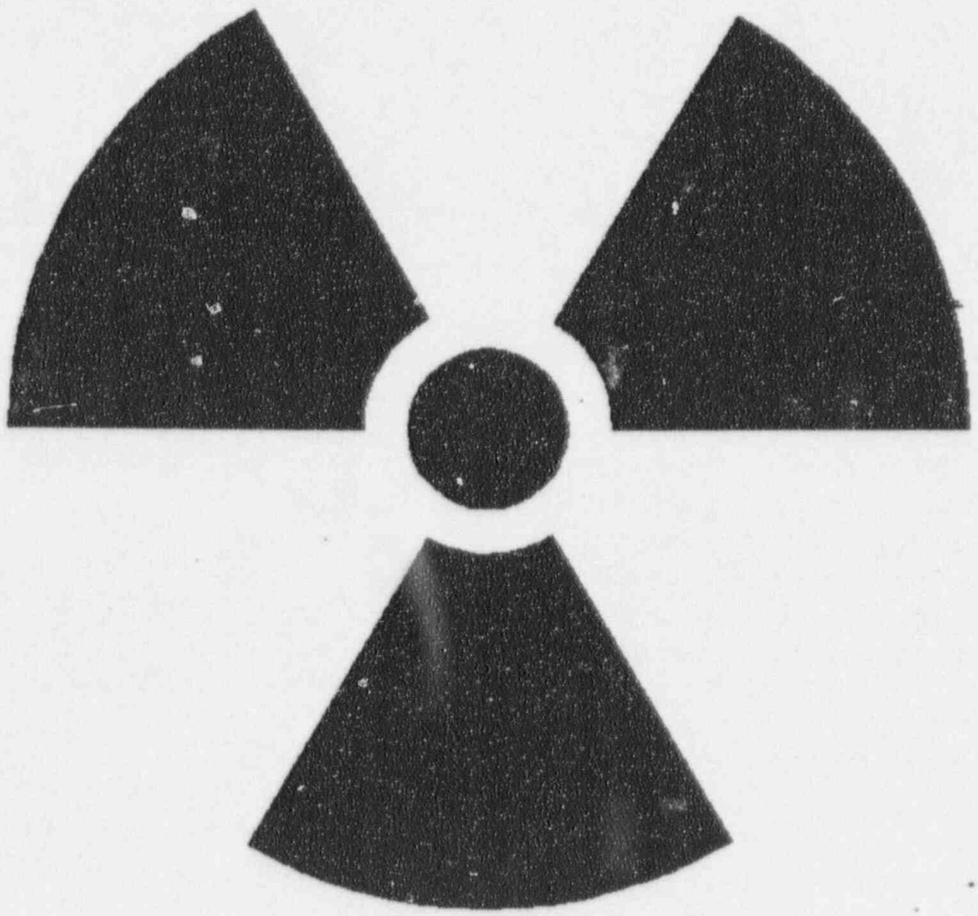
Radiation Worker Training Course



Presented by

FOSTER WHEELER

FOSTER WHEELER ENVIRONMENTAL CORPORATION

10900 NE 8th Street
Bellevue, WA 98004

MODULE 1: INTRODUCTION

LEARNING OBJECTIVES: Each module will list learning objectives. These objectives represent the minimum amount of information that should be gathered by the student. The instructor and the written material will:

1. DEFINE the learning objectives
2. COVER the material in the handout
3. AUGMENT the handout material with additional information
4. ENTERTAIN questions throught the classroom instruction
5. REVIEW the salient concepts covered in the module

I. OVERALL OBJECTIVE

The overall objective of this training manual is to provide the student adequate information to allow him to perform work in an area with radiation and radioactive material in a safe manner.

II. LEARNING MATERIALS

The material in this manual is meant to be an overview of the topics covered here, with additional detail provided during classroom instruction. This manual, couple with the classroom training is to be concidered as a tool for the worker to ensure that the overall objective of the training is met.

Trainee's Notes:

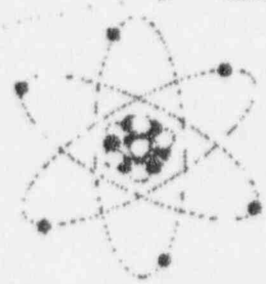
MODULE 2: ATOMIC STRUCTURE AND RADIOACTIVITY

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. DEFINE atom and identify the basic subatomic particles.
2. IDENTIFY neutrons, protons, and electrons.
3. DEFINE the structure of an atom and electrical balance.
4. INTRODUCE the concept of isotopes and naturally occurring isotopes
5. DESCRIBE the chart of the nuclides and how the radiation worker can use it.
6. IDENTIFY the elements, symbols, and atomic numbers.
7. DEFINE radioactivity, stable nuclides, and radioactive nuclides

I. ATOMIC STRUCTURE

A. Atoms are defined as the smallest part of an element that still retains the chemical properties of that element. Atoms themselves are composed primarily of three subatomic particles: protons, neutrons, and electrons.



B. Protons and neutrons are relatively heavy particles (on the atomic scale) and have approximately the same mass (about 1.67 x 10-24 gram). The electron is a much lighter particle with a mass about 1/1800 that of a proton or neutron, and carries an electric charge of -1. Protons carry an electric charge of + 1. The number of protons (called the atomic number, symbol Z) contained in an atom determines the element, and hence the chemical characteristics of that atom. Neutrons have no electric. The interaction between

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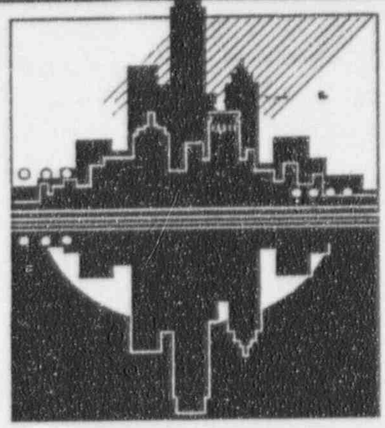
protons and neutrons supplies the force that keeps the nucleus together. Due to the repelling nature or the positively charged protons, the nucleus would tend to fly apart without this strong nuclear force.

C. All atoms have the same general structure. At the center is a nucleus in which almost all the mass of the atom is concentrated. Circling the nucleus in set orbits are the electrons. The electrons are arranged in shells which increase in energy as they move farther away from the nucleus. Tightly bound neutrons and protons (collectively called nucleons) make up the nucleus, which has a diameter of about 1/10,000 that of the atom itself. The actual diameter of a typical atom is about 0.00000001 centimeter. The atomic mass number (symbol A) represents the total number of neutrons and protons within the nucleus. The symbol N represents the number of neutrons present and is found by subtracting Z from A.

Did You Know?

If the nucleus of an atom was the size of a baseball, then the electrons would have an orbit the size of New York City.



D. Most of the objects encountered in everyday life are electrically neutral. Therefore the atoms that make up these objects must themselves be neutral. Since electrons and protons both contain electrical charges, differing only in sign, atoms must have the same number of protons and electrons; that is, they are electrically balanced (neutral). The number of neutrons an atom possesses has no effect on its charge.

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II. ISOTOPES

A. Any element may occur with different numbers of neutrons in its atoms. For example, the element potassium has an atomic number of 19 (each atom has 19 protons), but it occurs with differing numbers of neutrons. These different forms are called isotopes of potassium. In fact there are actually 19 different isotopes of potassium, 16 of which are radioactive.

B. Most elements occur naturally as a mixture of isotopes, each isotope having a certain percent abundance. For example, the radioactive potassium isotope, K-40, occurs in nature with a 0.0117 percent abundance. The most common isotope of potassium, K-39, has an abundance of 93.2581 percent. This means that if you extracted one kilogram (1,000 grams) of natural potassium from an average area of soil and rock, that sample would contain about 0.117 grams of radioactive K-40. Isotopes may also be produced by bombarding a naturally occurring isotope with nuclear particles in an accelerator or a nuclear reactor.

III. CHART OF THE NUCLIDES

A. The characteristics of all known isotopes have been summarized in a widely published table know as the Chart of the Nuclides. Radiation workers can use this chart to gather specific information about isotopes present in the workplace. The terms isotope and nuclide are essentially interchangeable.

B. Each isotope (nuclide) on the chart occupies a square with at least the following relevant data available: element name, atomic number and mass, percent natural abundance. If the nuclide is radioactive, the half-life, decay modes, and decay energies are listed.

IV. RADIOACTIVITY

A. Radioactivity may be defined as spontaneous nuclear transformations that result in the formation of new elements. These transformations are accomplished by one of several different mechanisms, including alpha particle emission, beta particle and positron emission, and orbital electron capture. These reactions may also be accompanied by

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gamma radiation. In the field of radiation protection, we are concerned with processes that result in the emission of any of four types of ionizing radiation.

B. Whether or not a nuclide is radioactive depends primarily upon the neutron-to-proton ratio within the nucleus. Stable atoms have a neutron-to-proton ratio close to 1.0 for low mass nuclei, and about 1.5 for the heaviest elements. If a graph is made of the number of protons versus the number of neutrons for stable nuclei, a curve can be established. This is known as the "line of stability" and can be seen on the Chart of the Nuclides.

C. Stable isotopes lie within a narrow range of this line, indicating that the neutron-proton ratio must lie within certain limits for a nucleus to be stable. The majority of radioactive isotopes lie outside this range of stability; most radioactive nuclei have either too many or too few neutrons compared to the number of protons they contain.

D. Radioactive nuclei want to become stable, seeking the ideal neutron-proton ratio. One example of this is when tritium changes to helium-3 (beta decay, neutron changes to a proton).

E. Each isotope undergoes radioactive transformation, or radioactive decay, at a unique rate. The time it takes for one-half of the atoms of a certain isotope to undergo radioactive decay is known as the half-life. A decay constant, unique to each isotope, can be used to estimate the amount of radioactive material present at any given time.

Radioactive Decay

$$N_t = N_0 \bullet e^{-\lambda \cdot t}$$

N_t is the number of atoms of the isotope at a given time t, N_0 is a known number of atoms of the isotope at a time set as zero, and λ is the radioactive decay constant for the isotope. The decay constant is equal to the ratio of the natural logarithm of 2 to the half-life for the isotope.

Radioactive Decay Constant

$$\lambda = \ln(2)/T_{1/2}$$

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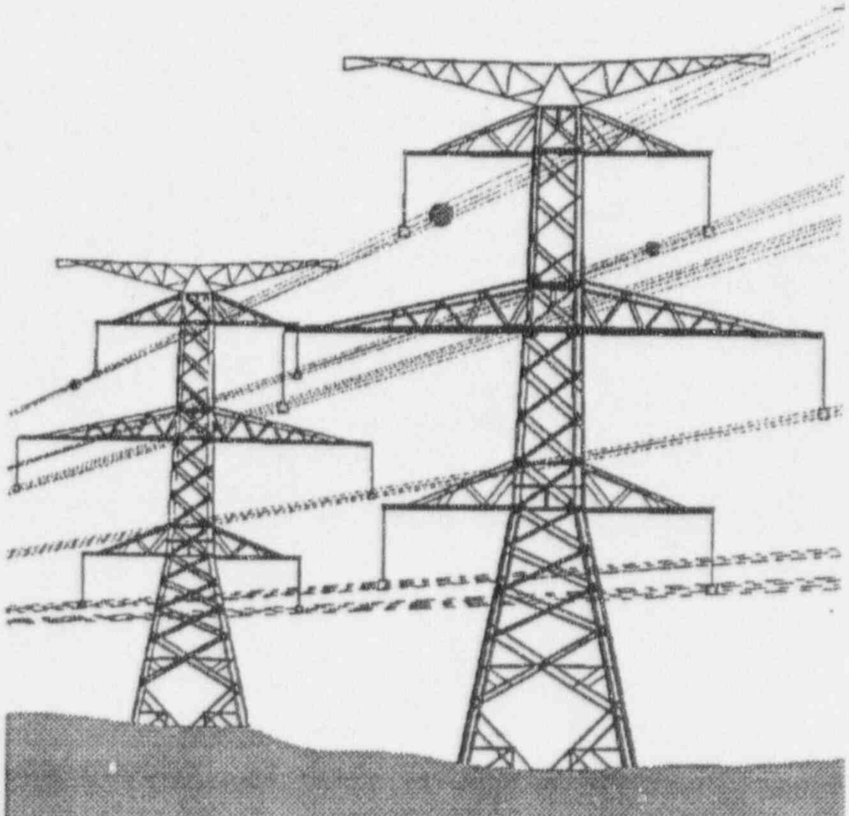
F. The two general categories of ionizing radiation are particulate (alpha, neutron, beta), where subatomic particles with mass are ejected from the nucleus, and electromagnetic (X-rays and gamma), which consists of small packets of energy called photons.

G. In addition to ionizing radiation, there is non ionizing radiation. Nonionizing radiation is similar to x- and gamma radiation, *i.e.*, it is electromagnetic radiation. However, nonionizing radiation interacts differently with matter as compared to ionizing radiation. The interaction of radiation with matter is discussed in a subsequent module. Examples of nonionizing radiation include radio waves, microwaves, lasers, and electromagnetic fields around power lines and appliances.



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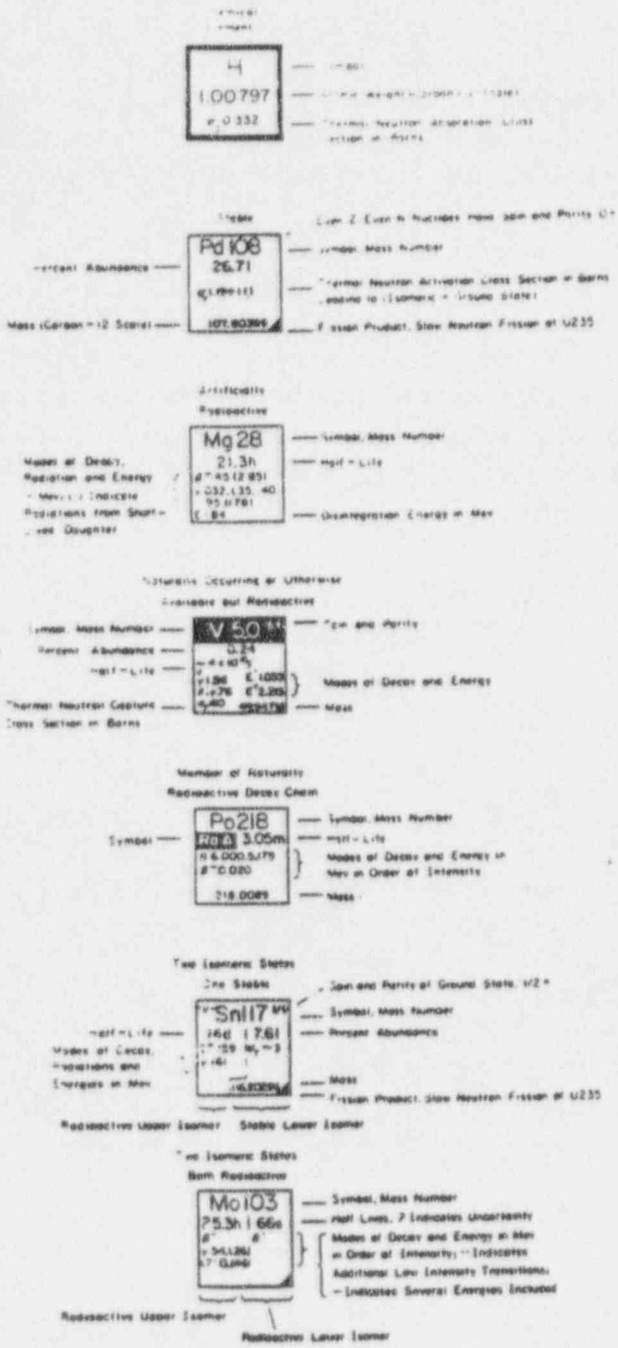
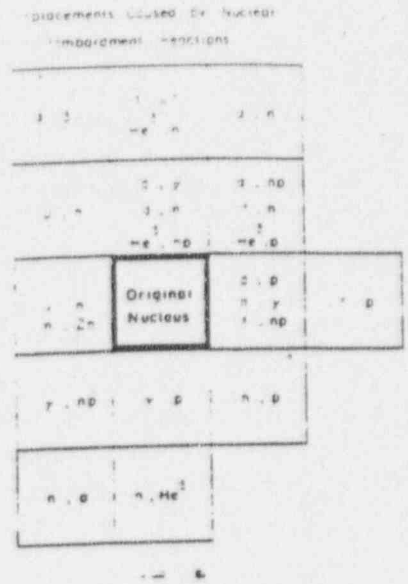
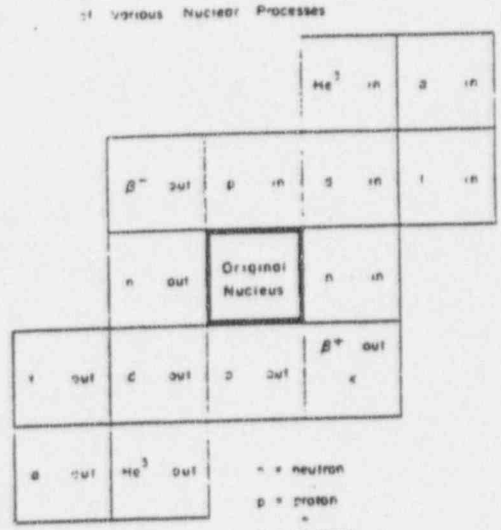




Relative Locations of the Products of Various Nuclear Processes



n = neutron
p = proton
d = deuteron
t = triton (H^3)
α = alpha particle
β^- = negative electron
β^+ = positron
ε = electron capture

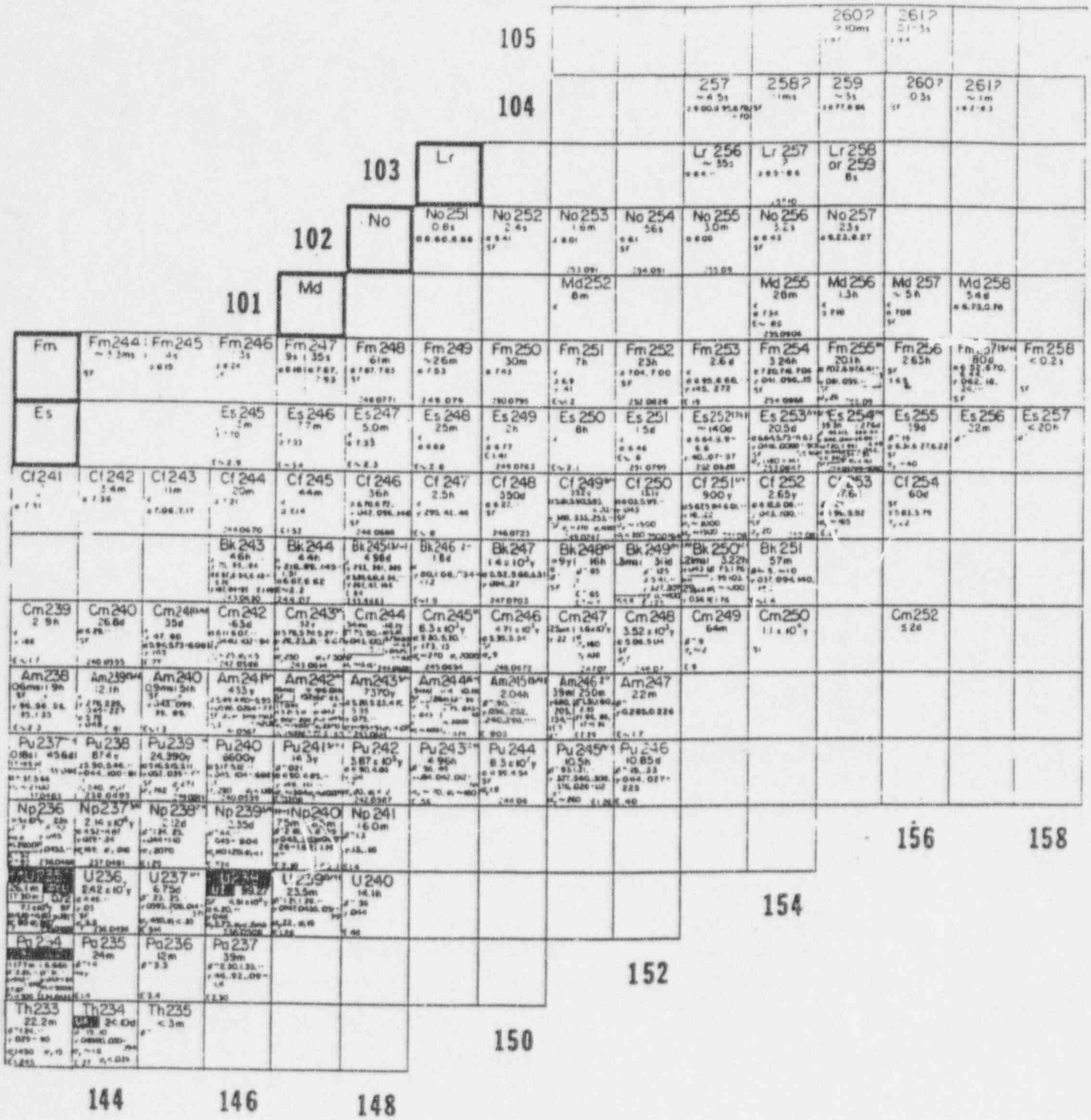
SYMBOLS

TIME

ms	miliseconds	(10^{-3} s)
μs	microseconds	(10^{-6} s)
s	seconds	
m	minutes	
h	hours	
d	days	
y	years	

RADIATIONS AND DECAY

α	alpha particle	ε	electron capture
β^-	negative electron	IT	isomeric transition
β^+	positron	D	radiation delayed
γ	gamma ray	SF	spontaneous fission
n	neutron	E	disintegration energy
p	proton	e^-	conversion electron



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MODULE 3: TYPES, CHARACTERISTICS, AND SOURCES OF IONIZING RADIATION

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses which verifies his/her ability to:

1. DESCRIBE the types of radiation including alpha, beta, gamma (and x-ray) and neutrons.
2. IDENTIFY the characteristics of ionizing radiation.
3. DEFINE the relative penetrating ability in tissue of the types of ionizing radiation.
4. IDENTIFY the sources of natural and manmade radiation.
5. STATE the total average dose per year to U.S. citizens from background (natural and manmade sources).
6. DISTINGUISH between ionizing and nonionizing radiation.
7. IDENTIFY the categories of ionizing radiation.

I. TYPES OF IONIZING RADIATION

The four basic types of ionizing radiation of concern in the nuclear industry are alpha particles, beta particles, gamma rays (and x-rays) and neutrons.

A. Alpha Particles consists of 2 protons and 2 neutrons. The alpha particle is the most massive of the particulate radiation. An alpha particle carries a charge of +2, travels a few inches in air, and will not penetrate the dead layer of skin.

Physical Characteristics. The alpha particle has a large mass and consists of two protons, two neutrons and no electrons. (Positive charge of plus two.) It is a highly charged particle that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (-) from nearby atoms as it passes through the material, thus ionizing these atoms.

Range. The alpha particle deposits a large amount of energy in a short distance of travel. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about one to two inches.

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Shielding. Most alpha particles are stopped by a few centimeters of air, a sheet of paper, or the dead layer (outer layer) of skin.

Biological Hazard. Alpha particles are not considered an external radiation hazard. This is because they are easily stopped by the dead layer of skin. Should an alpha emitter be inhaled or ingested, it becomes a source of internal exposure. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

B. Beta Particles

Physical Characteristics. The beta particle has a small mass and is negatively or positively charged. It is emitted from the nucleus of an atom and has an electrical charge of plus or minus one. Beta radiation causes ionization by displacing electrons from their orbits. The beta particle is physically identical to an electron. Ionization occurs due to the repulsive force between the beta particle (-) and the electron (-), which both have a charge of minus one, or the combination of an electron with a positron, ionizing an atom and creating two annihilation gamma photons of 0.51 MeV.

Range. Because of its single negative or positive charge, the beta particle has a limited penetrating ability. Range in air is about ten feet.

Shielding. Most beta particles are shielded by plastic, glass, metal foil, or safety glasses.

Biological Hazard. If ingested or inhaled, a beta emitter can be an internal hazard due to its short range. Externally, beta particles are potentially hazardous to the skin and eyes.

C. Gamma Rays and X-Rays

Physical Characteristics. Gamma/X-ray radiation is an electromagnetic wave or photon and has no electrical charge. Gamma rays are very similar to X-rays. The only difference is in the place of origin. Gamma/X-ray radiation can ionize as a

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result of direct interactions with orbital electrons. The energy of the gamma/X-ray radiation is transmitted directly to its target.

Range. Because gamma/X-ray radiation have no charge and no mass, they have a very high penetrating power. Range in air is very far. It will easily go several hundred feet.

Shielding. Gamma/X-ray radiation are best shielded by very dense materials such as concrete, lead, or steel.

Biological Hazard. Gamma/X-ray radiation can result in radiation exposure to the whole body.

Gamma rays are emitted from a radioactive atom when the nucleus has too much internal energy. Consider the nucleus as being like a light bulb. When there is no electricity, the light bulb is in a "stable" state. When the light switch is turned on, the light comes on, and the excess energy is radiated in all directions as visible light. The process is very similar with gamma emission. An excited nucleus needs to release this excess energy by radioactive decay. Often the result is a gamma ray. Alpha and beta emission alone do not always release enough energy for the nucleus to become stable. Because of this, most of the nuclides in the uranium decay chains also emit gamma radiation.

D. Neutron Particles

Physical Characteristics. Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. Due to their neutral charge, neutrons interact with matter either directly or indirectly. A direct interaction occurs as the result of a collision between a neutron and a nucleus. A charged particle or other ionizing radiation may be emitted during these interactions which can cause ionization in human cells.

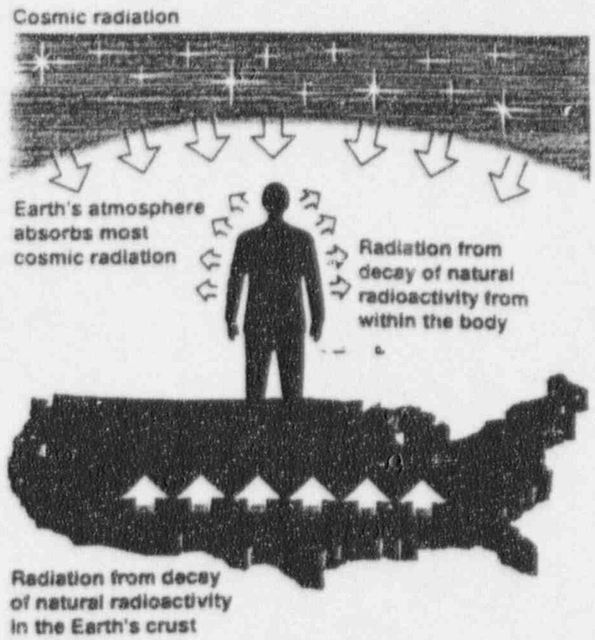
Range. Because of the lack of a charge, neutrons have a relatively high penetrating ability and are difficult to stop. Range in air is very far. Like gamma rays, they can easily travel several hundred feet in air.

Shielding. Neutron radiation is best shielded by materials with a high hydrogen content, such as water or plastic.

Trainee's Notes:

Biological Hazard. Neutrons are a whole body hazard due to their high penetrating ability.

II. SOURCES OF RADIATION



A. Man has always been exposed to naturally occurring ionizing radiation. The radiation that occurs naturally in man's environment is referred to as natural background radiation. The natural background of ionizing radiation received by man is comprised of cosmic rays and radiation from naturally occurring radionuclides in the environment (which may be absorbed via food commodities and are found to a varying degree within the body). There are some 40 naturally occurring radioelements and about twice this number of naturally occurring radioisotopes.

Cosmic radiation is a significant contributor to natural radiation absorbed dose. Cosmic radiation comes from the sun and outer space and consists of high-energy charged particles. At the outer limits of the earth's atmosphere, the composition of cosmic rays is 87 percent protons and 11 percent alpha particles, while the remaining two percent consists of other light nuclei.

Most of the exposure that we receive from cosmic rays is from the cascade of other ions produced by radiation interacting within the atmosphere. The earth's atmosphere acts as a shield to prevent most of the cosmic radiation that reaches the earth from affecting us. The intensity of cosmic radiation varies with altitude and latitude due to these shielding effects. People living at higher latitudes receive a higher dose from cosmic radiation due to the deflection of many of the charged particles northward and southward by the earth's magnetic field. Likewise, the

Trainee's Notes:

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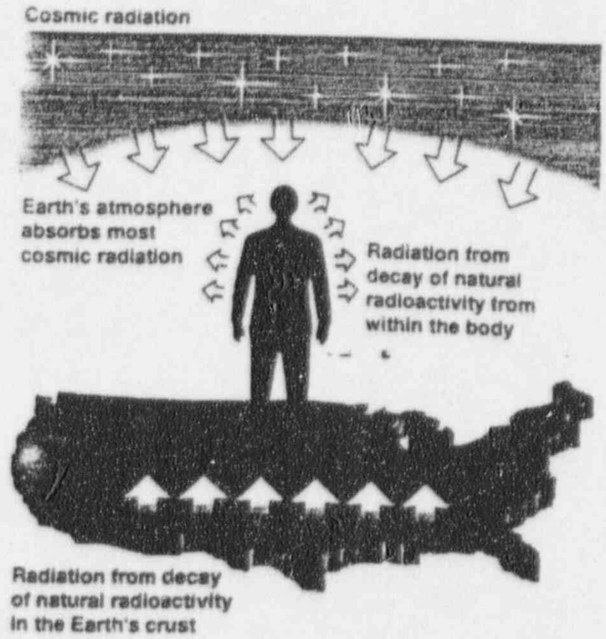
II. SOURCES OF RADIATION



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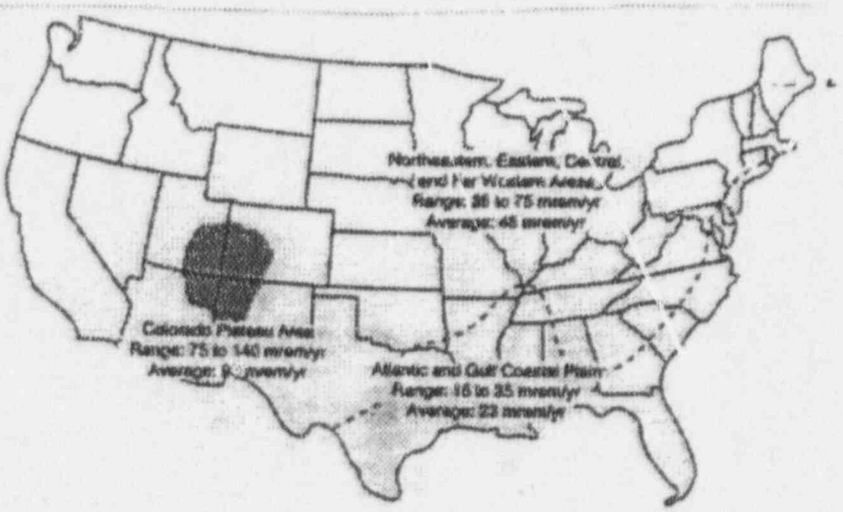
radiation dose due to cosmic rays increases by a factor of two going from sea level to 10,000 feet altitude and by about ten percent in going from zero to 50 degrees latitude.

Areas in the western part of the United States have a higher natural background dose rate than the eastern part because of the higher altitudes and greater quantities of exposed rock in those areas. Rocks contain a higher concentration of U-238, Th-232, and K-40 than do ordinary soil.



B. Terrestrial radiation is emitted by radionuclides found in the earth's crust. Some of these materials emit photons which penetrate the overlying rocks and cause a gamma ray field at the earth's surface.

Trainee's Notes:

There are a large number of naturally occurring radionuclides found in trace amounts in rocks, but the largest constituents are Ra-226, U-238, Th-232, and K-40. In the United States, on average, a square mile of surface dug out to a depth of one foot would contain one ton of K-40, three tons of U-238 and six tons of Th-232.

The dose rate from terrestrial sources varies greatly from one geographical location to another.

Population exposures from radon-222 arise from the natural occurrence of this nuclide in the soil, from which it is encountered in water, building materials, and the air we breathe. Depending on the type of house and its location, wide variations in air concentrations have been measured. This is because of the high content of radon-222 in some natural materials from which the gas slowly escapes. With the increased efficiency of home insulation, this source of radiation exposure could increase significantly due to tighter sealing of the house, which would retain the radon-222 instead of permitting it to leak out of doors. (See the end of the module for natural radioactive decay chains)

In addition to natural radionuclides found in rocks, others sometimes end up in food or water used for human consumption, or become airborne as radioactive gases or particulates. Some fraction of these, in turn, become deposited internally in the body. This "body burden" produces a dose as the radionuclide decays inside the body. Most of the dose (about 80 percent) is due to K-40, of which the body contains about 120 nanocuries (a nanocurie is 0.000000001 curies). Any food substance which contains natural potassium will contain a fraction of that natural potassium as radioactive K-40. The body cannot distinguish chemically between stable and unstable isotopes of an element and will use them similarly. For this reason, certain organs may be primary targets for the radiation from internally deposited radionuclides, such as I-131 which collects in thyroid glands, and K-40 which is deposited extensively in the central nervous system.

C. Man-made Radiation Sources

Man has learned to use the phenomenon of radiological decay and the energy produced in a number of ways. Examples include medical applications (x-ray diagnostics and radiation treatments for cancer), nuclear power generation, and

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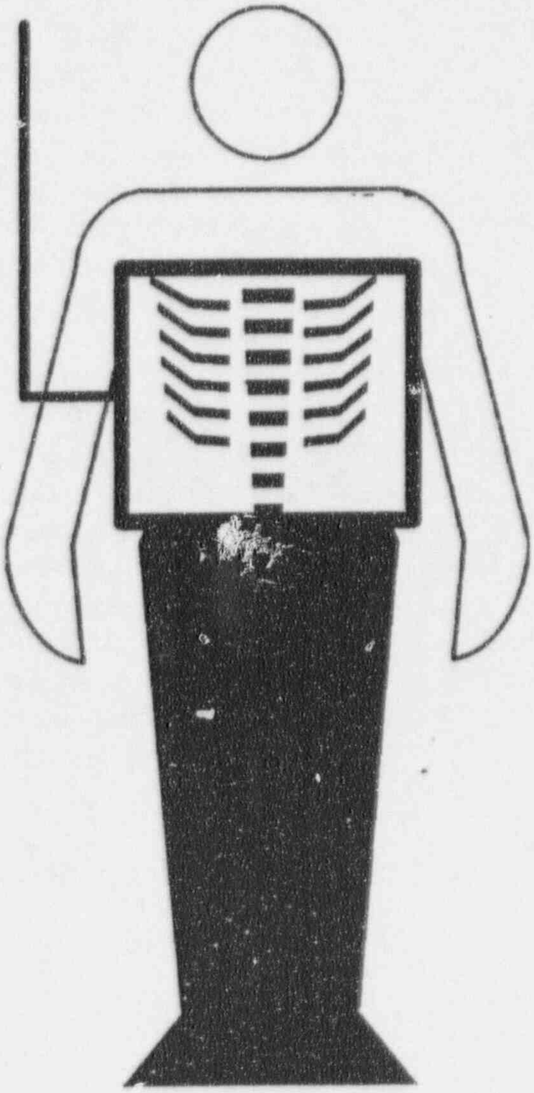
numerous consumer products (smoke alarms, television, instrumentation). Benefits nearly always exceed the risks of exposure.

Atmospheric testing of nuclear devices has released large quantities of radioactive material (fallout) into the biosphere. Devices detonated near the earth's surface will take up large amounts of soil which become radioactive through neutron exposure. Detonation of a one megaton device can activate up to 50,000 tons of debris. In 1987, the estimated annual dose to the general population from fallout was estimated to be less than one millirem per person.

Radioactivity is found in hundreds of consumer products. Man-made products, including X-ray machines, smoke detectors, color televisions, exit lights, and luminous dial instruments may contain radionuclides or produce radiation as a part of their normal functioning. The beneficial aspects of these products are considered to outweigh the potential harmful effects of the additional exposure. Other products contain natural radiation as a result of their construction or composition, such as cigarettes, which contain significant levels of alpha emitters Po-210 and Pb-210, and building masonry, which contains about one part per million of uranium and thorium.



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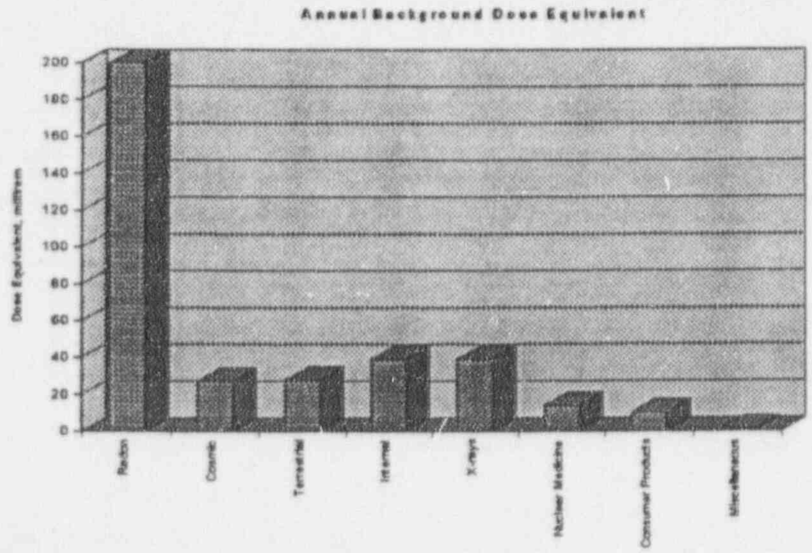
Radioactive materials are used routinely in two different general medical applications -diagnostic and therapeutic (for treatment). Small amounts of photon-emitting radioisotopes are attached ("tagged") to a drug or other pharmaceutical which is administered by mouth or injection. The drug carries the radioisotope to the organ of over the patient, and the pattern of radiation emitted is used to form an image of the organ or study the physiology of the area. Typical examples would be a thyroid scan or lung function test. Treatment of tumors and malignancies are frequently done by either exposing the afflicted area to intense sources during a one-time surgical procedure, by actually implanting the source in or nearby the tissue, or by injection of an organ-specific liquid radioisotope. Accelerators are also becoming more and more popular for such treatment.

D. Average Annual US Dose

The total average dose per year to U.S. citizens from all background sources (natural and man-made) is about 367 millirem/year. Eighty-two percent of that comes from natural sources, 15 percent comes from medical and dental uses of radiation, and the other three percent comes from other man-made sources (see chart).



Trainee's Notes:

Actinium Series (4n + 3)*

Nuclide	Historical Name	Half-life†	Major Radiation Energies (MeV) and Intensities† α	β	γ
[illegible]	Actinouranium	[illegible]	[illegible] ([illegible]) [illegible] (57%) 4.38c‡ (8%)	---	[illegible] ([illegible]) [illegible] ([illegible]) 0.204 (5%)
$^{231}_{90}$Th	Uranium Y	25.5h	---	0.140 (45%) 0.220 (15%) 0.305 (~0%)	0.026 (2%) 0.084c (10%)
$^{231}_{91}$Pa	Protoactinium	3.25x10⁴y	4.95 (22%) 5.01 (24%) 5.02 (23%)	---	0.027 (6%) 0.29c (6%)
$^{227}_{89}$Ac	Actinium	21.6y	4.86c (0.18%) 4.95c (1.2%)	0.043 (~99%)	0.070 (0.08%)
$^{227}_{90}$Th (98.6%)	Radioactinium	18.2d	5.76 (21%) 5.98 (24%) 6.04 (23%)	---	0.050 (8%) 0.237c (15%) 0.31c (8%)
$^{223}_{87}$Fr ([illegible]%)	Actinium K	22m	5.44 (~0.005%)	1.15 (~100%)	0.050 (40%) 0.080 (13%) 0.234 (4%)
$^{223}_{88}$Ra	Actinium X	11.4d	5.61 (26%) 5.71 (54%) 5.75 (9%)	---	0.149c (10%) 0.270 (10%) 0.33c (6%)
$^{219}_{86}$Rn	Emanation Actinon (An)	4.0s	6.42 (8%) 6.55 (11%) 6.82 (81%)	---	0.272 (9%) 0.401 (5%)
$^{215}_{84}$Po	Actinium A	1.78ms	7.38 (~100%)	0.74 (~.00023%)	---
$^{211}_{82}$Pb (~100%)	Actinium B	36.1m	---	0.29 (1.4%) 0.56 (9.4%) 1.39 (87.5%)	0.405 (3.4%) 0.427 (1.8%) 0.832 (3.4%)
$^{215}_{85}$At (.00023%)	Astatine	~0.1ms	8.01 (~100%)	---	---
$^{211}_{83}$Bi	Actinium C	2.15m	6.23 (16%) 6.62 (84%)	0.60 (0.28%)	0.351 (14%)
$^{211}_{84}$Po (0.28%)	Actinium C'	0.52s	7.45 (99%)	---	0.570 (0.5%) 0.90 (0.5%)
$^{207}_{81}$Tl (99.7%)	Actinium C"	4.79m	---	1.44 (99.8%)	0.897 (0.16%)
$^{207}_{82}$Pb	Actinium D	Stable	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{207}_{82}$Pb (4n + 3)......4(51) + 3 = 207

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

Thorium Series (4n)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
$^{232}_{90}Th$	Thorium	1.41×10^{10}y	3.95 (24%) 4.01 (76%)	---	---
$^{228}_{88}Ra$	Mesothorium I	6.7y	---	0.055 (100%)	---
$^{228}_{89}Ac$	Mesothorium II	6.13h	---	1.18 (35%) 1.75 (12%) 2.09 (12%)	0.34c‡ (15%) 0.908 (25%) 0.96c (20%)
$^{228}_{90}Th$	Radiothorium	1.910y	5.34 (28%) 5.43 (71%)	---	0.084 (1.6%) 0.214 (0.3%)
$^{224}_{88}Ra$	Thorium X	3.64d	5.45 (6%) 5.68 (94%)	---	0.241 (3.7%)
$^{220}_{86}Rn$	Emanation Thoron (Tn)	55s	6.29 (100%)	---	0.55 (0.07%)
$^{216}_{84}Po$	Thorium A	0.15s	6.78 (100%)	---	---
$^{212}_{82}Pb$	Thorium B	10.64h	---	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
$^{212}_{83}Bi$ 64.0% 36.0%	Thorium C	60.6m	6.05 (25%) 6.09 (10%)	1.55 (5%) 2.26 (55%)	0.040 (2%) 0.727 (7%) 1.620 (1.8%)
$^{212}_{84}Po$	Thorium C'	304ns	8.78 (100%)	---	---
$^{208}_{81}Tl$	Thorium C"	3.10m	---	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)
$^{208}_{82}Pb$	Thorium D	Stable	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{232}_{90}Th$ (4n)......4(58) = 232

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Lederer, C. M., Hollander, J. M., and Perlman, I., Table of Isotopes (6th ed.; New York: John Wiley & Sons, Inc., 1967) and Hogan, O. H., Zigman, P. E., and Mackin, J. L., Beta Spectra (USNRDL-TR-802 [Washington, D.C.: U.S. Atomic Energy Commission, 1964]).

Neptunium Series (4n + 1)*

Nuclide	Element Name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{241}_{94}Pu$	Plutonium	13.2y	4.85 (0.0003%) 4.90 (0.0019%)	0.021 (~100%)	0.145 (.00016%)
$^{241}_{95}Am$	Americium	458y	5.44 (13%) 5.49 (85%)	---	0.060 (36%) 0.101c‡ (0.04%)
$^{237}_{92}U$	Uranium	6.75d	---	0.248 (96%)	0.060 (36%) 0.208 (23%)
$^{237}_{93}Np$	Neptunium	2.14×10^{6}y	4.65c (12%) 4.78c (75%)	---	0.030 (14%) 0.086 (14%) 0.145 (1%)
$^{233}_{91}Pa$	Protactinium	27.0d	---	0.145 (37%) 0.257 (58%) 0.568 (5%)	0.31c (44%)
$^{233}_{92}U$	Uranium	1.62×10^{5}y	4.78 (15%) 4.82 (83%)	---	0.042 (?) 0.097 (?)
$^{229}_{90}Th$	Thorium	7340y	4.84 (58%) 4.90 (11%) 5.05 (7%)	---	~0.137c (~3%) 0.20c (~10%)
$^{225}_{88}Ra$	Radium	14.8d	---	0.32 (100%)	0.040 (33%)
$^{225}_{89}Ac$	Actinium	10.0d	5.73c (10%) 5.79 (28%) 5.83 (54%)	---	0.099 (?) 0.150 (?) 0.187 (?)
$^{221}_{87}Fr$	Francium	4.8m	6.12 (15%) 6.34 (82%)	---	0.218 (14%)
$^{217}_{85}At$	Astatine	0.032s	7.07 (~100%)	---	---
$^{213}_{83}Bi$	Bismuth	47m	5.87 (~2.2%)	1.39 (~97.8%)	0.437 (?)
$^{213}_{84}Po$	Polonium	4.2μs	8.38 (~100%)	---	---
$^{209}_{81}Tl$	Thallium	2.2m	---	1.99 (100%)	0.12 (50%) 0.45 (100%) 1.56 (100%)
$^{209}_{82}Pb$	Lead	3.30h	---	0.637 (100%)	---
$^{209}_{83}Bi$	Bismuth	Stable (>2×10^{18}y)	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{229}_{90}Th$ (4n + 1)......4(57) + 1 = 229
The (4n + 1) series is included here for completion. It is not found as a naturally-occurring series.
†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.
‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

Uranium Series (4n + 2)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities† α	β	γ
$^{238}_{92}U$	Uranium I	4.51x10^9 y	4.15 (25%) 4.20 ([illegible])	---	---
$^{234}_{90}Th$	Uranium X1	24.1d	---	0.103 (21%) 0.193 (79%)	0.063c‡ (3.5%) 0.093c (4%)
$^{234m}_{91}Pa$	Uranium X2	1.17m	---	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
99.87% ↓ 0.13%					
$^{234}_{91}Pa$	Uranium Z	6.75h	---	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}U$	Uranium II	2.47x10^5 y	4.72 (28%) 4.77 (72%)	---	0.053 (0.2%)
$^{230}_{90}Th$	Ionium	8.0 x10^4 y	4.62 (24%) 4.68 (76%)	---	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}Ra$	Radium	602y	4.60 (6%) 4.78 (95%)	---	0.186 (4%)
$^{222}_{86}Rn$	Emanation Radon (Rn)	3.823d	5.49 (100%)	---	0.510 (0.07%)
$^{218}_{84}Po$	Radium A	3.05m	6.00 (~100%)	0.33 (~0.019%)	---
99.98% ↓ 0.02%					
$^{214}_{82}Pb$	Radium B	26.8m	---	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}At$	Astatine	~2s	6.65 (6%) 6.70 (94%)	? (~0.1%)	---
$^{214}_{83}Bi$	Radium C	19.7m	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
99.98% ↓ 0.02%					
$^{214}_{84}Po$	Radium C'	164μs	7.69 (100%)	---	0.799 (0.014%)
$^{210}_{81}Tl$	Radium C"	1.3m	---	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{210}_{82}Pb$	Radium D	21y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{210}_{83}Bi$	Radium E	5.01d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	---
~100% ↓ .00013%					
$^{210}_{84}Po$	Radium F	138.4d	5.305 (100%)	---	0.803 (0.0011%)
$^{206}_{81}Tl$	Radium E"	4.19m	---	1.571 (100%)	---
$^{206}_{82}Pb$	Radium G	Stable	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{206}_{82}Pb$ (4n + 2)......4(51) + 2 = 206

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

AVERAGE PERSONAL RADIATION DOSE

We live in a radioactive world — always have. Radiation is all about us as part of our natural environment. It is measured in terms of millirem (mrem). *Compare your annual dose to the U.S. annual average of 360 mrem.*

WHERE YOU LIVE	Location: Cosmic radiation at sea level	26
	For your elevation (in feet) — add this number in mrem	______
	Elevation — mrem 1000 - 2 4000 - 15 7000 - 40 2000 - 5 5000 - 21 8000 - 53 3000 - 9 6000 - 29 9000 - 70 Elevation of some U.S. cities (in feet): Atlanta 1050; Chicago 595; Dallas 435; Denver 5280; Las Vegas 2000; Minneapolis 815; Pittsburgh 1200; St. Louis 455; Salt Lake City 4400; Cincinnati 760. (Coastal cities are assumed to be zero, or sea level)	
	Radon: U.S. average	200
	Ground: U.S. average	28
	House Construction: For stone, concrete or masonry building, add 7	______
WHAT YOU EAT, DRINK, AND BREATHE	Food Water U.S. Average Air	40
	Weapons test fallout	3
HOW YOU LIVE	X-ray and radiopharmaceutical diagnosis Number of chest x-rays ______ x 10 . . . . Number of lower gastrointestinal (GI) tract x-rays ______ x 500 . Number of radiopharmaceutical examinations ______ x 300 . . . . (Average dose to total U.S. population: 92 mrem	______ ______ ______
	Jet plane travel: For each 2500 miles add 1 mrem	______
	TV viewing: For each hour per day ______ x 0.15	______
HOW CLOSE YOU LIVE TO A NUCLEAR PLANT	At site boundary: average number of hours per day ______ x 0.2 . . . . . One mile away: average number of hours per day ______ x 0.02 . . . . . Five miles away: average number of hours per day ______ x 0.002 . . . . Over 5 miles away: . . . . None *Note*: Maximum allowable dose determined by ALARA criteria established by the NRC (Nuclear Regulatory Commission). Experience shows that your actual dose is substantially less than these limits.	______ ______ ______

My total annual dose (mrem): ______

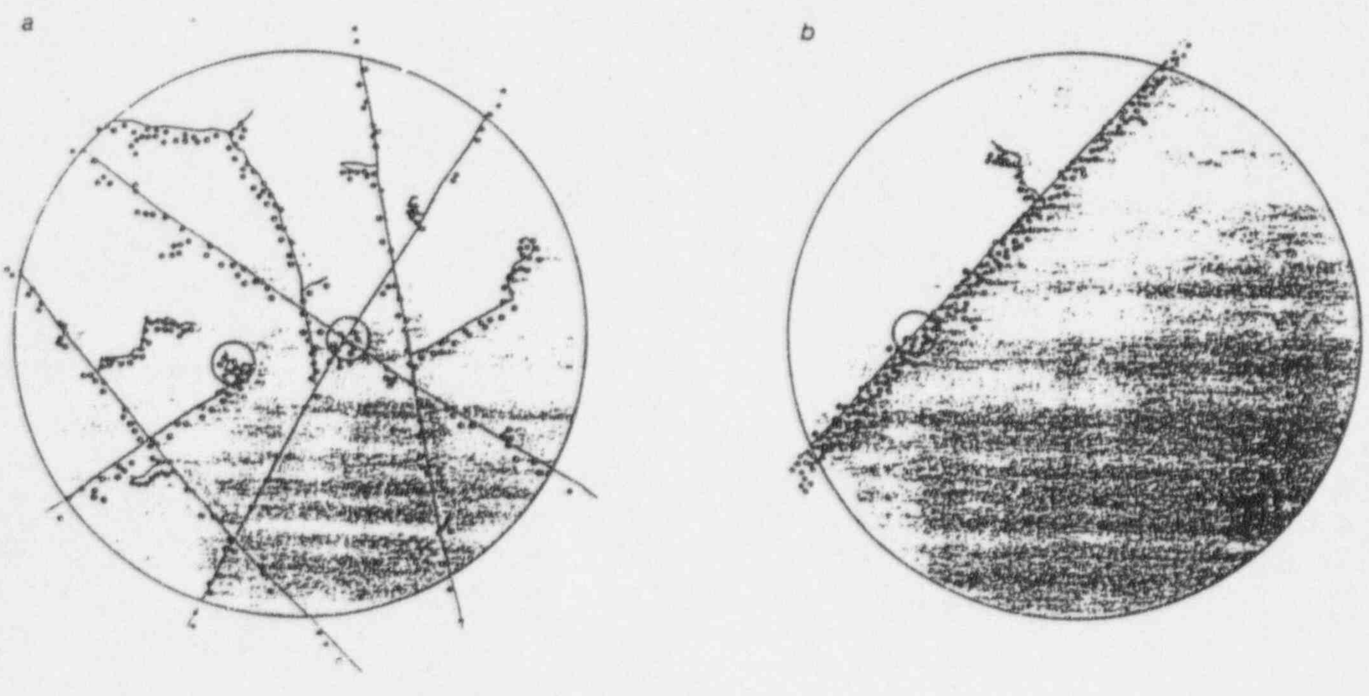
MODULE 4: RADIATION INTERACTION WITH MATTER

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. STATE the distinction between ionizing and nonionizing radiation as it relates to interaction with matter.
2. STATE the ionization characteristics for alpha, beta, and gamma radiation.
3. IDENTIFY the three mechanisms for gamma radiation to interact with matter
4. IDENTIFY interaction mechanisms for nonionizing radiation.

I. INTRODUCTION

How radiation interacts with matter is the single most important concept in radiation protection. The interaction of radiation with matter dictates the type and magnitude of the damage caused by the radiation. The interaction of radiation with matter also dictates the types of shielding that is required to protect individuals from radiation sources.

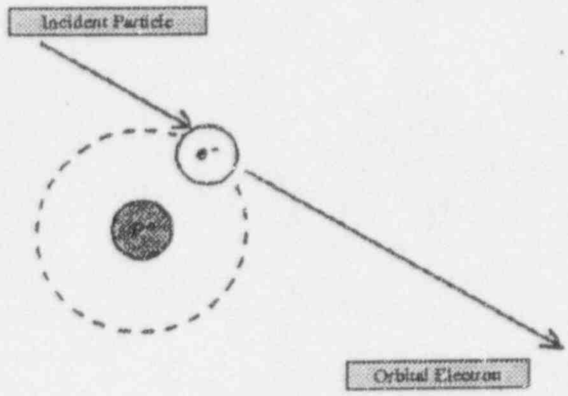


II IONIZING RADIATION

As the name implies, ionizing radiation interacts with matter by ionizing atoms that comprise the matter. The radiation imparts some of its energy to an orbital electron. Some of the energy goes to overcoming the electrical attraction between the orbital electron and the nucleus of the atom. The remainder of the energy either goes to the kinetic energy of the orbital electron, remains with the incident radiation, or both.

The four types of ionizing radiation, gamma or x-radiation, beta radiation, alpha radiation, and neutrons, imparts its energy differently. This difference translates into different biological effects and different approaches to shielding.

A. Alpha radiation imparts it energy over a very short range of matter. Because the particle is relatively massive and has a +2 charge, it transfers its energy rapidly, with many ionizations in a small area. Since alpha particles transfer their energy over short distances, they cause significant damage to the matter along the path traveled. However, this characteristic makes alpha particles easy to shield. A piece of paper or the dead layer of skin can stop alpha particles.



Trainee's Notes:

B. Beta Particles

Beta particles have much less mass and half the charge of an alpha particle. Consequently, the particle imparts its energy over a great distance than the alpha particle. Since the beta particle has the same mass as an orbital electron, the path of the particle is easily deflected, making the path of ionization tortuous. As a result, the amount of damage done to matter is less for a beta particle compared to an alpha particle. However, the longer range of beta particles mean that beta particles are not as easy to shield as alpha particles. It takes a thin piece of aluminum or Plexiglas to stop beta particles.

C. Gamma and X- Radiation

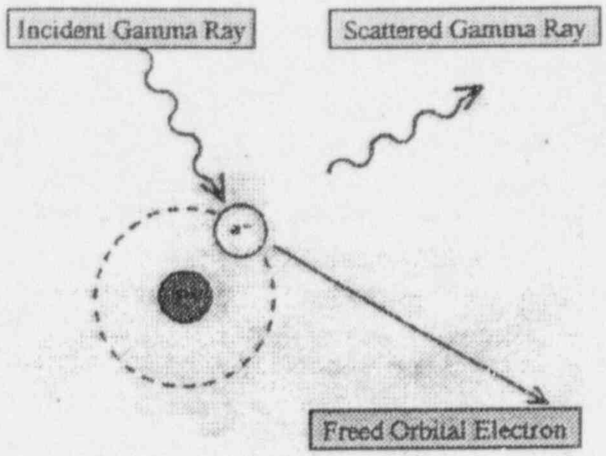
Gamma radiation has the greatest range in matter. Incident gamma radiation causes ionizations over a very long path, but the density of these ionizations are much less than for alpha particles. Gamma radiation interacts with matter in three ways: photoelectric effect, Compton effect, and pair production.

Photoelectric effect. In the photoelectric effect, the gamma radiation has enough energy to ionize the atom, but the incident gamma ray is dissipated.

Compton effect. In the Compton effect, the incident gamma radiation continues on after an ionization event, but at a reduced energy. Ionizations can continue to occur by both the freed orbital electron and the scattered gamma ray.

Pair production. In pair production, a gamma ray, influenced by the attraction of a nucleus, turns into a electron/positron pair. Pair production occurs when the gamma ray energy is greater than the rest mass of the electron/positron pair (1.02 MeV).

Trainee's Notes:



D. Neutrons

Neutrons interact with matter differently than the other three types. Neutrons ionize matter *indirectly*. The neutron collides with nuclei in the atoms making up the matter, transferring its energy to the nuclei. This transfer of energy is similar to a billiard ball hitting one another. The closer the nucleus is in size to the neutron, the less bounces are needed to deplete the neutrons energy. A hydrogen atom, which is a single proton, reduces the absorbs almost all of the neutron's energy in a single collision.

Once the energy is transferred to the matter, the nuclei either recoils, causing ionization, or absorb the energy. After they absorb the energy, the nuclei will release it in the form of a gamma ray. This gamma ray causes ionizations. This mechanism is how neutrons indirectly ionize matter.

Matter with low atomic weight (water, carbon, plastic) make good shields. The low atomic weight means that the nuclei in the matter are close to the mass of the neutron, allow for a complete transfer of energy in a small number of collisions.

Trainee's Notes:

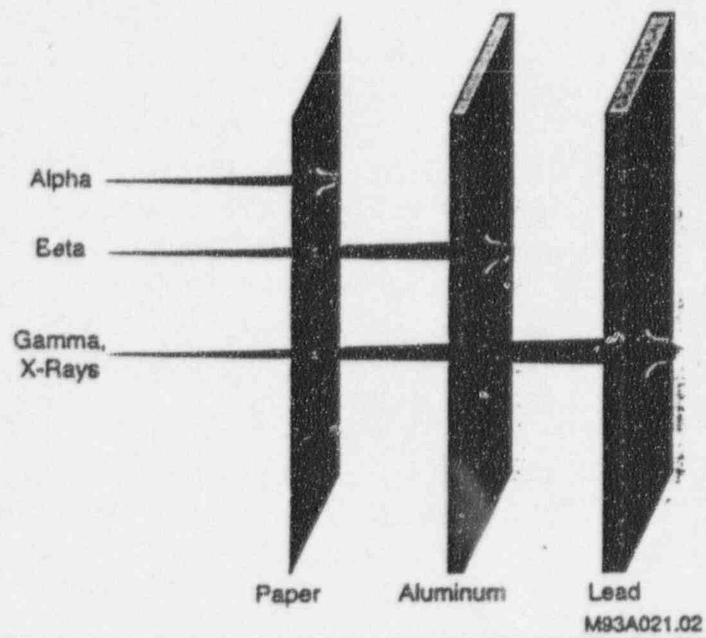
III. Nonionizing Radiation

Nonionizing radiation interacts with matter principally in two ways: thermal or photochemical. With thermal interactions, the electromagnetic waves imparts energy by causing the matter to vibrate. The vibration causes the matter to increase in temperature. This is a common effect with water molecules. The polar nature of water causes it to vibrate when exposed to certain wavelengths of radiation. This is the operating principle of a microwave oven. With photochemical reactions, matter that is sensitive to a certain wavelength of radiation will undergo a chemical reaction. One example is a sun tan. Skin pigmentation reacts when exposed to ultraviolet light, causing the skin to tan. Increased doses of ultraviolet light can cause more serious damage.

Penetrating Power of Radiation

Some types of radiation can easily be shielded against. For example, a sheet of paper is sufficient to stop an alpha particle. Gamma rays can pass through paper but can be stopped by the appropriate amount of lead.

Radiation's ability to penetrate is an important consideration in protecting human health. Adequate shielding decreases the power of the radiation by absorbing part or all of it.



Trainee's Notes:

IV. RADIATION DETECTION

Unlike other harmful agents at industrial facilities and hazardous waste sites, radiation can be readily measured. The principles of radiation detection are based on the ways radiation interact with matter. Specifically, most detector systems measure the ionization produced in a material and translate the quantity of ionizations to an exposure or dose rate. Other detectors are comprised of material the scintillate, give of light, when hit by radiation.

Some detectors can not discriminate what type of radiation or energy caused the ionization. Others are specific to only one type of radiation and can discriminate the energy of the radiation. This discrimination allows detector systems to identify and quantify the specific radionuclides in a sample.

Types of Detectors
Gas-Filled Ionization Detectors
Ion Chamber
Proportional Counter
Geiger-Muller (G-M) Counter
Scintillation Detectors
Sodium Iodide (NaI) Detector
Germanium (Lithium) Detector
Liquid Scintillation Detector

Trainee's Notes:

MODULE 5: RADIOACTIVITY, CONTAMINATION, AND RADIOLOGICAL DOSE

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. IDENTIFY the basic quantities and units used to measure radiation and radioactivity.
2. CONVERT rem to millirem and millirem to rem.
3. STATE the difference between radiation and contamination.
4. STATE the difference between dose and dose rate.

I. RADIOACTIVITY AND CONTAMINATION

A. Radioactivity

Radioactivity is the property possessed by certain material of spontaneously emitting radiation (x- or gamma rays, alpha or beta particles, or neutrons). This action is radioactive decay. The measure of the amount of this material present is activity. The unit of activity is the curie (Ci). One curie is equal to 37 billion decays per second.

How Much Dose a Curie Weigh?

1 Ci of U-238	=	3,000 kilograms
1 Ci of Ra-226	=	1 gram
1 Ci of Co-60	=	0.8 milligrams
1 Ci of Tc-99m	=	0.2 μgrams

Trainee's Notes:

B. Contamination, as it relates to radiation safety, is radioactive material in a place where it should not be. Contamination and radiation are not synonymous (see below).

The radiation given off by the contamination can be measured. The count rate is a measure of the number of radioactive decays which are detected by a particular radiation detection instrument on a surface or object per unit of time. Count rate is most commonly expressed in terms of counts per minute (cpm). CPM is generally used to express surface contamination, either based on *in situ* measurements or measurements of smears of a contaminated surface.

Count rate is related to the activity by the efficiency of the detector system.

activity (disintegrations per minute - dpm) = count rate (cpm) • efficiency

The efficiency of a detector system is a function of the type and energy of the radiation being measured and the detector used. "Disintegration" is synonymous with "decay". To convert the activity in dpm to the activity in curies, divide the dpm number by 2,220,000,000,000.

Activity (Ci) = Activity (dpm) / [37,000,000,000 dps per Ci • 60 seconds/minute]

C. Radiation vs. Contamination

Radiation is the *electromagnetic energy or particles* given off by unstable nuclides. Contamination is radioactive material in a place where it is not supposed to be. An example to illustrate the distinction is a pipe carrying radioactive liquid (*e.g.*, core coolant at a nuclear reactor). Gamma radiation passes through the pipe wall and can be measured at the outside of the pipe. The radiation is from the radioactive material passing in the pipe. As long as the material remains in the pipe, the material is not contamination. If a leak occurs and some radioactive liquid spills to the floor, then this spill is contamination - radioactive material where it is not suppose to be.

Trainee's Notes:

II. RADIATION QUANTITIES

A. Exposure

Exposure is the measure of the amount of ionization that occurs in air from a source of x- or gamma rays. The roentgen (R) is a unit for measuring exposure. Since the quantity is so narrowly defined, exposure has limited in determining the effects of radiation on people. Exposure is a convenient quantity to measure.

Unit Basics		
centi (c)	=	1/100
milli (m)	=	1/1,000
micro (μ)	=	1/1,000,000
nano (n)	=	1/1,000,000,000
pico (p)	=	1/1,000,000,000,000
kilo (k)	=	1,000
mega (M)	=	1,000,000

B. Absorbed Dose

Absorbed dose is the measure of the amount of energy from ionizing radiation absorbed in a gram of matter. The rad is a unit for measuring absorbed dose in any material. It is defined for any material. It applies to all types of radiation.

1 rad = 100 ergs per gram of matter

One rad of absorbed dose in the human body is equal to 100 ergs of energy deposited in 1 gram of tissue, whether the type of radiation is alpha particles, beta particles, x- or gamma rays, or neutrons.

Absorbed dose does not take into account the potential effect that different types of radiation have on the body.

Trainee's Notes:

C. Dose Equivalent

Dose equivalent is the measure of the effect that radiation has on human tissue. The unit for dose equivalent is the rem.

The dose equivalent, in rem = the absorbed dose , in rad • quality factor

The same quantity of absorbed dose from different types of radiation inflicts different levels of damage to human tissue The quality factor represents the relative damage that a type of radiation can inflict.

Type of Radiation	Quality Factor
Alpha	20
Beta	1
Gamma and x-rays	1
Neutrons	2-10

III. EXPOSURE AND DOSE RATE

Exposure is how much ionization in air occurs from x- or gamma radiation. Dose is how much radiation dose (either absorbed dose or dose equivalent) is received. Rate is the how fast the exposure is received. Exposure or dose rate, then, is how much exposure, absorbed dose, or dose equivalent, is received over a certain amount of time.

Examples:

milliroentgen (mR)/hour　　rem/year　　microrad (μrad)/hour

A rem is a rad is a Roentgen!

For x- and gamma radiation, one R of exposure is approximately equal to one rad of absorbed dose which is equal to one rem of dose equivalent. The three quantities are often used interchangeably when measuring gamma and x-rays.

Trainee's Notes:

Dose Terminology

absorbed dose	the quantity of radiation energy absorbed by an organ divided by an organ's mass
dose equivalent	the absorbed dose to an organ multiplied by a quality factor
effective dose equivalent	the single weighted sum of combined dose equivalents received by all organs
committed dose equivalent	the effective dose equivalent to an organ over a 50-year period following intake
committed effective dose equivalent	the total effective dose equivalent to all organs in the human body over a 50-year period following intake
collective effective dose equivalent	the sum of effective dose equivalents of all members of a given population
quality factor	a modifying factor that adjusts for the effect of the type of radiation, e.g., alpha particles or gamma rays, on tissue
weighting factor	a tissue-specific modifying factor representing the fraction of the total health risk from uniform, whole-body exposure

Trainee's Notes:

MODULE 6: DOSE LIMITS, DOSIMETRY, RADIATION EXPOSURE, AND PERSONNEL PROTECTION

LEARNING OBJECTIVES: Upon completing this unit, the participant will be able to identify restrictions regarding dose limits and administrative control levels. The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. DISCUSS external dosimetry relative to the hazards associated with the types of radiation.
2. STATE radiation dose limits for the NRC.
3. STATE the limits and constraints concerning prenatal radiation exposure.
4. DEFINE internal dosimetry.
5. DESCRIBE methods of entry of radionuclides into the body.
6. DISCUSS prevention of uptake.
7. PRESENT internal exposure monitoring techniques.

I. DOSE EQUIVALENT REGULATORY LIMITS

Federal and State agencies establish limits on the annual dose equivalent that a worker can receive. These radiation dose limits are established for based on guidance from:

- The U.S. Environmental Protection Agency (EPA)
- The National Council on Radiation Protection and Measurements (NCRP)
- The International Commission on Radiological Protection (ICRP).

A. 10 CFR Part 20

Occupational Limits. The U.S Nuclear Regulatory Commission (NRC) limits the dose equivalent delivered to workers of licensees over a year. The NRC limits the total effective dose equivalent to 5 rem. The deep-dose limit and committed dose equivalent to an organ (other than the lense of eye) to 50 rem.

Trainee's Notes:

The limit to the lense of the eye is 15 rem and the limit for shallow dose equivalent to the skin or any extremity of 50 rem.

The dose limits are for the sum of external and internal radiation dose equivalent.

The NRC also establishes annual limits on intake (ALIs) for the intake of material through inhalation or ingestion. ALIs are determined by estimating the dose equivalent delived by a unit quanity of a specific radionuclide in the body, applying the appropriate dose limit to determine the maximum amount of material that can be in the body, then translating the maximum quantity in the body to an allowable intake quantity. The ALIs depend on the radionuclide and route of entry.

Pregnant Worker. For a *declared* pregnant worker who chooses-to-continue working as a radiological worker, the following radiation dose limit will apply. The dose limit for the embryo/fetus (during entire gestation period) is 500 mrem. Efforts should be made to avoid exceeding 50 mrem/month to the pregnant worker. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

An employer can not limit the radiation dose to a fetus from an undeclared pregnancy.

II. PERSONAL EXPOSURE DOSIMETRY

A. Dosimeters

Radiation and contamination environments have the potential for at least minimally exposing workers. To quantify the level of exposure received by a worker, a dosimeter or dosimeters are worn. The most common dosimeter is a thermoluminescent dosimeter (TLD). The TLD is a crystal worn in a protective badge (*e.g.*, a plastic case). This crystal absorbs energy from radiation. The TLD is routinely collected and the amount of absorbed energy is measured. The amount of energy absorbed is then translated into the amount of *external*

Trainee's Notes:

radiation received by the individual. TLD materials vary and are sensitive to different types of radiation.

How a TLD Works

When ionizing radiation interacts with the lithium fluoride crystals contained in the TLD, electrons in the outer shells of the atoms in the crystals are lifted into higher orbits. Impurities in the crystals (such as manganese) enable the electrons to stay "trapped" in their excited state until the TLD is read. When the crystal is heated to 220°C, the electrons fall back into their lower orbits, giving off pulses of light. These light pulses are changed into electrical signals and amplified by a photo-multiplier tube. The magnitude of these electrical signals is directly proportional to the amount of ionizing radiation received by the wearer of the TLD.

Another popular medium for a dosimeter is film. The film is contained in a plastic case. The radiation exposes the film, much like light exposes a film in a camera. The film is collected and the intensity of the exposure is evaluated. The intensity of the exposure of the film is directly proportional to the radiation dose. The film can be retained as a permanent record of the exposure (unlike TLDs). However, industry-wide, the TLD has all but replaced the film badge.

B. External Monitoring for Different Types of Radiation.

Alpha Radiation. Alpha radiation is not monitored with external dosimeters because it travels only several inches in air and will not penetrate the outer dead layer of skin. Because of this low penetrating ability, alpha is not an external radiation hazard. However, if an alpha emitter is taken into the body, all of the energy of its radiation will be deposited in a very short range of living tissue. Hence, aloha radiation is an internal hazard (see discussion below).

Beta Radiation. Beta radiation is a concern for external dosimetry purposes because it will penetrate a few millimeters of tissue (depending on its energy. Because it is not highly penetrating, beta radiation is not a hazard to the "whole body"; it generally cannot reach any internal organs except the lens of the eye.

Trainee's Notes:

Many TLD badges include crystals to quantify the amount of beta radiation received by the individual.

<u>X- and Gamma Radiation</u>. Gamma and x- radiation are the primary concerns for externalmonitoring purposes. Gamma and x-rays have a very long range in air and will penetrate deeply into the potentially causing damage. For this reason, gamma and radiation are termed "penetrating whole-body radiation" and are the main hazards associated with external exposures.

III. INTERNAL DOSIMETRY

The primary sources of internal exposure are alpha and beta emitters which have entered the body. Alpha and beta deposit all of their energy in a very short range of tissue and thus can cause a great deal of damage to the living tissue or organ into which they are deposited. They are not energetic enough to reach these internal organs from outside the body.

A. Quantifying Internal Radioactive Material

Another important facet of the dosimetry program is quantifying the dose equivalent received from a radionuclide that has been taken into the body. Recalling the earlier discussion on background radiation, the body contains radioactive material and receives a dose equivalent of approximately 25 millirem per year. Accidental or inadvertent internal uptake of radioactive material will result in an additional dose to the whole body or to individual organs. Quantifying and identifying the material taken into the body and estimating the dose equivalent associated with the uptake are all part of the internal dosimetry program.

Whole (*in vivo*) body scanners can be used to measure the total activity contained in
the body. A dose assessment can be made based on that measured activity. These data
are incorporated into an individuals radiation exposure method. Whole body counters are usually a chair or a bed that contains a number of radiation detectors. The detectors measure the amount and energy of the gamma or x-

Trainee's Notes:

radiation emitted from the individual's body and determines the uptake of radioactive material.

Estimating the activity of an internally deposited radionuclide also can involve analyzing activity in a body elimination product, usually urine. Relationships have been developed to determine the quantity of material taken into the body base on the elimination rate of the body.

B. Methods of Entry of Radionuclides into the Body

By far, the most common routes of entryfor radionuclides intothe body are inhalation and ingestion. In many cases, the route of entry into the body must be determined before a complete assessment of the dose can be per formed.

METHODS OF UPTAKE OF RADIONUCLIDES

- Inhalation
- Ingestion
- Absorption (through unbrokenskin)
- Absorption (through broken skin)
- Injection

C. Prevention of Uptake

<u>Source Containment</u>. Source Containment of radioactive material is the most important means of preventing uptake of radionuclides. For nuclear facilities in general, proper use of glove boxes, containments, storage bags, material transfer tags, ventilation controls, and area controls will minimize personnel contact with contamination. If possible and practical, contaminated areas should be decontaminated to allow free access to the areas. This will minimize exposure and the chance of uptake, as well as increasing work efficiency at the work sites. The remediation of a radiologically contaminated site represents a form of source containment. Additionally, source containment practices could be placed during remediation to protect the workers.

<u>Protective Clothing</u>. Protective clothing, such as lab coats or tyvek coveralls prevent the individual from getting contaminated and subsequently uptaking the

Trainee's Notes:

contamination into his body. Protective clothing is only effective if the right clothing is selected for the job and worn properly. Radiation work permits or health and safety plans should delineate the types of clothing to be worn and what to do under changing conditions. A later module discussess personal protective equipment.

Respiratory Protection. Respiratory equipment, such as filter masks and supplied air devices, will prevent the inhalation of loose and airborne contamination either by filtration or by providing contamination-free air from an external source. Filter masks include half-face and full face. A later module discussess personal protective equipment.

Trainee's Notes:

MODULE 7: CONTAMINATION CONTROL

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. DEFINE fixed, removable or loose, and airborne contamination.
2. STATE sources of radioactive contamination.
3. STATE the appropriate response to indicators of potential area contamination and personnel contamination alarms.
4. IDENTIFY methods used to control radioactive contamination.
5. IDENTIFY the proper use of protective clothing.
6. EXPLAIN the purpose and use of personnel contamination monitors.
7. IDENTIFY the normal methods used for decontamination.

I. TYPES OF CONTAMINATION

A. Contamination is radioactive material in any place where it is not supposed to be, especially where its presence may be harmful due to the possibility of internal or external exposure, or where it may be picked up and spread if disturbed. Contamination itself is not radiation; contamination consists of solids, gases, liquids, or vapors which emit radiation. If a radioactive material is properly contained and controlled, it will emit radiation and may be an external exposure hazard, but it will not be a contamination or internal exposure hazard. Contamination becomes a hazard when it escapes from its container or control area, or is improperly handled.

<u>Loose contamination</u>. Loose (transferable or removable) contamination is a form of surface contamination that is easily spread to adjacent areas and can be ingested or inhaled. It can be detected by the use of smears or large area wipes, and is easily removed by normal decontamination techniques. When very high levels of loose surface contamination are present, control of external exposure or airborne radioactivity may also be necessary. The possibility of loose contamination becoming airborne or being transferred can be eliminated by "fixing" the contamination on the surface or decontaminating the surface. For remediations of radioactively contaminated sites, remediation equipment is likely to have loose contamination.

Trainee's Notes:

Fixed Contamination. Fixed contamination is radioactive material on surfaces which cannot be removed easily by normal decontamination techniques and cannot be detected by smears. It is detected by directly monitoring the surface with a detection instrument. Fixed contamination can be released by grinding, welding, or sanding, and such operations require imposition of the same precautions as loose contamination. Fixed contamination is common at many nuclear facilities. Remediations that include radioactively contaminated site buildings will usually encounter fixed contamination.

Airborne Contamination. Airborne radioactivity may exist as particulate or gaseous forms. Airborne radionuclides, when inhaled, can deposit in the lungs or other organs. Respiratory protection may be required while in an airborne contamination area to prevent the particles from entering the body. Particulate emissions could be generated by remedial activities at a radioactively contaminated site.

II. SOURCES OF RADIOACTIVE CONTAMINATION

Contamination is a fundamental component of nuclear facilities or remediations at radioactively contaminated sites. Handling radioactive material results in contamination. However, actions during site remediations can spread the contamination. Properly delineating work areas, limiting actions in contamination zones to only those needed to remediate the site, and complying with housekeeping rules can prevent the spread of contamination.

III. TECHNIQUES FOR MONITORING OF CONTAMINATION

A. Smears (sometimes called swipes) are used to detect the presence of loose contamination. They are about 1/2 inches in diameter and are usually made of paper or cloth. The smear is rubbed over the contaminated surface in an "S" pattern about 16 inches in length: this will smear an area of about 16 square inches (about 100 square centimeters). The smear may be counted "in the field" to determine gross contamination with a portable instrument but eventually will be placed in a specially designed smear counting instrument for a more accurate measurement. The net count rate (smear count rate minus background) is

Trainee's Notes:

multiplied by a correction factor unique to each instrument, and the contamination level is reported in units of decays per minute per 100 square centimeters, or dpm/100 cm^2.

B. Loose contamination can also be detected by direct "frisk." Frisking consists of placing the probe of a radiation detection instrument close to the surface to be monitored, then observing both the instrument reading and audible response for any rise above the background count rate. Correction factors for probe type, radiation energy, or surface configuration may be used by the Health Physicist to convert the instrument reading in counts per minute to dpm/100 cm^2. For fixed contamination, direct measurement is the only method that can be used. For surfaces with both fixed and loose contamination, a combination of both methods needs to be used.

C. Constant Air Monitors (CAMS) are instruments that constantly monitor the air for contamination. The sampled air passes through a filter where any radioactive particles are deposited. Radioactivity collected on the filter is detected and triggers an if the level exceeds the setpoint. The instruments are designed for monitoring either alpha or beta/gamma emitters in the air. So-called "grab samples" can be taken with portable air monitoring equipment when immediate airborne concentration levels are needed or a permanent constant air monitor is not available.

IV. GENERAL PRECAUTIONS FOR WORKING IN A CONTAMINATED AREA

A. Protective Clothing

The appropriate protective clothing and respiratory equipment, when require, must be worn to ensure that contamination is not spread, ultimately leading to accidental intake of radioactive material. This may involve as little as gloves, coveralls or lab coat, and shoe coverings or as much as a complete anti-C (anti-contamination) clothing dressout with respirator. The proper protective clothing required can be determined by referring either to the posted signs at the Contamination Area, the Radiation Work Permit (if one is issued for the job), or a health and safety plan. Protective equipment may also be specified in operating procedures.

Trainee's Notes:

Ensure that protective clothing retain their protective factors during work. If protective clothing is ripped, stop work when it is safe to do so or otherwise follow approved procedures an replace the clothing.

B. Eating, Drinking, and Smoking

Eating, drinking, smoking, and chewing are generally strictly forbidden in contaminated areas to prevent the ingestion of radionuclides. Exceptions are made for certain actions. For example, it may be permitted to drink water at sites where there is a heat stress possibility. However, in these cases, the action is highly controlled - essentially operating a "contamination-free" zone inside the contamination area.

C. Operating Practices

Instructions. Obey all posted signs and instructions, which may include: posted regulations at the area, company procedures, NRC regulations, site health and safety plans, and any oral or written instructions provided by health and safety officials

Practices. Minimize what is brought into a contaminated area. The less equipment in the area, the less chance for contamination and the ultimate spread of contamination. This practice includes personal items (watches, notebooks, *et cetera*). Only essential material should be taken into a contamination area.

Exiting Contamination Area. In most cases, exit from a contaminated area will be directly through a self-monitoring survey station or decontamination line. Anything and anyone leaving a contaminated area must be monitored for contamination before exiting. Either portable or fixed monitoring instruments will normally be located at the exit points of such areas and health and safety assistance should be available to assist in the use of these instruments. Contamination areas should only be exited through these designated points.

Trainee's Notes:

V. PERSONAL PROTECTIVE EQUIPMENT (PEP)

The primary purpose of protective clothing, from a radiological standpoint, is to prevent contamination from coming in contact with the skin and clothing. Ultimately, the equipment prevent the inadvertent spread of contamination and the ultimate intake of the radioactive material.

Protective clothing does not protect the wearer from penetrating radiation. Depending on the type of clothing and the energy of the radiation, protective clothing may offer some degree of protection from beta particles.

A. Examples of Protective Clothing

EXAMPLES OF PROTECTIVE APPAREL

- Coveralls/Smocks
- Protective Gloves (Rubber, Cloth)
- Shoe Covers (Plastic, Rubber, Cloth)
- Safety Glasses
- Hard Hat, Head Covers

Tyvec coveralls. Tyvec coveralls are common to hazardous waste site characterization and remediation. The coveralls provide a convenient disposable layer of protection from contamination to the wearer. At some nuclear facilities or waste sites, cotton coveralls or lab coats may be sufficient. They are sufficient when there is only a small change for transferring contamination.

Gloves and Shoe Covers. The hands are one of the most likely places to become contaminated. Protection for the hands is usually provided by rubber gloves. Shoes are another location likely to become contaminated. Shoe covers made of rubber, plastic, or cloth should be worn.

Respirators. Respirators must be worn whenever there is a chance of ingesting or inhaling a significant amount of contamination (and other control methods are not feasible). Respirators come in a variety of styles and sizes to provide protection under many contamination conditions, whether the contamination is loose surface or airborne. Filter masks remove the particulate contamination from the air before it enters the lungs, but usually cannot remove gaseous

Trainee's Notes:

radionuclides. Supplied-air breathing systems, such as airline suits and self-contained breathing apparatus (e.g., Scott Air-Packs) are used in IDLH atmospheres or areas of high airborne contamination.

SCREENING & TRAINING OF PERSONNEL

Screening of Personnel
- Psychological
- Physical

Training of Personnel
- **Radiation Protection**
- Industrial Hygiene

B. Factors Affecting the Selection of Protective Clothing

Amount of Contamination. The more contamination present, the greater the degree of protection required. This is especially true for airborne radioactivity or loose surface contamination that may become airborne.

Chemical and Physical Form. The chemical and physical form of the contaminant must be considered. Is thecontamination wet or dry? Is the contamination loose, fixed, or airborne? Is the airborne contamination in particulate or gaseous form? Does the chemical form of the contaminant make it toxic or hazardous in some other way? Is the radionuclide itself highly toxic?

FACTORS IN SELECTING PROTECTIVE APPAREL

- Amount of Contamination Present
- Type and Form of Contaminant
- Nature of Work to be Performed
- Access to Decon Facilities
- Other (Non-Radiological) Hazard

Trainee's Notes:

Nature of the Work Action. Consideration must be given to the nature of the work to be performed, especially if it involves close contact with contaminated surfaces or materials. The more intrusive the work is, generally the more stringent the PPE requirements.

Type of Support Facilities Present. Access to change or decontamination facilities is an important consideration. An extra layer of protective clothing may be necessary. Decontamination of personnel must take place at a designated sink, shower, or like facility. Transporting contaminated personnel from one facility to another is not desirable.

Non-radiological Considerations. Besides the radiological ones, there may be other hazards to contend with in the contaminated work environment. These may include mechanical, electrical, height,. slipping, suffocation, and lead and asbestos hazards. Other safety equipment may be needed in addition to the radiological protection.

C. Donning and Removing Protective Clothing

The two most important points to remember when donning protective clothing is to achieve proper layering and, if specified, to tape all seams in order to effectively prevent contamination from contacting the skin underneath. It is also important for the clothing to fit reason ably well for mobility and to prevent being caught by rotating equipment or snagged on protruding objects.

Strict adherence to clothing removal procedures is vital to prevent cross-contamination of the layer of clothing or skin underneath. In general, the removing procedure starts with the pieces of clothing with the greatest potential of contamination (or causing cross contamination) to pieces with less contamination.

D Self-Monitoring For Contamination

Due to the very nature of remediation of a radiological contaminated site, work inside contaminated areas is necessary. These areas may or may not have well defined boundaries. Personnel and equipment must be monitored for contamination prior to leaving contaminated areas to minimize the potential for

Trainee's Notes:

spread of contamination outside of these areas. If the contamination is spread to an uncontrolled area, not only does it pose a health hazard, but the area must be decontaminated or the boundaries of the current contamination area must be expanded. The impact on operations can be significant.

Exit monitoring stations exist at designated points and serve as control points for the spread of contamination. The general procedure for self-monitoring is:

- Check hand for contamination first, if possible (to avoid probe contamination), then pick up probe.

- Check the probe, instrument, and cord for any signs of damage. Do not use the instrument if it appears damaged. Notify the health and safety representative.

- Check the background count rate. While you are frisking, you will be looking for a rise in the meter count rate above the background rate. It is necessary to know the background rate to compare the two readings; 2) if the background rate is too high, you may not be able to detect small amounts of contamination. Any rise in the count rate may be masked by the natural variation in the background. In this case, consideration will be given to shielding the probe or moving to a new location with a lower background rate.

- Slowly scan the your body, moving the beta/gamma probe two inches per second not more than 1/2 inch from the skin or clothing. Linger over areas with the highest potential for contamination, for example, places that were at the edge of the PPE.

- If using an alpha probe, place the probe face within 1/4 inch of the skin or clothing and hold for several seconds before moving to another spot, or move the probe about one inch per second. It is important to allow time for any detection instrument to respond to contamination before moving to another location.

- Listen carefully to the audible signal and observe the meter reading. If the instrument reading rises above background (and stays there when you hold the probe over the spot) you should notify the health and safety representative and not leave the area.

Trainee's Notes:

- Once finished, return the probe to resting place, with the probe face out (so that the next person can monitor their hand before picking up the probe.

E. Donning and Doffing Respirators

Half-Face Air Purifying Respirators

Inspection Steps

1. Half-mask Air Purifying Respirators (APRs) must be inspected prior to each use.
2. Visually inspect the half-mask APR. Check for dirt, tears, and misshapen areas, especially on the sealing surface.
3. Check the straps to verify they are not dirty or stretched out.
4. Check that the cartridges are not dented or damaged. Visually check that the cartridges are not cross threaded. Do not remove the cartridges.
5. On belt-mounted half-mask APRs, check that the flexible tube is securely attached

Inspection Failure

1. If the half-mask APR fails any of the inspection points do not use the respirator.
2. Give the half-mask APR to your supervisor and explain why the respirator did not pass inspection.

Donning

1. Verify the straps are loosened.
2. Connect the neck straps behind your head.
3. Place your chin inside the chin area and pull the head strap across the top of your head.
4. Verify the half-mask APR fits comfortably on your face and tighten the straps.
5. Verify the half-mask APR is tight enough to provide a good seal, but not so tight as to be painful.
6. Belt-mounted half-mask APRs
7. Check that the breathing tube is not cracked
8. Clip the cartridge holder on your belt.

Positive and Negative Pressure Fit Checks

Trainee's Notes:

1. Prior to each use, perform a positive or negative pressure fit check to verify the half-face APR is functioning properly.

Positive Pressure Fit Check

1. Place your hand over the exhalation valve and gently breath out.
2. If the half-mask APR is fitted correctly, you should feel the facepiece slightly move away from your face.

Negative Pressure Fit Check

1. Place your palms over the inhalation area on the cartridges and inhale.

2. Hold your breath for 5-10 seconds.

3. The facepiece should collapse toward your face.

Fit Check Failure

1. If the half-mask APR fails either test, remove it, inspect it, don it, and try the test again
2. If the half-mask APR fails the second time, do not use the respirator.
3. Contact your supervisor regarding the problem.
4. Try a second half-mask APR.
5. If the second respirator fails either test, schedule a fit test prior to further half-mask APR, full-facepiece APR, or SCBA use.

Removal (Doffing)

1. Disconnect half-mask APR straps.
2. Remove half-mask APR and unclip the cartridges if using a belt-mounted half-mask APR.
3. Place the half-mask APR in a designated location within the facility, after the final use.

Trainee's Notes:

Full-Face Air Purifying Respirators

Inspection Steps

1. Full-facepiece APRs must be inspected prior to each use.
2. Visually inspect the full-facepiece APR. Check for dirt, tears, and misshapen areas, especially on the sealing surface.
3. Check the visor to verify it is clean, not cracked, and not so badly scratched it will impair vision
4. Check the straps to verify they are not dirty or stretched out.
5. Check that the cartridges are not dented or damaged. Visually check that the cartridges are not cross threaded. Do not remove the cartridges.

Inspection Failure

1. If the full-facepiece APR fails any of the inspection points do not use the respirator.
2. Give the full-facepiece APR to your Supervisor or health and safety representative and explain why the respirator did not pass inspection.

Donning

1. When using the welding lens adapter, snap the adapter onto the visor.
2. Verify the straps are loosened.
3. Place your chin inside the chin area and pull the head harness over your head.
4. Verify the full-facepiece APR fits comfortably on your face and tighten the straps by pulling straps on either side of the respirator at the same time and with equal force.
5. Tighten the bottom straps, temple straps, and finally the top strap.
6. Verify the respirator is tight enough to provide a good seat but not so tight as to be painful.

Positive and Negative Pressure Fit Checks

1. Prior to each use, perform a positive and/or negative pressure fit check to verify the full-face APR is functioning properly.

Trainee's Notes:

Positive Pressure Fit Test

1. Place your hand over the exhalation valve and gently breath out.
2. If the full-facepiece APR is fitted correctly, you should see the visor slightly move away from your face.

Negative Pressure Fit Check

1. Place your palms over the inhalation area on the cartridges and inhale.
2. Hold your breath for 5-10 seconds.
3. The facepiece should collapse toward your face.

Fit Check Failure

1. If the full-facepiece APR fails either test, remove it, inspect it, don it, and try the test again.
2. If the full-facepiece APR fails the second time, do not use the respirator.
3. Contact your Supervisor.
4. Try a second full-facepiece APR
5. If the second respirator fails either test, schedule a fit test prior to further half-mask APR, full-facepiece APR, powered air purifying respirator, SCBA use.

Removal (Doffing)

1. Place hands on either side of the exhalation valve so that the thumb is under the chin and the first finger extends toward the nose.
2. Bend forward and pull the respirator away from your face and forward.

VI. EMERGENCY PROCEDURES

A. Radiological Emergency Situations

Working in a radiological environment requires more precautionary measures than performing the same job in a nonradiological setting. This premise holds true if an emergency arises during radiological work.

Trainee's Notes:

Personnel Injuries In Radiologically Controlled Areas. For minor injuries in a radiologically controlled area, you should:

1. Leave the immediate work area following normal Health Protection procedures, if possible, and notify Health Protection personnel.
2. Health and safety personnel (either on- or off-site) will survey the injury and will determine the need for further treatment.

For serious injuries in a radiologically controlled area, you should give to the immediate health of the individual rather than routine health and safety procedures, such as monitoring or removing protective clothing. If you discover a person needing immediate attention, you should follow the emergency procedures for the given facility or site.

B. Radioactive Spill Control

The acronym SWIMS can be used to deall with radioactive spills.

STOP
1) Stop and evaluate the situation:
- Stop work that is in progress.
- Evaluate for supplemental actions to take.

WARN
1) Warn others of the hazard and evacuate the area.
2) Inform operations and other personnel in the area of the problem.
3) Send others for help if you can't leave. This prevents accidental contamination of other personnel and prevents the spread of contamination to other areas.
4) Information to be passed to others includes the following:
- type of spill
- quantity of the spill
- location of the spill
- any contaminated personnel
- additional information pertinent to the situation

Trainee's Notes:

ISOLATE 1) Isolate the area.
2) Isolating the area will minimize the spread of contamination
3) It will also assist the clean-up personnel in knowing the extent of the spill.
4) Personnel, rope, or tape placed at the entry points is used to limit access into the area.

MINIMIZE 1) Minimize exposure to both contamination and radiation.
2) To minimize your exposure to contamination, take the following precautions:

- stand upwind and move toward the edge of the spill.
- use protective clothing if available.
- do not touch areas suspected of being contaminated.
- prevent tracking contamination to other areas.

SURVEY 1) A survey will be performed by Health Protection Dersonnel. 2) Health and safety surveys will determine the following:

- areas affected by the spill.
- areas requiring cleanup.
- radiological conditions in the area.

Trainee's Notes:

MODULE 8: ALARA

LEARNING OBJECTIVES: Upon completion of this unit, the participant will be able to explain the methods used to implement an ALARA Program. The participant will be able to select the correct response from a group of responses that verifies his ability to:

1. STATE the ALARA concept.
2. IDENTIFY the basic protective measures of time, distance, shielding, contamination control, and personnel protection.
3. IDENTIFY methods for reducing external and internal radiation dose.
4. IDENTIFY methods for waste minimization and contamination control.

I. INTRODUCTION

Even though there are dose limits and other control levels it is prudent to keep radiation exposure well below these. Employees should always try to maintain their radiation dose As Low As Reasonably Achievable (ALARA) and prevent the spread of contamination at the facility.

For remediation of the Dollar Road site, the most important ALARA practices are contamination control and personnel protection. The nature of the radioactive materials, uranium and its daughter products, and the presence of loose contamination at the site indicate that the most significant hazard is internal exposure.

II. DEFINITION AND DESCRIPTION OF THE ALARA PHILOSOPHY

ALARA stands for: As Low As Reasonably Achievable. It is an approach to radiation protection to control or manage exposures (both individual dose equivalents and total collective dose) as low as social, technical, economic, practical, and public policy considerations permit.

The principle objective of the ALARA policy is to reduce the dose to personnel, the public, and the environment to the lowest levels in keeping with good

Trainee's Notes:

operating practices. The ALARA program establishes annual radiation dosage goals and management commitments to assist in meeting those goals. In all cases, this is done within the requirements of DOE orders.

A. International Commission on Radiological Protection

The ICRP, in their Publication 26, incorporated ALARA as an essential component in any radiation safety program. Subsequently, the NRC has adopted the ALARA principle, requiring ALARA programs for all licensees.

ICRP 26 Dose Limitation Tenets:

1. No practice shall be adopted unless its introduction produces a net positive benefit.
2. All exposures shall be kept as low as reasonably achievable, when economic and social benefits are taken into account. Although it may be quite possible to reduce occupational exposures to almost zero by building elaborate shielding systems and designing radiological facilities with complex remote control systems, it is recognized that the expense and limitation on operations might be prohibitive. Radiation workers may accept the additional exposure received (above the natural back ground) because of the salary, benefits, and medical surveillance received. By analogy, the risk of additional exposure to the public from such devices as x-ray machines used for airport security is considered acceptable compared with the social benefit of fewer weapons and explosives taken aboard airplanes.

Dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances. This philosophy applies not only to local administrative exposure guidelines and Federal limits, but to exposures received during emergency operations and other special situations as well

No practice shall be adopted unless its introduction produces a positive net benefit. All exposures shall be kept as low as reasonably achievable, economic and social factors taken into account. Doses to individuals shall not exceed the limits recommended for the immediate circumstances.

Trainee's Notes:

B. General Application

For nuclear facilities and radiologically contaminated remediation sites, ALARA is considered at all phases of work. Work activities are evaluated with respect to worker dose as an integral component of planning.

Employees must be trained in the principles of radiation safety. A working knowledge of what radiation is, where it comes from, how it is harmful to humans, how we can measure and control it, and how personnel can minimize their exposure is essential.

An effective radiation protection, monitoring, planning, and auditing program must be provided. Audible and visible radiation detection and monitoring devices must be available at facilities to clearly notify personnel of the radiological conditions in their working environment. Health and safety personnel is responsible for the implementation of the radiological protection program.
The ultimate responsibility for keeping exposures ALARA rests with the worker who is receiving the exposure. Although numerous sources of assistance and guidance exist, one must make the effort to be aware of the radiological conditions and precautions at the work place. Accurate knowledge of these conditions, and the use of time, distance, shielding, and source reduction, are the best tools for minimizing exposure.

III. METHODS FOR REDUCING AN INDIVIDUAL'S EXTERNAL EXPOSURE

A. Source Reduction

In planning a job or operation involving radiation exposure, consideration should be given to removal of as much of the radiation source(s) as possible. This may include decontamination of area work surfaces, removal of nonessential radioactive material or equipment from the vicinity, draining or flushing of radioactive liquids from fluid systems, or ventilation of airborne radioactivity areas (with appropriate filtering of the air). Remediation activities, of course, are designed to remove contamination sources.

Trainee's Notes:

Minimizing Exposure
• Source Reduction • Time • Distance • Shielding • Manpower Optimization

B. Time

The amount of dose received is directly proportional to the amount of time spent in a given dose-rate field; therefore, exposure is minimized if time spent in that radiation field is minimized. If a one hour job can be cut to a half-hour, the exposure will be cut in half. Stay-time calculations (found by dividing the dose allowed by the area dose rate
and entered on the Radiation Work Permit) must be done for most work in High and Very High Radiation Areas. Adhering to a stay time can help prevent exceeding exposure limits.

Pre-planning for the job is the best way to limit the time required in a radiation area. Whenever possible, mock-ups or simulator training should be performed prior to doing the actual job. This is particularly important if the job involves large amounts of radiation exposure to workers. Other preplanning methods include:

1. schedule effectively;
2. review similar previous job/exposure experience;
3. anticipate and obtain the necessary tools and parts;
4. pre-assemble parts outside radiation areas;
5. perform operability checks (e.g., clean, service, prepare) on equipment prior to entry;
6. determine route to, from, and through areas; g. become familiar with procedures to be used; and h. perform manipulations in a timely manner.

Trainee's Notes:

C. Distance

Maintaining a maximum distance from a radiation source will reduce exposure. For a point source (in which the size of the source is very small compared to the distance from it), radiation intensity varies inversely with the square of the distance from the source. This is called the inverse square law:

INVERSE SQUARE LAW

$$I_2 = I_1 (d_1/d_2)^2$$

where I_1 and I_2 are the intensities of the radiation (dose rates) at points 1 and 2 respectively, and d_1 and d_2 are the distances from the point source at 1 and 2. For example, if the dose rate from a small valve is 100 millirem/hour at one foot, it will be 25 millirem/hour at two feet.

The effect of reducing exposure with distance is somewhat less where large sources such as pipes, tanks, floors, and walls are concerned, but the exposure rate will still decrease in proportion to the distance from any source.

Ways to use distance to reduce exposure include:

1. avoid hot spots;
2. use low background areas during work delays;
3. use low background areas for as much work as possible;
4. work at arm's length from source; and
5. use remote handling devices when possible (for high radiation fields).

D. Shielding

In general, any material through which ionizing radiation passes will absorb some or all of the radiation. This attenuation will depend on the type and energy of the radiation, as well as the thickness and composition of the "shielding" material. Considerable thought is given to incorporating adequate shielding systems during the design of a radiological facility. This shielding can be quite elaborate in some cases, and may even consist of several layers of different materials best suited for different types of radiation.

Trainee's Notes:

Typical shielding materials for the types of radiation include:

1. Alpha: due to the extremely low penetrating ability of alpha particles, shielding is not an important means of control (most can be stopped by a single sheet of paper).
2. Beta: Plexiglas, aluminum, wood, rubber, and plastic. Due to the creation of X-rays when beta particles are stopped by materials with a high atomic number such as lead and steel, these materials are inappropriate for shielding beta particles (unless they are sufficiently thick to stop the X rays also). Recall that this radiation effect is called braking radiation, or "bremsstrahlung."
3. Gamma: lead, concrete, steel. The denser the material, the better suited it is for attenuation of gamma and X-rays.

When preplanning a job, consideration should be given to the use of temporary shielding if the work involves proximity to "hot spots" or other intense sources of radiation such as piping. This shielding usually consists of lead in the form of bricks, sheets, or vinyl-covered blankets, and will be secured as close as possible to the source of radiation. In some cases, the added exposure to personnel installing the shielding (a time-consuming task itself) does not warrant its use.

Other techniques for utilizing shielding to minimize exposure include:

1. Using installed equipment or other structures (or people) for shielding, especially if not currently involved in the work, or leave the area entirely;
2. Using shielded glove boxes or other containment; and
3. Wearing plastic or glass goggles to protect the eyes from beta radiation.

E. Manpower Optimization

Manpower must be utilized as efficiently as possible when the job involves dose. It is important that the dose to each worker be minimized as well as the collective dose to all workers (man-rem).Generally, this means reducing the

Trainee's Notes:

number of workers required to perform a certain task so long as the time spent on the task is not increased substantially.

F. Site Knowledge and Experience

Knowledge of the work area will enable workers to use source reduction. time, distance, shielding, and manpower optimization to minimize their exposure. Workers must become familiar with the job, work procedures, and safety instructions. They must also know where the highest and lowest areas of radiation and contamination are located. Any prior knowledge of possible changes in the radiation or contamination fields should be discussed before entering any area. Any time a worker can suggest a method or technique that might further reduce radiation exposure or better contamination control, they should provide this information to the job supervisor and the health and safety representative.

Trainee's Notes:

MODULE 9: BIOLOGICAL EFFECTS, AND RISKS OF IONIZING RADIATION

LEARNING OBJECTIVES: The participant will be able to select the correct response from a group of responses which verifies his/her ability to:

1. STATE the method by which radiation causes damage to cells.
2. IDENTIFY the possible effects of radiation on cells.
3. DEFINE the terms *acute dose* and *chronic dose*.
4. STATE examples of a chronic radiation dose.
5. DEFINE the terms *somatic effect, genetic effect* and *teratogenic effect*.
6. IDENTIFY sources of nonionizing rdiation.
7. STATE examples of nonionizing radiation effects.
8. COMPARE the biological risks from chronic radiation doses to health risks workers are subjected to in industry and daily life.

I. EFFECTS OF RADIATION ON CELLS

A. IONIZING RADIATION

General. The human body is made up of many organs and each organ of the body is made up of specialized cells. Ionizing radiation can potentially affect the normal operation of these cells.

Biological effects begin with the ionization of atoms. The method by which radiation causes damage to human cells is by ionization of atoms in the cells. Atoms make up cells that make up the tissues of the body. These tissues make up the organs of which our body consists. Any potential radiation damage to our body begins with damage to atoms.

A cell is made up of two principle parts--the body of the cell and the nucleus which is like the brain of the cell. When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell. This occurrence is similar to being struck by a bullet--it may strike a vital part such as your head, or may stroke a less vital part such as your toe.

Trainee's Notes:

Cell Sensitivity. Some cells are more sensitive to environmental factors such as viruses, toxins, and ionizing radiation. Radiation damage to cells may depend on how sensitive the cells are to radiation. Cells that undergo frequent cell division are more sensitive than cells that do not. When the cell divides, the chromosomes become prominent and the probability is increased that a chromosome will be hit and damaged. Cells that rapidly divide include: blood-forming cells, the cells that line our intestinal tract, hair follicles, and cells that form sperm. Cells that do not rapidly divide include nerve cells and brain cells.

Possible Effects of Ionizing Radiation on Cells. When a cell is damaged by something in its environment, such as ionizing radiation, several things can happen. The following are possible effects of radiation on cells.

1. There is No Damage
2. Cells Repair the Damage and Operate Normally

The body of most cells is made up primarily of water. Therefore, when ionizing radiation hits a cell, it is most likely to interact with the water in the cell. Often the cell can repair this type of damage.

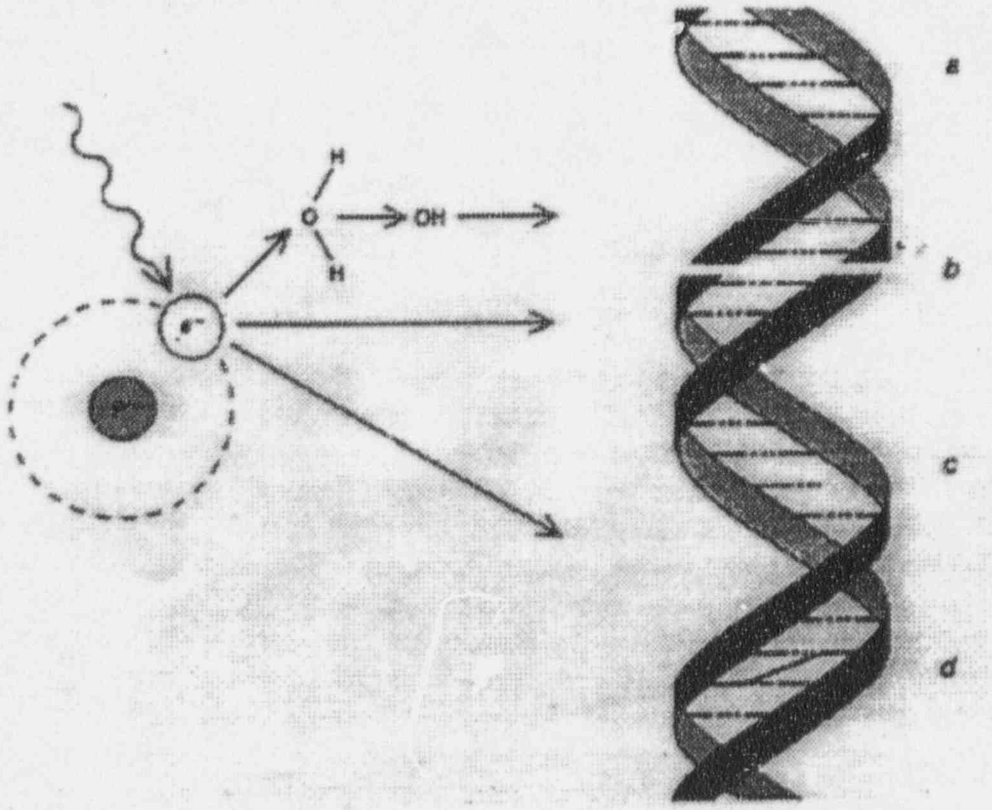
Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell such as chromosomes. (The chromosomes determine the cell's function.) When chromosomes duplicate themselves, they transfer their information to new cells. Damage to chromosomes, although often more difficult, can also be repaired. In fact, the average person repairs 100,000 chromosome breaks per day.

3. Cells are Damaged and Operate Abnormally

We know that the human cell is very resilient and in many cases it just repairs the damage and goes about its business as mentioned above. But the damage may not be repaired or may be incompletely repaired. In that case, the cell may not be able to do its function or it may die. It is possible that a chromosome in the cell nucleus could be damaged and not be repaired correctly.

Trainee's Notes:

At any given moment, thousands of our cells are dying and being replaced by normal cells nearby. It is only when the dose of radiation is very high or is delivered very rapidly that the cell may not be able to repair itself or be replaced.



a. normal DNA, b. double strand break, c. deletion of a base, d. chemical cross linking

Trainee's Notes:

B. NONIONIZING RADIATION

Nonionizing radiation interacts with tissue principally in two ways: thermal or photochemical. With thermal interactions, the electromagnetic waves imparts energy by causing the matter to vibrate. The vibration causes the matter to increase in temperature. This is a common effect with water molecules. The polar nature of water causes it to vibrate when exposed to certain wavelengths of radiation. This is the operating principle of a microwave oven. An example of thermal damage is the development of a retinal lesion following laser exposure to the eye. With photochemical reactions, matter that is sensitive to a certain wavelength of radiation will undergo a chemical reaction. One example is a sun tan. Skin pigmentation reacts when exposed to ultraviolet light, causing the skin to tan. Increased doses of ultraviolet light can cause more serious damage.

II. STOCHASTIC AND NON-STOCHASTIC EFFECTS

A. A health effect is said to be "non-stochastic" when a known dose causes a known effect and when the degree of damage is proportional to or related to the exposure dose. This is the non-probabilistic side of radiation exposure. For example, it takes about 600 to 900 rem acute dose to the eye to cause a cataract. Doses significantly lower than this level are not capable of causing a cataract. Another characteristic of a non-stochastic effect is that the severity of the condition is proportional to the dose. A more prominent and serious cataract will result from doses significantly higher than 900 rem. Other non-stochastic effects include skin burns, lower blood cell count, the three acute dose syndromes, and radiation sickness in general.

Trainee's Notes:

Acute Radiation Syndromes

At high radiation dose rates, significant damage can be done to the human body over a short period of time. The effects can be categorized into one of three syndromes.

Hemopoetic Syndrome - 100 to 1000 rads. Radiation affects the blood forming organs in the bone marrow. Body is unable to keep up with the demand for red and white blood cells. Death, if it occurs, occurs in 30 to 60 days. Cause of death is usually complications from infection. $LD_{50/30}$ = 450 to 650 rad.

Gastrointestinal Syndrome - 1000 to 5000 rads. Radiation affects the cells that transfer nutrients from the small intestine to the blood stream. Body can not control electrolyte balance. Death is in 3 to 5 days.

Central Nervous System Syndrome - 5000 rads +. Significant damage to cells in the central nervous system. Death usually occurs in less than a day.

B. STOCHASTIC EFFECTS

Stochastic, or probabilistic, effects have no known threshold dose level. The probability of contracting the condition (but not its severity) is proportional to the dose received by an exposed population. The induction of cancer and leukemia are examples of stochastic effects. Even low dose levels are thought to be potentially cancer-causing. Other examples of these conditions include lifespan-shortening and genetic effects.

C. ACUTE VS. CHRONIC

Acute exposures to radiation occur over a short time while chronic exposures occur over a long period of time. Exposure to cosmic radiation is an example of acute exposure. A chest x-ray is an example of an acute exposure. The longer the

Trainee's Notes:

exposure time (the smaller the dose rate), the more likely the body can repair the damage from radiation.

D. SOMATIC VS. GENETIC VS. TERATOGENIC EFFECTS

1. Somatic Effects. Somatic effects are effects from exposure to radiation that manifest themselves in the person who is exposed. Somatic effects can be either stochastic or nonstochastic. Examples include cataracts and cancer.

2. Genetic Effects. A genetic effect is an effect passed on to an offspring of the individual exposed. In the case of genetic effects, the individual has experienced damage to some genetic material in reproduction cells. This damage doesn't affect the individual but is passed on to future generations. Genetic effects from radiation have never been observed in humans but have been observed in studies of plants and animals. This includes the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki. (These are children who were conceived after the atom bomb.) Studies have followed these children, their children, and their grandchildren.

3. Teratogenic Effects. Although no effects were seen in Japanese children conceived after the atomic bomb, there were effects seen in some children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki. Embryo/fetal cells are rapidly dividing which makes them sensitive to any environmental factors such as ionizing radiation.

Many chemical and physical (environmental factors) are suspected or known to cause damage to an unborn child, especially early in the pregnancy. Alcohol consumption, exposure to lead, and heat from hot tubs are only a few that have been publicized lately. Some children who were exposed while in the womb to the radiation from the atomic bomb were born with low birth weights and mental retardation (small head size). It has been suggested but not proven that exposures to the unborn may also increase the chance of childhood cancer.

In an effort to be prudent, limits are established to protect the embryo/fetus from any potential effects which may occur from a significant amount of exposure to radiation. This exposure may be the result of exposure to external sources of

Trainee's Notes:

radiation or internal sources of radioactive material. At present occupational dose limits, the actual risk to the embryo/fetus is negligible when compared to normal risk of pregnancy.

E. SUMMARY: FACTORS AFFECTING BIOLOGICAL DAMAGE DUE TO EXPOSURE TO RADIATION

- Total dose. The greater the dose, the greater the effect (or chance of effect)
- Dose rate. The faster the dose is delivered, the less chance for repair and the greater the chance for damage.
- Type of radiation. A rad of alpha radiation is more damaging than a rad of gamma radiation.
- Area of the body exposed. The more exposure to radiosensitive tissues, the more likely that damage will occur. A developing fetus is extremely radiosensitive, specially in the first trimester.

III. RISKS FROM RADIATION

Risks from exposure to ionizing radiation are expressed in terms of the probability of contracting a fatal cancer or causing a genetic effect. Studies based on medical observation and death record review have examined the incident of cancer in a given population exposed to radiation.

A. Recent studies by the American Cancer Society have stated that the average American has a one-in-four chance of contracting cancer and a one-in-five chance of contracting a fatal cancer. The cause of these cancers vary greatly. The causes include smoking, heredity, and radon.

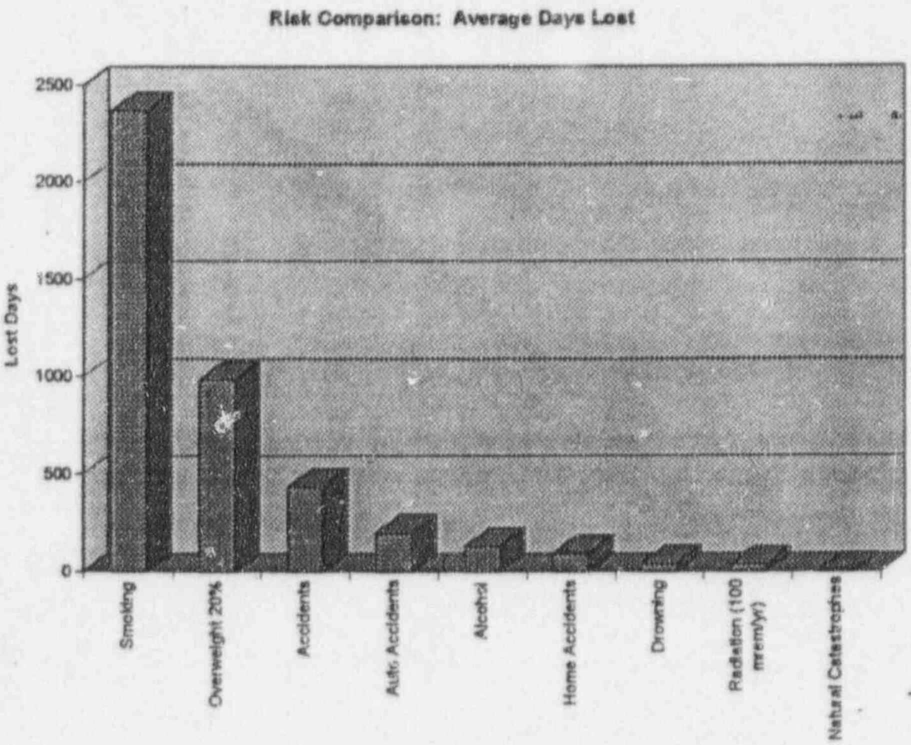
The most current estimate for the risks from ionizing radiation comes from BEIR V. BEIR stands for the Committee on the Biological Effects of Ionizing Radiation. In their fifth publication, they cull all the data on radiation exposure and estimate the risks from th[illegible] exposure. The risk factors they developed are:

Trainee's Notes:

- For a continuous exposure to low levels of radiation (100 millirem per year)

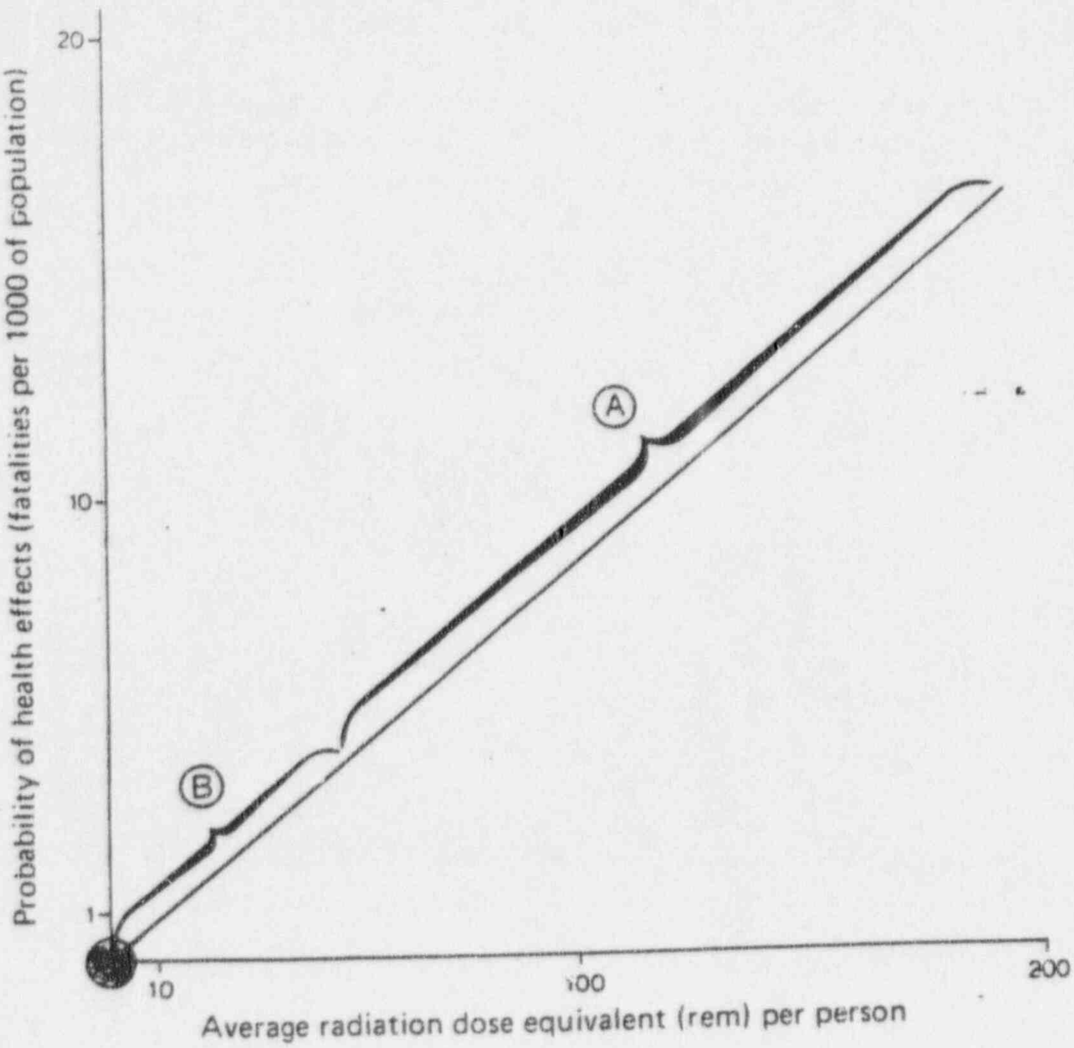
Male:	520 cancers to a population of 100,000 for the exposure
Female:	600 cancers to a population of 100,000 for the exposure
Total:	560 cancers to a population of 100,000 for the exposure

- A one-in-a-million risk of contracting a fatal cancer translates into 1.25 millirem of exposure each year for 70 years The average loss in life associated with the 100 millirem per year exposure is 35 days. For comparison:



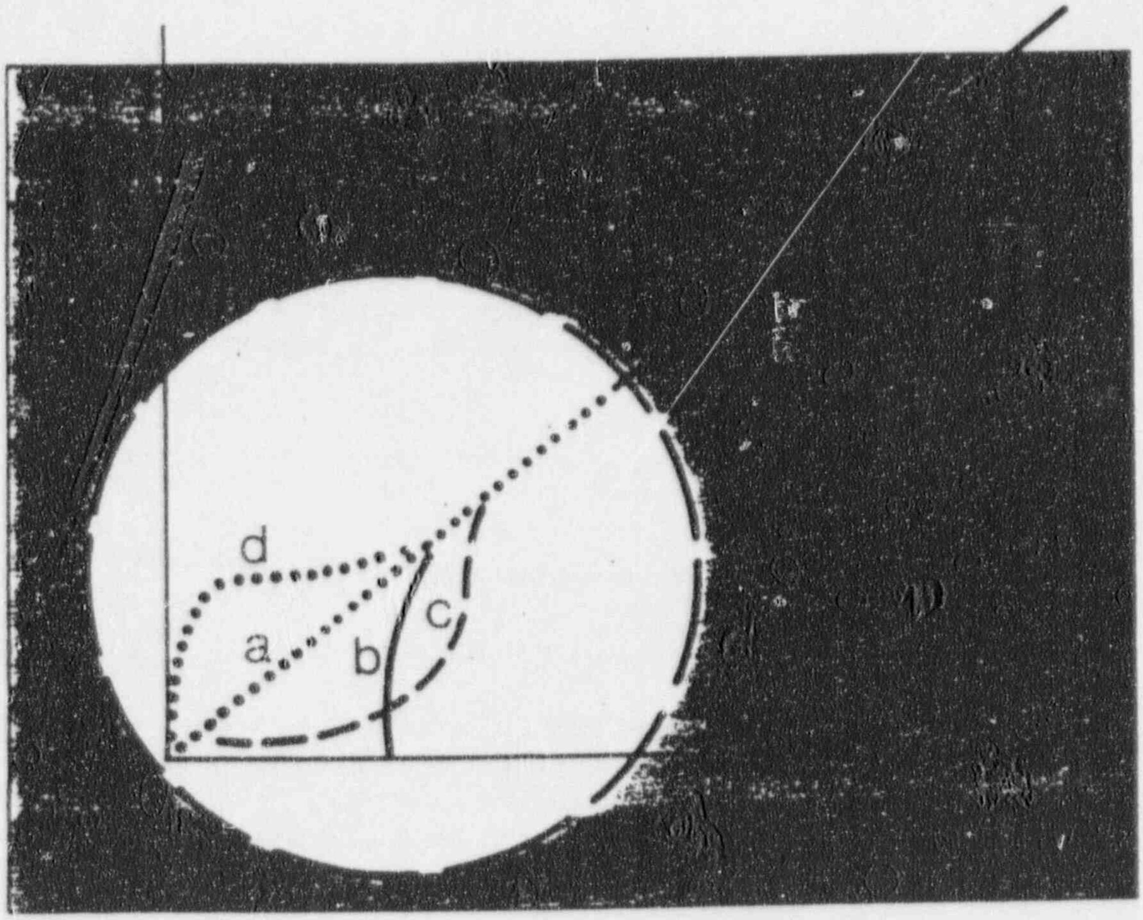
Trainee's Notes:

Linear Non-Threshold Model for Radiation Risk



Trainee's Notes:

Alternative Low-Level Exposure Risk Models



Trainee's Notes:

GLOSSARY

Absorbed dose - Expressed in rads (SI unit = Grays), it is the amount of energy deposited by any type of radiation in any material (one rad = 100 ergs deposited per gram of material).

Acute exposure - A large exposure (or dose) received in a short period of time.

ALARA - As Low as Reasonably Achievable.

Airborne contamination - Radioactive particles or gases in the air.

Annual Dose Equivalent - The dose equivalent received in a year. Annual dose equivalent is expressed in units of rem.

Atom - The smallest part of an element that still retains the chemical properties of that element. The atom is made up of three subatomic particles: protons, neutrons, and electrons.

Bioassay - Analysis of biological samples (e.g., urine, feces) for radioactivity and subsequent estimate of dose

Chronic exposure - Small amounts of radiation received over a long period of time.

Contamination - Radioactive material in an undesirable location.

Delayed somatic effect - Biological effects of radiation that show up many months or years after the dose to the individual

Derived Air Concentration (DAC) - Quantity obtained by dividing the annual limit on intake (ALI) for any given radionuclide by the volume of air breathed by the "reference man" in a year (2.4 x 103 cubic meters).

Dose equivalent- Expressed in rem (SI unit = Seiverts), it is an administrative unit used to relate the absorbed dose (in rads) to the amount of biological damage done by a particular type of radiation (dose equivalent = absorbed dose x quality factor).

Dose rate - The rate at which the body absorbs radiation energy.

Electron - A negatively charged particle orbiting the nucleus of an atom.

Exposure - Expressed in roentgens (or coulombs/kilogram), it is a measure of the amount of ionization produced in air by gamma or X-ray radiation. Exposure has come to be a generic term for radiation dose

External radiation - Radiation that comes from a source outside the body.

Fissile material - A material capable of undergoing fission in the presence of a thermal neutron flux.

Genetic effect - An effect of radiation exposure which may be passed on to a future generation.

Internal radiation - Radiation from a source that has been taken into the body.

Ionizing radiation - Particles or electromagnetic waves that are energetic enough (as opposed to non-ionizing radiation) to produce ion pairs in the material through which they pass.

Natural background radiation - Radiation that comes from the earth, rocks, and soil, which contain naturally occurring radioactive isotopes such as radon, thorium, uranium, and radium or from cosmic rays from the sun and other sources in space.

Neutron - A particle residing within the nucleus of an atom which has nearly the same mass as a proton but carries no electrical charge.

Non-stochastic effects - Effects for which the severity varies with the amount of dose and for which a tnreshold dose may exist.

Prompt somatic effect - The effects which occur almost immediately or within a few days or weeks after radiation exposure.

Proton - Positively charged particle in the nucleus of an atom.

Rad - Unit of absorbed dose.

Rem - Unit of dose equivalent. The rem is a very large unit for most occupational exposure applications, so a smaller unit is used - the millirem. For example:

1 rem = 1,000 millirem
0.3 rem = 300 millirem

Roentgen - The unit of exposure used to measure the amount of ionization in air by gamma or x-rays.

RWP - Radiation Work Permit.

Stochastic effects - Effects that have no known threshold dose (they may occur even after very small doses), and the severity of the effect is not proportional to the amount of dose received.

TLD - Thermoluminescent dosimeter.

Whole body - For radiation protection purposes, it is the trunk of the body from the waist up, plus the head.

Whole body count - A method of detecting and measuring internally deposited radionuclides using a very sensitive gamma detector outside the body.

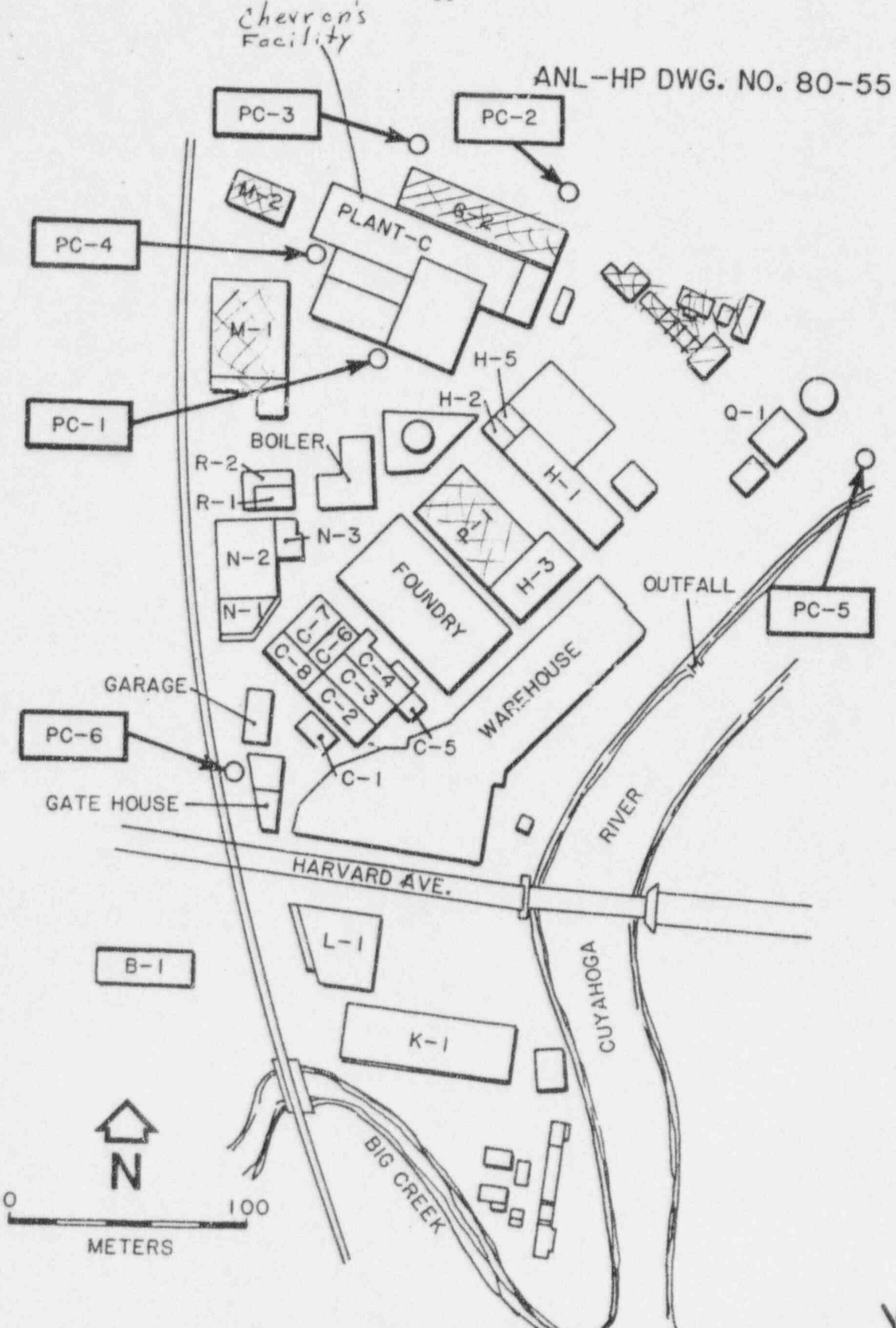
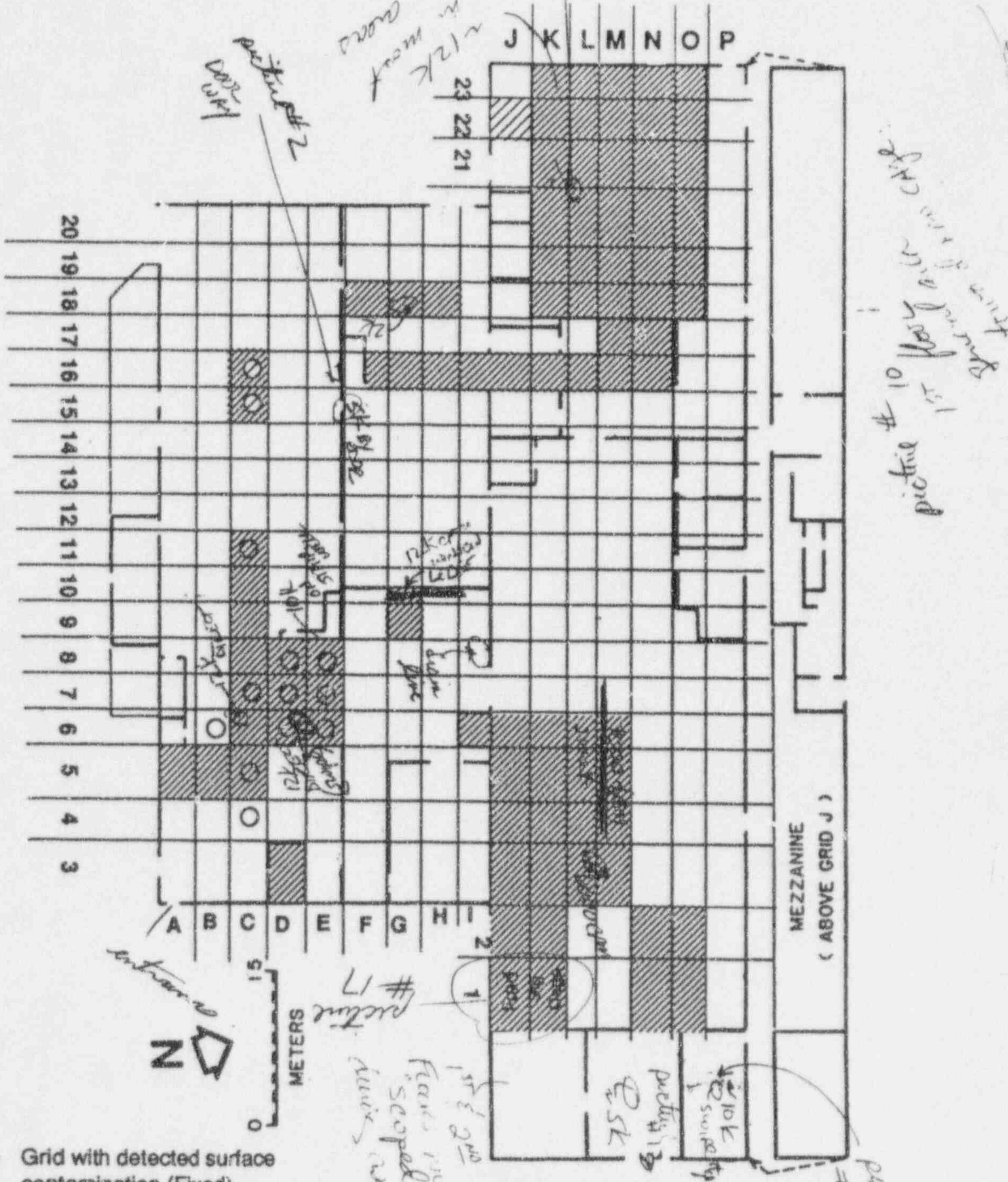


Figure 2. Harshaw Complex Buildings and Soil Sample Locations.

CR

FIGURE 4.4-1

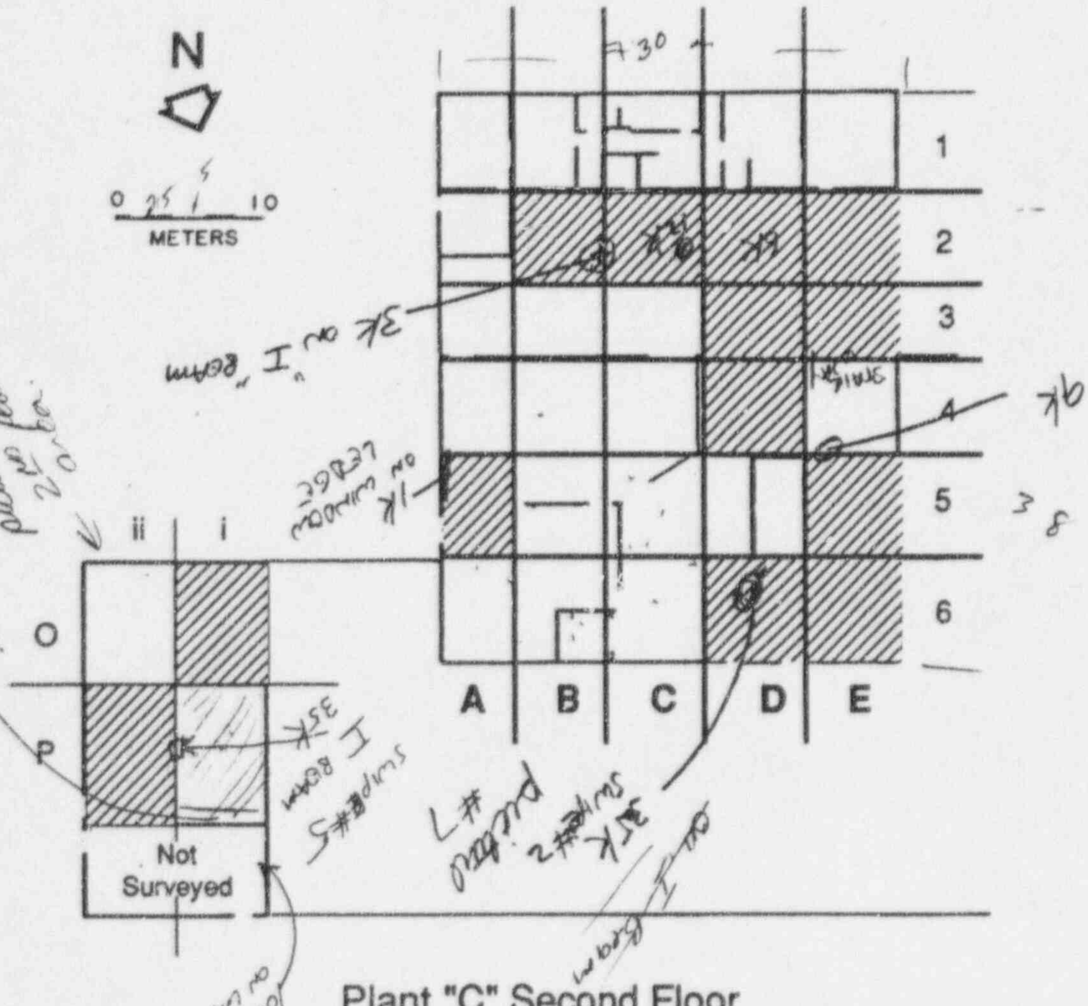


▨ = Grid with detected surface contamination (Fixed)

○ = Grid with detected surface contamination (Removable)

Plant "C" First Floor

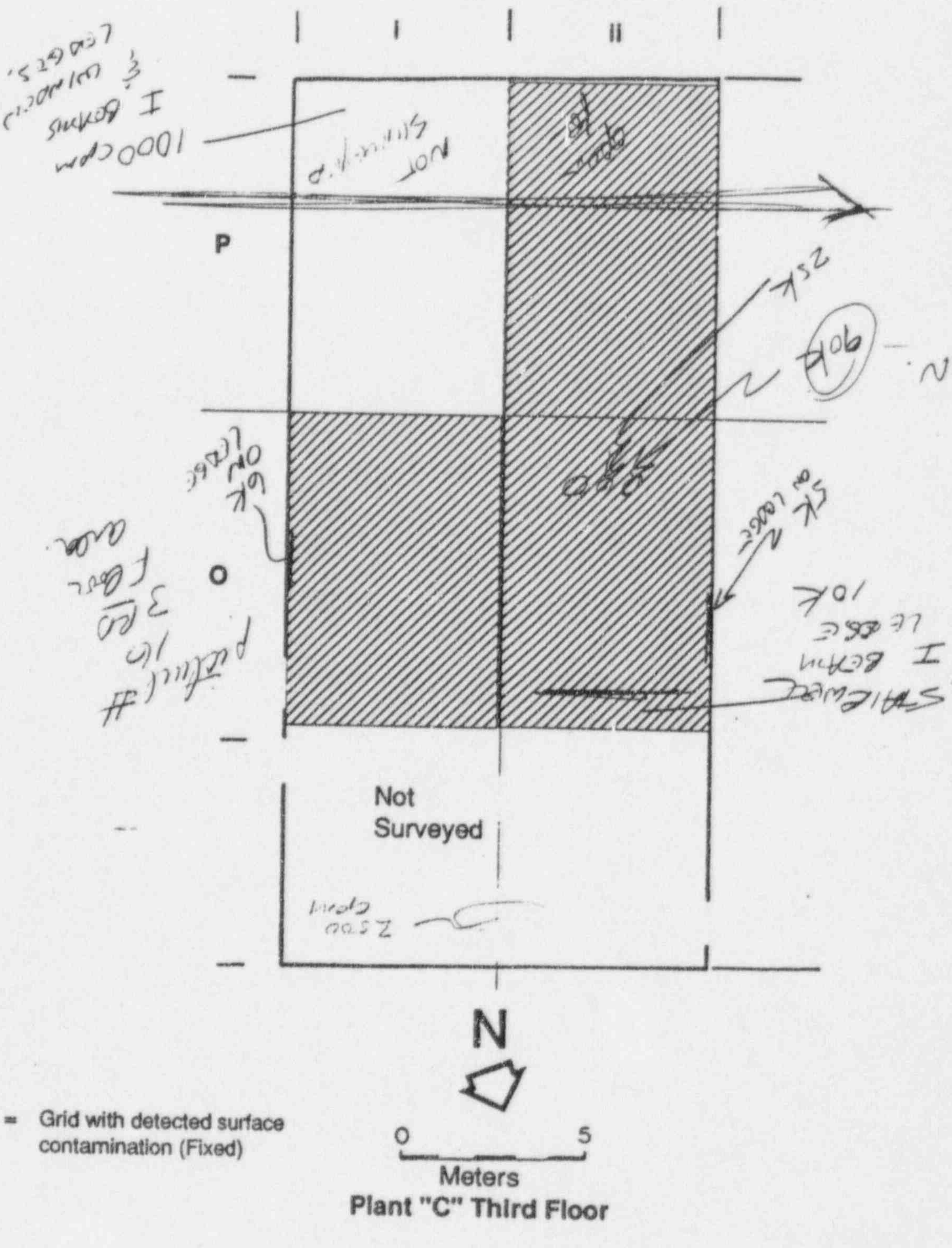
FIGURE 4.4-2



Plant "C" Second Floor

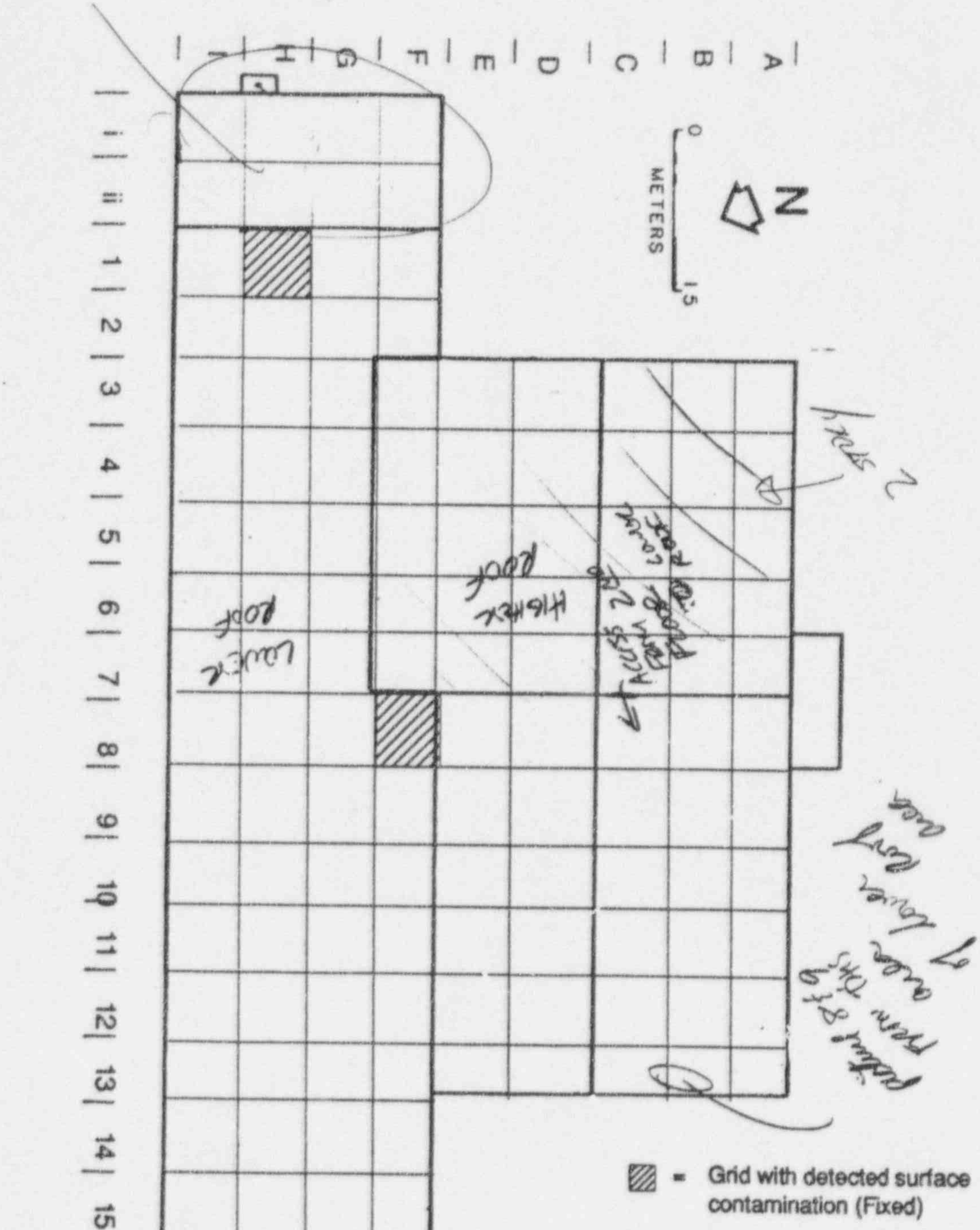
▨ = Grid with detected surface contamination (Fixed)

FIGURE 4.4-3



Plant "C" Third Floor

FIGURE 4.4-4



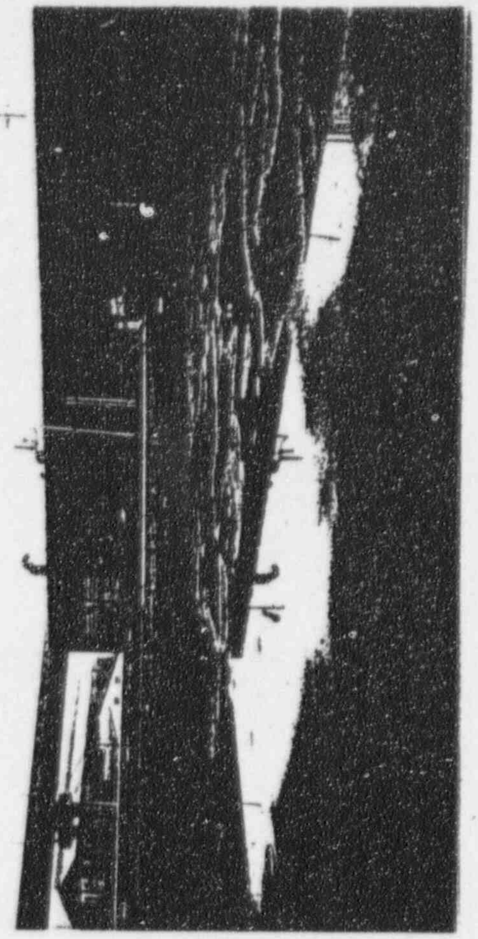
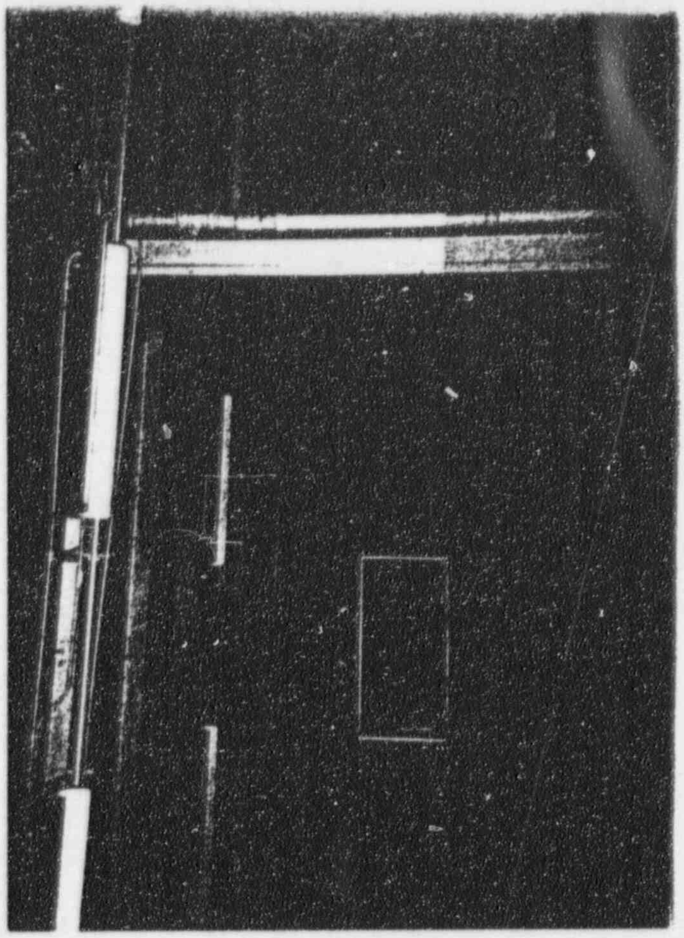
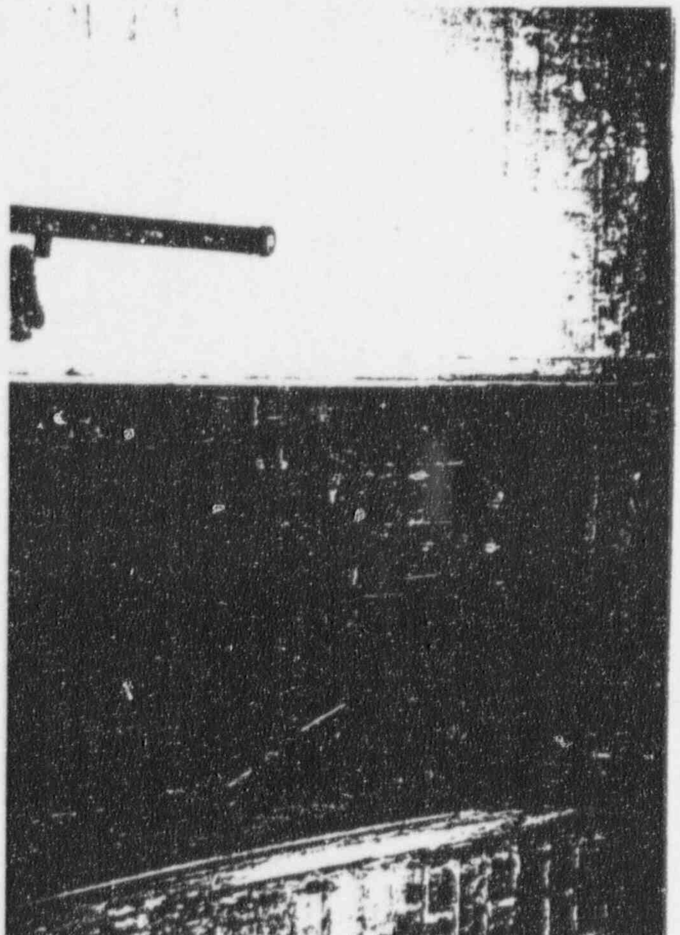
Plant "C" Roof

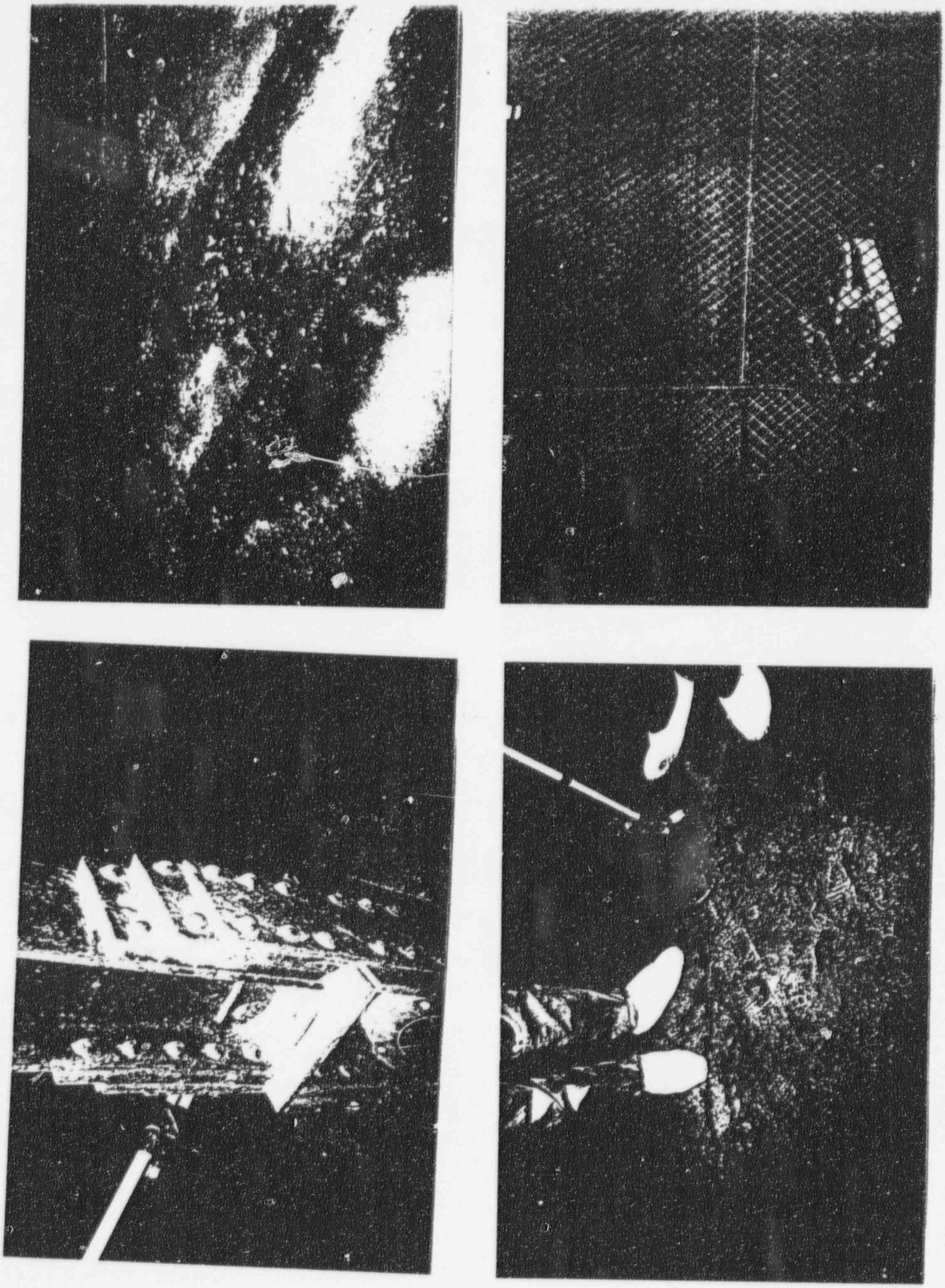
UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION III
801 WARRENVILLE ROAD
LISLE, ILLINOIS 60532-4351

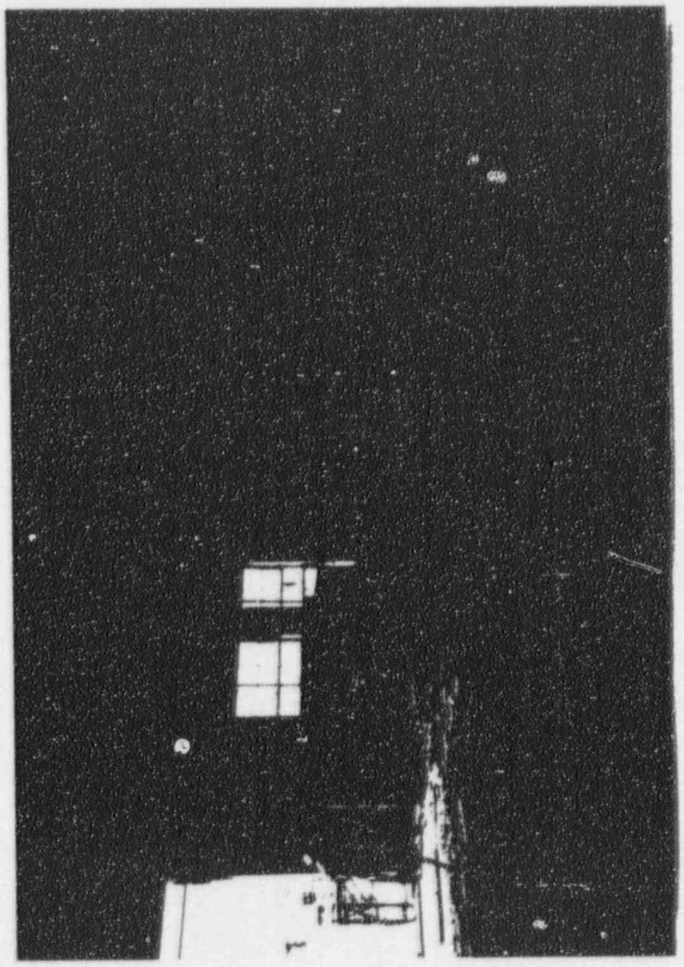
OFFICIAL BUSINESS
PENALITY FOR PRIVATE USE, $300

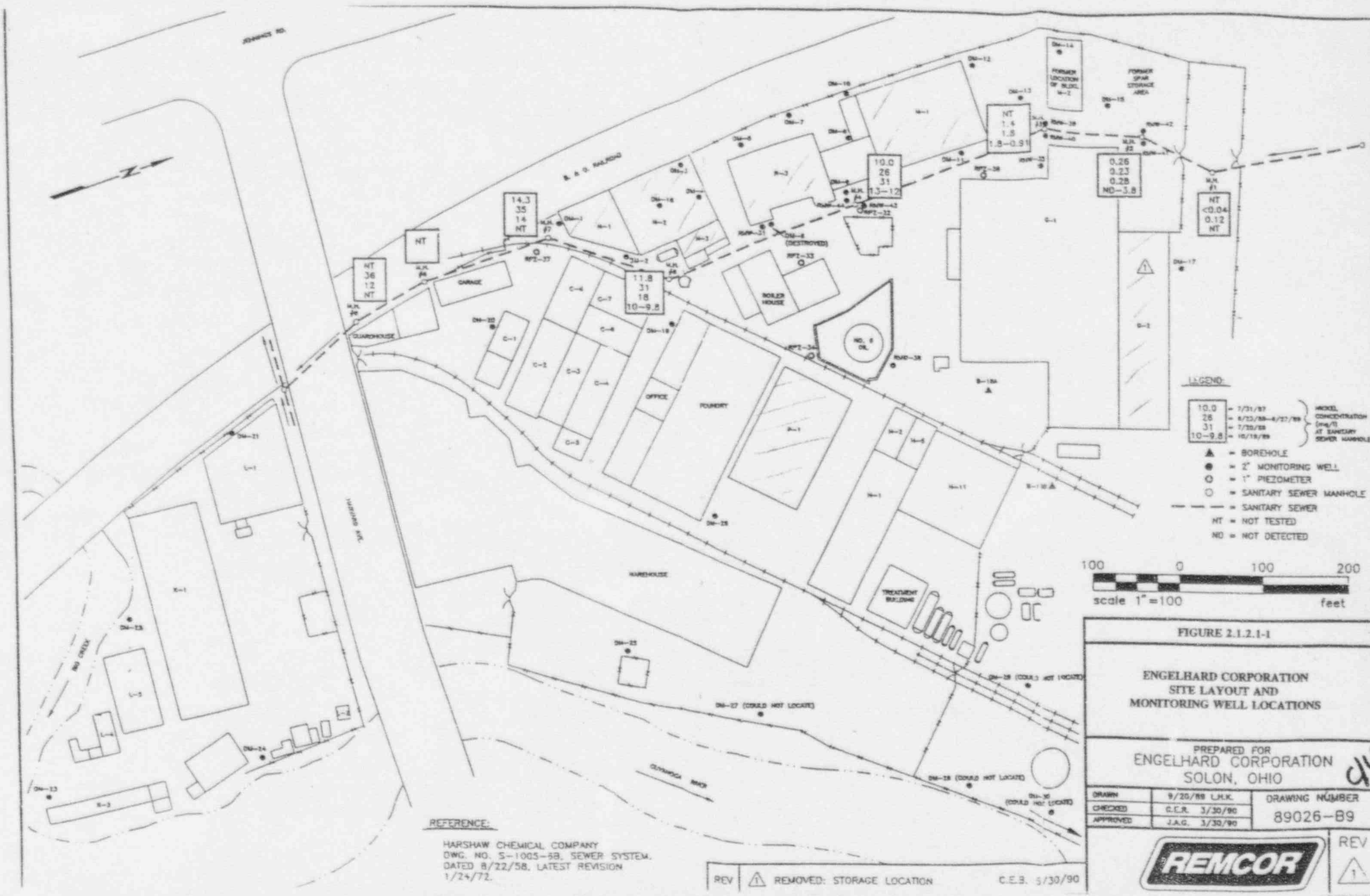
Chevron bldg
Harvard Ave
Cleveland, OH

C/3





REFERENCE:

HARSHAW CHEMICAL COMPANY
DWG. NO. S-1005-58, SEWER SYSTEM,
DATED 8/22/58, LATEST REVISION
1/24/72.

FIGURE 2.1.2.1-1

ENGELHARD CORPORATION
SITE LAYOUT AND
MONITORING WELL LOCATIONS

PREPARED FOR
ENGELHARD CORPORATION
SOLON, OHIO

94

DRAWN	9/20/88 L.H.K.	DRAWING NUMBER
CHECKED	C.E.R. 3/30/90	89026-B9
APPROVED	J.A.G. 3/30/90	

REMCOR

REV 1

Chevron

Chevron Chemical Company
6001 Bollinger Canyon Road, San Ramon, California
Mail Address: P.O. Box 5047, San Ramon, CA 94583-0947

Harshaw Chemical
Harvard Ave.
Lic. No. SMC-606
Exp. date 5/31/73
Terminated 1976
Argonne conducted survey in 1984

R. Wm. Potter
(510) 842-1000

April 5, 1993

Decommissioning of the
Harshaw Chemical Building C Site

Left message 5-6-93 1400

Mr. Robert E. Owen, Chief
Bureau of Radiological Health Services
Ohio Department of Health
Post Office Box 118
246 N. High Street
Columbus, Ohio 43266-0118

Dear Mr. Owen:

The Chevron Chemical Company (Chevron) intends to decommission the former Harshaw Chemicals Building C Site on Harvard Avenue in Cleveland, Ohio. As you know, this site was dropped from the USDOE FUSRAP list of facilities and therefore, is a site which is licensed by neither the USNRC nor the Ohio Department of Health (ODH).

It is our understanding that the ODH and the USNRC previously agreed that the ODH may take regulatory responsibility for the site. In addition, Chevron has previously received requests from the ODH to register the site. However, it remains unclear what entity has regulatory authority, will grant release of the site for unconditional use, and has the authority to release Chevron from future cleanup of the site.

Chevron has retained a decommissioning contractor which possesses an USNRC license which allows the contractor to take possession of the radioactive materials for the purposes of decontamination, packaging and transport. The overall decommissioning plan is as follows:

- Prepare a Decommissioning Plan in accordance with USNRC Regulatory Guide 3.65;
- Complete on-site decontamination and removal activities in 1993;
- Perform Final Release Surveys in accordance with NUREG-2082/NUREG-CR-5849;
- Meet Final Release Limits and;
- Submit a Final Report for regulatory review and request a statement specifying unrestricted release of the Building C site.

Of critical importance to Chevron is protection from future USNRC or ODH requirements for cleanup. At a recent Site Decommissioning Management Plan meeting in Washington, D.C., the USNRC stated that it will guarantee no future action against a site which is released for unconditional use via current release limits. Chevron expects that should it proceed with decommissioning of the site to meet either current USNRC or ODH unrestricted release limits, no future action will be required by either the USNRC or ODH.

APR 22 1993

d17

Therefore, Chevron requests that the ODH state its position (with USNRC concurrence) regarding release of Chevron from future cleanup should Chevron complete decommissioning of the Building C site in accordance with current regulatory guidelines and release limits. Your response is requested by April 30, 1993, in order to complete a timely decommissioning in 1993.

Sincerely,

R. William Potter
Senior Environmental Projects Engineer

RWP:mal

cc: K. Driesrbach - Integrated Environmental Services Inc.
G. C. Jobson - RUST Remedial Services Inc.
K. J. Lambert - USNRC
M. W. Roberts - Engelhard Corp.

CONVERSATION RECORD

TIME	DATE
	5/13/93

TYPE

☐ VISIT ☐ CONFERENCE ☐ TELEPHONE ☐ INCOMING ☐ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Dwain Barr	ODOH	

SUBJECT

Chevron / Engelhard

Remediation

SUMMARY

P-1 bldg - was contaminated + decomm'd by Engelhard in 1991.

Originally to be decommd by Harshaw and released by DOE.

72 - Argon conducted studies

Engelhard

Max Scott - CHP. consultant. for D+D of P-1 bldg.

ACTION REQUIRED

ODOH - does not have registration. Legal staff is currently reviewing the matter. Engelhard is reviewing registration.

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE

ACTION TAKEN

SIGNATURE	TITLE	DATE

C18

CONVERSATION RECORD

TIME	DATE
	5/11/93

TYPE

☐ VISIT ☐ CONFERENCE ☐ TELEPHONE ☐ INCOMING ☐ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Bill Potter	Chevron	510 842-5882

SUBJECT

Chevron, Harshaw Chemical

SUMMARY

Englehart used [illegible] @ 1000 [illegible] Ave.

Andy Popos - (216) 329-2553

54-55 Chevron acquired Gulf, which had acquired Harshaw Chemical

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE

ACTION TAKEN

SIGNATURE	TITLE	DATE

OHIO DEPARTMENT OF HEALTH

DIVISION OF ENVIRONMENTAL HEALTH SERVICES

BUREAU OF RADIOLOGICAL HEALTH SERVICES

NUCLEAR SAFETY PROGRAM

TRANSMITTAL COVER SHEET

NUMBER OF PAGES INCLUDING COVER SHEET: FIVE (5)

DATE: 12·09·93 THURSDAY TIME: 7:15 A.M.

TO: KEN LAMBERT POSITION: FIELD COORDINATOR

ORGANIZATION/AGENCY: NUCLEAR REGULATORY COMMISSION (NRC)

FAX TELEPHONE NUMBER: 1·708·790·5665

OFFICE TELEPHONE NUMBER: 1·708·790·5292

FROM: DWAIN C. BAER POSITION: SENIOR HEALTH PHYSICIST

FAX TELEPHONE NUMBER: 1·614·644·1909

OFFICE TELEPHONE NUMBER: 1·614·2228

SUBJECT: ENGELHARD CORPORATION, ~~THE~~ CLOSE-OUT REPORT ON BUILDING P-1. ALSO, INTERIM LLRW REPORT

C19

246 N. High Street
Post Office Box 118
Columbus, Ohio 43266-0118

Telephone (614) 466-3543

DEPARTMENT OF HEALTH
STATE OF OHIO

GEORGE V. VOINOVICH
Governor

August 05, 1991

Mr. Andrew G. Kopas, Manager of
Environmental Services
ENGELHARD CORPORATION
CATALYST AND CHEMICAL DIVISION
1000 Harvard Avenue
Cleveland, Ohio 44109

Mr. Kopas,

After the radiological survey which the ODH health physicists conducted on Thursday August 01, 1991, building P-1 is now ready for demolition. All survey readings were below the USNRC Regulatory 1.86 Guide. Please provide our office with documentation which will support the disposal of the contaminated structural steel beam, electrical junction box and associated components. Also, as stated in our close-out meeting, please mail us a copy of the low level waste shipping papers which will indicate the number of low level waste barrels and their destination. For your records I have sent two copies of our close-out radiological confirmation survey report.

If you have additional comments, concerns or questions please contact me at 1-800-523-4439.

Dwain C. Baer
Health Physicist II

ENGELHARD

1000 Harvard Avenue

Cleveland, Ohio

CLOSE-OUT RADIOLOGICAL

CONFIRMATION SURVEY

August 01, 1991

Report by: Dwain C. Baer

BACKGROUND:

Meetings between Engelhard and Ohio's Department of Health, Radiological Unit were held on December 18, 1990 and February 19, 1991 to discuss decontamination and demolition of building P-1. The Engelhard plant was formerly owned by Harshaw Chemical Company, which conducted various activities for the Manhattan project and it's successor, the Atomic Energy Commission. As a result, building P-1 was contaminated with chemically pure uranium, 238(99.3%), 235(.699%), 234(.001%) those found in nature and identified by gamma spectroscopy.

The manager of Engelhard's Environmental Services, Andrew Kopas, hired L. Max Scott, Ph.D., and Certified Health Physicist to conduct the initial radiological survey, and to coordinate decontamination activities. During the "decon" process, ODH health physicists conducted radiological surveys to verify compliance with USNRC Regulatory 1.86 Guide ("Termination of Operation of Operating License for Nuclear Reactors").

USNRC 1.86 GUIDE COMPLIANCE:

On August 01, 1991, health physicists from the Ohio Department of Health, Radiological Unit conducted a close-out radiological confirmation survey of Engelhard's P-1 building. The team was looking for areas of contamination with 5,000 DPM or higher per square meter. For safety reasons, one structural steel beam, one electrical junction box and associated components were marked with black spray paint and will be removed during demolition. Also, the concrete floor of building P-1 and two concrete tank supports will not be demolished or removed. Both the floor and tank supports were marked and dated with black spray paint, to indicate that they will not be removed from the site. The ODH health physicists did not find contamination levels close to 5,000 DPM per square meter. All square meter readings were around background levels.

CONCLUSION:

A close-out meeting was held between the ODH health physicists, Andrew Kopas and Max Scott. All survey readings were discussed and confirmed. Mr. Kopas stated that he would mail copies of low level waste shipping papers to the Ohio Department of Health. These papers will indicate the number and destination of waste barrels. Demolition of building P-1 is scheduled to begin immediately.

FEDERAL EXPRESS

ENGELHARD

ENGELHARD CORPORATION
CHEMICAL CATALYSTS GROUP
120 PINE STREET
ELYRIA, OHIO 44035
(216) 322-3741

26-Jul-93

Mr. Dwain C. Baer
Ohio Department of Health
Radiological Unit
Post Office Box 18
Columbus, OH 43266-0118

Subject: INTERIM REPORT OF SHIPMENT OF RADIOACTIVE WASTE TO U.S. ECOLOGY RICHLAND, WASHINGTON

Dear Mr. Baer:

Late in 1992, Engelhard Corporation began to dispose of construction debris (from the Cleveland Harvard-Denison Plant) contaminated with low levels of natural uranium. As you are aware, if the uranium concentration is less than .05%, the material is exempt from U.S. Nuclear Regulatory Commission regulations and can be disposed of as naturally occurring radioactive material (NORM) waste. However, material with uranium concentrations in excess of .05% must be disposed of as low level radioactive waste.

To date, Engelhard Corporation has shipped 854 ft^3 of NORM waste containing 3.482 mCi and 886 ft^3 of low level radioactive waste containing 26.290 mCi.

Please contact me at (216) 329-2553 if you require any additional information.

Sincerely,

A. Kopas

Andrew Kopas, Manager
Environmental Services

AK/dck

[redacted]

OHIO DEPARTMENT OF HEALTH

DIVISION OF ENVIRONMENTAL HEALTH SERVICES

BUREAU OF RADIOLOGICAL HEALTH SERVICES

NUCLEAR SAFETY PROGRAM

TRANSMITTAL COVER SHEET

NUMBER OF PAGES INCLUDING COVER SHEET: ONE (1)

DATE: 12·09·93 THURSDAY TIME: 8:15 A.M.

TO: KEN LAMBERT POSITION: FIELD COORDINATOR

ORGANIZATION/AGENCY: NRC REGION III

FAX TELEPHONE NUMBER: 1·708·790·5665

OFFICE TELEPHONE NUMBER: 1·708·790·5292

FROM: DWAIN C. BAER POSITION: SENIOR HEALTH PHYSICIST

FAX TELEPHONE NUMBER: 1·614·644·1909

OFFICE TELEPHONE NUMBER: 1·614·644·2727

SUBJECT: CHEMICAL WASTE MANAGEMENT PERFORMED A RADIOLOGICAL ASSESSMENT OF CHEVRON BUILDING "C" LOCATED IN CLEVELAND, OHIO, AND WAS COMPLETED IN APRIL 1992. YOU MAY BE ABLE TO GET A COPY OF THE REPORT FROM MIKE LEARY (510)842·5887.

910

246 N. High Street
P.O. Box 118
Columbus, OH 43266-0118

Telephone (614) 466-3543

GEORGE V. VOINOVICH
Governor

Od —
Plz call
me re this. Thanks
Berson
x732

PRIORITY ROUTING

February 26, 1991

Mr. Bruce A. Berson, Legal Counsel
Nuclear Regulatory Commission
Region 3
799 Roosevelt
Glen Ellen, Illinois 60137

RE: Licensure Status; Inglehart and Clecon Metals Sites

Dear Mr. Berson:

The Ohio Department of Health, Bureau of Technical Environmental Health Services, has been informed by the United States Department of Energy that the following sites have radiation contamination:

Inglehart site (formerly Hartshall Chemical)
1000 Harvard Avenue, Cleveland, Ohio

Clecon Metals, Inc. (formerly Horizons, Inc.)
2905 E. 79th Street, Cleveland, Ohio

These two sites were formerly under the jurisdiction of the United States Department of Energy (DOE). The DOE has informed the Ohio Department of Health (ODH) that the DOE has eliminated these sites from its remedial action list after determining that DOE does not have the authority to perform remedial efforts at these sites. Therefore, DOE does not intend to conduct any clean up efforts.

ODH would like to require registration of these sites so that ODH can monitor radioactive materials at the site and any clean-up efforts. After speaking to Don Seronoski of the Nuclear Regulatory Commission Region 3 (NRC), it is the understanding of ODH that the NRC cannot and will not require licensure of these sites since they are former DOE sites. It is also our understanding that the NRC would not object to ODH requiring these sites to register at the state level.

ODH would appreciate confirmation that NRC has no objection to ODH requiring registration of these sites as it appears that there may be building demolition at one of the sites in the immediate future.

MAR 11 1991

9104150059

If I do not hear from you within thirty (30) days of the date of this letter, we will assume that the information provided by Mr. Seronoski is correct, and that the NRC has no objection to ODH registering these sites.

If you have any questions or need additional information, please do not hesitate to contact me at (614)644-1407.

Sincerely,

Carol L. Ray

Carol L. Ray
Assistant Legal Counsel

cc: Roger Suppes
Bob Owen

March 27, 1991

Ms. Carol L. Ray
Assistant Legal Counsel
Ohio Department of Health
246 N. High Street
Post Office Box 118
Columbus, OH 43266-0118

Dear Ms. Ray:

This is in regard to your letter of February 26, 1991, and our telephone conversation of March 22, 1991, concerning two former United States Department of Energy sites, Harshaw Chemical and Horizons, Inc. This will confirm that we have no objection to the Ohio Department of Health seeking registration of the sites at the state level for the purpose of monitoring radioactive materials at the site and any cleanup efforts as stated in your letter.

Sincerely,

Original signed by
Bruce A. Berson

Bruce A. Berson
Regional Counsel

cc: DCD/DCB (RIDS) w/incoming
letter dated 02/26/91

bcc w/incoming letter dated
02/26/91:
A. B Davis, RIII
R. M. Lickus, RIII
R. L. Fonner, OGC

RIII
Sreniawski
03/26/91

RIII
Norelius
03/26/91

RIII
Berson/jr
03/27/91

9104150056

246 N. High Street
Post Office Box 118
Columbus, Ohio 43266-0118

Telephone (614) 466-3543

GEORGE V. VOINOVICH
Governor

PRIORITY ROUTING

FILE HB3

February 26, 1991

Mr. Bruce A. Berson, Legal Counsel
Nuclear Regulatory Commission
Region 3
799 Roosevelt
Glen Ellen, Illinois 60137

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Sincerely,

Carol L. Ray

Carol L. Ray
Assistant Legal Counsel

cc: Roger Suppes
Bob Owen