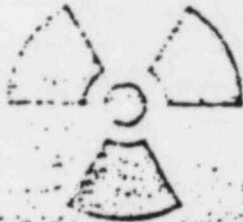


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COBALT-60	CURIES
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	NEUTRON PRODUCTS Dickerson, Maryland

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SUPPLEMENT #4

Item 10, Form NRC 313 I, Radiation Detection Instruments.

Portable Instruments

<u>TYPE</u>	<u>MANUFACTURER</u>	<u>MODEL #</u>	<u>NO. AVAIL</u>	<u>RADIATION DETECTED</u>	<u>SENSITIVITY RANGE</u>
Proportional	Nuclear Measurements Corp.	PC-4	1	Alpha, beta	0-3.5 x 10 ⁶ cpm
G-M	Ludlum Measurements Inc.	Model 2	2	Beta, gamma	0.1-50 mR/hr
G-M	Victoreen	Thyac II, Model 489	1	Alpha, beta, gamma	0.05 - 20 mR/hr 50 - 800 cpm
G-M	Victoreen	Thyac III, Model 490	1	Beta, gamma	0.05 - 200 mR/hr
Ion Chamber	Victoreen	Model 440-RF	1	Gamma	1 - 300 mR/hr
Scintillation	Eberline Instrument	Gadora-1B	1	Gamma	1 - 1000 R/hr
Ion Chamber	Nuclear Chicago	Model 2592	1	Gamma, beta	0.5 - 1000 mR/hr 0 - 10 mR
G-M	Eberline Instrument	Teletector 6112B	2	Gamma, beta	0.01 - 10 ⁶ mR/hr
<u>Area/Resin Bed Monitors</u>					
Scintillation	Nuclear Measurements Corp	Model GA-2T0	1	Gamma	0.1 - 1000 mR/hr
Scintillation	Nuclear Measurements Corp	Model GA-2T0	2	Gamma	1.0 mR/hr - 100 R/hr
Scintillation	Nuclear Measurements Corp	Model GA-2TA	1	Gamma	0.1 - 1000 mR/hr
Scintillation	Ludlum Measurements Inc.	Model 44	1	Gamma	0.02 - 20 mR/hr

Supplement #4 continued

Item 11, Form NRC 313 I, Calibration of Instruments

Portable instruments are calibrated quarterly by Rad Services, Inc., as indicated on Form NRC 313 I. A certificate of calibration by a NBS traceable source is issued by Rad Services and kept on file in the HDL Safety Office. Sources listed below are available for constancy checks.

Remote Area and Resin Bed Monitors permanently installed in the Gamma Radiation Facility are calibrated at periods not to exceed three months. Instruments are placed a known distance from a known source. Calculated values at various distances from the known sources are compared with the observed meter response. The following sources are available for calibration and constance checks:

- a. 1 Co-60 source, 12.3 mR/h at one meter, 26 Jan 1961 (NBS calibrated)
- b. 1 Co-60 source, 1.07 mR/h at one meter, 26 Jan 1961 (NBS calibrated)
- c. 1 Co-60 source, 2.58 mR/h at one meter, 30 Nov 1972 (US Army calibrated)
- d. 1 Cs-137 " , 32.6 R/h at one meter, 2 Mar 1970 (AFRRI calibrated, traceable to NBS)
- e. Radium (D&E) check source obtained from the National Bureau of Standards approximately 28,000 counts/min alpha, plus beta, 23 Mar 1962.

See Supplement #6, Annex 6-F for calibration procedure.

SUPPLEMENT #5

Item 13, Form NRC 313 I, Facilities and Equipment.

1. Area Description and General Features of Facility Construction.

a. Facility Location and Structural Characteristics. The Cobalt-60 Gamma Radiation Facility is comprised of four rooms which are located in the Building 504 Radiation Facility at Harry Diamond Laboratories (HDL), 2800 Powder Mill Road, Adelphi, Maryland. Plan/elevation drawings which characterize the construction of the Radiation Facility and the surrounding area were presented in the initial application as Figures 5-1 through 5-33. Figure 5-1 was included in order to indicate the geographical location of the HDL Radiation Facility and its relationship to the surrounding Washington, DC suburban area. Figures 5-2 through 5-4 were included in order to present a more detailed overview of the HDL complex and provide topographical information about the area immediately surrounding the Radiation Facility. Figures 5-5 through 5-33 are the architect's drawings/specifications from which the Radiation Facility was constructed. The entire building is classified as a "noncombustible construction" type structure as defined in the National Fire Codes, Volume 9, Part 220, published by the National Fire Protection Association in 1975.

b. Location of Cobalt-60. Within the Building 504 Radiation Facility are the four rooms which comprise the Cobalt-60 Gamma Radiation Facility. These rooms are numerically designated on Figures 5-5 through 5-33 as follows: Room 2 is the Exposure Room in which all of the cobalt-60 source elements will be used and stored. Room 4 is the Control Room from which the source elevator is remotely controlled. Room 1 is an entrance maze which connects the Exposure Room to the Control Room. Room 9 is a Mechanical Equipment room which houses the Cobalt-60 elevator drive mechanism and Exposure Room air handling equipment. The cobalt-60 source elements will always be stored at the bottom of the water-filled cylindrical pool which is located in the Exposure Room, except when they are raised above the surface of the pool water via a remotely controlled source elevator. The dimensions of Rooms 1, 2, 4, and 9 are presented in Figures 5-5 and 5-7.

c. Radiation Shielding. The Exposure Room (Rm. 2) and the source storage pool located therein are designed to provide personnel protection from the ionizing radiation emanating from a 40,000 curie cobalt-60 source. The pool is designed to provide 11 feet of deionized water shielding over the sources when they are located at the bottom of the pool. As illustrated by Figure 6-1 of Supplement 6, this amount of shielding will reduce the exposure rate at the surface of the pool to less than 0.25 mR/h. Details concerning the construction of the pool are presented in Paragraph 2.a of this supplement. For in-air irradiation, the Exposure Room walls are designed for a maximum transmitted exposure rate of 0.5 mR/h to the unrestricted areas external to the Exposure Room; the roof is designed for a maximum transmitted exposure rate of 10 mR/h at the roof surface external to the Exposure Room and the entrance maze is designed for a maximum transmitted exposure rate to the maze door of less than 0.25 mR/h. The Exposure Room floor, regolith upon which it rests, and the extension of the Exposure Room walls well into the earth serve to shield the

Supplement No. 5 continued.

building and grounds areas external to the Exposure Room from exposure rates in excess of 0.25 mR/h. Since all shielding calculations involving the use of concrete were based on the assumption that the concrete would have a density of 147 pounds per cubic foot, random pour-samples were analyzed. All samples were found to meet or exceed the assumed density. Figures 5-5 and 5-7 present information concerning the thickness and composition of the radiation shielding.

d. Radiation Levels. The Cobalt-60 Gamma Radiation Facility shielding is designed to limit the exposure rate to "unrestricted areas" in and around the building to 0.5 mrem per hour. This level of exposure satisfies the requirement for "unrestricted areas" as defined in Title 10, Chapter 1, Code of Federal Regulations, Part 20.

(1) Exposure Room. Since in-air exposures require that the cobalt-60 source elements be raised from the pool via the source elevator, the source elements will be located 6 feet from the east and west walls, 28.33 feet from the north wall, 14.3 feet from the south wall and 8.5 feet from the ceiling. For purposes of in-air exposure calculations presented below, it is assumed that 32 source elements, containing a total of 40,000 curies of Co-60, are arranged in a circle with a radius of 14.49 centimeters, and raised via the elevator to a height of 5.5 feet from the Exposure Room floor. The list of references used to perform the following analysis is found in paragraph 1d(3) of this supplement.

(a) East and West Walls. According to Reference 1, page 7-71, the source-field geometry for the east and west walls requires the use of "point isotropic" build-up factors in order to calculate the attenuation provided by the concrete walls. This determination is made as follows:

$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut}$ and $d > t$, use "plane collimated" build-up factor. If both conditions are not true, use "point source" build-up factor.

d = distance from source array to shield = 182.98 cm
 a = maximum radius of source array, measured perpendicular to d = 14.49 cm
 t = shield thickness = 152.4 cm
 u = linear attenuation coefficient for 1.25 MeV photons in concrete of density 2.35 gm/cm³ = 0.1332 cm⁻¹ (Reference 1, page 7-62)
 $d > t$ = 182.88 cm > 152.4 cm (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(182.88 \text{ cm}) - (152.4 \text{ cm})} < \frac{\sqrt{2(.1332)(152.4 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} =$$

0.4754 < 0.3177. Since the second condition is not satisfied, one should use point isotropic source build-up factors for east and west shield wall attenuation calculations.

Use of Capo's formula for a "point source" in an infinite medium, presented in Reference 2, page 213-217, yields a conservative build-up factor of 62.4 for 1.25 MeV photons passing through 152.4 cm of ordinary concrete with a density of 2.35 gm/cm³. (uX = 20.30 mean free path lengths)

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The attenuation factor "A_R" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is $A = I/I_0 = b \exp(-uX)$.

- I₀ = original exposure rate to unshielded external wall surface
- I = attenuated radiation exposure rate due to shield
- u = linear absorption coefficient (0.1332 cm⁻¹)
- X = shield thickness (152.4 cm concrete)
- b = build-up factor = 62.4

$$I_0 = \left(\frac{3.28'}{11'}\right)^2 \times (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter/Ci}) = 4.695 \times 10^3 \text{ R/h}$$

Required attenuation factor for "unrestricted areas": A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 4.695 \times 10^6 \text{ mR/h} = 10.65 \times 10^{-8}$$

Attenuation factor provided by 152.4 cm of concrete =

$$A_p = b e^{-uX}$$

$$A_p = (62.4) (e^{-(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})}) = 62.4(1.527 \times 10^{-9}) \\ = 9.53 \times 10^{-8}$$

Since $A_p < A_R$ (ie, $9.53 \times 10^{-8} < 10.65 \times 10^{-8}$) the shielding for both the east and west walls in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the walls to < 0.5 mR/h.

(b) North Wall. According to Reference 1, the source-shield geometry for the north wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the north wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$d > t = 863.6 \text{ cm} > 137.16 \text{ cm}$, (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut + 1}}{ut} = \frac{14.49 \text{ cm}}{(863.6 \text{ cm}) - (137.16 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(137.16 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(137.16 \text{ cm})} =$$

0.020 < 0.335. Since this condition is also satisfied, one should use "plane collimated" build-up factors for north wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 17 for a broad parallel beam of 1.25 MeV photons passing through 137.16 cm ($uX = 18.28$ mean free paths) of ordinary concrete.

The attenuation factor "A_R" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

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$$I_0 = \left(\frac{3.28'}{32.83'}\right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter/Ci}) = 5.270 \times 10^2 \text{ R/h}$$

Required attenuation factor for "unrestricted area" = A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 5.269 \times 10^5 \text{ mR/h} = 9.489 \times 10^{-7}$$

Attenuation factor provided by 137.2 cm of concrete:

$$A_p = b e^{-uX}$$

$$A_p = 17 e^{-(0.1332 \text{ cm}^{-1})(137.2 \text{ cm})} = 17(1.157 \times 10^{-8}) \\ = 1.967 \times 10^{-7}$$

Since $A_p < A_R$ (ie, $1.967 \times 10^{-7} < 9.489 \times 10^{-7}$) the shielding for the north wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to $< 0.5 \text{ mR/h}$.

(c) South Wall. According to Reference 1, the source-shield geometry for the south wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the south wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$$d > t = 441.96 \text{ cm} > 152.4 \text{ cm, (condition satisfied)}$$

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(441.96 \text{ cm}) - (152.4 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(152.4 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} =$$

$0.05 < 0.3177$. Since this condition is also satisfied, one should use "plane collimated" build-up factors for south wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 20 for a broad parallel beam of 1.25 MeV photons passing through 152.4 cm ($uX = 20.30$ mean free paths) of ordinary concrete.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_0 = \left(\frac{3.28'}{19.5'}\right)^2 (40,000 \text{ curies}) (1.32 \text{ R/h at 1 meter/Ci}) = 1.494 \times 10^3 \text{ R/h}$$

Required attenuation factor for unrestricted area = A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 1.494 \times 10^6 \text{ mR/h} = 3.347 \times 10^{-7}$$

Attenuation factor provided by 152.4 cm of concrete:

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$$A_p = b e^{-uX}$$

$$A_p = 20 e^{-(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} = 20(1.527 \times 10^{-9}) \\ = 3.055 \times 10^{-8}$$

Since $A_p < A_R$ (ie, $3.055 \times 10^{-8} < 3.347 \times 10^{-7}$) the shielding for the south wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to $< 0.5 \text{ mR/h}$.

(d) Roof. The roof over the Cobalt-60 Gamma Radiation Facility Exposure Room is a "restricted area". Personnel access to this area is not permitted during periods when in-air irradiation are in progress. Consequently, an exposure rate of 5 mR/h at a distance of 6 inches from the outer surface of the Exposure Room roof shield slab is considered adequate.

According to Reference 1, the source-shield geometry for the roof requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the roof. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$$d > t = (213.36 \text{ cm}) > (121.92 \text{ cm}), \text{ (condition satisfied)}$$

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(213.36 \text{ cm}) - (121.92 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(121.92 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(121.92 \text{ cm})} =$$

$0.158 < 0.356$. Since this condition is also satisfied, one should use "plane collimated" build-up factors for roof shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 15 for a broad parallel beam of 1.25 MeV photons passing through 121.92 cm ($uX = 16.24$ mean free paths) of ordinary concrete.

The attenuation factor " A_R " required to reduce the exposure rate from $40,000$ curies of cobalt-60 to 5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_0 = \left(\frac{3.28'}{13'}\right)^2 (40,000 \text{ curies})(1.32 \text{ R/h at 1 meter/curie}) = 3.361 \times 10^3 \text{ R/h}$$

Required attenuation factor for 5 mR/h "restricted area" roof = A_R

$$A_R = \frac{I}{I_0} = 5 \text{ mR/h} / 3.361 \times 10^6 \text{ mR/h} = 1.488 \times 10^{-6}$$

Attenuation factor provided by 121.92 cm of concrete:

$$A_p = b e^{-uX}$$

$$A_p = 15 e^{-(0.1332 \text{ cm}^{-1})(121.92 \text{ cm})} = 15(8.878 \times 10^{-8}) \\ = 1.332 \times 10^{-6}$$

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Since $A_p < A_R$ (ie, $1.332 \times 10^{-6} < 1.488 \times 10^{-6}$) the shielding for the roof in the worst case is adequate to reduce the exposure rate at 6 inches past the external surface of the roof shield slab to < 5 mR/h.

(e) Floor. As illustrated on Figure 5-7, all Exposure Room walls extend well past the floor into the soil. This structural characteristic serves to shield personnel located outside of the Exposure Room from scattered photons which have passed through the floor during in-air irradiations. Since the north wall of the Exposure Room extends the shortest distance into the soil, less shielding is provided by the soil in this area than in any other. Consequently, the following analysis presents the "worst case" situation.

The shortest distance between the exposed source and a point beneath the north wall where a scatter angle of 30° exists is (18' air + 14' soil) = 32 feet.

Since the density of the sandy soil on which the facility is built is approximately equal to concrete, a conservative estimate of the soil build-up factor is obtained by extrapolation of Figure 4.3-24 in Reference 2, page 222. For 1.25 MeV photons passing through 426 cm of soil ($\mu X = 60$ mean free paths) a build-up factor 300 is chosen.

The mass attenuation coefficient (μ/p) for sandy soil is determined by using the weighted average method presented in Reference 2, page 172. The chemical composition of the soil necessary for the determination of μ/p was obtained from Reference 3. The value of μ/p obtained via this method = $0.05695 \text{ cm}^2/\text{gm}$. The density of the sandy soil used for the determination of μ/p is 2.471 gm/cm^3 .

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_o = \left(\frac{3.28'}{32'} \right)^2 (40,000 \text{ curies}) (1.32 \text{ R/h at 1 meter/Ci}) = 5.55 \times 10^2 \text{ R/h}$$

$$A_R = \frac{I}{I_o} = \frac{0.5 \text{ mR/h}}{5.55 \times 10^2 \text{ mR/h}} = 9.01 \times 10^{-7}$$

Attenuation factor provided by 426 cm of soil:

$$A_p = b e^{-\mu X}$$

$$A_p = 300 e^{-(0.1407 \text{ cm}^{-1})(426 \text{ cm})} = 2.79 \times 10^{-24}$$

Since $A_p < A_R$ (ie, $2.79 \times 10^{-24} < 9.01 \times 10^{-7}$) the shielding provided by the soil in the worst case is adequate to reduce the exposure rate to well below 0.5 mR/h before the photons can pass from the scatter point beneath the wall to any point exterior to the building.

(f) Exposure Room Entrance Maze. As illustrated on Sketch 5-1, the maze leading from the Exposure Room to the Control Room present a path for gamma

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radiation, originating at the source elevator, which contains 3 right-angle bends. In order to conservatively calculate the exposure rate to the maze-side of the maze entrance door, the data presented in Reference 4, page 73, will be used.

The concrete walls, ceilings, and floor of the Exposure Room and Maze are in excess of 2 mean free path lengths thick (5.9 in.), and therefore are treated as being infinitely thick reflectors of 1.25 MeV cobalt-60 gamma photons. This assumption is supported by Reference 5.

Since the maze contains three right-angle bends and both the calculated and measured dose rates (D/D_0) (10^4) given in Reference 4, Table II, are for two-legged concrete ducts, the maze will be treated as a combination of 2, two-legged duct arrangements, connected in series. The dose rate at point P_2 , resulting from the cobalt-60 source located at point P_1 , is calculated. Then the dose rate at point P_3 is calculated using the dose rate at the point P_2 as the source of gamma radiation. Since the gamma photons at point P_2 will be primarily the result of Compton interaction and the data given in Reference 4, Table II is based on cobalt-60 source emitting photons with a mean energy of 1.25 MeV, the dose rate calculated for point P_3 will be conservative. In addition, the dose rate values extracted from Table II for this analysis will be greater than encountered in the actual maze due to the fact that the duct dimensions corresponding to the exposure rate values in Table II are chosen for smaller values of W , smaller values of L_1/W and smaller values of L_2/W than are encountered in the actual maze.

In addition to the symbols presented on Sketch 5-1, the following notation will be used in the calculations: D_0 = dose rate at 1 foot from the source
 D = dose rate at a point located in the second leg of a two-legged duct (ie, P_2 and P_3)

$$\begin{aligned} \underline{D_0 \text{ (point } P_1)} &= \left(\frac{3.28}{1}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) \\ &= 5.68 \times 10^5 \text{ R/h} \end{aligned}$$

D at point P_2 : Value of ($D/D_0 \times 10^4$) selected using Table II data for Terrell's work which involved the use of a 3.67 Ci Co-60 source in a duct with specifications $W = 6'$, $L_1/W = 2.0$, and $L_2/W = 3.17$.

$$\begin{aligned} D/(D_0 \times 10^{-4}) &= 0.203 \therefore D = (0.203) (D_0) (10^{-4}) \\ &= (0.203) (5.68 \times 10^5 \text{ R/h}) (10^{-4}) \\ &= 11.53 \text{ R/h at point } P_2 \end{aligned}$$

D at point P_3 : Using the dose rate calculated above at point P_2 as the origin of the gamma radiation one may conservatively calculate the dose rate at point P_3 . The value of ($D/D_0 \times 10^4$) is selected using Table II data for Chapman's work which involved the use of a 2.4 Ci Co-60 source in a duct with specifications $W = 3'$, $L_1/W = 2$, and $L_2/W = 1.67$.

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$$\begin{aligned} D/(D_0 \times 10^{-4}) &= 5.95 \therefore D = (5.95)(D_0)(10^{-4}) \\ &= (5.95)(11.53 \text{ R/h})(10^{-4}) \\ &= 6.9 \times 10^{-3} \text{ R/h at point } P_3 \end{aligned}$$

Consequently, assuming air attenuation to be negligible, the dose rate at the center of the maze-side surface of the maze doors will be approximately:

$$I_1 = \frac{I_0 d_0^2}{d_1^2} = \frac{(6.9 \times 10^{-3} \text{ R/h})(2.5')^2}{(10')^2 (10^3)} = 0.43 \text{ mR/h}$$

(g) West Wall of Maze. Since the dose rate at the point P_2 (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value is used to evaluate the adequacy of shielding provided by the west wall of the maze. The most probable energy of the cobalt-60 gamma photons scattered through an angle of 90° as a result of a single collision is 0.362 MeV according to Reference 6, page 59. The mass attenuation coefficient from Reference 1 for 0.5 MeV gamma photons in concrete will be used in the following calculations. The dose rate at the outside surface of the west maze wall without shielding = I_0 .

$$I_0 = \frac{(11.53 \text{ R/h})(1')^2}{(14.49')^2} = 5.49 \times 10^{-2} \text{ R/h}$$

The shielding factor required to reduce the exposure rate at the outside surface of the west maze wall = A_R .

$$A_R = I/I_0 = 0.5 \text{ mR/h}/54.9 \text{ mR/h} = 9.11 \times 10^{-3}$$

The shielding factor provided by the west maze wall (61 cm of concrete) = $A_p = b e^{-uX}$

"b" for 12.5 mean free path lengths in concrete ≈ 15 [note $uX = (0.2045)(61 \text{ cm}) = 12.47$] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 15 e^{-(.2045 \text{ cm}^{-1})(61 \text{ cm})} = 5.73 \times 10^{-5}$$

Since $A_p < A_R$ (ie, $5.73 \times 10^{-5} < 9.11 \times 10^{-3}$) the shielding for the west wall of the maze is sufficient to reduce the dose rate at the "unrestricted area" side of the wall to $< 0.5 \text{ mR/h}$.

(h) Maze Scatter Shield. Since the dose rate at the point P_2 (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value will be used to evaluate the adequacy of shielding provided to the Control Room by the maze scatter shield. As in the analysis presented in paragraph 1d(1)(g), it will be assumed that the gamma photons have an initial energy of 0.5 MeV.

Shield factor required to reduce the dose rate at the maze-side of the maze entrance door to 0.5 mR/h is A_R .

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$$I_0 = \frac{(11.53 \text{ R/h})(1)^2}{(8.5')^2} = 1.6 \times 10^{-1} \text{ R/h}$$

$$A_R = I/I_0 = 0.5 \text{ mR/h}/160 \text{ mR/h} = 3.125 \times 10^{-3}$$

The shielding factor provided by the maze scatter shield is $A_p = b e^{-uX}$.

"b" for 9.4 mean free paths in concrete ≈ 10 [note $uX = (0.2045 \text{ cm}^{-1})(45.7 \text{ cm}) = 9.35$] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 10 e^{-(.2045 \text{ cm}^{-1})(45.7 \text{ cm})} = 8.73 \times 10^{-4}$$

Since $A_p < A_R$ (ie, $8.73 \times 10^{-4} < 3.125 \times 10^{-3}$) the shielding provided by the maze scatter shield is sufficient to reduce the dose rate at the maze-side of the maze entrance door to less than 0.5 mR/h. Consequently, the dose rate at the Control Room side of the maze entrance doors will also be less than 0.5 mR/h.

(2) Exposure Room Shielding Penetrations

(a) Exhaust Ventilation Duct. The exhaust ventilation duct penetrates the Exposure Room roof slab at a location near the south wall. As illustrated on Figures 5-7, 5-12, and Sketch 5-2, the exhaust duct is designed to provide shielding for both direct and scattered gamma radiation emanating from the cobalt-60 sources when they are utilized for in-air irradiations. All primary cobalt-60 gamma photons entering the "radiation trap" will be attenuated by a minimum of 46 inches of concrete. This amount of shielding is sufficient to reduce the exposure rate at a distance of one foot from the external surface of the "radiation trap" to less than 5 mR/h. The following "worst case" analysis assumes that the path of primary gamma photons is through 4 inches of the corner lip of the first right-angle bend in the duct prior to impinging on the south shield wall of the "radiation trap".

$$I_0 = \left(\frac{3.28'}{26'}\right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 8.403 \times 10^2 \text{ R/h}$$

Attenuation required to reduce the exposure rate to 5.0 mR/h at a distance of 1 foot from the external surface of the shield = A_R .

$$A_R = I/I_0 = 5 \text{ mR/h}/8.403 \times 10^5 \text{ mR/h} = 5.95 \times 10^{-6}$$

Attenuation provided by the concrete shield for 1.25 MeV gamma photons = A_p .

$$A_p = b e^{-uX}$$

"b" for 15.5 mean free paths = 30 (conservative estimate from Table 43.3-7, Reference 1, page 224 for $\cos \theta = 0.75$)

$$A_p = (30) e^{-(0.1332 \text{ cm}^{-1})(116.84 \text{ cm})} = 5.226 \times 10^{-6}$$

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Since $A_p < A_R$ (ie, $5.226 \times 10^{-6} < 5.95 \times 10^{-6}$) the "radiation trap" shielding for primary gamma radiation from a 40,000 curie cobalt-60 source is sufficient to reduce the exposure rate to less than 5 mR/h at a distance of one foot from the external surface of the "radiation trap".

A conservative estimate of the exposure rate at the exhaust point of the ventilation duct which passes through the "radiation trap" is obtained by using the data presented by Green in Reference 4, Table II and assuming that the exposure rate at the Exposure Room side of the duct is due to primary cobalt-60 gamma photons from a point source. In order to use the data in Reference 4, it will be assumed that the width (W) of the "radiation trap" duct is 9.47 inches instead of the actual dimension of 34 inches. The exposure rate value calculated assuming a 9.47 inch duct width will be increased by a factor of 3.59 in order to estimate the total exposure rate from the 34 inch wide duct. Use of this method effectively increases the primary and multiple surface scatter areas by 76%. Since, according to Reference 4, the primary scatter areas contribute 42% and the multiple surface scatter contributes 32% of the total dose in the second leg of a two-legged duct, the final exposure rate estimate will be approximately 56% high. In addition, the dose rate values selected from Table II are values which represent a worst case estimate. The "radiation trap" will be treated as a combination of 2, two-legged ducts connected in series. With references to Sketch 5-2, the dose rate at the point P_2 resulting from a cobalt-60 source located at point P_0 is calculated. Then, the dose rate at point P_4 is calculated using the dose rate at the point P_2 as the source of gamma radiation. Although the energy of the cobalt-60 gamma photons traveling from point P_2 to point P_3 will be degraded from previous Compton interactions, it will be assumed that they have an energy of 1.25 MeV. This assumption will also result in a higher calculated dose rate at the exhaust point than will actually be encountered.

Data for First 2 Legged Duct Section

$L_1 = 18''$
 $L_2 = 28''$
 $W = 9.47''$
 $L_1/W = 1.90$
 $L_2/W = 2.96$
 $(D/Do) \times (10^4)$ value selected: 66.0

Data for Second 2 Legged Duct Section

$L_3 = 54''$
 $L_4 = 52''$
 $W = 9.47''$
 $L_3/W = 5.70$
 $L_4/W = 5.49$
 $(D/Do) \times (10^4)$ value selected: 2.34

Exposure rate at point $P_0 = Do$

$$Do = \left(\frac{3.28'}{17'}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 1.966 \times 10^3 \text{ R/h}$$

$$\begin{aligned} \text{Dose at Point } P_2 = D / (Do \times 10^{-4}) = 66 \therefore D &= (66) (Do) (10^{-4}) \\ &= (66) (1.966 \times 10^6 \text{ mR/h}) (10^{-4}) \\ &= 1.297 \times 10^4 \text{ mR/h} \end{aligned}$$

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$$\begin{aligned} \text{Dose at Point } P_4 &= D / (D_0 \times 10^{-4}) = 2.34 \therefore D = (2.34) (D_0) (10^{-4}) \\ &= (2.34) (1.297 \times 10^4 \text{ mR/h}) (10^{-4}) \\ &= 3.035 \text{ mR/h} \end{aligned}$$

Conservative estimate of the exposure rate at the exhaust point of the ventilation duct (point P_4): $(3.035 \text{ mR/h/section})(3.59 \text{ sections}) = 10.9 \text{ mR/h}$

(b) Elevator-Drive Cable-Ducts. Figures 5-18, 5-19 and Sketch 5-3 illustrate the wall penetrations between the Exposure Room (Rm. 2) and the Mechanical Equipment Room (Rm. 9) which serve to provide a path for the source-elevator drive-cables. Both cable-ducts are also pathways for scattered gamma radiation-streaming during in-air irradiation procedures. The following determination of exposure rate in the Mechanical Equipment Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to an in-air irradiation position 5.5 feet above the Exposure Room floor. Due to the location of the two cable-ducts, it is also assumed that all gamma photons passing through them have a reflected flight-path which is approximately parallel to the axis of the cable-duct. In order to estimate the exposure rate in the Mechanical Equipment Room from scattered gamma radiation streaming through the cable-ducts, the differential dose albedo formulas and constants presented in Reference 7 will be used. Sketch 5-3 is annotated to define the reference points used in the calculations. Since this represents a "worst case" analysis, only the lower cable-duct is considered.

Formulas Used

$$dD = \frac{D_0 \omega d \cos \theta_0 dA}{r_2^2} \quad (\text{Ref. 7})$$

Where: dD = differential dose at point of interest due to scatter
 D_0 = dose in incident beam at area dA
 r_2 = distance from scatter area to point of interest
 θ_0 = polar angle of incident radiation
 dA = differential area of reflecting surface
 ωd = differential albedo

$$\omega d = \frac{C K(\theta_s) 10^{26} + C'}{1 + \cos \theta_0 \sec \theta} \quad (\text{Ref 7})$$

Where: C & C' = Parameters for semiempirical formula given in Ref 7, Table 1, for 1 MeV photons.
 $K(\theta_s)$ = Klein-Nashina value of the energy scattering cross section per electron depending on the scatter angle θ_s [ie, (Photon scattering cross section) x (ratio of scattered to incident energy)]
 θ_0 = polar angle of incident radiation
 θ = polar angle of reflected radiation

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$$E = \frac{E_0}{1 + (E_0/0.511) (1 - \cos \theta_s)} \quad (\text{Ref 2})$$

Where: E = energy in MeV of photon after one Compton scatter
E₀ = energy in MeV of photon before Compton scatter
θ_s = angle through which the photon is scattered

Differential dose at point P₅ resulting from gamma photons reflected parallel to the cable duct axis at point P₂.

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25 \text{ MeV}/0.511) (1 - \cos 131^\circ)} = 0.219 \text{ MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.219 \text{ MeV}}{1.25 \text{ MeV}} \right) = 3.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (3.5 \times 10^{-26}) (10^{26}) + (0.0111)}{1 + (\cos 49^\circ) (\sec 0^\circ)} = 0.122 \text{ sr}^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3 \text{ R/h}) (0.122 \text{ sr}^{-1}) (0.660) (5 \text{ cm}^2)}{(518 \text{ cm})^2} = 1.03 \times 10^{-2} \text{ R/h}$$

Differential dose at point P₅ resulting from gamma photons undergoing one Compton scatter in the west wall of the exposure room which redirects their flight path along the axis of the cable-duct.

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25 \text{ MeV}/0.511) (1 - \cos 49^\circ)} = 0.679 \text{ MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.679 \text{ MeV}}{1.25 \text{ MeV}} \right) = 10.9 \times 10^{-26}$$

$$\omega d = \frac{(0.0547) (10.9 \times 10^{-26}) (10^{26}) + (0.0111)}{1 + (\cos 41^\circ \sec 89^\circ)} = 0.014 \text{ sr}^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3 \text{ R/h}) (0.014 \text{ sr}^{-1}) (0.755) (5 \text{ cm}^2)}{(152 \text{ cm})^2} = 15.6 \text{ mR/h}$$

Since the exposure rate on the Mechanical Equipment Room side of the cable-duct is estimated to be in excess of 0.5 mR/h, the room will be treated as a "restricted area" during in-air irradiation procedures. Unless the initial radiation survey of the facility indicates the restriction may be removed, access to the Mechanical Equipment Room will be controlled by the Cobalt-60 Facility Supervisor via control of the door key for this room.

(c) Conduit Maze in West Wall. Figure 5-16 illustrates a conduit maze consisting of four aluminum conduits, each of which contain two right-angle bends. These 4-inch diameter conduits serve as raceways between the Exposure

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Room and Control Room. The following estimate of the exposure rate to be expected in the Control Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height above the floor equal to that of the conduit. Since the two conduits closest to the source represent the "worst case" for gamma radiation streaming, only these conduits are examined in the following analysis. Also, since the total mass attenuation coefficients for concrete and aluminum are nearly equal, the walls of the conduit are considered to be concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

Exposure rate to conduit opening = D_o

$$D_o = \left(\frac{3.28}{8.71}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 7.5 \times 10^3 \text{ R/h}$$

E = energy in MeV after one Compton scatter

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25/0.511)(1 - \cos 46^\circ)} = 0.71 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.71}{1.25}\right) = 1.14 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547)(1.14 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-})(10^{26}) + (0.0111)}{1 + (0.728)(57.3)} = 0.015 \text{ sr}^{-1}$$

Assume that the first leg of the conduit perpendicular to the plane of the wall extends a distance of 2.5 feet into the wall. Then the exposure rate at the beginning of the first right-angle bend = dD .

$$dD = \frac{(7.5 \times 10^6 \text{ mR/h})(0.015 \text{ sr}^{-1})(0.728)(81 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.14 \times 10^3 \text{ mR/h}$$

The exposure rate at the surface of the shield wall in the Control Room due to a collimated source of 0.8 MeV photons, which yields an exposure rate of 1.14×10^3 mR/h, and is located midway in the west wall = I .

$$I = I_o b e^{-uX} = (1.14 \times 10^3 \text{ mR/h})(5) \exp^{-(0.1659)(76.2 \text{ cm})}$$

$I = 1.8410^{-2}$ mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of the conduit is 3 feet long and is directed away from the first leg of conduit at an angle of 89° . The exposure rate at the end of the second leg of conduit is:

$$E = \frac{0.71 \text{ MeV}}{1 + \left(\frac{0.71}{0.511}\right)(1 - 0.707)} = 0.505$$

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$$K(\theta_s) = (0.25 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.505}{0.71} \right) = 17.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (17.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (1)(57.3)} = 0.017 \text{ sr}^{-1}$$

$$dD = \frac{(1.14 \times 10^3 \text{ mR/h}) (0.017 \text{ sr}^{-1}) (1) (81 \text{ cm}^2)}{8.36 \times 10^3 \text{ cm}^2} = 0.188 \text{ mR/h}$$

Since the exposure rate at the beginning of the second right-angle bend will be less than 0.5 mR/h, the exposure rate at the point the conduit exits in the Control Room will also be less than 0.5 mR/h.

(d) Water Pipe for Emergency Pool Water Makeup. Figures 5-13, 5-14 and 5-21 illustrate the emergency pool water makeup which is located in the wall which separates the Exposure Room from the Mechanical Equipment Room. This 2-inch diameter pipe contains two right-angle bends and is positioned such that the point of entry in the Mechanical Equipment Room is 2 feet above the floor and the point of exit in the Exposure Room is 6 inches above the floor. The following estimate of the expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semicompilical formula for differential dose albedo presented in Reference 7 is used in the following calculations. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

D_0 = Exposure rate to wall at point of pipe penetration

$$D_0 = \left(\frac{3.28'}{8.06'} \right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 8.74 \times 10^3 \text{ R/h}$$

E = Energy in MeV after 1 Compton scatter through 18°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511} \right) (1 - \cos 18^\circ)} = 1.12 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{1.12}{1.25} \right) = 1.79 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (1.79 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 72^\circ) (\sec 89^\circ)} = 0.053 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (i.e., 2.5 feet into the shield wall) = dD

$$dD = \frac{(8.74 \times 10^6 \text{ mR/h}) (0.053 \text{ sr}^{-1}) (0.309) (20 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 4.93 \times 10^2 \text{ mR/h}$$

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The exposure rate at the Control Room surface of the shield wall resulting from a 493 mR/h source of 1.12 MeV gamma photons located behind 2.5 feet of concrete = I.

$$I = I_0 b e^{-uX} = (493 \text{ mR/h})(10) e^{-(0.1492)(76.2 \text{ cm})}$$

I = 0.06 mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of the pipe is 5 feet long and is directed away from the first leg at an angle of 89°. The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:

$$E = \frac{1.12 \text{ MeV}}{1 + \frac{1.12}{(0.511)}(1 - \cos 89^\circ)} = 0.355 \text{ MeV}$$

$$K(\theta_s) = (0.2023 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.355}{1.12} \right) = 0.64 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (6.4 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 0^\circ)(\sec 89^\circ)} = 6.2 \times 10^{-3} \text{ sr}^{-1}$$

$$dD = \frac{(493 \text{ mR/h})(6.2 \times 10^{-3} \text{ sr}^{-1})(1)(20 \text{ cm}^2)}{(2.32 \times 10^4 \text{ cm}^2)} = 2.64 \times 10^{-3} \text{ mR/h}$$

Since the exposure rate at the beginning of the second right-angle bend is less than 0.5 mR/h, the exposure rate at the point the pipe exits into the Mechanical Equipment Room will also be less than 0.5 mR/h.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.7 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the final right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

I_0 = Exposure rate at second right-angle bend without shield.

$$I_0 = \left(\frac{3.28}{9} \right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 7.01 \times 10^3 \text{ R/h}$$

Exposure rate at second right-angle bend with 2.7 feet of concrete shielding = I

$$I = I_0 b e^{-uX} = (7.01 \times 10^6 \text{ mR/h})(20) e^{-(.1332 \text{ cm}^{-1})(82 \text{ cm})} = 2.53 \times 10^3 \text{ mR/h}$$

$$K(\theta_s) = (0.20 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.8}{1.25} \right) = 12.2 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

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$$\omega d = \frac{(0.0547)(12.2 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-})(10^{26}) + (0.0111)}{1 + (\text{Cos } 69^\circ)(\text{sec } 89^\circ)} = 3.15 \times 10^{-2} \text{ sr}^{-1}$$

$$dD = \frac{(2.53 \times 10^3 \text{ mR/h})(3.15 \times 10^{-2} \text{ sr}^{-1})(0.358)(5 \text{ cm}^2)}{5.81 \times 10^3 \text{ cm}^2} = 0.026 \text{ mR/h}$$

which is also less than the 0.5 mR/h limit for "unrestricted areas".

(e) Water Pipe for Normal Pool Water Makeup. Figures 5-13 and 5-14 illustrate a $\frac{1}{2}$ -inch diameter water pipe, which passes from the Mechanical Equipment Room through the west shield wall to the southwest corner of the Exposure Room. The pipe passes horizontally through the shield wall at a distance of 2.5' beneath the floor and contains a right-angle bend on each side of the shield wall which allows vertical floor penetration in both rooms. Since this pipe is part of the automatic pool water makeup system, it is normally filled with water. Consequently, all gamma radiation entering the pipe during in-air irradiation procedures will be attenuated to some degree. The following estimate of the exposure rate to be expected in the Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a position 5.5 feet above the Exposure Room floor. Conservatively assuming that all gamma photons reaching the Mechanical Equipment Room through the pipe have scattered through an angle of 90° as a result of a single collision, their most probable energy will be approximately 0.4 MeV (Reference 6). Also assuming that the gamma photons travel a straight line distance equivalent to the total length of the water-filled pipe, allows a conservative estimate of the exposure rate at the Mechanical Equipment Room side of the pipe.

I_0 = exposure rate at the pipe location in the Exposure Room.

$$I_0 = \left(\frac{3.28}{15.98'}\right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 2.22 \times 10^3 \text{ R/h}$$

$I = I_0 b \exp(-uX)$ = exposure rate at pipe location in Mechanical Equipment Room.

Where: u = linear attenuation coefficient for 0.4 MeV photons in water = 0.106 cm^{-1}

X = total length of photon path in pipe = 304.8 cm

b = buildup factor for 0.4 MeV photons in water, with $uX = 32.3$ is $\approx 10^3$ (Reference 6).

$$I = (2.22 \times 10^6 \text{ mR/h})(10^3) \exp^{-(0.106 \text{ cm}^{-1})(304.8 \text{ cm})} = 2.1 \times 10^{-5} \text{ mR/h}$$

NOTE: Assuming a gamma photon energy of 1.25 MeV and a straight line distance of 304.8 cm, the exposure rate at the pipe location in the Mechanical Equipment Room is 0.2 mR/h.

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(f) Emergency Air Pressure Release Line for Elevator Drive. Figures 5-14 and 5-20 illustrate the 3/8-inch diameter air line which passes through the shield wall between the Exposure Room and Mechanical Equipment Room. This line connects the emergency-air pressure release valve in the Exposure Room to the air supply for the pneumatically driven elevator drive piston located in the Mechanical Equipment Room. This pipe contains two right-angle bends, and is located 4 feet above floor level. The following estimate of expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

D_0 = exposure rate to wall at point of pipe penetration.

$$D_0 = \left(\frac{3.28'}{8'}\right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 8.88 \times 10^3 \text{ R/h}$$

E = Energy in MeV after one Compton Scatter through 41°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511}\right) (1 - \cos 41^\circ)} = 0.782 \text{ MeV}$$

$$K_{9s} = \left(0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}}\right) \left(\frac{0.782}{1.25}\right) = 12.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}$$

$$\omega_d = \frac{(0.0547) (12.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}) (10^{26}) + (0.0111)}{1 + (\cos 49^\circ) (\sec 89^\circ)} = 0.018 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD .

$$dD = \frac{(8.88 \times 10^6 \text{ mR/h}) (0.018 \text{ sr}^{-1}) (0.656) (1 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 180.6 \text{ mR/h}$$

The exposure rate at the Control Room surface of the shield wall resulting from a 181 mR/h source of 0.8 MeV photons located behind 2.5 feet of concrete = I .

$$I = I_0 b e^{-uX} = (181 \text{ mR/h}) (20) e^{-(0.1659 \text{ cm}^{-1}) (76.2)} = 0.012 \text{ mR/h}$$

$I = 0.012 \text{ mR/h}$, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of pipe is 5 feet long and is directed away from the first leg at an angle of 89° . The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:

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$$E = \frac{0.782 \text{ MeV}}{1 + (0.782/0.511)(1 - \cos 89^\circ)} = 0.312 \text{ MeV}$$

$$K(\theta_s) = (0.24 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.312}{0.782} \right) = 9.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547)(9.6 \times 10^{-26})(10^{26}) + (0.0111)}{1 + (\cos 0^\circ)(\sec 89^\circ)} = 0.01 \text{ sr}^{-1}$$

$$dD = \frac{(181 \text{ mR/h})(0.01 \text{ sr}^{-1})(1)(1 \text{ cm}^2)}{(2.32 \times 10^4 \text{ cm}^2)} = 7.8 \times 10^{-5} \text{ mR/h}$$

Since the exposure rate at the beginning of the second right angle bend is less than 0.5 mR/h, it will also be less than 0.5 mR/h at the point the pipe exits in the Mechanical Equipment Room.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.54 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the second right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

I_0 = Exposure rate at right-angle bend without shield.

$$I_0 = \left(\frac{3.28}{8.63} \right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 7.63 \times 10^3 \text{ R/h}$$

The exposure rate at the second right-angle bend with 2.54 feet of concrete shielding = I .

$$I = I_0 b e^{-uX} = (7.63 \times 10^6 \text{ mR/h})(20) e^{-(0.1332 \text{ cm}^{-1})(77.4 \text{ cm})}$$

$$I = 5.08 \times 10^3 \text{ mR/h}$$

$$K(\theta_s) = (0.20 \times 10^{-24}) \left(\frac{0.8}{1.25} \right) = 12.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547)(12.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-})(10^{26}) + (0.0111)}{1 + (\cos 10^\circ)(\sec 89^\circ)} = 0.0002 \text{ sr}^{-1}$$

$$dD = \frac{(5.08 \times 10^3 \text{ mR/h})(0.0002 \text{ sr}^{-1})(0.985)(1 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.7 \times 10^{-4} \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for "unrestricted areas".

(g) Electrical Conduits. Figure 5-18 illustrates three electrical conduits which are 2 inches in diameter and pass through the west shield wall of the

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Exposure Room at a height of 8 feet above the floor. The physical dimensions of all three conduits are identical and each contains 2 right-angle bends. Since "conduit B" is located closest to the cobalt-60 sources during in-air irradiations, it provides a more direct path for gamma radiation streaming than either of the other two conduits. Consequently, the following estimate of the exposure rate in "unrestricted areas" due to any of the three conduits is based on "conduit B". It is further assumed that the conduit is filled with air, that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor and that the total mass attenuation coefficient of the conduit material is equal to that of concrete. The semi-empirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

D_0 = exposure rate to wall at point of conduit penetration.

$$D_0 = \left(\frac{3.28^2}{7.4'} \right) (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 1.04 \times 10^4 \text{ R/h}$$

E = energy in MeV after one Compton scatter through 36°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511} \right) (1 - \cos 36^\circ)} = 0.85 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.85}{1.25} \right) = 13.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega_d = \frac{(0.0547) (13.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 54^\circ) (\sec 89^\circ)} = 0.022 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD .

$$dD = \frac{(1.04 \times 10^7 \text{ mR/h}) (0.022 \text{ sr}^{-1}) (0.588) (20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 4.64 \times 10^3 \text{ mR/h}$$

The exposure rate at the Control Room surface of the shield wall resulting from a 4.64×10^3 mR/h source of 0.85 MeV photons located behind 2.5 feet of concrete = I .

$$I = I_0 b e^{-uX} = (4.64 \times 10^3 \text{ mR/h}) (20) e^{-(0.1659 \text{ cm}^{-1}) (76.2 \text{ cm})} = 0.3 \text{ mR/h}$$

$I = 0.3$ mR/h, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume the second leg of conduit is 2.5 feet long and is directed away from the first leg at an angle of 89° . The exposure rate at the end of the second leg of conduit, located at the beginning of the second right-angle bend, is:

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$$E = \frac{0.85 \text{ MeV}}{1 + \left(\frac{0.85}{0.511}\right) (1 - \cos 89^\circ)} = 0.32 \text{ MeV}$$

$$K(\theta_s) = (0.23 \times 10^{-24} \frac{\text{cm}^2}{\text{e}}) \left(\frac{0.32}{0.85}\right) = 8.66 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}$$

$$\omega_d = \frac{(0.0547) (8.66 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}) (10^{26}) + (0.0111)}{1 + (\cos 0^\circ) (\sec 89^\circ)} = 0.008 \text{ sr}^{-1}$$

$$dD = \frac{(4.64 \times 10^3 \text{ mR/h}) (0.008 \text{ sr}^{-1}) (1) (20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 1.28 \text{ mR/h}$$

The exposure rate at the point the conduit enters the Control Room resulting from a 1.76 mR/h source of 0.3 MeV photons which pass from the location of the second right-angle bend to the Control Room via 2.5 feet of air-filled conduit is estimated below. For a straight cylindrical duct with radius R and length L, the line-of-sight exposure contribution at the end of the duct due to a point isotropic source at the entrance of the duct is proportional to $1/L^2$ (Reference 2, paragraph 8.1.2).

$$I = I_0/L^2 = 1.76 \text{ mR/h} / (2.5)^2 = 0.28 \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for unrestricted areas.

(3) References.

(a) Reference 1: Etherington, Nuclear Engineering Handbook, McGraw-Hill Book Company Inc., New York, (1958).

(b) Reference 2: Engineering Compendium on Radiation Shielding, Volume I, "Shielding Fundamentals and Methods", Springer-Verlag New York Inc., (1968).

(c) Reference 3: F. E. Bear, Chemistry of the Soil, 2nd Ed., (1964), 118.

(d) Reference 4: J. M. Chapman and C. M. Huddleston, "Dose Attenuation in Two-Legged Concrete Ducts for Various Gamma Ray Energies", Nuclear Science and Engineering, Volume 25, American Nuclear Society Inc., Hinsdale, IL, (1966), 66-74.

(e) Reference 5: Martin-Leimdörfer, "The Backscattering of Gamma Radiation from Plane Concrete Walls", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 345-351.

(f) Reference 6: Price, Horton and Spinney, Radiation Shielding, Pergamon Press, (1957).

(g) Reference 7: A. B. Chilton, "A Semiempirical Formula for Differential Dose Albedo for Gamma Rays on Concrete", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 419-424.

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(4) Occupancy of Shielded Areas: Immediately surrounding the Exposure Room are building and grounds areas which are shielded against the ionizing radiation emanating from the cobalt-60 sources during in-air irradiations. An estimate of the degree and type of occupancy for these areas during in-air irradiation procedures is given below. This estimate assumes normal operating conditions during a 40 hour work week. The calculated exposure rate values given in the table are "worst case" values which result from the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the Exposure Room floor.

AREA	TYPE OCCUPANCY	DEGREE OF OCCUPANCY	CALCULATED EXPOSURE RATE
Entrance Maze (Rm. 1)	None	0%	>0.5 mR/h
Control Room (Rm. 4)	Radiation Worker	100%	<0.5 mR/h
Mechanical Equip. Rm. (Rm. 9)	None	0%	<16.0 mR/h
Restroom (Rm. 8)	Non-Radiation Worker	25%	<0.5 mR/h
Plasma Lab (Rm. 18)	Non-Radiation Worker	100%	<0.5 mR/h
Rad. Material Storage (Rm. 19)	Radiation Worker	25%	<0.5 mR/h
Decon Area (Rms. 20, 21, 22)	Radiation Worker	0%	<0.5 mR/h
Preparation Room (Rm. 10)	Non-Radiation Worker	100%	<0.5 mR/h
Instrumentation Room (Rm. 5)	Non-Radiation Worker	100%	<0.5 mR/h
Van de Graaf Room (Rm. 3)	Radiation Worker	100%	<0.5 mR/h
Exposure Room Roof	None	0%	<10.0 mR/h
Grounds Area	Non-Radiation Worker	25%	<0.5 mR/h

e. Personnel Exclusion Barriers. (1) The sole entrance to the Cobalt-60 Exposure Room is provided by the double doors between the Control Room and the entrance maze which leads to the Cobalt-60 Exposure Room. These doors are interlocked to preclude the possibility that an individual could inadvertently enter the Exposure Room during in-air-irradiation procedures. Before the source elevator drive system is functional, the operator must (1) enter the Exposure Room, (2) actuate the in-cell reset switch with the same key that operates the elevator system, (3) exit from the Exposure Room, and (4) close the maze entrance doors within approximately 15 seconds from the time the in-cell reset switch is actuated. If this sequence of operator actions is accomplished in the prescribed period of time, the maze entrance doors are automatically locked and the elevator drive controls become operational. Should the operator fail to accomplish this sequence of procedures in the prescribed time, no power is available to the elevator drive system and the procedure must be repeated before elevator operation may commence. In order to ensure that no individual is prevented from leaving the Exposure Room, a manually operated "crash bar" is installed on the maze-side of the doors which provides a means of emergency exit at all times. If either of the maze entrance doors are opened after the operator completes the preoperational sequences described above, the electrical power necessary to raise and sustain the elevator car in an uplifted position is lost until the preoperational sequence is performed again.

(2) The mechanical equipment room (Rm. 9) contains the only roof scuttle in the Building 504 Radiation Facility. Access to the roof via this scuttle

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will be denied during in-air-irradiation procedures, which cause the exposure rate at the surface of the roof to exceed 0.5 mR/h, by locking the door to the mechanical equipment room. During these periods, access to the mechanical equipment room will be controlled by the Cobalt-60 Facility Supervisor, Chief Operator, or Alternate Operator.

f. Contamination Control. (1) Although each of the cobalt-60 source elements is doubly encapsulated, as described in Supplement No. 1 of this application, the Exposure Room, Entrance Maze, and Control Room are designed to ensure containment/entrapment of soluble and insoluble particulates. All three areas are equipped with seamless; acid-resistant floors, and epoxy-coated walls and ceilings. The floor drain in the Exposure Room and sink drain in the Control Room vent to a 4000 gallon acid-resistant holding tank. Due to the remote possibility that the liquid effluents might contain trace amounts of radioactive material, no fluid from the holding tank will be discharged to the sanitary sewage system unless an analysis has been performed to assure that it does not exceed the maximum permissible concentration (MPC) guides set forth in Title 10, Code of Federal Regulations, Part 20. The plumbing plan and holding tank for liquid effluents are illustrated on Figures 5-13 and 5-14 respectively.

(2) Heating and cooling of the Exposure Room is accomplished via a "closed-loop" air conditioning system which isolates the supply and exhaust air for this area from the rest of the Building 504 Radiation Facility. As illustrated on Figures 5-11 and 5-12, the exhaust plenum in the Exposure Room is equipped with high-efficiency-particulate-air (HEPA) filters through which all effluent room air must pass. The air handling system continuously delivers air to the Exposure Room at a rate of 2885 cubic feet per minute (CFM) and exhausts it at a rate of 3000 CFM. Consequently, a negative pressure is maintained in the Exposure Room which assures filtration of all room air. After passing through the exhaust filters in the Exposure Room, 290 CFM is discharged to the outside environment and 2710 CFM is recirculated to the air handling unit (AH-1). Finally, fresh air is added to the recirculated air at a rate of 175 CFM in order to sustain the 2885 CFM delivery of conditioned air to the Exposure Room.

g. Ozone Production, Detection, and Control. (1) During in-air irradiation procedures ozone will be produced in the Exposure Room as a result of air ionization processes. The following analysis of radiation-induced ozone formation in the Exposure Room assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a height of 5.5 feet above the floor. It is further assumed that each gamma photon emanating from the cobalt-60 source travels the entire length of the Exposure Room. The investigation of G. R. A. Johnson and J. M. Warman presented in "Formation of Ozone from Oxygen by the Action of Ionizing Radiations", Discussions of the Faraday Society, Volume 37, (1964), 87-95, indicates that the yield of O_3 from O_2 may be as high as $G(O_3) = 13$ molecules of O_3 per 100 eV. Although this value of $G(O_3)$ may be somewhat high, due to the presence of other rare gasses in breathing air, it will be used to ensure that the following analysis yields conservative results.

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Exposure room volume: $2.04 \times 10^8 \text{ cm}^3$

Air path for each photon: $r = 1.31 \times 10^3 \text{ cm}$

Linear energy absorption coefficient for air = $u_a = 0.32 \times 10^{-4} \text{ cm}^{-1}$

$$u_{ar} = (1.31 \times 10^3 \text{ cm})(0.32 \times 10^{-4} \text{ cm}^{-1}) = 0.04192$$

Since 21% of air is O_2 , multiply u_{ar} by 0.21

$$u_{ar} = (0.04192)(0.21) = 8.8 \times 10^{-3}$$

$$\begin{aligned} \therefore \text{the energy absorbed by } O_2 \text{ in 1310 cm of air} &= 1 - e^{-u_{ar}} \\ &= 1 - e^{-0.0088} \\ &= 0.009 \end{aligned}$$

Since cobalt-60 emits an average of 2.5 MeV/dis. the energy absorbed by room air per second = $(4 \times 10^4 \text{ ci})(3.7 \times 10^{10} \text{ dis/sec-ci})(2.5 \text{ MeV/dis})(0.009) = 3.33 \times 10^{13} \text{ MeV/sec}$.

$$(3.33 \times 10^{19} \text{ eV/sec})(13 \text{ molecules/100 eV}) = 4.33 \times 10^{18} \text{ molecules } O_3/\text{sec}$$

$$\left(\frac{4.33 \times 10^{18} \text{ molecules } O_3/\text{sec}}{6.02 \times 10^{23} \text{ molecules/gm mole}} \right) \left(\frac{48 \text{ gm } O_3}{\text{gm mole}} \right) = 3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}$$

$\therefore 3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}$ is produced in the Exposure Room.

$$\frac{3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}}{2.04 \times 10^8 \text{ cm}^3 \text{ air}} = 1.69 \times 10^{-12} \text{ gm } O_3/\text{sec cm}^3 \text{ air}$$

$$\frac{1.69 \times 10^{-12} \text{ gm } O_3/\text{sec cm}^3 \text{ air}}{1.293 \times 10^{-3} \text{ gm air/cm}^3 \text{ air}} = 1.31 \times 10^{-9} \text{ gm } O_3/\text{sec-gm air}$$

$$\& (1.31 \times 10^{-9} \text{ gm } O_3/\text{sec-gm air})(3.6 \times 10^3 \text{ sec/hr}) = 4.72 \times 10^{-6} \text{ gm } O_3/\text{hr-gm air}$$

= 4.72 PPM O_3 produced in the Exposure Room air in a period of one hour as a result of the photons emanating from a 40,000 curie cobalt-60 source.

(2) Since the approximate half-life of ozone at 20°C is 3 days, and also since 90% of the air removed from the Exposure Room is returned during the normal operating mode of the "closed-loop" ventilation system, the Cobalt-60 Gamma Radiation Facility is equipped with ozone detection and control equipment. In order to continuously measure the ozone concentration in the Exposure Room during in-air-irradiation procedures, a Bendix Ozone Detector, Model 8002, is installed in the Control Room. A sampling tube, extending from the unit to a location adjacent to the source elevator, provides the unit with a representative sample of Exposure Room air. The detector analyzes the air sample by the chemiluminescence principle, and displays results which lie within a 0.01 to 1.0 PPM O_3 range. As illustrated on Figure 5-23, the Cobalt-60 Facility control-console houses a meter which reproduces the reading displayed at the detector unit. In addition, the VISI-CON Annunciator Monitor, located adjacent to the control console, produces an

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audio-visual signal if the ozone monitor is not operating or if high ozone concentrations are present in the Exposure Room.

(3) The normal operating mode of the "closed-loop" ventilation system keeps the Exposure Room at negative pressure with respect to the rest of the building. Consequently, unless exhausted to the roof of Building 504, any ozone produced by in-air irradiation procedures will remain in the Exposure Room and in the ducts of the "closed-loop" ventilation system. When it is desirable to reduce the ozone concentration in the Exposure Room, the control-console operator manually actuates a "purge cycle" control switch. During a purge cycle, the air handling system continuously delivers fresh air to the Exposure Room at a rate of 3000 CFM and exhausts air from the Exposure Room to the roof of Building 504 at the same rate. No room air is recirculated during a purge cycle. Thus, the control console operator is always able to reduce the ozone concentration in the Exposure Room to the 0.1 PPM threshold limit value recommended by the Occupational Health and Safety Administration (OSHA).

h. Fire Protection. As pointed out in paragraph 1a of this supplement, the Cobalt-60 Gamma Radiation Facility is located within a building which is classed as a "noncombustible construction" type structure. All areas within Building 504 are equipped with fire detection/alarm units which provide local warning to building occupants and also transmit the alarm signal to a panel which is monitored in the HDL Central Guard Office. The Cobalt-60 Facility is equipped with combination fixed temperature/rate of rise Thermal Fire Detectors in order to ensure reliability both during and after exposures to high levels of ionizing radiation. Emergency response to fire alarms is provided by HDL fire protection personnel, four nearby county fire departments and the Naval Surface Weapons Center Fire Department which is located adjacent to HDL.

i. Seismic Analysis. (1) The Building 504 Radiation Facility was designed in accordance with the criteria, guidance, and standards furnished in US Army Technical Manual 5-809-10, "Seismic Design for Buildings", published March 1966. This manual assigns each geographical location in the United States to one of five "seismic zones" which are designated by the numbers 0 through 4. Assignment of a high seismic zone number to a region, indicates that a high probability of severe, frequent and damaging earthquakes exists in that region. The fact that the entire State of Maryland is designated as being in Seismic Probability Zone 1 indicates only minor damage is to be expected from any earthquake which might occur in this region. Although the evidence is not conclusive, and any prediction is uncertain at best, Freeman states (Freeman, John R., 1932, Earthquake Damage and Earthquake Insurance, New York: McGraw-Hill Book Co.) that only one destructive earthquake may be expected per century in the Atlantic region, comprising 600,000 square miles and extending from Quebec to Florida. The likelihood that the epicenter of a destructive earthquake would be in or near the Washington, DC area seems remote.

(2) Since the Cobalt-60 Gamma Radiation Facility is located in a building which was designed in accordance with US Army seismic design criteria for this geographical region, it seems highly unlikely that the shielding, pool, or

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complementary structures would be subject to rupture, shifting, or tilting as a result of any probable seismic phenomena.

2. Irradiator System and Operational Characteristics.

a. Pool and Associated Equipment. (1) The cobalt-60 source elements will be stored in the exposure room at the bottom of the 12 feet deep, water filled pool illustrated in Figures 5-5, 5-7, and 5-18. The concrete used to construct the one foot thick walls and floor of the pool were poured monolithically in one continuous pour and thoroughly vibrated by mechanical vibrators. The entire internal surface area of the pool is lined with a 3/16 inch thick, A-304 stainless steel liner in order to ensure water-tight integrity. Immediately surrounding the edge of the pool is a concrete toeboard which is 4 inches in height. Removable pipe railings, which meet the specifications presented in 29 CFR Part 1910-23, Occupational Safety and Health Act, are inserted into the toeboard on all sides of the pool in order to provide a personnel protective barrier for the floor opening. In addition to the toeboard and railing, the surface area of the pool is protected by a "metal grating" type floor-hole cover which is designed to support a live load of 200 pounds per square foot. As illustrated in Figure 5-6, the floor hole cover consists of 10 sections of removable grating and two removable supports which accommodate the rails for a movable cart. By removing a section of grating, an individual may work safely over the pool while supported by the remaining sections of the floor hole cover. Two underwater lighting fixtures, similar to those illustrated on Figure 5-15, are attached to removable sections of grating and suspended beneath the surface of the pool water in order to provide sufficient light for source element manipulation and accurate positioning of experiment containers. Both fixtures meet the specification and installation requirement set forth in the National Electrical Code (NFPA No. 70-1975) for "underwater lighting fixtures".

(2) The pool water circulation/treatment system consists of a 50 gallon per minute circulating pump, a replaceable sediment filter, and two mixed-bed resin demineralizers. As illustrated on Figures 5-17, 5-18, and 5-21, pool water is continuously extracted at a point two feet below the pool curb and is filtered and deionized before being returned to the bottom of the pool. Since the circulation system inlet is located one foot below the water, it is impossible to remove more than one foot of water shielding should one of the system water lines accidentally burst. This system will recirculate the entire volume of pool water approximately 28 times a day and maintain pool water conductivity at less than 10 micromhos per centimeter without difficulty. A pool water conductivity monitor, installed at the inlet of the circulation pump, continuously analyzes the pool water and transmits an alarm to the Control Room annunciator panel if the ion concentration in the pool water is detrimental to source encapsulation life expectancy. Two in-line pressure gauges, one on each side of the sediment filter, provides a visual indication of water circulation system performance.

(3) Pool water is maintained at a depth of 11 feet by an automatic water level sensing/replacement system. As illustrated in Figures 5-17, 5-18, and 5-23, the pool water level indicator, located in the Control Room, indicates the water level in the pool by responding to a change in the water pressure applied to an evacuated tube. Four adjustable, pressure-actuated switches are attached to the water level indicator for the purpose of providing electrical contact openings for alarm and water level control equipment circuits. Switch #1 initiates a "high level" alarm on the control room annunciator panel when the pool water level is between 136 and 138 inches. Switch #2 interrupts power to the pool water circulation pump when the pool water level is between 126 and 130 inches. Switch #3 energizes the solenoid valves illustrated on Figure 5-21 to refill the pool when the water level is between 132 and 135 inches. Switch #4 initiates a "low level" alarm on the control room annunciator panel if the pool water level drops to 126 inches. The solenoid valves actuated by switch #3 may also be operated manually from the control console. Although water will normally be added to the pool via the above mentioned solenoid valves, one may always add water manually by utilizing the emergency-fill water system illustrated on Figures 5-14, 5-18, and 5-21. The manually operated gate valve for this system is located in the Mechanical Equipment Room in order to assure that water may always be added to the pool without entering the Exposure Room.

(4) If an unexpected event causes overflowing of the pool, the excess water will be contained by the seamless, acid-resistant floor of the Exposure Room and vented to a 4000 gallon acid-resistant holding tank via the Exposure Room floor drain. As explained in paragraph 1f(1) of this supplement, no fluid is discharged from this holding tank to the sanitary sewage system unless an analysis confirms that radioactive material concentrations are below the maximum permissible concentration guides set forth in Title 10, Code of Federal Regulations, Part 20.

b. Cobalt-60 Source Elevator and Associated Equipment. (1) The Cobalt-60 Source Elevator system is designed for two principle modes of operation. The Console Operational Mode (COM) permits one to operate the system from the Control Room during free-air-irradiation procedures. The In-cell Operational Mode (ICOM) permits operation of the system using controls located adjacent to the pool. Use of the ICOM is restricted to operations involving maintenance of the elevator system, attachment of source holding fixtures to the elevator car platform, and lowering experimental products to the bottom of the pool, where the source material is stored.

(2) Mechanical design of the elevator system incorporates both safety and utilitarian considerations. As illustrated on Figure 5-18, the elevator assembly used to raise cobalt-60 source elements for free air irradiation, or to lower product to the source elements for in pool irradiation, is permanently positioned against the wall of the exposure room pool and contains a multiplicity of $1\frac{1}{2}$ inch diameter holes in order to ensure that the water level in the shaft equals that of the pool. The cable-driven elevator car,

illustrated on Figures 5-18 and 5-19, is mechanically restricted to vertical movement along an elevator shaft which extends from the bottom of the pool to a distance of 7 feet above the exposure room floor. A platform, containing tapped holes to permit rigid attachment of a variety of source holding fixtures, is bolted to the base of the elevator car. The design of each source holding fixture will be reviewed by the HDL Radiation Control Committee prior to fabrication or use in order to assure that the fixture will restrain source element movement under all conceivable conditions. Structural design of the elevator limits the maximum distance the platform may rise above the exposure room floor to 5 feet 8 inches. The speed and distance traveled by the cable-driven elevator car is controlled by adjusting the speed and distance traveled by an aircraft cable attached to a pneumatic piston and counter weight assembly located in the mechanical equipment room and control room respectively. As illustrated on Figures 5-18 and 5-20, an Air Control Box located in the mechanical equipment room contains (1) an air supply valve for the elevator drive cylinder; (2) an air pressure regulator assembly for limiting, regulating and conditioning the air supply for the elevator drive; (3) a descent control valve for limiting elevator car descent speed; (4) an ascent control valve for limiting elevator car ascent speed; and (5) a four way solenoid valve used to change the routing of the air supply on command of the control console causing either ascent or descent of the elevator car. A 150 PSI reserve surge tank is incorporated into the air supply system for the purpose of supplying sufficient reserve air capacity to return the elevator car to the pool bottom in the event the power and/or primary air supply system fails. An additional positive down-drive for the elevator car is provided by the aforementioned 50 pound counter weight assembly located in the control room. Although it is not well illustrated by Figures 5-18, 5-19, and 5-20, the counter weight assembly is designed to continuously exert a downward force on the elevator car by routing the counter weight support cable to the base of the elevator car via a sheave assembly welded to the bottom of the pool. Consequently, the elevator drive system must exert sufficient pneumatic force to raise both the elevator car and the counter weight when sources are raised from the pool bottom. If the pneumatic elevator drive system loses the air pressure necessary to maintain the elevator car and counter weight in an elevated position, the counter weight assembly will pull the elevator car back to the bottom of the pool. Should mechanical binding between the elevator car and shaft occur, the counter weight/elevator drive assembly cables are accessible from a location external to the Exposure Room and provide an effective means of freeing the elevator car.

(3) A functional description of the operational characteristics associated with the elevator control system is provided in Annex 5-A to this supplement. Additionally, the following figures illustrate electrical circuitry and equipment incorporated into the elevator control system design: Figure 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS); Figure 5-30 (IRRADIATOR CONSOLE LAYOUT); Figure 5-31 (CONTROL CONSOLE WIRING); and Figures 5-32 and 5-33 (IRRADIATOR WIRING DIAGRAM).

c. Radiation Safety Interlock System. Operation of the elevator control system is limited by a radiation safety interlock system designed and installed for the purpose of assuring that no individual will be exposed to an area where it is possible to receive a dose in excess of 100 mrem in one hour as a result of free-air-irradiation procedures initiated at the Cobalt-60 Facility. The following information catalogs the radiation safety control functions provided by the interlock system.

(1) The sole entrance door to the Exposure Room is automatically locked immediately prior to, and during, free-air-irradiation procedures in order to prevent an individual from entering when it is possible to receive a dose in excess of 100 mrem in one hour. This Exposure Room access control device permits deliberate entry to the Exposure Room only when radiation levels therein are less than 20 mR/h.

(2) The Visi-Con Annunciator Monitor, located in the Control Room, automatically provides both audible and visual signals to the operator of the elevator system if the Exposure Room access control device (electric lock) fails to function properly. Nonilluminated legends on the Visi-Con Annunciator Monitor indicate that the access control device is functioning properly.

(3) Crash bars are installed on the maze side of the entrance door to the Exposure Room in order to assure that no individual will be prevented from leaving the Exposure Room.

(4) Should the Exposure Room access control device (electric lock) fail immediately prior to free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically terminates the electrical power necessary to raise the source elevator car. If this access device fails during free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically returns the source elevator car to the bottom of the pool. In either case, the radiation level within the Exposure Room is reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour.

(5) Any person attempting to enter the Exposure Room during free-air-irradiation procedures is automatically warned that a radiation hazard exists therein by a large purple beacon located at the entrance to the maze which flashes continuously when the source elevator car is not located at the bottom of the pool. The console operator is automatically notified by the Visi-Con Annunciator Monitor if the light has burned out. In addition, the action of defeating the control access device (electric lock) for the Exposure Room entrance door automatically actuates two visible and audible alarms located on the Visi-Con Annunciator Monitor that serve to warn both the console operator and the individual attempting to enter the Exposure Room that a hazardous condition exists.

(6) Failure or removal of the Exposure Room access door automatically terminates the electrical power necessary to raise the source elevator car and automatically returns the elevator car to the bottom of the pool if it is in an elevated position. Since this action places the pool water shielding over the source elements, the radiation level in the Exposure Room is automatically reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour. Visual and audible alarm signals are automatically actuated on the Visi-Con Annunciator Monitor which warn the console operator and all potentially affected individuals that the physical barrier to the Exposure Room has failed or has been removed prior to and during free-air-irradiation procedures.

(7) A fifteen second delay exists between the time the console operator actuates the elevator drive key switch and the time the elevator starts its ascent. During this fifteen second period, a horn located in the Exposure Room automatically sounds and rotating purple beacons located in the Exposure Room and Exposure Room Entrance Maze automatically flash to alert personnel located in the Exposure Room/Maze areas that free-air-irradiation procedures are in progress. This warning period allows sufficient time for an individual located in the Exposure Room to actuate any one of four control devices which prevent raising of the elevator car. Located adjacent to the Exposure Room Pool and in the Entrance Maze are switches with large red mushroom caps bearing the words "EMERGENCY SHUTDOWN". Depressing either of these switches will cause immediate shutdown of the elevator energizing system until they are manually reset by the console operator. Also located adjacent to the Exposure Room Pool is a safety air valve with a large red mushroom cap, which will vent the air supply necessary to raise the source elevator car when the valve cap is depressed. Should the individual elect to leave the Exposure Room/Maze area without first actuating one of the aforementioned elevator control devices, the action of opening the Exposure Room access door will deenergize the elevator system until the console operator enters the Exposure Room and resets the radiation safety interlock system.

(8) In order to assure that the Exposure Room and Maze are cleared of personnel prior to each free-air-irradiation procedure using the COM, the elevator control system is interlocked with an "Operate Key Switch" located adjacent to the Exposure Room Pool. Prior to each raising of the elevator car, the console operator is required to enter the Exposure Room, actuate the "Operate Key Switch" with the same key that actuates the elevator drive system switch on the console, exit from the Exposure Room, and close the access doors in a time period of 15 seconds. This operation is intended to enforce a final visual inspection of the Exposure Room/Maze areas immediately prior to each in-air-irradiation procedure. Should the console operator fail to accomplish this task in the prescribed period of time, no electrical power is available to the elevator drive system. Additionally, opening the Exposure Room access door after accomplishment of this preoperational sequence terminates electrical power for the elevator drive system until the console operator reenters the Exposure Room and repeats the procedure. If the preoperational

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sequence is not successfully completed or if the Exposure Room access door is opened after successful completion, audible and visual alarms are automatically actuated on the Visi-Con Annunciator Monitor in the Control Room to notify the console operator that the safety interlock system has been violated. If the Exposure Room access doors remain closed after the pre-operational sequence, the action of operating the console key switch for the elevator drive system automatically locks the Exposure Room access doors.

(9) Three Remote Area Monitors (RAM's) for ionizing radiation detection are incorporated into the radiation safety interlock system. RAM #1 is located in the Control Room and has a four decade logarithmic meter scale from 0.1 mR/h to 1.0 R/h. RAM #2 and #3 are located in the Exposure Room and have five decade logarithmic scales from 1.0 mR/h to 100 R/h. All three RAM's are Nuclear Measurements Corporation Model GA-2T0 plastic scintillation type ionizing radiation detectors and are installed to provide remote readouts in the Control Room. In addition to providing continuous physical radiation measurements of the Exposure Room, RAM #2 and #3 function to keep the Exposure Room access door locked when the radiation level in the Exposure Room exceeds 20 mR/h during COM free-air-irradiation procedures. RAM #2 and #3 also function to automatically cause the elevator car to return to the bottom of the pool if the radiation level in the Exposure Room exceeds 20 mR/h during activities involving the ICOM. RAM #2 and #3 automatically ensure that physical radiation measurements of the Exposure Room are accomplished prior to entry of the first individual following free-air-irradiation procedures. In addition to consulting the RAM readouts in the Control Room, the first individual to enter the Exposure Room following free-air-irradiation procedures is required to carry a portable ionizing radiation detection survey instrument and assure that the radiation level in the Exposure Room is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(10) The above enumerated and other features of the radiation safety interlock system are thoroughly described in Annex 5-A to this supplement. Figures 5-18 (GENERAL ARRANGEMENT, COBALT-60 FACILITY), 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS), 5-24 (CONDUCTIVITY, OZONE MONITORS), and 5-25 through 5-29 (INTERLOCK SCHEMATICS) illustrate electrical circuitry and equipment incorporated into the radiation safety interlock system design.

d. Equipment for Manual, In-Pool Irradiation Procedures. Although the Cobalt-60 Facility is designed primarily for free-air-irradiations, occasionally it is desirable to place the experimental product inside a water-tight experiment container and lower it to a position adjacent to the sources located at the bottom of the water-filled Exposure Room pool. The equipment necessary to safely perform this task is described in the following paragraphs.

(1) Source Holders. Permanently located at the bottom of the Cobalt-60 Exposure Room Pool are two source holding fixtures mounted on 16 gauge stainless steel stands. These fixtures are designed to hold/position the source

elements in a vertical, bolt-circle configuration when they are not being used for free-air-irradiations. As illustrated on Figure 5-17 to this supplement, holes have been drilled in the base plate of each source holder to accommodate source elements in 5, 8, and 12-inch diameter bolt-circle arrangements. A fixed upper plate contains holes to accommodate the upper end of the source elements located on the 12-inch diameter bolt-circle. This fixed upper plate has a step on its inner diameter which will accommodate a stainless steel ring containing holes used to position the source elements on an 8-inch diameter bolt-circle. This ring in turn is stepped to receive a smaller stainless steel ring containing holes used to position the source elements on a 5-inch diameter bolt-circle. In use, the innermost ring must be of the diameter appropriate for the bolt-circle arrangement used.

(2) Source Protectors. Since manual, in-pool irradiation procedures require lowering experimental materials to the bottom of the water-filled pool and positioning them in the center of, or adjacent to, the source holders, a 16 gauge stainless steel protective cover is installed over each source holder. The cover is intended to protect the cobalt-60 source elements from physical damage which could result from the positioning of experimental materials or the accidental dropping of a heavy object into the pool. Figure 5-17 to this supplement displays the protective source holder cover in the functional position.

(3) Experiment Containers. During manual in-pool irradiation procedures, it is generally desirable to protect the materials to be irradiated from the pool water. Consequently, the materials will usually be placed in water-tight metal containers. Typically, the containers are designed with a 4-inch outside diameter in order to assure that they may be positioned in the center of the source holding fixture when maximum exposure rates are desired. The containers may also be positioned at varying distances from the source holding fixtures depending on the exposure rate requirements of the experiment. Although the length and diameter of the experiment container may vary, the typical design incorporates a water-tight lid with an attachment for connecting a 15 foot handle. After the materials to be irradiated have been placed in the experiment container, the lid is secured in place and the handle is attached to the lid. Using the handle, the experiment container is lowered into the Cobalt Facility Pool and placed at a position near the cobalt-60 source elements. Duplication of source to container position may be accomplished by inserting a nipple on the container base into the holes provided in the source holder stand. All pipes serving as handles for the experiment containers are fabricated with "S" bends near the base to preclude the possibility of radiation streaming through the pipe.

(4) Radiation Warning System. As explained in Annex 5-A to this supplement, the Control and Exposure Rooms are equipped with three ionizing radiation remote area monitors (RAM's) designed, installed and operated to provide continuous monitoring of radiation levels in the facility on a 24 hour basis.

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RAM #1 detects and indicates the radiation level in the Control Room and is adjusted to provide an audio-visual alarm if the high level alarm setting of 2.5 mR/h is exceeded. RAM's #2 and #3 detect the radiation level in the Exposure Room and are adjusted to provide audio-visual alarms in the Control Room if the high level alarm setting of 20 mR/h is exceeded. All three RAM's are Nuclear Measurement Corporation Model GA-2TO transistorized gamma alarms, utilizing gamma sensitive plastic phosphors in a detector probe that is connected by electrical cables to "NEMA boxes" that house an indicating meter, relays to provide high current alarm context, alarm lights, bells, and voltage supplies. The meter readings and audio-visual alarms displayed by the "NEMA boxes" mounted on the east wall of the Control Room are also relayed to the Visi-Con Annunciator Monitor located in the Control Room. Since the alarms may be heard in the Control Room, Maze, and Exposure Room, an individual desiring to perform manual, in-pool irradiations is automatically alerted if hazardous ionizing radiation conditions exist in the Exposure Room prior to, during, and after experimental procedures are conducted at the Cobalt-60 Facility.

3. Collateral Equipment. a. Remote Handling Tool. A remote handling tool is available for the purpose of manipulating objects at the bottom of the 12 foot deep pool while standing at the pool edge. This tool is 15 feet long and fabricated with a pistol grip handle, dual rubber-lined grip jaw, and a mechanism that allows adjustment of the grip jaw from the pistol grip handle. This tool is conspicuously marked at a distance of 6 feet 8 inches from the uppermost section of the source-gripping jaw and displays a warning sign that instructs users not to raise the tool above the mark when it holds one of the source elements. At a distance 4 feet above the pool surface, the exposure rate from a 1554 curie source element will be less than 0.25 mR/h when the handling tool is raised to the tool warning mark. This tool contains a multiplicity of $\frac{1}{2}$ -inch holes to allow a flow of water into the tool as it is inserted in the pool. Since operation of this tool is restricted to the Facility Supervisor, Chief Operator, Alternate Operator, and the HDL Radiation Protection Officer, it will be secured from unauthorized use.

b. Source Leak-Test/Isolation Containers. Figure 5-17 to this supplement illustrates the source Leak-Test/Isolation Containers. The two metal containers are designed so that they can be loaded, sealed, sampled, pumped dry, and flushed with clean water while at a depth of 10 feet below the surface of the water. Each container is capable of holding ten source elements. Both containers are mounted on a metal frame which allows both units to be lowered into and extracted from the pool. Both containers are remotely sealed by use of a handling tool which is designed to manipulate a rubber-coated, adjustable diameter, "Turn-Tite Plug". This handling tool also fills with water as it is inserted into the pool. These containers will be used to perform the required 6 month leak test of the source elements (as described in Supplement 6 of this application) and also to isolate any leaking source elements until disposition instructions are obtained.

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c. Monorail and Hoist. Figures 5-5 and 5-7 illustrate the location of the monorail used to support an 8-ton capacity trolley and motorized bridge hoist. This overhead monorail hoist will be used to manipulate the shielded containers necessary to accomplish transfer operations involving cobalt-60 source elements. The marking, construction, and installation of the monorail hoist is in accordance with American National Standard ANSI B30.16-1973. Inspection, testing, maintenance and operation of the monorail hoist will comply with the provisions of 29CFR1910.179 of the Occupational Safety and Health Act in order to assure safe, reliable operation.

d. Exposure Room Floor Track. Figure 5-5 illustrates two floor tracks extending from the north wall of the Exposure Room to the southern edge of the pool. Figure 5-6 illustrates, and provides specification for, the track supports that span the pool. All floor track installed in the Exposure Room is American Society of Civil Engineers (ASCE), 60 pounds light rail, 4½ inches by 4½ inches. The floor track is installed to provide stationary rails for a light-weight cart used to position experimental materials at varying distances from the cobalt-60 source elements during free-air-irradiation procedures. Although the floor tracks currently exist, a cart has not been fabricated to utilize them. Should the necessity for a cart arise in the future, the design will be reviewed by the HDL Radiation Control Committee prior to fabrication in order to assure that its design and intended use complement all safety considerations.

e. Emergency Lighting. Emergency light equipment, approved by Underwriter's Laboratory Standards for safety, provides emergency light to the Exposure Room/Maze areas automatically and instantaneously upon failure or interruption of normal electric power. The emergency power source for this unit is a maintenance-free, 6 volt, lead-acid rechargeable battery with up to 100 lamp watts output at 6 volts DC. One side of the unit has an observation post for visual inspection of battery liquid level. Additionally, the unit is equipped with a ready/off switch; a front-mounted "Press-to-Test" switch for quick testing of lamps and battery; an amber light which glows when the unit is in the ready state; a red light to indicate that the unit is on the high rate of charge; and a front mounted voltmeter to indicate battery condition.

f. Warning Signs. (1) In accordance with Section 20.203, 10 CFR Part 20, the entrance to the Cobalt-60 Exposure Room will be conspicuously posted with one sign bearing the radiation caution symbol and the words "Caution - High Radiation Area".

(2) The entrance to the Cobalt-60 Exposure Room will also be conspicuously posted with a sign bearing the radiation caution symbol, the words "Caution - Radioactive Material", isotope identification information, isotope quantity information, the date measurement of the isotope quantity was performed, and the manufacturer's trademark.

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(3) The wall opposite the maze entrance to the Cobalt-60 Exposure Room (east wall) shall be conspicuously posted with a large sign bearing the radioactive caution symbol and the words "Caution - Large Quantity of Radioactive Material Located at Bottom of Pool, Immediate Evacuation Required in Case of: 1. Fire or other Hazardous Condition; 2. Continuous actuation of radiation alarms; 3. Low pool water level."

(4) After installation of the Cobalt-60 sources and prior to the initiation of the irradiation program, a radiation survey shall be conducted to determine the maximum radiation levels above the pool and in each area adjoining the Exposure Room/Maze area. Should the radiation survey indicate the need for additional caution signs in order to comply with the posting requirements enumerated in Section 20.203, 10 CFR 20, they will be obtained and posted prior to the initiation of the irradiation program.

COBALT-60 IRRADIATOR SYSTEM FOR HARRY DIAMOND LABORATORIES

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- II. Safety Considerations
- III. Description of Radiation Safety Interlock System
- IV. Functional Description of Safety and Operation Components
- V. Operation Instructions

[REDACTED CONTENT]

NEUTRON PRODUCTS inc

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I. Introduction

The cobalt-60 irradiator system designed, constructed, and installed by Neutron Products, Inc. for the Harry Diamond Laboratories consists of the following principal components:

1. Elevator and elevator drive assembly.
2. Console and in-cell elevator controls.
3. Radiation safety interlock system.
4. Status and alarm annunciator.
5. Water quality system.
6. Ozone detector.

This system is designed to be operated in two principal modes. The first is the Console Operational Mode (COM) where the operation is controlled from the console located in the control room. The source material is located on the elevator and the product to be irradiated located in the cell adjacent to the pool. The second mode of operation is the In-cell Operational Mode (ICOM) where the product to be irradiated is placed on the elevator and lowered into the pool where the source material is stored.

II. Safety Considerations.

Cobalt-60 emits ionization radiation in the form of highly penetrating gamma photons which are capable of causing injury and death. In a cobalt-60 irradiator, therefore, there is significant potential for person injury from the radiation and from the by-products of the interaction of this radiation with air or other materials. Supplementing administrative controls necessary to achieve the safe operation,

is a radiation safety interlock system which primarily functions to subject the source/sample elevator operation to controls imposed by various mechanical and electrical safety devices. The elevator control system is interlocked with the hazard detection system and status-alarm annunciator to provide for the safety of operating personnel. The system should never be operated by persons not thoroughly familiar with basic radiation safety concepts and the functioning of all of the system's pertinent components. Under no circumstances should efforts be made to defeat any components of the radiation safety interlock system.

III. Description of the Radiation Safety Interlock System

The radiation safety interlock system functions as follows:

- A. The source/sample elevator cannot be raised from the bottom of the pool in the console operational mode (COM) if any one of the following conditions exist:
1. Console power is not on;
 2. The irradiator room TV monitor is not on;
 3. Low pressure exists in the compressed air supply;
 4. The safety air valve in the irradiator room has been pushed;
 5. Any one of the three emergency stop bottoms has been pushed;
 6. Any one of the three irradiation monitors is not electrically energized and operational;
 7. The operator has not entered the irradiator and turned the in-cell reset switch and exited from the irradiator closing the maze entrance doors in the prescribed time period of approximately 15 seconds. This operation is intended to enforce a final visual inspection of the irradiator cell; and,

8. The maze doors are opened after the prescribed time has passed following the operation of the in-cell reset switch.

B. The source/sample elevator cannot be raised from the bottom of the pool in the in-cell operational mode (ICOM) if any one of the following conditions exist:

1. The console power is not on;
2. The irradiator room TV monitor is not on;
3. Low pressure exists in the compressed air supply;
4. The safety air valve in the irradiator room has been pushed.
5. Any one of the three irradiation monitors is not electrically energized and operational;
6. Any one of the three emergency stop buttons has been pushed;
7. The operator has not turned the in-cell reset key switch; and,
8. The operator does not hold the in-cell elevator control key switch in its "On" position.

C. Once in its up position, the source/sample elevator will immediately return to the pool bottom if any one of the following conditions occurs:

1. One of the three emergency switches is pushed;
2. A hazardous radiation level is present in the control room;
3. A maze door is opened (except during the ICOM);
4. The air supply pressure drops; and,
5. The TV monitor is turned off.

C'. Since the system also allows for using the elevator to lower product to a source array located on the pool bottom in the in-cell operational mode (ICOM), protection for the operator controlling the elevator from within the irradiator is provided by the two in-cell Radiation Area Monitors which will immediately return the elevator

to the pool bottom in the event that the high radiation level in the irradiator is detected within the cell during or after elevator ascent in ICOM.

D. Additional safety features are as follows:

1. The doors are locked when the prescribed time of approximately 15 seconds has elapsed following the operation of the in-cell reset switch and the operating key switch is turned on during the Console Operational Mode (COM). The door remains locked until the switch is turned off and no high radiation level exists in the cell.
2. A visual and audible alarm sounds at the annunciator whenever the maze door is opened once the in-cell reset switch has been operated during COM. A subsequent reset operation is required.
3. Visual and audible alarm sounds when the concentration of ozone in the irradiator cell reaches a preset level.
4. The door when electrically locked to prevent entrance can be opened at all times from within the cell for unrestricted exit.
5. For a preset time before the elevator starts its ascent a horn sounds and rotating light beams located within the cell and maze are energized. A separate circuit detects a burned out light and indicates this on the annunciator.
6. A single operation key is used for all functions except the console power switch for which a separate key is provided. This key arrangement for the reset and operating switch is designed to insure that the elevator system cannot be operated in an improper sequence.

7. The elevator drive system which is composed of a pneumatic piston and counter weight assembly will operate to return the elevator to the pool bottom in the event of either an electrical power failure or a loss of operating air.
8. High and low pool water level detectors alert the operator from the annunciator in the control room and a remote monitoring station of potential unsafe conditions.
9. The water conditioning system filters and deionizes the pool water to protect the source encapsulation from corrosion. A conductivity analyzer alerts the operator of high water conductivity.
10. The status and alarm annunciating system allows the operator at a glance to check the present status (normal or abnormal) of various components of the system and notifies the operator by audible signal of a change in status. Certain key signals may be transmitted to a remote monitoring station if desired.

IV. Functional Description of Components

- A. RAM #1 - Detects and indicates the radiation level in the control room and will not allow the elevator to be raised or will lower the elevator should the level exceed the high level alarm setting of 2.5 mR/hr.
- B. RAM #2 - Detects and indicates the radiation level of the irradiator room. During the period that the radiation exceeds the high level setting of 20 mR/hr it will keep the irradiator door locked or in the in-cell operational mode (ICOM) of the system, will automatically cause the elevator to return to the pool bottom.
- C. RAM #3 - Detects and indicates the radiation level adjacent to the demineralizer system and will alarm when this level

exceeds the selected high level alarm setting of 20 mR/hr. It

functions also to provide a redundant high level detection and

alarm during ICOM and causes elevator to return to pool bottom

position if a high radiation level is detected.

- D. Emergency push button switches located on the operating console, in the maze, and in the irradiator will cause immediate shut down of the elevator energizing system, and lower the elevator.
- E. Safety Air Valve located in the irradiator will vent the air supply before the elevator drive piston so that the elevator cannot be raised. This valve should be pushed in whenever working in the irradiator room.
- F. Level Gauge with read out located in the control room indicates the water level in the pool and provides electrical contact openings at adjustable levels to provide alarm and control functions.
1. Contact set #1 causes a high level alarm to be initiated when the pool water level is between 136 and 138 inches.
 2. Contact set #2 causes the demineralizer pump to shut down when the level drops to a point just above the pump intake foot valve, 126 to 130 inches.
 3. Contact set #3 energizes solenoid valves to refill the pool when the water level is between 132 and 135 inches.
 4. Contact set #4 provides a low level alarm if the pool water level drops to 126 inches.
- G. Radiation Indicator Lights which flash purple are illuminated when the elevator is not in its pool bottom position, except in the in-cell operational mode (ICOM).
- H. Horn - Sounds for 15 seconds before the elevator starts its

ascent except in the in-cell operational mode.

- I. Door Position Switches - Will not allow the elevator to ascend if a maze door is opened and more than 15 seconds has elapsed since the system has been reset. If a door opens after the elevator has ascended, it will immediately descend and remain at the bottom until the system is again reset. In the in-cell operational mode (ICOM) these switches have no function.
- J. Door Lock - Prevents the entrance door from being opened once 15 seconds have passed since the in-cell reset switch has been operated but allows the emergency exit door to be opened from inside the irradiator. The lock can be bypassed by turning the Door Lock Bypass Switch in a non routine operation.
- K. Door Lock Bypass Switch - Disengages the door lock except when the radiation level in the irradiator exceeds the high level alarm setting of RAM #2 or RAM #3.
- L. Reset Key Switch located within the irradiator - Must be turned momentarily to reset the control circuit and provide for an elevator ascent. This operation requires that the maze door has not been opened at any time once 15 seconds have elapsed after the reset switch has been operated in the console operational mode (COM). In the in-cell operational mode (ICOM), the reset key switch must be turned before the ICOM key switch is used to lift the elevator.
- M. In-cell Operational Mode Key Switch - Which must be held in position, raises and lowers the elevator from inside the irradiator as described in L, above when operating in the ICOM providing the ICOM key switch has been, and remains turned within 15 seconds of the reset switch operation.

- N. Console Power Key Switch with its own key applies power to the console circuitry, and must remain on except when working on the system since it controls power to the water circulating system, and the control and alarm functions which must operate continuously.
- O. Console Pump Switch - Turns the water quality pump on and off. For the pump to be on, the pool water level must be correct and the console pump key switch must be "On".
- P. Console Fill Valve Push Button - Used to manually add water to the pool or prime the water quality pump.
- R. Annunciator - Provides visual status indication of monitored conditions throughout the Control System. An illuminated legend indicates an abnormal status; a flashing legend (accompanied by an audible alarm) indicates a status which has changed from normal to abnormal; a nonilluminated legend indicates a normal status.
- S. Annunciator Ack (Acknowledge) - Clears the audible and visual annunciator indications. The visual indications then are of present conditions.
- T. Annunciator Sil (Silence) - Clears the audible annunciator indication. Visual indication remains unchanged. A flashing indication means a change from normal conditions has occurred and may still exist.
- U. Annunciator Test - Tests all annunciator channels for proper operation. All channels must flash and the audible signal must be present.

- V. Remote Annunciator Switch - Connects the master annunciator to a remote monitoring point if desired.
- W. Ozone Monitor - Samples the ozone content in the irradiator and in conjunction with the annunciator, warns personnel of potentially hazardous concentrations.
- X. Conductivity Monitor - Determines the conductivity of the pool water at the inlet of the water quality pump and in conjunction with the annunciator, warns operations personnel of water conductivity which may be detrimental to source encapsulation life expectancy.
- Y. Water Quality System
1. Pump - Circulates pool water through the water quality system. Note: The pump may have to be primed if turned off for an extended period of time.
 2. Filter - Removes particulate matter from the pool water.
 3. Pressure Gauges - Provides visual indication of water conditioning systems performance as follows:
 - a. Both readings high and approximately equal indicates restricted flow through demineralizer tanks or return line to pool.
 - b. Both readings low, pulsating, or zero - pump not on or loss of prime.
 - c. One reading high and the other low indicates plugged filter.
 - d. Both readings moderate with 20 - 30 percent differences in reading indicates normal conditions.
 4. Deionizer Tanks - Removes ionic species from the pool water.

2. Air Control Box

1. Air Supply Shut-off Valve - When open supplies air pressure for the elevator drive cylinder and pool level gauge.
2. Pressure Regulator Assembly - Limits, regulates, and conditions the air supply for the elevator drive and pool level gauge.
3. Descent Control Valve - Limits the elevator descent speed.
4. Ascent Control Valve - Limits the elevator ascent speed.
5. Solenoid Valve (4 way) - Changes the routing of the air supply on command of the control console, to cause either ascent or descent of the elevator.
6. Reserve Tank - Supplies sufficient reserve air capacity to return to the elevator to the pool bottom in the event of power failure and/or primary air supply system failure.

V. Operating Instructions

Note 1: The following procedure assumes that the total system is operational and that all adjustments have been made and the system is on stand by (i.e. The RAMs and other instruments are calibrated and alarm levels are properly set, the compressed air supply is on, etc.). (See also Note 2 at end of Section V., Operating Instructions, for additional start up instructions.)

1. Check the console power indicating light. The light should be on.
2. Turn the remote annunciator off.
3. Turn on the closed circuit TV monitor.
4. Turn on the ozone monitor.
5. Turn on the conductivity monitor.
6. After 15 minutes has elapsed check and adjust the TV.
7. Push the annunciator test switch and verify that all the annunciator channels are working.

8. Acknowledge the annunciator.
9. Check the pool level indicator for the proper water level.
10. Check the operation of the RAMs by pushing the up scale check button. An annunciator should indicate an abnormal condition for each.
11. Acknowledge the annunciator. Hereafter, check the cause of any audible annunciator change and correct any abnormal condition.
12. Verify the following annunciator channel conditions:

<u>Channel</u>	<u>Condition</u>
RAM Power	Out
RAM 1 Level	Out
RAM 2 Level	Out
RAM 3 Level	Out
High Water Level	Out
Low Water Level	Out
Low Air Pressure	Out
Sol. Circuit 1	On
Sol. Circuit 2	On
System Not Reset	On
TV Power	Out
Door Bypassed	Out
Source on Bottom	Out
High Ozone	Out

13. Investigate and correct any improper condition before continuing.

14. Enter the irradiator.
15. Depress manual air vent safety valve before proceeding with any operations within the irradiator cell.
16. When ready to raise source/sample elevator close the manual air vent safety valve.
17. Clear the room of all personnel, Reset - Operate Key Switch.
18. Make a rapid exit from the irradiator.
19. After the irradiator door has closed, check the System Reset annunciator indication. The light must be out to proceed with the operation. If not, this indicates a delay between the operation of the in-cell reset and closing the door. Repeat steps 14 and 15, and make a speedier exit.
20. Turn the console operate key switch to "Operate".
21. Observe the elevator operation via the TV monitor and counterweight.
22. Return the Operate keyswitch to its off position to return the elevator to the pool bottom.
23. Observe the elevator operation via the TV monitor and/or counterweight.
24. Repeat steps 11 through 13 when re-entering the irradiator or leaving the facility.
25. Turn off the TV, conductivity monitor, and ozone monitor.
26. Acknowledge the annunciator.
27. Turn the remote annunciator on.

To irradiate materials at the pool bottom, replace steps 17 through 22 with the following:

- 17A. Inspect the elevator to be certain that no source material is attached.

- 18A. Position knowledgeable co-worker with operative survey meter set on the proper range to detect any increase in dose rate as elevator rises.
- 19A. Turn the Reset-Operate Keyswitch.
- 20A. Turn the Remote Operate Keyswitch and hold in position until the elevator rises and the material is loaded or unloaded.
- 21A. Release the Remote Operate Keyswitch to lower the elevator to the bottom.
- 22A. To remove the material, repeat steps 14, 15, 16, 17A, 18A, 19A, 20A, and 21A. Then, proceed to step 24.

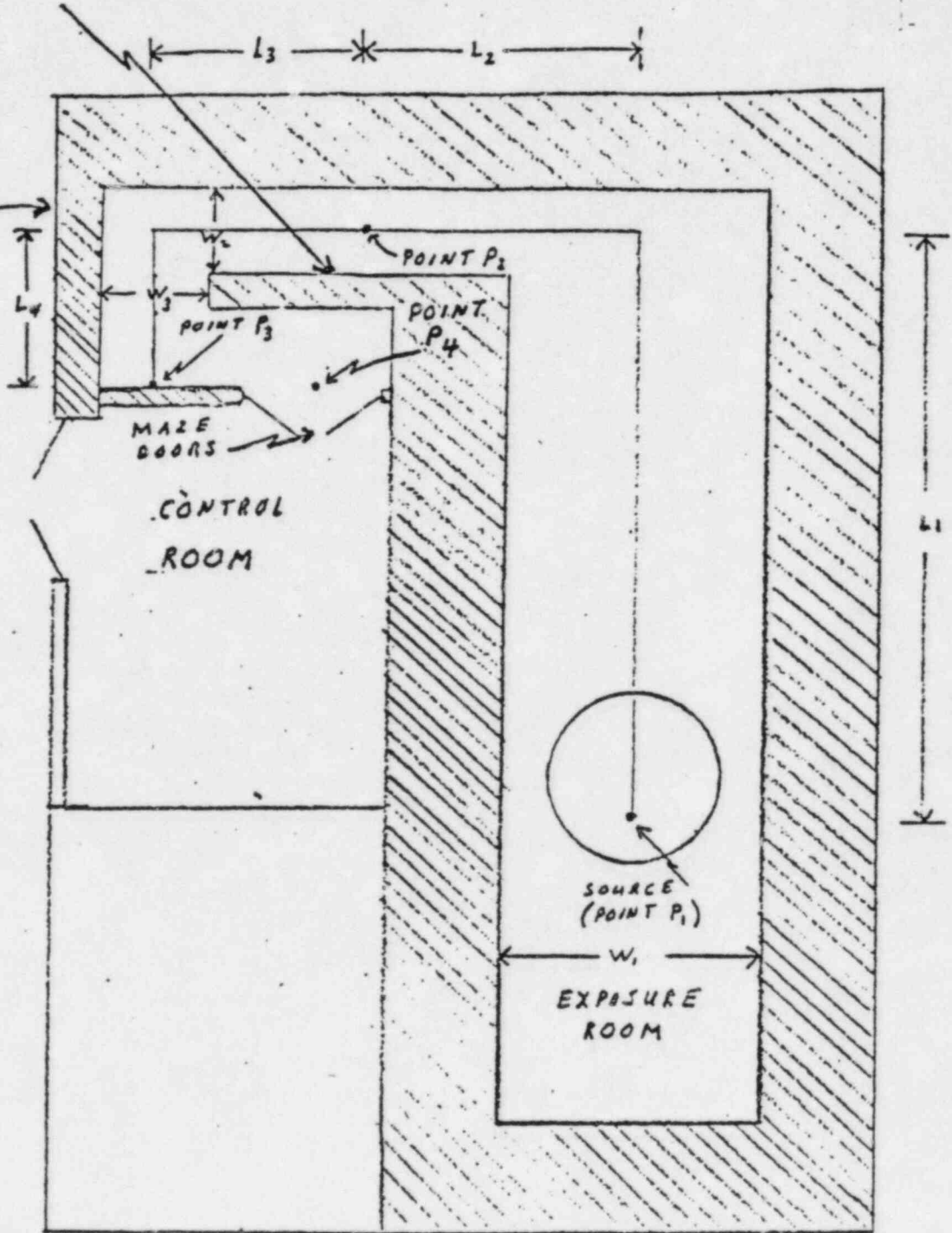
Note 2: If system is off, i.e. not stand by, the following additional steps are required:

- 1. Turn power on to radiation area monitors circuit breaker, control console circuit breaker, instrument rack circuit breaker, and water circulating pump circuit breaker in mechanical equipment room.
- 2. Turn on air supply (closing bleed valve if open).
- 3. Turn on console power keyswitch.
- 4. Perform any required scheduled maintenance.

HDL COBALT-60 FACILITY

MAZE SCATTER SHIELD

WEST WALL OF MAZE



$$W_1 = 12''$$

$$W_2 = 4''$$

$$W_3 = 5''$$

$$L_1 = 26.33''$$

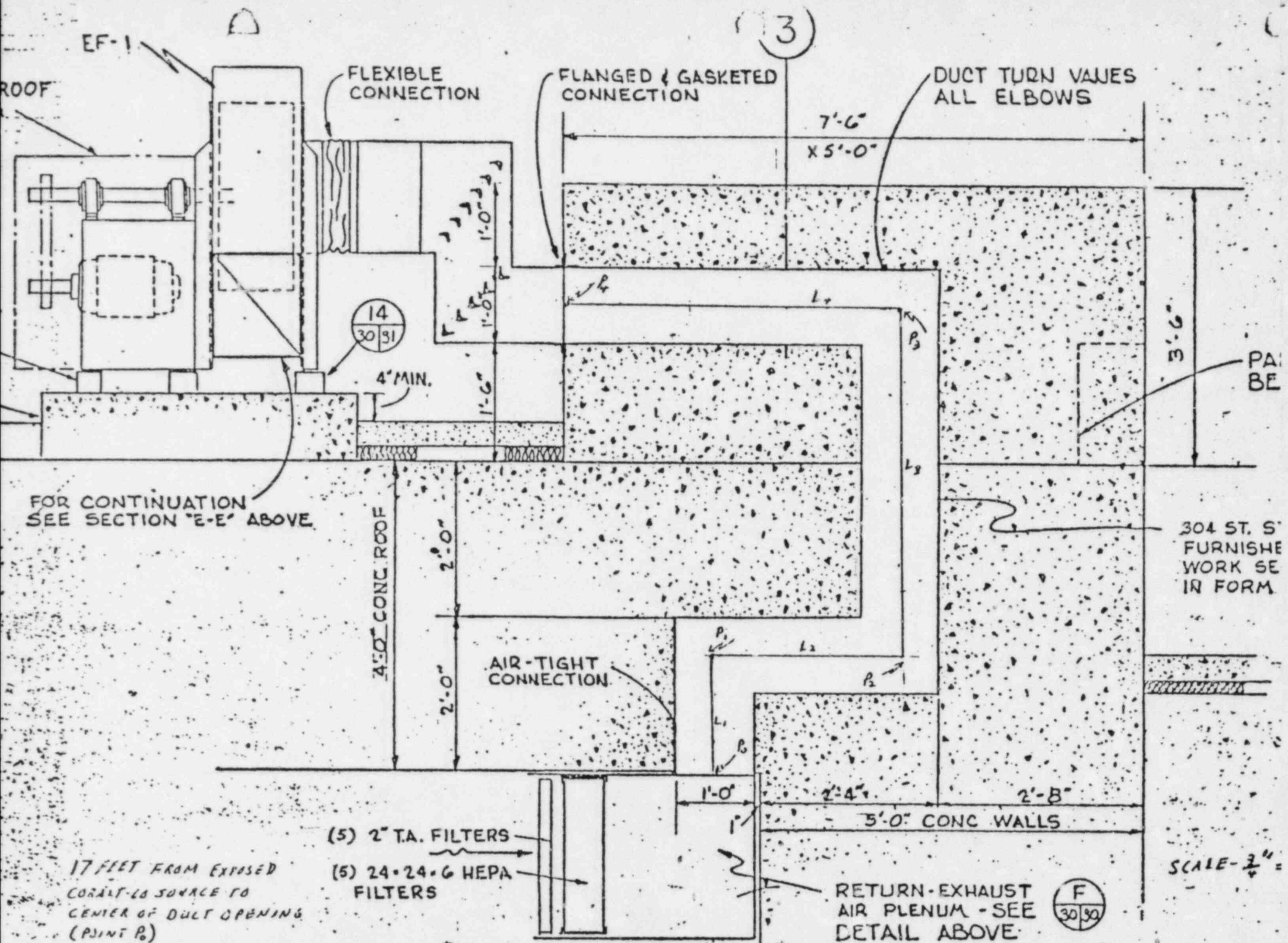
$$L_2 = 12.68''$$

$$L_3 = 8.99''$$

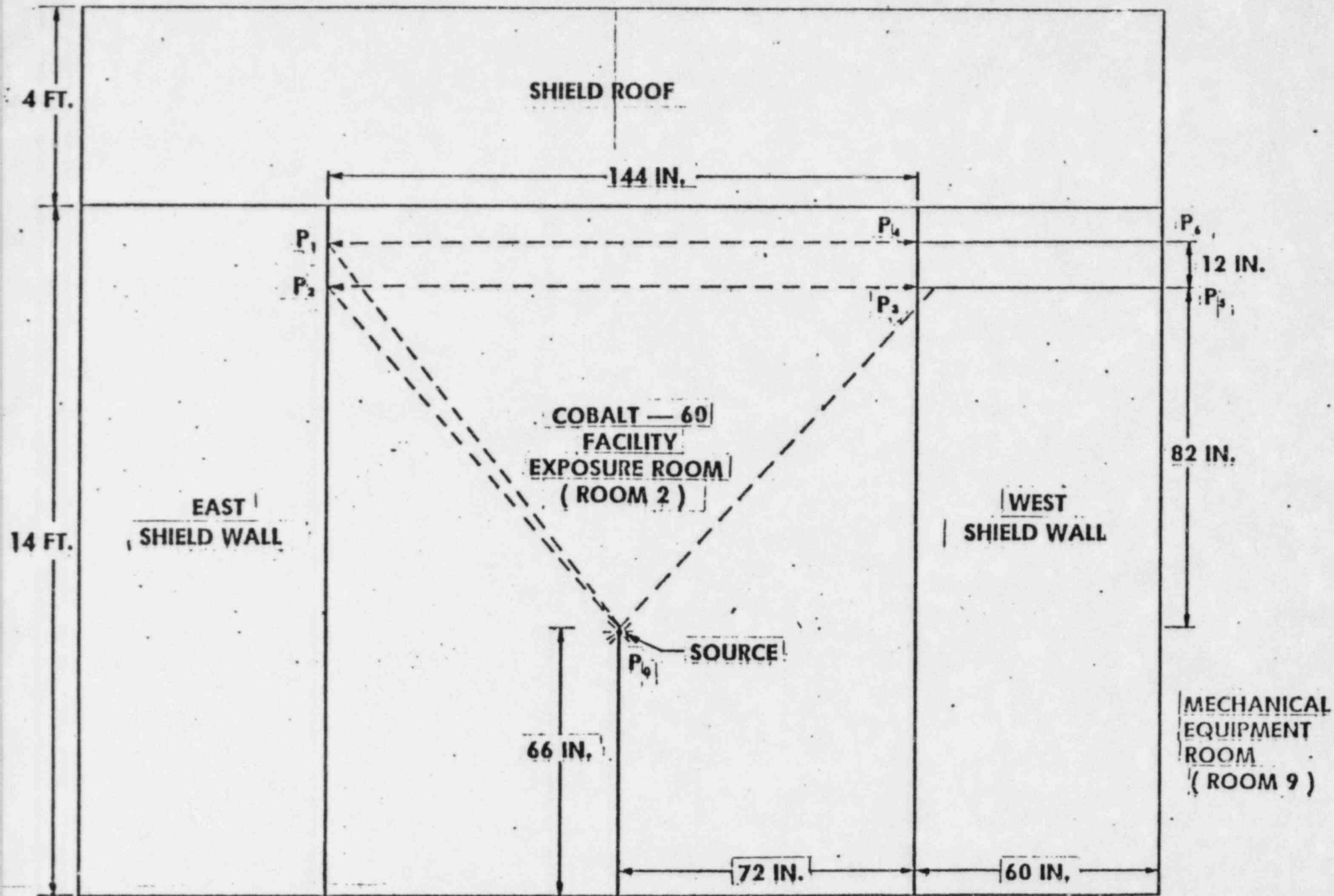
$$L_4 = 7.5''$$

$$P_3 \rightarrow P_4 = 7.5''$$

SKETCH 5-1



RADIATION TRAP FOR COBALT-60 SOURCE EVALUATION SYSTEM



SKETCH 5-3

SUPPLEMENT #6

Item 15, Form NRC 313 I, Radiation Protection Program

1. Administrative Organization and Responsibilities.

a. Harry Diamond Laboratories (HDL) functions as a research and development laboratory of the US Army Materiel Development and Readiness Command (formerly known as the US Army Materiel Command, AMC, until February 1976). Consequently, the overall direction of the HDL ionizing radiation safety program is still guided by AMC Regulation 385-25, w/Ch 1, "Safety - Radiation Protection" attached as Annex 6-A to this supplement. This regulation is supplemented by HDL Regulation 385-20, "Ionizing Radiation Protection Program" (attached as Annex 6-B) in order to provide local guidance to HDL personnel concerning the operational requirements and administrative procedures necessary for the control of ionizing radiation sources at HDL. A description of the organization, and how authority and responsibility is delegated to personnel directly responsible for the overall radiation protection program is found in Annex 6-B, Paragraph 5.

b. The HDL Radiation Protection Officer is responsible for the radiological safety of personnel using the cobalt facility. He directs all operations which involve the exposure of personnel to ionizing radiation in order to ensure that exposures are kept within tolerance. In addition, he maintains strict administrative control to minimize hazards during cobalt facility operations and ensures that all provisions of the NRC license and applicable regulations are complied with. Although, in general, the Radiation Protection Officer acts through the Cobalt Facility Supervisor, he has the authority to halt any operation at the Cobalt Facility that he considers a potential radiological or safety hazard.

c. The responsibility for operation of the Cobalt Facility is delegated by the Commander, HDL, to the Cobalt Facility Operator via the following chain of command:

HDL Technical Director
Associate Technical Director, 002
Chief, Nuclear Radiation Effect Laboratory, 200
Chief, Simulation Technology Branch, 290
Cobalt Facility Supervisor
Cobalt Facility Chief Operator and Alternate Operator

The Cobalt Facility Supervisor, Chief Operator, and Alternate Operator are individuals authorized to manipulate the source elements, source elevator, console controls, and other equipment associated with the control, handling, and maintenance of the facility. These individuals will satisfy the HDL Radiation Control Committee as to their training and experience in the area of radiological safety and in the use of radioisotopes. Also, these individuals must demonstrate a thorough knowledge of the Cobalt Facility operating procedures and applicable safety regulations. In addition to the responsibilities outlined in Annex 6-B, Paragraph 5d, the Facility

Supplement No. 6 continued.

Supervisor will ensure that the following tasks are accomplished prior to conducting experiments in the Cobalt Facility.

(1) Verify that all experiments involving the use of the Cobalt Facility have received review and approval of the HDL Radiation Control Committee in accordance with the procedures set forth in Annex 6-B, Paragraph 11, of this application.

(2) Ensure that the Cobalt Facility Standing Operating/Emergency Procedure (included as Annex 6-C to this supplement) is conspicuously posted in the Cobalt Facility and that experimenters are aware of its content.

(3) Determine that all safety equipment and devices are functioning properly.

2. Administrative Controls and Procedures.

a. All personnel entering the Cobalt Facility will be aware of and adhere to the procedures set forth in the Cobalt Facility Standing Operating/Emergency Procedure which is included as Annex 6-C to this supplement.

b. All maintenance, repair, or experimental procedures involving the manipulation of the source elements will require the presence of at least two individuals; one of which must be the HDL Radiation Protection Officer, the Cobalt Facility Supervisor, the Chief Operator, or the Alternate Operator.

c. Personnel exposures will be limited by the HDL Radiation Protection Officer in accordance with current AEC and Army instructions.

d. All proposed modifications to the Cobalt Facility, including all proposed deviations from established operational or administrative procedures shall be submitted to the HDL Radiation Control Committee. This committee shall review such proposals and determine whether or not they are advantageous to the operation of the facility. All proposals will be classified in one of the following categories.

(1) Major Safety Change: Any change which affects the degree of hazard associated with the operation of the Cobalt Facility.

(2) Minor Safety Change: Any change not classified as a major change which is directly associated with the safety of the Cobalt Facility. Included in this category are changes in the principal administration and operational procedures, health physics procedures and mechanical or electrical system alterations to the facility.

(3) Routine Change: Changes which have no bearing on the safety characteristics of the Cobalt Facility.

Supplement No. 6 continued.

e. All major and minor safety changes require the approval of the HDL Radiation Control Committee prior to requesting approval of proposed changes, through appropriate channels, from the Nuclear Regulatory Commission.

f. The Cobalt Facility Supervisor will ensure that the tasks enumerated in "Cobalt-60 Facility Weekly Checklist" (Annex 6-D), the "Periodic Maintenance Schedule" (Annex 6-E), and the "Periodic Calibration Schedule/Procedures" (Annex 6-F) are performed as specified therein.

g. The Radiation Protection Officer shall perform monthly inspections of the Cobalt Facility in order to accomplish the following:

(1) Verify that the facility is being used in accordance with prescribed operating procedures.

(2) Perform functional checks on the radiation detection alert systems.

3. Facility Operations.

a. In order to assure that only authorized persons will use or have access to the Cobalt-60 Facility, the following physical/administrative controls have been imposed.

(1) The Maze door, installed to control access from the Control Room to the Exposure Room/Maze, will be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel.

(2) The Control Room door, installed to control access from the grounds surrounding Building 504 to the Control Room, will also be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel. In addition to the door lock, the Control Room door is equipped with a high-security hasp and padlock which is controlled exclusively by the HDL Security Guards. The high-security hasp and padlock will be unlocked during working hours, and will be secured at all other times.

(3) As enumerated in the Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C), the separate keys to the Control Room door, Maze door, console power switch and elevator drive switch are rigorously controlled by the Cobalt-60 Facility Supervisor, Chief Operator and Alternate Operator.

(4) All exterior windows installed in Building 504, and any openings (such as air vents) which are 96 square inches or over are protected against incursion by permanent, steel security grills.

Supplement No. 6 continued.

(5) The HDL Security Guards provide continuous surveillance of the Cobalt-60 Facility by performing periodic patrols and also by remotely monitoring the electromechanical intrusion alarms and ultrasonic motion detectors installed in the Cobalt-60 Facility Control Room. Actuation of a surveillance alarm transmits an audio-visual signal to an annunciator panel monitored by security personnel at the main guard office. Upon receipt of an alarm, security guards are immediately deployed to arrive at the site of intrusion in approximately 2 minutes. In addition to the security precautions presented above, the entire HDL complex is surrounded by a 9 gage chain link perimeter fence in order to restrict or impede access by unauthorized individuals.

(6) The Cobalt-60 Facility Standard Operating/Emergency Procedure (Annex 6-C) delineates the administrative/physical actions required of individuals desiring authorized access to the Exposure Room. Annex 6-C and Supplement No. 5 to this application also define the conditions which must exist within the Exposure Room/Maze Area before entry is permitted during the various operational modes.

b. The HDL Cobalt-60 Facility will be used to conduct free-air and water-well irradiation in order to perform radiation effects testing on electronic components and for the performance of radiochemistry and dosimetry experiments. Highly flammable or explosive materials will not be irradiated at the Cobalt-60 Facility regardless of the operational mode. In addition to the administrative controls on experiments and experimenters thus far described in this supplement, all the safety provisions delineated in the Cobalt-60 Facility Standing Operating/Emergency Procedures will be strictly adhered to and enforced. A complete description of the functional characteristics associated with Cobalt-60 Facility irradiator system and safety support equipment is presented in paragraphs 2 and 3 of Supplement No. 5 to this application. The step-by-step operating instructions which must be followed by the console operator in order to perform free-air irradiations or water well irradiations involving use of the elevator is presented in paragraph V of Annex 5-A to this application.

c. In order to assure that the facility is being operated only when all safety interlocks and devices are functioning properly, the Cobalt-60 Supervisor is assigned the responsibility of assuring that the equipment checks, maintenance, and calibrations set forth in Annexes 6-D, 6-E, and 6-F of this application are thoroughly performed at the time intervals specified. Should any of the primary safety support equipment fail to function properly, use of the Cobalt-60 Facility shall be terminated until the cause of the malfunction has been determined and corrected.

4. Routine Monitoring Program. a. Radiation Area Monitors (RAM):

(1) The Control Room and Exposure Room areas are equipped with three Nuclear Measurements Corporation Model GA-2T0 ionizing radiation area monitors installed for the purpose of detecting radiation levels in these

Supplement No. 6 continued.

areas on a 24 hour-a-day basis. These RAMs are incorporated into the Radiation Safety Interlock System and the Radiation Warning System as described in paragraph 2c and paragraph 2d(4) of Supplement No. 5 to this application. In the event of an alarm, the Cobalt Facility will be evacuated and the Radiation Protection Officer will be notified. The Exposure Room/Maze Area of the facility will not be reentered until the reason for the alarm has been ascertained or until a radiation safety survey has been performed.

b. Resin Bed Radiation Monitor (RBM).

(1) In addition to functioning as an Exposure Room Radiation Area Monitor, RAM No. 3 serves as a Resin Bed Monitor (RBM). This monitor is positioned adjacent to the pool water deionization resin bed tanks in order to provide continuous monitoring of the Cobalt-60 Facility pool water for the presence of a leaking source element.

(2) Removal of cobalt-60 from the pool water by the water purification system (a mixed resin bed) will have its greatest effect if all the activity passing through the demineralizer is removed from the water. Assuming a constant leak rate from a source element, the activity remaining in the water would be:

$$A = \frac{A_1}{F/V} [1 - e^{-Ft/V}]$$

Where A = total activity in the water

A_1 = leak rate

F = water flow rate through purification system

V = pool water volume

t = time since start of leak

exp = exponential function

The fraction of activity in the water of the total released would then be:

$$\frac{A}{A_1 t} = \frac{1 - e^{-Ft/V}}{(F/V) t}$$

The fraction of activity concentrated in the resin bed of the total released is $1 - A/A_1 t$. Some calculated values of this fraction for normal values of the parameters for the facility are presented below (V = 2327 gal, F = 50 gpm).

<u>DURATION OF LEAK (DAYS)</u>	<u>FRACTION OF ACTIVITY RELEASED AND DEPOSITED IN RESIN BED</u>
1	0.968
2	0.983
3	0.989
4	0.992
7	0.995

Supplement No. 6 continued.

(3) Since the resin bed tanks are cylindrical one may use the formulas and associated data presented in Applied Dosimetry, K. K. Aglintsev, London Iliffe Books Ltd., 1965, to calculate the exposure rate at the surface of the resin bed tank due to the presence of cobalt-60 evenly distributed in the resin. The following calculation assumes that the resin bed has accumulated 1 microcurie of cobalt-60 from a leaking source element.

$$P = P_0 \Gamma f B$$

Where P = exposure rate from a solid cylindrical source
 P_0 = exposure rate from emitter if all activity were concentrated at the center
 Γ = coefficient which allows for the geometry of the source and the distance from it
 f = self-absorption coefficient (0.369)
 B = build-up factor (1.3)

$$P_0 \Gamma = \pi P_{\gamma} q_{vol} R_0 \left\{ \frac{H}{R_0} (1 - \ln 2H/R_0) + \frac{H}{R_0} \ln \left[\frac{H}{R_0} + \sqrt{\left(\frac{H}{R_0}\right)^2 + 4} \right] + 2 - \sqrt{\left(\frac{H}{R_0}\right)^2 + 4} \right\} = 0.015 \text{ mR/h}$$

Where $P_0 \Gamma$ = exposure rate on surface of cylindrical source
 q_{vol} = specific activity of source (1.511×10^{-8} mCi/cm³)
 H = cylinder height (106.68 cm)
 R_0 = cylinder radius (15.24 cm)

$$P_{\gamma} = R \text{ cm}^2/\text{mCi h for Co-60 (13R/h mCi at 1 cm)}$$

$$\text{Now } P = P_0 \Gamma f B = (0.015 \text{ mR/h})(0.369)(1.3) = 0.001 \text{ mR/h}$$

The above calculations assume that the cylindrical source is homogeneous and has the density of water. In order to find the true exposure rate at the outside surface of the 1/16 inch thick steel tank one must calculate the shielding effect of the resin bed tank material.

$$\text{Thus: } D = B D_0 e^{-uX}$$

Where D = exposure rate at outside surface of resin tank
 D_0 = exposure rate at inside surface of resin tank
 B = Build-up factor (1.0)
 u = linear absorption coefficient (0.4672 cm^{-1})
 X = shield thickness (0.1588 cm)
exp = exponential function

$$D = (1.0)(0.001 \text{ mR/h})(.9285) = 0.001 \text{ mR/h}$$

(4) Since $P_{\gamma} = 13 \text{ mR/h uCi at 1 cm for Co-60}$, and the exposure rate at the surface of the resin bed tank is 0.001 mR/h for each microcurie of Co-60 evenly distributed inside the resin bed tank, the Resin Bed Monitor will be exposed to approximately 0.1% of the activity in the tank. Assuming a background count rate of 1000 CPM and a 6% efficiency for the detector, the Resin Bed Monitor has a minimum sensitivity of 7.12×10^{-4} uCi as shown below:

Supplement No. 6 continued.

$$\begin{aligned}\text{Min. Sens.} &= 3/\epsilon X (\text{CPM}_{\text{BKG}}/t)^{1/2} \\ &= 3/(\text{.06})(\text{.001}) (1000/t)^{1/2} = 1.581 \times 10^3 \text{ DPM} \\ &= 7.12 \times 10^{-4} \text{ uCi}\end{aligned}$$

Where ϵ = counting efficiency
 X = fraction of total sample presented to detector
 t = counting time
 CPM_{BKG} = background count rate

(5) Considering the results of the above calculations pertaining to the Resin Bed Radiation Monitor, it appears that this system will provide adequate early warning in the case of a leaking source element between routine leak testing procedures.

c. Routine/Emergency Leak Testing.

(1) At periods not to exceed 6 months the HDL Radiation Protection Officer will perform leak tests of all source elements in order to assure that the integrity of the source elements have not been violated. The leak testing method used will be sufficiently sensitive to detect a 2×10^{-4} uCi loss in 24 hours, which is equivalent to less than a 0.05 uCi loss in 6 months. This leak test procedure will also be initiated should the Resin Bed Radiation Monitor indicate that a source element is leaking.

(2) Procedure: The basic procedure involved in routine leak testing or in identification of a leaking element will be to isolate groups of the source elements in the sealed Leak Test/Isolation Containers described in Supplement 5 of this application. These containers are designed so that they can be loaded with 10 source elements each, sealed, sampled, pumped dry, and flushed with clean water while at a safe depth under water. Once the source elements are isolated in the Leak Test/Isolation Containers they will be steeped in clean water for a period of at least 24 hours and sampled to show an activity loss of less than 2×10^{-4} uCi/24 hours. Should testing results indicate that a container houses a leaking element, the elements in that container will be divided up between the two leak test containers and the procedure repeated until the leaking element is located.

(3) Sampling sensitivity: An example of an available system on which the above test may be performed with the required sensitivity is the Nuclear Measurements Corporation, Model PC-4, gas flow proportional counter. A one liter water sample evaporated to dryness (conservatively assuming a 50% collection efficiency) and counted for 960 minutes, will give a minimum sensitivity of 2.24×10^{-8} uCi/cm³:

$$\begin{aligned}\text{Min. Sens.} &= 3/\epsilon Vc (\text{CPM}_{\text{BKG}}/t)^{1/2} \\ &= 3/(0.55)(1000)(0.5) (46.0/960)^{1/2} = 4.98 \times 10^{-2} \text{ dpm/cm}^3 \\ &= 2.24 \times 10^{-8} \text{ uCi/cm}^3\end{aligned}$$

Supplement No. 6 continued.

Where ϵ = counting efficiency
 V = sample volume
 c = collection efficiency during sample reduction
 t = counting time
 CPM_{BKG} = background count rate

(4) No servicing, maintenance, or repair of sources will be done at Harry Diamond Laboratories. Should a source element be found faulty, it will be transferred to a Source Leak Test/Isolation Container which will then be sealed. Upon receipt of instructions for disposition, the source will be shipped to a licensed facility for repair or ultimate disposal. Should waste disposal procedures be necessary, it will be handled by the US Army Armament Materiel Readiness Command, Rock Island, IL in accordance with the procedures delineated in Army Regulation 755-15, "Disposal of Unwanted Radioactive Material."

5. Emergency Organization and Procedures.

a. Organization for Emergencies:

(1) Any individual discovering fire or other hazardous conditions at the Cobalt Facility is required by the "Cobalt Facility Standing Operating/Emergency Procedure" (attached as Annex 6-C to this supplement) to evacuate the building, report the nature of the problem to the HDL Guard Office, and muster in the Bldg. 504 parking lot to await further instructions.

(2) Upon notification of the emergency condition the HDL Disaster Control Plan specifies the following course of action.

(a) The HDL Guard Office will notify the Fire Department, the HDL Fire Chief in case of fire, the Medical Office in case of injuries, the Safety Office, Radiation Protection Officer, and the Commander. The Guard Force will deploy personnel to direct emergency personnel to the scene and advise them of the fact that a radiation hazard may exist. All uninjured personnel who may have been exposed to ionizing radiation or contaminated with radioactive material will be directed and detained in a safe area by the Guard Force until monitoring and decontamination assistance is available.

(b) The Medical Office will treat injured personnel brought to the office or the Nurse will visit the scene to render First Aid assistance and summon additional assistance if necessary.

(c) The Motor Pool Officer will be alerted to stand-by to furnish transportation to hospitals.

(d) The Radiological Protection Officer will represent the Safety Office at the scene of the emergency in order to advise emergency personnel of the radiological hazards associated with the incident and assist in evaluating plans for remedial actions.

Supplement No. 6 continued.

(e) The Safety Branch, HDL Fire Chief (in case of fire) and the Branch Chief of involved personnel will investigate the accident after measures to eliminate the hazardous condition have been performed.

b. Hazard Due to Abnormal Water Levels or Non-Returning Exposed Source.

(1) The exposure rate at the normal surface of the pool has been calculated for several water levels and is presented in Figures 6-1 and 6-2. These were calculated using the exposure buildup factors for a point isotropic source, infinite medium, calculated by Goldstein and Watkins and presented in Engineering Compendium on Radiation Shielding, Volume 1, Springer-Verlag New York Inc., 1968. As shown by Figures 6-1 and 6-2, the situations in which low water levels occur do not represent serious emergencies except in extreme cases, ie, very little or no water. In the extreme case, emergency personnel have the capability of flooding the pool from a location external to the Exposure Room by utilizing the emergency fill water system installed specifically for that purpose; this system is described and illustrated in Supplement No. 5 to this application. Consequently, the size of the leak required to maintain the sources in an unshielded condition (ie, a dry pool) would require the occurrence of a very improbable event.

(2) Actions taken in the event of an abnormal water level or source position are predicated on the assumption that as long as the Exposure Room remains secured, there is no problem with regard to personnel radiation hazards. The only personnel exposure hazards that might arise would be created by the process of correcting the problem. In the case of a non-returning, fully exposed source, any procedure which might be initiated, other than those built in to the system, would be transmitted to the US Nuclear Regulatory Commission prior to implementation. However, considering the free fall design of the source elevator and the back-up emergency haul-down capability (described in paragraph 2b of Supplement No. 5 to this application) the likelihood of this possibility is very minuscule.

c. Remote Emergency Situations:

(1) The possibility of personnel exposure from falling into the Cobalt-60 Facility pool is minimized by pool design and administrative procedure. As recommended by the Occupational Safety and Health Act Regulations, 29 CFR, Part 1910, the pool is guarded by a standard railing with standard toeboard on all sides and a hinged floor hole cover of standard strength (see Supplement No. 5). The Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C of this supplement) requires that at least two persons be in the facility when a task requires standing over the exposed tank. Restricted access to the pool surface and the requirement that two persons be present when work involves removal of the pool cover minimizes the possibility that an unaided individual could fall into the pool.

(2) Rupture or shifting and tilting of the Cobalt-60 Facility due to earth movement is unlikely due to the extremely remote possibility of a

Supplement No. 6 continued.

destructive earthquake in the Washington area. The seismic analysis, presented in paragraph 1i of Supplement No. 5 to this application, indicates that the structural characteristics of the Cobalt-60 Facility are adequate to cope with any probable seismic phenomena.

6. Source Installation. a. The initial shipment and installation of all cobalt-60 source elements for the HDL Cobalt-60 Facility will be performed by the source manufacturer (Neutron Products Inc., Dickerson, Maryland) in accordance with the step-by-step procedures enumerated in NPI Specification P-5, attached as Annex 6-G to this supplement. The names of the persons who will be unloading the shipping containers and a description of their training and experience in performing such operations is presented in Annex 6-H to this supplement. As indicated by Annex 6-G, the Department of Transportation approved source transfer container will be lowered to the bottom of the 12 feet deep water filled pool prior to removal of the source elements from the transfer container. The remote handling tool described in Supplement 5 to this application will then be used to extract the source elements from the transfer container and install them in the source holding fixtures located at the bottom of the same pool. Prior to the installation of the source elements in the irradiation facility the following conditions shall prevail:

(1) The transfer will not be attempted until the HDL Radiation Protection Officer is present and certain that all individuals are competent in all phases of the operation and are familiar with the loading and monitoring procedures.

(2) The HDL Radiation Control Committee must approve all source transfer procedures prior to their implementation.

(3) An exclusion area shall be established and cleared of all personnel not directly involved with the source transfer operation.

During the actual installation of source elements into the source holding fixtures the following precautions shall be taken:

(1) The HDL Radiation Protection Officer shall perform a series of leak tests to check for source leakage that may have occurred while the sources were in transit to HDL. Leak test smears will be removed to non-radiation areas and checked with a G-M survey meter. If no significant activity is detected on the smears they will be placed in a gas flow proportional counter for accurate analysis and documentation of activity levels. If significant activity is found on smears, the transfer operation will cease until the source of contamination is found and appropriate corrective action taken.

(2) Continuous monitoring of the radiation levels inside the exclusion zone will be made during the transfer operation. This monitoring will be accomplished by use of portable survey meters and also by the remote area monitors installed in the Control and Exposure Rooms.

b. After all source elements have been loaded into the source holding fixtures at the bottom of the pool a complete radiation monitoring survey will be performed by the HDL Radiation Protection Officer. All areas of the building normally occupied by personnel will be checked with portable survey meters. All equipment used to transfer the source elements and the surface area over which the source transfer operation was conducted will be checked for radioactive contamination by wiping the surfaces with filter paper and analyzing the filter paper in a gas flow proportional counter to ensure that removable surface contamination does not exceed 100 disintegrations per minute per 100 square centimeters. Should contamination in excess of 100 dpm/100 cm² exist, the source of contamination shall be determined, eliminated, and decontamination procedures implemented until all affected surface areas are within acceptable contamination limits.

7. Initial Shielding Survey. The shield survey will be performed in two steps. A cursory survey of the areas adjacent to the Exposure Room/Maze Areas, such as the Control Room, Mechanical Equipment Room, Radioactive Materials Storage Room, HIFX Exposure Room, HIFX RF Shielded Room, roof and exterior building walls, will be made while the source elevator car sustains approximately 5 kCi of cobalt-60 in the free-air-irradiation position. Following this, a more comprehensive survey will be performed with the maximum loading of the irradiator elevator allowed by this application. With the maximum loading of cobalt-60 sustained in the free-air-irradiation position by the elevator, all areas adjacent to the Exposure Room/Maze Area, the bulk shielding, and shielded penetrations such as conduits and air ventilation ducts will be surveyed. These locations will be surveyed with the sources raised to the most hazardous position with respect to the particular area being surveyed.

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D.C. 20315

AMC REGULATION
No. 385-25
CHANGE 1

10 February 1969

SAFETY

RADIATION PROTECTION

AMCR 385-25, 12 August 1968, is changed as follows:

a. Paragraph 5f is added:

"f. The AMC Surgeon (AMCPT-H) provides medical guidance for the protection of health of personnel in use of radiation sources."

b. Make the following changes:

(1) Paragraphs 5d, sixth line; 6b(3), sixth line; 12b, fourth line; 21d, third line; 30d(1)(j), fifth line; and 31, sixth line. Change "AMCAD-S" to "AMCSF."

(2) Paragraph 5e, first line. Change "Division" to "Office."

(3) Page 48, top of page. Change "(AMCAD-S)" to "(AMCSF)."

(AMCSF)

FOR THE COMMANDER:

OFFICIAL:

CLARENCE J. LANG
Major General, USA
Chief of Staff


WM. A. GREGORY
Colonel, GS
Chief, Administrative Office

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UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D.C. 20315

AMC REGULATION
No. 385-25

12 August 1968

SAFETY
RADIATION PROTECTION

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1. Purpose. This regulation establishes U.S. Army Materiel Command (AMC) ionizing radiation protection standards.

2. Scope. This regulation applies to all AMC elements procuring, receiving, storing, shipping, using, transporting, maintaining, or disposing of ionizing radiation-producing materials and/or equipment. This regulation does not apply to nuclear weapons, nuclear reactor systems, or spent fuel from nuclear reactors, nor does it apply to LASER or microwave radiation.

3. General. This regulation supplements AMCR 385-224 and is to be used in conjunction with AMCR 385-224.

a. Waivers of radiation safety requirements of this regulation are the same as those set forth in AMCR 385-224.

b. National Bureau of Standards handbooks on radiation protection shall be used as AMC standards in planning of facilities and local procedures except where such publications conflict with the requirements of this regulation in which case this regulation shall apply.

c. The terms shall, will, or must indicate mandatory requirements. The term may or should is advisory.

4. Definitions. See appendix A.

5. Policy. a. Prior to the use of sources of ionizing radiation in any program or project, and prior to the incorporation of a source of ionizing radiation into an item of supply (issue items), the cost effectiveness and safety of such use must be weighed against the use of alternate methods or materials to achieve project or program goals. The radiological hazards shall be investigated and written guidance prepared before supply items containing sources of ionizing radiation are issued for field use. (The word "radiation" will be used in this regulation for "ionizing radiation.")

b. Without proper controls, radiation can be hazardous to health and property. Consequently, proposals to obtain, use, store, transport, maintain, or dispose of items which are, or contain, sources of ionizing

radiation will be carefully evaluated to assure that all resulting exposures to radiation will be kept to a minimum.

c. Adequate procedures, facilities, equipment, and trained personnel will be provided to assure the safe use of materials or equipment capable of producing radiation. Failure to meet this requirement will result in cessation of operations or delay in start-up.

d. Commanders of separate activities tenanted upon an installation will be guided by the installation radiation protection standards. Local radiation protection standards will not be less restrictive than those standards established by Federal, Army, or AMC regulations. Should a separate activity's mission be hampered or restricted by the installation requirements, and the difficulty cannot be resolved at local level, the problem will be forwarded to the Commanding General, AMC, ATTN: AMCAD-S.

e. Headquarters, AMC Safety Division, develops and directs the AMC Radiation Protection (health physics) Program.

6. Responsibilities. a. Installations and activities. Commanders of installations and activities that procure, receive, store, ship, use, transport, maintain, or dispose of sources of radiation will:

- (1) Establish a formal, written radiation safety program.
- (2) Appoint a radiation control committee.
- (3) Appoint a qualified individual as radiological protection officer (AR 40-14) and an alternate to provide continuity of operations.
- (4) Assure compliance with Federal, State, and local regulations.

b. Radiation control committee. The committee will consist of the commander or his designated representative, the radiological protection officer, medical officer (where the establishment has a medical facility), the safety director, and other persons who are knowledgeable in the safe use of radiation, as are deemed necessary.

(1) Responsibilities of this committee will include:

(a) Recommending to the commander policies on the safe use, handling, storage, transport, receipt, shipment, and disposal of sources of radiation.

(b) Reviewing the radiation safety aspects of proposals for the procurement and use of sources of radiation, the modification of existing radiological operations and operating procedures, and providing recommendations to the commander for appropriate action.

(c) Reviewing applications for Atomic Energy Commission (AEC) licenses or Department of the Army authorizations.

(d) Reviewing and approving the qualifications of users of radiation.

(e) Reviewing reports of radiation accidents and incidents to determine the cause and recommending appropriate action to the commander.

(2) The radiation control committee should not exercise the functions of a clinical committee on radioisotopes in a medical facility, or of a reactor safeguards committee. However, handling, receiving, shipping, storage, transport, or disposal of radioisotopes beyond the control of the immediate medical or reactor staff is subject to the review of the radiation control committee.

(3) The committee membership will be kept up-to-date. Training and experience résumés for each member of the committee will be kept on file by the radiological protection officer. In those cases where the committee membership list and résumés are on file at the AEC, the AEC will be advised of membership changes by letter forwarded through the Commanding General, AMC, ATTN: AMCAD-S. (See AMCR 385-9.)

c. Radiological protection officer (RPO). The training and experience of the radiological protection officer and his alternate must be commensurate with the type and hazard of the radiation source(s) for which they will be responsible. As a minimum, the formal training of the radiological protection officer and his alternate will be successful completion of the U.S. Public Health Service Occupational Radiation Protection Course or equivalent. Organizationally, he should

be in a position wherein he can effectively advise the commander and the radiation workers on matters of radiation safety.

(1) In cases involving more than 100 millicuries of unsealed sources and more than 10 curies of sealed sources, the radiological protection officer should be an individual other than a radiation user.

(2) Responsibilities of the radiological protection officer will include:

(a) Providing the commander, radiation control committee, and radiation users with advice and assistance on all matters pertaining to radiation safety. (Advice includes instructing and training of workers and visitors in the safe use of protective equipment and procedures.)

(b) Implementing the radiation protection safety program.

(c) Reviewing radiological operations to determine compliance with regulations and approved procedures.

(d) Maintaining an accurate record of the inventory of sources of radiation possessed by the installation or activity in accordance with AR 700-52. The record for each item should include: Federal stock number and nomenclature, manufacturer's model number, description and serial number, the isotope, source radioactivity and date radioactivity was determined, chemical and physical form, whether sealed or unsealed, date received, and using organization and location.

(e) Maintaining radiation protection records.

(f) Performing radiation surveys and leak tests, or causing such surveys and tests to be performed. The accuracy of tests and surveys if performed by others remains the responsibility of the radiological protection officer.

(g) Evaluating the hazard potential and adequacy of protective measures for existing and proposed operations.

(h) Reviewing standing operating procedures (SOP's) for operations involving sources of radiation prior to review by the radiation control committee.

(i) Investigating radiation accidents and incidents.

(j) Reporting the findings of investigations (para 30) in accordance with AMCR 385-3.

(k) Assuring that radiation detection instruments are properly calibrated and are available to radiation workers.

(l) Monitoring incidents wherein unusual levels of radiation or contamination are suspected.

(m) Prior to being relieved of his duties, the radiological protection officer will take the following action with regard to radioactive materials and equipment for which he is responsible:

1. Secure all material and equipment in such a manner as to preclude use or removal during the period for which there is no radiological protection officer appointed; or

2. Turn over to a properly qualified and authorized individual, all materials and records for which he is responsible. Such an authorized individual will have the qualifications and training required of a radiological protection officer.

d. Supervisors of radiation workers or radiological projects will be responsible for:

(1) Maintaining a current inventory of all sources of radiation for which they are responsible.

(2) Knowing the exact location of all sources of radiation for which they are responsible.

(3) Posting appropriate warning signs and notices.

(4) Assuring that their personnel have received adequate instruction and experience prior to using or being exposed to radiation.

(5) Controlling contamination.

(6) Assuring sources are secured against unauthorized use.

(7) Controlling personnel exposures.

(8) Preparing, prior to the start of any operation involving radioactive material or possible exposure to radiation, an adequate SOP for review by the Radiological Protection Officer and the Radiation Control Committee prior to final approval in accordance with paragraph 1625, AMCR 385-224. The SOP will contain, as a minimum, responsibilities, maximum permissible levels of radiation in the areas concerned, storage of sources, procedures regarding dosimetry, decontamination, and emergencies. (This SOP is mandatory for operations in which there is a reasonable probability of exposure beyond established limits.)

(9) Enforcing SOP's, rules, and special precautions.

(10) Reporting to the radiological protection officer, any accident, unusual incident, personnel injury, however slight, suspected overexposure, and/or suspected internal exposure, as soon as possible after occurrence.

(11) Prior to being relieved of his duties, each radiation supervisor will take the following action with regard to all radioactive materials and equipment for which he is responsible:

(a) Secure all material and equipment in such a manner as to preclude use or removal while not under the immediate supervision of a qualified and authorized individual; or

(b) Turn over to a properly qualified and authorized individual, all materials and equipment for which he is responsible. Such an individual will have the qualifications and training required for the safe handling of the materials involved.

e. Radiation workers will be responsible for:

(1) Knowing and following SOP's, rules, and special instructions.

(2) Using safety equipment properly.

(3) Reporting to the supervisor any accident; unusual incident; personal injury, however slight; suspected overexposure and/or suspected internal exposure; as soon as possible after the occurrence.

7. AEC licenses and Department of the Army authorizations. AMCR 385-9 furnishes guidance for installations and activities for obtaining AEC licenses and Department of the Army (DA) authorizations required by AR 700-52.

8. Local control of radioactive material. a. Activity and installation commanders will establish internal procedures to control the procurement, receipt, shipping, transport, use, maintenance, storage, and/or disposal of the following radiation sources:

(1) Radioactive solids in excess of 1 microcurie or with a specific radioactivity exceeding 0.002 microcuries per gram or emitting a dose rate of 0.1 millirad/hr at contact.

(2) AEC-controlled materials in excess of the quantities listed in Title 10, Code of Federal Regulations, Section 31.100.

(3) Machines which produce radiation; e.g., X-ray devices, accelerators, electron microscopes, etc.

(4) Radioactive gases or liquids of concentrations in excess of the values listed in Table II, Appendix B, Title 10, Code of Federal Regulations, Part 20. (See para 19 and 20 for disposal and release requirements.)

(5) Items activated in nuclear reactors (including Army reactors), by accelerators or by nuclear weapons.

b. Activity or installation approval of proposed procurement, receipt, use, transport, storage, maintenance, and/or disposal of radioactive material will be based upon the following considerations:

(1) Organizational element responsible for the proposed operation.

(2) Purpose for which the materials will be used, including the desired initiation date and estimated duration of the project.

(3) Materials desired, including:

(a) Isotopes and maximum activities to be used and possessed at any one time.

(b) Whether sealed or unsealed.

(c) Chemical and physical form.

(4) Qualifications and experience of persons who will directly supervise the operation and of the Radiological Protection Officer.

(5) Qualifications and experience of persons who will use or handle the material.

(6) Locations where sources will be used or stored (building number, room, and/or area number).

(7) Radiac instrumentation available to support the operation.

(8) Adequacy of facilities and equipment, storage containers, exhaust hoods, handling equipment, and protective equipment available.

(9) Adequacy of operational procedures, including procedures to be followed for collection and disposal of contaminated waste materials.

(10) Adequacy of radiation protection procedures to include safeguards to preclude emergencies, and actions to be taken should an emergency occur.

(11) Estimated exposure of operational and nearby non-operational personnel.

(12) Authority and conditions established in the AEC license or DA authorization issued to the installation or activity.

c. Activity or installation approval for programs involving machines which produce radiation will be based on the following information:

(1) Type of device.

(a) Function.

(b) Manufacturer and model number.

(c) Radiation output.

(d) Anticipated workload (hours/month).

(e) Whether fixed or mobile operation is anticipated.

(f) Whether single or multiposition exposure head is to be used.

(g) Pulse duration and anticipated workload.

(h) Target.

(i) Calibration procedure and frequency.

(j) For accelerators, the curie level of the target, the mode of operation (positive or negative), energy of accelerator particles, the procedures for exchange of targets, and the available ventilation will also be considered.

(2) Safeguards.

(a) Shielding.

- (b) Interlock provisions and console locations.
- (c) Estimated exposure based on seven consecutive day operations modified by the planned workload. (Exposures of operational and nonoperational personnel must be considered.)
- (d) Occupied locations nearby.
- (e) Boundaries of restricted area.

(3) Training and experience of operators.

d. Approval of the commander should be withheld until the radiation control committee has determined that:

(1) The proposed operation complies with regulations, current standards, and conditions contained in applicable licenses and/or DA authorizations.

(2) The operation will not present undue personnel exposure damage to property.

(3) Personnel are adequately trained.

(4) Facilities, equipment, locations, and procedures are adequate to assure safe operation.

(5) Necessary conditions and controls are provided.

9. Radioactive material. a. Unsealed radioactive material should not be used where sealed sources can perform the desired function. Unsealed radioactive material may result in the contamination of personnel and equipment if not properly handled.

b. The least hazardous chemical and physical form should be selected.

c. Storage or use of eating, drinking, chewing, smoking, and cosmetic materials will be prohibited in the immediate areas containing radioactive materials.

d. Radioactive solutions will not be pipetted by mouth.

e. Disposable paper towels and handkerchiefs will be provided workers in areas containing unsealed radioactive materials. Properly marked receptacles will be provided for the disposal of such materials.

f. Operations and facilities involving radioactive materials should be planned to limit the spread of radioactive material.

(1) Work areas will be designated, marked, and monitored.

(2) Movement of personnel and unsealed radioactive material will be minimized.

g. Ventilating systems will be designed so as to preclude the spread of radioactive materials.

h. In the case of sealed sources, the capsule enclosing the radioactive material and the physical form of the radioisotope will be chosen to minimize the possibility of dispersion, inhalation, and ingestion of the material. The capsule and container should be resistant to fire and corrosion.

i. Operations using remote-control devices to control sealed sources of radiation should be designed to prevent leakage or rupture of the source capsules; to provide a positive means of containment of contamination in case of leakage, rupture or other damage to the capsule; a positive means of control of the sources from "safe" to "exposed" position; and an interlock, visual or audible alarm system to prevent entry of personnel into the radiation field while the sources are in the "exposed" position. Compressed gas systems are considered to be the least likely type of system to meet these requirements.

j. TB MED 232 provides guidance concerning storage and maintenance of self-luminous devices.

10. Safe handling of radioactive materials. Additional guidance on the safe handling of radioactive materials is available in National Bureau of Standards Handbook 92.

11. Other sources of radiation. a. Guidance for design of facilities and preparation of operating procedures for other sources of radiation, such as X-ray units, accelerators, and electron microscopes, can be found in National Bureau of Standards Handbooks 50, 55, 63, 66, 76, and 97, or replacement documents, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

b. Hazards associated with the high voltage, secondary beam, scattered radiation and activated material must also be considered. Ventilation, interlock provisions, shielding design, remote control, and handling procedures are essential considerations.

c. Prior to operation, X-ray, accelerator, and similar facilities should be surveyed by a competent individual for radiological safety hazards in construction and operation. The services of the U.S. Army Environmental Hygiene Agency are available for these surveys (AMCR 385-7). In order to avoid modification of or delay in operation of these facilities, the construction plans should be reviewed by a competent person.

12. Personnel exposure. The radiation exposure standards contained in this section are applicable to all personnel. Exposures incurred during examination or treatment for medical or dental purposes are not to be included in calculations for compliance with this section. However, medical exposures should be considered in the programming occupational exposures.

a. Exposure of personnel will not exceed the following values:

(1) Personnel 19 years of age and over who are occupationally exposed to radiation:

(a) Accumulated dose to the whole body, head and trunk, active blood-forming organs, gonads, or lens of the eye will not exceed:

1. 3 rem in any calendar quarter, or
2. $5(N-18)$ rem total lifetime dose where N equals the present age in years.

(b) Accumulated dose to the skin of the whole body or the thyroid will not exceed $7\frac{1}{2}$ rem in any calendar quarter or 30 rem in any calendar year.

(c) Accumulated dose of radiation to the hands and forearms and to the feet and ankles will not exceed $18\frac{3}{4}$ rem in any calendar quarter or 75 rem in any calendar year.

(2) Members of the general public, personnel not occupationally exposed, and persons who are less than 19 years of age will not be exposed in any calendar quarter in excess of 0.125 rem or in excess of 0.500 rem in any calendar year. Pregnant women will not be exposed to ionizing radiation for other than medical reasons (AR 40-5). At the first indication of pregnancy, women should notify their supervisor.

b. Before permitting any individual to receive an exposure in excess of the limits in a(1) above, the installation or activity will forward a request through channels, to the Commanding General, AMC, ATTN: AMCAD-S, for review and coordination. In addition to the information required in Title 10, Code of Federal Regulations, Section 20.102, the proposal must contain complete justification and describe the means for assuring that the higher levels requested will not be exceeded.

c. Personnel exposure will be kept as low as practicable. The necessity for exposure must be weighed against the benefits expected.

d. When an individual has received exposure in excess of the amount established for a calendar quarter, he shall be removed from duties involving exposures to radiation until subsequent exposure limitations are established through consultation with competent medical authority. When an individual has received exposure in excess of that established for a calendar year, he shall be removed from duties involving further exposure until his exposure records have been evaluated by Headquarters, AMC, and subsequent exposure limitations are established. When an individual has received an accumulated dose of radiation in excess of 5(N-18) rem, he shall be removed from duties involving occupational exposure to ionizing radiation until his exposure record has been evaluated by The Surgeon General, Headquarters, DA, and subsequent exposure limitations are established.

e. Radiation workers may be exposed to the limits established in a(1) above, when warranted. However, personnel exposure will be kept as low as practical. The necessity of exposure must be weighed against the benefits expected. Should an individual receive exposure in excess of the limits listed below, the circumstances involved will be recorded in the radiation protection records and the affected individual's DD Form 1141.

(1) 0.3 rem in any seven consecutive days, or

(2) 1.0 rem in any calendar month.

f. Should an individual be exposed to external radiation as well as internal radiation, his total exposure must be considered and recorded. For example, should an individual's thyroid receive eight rem in a calendar quarter as a result of a radioiodine spill, that exposure should be added to his whole body exposure to determine the total dose received by the thyroid.

g. Additional guidance concerning maximum permissible concentration and control of internal radiation hazards are contained in Title 10, Code of Federal Regulation, Part 20, and National Bureau of Standards Handbook 69.

13. Medical examinations. a. Radiation workers should be given a preemployment examination which includes medical history, radiation exposure history, physical examination, and a complete blood count. Personnel who are to be occupationally exposed to neutrons will be given a slit-lamp test prior to exposure. If radiation workers are to be exposed to unsealed radiation sources, appropriate bio-assay should be taken to establish base lines.

b. Any abnormalities will be recorded and carefully considered prior to exposure or continued exposure.

c. If a similar examination has been conducted within the past 6 months, those portions of the examination need not be repeated for which results are entered in the individual's record.

d. Visitors and personnel on temporary duty for less than 30 days do not require a medical examination provided they will not be exposed to radiation in excess of the levels established in paragraph 12a(1), or to radioactive concentration in excess of those given in Title 10, Code of Federal Regulations, Part 20, Appendix B, Table II.

14. Periodic medical examinations. a. Radiation workers should be given a medical examination at least once every 3 years. Dependent upon the work involved, the medical officer may desire to repeat the examination more frequently.

b. Upon termination of the occupational exposure, the individual should be given a medical examination.

c. In the event of an overexposure, a medical examination may be necessary.

15. Training and experience of personnel. a. Personnel, including visitors, who will be exposed to radiation and/or radioactive materials will be informed of the following information prior to exposure:

- (1) The presence of radiation or radioactive material.
- (2) Health hazards associated with exposure to such materials and/or radiation.
- (3) Procedures and precautions to minimize exposures.

(4) Applicable provisions of AEC licenses, DA authorizations, regulations, and standing operating procedures.

(5) Emergency procedures.

(6) Right to receive a report of his exposure incurred.

(7) Proper use of protective equipment and clothing.

b. Radiation workers will receive the instruction in a above. In addition they will be instructed in the following areas:

(1) Maximum exposure and contamination levels.

(2) Safe methods of performing work. (The use of protective equipment and the operational steps involved will be demonstrated.)

(3) Procedures to minimize contamination and to secure sources of radiation from unauthorized use.

c. Before an individual uses or supervises the use of sources of radiation, the radiation control committee should determine that his training and experience are sufficient to enable him to deal safely with materials involved.

d. An individual whose training and experience is not adequate will be required to work under the direct supervision of a person known to be qualified until such time that the individual can demonstrate his ability on the job. In the event such training is not available locally, inquiry should be made into the possibility of the employee receiving the required training and experience at another AMC installation or activity.

e. Emergency and security personnel will be trained and equipped to cope with radiological hazards that may be encountered in the performance of their duties. Training will be sufficient to enable such personnel to function without waiting for the guidance of the radiological protection officer, or other individuals not part of their immediate group. Such persons will be informed of the existence of situations that might become hazardous during special or unusual circumstances.

f. A record of training will be recorded on DA Form 750 (Record of Training) and placed in each employee's official personnel folder.

16. Personnel dosimetry. a. Dosimetry requirements contained in this paragraph are not applicable to persons exposed while being examined or treated for medical or dental purposes.

b. Knowledge of the radiation exposure received by personnel is necessary to prevent future overexposure and possible injury. The Army film badge packet described in SB 11-206 will be used as the primary device to officially determine personnel exposure.

c. Film badges will be worn by each individual who is likely to be exposed to radiation or radioactive materials. This requirement applies to visitors as well as installation or activity personnel.

d. Pocket chambers or self-reading pocket dosimeters may be used to supplement the film badge dosimeter. Such devices are useful when worn in areas in which an individual is likely to receive five or more millirem in 1 hour. In areas in which an individual is likely to receive 100 millirem or more of radiation in 1 hour, personnel will wear self-reading pocket dosimeters in addition to the film badge.

e. The type of film badge (range and type of radiation detected), the part of the body upon which the badge is to be worn (lapel, belt, wrist, hand, etc.) and the need for additional dosimetric devices must be determined by taking into account the type of radiation exposures to be experienced.

f. In the event of failure or loss of dosimetric devices, personnel exposure will be calculated or estimated from past exposure histories, results of radiation survey, the exposures of other personnel under similar circumstances, breath sampling, bio-assay techniques, and whole body counting and scanning.

g. AMC personnel who may be exposed to radiation at non-Army sites will wear film badges obtained from the radiological protection officer of their home installation/activity. On-site film badges may be worn in addition to the Army badges, but not as substitutes for the Army badges. AMC personnel who may be exposed to radiation while on travel status will furnish the radiological protection officer with a copy of any reports of exposure received for inclusion in the DD Form 1141 (Record of Occupational Exposure to Ionizing Radiation) and the appropriate radiation protection records. In the event differences between the reading of on-site film badges and Army film badges cannot be resolved, the Army reading will be recorded in the individual's health record.

h. Procedures will be established for the centralized issue and control of dosimetric devices:

(1) Personnel will be instructed not to tamper with dosimetric devices, either physically, or by causing them to indicate readings that are not indicative of the personnel exposure.

(2) Facilities will be provided for the storage of dosimetric devices when the devices are not being worn. These storage facilities should be located so that the dosimeters will not be exposed to radiation, or excesses of heat or light. Each film badge dosimeter storage facility will be equipped with a control badge, in accordance with SB 11-206.

(3) Because of the possibility of being lost, or forgotten or the possibility of recording a faulty exposure, dosimetric devices must be stored in a designated receptacle when not being worn.

(4) Personnel on TDY will store their badges in such a manner that they will not be exposed to radiation when not being worn. However, personnel on TDY will wear film badges whenever they are exposed to radiation, whether or not during normal duty hours.

17. Radiation surveys. Surveys should be made under representative conditions. The following describes certain types of radiation surveys.

a. Initial surveys. An initial survey will be made by the radiological protection officer of sites and areas where sources of radiation will be used and/or stored before an operation involving radiation is initiated or operational changes are approved, or upon installation of a device which produces ionizing radiation.

b. Routine surveys.

(1) Surveys of each area in which sources of radiation are used and/or stored shall be performed by or under the direction of the radiological protection officer at least once each month. The radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation will be evaluated. Such an evaluation includes a physical survey of the location of materials and equipment, measurements of levels of radiation and/or concentrations of radioactive material in and around the site. Conditions of stable storage may be exempted from monthly surveys at the discretion of the local radiation control committee. However, the intervals of surveys of storage areas will not exceed 3 months.

(2) The area survey will be performed using suitable instruments, and, when appropriate, smear and air sampling techniques. Work habits of personnel should be observed to obtain data regarding additional sites to be monitored or areas of improvement for the operational procedures. Locations of the monitoring points with the results, statement of the hazard, and any recommendations as to decontamination, shielding, procedural changes, etc., will be recorded and filed.

c. In addition to the surveys in a and b above, special surveys are required in the event of the following occurrences:

(1) Shipment or receipt of radioactive materials. Packages and the unloaded vehicles must be surveyed.

(2) Termination of a project involving radioactive materials. A survey is required to determine that no contamination exists and that sources of radiation are properly stored or have been disposed of properly.

(3) Unplanned events. Loss of control, spill, overexposure, or any unplanned event which could adversely or did adversely affect the safety of the operation must be monitored. Control must be re-established to prevent the hazard from increasing.

(4) Hazardous operations. Particularly hazardous operations, such as decontamination, encapsulation, or smelting of radioactive materials, as authorized by AEC license or DA authorization, must be continually monitored.

d. All places, equipment, persons, and animals suspected or known to have been in contact with radioactive material will be monitored for contamination. Personnel must be monitored before eating, smoking, chewing, drinking, or leaving the area in which radioactive materials are located.

e. Environmental monitoring. Environmental monitoring will be performed whenever radiological operations are such that they might have an adverse impact upon the surrounding environment. Ideally, such monitoring should be done prior to the inception of radiological operations at an installation and periodically thereafter. The results of such environmental monitoring should be used to determine the need to modify controls and/or operations.

18. Radiation warning signs. a. Areas, buildings, inclosures, packages, and containers will be conspicuously posted with radiation warning signs as required by AR 385-30; AR 55-55; Title 10 of the Code of Federal Regulations, Part 20; and Title 49 of the Code of Federal Regulations.

b. Additional instructional or precautionary information may be posted as desired, but not substituted for the signs required in a above.

19. Construction of radiation facilities. a. Selection of a radiation facility site will include consideration of the following factors:

facility: (1) Impact of surrounding operations upon the proposed

- (a) Radiation background.
- (b) Effluents from nearby operations.
- (c) Fire and explosive hazard.
- (d) Capability of controlling access.

(e) Possibility of expanding the facility or of using larger sources.

(2) Impact of proposed facility upon operations in surrounding areas and in areas downwind and downstream of the proposed site:

- (a) Increased radiation background.
- (b) Effect of effluent discharge.
- (c) Impact of most severe plausible radiation incident.

(3) Possibility of flood or land movement.

(4) Waste disposal. A separate piping system may be desirable for the disposal of liquid waste.

b. A radiation facility should be a single story structure without a basement, and of noncombustible construction. Floors, walls, surfaces, and equipment should be nonporous and easy to clean. Fire fighting in radiation controlled areas presents problems that must be considered before any installation of fire fighting devices. While the containment and extinguishment of fires is desirable, the installation of fire fighting devices must be such that will not result in the contamination of drainage systems due to runoff; that will not result in the spread of contamination; or increase the hazard to personnel. In many instances, "fog" and "foam" type devices meet these requirements. Where practical, an automatic fire alarm system, reporting directly to the fire department, should be installed.

c. Ventilation systems must be planned carefully:

(1) Recirculation of air should not be permitted within buildings containing radioactive materials.

(2) Air intakes will be located to prevent the entrance of radioactive effluent from the same or nearby buildings into the ventilation system.

(3) Air flow will be from nonactive to "hot" areas, through filters, to the discharge. "Hot" areas should be maintained at a negative pressure to reduce the spread of contamination. Blowers should be positioned downstream from the filter so that the air is sucked rather than pushed through the filter.

(4) Hoods will be interlocked or designed to prevent reverse flow when all of the hoods are not operating at the same time. The air-flow rate through openings of the hood should be at least 100 linear feet per minute. (See NBS Handbook No. 92.)

(5) Hoods, dry boxes, and traps are useful laboratory tools for minimizing contamination. Dry boxes may not be used for storing or handling radioactive materials involving explosives or flammable solvents unless designed to function as operational shields for the quantities of explosives or flammables involved.

d. Buildings in which unsealed radioactive materials are handled should be equipped with shower and monitoring facilities. Two separate locker rooms separated by a wash and shower room should be provided. The one locker room is for storage of the worker's street clothing; the other, for his work clothing.

20. Operational safety procedures. a. High radiation areas should be interlocked to halt the irradiation upon the entry of personnel to the area, or otherwise to alert workers of the entry of personnel into the area during irradiation. The alarm system should be of a fail-safe design of such type that in case of primary alarm circuit failure the secondary alarm circuit is set off. High radiation areas that exist for more than 30 days will be equipped with automatic alarms and devices as required by Title 10, Code of Federal Regulations, Part 20. In high radiation areas that exist for less than 30 days, appropriate protective measures, such as close supervision to prevent unauthorized entry and exposure, will be taken.

b. Work areas will be designated and marked. Radiation levels should be measured, and marked where practical.

c. Process control devices, such as thickness gages and moisture gages, involving radioactive sources, will be designed to protect the source(s) against mechanical damage and to limit the exposure of operators and maintenance personnel to limits established for the general public. The device will be conspicuously and permanently marked with a radiation warning sign.

d. Each AMC installation or activity having radiation counting facilities should perform surveys for smearable contamination on outdoor surfaces.

(1) Levels of radiation sufficiently high to be significant may result from various sources, such as poor radioactive waste disposal practices, radiation incidents, and nuclear weapons testing.

(2) If significant levels of radioactive material are deposited out of doors, this contamination, if not detected, can be tracked into "clean" areas and sensitive "low level" laboratories.

e. Emergency exits, passageways, and doorways must be planned to enable safe movement of personnel in the event of an emergency.

f. "Hot" drains and tanks should be planned on the assumption that they will leak and will require maintenance. Unless criticality requirements prohibit, "hot" drains should empty into hold up tanks in order that samples can be analyzed to effect proper disposal.

g. Whenever a high radiation area is not mechanically secured to prevent unauthorized entry, a guard will be posted.

h. Secure, centralized storage facilities will be provided for radioactive materials not required in the immediate work areas.

i. Before initiation of an operation or modifying an operation involving radiation, the operating and emergency procedures should be practiced using a dummy source or other non-radioactive material.

j. Explosives, propellants, and excessive flammables will be excluded from areas in which radioactive materials are used or stored unless specifically approved in a DA authorization or AEC license.

k. Personnel with open skin wounds will not be permitted to work with unsealed radioactive material without an adequate waterproof covering on the wound and the approval of the medical officer.

l. Containers of radioactive liquids should be provided with secondary containment.

m. Except in an emergency, anti-contamination equipment and clothing will be worn in radiation controlled areas only.

n. Each item of equipment being released from a "hot" area to a "clean" area will be monitored, and decontaminated if necessary, and certified by the monitor to have contamination levels below those listed in table 1.

o. Maintenance that must be performed in a radiation controlled area will be cleared with the radiological protection officer and area supervisor prior to initiation.

p. Sealed sources will be leak tested within 5 days after receipt; at least once every 6 months (alpha sources every 3 months); prior to shipments; suspect sources will be withheld from use until leak tested; and after any suspected or actual damage. Unless required otherwise by Army directives, sealed sources containing less than 10 microcuries of activity or containing only natural uranium, natural thorium, or depleted uranium need not be tested. Leak test results will be recorded in terms of microcuries.

q. The quantity of radioactive material stored within a working area should be limited to the smallest reasonable quantity consistent with operational requirements.

r. Anti-contamination clothing and equipment will be prescribed by the radiological protection officer and will be marked in accordance with TM 3-261.

21. Disposal. a. Unwanted radioactive materials will be disposed of in accordance with AR 755-15 (Disposal of Unwanted Radioactive Material).

b. Radioactive material will not be buried on any AMC installation.

c. Disposal of radioactive effluents (liquids or gases) into unrestricted areas will be in accordance with Title 10, Code of Federal Regulations, Sections 20.106 and 20.303, provided local governments do not prohibit such disposal. Compliance with concentration levels established in Appendix B, Title 10, Code of Federal Regulations, Part 20, will be determined by averaging concentrations on a monthly basis instead of an annual basis. The total quantity of radioactive effluents discharged at any installation will not exceed the amount authorized a single licensee under Title 10, Code of Federal Regulations, Part 20. At installations where more than one licensee desires to discharge radioactive effluents, the commander will apportion the amounts to be authorized each licensee.

d. Radioactive materials will not be burned or incinerated except as specifically authorized by prior approval of Headquarters, AMC (AMCAD-S).

22. Contamination levels. Maximum permissible contamination levels and indicated actions are contained in tables 1, 2, and 3 below. The following notes and definitions will apply to the use of tables 1, 2, and 3:

a. "None" shall be defined as the amount of activity which, in the same counting time, gives a count which is not different from the

background count. (See National Bureau of Standards Handbook No. 80, Section 2.5.3, para 2.)

b. No allowance shall be made for particle size or for the use of protective clothing or equipment for determining whether an individual is exposed to radioactive concentrations in excess of the levels specified in this regulation.

c. Items which cannot be decontaminated will be marked and tagged to indicate their condition, and will be removed from use pending further decontamination or disposal.

d. Contamination should be kept at a minimum at all times. The publication of maximum permissible contamination levels should not be used as a license for unwarranted relaxation of controls.

e. Abbreviations used in tables 1, 2, and 3 have the following meaning:

dpm = disintegration per minute

cm² = square centimeter

MPC = Maximum Permissible Concentration. See Title 10, Code of Federal Regulations, Part 20, and National Bureau of Standards Handbook 69 for Maximum Permissible Concentrations of Radionuclides in Air.

Table 1. Maximum permissible contamination on inanimate objects.

Item and Corrective Action	Fixed (F) or Removable (R)	CONTAMINATION LEVEL			
		Alpha		Beta-Gamma	
		dpm/100 cm ² Instrument	dpm/100 cm ² Smear	mrad/hr at 1 in.	dpm/100 cm ²
1. Personal clothing, including shoes. Replace, decontaminate or store for decay, if above:	F R	200	None	0.2	None
2. <u>Protective clothing</u> , incl. shoes.					
a. General. Should be replaced or decontaminated, if above:	F R	1,000	200	0.5	1,000
b. Laundry. Do not release to public laundry, if above:	F R	200	50	0.4	200
c. Respirators	F R	200	None	0.06	None
3. Laboratories and work areas:					
a. <u>Uncontrolled areas</u> . Require controls and posting or decontaminate, if above:	F R	200	30	0.25	100
b. <u>Controlled areas</u> . Decontaminate, or if impossible, fix with periodic check on fixation, if above:	F R	1,000	200	2.0	1,000
4. Vehicles:					
a. <u>Use in controlled areas</u> . Decontaminate or if impossible, fix, if above:	F R	1,000	300	2.0	1,000
b. <u>Use in uncontrolled areas</u> . Decontaminate, if above:	F R	500	30	0.4	500
5. Tools, equipment and containers. Prior to non-radioactive use, decon if above:	F R	200	50	0.25	100
6. Shipping containers, outside surfaces, decon if above:	F R	500	None	0.25	None

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Table 2. Airborne contamination levels.

Required respiratory protection	Alpha Concentration	Beta Concentration
¹ Half face mask with filter or canister respirator.	1 MPC	1 MPC
Supplied air or self-contained air supply with full face mask.	5 MPC	10 MPC

¹For operations under the control of an AEC license, specific approval of the AEC must be obtained before making any allowance for use of respiratory equipment.

Table 3. Maximum permissible personnel contamination.

Area and action	Alpha or Beta-Gamma
1. <u>Skin</u> . Contact medical officer if contaminated on face or over major area of the body. Continue decontamination, if above:	Any detectable level above background.
2. <u>Hands</u> . Continue decontamination, if above:	Any detectable level above background.

23. Personnel decontamination. a. Thorough washing with non-abrasive soap and lukewarm water is the best general method of decontamination of the hands and other parts of the body regardless of the contaminant. If the contaminant is localized, it is often more practical to mask off the affected area and cleanse with swabs, rather than risk the danger of spreading the contaminant by general washing. Organic solvents must be avoided as decontamination agents because they may increase the probability of the radioactive materials entering the body through skin absorption. Special attention must be given to the areas between the fingers and around the nails. The outer edges of the hands are readily contaminated and often neglected in the washing.

b. After repeated washings, the skin may tend to chap. To avoid this, apply lanolin or hand cream and then continue to wash. If repeated washing with soap and water is unsuccessful in decontamination, the individual should be referred to the local medical officer for application of the more drastic chemical decontamination procedures listed in the National Bureau of Standards Handbook No. 48.

c. If it is suspected that any person, by inhalation, ingestion, or by any other manner, has introduced radioactive materials into his body, the local medical officer will be notified immediately so that medical procedures can be initiated to facilitate the elimination of such material. Contamination over a large area of his body or his face will be the basis for suspecting that the person is internally contaminated.

d. In the event an individual is contaminated on a large portion of his body, the following decontamination procedure is recommended:

- (1) Place the individual under a lukewarm shower.
- (2) Using a mild toilet soap, individual will cover his entire body with lather.
- (3) While still covered with lather, the individual will step out of the shower. An assistant will then cover the individual with a heavy coat of mild soap flakes. (The purpose of the lather is to cause the soap flakes to adhere to the person.)
- (4) Using his hands, the contaminated individual will rub the soap flakes on his body into a paste.
- (5) Individual will then return to shower and attempt to rinse off the soap by starting at the top and working his way down. (Note. It will be necessary for the individual to rub body surfaces with his hands while rinsing, in order to remove soap paste.) Soap paste will remain in

those areas that have not been thoroughly rinsed. Although a soft cloth may be used, a brush may not. Particular attention should be given the hairy portions of the body.

(6) When the individual has rinsed himself to the point that he no longer feels slimy and while still under the shower, he will be examined by an assistant for traces of soap. The presence of soap will indicate which areas of the body have not been decontaminated.

(7) After removing all traces of soap, the individual will leave the shower and dry himself.

(8) After drying off, the individual will be monitored. If the individual is still contaminated, procedures outlined above will be repeated.

d. In all cases of personnel contamination, the radiological protection officer will be consulted.

e. All water used in the washing and rinsing described above will be contaminated and its disposal should be conditioned by this fact.

24. Equipment and area decontamination. a. General methods.

(1) Care must be taken during the decontamination process to avoid further spread of the contaminant which can be accomplished by:

(a) Always taking precautions to contain the contamination by the use of monitoring, protective clothing, and shoe covers.

(b) Always working from the areas of least contamination toward the area(s) of the heaviest contamination.

(c) Using a minimum amount of decontamination liquids and being aware that the runoff solutions, mops, rags, and brushes will all be contaminated.

(2) The methods listed below should be tried in the following sequence:

(a) Damp mopping. The area is wiped with a damp rag. The wiping surface of the rag is changed repeatedly to minimize spreading of the contaminant.

(b) Water and detergent. The area is wetted with a minimum amount of detergent solution. The area is then wiped dry with absorbent gauze or cloth.

(c) Steam cleaning.

(d) Cleaning with solvents other than water.

(e) Surface removal by use of chemicals, abrasives, sand blasting, grinding, etc.

(3) Vacuum cleaners. Only vacuum cleaners which are equipped with absolute filters and which have been tested for filtration efficiency may be used. The filtration efficiency will be tested after each replacement of the filter and each time contents are emptied.

b. Specific methods. If the above methods (a above) do not work, the following specific methods may be tried:

(1) Metals.

(a) Remove any oil from the surface with organic solvents.

(b) Soak in a solution of citric acid prepared by addition of one pound of citric acid to one gallon of water.

(c) Soak in a solution of diluted hydrochloric acid prepared by carefully adding one part of commercial grade concentrated hydrochloric acid to four parts of water. Hydrochloric acid should not be used on stainless steel because of the etching which will take place and destroy the smooth surface of the metal.

(d) Use metal polish.

(2) Plastics. Clean with ammonium citrate, dilute acids, or organic solvents (of a type not injurious to the plastics).

(3) Glass and porcelain. Clean with detergent solution. If this method fails, soak in concentrated nitric acid or chromic acid cleaning solution.

(4) Painted surfaces. Use paint remover, or, in cases where surfaces were coated with a strippable paint, peel the paint from surface.

(5) Rubber, including respirators and gas masks. Wash with detergent and water or with a warm 20 per cent (by weight) water solution of sodium citrate.

c. Decontamination of clothing.

(1) Determine extent of contamination using an AN/PDR-27, or equivalent, with the beta shield removed, and with the AN/PDR-60, or equivalent.

(2) Wash in special laundry facility (home type or other washer and dryer kept in the facility for washing "hot" clothing only). Use the following steps:

(a) Soak overnight in water solution of laundry detergent.

(b) Drain.

(c) Wash for full cycle with hot water and laundry detergent.

(d) Rinse, dry and remonitor.

(3) Water utilized for washing, rinsing or soaking contaminated clothing will be contaminated as a result of such usage and its disposal should be conditioned by this fact. Laundry equipment may become contaminated also.

d. Monitoring technique. Check crevices and inside corners of areas, tools, and equipment. Special attention should be given to oily and greasy surfaces such as those on automotive equipment.

25. Storage of radioactive materials. a. Areas will be set aside for the secure storage of radioactive materials. These areas will be used to store only radioactive materials. The storage area will be free from the danger of flooding and outside the danger radius of flammables or explosives. Physical security standards for storing radioactive materials are contained in appendix A, AMCR 190-3.

b. Each storage and shipping container will be marked as required by AR 55-55 and AR 385-30, whether or not the radioactive material is under the license control of the AEC. Laboratory containers such as flasks and test tubes need not be marked as long as the user is continuously present.

c. Radioisotopes will not be stored in glass containers unless secondary containment is provided.

d. Radioisotopes should not be transferred from one storage container to another within the storage area. A system will be provided to control and record the "check in" and "check out" and monitoring of radioactive materials.

e. Storage areas will be adequately ventilated as determined by the RPO if gaseous sources are being stored.

f. All sources and containers will be labeled. The areas will be monitored periodically to assure adequate shielding and to detect any contamination.

g. Dose rates of a shipping container should not exceed 200 mrem/hr at the surface nor 10 mrem/hr at 3 feet from any surface of the container.

h. Operating officials will keep a current record of all stored radioactive material, and a copy of this record will be forwarded to the RPO. The RPO will conduct a physical inventory every 6 months.

26. On-post transportation of radioactive materials. Within an installation, it is usually not convenient to package and transport radioactive materials in the manner required for off-post shipments. However, the following precautions will be observed:

a. In loading the vehicles:

(1) Keep within the weight limitations.

(2) Limit or arrange cargo to keep radiation levels, to which personnel (including the driver) will be exposed during transportation, as low as possible. Maximum permissible dose rate in occupied areas of the vehicle will depend upon the time required to transport the material. The driver will wear a film badge and will not be exposed to ionizing radiation in excess of the limits indicated in paragraph 12a.

(3) Keep the containers away from the cab of the vehicle.

b. Do not haul loose radioactive materials. Tail gates should be closed to minimize the chance of cargo loss.

c. Containers should be sturdily constructed, sealed air-tight, and be free of removable contamination. Each container must have a completed DA Label 15 (Caution: Radioactive Materials) unless specifically exempt by military specification M-19590C.

d. The route used should be planned to avoid areas in which explosives are stored or handled and in which there is heavy traffic or personnel activity. The fire department, guard force, and safety director should be informed of the exact route and time of movement in sufficient time to allow implementation of any special protective measures required.

e. A suitable vehicle should be used. Vehicles that are difficult to decontaminate, and privately-owned automobiles should not be used.

f. Unless emergency personnel (guard force and fire department) have demonstrated a capability to cope with a radiological emergency, a technically trained person should accompany the movement to be able to advise in the event of an emergency.

27. Off-post transportation of radioactive materials. a. Radioactive material will be transported in accordance with AR 55-55 and applicable Federal and State regulations.

b. Radioactive material should not be forwarded through the U.S. mail channels except in an emergency. Should transmission by mail be necessary, shipment will comply with Part 125.24, U.S. Postal Manual, and will be registered.

c. Containers should be secured by blocking or tie down, when appropriate.

d. Materials shipped will be properly addressed to insure delivery to the proper installation and section within the installation.

e. Personnel who will transport and/or escort radioactive shipments will be briefed as to potential hazards, methods to minimize hazards and emergency procedures. In addition to the briefing, personnel engaged to transport the radioactive material will be given a completed DD Form 836 (Special Instructions for Motor Vehicle Drivers) supplemented with written emergency procedures. Written information will be provided as to the means for obtaining assistance of radiological emergency teams off-post.

f. Consignees will be notified in advance of impending shipments in order that consignees may assure that they have the capability to receive and handle the materials being shipped.

28. On-site command of emergency during transportation. The ranking person accompanying the shipment will take immediate steps to clear the area and request assistance. He retains command at the accident site pending the arrival of the commander of the nearest military installation or his representative. The designated Army area representative assumes responsibility upon his arrival.

29. Radiac instrumentation. a. Sufficient radiac instruments will be available to properly support the use of radiation sources. The instruments will be capable of detecting the types and levels of radiation involved and any possible resulting contamination.

b. Personnel monitoring devices will be immediately available in areas in which radioactive materials are handled.

c. All instruments used for radiation protection will be calibrated at least every 3 months, and after each maintenance or battery change. More frequent calibration will be necessary for instruments which receive heavy use. Dosimeters need to be calibrated only at 6-month intervals. Dose rate instruments used to determine time of stay and exposure estimates should be calibrated at a minimum of two points on each instrument scale. The instruments will be labeled with DA Label 80 (U.S. Army Calibration System) to show the date of the last calibration, source or method used for calibration, and the initials of the calibrator.

d. Faulty instruments will be tagged with DA Form 2417 (Unserviceable Test Instrument or Standard) to prevent their being used before having been repaired.

e. Each instrument used for radiation protection should be provided with a check source or test sample.

f. Pocket dosimeters should be calibrated every 6 months. At the time of calibration, the correction factor for the dosimeter should be determined. Dosimeters which leak more than 5 percent of full scale after 24 hours in a radiation free area or which have an error of more than 10 percent should be repaired. Dosimeters should be calibrated by exposing them to known sources of an energy level comparable to that which the dosimeter will be exposed during use. Each dosimeter will bear a label showing the correction factor and the date of calibration. The correction factor is determined by dividing the actual level of radiation by the indicated level.

g. Dosimeters are used to give the wearer an estimate of his exposure while receiving the dose, in order that he may limit himself to permissible levels. Disagreement between dosimeter and film badge measurements is to be expected. The film badge reading will be used as the official dose for record purposes unless the badge is proven to have recorded an incorrect exposure.

h. Instrumentation must be selected based on the type and level of radioactive material and/or radiation to be encountered. In high radiation areas, it is desirable to have a high-range survey meter in addition to a low-range meter, in order to cover the range of dose rates likely to be encountered.

i. If funds permit, duplicate radiation protection instruments should be available. The duplicate instruments will avoid the necessity of shutting down a radiological operation until an instrument can be repaired or replaced.

30. Emergency procedures. a. In view of the complicating factors that may arise in an emergency, it is impossible to establish simple rules of procedure to cover all situations of a radiation emergency. However, in any emergency, the primary concern must always be the protection of personnel from radiation hazards. Confinement of the contamination to the immediate environment of the accident should be a secondary concern. Copies of the investigation report, relative to exposures received by the personnel involved, will be given to each individual involved in that emergency.

b. Emergencies will probably be of the following types:

- (1) Spill of radioactive material.
- (2) Explosion.
- (3) Fire.
- (4) Overexposure.
- (5) Injury to personnel.
- (6) Loss of radioactive source.
- (7) Vehicular accident involving radioactive material.

c. The medical officer of each AMC element having radiation sources shall establish written medical procedures for radiation casualties.

d. Emergency procedures will be preplanned and rehearsed at least once each year. In the event of an emergency, the following action will be taken:

(1) Spills or uncontrolled spread of contamination.

(a) Notify all persons not involved with the spill to vacate the area at once.

(b) If the spill is liquid and the hands and clothing are protected, right the container and take steps to contain the spillage.

(c) If the spill is on the skin, flush thoroughly.

(d) If the spill is on the clothing, discard outer or protective clothing at once.

(e) Notify the local radiological protection officer.

- (f) Decontaminate personnel.
- (g) Decontaminate the area.
- (h) Monitor all persons involved in the spill and cleaning operation to determine adequacy of decontamination.
- (i) Permit no person to resume work in the area until an area survey is made and the area is cleared by the radiological protection officer.

(j) Prepare a complete history of the incident and decontamination operation related thereto for the facility or area records. The history will include a statement of the corrective actions taken to prevent a recurrence. Forward within 2 weeks of the accident, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(2) Accidents involving radioactive dusts, mists, fumes, organic vapors, and gases.

- (a) Notify all personnel not directly involved with the incident to vacate the area immediately.
- (b) Hold breath, and switch off any air circulating devices; e.g., fans, air conditioners, blowers, etc.
- (c) Vacate the area to a predesignated region, and allow no person to leave until monitored.
- (d) Close and seal all entrances into the area and post conspicuous warning signs or guards to prevent doors from being opened accidentally.
- (e) Notify the RPO.
- (f) Immediately report all known or suspected inhalations of radioactive materials to the local RPO and the medical officer.
- (g) Evaluate the hazards and the safety devices required for safe re-entry and apply the "two man rule."
- (h) Determine cause of contamination and rectify the condition.
- (i) Decontaminate the area.

(j) Perform an area survey (including air sampling) of the area before resuming normal operations.

(k) Monitor all persons suspected of contamination.

(l) Prepare a complete history of the accident and subsequent activity related thereto for the facility records. Forward, within 2 weeks of the incident, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(3) Injuries to personnel involving radiation.

(a) Wash minor wounds immediately under running water while spreading the edges of the wound.

(b) Contaminated personnel who are injured In any radiological accident involving injured personnel, the local medical officer will be notified immediately. Unless an emergency medical reason requires that the injured person be removed immediately, the injured person will not be transported until a litter or ambulance is available. If, however, other emergencies exist (e.g., fire or possible explosion), good common judgment should be used. Moving of the patient may become imperative.

(c) Personnel with minor wounds will be monitored and decontaminated, if necessary, before leaving the radiation facility. If the wounds are of a serious nature, the injured individual will be wrapped in a blanket to prevent the further spread of contamination, and immediately be removed to the nearest medical facility. Persons accompanying the individual will warn the medical personnel that there is a possibility that the injured is contaminated.

(d) Report all radiation accidents (overexposure, wounds, ingestion, inhalation) to the personnel involved, to the medical officer, and to the RPO.

(e) Permit no person involved in radiation injury to return to work without the approval of the attending physician and the RPO.

(f) Prepare a complete history of the accident and subsequent activity related thereto for the radiation facility records. The history will include a statement of the corrective actions taken to prevent a recurrence. Forward, within 2 weeks of the occurrence, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(4) Fires and other major emergencies.

(a) Notify all persons not directly involved with the incident who are in the area.

(b) Notify the fire department and other emergency personnel.

(c) Attempt extinguishment of fires using readily available first-aid type extinguishers if a radiation hazard is not immediately present. Efforts should be made to prevent water or fire fighting chemical from coming in contact with the radiation source. Attempt to control runoff, preventing it from entering sewers or drainage systems until it has been monitored.

(d) Notify the RPO.

(e) The RPO will advise and assist the emergency personnel.

(f) Following the emergency, monitor the area and determine the protective devices necessary for safe decontamination.

(g) Decontaminate.

(h) Monitor all persons who were in the emergency area and those who were involved in combating the emergency.

(i) Monitor downwind, delineate all contaminated areas, and restrict access as necessary.

31. Additional requirements. The above reporting requirements are in addition to the requirements of AR 385-40; AMCR 385-2; AMCR 385-3; and in addition to Title 10, Code of Federal Regulations, Sections 20.401, .402 and .403, when AEC-licensed material is involved. Information copies of reports to the AEC will be forwarded (AMCR 385-9) immediately, through channels, to the Commanding General, AMC, ATTN: AMCAD-S.

32. Key emergency personnel. Key emergency personnel, such as Provost Marshal, Fire Chief, Medical Officer, and Safety Officer will be kept currently informed of the receipt, storage, use, disposal, or transfer of radiation sources and will be sufficiently trained and equipped to cope with radiological emergencies independent of the presence of the RPO.

33. Records. Records will be maintained to document all aspects of the radiation protection effort. Included are:

- a. Licenses, authorizations, and supporting applications.
- b. Receipts, transfers and shipment records, notification of movement, and instructions to drivers.
- c. Inventory and leak test records.
- d. Instrument and source calibration records and certificates.
- e. Utilization logs and radiation work permits.
- f. Radiation survey records which include description of each use, operation or work performed; radiation levels and personnel exposure rates encountered; airborne and smearable contamination detected; hazards and corrective action, estimated personnel exposure; and disposition of radiation sources.
- g. Environmental monitoring records.
- h. Waste disposal records.
- i. Records of training, plans of instruction, experience and certification of radiation workers.
- j. Standing operating procedures.
- k. Records of special studies, investigations.
- l. Copies of reports originated and received.
- m. Inspection reports and related papers.
- n. Radiation analysis files.
- o. Minutes of committee meetings.
- p. Directives and interpretation of regulations.
- q. Personnel occupational exposure records. AR 40-14 requires the custodian of the medical records to prepare and maintain DD Form 1141 for each person occupationally exposed to ionizing radiation. For administrative control purposes, it is recommended that the Radiological Protection Officer maintain forms AEC-4 and AEC-5 also, where AEC licenses are involved. These forms are available at the U.S. Atomic Energy Commission, Division of Materials Licensing, Washington, D.C. 20545, and may be reproduced locally.

Appendix A

GLOSSARY OF RADIATION SAFETY TERMS

APPROVAL. Official certification of compliance with the provisions of this regulation and with instructions and directives as issued by Headquarters, AMC, or with those of other approving agencies specifically referred to in this regulation.

BACKGROUND RADIATION. Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

CONTAMINATION (RADIOACTIVE). Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence can be harmful. The harm may be in invalidating an experiment or a procedure, or in actually being a source of danger to persons.

CURIE. A unit of activity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10}

- millicurie - One-thousandth of a curie (3.700×10^7 disintegrations per second).

- microcurie - One-millionth of a curie (3.700×10^4 disintegrations per second).

DOSE.

1. Absorbed Dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit mass of irradiated material at the place of interest is called the absorbed dose and is measured in rads, where

$$1 \text{ rad} = 100 \text{ erg/gm} = 1/100 \text{ joule/kg.}$$

The rad unit is applicable to any type of ionizing radiation, but in reporting dose, the type, as well as irradiated material (for instance, tissue), and the place of interest must be specified. Without the above three factors, a statement of absorbed dose received is incomplete and probably useless, since the same dose of different kinds of radiation, even delivered to the same place, can produce entirely different effects.

2. Exposure Dose. See EXPOSURE

3. Biological Dose. The radiation dose absorbed in biological material. It is measured in rems.

DOSE EQUIVALENT. The term "RBE" dose has been used in the past in both radiobiology and radiation safety. It is now recommended that the term RBE be used in radiobiology only and that another term be used for purposes of radiation safety. The linear-energy-transfer factor is multiplied by the absorbed dose, D_a , to obtain a quantity that expresses on a common scale the irradiation received by persons exposed to all ionizing radiations. The name recommended for the linear-energy-transfer-dependent factor is quality factor, QF. Other factors must also be considered for the purposes of radiation safety. A distribution factor, DF, is used to express the modification of the biological effect of radiation due to a nonuniform distribution of isotopes in the body. The distribution factor, like the quality factor, also affects the absorbed dose when radiation safety is being considered. It is recommended by the International Commission on Radiological Units and Measurements that the final calculated dose received by an individual after the absorbed dose is modified by the above-mentioned factors, plus any other factors that may effect the incoming radiation, be called the dose equivalent, DE. If the only apparent modifying factors are QF and DF, then:

$$DE = D_a (QF) (DF).$$

If other factors must be considered and are defined, then:

$$DE = D_a (QF)(DF)\dots\dots$$

where the dots take into account the product of these other factors. The unit of dose equivalent, DE is the rem. The unit of absorbed dose, D_a , is the rad. (Compare definitions of Rem and Rad.) Although the above definition of dose equivalent does not cover a number of theoretical aspects (in particular the physical dimensions of some of the quantities) it fulfills the immediate requirement for an unequivocal specification of a scale that may be used for numerical expression in radiation safety.

EXPOSURE. The term "Exposure Dose" is obsolete. Exposure is a term adopted by the International Commission on Radiological Units and Measurements in 1962 to replace the term "exposure dose" introduced in their 1956 report. The quantity is used for X- and gamma radiation. Exposure is the measure at a certain place of radiation which has the ability to produce ionization. The unit of exposure is the roentgen, R, where 1R equals 2.58×10^{-4} coulombs/kilogram. The definition thus corresponds to the terms roentgen dose and air dose.

EXPOSURE, OCCUPATIONAL. Exposure to ionizing radiation that is incurred as a result of an individual's employment or duties which are in support of facilities which use materials or machinery capable of producing ionizing radiation. Exposure of an individual to ionizing radiation for medical or dental diagnosis or therapy shall not be deemed as occupational exposure.

FAIL-SAFE. A design characteristic of the hardware, component or system which, in the event of a malfunction, will not result in a degradation of safety.

FILM BADGE. A pack of appropriate photographic film and filters used to determine radiation exposure.

HAZARD, RADIATION. See RADIATION HAZARD.

INTERLOCK. A device, usually electrical and/or mechanical in nature, to prevent activation of a control until a preliminary condition has been met or to prevent hazardous operations. Its purpose usually is safety of personnel or equipment. For example, it may be used to warn responsible personnel of an unsafe condition or unauthorized entry of personnel.

IONIZING RADIATION. See RADIATION.

LEAK TEST. A determination of the integrity of a sealed source encapsulation by detection of leakage or escape of radioactive contamination.

NUCLEAR REACTOR SYSTEM. Any equipment or device, except a nuclear weapon, capable of neutron multiplication through fission of special nuclear material. This definition includes nuclear reactors and subcritical assemblies of special nuclear material and the supporting equipment or device (if any) associated with them.

RAD. The rad is defined as the unit of absorbed dose of any nuclear (or ionizing) radiation which is accompanied by the liberation of 100 ergs of energy per gram of absorbing material. Or, one rad is approximately equal to absorbed dose delivered when soft tissue is exposed to one roentgen of medium voltage X-radiation. The rad is to be used solely with absorbed dose.

$$1 \text{ rad} = 100 \text{ erg/gram} = 1/100 \text{ joule/kg.}$$

RADIATION. Energy propagated through space. As used in this regulation, the term refers to two kinds of ionizing radiation:

1. Electromagnetic waves (X-rays, gamma rays), and
2. Corpuscular emissions from radioactive substances or other sources (alpha and beta particles, etc.). Ionizing radiation is any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

RADIATION CONTROLLED AREAS. Any area, whose access or occupancy is controlled for the purpose of protection of individuals from exposure to ionizing radiation and radioactive materials.

RADIATION CONTROL COMMITTEE. A group of persons appointed by the commander to advise him on policy and actions necessary to ensure safety of personnel and property from hazards of radiation. Synonymous with "Isotope Committee," "Radiological Health and Safety Committee," "Radiation Protection Committee," and other similar titles of committees with the same purpose

RADIATION HAZARD. A condition under which persons might receive radiation in excess of the applicable maximum permissible dose, or where radiation damage might be caused to materials or personnel.

RADIATION SOURCES. Materials, equipment or devices which generate or are capable of generating ionizing radiation, including: (1) naturally occurring radioactive materials, (2) by-product materials, (3) source materials, (4) special nuclear materials, (5) fission products, (6) materials containing induced or deposited radioactivity, (7) nuclear reactors, (8) radiographic and fluoroscopic equipment, (9) particle generators and accelerators, and (10) radio frequency generators such as klystrons and magnetrons which produce X-rays.

RADIATION WORKER. Any person occupationally exposed to ionizing radiation and/or radioactive materials. (Job descriptions of radiation workers should reflect that the individual is potentially exposed to ionizing radiation.)

RADIOACTIVE MATERIAL. Any substance which undergoes spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides (a species of atom characterized by the constitution of its nucleus). The process is accompanied by the emission of one or more types of ionizing radiation. Included are materials possessing artificial, induced and natural radioactivity.

1. By-product materials. Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material.

2. Source material. Uranium or thorium or a combination thereof, in any physical or chemical form or ores which contain by weight, one-twentieth of one per cent (0.05 per cent) or more of uranium, thorium or any combination thereof. Source material does not include special nuclear material.

3. Special nuclear material. Plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, or any other material which the U. S. Atomic Energy Commission pursuant to the provisions of section 51 of the Atomic Energy Act of 1954, 42 USC section 2071, determines to be

special nuclear materials, but does not include source material; or any material artificially enriched by any of the foregoing but does not include source material.

4. Naturally occurring radioactive material. Substances which are radioactive in the natural state, such as radium and thorium and their decay products, except those defined as source and special nuclear material.

RADIOLOGICAL PROTECTION OFFICER. An individual designated by the commander to provide consultation and on the degree of hazards associated with ionizing radiation and the effectiveness of measures to control these hazards. This individual shall be technically qualified by virtue of education, military training, and/or professional experience to assure a capability commensurate with the assignment. The term "Radiological Protection Officer" is a functional title and is not intended to denote a commissioned status or job classification within the Armed Forces.

RBE. (Relative Biological Effectiveness.) The RBE of a given radiation is defined as the ratio of the absorbed dose in rads of gamma radiation (of a specific energy) to the absorbed dose in rads of the given radiation having the same biological effect. (See Dose Equivalent.)

REM (Roentgen Equivalent Mammal). One rem is the quantity of ionizing radiation of any type which, when absorbed by man or other mammal produces a physiological effect equivalent to that produced by the absorption of one roentgen of X-ray or gamma radiation. Dose in rems equals RBE times dose in rads. The rem provides an indication of the extent of biological injury (of a given type) that would result from the absorption of nuclear radiation. Thus, the rem is a dose unit of biological effect, whereas the rad is a unit of absorbed energy dose, and the roentgen (for X-ray and gamma rays only) is one of exposure. The rem can also be defined as the unit of dose equivalent. The dose equivalent is numerically equal to the dose in rads, multiplied by the appropriate modifying factors.

ROENTGEN. The quantity of gamma or X-radiation which will give rise to the formation of 2.08×10^9 ion pairs per cubic centimeter of dry air, STP (0°C, 1 atm). This is equivalent to the release of 87.7 ergs of energy when one gram of dry air under STP conditions is exposed to one roentgen of radiation. The roentgen is to be used solely as the unit for exposure.

$$1 \text{ R} = 2.58 \times 10^{-4} \text{ coulombs/kg.}$$

SEALED SOURCE. Radioactive material that is encased in and is to be used in a container in a manner to prevent leakage or escape of the radioactive material.

UNSEALED SOURCE. A discrete amount of radioactive material that is not encapsulated in a container to prevent leakage or escape of the radioactive material.

USER. The activity, section, division or other organizational unit which has been assigned responsibility for the use, handling, operation or storage of radiation sources.

Appendix B

RECOMMENDED DOCUMENTS FOR A REFERENCE LIBRARY

1. Army regulations. AR's 40-4, 40-5, 40-14, 40-37, 40-501, 55-55, 55-355, 385-10, 385-12, 385-30, 385-32, 385-40, 385-80, 700-25, 700-52, 700-63, 700-64, and 755-15.
2. AMC regulations. AMCR's 190-3, 385-1, 385-3, 385-7, 385-9, 385-13, and 385-15.
3. Field manual. FM 3-15.
4. Table of allowances. TA 50-914.
5. Supply bulletin. SB 11-206.
6. Technical bulletins. TB's CML 52, CML 53, CML 63, 3-6665-200-12, 3-6665-201-12, 3-6665-202-12, 3-6665-203-12, 3-6665-204-12, MED 62, MED 223, MED 232, MED 249, SIG 226-8, SIG 226-9, TC 7, and 5-6600-227-15/1.
7. Technical manuals. TM's 3-220, 3-260, 3-261, 3-6665-214-15, 11-5514, 11-5514A, 11-5543, 11-6665-204-12, 11-6665-206-12, 11-6665-208-15, 11-6665-209-15, 11-6665-216-15, 11-6665-221-15, 11-6665-224-15, 38-250, 38-750, 39-20-3, 39-20-6, 39-35-15, 39-N-11.
8. Military standards and specifications.¹
 - a. MIL-STD-129 Marking for Shipment and Storage.
 - b. MIL-M-3935A Markers, Self-Luminous.
 - c. MIL-C-10436 Compasses, Lensatic, Luminous Dial.
 - d. MIL-M-19590 Marking of Commodities and Containers to Indicate Radioactive Material.
 - e. MIL-STD-450 Radiation Hazard Symbol Contaminated Areas.
9. Miscellaneous.
 - a. DOD 4160.21-M, Defense Disposal Manual.
 - b. Title 10, Code of Federal Regulations. Atomic Energy.²
 - c. Title 14, Part 49 of Code of Federal Regulations.²
 - d. Title 46, Part 146 of Code of Federal Regulations²
 - e. Title 49, Parts 171 through 178 of Code of Federal Regulations.^{2 3}
 - f. U.S. Postal Manual, Chapter 1, Sections 124.24 and 125.24.⁴

^{1 2 3 4} See footnotes on page 47.

g. Radiological Health Handbook, U.S. Department of Health, Education and Welfare.⁴

10. U.S. Department of Commerce, National Bureau of Standards Handbooks.

- 48 - Control and Removal of Radioactive Contamination in Laboratories.
- 49 - Recommendations for Waste Disposal of Phosphorus 32 and Iodine 131 for Medical Users.
- 51 - Radiological Monitoring Methods and Instruments.
- 53 - Recommendations for the Disposal for Carbon-14.
- 55 - Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts.
- 57 - Photographic Dosimetry of X- and Gamma Rays.
- 58 - Radioactive Waste Disposal in the Ocean.
- 59 - Permissible Dose for External Sources of Ionizing Radiation.
- 63 - Protection Against Neutron Radiation up to 30 Million Electron Volts.
- 65 - Safe Handling of Bodies Containing Radioactive Isotopes.
- 66 - Safe Design and Use of Industrial Beta-Ray Sources.
- 69 - Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.
- 72 - Measurement of Neutron Flux and Spectra for Physical and Biological Applications.
- 73 - Protection Against Radiation from Sealed Gamma Sources.
- 75 - Measurement of Absorbed Doses of Neutrons and of Mixtures of Neutrons and Gamma Rays.
- 76 - Medical X-ray Protection up to 3 Million Volts.
- 78 - Report of International Commission on Radiological Units. and Measurements
- 80 - A Manual of Radioactivity Procedures.

⁴See footnotes on page 47.

- 84 - Radiation Quantities and Units (ICRU Report 10a).
- 85 - Physical Aspects of Irradiation (ICRU Report 10b).
- 86 - Radioactivity (ICRU Report 10c).
- 87 - Clinical Dosimetry (ICRU Report 10d).
- 88 - Radiobiological Dosimetry (ICRU Report 10e).
- 89 - Methods of Evaluating Radiological Equipment and Materials (ICRU Report 10f).
- 92 - Safe Handling of Radioactive Materials.
- 93 - Safety Standard for Non-Medical X-ray and Sealed Gamma Ray Sources: Part I. General.

11. Federal Radiation Council Reports⁴

- No. 1 - Background Material for the Development of Radiation Protection Standards.
- No. 2 - Background Material for the Development of Radiation Protection Standards.

12. International Atomic Energy Agency Regulations⁵

- Safety Series No. 1 - Safe Handling of Radioisotopes.
- Safety Series No. 2 - Safe Handling of Radioisotopes: Health Physics Addendum.
- Safety Series No. 3 - Safe Handling of Radioisotopes: Medical Addendum.
- Safety Series No. 4 - Safe Operation of Critical Assemblies and Research Reactors.
- Safety Series No. 6 - Regulations for the Safe Transport of Radioactive Materials.
- Safety Series No. 7 - Regulations for the Safe Transport of Radioactive Materials. Notes on Certain Aspects of the Regulations.
- Safety Series No. 8 - The Use of Film Badges for Personnel Monitoring.

⁴ ⁵See footnotes on page 47.

Safety Series No. 9 - Basic Safety Standards for Radiation Protection.

Review Series No. 12 - The Packaging, Transport and Related Handling of Radioactive Materials.

Review Series No. 18 - Processing of Radioactive Wastes.

13. National Fire Protection Association Publications⁶

Fire Protection Handbook, 12th Edition, 1962.

National Fire Codes -

Pamphlet 801, Laboratories Handling Radioactive Material, 1955.

Pamphlet 802, Nuclear Reactors, 1960.

14. USA Standards Institute Publications⁷

ASA N6.1 - Safety Standard for Operations with Fissionable Materials Outside Reactors, 1964.

ASA N5.2 - Design Guide for a Radioisotope Laboratory (Type B), 1963.

¹Military standards and specifications are available from the Commanding Officer, U.S. Naval Supply Depot (NSD 103), 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

²Copies of the Code of Federal Regulations are normally available from the Post Judge Advocate. Copies can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

³The Interstate Commerce Commission regulations are also published as "Agent TC George's Tariff No. 19", available from the Bureau of Explosives of the American Association of Railroads, 30 Vesey Street, New York, New York. Installation Transportation Officers usually have copies of George's Tariff No. 19.

⁴Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

⁵Available from National Agency for International Publications, Inc., 801 Third Avenue, New York, New York 10022

⁶Available from National Fire Protection Association, 60 Batterymarch Street, Boston, Massachusetts 02110.

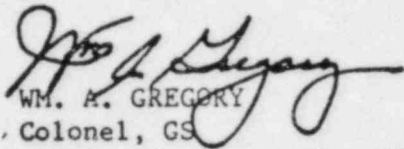
⁷Available from USA Standards Institute, 70 East 45th Street, New York, New York 10017.

AMCR 385-25

(AMCAD-S)

FOR THE COMMANDER:

OFFICIAL:



WM. A. GREGORY
Colonel, GS
Chief, Administrative Office

CLARENCE J. LANG
Major General, USA
Chief of Staff

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A and B

DEPARTMENT OF THE ARMY
HARRY DIAMOND LABORATORIES
2800 Powder Mill Rd., Adelphi, MD 20783

HDL MEMORANDUM
No. 385-20

24 March 1980

Safety

IONIZING RADIATION PROTECTION PROGRAM

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1. Purpose. This memorandum establishes the Ionizing Radiation Protection Program, outlines duties of the Radiation Protection Officer, the Radiation Control Committee and prescribes procedures and safe working practices which must be observed by personnel engaged in operations involving ionizing radiation sources.
2. Scope. The provisions of the Ionizing Radiation Protection Program apply to all the military and civilian personnel under the administrative control of the Commander, Harry Diamond Laboratories, to the employees of contractors and to military and civilian personnel of other Government agencies authorized to receive, use, store, transport, or dispose of ionizing radiation sources at Harry Diamond Laboratories. This memorandum does not apply to sources of non-ionizing radiation such as lasers and microwave producing equipment.
3. Definitions:
 - a. Accelerator. A device for imparting kinetic energy to charged particles, such as electrons, protons, deuterons, and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator and Van-de-Graff electrostatic generators.
 - b. Background Radiation. Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.
 - c. Contamination (Radioactive). Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence can be harmful. The harm may be in invalidating an experiment or a procedure, or in actually being a source of danger to persons.

*This Memorandum supersedes HDLR 385-20, 7 August 1973

d. Curie. A unit of activity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10} .

e. Dose. (1) Absorbed Dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit of mass of irradiated material at the place of interest is called the absorbed dose and is measured in rads, where

$$1 \text{ rad} = 100 \text{ erg/gm} = 1/100 \text{ joule/kg}$$

The rad unit is applicable to any type of ionizing radiation, but in reporting dose, the type, as well as irradiated material (for instance, tissue), and the place of interest must be specified. Without the above three factors, a statement of absorbed dose received is incomplete and probably useless, since the same dose of different kinds of radiation, even delivered to the same place, can produce entirely different effects.

(2) Exposure Dose. See Exposure.

(3) Biological Dose. The radiation dose absorbed in biological material. It is measured in rems.

f. Dose Equivalent. The term "RBE" dose has been used in the past in both radiobiology and radiation safety. It is now recommended that the term RBE be used in radiobiology only and that another term be used for purposes of radiation safety. The linear-energy-transfer factor is multiplied by the absorbed dose, D_a , to obtain a quantity that expresses on a common scale irradiation received by persons exposed to all ionizing radiations. The name recommended for the linear-energy-transfer-dependent factor is quality factor, QF. Other factors must also be considered for the purpose of radiation safety. A distribution factor, DF; is used to express the modification of the biological effect of radiation due to a nonuniform distribution of isotopes in the body. The distribution factor, like the quality factor, also affects the absorbed dose when radiation safety is being considered. It is recommended by the International Commission on Radiological Units and Measurements that the final calculated dose received by an individual after the absorbed dose is modified by the above-mentioned factors, plus any other factors that may affect the incoming radiation, be called the dose equivalent, DE. If the only apparent modification factors are QF and DF, then:

$$DE = D_a (QF) (DF).$$

If other factors must be considered and are defined, then:

$$DE = D_a (DF) (DF) \dots\dots\dots$$

where the dots take into account the product of these other factors. The unit of dose equivalent, DE is the rem. The unit of absorbed dose, D_a , is the rad. (Compare definitions of Rem and Rad.) Although the above definition of dose equivalent does not cover a number of theoretical aspects (in particular the physical dimensions of some of the quantities) it fulfills the immediate requirement for an unequivocal specification of a scale that may be used for numerical expression in radiation safety.

g. Exposure. The term "Exposure Dose" is obsolete. Exposure is a term adopted by the International Commission on Radiological Units and Measurements in 1962 to replace the term "exposure dose" introduced in their 1956 report. The quantity is used for X- and gamma radiation. Exposure is the measure at a certain place of radiation which has the ability to produce ionization. The unit of exposure is the roentgen, R, where 1R equals 2.58×10^{-4} coulombs/kilogram. The definition thus corresponds to the terms roentgen dose and air dose.

h. Exposure, Occupational. Exposure to ionizing radiation that is incurred as a result of an individual's employment or duties which are in support of facilities which use materials or machinery capable of producing ionizing radiation. Exposure of an individual to ionizing radiation for medical or dental diagnosis or therapy shall not be deemed as occupational exposure.

i. Film Badge. A pack of appropriate photographic film and filters used to determine radiation exposure.

j. Interlock. A device, usually electrical and/or mechanical in nature, to prevent activation of a control until a preliminary condition has been met or to prevent hazardous operations. Its purpose usually is safety of personnel or equipment. For example, it may be used to warn responsible personnel of an unsafe condition or unauthorized entry of personnel.

k. Ionizing Radiation. Electromagnetic or particulate radiation capable of producing ions, directly or indirectly in its passage through matter. For purposes of this memorandum, alpha and beta particles, gamma rays, X-rays, and neutrons are examples of ionizing radiation. This type of radiation does not include sound or radio waves, visible, infra-red or ultraviolet light or lasers.

l. Leak Test. A determination of the integrity of a sealed source encapsulation by detection of leakage or escape of radioactive contamination.

m. Rad. The rad is defined as a unit of absorbed dose of any nuclear (or ionizing) radiation which is accompanied by the liberation of 100 erg of energy per gram of absorbing material. Or, one rad is approximately equal to absorbed dose delivered when soft tissue is exposed to one roentgen of medium voltage, X-ray radiation. The rad is to be used solely with absorbed dose.

1 rad - 100 erg/grams = 1/100 joule/kg.

n. Radiation. See Ionizing Radiation.

o. Radiation Areas.

(1) Restricted Area. Any area access which is controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(2) Unrestricted Area. Any area access which is not controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(3) Radiation Area. Any area accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirem.

(4) High Radiation Area. Any area accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

p. Radiation Hazard. A condition under which persons might receive radiation in excess of the applicable maximum permissible dose, or where radiation damage might be caused to materials or personnel.

q. Radiation-Producing Devices. See Radiation Sources.

r. Radiation Sources. Materials, equipment or devices which generate or are capable of generating ionizing radiation, including: (1) naturally occurring radioactive materials, (2) byproduct materials, (3) source materials, (4) special nuclear materials, (5) fission products, (6) materials containing induced or deposited radioactivity, (7) nuclear reactors, (8) radiographic and fluoroscopic equipment, (9) particle generators and accelerators, and (10) radio frequency generators such as klystrons and magnetrons which produce X-rays.

s. Radiation Worker. Any person occupationally exposed to ionizing radiation and/or radioactive materials. (Job descriptions of radiation workers should reflect that the individual is potentially exposed to ionizing radiation.)

t. Radioactive Material. Any substance which undergoes spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides (a species of atom characterized by the constitution of its nucleus.) The process is accompanied by the emission of one or more types of ionizing radiation. Included are materials possessing artificial, induced and natural radioactivity.

(1) Byproduct Materials. Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material.

(2) Source Material. Uranium or thorium or a combination thereof, in any physical or chemical form or ores which contain by weight, one-twentieth of one per cent (0.05 percent) or more of uranium, thorium, or any combination thereof. Source material does not include special nuclear material.

(3) Special Nuclear Material. Plutonium, uranium 233, uranium enriched in the isotope 233 or any other material which the U.S. Atomic Energy Commission pursuant to the provisions of Section 51 of the Atomic Energy Act of 1954, 42 USC Section 2071, determines to be special nuclear materials, or any material artificially enriched by any of the foregoing but does not include source material.

(4) Naturally Occurring Radioactive Material. Substances which are radioactive in the natural state, such as radium and thorium and their decay products, except those defined as source and special nuclear material.

u. RBE. (Relative Biological Effectiveness) The RBE of a given radiation is defined as the ratio of the absorbed dose in rads of gamma radiation (of a specific energy) to the absorbed dose in rads of the given radiation having the same biological effect. (See Dose Equivalent.)

v. REM. (Roentgen Equivalent Man). One rem is the quantity of ionizing radiation of any type which, when absorbed by man or other mammal, produces a physiological effect equivalent to that produced by the absorption of one roentgen of X-ray or gamma radiation. Dose in rems equals RBE times dose in rads. The rem provides an indication of the extent of biological injury (of a given type) that would result from the absorption of nuclear radiation. Thus, the rem is a dose unit of biological effect, whereas the rad is a unit of absorbed energy dose, and the roentgen (for X-ray and gamma rays only) is one of exposure. The rem can also be defined as the unit dose equivalent. The dose equivalent is numerically equal to the dose in rads, multiplied by the appropriate modifying factors.

w. Roentgen. The quantity of gamma or X-radiation which will give rise to the formation of 2.08×10^9 ion pairs per cubic centimeter of dry air, STP (0°C, 1 atm). This is equivalent to the release of 87.7 ergs of energy when one gram of dry air under STP conditions is exposed to one roentgen of radiation. The roentgen is to be used solely as the unit for exposure.

$$1 R = 2.58 \times 10^{-4} \text{ coulombs/kg.}$$

x. Sealed Source. Radioactive material that is encased in and is to be used in a container in a manner to prevent leakage or escape of the radioactive material.

y. Unsealed Source. A discrete amount of radioactive material that is not encapsulated in a container to prevent leakage or escape of the radioactive material.

z. User. The activity, section, division or other organizational unit which has been assigned responsibility for the use, handling, operation or storage of radiation sources.

4. Policy. Work with radiation sources may present a biological hazard. Failure to exercise proper controls can be hazardous to health and may also result in property damage. Therefore, proposals to obtain and use such sources will be evaluated carefully to assure that any exposure to radiation will be kept to a minimum. Adequate written procedures, facilities, equipment, and trained personnel must be provided where radiation sources are used or operated. Failure to meet these requirements will result in cessation of operations.

5. Responsibilities. a. Commander. The Commander will:

- (1) Establish a formal, written Ionizing Radiation Protection Program.
- (2) Appoint a Radiation Control Committee.
- (3) Appoint a qualified individual as Radiation Protection Officer and alternate to provide continuity of operations.
- (4) Assure compliance with Federal, State, and local regulations.

b. Radiation Control Committee (RCC).

- (1) The committee will consist of the Radiation Protection Officer, the Safety Director, and several technical members trained and experienced in the safe use of radiation.
- (2) Specifically, the committee will:
 - (a) Advise the Commander on the status of the radiation protection program.
 - (b) Prepare, amend and review rules and regulations pertaining to the safe use, storage and disposal of radiation sources.
 - (c) Review and approve proposed location of radiation sources.
 - (d) Review and authorize uses of existing and proposed radiation sources.
 - (e) Serve as reviewing committee for incidents involving the use of radiation sources which result in over-exposure.
 - (f) Recommend appropriate action to be taken when individuals using radiation fail to observe safety recommendations, rules, or regulations.
 - (g) Review any instance in which radiation safety regulations impede operations considered essential by the laboratory concerned.
 - (h) Assure that minutes of the RCC's proceedings and actions taken or recommended are maintained.
- (3) Primary responsibility for the enforcement of established rules and regulations is not the responsibility of the RCC but rather the responsibility of each individual and his direct supervisor.

c. Radiation Protection Officer (RPO)

- (1) The training and experience of the RPO and his alternate must be commensurate with the type and hazard of the radiation sources at HDL. As a minimum, the formal training of the RPO and his alternate will be the successful completion of the U.S. Public Health Service Occupational Radiation Protection course or equivalent.
- (2) The Radiation Protection Officer will:
 - (a) Act as Chairman of the RCC.
 - (b) Provide the Commander, the RCC, and radiation users with advice and assistance on all matters pertaining to radiation safety.
 - (c) Review all plans for the proposed use of radiation sources and make the appropriate recommendations.
 - (d) Review all requisitions for procurement of radiation sources.
 - (e) Maintain an accurate record of the inventory of the radiation sources possessed by HDL.
 - (f) Perform radiation protection surveys of radiation sources to determine compliance with regulations and approved procedures.
 - (g) Maintain radiation protection records.
 - (h) Calibrate, or arrange for calibration of, survey instruments.
 - (i) Supply personnel monitoring devices, provide instructions in their use, and maintain records of exposure.
 - (j) Monitor shipments of radioactive materials.

- (k) Supervise decontamination of materials or personnel.
- (l) Monitor storage and working areas as required.
- (m) Supervise the disposal of radioactive wastes.
- (n) Maintain complete records of the receipt, transfer, and disposal of radiation sources.
- (o) Maintain records of unusual incidents such as overexposures, radioactive spills, or the loss of radioactive materials.
- (p) Arrange for radiation safety orientation and training of laboratory personnel.
- (q) Prepare and submit applications for NRC licenses.
- (r) Review, update, and amend NRC licenses presently in effect.
- (s) Prior to being relieved of his duties, the RPO will take the following action with regard to radiation sources for which he is responsible.

1. Secure all sources in such a manner as to preclude use or removal during the period for which there is no RPO appointed; or

2. turn over to a properly qualified and authorized individual, all materials and records for which he is responsible. Such an authorized individual will have the qualifications and training required of an RPO.—

d. Supervisors of radiation workers and radiation projects will:

- (1) Maintain a current inventory of all radiation sources for which they are responsible.
- (2) Know the exact location of all radiation sources for which they are responsible.
- (3) Post appropriate warning signs and notices.
- (4) Assure that their personnel have received adequate instruction and experience prior to using or being exposed to radiation.
- (5) Control contamination.
- (6) Assure radiation sources are secured against unauthorized use.
- (7) Control personnel exposures.
- (8) Prepare, prior to the start of any operation involving radiation sources, a written SOP for review and approval by the RPO and RCC. The SOP will contain, as a minimum: responsibilities, maximum permissible levels of radiation in the areas concerned, storage of radioactive materials, procedures regarding dosimetry, interlocks, decontamination and emergencies.
- (9) Enforce SOP's, rules and special precautions.
- (10) Report to the RPO an accident, unusual incident, personnel injury, or suspected overexposure immediately after occurrence.
- (11) Prior to being relieved of his duties, each radiation supervisor will take the following action with regard to all radiation sources for which he is responsible:
 - (a) Secure all radiation sources in such a manner as to preclude use or removal while not under the immediate supervision of a qualified and authorized individual; or
 - (b) turn over to a properly qualified and authorized individual all radiation sources for which he is responsible. Such an individual will have the qualification and training required for the safe handling of the materials involved.

e. Radiation workers will: (1) Know and follow SOP's, rules, and special instructions.

(2) Use safety equipment properly.

(3) Report to the supervisor any accident, unusual incident, personal injury, or suspected overexposure immediately after the occurrence.

f. Supervisors of Radiation Facilities will assure that each procurement document for a "basic component" for a radiation facility, i.e., Nuclear Reactor, Cobalt Irradiator, etc., licensed pursuant to Title 10 Code of Federal Regulations, specifies that the provisions of 10 CFR Part 21 apply. A "basic component" means a component, structure, system or part thereof in which a defect could create a substantial safety hazard, i.e., loss of safety function to the extent that there is a major reduction in the degree of protection provided to public health and safety.

6. Personnel Exposures. The radiation exposure standards contained in this section are applicable to all personnel. Present day philosophy of the Nuclear Regulatory Commission (NRC) is that radiation exposures be kept "as low as reasonable achievable" (ALARA). Applications for licenses to operate radiation facilities must address and emphasize the ALARA concept. The NRC presently requires that the concentrations of ionizing radiation materials be kept at less than ten percent of the levels listed in 10 CFR 20. If these concentrations and exposure levels cannot be maintained, then justification for higher concentrations and exposure levels must be made in the license application. The following personnel exposure limits are those currently listed in 10 CFR 20.

a. Personnel 19 years of age and over who are occupationally exposed to radiation:

(1) Accumulated dose to the whole body, head, trunk, blood-forming organs, gonads or lens of the eye is not to exceed 1.25 rem in any calendar quarter.

(2) Accumulated dose to the skin of the whole body or thyroid is not to exceed 7.5 rem per calendar quarter.

(3) Accumulated dose to the hands, forearms or feet is not to exceed 18.75 rem per calendar quarter.

b. Members of the general public, personnel not occupationally exposed, and those under 18 years of age will not be exposed, in any one calendar quarter, in excess of 0.125 rem.

c. Pregnant women will not be exposed to ionizing radiation for other than medical reasons (AR 40-5). At the first indication of pregnancy, women should notify their supervisor so they can be removed from work involving exposures.

7. Medical Examinations. a. Prior to beginning work with radiation sources, employees will be given an examination to include medical history, radiation exposure history, physical examination, and a complete blood count. Personnel, who are to be occupationally exposed to neutrons, will be given a slit-lamp test prior to exposure.

b. If a similar examination has been conducted within the previous 6 months, those portions of the examination need not be repeated for which results are entered in the individual's record.

c. Visitors and personnel on temporary duty for less than 30 days do not require a medical examination provided they will not be exposed to radiation in excess of the levels established in paragraph 6a.

d. Radiation workers will be given a medical examination at least once every 3 years. However, depending upon the work involved, the Medical Officer may desire to repeat the examination more frequently.

e. In addition, a full examination will be requested in event of overexposure, suspected overexposure, transfer to other operations not involving radiation, or prior to separation from HDL.

f. Supervisors will advise the RPO of new employees working with radiation sources so that appropriate orientation and physical examination can be arranged. The RPO should be notified as far

as possible in advance of transfers and termination of employment of radiation workers so arrangements can be made for final examination.

8. Personnel Dosimetry. a. All persons occupationally exposed to ionizing radiation will utilize film badges. The RPO will control the distribution and collection of film badges.

b. Before starting to work with any radiation source, the individual must obtain a film badge from the RPO. It is the responsibility of the individual and his supervisor to obtain the required film badge before beginning work with ionizing radiation.

c. It is important that the film badge be worn rather than left in a desk drawer or pinned on a laboratory coat not being worn. Any person who suspects that he has been exposed to ionizing radiation while not wearing his film badge will report the same to the RPO. Also, any person who suspects that his badge has been exposed to ionizing radiation to which he was not exposed will immediately report same to the RPO.

d. Off-site personnel monitoring.

(1) Arrangements will be made with the RPO to provide the necessary personnel-monitoring services to HDL personnel on official duty in places where film badge service is not available.

(2) The names of HDL personnel assigned to duties at places where personnel-monitoring services are available must be submitted to the RPO by the laboratory concerned.

e. All visitors, experimenters at HDL facilities, who may become exposed to ionizing radiation must wear film badges. It is the responsibility of the facility supervisor to obtain visitor badges from the RPO and enforce wearing of the badges. The supervisor will maintain a monthly record of visitors, listing the name, business address and social security number of the visitor plus the badge number issued. Badges will not be issued to more than one person.

9. Precautions in Handling Radiation Sources. a. Consider the relationships which will develop between the source and the persons involved in its use. Remember that the objective is to keep all occupational exposures as far below 100 mrem/week as is practicable. The individual who is assigned the radiation source has the responsibility to see that this objective is attained.

b. Determine before irradiation occurs what dose rate will be experienced by each individual under each conceivable circumstance. Advise the individual before he begins work regarding the dose rate he will incur in each situation. Be sure that he knows the location of the sources involved as well as the protective measures to be employed.

c. Take steps to ensure that no one may be exposed inadvertently. Also, prevent radiation sources from being removed from the work area. Prevent transmission of contamination by persons, tools, packages, document, vehicles, etc. Keep radioactive materials out of ordinary channels of waste disposal.

10. Contamination Control. a. The Radiation Protection Officer will issue expendable clothing to those persons working in areas where contamination is reasonable possible.

b. Cross-contamination may be limited by employing practical handling techniques. Simple acts such as handling telephones, reports, etc. while contaminated can result in the spread of contamination. Only things which may safely become radioactive should be permitted to touch radioactive items, and once such a contact is made, both items are thereafter treated as being radioactive.

c. Individuals who contaminate themselves or others, or who cause the contamination of areas, floors, equipment, etc. will notify the RPO at once. The RPO will assess the extent of the contamination and supervise the necessary decontamination procedures. It is not the duty of the RPO to perform the actual decontamination. It is the responsibility of the person causing the contamination to carry out the necessary clean-up procedures.

11. Authorization for Procurement of Radioactive Materials. a. The HDL Radiation Control Committee must authorize all proposals for work with radioactive materials.

b. The person responsible for and directing the undertaking of the use of radioactive material, the principal user, will submit a memorandum in duplicate to the RCC containing all pertinent information concerning the proposed operation. The memorandum will include:

- (1) Organizational element responsible for the proposed operation.
- (2) Purpose for which the materials will be used, including the desired initiation date and estimated duration of the project.
- (3) Materials desired, including:
 - (a) Isotope and maximum activities to be used and processed at any one time.
 - (b) Whether sealed or unsealed.
 - (c) Chemical or physical form.
- (4) Qualifications and experience of the persons who will directly supervise the operation.
- (5) Qualifications and experience of persons who will use or handle the material.
- (6) Locations where materials will be used or stored.
- (7) Monitoring equipment available to support the operation.
- (8) Facilities, equipment storage containers, exhaust hoods, handling equipment, and protective equipment available.
- (9) Operational procedures.
- (10) Radiation protection procedures to include safeguards to preclude emergencies, and actions to be taken should an emergency occur.
- (11) Estimated exposure of operational and nearby nonoperational personnel.

c. The Radiation Control Committee will then review the proposal.

- (1) Proposals rejected by the committee will be returned to the principal user with the reason for rejection indicated.
- (2) If approved, the original copy of the approved proposal will be returned to the principal user and the duplicate will be kept in the RCC file.
- (3) Once operations have been approved, no changes will be allowed prior to review and approval by the RCC.

d. Requests for the procurement of all radioactive materials will be processed through the RCC. No order for radioactive material may be placed without having obtained the authorization of the RCC for the intended use of the material. The RPO will act for the RCC for routine procurement requests.

- (1) The purchase requisition (DELHD 960) is first sent to the RPO with a duplicate copy.
- (2) The purchase requisition must be identified with the proposal for which the material is ordered and for which prior authorization of the RCC has been obtained.
- (3) The RPO will then endorse the purchase request and forward it to the Procurement Office, or will hold the request for further study and consultation with the person making the request.
- (4) If the radioactive material is obtained by means other than a purchase request, a memorandum should be sent to the RPO as far in advance as possible and in any case before the material is brought into the laboratories. The memorandum will contain the proposal for which the material is ordered and for which the authorization of the RCC has been obtained.

12. Authorization for Procurement/Use of Radiation Producing Devices.

a. The HDL RCC must authorize all proposals for work with radiation producing devices at HDL.

b. The person responsible for and directing the undertaking of (the principal user) operations involving radiation producing devices will submit a memorandum in duplicate to the RCC containing all pertinent information of the proposed operation. The memorandum will include (where applicable):

(1) Type of device.

(a) Function.

(b) Manufacturer and Model Number.

(c) Radiation output.

(d) Anticipated workload.

(e) Whether fixed or mobile operation is anticipated.

(f) Whether single or multiposition exposure head is to be used.

(g) Pulse duration and anticipated workload.

(h) Target.

(i) Calibration procedure and frequency.

(j) For accelerators: the curie level of the target, the mode of operation (positive or negative), energy of accelerator particles, the procedures for exchange of targets, and the available ventilation.

(2) Safeguards.

(a) Shielding.

(b) Interlock provisions and console locations.

(c) Estimated exposure based on seven-consecutive day operation modified by the planned workload. (Exposures of operational and non-operational personnel must be considered.)

(d) Occupied locations nearby.

(3) Training and experience of operators.

c. The RCC will then review the memorandum.

(1) Proposals rejected by the committee will be returned to the principal user with the reason for the rejection indicated.

(2) If approved, the original copy of the approved proposal will be returned to the principal user and the duplicate will be left in the RCC file.

(3) Changes to originally approved operations must be submitted to the RCC for review and approval.

d. Requests for the procurement of all radiation-producing devices will be processed through the RCC. No order for radiation-producing devices may be placed without having obtained the authorization of the RCC for the intended use of the machine. The RPO will act for the RCC for routing procurement requests.

(1) The purchase requisition (DELHD Form 960) is first sent to the RPO with a duplicate copy.

(2) The purchase requisition must be identified with the proposal for which the machine is ordered and for which prior authorization of the RCC has been obtained.

(3) The RPO will then endorse the purchase request and forward it to the Procurement Office, or will hold the request for further study and consultation with the person making the request.

13. Shipment of Radioactive Materials. a. Incoming.

(1) All radioactive material shipments must be shipped to and received by the RPO unless prior authorization for another procedure has been granted by the RCC.

(2) The Logistics Management Office will take the following action:

(a) The pickup of radioactive material will be accomplished as soon as practicable after receiving notification by the carrier that the material is available.

(b) Contact the RPO immediately when a package arrives at HDL. Packages must be monitored for excessive leakage and contamination by the RPO within 3 hours of receipt during duty hours or within 18 hours of receipt during non-duty hours.

(c) Insure that the RPO monitors each package inside and out while it is being opened and before the packaging of the contents are moved away from the unpacking location.

(3) The Radiation Protection Office will:

(a) Monitor the radioactive material for excessive external radiation or contamination prior to unloading.

(b) Check the vehicle for contamination immediately after unloading the radioactive item.

(c) Direct decontamination of materials if contamination is evident.

(d) Irrespective of the physical condition of the package, the package must be accepted. If damaged, active steps must be taken to minimize exposure of personnel and contamination of property.

(e) Upon receipt of the shipment, a record of the condition and dose rate levels of radiation will be entered on DA Form 2791-R. DA Form 2791-R will be reproduced locally to furnish the Radiation Protection Officer with a copy. The original DA Form 2791-R will be attached to the shipping documents and become a part of the permanent record of the shipment.

(f) Direct movement of the item to the individual laboratory or to those staging and storage areas determined by the RCC.

b. Outgoing. (1) The requestor:

(a) Prepares DELHD Form 57 (Shipping Request) and forwards it to the RPO with an extra copy.

(b) Insures that items are checked, tagged and approved by the RPO prior to sending to the Logistics Management Office unless authorization for another procedure has been granted by the RCC.

(c) When applicable, determines that the recipient is properly licensed by the NRC to receive the shipment.

(2) The Radiation Protection Officer:

(a) Verifies that the recipient is properly licensed by NRC to receive the shipment.

(b) Checks and monitors the items being packaged in the Logistics Management Office for conformance with DARCOM, DA, NRC, and DOT regulation.

(c) Forwards the shipping request to the Logistics Management Office.

(d) Furnishes the Travel and Transportation Branch a completed DA Form 2791-R showing that containers, as well as the manner of packaging within containers, meet all radiation safety requirements. DA Form 2791-R will be reproduced locally to furnish the RPO with a copy.

(3) The Logistics Management Office. If the shipment is by common carrier, forward the shipping request to the Travel and Transportation Branch.

(4) The Travel and Transportation Branch:

(a) Prepares the Government Bill of Lading.

(b) Forwards shipping papers to the RPO.

(5) The Radiation Protection Officer:

(a) Attaches to the shipping papers all special labels required for shipment.

(b) Authorizes release of the shipment and the Bill of Lading to the vehicle driver.

(6) Logistics Management Office:

(a) Arranges for dispatch and mechanical inspection of the vehicle for transporting radioactive items.

(b) Delivers the shipment to the common carrier or the destination, as applicable.

(c) Returns the Bill of Lading to the Travel and Transportation Branch.

(d) Arranges for the monitoring of the vehicle by the RPO or his designated alternate either at the destination or immediately upon return to HDL.

(7) The Travel and Transportation Branch returns one copy of receipted Bill of Lading to the RPO.

14. Transfer of Radioactive Materials. Before radioactive material is transferred from one location to another within the Laboratories, the RPO must be notified by the person requesting the transfer so that the operation can be properly surveyed.

15. Storage of Radioactive Materials. All radioactive materials must be clearly labelled at all times, giving pertinent and accurate information about the contents as well as identifying the person who is responsible for the item.

a. Permanent Storage Locations:

(1) Permanent storage locations will be established with the cognizance of the RCC.

(2) Permanent storage locations will be protected from entrance by unauthorized personnel and posted as required.

(3) Work areas adjacent to permanent storage areas shall be below 0.25 mrem/hr.

b. Temporary Storage Locations.

(1) Temporary storage of radioactive material which has been issued to an individual is the direct responsibility of that individual. The storage area will conform with radiation limits of 0.25 mrem/hr as set forth for permanent storage locations.

(2) Temporary storage locations will be identified by the appropriate radiation signs indicating the radiation characteristics, the actual physical location of the material, and the precautions to be taken.

16. Radioactive Waste. a. Dry Waste. Radioactive dry waste must be placed in cans with plastic liners, labelled with the standard radiation symbol, and marked "Radioactive Waste". Cans and the

liner bags may be obtained by contacting the RPO. Do not place radioactive waste in any waste-basket other than the designated basket.

b. Liquid Waste. Radioactive liquid waste must be placed in suitably shielded plastic bottles labelled with the standard radiation symbol and specifying the type and approximate amount of radio-isotopes present. No liquid radioactive waste, regardless of half-life, will be disposed of by pouring into any drains other than those designated by the RPO.

17. Protection of Maintenance and Construction Workers from Radiation Hazard.

a. Whenever maintenance or construction work is required in an area where an individual could conceivably receive a radiation exposure or where there is a possibility of contamination being present, it must be stated on the service request and the request must be approved by the RPO.

b. It will be the responsibility of all maintenance and construction supervisors concerned to insure that all workers are familiar with the radiation signs and to see that these signs are obeyed.

(1) Supervisor must submit to the RPO the names of workers assigned to areas where a radiation exposure is possible. The RPO will provide these workers with the necessary personnel monitoring equipment. The supervisor will notify the RPO when the job is completed.

(2) Upon request the RPO will provide instruction in radiation safety to maintenance and construction crews.

18. Emergency Procedures. a. Because of potential hazards created by breakage of sealed containers of radioactive materials, all such incidents should be reported to the RPO and the HDL Safety Manager.

b. Actions to be taken in sequence:

(1) Shut off all air conditioners and fans in the immediate area.

(2) Evacuate the area promptly, making no attempt to remove debris.

(3) Secure the area to prevent entry by others.

(4) Contact either of the above named officers and comply with additional instructions.

c. Procedure to be followed in the event of a wound incurred while working with radioactive materials:

(1) Wash the injured area at once with running water.

(2) Immediately secure medical attention from the HDL Medical Office.

(3) Notify or have someone else notify the RPO.

19. Fire. a. In the event of a fire within one of the posted radiation areas, the individual discovering the fire will immediately notify the RPO, the Safety Manager and Fire Marshall.

b. All persons entering a posted area will wear self-contained breathing apparatus unless otherwise directed by the RPO or his alternate.

c. Every effort will be made to determine the exposure received by the fire fighters. A radiation survey of the area should be made and film badges should be worn by all persons entering the area.

d. The supervisory Guard Officer will post a guard to prevent entrance of unauthorized personnel. After the fire, the area will be surveyed and cleared by the RPO for normal occupancy.

e. All fire fighters engaged in operations where radioactive materials are involved should take a thorough shower bath as soon as possible after the fire is over. The RPO will check the

fire fighters for contamination following the shower bath.

20. Training. a. Personnel, including visitors, who will be exposed to radiation and/or radioactive materials will be informed of the following information prior to exposure:

- (1) The presence of radiation or radioactive material.
- (2) Health hazards associated with exposure to such materials and/or radiation.
- (3) Procedures and precautions to minimize exposures.
- (4) Applicable provisions of AEC licenses, DA authorizations, regulations, and standing operating procedures, and applicable portions of Title 10 CFR, para 19, 20, and 21.
- (5) Emergency procedures.
- (6) Right to receive a report of his exposure incurred.
- (7) Proper use of protective equipment and clothing.

b. Radiation workers will receive the instruction in a, above. In addition, they will be instructed in the following areas:

- (1) Maximum exposure and contamination levels.
- (2) Safe methods of performing work. (The use of protective equipment and the operational steps involved will be demonstrated.)
- (3) Procedures to minimize contamination and to secure sources of radiation from authorized use.

c. Before an individual uses or supervises the use of sources of radiation, the RCC should determine that his training and experience are sufficient to enable him to deal safely with materials involved.

d. An individual whose training and experience is not adequate will be required to work under the direct supervision of a person known to be qualified until such time that the individual can demonstrate his ability on the job. In the event such training is not available locally, inquiry should be made into the possibility of the employee receiving the required training and experience at another DARCOT installation or activity.

e. Emergency and security personnel will be trained and equipped to cope with radiological hazards that may be encountered in the performance of their duties. Training will be sufficient to enable such personnel to function without waiting for the guidance of the RPO, or other individuals not part of their immediate group. Such persons will be informed of the existence of situations that might become hazardous during special or unusual circumstances.

f. A record of training will be recorded on DA Form 750 (Record of Training) and placed in each employee's official personnel folder.

g. Radiation workers will receive annual refresher training. A written record of initial and periodic refresher training will be maintained by the RPO.

21. References.

a. Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" and Title 29, Code of Federal Regulations, Part 1910, "Occupational Safety and Health Standards."

b. AR's 40-14, 55-55, 385-30 and 700-52.

c. AMCR's 385-25, 385-30.

HDLW 385-20

d. U.S. Department of Commerce, National Bureau of Standards Handbooks Numbers 48, 51, 55, 59, 63, 66, 69, 73, 75, and 78.

The proponent command of this publication is the Harry Diamond Laboratories Safety Office. Users are invited to send comments and suggested improvements on DA Form 2028 to the Commander, HDL, ATTN: DELHD-SA, 2800 Powder Mill Rd., Adelphi, MD 20783.

William R. Bennett

WILLIAM R. BENNETT

COL, TC
Commanding

DISTRIBUTION
C

STANDING OPERATING/EMERGENCY PROCEDURE
BUILDING 504 COBALT-60 SOURCE, ADELPHI, MD

Revision 3, 1 Apr 82

PURPOSE: To insure the radiological safety of personnel using the cobalt-60 source and to protect the integrity of the source elements.

PROCEDURE FOR IN-POOL IRRADIATIONS:

1. The cobalt-60 source control room door and maze entry door will be locked at all times, unless the rooms are occupied.
2. There will be two different keys, #1 which unlocks the control room door, and #2 which unlocks the maze entrance door. In addition, the control room door has a high-security hasp and padlock. This high-security hasp and padlock will be unlocked by HDL security guards during working hours, and will be secured otherwise.
3. Key #1 will be issued only to the Facility Supervisor, the Chief Operator, the Alternate Operator, the HDL Radiation Protection Officer, and to HDL security personnel.
4. There will be only one copy of key #2. It will be kept in a locked container located in HDL Bldg. 500 (AURORA). The Facility Supervisor, the Chief Operator, the Alternate Operator, and the HDL Radiation Protection Officer will be the only persons who have access to this container.
5. Experimenters (i.e. everyone participating in an experiment) who desire to use the source during normal duty hours (0800-1630) must enter their name and time of entry in the logbook provided for this purpose in the Cobalt Facility Control Room. One member of the experimental group must sign for keys #1 and #2. Keys #1 and #2 will be issued at Bldg. 500, AURORA by one of the four persons identified in paragraph 4, above. Upon completion of their experiment, he must return the keys to Bldg. 500 and sign out. Under no circumstances may the keys be removed from the immediate vicinity of the Bldg. 500/504 complex. This sign out procedure also applies to lunch breaks and short trips to the HDL main complex. Experimenters who remove the keys from the Bldg. 500/504 area, even for short periods of time, will be removed from the list of authorized experimenters.
6. If an experimenter desires to work later than 1630, he will so notify the HDL guard office (X-41117) before 1600. The security guard will then take the cobalt-60 logbook to the HDL guard office when he locks up Bldg. 500. Upon leaving Bldg. 504 for the night, experimenters will sign out and leave the keys and their film badges at the HDL guard office. The security guard will return the keys, the logbook, and the film badges to Bldg. 500 the next morning.
7. If an experimenter desires to begin work earlier than 0800 or work on weekends he will so notify the HDL guard office before 1600 of the previous working day. The security guard will then take the keys, the logbook and the experimenters film badges to the HDL guard office when he locks up Bldg. 500. When the experimenter comes in he will log in at the HDL guard office. The security guard will return the logbook to Bldg. 500 when he, unlocks it at 0745.

8. Experimenters must wear a film badge while they are in the Cobalt-60 Facility.

9. At least two persons must be in the Facility when a task requires working around the pool with one or more of the three major grating sections removed. Guard rails will be in place during any such operation.

PROCEDURE FOR FREE-AIR IRRADIATIONS:

1. Free air irradiations will only be undertaken by the following persons:

Facility Supervisor
Chief Operator
Alternate Operator
HDL Radiation Protection Officer

2. Two keys are required to perform free air irradiations: Key #3 which activates the console power, and Key #4 which activates the reset station and controls source elevator motion. There will be only one set of Keys #3 and #4. They will be kept in a locked key box in the Cobalt Facility Control Room. The only persons who will have access to this key box will be the Facility Supervisor, the Chief Operator, the Alternate Operator, and the HDL Radiation Protection Officer.

3. Two people must be present in the Facility whenever sources are moved around in the bottom of the pool. This specifically includes moving sources onto or off the source elevator. One of the people will have a calibrated ionizing radiation detection monitoring instrument to ensure that a hazardous condition is not created by source manipulation procedures.

4. Prior to raising the source elevator, the operator will visually inspect the irradiation room to insure that it is unoccupied. He will then activate the reset switch with Key #4, go out through the maze, and close the maze entrance door.

5. The operator may then raise the source elevator at his convenience, observing the T.V. monitor and control room Remote Area Monitor (RAM) #1. If he detects any unsafe condition such as mechanical interference with source elevator movement or an increase in the radiation exposure rate on RAM #1, he will immediately lower the source elevator.

6. The operator must be in attendance in the control room for the entire time the elevator is raised.

7. After the termination of each free-air irradiation procedure the operator will enter the exposure room with a calibrated ionizing radiation monitoring instrument and determine that no radiation hazard exists before any other personnel are allowed to enter.

8. Any malfunction shall be reported immediately to the HDL Radiation Protection Officer and to the Facility Supervisor.

PROCEDURE FOR OPERATING ELEVATOR FROM COBALT-60 ROOM:

1. Two persons are required to operate the source elevator in the in-cell operating mode.
2. Both persons must visually verify that there is no source element on the elevator platform.
3. When ready to raise the elevator, one person will stand by the pool with a monitoring instrument to detect any increase in the ionizing radiation level while the second person energizes the elevator control.
4. When the elevator is fully raised and it has been verified that there has been no increase in the radiation level, one of the operators may work on the elevator platform while the other operator holds the key switch.

AUTHORIZED EXPERIMENTS:

1. All experiments involving use of the Cobalt Facility must be reviewed and approved by the HDL Radiation Control Committee in accordance with the procedures set forth in HDLM 385-20, Paragraph 11.
2. Irradiation of the following classes of materials is strictly prohibited:
 - a. Explosives or Flammable Liquids
 - b. Corrosive materials
 - c. Any material which could violate the integrity of the source pencil encapsulation.
3. Manipulation of source elements by experimenters is strictly prohibited.

AUTHORIZED EXPERIMENTERS:

1. All experimenters must be supervised by employees of Harry Diamond Laboratories. Non HDL experimenters must have a film badge and an HDL security badge.
2. All experimenters must be approved (once only) by one of the following:

Facility Supervisor
RPO
Alternate RPO

A list of the approved experimenters will be maintained with the Cobalt-60 source logbook.

EMERGENCY PROCEDURES:

1. Major Emergencies:


- a. TYPES: Fire or other hazardous condition.
Continuous actuation of radiation alarms.
Abnormal pool water level.
- b. RESPONSE: Evacuate the Cobalt Facility immediately.
Report the nature and location of emergency to the HDL Guard Office (X-41117).
Assemble in Bldg 504 parking lot.

2. Other Emergencies:


- a. TYPE: Object dropped into pool.
- b. RESPONSE: Notify Facility Supervisor (x42290)

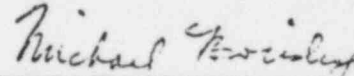
3. Use of the Facility shall not resume until the cause of the emergency condition has been determined and corrected to the satisfaction of the HDL Radiation Control Committee.

PREPARED BY:


KLAUS G. KERRIS, Facility Supervisor


APPROVED BY:


KLAUS G. KERRIS, Chief (A), Br. 22900


MICHAEL BORISKY, RFO, HDL

REVIEWED AND APPROVED BY RCC:

02 April 82
Date


Initials

COBALT-60 FACILITY WEEKLY CHECKLIST

HDL BLDG. 504

1. Verify the status of the following systems:

System Air Pressure:
Console Power: ON
RAM Power: ON

psig
RAM1
RAM2
RAM3
inches

Tank-O-Meter flow rate
water level

2. Verify that the circulating pump is running:

Check condition of sediment filter by measuring inlet and outlet pressure. Replace filter if pressure drop exceeds 15 psi:

IN	psig
OUT	psig
DROP	psi

Check pool water resistivity at inlet and outlet of deionizer tanks. Inlet resistivity should not be less than .05 M Ω -cm:

IN	M Ω -cm
OUT	M Ω -cm

3. Check operation of RAM 1, 2, & 3 by actuating the lamp which is built into the probe. Verify that this check causes an up-scale meter reading with the associated audio & visual alarm response for each RAM:

RAM1
RAM2
RAM3

REMARKS:

MONITOR'S NAME: _____

DATE: _____

PERIODIC MAINTENANCE SCHEDULE
COBALT-60 FACILITY
HDL BLDG. 504

Checked
(Initial)

I. ADJUSTMENTS

A. Quarterly

1. Check elevator air system pressure. Adjust to 10 psi greater than that required to lift the required maximum elevator load.
2. Adjust the descent speed valve to limit elevator descent speed when fully loaded.
3. Adjust the ascent speed valve to limit elevator ascent speed with no load.

B. Semiannually

1. Turn off pool water supply valve.

Check trip settings on pool level gauge switches by isolating level gauge from pool and pressurizing it. Switch trip settings should be as follows:

- a. High water level alarm: actuation point: 137 inches
- b. Fill valve: actuation point: 137 inches
- c. Pump cutout switch: reactuation point: 132 inches
- d. Low water level alarm: reactuation point: 126 inches

- Adjust all switches to within ± 1 inch.

Turn pool water supply valve back on.

2. Check the console timers for proper functioning and time delay setting. Adjust or replace as necessary.

II. PREVENTIVE MAINTENANCE

A. Quarterly

1. Oil all elevator drive pulleys (except submerged) with light machine oil.
2. Check ethylene bottle reserve and replace if necessary.
3. Check annunciator and interlock system for proper operation in all modes. Replace defective components as required.
4. Inspect entire elevator cable for signs of wear.

CO⁶⁰ Form 4 Rev. Dec 51

B. Annually

1. Remove air pressure regulator dust and oiler bowls in elevator air control system. Clean bowls and refill oiler bowl with clean oil.

2. Measure the insulation resistance of the dummy control wire in the cable tray. If this wire has less than 1×10^7 ohms resistance to ground, check all control wires and replace those which are less than 1×10^7 ohms to ground.

3. Visually inspect wire insulation in cable trays for radiation damage such as brittleness or crumbling in insulation. Replace all defective wiring.

III. REMARKS:

CHECKED BY: _____

DATE: _____

PERIODIC CALIBRATION SCHEDULE/PROCEDURES

COBALT-60 FACILITY

HDL BLDG. 504

I. CALIBRATION OF REMOTE AREA MONITORS

A. There are three remote area monitors in Building 504. RAM 1 is located in the control room. It has a 4-decade logarithmic meter calibrated from 0.1 mR/hr to 1R/hr. RAMs 2 and 3 are located in the exposure room. They have 5-decade logarithmic scales calibrated from 1.0 mR/hr to 100 R/hr.

B. All RAMs must be calibrated quarterly, following the calibration instructions given in the NMC Model GA-2TO instruction manual with the following exceptions and additions:

1) The only function of RAMs 2 and 3 is to detect radiation levels which are significantly above background. It is therefore not necessary to calibrate them over their entire meter range. RAMs 2 and 3 will be calibrated from 1.0 mR/hr to 1R/hr. A label will be affixed to RAMs 2 and 3 stating that they are uncalibrated above 1R/hr.

2) All three RAMs have a remote meter readout at the control console. These remote meters are to be included in the calibration procedure.

C. At the same time the RAMs are calibrated, high radiation alarm trip points should be set as follows:

RAM 1:	2.5 mR/hr
RAM 2:	20. mR/hr
RAM 3:	20. mR/hr.

D. The calibration and alarm adjustment procedures are attached.

II. CALIBRATION OF OZONE MONITOR

A. A Bendix Ozone Detector, Model 8002 is installed in the control room. This unit continuously measures the ozone concentration in the exposure room during in-air-irradiation procedures. A sampling tube, extending from the unit to a location adjacent to the source elevator, provides the unit with a representative sample of exposure room air. The detector analyzes the air sample and displays results which lie within a 0.01 to 1.0 PPM O_3 range.

B. This detector must be calibrated semiannually, following the calibration instructions given in the Bendix Ozone Detector, Model 8002 instruction manual with the following additions:

1) The remote meter readout at the control console reproduces the reading displayed at the detector unit. This remote meter is to be included in the calibration procedure.

12912

2) The high ozone alarm trip point should be set at 0.1 PPM. Therefore, adjust the "range switch" on the ozone detector and the red pointer on the remote meter readout at the control console to 0.1 PPM.

C. The calibration and alarm adjustment procedure for the ozone detector is attached.

CALIBRATION PROCEDURE

To calibrate the Model GA-2T0, the following steps should be followed:

A. Four-Cycle Scale (RAM 1)

1. Before turning on the instrument mechanically reset the indicating meter to mechanical zero by means of the adjusting screw on the meter face. Note: If external recorder is used, it must be connected during calibration.
2. Refer to the diagram showing location of controls before making any adjustment. Turn on the instrument and allow 30 minutes to elapse before making any test except to adjust the regulated B+ to 13.4V DC. Notes: Probes that have just been assembled must be allowed to set 15 hours before attempting to calibrate.
3. Turn artificial background control counterclockwise until it rests against stop. The artificial background control, when advanced clockwise, provides a small amount of current to flow through a #344 lamp, located at the photo-cathode surface of the 6655 tube, to keep the lamp dimly lighted. The lamp provides the up-scale reading in addition to providing an up-scale check of the instrument operation.
4. Connect a high voltage meter (negative to the violet stand-off located on the probe amplifier, positive to gnd) and observe the drop in high voltage when a source corresponding to the lowest indicated level is applied to the probe. This drop should be 80 to 120 volts.
5. Four adjusting points are used to calibrate a 4-cycle GA-2T0: a ceramic potentiometer which is used for level shifting, and three color-coded potentiometers, which are:

brown	-	lowest indicated level adjustment	(0.1 mR/hr)
red	-	third cycle adjustment	(100 mR/hr)
orange	-	fourth cycle adjustment	(1 R/hr)
6. Present a 0.1 mR/hr source to the probe and adjust the brown pot until the meter reads correctly.
7. With a 100 mR/hr source, adjust the red pot for the proper meter value.
8. Using a 1R/hr source adjust the ceramic pot for a meter reading of about 1/4" up-scale from the 1R/hr point.
9. Using the orange pot adjust for 1R/hr meter reading.
10. Repeat steps 7 and 9 until correct calibration is achieved.
11. Repeat steps 6, 7 and 9.
12. Check the calibration of the 1 mR/hr and 10 mR/hr points. If these points read too high repeat steps 8, 9, 10, 11 and 12. If the first and second cycle points read too low, then turn the ceramic pot counterclockwise a very small increment. Using the orange pot and a 1 R/hr source, set the meter on the correct reading. Repeat steps 6, 7, 9, 10 and 12.

B. Five-Cycle Adjustment (RAMs 2 and 3)

1. Same as steps 1-4 on four-cycle adjustment.
2. Using a 10 mR/hr source adjust the brown pot until the meter reads correctly.
3. Using 1 R/hr source adjust the red pot for the correct meter reading.

C. Calibration of Fail-Safe and Alarm System

The following controls are used in the fail-safe and alarm calibration. Refer to the location of the controls diagram before making any adjustment.

1. Alarm limit adjust.
2. Fail-Safe limit adjust.

With no source applied to the photomultiplier tube the fail-safe light will be on.

1. Turn the alarm level pot to 10, the alert level pot to 5 (if one is used), and the fail-safe level pot to zero.
2. Remove any artificial background source if used, or rotate artificial background fully counterclockwise.
3. Push the up-scale check button and hold down.
4. Adjust the up-scale control until the panel meter reads at the beginning of the low end of the meter scale.
5. Rotate the low limit control until the yellow light is lighted. Move the low limit control slowly in the opposite direction until the lamp extinguishes.
6. Turn up-scale check control until the panel meter reads 2.5 mR/hr on RAM 1 or 20 mR/hr on RAMs 2 and 3.
7. Adjust the high limit control until the red lamp extinguishes. Rotate the high limit control slowly in the opposite direction until the red lamp is lighted.
8. Repeat steps 3 through 7 until satisfactory calibration is achieved.
9. Adjust the up-scale check control until the panel meter reads just past full scale.
10. Reposition the artificial background source if used, or turn the artificial background control clockwise until a suitable background reading is obtained.

II. To calibrate the BENDIX Model 8002 Ozone Analyzer, the following steps should be followed:

A. Check the SAMPLE PLUS ETHYLENE flow rate to verify that the flow rate meter indicates 28.5 mm Hg pressure. If necessary, adjust the SAMPLE PLUS ETHYLENE needle valve to obtain the correct flow rate.

B. Place the MODE SELECTOR switch in the ZERO position.

C. Place the TIME CONSTANT SELECTOR switch in the 1 SEC position.

D. Slowly switch the FULL SCALE RANGE SELECTOR switch progressively down scale, allowing the meter to settle at each position, until the switch is in the .01 position.

E. Unlock the ZERO adjustment control and set it for an exact zero indication on the O₃ CONCENTRATION meter. Lock the ZERO adjustment control.

F. Place the FULL SCALE RANGE SELECTOR switch to the .5 position.

G. Place the MODE SELECTOR switch to the CALIBRATE position.

NOTE

Wait 15 minutes to allow
the unit's ozone generator
to stabilize.

H. Unlock the CALIBRATE adjustment control and set it to obtain an O₃ CONCENTRATION meter indication of 69.

I. Lock the CALIBRATE adjustment control.

LOADING AND UNLOADING PROCEDURE FOR
NPI RADIOACTIVE SHIPPING CONTAINERS

Assuming container is in pool loaded with cobalt-60, the following procedures must be followed in loading trailer and unloading at other end:

1. Lower top cover in place making sure that the gasket is properly in place.
2. Raise top of container to surface of pool, measuring radiation level continuously, and install cover bolts.
3. Raise container completely out of water measuring radiation level continuously and washing outside of container with demineralized water. Should radiation level measure in excess of 5 R/hr at contact, the container shall be lowered back in pool, the cover removed, and enough cobalt removed to lower radiation level to less than 5 R/hr.
4. If the surface radiation level is less than 5 R/hr, allow container to remain over pool until there is no significant amount of water dripping, then place in horizontal position over drains at side of pool.
5. Place lead-wire seal on cover.
6. Connect demineralized water to vent openings and flush container for one hour.
7. Remove water connection and connect helium to container and flush until gas appears dry.
8. Install quick disconnect fitting, pressure gage, and relief valve filter assembly. Pressurize in excess of 45 psig and check relief valve.
9. Vent and pressurize to a minimum of 5 psig maximum of 10 psig with Helium through quick disconnect fitting.
10. Wipe outside of container dry and smear for surface contamination. Allowable surface contamination is 2200 DPM. Decontamination is required for activity in excess of the above.

11. Measure maximum activity 3 feet from container and note on shipping form. Activity must be less than 1 R/hr for shipment.
 12. Fill out DOT Radioactive Group III labels and place on both ends of container.
 13. Bolt container to trailer and install cage.
 14. Measure maximum radiation level at the following points:
 - a. Edge of cage.
 - b. Edge of trailer (must be less than 200 mr/hr).
 - c. Six feet from trailer (must be less than 10 mr/hr).
 - d. Tractor cab (must be less than 2 mr/hr).
 15. Place DOT "Radioactive" placards on rear and both sides of trailer and on front of tractor.
 16. Complete NPI "Radioactive Shipment" form.
 17. Prior to departure of a radioactive shipment, the consignee must be notified as to arrival date and time. In addition, the Maryland Radiological Health Authority, Mr. Corcran, Chief (Telephone 301/383-3010) must be notified by telephone and given all of the above information plus the routing in Maryland.
 18. While enroute the following must be checked at all stops:
 - a. Tractor-trailer tires.
 - b. Container hold down bolts.
 - c. Container pressure.
 - d. Survey container and note any changes in radiation levels.
- Note: Tractor-trailer must not be left unattended at any time while loaded.
19. Upon arrival at destination, check in with consignee and have his Health Physicist survey and accept container for unloading.

20. Upon acceptance by consignee:

- a. Remove cage.
- b. Remove hold down bolts and container.
- c. Vent container through quick-disconnect into pool.
- d. Break lead-wire seal on cover and remove bolts.
- e. Remove relief valve, pressure gage, and quick disconnect fittings.
- f. Lower into pool - remove lid and cobalt.

21. Remove container from pool and have facility Health Physicist conduct internal and external radiation survey of container.

22. Replace container cover, relief valve and pressure gage. Remove DOT "Radioactive" labels and place "EMPTY" placard or sign on either end of container.

23. Remove or cover DOT "Radioactive" signs on tractor-trailer and load container and cage.

NOTE: The following documents must be in NPI driver's possession at all times during a radioactive shipment:

- a. DOT Special Permit.
- b. AEC License and Cask or Container Analysis.
- c. NPI "Radioactive Shipment" form.
- d. NPI Operating and Emergency Procedures for Radioactive Shipments.
- e. Drivers daily log book (DOT).
- f. Copy of latest revision of ICC Motor Carrier Safety Regulations with accident forms.
- g. Name, address, and telephone number of consignee.

DALE L. REPP
Manager, Field Services
Plant Superintendent

EDUCATION

16 weeks formal classes - National Bureau of Standards - 1965 - in health physics, reactor physics and nuclear instrumentation.

3 weeks training - Naval Research Laboratory Reactor - 1965 - in health physics and reactor operation.

2 weeks training - Naval Research Laboratory - 1965 - in hot cell operations with MTR type fuel elements.

3 credit hours in chemistry; 3 credit hours in math; 3 credit hours in engineering graphics; 3 non credit hours in physics, math and english - 1965.

20 weeks informal classes - 1966 - in reactor systems and operating procedures.

4 weeks courses - National Bureau of Standards - 1966 - in metal machine shop and welding.

EXPERIENCE

1967-Present - Neutron Products, Inc.

Initial cobalt-60 calibration and removal from Big Rock Point Power Reactor, Charlevoix, Michigan. Started construction of NPI pool facility. Decanning and calibration of cobalt-60 sources at Westinghouse pool facility, Waltz Mill, Pennsylvania. Construction of NPI pool facility and liquid phase irradiator. Transported 300,000 curies cobalt-60 from Waltz Mill, Pennsylvania to Dickerson, Maryland. Initial loading and shield testing of liquid phase irradiator. Operation of liquid phase irradiator and pool storage facility. Second encapsulation of 250,000 curies cobalt-60 at IRL, Plainsboro, New Jersey including loading and transfer in 30,000 curie lots in transfer cask from reactor storage pool to hot cells. Operation of liquid phase irradiator and NPI pool facility. Construction and operation of NPI dry package irradiator. Construction of NPI hot cell, storage canal and warehouse. Hot Cell Supervisor - encapsulation of 1,000,000 curies cobalt-60. Plant Superintendent - construction of second dry package irradiator. Manager, Field Services - teletherapy source transfers - animal irradiator removals.

NEUTRON PRODUCTS inc

DALE L. REPP

Page Two

1964-1967 - National Bureau of Standards, Gaithersburg, Maryland,
Nuclear Engineering Technician

Assisted in chemical cleaning of the reactor primary systems; check out of control systems and interlocks, and final assembly of reactor components. Participated in testing and evaluation of heavy water diaphragm valves. Assembled a dummy core in the reactor vessel to simulate actual flow conditions and facilitate testing of reactor control and shutdown systems. Responsible for debugging and testing of reactor emergency cooling systems, to insure that systems operated faultlessly and met written specifications. Check out of reactor purification system, shielding of the ion exchangers and loading of the mixed bed into the I. X. vessels. Assisted in the assembly of work lists and schedules to insure the on time completion of reactor testing. In addition, I performed routine maintenance on reactor systems and components as well as auxiliary and secondary systems.

1963-1964 - Blount Brothers Corporation, Inc., Montgomery, Alabama,
Assistant Field Engineer

Interested in nuclear field while building reactor. Involved transit, level and stake-out for general building control. Building layout for excavating, reinforcing steel and concrete form work. Included "take off" from blueprints of architectural and structural materials, helped check out major reactor components for "as built" dimensions and in-place alignment. I coordinated certain phases of field work with structural and mechanical sub-contractors and helped schedule delivery of material.

1962-1963 - Blake Construction Company, Inc., Washington, D. C., Engineer's
Helper - Instrument Man

Building layout for excavating, reinforcing steel, and concrete form work. Involved transit, level and stake-out work for general building control.

1962-1962 - S. W. Jack Drilling Company, Avonmore, Pennsylvania

Took strata samples and recorded operating data in log books. Mechanical work consisted of preventative maintenance and repair of diesel and gas engines, air compressors, draw works, gear boxes, cables and rigging drums, turn tables, soap, gel and mud pumps, water pumps and other hydraulic and pneumatic equipment.

NEUTRON PRODUCTS inc

DALE L. REPP
Page Three

1961-1962 - Ralph William Stonesifer, Keyman, Maryland

Mechanical work, repair of trucks, backhoes, and dozers. Field layout of roadways, sewerage systems and conservation drainage.

1958-1961 - R. H. Morningstar, Middleburg, Maryland

General dairy farm work. Installation and service of refrigeration units and bulk milk tanks.

NEUTRON PRODUCTS inc

RESUME

J. RICHARD DEMORY

Employer: Neutron Products, Inc., 1967 to present

Duties: Design, construction, and operation of main processing pool containing megacurie quantities of cobalt-60.

Design and fabrication of special purpose underwater tools for handling, processing, and testing cobalt-60 sources.

Inventory control for multimegacurie cobalt-60 inventory.

Shipping large quantities of cobalt-60 utilizing a series of NPI designed casks licensed for from 120,000 to 600,000 curies.

Superintendent on building and radiation facility construction when NPI acts as general contractor.

Previously had responsibility as health physics technician in multi-megacurie cobalt-60 facility, operated radiation synthesis chemical processing plant, and hot cell operator.

Employer: Justrite Homes, 1966-1967

Duties: Mason Foreman

Employer: Craftsman, 1964-1966

Duties: Bricklayer

NEUTRON PRODUCTS inc

ISOTOPE HANDLING EXPERIENCE

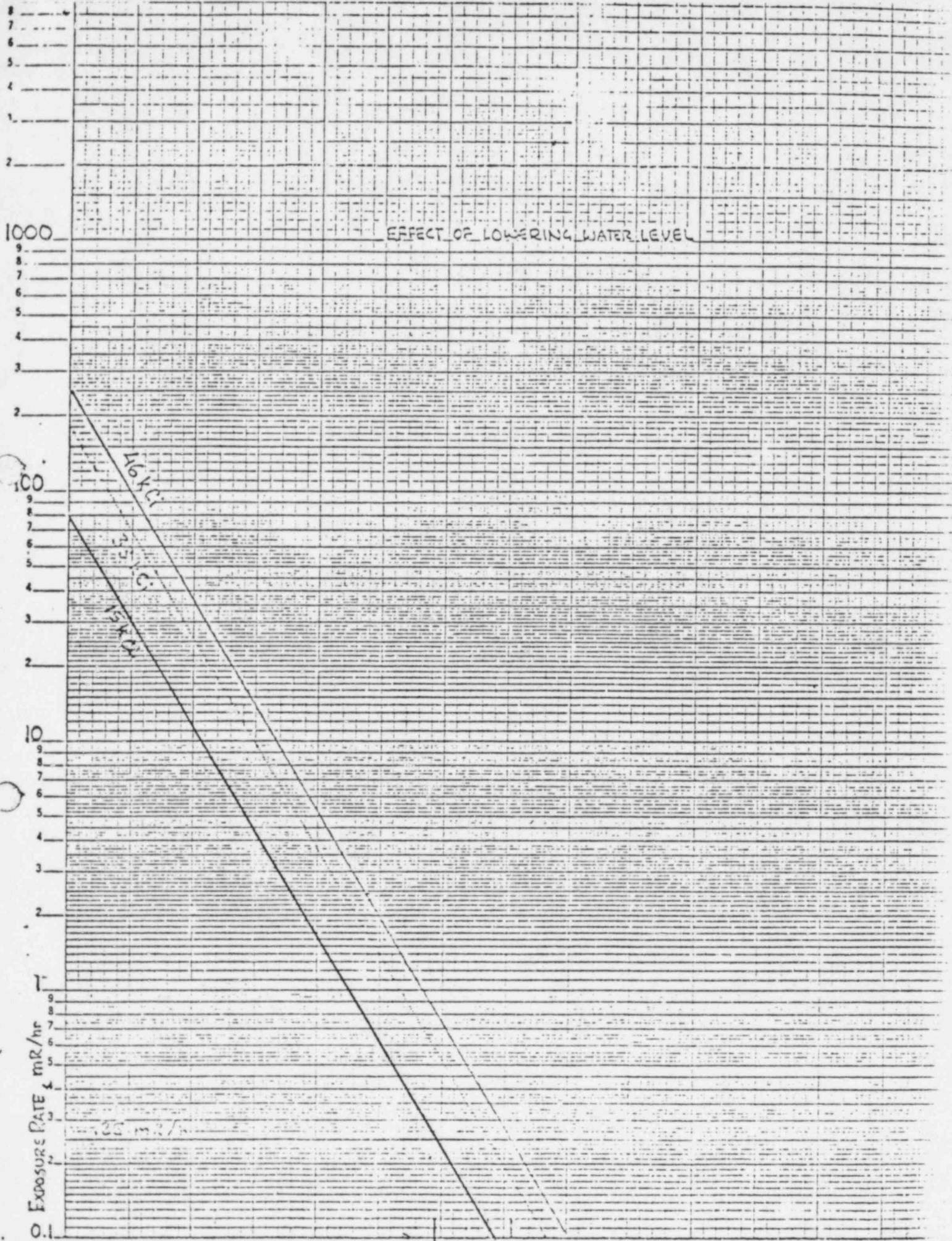
NAME: J. RICHARD DEMORY

Isotope	Maximum Amount	Where Experience Was Gained	Duration of Experience	Type of Use
Cobalt-60	5,700,000 curies	Neutron Products	1967-1977	Storage, handling and shipping
Cobalt-60	50,000 curies	Dow Corning	3 days	Loading and/or unloading shipping cask
Cobalt-60	10,000 curies	Univ. of Michigan	1 day	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Gamma Processing	2 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Industrial Reactor Laboratories	3 days	Loading and/or unloading shipping cask
Cobalt-60	300,000 curies	Battelle Memorial Institute	20 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Atlantic Richfield Company	4 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Radiation Machinery	2 days	Loading and/or unloading shipping cask
Cobalt-60	100,000 curies	American Novawood	2 days	Loading and/or unloading shipping cask
Cobalt-60	1,500 curies	Massachusetts General Hospital	2 days	Load teletherapy source

COMPANY: NEUTRON PRODUCTS, INC.

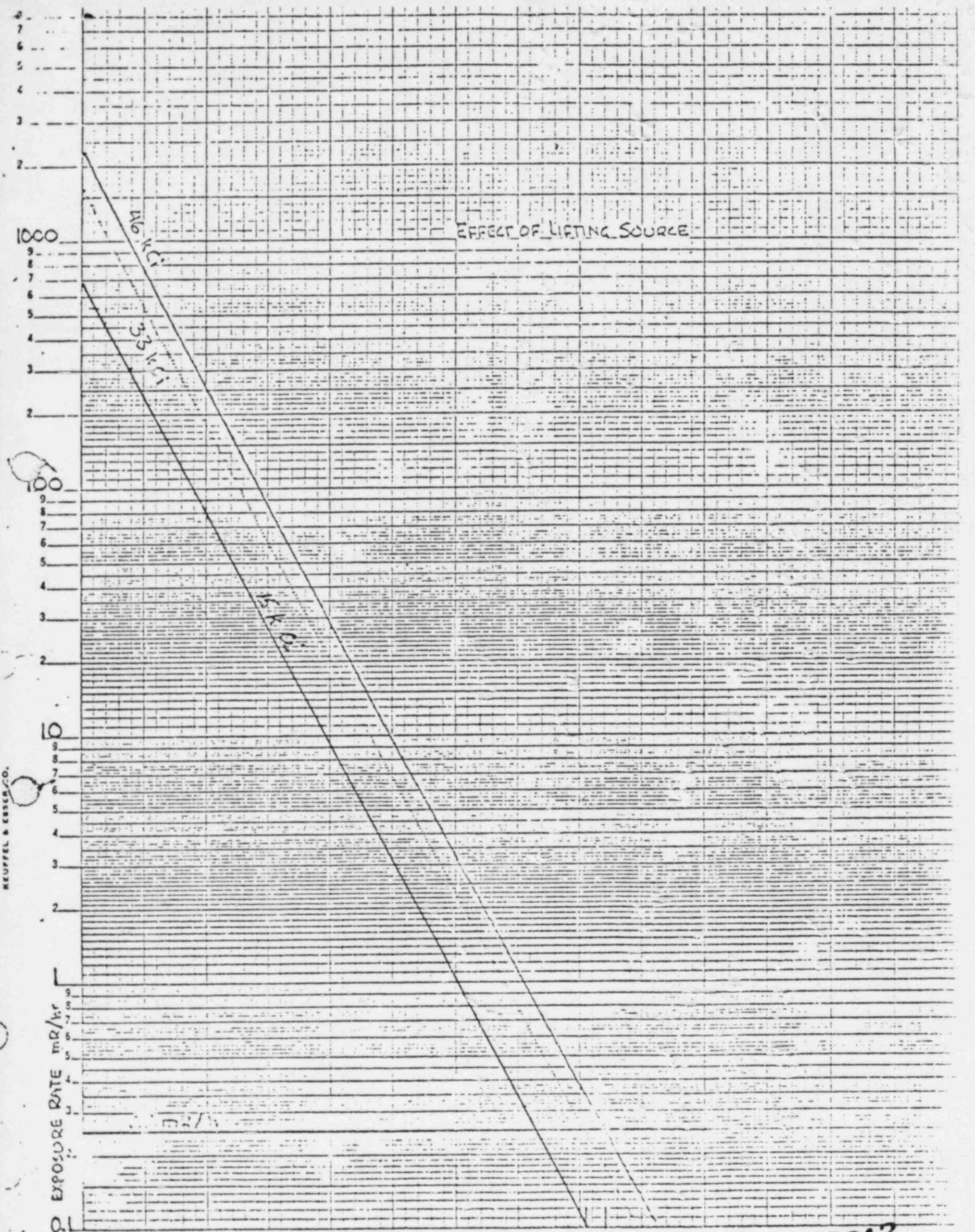
NAME: J. RICHARD DEMORY

Type of Training	Where Trained	Duration of Training	On Job		Formal Course	
			Yes	No	Yes	No
1. Principles and practices of radiological health safety	Neutron Products	9 years	X		X	
2. Radioactivity measurements standardization and monitoring techniques and instruments	Neutron Products	9 years	X		X	
3. Mathematics and calculations basic to the use and measurement of radioactivity	Neutron Products	9 years	X		X	
4. Biological effects of radiation	Neutron Products	9 years	X			X
5. Actual use of radioisotopes in the types and quantities for which application is being made, or equivalent	Neutron Products	9 years	X		X	



KEUFFEL & ESSER, CO.

6-1 5 THICKNESS OF H₂O LAYER 6 FEET 7 FEET 8 FEET 9 10 11 12
 6 DEPTH OF H₂O IN POOL 4 1/4 9 1/2 10 11 12



NEUFFEL & ESSER CO.

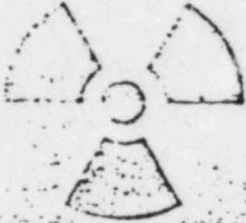
SUPPLEMENT #1

Item 8B, Form NRC-3131, Description of Cobalt-60 Sources

1. General Information: Each of the doubly encapsulated sources is comprised of a type 304L stainless steel tube containing a Model NPI 12CC5 clad wire coil of Cobalt-60. The outer capsule has stainless steel end caps and is sealed by TIG welding. The clad wire coil itself constitutes a singly encapsulated source. It consists of a cobalt wire approximately .060 inch in diameter which is contained within a stainless steel tube having an outer diameter of approximately .072 inch. The contained wire is sealed at both ends by TIG welding, and then wound into the shape of a coil prior to irradiation. It is subjected to an acid leak test prior to irradiation, and subsequent to irradiation it is subjected to a corrosion test and is also smeared to assure that cladding integrity has not been violated.

2. Specific Information: a. In addition to the information provided in Item 8 of the inclosed Form NRC 3131, the USNRC publication entitled "Guide-Information to be Submitted Concerning Sealed Sources Containing Radioactive Materials" solicits additional information concerning the radioisotope, construction, prototype tests, quality control and labeling data. Since all source specification drawings, construction specifications, prototype testing specifications, and quality control specifications are considered to be proprietary information by Neutron Products Inc., it is requested that the USNRC glean specific information concerning Neutron Products Inc, Model 12CC5 single encapsulated source, which has been double encapsulated in accordance with NPI's Procedure P2, from the USNRC Sealed Source/Device Catalog. This method of presenting required proprietary information was approved by the USNRC during the review of the initial license request application.

b. Since the sources and source holders are stored under water, it would not be effective to attach labels which present the information required by the USNRC "Guide" to either the sources or the source holder. Consequently, a label which identifies the isotope, quantity of isotope, date of measurement, manufacturer's trademark, and contains the words "Caution - Radioactive Material," and the radiation symbol will be attached to the entrance door of the Cobalt-60 Facility Exposure Room. Attached as Annex 1A to this supplement is a facsimile of the label to be used.

CAUTION	CATALOG NO.
	<input type="text"/>
RADIOACTIVE MATERIAL	SERIAL NO.
COBALT 60	<input type="text"/>
	CURIES
	<input type="text"/>
	DATE OF CAL.
	<input type="text"/>
	NEUTRON PRODUCTS INC. Dickerson, Maryland

SUPPLEMENT #4

Item 10, Form NRC 313 I, Radiation Detection Instruments.

Portable Instruments

<u>TYPE</u>	<u>MANUFACTURER</u>	<u>MODEL #</u>	<u>NO. AVAIL</u>	<u>RADIATION DETECTED</u>	<u>SENSITIVITY RANGE</u>
Proportional	Nuclear Measurements Corp.	PC-4	1	Alpha, beta	0-3.5 x 10 ⁶ cpm
G-M	Ludlum Measurements Inc.	Model 2	2	Beta, gamma	0.1-50 mR/hr
G-M	Victoreen	Thyac II, Model 489	1	Alpha, beta, gamma	0.05 - 20 mR/hr 50 - 800 cpm
G-M	Victoreen	Thyac III, Model 490	1	Beta, gamma	0.05 - 200 mR/hr
Ion Chamber	Victoreen	Model 440-RF	1	Gamma	1 - 300 mR/hr
Scintillation	Eberline Instrument	Gadora-1B	1	Gamma	1 - 1000 R/hr
Ion Chamber	Nuclear Chicago	Model 2592	1	Gamma, beta	0.5 - 1000 mR/hr 0 - 10 mR
G-M	Eberline Instrument	Teletector 6112B	2	Gamma, beta	0.01 - 10 ⁶ mR/hr

Area/Resin Bed Monitors

Scintillation	Nuclear Measurements Corp	Model GA-2T0	1	Gamma	0.1 - 1000 mR/hr
Scintillation	Nuclear Measurements Corp	Model GA-2T0	2	Gamma	1.0 mR/hr - 100 R/hr
Scintillation	Nuclear Measurements Corp	Model GA-2TA	1	Gamma	0.1 - 1000 mR/hr
Scintillation	Ludlum Measurements Inc.	Model 44	1	Gamma	0.02 - 20 mR/hr

Supplement #4 continued

Item 11, Form NRC 313 I, Calibration of Instruments

Portable instruments are calibrated quarterly by Rad Services, Inc., as indicated on Form NRC 313 I. A certificate of calibration by a NBS traceable source is issued by Rad Services and kept on file in the HDL Safety Office. Sources listed below are available for constancy checks.

Remote Area and Resin Bed Monitors permanently installed in the Gamma Radiation Facility are calibrated at periods not to exceed three months. Instruments are placed a known distance from a known source. Calculated values at various distances from the known sources are compared with the observed meter response. The following sources are available for calibration and constancy checks:

- a. 1 Co-60 source, 12.3 mR/h at one meter, 26 Jan 1961 (NBS calibrated)
- b. 1 Co-60 source, 1.07 mR/h at one meter, 26 Jan 1961 (NBS calibrated)
- c. 1 Co-60 source, 2.58 mR/h at one meter, 30 Nov 1972 (US Army calibrated)
- d. 1 Cs-137 " , 32.6 R/h at one meter, 2 Mar 1970 (AFRRI calibrated, traceable to NBS)
- e. Radium (D&E) check source obtained from the National Bureau of Standards approximately 28,000 counts/min alpha, plus beta, 23 Mar 1962.

See Supplement #6, Annex 6-F for calibration procedure.

SUPPLEMENT #5

Item 13, Form NRC 313 I, Facilities and Equipment.

1. Area Description and General Features of Facility Construction.

a. Facility Location and Structural Characteristics. The Cobalt-60 Gamma Radiation Facility is comprised of four rooms which are located in the Building 504 Radiation Facility at Harry Diamond Laboratories (HDL), 2800 Powder Mill Road, Adelphi, Maryland. Plan/elevation drawings which characterize the construction of the Radiation Facility and the surrounding area were presented in the initial application as Figures 5-1 through 5-33. Figure 5-1 was included in order to indicate the geographical location of the HDL Radiation Facility and its relationship to the surrounding Washington, DC suburban area. Figures 5-2 through 5-4 were included in order to present a more detailed overview of the HDL complex and provide topographical information about the area immediately surrounding the Radiation Facility. Figures 5-5 through 5-33 are the architect's drawings/specifications from which the Radiation Facility was constructed. The entire building is classified as a "noncombustible construction" type structure as defined in the National Fire Codes, Volume 9, Part 220, published by the National Fire Protection Association in 1975.

b. Location of Cobalt-60. Within the Building 504 Radiation Facility are the four rooms which comprise the Cobalt-60 Gamma Radiation Facility. These rooms are numerically designated on Figures 5-5 through 5-33 as follows: Room 2 is the Exposure Room in which all of the cobalt-60 source elements will be used and stored. Room 4 is the Control Room from which the source elevator is remotely controlled. Room 1 is an entrance maze which connects the Exposure Room to the Control Room. Room 9 is a Mechanical Equipment room which houses the Cobalt-60 elevator drive mechanism and Exposure Room air handling equipment. The cobalt-60 source elements will always be stored at the bottom of the water-filled cylindrical pool which is located in the Exposure Room, except when they are raised above the surface of the pool water via a remotely controlled source elevator. The dimensions of Rooms 1, 2, 4, and 9 are presented in Figures 5-5 and 5-7.

c. Radiation Shielding. The Exposure Room (Rm. 2) and the source storage pool located therein are designed to provide personnel protection from the ionizing radiation emanating from a 40,000 curie cobalt-60 source. The pool is designed to provide 11 feet of deionized water shielding over the sources when they are located at the bottom of the pool. As illustrated by Figure 6-1 of Supplement 6, this amount of shielding will reduce the exposure rate at the surface of the pool to less than 0.25 mR/h. Details concerning the construction of the pool are presented in Paragraph 2.a of this supplement. For in-air irradiation, the Exposure Room walls are designed for a maximum transmitted exposure rate of 0.5 mR/h to the unrestricted areas external to the Exposure Room; the roof is designed for a maximum transmitted exposure rate of 10 mR/h at the roof surface external to the Exposure Room and the entrance maze is designed for a maximum transmitted exposure rate to the maze door of less than 0.25 mR/h. The Exposure Room floor, regolith upon which it rests, and the extension of the Exposure Room walls well into the earth serve to shield the

Supplement No. 5 continued.

building and grounds areas external to the Exposure Room from exposure rates in excess of 0.25 mR/h. Since all shielding calculations involving the use of concrete were based on the assumption that the concrete would have a density of 147 pounds per cubic foot, random pour-samples were analyzed. All samples were found to meet or exceed the assumed density. Figures 5-5 and 5-7 present information concerning the thickness and composition of the radiation shielding.

d. Radiation Levels. The Cobalt-60 Gamma Radiation Facility shielding is designed to limit the exposure rate to "unrestricted areas" in and around the building to 0.5 mrem per hour. This level of exposure satisfies the requirement for "unrestricted areas" as defined in Title 10, Chapter 1, Code of Federal Regulations, Part 20.

(1) Exposure Room. Since in-air exposures require that the cobalt-60 source elements be raised from the pool via the source elevator, the source elements will be located 6 feet from the east and west walls, 28.33 feet from the north wall, 14.5 feet from the south wall and 8.5 feet from the ceiling. For purposes of in-air exposure calculations presented below, it is assumed that 32 source elements, containing a total of 40,000 curies of Co-60, are arranged in a circle with a radius of 14.49 centimeters, and raised via the elevator to a height of 5.5 feet from the Exposure Room floor. The list of references used to perform the following analysis is found in paragraph 1d(3) of this supplement.

(a) East and West Walls. According to Reference 1, page 7-71, the source-shield geometry for the east and west walls requires the use of "point isotropic" build-up factors in order to calculate the attenuation provided by the concrete walls. This determination is made as follows:

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut}$$

If $d-t < \frac{\sqrt{2ut+1}}{ut}$ and $d > t$, use "plane collimated" build-up factor. If both conditions are not true, use "point source" build-up factor.

d = distance from source array to shield = 182.88 cm

a = maximum radius of source array, measured perpendicular to d = 14.49 cm

t = shield thickness = 152.4 cm

u = linear attenuation coefficient for 1.25 MeV photons in concrete of density $2.35 \text{ gm/cm}^3 = 0.1332 \text{ cm}^{-1}$ (Reference 1, page 7-62)

$d > t = 182.88 \text{ cm} > 152.4 \text{ cm}$ (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(182.88 \text{ cm}) - (152.4 \text{ cm})} < \frac{\sqrt{2(.1332)(152.4 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} =$$

$0.4754 < 0.3177$. Since the second condition is not satisfied, one should use point isotropic source build-up factors for east and west shield wall attenuation calculations.

Use of Capo's formula for a "point source" in an infinite medium, presented in Reference 2, page 213-217, yields a conservative build-up factor of 62.4 for 1.25 MeV photons passing through 152.4 cm of ordinary concrete with a density of 2.35 gm/cm^3 . ($uX = 20.30$ mean free path lengths)

Supplement No. 5 continued.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is $A = I/I_0 = b \exp(-uX)$.

- I_0 = original exposure rate to unshielded external wall surface
- I = attenuated radiation exposure rate due to shield
- u = linear absorption coefficient (0.1332 cm^{-1})
- X = shield thickness (152.4 cm concrete)
- b = build-up factor = 62.4

$$I_0 = \left(\frac{3.28'}{11'}\right)^2 \times (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter/Ci}) = 4.695 \times 10^3 \text{ R/h}$$

Required attenuation factor for "unrestricted areas": A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 4.695 \times 10^6 \text{ mR/h} = 10.65 \times 10^{-8}$$

Attenuation factor provided by 152.4 cm of concrete =

$$A_p = b e^{-uX}$$

$$A_p = (62.4) (e^{-(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})}) = 62.4(1.527 \times 10^{-9}) \\ = 9.53 \times 10^{-8}$$

Since $A_p < A_R$ (ie, $9.53 \times 10^{-8} < 10.65 \times 10^{-8}$) the shielding for both the east and west walls in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the walls to $< 0.5 \text{ mR/h}$.

(b) North Wall. According to Reference 1, the source-shield geometry for the north wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the north wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$$d > t = 863.6 \text{ cm} > 137.16 \text{ cm}, \text{ (condition satisfied)}$$

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(863.6 \text{ cm}) - (137.16 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(137.16 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(137.16 \text{ cm})} =$$

$0.020 < 0.335$. Since this condition is also satisfied, one should use "plane collimated" build-up factors for north wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 17 for a broad parallel beam of 1.25 MeV photons passing through 137.16 cm ($uX = 18.28$ mean free paths) of ordinary concrete.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

Supplement No. 5 continued.

$$I_0 = \left(\frac{3.28'}{32.83'}\right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter/Ci}) = 5.270 \times 10^2 \text{ R/h}$$

Required attenuation factor for "unrestricted area" = A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 5.269 \times 10^5 \text{ mR/h} = 9.489 \times 10^{-7}$$

Attenuation factor provided by 137.2 cm of concrete:

$$A_p = b e^{-uX}$$

$$A_p = 17 e^{-(0.1332 \text{ cm}^{-1})(137.2 \text{ cm})} = 17(1.157 \times 10^{-8}) \\ = 1.967 \times 10^{-7}$$

Since $A_p < A_R$ (ie, $1.967 \times 10^{-7} < 9.489 \times 10^{-7}$) the shielding for the north wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to $< 0.5 \text{ mR/h}$.

(c) South Wall. According to Reference 1, the source-shield geometry for the south wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the south wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$d > t = 441.96 \text{ cm} > 152.4 \text{ cm}$, (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49 \text{ cm}}{(441.96 \text{ cm}) - (152.4 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(152.4 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} =$$

$0.05 < 0.3177$. Since this condition is also satisfied, one should use "plane collimated" build-up factors for south wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 20 for a broad parallel beam of 1.25 MeV photons passing through 152.4 cm ($uX = 20.30$ mean free paths) of ordinary concrete.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_0 = \left(\frac{3.28'}{19.5'}\right)^2 (40,000 \text{ curies}) (1.32 \text{ R/h at 1 meter/Ci}) = 1.494 \times 10^3 \text{ R/h}$$

Required attenuation factor for unrestricted area = A_R

$$A_R = \frac{I}{I_0} = 0.5 \text{ mR/h} / 1.494 \times 10^6 \text{ mR/h} = 3.347 \times 10^{-7}$$

Attenuation factor provided by 152.4 cm of concrete:

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$$A_p = b e^{-uX}$$

$$A_p = 20 e^{-(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} = 20(1.527 \times 10^{-9}) \\ = 3.055 \times 10^{-8}$$

Since $A_p < A_R$ (ie, $3.055 \times 10^{-8} < 3.347 \times 10^{-7}$) the shielding for the south wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to < 0.5 mR/h.

(d) Roof. The roof over the Cobalt-60 Gamma Radiation Facility Exposure Room is a "restricted area". Personnel access to this area is not permitted during periods when in-air irradiation are in progress. Consequently, an exposure rate of 5 mR/h at a distance of 6 inches from the outer surface of the Exposure Room roof shield slab is considered adequate.

According to Reference 1, the source-shield geometry for the roof requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the roof. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$$d > t = (213.36 \text{ cm}) > (121.92 \text{ cm}), \text{ (condition satisfied)}$$

$$\frac{a}{d-t} < \frac{\sqrt{2ut + 1}}{ut} = \frac{14.49 \text{ cm}}{(213.36 \text{ cm}) - (121.92 \text{ cm})} < \frac{\sqrt{2(0.1332 \text{ cm}^{-1})(121.92 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(121.92 \text{ cm})} =$$

$0.158 < 0.356$. Since this condition is also satisfied, one should use "plane collimated" build-up factors for roof shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 15 for a broad parallel beam of 1.25 MeV photons passing through 121.92 cm ($uX = 16.24$ mean free paths) of ordinary concrete.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_0 = \left(\frac{3.28'}{13'}\right)^2 (40,000 \text{ curies})(1.32 \text{ R/h at 1 meter/curie}) = 3.361 \times 10^3 \text{ R/h}$$

Required attenuation factor for 5 mR/h "restricted area" roof = A_R

$$A_R = \frac{I}{I_0} = 5 \text{ mR/h} / 3.361 \times 10^6 \text{ mR/h} = 1.488 \times 10^{-6}$$

Attenuation factor provided by 121.92 cm of concrete:

$$A_p = b e^{-uX}$$

$$A_p = 15 e^{-(0.1332 \text{ cm}^{-1})(121.92 \text{ cm})} = 15(8.878 \times 10^{-8}) \\ = 1.332 \times 10^{-6}$$

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Since $A_p < A_R$ (ie, $1.332 \times 10^{-6} < 1.488 \times 10^{-6}$) the shielding for the roof in the worst case is adequate to reduce the exposure rate at 6 inches past the external surface of the roof shield slab to < 5 mR/h.

(e) Floor. As illustrated on Figure 5-7, all Exposure Room walls extend well past the floor into the soil. This structural characteristic serves to shield personnel located outside of the Exposure Room from scattered photons which have passed through the floor during in-air irradiations. Since the north wall of the Exposure Room extends the shortest distance into the soil, less shielding is provided by the soil in this area than in any other. Consequently, the following analysis presents the "worst case" situation.

The shortest distance between the exposed source and a point beneath the north wall where a scatter angle of 30° exists is (18' air + 14' soil) = 32 feet.

Since the density of the sandy soil on which the facility is built is approximately equal to concrete, a conservative estimate of the soil build-up factor is obtained by extrapolation of Figure 4.3-24 in Reference 2, page 222. For 1.25 MeV photons passing through 426 cm of soil ($uX = 60$ mean free paths) a build-up factor 300 is chosen.

The mass attenuation coefficient (u/p) for sandy soil is determined by using the weighted average method presented in Reference 2, page 172. The chemical composition of the soil necessary for the determination of u/p was obtained from Reference 3. The value of u/p obtained via this method = $0.05695 \text{ cm}^2/\text{gm}$. The density of the sandy soil used for the determination of u/p is $2.471 \text{ gm}/\text{cm}^3$.

The attenuation factor " A_R " required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$I_0 = \left(\frac{3.28'}{32'} \right)^2 (40,000 \text{ curies}) (1.32 \text{ R/h at 1 meter/Ci}) = 5.55 \times 10^2 \text{ R/h}$$

$$A_R = \frac{I}{I_0} = \frac{0.5 \text{ mR/h}}{5.55 \times 10^2 \text{ mR/h}} = 9.01 \times 10^{-7}$$

Attenuation factor provided by 426 cm of soil:

$$A_p = b e^{-uX}$$

$$A_p = 300 e^{-(0.1407 \text{ cm}^{-1})(426 \text{ cm})} = 2.79 \times 10^{-24}$$

Since $A_p < A_R$ (ie, $2.79 \times 10^{-24} < 9.01 \times 10^{-7}$) the shielding provided by the soil in the worst case is adequate to reduce the exposure rate to well below 0.5 mR/h before the photons can pass from the scatter point beneath the wall to any point exterior to the building.

(f) Exposure Room Entrance Maze. As illustrated on Sketch 5-1, the maze leading from the Exposure Room to the Control Room present a path for gamma

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radiation, originating at the source elevator, which contains 3 right-angle bends. In order to conservatively calculate the exposure rate to the maze-side of the maze entrance door, the data presented in Reference 4, page 73, will be used.

The concrete walls, ceilings, and floor of the Exposure Room and Maze are in excess of 2 mean free path lengths thick (5.9 in.), and therefore are treated as being infinitely thick reflectors of 1.25 MeV cobalt-60 gamma photons. This assumption is supported by Reference 5.

Since the maze contains three right-angle bends and both the calculated and measured dose rates (D/D_0) (10^4) given in Reference 4, Table II, are for two-legged concrete ducts, the maze will be treated as a combination of 2, two-legged duct arrangements, connected in series. The dose rate at point P_2 , resulting from the cobalt-60 source located at point P_1 , is calculated. Then the dose rate at point P_3 is calculated using the dose rate at the point P_2 as the source of gamma radiation. Since the gamma photons at point P_2 will be primarily the result of Compton interaction and the data given in Reference 4, Table II is based on cobalt-60 source emitting photons with a mean energy of 1.25 MeV, the dose rate calculated for point P_3 will be conservative. In addition, the dose rate values extracted from Table II for this analysis will be greater than encountered in the actual maze due to the fact that the duct dimensions corresponding to the exposure rate values in Table II are chosen for smaller values of W , smaller values of L_1/W and smaller values of L_2/W than are encountered in the actual maze.

In addition to the symbols presented on Sketch 5-1, the following notation will be used in the calculations: D_0 = dose rate at 1 foot from the source
 D = dose rate at a point located in the second leg of a two-legged duct (ie, P_2 and P_3)

$$\begin{aligned} \underline{D_0 \text{ (point } P_1)} &= \left(\frac{3.28}{1}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) \\ &= 5.68 \times 10^5 \text{ R/h} \end{aligned}$$

D at point P_2 : Value of ($D/D_0 \times 10^4$) selected using Table II data for Terrell's work which involved the use of a 3.67 Ci Co-60 source in a duct with specifications $W = 6'$, $L_1/W = 2.0$, and $L_2/W = 3.17$.

$$\begin{aligned} D/(D_0 \times 10^{-4}) &= 0.203 \therefore D = (0.203)(D_0)(10^{-4}) \\ &= (0.203)(5.68 \times 10^5 \text{ R/h})(10^{-4}) \\ &= 11.53 \text{ R/h at point } P_2 \end{aligned}$$

D at point P_3 : Using the dose rate calculated above at point P_2 as the origin of the gamma radiation one may conservatively calculate the dose rate at point P_3 . The value of ($D/D_0 \times 10^4$) is selected using Table II data for Chapman's work which involved the use of a 2.4 Ci Co-60 source in a duct with specifications $W = 3'$, $L_1/W = 2$, and $L_2/W = 1.67$.

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$$\begin{aligned} D/(D_0 \times 10^{-4}) &= 5.95 \therefore D = (5.95)(D_0)(10^{-4}) \\ &= (5.95)(11.53 \text{ R/h})(10^{-4}) \\ &= 6.9 \times 10^{-3} \text{ R/h at point } P_3 \end{aligned}$$

Consequently, assuming air attenuation to be negligible, the dose rate at the center of the maze-side surface of the maze doors will be approximately:

$$I_1 = \frac{I_0 d_0^2}{d_1^2} = \frac{(6.9 \times 10^{-3} \text{ R/h})(2.5')^2}{(10')^2} = 0.43 \text{ mR/h}$$

(g) West Wall of Maze. Since the dose rate at the point P_2 (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value is used to evaluate the adequacy of shielding provided by the west wall of the maze. The most probable energy of the cobalt-60 gamma photons scattered through an angle of 90° as a result of a single collision is 0.362 MeV according to Reference 6, page 59. The mass attenuation coefficient from Reference 1 for 0.5 MeV gamma photons in concrete will be used in the following calculations. The dose rate at the outside surface of the west maze wall without shielding = I_0 .

$$I_0 = \frac{(11.53 \text{ R/h})(1')^2}{(14.49')^2} = 5.49 \times 10^{-2} \text{ R/h}$$

The shielding factor required to reduce the exposure rate at the outside surface of the west maze wall = A_R .

$$A_R = I/I_0 = 0.5 \text{ mR/h}/54.9 \text{ mR/h} = 9.11 \times 10^{-3}$$

The shielding factor provided by the west maze wall (61 cm of concrete) =
 $A_p = b e^{-uX}$

"b" for 12.5 mean free path lengths in concrete ≈ 15 [note $uX = (0.2045)(61 \text{ cm}) = 12.47$] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 15 e^{-(.2045 \text{ cm}^{-1})(61 \text{ cm})} = 5.73 \times 10^{-5}$$

Since $A_p < A_R$ (ie, $5.73 \times 10^{-5} < 9.11 \times 10^{-3}$) the shielding for the west wall of the maze is sufficient to reduce the dose rate at the "unrestricted area" side of the wall to $< 0.5 \text{ mR/h}$.

(h) Maze Scatter Shield. Since the dose rate at the point P_2 (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value will be used to evaluate the adequacy of shielding provided to the Control Room by the maze scatter shield. As in the analysis presented in paragraph 1d(1)(g), it will be assumed that the gamma photons have an initial energy of 0.5 MeV.

Shield factor required to reduce the dose rate at the maze-side of the maze entrance door to 0.5 mR/h is A_R .

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$$I_0 = \frac{(11.53 \text{ R/h})(1)^2}{(8.5')^2} = 1.6 \times 10^{-1} \text{ R/h}$$

$$A_R = I/I_0 = 0.5 \text{ mR/h}/160 \text{ mR/h} = 3.125 \times 10^{-3}$$

The shielding factor provided by the maze scatter shield is $A_p = b e^{-uX}$.

"b" for 9.4 mean free paths in concrete ≈ 10 [note $uX = (0.2045 \text{ cm}^{-1})(45.7 \text{ cm}) = 9.35$] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 10 e^{-(.2045 \text{ cm}^{-1})(45.7 \text{ cm})} = 8.73 \times 10^{-4}$$

Since $A_p < A_R$ (ie, $8.73 \times 10^{-4} < 3.125 \times 10^{-3}$) the shielding provided by the maze scatter shield is sufficient to reduce the dose rate at the maze-side of the maze entrance door to less than 0.5 mR/h. Consequently, the dose rate at the Control Room side of the maze entrance doors will also be less than 0.5 mR/h.

(2) Exposure Room Shielding Penetrations

(a) Exhaust Ventilation Duct. The exhaust ventilation duct penetrates the Exposure Room roof slab at a location near the south wall. As illustrated on Figures 5-7, 5-12, and Sketch 5-2, the exhaust duct is designed to provide shielding for both direct and scattered gamma radiation emanating from the cobalt-60 sources when they are utilized for in-air irradiations. All primary cobalt-60 gamma photons entering the "radiation trap" will be attenuated by a minimum of 46 inches of concrete. This amount of shielding is sufficient to reduce the exposure rate at a distance of one foot from the external surface of the "radiation trap" to less than 5 mR/h. The following "worst case" analysis assumes that the path of primary gamma photons is through 4 inches of the corner lip of the first right-angle bend in the duct prior to impinging on the south shield wall of the "radiation trap".

$$I_0 = \left(\frac{3.28'}{26'}\right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 8.403 \times 10^2 \text{ R/h}$$

Attenuation required to reduce the exposure rate to 5.0 mR/h at a distance of 1 foot from the external surface of the shield = A_R .

$$A_R = I/I_0 = 5 \text{ mR/h}/8.403 \times 10^5 \text{ mR/h} = 5.95 \times 10^{-6}$$

Attenuation provided by the concrete shield for 1.25 MeV gamma photons = A_p .

$$A_p = b e^{-uX}$$

"b" for 15.5 mean free paths = 30 (conservative estimate from Table 43.3-7, Reference 1, page 224 for $\cos \theta = 0.75$)

$$A_p = (30) e^{-(0.1332 \text{ cm}^{-1})(116.84 \text{ cm})} = 5.226 \times 10^{-6}$$

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Since $A_D < A_R$ (ie, $5.226 \times 10^{-6} < 5.95 \times 10^{-6}$) the "radiation trap" shielding for primary gamma radiation from a 40,000 curie cobalt-60 source is sufficient to reduce the exposure rate to less than 5 mR/h at a distance of one foot from the external surface of the "radiation trap".

A conservative estimate of the exposure rate at the exhaust point of the ventilation duct which passes through the "radiation trap" is obtained by using the data presented by Green in Reference 4, Table II and assuming that the exposure rate at the Exposure Room side of the duct is due to primary cobalt-60 gamma photons from a point source. In order to use the data in Reference 4, it will be assumed that the width (W) of the "radiation trap" duct is 9.47 inches instead of the actual dimension of 34 inches. The exposure rate value calculated assuming a 9.47 inch duct width will be increased by a factor of 3.59 in order to estimate the total exposure rate from the 34 inch wide duct. Use of this method effectively increases the primary and multiple surface scatter areas by 76%. Since, according to Reference 4, the primary scatter areas contribute 42% and the multiple surface scatter contributes 32% of the total dose in the second leg of a two-legged duct, the final exposure rate estimate will be approximately 56% high. In addition, the dose rate values selected from Table II are values which represent a worst case estimate. The "radiation trap" will be treated as a combination of 2, two-legged ducts connected in series. With references to Sketch 5-2, the dose rate at the point P_2 resulting from a cobalt-60 source located at point P_0 is calculated. Then, the dose rate at point P_4 is calculated using the dose rate at the point P_2 as the source of gamma radiation. Although the energy of the cobalt-60 gamma photons traveling from point P_2 to point P_3 will be degraded from previous Compton interactions, it will be assumed that they have an energy of 1.25 MeV. This assumption will also result in a higher calculated dose rate at the exhaust point than will actually be encountered.

<u>Data for First 2 Legged Duct Section</u>	<u>Data for Second 2 Legged Duct Section</u>
$L_1 = 18''$	$L_3 = 54''$
$L_2 = 28''$	$L_4 = 52''$
$W = 9.47''$	$W = 9.47''$
$L_1/W = 1.90$	$L_3/W = 5.70$
$L_2/W = 2.96$	$L_4/W = 5.49$
$(D/Do) \times (10^4)$ value selected: 66.0	$(D/Do) \times (10^4)$ value selected: 2.34

Exposure rate at point $P_0 = D_0$

$$D_0 = \left(\frac{3.28'}{17'}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 1.966 \times 10^3 \text{ R/h}$$

$$\begin{aligned} \text{Dose at Point } P_2 = D / (D_0 \times 10^{-4}) = 66 \therefore D &= (66) (D_0) (10^{-4}) \\ &= (66) (1.966 \times 10^6 \text{ mR/h}) (10^{-4}) \\ &= 1.297 \times 10^4 \text{ mR/h} \end{aligned}$$

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$$\begin{aligned} \text{Dose at Point } P_4 &= D / (D_0 \times 10^{-4}) = 2.34 \therefore D = (2.34) (D_0) (10^{-4}) \\ &= (2.34) (1.297 \text{ mR/h}) (10^{-4}) \\ &= 3.035 \text{ mR/h} \end{aligned}$$

Conservative estimate of the exposure rate at the exhaust point of the ventilation duct (point P_4): $(3.035 \text{ mR/h/section})(3.59 \text{ sections}) = 10.9 \text{ mR/h}$

(b) Elevator-Drive Cable-Ducts. Figures 5-18, 5-19 and Sketch 5-3 illustrate the wall penetrations between the Exposure Room (Rm. 2) and the Mechanical Equipment Room (Rm. 9) which serve to provide a path for the source-elevator drive-cables. Both cable-ducts are also pathways for scattered gamma radiation-streaming during in-air irradiation procedures. The following determination of exposure rate in the Mechanical Equipment Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to an in-air irradiation position 5.5 feet above the Exposure Room floor. Due to the location of the two cable-ducts, it is also assumed that all gamma photons passing through them have a reflected flight-path which is approximately parallel to the axis of the cable-duct. In order to estimate the exposure rate in the Mechanical Equipment Room from scattered gamma radiation streaming through the cable-ducts, the differential dose albedo formulas and constants presented in Reference 7 will be used. Sketch 5-3 is annotated to define the reference points used in the calculations. Since this represents a "worst case" analysis, only the lower cable-duct is considered.

Formulas Used

$$dD = \frac{D_0 \omega d \cos \theta_0 dA}{r_2^2} \quad (\text{Ref. 7})$$

Where: dD = differential dose at point of interest due to scatter
 D_0 = dose in incident beam at area dA
 r_2 = distance from scatter area to point of interest
 θ_0 = polar angle of incident radiation
 dA = differential area of reflecting surface
 ωd = differential albedo

$$\omega d = \frac{C K(\theta_s) 10^{26} + C'}{1 + \cos \theta_0 \sec \theta} \quad (\text{Ref 7})$$

Where: C & C' = Parameters for semiempirical formula given in Ref 7, Table 1, for 1 MeV photons.
 $K(\theta_s)$ = Klein-Nashina value of the energy scattering cross section per electron depending on the scatter angle θ_s [ie, (Photon scattering cross section) x (ratio of scattered to incident energy)]
 θ_0 = polar angle of incident radiation
 θ = polar angle of reflected radiation

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$$E = \frac{E_0}{1 + (E_0/0.511) (1 - \cos \theta_s)} \quad (\text{Ref 2})$$

Where: E = energy in MeV of photon after one Compton scatter
 E_0 = energy in MeV of photon before Compton scatter
 θ_s = angle through which the photon is scattered

Differential dose at point P_5 resulting from gamma photons reflected parallel to the cable duct axis at point P_2 .

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25 \text{ MeV}/0.511) (1 - \cos 131^\circ)} = 0.219 \text{ MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.219 \text{ MeV}}{1.25 \text{ MeV}} \right) = 3.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (3.5 \times 10^{-26}) (10^{26}) + (0.0111)}{1 + (\cos 49^\circ) (\sec 0^\circ)} = 0.122 \text{ sr}^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3 \text{ R/h}) (0.122 \text{ sr}^{-1}) (0.660) (5 \text{ cm}^2)}{(518 \text{ cm})^2} = 1.03 \times 10^{-2} \text{ R/h}$$

Differential dose at point P_5 resulting from gamma photons undergoing one Compton scatter in the west wall of the exposure room which redirects their flight path along the axis of the cable-duct.

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25 \text{ MeV}/0.511) (1 - \cos 49^\circ)} = 0.679 \text{ MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.679 \text{ MeV}}{1.25 \text{ MeV}} \right) = 10.9 \times 10^{-26}$$

$$\omega d = \frac{(0.0547) (10.9 \times 10^{-26}) (10^{26}) + (0.0111)}{1 + (\cos 41^\circ \sec 89^\circ)} = 0.014 \text{ sr}^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3 \text{ R/h}) (0.014 \text{ sr}^{-1}) (0.755) (5 \text{ cm}^2)}{(152 \text{ cm})^2} = 15.6 \text{ mR/h}$$

Since the exposure rate on the Mechanical Equipment Room side of the cable-duct is estimated to be in excess of 0.5 mR/h, the room will be treated as a "restricted area" during in-air irradiation procedures. Unless the initial radiation survey of the facility indicates the restriction may be removed, access to the Mechanical Equipment Room will be controlled by the Cobalt-60 Facility Supervisor via control of the door key for this room.

(c) Conduit Maze in West Wall. Figure 5-16 illustrates a conduit maze consisting of four aluminum conduits, each of which contain two right-angle bends. These 4-inch diameter conduits serve as raceways between the Exposure

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Room and Control Room. The following estimate of the exposure rate to be expected in the Control Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height above the floor equal to that of the conduit. Since the two conduits closest to the source represent the "worst case" for gamma radiation streaming, only these conduits are examined in the following analysis. Also, since the total mass attenuation coefficients for concrete and aluminum are nearly equal, the walls of the conduit are considered to be concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

Exposure rate to conduit opening = D_o

$$D_o = \left(\frac{3.28}{8.71}\right)^2 (4.0 \times 10^4 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 7.5 \times 10^3 \text{ R/h}$$

E = energy in MeV after one Compton scatter

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25/0.511)(1 - \cos 46^\circ)} = 0.71 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.71}{1.25}\right) = 1.14 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\alpha d = \frac{(0.0547) (1.14 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (0.728)(57.3)} = 0.015 \text{ sr}^{-1}$$

Assume that the first leg of the conduit perpendicular to the plane of the wall extends a distance of 2.5 feet into the wall. Then the exposure rate at the beginning of the first right-angle bend = dD .

$$dD = \frac{(7.5 \times 10^6 \text{ mR/h}) (0.015 \text{ sr}^{-1}) (0.728) (31 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.14 \times 10^3 \text{ mR/h}$$

The exposure rate at the surface of the shield wall in the Control Room due to a collimated source of 0.8 MeV photons, which yields an exposure rate of 1.14×10^3 mR/h, and is located midway in the west wall = I .

$$I = I_o b e^{-uX} = (1.14 \times 10^3 \text{ mR/h}) (5) \exp^{-(0.1659)(76.2 \text{ cm})}$$

$I = 1.8410^{-2}$ mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of the conduit is 3 feet long and is directed away from the first leg of conduit at an angle of 89° . The exposure rate at the end of the second leg of conduit is:

$$E = \frac{0.71 \text{ MeV}}{1 + \left(\frac{0.71}{0.511}\right) (1 - 0.707)} = 0.505$$

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$$K(\theta_s) = (0.25 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.505}{0.71} \right) = 17.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (17.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (1)(57.3)} = 0.017 \text{ sr}^{-1}$$

$$dD = \frac{(1.14 \times 10^3 \text{ mR/h}) (0.017 \text{ sr}^{-1}) (1) (81 \text{ cm}^2)}{8.36 \times 10^3 \text{ cm}^2} = 0.188 \text{ mR/h}$$

Since the exposure rate at the beginning of the second right-angle bend will be less than 0.5 mR/h, the exposure rate at the point the conduit exits in the Control Room will also be less than 0.5 mR/h.

(d) Water Pipe for Emergency Pool Water Makeup. Figures 5-13, 5-14 and 5-21 illustrate the emergency pool water makeup which is located in the wall which separates the Exposure Room from the Mechanical Equipment Room. This 2-inch diameter pipe contains two right-angle bends and is positioned such that the point of entry in the Mechanical Equipment Room is 2 feet above the floor and the point of exit in the Exposure Room is 6 inches above the floor. The following estimate of the expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

D_0 = Exposure rate to wall at point of pipe penetration

$$D_0 = \left(\frac{3.28'}{8.06'} \right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 8.74 \times 10^3 \text{ R/h}$$

E = Energy in MeV after 1 Compton scatter through 18°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511} \right) (1 - \cos 18^\circ)} = 1.12 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{1.12}{1.25} \right) = 1.79 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (1.79 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 72^\circ) (\sec 89^\circ)} = 0.053 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD

$$dD = \frac{(8.74 \times 10^6 \text{ mR/h}) (0.053 \text{ sr}^{-1}) (0.309) (20 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 4.93 \times 10^2 \text{ mR/h}$$

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The exposure rate at the Control Room surface of the shield wall resulting from a 493 mR/h source of 1.12 MeV gamma photons located behind 2.5 feet of concrete = I.

$$I = I_0 b e^{-uX} = (493 \text{ mR/h})(10) e^{-(0.1492)(76.2 \text{ cm})}$$

$$I = 0.06 \text{ mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".}$$

Assume that the second leg of the pipe is 5 feet long and is directed away from the first leg at an angle of 89°. The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:

$$E = \frac{1.12 \text{ MeV}}{1 + \frac{1.12}{(0.511)}(1 - \cos 89^\circ)} = 0.355 \text{ MeV}$$

$$K(\theta_s) = (0.2023 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.355}{1.12} \right) = 0.64 \times 10^{-25} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547) (6.4 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 0^\circ)(\sec 89^\circ)} = 6.2 \times 10^{-3} \text{ sr}^{-1}$$

$$dD = \frac{(493 \text{ mR/h}) (6.2 \times 10^{-3} \text{ sr}^{-1}) (1) (20 \text{ cm}^2)}{(2.32 \times 10^4 \text{ cm}^2)} = 2.64 \times 10^{-3} \text{ mR/h}$$

Since the exposure rate at the beginning of the second right-angle bend is less than 0.5 mR/h, the exposure rate at the point the pipe exits into the Mechanical Equipment Room will also be less than 0.5 mR/h.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.7 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the final right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

I_0 = Exposure rate at second right-angle bend without shield.

$$I_0 = \left(\frac{3.28}{91} \right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 7.01 \times 10^3 \text{ R/h}$$

Exposure rate at second right-angle bend with 2.7 feet of concrete shielding = I

$$I = I_0 b e^{-uX} = (7.01 \times 10^6 \text{ mR/h})(20) e^{-(.1332 \text{ cm}^{-1})(82 \text{ cm})} = 2.53 \times 10^3 \text{ mR/h}$$

$$K(\theta_s) = (0.20 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.8}{1.25} \right) = 12.2 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

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$$\omega d = \frac{(0.0547) (12.2 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\text{Cos } 69^\circ) (\text{sec } 89^\circ)} = 3.15 \times 10^{-2} \text{ sr}^{-1}$$

$$dD = \frac{(2.53 \times 10^3 \text{ mR/h}) (3.15 \times 10^{-2} \text{ sr}^{-1}) (0.358) (5 \text{ cm}^2)}{5.81 \times 10^3 \text{ cm}^2} = 0.026 \text{ mR/h}$$

which is also less than the 0.5 mR/h limit for "unrestricted areas".

(e) Water Pipe for Normal Pool Water Makeup. Figures 5-13 and 5-14 illustrate a $\frac{1}{2}$ -inch diameter water pipe, which passes from the Mechanical Equipment Room through the west shield wall to the southwest corner of the Exposure Room. The pipe passes horizontally through the shield wall at a distance of 2.5' beneath the floor and contains a right-angle bend on each side of the shield wall which allows vertical floor penetration in both rooms. Since this pipe is part of the automatic pool water makeup system, it is normally filled with water. Consequently, all gamma radiation entering the pipe during in-air irradiation procedures will be attenuated to some degree. The following estimate of the exposure rate to be expected in the Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a position 5.5 feet above the Exposure Room floor. Conservatively assuming that all gamma photons reaching the Mechanical Equipment Room through the pipe have scattered through an angle of 90° as a result of a single collision, their most probable energy will be approximately 0.4 MeV (Reference 6). Also assuming that the gamma photons travel a straight line distance equivalent to the total length of the water-filled pipe, allows a conservative estimate of the exposure rate at the Mechanical Equipment Room side of the pipe.

I_0 = exposure rate at the pipe location in the Exposure Room.

$$I_0 = \left(\frac{3.28}{15.98} \right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 2.22 \times 10^3 \text{ R/h}$$

$I = I_0 b \exp(-uX)$ = exposure rate at pipe location in Mechanical Equipment Room.

Where: u = linear attenuation coefficient for 0.4 MeV photons in water = 0.106 cm^{-1}

X = total length of photon path in pipe = 304.8 cm

b = buildup factor for 0.4 MeV photons in water, with $uX = 32.3$ is $\approx 10^3$ (Reference 6).

$$I = (2.22 \times 10^6 \text{ mR/h}) (10^3) \exp^{-(0.106 \text{ cm}^{-1}) (304.8 \text{ cm})} = 2.1 \times 10^{-5} \text{ mR/h}$$

NOTE: Assuming a gamma photon energy of 1.25 MeV and a straight line distance of 304.8 cm, the exposure rate at the pipe location in the Mechanical Equipment Room is 0.2 mR/h.

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(f) Emergency Air Pressure Release Line for Elevator Drive. Figures 5-14 and 5-20 illustrate the 3/8-inch diameter air line which passes through the shield wall between the Exposure Room and Mechanical Equipment Room. This line connects the emergency-air pressure release valve in the Exposure Room to the air supply for the pneumatically driven elevator drive piston located in the Mechanical Equipment Room. This pipe contains two right-angle bends, and is located 4 feet above floor level. The following estimate of expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

D_0 = exposure rate to wall at point of pipe penetration.

$$D_0 = \left(\frac{3.28'}{8'}\right)^2 (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 8.88 \times 10^3 \text{ R/h}$$

E = Energy in MeV after one Compton Scatter through 41°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511}\right) (1 - \cos 41^\circ)} = 0.782 \text{ MeV}$$

$$K\theta_s = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}}) \left(\frac{0.782}{1.25}\right) = 12.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}$$

$$\langle d = \frac{(0.0547) (12.5 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}) (10^{26}) + (0.0111)}{1 + (\cos 49^\circ) (\sec 89^\circ)} = 0.018 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD .

$$dD = \frac{(8.88 \times 10^6 \text{ mR/h}) (0.018 \text{ sr}^{-1}) (0.656) (1 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 180.6 \text{ mR/h}$$

The exposure rate at the Control Room surface of the shield wall resulting from a 181 mR/h source of 0.8 MeV photons located behind 2.5 feet of concrete = I .

$$I = I_0 b e^{-uX} = (181 \text{ mR/h}) (20) e^{-(0.1659 \text{ cm}^{-1}) (76.2)} = 0.012 \text{ mR/h}$$

$I = 0.012 \text{ mR/h}$, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of pipe is 5 feet long and is directed away from the first leg at an angle of 89° . The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:

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$$E = \frac{0.782 \text{ MeV}}{1 + (0.782/0.511)(1 - \cos 89^\circ)} = 0.312 \text{ MeV}$$

$$K(\theta_s) = (0.24 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.312}{0.782} \right) = 9.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547)(9.6 \times 10^{-26})(10^{26}) + (0.0111)}{1 + (\cos 0^\circ)(\sec 89^\circ)} = 0.01 \text{ sr}^{-1}$$

$$dD = \frac{(181 \text{ mR/h})(0.01 \text{ sr}^{-1})(1)(1 \text{ cm}^2)}{(2.32 \times 10^4 \text{ cm}^2)} = 7.8 \times 10^{-5} \text{ mR/h}$$

Since the exposure rate at the beginning of the second right angle bend is less than 0.5 mR/h, it will also be less than 0.5 mR/h at the point the pipe exits in the Mechanical Equipment Room.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.54 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the second right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

I_0 = Exposure rate at right-angle bend without shield.

$$I_0 = \left(\frac{3.28}{8.63} \right)^2 (40,000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 7.63 \times 10^3 \text{ R/h}$$

The exposure rate at the second right-angle bend with 2.54 feet of concrete shielding = I .

$$I = I_0 b e^{-uX} = (7.63 \times 10^6 \text{ mR/h})(20) e^{-(0.1332 \text{ cm}^{-1})(77.4 \text{ cm})}$$

$$I = 5.08 \times 10^3 \text{ mR/h}$$

$$K(\theta_s) = (0.20 \times 10^{-24}) \left(\frac{0.8}{1.25} \right) = 12.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega d = \frac{(0.0547)(12.8 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-})(10^{26}) + (0.0111)}{1 + (\cos 10^\circ)(\sec 89^\circ)} = 0.0002 \text{ sr}^{-1}$$

$$dD = \frac{(5.08 \times 10^3 \text{ mR/h})(0.0002 \text{ sr}^{-1})(0.985)(1 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.7 \times 10^{-4} \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for "unrestricted areas".

(g) Electrical Conduits. Figure 5-18 illustrates three electrical conduits which are 2 inches in diameter and pass through the west shield wall of the

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Exposure Room at a height of 8 feet above the floor. The physical dimensions of all three conduits are identical and each contains 2 right-angle bends. Since "conduit B" is located closest to the cobalt-60 sources during in-air irradiations, it provides a more direct path for gamma radiation streaming than either of the other two conduits. Consequently, the following estimate of the exposure rate in "unrestricted areas" due to any of the three conduits is based on "conduit B". It is further assumed that the conduit is filled with air, that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor and that the total mass attenuation coefficient of the conduit material is equal to that of concrete. The semi-empirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

D_0 = exposure rate to wall at point of conduit penetration.

$$D_0 = \left(\frac{3.28^2}{7.41} \right) (40,000 \text{ Ci}) (1.32 \text{ R/h at 1 meter per Ci}) = 1.04 \times 10^4 \text{ R/h}$$

E = energy in MeV after one Compton scatter through 36°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511} \right) (1 - \cos 36^\circ)} = 0.85 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{\text{cm}^2}{\text{e}^-}) \left(\frac{0.85}{1.25} \right) = 13.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}$$

$$\omega_d = \frac{(0.0547) (13.6 \times 10^{-26} \frac{\text{cm}^2}{\text{e}^-}) (10^{26}) + (0.0111)}{1 + (\cos 54^\circ) (\sec 89^\circ)} = 0.022 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD .

$$dD = \frac{(1.04 \times 10^7 \text{ mR/h}) (0.022 \text{ sr}^{-1}) (0.588) (20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 4.64 \times 10^3 \text{ mR/h}$$

The exposure rate at the Control Room surface of the shield wall resulting from a 4.64×10^3 mR/h source of 0.85 MeV photons located behind 2.5 feet of concrete = I .

$$I = I_0 b e^{-uX} = (4.64 \times 10^3 \text{ mR/h}) (20) e^{-(0.1659 \text{ cm}^{-1}) (76.2 \text{ cm})} = 0.3 \text{ mR/h}$$

$I = 0.3$ mR/h, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume the second leg of conduit is 2.5 feet long and is directed away from the first leg at an angle of 89° . The exposure rate at the end of the second leg of conduit, located at the beginning of the second right-angle bend, is:

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$$E = \frac{0.85 \text{ MeV}}{1 + \left(\frac{0.85}{0.511}\right) (1 - \cos 89^\circ)} = 0.32 \text{ MeV}$$

$$K(\theta_s) = (0.23 \times 10^{-24} \frac{\text{cm}^2}{\text{e}}) \left(\frac{0.32}{0.85}\right) = 8.66 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}$$

$$\omega_d = \frac{(0.0547) (8.66 \times 10^{-26} \frac{\text{cm}^2}{\text{e}}) (10^{26}) + (0.0111)}{1 + (\cos 0^\circ) (\sec 89^\circ)} = 0.008 \text{ sr}^{-1}$$

$$dD = \frac{(4.64 \times 10^3 \text{ mR/h}) (0.008 \text{ sr}^{-1}) (1) (20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 1.28 \text{ mR/h}$$

The exposure rate at the point the conduit enters the Control Room resulting from a 1.76 mR/h source of 0.3 MeV photons which pass from the location of the second right-angle bend to the Control Room via 2.5 feet of air-filled conduit is estimated below. For a straight cylindrical duct with radius R and length L, the line-of-sight exposure contribution at the end of the duct due to a point isotropic source at the entrance of the duct is proportional to $1/L^2$ (Reference 2, paragraph 8.1.2).

$$I = I_0/L^2 = 1.76 \text{ mR/h} / (2.5)^2 = 0.28 \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for unrestricted areas.

(3) References.

(a) Reference 1: Etherington, Nuclear Engineering Handbook, McGraw-Hill Book Company Inc., New York, (1958).

(b) Reference 2: Engineering Compendium on Radiation Shielding, Volume I, "Shielding Fundamentals and Methods", Springer-Verlag New York Inc., (1968).

(c) Reference 3: F. E. Bear, Chemistry of the Soil, 2nd Ed., (1964), 118.

(d) Reference 4: J. M. Chapman and C. M. Huddleston, "Dose Attenuation in Two-Legged Concrete Ducts for Various Gamma Ray Energies", Nuclear Science and Engineering, Volume 25, American Nuclear Society Inc., Hinsdale, IL, (1966), 66-74.

(e) Reference 5: Martin-Leimdörfer, "The Backscattering of Gamma Radiation from Plane Concrete Walls", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 345-351.

(f) Reference 6: Price, Horton and Spinney, Radiation Shielding, Pergamon Press, (1957).

(g) Reference 7: A. B. Chilton, "A Semiempirical Formula for Differential Dose Albedo for Gamma Rays on Concrete", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 419-424.

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(4) Occupancy of Shielded Areas: Immediately surrounding the Exposure Room are building and grounds areas which are shielded against the ionizing radiation emanating from the cobalt-60 sources during in-air irradiations. An estimate of the degree and type of occupancy for these areas during in-air irradiation procedures is given below. This estimate assumes normal operating conditions during a 40 hour work week. The calculated exposure rate values given in the table are "worst case" values which result from the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the Exposure Room floor.

AREA	TYPE OCCUPANCY	DEGREE OF OCCUPANCY	CALCULATED EXPOSURE RATE
Entrance Maze (Rm. 1)	None	0%	>0.5 mR/h
Control Room (Rm. 4)	Radiation Worker	100%	<0.5 mR/h
Mechanical Equip. Rm. (Rm. 9)	None	0%	<16.0 mR/h
Restroom (Rm. 8)	Non-Radiation Worker	25%	<0.5 mR/h
Plasma Lab (Rm. 18)	Non-Radiation Worker	100%	<0.5 mR/h
Rad. Material Storage (Rm. 19)	Radiation Worker	25%	<0.5 mR/h
Decon Area (Rms. 20, 21, 22)	Radiation Worker	0%	<0.5 mR/h
Preparation Room (Rm. 10)	Non-Radiation Worker	100%	<0.5 mR/h
Instrumentation Room (Rm. 5)	Non-Radiation Worker	100%	<0.5 mR/h
Van de Graaf Room (Rm. 3)	Radiation Worker	100%	<0.5 mR/h
Exposure Room Roof	None	0%	<10.0 mR/h
Grounds Areas	Non-Radiation Worker	25%	<0.5 mR/h

e. Personnel Exclusion Barriers. (1) The sole entrance to the Cobalt 60 Exposure Room is provided by the double doors between the Control Room and the entrance maze which leads to the Cobalt-60 Exposure Room. These doors are interlocked to preclude the possibility that an individual could inadvertently enter the Exposure Room during in-air-irradiation procedures. Before the source elevator drive system is functional, the operator must (1) enter the Exposure Room, (2) actuate the in-cell reset switch with the same key that operates the elevator system, (3) exit from the Exposure Room, and (4) close the maze entrance doors within approximately 15 seconds from the time the in-cell reset switch is actuated. If this sequence of operator actions is accomplished in the prescribed period of time, the maze entrance doors are automatically locked and the elevator drive controls become operational. Should the operator fail to accomplish this sequence of procedures in the prescribed time, no power is available to the elevator drive system and the procedure must be repeated before elevator operation may commence. In order to ensure that no individual is prevented from leaving the Exposure Room, a manually operated "crash bar" is installed on the maze-side of the doors which provides a means of emergency exit at all times. If either of the maze entrance doors are opened after the operator completes the preoperational sequences described above, the electrical power necessary to raise and sustain the elevator car in an uplifted position is lost until the preoperational sequence is performed again.

(2) The mechanical equipment room (Rm. 9) contains the only roof scuttle in the Building 504 Radiation Facility. Access to the roof via this scuttle

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will be denied during in-air-irradiation procedures, which cause the exposure rate at the surface of the roof to exceed 0.5 mR/h, by locking the door to the mechanical equipment room. During these periods, access to the mechanical equipment room will be controlled by the Cobalt-60 Facility Supervisor, Chief Operator, or Alternate Operator.

f. Contamination Control. (1) Although each of the cobalt-60 source elements is doubly encapsulated, as described in Supplement No. 1 of this application, the Exposure Room, Entrance Maze, and Control Room are designed to ensure containment/entrapment of soluble and insoluble particulates. All three areas are equipped with seamless; acid-resistant floors, and epoxy-coated walls and ceilings. The floor drain in the Exposure Room and sink drain in the Control Room vent to a 4000 gallon acid-resistant holding tank. Due to the remote possibility that the liquid effluents might contain trace amounts of radioactive material, no fluid from the holding tank will be discharged to the sanitary sewage system unless an analysis has been performed to assure that it does not exceed the maximum permissible concentration (MPC) guides set forth in Title 10, Code of Federal Regulations, Part 20. The plumbing plan and holding tank for liquid effluents are illustrated on Figures 5-13 and 5-14 respectively.

(2) Heating and cooling of the Exposure Room is accomplished via a "closed-loop" air conditioning system which isolates the supply and exhaust air for this area from the rest of the Building 504 Radiation Facility. As illustrated on Figures 5-11 and 5-12, the exhaust plenum in the Exposure Room is equipped with high-efficiency-particulate-air (HEPA) filters through which all effluent room air must pass. The air handling system continuously delivers air to the Exposure Room at a rate of 2885 cubic feet per minute (CFM) and exhausts it at a rate of 3000 CFM. Consequently, a negative pressure is maintained in the Exposure Room which assures filtration of all room air. After passing through the exhaust filters in the Exposure Room, 290 CFM is discharged to the outside environment and 2710 CFM is recirculated to the air handling unit (AH-1). Finally, fresh air is added to the recirculated air at a rate of 175 CFM in order to sustain the 2885 CFM delivery of conditioned air to the Exposure Room.

g. Ozone Production, Detection, and Control. (1) During in-air irradiation procedures ozone will be produced in the Exposure Room as a result of air ionization processes. The following analysis of radiation-induced ozone formation in the Exposure Room assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a height of 5.5 feet above the floor. It is further assumed that each gamma photon emanating from the cobalt-60 source travels the entire length of the Exposure Room. The investigation of G. R. A. Johnson and J. M. Warman presented in "Formation of Ozone from Oxygen by the Action of Ionizing Radiations", Discussions of the Faraday Society, Volume 37, (1964), 87-95, indicates that the yield of O_3 from O_2 may be as high as $G(O_3) = 13$ molecules of O_3 per 100 eV. Although this value of $G(O_3)$ may be somewhat high, due to the presence of other rare gasses in breathing air, it will be used to ensure that the following analysis yields conservative results.

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Exposure room volume: $2.04 \times 10^8 \text{ cm}^3$

Air path for each photon: $r = 1.31 \times 10^3 \text{ cm}$

Linear energy absorption coefficient for air = $u_a = 0.32 \times 10^{-4} \text{ cm}^{-1}$

$$u_{ar} = (1.31 \times 10^3 \text{ cm})(0.32 \times 10^{-4} \text{ cm}^{-1}) = 0.04192$$

Since 21% of air is O_2 , multiply u_{ar} by 0.21

$$u_{ar} = (0.04192)(0.21) = 8.8 \times 10^{-3}$$

$$\begin{aligned} \therefore \text{the energy absorbed by } O_2 \text{ in 1310 cm of air} &= 1 - e^{-u_{ar}} \\ &= 1 - e^{-0.0088} \\ &= 0.009 \end{aligned}$$

Since cobalt-60 emits an average of 2.5 MeV/dis. the energy absorbed by room air per second = $(4 \times 10^4 \text{ ci})(3.7 \times 10^{10} \text{ dis/sec-ci})(2.5 \text{ MeV/dis})(0.009) = 3.33 \times 10^{13} \text{ MeV/sec}$.

$$(3.33 \times 10^{19} \text{ eV/sec})(13 \text{ molecules/100 eV}) = 4.33 \times 10^{18} \text{ molecules } O_3/\text{sec}$$

$$\left(\frac{4.33 \times 10^{18} \text{ molecules } O_3/\text{sec}}{6.02 \times 10^{23} \text{ molecules/gm mole}} \right) \left(\frac{48 \text{ gm } O_3}{\text{gm mole}} \right) = 3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}$$

$\therefore 3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}$ is produced in the Exposure Room.

$$\frac{3.45 \times 10^{-4} \text{ gm } O_3/\text{sec}}{2.04 \times 10^8 \text{ cm}^3 \text{ air}} = 1.69 \times 10^{-12} \text{ gm } O_3/\text{sec cm}^3 \text{ air}$$

$$\& \frac{1.69 \times 10^{-12} \text{ gm } O_3/\text{sec cm}^3 \text{ air}}{1.293 \times 10^{-3} \text{ gm air/cm}^3 \text{ air}} = 1.31 \times 10^{-9} \text{ gm } O_3/\text{sec-gm air}$$

$$\& (1.31 \times 10^{-9} \text{ gm } O_3/\text{sec-gm air})(3.6 \times 10^3 \text{ sec/hr}) = 4.72 \times 10^{-6} \text{ gm } O_3/\text{hr-gm air}$$

= 4.72 PPM O_3 produced in the Exposure Room air in a period of one hour as a result of the photons emanating from a 40,000 curie cobalt-60 source.

(2) Since the approximate half-life of ozone at 20°C is 3 days, and also since 90% of the air removed from the Exposure Room is returned during the normal operating mode of the "closed-loop" ventilation system, the Cobalt-60 Gamma Radiation Facility is equipped with ozone detection and control equipment. In order to continuously measure the ozone concentration in the Exposure Room during in-air-irradiation procedures, a Bendix Ozone Detector, Model 8002, is installed in the Control Room. A sampling tube, extending from the unit to a location adjacent to the source elevator, provides the unit with a representative sample of Exposure Room air. The detector analyzes the air sample by the chemiluminescence principle, and displays results which lie within a 0.01 to 1.0 PPM O_3 range. As illustrated on Figure 5-23, the Cobalt-60 Facility control-console houses a meter which reproduces the reading displayed at the detector unit. In addition, the VISI-CON Annunciator Monitor, located adjacent to the control console, produces an

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audio-visual signal if the ozone monitor is not operating or if high ozone concentrations are present in the Exposure Room.

(3) The normal operating mode of the "closed-loop" ventilation system keeps the Exposure Room at negative pressure with respect to the rest of the building. Consequently, unless exhausted to the roof of Building 504, any ozone produced by in-air irradiation procedures will remain in the Exposure Room and in the ducts of the "closed-loop" ventilation system. When it is desirable to reduce the ozone concentration in the Exposure Room, the control-console operator manually actuates a "purge cycle" control switch. During a purge cycle, the air handling system continuously delivers fresh air to the Exposure Room at a rate of 3000 CFM and exhausts air from the Exposure Room to the roof of Building 504 at the same rate. No room air is recirculated during a purge cycle. Thus, the control console operator is always able to reduce the ozone concentration in the Exposure Room to the 0.1 PPM threshold limit value recommended by the Occupational Health and Safety Administration (OSHA).

h. Fire Protection. As pointed out in paragraph 1a of this supplement, the Cobalt-60 Gamma Radiation Facility is located within a building which is classed as a "noncombustible construction" type structure. All areas within Building 504 are equipped with fire detection/alarm units which provide local warning to building occupants and also transmit the alarm signal to a panel which is monitored in the HDL Central Guard Office. The Cobalt-60 Facility is equipped with combination fixed temperature/rate of rise Thermal Fire Detectors in order to ensure reliability both during and after exposures to high levels of ionizing radiation. Emergency response to fire alarms is provided by HDL fire protection personnel, four nearby county fire departments and the Naval Surface Weapons Center Fire Department which is located adjacent to HDL.

i. Seismic Analysis. (1) The Building 504 Radiation Facility was designed in accordance with the criteria, guidance, and standards furnished in US Army Technical Manual 5-809-10, "Seismic Design for Buildings", published March 1966. This manual assigns each geographical location in the United States to one of five "seismic zones" which are designated by the numbers 0 through 4. Assignment of a high seismic zone number to a region, indicates that a high probability of severe, frequent and damaging earthquakes exists in that region. The fact that the entire State of Maryland is designated as being in Seismic Probability Zone 1 indicates only minor damage is to be expected from any earthquake which might occur in this region. Although the evidence is not conclusive, and any prediction is uncertain at best, Freeman states (Freeman, John R., 1932, Earthquake Damage and Earthquake Insurance, New York: McGraw-Hill Book Co.) that only one destructive earthquake may be expected per century in the Atlantic region, comprising 600,000 square miles and extending from Quebec to Florida. The likelihood that the epicenter of a destructive earthquake would be in or near the Washington, DC area seems remote.

(2) Since the Cobalt-60 Gamma Radiation Facility is located in a building which was designed in accordance with US Army seismic design criteria for this geographical region, it seems highly unlikely that the shielding, pool, or

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complementary structures would be subject to rupture, shifting, or tilting as a result of any probable seismic phenomena.

2. Irradiator System and Operational Characteristics.

a. Pool and Associated Equipment. (1) The cobalt-60 source elements will be stored in the exposure room at the bottom of the 12 feet deep, water filled pool illustrated in Figures 5-5, 5-7, and 5-18. The concrete used to construct the one foot thick walls and floor of the pool were poured monolithically in one continuous pour and thoroughly vibrated by mechanical vibrators. The entire internal surface area of the pool is lined with a 3/16 inch thick, A-304 stainless steel liner in order to ensure water-tight integrity. Immediately surrounding the edge of the pool is a concrete toeboard which is 4 inches in height. Removable pipe railings, which meet the specifications presented in 29 CFR Part 1910-23, Occupational Safety and Health Act, are inserted into the toeboard on all sides of the pool in order to provide a personnel protective barrier for the floor opening. In addition to the toeboard and railing, the surface area of the pool is protected by a "metal grating" type floor-hole cover which is designed to support a live load of 200 pounds per square foot. As illustrated in Figure 5-6, the floor hole cover consists of 10 sections of removable grating and two removable supports which accommodate the rails for a movable cart. By removing a section of grating, an individual may work safely over the pool while supported by the remaining sections of the floor hole cover. Two underwater lighting fixtures, similar to those illustrated on Figure 5-15, are attached to removable sections of grating and suspended beneath the surface of the pool water in order to provide sufficient light for source element manipulation and accurate positioning of experiment containers. Both fixtures meet the specification and installation requirement set forth in the National Electrical Code (NFPA No. 70-1975) for "underwater lighting fixtures".

(2) The pool water circulation/treatment system consists of a 50 gallon per minute circulating pump, a replaceable sediment filter, and two mixed-bed resin demineralizers. As illustrated on Figures 5-17, 5-18, and 5-21, pool water is continuously extracted at a point two feet below the pool curb and is filtered and deionized before being returned to the bottom of the pool. Since the circulation system inlet is located one foot below the water, it is impossible to remove more than one foot of water shielding should one of the system water lines accidentally burst. This system will recirculate the entire volume of pool water approximately 28 times a day and maintain pool water conductivity at less than 10 micromhos per centimeter without difficulty. A pool water conductivity monitor, installed at the inlet of the circulation pump, continuously analyzes the pool water and transmits an alarm to the Control Room annunciator panel if the ion concentration in the pool water is detrimental to source encapsulation life expectancy. Two in-line pressure gauges, one on each side of the sediment filter, provides a visual indication of water circulation system performance.

(3) Pool water is maintained at a depth of 11 feet by an automatic water level sensing/replacement system. As illustrated in Figures 5-17, 5-18, and 5-23, the pool water level indicator, located in the Control Room, indicates the water level in the pool by responding to a change in the water pressure applied to an evacuated tube. Four adjustable, pressure-actuated switches are attached to the water level indicator for the purpose of providing electrical contact openings for alarm and water level control equipment circuits. Switch #1 initiates a "high level" alarm on the control room annunciator panel when the pool water level is between 136 and 138 inches. Switch #2 interrupts power to the pool water circulation pump when the pool water level is between 126 and 130 inches. Switch #3 energizes the solenoid valves illustrated on Figure 5-21 to refill the pool when the water level is between 132 and 135 inches. Switch #4 initiates a "low level" alarm on the control room annunciator panel if the pool water level drops to 126 inches. The solenoid valves actuated by switch #3 may also be operated manually from the control console. Although water will normally be added to the pool via the above mentioned solenoid valves, one may always add water manually by utilizing the emergency-fill water system illustrated on Figures 5-14, 5-18, and 5-21. The manually operated gate valve for this system is located in the Mechanical Equipment Room in order to assure that water may always be added to the pool without entering the Exposure Room.

(4) If an unexpected event causes overflowing of the pool, the excess water will be contained by the seamless, acid-resistant floor of the Exposure Room and vented to a 4000 gallon acid-resistant holding tank via the Exposure Room floor drain. As explained in paragraph 1f(1) of this supplement, no fluid is discharged from this holding tank to the sanitary sewage system unless an analysis confirms that radioactive material concentrations are below the maximum permissible concentration guides set forth in Title 10, Code of Federal Regulations, Part 20.

b. Cobalt-60 Source Elevator and Associated Equipment. (1) The Cobalt-60 Source Elevator system is designed for two principle modes of operation. The Console Operational Mode (COM) permits one to operate the system from the Control Room during free-air-irradiation procedures. The In-cell Operational Mode (ICOM) permits operation of the system using controls located adjacent to the pool. Use of the ICOM is restricted to operations involving maintenance of the elevator system, attachment of source holding fixtures to the elevator car platform, and lowering experimental products to the bottom of the pool, where the source material is stored.

(2) Mechanical design of the elevator system incorporates both safety and utilitarian considerations. As illustrated on Figure 5-18, the elevator assembly used to raise cobalt-60 source elements for free air irradiation, or to lower product to the source elements for in pool irradiation, is permanently positioned against the wall of the exposure room pool and contains a multiplicity of $1\frac{1}{2}$ inch diameter holes in order to ensure that the water level in the shaft equals that of the pool. The cable-driven elevator car,

illustrated on Figures 5-18 and 5-19, is mechanically restricted to vertical movement along an elevator shaft which extends from the bottom of the pool to a distance of 7 feet above the exposure room floor. A platform, containing tapped holes to permit rigid attachment of a variety of source holding fixtures, is bolted to the base of the elevator car. The design of each source holding fixture will be reviewed by the HDL Radiation Control Committee prior to fabrication or use in order to assure that the fixture will restrain source element movement under all conceivable conditions. Structural design of the elevator limits the maximum distance the platform may rise above the exposure room floor to 5 feet 8 inches. The speed and distance traveled by the cable-driven elevator car is controlled by adjusting the speed and distance traveled by an aircraft cable attached to a pneumatic piston and counter weight assembly located in the mechanical equipment room and control room respectively. As illustrated on Figures 5-18 and 5-20, an Air Control Box located in the mechanical equipment room contains (1) an air supply valve for the elevator drive cylinder; (2) an air pressure regulator assembly for limiting, regulating and conditioning the air supply for the elevator drive; (3) a descent control valve for limiting elevator car descent speed; (4) an ascent control valve for limiting elevator car ascent speed; and (5) a four way solenoid valve used to change the routing of the air supply on command of the control console causing either ascent or descent of the elevator car. A 150 PSI reserve surge tank is incorporated into the air supply system for the purpose of supplying sufficient reserve air capacity to return the elevator car to the pool bottom in the event the power and/or primary air supply system fails. An additional positive down-drive for the elevator car is provided by the aforementioned 50 pound counter weight assembly located in the control room. Although it is not well illustrated by Figures 5-18, 5-19, and 5-20, the counter weight assembly is designed to continuously exert a downward force on the elevator car by routing the counter weight support cable to the base of the elevator car via a sheave assembly welded to the bottom of the pool. Consequently, the elevator drive system must exert sufficient pneumatic force to raise both the elevator car and the counter weight when sources are raised from the pool bottom. If the pneumatic elevator drive system loses the air pressure necessary to maintain the elevator car and counter weight in an elevated position, the counter weight assembly will pull the elevator car back to the bottom of the pool. Should mechanical binding between the elevator car and shaft occur, the counter weight/elevator drive assembly cables are accessible from a location external to the Exposure Room and provide an effective means of freeing the elevator car.

(3) A functional description of the operational characteristics associated with the elevator control system is provided in Annex 5-A to this supplement. Additionally, the following figures illustrate electrical circuitry and equipment incorporated into the elevator control system design: Figure 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS); Figure 5-30 (IRRADIATOR CONSOLE LAYOUT); Figure 5-31 (CONTROL CONSOLE WIRING); and Figures 5-32 and 5-33 (IRRADIATOR WIRING DIAGRAM).

c. Radiation Safety Interlock System. Operation of the elevator control system is limited by a radiation safety interlock system designed and installed for the purpose of assuring that no individual will be exposed to an area where it is possible to receive a dose in excess of 100 mrem in one hour as a result of free-air irradiation procedures initiated at the Cobalt-60 Facility. The following information catalogs the radiation safety control functions provided by the interlock system.

(1) The sole entrance door to the Exposure Room is automatically locked immediately prior to, and during, free-air-irradiation procedures in order to prevent an individual from entering when it is possible to receive a dose in excess of 100 mrem in one hour. This Exposure Room access control device permits deliberate entry to the Exposure Room only when radiation levels therein are less than 20 mR/h.

(2) The Visi-Con Annunciator Monitor, located in the Control Room, automatically provides both audible and visual signals to the operator of the elevator system if the Exposure Room access control device (electric lock) fails to function properly. Nonilluminated legends on the Visi-Con Annunciator Monitor indicate that the access control device is functioning properly.

(3) Crash bars are installed on the maze side of the entrance door to the Exposure Room in order to assure that no individual will be prevented from leaving the Exposure Room.

(4) Should the Exposure Room access control device (electric lock) fail immediately prior to free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically terminates the electrical power necessary to raise the source elevator car. If this access device fails during free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically returns the source elevator car to the bottom of the pool. In either case, the radiation level within the Exposure Room is reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour.

(5) Any person attempting to enter the Exposure Room during free-air-irradiation procedures is automatically warned that a radiation hazard exists therein by a large purple beacon located at the entrance to the maze which flashes continuously when the source elevator car is not located at the bottom of the pool. The console operator is automatically notified by the Visi-Con Annunciator Monitor if the light has burned out. In addition, the action of defeating the control access device (electric lock) for the Exposure Room entrance door automatically actuates two visible and audible alarms located on the Visi-Con Annunciator Monitor that serve to warn both the console operator and the individual attempting to enter the Exposure Room that a hazardous condition exists.

(6) Failure or removal of the Exposure Room access door automatically terminates the electrical power necessary to raise the source elevator car and automatically returns the elevator car to the bottom of the pool if it is in an elevated position. Since this action places the pool water shielding over the source elements, the radiation level in the Exposure Room is automatically reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour. Visual and audible alarm signals are automatically actuated on the Visi-Con Annunciator Monitor which warn the console operator and all potentially affected individuals that the physical barrier to the Exposure Room has failed or has been removed prior to and during free-air-irradiation procedures.

(7) A fifteen second delay exists between the time the console operator actuates the elevator drive key switch and the time the elevator starts its ascent. During this fifteen second period, a horn located in the Exposure Room automatically sounds and rotating purple beacons located in the Exposure Room and Exposure Room Entrance Maze automatically flash to alert personnel located in the Exposure Room/Maze areas that free-air-irradiation procedures are in progress. This warning period allows sufficient time for an individual located in the Exposure Room to actuate any one of four control devices which prevent raising of the elevator car. Located adjacent to the Exposure Room Pool and in the Entrance Maze are switches with large red mushroom caps bearing the words "EMERGENCY SHUTDOWN". Depressing either of these switches will cause immediate shutdown of the elevator energizing system until they are manually reset by the console operator. Also located adjacent to the Exposure Room Pool is a safety air valve with a large red mushroom cap, which will vent the air supply necessary to raise the source elevator car when the valve cap is depressed. Should the individual elect to leave the Exposure Room/Maze area without first actuating one of the aforementioned elevator control devices, the action of opening the Exposure Room access door will deenergize the elevator system until the console operator enters the Exposure Room and resets the radiation safety interlock system.

(8) In order to assure that the Exposure Room and Maze are cleared of personnel prior to each free-air-irradiation procedure using the COM, the elevator control system is interlocked with an "Operate Key Switch" located adjacent to the Exposure Room Pool. Prior to each raising of the elevator car, the console operator is required to enter the Exposure Room, actuate the "Operate Key Switch" with the same key that actuates the elevator drive system switch on the console, exit from the Exposure Room, and close the access doors in a time period of 15 seconds. This operation is intended to enforce a final visual inspection of the Exposure Room/Maze areas immediately prior to each in-air-irradiation procedure. Should the console operator fail to accomplish this task in the prescribed period of time, no electrical power is available to the elevator drive system. Additionally, opening the Exposure Room access door after accomplishment of this preoperational sequence terminates electrical power for the elevator drive system until the console operator reenters the Exposure Room and repeats the procedure. If the preoperational

sequence is not successfully completed or if the Exposure Room access door is opened after successful completion, audible and visual alarms are automatically actuated on the Visi-Con Annunciator Monitor in the Control Room to notify the console operator that the safety interlock system has been violated. If the Exposure Room access doors remain closed after the pre-operational sequence, the action of operating the console key switch for the elevator drive system automatically locks the Exposure Room access doors.

(9) Three Remote Area Monitors (RAM's) for ionizing radiation detection are incorporated into the radiation safety interlock system. RAM #1 is located in the Control Room and has a four decade logarithmic meter scale from 0.1 mR/h to 1.0 R/h. RAM #2 and #3 are located in the Exposure Room and have five decade logarithmic scales from 1.0 mR/h to 100 R/h. All three RAM's are Nuclear Measurements Corporation Model GA-2T0 plastic scintillation type ionizing radiation detectors and are installed to provide remote readouts in the Control Room. In addition to providing continuous physical radiation measurements of the Exposure Room, RAM #2 and #3 function to keep the Exposure Room access door locked when the radiation level in the Exposure Room exceeds 20 mR/h during COM free-air-irradiation procedures. RAM #2 and #3 also function to automatically cause the elevator car to return to the bottom of the pool if the radiation level in the Exposure Room exceeds 20 mR/h during activities involving the ICOM. RAM #2 and #3 automatically ensure that physical radiation measurements of the Exposure Room are accomplished prior to entry of the first individual following free-air-irradiation procedures. In addition to consulting the RAM readouts in the Control Room, the first individual to enter the Exposure Room following free-air-irradiation procedures is required to carry a portable ionizing radiation detection survey instrument and assure that the radiation level in the Exposure Room is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(10) The above enumerated and other features of the radiation safety interlock system are thoroughly described in Annex 5-A to this supplement. Figures 5-18 (GENERAL ARRANGEMENT, COBALT-60 FACILITY), 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS), 5-24 (CONDUCTIVITY, OZONE MONITORS), and 5-25 through 5-29 (INTERLOCK SCHEMATICS) illustrate electrical circuitry and equipment incorporated into the radiation safety interlock system design.

d. Equipment for Manual, In-Pool Irradiation Procedures. Although the Cobalt-60 Facility is designed primarily for free-air-irradiations, occasionally it is desirable to place the experimental product inside a water-tight experiment container and lower it to a position adjacent to the sources located at the bottom of the water-filled Exposure Room pool. The equipment necessary to safely perform this task is described in the following paragraphs.

(1) Source Holders. Permanently located at the bottom of the Cobalt-60 Exposure Room Pool are two source holding fixtures mounted on 16 gauge stainless steel stands. These fixtures are designed to hold/position the source

elements in a vertical, bolt-circle configuration when they are not being used for free-air-irradiations. As illustrated on Figure 5-17 to this supplement, holes have been drilled in the base plate of each source holder to accommodate source elements in 5, 8, and 12-inch diameter bolt-circle arrangements. A fixed upper plate contains holes to accommodate the upper end of the source elements located on the 12-inch diameter bolt-circle. This fixed upper plate has a step on its inner diameter which will accommodate a stainless steel ring containing holes used to position the source elements on an 8-inch diameter bolt-circle. This ring in turn is stepped to receive a smaller stainless steel ring containing holes used to position the source elements on a 5-inch diameter bolt-circle. In use, the innermost ring must be of the diameter appropriate for the bolt-circle arrangement used.

(2) Source Protectors. Since manual, in-pool irradiation procedures require lowering experimental materials to the bottom of the water-filled pool and positioning them in the center of, or adjacent to, the source holders, a 16 gauge stainless steel protective cover is installed over each source holder. The cover is intended to protect the cobalt-60 source elements from physical damage which could result from the positioning of experimental materials or the accidental dropping of a heavy object into the pool. Figure 5-17 to this supplement displays the protective source holder cover in the functional position.

(3) Experiment Containers. During manual in-pool irradiation procedures, it is generally desirable to protect the materials to be irradiated from the pool water. Consequently, the materials will usually be placed in water-tight metal containers. Typically, the containers are designed with a 4-inch outside diameter in order to assure that they may be positioned in the center of the source holding fixture when maximum exposure rates are desired. The containers may also be positioned at varying distances from the source holding fixtures depending on the exposure rate requirements of the experiment. Although the length and diameter of the experiment container may vary, the typical design incorporates a water-tight lid with an attachment for connecting a 15 foot handle. After the materials to be irradiated have been placed in the experiment container, the lid is secured in place and the handle is attached to the lid. Using the handle, the experiment container is lowered into the Cobalt Facility Pool and placed at a position near the cobalt-60 source elements. Duplication of source to container position may be accomplished by inserting a nipple on the container base into the holes provided in the source holder stand. All pipes serving as handles for the experiment containers are fabricated with "S" bends near the base to preclude the possibility of radiation streaming through the pipe.

(4) Radiation Warning System. As explained in Annex 5-A to this supplement, the Control and Exposure Rooms are equipped with three ionizing radiation remote area monitors (RAM's) designed, installed and operated to provide continuous monitoring of radiation levels in the facility on a 24 hour basis.

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RAM #1 detects and indicates the radiation level in the Control Room and is adjusted to provide an audio-visual alarm if the high level alarm setting of 2.5 mR/h is exceeded. RAM's #2 and #3 detect the radiation level in the Exposure Room and are adjusted to provide audio-visual alarms in the Control Room if the high level alarm setting of 20 mR/h is exceeded. All three RAM's are Nuclear Measurement Corporation Model GA-2T0 transistorized gamma alarms, utilizing gamma sensitive plastic phosphors in a detector probe that is connected by electrical cables to "NEMA boxes" that house an indicating meter, relays to provide high current alarm context, alarm lights, bells, and voltage supplies. The meter readings and audio-visual alarms displayed by the "NEMA boxes" mounted on the east wall of the Control Room are also relayed to the Visi-Con Annunciator Monitor located in the Control Room. Since the alarms may be heard in the Control Room, Maze, and Exposure Room, an individual desiring to perform manual, in-pool irradiations is automatically alerted if hazardous ionizing radiation conditions exist in the Exposure Room prior to, during, and after experimental procedures are conducted at the Cobalt-60 Facility.

3. Collateral Equipment. a. Remote Handling Tool. A remote handling tool is available for the purpose of manipulating objects at the bottom of the 12 foot deep pool while standing at the pool edge. This tool is 15 feet long and fabricated with a pistol grip handle, dual rubber-lined grip jaw, and a mechanism that allows adjustment of the grip jaw from the pistol grip handle. This tool is conspicuously marked at a distance of 6 feet 8 inches from the uppermost section of the source-gripping jaw and displays a warning sign that instructs users not to raise the tool above the mark when it holds one of the source elements. At a distance 4 feet above the pool surface, the exposure rate from a 1554 curie source element will be less than 0.25 mR/h when the handling tool is raised to the tool warning mark. This tool contains a multiplicity of $\frac{1}{2}$ -inch holes to allow a flow of water into the tool as it is inserted in the pool. Since operation of this tool is restricted to the Facility Supervisor, Chief Operator, Alternate Operator, and the HDL Radiation Protection Officer, it will be secured from unauthorized use.

b. Source Leak-Test/Isolation Containers. Figure 5-17 to this supplement illustrates the source Leak-Test/Isolation Containers. The two metal containers are designed so that they can be loaded, sealed, sampled, pumped dry, and flushed with clean water while at a depth of 10 feet below the surface of the water. Each container is capable of holding ten source elements. Both containers are mounted on a metal frame which allows both units to be lowered into and extracted from the pool. Both containers are remotely sealed by use of a handling tool which is designed to manipulate a rubber-coated, adjustable diameter, "Turn-Tite Plug". This handling tool also fills with water as it is inserted into the pool. These containers will be used to perform the required 6 month leak test of the source elements (as described in Supplement 6 of this application) and also to isolate any leaking source elements until disposition instructions are obtained.

c. Monorail and Hoist. Figures 5-5 and 5-7 illustrate the location of the monorail used to support an 8-ton capacity trolley and motorized bridge hoist. This overhead monorail hoist will be used to manipulate the shielded containers necessary to accomplish transfer operations involving cobalt-60 source elements. The marking, construction, and installation of the monorail hoist is in accordance with American National Standard ANSI B30.16-1973. Inspection, testing, maintenance and operation of the monorail hoist will comply with the provisions of 29CFR1910.179 of the Occupational Safety and Health Act in order to assure safe, reliable operation.

d. Exposure Room Floor Track. Figure 5-5 illustrates two floor tracks extending from the north wall of the Exposure Room to the southern edge of the pool. Figure 5-6 illustrates, and provides specification for, the track supports that span the pool. All floor track installed in the Exposure Room is American Society of Civil Engineers (ASCE), 60 pounds light rail, 4½ inches by 4½ inches. The floor track is installed to provide stationary rails for a light-weight cart used to position experimental materials at varying distances from the cobalt-60 source elements during free-air-irradiation procedures. Although the floor tracks currently exist, a cart has not been fabricated to utilize them. Should the necessity for a cart arise in the future, the design will be reviewed by the HDL Radiation Control Committee prior to fabrication in order to assure that its design and intended use complement all safety considerations.

e. Emergency Lighting. Emergency light equipment, approved by Underwriter's Laboratory Standards for safety, provides emergency light to the Exposure Room/Maze areas automatically and instantaneously upon failure or interruption of normal electric power. The emergency power source for this unit is a maintenance-free, 6 volt, lead-acid rechargeable battery with up to 100 lamp watts output at 6 volts DC. One side of the unit has an observation post for visual inspection of battery liquid level. Additionally, the unit is equipped with a ready/off switch; a front-mounted "Press-to-Test" switch for quick testing of lamps and battery; an amber light which glows when the unit is in the ready state; a red light to indicate that the unit is on the high rate of charge; and a front mounted voltmeter to indicate battery condition.

f. Warning Signs. (1) In accordance with Section 20.203, 10 CFR Part 20, the entrance to the Cobalt-60 Exposure Room will be conspicuously posted with one sign bearing the radiation caution symbol and the words "Caution - High Radiation Area".

(2) The entrance to the Cobalt-60 Exposure Room will also be conspicuously posted with a sign bearing the radiation caution symbol, the words "Caution - Radioactive Material", isotope identification information, isotope quantity information, the date measurement of the isotope quantity was performed, and the manufacturer's trademark.

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(3) The wall opposite the maze entrance to the Cobalt-60 Exposure Room (east wall) shall be conspicuously posted with a large sign bearing the radioactive caution symbol and the words "Caution - Large Quantity of Radioactive Material Located at Bottom of Pool, Immediate Evacuation Required in Case of: 1. Fire or other Hazardous Condition; 2. Continuous actuation of radiation alarms; 3. Low pool water level."

(4) After installation of the Cobalt-60 sources and prior to the initiation of the irradiation program, a radiation survey shall be conducted to determine the maximum radiation levels above the pool and in each area adjoining the Exposure Room/Maze area. Should the radiation survey indicate the need for additional caution signs in order to comply with the posting requirements enumerated in Section 20.203, 10 CFR 20, they will be obtained and posted prior to the initiation of the irradiation program.

I. Introduction

The cobalt-60 irradiator system designed, constructed, and installed by Neutron Products, Inc. for the Harry Diamond Laboratories consists of the following principal components:

1. Elevator and elevator drive assembly.
2. Console and in-cell elevator controls.
3. Radiation safety interlock system.
4. Status and alarm annunciator.
5. Water quality system.
6. Ozone detector.

This system is designed to be operated in two principal modes. The first is the Console Operational Mode (COM) where the operation is controlled from the console located in the control room. The source material is located on the elevator and the product to be irradiated located in the cell adjacent to the pool. The second mode of operation is the In-cell Operational Mode (ICOM) where the product to be irradiated is placed on the elevator and lowered into the pool where the source material is stored.

II. Safety Considerations.

Cobalt-60 emits ionization radiation in the form of highly penetrating gamma photons which are capable of causing injury and death. In a cobalt-60 irradiator, therefore, there is significant potential for personal injury from the radiation and from the by-products of the interaction of this radiation with air or other materials. Supplementing administrative controls necessary to achieve the safe operation,

is a radiation safety interlock system which primarily functions to subject the source/sample elevator operation to controls imposed by various mechanical and electrical safety devices. The elevator control system is interlocked with the hazard detection system and status-alarm annunciator to provide for the safety of operating personnel. The system should never be operated by persons not thoroughly familiar with basic radiation safety concepts and the functioning of all of the system's pertinent components. Under no circumstances should efforts be made to defeat any components of the radiation safety interlock system.

III. Description of the Radiation Safety Interlock System

The radiation safety interlock system functions as follows:

- A. The source/sample elevator cannot be raised from the bottom of the pool in the console operational mode (COM) if any one of the following conditions exist:
1. Console power is not on;
 2. The irradiator room TV monitor is not on;
 3. Low pressure exists in the compressed air supply;
 4. The safety air valve in the irradiator room has been pushed;
 5. Any one of the three emergency stop bottoms has been pushed;
 6. Any one of the three irradiation monitors is not electrically energized and operational;
 7. The operator has not entered the irradiator and turned the in-cell reset switch and exited from the irradiator closing the maze entrance doors in the prescribed time period of approximately 15 seconds. This operation is intended to enforce a final visual inspection of the irradiator cell; and,

8. The maze doors are opened after the prescribed time has passed following the operation of the in-cell reset switch.
- B. The source/sample elevator cannot be raised from the bottom of the pool in the in-cell operational mode (ICOM) if any one of the following conditions exist:
1. The console power is not on;
 2. The irradiator room TV monitor is not on;
 3. Low pressure exists in the compressed air supply;
 4. The safety air valve in the irradiator room has been pushed.
 5. Any one of the three irradiation monitors is not electrically energized and operational;
 6. Any one of the three emergency stop buttons has been pushed;
 7. The operator has not turned the in-cell reset key switch; and,
 8. The operator does not hold the in-cell elevator control key switch in its "On" position.
- C. Once in its up position, the source/sample elevator will immediately return to the pool bottom if any one of the following conditions occurs:
1. One of the three emergency switches is pushed;
 2. A hazardous radiation level is present in the control room;
 3. A maze door is opened (except during the ICOM);
 4. The air supply pressure drops; and,
 5. The TV monitor is turned off.
- C'. Since the system also allows for using the elevator to lower product to a source array located on the pool bottom in the in-cell operational mode (ICOM), protection for the operator controlling the elevator from within the irradiator is provided by the two in-cell Radiation Area Monitors which will immediately return the elevator

to the pool bottom in the event that the high radiation level in the irradiator is detected within the cell during or after elevator ascent in ICOM.

D. Additional safety features are as follows:

1. The doors are locked when the prescribed time of approximately 15 seconds has elapsed following the operation of the in-cell reset switch and the operating key switch is turned on during the Console Operational Mode (COM). The door remains locked until the switch is turned off and no high radiation level exists in the cell.
2. A visual and audible alarm sounds at the annunciator whenever the maze door is opened once the in-cell reset switch has been operated during COM. A subsequent reset operation is required.
3. Visual and audible alarm sounds when the concentration of ozone in the irradiator cell reaches a preset level.
4. The door when electrically locked to prevent entrance can be opened at all times from within the cell for unrestricted exit.
5. For a preset time before the elevator starts its ascent a horn sounds and rotating light beams located within the cell and maze are energized. A separate circuit detects a burned out light and indicates this on the annunciator.
6. A single operation key is used for all functions except the console power switch for which a separate key is provided. This key arrangement for the reset and operating switch is designed to insure that the elevator system cannot be operated in an improper sequence.

7. The elevator drive system which is composed of a pneumatic piston and counter weight assembly will operate to return the elevator to the pool bottom in the event of either an electrical power failure or a loss of operating air.
8. High and low pool water level detectors alert the operator from the annunciator in the control room and a remote monitoring station of potential unsafe conditions.
9. The water conditioning system filters and deionizes the pool water to protect the source encapsulation from corrosion. A conductivity analyzer alerts the operator of high water conductivity.
10. The status and alarm annunciating system allows the operator at a glance to check the present status (normal or abnormal) of various components of the system and notifies the operator by audible signal of a change in status. Certain key signals may be transmitted to a remote monitoring station if desired.

IV. Functional Description of Components

- A. RAM #1 - Detects and indicates the radiation level in the control room and will not allow the elevator to be raised or will lower the elevator should the level exceed the high level alarm setting of 2.5 mR/hr.
- B. RAM #2 - Detects and indicates the radiation level of the irradiator room. During the period that the radiation exceeds the high level setting of 20 mR/hr it will keep the irradiator door locked or in the in-cell operational mode (ICOM) of the system, will automatically cause the elevator to return to the pool bottom.
- C. RAM #3 - Detects and indicates the radiation level adjacent to the demineralizer system and will alarm when this level

exceeds the selected high level alarm setting of 20 mR/hr. It

functions also to provide a redundant high level detection and alarm during ICOM and causes elevator to return to pool bottom position if a high radiation level is detected.

- D. Emergency push button switches located on the operating console, in the maze, and in the irradiator will cause immediate shut down of the elevator energizing system, and lower the elevator.
- E. Safety Air Valve located in the irradiator will vent the air supply before the elevator drive piston so that the elevator cannot be raised. This valve should be pushed in whenever working in the irradiator room.
- F. Level Gauge with read out located in the control room indicates the water level in the pool and provides electrical contact openings at adjustable levels to provide alarm and control functions.
 1. Contact set #1 causes a high level alarm to be initiated when the pool water level is between 136 and 138 inches.
 2. Contact set #2 causes the demineralizer pump to shut down when the level drops to a point just above the pump intake foot valve, 126 to 130 inches.
 3. Contact set #3 energizes solenoid valves to refill the pool when the water level is between 132 and 135 inches.
 4. Contact set #4 provides a low level alarm if the pool water level drops to 126 inches.
- G. Radiation Indicator Lights which flash purple are illuminated when the elevator is not in its pool bottom position, except in the in-cell operational mode (ICOM).
- H. Horn - Sounds for 15 seconds before the elevator starts its

ascent except in the in-cell operational mode.

- I. Door Position Switches - Will not allow the elevator to ascend if a maze door is opened and more than 15 seconds has elapsed since the system has been reset. If a door opens after the elevator has ascended, it will immediately descend and remain at the bottom until the system is again reset. In the in-cell operational mode (ICOM) these switches have no function.
- J. Door Lock - Prevents the entrance door from being opened once 15 seconds have passed since the in-cell reset switch has been operated but allows the emergency exit door to be opened from inside the irradiator. The lock can be bypassed by turning the Door Lock Bypass Switch in a non routine operation.
- K. Door Lock Bypass Switch - Disengages the door lock except when the radiation level in the irradiator exceeds the high level alarm setting of RAM #2 or RAM #3.
- L. Reset Key Switch located within the irradiator - Must be turned momentarily to reset the control circuit and provide for an elevator ascent. This operation requires that the maze door has not been opened at any time once 15 seconds have elapsed after the reset switch has been operated in the console operational mode (COM). In the in-cell operational mode (ICOM), the reset key switch must be turned before the ICOM key switch is used to lift the elevator.
- M. In-cell Operational Mode Key Switch - Which must be held in position, raises and lowers the elevator from inside the irradiator as described in L, above when operating in the ICOM providing the ICOM key switch has been, and remains turned within 15 seconds of the reset switch operation.

- N. Console Power Key Switch with its own key applies power to the console circuitry, and must remain on except when working on the system since it controls power to the water circulating system, and the control and alarm functions which must operate continuously.
- O. Console Pump Switch - Turns the water quality pump on and off. For the pump to be on, the pool water level must be correct and the console pump key switch must be "On".
- P. Console Fill Valve Push Button - Used to manually add water to the pool or prime the water quality pump.
- R. Annunciator - Provides visual status indication of monitored conditions throughout the Control System. An illuminated legend indicates an abnormal status; a flashing legend (accompanied by an audible alarm) indicates a status which has changed from normal to abnormal; a nonilluminated legend indicates a normal status.
- S. Annunciator Ack (Acknowledge) - Clears the audible and visual annunciator indications. The visual indications then are of present conditions.
- T. Annunciator Sil (Silence) - Clears the audible annunciator indication. Visual indication remains unchanged. A flashing indication means a change from normal conditions has occurred and may still exist.
- U. Annunciator Test - Tests all annunciator channels for proper operation. All channels must flash and the audible signal must be present.

- V. Remote Annunciator Switch - Connects the master annunciator to a remote monitoring point if desired.
- W. Ozone Monitor - Samples the ozone content in the irradiator and in conjunction with the annunciator, warns personnel of potentially hazardous concentrations.
- X. Conductivity Monitor - Determines the conductivity of the pool water at the inlet of the water quality pump and in conjunction with the annunciator, warns operations personnel of water conductivity which may be detrimental to source encapsulation life expectancy.
- Y. Water Quality System
 1. Pump - Circulates pool water through the water quality system. Note: The pump may have to be primed if turned off for an extended period of time.
 2. Filter - Removes particulate matter from the pool water.
 3. Pressure Gauges - Provides visual indication of water conditioning systems performance as follows:
 - a. Both readings high and approximately equal indicates restricted flow through demineralizer tanks or return line to pool.
 - b. Both readings low, pulsating, or zero - pump not on or loss of prime.
 - c. One reading high and the other low indicates plugged filter.
 - d. Both readings moderate with 20 - 30 percent differences in reading indicates normal conditions.
 4. Deionizer Tanks - Removes ionic species from the pool water.

Z. Air Control Box

1. Air Supply Shut-off Valve - When open supplies air pressure for the elevator drive cylinder and pool level gauge.
2. Pressure Regulator Assembly - Limits, regulates, and conditions the air supply for the elevator drive and pool level gauge.
3. Descent Control Valve - Limits the elevator descent speed.
4. Ascent Control Valve - Limits the elevator ascent speed.
5. Solenoid Valve (4 way) - Changes the routing of the air supply on command of the control console, to cause either ascent or descent of the elevator.
6. Reserve Tank - Supplies sufficient reserve air capacity to return to the elevator to the pool bottom in the event of power failure and/or primary air supply system failure.

V. Operating Instructions

Note 1: The following procedure assumes that the total system is operational and that all adjustments have been made and the system is on stand by (i.e. The RAMs and other instruments are calibrated and alarm levels are properly set, the compressed air supply is on, etc.). (See also Note 2 at end of Section V., Operating Instructions, for additional start up instructions.)

1. Check the console power indicating light. The light should be on.
2. Turn the remote annunciator off.
3. Turn on the closed circuit TV monitor.
4. Turn on the ozone monitor.
5. Turn on the conductivity monitor.
6. After 15 minutes has elapsed check and adjust the TV.
7. Push the annunciator test switch and verify that all the annunciator channels are working.

8. Acknowledge the annunciator.
9. Check the pool level indicator for the proper water level.
10. Check the operation of the RAMs by pushing the up scale check button. An annunciator should indicate an abnormal condition for each.
11. Acknowledge the annunciator. Hereafter, check the cause of any audible annunciator change and correct any abnormal condition.
12. Verify the following annunciator channel conditions:

<u>Channel</u>	<u>Condition</u>
RAM Power	Out
RAM 1 Level	Out
RAM 2 Level	Out
RAM 3 Level	Out
High Water Level	Out
Low Water Level	Out
Low Air Pressure	Out
Sol. Circuit 1	On
Sol. Circuit 2	On
System Not Reset	On
TV Power	Out
Door Bypassed	Out
Source on Bottom	Out
High Ozone	Out

13. Investigate and correct any improper condition before continuing.

14. Enter the irradiator.
15. Depress manual air vent safety valve before proceeding with any operations within the irradiator cell.
16. When ready to raise source/sample elevator close the manual air vent safety valve.
17. Clear the room of all personnel, Reset - Operate Key Switch.
18. Make a rapid exit from the irradiator.
19. After the irradiator door has closed, check the System Reset annunciator indication. The light must be out to proceed with the operation. If not, this indicates a delay between the operation of the in-cell reset and closing the door. Repeat steps 14 and 15, and make a speedier exit.
20. Turn the console operate key switch to "Operate".
21. Observe the elevator operation via the TV monitor and counterweight.
22. Return the Operate keyswitch to its off position to return the elevator to the pool bottom.
23. Observe the elevator operation via the TV monitor and/or counterweight.
24. Repeat steps 11 through 13 when re-entering the irradiator or leaving the facility.
25. Turn off the TV, conductivity monitor, and ozone monitor.
26. Acknowledge the annunciator.
27. Turn the remote annunciator on.

To irradiate materials at the pool bottom, replace steps 17 through 22 with the following:

- 17A. Inspect the elevator to be certain that no source material is attached.

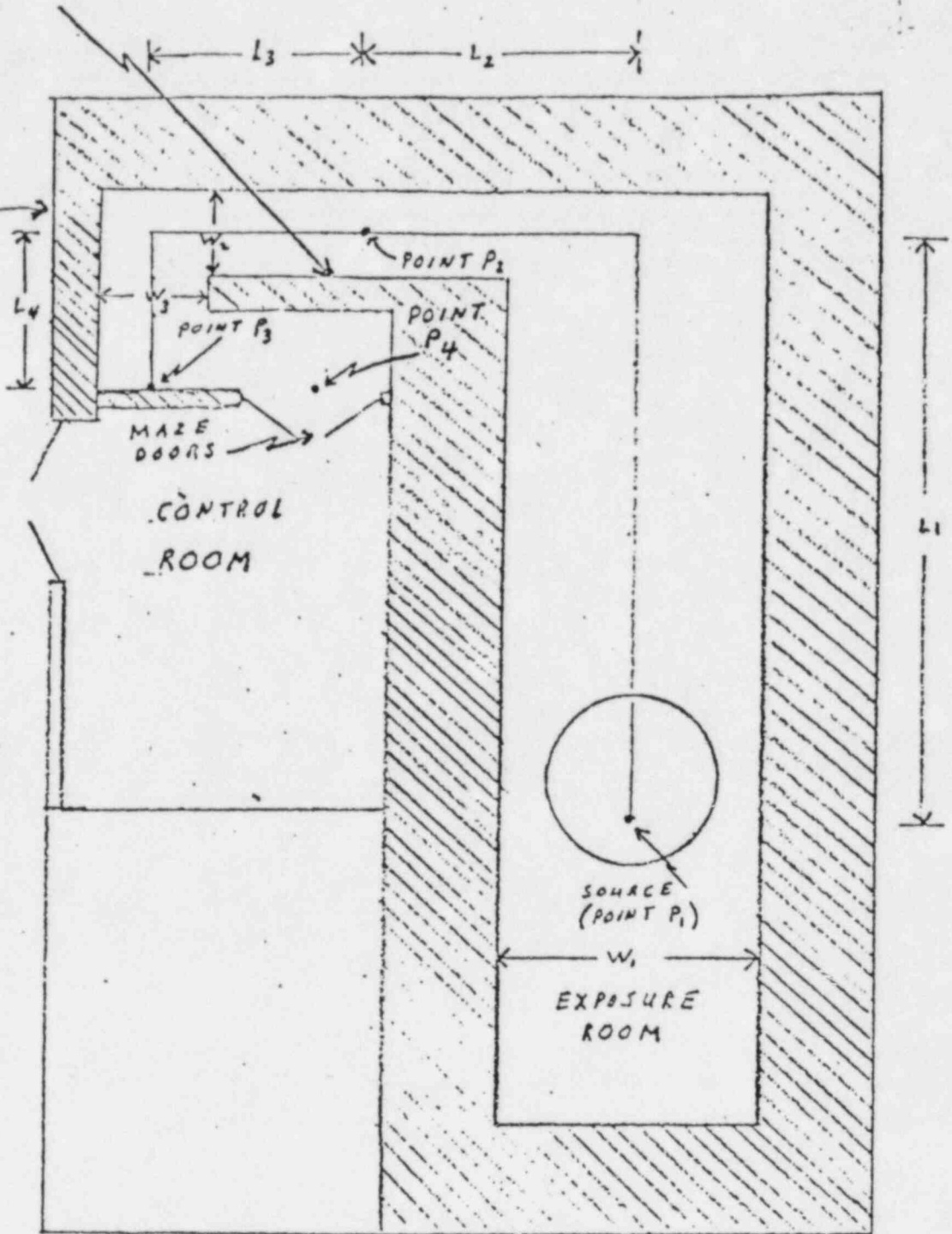
- 18A. Position knowledgeable co-worker with operative survey meter set on the proper range to detect any increase in dose rate as elevator rises.
- 19A. Turn the Reset-Operate Keyswitch.
- 20A. Turn the Remote Operate Keyswitch and hold in position until the elevator rises and the material is loaded or unloaded.
- 21A. Release the Remote Operate Keyswitch to lower the elevator to the bottom.
- 22A. To remove the material, repeat steps 14, 15, 16, 17A, 18A, 19A, 20A, and 21A. Then, proceed to step 24.

Note 2: If system is off, i.e. not stand by, the following additional steps are required:

- 1. Turn power on to radiation area monitors circuit breaker, control console circuit breaker, instrument rack circuit breaker, and water circulating pump circuit breaker in mechanical equipment room.
- 2. Turn on air supply (closing bleed valve if open).
- 3. Turn on console power keyswitch.
- 4. Perform any required scheduled maintenance.

MAZE SCATTER SHIELD

WEST WALL OF MAZE



$W_1 = 12''$

$W_2 = 4''$

$W_3 = 5''$

$L_1 = 26.33''$

$L_2 = 12.68''$

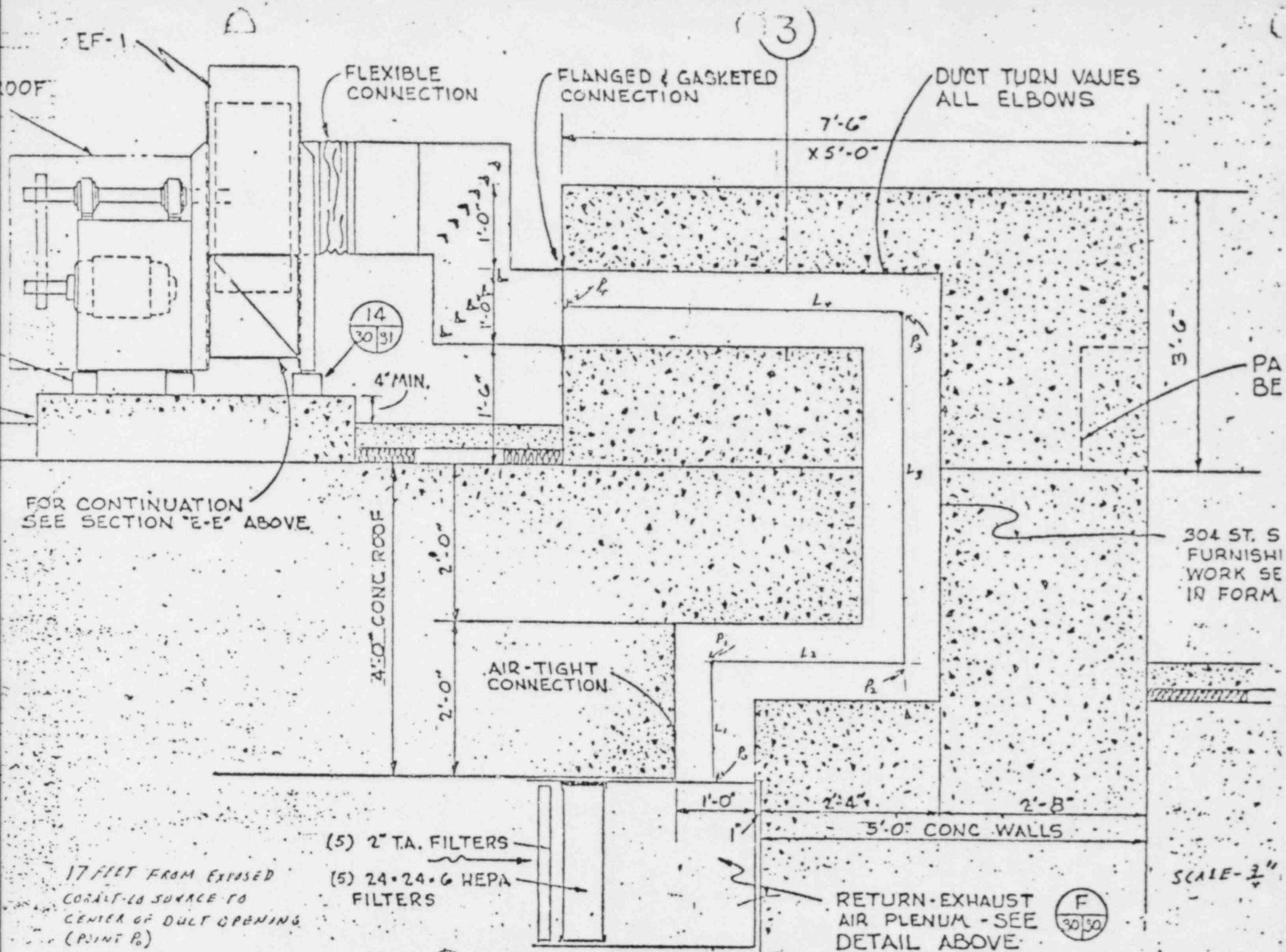
$L_3 = 8.99''$

$L_4 = 7.5''$

$P_3 \rightarrow P_4 = 7.5''$

SKETCH 5-1

(3)



EF-1

ROOF

FLEXIBLE CONNECTION

FLANGED & GASKETED CONNECTION

DUCT TURN VALVES ALL ELBOWS

7'-6"
x 5'-0"

14
30/31

4" MIN.

PA
BE

FOR CONTINUATION
SEE SECTION "E-E" ABOVE.

4'-0" CONC. ROOF

304 ST. S
FURNISH
WORK SEE
IR FORM.

AIR-TIGHT
CONNECTION

5'-0" CONC WALLS

(5) 2" T.A. FILTERS

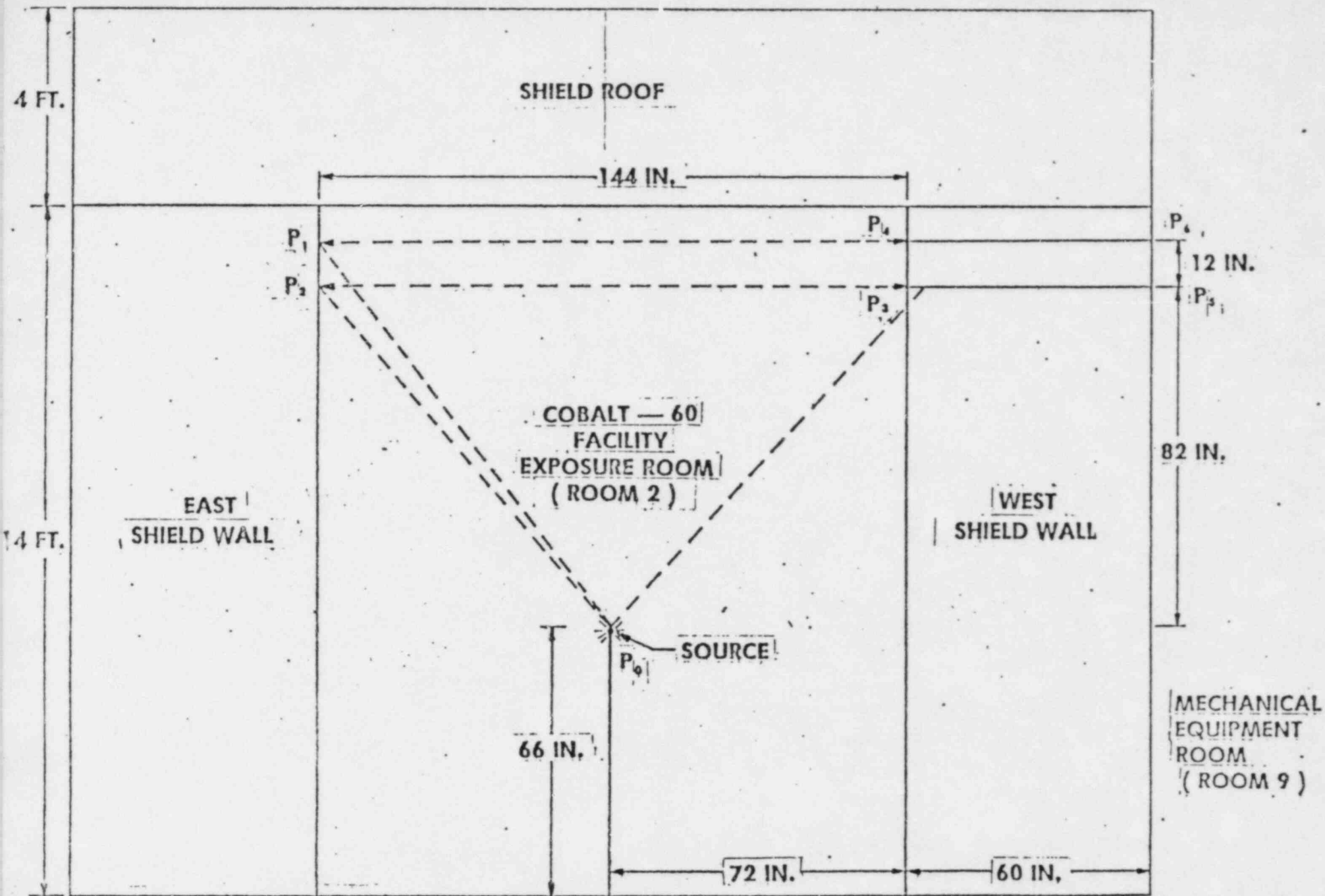
(5) 24" 24" G HEPA
FILTERS

RETURN-EXHAUST
AIR PLENUM - SEE
DETAIL ABOVE

F
30/30

SCALE - 3/4"

RADIATION TRAP FOR CO₂ LASER EXHAUST SYSTEM



SKETCH 5-3

SUPPLEMENT #6

Item 15, Form NRC 313 I, Radiation Protection Program

1. Administrative Organization and Responsibilities.

a. Harry Diamond Laboratories (HDL) functions as a research and development laboratory of the US Army Materiel Development and Readiness Command (formerly known as the US Army Materiel Command, AMC, until February 1976). Consequently, the overall direction of the HDL ionizing radiation safety program is still guided by AMC Regulation 385-25, w/Ch 1, "Safety - Radiation Protection" attached as Annex 6-A to this supplement. This regulation is supplemented by HDL Regulation 385-20, "Ionizing Radiation Protection Program" (attached as Annex 6-B) in order to provide local guidance to HDL personnel concerning the operational requirements and administrative procedures necessary for the control of ionizing radiation sources at HDL. A description of the organization, and how authority and responsibility is delegated to personnel directly responsible for the overall radiation protection program is found in Annex 6-B, Paragraph 5.

b. The HDL Radiation Protection Officer is responsible for the radiological safety of personnel using the cobalt facility. He directs all operations which involve the exposure of personnel to ionizing radiation in order to ensure that exposures are kept within tolerance. In addition, he maintains strict administrative control to minimize hazards during cobalt facility operations and ensures that all provisions of the NRC license and applicable regulations are complied with. Although, in general, the Radiation Protection Officer acts through the Cobalt Facility Supervisor, he has the authority to halt any operation at the Cobalt Facility that he considers a potential radiological or safety hazard.

c. The responsibility for operation of the Cobalt Facility is delegated by the Commander, HDL, to the Cobalt Facility Operator via the following chain of command:

HDL Technical Director
Associate Technical Director, 002
Chief, Nuclear Radiation Effect Laboratory, 200
Chief, Simulation Technology Branch, 290
Cobalt Facility Supervisor
Cobalt Facility Chief Operator and Alternate Operator

The Cobalt Facility Supervisor, Chief Operator, and Alternate Operator are individuals authorized to manipulate the source elements, source elevator, console controls, and other equipment associated with the control, handling, and maintenance of the facility. These individuals will satisfy the HDL Radiation Control Committee as to their training and experience in the area of radiological safety and in the use of radioisotopes. Also, these individuals must demonstrate a thorough knowledge of the Cobalt Facility operating procedures and applicable safety regulations. In addition to the responsibilities outlined in Annex 6-B, Paragraph 5d, the Facility

Supplement No. 6 continued.

Supervisor will ensure that the following tasks are accomplished prior to conducting experiments in the Cobalt Facility.

(1) Verify that all experiments involving the use of the Cobalt Facility have received review and approval of the HDL Radiation Control Committee in accordance with the procedures set forth in Annex 6-B, Paragraph 11, of this application.

(2) Ensure that the Cobalt Facility Standing Operating/Emergency Procedure (included as Annex 6-C to this supplement) is conspicuously posted in the Cobalt Facility and that experimenters are aware of its content.

(3) Determine that all safety equipment and devices are functioning properly.

2. Administrative Controls and Procedures.

a. All personnel entering the Cobalt Facility will be aware of and adhere to the procedures set forth in the Cobalt Facility Standing Operating/Emergency Procedure which is included as Annex 6-C to this supplement.

b. All maintenance, repair, or experimental procedures involving the manipulation of the source elements will require the presence of at least two individuals; one of which must be the HDL Radiation Protection Officer, the Cobalt Facility Supervisor, the Chief Operator, or the Alternate Operator.

c. Personnel exposures will be limited by the HDL Radiation Protection Officer in accordance with current AEC and Army instructions.

d. All proposed modifications to the Cobalt Facility, including all proposed deviations from established operational or administrative procedures shall be submitted to the HDL Radiation Control Committee. This committee shall review such proposals and determine whether or not they are advantageous to the operation of the facility. All proposals will be classified in one of the following categories.

(1) Major Safety Change: Any change which affects the degree of hazard associated with the operation of the Cobalt Facility.

(2) Minor Safety Change: Any change not classified as a major change which is directly associated with the safety of the Cobalt Facility. Included in this category are changes in the principal administration and operational procedures, health physics procedures and mechanical or electrical system alterations to the facility.

(3) Routine Change: Changes which have no bearing on the safety characteristics of the Cobalt Facility.

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e. All major and minor safety changes require the approval of the HDL Radiation Control Committee prior to requesting approval of proposed changes, through appropriate channels, from the Nuclear Regulatory Commission.

f. The Cobalt Facility Supervisor will ensure that the tasks enumerated in "Cobalt-60 Facility Weekly Checklist"(Annex 6-D), the "Periodic Maintenance Schedule" (Annex 6-E), and the "Periodic Calibration Schedule/Procedures" (Annex 6-F) are performed as specified therein.

g. The Radiation Protection Officer shall perform monthly inspections of the Cobalt Facility in order to accomplish the following:

(1) Verify that the facility is being used in accordance with prescribed operating procedures.

(2) Perform functional checks on the radiation detection alert systems.

3. Facility Operations.

a. In order to assure that only authorized persons will use or have access to the Cobalt-60 Facility, the following physical/administrative controls have been imposed.

(1) The Maze door, installed to control access from the Control Room to the Exposure Room/Maze, will be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel.

(2) The Control Room door, installed to control access from the grounds surrounding Building 504 to the Control Room, will also be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel. In addition to the door lock, the Control Room door is equipped with a high-security hasp and padlock which is controlled exclusively by the HDL Security Guards. The high-security hasp and padlock will be unlocked during working hours, and will be secured at all other times.

(3) As enumerated in the Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C), the separate keys to the Control Room door, Maze door, console power switch and elevator drive switch are rigorously controlled by the Cobalt-60 Facility Supervisor, Chief Operator and Alternate Operator.

(4) All exterior windows installed in Building 504, and any openings (such as air vents) which are 90 square inches or over are protected against incursion by permanent, steel security grills.

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(5) The HDL Security Guards provide continuous surveillance of the Cobalt-60 Facility by performing periodic patrols and also by remotely monitoring the electromechanical intrusion alarms and ultrasonic motion detectors installed in the Cobalt-60 Facility Control Room. Actuation of a surveillance alarm transmits an audio-visual signal to an annunciator panel monitored by security personnel at the main guard office. Upon receipt of an alarm, security guards are immediately deployed to arrive at the site of intrusion in approximately 2 minutes. In addition to the security precautions presented above, the entire HDL complex is surrounded by a 9 gage chain link perimeter fence in order to restrict or impede access by unauthorized individuals.

(6) The Cobalt-60 Facility Standard Operating/Emergency Procedure (Annex 6-C) delineates the administrative/physical actions required of individuals desiring authorized access to the Exposure Room. Annex 6-C and Supplement No. 5 to this application also define the conditions which must exist within the Exposure Room/Maze Area before entry is permitted during the various operational modes.

b. The HDL Cobalt-60 Facility will be used to conduct free-air and water-well irradiation in order to perform radiation effects testing on electronic components and for the performance of radiochemistry and dosimetry experiments. Highly flammable or explosive materials will not be irradiated at the Cobalt-60 Facility regardless of the operational mode. In addition to the administrative controls on experiments and experimenters thus far described in this supplement, all the safety provisions delineated in the Cobalt-60 Facility Standing Operating/Emergency Procedures will be strictly adhered to and enforced. A complete description of the functional characteristics associated with Cobalt-60 Facility irradiator system and safety support equipment is presented in paragraphs 2 and 3 of Supplement No. 5 to this application. The step-by-step operating instructions which must be followed by the console operator in order to perform free-air irradiations or water well irradiations involving use of the elevator is presented in paragraph V of Annex 5-A to this application.

c. In order to assure that the facility is being operated only when all safety interlocks and devices are functioning properly, the Cobalt-60 Supervisor is assigned the responsibility of assuring that the equipment checks, maintenance, and calibrations set forth in Annexes 6-D, 6-E, and 6-F of this application are thoroughly performed at the time intervals specified. Should any of the primary safety support equipment fail to function properly, use of the Cobalt-60 Facility shall be terminated until the cause of the malfunction has been determined and corrected.

4. Routine Monitoring Program. a. Radiation Area Monitors (RAM):

(1) The Control Room and Exposure Room areas are equipped with three Nuclear Measurements Corporation Model GA-2TO ionizing radiation area monitors installed for the purpose of detecting radiation levels in these

Supplement No. 6 continued.

areas on a 24 hour-a-day basis. These RAMs are incorporated into the Radiation Safety Interlock System and the Radiation Warning System as described in paragraph 2c and paragraph 2d(4) of Supplement No. 5 to this application. In the event of an alarm, the Cobalt Facility will be evacuated and the Radiation Protection Officer will be notified. The Exposure Room/Maze Area of the facility will not be reentered until the reason for the alarm has been ascertained or until a radiation safety survey has been performed.

b. Resin Bed Radiation Monitor (RBM).

(1) In addition to functioning as an Exposure Room Radiation Area Monitor, RAM No. 3 serves as a Resin Bed Monitor (RBM). This monitor is positioned adjacent to the pool water deionization resin bed tanks in order to provide continuous monitoring of the Cobalt-60 Facility pool water for the presence of a leaking source element.

(2) Removal of cobalt-60 from the pool water by the water purification system (a mixed resin bed) will have its greatest effect if all the activity passing through the demineralizer is removed from the water. Assuming a constant leak rate from a source element, the activity remaining in the water would be:

$$A = \frac{A_1}{F/V} [1 - e^{-Ft/V}]$$

Where A = total activity in the water

A₁ = leak rate

F = water flow rate through purification system

V = pool water volume

t = time since start of leak

exp = exponential function

The fraction of activity in the water of the total released would then be:

$$\frac{A}{A_1 t} = \frac{1 - e^{-Ft/V}}{(F/V) t}$$

The fraction of activity concentrated in the resin bed of the total released is $1 - A/A_1 t$. Some calculated values of this fraction for normal values of the parameters for the facility are presented below (V = 2327 gal, F = 50 gpm).

<u>DURATION OF LEAK (DAYS)</u>	<u>FRACTION OF ACTIVITY RELEASED AND DEPOSITED IN RESIN BED</u>
1	0.968
2	0.983
3	0.989
4	0.992
7	0.995

Supplement No. 6 continued.

(3) Since the resin bed tanks are cylindrical one may use the formulas and associated data presented in Applied Dosimetry, K. K. Aglintsev, London Iliffe Books Ltd., 1965, to calculate the exposure rate at the surface of the resin bed tank due to the presence of cobalt-60 evenly distributed in the resin. The following calculation assumes that the resin bed has accumulated 1 microcurie of cobalt-60 from a leaking source element.

$$P = P_0 \Gamma f B$$

Where P = exposure rate from a solid cylindrical source
 P_0 = exposure rate from emitter if all activity were concentrated at the center
 Γ = coefficient which allows for the geometry of the source and the distance from it
 f = self-absorption coefficient (0.369)
 B = build-up factor (1.3)

$$P_0 \Gamma = \pi P_{\gamma} q_{vol} R_0 \left\{ \frac{H}{R_0} (1 - \ln 2H/R_0) + \frac{H}{R_0} \ln \left[\frac{H}{R_0} + \sqrt{\left(\frac{H}{R_0}\right)^2 + 4} \right] + 2 - \sqrt{\left(\frac{H}{R_0}\right)^2 + 4} \right\} = 0.015 \text{ mR/h}$$

Where $P_0 \Gamma$ = exposure rate on surface of cylindrical source
 q_{vol} = specific activity of source (1.511×10^{-8} mCi/cm³)
 H = cylinder height (106.68 cm)
 R_0 = cylinder radius (15.24 cm)

$$P_{\gamma} = R \text{ cm}^2/\text{mCi h for Co-60 (13R/h mCi at 1 cm)}$$

$$\text{Now } P = P_0 \Gamma f B = (0.015 \text{ mR/h})(0.369)(1.3) = 0.001 \text{ mR/h}$$

The above calculations assume that the cylindrical source is homogeneous and has the density of water. In order to find the true exposure rate at the outside surface of the 1/16 inch thick steel tank one must calculate the shielding effect of the resin bed tank material.

$$\text{Thus: } D = B D_0 e^{-uX}$$

Where D = exposure rate at outside surface of resin tank
 D_0 = exposure rate at inside surface of resin tank
 B = Build-up factor (1.0)
 u = linear absorption coefficient (0.4672 cm^{-1})
 X = shield thickness (0.1588 cm)
exp = exponential function

$$D = (1.0)(0.001 \text{ mR/h})(.9285) = 0.001 \text{ mR/h}$$

(4) Since $P_{\gamma} = 13 \text{ mR/h } \mu\text{Ci at 1 cm for Co-60}$, and the exposure rate at the surface of the resin bed tank is 0.001 mR/h for each microcurie of Co-60 evenly distributed inside the resin bed tank, the Resin Bed Monitor will be exposed to approximately 0.1% of the activity in the tank. Assuming a background count rate of 1000 CPM and a 6% efficiency for the detector, the Resin Bed Monitor has a minimum sensitivity of $7.12 \times 10^{-4} \text{ } \mu\text{Ci}$ as shown below:

Supplement No. 6 continued.

$$\begin{aligned}\text{Min. Sens.} &= 3/\epsilon X (\text{CPM}_{\text{BKG}}/t)^{1/2} \\ &= 3/((.06)(.001)) (1000/1)^{1/2} = 1.581 \times 10^3 \text{ DPM} \\ &= 7.12 \times 10^{-4} \text{ uCi}\end{aligned}$$

Where ϵ = counting efficiency
 X = fraction of total sample presented to detector
 t = counting time
 CPM_{BKG} = background count rate

(5) Considering the results of the above calculations pertaining to the Resin Bed Radiation Monitor, it appears that this system will provide adequate early warning in the case of a leaking source element between routine leak testing procedures.

c. Routine/Emergency Leak Testing.

(1) At periods not to exceed 6 months the HDL Radiation Protection Officer will perform leak tests of all source elements in order to assure that the integrity of the source elements have not been violated. The leak testing method used will be sufficiently sensitive to detect a 2×10^{-4} uCi loss in 24 hours, which is equivalent to less than a 0.05 uCi loss in 6 months. This leak test procedure will also be initiated should the Resin Bed Radiation Monitor indicate that a source element is leaking.

(2) Procedure: The basic procedure involved in routine leak testing or in identification of a leaking element will be to isolate groups of the source elements in the sealed Leak Test/Isolation Containers described in Supplement 5 of this application. These containers are designed so that they can be loaded with 10 source elements each, sealed, sampled, pumped dry, and flushed with clean water while at a safe depth under water. Once the source elements are isolated in the Leak Test/Isolation Containers they will be steeped in clean water for a period of at least 24 hours and sampled to show an activity loss of less than 2×10^{-4} uCi/24 hours. Should testing results indicate that a container houses a leaking element, the elements in that container will be divided up between the two leak test containers and the procedure repeated until the leaking element is located.

(3) Sampling sensitivity: An example of an available system on which the above test may be performed with the required sensitivity is the Nuclear Measurements Corporation, Model PC-4, gas flow proportional counter. A one liter water sample evaporated to dryness (conservatively assuming a 50% collection efficiency) and counted for 960 minutes, will give a minimum sensitivity of 2.24×10^{-8} uCi/cm³:

$$\begin{aligned}\text{Min. Sens.} &= 3/\epsilon Vc (\text{CPM}_{\text{BKG}}/t)^{1/2} \\ &= 3/(0.55)(1000)(0.5) (46.0/960)^{1/2} = 4.98 \times 10^{-2} \text{ dpm/cm}^3 \\ &= 2.24 \times 10^{-8} \text{ uCi/cm}^3\end{aligned}$$

Supplement No. 6 continued.

Where ϵ = counting efficiency
V = sample volume
c = collection efficiency during sample reduction
t = counting time
 CPM_{BKG} = background count rate

(4) No servicing, maintenance, or repair of sources will be done at Harry Diamond Laboratories. Should a source element be found faulty, it will be transferred to a Source Leak Test/Isolation Container which will then be sealed. Upon receipt of instructions for disposition, the source will be shipped to a licensed facility for repair or ultimate disposal. Should waste disposal procedures be necessary, it will be handled by the US Army Armament Materiel Readiness Command, Rock Island, IL in accordance with the procedures delineated in Army Regulation 755-15, "Disposal of Unwanted Radioactive Material."

5. Emergency Organization and Procedures.

a. Organization for Emergencies:

(1) Any individual discovering fire or other hazardous conditions at the Cobalt Facility is required by the "Cobalt Facility Standing Operating/Emergency Procedure" (attached as Annex 6-C to this supplement) to evacuate the building, report the nature of the problem to the HDL Guard Office, and muster in the Bldg. 504 parking lot to await further instructions.

(2) Upon notification of the emergency condition the HDL Disaster Control Plan specifies the following course of action.

(a) The HDL Guard Office will notify the Fire Department, the HDL Fire Chief in case of fire, the Medical Office in case of injuries, the Safety Office, Radiation Protection Officer, and the Commander. The Guard Force will deploy personnel to direct emergency personnel to the scene and advise them of the fact that a radiation hazard may exist. All uninjured personnel who may have been exposed to ionizing radiation or contaminated with radioactive material will be directed and detained in a safe area by the Guard Force until monitoring and decontamination assistance is available.

(b) The Medical Office will treat injured personnel brought to the office or the Nurse will visit the scene to render First Aid assistance and summon additional assistance if necessary.

(c) The Motor Pool Officer will be alerted to stand-by to furnish transportation to hospitals.

(d) The Radiological Protection Officer will represent the Safety Office at the scene of the emergency in order to advise emergency personnel of the radiological hazards associated with the incident and assist in evaluating plans for remedial actions.

Supplement No. 6 continued.

(e) The Safety Branch, HDL Fire Chief (in case of fire) and the Branch Chief of involved personnel will investigate the accident after measures to eliminate the hazardous condition have been performed.

b. Hazard Due to Abnormal Water Levels or Non-Returning Exposed Source.

(1) The exposure rate at the normal surface of the pool has been calculated for several water levels and is presented in Figures 6-1 and 6-2. These were calculated using the exposure buildup factors for a point isotropic source, infinite medium, calculated by Goldstein and Watkins and presented in Engineering Compendium on Radiation Shielding, Volume 1, Springer-Verlag New York Inc., 1968. As shown by Figures 6-1 and 6-2, the situations in which low water levels occur do not represent serious emergencies except in extreme cases, ie, very little or no water. In the extreme case, emergency personnel have the capability of flooding the pool from a location external to the Exposure Room by utilizing the emergency fill water system installed specifically for that purpose; this system is described and illustrated in Supplement No. 5 to this application. Consequently, the size of the leak required to maintain the sources in an unshielded condition (ie, a dry pool) would require the occurrence of a very improbable event.

(2) Actions taken in the event of an abnormal water level or source position are predicated on the assumption that as long as the Exposure Room remains secured, there is no problem with regard to personnel radiation hazards. The only personnel exposure hazards that might arise would be created by the process of correcting the problem. In the case of a non-returning, fully exposed source, any procedure which might be initiated, other than those built in to the system, would be transmitted to the US Nuclear Regulatory Commission prior to implementation. However, considering the free fall design of the source elevator and the back-up emergency haul-down capability (described in paragraph 2b of Supplement No. 5 to this application) the likelihood of this possibility is very minuscule.

c. Remote Emergency Situations:

(1) The possibility of personnel exposure from falling into the Cobalt-60 Facility pool is minimized by pool design and administrative procedure. As recommended by the Occupational Safety and Health Act Regulations, 29 CFR, Part 1910, the pool is guarded by a standard railing with standard toeboard on all sides and a hinged floor hole cover of standard strength (see Supplement No. 5). The Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C of this supplement) requires that at least two persons be in the facility when a task requires standing over the exposed tank. Restricted access to the pool surface and the requirement that two persons be present when work involves removal of the pool cover minimizes the possibility that an unaided individual could fall into the pool.

(2) Rupture or shifting and tilting of the Cobalt-60 Facility due to earth movement is unlikely due to the extremely remote possibility of a

Supplement No. 6 continued.

destructive earthquake in the Washington area. The seismic analysis, presented in paragraph 11 of Supplement No. 5 to this application, indicates that the structural characteristics of the Cobalt-60 Facility are adequate to cope with any probable seismic phenomena.

6. Source Installation. a. The initial shipment and installation of all cobalt-60 source elements for the HDL Cobalt-60 Facility will be performed by the source manufacturer (Neutron Products Inc., Dickerson, Maryland) in accordance with the step-by-step procedures enumerated in NPI Specification P-5, attached as Annex 6-G to this supplement. The names of the persons who will be unloading the shipping containers and a description of their training and experience in performing such operations is presented in Annex 6-H to this supplement. As indicated by Annex 6-G, the Department of Transportation approved source transfer container will be lowered to the bottom of the 12 feet deep water filled pool prior to removal of the source elements from the transfer container. The remote handling tool described in Supplement 5 to this application will then be used to extract the source elements from the transfer container and install them in the source holding fixtures located at the bottom of the same pool. Prior to the installation of the source elements in the irradiation facility the following conditions shall prevail:

(1) The transfer will not be attempted until the HDL Radiation Protection Officer is present and certain that all individuals are competent in all phases of the operation and are familiar with the loading and monitoring procedures.

(2) The HDL Radiation Control Committee must approve all source transfer procedures prior to their implementation.

(3) An exclusion area shall be established and cleared of all personnel not directly involved with the source transfer operation.

During the actual installation of source elements into the source holding fixtures the following precautions shall be taken:

(1) The HDL Radiation Protection Officer shall perform a series of leak tests to check for source leakage that may have occurred while the sources were in transit to HDL. Leak test smears will be removed to non-radiation areas and checked with a G-M survey meter. If no significant activity is detected on the smears they will be placed in a gas flow proportional counter for accurate analysis and documentation of activity levels. If significant activity is found on smears, the transfer operation will cease until the source of contamination is found and appropriate corrective action taken.

(2) Continuous monitoring of the radiation levels inside the exclusion zone will be made during the transfer operation. This monitoring will be accomplished by use of portable survey meters and also by the remote area monitors installed in the Control and Exposure Rooms.

b. After all source elements have been loaded into the source holding fixtures at the bottom of the pool a complete radiation monitoring survey will be performed by the HDL Radiation Protection Officer. All areas of the building normally occupied by personnel will be checked with portable survey meters. All equipment used to transfer the source elements and the surface area on which the source transfer operation was conducted will be checked for radioactive contamination by wiping the surfaces with filter paper and analyzing the filter paper in a gas flow proportional counter to ensure that removable surface contamination does not exceed 100 disintegrations per minute per 100 square centimeters. Should contamination in excess of 100 dpm/100 cm² exist, the source of contamination shall be determined, eliminated, and decontamination procedures implemented until all affected surface areas are within acceptable contamination limits.

7. Initial Shielding Survey. The shield survey will be performed in two steps. A cursory survey of the areas adjacent to the Exposure Room/Maze Areas, such as the Control Room, Mechanical Equipment Room, Radioactive Materials Storage Room, HIFX Exposure Room, HIFX RF Shielded Room, roof and exterior building walls, will be made while the source elevator car sustains approximately 5 kCi of cobalt-60 in the free-air-irradiation position. Following this, a more comprehensive survey will be performed with the maximum loading of the irradiator elevator allowed by this application. With the maximum loading of cobalt-60 sustained in the free-air-irradiation position by the elevator, all areas adjacent to the Exposure Room/Maze Area, the bulk shielding, and shielded penetrations such as conduits and air ventilation ducts will be surveyed. These locations will be surveyed with the sources raised to the most hazardous position with respect to the particular area being surveyed.

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D.C. 20315

AMC REGULATION
No. 385-25
CHANGE 1

10 February 1969

SAFETY

RADIATION PROTECTION

AMCR 385-25, 12 August 1968, is changed as follows:

a. Paragraph 5f is added:

"f. The AMC Surgeon (AMCPT-H) provides medical guidance for the protection of health of personnel in use of radiation sources."

b. Make the following changes:

(1) Paragraphs 5d, sixth line; 6b(3), sixth line; 12b, fourth line; 21d, third line; 30d(1)(j), fifth line; and 31, sixth line. Change "AMCAD-S" to "AMCSF."

(2) Paragraph 5e, first line. Change "Division" to "Office."

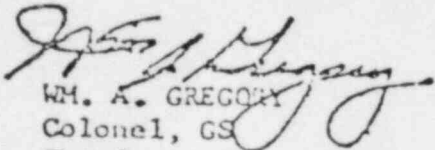
(3) Page 48, top of page. Change "(AMCAD-S)" to "(AMCSF)."

(AMCSF)

FOR THE COMMANDER:

OFFICIAL:

CLARENCE J. LANG
Major General, USA
Chief of Staff


WM. A. GREGORY
Colonel, GS
Chief, Administrative Office

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AMC REGULATION
No. 385-25

12 August 1968

SAFETY
RADIATION PROTECTION

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1. Purpose. This regulation establishes U.S. Army Materiel Command (AMC) ionizing radiation protection standards.

2. Scope. This regulation applies to all AMC elements procuring, receiving, storing, shipping, using, transporting, maintaining, or disposing of ionizing radiation-producing materials and/or equipment. This regulation does not apply to nuclear weapons, nuclear reactor systems, or spent fuel from nuclear reactors, nor does it apply to LASER or microwave radiation.

3. General. This regulation supplements AMCR 385-224 and is to be used in conjunction with AMCR 385-224.

a. Waivers of radiation safety requirements of this regulation are the same as those set forth in AMCR 385-224.

b. National Bureau of Standards handbooks on radiation protection shall be used as AMC standards in planning of facilities and local procedures except where such publications conflict with the requirements of this regulation in which case this regulation shall apply.

c. The terms shall, will, or must indicate mandatory requirements. The term may or should is advisory.

4. Definitions. See appendix A.

5. Policy. a. Prior to the use of sources of ionizing radiation in any program or project, and prior to the incorporation of a source of ionizing radiation into an item of supply (issue items), the cost effectiveness and safety of such use must be weighed against the use of alternate methods or materials to achieve project or program goals. The radiological hazards shall be investigated and written guidance prepared before supply items containing sources of ionizing radiation are issued for field use. (The word "radiation" will be used in this regulation for "ionizing radiation.")

b. Without proper controls, radiation can be hazardous to health and property. Consequently, proposals to obtain, use, store, transport, maintain, or dispose of items which are, or contain, sources of ionizing

radiation will be carefully evaluated to assure that all resulting exposures to radiation will be kept to a minimum.

c. Adequate procedures, facilities, equipment, and trained personnel will be provided to assure the safe use of materials or equipment capable of producing radiation. Failure to meet this requirement will result in cessation of operations or delay in start-up.

d. Commanders of separate activities tenanted upon an installation will be guided by the installation radiation protection standards. Local radiation protection standards will not be less restrictive than those standards established by Federal, Army, or AMC regulations. Should a separate activity's mission be hampered or restricted by the installation requirements, and the difficulty cannot be resolved at local level, the problem will be forwarded to the Commanding General, AMC, ATTN: AMCAD-S.

e. Headquarters, AMC Safety Division, develops and directs the AMC Radiation Protection (health physics) Program.

6. Responsibilities. a. Installations and activities. Commanders of installations and activities that procure, receive, store, ship, use, transport, maintain, or dispose of sources of radiation will:

- (1) Establish a formal, written radiation safety program.
- (2) Appoint a radiation control committee.
- (3) Appoint a qualified individual as radiological protection officer (AR 40-14) and an alternate to provide continuity of operations.
- (4) Assure compliance with Federal, State, and local regulations.

b. Radiation control committee. The committee will consist of the commander or his designated representative, the radiological protection officer, medical officer (where the establishment has a medical facility), the safety director, and other persons who are knowledgeable in the safe use of radiation, as are deemed necessary.

(1) Responsibilities of this committee will include:

(a) Recommending to the commander policies on the safe use, handling, storage, transport, receipt, shipment, and disposal of sources of radiation.

(b) Reviewing the radiation safety aspects of proposals for the procurement and use of sources of radiation, the modification of existing radiological operations and operating procedures, and providing recommendations to the commander for appropriate action.

(c) Reviewing applications for Atomic Energy Commission (AEC) licenses or Department of the Army authorizations.

(d) Reviewing and approving the qualifications of users of radiation.

(e) Reviewing reports of radiation accidents and incidents to determine the cause and recommending appropriate action to the commander.

(2) The radiation control committee should not exercise the functions of a clinical committee on radioisotopes in a medical facility, or of a reactor safeguards committee. However, handling, receiving, shipping, storage, transport, or disposal of radioisotopes beyond the control of the immediate medical or reactor staff is subject to the review of the radiation control committee.

(3) The committee membership will be kept up-to-date. Training and experience résumés for each member of the committee will be kept on file by the radiological protection officer. In those cases where the committee membership list and résumés are on file at the AEC, the AEC will be advised of membership changes by letter forwarded through the Commanding General, AMC, ATTN: AMCAD-S. (See AMCR 385-9.)

c. Radiological protection officer (RPO). The training and experience of the radiological protection officer and his alternate must be commensurate with the type and hazard of the radiation source(s) for which they will be responsible. As a minimum, the formal training of the radiological protection officer and his alternate will be successful completion of the U.S. Public Health Service Occupational Radiation Protection Course or equivalent. Organizationally, he should

be in a position wherein he can effectively advise the commander and the radiation workers on matters of radiation safety.

(1) In cases involving more than 100 millicuries of unsealed sources and more than 10 curies of sealed sources, the radiological protection officer should be an individual other than a radiation user.

(2) Responsibilities of the radiological protection officer will include:

(a) Providing the commander, radiation control committee, and radiation users with advice and assistance on all matters pertaining to radiation safety. (Advice includes instructing and training of workers and visitors in the safe use of protective equipment and procedures.)

(b) Implementing the radiation protection safety program.

(c) Reviewing radiological operations to determine compliance with regulations and approved procedures.

(d) Maintaining an accurate record of the inventory of sources of radiation possessed by the installation or activity in accordance with AR 700-52. The record for each item should include: Federal stock number and nomenclature, manufacturer's model number, description and serial number, the isotope, source radioactivity and date radioactivity was determined, chemical and physical form, whether sealed or unsealed, date received, and using organization and location.

(e) Maintaining radiation protection records.

(f) Performing radiation surveys and leak tests, or causing such surveys and tests to be performed. The accuracy of tests and surveys if performed by others remains the responsibility of the radiological protection officer.

(g) Evaluating the hazard potential and adequacy of protective measures for existing and proposed operations.

(h) Reviewing standing operating procedures (SOP's) for operations involving sources of radiation prior to review by the radiation control committee.

(i) Investigating radiation accidents and incidents.

(j) Reporting the findings of investigations (para 30) in accordance with AMCR 385-3.

(k) Assuring that radiation detection instruments are properly calibrated and are available to radiation workers.

(l) Monitoring incidents wherein unusual levels of radiation or contamination are suspected.

(m) Prior to being relieved of his duties, the radiological protection officer will take the following action with regard to radioactive materials and equipment for which he is responsible:

1. Secure all material and equipment in such a manner as to preclude use or removal during the period for which there is no radiological protection officer appointed; or

2. Turn over to a properly qualified and authorized individual, all materials and records for which he is responsible. Such an authorized individual will have the qualifications and training required of a radiological protection officer.

d. Supervisors of radiation workers or radiological projects will be responsible for:

(1) Maintaining a current inventory of all sources of radiation for which they are responsible.

(2) Knowing the exact location of all sources of radiation for which they are responsible.

(3) Posting appropriate warning signs and notices.

(4) Assuring that their personnel have received adequate instruction and experience prior to using or being exposed to radiation.

(5) Controlling contamination.

(6) Assuring sources are secured against unauthorized use.

(7) Controlling personnel exposures.

(8) Preparing, prior to the start of any operation involving radioactive material or possible exposure to radiation, an adequate SOP for review by the Radiological Protection Officer and the Radiation Control Committee prior to final approval in accordance with paragraph 1625, AMCR 385-224. The SOP will contain, as a minimum, responsibilities, maximum permissible levels of radiation in the areas concerned, storage of sources, procedures regarding dosimetry, decontamination, and emergencies. (This SOP is mandatory for operations in which there is a reasonable probability of exposure beyond established limits.)

(9) Enforcing SOP's, rules, and special precautions.

(10) Reporting to the radiological protection officer, any accident, unusual incident, personnel injury, however slight, suspected overexposure, and/or suspected internal exposure, as soon as possible after occurrence.

(11) Prior to being relieved of his duties, each radiation supervisor will take the following action with regard to all radioactive materials and equipment for which he is responsible:

(a) Secure all material and equipment in such a manner as to preclude use or removal while not under the immediate supervision of a qualified and authorized individual; or

(b) Turn over to a properly qualified and authorized individual, all materials and equipment for which he is responsible. Such an individual will have the qualifications and training required for the safe handling of the materials involved.

e. Radiation workers will be responsible for:

(1) Knowing and following SOP's, rules, and special instructions.

(2) Using safety equipment properly.

(3) Reporting to the supervisor any accident; unusual incident; personal injury, however slight; suspected overexposure and/or suspected internal exposure; as soon as possible after the occurrence.

7. AEC licenses and Department of the Army authorizations. AMCR 385-9 furnishes guidance for installations and activities for obtaining AEC licenses and Department of the Army (DA) authorizations required by AR 700-52.

8. Local control of radioactive material. a. Activity and installation commanders will establish internal procedures to control the procurement, receipt, shipping, transport, use, maintenance, storage, and/or disposal of the following radiation sources:

(1) Radioactive solids in excess of 1 microcurie or with a specific radioactivity exceeding 0.002 microcuries per gram or emitting a dose rate of 0.1 millirad/hr at contact.

(2) AEC-controlled materials in excess of the quantities listed in Title 10, Code of Federal Regulations, Section 31.100.

(3) Machines which produce radiation; e.g., X-ray devices, accelerators, electron microscopes, etc.

(4) Radioactive gases or liquids of concentrations in excess of the values listed in Table II, Appendix B, Title 10, Code of Federal Regulations, Part 20. (See para 19 and 20 for disposal and release requirements.)

(5) Items activated in nuclear reactors (including Army reactors), by accelerators or by nuclear weapons.

b. Activity or installation approval of proposed procurement, receipt, use, transport, storage, maintenance, and/or disposal of radioactive material will be based upon the following considerations:

(1) Organizational element responsible for the proposed operation.

(2) Purpose for which the materials will be used, including the desired initiation date and estimated duration of the project.

(3) Materials desired, including:

(a) Isotopes and maximum activities to be used and possessed at any one time.

(b) Whether sealed or unsealed.

(c) Chemical and physical form.

(4) Qualifications and experience of persons who will directly supervise the operation and of the Radiological Protection Officer.

(5) Qualifications and experience of persons who will use or handle the material.

(6) Locations where sources will be used or stored (building number, room, and/or area number).

(7) Radiac instrumentation available to support the operation.

(8) Adequacy of facilities and equipment, storage containers, exhaust hoods, handling equipment, and protective equipment available.

(9) Adequacy of operational procedures, including procedures to be followed for collection and disposal of contaminated waste materials.

(10) Adequacy of radiation protection procedures to include safeguards to preclude emergencies, and actions to be taken should an emergency occur.

(11) Estimated exposure of operational and nearby non-operational personnel.

(12) Authority and conditions established in the AEC license or DA authorization issued to the installation or activity.

c. Activity or installation approval for programs involving machines which produce radiation will be based on the following information:

(1) Type of device.

(a) Function.

(b) Manufacturer and model number.

(c) Radiation output.

(d) Anticipated workload (hours/month).

(e) Whether fixed or mobile operation is anticipated.

(f) Whether single or multiposition exposure head is to be used.

(g) Pulse duration and anticipated workload.

(h) Target.

(i) Calibration procedure and frequency.

(j) For accelerators, the curie level of the target, the mode of operation (positive or negative), energy of accelerator particles, the procedures for exchange of targets, and the available ventilation will also be considered.

(2) Safeguards.

(a) Shielding.

- (b) Interlock provisions and console locations.
- (c) Estimated exposure based on seven consecutive day operations modified by the planned workload. (Exposures of operational and nonoperational personnel must be considered.)
- (d) Occupied locations nearby.
- (e) Boundaries of restricted area.

(3) Training and experience of operators.

d. Approval of the commander should be withheld until the radiation control committee has determined that:

- (1) The proposed operation complies with regulations, current standards, and conditions contained in applicable licenses and/or DA authorizations.
- (2) The operation will not present undue personnel exposure damage to property.
- (3) Personnel are adequately trained.
- (4) Facilities, equipment, locations, and procedures are adequate to assure safe operation.
- (5) Necessary conditions and controls are provided.

9. Radioactive material. a. Unsealed radioactive material should not be used where sealed sources can perform the desired function.. Unsealed radioactive material may result in the contamination of personnel and equipment if not properly handled.

b. The least hazardous chemical and physical form should be selected.

c. Storage or use of eating, drinking, chewing, smoking, and cosmetic materials will be prohibited in the immediate areas containing radioactive materials.

d. Radioactive solutions will not be pipetted by mouth.

e. Disposable paper towels and handkerchiefs will be provided workers in areas containing unsealed radioactive materials. Properly marked receptacles will be provided for the disposal of such materials.

f. Operations and facilities involving radioactive materials should be planned to limit the spread of radioactive material.

(1) Work areas will be designated, marked, and monitored.

(2) Movement of personnel and unsealed radioactive material will be minimized.

g. Ventilating systems will be designed so as to preclude the spread of radioactive materials.

h. In the case of sealed sources, the capsule enclosing the radioactive material and the physical form of the radioisotope will be chosen to minimize the possibility of dispersion, inhalation, and ingestion of the material. The capsule and container should be resistant to fire and corrosion.

i. Operations using remote-control devices to control sealed sources of radiation should be designed to prevent leakage or rupture of the source capsules; to provide a positive means of containment of contamination in case of leakage, rupture or other damage to the capsule; a positive means of control of the sources from "safe" to "exposed" position; and an interlock, visual or audible alarm system to prevent entry of personnel into the radiation field while the sources are in the "exposed" position. Compressed gas systems are considered to be the least likely type of system to meet these requirements.

j. TB MED 232 provides guidance concerning storage and maintenance of self-luminous devices.

10. Safe handling of radioactive materials. Additional guidance on the safe handling of radioactive materials is available in National Bureau of Standards Handbook 92.

11. Other sources of radiation. a. Guidance for design of facilities and preparation of operating procedures for other sources of radiation, such as X-ray units, accelerators, and electron microscopes, can be found in National Bureau of Standards Handbooks 50, 55, 63, 66, 76, and 97, or replacement documents, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

b. Hazards associated with the high voltage, secondary beam, scattered radiation and activated material must also be considered. Ventilation, interlock provisions, shielding design, remote control, and handling procedures are essential considerations.

c. Prior to operation, X-ray, accelerator, and similar facilities should be surveyed by a competent individual for radiological safety hazards in construction and operation. The services of the U.S. Army Environmental Hygiene Agency are available for these surveys (AMCR 385-7). In order to avoid modification of or delay in operation of these facilities, the construction plans should be reviewed by a competent person.

12. Personnel exposure. The radiation exposure standards contained in this section are applicable to all personnel. Exposures incurred during examination or treatment for medical or dental purposes are not to be included in calculations for compliance with this section. However, medical exposures should be considered in the programming occupational exposures.

a. Exposure of personnel will not exceed the following values:

(1) Personnel 19 years of age and over who are occupationally exposed to radiation:

(a) Accumulated dose to the whole body, head and trunk, active blood-forming organs, gonads, or lens of the eye will not exceed:

1. 3 rem in any calendar quarter, or
2. $5(N-18)$ rem total lifetime dose where N equals the present age in years.

(b) Accumulated dose to the skin of the whole body or the thyroid will not exceed $7\frac{1}{2}$ rem in any calendar quarter or 30 rem in any calendar year.

(c) Accumulated dose of radiation to the hands and forearms and to the feet and ankles will not exceed $18\frac{3}{4}$ rem in any calendar quarter or 75 rem in any calendar year.

(2) Members of the general public, personnel not occupationally exposed, and persons who are less than 19 years of age will not be exposed in any calendar quarter in excess of 0.125 rem or in excess of 0.500 rem in any calendar year. Pregnant women will not be exposed to ionizing radiation for other than medical reasons (AR 40-5). At the first indication of pregnancy, women should notify their supervisor.

b. Before permitting any individual to receive an exposure in excess of the limits in a(1) above, the installation or activity will forward a request through channels, to the Commanding General, AMC, ATTN: AMCAD-S, for review and coordination. In addition to the information required in Title 10, Code of Federal Regulations, Section 20.102, the proposal must contain complete justification and describe the means for assuring that the higher levels requested will not be exceeded.

c. Personnel exposure will be kept as low as practicable. The necessity for exposure must be weighed against the benefits expected.

d. When an individual has received exposure in excess of the amount established for a calendar quarter, he shall be removed from duties involving exposures to radiation until subsequent exposure limitations are established through consultation with competent medical authority. When an individual has received exposure in excess of that established for a calendar year, he shall be removed from duties involving further exposure until his exposure records have been evaluated by Headquarters, AMC, and subsequent exposure limitations are established. When an individual has received an accumulated dose of radiation in excess of 5(N-18) rem, he shall be removed from duties involving occupational exposure to ionizing radiation until his exposure record has been evaluated by The Surgeon General, Headquarters, DA, and subsequent exposure limitations are established.

e. Radiation workers may be exposed to the limits established in a(1) above, when warranted. However, personnel exposure will be kept as low as practical. The necessity of exposure must be weighed against the benefits expected. Should an individual receive exposure in excess of the limits listed below, the circumstances involved will be recorded in the radiation protection records and the affected individual's DD Form 1141.

(1) 0.3 rem in any seven consecutive days, or

(2) 1.0 rem in any calendar month.

f. Should an individual be exposed to external radiation as well as internal radiation, his total exposure must be considered and recorded. For example, should an individual's thyroid receive eight rem in a calendar quarter as a result of a radioiodine spill, that exposure should be added to his whole body exposure to determine the total dose received by the thyroid.

g. Additional guidance concerning maximum permissible concentration and control of internal radiation hazards are contained in Title 10, Code of Federal Regulation, Part 20, and National Bureau of Standards Handbook 69.

13. Medical examinations. a. Radiation workers should be given a preemployment examination which includes medical history, radiation exposure history, physical examination, and a complete blood count. Personnel who are to be occupationally exposed to neutrons will be given a slit-lamp test prior to exposure. If radiation workers are to be exposed to unsealed radiation sources, appropriate bio-assay should be taken to establish base lines.

b. Any abnormalities will be recorded and carefully considered prior to exposure or continued exposure.

c. If a similar examination has been conducted within the past 6 months, those portions of the examination need not be repeated for which results are entered in the individual's record.

d. Visitors and personnel on temporary duty for less than 30 days do not require a medical examination provided they will not be exposed to radiation in excess of the levels established in paragraph 12a(1), or to radioactive concentration in excess of those given in Title 10, Code of Federal Regulations, Part 20, Appendix B, Table II.

14. Periodic medical examinations. a. Radiation workers should be given a medical examination at least once every 3 years. Dependent upon the work involved, the medical officer may desire to repeat the examination more frequently.

b. Upon termination of the occupational exposure, the individual should be given a medical examination.

c. In the event of an overexposure, a medical examination may be necessary.

15. Training and experience of personnel. a. Personnel, including visitors, who will be exposed to radiation and/or radioactive materials will be informed of the following information prior to exposure:

- (1) The presence of radiation or radioactive material.
- (2) Health hazards associated with exposure to such materials and/or radiation.
- (3) Procedures and precautions to minimize exposures.

(4) Applicable provisions of AEC licenses, DA authorizations, regulations, and standing operating procedures.

(5) Emergency procedures.

(6) Right to receive a report of his exposure incurred.

(7) Proper use of protective equipment and clothing.

b. Radiation workers will receive the instruction in a above. In addition they will be instructed in the following areas:

(1) Maximum exposure and contamination levels.

(2) Safe methods of performing work. (The use of protective equipment and the operational steps involved will be demonstrated.)

(3) Procedures to minimize contamination and to secure sources of radiation from unauthorized use.

c. Before an individual uses or supervises the use of sources of radiation, the radiation control committee should determine that his training and experience are sufficient to enable him to deal safely with materials involved.

d. An individual whose training and experience is not adequate will be required to work under the direct supervision of a person known to be qualified until such time that the individual can demonstrate his ability on the job. In the event such training is not available locally, inquiry should be made into the possibility of the employee receiving the required training and experience at another AMC installation or activity.

e. Emergency and security personnel will be trained and equipped to cope with radiological hazards that may be encountered in the performance of their duties. Training will be sufficient to enable such personnel to function without waiting for the guidance of the radiological protection officer, or other individuals not part of their immediate group. Such persons will be informed of the existence of situations that might become hazardous during special or unusual circumstances.

f. A record of training will be recorded on DA Form 750 (Record of Training) and placed in each employee's official personnel folder.

16. Personnel dosimetry. a. Dosimetry requirements contained in this paragraph are not applicable to persons exposed while being examined or treated for medical or dental purposes.

b. Knowledge of the radiation exposure received by personnel is necessary to prevent future overexposure and possible injury. The Army film badge packet described in SB 11-206 will be used as the primary device to officially determine personnel exposure.

c. Film badges will be worn by each individual who is likely to be exposed to radiation or radioactive materials. This requirement applies to visitors as well as installation or activity personnel.

d. Pocket chambers or self-reading pocket dosimeters may be used to supplement the film badge dosimeter. Such devices are useful when worn in areas in which an individual is likely to receive five or more millirem in 1 hour. In areas in which an individual is likely to receive 100 millirem or more of radiation in 1 hour, personnel will wear self-reading pocket dosimeters in addition to the film badge.

e. The type of film badge (range and type of radiation detected), the part of the body upon which the badge is to be worn (lapel, belt, wrist, hand, etc.) and the need for additional dosimetric devices must be determined by taking into account the type of radiation exposures to be experienced.

f. In the event of failure or loss of dosimetric devices, personnel exposure will be calculated or estimated from past exposure histories, results of radiation survey, the exposures of other personnel under similar circumstances, breath sampling, bio-assay techniques, and whole body counting and scanning.

g. AMC personnel who may be exposed to radiation at non-Army sites will wear film badges obtained from the radiological protection officer of their home installation/activity. On-site film badges may be worn in addition to the Army badges, but not as substitutes for the Army badges. AMC personnel who may be exposed to radiation while on travel status will furnish the radiological protection officer with a copy of any reports of exposure received for inclusion in the DD Form 1141 (Record of Occupational Exposure to Ionizing Radiation) and the appropriate radiation protection records. In the event differences between the reading of on-site film badges and Army film badges cannot be resolved, the Army reading will be recorded in the individual's health record.

h. Procedures will be established for the centralized issue and control of dosimetric devices:

(1) Personnel will be instructed not to tamper with dosimetric devices, either physically, or by causing them to indicate readings that are not indicative of the personnel exposure.

(2) Facilities will be provided for the storage of dosimetric devices when the devices are not being worn. These storage facilities should be located so that the dosimeters will not be exposed to radiation, or excesses of heat or light. Each film badge dosimeter storage facility will be equipped with a control badge, in accordance with SB 11-206.

(3) Because of the possibility of being lost, or forgotten or the possibility of recording a faulty exposure, dosimetric devices must be stored in a designated receptacle when not being worn.

(4) Personnel on TDY will store their badges in such a manner that they will not be exposed to radiation when not being worn. However, personnel on TDY will wear film badges whenever they are exposed to radiation, whether or not during normal duty hours.

17. Radiation surveys. Surveys should be made under representative conditions. The following describes certain types of radiation surveys.

a. Initial surveys. An initial survey will be made by the radiological protection officer of sites and areas where sources of radiation will be used and/or stored before an operation involving radiation is initiated or operational changes are approved, or upon installation of a device which produces ionizing radiation.

b. Routine surveys.

(1) Surveys of each area in which sources of radiation are used and/or stored shall be performed by or under the direction of the radiological protection officer at least once each month. The radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation will be evaluated. Such an evaluation includes a physical survey of the location of materials and equipment, measurements of levels of radiation and/or concentrations of radioactive material in and around the site. Conditions of stable storage may be exempted from monthly surveys at the discretion of the local radiation control committee. However, the intervals of surveys of storage areas will not exceed 3 months.

(2) The area survey will be performed using suitable instruments, and, when appropriate, smear and air sampling techniques. Work habits of personnel should be observed to obtain data regarding additional sites to be monitored or areas of improvement for the operational procedures. Locations of the monitoring points with the results, statement of the hazard, and any recommendations as to decontamination, shielding, procedural changes, etc., will be recorded and filed.

c. In addition to the surveys in a and b above, special surveys are required in the event of the following occurrences:

(1) Shipment or receipt of radioactive materials. Packages and the unloaded vehicles must be surveyed.

(2) Termination of a project involving radioactive materials. A survey is required to determine that no contamination exists and that sources of radiation are properly stored or have been disposed of properly.

(3) Unplanned events. Loss of control, spill, overexposure, or any unplanned event which could adversely or did adversely affect the safety of the operation must be monitored. Control must be re-established to prevent the hazard from increasing.

(4) Hazardous operations. Particularly hazardous operations, such as decontamination, encapsulation, or smelting of radioactive materials, as authorized by AEC license or DA authorization, must be continually monitored.

d. All places, equipment, persons, and animals suspected or known to have been in contact with radioactive material will be monitored for contamination. Personnel must be monitored before eating, smoking, chewing, drinking, or leaving the area in which radioactive materials are located.

e. Environmental monitoring. Environmental monitoring will be performed whenever radiological operations are such that they might have an adverse impact upon the surrounding environment. Ideally, such monitoring should be done prior to the inception of radiological operations at an installation and periodically thereafter. The results of such environmental monitoring should be used to determine the need to modify controls and/or operations.

18. Radiation warning signs. a. Areas, buildings, inclosures, packages, and containers will be conspicuously posted with radiation warning signs as required by AR 385-30; AR 55-55; Title 10 of the Code of Federal Regulations, Part 20; and Title 49 of the Code of Federal Regulations.

b. Additional instructional or precautionary information may be posted as desired, but not substituted for the signs required in a above.

19. Construction of radiation facilities. a. Selection of a radiation facility site will include consideration of the following factors:

facility: (1) Impact of surrounding operations upon the proposed

- (a) Radiation background.
- (b) Effluents from nearby operations.
- (c) Fire and explosive hazard.
- (d) Capability of controlling access.
- (e) Possibility of expanding the facility or of using larger sources.

(2) Impact of proposed facility upon operations in surrounding areas and in areas downwind and downstream of the proposed site:

- (a) Increased radiation background.
- (b) Effect of effluent discharge.
- (c) Impact of most severe plausible radiation incident.

(3) Possibility of flood or land movement.

(4) Waste disposal. A separate piping system may be desirable for the disposal of liquid waste.

b. A radiation facility should be a single story structure without a basement, and of noncombustible construction. Floors, walls, surfaces, and equipment should be nonporous and easy to clean. Fire fighting in radiation controlled areas presents problems that must be considered before any installation of fire fighting devices. While the containment and extinguishment of fires is desirable, the installation of fire fighting devices must be such that will not result in the contamination of drainage systems due to runoff; that will not result in the spread of contamination; or increase the hazard to personnel. In many instances, "fog" and "foam" type devices meet these requirements. Where practical, an automatic fire alarm system, reporting directly to the fire department, should be installed.

c. Ventilation systems must be planned carefully:

(1) Recirculation of air should not be permitted within buildings containing radioactive materials.

(2) Air intakes will be located to prevent the entrance of radioactive effluent from the same or nearby buildings into the ventilation system.

(3) Air flow will be from nonactive to "hot" areas, through filters, to the discharge. "Hot" areas should be maintained at a negative pressure to reduce the spread of contamination. Blowers should be positioned downstream from the filter so that the air is sucked rather than pushed through the filter.

(4) Hoods will be interlocked or designed to prevent reverse flow when all of the hoods are not operating at the same time. The air-flow rate through openings of the hood should be at least 100 linear feet per minute. (See NBS Handbook No. 92.)

(5) Hoods, dry boxes, and traps are useful laboratory tools for minimizing contamination. Dry boxes may not be used for storing or handling radioactive materials involving explosives or flammable solvents unless designed to function as operational shields for the quantities of explosives or flammables involved.

d. Buildings in which unsealed radioactive materials are handled should be equipped with shower and monitoring facilities. Two separate locker rooms separated by a wash and shower room should be provided. The one locker room is for storage of the worker's street clothing; the other, for his work clothing.

20. Operational safety procedures. a. High radiation areas should be interlocked to halt the irradiation upon the entry of personnel to the area, or otherwise to alert workers of the entry of personnel into the area during irradiation. The alarm system should be of a fail-safe design of such type that in case of primary alarm circuit failure the secondary alarm circuit is set off. High radiation areas that exist for more than 30 days will be equipped with automatic alarms and devices as required by Title 10, Code of Federal Regulations, Part 20. In high radiation areas that exist for less than 30 days, appropriate protective measures, such as close supervision to prevent unauthorized entry and exposure, will be taken.

b. Work areas will be designated and marked. Radiation levels should be measured, and marked where practical.

c. Process control devices, such as thickness gages and moisture gages, involving radioactive sources, will be designed to protect the source(s) against mechanical damage and to limit the exposure of operators and maintenance personnel to limits established for the general public. The device will be conspicuously and permanently marked with a radiation warning sign.

d. Each AMC installation or activity having radiation counting facilities should perform surveys for smearable contamination on outdoor surfaces.

(1) Levels of radiation sufficiently high to be significant may result from various sources, such as poor radioactive waste disposal practices, radiation incidents, and nuclear weapons testing.

(2) If significant levels of radioactive material are deposited out of doors, this contamination, if not detected, can be tracked into "clean" areas and sensitive "low level" laboratories.

e. Emergency exits, passageways, and doorways must be planned to enable safe movement of personnel in the event of an emergency.

f. "Hot" drains and tanks should be planned on the assumption that they will leak and will require maintenance. Unless criticality requirements prohibit, "hot" drains should empty into hold up tanks in order that samples can be analyzed to effect proper disposal.

g. Whenever a high radiation area is not mechanically secured to prevent unauthorized entry, a guard will be posted.

h. Secure, centralized storage facilities will be provided for radioactive materials not required in the immediate work areas.

i. Before initiation of an operation or modifying an operation involving radiation, the operating and emergency procedures should be practiced using a dummy source or other non-radioactive material.

j. Explosives, propellants, and excessive flammables will be excluded from areas in which radioactive materials are used or stored unless specifically approved in a DA authorization or AEC license.

k. Personnel with open skin wounds will not be permitted to work with unsealed radioactive material without an adequate waterproof covering on the wound and the approval of the medical officer.

l. Containers of radioactive liquids should be provided with secondary containment.

m. Except in an emergency, anti-contamination equipment and clothing will be worn in radiation controlled areas only.

n. Each item of equipment being released from a "hot" area to a "clean" area will be monitored, and decontaminated if necessary, and certified by the monitor to have contamination levels below those listed in table 1.

o. Maintenance that must be performed in a radiation controlled area will be cleared with the radiological protection officer and area supervisor prior to initiation.

p. Sealed sources will be leak tested within 5 days after receipt; at least once every 6 months (alpha sources every 3 months); prior to shipments; suspect sources will be withheld from use until leak tested; and after any suspected or actual damage. Unless required otherwise by Army directives, sealed sources containing less than 10 microcuries of activity or containing only natural uranium, natural thorium, or depleted uranium need not be tested. Leak test results will be recorded in terms of microcuries.

q. The quantity of radioactive material stored within a working area should be limited to the smallest reasonable quantity consistent with operational requirements.

r. Anti-contamination clothing and equipment will be prescribed by the radiological protection officer and will be marked in accordance with TM 3-261.

21. Disposal. a. Unwanted radioactive materials will be disposed of in accordance with AR 755-15 (Disposal of Unwanted Radioactive Material).

b. Radioactive material will not be buried on any AMC installation.

c. Disposal of radioactive effluents (liquids or gases) into unrestricted areas will be in accordance with Title 10, Code of Federal Regulations, Sections 20.106 and 20.303, provided local governments do not prohibit such disposal. Compliance with concentration levels established in Appendix B, Title 10, Code of Federal Regulations, Part 20, will be determined by averaging concentrations on a monthly basis instead of an annual basis. The total quantity of radioactive effluents discharged at any installation will not exceed the amount authorized a single licensee under Title 10, Code of Federal Regulations, Part 20. At installations where more than one licensee desires to discharge radioactive effluents, the commander will apportion the amounts to be authorized each licensee.

d. Radioactive materials will not be burned or incinerated except as specifically authorized by prior approval of Headquarters, AMC (AMCAD-S).

22. Contamination levels. Maximum permissible contamination levels and indicated actions are contained in tables 1, 2, and 3 below. The following notes and definitions will apply to the use of tables 1, 2, and 3:

a. "None" shall be defined as the amount of activity which, in the same counting time, gives a count which is not different from the

background count. (See National Bureau of Standards Handbook No. 80, Section 2.5.3, para 2.)

b. No allowance shall be made for particle size or for the use of protective clothing or equipment for determining whether an individual is exposed to radioactive concentrations in excess of the levels specified in this regulation.

c. Items which cannot be decontaminated will be marked and tagged to indicate their condition, and will be removed from use pending further decontamination or disposal.

d. Contamination should be kept at a minimum at all times. The publication of maximum permissible contamination levels should not be used as a license for unwarranted relaxation of controls.

e. Abbreviations used in tables 1, 2, and 3 have the following meaning:

dpm = disintegration per minute

cm² = square centimeter

MPC = Maximum Permissible Concentration. See Title 10, Code of Federal Regulations, Part 20, and National Bureau of Standards Handbook 69 for Maximum Permissible Concentrations of Radionuclides in Air.

Table 1. Maximum permissible contamination on inanimate objects.

Item and Corrective Action	Fixed (F) or Removable (R)	CONTAMINATION LEVEL			
		Alpha		Beta-Gamma	
		dpm/100 cm ² Instrument	dpm/100 cm ² Smear	mrad/hr at 1 in.	dpm/100 cm ²
1. Personal clothing, including shoes. Replace, decontaminate or store for decay, if above:	F R	200	None	0.2	None
2. Protective clothing, incl. shoes.					
a. General. Should be replaced or decontaminated, if above:	F R	1,000	200	0.5	1,000
b. Laundry. Do not release to public laundry, if above:	F R	200	50	0.4	200
c. Respirators	F R	200	None	0.06	None
3. Laboratories and work areas:					
a. <u>Uncontrolled areas</u> . Require controls and posting or decontaminate, if above:	F R	200	30	0.25	100
b. <u>Controlled areas</u> . Decontaminate, or if impossible, fix with periodic check on fixation, if above:	F R	1,000	200	2.0	1,000
4. Vehicles:					
a. <u>Use in controlled areas</u> . Decontaminate or if impossible, fix, if above:	F R	1,000	300	2.0	1,000
b. <u>Use in uncontrolled areas</u> . Decontaminate, if above:	F R	500	30	0.4	500
5. Tools, equipment and containers. Prior to non-radioactive use, decon if above:	F R	200	50	0.25	100
6. Shipping containers, outside surfaces, decon if above:	F R	500	None	0.25	None

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Table 2. Airborne contamination levels.

Required respiratory protection	Alpha Concentration	Beta Concentration
¹ Half face mask with filter or canister respirator.	1 MPC	1 MPC
Supplied air or self-contained air supply with full face mask.	5 MPC	10 MPC

¹For operations under the control of an AEC license, specific approval of the AEC must be obtained before making any allowance for use of respiratory equipment.

Table 3. Maximum permissible personnel contamination.

Area and action	Alpha or Beta-Gamma
1. <u>Skin</u> . Contact medical officer if contaminated on face or over major area of the body. Continue decontamination, if above:	Any detectable level above background.
2. <u>Hands</u> . Continue decontamination, if above:	Any detectable level above background.

23. Personnel decontamination. a. Thorough washing with non-abrasive soap and lukewarm water is the best general method of decontamination of the hands and other parts of the body regardless of the contaminant. If the contaminant is localized, it is often more practical to mask off the affected area and cleanse with swabs, rather than risk the danger of spreading the contaminant by general washing. Organic solvents must be avoided as decontamination agents because they may increase the probability of the radioactive materials entering the body through skin absorption. Special attention must be given to the areas between the fingers and around the nails. The outer edges of the hands are readily contaminated and often neglected in the washing.

b. After repeated washings, the skin may tend to chap. To avoid this, apply lanolin or hand cream and then continue to wash. If repeated washing with soap and water is unsuccessful in decontamination, the individual should be referred to the local medical officer for application of the more drastic chemical decontamination procedures listed in the National Bureau of Standards Handbook No. 48.

c. If it is suspected that any person, by inhalation, ingestion, or by any other manner, has introduced radioactive materials into his body, the local medical officer will be notified immediately so that medical procedures can be initiated to facilitate the elimination of such material. Contamination over a large area of his body or his face will be the basis for suspecting that the person is internally contaminated.

d. In the event an individual is contaminated on a large portion of his body, the following decontamination procedure is recommended:

- (1) Place the individual under a lukewarm shower.
- (2) Using a mild toilet soap, individual will cover his entire body with lather.
- (3) While still covered with lather, the individual will step out of the shower. An assistant will then cover the individual with a heavy coat of mild soap flakes. (The purpose of the lather is to cause the soap flakes to adhere to the person.)
- (4) Using his hands, the contaminated individual will rub the soap flakes on his body into a paste.
- (5) Individual will then return to shower and attempt to rinse off the soap by starting at the top and working his way down. (Note. It will be necessary for the individual to rub body surfaces with his hands while rinsing, in order to remove soap paste.) Soap paste will remain in

those areas that have not been thoroughly rinsed. Although a soft cloth may be used, a brush may not. Particular attention should be given the hairy portions of the body.

(6) When the individual has rinsed himself to the point that he no longer feels slimy and while still under the shower, he will be examined by an assistant for traces of soap. The presence of soap will indicate which areas of the body have not been decontaminated.

(7) After removing all traces of soap, the individual will leave the shower and dry himself.

(8) After drying off, the individual will be monitored. If the individual is still contaminated, procedures outlined above will be repeated.

d. In all cases of personnel contamination, the radiological protection officer will be consulted.

e. All water used in the washing and rinsing described above will be contaminated and its disposal should be conditioned by this fact.

24. Equipment and area decontamination. a. General methods.

(1) Care must be taken during the decontamination process to avoid further spread of the contaminant which can be accomplished by:

(a) Always taking precautions to contain the contamination by the use of monitoring, protective clothing, and shoe covers.

(b) Always working from the areas of least contamination toward the area(s) of the heaviest contamination.

(c) Using a minimum amount of decontamination liquids and being aware that the runoff solutions, mops, rags, and brushes will all be contaminated.

(2) The methods listed below should be tried in the following sequence:

(a) Damp mopping. The area is wiped with a damp rag. The wiping surface of the rag is changed repeatedly to minimize spreading of the contaminant.

(b) Water and detergent. The area is wetted with a minimum amount of detergent solution. The area is then wiped dry with absorbent gauze or cloth.

(c) Steam cleaning.

(d) Cleaning with solvents other than water.

(e) Surface removal by use of chemicals, abrasives, sand blasting, grinding, etc.

(3) Vacuum cleaners. Only vacuum cleaners which are equipped with absolute filters and which have been tested for filtration efficiency may be used. The filtration efficiency will be tested after each replacement of the filter and each time contents are emptied.

b. Specific methods. If the above methods (a above) do not work, the following specific methods may be tried:

(1) Metals.

(a) Remove any oil from the surface with organic solvents.

(b) Soak in a solution of citric acid prepared by addition of one pound of citric acid to one gallon of water.

(c) Soak in a solution of diluted hydrochloric acid prepared by carefully adding one part of commercial grade concentrated hydrochloric acid to four parts of water. Hydrochloric acid should not be used on stainless steel because of the etching which will take place and destroy the smooth surface of the metal.

(d) Use metal polish.

(2) Plastics. Clean with ammonium citrate, dilute acids, or organic solvents (of a type not injurious to the plastics).

(3) Glass and porcelain. Clean with detergent solution. If this method fails, soak in concentrated nitric acid or chromic acid cleaning solution.

(4) Painted surfaces. Use paint remover, or, in cases where surfaces were coated with a strippable paint, peel the paint from surface.

(5) Rubber, including respirators and gas masks. Wash with detergent and water or with a warm 20 per cent (by weight) water solution of sodium citrate.

c. Decontamination of clothing.

(1) Determine extent of contamination using an AN/PDR-27, or equivalent, with the beta shield removed, and with the AN/PDR-60, or equivalent.

(2) Wash in special laundry facility (home type or other washer and dryer kept in the facility for washing "hot" clothing only). Use the following steps:

- (a) Soak overnight in water solution of laundry detergent.
- (b) Drain.
- (c) Wash for full cycle with hot water and laundry detergent.
- (d) Rinse, dry and remonitor.

(3) Water utilized for washing, rinsing or soaking contaminated clothing will be contaminated as a result of such usage and its disposal should be conditioned by this fact. Laundry equipment may become contaminated also.

d. Monitoring technique. Check crevices and inside corners of areas, tools, and equipment. Special attention should be given to oily and greasy surfaces such as those on automotive equipment.

25. Storage of radioactive materials. a. Areas will be set aside for the secure storage of radioactive materials. These areas will be used to store only radioactive materials. The storage area will be free from the danger of flooding and outside the danger radius of flammables or explosives. Physical security standards for storing radioactive materials are contained in appendix A, AMCR 190-3.

b. Each storage and shipping container will be marked as required by AR 55-55 and AR 385-30, whether or not the radioactive material is under the license control of the AEC. Laboratory containers such as flasks and test tubes need not be marked as long as the user is continuously present.

c. Radioisotopes will not be stored in glass containers unless secondary containment is provided.

d. Radioisotopes should not be transferred from one storage container to another within the storage area. A system will be provided to control and record the "check in" and "check out" and monitoring of radioactive materials.

e. Storage areas will be adequately ventilated as determined by the RPO if gaseous sources are being stored.

f. All sources and containers will be labeled. The areas will be monitored periodically to assure adequate shielding and to detect any contamination.

g. Dose rates of a shipping container should not exceed 200 mrem/hr at the surface nor 10 mrem/hr at 3 feet from any surface of the container.

h. Operating officials will keep a current record of all stored radioactive material, and a copy of this record will be forwarded to the RPO. The RPO will conduct a physical inventory every 6 months.

26. On-post transportation of radioactive materials. Within an installation, it is usually not convenient to package and transport radioactive materials in the manner required for off-post shipments. However, the following precautions will be observed:

a. In loading the vehicles:

(1) Keep within the weight limitations.

(2) Limit or arrange cargo to keep radiation levels, to which personnel (including the driver) will be exposed during transportation, as low as possible. Maximum permissible dose rate in occupied areas of the vehicle will depend upon the time required to transport the material. The driver will wear a film badge and will not be exposed to ionizing radiation in excess of the limits indicated in paragraph 12a.

(3) Keep the containers away from the cab of the vehicle.

b. Do not haul loose radioactive materials. Tail gates should be closed to minimize the chance of cargo loss.

c. Containers should be sturdily constructed, sealed air-tight, and be free of removable contamination. Each container must have a completed DA Label 15 (Caution: Radioactive Materials) unless specifically exempt by military specification M-19590C.

d. The route used should be planned to avoid areas in which explosives are stored or handled and in which there is heavy traffic or personnel activity. The fire department, guard force, and safety director should be informed of the exact route and time of movement in sufficient time to allow implementation of any special protective measures required.

e. A suitable vehicle should be used. Vehicles that are difficult to decontaminate, and privately-owned automobiles should not be used.

f. Unless emergency personnel (guard force and fire department) have demonstrated a capability to cope with a radiological emergency, a technically trained person should accompany the movement to be able to advise in the event of an emergency.

27. Off-post transportation of radioactive materials. a. Radioactive material will be transported in accordance with AR 55-55 and applicable Federal and State regulations.

b. Radioactive material should not be forwarded through the U.S. mail channels except in an emergency. Should transmission by mail be necessary, shipment will comply with Part 125.24, U.S. Postal Manual, and will be registered.

c. Containers should be secured by blocking or tie down, when appropriate.

d. Materials shipped will be properly addressed to insure delivery to the proper installation and section within the installation.

e. Personnel who will transport and/or escort radioactive shipments will be briefed as to potential hazards, methods to minimize hazards and emergency procedures. In addition to the briefing, personnel engaged to transport the radioactive material will be given a completed DD Form 836 (Special Instructions for Motor Vehicle Drivers) supplemented with written emergency procedures. Written information will be provided as to the means for obtaining assistance of radiological emergency teams off-post.

f. Consignees will be notified in advance of impending shipments in order that consignees may assure that they have the capability to receive and handle the materials being shipped.

28. On-site command of emergency during transportation. The ranking person accompanying the shipment will take immediate steps to clear the area and request assistance. He retains command at the accident site pending the arrival of the commander of the nearest military installation or his representative. The designated Army area representative assumes responsibility upon his arrival.

29. Radiac instrumentation. a. Sufficient radiac instruments will be available to properly support the use of radiation sources. The instruments will be capable of detecting the types and levels of radiation involved and any possible resulting contamination.

b. Personnel monitoring devices will be immediately available in areas in which radioactive materials are handled.

c. All instruments used for radiation protection will be calibrated at least every 3 months, and after each maintenance or battery change. More frequent calibration will be necessary for instruments which receive heavy use. Dosimeters need to be calibrated only at 6-month intervals. Dose rate instruments used to determine time of stay and exposure estimates should be calibrated at a minimum of two points on each instrument scale. The instruments will be labeled with DA Label 80 (U.S. Army Calibration System) to show the date of the last calibration, source or method used for calibration, and the initials of the calibrator.

d. Faulty instruments will be tagged with DA Form 2417 (Unserviceable Test Instrument or Standard) to prevent their being used before having been repaired.

e. Each instrument used for radiation protection should be provided with a check source or test sample.

f. Pocket dosimeters should be calibrated every 6 months. At the time of calibration, the correction factor for the dosimeter should be determined. Dosimeters which leak more than 5 percent of full scale after 24 hours in a radiation free area or which have an error of more than 10 percent should be repaired. Dosimeters should be calibrated by exposing them to known sources of an energy level comparable to that which the dosimeter will be exposed during use. Each dosimeter will bear a label showing the correction factor and the date of calibration. The correction factor is determined by dividing the actual level of radiation by the indicated level.

g. Dosimeters are used to give the wearer an estimate of his exposure while receiving the dose, in order that he may limit himself to permissible levels. Disagreement between dosimeter and film badge measurements is to be expected. The film badge reading will be used as the official dose for record purposes unless the badge is proven to have recorded an incorrect exposure.

h. Instrumentation must be selected based on the type and level of radioactive material and/or radiation to be encountered. In high radiation areas, it is desirable to have a high-range survey meter in addition to a low-range meter, in order to cover the range of dose rates likely to be encountered.

i. If funds permit, duplicate radiation protection instruments should be available. The duplicate instruments will avoid the necessity of shutting down a radiological operation until an instrument can be repaired or replaced.

30. Emergency procedures. a. In view of the complicating factors that may arise in an emergency, it is impossible to establish simple rules of procedure to cover all situations of a radiation emergency. However, in any emergency, the primary concern must always be the protection of personnel from radiation hazards. Confinement of the contamination to the immediate environment of the accident should be a secondary concern. Copies of the investigation report, relative to exposures received by the personnel involved, will be given to each individual involved in that emergency.

b. Emergencies will probably be of the following types:

- (1) Spill of radioactive material.
- (2) Explosion.
- (3) Fire.
- (4) Overexposure.
- (5) Injury to personnel.
- (6) Loss of radioactive source.
- (7) Vehicular accident involving radioactive material.

c. The medical officer of each AMC element having radiation sources shall establish written medical procedures for radiation casualties.

d. Emergency procedures will be preplanned and rehearsed at least once each year. In the event of an emergency, the following action will be taken:

(1) Spills or uncontrolled spread of contamination.

(a) Notify all persons not involved with the spill to vacate the area at once.

(b) If the spill is liquid and the hands and clothing are protected, right the container and take steps to contain the spillage.

(c) If the spill is on the skin, flush thoroughly.

(d) If the spill is on the clothing, discard outer or protective clothing at once.

(e) Notify the local radiological protection officer.

- (f) Decontaminate personnel.
- (g) Decontaminate the area.
- (h) Monitor all persons involved in the spill and cleaning operation to determine adequacy of decontamination.
- (i) Permit no person to resume work in the area until an area survey is made and the area is cleared by the radiological protection officer.
- (j) Prepare a complete history of the incident and decontamination operation related thereto for the facility or area records. The history will include a statement of the corrective actions taken to prevent a recurrence. Forward within 2 weeks of the accident, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(2) Accidents involving radioactive dusts, mists, fumes, organic vapors, and gases.

- (a) Notify all personnel not directly involved with the incident to vacate the area immediately.
- (b) Hold breath, and switch off any air circulating devices; e.g., fans, air conditioners, blowers, etc.
- (c) Vacate the area to a predesignated region, and allow no person to leave until monitored.
- (d) Close and seal all entrances into the area and post conspicuous warning signs or guards to prevent doors from being opened accidentally.
- (e) Notify the RPO.
- (f) Immediately report all known or suspected inhalations of radioactive materials to the local RPO and the medical officer.
- (g) Evaluate the hazards and the safety devices required for safe re-entry and apply the "two man rule."
- (h) Determine cause of contamination and rectify the condition.
- (i) Decontaminate the area.

(j) Perform an area survey (including air sampling) of the area before resuming normal operations.

(k) Monitor all persons suspected of contamination.

(l) Prepare a complete history of the accident and subsequent activity related thereto for the facility records. Forward, within 2 weeks of the incident, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(3) Injuries to personnel involving radiation.

(a) Wash minor wounds immediately under running water while spreading the edges of the wound.

(b) Contaminated personnel who are injured. In any radiological accident involving injured personnel, the local medical officer will be notified immediately. Unless an emergency medical reason requires that the injured person be removed immediately, the injured person will not be transported until a litter or ambulance is available. If, however, other emergencies exist (e.g., fire or possible explosion), good common judgment should be used. Moving of the patient may become imperative.

(c) Personnel with minor wounds will be monitored and decontaminated, if necessary, before leaving the radiation facility. If the wounds are of a serious nature, the injured individual will be wrapped in a blanket to prevent the further spread of contamination, and immediately be removed to the nearest medical facility. Persons accompanying the individual will warn the medical personnel that there is a possibility that the injured is contaminated.

(d) Report all radiation accidents (overexposure, wounds, ingestion, inhalation) to the personnel involved, to the medical officer, and to the RPO.

(e) Permit no person involved in radiation injury to return to work without the approval of the attending physician and the RPO.

(f) Prepare a complete history of the accident and subsequent activity related thereto for the radiation facility records. The history will include a statement of the corrective actions taken to prevent a recurrence. Forward, within 2 weeks of the occurrence, an information copy to the Commanding General, AMC, ATTN: AMCAD-S.

(4) Fires and other major emergencies.

(a) Notify all persons not directly involved with the incident who are in the area.

(b) Notify the fire department and other emergency personnel.

(c) Attempt extinguishment of fires using readily available first-aid type extinguishers if a radiation hazard is not immediately present. Efforts should be made to prevent water or fire fighting chemical from coming in contact with the radiation source. Attempt to control runoff, preventing it from entering sewers or drainage systems until it has been monitored.

(d) Notify the RPO.

(e) The RPO will advise and assist the emergency personnel.

(f) Following the emergency, monitor the area and determine the protective devices necessary for safe decontamination.

(g) Decontaminate.

(h) Monitor all persons who were in the emergency area and those who were involved in combating the emergency.

(i) Monitor downwind, delineate all contaminated areas, and restrict access as necessary.

31. Additional requirements. The above reporting requirements are in addition to the requirements of AR 385-40; AMCR 385-2; AMCR 385-3; and in addition to Title 10, Code of Federal Regulations, Sections 20.401, .402 and .403, when AEC-licensed material is involved. Information copies of reports to the AEC will be forwarded (AMCR 385-9) immediately, through channels, to the Commanding General, AMC, ATTN: AMCAD-S.

32. Key emergency personnel. Key emergency personnel, such as Provost Marshal, Fire Chief, Medical Officer, and Safety Officer will be kept currently informed of the receipt, storage, use, disposal, or transfer of radiation sources and will be sufficiently trained and equipped to cope with radiological emergencies independent of the presence of the RPO.

33. Records. Records will be maintained to document all aspects of the radiation protection effort. Included are:

- a. Licenses, authorizations, and supporting applications.
- b. Receipts, transfers and shipment records, notification of movement, and instructions to drivers.
- c. Inventory and leak test records.
- d. Instrument and source calibration records and certificates.
- e. Utilization logs and radiation work permits.
- f. Radiation survey records which include description of each use, operation or work performed; radiation levels and personnel exposure rates encountered; airborne and smearable contamination detected; hazards and corrective action, estimated personnel exposure; and disposition of radiation sources.
- g. Environmental monitoring records.
- h. Waste disposal records.
- i. Records of training, plans of instruction, experience and certification of radiation workers.
- j. Standing operating procedures.
- k. Records of special studies, investigations.
- l. Copies of reports originated and received.
- m. Inspection reports and related papers.
- n. Radiation analysis files.
- o. Minutes of committee meetings.
- p. Directives and interpretation of regulations.
- q. Personnel occupational exposure records. AR 40-14 requires the custodian of the medical records to prepare and maintain DD Form 1141 for each person occupationally exposed to ionizing radiation. For administrative control purposes, it is recommended that the Radiological Protection Officer maintain forms AEC-4 and AEC-5 also, where AEC licenses are involved. These forms are available at the U.S. Atomic Energy Commission, Division of Materials Licensing, Washington, D.C. 20545, and may be reproduced locally.

Appendix A

GLOSSARY OF RADIATION SAFETY TERMS

APPROVAL. Official certification of compliance with the provisions of this regulation and with instructions and directives as issued by Headquarters, AMC, or with those of other approving agencies specifically referred to in this regulation.

BACKGROUND RADIATION. Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

CONTAMINATION (RADIOACTIVE). Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence can be harmful. The harm may be in invalidating an experiment or a procedure, or in actually being a source of danger to persons.

CURIE. A unit of activity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10}

- millicurie - One-thousandth of a curie (3.700×10^7 disintegrations per second).

- microcurie - One-millionth of a curie (3.700×10^4 disintegrations per second).

DOSE.

1. Absorbed Dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit mass of irradiated material at the place of interest is called the absorbed dose and is measured in rads, where

$$1 \text{ rad} = 100 \text{ erg/gm} = 1/100 \text{ joule/kg.}$$

The rad unit is applicable to any type of ionizing radiation, but in reporting dose, the type, as well as irradiated material (for instance, tissue), and the place of interest must be specified. Without the above three factors, a statement of absorbed dose received is incomplete and probably useless, since the same dose of different kinds of radiation, even delivered to the same place, can produce entirely different effects.

2. Exposure Dose. See EXPOSURE

3. Biological Dose. The radiation dose absorbed in biological material. It is measured in rems.

DOSE EQUIVALENT. The term "RBE" dose has been used in the past in both radiobiology and radiation safety. It is now recommended that the term RBE be used in radiobiology only and that another term be used for purposes of radiation safety. The linear-energy-transfer factor is multiplied by the absorbed dose, D_a , to obtain a quantity that expresses on a common scale the irradiation received by persons exposed to all ionizing radiations. The name recommended for the linear-energy-transfer-dependent factor is quality factor, QF. Other factors must also be considered for the purposes of radiation safety. A distribution factor, DF, is used to express the modification of the biological effect of radiation due to a nonuniform distribution of isotopes in the body. The distribution factor, like the quality factor, also affects the absorbed dose when radiation safety is being considered. It is recommended by the International Commission on Radiological Units and Measurements that the final calculated dose received by an individual after the absorbed dose is modified by the above-mentioned factors, plus any other factors that may effect the incoming radiation, be called the dose equivalent, DE. If the only apparent modifying factors are QF and DF, then:

$$DE = D_a (QF) (DF).$$

If other factors must be considered and are defined, then:

$$DE = D_a (QF)(DF).....$$

where the dots take into account the product of these other factors. The unit of dose equivalent, DE is the rem. The unit of absorbed dose, D_a , is the rad. (Compare definitions of Rem and Rad.) Although the above definition of dose equivalent does not cover a number of theoretical aspects (in particular the physical dimensions of some of the quantities) it fulfills the immediate requirement for an unequivocal specification of a scale that may be used for numerical expression in radiation safety.

EXPOSURE. The term "Exposure Dose" is obsolete. Exposure is a term adopted by the International Commission on Radiological Units and Measurements in 1962 to replace the term "exposure dose" introduced in their 1956 report. The quantity is used for X- and gamma radiation. Exposure is the measure at a certain place of radiation which has the ability to produce ionization. The unit of exposure is the roentgen, R, where 1R equals 2.58×10^{-4} coulombs/kilogram. The definition thus corresponds to the terms roentgen dose and air dose.

EXPOSURE, OCCUPATIONAL. Exposure to ionizing radiation that is incurred as a result of an individual's employment or duties which are in support of facilities which use materials or machinery capable of producing ionizing radiation. Exposure of an individual to ionizing radiation for medical or dental diagnosis or therapy shall not be deemed as occupational exposure.

FAIL-SAFE. A design characteristic of the hardware, component or system which, in the event of a malfunction, will not result in a degradation of safety.

FILM BADGE. A pack of appropriate photographic film and filters used to determine radiation exposure.

HAZARD, RADIATION. See RADIATION HAZARD.

INTERLOCK. A device, usually electrical and/or mechanical in nature, to prevent activation of a control until a preliminary condition has been met or to prevent hazardous operations. Its purpose usually is safety of personnel or equipment. For example, it may be used to warn responsible personnel of an unsafe condition or unauthorized entry of personnel.

IONIZING RADIATION. See RADIATION.

LEAK TEST. A determination of the integrity of a sealed source encapsulation by detection of leakage or escape of radioactive contamination.

NUCLEAR REACTOR SYSTEM. Any equipment or device, except a nuclear weapon, capable of neutron multiplication through fission of special nuclear material. This definition includes nuclear reactors and subcritical assemblies of special nuclear material and the supporting equipment or device (if any) associated with them.

RAD. The rad is defined as the unit of absorbed dose of any nuclear (or ionizing) radiation which is accompanied by the liberation of 100 ergs of energy per gram of absorbing material. Or, one rad is approximately equal to absorbed dose delivered when soft tissue is exposed to one roentgen of medium voltage X-radiation. The rad is to be used solely with absorbed dose.

$$1 \text{ rad} = 100 \text{ erg/gram} = 1/100 \text{ joule/kg.}$$

RADIATION. Energy propagated through space. As used in this regulation, the term refers to two kinds of ionizing radiation:

1. Electromagnetic waves (X-rays, gamma rays), and
2. Corpuscular emissions from radioactive substances or other sources (alpha and beta particles, etc.). Ionizing radiation is any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

RADIATION CONTROLLED AREAS. Any area, whose access or occupancy is controlled for the purpose of protection of individuals from exposure to ionizing radiation and radioactive materials.

RADIATION CONTROL COMMITTEE. A group of persons appointed by the commander to advise him on policy and actions necessary to ensure safety of personnel and property from hazards of radiation. Synonymous with "Isotope Committee," "Radiological Health and Safety Committee," "Radiation Protection Committee," and other similar titles of committees with the same purpose.

RADIATION HAZARD. A condition under which persons might receive radiation in excess of the applicable maximum permissible dose, or where radiation damage might be caused to materials or personnel.

RADIATION SOURCES. Materials, equipment or devices which generate or are capable of generating ionizing radiation, including: (1) naturally occurring radioactive materials, (2) by-product materials, (3) source materials, (4) special nuclear materials, (5) fission products, (6) materials containing induced or deposited radioactivity, (7) nuclear reactors, (8) radiographic and fluoroscopic equipment, (9) particle generators and accelerators, and (10) radio frequency generators such as klystrons and magnetrons which produce X-rays.

RADIATION WORKER. Any person occupationally exposed to ionizing radiation and/or radioactive materials. (Job descriptions of radiation workers should reflect that the individual is potentially exposed to ionizing radiation.)

RADIOACTIVE MATERIAL. Any substance which undergoes spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides (a species of atom characterized by the constitution of its nucleus). The process is accompanied by the emission of one or more types of ionizing radiation. Included are materials possessing artificial, induced and natural radioactivity.

1. By-product materials. Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material.

2. Source material. Uranium or thorium or a combination thereof, in any physical or chemical form or ores which contain by weight, one-twentieth of one per cent (0.05 per cent) or more of uranium, thorium or any combination thereof. Source material does not include special nuclear material.

3. Special nuclear material. Plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, or any other material which the U. S. Atomic Energy Commission pursuant to the provisions of section 51 of the Atomic Energy Act of 1954, 42 USC section 2071, determines to be

special nuclear materials, but does not include source material; or any material artificially enriched by any of the foregoing but does not include source material.

4. Naturally occurring radioactive material. Substances which are radioactive in the natural state, such as radium and thorium and their decay products, except those defined as source and special nuclear material.

RADIOLOGICAL PROTECTION OFFICER. An individual designated by the commander to provide consultation and on the degree of hazards associated with ionizing radiation and the effectiveness of measures to control these hazards. This individual shall be technically qualified by virtue of education, military training, and/or professional experience to assure a capability commensurate with the assignment. The term "Radiological Protection Officer" is a functional title and is not intended to denote a commissioned status or job classification within the Armed Forces.

RBE. (Relative Biological Effectiveness.) The RBE of a given radiation is defined as the ratio of the absorbed dose in rads of gamma radiation (of a specific energy) to the absorbed dose in rads of the given radiation having the same biological effect. (See Dose Equivalent.)

REM (Roentgen Equivalent Mammal). One rem is the quantity of ionizing radiation of any type which, when absorbed by man or other mammal produces a physiological effect equivalent to that produced by the absorption of one roentgen of X-ray or gamma radiation. Dose in rems equals RBE times dose in rads. The rem provides an indication of the extent of biological injury (of a given type) that would result from the absorption of nuclear radiation. Thus, the rem is a dose unit of biological effect, whereas the rad is a unit of absorbed energy dose, and the roentgen (for X-ray and gamma rays only) is one of exposure. The rem can also be defined as the unit of dose equivalent. The dose equivalent is numerically equal to the dose in rads, multiplied by the appropriate modifying factors.

ROENTGEN. The quantity of gamma or X-radiation which will give rise to the formation of 2.08×10^7 ion pairs per cubic centimeter of dry air, STP (0°C , 1 atm). This is equivalent to the release of 87.7 ergs of energy when one gram of dry air under STP conditions is exposed to one roentgen of radiation. The roentgen is to be used solely as the unit for exposure.

$$1 \text{ R} = 2.58 \times 10^{-4} \text{ coulombs/kg.}$$

SEALED SOURCE. Radioactive material that is encased in and is to be used in a container in a manner to prevent leakage or escape of the radioactive material.

UNSEALED SOURCE. A discrete amount of radioactive material that is not encapsulated in a container to prevent leakage or escape of the radioactive material.

USER. The activity, section, division or other organizational unit which has been assigned responsibility for the use, handling, operation or storage of radiation sources.

Appendix B

RECOMMENDED DOCUMENTS FOR A REFERENCE LIBRARY

1. Army regulations. AR's 40-4, 40-5, 40-14, 40-37, 40-501, 55-55, 55-355, 385-10, 385-12, 385-30, 385-32, 385-40, 385-80, 700-25, 700-52, 700-63, 700-64, and 755-15.
2. AMC regulations. AMCR's 190-3, 385-1, 385-3, 385-7, 385-9, 385-13, and 385-15.
3. Field manual. FM 3-15.
4. Table of allowances. TA 50-914.
5. Supply bulletin. SB 11-206.
6. Technical bulletins. TB's CML 52, CML 53, CML 63, 3-6665-200-12, 3-6665-201-12, 3-6665-202-12, 3-6665-203-12, 3-6665-204-12, MED 62, MED 223, MED 232, MED 249, SIG 226-8, SIG 226-9, TC 7, and 5-6600-227-15/1.
7. Technical manuals. TM's 3-220, 3-260, 3-261, 3-6665-214-15, 11-5514, 11-5514A, 11-5543, 11-6665-204-12, 11-6665-206-12, 11-6665-208-15, 11-6665-209-15, 11-6665-216-15, 11-6665-221-15, 11-6665-224-15, 38-250, 38-750, 39-20-3, 39-20-6, 39-35-15, 39-N-11.
8. Military standards and specifications.¹
 - a. MIL-STD-129 Marking for Shipment and Storage.
 - b. MIL-M-3935A Markers, Self-Luminous.
 - c. MIL-C-10436 Compasses, Lensatic, Luminous Dial.
 - d. MIL-M-19590 Marking of Commodities and Containers to Indicate Radioactive Material.
 - e. MIL-STD-450 Radiation Hazard Symbol Contaminated Areas.
9. Miscellaneous.
 - a. DOD 4160.21-M, Defense Disposal Manual.
 - b. Title 10, Code of Federal Regulations. Atomic Energy.²
 - c. Title 14, Part 49 of Code of Federal Regulations.²
 - d. Title 46, Part 146 of Code of Federal Regulations.²
 - e. Title 49, Parts 171 through 178 of Code of Federal Regulations.^{2 3}
 - f. U.S. Postal Manual, Chapter 1, Sections 124.24 and 125.24.⁴

^{1 2 3 4} See footnotes on page 47.

g. Radiological Health Handbook, U.S. Department of Health, Education and Welfare.⁴

10. U.S. Department of Commerce, National Bureau of Standards Handbooks.

- 48 - Control and Removal of Radioactive Contamination in Laboratories.
- 49 - Recommendations for Waste Disposal of Phosphorus 32 and Iodine 131 for Medical Users.
- 51 - Radiological Monitoring Methods and Instruments.
- 53 - Recommendations for the Disposal for Carbon-14.
- 55 - Protection Against Betatron-Synchrotron Radiations up to 100 Million Electron Volts.
- 57 - Photographic Dosimetry of X- and Gamma Rays.
- 58 - Radioactive Waste Disposal in the Ocean.
- 59 - Permissible Dose for External Sources of Ionizing Radiation.
- 63 - Protection Against Neutron Radiation up to 30 Million Electron Volts.
- 65 - Safe Handling of Bodies Containing Radioactive Isotopes.
- 66 - Safe Design and Use of Industrial Beta-Ray Sources.
- 69 - Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.
- 72 - Measurement of Neutron Flux and Spectra for Physical and Biological Applications.
- 73 - Protection Against Radiation from Sealed Gamma Sources.
- 75 - Measurement of Absorbed Doses of Neutrons and of Mixtures of Neutrons and Gamma Rays.
- 76 - Medical X-ray Protection up to 3 Million Volts.
- 78 - Report of International Commission on Radiological Units. and Measurements
- 80 - A Manual of Radioactivity Procedures.

⁴See footnotes on page 47.

- 84 - Radiation Quantities and Units (ICRU Report 10a).
- 85 - Physical Aspects of Irradiation (ICRU Report 10b).
- 86 - Radioactivity (ICRU Report 10c).
- 87 - Clinical Dosimetry (ICRU Report 10d).
- 88 - Radiobiological Dosimetry (ICRU Report 10e).
- 89 - Methods of Evaluating Radiological Equipment and Materials (ICRU Report 10f).
- 92 - Safe Handling of Radioactive Materials.
- 93 - Safety Standard for Non-Medical X-ray and Sealed Gamma Ray Sources: Part I. General.

11. Federal Radiation Council Reports⁴

- No. 1 - Background Material for the Development of Radiation Protection Standards.
- No. 2 - Background Material for the Development of Radiation Protection Standards.

12. International Atomic Energy Agency Regulations⁵

- Safety Series No. 1 - Safe Handling of Radioisotopes.
- Safety Series No. 2 - Safe Handling of Radioisotopes: Health Physics Addendum.
- Safety Series No. 3 - Safe Handling of Radioisotopes: Medical Addendum.
- Safety Series No. 4 - Safe Operation of Critical Assemblies and Research Reactors.
- Safety Series No. 6 - Regulations for the Safe Transport of Radioactive Materials.
- Safety Series No. 7 - Regulations for the Safe Transport of Radioactive Materials. Notes on Certain Aspects of the Regulations.
- Safety Series No. 8 - The Use of Film Badges for Personnel Monitoring.

⁴ ⁵ See footnotes on page 47.

Safety Series No. 9 - Basic Safety Standards for Radiation Protection.

Review Series No. 12 - The Packaging, Transport and Related Handling of Radioactive Materials.

Review Series No. 18 - Processing of Radioactive Wastes.

13. National Fire Protection Association Publications⁶

Fire Protection Handbook, 12th Edition, 1962.

National Fire Codes -

Pamphlet 801, Laboratories Handling Radioactive Material, 1955.

Pamphlet 802, Nuclear Reactors, 1960.

14. USA Standards Institute Publications⁷

ASA N6.1 - Safety Standard for Operations with Fissionable Materials Outside Reactors, 1964.

ASA N5.2 - Design Guide for a Radioisotope Laboratory (Type B), 1963.

¹Military standards and specifications are available from the Commanding Officer, U.S. Naval Supply Depot (NSD 103), 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

²Copies of the Code of Federal Regulations are normally available from the Post Judge Advocate. Copies can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

³The Interstate Commerce Commission regulations are also published as "Agent TC George's Tariff No. 19", available from the Bureau of Explosives of the American Association of Railroads, 30 Vesey Street, New York, New York. Installation Transportation Officers usually have copies of George's Tariff No. 19.

⁴Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

⁵Available from National Agency for International Publications, Inc., 801 Third Avenue, New York, New York 10022

⁶Available from National Fire Protection Association, 60 Batterymarch Street, Boston, Massachusetts 02110.

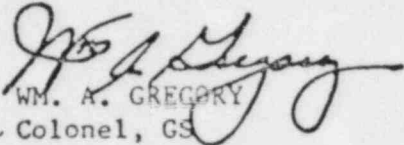
⁷Available from USA Standards Institute, 70 East 45th Street, New York, New York 10017.

AMCR 385-25

(AMCAD-S)

FOR THE COMMANDER:

OFFICIAL:



WM. A. GREGORY
Colonel, GS
Chief, Administrative Office

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A and B

DEPARTMENT OF THE ARMY
 HARRY DIAMOND LABORATORIES
 2800 Powder Mill Rd., Adelphi, MD 20783

HDL MEMORANDUM
 No. 385-20

24 March 1980

Safety

IONIZING RADIATION PROTECTION PROGRAM

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1. Purpose. This memorandum establishes the Ionizing Radiation Protection Program, outlines duties of the Radiation Protection Officer, the Radiation Control Committee and prescribes procedures and safe working practices which must be observed by personnel engaged in operations involving ionizing radiation sources.

2. Scope. The provisions of the Ionizing Radiation Protection Program apply to all the military and civilian personnel under the administrative control of the Commander, Harry Diamond Laboratories, to the employees of contractors and to military and civilian personnel of other Government agencies authorized to receive, use, store, transport, or dispose of ionizing radiation sources at Harry Diamond Laboratories. This memorandum does not apply to sources of non-ionizing radiation such as lasers and microwave producing equipment.

3. Definitions:
 - a. Accelerator. A device for imparting kinetic energy to charged particles, such as electrons, protons, deuterons, and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator and Van-de-Graff electrostatic generators.

 - b. Background Radiation. Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

 - c. Contamination (Radioactive). Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence can be harmful. The harm may be in invalidating an experiment or a procedure, or in actually being a source of danger to persons.

**This Memorandum supersedes HDLR 385-20, 7 August 1973

d. Curie. A unit of activity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10} .

e. Dose. (1) Absorbed Dose. When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit of mass of irradiated material at the place of interest is called the absorbed dose and is measured in rads, where

$$1 \text{ rad} = 100 \text{ erg/gm} = 1/100 \text{ joule/kg}$$

The rad unit is applicable to any type of ionizing radiation, but in reporting dose, the type, as well as irradiated material (for instance, tissue), and the place of interest must be specified. Without the above three factors, a statement of absorbed dose received is incomplete and probably useless, since the same dose of different kinds of radiation, even delivered to the same place, can produce entirely different effects.

(2) Exposure Dose. See Exposure.

(3) Biological Dose. The radiation dose absorbed in biological material. It is measured in rems.

f. Dose Equivalent. The term "RBE" dose has been used in the past in both radiobiology and radiation safety. It is now recommended that the term RBE be used in radiobiology only and that another term be used for purposes of radiation safety. The linear-energy-transfer factor is multiplied by the absorbed dose, D_a , to obtain a quantity that expresses on a common scale irradiation received by persons exposed to all ionizing radiations. The name recommended for the linear-energy-transfer-dependent factor is quality factor, QF. Other factors must also be considered for the purpose of radiation safety. A distribution factor, DF; is used to express the modification of the biological effect of radiation due to a nonuniform distribution of isotopes in the body. The distribution factor, like the quality factor, also affects the absorbed dose when radiation safety is being considered. It is recommended by the International Commission on Radiological Units and Measurements that the final calculated dose received by an individual after the absorbed dose is modified by the above-mentioned factors, plus any other factors that may affect the incoming radiation, be called the dose equivalent, DE. If the only apparent modification factors are QF and DF, then:

$$DE = D_a (QF) (DF).$$

If other factors must be considered and are defined, then:

$$DE = D_a (DF) (DF) \dots\dots\dots$$

where the dots take into account the product of these other factors. The unit of dose equivalent, DE is the rem. The unit of absorbed dose, D_a , is the rad. (Compare definitions of Rem and Rad.) Although the above definition of dose equivalent does not cover a number of theoretical aspects (in particular the physical dimensions of some of the quantities) it fulfills the immediate requirement for an unequivocal specification of a scale that may be used for numerical expression in radiation safety.

g. Exposure. The term "Exposure Dose" is obsolete. Exposure is a term adopted by the International Commission on Radiological Units and Measurements in 1962 to replace the term "exposure dose" introduced in their 1956 report. The quantity is used for X- and gamma radiation. Exposure is the measure at a certain place of radiation which has the ability to produce ionization. The unit of exposure is the roentgen, R, where 1R equals 2.58×10^{-4} coulombs/kilogram. The definition thus corresponds to the terms roentgen dose and air dose.

h. Exposure, Occupational. Exposure to ionizing radiation that is incurred as a result of an individual's employment or duties which are in support of facilities which use materials or machinery capable of producing ionizing radiation. Exposure of an individual to ionizing radiation for medical or dental diagnosis or therapy shall not be deemed as occupational exposure.

i. Film Badge. A pack of appropriate photographic film and filters used to determine radiation exposure.

j. Interlock. A device, usually electrical and/or mechanical in nature, to prevent activation of a control until a preliminary condition has been met or to prevent hazardous operations. Its purpose usually is safety of personnel or equipment. For example, it may be used to warn responsible personnel of an unsafe condition or unauthorized entry of personnel.

k. Ionizing Radiation. Electromagnetic or particulate radiation capable of producing ions, directly or indirectly in its passage through matter. For purposes of this memorandum, alpha and beta particles, gamma rays, X-rays, and neutrons are examples of ionizing radiation. This type of radiation does not include sound or radio waves, visible, infra-red or ultraviolet light or lasers.

l. Leak Test. A determination of the integrity of a sealed source encapsulation by detection of leakage or escape of radioactive contamination.

m. Rad. The rad is defined as a unit of absorbed dose of any nuclear (or ionizing) radiation which is accompanied by the liberation of 100 erg of energy per gram of absorbing material. Or, one rad is approximately equal to absorbed dose delivered when soft tissue is exposed to one roentgen of medium voltage, X-ray radiation. The rad is to be used solely with absorbed dose.

1 rad - 100 erg/grams = 1/100 joule/kg.

n. Radiation. See Ionizing Radiation.

o. Radiation Areas.

(1) Restricted Area. Any area access which is controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(2) Unrestricted Area. Any area access which is not controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(3) Radiation Area. Any area accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirem.

(4) High Radiation Area. Any area accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

p. Radiation Hazard. A condition under which persons might receive radiation in excess of the applicable maximum permissible dose, or where radiation damage might be caused to materials or personnel.

q. Radiation-Producing Devices. See Radiation Sources.

r. Radiation Sources. Materials, equipment or devices which generate or are capable of generating ionizing radiation, including: (1) naturally occurring radioactive materials, (2) byproduct materials, (3) source materials, (4) special nuclear materials, (5) fission products, (6) materials containing induced or deposited radioactivity, (7) nuclear reactors, (8) radiographic and fluoroscopic equipment, (9) particle generators and accelerators, and (10) radio frequency generators such as klystrons and magnetrons which produce X-rays.

s. Radiation Worker. Any person occupationally exposed to ionizing radiation and/or radioactive materials. (Job descriptions of radiation workers should reflect that the individual is potentially exposed to ionizing radiation.)

t. Radioactive Material. Any substance which undergoes spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides (a species of atom characterized by the constitution of its nucleus.) The process is accompanied by the emission of one or more types of ionizing radiation. Included are materials possessing artificial, induced and natural radioactivity.

(1) Byproduct Materials. Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material.

(2) Source Material. Uranium or thorium or a combination thereof, in any physical or chemical form or ores which contain by weight, one-twentieth of one per cent (0.05 percent) or more of uranium, thorium, or any combination thereof. Source material does not include special nuclear material.

(3) Special Nuclear Material. Plutonium, uranium 233, uranium enriched in the isotope 233 or any other material which the U.S. Atomic Energy Commission pursuant to the provisions of Section 51 of the Atomic Energy Act of 1954, 42 USC Section 2071, determines to be special nuclear materials, or any material artificially enriched by any of the foregoing but does not include source material.

(4) Naturally Occurring Radioactive Material. Substances which are radioactive in the natural state, such as radium and thorium and their decay products, except those defined as source and special nuclear material.

u. RBE. (Relative Biological Effectiveness) The RBE of a given radiation is defined as the ratio of the absorbed dose in rads of gamma radiation (of a specific energy) to the absorbed dose in rads of the given radiation having the same biological effect. (See Dose Equivalent.)

v. REM. (Roentgen Equivalent Man). One rem is the quantity of ionizing radiation of any type which, when absorbed by man or other mammal, produces a physiological effect equivalent to that produced by the absorption of one roentgen of X-ray or gamma radiation. Dose in rems equals RBE times dose in rads. The rem provides an indication of the extent of biological injury (of a given type) that would result from the absorption of nuclear radiation. Thus, the rem is a dose unit of biological effect, whereas the rad is a unit of absorbed energy dose, and the roentgen (for X-ray and gamma rays only) is one of exposure. The rem can also be defined as the unit dose equivalent. The dose equivalent is numerically equal to the dose in rads, multiplied by the appropriate modifying factors.

w. Roentgen. The quantity of gamma or X-radiation which will give rise to the formation of 2.08×10^9 ion pairs per cubic centimeter of dry air, STP (0° C, 1 atm). This is equivalent to the release of 87.7 ergs of energy when one gram of dry air under STP conditions is exposed to one roentgen of radiation. The roentgen is to be used solely as the unit for exposure.

$$1 R = 2.58 \times 10^{-4} \text{ coulombs/kg.}$$

x. Sealed Source. Radioactive material that is encased in and is to be used in a container in a manner to prevent leakage or escape of the radioactive material.

y. Unsealed Source. A discrete amount of radioactive material that is not encapsulated in a container to prevent leakage or escape of the radioactive material.

z. User. The activity, section, division or other organizational unit which has been assigned responsibility for the use, handling, operation or storage of radiation sources.

4. Policy. Work with radiation sources may present a biological hazard. Failure to exercise proper controls can be hazardous to health and may also result in property damage. Therefore, proposals to obtain and use such sources will be evaluated carefully to assure that any exposure to radiation will be kept to a minimum. Adequate written procedures, facilities, equipment, and trained personnel must be provided where radiation sources are used or operated. Failure to meet these requirements will result in cessation of operations.

5. Responsibilities. a. Commander. The Commander will:

- (1) Establish a formal, written Ionizing Radiation Protection Program.
- (2) Appoint a Radiation Control Committee.
- (3) Appoint a qualified individual as Radiation Protection Officer and alternate to provide continuity of operations.
- (4) Assure compliance with Federal, State, and local regulations.

b. Radiation Control Committee (RCC).

- (1) The committee will consist of the Radiation Protection Officer, the Safety Director, and several technical members trained and experienced in the safe use of radiation.
- (2) Specifically, the committee will:
 - (a) Advise the Commander on the status of the radiation protection program.
 - (b) Prepare, amend and review rules and regulations pertaining to the safe use, storage and disposal of radiation sources.
 - (c) Review and approve proposed location of radiation sources.
 - (d) Review and authorize uses of existing and proposed radiation sources.
 - (e) Serve as reviewing committee for incidents involving the use of radiation sources which result in over-exposure.
 - (f) Recommend appropriate action to be taken when individuals using radiation fail to observe safety recommendations, rules, or regulations.
 - (g) Review any instance in which radiation safety regulations impede operations considered essential by the laboratory concerned.
 - (h) Assure that minutes of the RCC's proceedings and actions taken or recommended are maintained.
- (3) Primary responsibility for the enforcement of established rules and regulations is not the responsibility of the RCC but rather the responsibility of each individual and his direct supervisor.

c. Radiation Protection Officer (RPO)

- (1) The training and experience of the RPO and his alternate must be commensurate with the type and hazard of the radiation sources at HDL. As a minimum, the formal training of the RPO and his alternate will be the successful completion of the U.S. Public Health Service Occupational Radiation Protection course or equivalent.
- (2) The Radiation Protection Officer will:
 - (a) Act as Chairman of the RCC.
 - (b) Provide the Commander, the RCC, and radiation users with advice and assistance on all matters pertaining to radiation safety.
 - (c) Review all plans for the proposed use of radiation sources and make the appropriate recommendations.
 - (d) Review all requisitions for procurement of radiation sources.
 - (e) Maintain an accurate record of the inventory of the radiation sources possessed by HDL.
 - (f) Perform radiation protection surveys of radiation sources to determine compliance with regulations and approved procedures.
 - (g) Maintain radiation protection records.
 - (h) Calibrate, or arrange for calibration of, survey instruments.
 - (i) Supply personnel monitoring devices, provide instructions in their use, and maintain records of exposure.
 - (j) Monitor shipments of radioactive materials.

- (k) Supervise decontamination of materials or personnel.
- (l) Monitor storage and working areas as required.
- (m) Supervise the disposal of radioactive wastes.
- (n) Maintain complete records of the receipt, transfer, and disposal of radiation sources.
- (o) Maintain records of unusual incidents such as overexposures, radioactive spills, or the loss of radioactive materials.
- (p) Arrange for radiation safety orientation and training of laboratory personnel.
- (q) Prepare and submit applications for NRC licenses.
- (r) Review, update, and amend NRC licenses presently in effect.
- (s) Prior to being relieved of his duties, the RPO will take the following action with regard to radiation sources for which he is responsible.

1. Secure all sources in such a manner as to preclude use or removal during the period for which there is no RPO appointed; or

2. turn over to a properly qualified and authorized individual, all materials and records for which he is responsible. Such an authorized individual will have the qualifications and training required of an RPO--

d. Supervisors of radiation workers and radiation projects will:

- (1) Maintain a current inventory of all radiation sources for which they are responsible.
- (2) Know the exact location of all radiation sources for which they are responsible.
- (3) Post appropriate warning signs and notices.
- (4) Assure that their personnel have received adequate instruction and experience prior to using or being exposed to radiation.
- (5) Control contamination.
- (6) Assure radiation sources are secured against unauthorized use.
- (7) Control personnel exposures.
- (8) Prepare, prior to the start of any operation involving radiation sources, a written SOP for review and approval by the RPO and RCC. The SOP will contain, as a minimum: responsibilities, maximum permissible levels of radiation in the areas concerned, storage of radioactive materials, procedures regarding dosimetry, interlocks, decontamination and emergencies.
- (9) Enforce SOP's, rules and special precautions.
- (10) Report to the RPO an accident, unusual incident, personnel injury, or suspected overexposure immediately after occurrence.
- (11) Prior to being relieved of his duties, each radiation supervisor will take the following action with regard to all radiation sources for which he is responsible:
 - (a) Secure all radiation sources in such a manner as to preclude use or removal while not under the immediate supervision of a qualified and authorized individual; or
 - (b) turn over to a properly qualified and authorized individual all radiation sources for which he is responsible. Such an individual will have the qualification and training required for the safe handling of the materials involved.

e. Radiation workers will: (1) Know and follow SOP's, rules, and special instructions.

(2) Use safety equipment properly.

(3) Report to the supervisor any accident, unusual incident, personal injury, or suspected overexposure immediately after the occurrence.

f. Supervisors of Radiation Facilities will assure that each procurement document for a "basic component" for a radiation facility, i.e., Nuclear Reactor, Cobalt Irradiator, etc., licensed pursuant to Title 10 Code of Federal Regulations, specifies that the provisions of 10 CFR Part 21 apply. A "basic component" means a component, structure, system or part thereof in which a defect could create a substantial safety hazard, i.e., loss of safety function to the extent that there is a major reduction in the degree of protection provided to public health and safety.

6. Personnel Exposures. The radiation exposure standards contained in this section are applicable to all personnel. Present day philosophy of the Nuclear Regulatory Commission (NRC) is that radiation exposures be kept "as low as reasonable achievable" (ALARA). Applications for licenses to operate radiation facilities must address and emphasize the ALARA concept. The NRC presently requires that the concentrations of ionizing radiation materials be kept at less than ten percent of the levels listed in 10 CFR 20. If these concentrations and exposure levels cannot be maintained, then justification for higher concentrations and exposure levels must be made in the license application. The following personnel exposure limits are those currently listed in 10 CFR 20.

a. Personnel 19 years of age and over who are occupationally exposed to radiation:

(1) Accumulated dose to the whole body, head, trunk, blood-forming organs, gonads or lens of the eye is not to exceed 1.25 rem in any calendar quarter.

(2) Accumulated dose to the skin of the whole body or thyroid is not to exceed 7.5 rem per calendar quarter.

(3) Accumulated dose to the hands, forearms or feet is not to exceed 18.75 rem per calendar quarter.

b. Members of the general public, personnel not occupationally exposed, and those under 18 years of age will not be exposed, in any one calendar quarter, in excess of 0.125 rem.

c. Pregnant women will not be exposed to ionizing radiation for other than medical reasons (AR 40-5). At the first indication of pregnancy, women should notify their supervisor so they can be removed from work involving exposures.

7. Medical Examinations. a. Prior to beginning work with radiation sources, employees will be given an examination to include medical history, radiation exposure history, physical examination, and a complete blood count. Personnel, who are to be occupationally exposed to neutrons, will be given a slit-lamp test prior to exposure.

b. If a similar examination has been conducted within the previous 6 months, those portions of the examination need not be repeated for which results are entered in the individual's record.

c. Visitors and personnel on temporary duty for less than 30 days do not require a medical examination provided they will not be exposed to radiation in excess of the levels established in paragraph 6a.

d. Radiation workers will be given a medical examination at least once every 3 years. However, depending upon the work involved, the Medical Officer may desire to repeat the examination more frequently.

e. In addition, a full examination will be requested in event of overexposure, suspected overexposure, transfer to other operations not involving radiation, or prior to separation from HDL.

f. Supervisors will advise the RPO of new employees working with radiation sources so that appropriate orientation and physical examination can be arranged. The RPO should be notified as far

as possible in advance of transfers and termination of employment of radiation workers so arrangements can be made for final examination.

8. Personnel Dosimetry. a. All persons occupationally exposed to ionizing radiation will utilize film badges. The RPO will control the distribution and collection of film badges.

b. Before starting to work with any radiation source, the individual must obtain a film badge from the RPO. It is the responsibility of the individual and his supervisor to obtain the required film badge before beginning work with ionizing radiation.

c. It is important that the film badge be worn rather than left in a desk drawer or pinned on a laboratory coat not being worn. Any person who suspects that he has been exposed to ionizing radiation while not wearing his film badge will report the same to the RPO. Also, any person who suspects that his badge has been exposed to ionizing radiation to which he was not exposed will immediately report same to the RPO.

d. Off-site personnel monitoring.

(1) Arrangements will be made with the RPO to provide the necessary personnel-monitoring services to HDL personnel on official duty in places where film badge service is not available.

(2) The names of HDL personnel assigned to duties at places where personnel-monitoring services are available must be submitted to the RPO by the laboratory concerned.

e. All visitors, experimenters at HDL facilities, who may become exposed to ionizing radiation must wear film badges. It is the responsibility of the facility supervisor to obtain visitor badges from the RPO and enforce wearing of the badges. The supervisor will maintain a monthly record of visitors, listing the name, business address and social security number of the visitor plus the badge number issued. Badges will not be issued to more than one person.

9. Precautions in Handling Radiation Sources. a. Consider the relationships which will develop between the source and the persons involved in its use. Remember that the objective is to keep all occupational exposures as far below 100 mrem/week as is practicable. The individual who is assigned the radiation source has the responsibility to see that this objective is attained.

b. Determine before irradiation occurs what dose rate will be experienced by each individual under each conceivable circumstance. Advise the individual before he begins work regarding the dose rate he will incur in each situation. Be sure that he knows the location of the sources involved as well as the protective measures to be employed.

c. Take steps to ensure that no one may be exposed inadvertently. Also, prevent radiation sources from being removed from the work area. Prevent transmission of contamination by persons, tools, packages, document, vehicles, etc. Keep radioactive materials out of ordinary channels of waste disposal.

10. Contamination Control. a. The Radiation Protection Officer will issue expendable clothing to those persons working in areas where contamination is reasonable possible.

b. Cross-contamination may be limited by employing practical handling techniques. Simple acts such as handling telephones, reports, etc. while contaminated can result in the spread of contamination. Only things which may safely become radioactive should be permitted to touch radioactive items, and once such a contact is made, both items are thereafter treated as being radioactive.

c. Individuals who contaminate themselves or others, or who cause the contamination of areas, floors, equipment, etc. will notify the RPO at once. The RPO will assess the extent of the contamination and supervise the necessary decontamination procedures. It is not the duty of the RPO to perform the actual decontamination. It is the responsibility of the person causing the contamination to carry out the necessary clean-up procedures.

11. Authorization for Procurement of Radioactive Materials. a. The HDL Radiation Control Committee must authorize all proposals for work with radioactive materials.

b. The person responsible for and directing the undertaking of the use of radioactive material, the principal user, will submit a memorandum in duplicate to the RCC containing all pertinent information concerning the proposed operation. The memorandum will include:

- (1) Organizational element responsible for the proposed operation.
- (2) Purpose for which the materials will be used, including the desired initiation date and estimated duration of the project.
- (3) Materials desired, including:
 - (a) Isotope and maximum activities to be used and processed at any one time.
 - (b) Whether sealed or unsealed.
 - (c) Chemical or physical form.
 - (d) Qualifications and experience of the persons who will directly supervise the operation.
 - (e) Qualifications and experience of persons who will use or handle the material.
 - (f) Locations where materials will be used or stored.
 - (g) Monitoring equipment available to support the operation.
 - (h) Facilities, equipment storage containers, exhaust hoods, handling equipment, and protective equipment available.
 - (i) Operational procedures.
 - (j) Radiation protection procedures to include safeguards to preclude emergencies, and actions to be taken should an emergency occur.
 - (k) Estimated exposure of operational and nearby nonoperational personnel.

c. The Radiation Control Committee will then review the proposal.

- (1) Proposals rejected by the committee will be returned to the principal user with the reason for rejection indicated.
- (2) If approved, the original copy of the approved proposal will be returned to the principal user and the duplicate will be kept in the RCC file.
- (3) Once operations have been approved, no changes will be allowed prior to review and approval by the RCC.

d. Requests for the procurement of all radioactive materials will be processed through the RCC. No order for radioactive material may be placed without having obtained the authorization of the RCC for the intended use of the material. The RPO will act for the RCC for routine procurement requests.

- (1) The purchase requisition (DELHD 960) is first sent to the RPO with a duplicate copy.
- (2) The purchase requisition must be identified with the proposal for which the material is ordered and for which prior authorization of the RCC has been obtained.
- (3) The RPO will then endorse the purchase request and forward it to the Procurement Office, or will hold the request for further study and consultation with the person making the request.
- (4) If the radioactive material is obtained by means other than a purchase request, a memorandum should be sent to the RPO as far in advance as possible and in any case before the material is brought into the laboratories. The memorandum will contain the proposal for which the material is ordered and for which the authorization of the RCC has been obtained.

12. Authorization for Procurement/Use of Radiation Producing Devices.

a. The HDL RCC must authorize all proposals for work with radiation producing devices at HDL.

b. The person responsible for and directing the undertaking of (the principal user) operations involving radiation producing devices will submit a memorandum in duplicate to the RCC containing all pertinent information of the proposed operation. The memorandum will include (where applicable):

- (1) Type of device.
 - (a) Function.
 - (b) Manufacturer and Model Number.
 - (c) Radiation output.
 - (d) Anticipated workload.
 - (e) Whether fixed or mobile operation is anticipated.
 - (f) Whether single or multiposition exposure head is to be used.
 - (g) Pulse duration and anticipated workload.
 - (h) Target.
 - (i) Calibration procedure and frequency.

(j) For accelerators: the curie level of the target, the mode of operation (positive or negative), energy of accelerator particles, the procedures for exchange of targets, and the available ventilation.

(2) Safeguards.

(a) Shielding.

(b) Interlock provisions and console locations.

(c) Estimated exposure based on seven-consecutive day operation modified by the planned workload. (Exposures of operational and non-operational personnel must be considered.)

(d) Occupied locations nearby.

(3) Training and experience of operators.

c. The RCC will then review the memorandum.

(1) Proposals rejected by the committee will be returned to the principal user with the reason for the rejection indicated.

(2) If approved, the original copy of the approved proposal will be returned to the principal user and the duplicate will be left in the RCC file.

(3) Changes to originally approved operations must be submitted to the RCC for review and approval.

d. Requests for the procurement of all radiation-producing devices will be processed through the RCC. No order for radiation-producing devices may be placed without having obtained the authorization of the RCC for the intended use of the machine. The RPO will act for the RCC for routing procurement requests.

(1) The purchase requisition (DELMD Form 960) is first sent to the RPO with a duplicate copy.

(2) The purchase requisition must be identified with the proposal for which the machine is ordered and for which prior authorization of the RCC has been obtained.

(3) The RPO will then endorse the purchase request and forward it to the Procurement Office, or will hold the request for further study and consultation with the person making the request.

13. Shipment of Radioactive Materials. a. Incoming.

(1) All radioactive material shipments must be shipped to and received by the RPO unless prior authorization for another procedure has been granted by the RCC.

(2) The Logistics Management Office will take the following action:

(a) The pickup of radioactive material will be accomplished as soon as practicable after receiving notification by the carrier that the material is available.

(b) Contact the RPO immediately when a package arrives at HDL. Packages must be monitored for excessive leakage and contamination by the RPO within 3 hours of receipt during duty hours or within 18 hours of receipt during non-duty hours.

(c) Insure that the RPO monitors each package inside and out while it is being opened and before the packaging of the contents are moved away from the unpacking location.

(3) The Radiation Protection Office will:

(a) Monitor the radioactive material for excessive external radiation or contamination prior to unloading.

(b) Check the vehicle for contamination immediately after unloading the radioactive item.

(c) Direct decontamination of materials if contamination is evident.

(d) Irrespective of the physical condition of the package, the package must be accepted. If damaged, active steps must be taken to minimize exposure of personnel and contamination of property.

(e) Upon receipt of the shipment, a record of the condition and dose rate levels of radiation will be entered on DA Form 2791-R. DA Form 2791-R will be reproduced locally to furnish the Radiation Protection Officer with a copy. The original DA Form 2791-R will be attached to the shipping documents and become a part of the permanent record of the shipment.

(f) Direct movement of the item to the individual laboratory or to those staging and storage areas determined by the RCC.

b. Outgoing. (1) The requestor:

(a) Prepares DELMD Form 57 (Shipping Request) and forwards it to the RPO with an extra copy.

(b) Insures that items are checked, tagged and approved by the RPO prior to sending to the Logistics Management Office unless authorization for another procedure has been granted by the RCC.

(c) When applicable, determines that the recipient is properly licensed by the NRC to receive the shipment.

(2) The Radiation Protection Officer:

(a) Verifies that the recipient is properly licensed by NRC to receive the shipment.

(b) Checks and monitors the items being packaged in the Logistics Management Office for conformance with DARCOM, DA, NRC, and DOT regulation.

(c) Forwards the shipping request to the Logistics Management Office.

(d) Furnishes the Travel and Transportation Branch a completed DA Form 2791-R showing that containers, as well as the manner of packaging within containers, meet all radiation safety requirements. DA Form 2791-R will be reproduced locally to furnish the RPO with a copy.

(3) The Logistics Management Office. If the shipment is by common carrier, forward the shipping request to the Travel and Transportation Branch.

(4) The Travel and Transportation Branch:

(a) Prepares the Government Bill of Lading.

(b) Forwards shipping papers to the RPO.

(5) The Radiation Protection Officer:

(a) Attaches to the shipping papers all special labels required for shipment.

(b) Authorizes release of the shipment and the Bill of Lading to the vehicle driver.

(6) Logistics Management Office:

(a) Arranges for dispatch and mechanical inspection of the vehicle for transporting radioactive items.

(b) Delivers the shipment to the common carrier or the destination, as applicable.

(c) Returns the Bill of Lading to the Travel and Transportation Branch.

(d) Arranges for the monitoring of the vehicle by the RPO or his designated alternate either at the destination or immediately upon return to HDL.

(7) The Travel and Transportation Branch returns one copy of receipted Bill of Lading to the RPO.

14. Transfer of Radioactive Materials. Before radioactive material is transferred from one location to another within the Laboratories, the RPO must be notified by the person requesting the transfer so that the operation can be properly surveyed.

15. Storage of Radioactive Materials. All radioactive materials must be clearly labelled at all times, giving pertinent and accurate information about the contents as well as identifying the person who is responsible for the item.

a. Permanent Storage Locations:

(1) Permanent storage locations will be established with the cognizance of the RCC.

(2) Permanent storage locations will be protected from entrance by unauthorized personnel and posted as required.

(3) Work areas adjacent to permanent storage areas shall be below 0.25 mrem/hr.

b. Temporary Storage Locations.

(1) Temporary storage of radioactive material which has been issued to an individual is the direct responsibility of that individual. The storage area will conform with radiation limits of 0.25 mrem/hr as set forth for permanent storage locations.

(2) Temporary storage locations will be identified by the appropriate radiation signs indicating the radiation characteristics, the actual physical location of the material, and the precautions to be taken.

16. Radioactive Waste. a. Dry Waste. Radioactive dry waste must be placed in cans with plastic liners, labelled with the standard radiation symbol, and marked "Radioactive Waste". Cans and the

liner bags may be obtained by contacting the RPO. Do not place radioactive waste in any waste-basket other than the designated basket.

b. Liquid Waste. Radioactive liquid waste must be placed in suitably shielded plastic bottles labelled with the standard radiation symbol and specifying the type and approximate amount of radio-isotopes present. No liquid radioactive waste, regardless of half-life, will be disposed of by pouring into any drains other than those designated by the RPO.

17. Protection of Maintenance and Construction Workers from Radiation Hazard.

a. Whenever maintenance or construction work is required in an area where an individual could conceivably receive a radiation exposure or where there is a possibility of contamination being present, it must be stated on the service request and the request must be approved by the RPO.

b. It will be the responsibility of all maintenance and construction supervisors concerned to insure that all workers are familiar with the radiation signs and to see that these signs are obeyed.

(1) Supervisor must submit to the RPO the names of workers assigned to areas where a radiation exposure is possible. The RPO will provide these workers with the necessary personnel monitoring equipment. The supervisor will notify the RPO when the job is completed.

(2) Upon request the RPO will provide instruction in radiation safety to maintenance and construction crews.

18. Emergency Procedures. a. Because of potential hazards created by breakage of sealed containers of radioactive materials, all such incidents should be reported to the RPO and the HDL Safety Manager.

b. Actions to be taken in sequence:

(1) Shut off all air conditioners and fans in the immediate area.

(2) Evacuate the area promptly, making no attempt to remove debris.

(3) Secure the area to prevent entry by others.

(4) Contact either of the above named officers and comply with additional instructions.

c. Procedure to be followed in the event of a wound incurred while working with radioactive materials:

(1) Wash the injured area at once with running water.

(2) Immediately secure medical attention from the HDL Medical Office.

(3) Notify or have someone else notify the RPO.

19. Fire. a. In the event of a fire within one of the posted radiation areas, the individual discovering the fire will immediately notify the RPO, the Safety Manager and Fire Marshall.

b. All persons entering a posted area will wear self-contained breathing apparatus unless otherwise directed by the RPO or his alternate.

c. Every effort will be made to determine the exposure received by the fire fighters. A radiation survey of the area should be made and film badges should be worn by all persons entering the area.

d. The supervisory Guard Officer will post a guard to prevent entrance of unauthorized personnel. After the fire, the area will be surveyed and cleared by the RPO for normal occupancy.

e. All fire fighters engaged in operations where radioactive materials are involved should take a thorough shower bath as soon as possible after the fire is over. The RPO will check the

fire fighters for contamination following the shower bath.

20. Training. a. Personnel, including visitors, who will be exposed to radiation and/or radioactive materials will be informed of the following information prior to exposure:

- (1) The presence of radiation or radioactive material.
- (2) Health hazards associated with exposure to such materials and/or radiation.
- (3) Procedures and precautions to minimize exposures.
- (4) Applicable provisions of AEC licenses, DA authorizations, regulations, and standing operating procedures, and applicable portions of Title 10 CFR, para 19, 20, and 21.
- (5) Emergency procedures.
- (6) Right to receive a report of his exposure incurred.
- (7) Proper use of protective equipment and clothing.

b. Radiation workers will receive the instruction in a, above. In addition, they will be instructed in the following areas:

- (1) Maximum exposure and contamination levels.
- (2) Safe methods of performing work. (The use of protective equipment and the operational steps involved will be demonstrated.)
- (3) Procedures to minimize contamination and to secure sources of radiation from authorized use.

c. Before an individual uses or supervises the use of sources of radiation, the RCC should determine that his training and experience are sufficient to enable him to deal safely with materials involved.

d. An individual whose training and experience is not adequate will be required to work under the direct supervision of a person known to be qualified until such time that the individual can demonstrate his ability on the job. In the event such training is not available locally, inquiry should be made into the possibility of the employee receiving the required training and experience at another DARCCM installation or activity.

e. Emergency and security personnel will be trained and equipped to cope with radiological hazards that may be encountered in the performance of their duties. Training will be sufficient to enable such personnel to function without waiting for the guidance of the RPO, or other individuals not part of their immediate group. Such persons will be informed of the existence of situations that might become hazardous during special or unusual circumstances.

f. A record of training will be recorded on DA Form 750 (Record of Training) and placed in each employee's official personnel folder.

g. Radiation workers will receive annual refresher training. A written record of initial and periodic refresher training will be maintained by the RPO.

21. References.

a. Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" and Title 29, Code of Federal Regulations, Part 1910, "Occupational Safety and Health Standards."

b. AR's 40-14, 55-55, 385-30 and 700-52.

c. AMCR's 385-25, 385-30.

HDLM 385-20

d. U.S. Department of Commerce, National Bureau of Standards Handbooks Numbers 48, 51, 55, 59, 63, 66, 69, 73, 75, and 78.

The proponent command of this publication is the Harry Diamond Laboratories Safety Office. Users are invited to send comments and suggested improvements on DA Form 2028 to the Commander, HDL, ATTN: DELHD-SA, 2800 Powder Mill Rd., Adelphi, MD 20783.

William R. Benoit
WILLIAM R. BENOIT
COL, TC
Commanding

DISTRIBUTION

C

Revision 3, 1 Apr 82

PURPOSE: To insure the radiological safety of personnel using the cobalt-60 source and to protect the integrity of the source elements.

PROCEDURE FOR IN-POOL IRRADIATIONS:

1. The cobalt-60 source control room door and maze entry door will be locked at all times, unless the rooms are occupied.
2. There will be two different keys, #1 which unlocks the control room door, and #2 which unlocks the maze entrance door. In addition, the control room door has a high-security hasp and padlock. This high-security hasp and padlock will be unlocked by HDL security guards during working hours, and will be secured otherwise.
3. Key #1 will be issued only to the Facility Supervisor, the Chief Operator, the Alternate Operator, the HDL Radiation Protection Officer, and to HDL security personnel.
4. There will be only one copy of key #2. It will be kept in a locked container located in HDL Bldg. 500 (AURORA). The Facility Supervisor, the Chief Operator, the Alternate Operator, and the HDL Radiation Protection Officer will be the only persons who have access to this container.
5. Experimenters (i.e. everyone participating in an experiment) who desire to use the source during normal duty hours (0800-1630) must enter their name and time of entry in the logbook provided for this purpose in the Cobalt Facility Control Room. One member of the experimental group must sign for keys #1 and #2. Keys #1 and #2 will be issued at Bldg. 500, AURORA by one of the four persons identified in paragraph 4, above. Upon completion of their experiment, he must return the keys to Bldg. 500 and sign out. Under no circumstances may the keys be removed from the immediate vicinity of the Bldg. 500/504 complex. This sign out procedure also applies to lunch breaks and short trips to the HDL main complex. Experimenters who remove the keys from the Bldg. 500/504 area, even for short periods of time, will be removed from the list of authorized experimenters.
6. If an experimenter desires to work later than 1630, he will so notify the HDL guard office (X-41117) before 1600. The security guard will then take the cobalt-60 logbook to the HDL guard office when he locks up Bldg. 500. Upon leaving Bldg. 504 for the night, experimenters will sign out and leave the keys and their film badges at the HDL guard office. The security guard will return the keys, the logbook, and the film badges to Bldg. 500 the next morning.
7. If an experimenter desires to begin work earlier than 0800 or work on weekends he will so notify the HDL guard office before 1600 of the previous working day. The security guard will then take the keys, the logbook, and the experimenters film badges to the HDL guard office when he locks up Bldg. 500. When the experimenter comes in he will log in at the HDL guard office. The security guard will return the logbook to Bldg. 500 when he, unlocks it at 0745.

8. Experimenters must wear a film badge while they are in the Cobalt-60 Facility.

9. At least two persons must be in the Facility when a task requires working around the pool with one or more of the three major grating sections removed. Guard rails will be in place during any such operation.

PROCEDURE FOR FREE-AIR IRRADIATIONS:

1. Free air irradiations will only be undertaken by the following persons:

Facility Supervisor
Chief Operator
Alternate Operator
HDL Radiation Protection Officer

2. Two keys are required to perform free air irradiations: Key #3 which activates the console power, and Key #4 which activates the reset station and controls source elevator motion. There will be only one set of Keys #3 and #4. They will be kept in a locked key box in the Cobalt Facility Control Room. The only persons who will have access to this key box will be the Facility Supervisor, the Chief Operator, the Alternate Operator, and the HDL Radiation Protection Officer.

3. Two people must be present in the Facility whenever sources are moved around in the bottom of the pool. This specifically includes moving sources onto or off the source elevator. One of the people will have a calibrated ionizing radiation detection monitoring instrument to ensure that a hazardous condition is not created by source manipulation procedures.

4. Prior to raising the source elevator, the operator will visually inspect the irradiation room to insure that it is unoccupied. He will then activate the reset switch with Key #4, go out through the maze, and close the maze entrance door.

5. The operator may then raise the source elevator at his convenience, observing the T.V. monitor and control room Remote Area Monitor (RAM) #1. If he detects any unsafe condition such as mechanical interference with source elevator movement or an increase in the radiation exposure rate on RAM #1, he will immediately lower the source elevator.

6. The operator must be in attendance in the control room for the entire time the elevator is raised.

7. After the termination of each free-air irradiation procedure the operator will enter the exposure room with a calibrated ionizing radiation monitoring instrument and determine that no radiation hazard exists before any other personnel are allowed to enter.

8. Any malfunction shall be reported immediately to the HDL Radiation Protection Officer and to the Facility Supervisor.

PROCEDURE FOR OPERATING ELEVATOR FROM COBALT-60 ROOM:

1. Two persons are required to operate the source elevator in the in-cell operating mode.
2. Both persons must visually verify that there is no source element on the elevator platform.
3. When ready to raise the elevator, one person will stand by the pool with a monitoring instrument to detect any increase in the ionizing radiation level while the second person energizes the elevator control.
4. When the elevator is fully raised and it has been verified that there has been no increase in the radiation level, one of the operators may work on the elevator platform while the other operator holds the key switch.

AUTHORIZED EXPERIMENTS:

1. All experiments involving use of the Cobalt Facility must be reviewed and approved by the HDL Radiation Control Committee in accordance with the procedures set forth in HDLM 385-20, Paragraph 11.
2. Irradiation of the following classes of materials is strictly prohibited:
 - a. Explosives or Flammable Liquids
 - b. Corrosive materials
 - c. Any material which could violate the integrity of the source pencil encapsulation.
3. Manipulation of source elements by experimenters is strictly prohibited.

AUTHORIZED EXPERIMENTERS:

1. All experimenters must be supervised by employees of Harry Diamond Laboratories. Non HDL experimenters must have a film badge and an HDL security badge.
2. All experimenters must be approved (once only) by one of the following:
 - Facility Supervisor
 - RPO
 - Alternate RPO

A list of the approved experimenters will be maintained with the Cobalt-60 source logbook.

EMERGENCY PROCEDURES:

1. Major Emergencies:


- a. TYPES: Fire or other hazardous condition.
Continuous actuation of radiation alarms.
Abnormal pool water level.
- b. RESPONSE: Evacuate the Cobalt Facility immediately.
Report the nature and location of emergency to the HDL Guard Office (X-41117).
Assemble in Bldg 504 parking lot.

2. Other Emergencies:


- a. TYPE: Object dropped into pool.
- b. RESPONSE: Notify Facility Supervisor (x42290)

3. Use of the Facility shall not resume until the cause of the emergency condition has been determined and corrected to the satisfaction of the HDL Radiation Control Committee.

PREPARED BY:


KLAUS G. KERRIS, Facility Supervisor

APPROVED BY:


KLAUS G. KERRIS, Chief (A), Br. 22900


MICHAEL BORISKY, RFO, HDL

REVIEWED AND APPROVED BY RCC:

02 April 82
Date



Initials

COBALT-60 FACILITY WEEKLY CHECKLIST

HDL BLDG. 504

1. Verify the status of the following systems:

System Air Pressure:
Console Power: ON
RAM Power: ON

_____	psig

RAM1	
RAM2	
RAM3	

_____	inches

Tank-O-Meter flow rate
water level

2. Verify that the circulating pump is running:

Check condition of sediment filter by measuring inlet and outlet pressure. Replace filter if pressure drop exceeds 15 psi:

IN	psig
OUT	psig
DROP	psi

Check pool water resistivity at inlet and outlet of deionizer tanks. Inlet resistivity should not be less than .05 M Ω -cm:

IN	M Ω -cm
OUT	M Ω -cm

3. Check operation of RAM 1, 2, & 3 by actuating the lamp which is built into the probe. Verify that this check causes an up-scale meter reading with the associated audio & visual alarm response for each RAM:

RAM1
RAM2
RAM3

REMARKS:

MONITOR'S NAME: _____

DATE: _____

PERIODIC MAINTENANCE SCHEDULE
 COBALT-60 FACILITY
 HDL BLDG. 504

Checked
(Initial)

I. ADJUSTMENTS

A. Quarterly

- 1. Check elevator air system pressure. Adjust to 10 psi greater than that required to lift the required maximum elevator load.
- 2. Adjust the descent speed valve to limit elevator descent speed when fully loaded.
- 3. Adjust the ascent speed valve to limit elevator ascent speed with no load.

B. Semiannually

- 1. Turn off pool water supply valve.

Check trip settings on pool level gauge switches by isolating level gauge from pool and pressurizing it. Switch trip settings should be as follows:

- a. High water level alarm: actuation point: 137 inches
- b. Fill valve: actuation point: 137 inches
- c. Pump cutout switch: reactivation point: 132 inches
- d. Low water level alarm: reactivation point: 126 inches

Adjust all switches to within ± 1 inch.

Turn pool water supply valve back on.

- 2. Check the console timers for proper functioning and time delay setting. Adjust or replace as necessary.

II. PREVENTIVE MAINTENANCE

A. Quarterly

- 1. Oil all elevator drive pulleys (except submerged) with light machine oil.
- 2. Check ethylene bottle reserve and replace if necessary.
- 3. Check annunciator and interlock system for proper operation in all modes. Replace defective components as required.
- 4. Inspect entire elevator cable for signs of wear.

B. Annually

1. Remove air pressure regulator dust and oiler bowls in elevator air control system. Clean bowls and refill oiler bowl with clean oil.

2. Measure the insulation resistance of the dummy control wire in the cable tray. If this wire has less than 1×10^7 ohms resistance to ground, check all control wires and replace those which are less than 1×10^7 ohms to ground.

3. Visually inspect wire insulation in cable trays for radiation damage such as brittleness or crumbling in insulation. Replace all defective wiring.

III. REMARKS:

CHECKED BY: _____

DATE: _____

PERIODIC CALIBRATION SCHEDULE/PROCEDURES

CORALT-60 FACILITY

HDL BLDG. 504

I. CALIBRATION OF REMOTE AREA MONITORS

A. There are three remote area monitors in Building 504. RAM 1 is located in the control room. It has a 4-decade logarithmic meter calibrated from 0.1 mR/hr to 1R/hr. RAMs 2 and 3 are located in the exposure room. They have 5-decade logarithmic scales calibrated from 10 mR/hr to 100 R/hr.

B. All RAMs must be calibrated quarterly, following the calibration instructions given in the NMC Model GA-2T0 instruction manual with the following exceptions and additions:

1) The only function of RAMs 2 and 3 is to detect radiation levels which are significantly above background. It is therefore not necessary to calibrate them over their entire meter range. RAMs 2 and 3 will be calibrated from 10mR/hr to 1R/hr. A label will be affixed to RAMs 2 and 3 stating that they are uncalibrated above 1R/hr.

2) All three RAMs have a remote meter readout at the control console. These remote meters are to be included in the calibration procedure.

C. At the same time the RAMs are calibrated, high radiation alarm trip points should be set as follows:

RAM 1:	2.5 mR/hr
RAM 2:	20. mR/hr
RAM 3:	20. mR/hr.

D. The calibration and alarm adjustment procedures are attached.

II. CALIBRATION OF OZONE MONITOR

A. A Bendix Ozone Detector, Model 8002 is installed in the control room. This unit continuously measures the ozone concentration in the exposure room during in-air-irradiation procedures. A sampling tube, extending from the unit to a location adjacent to the source elevator, provides the unit with a representative sample of exposure room air. The detector analyzes the air sample and displays results which lie within a 0.01 to 1.0 PPM O₃ range.

B. This detector must be calibrated semiannually, following the calibration instructions given in the Bendix Ozone Detector, Model 8002 instruction manual with the following additions:

1) The remote meter readout at the control console reproduces the reading displayed at the detector unit. This remote meter is to be included in the calibration procedure.

12912

2) The high ozone alarm trip point should be set at 0.1 PPM. Therefore, adjust the "range switch" on the ozone detector and the red pointer on the remote meter readout at the control console to 0.1 PPM.

C. The calibration and alarm adjustment procedure for the ozone detector is attached.

CALIBRATION PROCEDURE

To calibrate the Model GA-2T0, the following steps should be followed:

A. Four-Cycle Scale (RAM 1)

1. Before turning on the instrument mechanically reset the indicating meter to mechanical zero by means of the adjusting screw on the meter face. Note: If external recorder is used, it must be connected during calibration.
2. Refer to the diagram showing location of controls before making any adjustment. Turn on the instrument and allow 30 minutes to elapse before making any test except to adjust the regulated B+ to 13.4V DC. Notes: Probes that have just been assembled must be allowed to set 15 hours before attempting to calibrate.
3. Turn artificial background control counterclockwise until it rests against stop. The artificial background control, when advanced clockwise, provides a small amount of current to flow through a #344 lamp, located at the photo-cathode surface of the 6655 tube, to keep the lamp dimly lighted. The lamp provides the up-scale reading in addition to providing an up-scale check of the instrument operation.
4. Connect a high voltage meter (negative to the violet stand-off located on the probe amplifier, positive to gnd) and observe the drop in high voltage when a source corresponding to the lowest indicated level is applied to the probe. This drop should be 80 to 120 volts.
5. Four adjusting points are used to calibrate a 4-cycle GA-2T0: a ceramic potentiometer which is used for level shifting, and three color-coded potentiometers, which are:

brown	-	lowest indicated level adjustment	(0.1 mR/hr)
red	-	third cycle adjustment	(100 mR/hr)
orange	-	fourth cycle adjustment	(1 R/hr)
6. Present a 0.1 mR/hr source to the probe and adjust the brown pot until the meter reads correctly.
7. With a 100 mR/hr source, adjust the red pot for the proper meter value.
8. Using a 1R/hr source adjust the ceramic pot for a meter reading of about 1/4" up-scale from the 1R/hr point.
9. Using the orange pot adjust for 1R/hr meter reading.
10. Repeat steps 7 and 9 until correct calibration is achieved.
11. Repeat steps 6, 7 and 9.
12. Check the calibration of the 1 mR/hr and 10 mR/hr points. If these points read too high repeat steps 8, 9, 10, 11 and 12. If the first and second cycle points read too low, then turn the ceramic pot counterclockwise a very small increment. Using the orange pot and a 1 R/hr source, set the meter on the correct reading. Repeat steps 6, 7, 9, 10 and 12.

B. Five-Cycle Adjustment (RAMs 2 and 3)

1. Same as steps 1-4 on four-cycle adjustment.
2. Using a 10 mR/hr source adjust the brown pot until the meter reads correctly.
3. Using 1 R/hr source adjust the red pot for the correct meter reading.

C. Calibration of Fail-Safe and Alarm System

The following controls are used in the fail-safe and alarm calibration. Refer to the location of the controls diagram before making any adjustment.

1. Alarm limit adjust.
2. Fail-Safe limit adjust.

With no source applied to the photomultiplier tube the fail-safe light will be on.

1. Turn the alarm level pot to 10, the alert level pot to 5 (if one is used), and the fail-safe level pot to zero.
2. Remove any artificial background source if used, or rotate artificial background fully counterclockwise.
3. Push the up-scale check button and hold down.
4. Adjust the up-scale control until the panel meter reads at the beginning of the low end of the meter scale.
5. Rotate the low limit control until the yellow light is lighted. Move the low limit control slowly in the opposite direction until the lamp extinguishes.
6. Turn up-scale check control until the panel meter reads 2.5 mR/hr on RAM 1 or 20 mR/hr on RAMs 2 and 3.
7. Adjust the high limit control until the red lamp extinguishes. Rotate the high limit control slowly in the opposite direction until the red lamp is lighted.
8. Repeat steps 3 through 7 until satisfactory calibration is achieved.
9. Adjust the up-scale check control until the panel meter reads just past full scale.
10. Reposition the artificial background source if used, or turn the artificial background control clockwise until a suitable background reading is obtained.

II. To calibrate the BENDIX Model 8002 Ozone Analyzer, the following steps should be followed:

- A. Check the SAMPLE PLUS ETHYLENE flow rate to verify that the flow rate meter indicates 28.5 mm Hg pressure. If necessary, adjust the SAMPLE PLUS ETHYLENE needle valve to obtain the correct flow rate.
- B. Place the MODE SELECTOR switch in the ZERO position.
- C. Place the TIME CONSTANT SELECTOR switch in the 1 SEC position.
- D. Slowly switch the FULL SCALE RANGE SELECTOR switch progressively down scale, allowing the meter to settle at each position, until the switch is in the .01 position.
- E. Unlock the ZERO adjustment control and set it for an exact zero indication on the O₃ CONCENTRATION meter. Lock the ZERO adjustment control.
- F. Place the FULL SCALE RANGE SELECTOR switch to the .5 position.
- G. Place the MODE SELECTOR switch to the CALIBRATE position.

NOTE

Wait 15 minutes to allow
the unit's ozone generator
to stabilize.

- H. Unlock the CALIBRATE adjustment control and set it to obtain an O₃ CONCENTRATION meter indication of 69.
- I. Lock the CALIBRATE adjustment control.

LOADING AND UNLOADING PROCEDURE FOR
NPI RADIOACTIVE SHIPPING CONTAINERS

Assuming container is in pool loaded with cobalt-60, the following procedures must be followed in loading trailer and unloading at other end:

1. Lower top cover in place making sure that the gasket is properly in place.
2. Raise top of container to surface of pool, measuring radiation level continuously, and install cover bolts.
3. Raise container completely out of water measuring radiation level continuously and washing outside of container with demineralized water. Should radiation level measure in excess of 5 R/hr at contact, the container shall be lowered back in pool, the cover removed, and enough cobalt removed to lower radiation level to less than 5 R/hr.
4. If the surface radiation level is less than 5 R/hr, allow container to remain over pool until there is no significant amount of water dripping, then place in horizontal position over drains at side of pool.
5. Place lead-wire seal on cover.
6. Connect demineralized water to vent openings and flush container for one hour.
7. Remove water connection and connect helium to container and flush until gas appears dry.
8. Install quick disconnect fitting, pressure gage, and relief valve filter assembly. Pressurize in excess of 45 psig and check relief valve.
9. Vent and pressurize to a minimum of 5 psig maximum of 10 psig with Helium through quick disconnect fitting.
10. Wipe outside of container dry and smear for surface contamination. Allowable surface contamination is 2200 DPM. Decontamination is required for activity in excess of the above.

11. Measure maximum activity 3 feet from container and note on shipping form. Activity must be less than 1 R/hr for shipment.
12. Fill out DOT Radioactive Group III labels and place on both ends of container.
13. Bolt container to trailer and install cage.
14. Measure maximum radiation level at the following points:
 - a. Edge of cage.
 - b. Edge of trailer (must be less than 200 mr/hr).
 - c. Six feet from trailer (must be less than 10 mr/hr).
 - d. Tractor cab (must be less than 2 mr/hr).
15. Place DOT "Radioactive" placards on rear and both sides of trailer and on front of tractor.
16. Complete NPI "Radioactive Shipment" form.
17. Prior to departure of a radioactive shipment, the consignee must be notified as to arrival date and time. In addition, the Maryland Radiological Health Authority, Mr. Corcoran, Chief (Telephone 301/383-3010) must be notified by telephone and given all of the above information plus the routing in Maryland.
18. While enroute the following must be checked at all stops:
 - a. Tractor-trailer tires.
 - b. Container hold down bolts.
 - c. Container pressure.
 - d. Survey container and note any changes in radiation levels.

Note: Tractor-trailer must not be left unattended at any time while loaded.
19. Upon arrival at destination, check in with consignee and have his Health Physicist survey and accept container for unloading.

20. Upon acceptance by consignee:

- a. Remove cage.
 - b. Remove hold down bolts and container.
 - c. Vent container through quick-disconnect into pool.
 - d. Break lead-wire seal on cover and remove bolts.
 - e. Remove relief valve, pressure gage, and quick disconnect fittings.
 - f. Lower into pool - remove lid and cobalt.
21. Remove container from pool and have facility Health Physicist conduct internal and external radiation survey of container.
22. Replace container cover, relief valve and pressure gage. Remove DOT "Radioactive" labels and place "EMPTY" placard or sign on either end of container.
23. Remove or cover DOT "Radioactive" signs on tractor-trailer and load container and cage.

NOTE:

The following documents must be in NPI driver's possession at all times during a radioactive shipment:

- a. DOT Special Permit.
- b. AEC License and Cask or Container Analysis.
- c. NPI "Radioactive Shipment" form.
- d. NPI Operating and Emergency Procedures for Radioactive Shipments.
- e. Drivers daily log book (DOT).
- f. Copy of latest revision of ICC Motor Carrier Safety Regulations with accident forms.
- g. Name, address, and telephone number of consignee.

DALE L. REPP
Manager, Field Services
Plant Superintendent

EDUCATION

16 weeks formal classes - National Bureau of Standards - 1965 - in health physics, reactor physics and nuclear instrumentation.

3 weeks training - Naval Research Laboratory Reactor - 1965 - in health physics and reactor operation.

2 weeks training - Naval Research Laboratory - 1965 - in hot cell operations with MTR type fuel elements.

3 credit hours in chemistry; 3 credit hours in math; 3 credit hours in engineering graphics; 3 non credit hours in physics, math and english - 1965.

20 weeks informal classes - 1966 - in reactor systems and operating procedures.

4 weeks courses - National Bureau of Standards - 1966 - in metal machine shop and welding.

EXPERIENCE

1967-Present - Neutron Products, Inc.

Initial cobalt-60 calibration and removal from Big Rock Point Power Reactor, Charlevoix, Michigan. Started construction of NPI pool facility. Decanning and calibration of cobalt-60 sources at Westinghouse pool facility, Waltz Mill, Pennsylvania. Construction of NPI pool facility and liquid phase irradiator. Transported 300,000 curies cobalt-60 from Waltz Mill, Pennsylvania to Dickerson, Maryland. Initial loading and shield testing of liquid phase irradiator. Operation of liquid phase irradiator and pool storage facility. Second encapsulation of 250,000 curies cobalt-60 at IRL, Plainsboro, New Jersey including loading and transfer in 30,000 curie lots in transfer cask from reactor storage pool to hot cells. Operation of liquid phase irradiator and NPI pool facility. Construction and operation of NPI dry package irradiator. Construction of NPI hot cell, storage canal and warehouse. Hot Cell Supervisor - encapsulation of 1,000,000 curies cobalt-60. Plant Superintendent - construction of second dry package irradiator. Manager, Field Services - teletherapy source transfers - animal irradiator removals.

NEUTRON PRODUCTS inc

DALE L. REPP

Page Two

1964-1967 - National Bureau of Standards, Gaithersburg, Maryland,
Nuclear Engineering Technician

Assisted in chemical cleaning of the reactor primary systems; check out of control systems and interlocks, and final assembly of reactor components. Participated in testing and evaluation of heavy water diaphragm valves. Assembled a dummy core in the reactor vessel to simulate actual flow conditions and facilitate testing of reactor control and shutdown systems. Responsible for debugging and testing of reactor emergency cooling systems, to insure that systems operated faultlessly and met written specifications. Check out of reactor purification system, shielding of the ion exchangers and loading of the mixed bed into the I. X. vessels. Assisted in the assembly of work lists and schedules to insure the on time completion of reactor testing. In addition, I performed routine maintenance on reactor systems and components as well as auxiliary and secondary systems.

1963-1964 - Blount Brothers Corporation, Inc., Montgomery, Alabama,
Assistant Field Engineer

Interested in nuclear field while building reactor. Involved transit, level and stake-out for general building control. Building layout for excavating, reinforcing steel and concrete form work. Included "take off" from blueprints of architectural and structural materials, helped check out major reactor components for "as built" dimensions and in-place alignment. I coordinated certain phases of field work with structural and mechanical sub-contractors and helped schedule delivery of material.

1962-1963 - Blake Construction Company, Inc., Washington, D. C., Engineer's
Helper - Instrument Man

Building layout for excavating, reinforcing steel, and concrete form work. Involved transit, level and stake-out work for general building control.

1962-1962 - S. W. Jack Drilling Company, Avonmore, Pennsylvania

Took strata samples and recorded operating data in log books. Mechanical work consisted of preventative maintenance and repair of diesel and gas engines, air compressors, draw works, gear boxes, cables and rigging drums, turn tables, soap, gel and mud pumps, water pumps and other hydraulic and pneumatic equipment.

NEUTRON PRODUCTS inc

DALE L. REPP
Page Three

1961-1962 - Ralph William Stonesifer, Keymar, Maryland

Mechanical work, repair of trucks, backhoes, and dozers. Field layout of roadways, sewerage systems and conservation drainage.

1958-1961 - R. H. Morningstar, Middleburg, Maryland

General dairy farm work. Installation and service of refrigeration units and bulk milk tanks.

NEUTRON PRODUCTS inc

RESUME

J. RICHARD DEMORY

Employer: Neutron Products, Inc., 1967 to present

Duties: Design, construction, and operation of main processing pool containing megacurie quantities of cobalt-60.

Design and fabrication of special purpose underwater tools for handling, processing, and testing cobalt-60 sources.

Inventory control for multimegacurie cobalt-60 inventory.

Shipping large quantities of cobalt-60 utilizing a series of NPI designed casks licensed for from 120,000 to 600,000 curies.

Superintendent on building and radiation facility construction when NPI acts as general contractor.

Previously had responsibility as health physics technician in multi-megacurie cobalt-60 facility, operated radiation synthesis chemical processing plant, and hot cell operator.

Employer: Justrite Homes, 1966-1967

Duties: Mason Foreman

Employer: Craftsman, 1964-1966

Duties: Bricklayer

ISOTOPE HANDLING EXPERIENCE

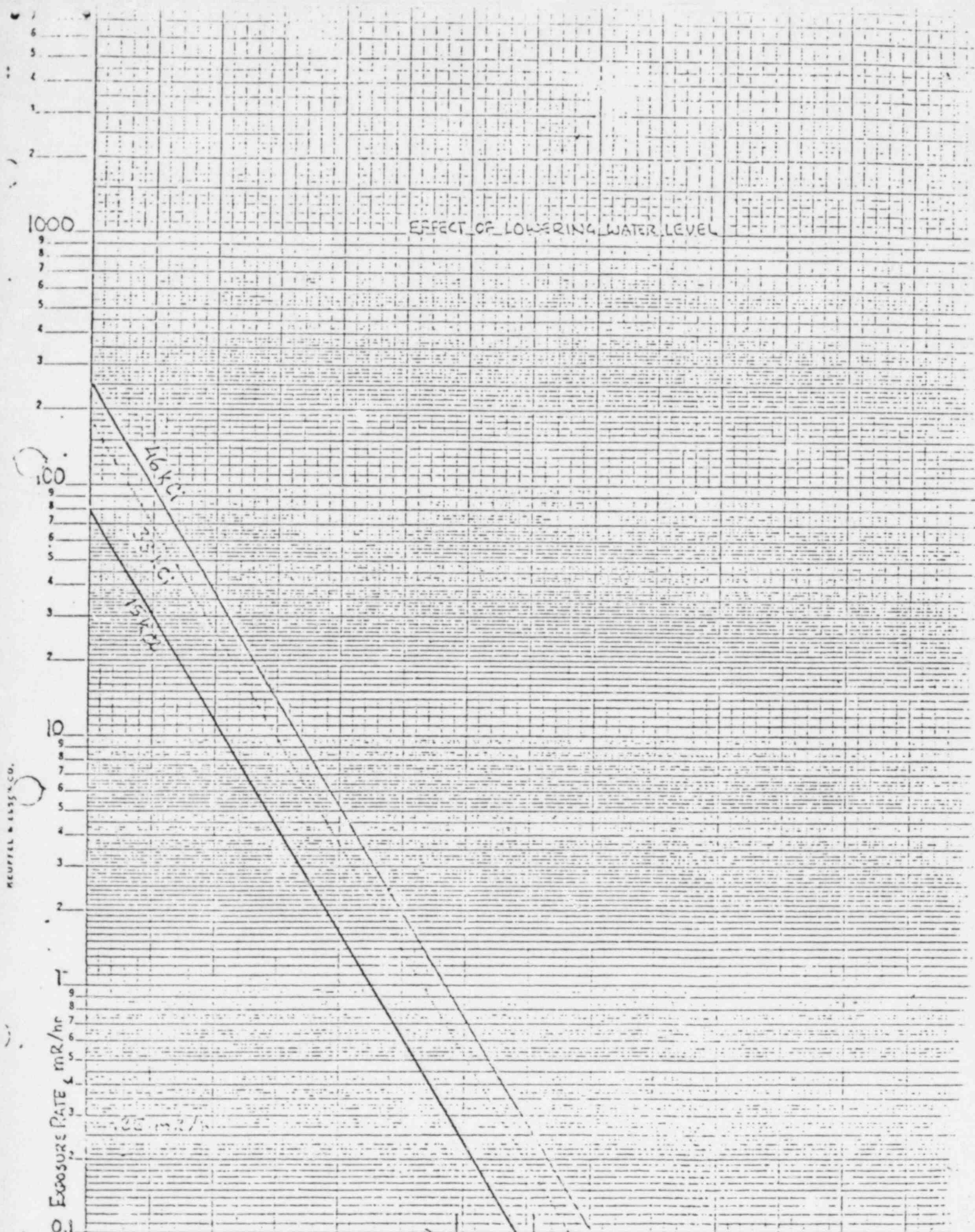
NAME: J. RICHARD DEMORY

Isotope	Maximum Amount	Where Experience Was Gained	Duration of Experience	Type of Use
Cobalt-60	5,700,000 curies	Neutron Products	1967-1977	Storage, handling and shipping
Cobalt-60	50,000 curies	Dow Corning	3 days	Loading and/or unloading shipping cask
Cobalt-60	10,000 curies	Univ. of Michigan	1 day	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Gamma Processing	2 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Industrial Reactor Laboratories	3 days	Loading and/or unloading shipping cask
Cobalt-60	300,000 curies	Battelle Memorial Institute	20 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Atlantic Richfield Company	4 days	Loading and/or unloading shipping cask
Cobalt-60	200,000 curies	Radiation Machinery	2 days	Loading and/or unloading shipping cask
Cobalt-60	100,000 curies	American Novawood	2 days	Loading and/or unloading shipping cask
Cobalt-60	1,500 curies	Massachusetts General Hospital	2 days	Load teletherapy source

COMPANY: NEUTRON PRODUCTS, INC.

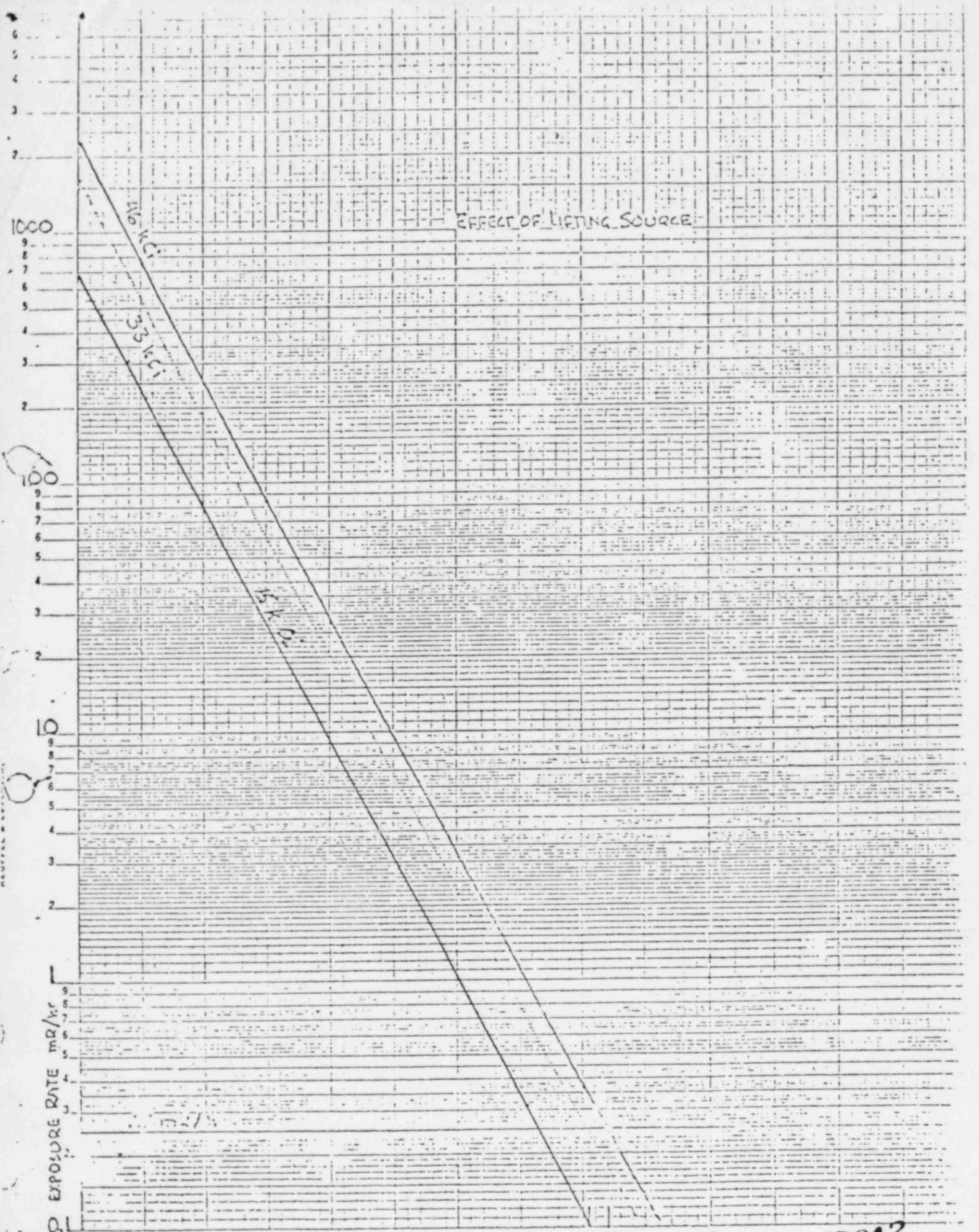
NAME: J. RICHARD DEMORY

Type of Training	Where Trained	Duration of Training	On Job		Formal Course	
			Yes	No	Yes	No
1. Principles and practices of radiological health safety	Neutron Products	9 years	X		X	
2. Radioactivity measurements standardization and monitoring techniques and instruments	Neutron Products	9 years	X		X	
3. Mathematics and calculations basic to the use and measurement of radioactivity	Neutron Products	9 years	X		X	
4. Biological effects of radiation	Neutron Products	9 years	X			X
5. Actual use of radioisotopes in the types and quantities for which application is being made, or equivalent	Neutron Products	9 years	X		X	



KEUFFEL & ESSER CO.

6-1 5 THICKNESS 6 OF H₂O LAYER 7 FEET 8 FEET 9 10 11 12
 6 DEPTH OF 7 H₂O IN Pool 8 FEET 9 9 1/2 9 7/8 10 11 12



7 DIST FROM 8 TOP OF SOURCE 9 TO REF. POINT 10 FEET 11 12 12912
 6 DIST FROM 5 BOTTOM OF 4 POOL TO 3 BOTTOM OF 2 SOURCE, FEET. 0

U. S. NUCLEAR REGULATORY COMMISSION
MATERIALS LICENSE
Supplementary Sheet

License Number 19-17250-04

Docket or Reference No. 30-12436

Amendment No. 03

Department of the Army
Harry Diamond Laboratories
2800 Powder Mill Road
Adelphi, Maryland 20783

In accordance with letter dated May 5, 1980, License Number 19-17250-04 is amended as follows:

Condition 14. is amended to read:

- 14. Except as specifically provided otherwise by this license, the licensee shall possess and use licensed material described in Items 6, 7, and 8 of this license in accordance with statements, representations, and procedures contained in application received January 18, 1978; application dated August 11, 1978; and letter dated May 5, 1980. The Nuclear Regulatory Commission's regulations shall govern the licensee's statements in applications or letters, unless the statements are more restrictive than the regulations.

JUL 09 1980

Date _____

For the U. S. Nuclear Regulatory Commission

by PAUL R. GUINN
Material Licensing Branch

Division of Fuel Cycle and
Material Safety
Washington, D.C. 20555

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