of force, which, when applied to a one kilogram mass will give it an acceleration of one meter per second per second, $1N = 1kg \times 1m/1s^2$.

Nuclear Energy:
The energy liberated by a nuclear reaction (fission or fusion) or by radioactive decay.

Nuclear Power Plant:
Any device, machine, or assembly that converts nuclear energy into some form of useful power, such as mechanical or electrical power. In a nuclear electric power plant, heat produced by a reactor is generally used to make steam to drive a turbine that in turn drives an electric generator.

Nuclear Reaction:
A reaction involving a change in an atomic nucleus, such as fission, fusion, neutron capture, or radioactive decay, as distinct from a chemical reaction, which is limited to change in the electron structure surrounding the nucleus.

Nuclear Reactor:
A device in which a fission chain reaction can be initiated, maintained, and controlled. Its essential component is a core with fissionable fuel. It usually has a moderator, a reflector, shielding, coolant, and control mechanism. Sometimes called an atomic "furnace", it is the basic machine of nuclear energy.

Nuclear Rocket:
A rocket powered by an engine that obtains energy for heating a propellant fluid (such as hydrogen) from a nuclear reactor rather than from chemical combustion.

Nuclear Superheating:
Superheating the steam produced in a reactor by using additional heat from a reactor. Two methods are commonly employed: recirculating the steam through the same core in which it is first produced (integral superheating) or passing the steam through a second and separate reactor.

Nucleon:
A constituent of an atomic nucleus, that is, a proton or a neutron.

Nucleonics:
The science and technology of nuclear energy and its applications.

Nucleus:
The small, positively charged core of an atom. It is only about 1/10,000 the diameter of the atom, but contains nearly all the atom's mass. All nuclei contain both protons and neutrons, except the nucleus of ordinary hydrogen, which consists of a single proton.

Nuclide:
A general term applicable to all atomic forms of the elements. The term is often erroneously used as a synonym for "isotope" which properly has a more limited definition. Whereas isotopes are the various forms of a single element (hence are a family of nuclides) and all have the same atomic number and number of protons, nuclides comprise all the isotopic forms of all the elements. The nuclear constitution is specified by the number of protons (Z), number of neutrons (N), and energy content; or alternatively, by the atomic number (Z), mass number ($A = N + Z$) and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time. Thus, nuclear isomers are separate nuclides, whereas promptly decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

O

Occupational Dose:
The dose received by an individual: 1) In a controlled area, or 2) In the course of employment, education, training, or other activities which involve exposure to radiation, except for that received for medical and dental diagnoses or medical therapy.

Open Cycle Reactor System:
A reactor system in which the coolant passes through the reactor core only once and is then discarded.

Orange Oxide:
Uranium trioxide.

Orbit:
The region occupied by an electron as it moves about the nucleus of an atom. Commonly called the electron cloud.

Organ:
A group of tissues which together perform one or more definite functions in a living body.

Organic Cooled Reactor:
A reactor that uses organic chemicals, such as mixtures of polyphenyls (diphenyls and terphenyls) as coolant.

Overpressure:
The transient pressure over and above atmospheric pressure caused by a shock wave from a nuclear explosion.

P

Package Power Reactor:
A small nuclear power plant designed to be created in packages small enough to be conveniently transported to remote locations.

Packing Fraction:
The difference between the actual mass of a nuclide and the nearest whole number divided by the mass number, A or (M-A)/A. An equivalent statement is that it is the mass defect divided by the mass number. It is positive for most nuclides with mass number less than 12 and more than 180 which, therefore, tend to be less stable, and negative for most other nuclides, which terd to be more stable.

Pair Production:
An absorption process for X-ray and gamma radiation in which the incident photon is annihilated in the vicinity of the nucleus of the absorbing atom, with subsequent production of an electron and positron pair. This reaction only occurs for incident photon energies exceeding 1.02 MeV (in simple terms, mass created from energy).

Parasitic Capture:
Any absorption (as in a reactor) of neutrons in reactions which do not cause further fission or the production of new fissionable material. In a reactor, the process is undesirable.

Parent:
A radionuclide that, upon radioactive decay or disintegration, yields a specific nuclide (the daughter) either directly or as a later member of a radioactive series.

Particle:
A minute constituent of matter, generally one with a measurable mass. The primary particles involved in radioactivity are alpha particles, beta particles, neutrons, and protons.

Particle Accelerator:
An accelerator.

Penetrometer:
A simple device for measuring the penetrating power of a beam of X-rays or other penetrating radiation by comparing transmission through various absorbers.

Period:
The time required for one cycle of a regularly repeated series of events. In a nuclear reactor, it is the time required for the power level to change by the factor 2·718, which is known as e (the base of natural logarithms).

Periodic Table:
The table based on the chemical law that the physical or chemical properties of the elements are periodic (regularly repeated) functions of their atomic weights, first proposed by the Russian chemist, Dmitri I. Mendeleev, in 1869. An arrangement of chemical elements in order of increasing atomic number. Elements of similar properties are placed one under the other, yielding groups and families of elements. Within each group there is a gradation of chemical and physical properties but in general a similarity of chemical behavior. From group to group, however, there is a progressive shift of chemical behavior from one end of the table to the other.

Personnel Monitoring Equipment:
Devices designed to be worn or carried by an individual for the purpose of measuring the dose received, e.g., film badge, pocket chamber, pocket dosimeter, film ring, etc.

Phantom:
A volume of material approximating as closely as possible the density and effective atomic number of tissue. Ideally a phantom should behave in respect to absorption of radiation in the same manner as tissue. Radiation dose measurements made within or on a phantom provide a means of determining the radiation dose within or on a body under similar exposure conditions. Some materials commonly used in phantoms are water, masonite, pressed wood, and beeswax.

Phosphor:
A luminescent substance. A material capable of emitting light when stimulated by radiation.

Phosphorescence:
Emission of radiation by a substance as a result of previous absorptions of radiation of shorter wavelength. In contrast to fluorescence, the emission may continue for a considerable time after cessation of the exciting irradiation.

Photoelectric Effect:
Process by which a photon ejects an electron from an atom. All the energy of the photon is absorbed in ejecting the electron and in imparting kinetic energy to it.

Photon:
The carrier of quantum of electromagnetic energy. Photons have an effective momentum but no mass or electrical charge.

Pico:
A prefix that divides a basic unit by one trillion, 10^{-12}. The same as micromicro.

Pig:
A heavily shielded container (usually lead) used to ship or store radioactive uranium.

Pile:
An old term for nuclear reactor. This name was used because the first reactor was built by piling up graphite blocks and natural uranium.

Pi-Meson:
See Pion.

Pinch Effect:
In controlled fusion experiments, the effect obtained with an electric current, flowing through a column of plasma, produces a magnetic field that confines and compresses the plasma.

Pion:
An elementary particle. The mass of a charged (positive or negative) pion is about 273 times that of an electron; that of an electrically neutral pion is 264 times that of an electron. (Contraction of pi-meson)

Planck Constant:
A natural constant of proportionality (h) relating the frequency of a quantum of energy to the total energy of the quantum:

$$h = \frac{E}{V} = 6.6256 \text{ a } 10^{-34} \text{ J sec.}$$

Plant Factor:
The ratio of the average power load of an electric power plant to its rated capacity. Sometimes called capacity factor.

Plasma:
An electrically neutral gaseous mixture of positive and negative ions. Sometimes called the "fourth state of matter" since it behaves differently from solids, liquids, and gases. High-temperature plasmas are used in controlled fusion experiments.

Plateau:
As applied to radiation detector chambers, the level portion of the counting rate-voltage curve where changes in operating voltage introduce minimum changes in the counting rate.

Plutonium:
A heavy radioactive man-made metallic element with atomic number 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation or uranium-238. It is used for reactor fuel and in weapons.

Poison:
Any material of high absorption cross-section that absorbs neutrons unproductively and hence removes them from the fission chain reaction in a reactor decreasing its reactivity.

Port:
An opening in a research reactor through which objects are inserted for irradiation or from which beams of radiation emerge for experimental use.

Positron:
An elementary particle with the mass of an electron but charged positively. It is the "antielectron" emitted in some radioactive disintegrations and is formed in pair production by the interaction of high-energy gamma rays with matter.

Potential Difference:
Work required to carry a unit positive charge from one point to another.

Potential Ionization:
The potential necessary to separate one electron from an atom, resulting in the formation of an ion pair.

Power Density:
The rate of heat generated per unit volume of a reactor core.

Power Reactor:
A reactor designed to produce useful nuclear power as distinguished from reactors used primarily for research or for producing radiation or fissionable materials.

Pressurized Water Reactor:
A power reactor in which heat is transferred from the core to a heat exchanger by water kept under high pressure to achieve high temperature without boiling in the primary system. Steam is generated in a secondary circuit. Many reactors producing electric power are pressurized water reactors.

Primary Fission Products:
Fission fragments.

Process, Regenerative:
The process by which damaged or destroyed cells are replaced by new ones of the same type.

Prompt Criticality:
The state of a reactor when the fission chain reaction is sustained solely by prompt neutrons, that is, without the help of delayed neutrons.

Prompt Neutrons:
Neutrons are emitted immediately following nuclear fission, as distinct from delayed neutrons, which are emitted for some time after fission has occurred. Prompt neutrons comprise more than 99% of fission neutrons.

Prompt Radiation:
Radiation produced by the primary fission or fusion process, as distinguished from the radiation from fission products, their decay chains and other later reactions.

Proportional Region:
Voltage range in which the gas amplification is greater than one and in which the charge collected is proportional to the charge produced by the initial ionizing event.

Protected Area:
An area encompassed by physical barriers and to which access is controlled.

Protection:
Provisions to reduce exposure of persons to radiation. For example, protective barriers to reduce external radiation or measures to prevent inhalation of radioactive materials.

Protective Clothing:
Special clothing worn by a radiation worker to prevent contamination of his body or his personal clothing.

Protective Survey:
An evaluation of the radiation hazards incidental to the production, use, or existence of radioactive materials or other sources of radiation under a specific set of conditions.

Protium:
A name sometimes applied to the hydrogen isotope of mass 1 to distinguish it from deuterium and tritium.

Proton:
An elementary particle with a single positive electrical charge and a mass approximately 1837 times that of the electron. The nucleus of an ordinary or light hydrogen atom. Protons are constituents of all nuclei. The atomic number (Z) of an atom is equal to the number of protons in its nucleus.

Proton Synchrotron:
A type of particle accelerator for producing beams of very high energy protons (in the BeV range).

Pulse:
An electrical signal arising from a single event of ionizing radiation.

Pulse Amplifier:
An amplifier designed specifically to amplify the intermittent signals of a radiation detection instrument, incorporating appropriate pulse-shaping characteristics.

Pulse Height:
The measure of the strength or signal amplitude of a pulse delivered by a detector; measured in volts.

Pulse Height Analyzer:
An electronic circuit which sorts and records pulses according to height or voltage.

Pulse Height Discriminator:
See Discriminator.

Pulse Height Selector:
A circuit designed to select and pass voltage pulses in a certain range of amplitudes.

Q

Q:
A unit used to express very large energy figures. One "Q" equals 10^{24} (a billion billion) British Thermal Units.

Quality Factor:
The linear energy transfer dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) and quantity that expresses (one common scale for all ionizing radiations) the effectiveness of the absorbed dose. (Abbreviated QF)

Quantum:
An observable quantity is said to be "quantized" when its magnitude is, in some or all of its range, restricted to a discrete set of values. It is equal to the product of the frequency of radiation of the energy and 6.6256×10^{-27} erg/sec. If the magnitude of the quantity is always a multiple of a definite unit, then that unit is called the quantum (of the quantity). For example, the quantum or unit of orbital angular momentum is h, and the quantum of energy of electromagnetic radiation of frequency v is hv. In field theories, a field (or the field equations) is quantized by application of a proper quantum-mechanical procedure. This results in the existence of a fundamental field particle, which may be called the field quantum. Thus, the photon is a quantum of the electromagnetic field and in nuclear field theories the meson is considered the quantum of the nuclear field.

Quantum Theory:
The statement, according to Max Plank, German physicist, that energy is not emitted or absorbed continuously, but in units or quanta. A corollary of this theory is that the energy of radiation is directly proportional to its frequency.

Quench:
To limit or stop the electrical discharge in an ionization detector.

Quenching Vapor:
Polyatomic gas used in Geiger-Mueller counters to quench or extinguish avalanche ionization.

R

Rad (Roentgen Absorbed Dose):
A measure of the dose of any ionizing radiation to any medium in terms of the energy absorbed per unit mass of medium. One rad is the dose corresponding to the absorption of 100 ergs per gram of any medium, 0.01 J/Kg.

Radiation:
1) The emission and propagation of energy through space or through a material medium in the form of waves, for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. 2) The energy propagated through space or through a material medium as waves, for example, energy in the form of electromagnetic waves or of elastic waves. The term radiation or radiant energy, when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified, according to frequency, as Hertzian, infrared, visible (light), ultra-violet, X-ray, gamma ray (see Photon). 3) By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, as cosmic radiation.

Annihilation Radiation:
Photons produced when an electron and a positron unite and cease to exist. The annihilation creates two photons, each of 0.51 MeV energy.

Background Radiation:
Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic or galactic rays and natural (terrestrial) radioactivity that is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Characteristic (Discrete) Radiation:
Radiation originating from an atom after removal of an electron or excitation of the nucleus. The wavelength of the emitted radiation is specific depending only upon the nuclide and particular energy levels involved.

External Radiation:
Radiation from a source outside the body. The radiation must penetrate the skin.

Internal Radiation:
Radiation from a source within the body (as a result of deposition of radionuclides in body tissues) e.g., barium for gastrointestinal and circulatory diagnostic tracing.

Ionizing Radiation:
Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

Leakage Radiation:
All radiation coming from the source housing except the useful beam.

Monochromatic Radiation:
Electromagnetic Radiation of a single wavelength, or radiation in which all the photons have the same energy, e.g., cesium-137.

Monoenergetic Radiation:
Radiation of a given type (alpha, beta, neutron, gamma, etc.) in which all particles of photons originate with and have the same energy.

Primary Radiation:
The useful beam of an X-ray tube.

Radiation Area:
Any accessible area in which the level of radiation is such that a major portion of an individual's body could receive in any one hour a dose in excess of 5 millirem, or in any five consecutive days a dose in excess of 100 millirem.

Radiation Burn:
Radiation damage to the skin. Beta burns result from prolonged skin contact with or exposure to emitters of beta particles. Flash burns result from sudden thermal radiation.

Radiation Chemistry:
The branch of chrmistry that is concerned with the chemical effects, including decomposition, of energetic radiation or particles on matter.

Radiation Damage:
A general term for the harmful effects of radiation on matter.

Radiation Detection Instruments:
Devices that detect and record the characteristics of ionizing radiation.

Radiation Illness:
An acute organic disorder that follows exposure to relatively severe doses of ionizing radiation. It is characterized by nausea, vomiting, diarrhea, blood cell changes, and in later stages, by hemorrhage, loss of hair, and brittle teeth.

Radiation Protection:
Legislation and regulations to protect the public and laboratory or industrial workers against radiation. Also, measures to reduce exposure to radiation.

Radiation Protection Guide:
The officially determined radiation doses which should not be exceeded without careful consideration of the reasons for doing so. These standards, established by the Federal Radiation Council, are equivalent to what was formerly called the maximum permissible dose, or maximum permissible exposure.

Radiation Shielding:
Reduction of radiation by interposing a shield of absorbing material between any radioactive source and a person, laboratory area, or radiation-sensitive device.

Radiation Standards:
Exposure standards, permissible concentrations, rules for safe handling, regulations for transportation, regulations for industrial control of radiation, and control of radiation exposure by legislative means.

Radiation Therapy:
Treatment of disease with any type of radiation.

Scattered Radiation:
Radiation which, during its passage through a substance, has been deviated in direction. It may also have been modified by a decrease in energy.

Secondary Radiation:
Radiation resulting from absorption of other radiation in matter. It may be either electromagnetic or particulate.

Radiation Machine:
Any device capable of producing radiation when the associated controls are operated, but excluding devices that produce radiation only by the use of radioactive material.

Radioactive Contamination:
Deposition of radioactive material in any place where it may harm persons, spoil experiments, or make products or equipment unsuitable or unsafe for some specific use. The presence of unwanted radioactive matter. Also, radioactive material found on the walls of vessels in used fuel processing plants, or radioactive material that has leaked into a reactor coolant. Often referred to only as contamination.

Radioactive Dating:
A technique for measuring the age of an object or sample of material by determining the ratios of various radioisotopes or products of radioactive decay it contains. For example, the ratio of carbon-14 or carbon-12 reveals the approximate age of bones, pieces of wood, or other archeological specimens that contain carbon extracted from the air at the time of their origin.

Radioactive Series:
A succession of nuclides, each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.

Radioactive Tracer:
A small quantity of radioactive isotope (either with carrier or carrier-free) used to follow biological, chemical, or other processes, by detection, determination, or localization of the radioactivity.

Radioactivity:
The property of substance which causes it to emit ionizing radiation. This property is the spontaneous transmutation of the atoms of the substance. It is measured in terms of disintegrations per unit time or in curies.

Artificial Radioactivity:
Man-made radioactivity produced by particle bombardment or electromagnetic irradiation, as opposed to natural radioactivity.

Induced Radioactivity:
Radioactivity produced in a substance after bombardment with neutrons or other particles. The resulting activity is "natural radioactivity" if formed by nuclear reactions occurring in nature, and "artificial radioactivity" if the reactions are caused by man.

Natural Radioactivity:
The property of radioactivity exhibited by more than fifty naturally occurring radionuclides.

Radiobiology:
The body of knowledge and the study of the principles, mechanisms, and effects of ionizing radiation on living matter.

Radiochemistry:
The body of knowledge and the study of the chemical properties and reactions of radioactive materials.

Radioecology:
The body of knowledge and the study of the effects of radiation on species of plants and animals in natural communities.

Radioelement:
An element containing one or more radioactive isotopes. A radioactive element.

Radiogenic:
Of radioactive origin. Produced by radioactive transformation.

Radiography:
The use of ionizing radiation for the production of shadow images on a photographic emulsion. Some of the rays (X-rays or gamma rays) pass through the subject, while others are partially or completely absorbed by the more opaque parts of the subject and thus cast a shadow on the photographic film.

Radioisotope:
A radioactive isotope. An unstable isotope of an element that decays or disintegrates spontaneously emitting radiation. More than 1300 natural and artificial radioisotopes have been identified.

Radioisotopic Generator:
A small power generator that converts the heat released during radioactive decay directly into electricity. These generators generally produce only a few watts of electricity and use thermoelectric or thermionic converters.

Radiology:
That branch of medicine which deals with the diagnostic and therapeutic applications of radiant energy including X-rays and radionuclides.

Radioluminescence:
Visible light caused by radiations from radioactive substances. An example is the glow from luminous paint containing radium and crystals of zinc sulfide, which give off light when struck by alpha particles from the radium.

Radiolysis:
The dissociation (or decomposition) of molecules by radiation. Example: A small proportion of water in a reactor core dissociates into hydrogen and oxygen during operation of the reactor.

Radiomimetic Substances:
Chemical substances which cause biological effects similar to those caused by ionizing radiation.

Radiomutation:
A permanent, transmissible change in form, quality, or other characteristic of a cell or offspring from the characteristics of its parent, due to radiation exposure.

Radioresistence:
Relative resistance of cells, tissues, organs, or organisms to the injurious action of radiation. The term may also be applied to chemical compounds or to any substances. (See Radiosensitivity.)

Radiosensitivity:
Relative susceptibility of cells, tissues, organs, organisms, or any living substance to the injurious action of radiation. Radioresistance and radiosensitivity are currently used in a comparative sense, rather than in an absolute one.

Radium:
A radioactive metallic element with atomic number 88. As found in nature, the most common isotope has an atomic weight of 226. It occurs in minute quantities associated with uranium in pitchblende, carnotite, and other minerals. The uranium decays to radium in a series of alpha and beta emissions. By virtue of being an alpha and gamma emitter, radium is used as a source of luminescence and as a radiation source in medicine and radiography. (Symbol Ra)

Radon:
A radioactive element, one of the heaviest gases known. Its atomic number is 86 and its atomic weight is 222. It is a daughter of radium in the uranium radioactive series. (Symbol Rn)

Radon Breath Analysis:
Examination of exhaled air for the presence of radon to determine the presence and quantity of radium in the human body.

Rare Earths:
A group of 15 chemically similar metallic elements, including Elements 57 through 71 on the Periodic Table of the Elements, also known as the Lanthanide Series.

Recombination:
The return of an ionized atom or molecule to the neutral state.

Recovery (Radiobiology):
The return toward normal of a particular cell, tissue, or organism after radiation injury.

Reflector:
A layer of material immediately surrounding a reactor core which scatters back or reflects into the core many neutrons that would otherwise escape. The returned neutrons can then cause more fissions and improve the neutron economy of the reactor. Common reflector materials are graphite, beryllium, and natural uranium.

Regulating Rod:
A reactor control rod used for making frequent fine adjustments in reactivity.

Relative Biological Effectiveness (RBE):
The RBE is a factor used to compare the biological effectiveness of absorbed radiation doses (i.e. rads) due to different types of ionizing radiation. More specifically, it is the experimentally determined ratio of an absorbed dose of a radiation in question to the absorbed dose of a reference radiation required to produce an identical biological effect in a particular experimental organism or tissue. NOTE: this term should not be used in radiation protection. (See Quality Factor.)

Rem (Roentgen Equivalent Man):
The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays. The dose (in rems) = QF x absorbed dose (in rads). Relationship of rem to R and rad: rem = R x QF = rad x QF; for X-ray and gamma: rem = R = rad x QF = 1.0.

Rep (Roentgen Equivalent Physical):
An obsolete unit of absorbed dose of any ionizing radiation, with a magnitude of 93 ergs per gram. It has been superseded by the rad.

Research Reactor:
A reactor primarily designed to supply neutrons or other ionizing radiation for experimental purposes. It may also be used for training, materials testing, and production of radioisotopes.

Resolving Time, Counter:
The minimum time interval between two distinct events which will permit both to be counted. It may refer to an electronic circuit, to a mechanical indicating device, or to a counter tube.

Resonance:
The phenomenon whereby particles such as neutrons exhibit a very high interaction probability with nuclei at specific kinetic energies of the particles. Cross-sections for neutron capture and scattering, for example, exhibit peaks at these so-called resonance energies and have relatively low values between the peaks. (This term is also applied to several other phenomena in physics.)

Restricted Area:
Any area to which access is controlled by the license for protection of individuals from exposure to radiation and radioactive materials. A restricted area shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

Rod:
A relatively long, slender body of material used in or in conjunction with a nuclear reactor. It may contain fuel, absorber, or material in which activation or transmutation is desired.

Roentgen:
A special unit of exposure. A term used to denote X-ray and gamma ray doses only. One roentgen is that amount of radiation that produces one electrostatic unit of charge of either sign per cubic centimeter of dry air at STP. This is equivalent to the production of 83 ergs per gram of dry air. R = 2.58 x 10^{4} coulomb per kilogram of air. (Abbreviated R)

Roentgenography:
Radiography by means of X-rays.

Roentgenology:
That part of radiology which pertains to X-rays.

Rutherford:
An obsolete unit of radioactivity equivalent to 10^6 disintegrations per second.

S

STP:
Standard Temperature and Pressure:

Scaler:
An electronic device which registers current pulses received over a given time interval.

Binary Scaler:
A scaler whose scaling factor is two per stage.

Decade Scaler:
A scaler whose scaling factor is a power of ten.

Scanner, Recilinear:
A device which employs a moving collimated detector and a moving recorder to produce an image of the radionuclide distribution within an organ or gland.

Scanning, Radioisotope:
A method of determining the location and amount of radioactive isotopes within the body by measurements taken with instruments outside the body. Usually the instrument, called a scanner, moves in a regular pattern over the area to be studied, or over the whole body, and makes a visual record.

Scattering:
Change of direction of subatomic particles or photons as a result of a collision or interaction.

Compton Scattering:
The scattering of a photon by an electron. Part of the energy and momentum of the incident photon is transferred to the electron and the remaining part is carried away by the scattered photon.

Elastic Scattering:
Scattering caused by elastic collisions, and therefore conserving kinetic energy of the system. Rayleigh scattering is a form of elastic scattering.

Inelastic Scattering:
The type of scattering which results in the nucleus being left in an excited state and the total kinetic energy being decreased.

Multiple Scattering:
Scattering of a particle or a photon in which the final displacement is the vector sum of many, usually small, displacements.

Plural Scattering:
Scattering of a particle or a photon in which the final deflection is the vector sum of a small number of displacements.

Rayleigh Scattering:
The elastic scattering of a photon without loss of photonic energy. Sometimes referred to as coherent scattering.

Single Scattering:
The deflection of a particle from its original path owing it to encounter with a single scattering center in the material traversed.

Scattering Coefficient, Compton:
That fractional decrease in the energy of a beam of X-ray or gamma radiation in an absorber due to the energy carried off by scattered photons in the Compton effect.

Scavenging:
In chemistry, the use of a non-specific precipitate to remove one or more undesirable radionuclides from solution by absorption or coprecipitation. In atmospheric physics, the removal of radionuclides from the atmosphere by the action of rain, snow, or dew.

Scintillation:
A flash of light produced in a phosphor by an ionizing event.

Scintillation Camera:
A device for visualizing the spatial distribution of a radionuclide within an organ or gland in the body. The gamma camera uses a stationary sodium iodine (NaI) crystal as the detection element. Positioning signals are generated from a bank of photomultiplier tubes and applied to a cathode ray tube. Counts are integrated on film to obtain an image of the radionuclide distribution.

Scintillation Counter:
An instrument that detects and measures ionizing radiation by counting the light flashes (scintillations) caused by radiation imprinting on certain materials (phosphors).

Scram:
The sudden shutdown of a nuclear reactor, usually by rapid insertion of the safety rods. Emergencies or deviations from normal reactor operation cause the reactor operator or automatic control equipment to scram the reactor.

Sealed Source:
A radioactive source sealed in an impervious container which has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

Series, Radioactive:
A succession of nuclides, each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the "parent", the intermediate members are called "daughters", and the final stable member is called the "end product".

Shell:
One of a series of concentric spheres, or orbits, at various distances from the nucleus, in which, according to atomic theory, electrons move around the nucleus of an atom. The shells are designated, in the order of increasing distance from the nucleus, as the k, l, m, n, o, p, and q shells. The number of electrons which each shell can contain is limited. Electrons in each shell have the same energy level and are further grouped into subshells.

Shield:
A body of material used to prevent or reduce the passage of particles or radiation. A shield may be designated according to what it is intended to absorb (as a gamma ray shield or neutron shield) or according to the kind of protection it is intended to give (as a background, biological, or thermal shield). The shield of a nuclear reactor is a body of material surrounding the reactor to prevent the escape of neutrons and radiation into a protected area, which frequently is the entire space external to the reactor. It may be required for the safety of personnel or to reduce radiation enough to allow use of counting instruments for research or for locating contamination or airborne radioactivity.

Slow Neutron:
A thermal neutron.

Softness:
A relative specification of the quality or penetrating power of X-rays. In general, the longer the wavelength, the softer the radiation.

Somatic Effects of Radiation:
Effects of radiation limited to the exposed individual, as distinguished from genetic effects (which also affect subsequent, unexposed generations). Large radiation doses can be fatal. Smaller doses may make the individual noticeably ill, may merely produce temporary changes in blood cell levels detectable only in the laboratory, or may produce no detectable effects whatever. Also called physiological effects of radiation.

Source:
Usually a man-made sealed source of radioactivity used in teletherapy, radiography, as a power source for batteries, or in various types of industrial gauges. Machines such as accelerators and radioisotopic generators, and natural radionuclides may also be considered as sources.

Source Material:
Natural or depleted uranium or natural thorium, or any combination thereof, in any physical or chemical form, or ores which contain 0.05% by weight or more of uranium, thorium, or any combination thereof. Source material does not include special nuclear material.

Spallation:
A term used to denote a nuclear reaction induced by high energy bombardment and involving the ejection of more than two or three particles (neutrons, protons, deuterons, alpha particles, etc.)

Spark Chamber:
An instrument for detecting and measuring the paths of elementary particles. It is analogous to the cloud chamber and bubble chamber. It consists of numerous electrically charged metal plates mounted in a parallel array, the spaces between the plates being filled with an inert gas. Any ionizing event causes sparks to jump between the plates along the radiation path through the chamber.

Special Nuclear Material:
In atomic energy law, this term refers to plutonium-239, uranium-233, uranium containing more than the natural abundance of uranium-235, or any material artificially enriched in any of these substances.

Special (or Restricted) Theory of Relativity:
A theory developed by Albert Einstein in 1905 that is of great importance in atomic and nuclear physics. It is especially useful in studies of objects moving with speeds approaching the speed of light. Two of the results of the theory with specific application in nuclear physics are the statements: 1) that the mass of an object increases with its velocity; and 2) that mass and energy are equivalent.

Species:
A particular kind of atomic nucleus, atom, molecule, or ion. A nuclide.

Specific Activity:
Total activity of a given nuclide per gram of a compound, element, or radioactive nuclide.

Specific Gamma Ray Constant:
For a nuclide emitting gamma radiation, the product of exposure rate at a given distance from a point source of that nuclide and the square of that distance divided by the activity of the source, neglecting attenuation.

Specific Ionization:
The number of ion pairs formed per unit of distance along the track of an ion passing through matter.

Spectrum:
A visual display, a photographic record, or a plot of the distribution of the intensity of a given type of radiation as a function of its wavelength, energy, frequency, momentum, mass, or any related quantity.

Spent (Depleted) Fuel:
Nuclear reactor fuel that has been irradiated (used) to the extent that it can no longer effectively sustain a chain reaction.

Spill:
The accidental release of radioactive material.

Spontaneous Fission:
Fission that occurs without an external stimulus. Several heavy isotopes decay mainly in this manner, e.g. californium-252 and californium-254. The process occurs occasionally in all fissionable materials, including uranium-235.

Stable:
Incapable of spontaneous change. Not radioactive or with a half-life greater than 1×10^{10} years.

Stable Isotope:
An isotope that does not undergo radioactive decay.

Standard, Radioactive:
A sample of radioactive material, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known. It may be used as a radiation source for calibrating radiation measurement equipment.

Statcoulomb (Electrostatic Unit of Charge):
That quantity of electric charge which, when placed in a vacuum one cm distant from an equal and like charge, will repel it with a force of one dyne. (Abbreviated esu) Preferred name for this unit is franklin. (Abbreviated Fr)

Sterility, Biological:
Temporary or permanent incapability to reproduce.

Sterilization:
Use of radiation to cause a plant or animal to become sterile, that is, incapable of reproduction. Also the use of radiation to kill all forms of life (especially bacteria) in food, surgical sutures, animal pelts, etc.

Stopping Power:
A measure of the effect of a substance upon the kinetic energy of a charged particle passing through it.

Strange Particles:
A class of very short lived elementary particles that decay more slowly than they are formed, indicating that the production process and decay process result from different fundamental reactions. They include K-mesons and hyperons.

Stray Radiation:
The sum of leakage and scattered radiation.

Stress Corrosion:
Chemical corrosion, such as of reactor pressure vessels, that is accelerated by stress concentrations either built into or resulting from a load.

Subatomic Particle:
Any of the constituent particles of an atom: an electron, neutron, proton, etc. Present theory proposes there may be as many as 250 subatomic constituents.

Subcritical Assembly:
A reactor consisting of a mass of fissionable material and moderator whose effective multiplication factor is less than one and that hence cannot sustain a chain reaction. Used primarily for educational purposes.

Subcritical Mass:
An amount of fissionable material insufficient in quantity or of improper geometry to sustain a fission chain reaction.

Subcritical Reactor:
A subcritical assembly.

Supercritical Mass:
A mass of fuel whose effective multiplication factor is greater than one.

Surface Contamination:
The deposition and attachment of radioactive materials to a surface.

Survey Meter:
Any portable radiation detection instrument especially adapted for surveying or inspecting an area to establish the existence and amount of radioactive material present.

Survey, Radiological:
Evaluation of the radiation hazards incident to the production, use, or existence of radioactive materials or other sources of radiation under specific conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

Survival Curve:
A curve obtained by plotting the number or percentage of organisms surviving at a given time against the dose of radiation, or the number surviving at different intervals after a particular dose of radiation.

Synchrocyclotron:
A cyclotron in which the frequency of the accelerating voltage is decreased with time so as to match exactly the slowing revolutions of the accelerated particles. The decrease in rate of acceleration of the particles results from the increase of mass with energy as predicted by the Special Theory of Relativity.

Synchrotron:
An accelerator in which particles are accelerated around a circular path by radio-frequency electric fields. The magnetic guiding and focusing fields are increased synchronously to match the energy gained by the particles so that the orbit radius remains constant.

Syndrome:
The complex of symptoms associated with any disease.

Systems for Nuclear Auxiliary Power:
An NRC program to develop small auxiliary nuclear power sources for specialized space, land, and sea uses. Two approaches are employed: the first uses heat from radioisotope decay to produce electricity directly by thermoelectric or thermio.ic methods; the second uses heat from small reactors to produce electricity by thermoelectric or thermionic methods or by turning a small turbine and electric generator. (Acronym SNAP)

T

T.I. :
Transportation Index is measured radiation level in mr/hr at one meter (39") from surface of source head.

Tag:
See Tracer, Isotopic.

Tails:
See Depleted Uranium.

Target:
Material subjected to particle bombardment (as in an accelerator) or irradiation (as in a research reactor) in order to induce a nuclear reaction. Also, a nuclide that has been bombarded or irradiated.

Teletherapy:
Radiation treatment administered by using a source that is at a distance from the body, usually employing gamma ray beams from radioisotope sources.

Test Reactor:
A reactor specially designed to test the behavior of materials and components under the neutron and gamma fluxes and temperature conditions of an operating reactor.

Therapy:
Medical treatment of a disease.

Brachytherapy (Therapy at Short Distances):
The treatment of disease with sealed radioactive sources placed near, or inserted directly into, the diseased area.

Contact Radiation Therapy:
X-ray therapy with specially constructed tubes in which the target skin distance is very short (less than 2 cm). The voltage is usually 40 to 60 kV.

Radiation Therapy:
Treatment of disease with any type of radiation.

Rotation Therapy:
Radiation therapy during which either the patient is rotated before the source of radiation or the source is revolved around the patient. In this way, a larger dose is built up at the center of rotation within the patient's body than on any area of the skin.

Teletherapy (Therapy at Long Distance):
The treatment of disease with gamma radiation from a source located at a distance from the patient.

Thermal Column:
A channel built into some research reactors to supply thermal neutrons for experimental purposes. It consists of a large body of moderator located adjacent to the core or reflector. Neutrons escaping from the reactor enter the thermal column where they are slowed down to thermal energies with velocities of about 2200 meters per second.

Thermal Neutron:
A neutron in thermal equilibrium with its surrounding medium. Thermal neutrons are those that have been slowed down by a moderator to an average speed of about 2200 meters per second, at room temperature, from the much higher initial speeds they had when expelled by fission. This velocity is similar to that of gas molecules at ordinary temperatures.

Thermal Radiation:
Electromagnetic radiation emitted from the fireball produced by a nuclear explosion. Thirty-five percent of the total energy of a nuclear explosion is emitted in the form of thermal radiation, as light, and as ultraviolet and infrared radiation.

Thermal Reactor:
A reactor in which the fission chain reaction is sustained primarily by thermal neutrons. Most reactors are thermal reactors.

Thorium:
A naturally radioactive element with atomic number 90 and, as found in nature, an atomic weight of approximately 232. The fertile thorium-232 isotope is abundant and can be transmuted to fissionable uranium-233 by neutron irradiation.

Thorium Series (Sequence):
The series of nuclides resulting from the radioactive decay of thorium-232. Many man-made nuclides decay into this sequence. The end product of this sequence in nature is lead-208.

Threshold Dose:
The minimum dose of radiation that will produce a detectable biological effect.

Threshold, Photoelectric:
The quantum of energy $h\nu_0$ that is just enough to release an electron from a given system in the photoelectric effect. The corresponding frequency, ν_0, and wavelength, λ_0, are the threshold frequency and wavelength respectively. For example, in the surface photoelectric effect, the threshold $h\nu_0$ for a particular surface is the energy of a photon, which, when incident on the surface, causes the electron to emerge with zero kinetic energy.

Time-Of-Flight Spectrometer:
A device for separating and sorting neutrons (or other particles) into categories of similar energy, measured by the time it takes the particles to travel a known distance.

Tissue Equivalent Material:
Material made up of the same elements in the same proportions as they occur in a particular biological tissue. In some cases, the equivalence may be approximated with sufficient accuracy on the basis of effective atomic number.

Tracer, Isotopic:
An isotope of an element, a small amount of which may be incorporated into a sample of material (the carrier) in order to follow (trace) the course of that element through a chemical, biological, or physical process, and thus also follow the larger sample. The tracer may be radioactive, in which case observations are made by measuring the radioactivity. If the tracer is stable, mass spectrometers, density measurement, or neutron activation analysis may be employed to determine isotopic composition. Tracers are also called labels or tags, and materials are said to be labeled or tagged when radioactive tracers are incorporated in them.

Track:
Visual manifestation of the path of an ionizing particle in a chamber or photographic emulsion.

Transformation, Nuclear:
Transmutation.

Transmutation:
Any process in which a nuclide is transformed into a different nuclide, or more specifically, when transformed into a different element by a nuclear reaction.

Transplutonium Element:
An element above plutonium in the Periodic Table, that is, one with an atomic number greater than 94.

Transuranic Element (Isotope):
An element above uranium in the Periodic Table, that is, with an atomic number greater than 92. All eleven transuranic elements are produced artificially and are radioactive. They are: neptunium, plutonium, americium, curcium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, and lawrencium.

Tritium:
The hydrogen isotope with one proton and two neutrons in the nucleus. It is man-made and is heavier than deutrium (heavy hydrogen). Tritium is used in industrial thickness gauges and as a label in experiments in chemistry and biology. Its nucleus is a triton.

Triton:
The nucleus of tritium, the hydrogen isotope of mass number 3, used as a nuclear projectile or as a product of a nuclear reaction.

Tube, Boron Counter:
A counter tube filled with the boron trifluoride (BF_3) and/or having electrodes coated with boron or boron compounds used for detecting slow neutrons by the n,α reaction of boron-10 (^{10}B).

Tube, Electron Multiplier:
A tube in which small electron currents are amplified by a cascade process employing secondary emission.

Tube, Photomultiplier:
An electron multiplier tube in which the electrons initiating the cascade originate by photoelectric emission.

Tumor:
In its general sense, a swelling. The term is often synonymous with neoplasm. A malignant tumor is capable of metastasizing.

U

Unstable Isotope:
A radioisotope.

Uranium:
A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7% of natural uranium), which is fissionable, and uranium-238 (99.3% of natural uranium), which is fertile. Natural uranium also includes a minute amount of uranium-234. Uranium is the basic raw material of nuclear energy. (Symbol U)

Uranium Hexafluoride:
A volatile compound of uranium and fluorine. UF_6 gas is the process fluid in the gaseous diffusion process. (Symbol UF_6)

Uranium Series:
The series of nuclides resulting from the radioactive decay of uranium-238, also known as the uranium-radium series. The end product of the series is lead-206. Many man-made nuclides decay into this sequence.

Uranium Tetrafluoride:
A solid green compound called green salt. An intermediate product is the production of uranium hexafluoride. (Symbol UF_4)

Uranium Trioxide:
An intermediate product in the refining of uranium, also called orange oxide.

V

Valence:
Number representing the combining or displacing power of an atom. Number of electrons lost, gained, or shared by an atom in a compound. Number of hydrogen atoms with which an atom will combine, or which it will displace.

Van de Graaff Generator (Accelerator):
An electrostatic machine in which electrically charged particles are sprayed on a moving belt and carried by it to build up a high potential on an insulated terminal. Charged particles are then accelerated along a discharge path through a vacuum tube by the potential difference between the insulated terminal and the opposite end of the machine. A Van de Graaff accelerator is often used to inject particles into larger accelerators. Named after R. S. Van de Graaff, who invented the device in 1931.

Volt:
The unit of electromotive force (1V = 1W/1A).

Voltage, Operating:
As applied to radiation detection instruments, the voltage across the electrodes in the detecting chamber required for proper detection of an ionizing event.

Voltage, Starting:
For a counter tube, the minimum voltage that must be applied to obtain counts with the particular circuit with which it is associated.

Volume, Sensitive:
That portion of a counter tube or ionization chamber which responds to a specific radiation.

W

Warning Symbol:
An officially prescribed symbol (a magenta trefoil on a yellow background) which should always be displayed when a radiation hazard exists.

Waste, Radioactive:
Equipment and materials (from nuclear operations) which are radioactive and for which there is no further use. Wastes are generally classified as high-level (having radioactivity concentrations of hundreds to thousands of curies per gallon or cubic foot), low-level (in the range of one microcurie per gallon or cubic foot), or intermediate (between these extremes).

Watt:
The unit of power equal to one joule per second (1W = 1J/1s).

Wavelength:
Distance between any two similar points of two consecutive waves (λ) for electromagnetic radiation. The wavelength is equal to the velocity of light (c) divided by the frequency of the wave (v), $\lambda = c/v$. The "effective wavelength" is the wavelength of monochromatic X-rays which would undergo the same percentage attenuation in a specified filter as the heterogeneous beam under consideration.

Whole Body Counter:
A device used to identify and measure the radiation in the body (body burden) of humans and animals. It uses heavy shielding to keep out background radiation and ultrasensitive scintillation detectors and electronic equipment.

X

X-ray:

A penetrating form of electromagnetic radiation emitted either when the inner orbital electrons of an excited atom return to their normal state (these are characteristic X-rays), or when a metal target is bombarded with high speed electrons (these are bremsstrahlung). X-rays are always non-nuclear in origin.

Y

Yield:

The total energy related in a nuclear explosion. It is usually expressed in equivalent tons of TNT (the quantity of TNT required to produce a corresponding amount of energy). Low yield is generally considered to be less than twenty kilotons; low intermediate yield from twenty to 200 kilotons; intermediate yield from 200 kilotons to one megaton. There is no standardized term to cover yields from one megaton upward.

Z

Zero-Power Reactor:

An experimental reactor operated at such low power levels that a coolant is not needed and little radioactivity is produced.