NUCLEAR CONSULTING SERVICES, INC.
P. O. Box 29151 Columbus, Ohio 43229
(614) 846-5710
TWX 810-337-2007

15 June 1981

USNRC
Region III
799 Roosevelt Road
Glen Ellyn IL 60137

Attn: Mr. D. J. Sreniawski
Chief, Materials Radiation Protection

Subject: NUCON* License 34-15216-01, inspection
by IE, Report No. 03008744/81-01

Ref: Your letter and notification of Violation
dated 21 May 1981

Dear Mr. Sreniawski:

This is our formal response to your subject letter and notice.

There were two items of violation:

1. Item 5, Training, Retraining and Instruction to Workers, 10CFR19.12

A. Instruction for receival of I131 shipments.

The employee responsible for initial receipt is the receptionist. She has been instructed in the correct procedures for safe receipt of these I131 packages. Attachment A summarizes these and is posted in her work area. She will be included in the general Health Physics/Radiation Safety training courses initiated by NUCON. All employees who may substitute and any new employee in this position shall receive this training. This was completed 23 Marcy 1981 and compliance was achieved on that date.

B. General training of employees working in the chemistry laboratory and those working in the loading dock/filter storage area shall be required. They shall attend formal NUCON HP/Radiation Safety Training Classes. The first formal class is scheduled for 1 July 1981. A copy of the course outline/handout is enclosed as NUCON 167. Additional material shall include samples of the required signs, labels and NRC notices so understanding of the significance of these items will be ensured.

Upon completion of the course each employee/student will be given a verbal exam. If after evaluation of this exam there is evidence of understanding of the subject matter a form (NUCON FC-29) will be signed by the employee and person who administered the exam.

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Attn: Mr. D. J. Sreniawski

Due to the diverse nature of the background of the employees it is expected that the time for successful completion of training will vary considerably. The laboratory personnel have technical training and should have completed the training by 17 July 1981. The shop personnel have little or no technical background and are expected to have completed the training by 31 July 1981.

Further differentiation shall be given between the laboratory employees and shop supervisors vs the shop personnel. A higher level of technical depth shall be required of the first group with only basic safety and regulatory instruction given the second group. This second group shall be instructed to immediately report any questions or concerns to their supervisors.

In the interim since the inspection, informal training has been given all personnel in the above catagories to ensure there is at least minimum basic understanding of Radiation Safety, and NUCON HP Procedures as carried out by more senior technical personnel. This was completed by 17 April 1981 and to the best of our understanding put us in basic compliance.

The formal training outlined above shall ensure continued compliance. All new employees in the subject areas shall be required to successfully complete this training.

2. Item 13 Surveys License Condition 20

A. Laboratory wipe tests and area surveys were covered by NUCON procedures at the time of the audit but had not been fully carried out in all cases.

The corrective action is twofold. The procedure NUCON PROC 70 has been revised to include a weekly check off by the RSO and requires a corporate officer to review and initial monthly.

Additional training and direction by NUCON management on the necessity of these surveys being carried out per the applicable procedure has been given.

A copy of PROC 70 Rev 1 dated 23 March 1981 is attached.

Full compliance was achieved on 23 March 1981.

B. Air Sampling was not an area of non-compliance but similar revisions to procedure NUCON PROC 72 has been made with similar management stress on its importance.

A copy of NUCON PROC 72 Rev 2 is attached.

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USNRC
Attn: Mr. D. J. Sreniawski

I believe that this answers the areas of non-compliance.

For Item 13 we have been in compliance since 23 March 1981.

For Item 5 we have been in substantial compliance since 17 April 1981 with the interim training program and will be in continued full compliance with our formal training program as detailed above.

I affrim that the above is true and accurate to the best of my knowledge and belief.

Very truly yours,

J. . Jacox
Vice President for
Nuclear Consulting Services, Inc.

cc: J. L. Kovach - President
B. J. Kovach
C. L. Kern
C. E. Graves
J. R. Hunt
F. C. Keledy

encl: NUCON PROC 70
NUCON PROC 72
Receival of Radioactive Material
NUCON 167

*Trademark of Nuclear Consuling Services, Inc.

JWJ:ld

FC-29

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CERTIFICATE OF SUCCESSFUL COMPLETION OF THE NUCON* RADIATION SAFETY AND HEALTH PHYSICS COURSE

Employee Name________________________________

Signature________________________________

SS No.________________________________

Date Completed________________________________

**Examination By: Name________________________

Signature________________________

Date________________________

** Qualification of person giving examination check appropriate line

NUCON* Radiation Safety Officer____________

NUCON* Health Physicist____________________

NUCON* Level III Engineer per ANSI N45.2.6-1978____________

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JUN 16 1981

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ATTACHMENT A

RECEIVAL OF RADIOACTIVE MATERIAL

1) Visually inspect package for damage through the reception window.

A) If package is damaged (crushed or wet, for example), have the package left in the front lobby. Have the delivery man wait outside. Immediately contact one of the following:

John Grimm	John R. Hunt
Tim Walker	
Larry Kern	
Bela Kovach	

B) If package is not damaged, have the delivery man leave the package in the front lobby. Contact the radioisotope lab personnel, who will immediately pick up the package.

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AREA SURVEY PROCEDURES

NUCON PROC 70

NUCON PROC

Original Issue	Prepared By	Reviewed By	Approved By
17 Nov 80			
Revision 1 23 March 81	J.J. Grimm	Bela J. Kovach	D. W. Jacox

I. SCOPE

To provide a general guideline for personnel on area survey procedures.

II. EQUIPMENT

Radiation monitoring equipment

III. PROCEDURE

1. The radioisotope lab and adjacent equipment will be surveyed weekly and decontaminated if necessary.

2. The weekly survey will consist of:

a) A measurement of radiation levels with a survey meter sufficiently sensitive to detect 0.1 mR/hr. Levels exceeding 100 mR/hr shall be identified and controlled.

b) A series of wipe tests to measure contamination levels. The wipe test method will be sufficiently sensitive to detect 100 dpm/100 cm^2 for the contaminant involved. Each wipe should cover an area equal to 100 cm^2.

3. A permanent record will be kept of all survey results. (See attached form.)

4. Area will be cleaned if the removable contamination level exceeds 200 dpm/100 cm^2 above background and if fixed contamination levels exceed 3,000 dpm/100 cm^2.

IV. REPORTING

1. All date shall be reported on NUCON Form FR-10 and placed in the permanent wipe/air survey log book.

2. The log book shall be reviewed and initialed weekly by the R.S.O..

3. The log book shall be reviewed and initialed monthly by a corporate officer.

FR-10

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RADIATION AREA SURVEY

RADIATION AREA SURVEY ______________ Bldg. Add. ______________

Location-Dept, Rm, etc.: ______________

SURVEY INSTRUMENTS

Type ______________

Model ______________

s/n ______________

Radiation Detected ______________

Range ______________

Cal. Date ______________

____

WIPE MATERIAL ______________

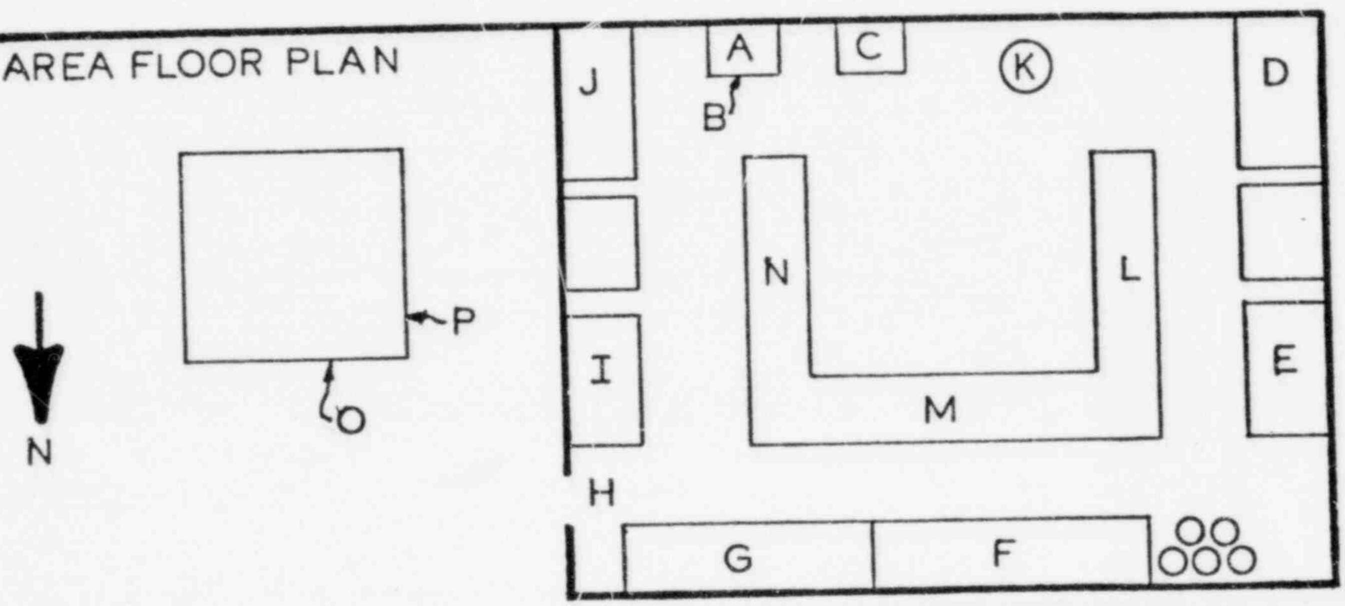
____

SURVEY METHOD(S) Description ______________

____

____

AREA FLOOR PLAN



WIPE BACKGROUND (DPM) ______________

SURVEY RESULTS			DATE			BY			
AREA	CPM	DPM	NET	Mr/Hr	AREA	CPM	DPM	NET	Mr/Hr
A					I				
B					J				
C					K				
D					L				
E					M				
F					N				
G					O				
H					P				

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AIR SAMPLING PROCEDURE

NUCON PROC 72

JUN 1 6 1981

NUCON PROC 72

Original Issue	Prepared By	Reviewed By	Approved By
17 Nov 80			
Rev. 1			
4 Feb 81			
Rev. 2			
23 March 81	John J. Grimm	Bela J. Kovach	J. W. Jacox

I. SCOPE

To monitor airborne contamination levels on a periodic basis or under spill or accidental release conditions.

II. EQUIPMENT

Air sampling device consisting of vacuum pump in line with flowmeter (0-100 CFM) and 2" X 2" diameter sample holder containing activated carbon (TEDA impregnated) cartridge. A paper filter shall be placed over each carbon cartridge, inside cartridge holder.

III. PROCEDURE

1. Remove tape from inlet face of sample cartridge holder.

2. Plug in vacuum pump and adjust flowmeter to desired volume flow (40 lpm - 85 cfh for accident; conditions 20 lpm - 42 cfm for periodic sampling).

3. Note starting time and flow. Record on NUCON Form FI-15A.

4. Turn off pump after desired interval; note and record time on NUCON Form FI-15A.

5. Assay sample cartridge and paper filter. Express airborne contamination in uCi/cc. Record data on NUCON Forms FI-15A & FI-15B. Label data as carbon or paper filter.

6. Install fresh cartridge and paper filter in holder and seal inlet face with tape.

7. Routine air sampling shall be performed weekly. An air sample shall be taken in the radioisotope laboratory and also at the final release point of the laboratory ventilation system.

IV. REPORTING

1. All data shall be reported on NUCON Form FI-15A and filed permanently in the wipe/air survey log book.

2. The log book shall be reviewed and initialed weekly by the R.S.O.

3. The log book shall be reviewed and initialed monthly by a corporate officer.

FI-15A

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AIR SAMPLE LOG

INSIDE AIR SAMPLE FOR - __________ 19____

DATE / INITIAL	TIME		SAMPLING TIME (HRS)	SAMPLE FLOW RATE (LPM)	SAMPLE VOLUME (L)	TOTAL I131 CONC.		AVG I131 CONC. (µCi/cc)
	START	STOP				(DPM)	(µCi)	

POINT OF RELEASE SAMPLE FOR __________ 19____

DATE / INITIAL	TIME		SAMPLING TIME (HRS)	SAMPLE FLOW RATE (LPM)	SAMPLE VOLUME (L)	TOTAL I131 CONC.		AVG I131 CONC. (µCi/cc)
	START	STOP				(DPM)	(µCi)	

INSIDE AIR SAMPLE FOR - __________ 19____

DATE / INITIAL	TIME		SAMPLING TIME (HRS)	SAMPLE FLOW RATE (LPM)	SAMPLE VOLUME (L)	TOTAL I131 CONC		AVG I131 CONC. (µCi/cc)
	START	STOP				(DPM)	(µCi)	

POINT OF RELEASE SAMPLE FOR __________ 19____

DATE / INITIAL	TIME		SAMPLING TIME (HRS)	SAMPLE FLOW RATE (LPM)	SAMPLE VOLUME (L)	TOTAL I131 CONC.		AVG I131 CONC. (µCi/cc)
	START	STOP				(DPM)	(µCi)	

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AIR SAMPLE RAW DATA SHEET

	ROOM AIR			
	AIR BKG	CARBON BKG	FIL LOAD	SAMPLE LOAD
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
CPM AVG.				
COUNTER EFF				
DPM				
DPM/ AIR				
DPM BKG				
NET DPM				

DATE ________________

	POINT OF RELEASE			
	AIR BKG	CARBON BKG	FIL LOAD	SAMPLE LOAD
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
CPM AVG.				
COUNTER EFF				
DPM				
DPM/ AIR				
DPM BKG				
NET DPM				

DATE ________________

Notes:

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HEALTH PHYSICS TRAINING
PHASE I - GENERAL

Internal Use Only

NUCON 167
Interal Use Only

A. INTRODUCTION

1. Subjects to be covered

   a. Radioactivity, its decay, half-life and units

   b. Radiation types, its interaction with matter and shielding

   c. Units of dose, control of external radiation

   d. Exposure limits

   e. Dosimetery and portable monitors

   f. Biological effects of radiation

   g. Review of Administrative Procedures A1.

2. Goals

   a. To make operating personnel aware of radiation hazard, dosimetery required and limits to be observed.

   b. To familiarize operating personnel with radiation detection instruments.

   c. To refamiliarize operating personnel with the proper procedures for taking radiation, contamination and airborne activity surveys.

B. PRESENTATION

1. Radioactivity

All elements with atomic numbers greater than 82 are radioactive and will emit alpha particles, beta particles, and gamma rays until a stable end product is reached.

Three distinct radioactive series exist on earth:

1. Thorium

2. Uranium

3. Actinium

The starting element in each series has a T1/2 comparable to the age of the earth $\sim 10^{10}$ years.

Three starting elements are:

1. $_{90}Th^{232}$ — Half Life 1.39×10^{10} years

2. $_{92}U^{238}$ — Half Life 4.51×10^{9} years

3. $_{92}U^{235}$ — Half Life 7.07×10^{8} years

All series behave the same. They start with a very long life element and eventually decay to a stable isotope of lead $_{82}Pb^{206-207}$ or ^{208}.

2. Rate of Radioactive Decay

Any given radioactive element has a definite decay rate or decay constant (λ), which determines the number of atoms decaying per unit time. The value is a physical characteristic of the atomic nucleus, and cannot be changed by varying external conditions such as temp., pressure, and magnetic field.

Rate of decay or activity (D.P.S.) is equal to the product of the decay constant and the number of atoms.

$$A = \lambda N$$

A=Rate of Decay (dis/sec)

λ =Decay Constant (sec^{-1})

N=Number of Atoms Present

Each disintegration reduces the number of atoms of the sample, so that the number of atoms present is continually changing as time passes. To find the number of atoms present at any time the following formula is used.

$$N = No\ e^{-\lambda \Delta T}$$

Example problem.

A radioactive sample has a decay constant $\lambda = 10^{-7} sec^{-1}$. Number of atoms $N = 10^{10}$. How many atoms present at the end of one year.

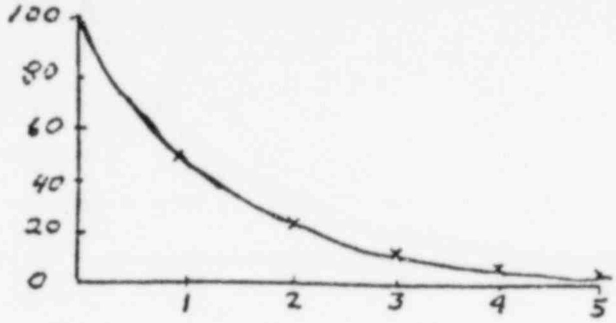
ΔT = 1 year = 3.15×10^7 sec

$$N = No\ e^{-\lambda \Delta T}$$
$$N = 10^{10}\ e^{-(10^{-7}\ sec^{-1})(3.15 \times 10^7\ sec)}$$
$$N = 10^{10}\ e^{-3.15}$$
$$N = 4.29 \times 10^8 \text{ atoms}$$

3. Half Life

The length of time required for one half of the atoms in a radioactive sample to decay.

$$\text{Half Life} = T1/2 = \frac{.693}{\lambda}$$



Fraction of initial activity present after (n) half lives have elasped is expressed by the formula:

$$\frac{AT}{AO} = \left(\frac{1}{2}\right)^n$$

AT = Rate of decay at time T

Ao = Rate of decay at time To

n = Number of half lives in the time interval

Example:

A radioactive material having a half-life of two hours has an initial activity of 10^8 DPS, what is the activity after 6 hours.

$$n = \frac{6 \text{ hr.}}{2 \text{ hr.}} = 3$$

$$\frac{AT}{Ao} = \left(\frac{1}{2}\right)^n$$

$$AT = Ao \left(\frac{1}{2}\right)^n$$

$$AT = (10^8 \text{ dps}) \left(\frac{1}{2}\right) 3$$

$$AT = (10^8)\ (.125)$$

$$AT = 1.25 \times 10^7 \text{ D.P.S.}$$

4. Unit of Radioactivity

The unit of radioactivity which expresses the rate at which a substance decays is the curie. One curie (ci) of any radioactive isotope is the quantity of the isotope which is decaying at the rate of 3.7×10^{10} D.P.S.

$1\ ci = 3.7 \times 10^{10}$ D.P.S.

$1\ mci = 3.7 \times 10^{7}$

$1\ \mu c = 3.7 \times 10^{4}$

$1\ \mu\mu c = 37$ D.P.S.

$$ci = \frac{\lambda N}{3.7 \times 10^{10}}$$

Amount of material necessary to produce 1 curie of activity

Isotope	T1/2	Amt. of material
U^{238}	4.5×10^{9} years	3.3 Tons
Ra^{228}	1620 years	1.0 gram
Co^{60}	5.27 years	$.88 \times 10^{-3}$ gm.
I^{131}	8.05 day	8.2×10^{-6} gm.

5. Radiation

There are four types:

1. Alpha α
2. Beta β
3. Gamma γ
4. Neutrons $_{0}N^{1}$

Each type of radiation interacts differently with the material medium. It is important to utilize the known characteristics of each type in the design of instrumentation and shielding.

6. Interaction of Rad. with matter

Direct ionization - directly ionizing particles on charged particles (Alpha & Beta & Protons) which have sufficient kinetic energy to cause ionization by collision and direct electrical force.

Indirect ionization - radiation does not carry electric ($_0N^1$ and γ) charges. Nevertheless, in its passage through matter, it can eject charged particles, such as electrons, which in turn interact electrically with the atoms in the material.

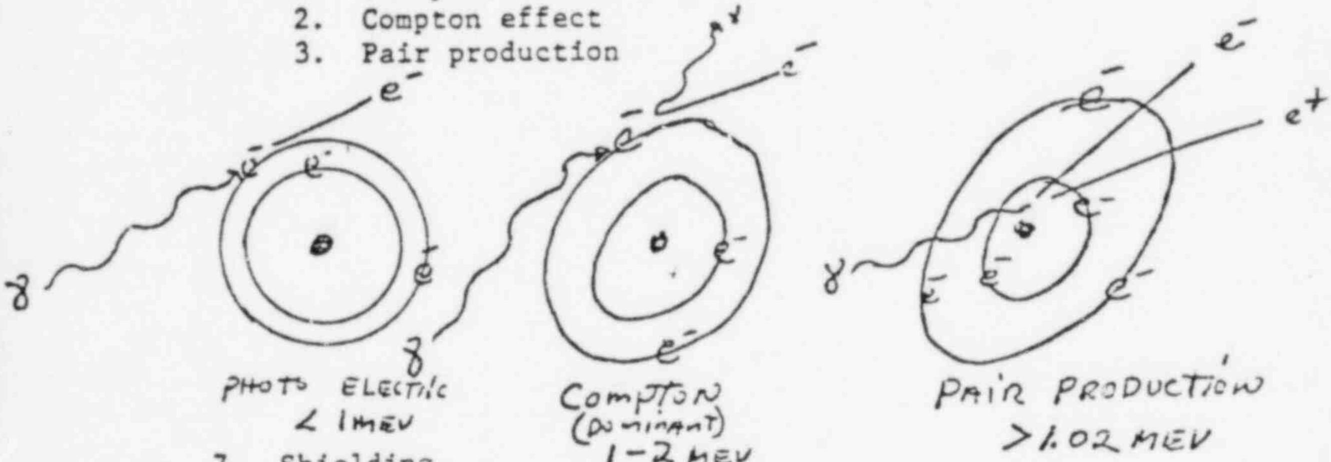
Alpha - Lose energy rapidly in any medium because of their relatively high specific ionization, may be stopped by a few sheets of paper or aluminum foil. The outer layer of skin in our body will absorb alpha particles up to ~7.5 MEV.

Beta - Process similar to that for alpha, except it has very small mass and one-half the charge on an alpha particle. Therefore, for a given energy, a particle will have a much greater velocity than an α , which means that its penetration in any absorber will be much greater.

Shielding 1 MEV	10' air
	.1" alum.
	.024" lead

Gamma - Attentuated in matter by:

1. The photoelectric effect
2. Compton effect
3. Pair production



7. Shielding

As Gamma rays pass through materials, their intensity decreases exponentially with distance. Rather than define a gamma range in various materials it is more common to define quantities called the half-value thickness and tenth-value thickness of the material, the amt. of material needed to reduce the incident radiation by 1/2 and 1/10.

Ex. tenth-value thickness for 5 MEV Gamma

	1/10	T1/2
Water	30"	10"
Concrete	13.2"	4.3
Iron	3.68"	1.14
Lead	1.8"	.55

$\frac{I0}{I} = 2$

I = intensity

Io = initial intensity

n = number of half-value thicknesses

Problem:

It is desired to reduce a 5 MEV gamma from 650 mr/hr. to 40 mr/hr. using Pb as a shield. How many half value thicknesses are required?

$$\frac{IO}{I} = \frac{650}{40} \qquad \frac{IO}{I} = 2^n$$

$$\frac{650}{40} = 2^n$$

$$\ln 16 = n \ln 2$$

$$n = \frac{\ln 16}{\ln 2}$$

$$n = \frac{2.773}{.693}$$

$$n = 4 \text{ HVT}$$

HVT for lead = .55"

.55 x 4 = 2.2" of lead required

How many TVT's required?

$$\frac{IO}{I} = 10^n$$

$$\frac{650}{40} = 10^n$$

$$\ln 16 = n \ln 10$$

$$n = \frac{\ln 16}{\ln 10}$$

$$n = \frac{2.773}{2.3026}$$

$$n = 1.2 \text{ TVT}$$

TVT = 1.8" lead 1.8 x 1.2 = 2.16

$$IO = I\ 10^{\frac{x}{TVT}}$$

8. Units of Dose

Rad = Radiation absorbed dose is that amount of radiation which causes liberation of 100 ergs of energy per gram of absorbing material.

The biological effect will vary appreciably from one type of radiation to another. That is, 100 ergs/gm. of energy deposited in human tissue by thermal neutrons will have a much more serious effect than 100 ergs /gm. of gamma radiation. Therefore, it is necessary to use a quality factor (Q.F.) to convert all radiation to a unit which produces the same biological damage, which is called REM (Roentgen Equivalent Man).

REM = QF x Rads

Equivalents of radiation

Type	QF or RBE
Gamma or X-Ray	1
Beta	1
Thermal Neutron	5
Fast Neutron	10
Alpha	20

Thermal	.025 ev
Slow	.01 mev
Fast	10 mev

9. Control of External Radiation

A thumb-rule that can be used to estimate the radiation field intensity for simple sources of radioactive material is: 1 curie at 1 meter equals 1 R/hr. A more refined statement of this rule of thumb is called the 6CE formula.

$$R/Hr. = \frac{6CE}{D2\ (ft)}$$

Ex: A two ci of Argon-41 which decays by Gamma with energy of 1.37 MEV. What is the radiation level at 5 ft.

$$R = \frac{6CiE}{D2}$$

$$R = \frac{(6)\ (2)\ (1.37)}{5^2}$$

$$R = \frac{16.45}{25}$$

$$R = .657\ r/hr.$$

Radiation attenuation in air is inversly proportional to the square of the distance (assuming point source)

$$R_1D_1 2 = R_2D_2{}^2$$

Ex: You have 2 R/hr at one foot, how many feet away must you be to get a reading of 100 MR/hr.

$$R_1D_1^{\,2} = R_2D_2^{\,2}$$

$$(2)\ (1^2) = (.1)\ (D_2^{\,2})$$

$$\frac{2}{.1} = D_2^{\,2}$$

$$20 = D_2^{\,2}$$

$$20 = D_2$$

$$D_2 = 4.47 \text{ ft.}$$

10. Exposure Limits

	Whole Body Dose	Skin Dose	Extremity dos
Daily	100 M/Rem S/D 200 M/REM		
Weekly	300 M/Rem S/D 500 M/REM.	600 M Rem	1500 M Rem
Quarterly	2 Rem EXT. 2 1/4 REM.	7-1/2 Rem	18-3/4 Rem
13 Consecutive weeks	3 Rem	10 Rem	25 Rem
Lifetime	5(N-18) Rem		

Emergency and Unusual Exposure

Emergency situations where immediate action is required to save or protect an individual or valuable property.

These exposures must be documented by H.P. and requires notification of N.R.C.

* To save or shutdown vital equipment 25R
To save human life 100R

Requirements 1.* above

2. voluntary men only

3. once in a lifetime

4. H.P. & Plant Super. immediately notified

5. Action not delayed because of lack of approval on work permits

6. If possible use respiratory protection and prot. clothing

7. Personnel exposures shall be estimated and recorded, but not affect the accumulated occupational dose.

11. Dosimetry

Film Badges

Photographic film, silver bromide becomes ionized by impinging radiation and lays down a latent image which appears as black specks when developed. Film density can be related to dose received.

Gamma is distinguished from beta by use of a beta window.

Neutron Film Badges

Compares film densities under cadmium and brass filters. These filters attenuate the gamma by the same amount. However, because of the neutron-gamma reaction induced in the cadmium by the thermal neutrons, the film behind the cadmium is higher than that behind the brass. When thermal neutrons are present, differential density measurements are calibrated in terms of thermal neutron exposure.

Pocket dosimeter

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

A positive charge between the frame and quartz fiber hold them apart giving a zero reading. Ionization reduces positive charge permitting the fiber to move closer to the frame which, in turn, causes the shadow of the fiber to move across the calibrated scale.

* Picture

Typical ranges - 0-200 mr
0-500 mr
0-1 R
0-5 R

T.L.D.

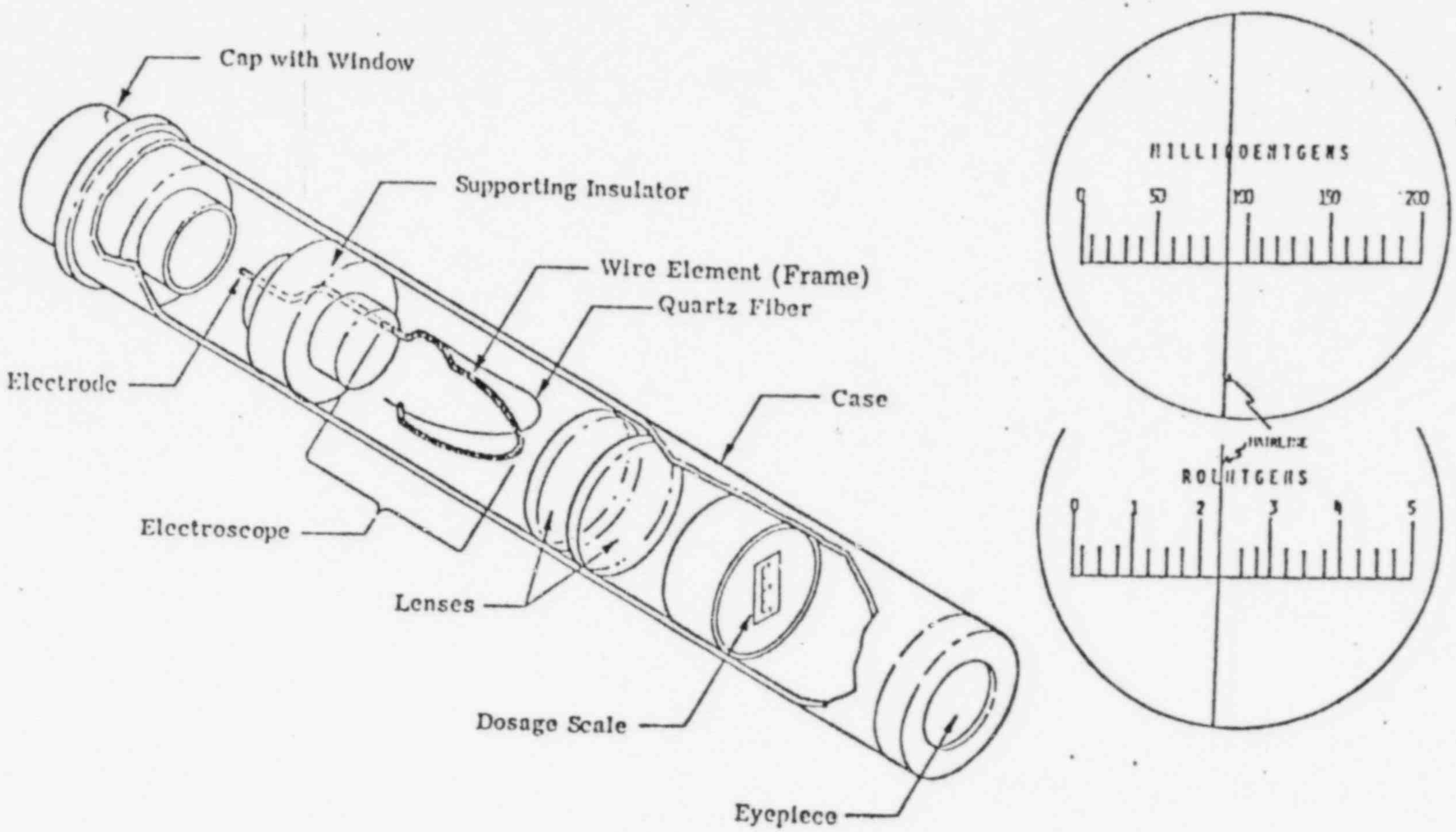
Thermoluminescent dosimeter

The TLD uses a chip of material which, when exposed to radiation stores some of the radiation. This chip is read out on site by heating the chip. When heated the chip gives up the energy it stored as light which can be read as your radiation exposure.

12. Portable monitors

Jordan Radgun

Used for beta-gamma dose rate measurements. Argon filled, pressurized ion chamber.


Cap with Window
Supporting Insulator
Wire Element (Frame)
Quartz Fiber
Electrode
Case
Electroscope
Lenses
Dosage Scale
Eyepiece
MILLIROENTGENS
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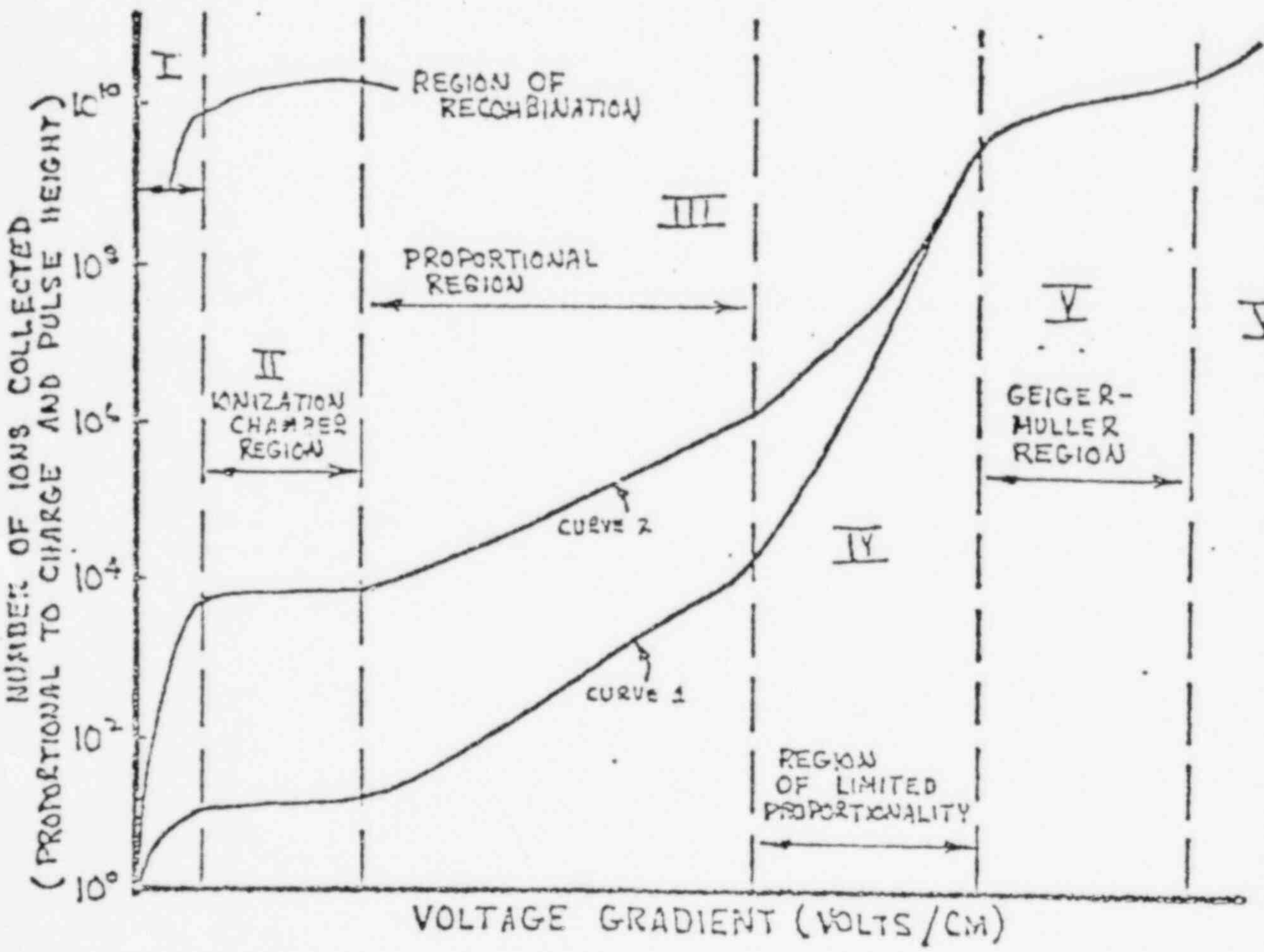
1
2
3
4
5


NUMBER OF IONS COLLECTED
(PROPORTIONAL TO CHARGE AND PULSE HEIGHT)
VOLTAGE GRADIENT (VOLTS/CM)
I
REGION OF RECOMBINATION
II
IONIZATION CHAMBER REGION
III
PROPORTIONAL REGION
IV
REGION OF LIMITED PROPORTIONALITY
V
GEIGER-MULLER REGION
VI
CURVE 1
CURVE 2

Scales

.01 - 10 mr/hr.
.01 - 10 r/hr.
.01 - 10 kr/hr.

Teletector

Is a Gamma dose rate instrument, with a telescoping probe for use in very high radiation areas. By use of two G-M tubes.

Scales

Lo range 0-2 mr/hr, 0-50 mr/hr. 0-2 R/hr.
Hi range 0-50 R/hr., 0-1000 R/hr.

20" to 13 feet

RAD Owl

Used to measure beta-gamma radiation. Detector is an ion chamber vented to atmosphere.

Scales

A. Dose Rate

Lo: 0-5 mr/hr.	High: 0-5 r/hr.
0-50 mr/hr.	0-50 r/hr.
0-500 mr/hr.	0-500 r/hr.

B. Integrated

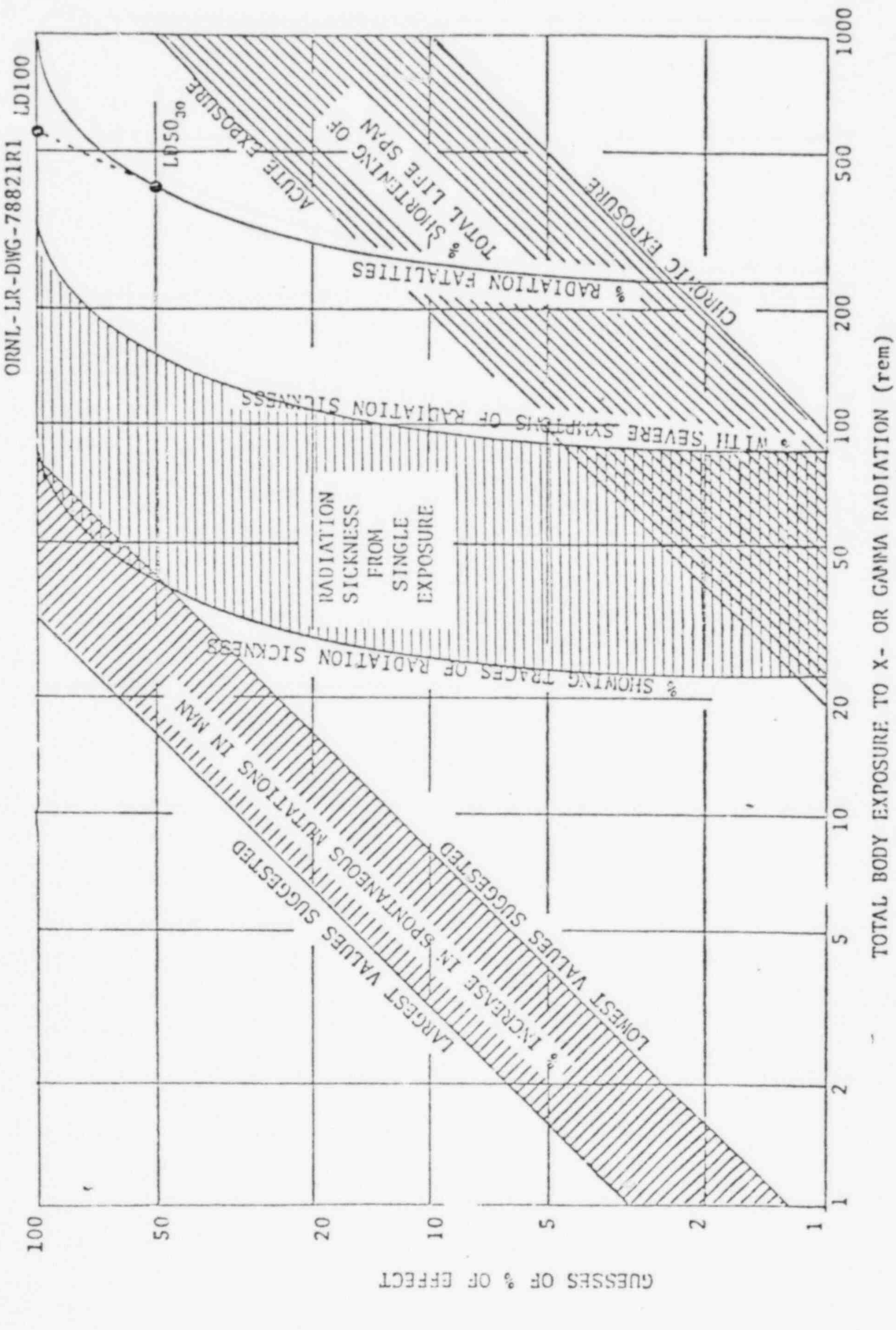
0-5 mr
0-50 mr
0-500 mr

13. Biological effects of radiation

The amount of damage is affected by:

1. Dose

The amount of biologically harmful agent (radiation) administered will determine the frequency of a given abnormality, or the incidence of some chronic disease.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LD100
LD50$_{30}$
ACUTE EXPOSURE
% SHORTENING OF TOTAL LIFE SPAN
CHRONIC EXPOSURE
% RADIATION FATALITIES
% WITH SEVERE SYMPTOMS OF RADIATION SICKNESS
RADIATION SICKNESS FROM SINGLE EXPOSURE
% SHOWING TRACES OF RADIATION SICKNESS
LARGEST VALUES SUGGESTED
% INCREASE IN SPONTANEOUS MUTATIONS IN MAN
LOWEST VALUES SUGGESTED
1
2
5
10
20
50
100
200
500
1000
TOTAL BODY EXPOSURE TO X- OR GAMMA RADIATION (rem)
100
50
20
10
5
2
1
GUESSES OF % OF EFFECT

2. Rate of Absorption

The rate at which the radiation is administered or abosrbed is most important in the determination of what effects will occur. Since a considerable degree of recovery occurs from the radiation damage, a given dose will produce less of an effect if divided (thus allowing time for recovery between dose increments) than if it were given in a single exposure.

3. Area Exposed

Generally, when an external radiation exposure is referred to without qualification as to the area of the body involved, whole-body irradiation is assumed. The portion of the body irradiated is an important exposure parameter because the larger the area exposed, other factors being equal, the greater the overall damage to the organism. Even partial shielding of the highly radioactive blood forming organs such as the spleen and bone marrow can mitigate the total effect considerably. An example is radiation therapy.

4. Variations in species and individuals

There is a wide variation in the radiosensitivity of various species. Lethal doses for plants and microorganisms, for example, are usually hundred of times larger than those for mammals. Even among different species of rodents, it is not unusual for one to demonstrate three or four times the sensitivity of another. There is also a large difference in sensitivity within the same species.

5. Cell Sensitivity

Within the same individual there is a large variation in cell sensitivity.

1. Most sensitive - white blood cells
2. Moderately sensitive - epithelial cells (which line and cover organs)
3. Least sensitive - muscle and nerve

Summary of Effects Resulting from Acute Whole-Body External Exposure of Radiation to Man

0-25 R	0-100 R	100-200 R	200-300 R	300-600 R	600 or more R
No detectable clinical effects.	Slight transient reductions in white blood cells and nerve cells.	Nausea and fatigue, with possible vomiting above 125 R.	Nausea and vomiting on first day.	Nausea, vomiting and diarrhea in first few hours.	Nausea, vomiting and diarrhea in first few hours.
Delayed effects may occur.	Disabling sickness not common, exposed individuals should be able to proceed with usual duties.	Reduction in white blood cells and nerve cells with delayed recovery.	Latent period up to 2 weeks or perhaps longer.	Latent period with no definite symptoms, perhaps as long as 1 week.	Short latent period with no definite symptoms in some cases during first week.
	Delayed effects possible, but serious effects on average individual very improbable.	Delayed effects may shorten life expectancy in the order of 1%.	Following latent period symptoms appear but are not severe: loss of appetite, and general malaise, sore throat, pallor, petecheae, diarrhea, moderate emaciation.	Epilation, loss of appetite, general malaise, and fever during second week followed by hemorrhage, purpura, petecheae, inflammation of mouth and throat, diarrhea, and emaciation in the third week.	Diarrhea, hemorrhage, purpura, inflammation of mouth and throat, fever toward end of first week.
			Recovery likely in about 3 months, unless complicated by poor previous health, superimposed injuries or infections.	Some deaths in 2 to 6 weeks. Possible eventual death to 50% of the exposed individuals for about 450 R.	Rapid emaciation and death as early as the second week with possible eventual death of up to 100% of exposed individuals.

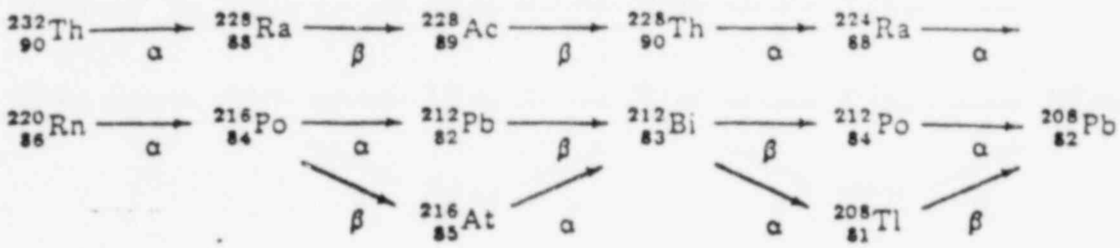
Half-Value Thickness for Various Materials

Energy (Mev)	Half-Value Thickness (inches)				
	Air (in miles)	Water	Ordinary Concrete	Iron	Lead
0.1	0.022	1.634	0.688	0.101	0.005
0.2	0.027	2.009	0.938	0.251	0.027
0.5	0.038	2.829	1.335	0.419	0.166
1.0	0.053	3.872	1.828	0.583	0.352
2.0	0.073	5.544	2.605	0.818	0.527
3.0	0.093	6.896	3.194	0.961	0.571
4.0	0.107	8.049	3.667	1.052	0.573
6.0	0.132	9.928	4.331	1.142	0.552
8.0	0.149	11.379	4.779	1.177	0.524
10.0	0.164	12.464	5.058	1.181	0.492

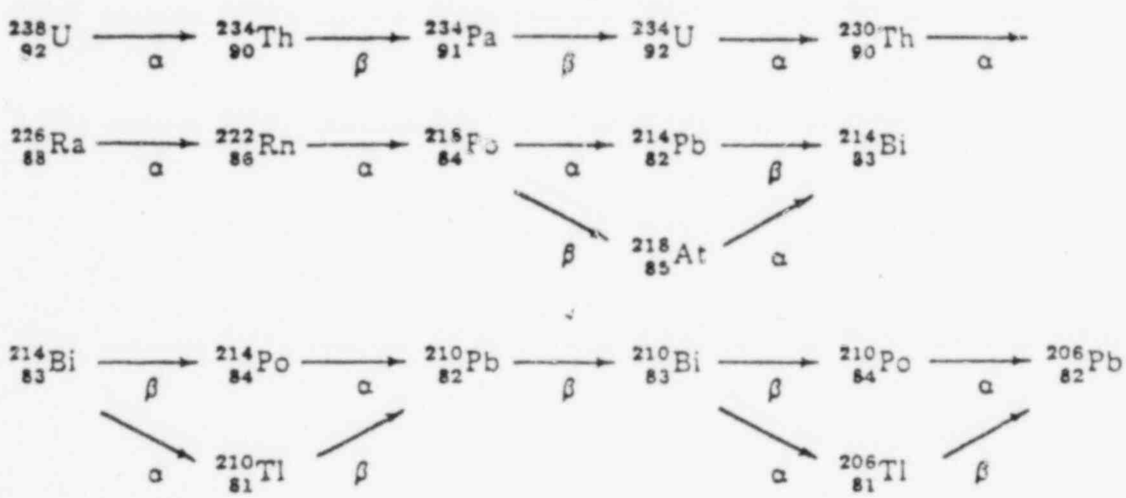
Tenth-Value Thickness for Various Materials

Energy (Mev)	Tenth-Value Thickness (inches)				
	Air (in miles)	Water	Ordinary Concrete	Iron	Lead
0.1	0.071	5.425	2.282	0.335	0.015
0.2	0.089	6.667	3.112	0.835	0.089
0.5	0.125	9.388	4.432	1.391	0.551
1.0	0.175	12.849 (24)	6.069 (12)	1.936 (3.0)	1.168 (1.5)
2.0	0.242	18.400	8.647	2.715	1.748
3.0	0.310	22.886	10.599	3.190	1.896
4.0	0.356	26.713	12.169	3.490	1.901
6.0	0.439	32.951 (48)	14.375 (20)	3.789 (5.0)	1.831 (2.0)
8.0	0.496	37.767	15.862	3.905	1.740
10.0	0.543	41.367	16.788	3.918	1.634

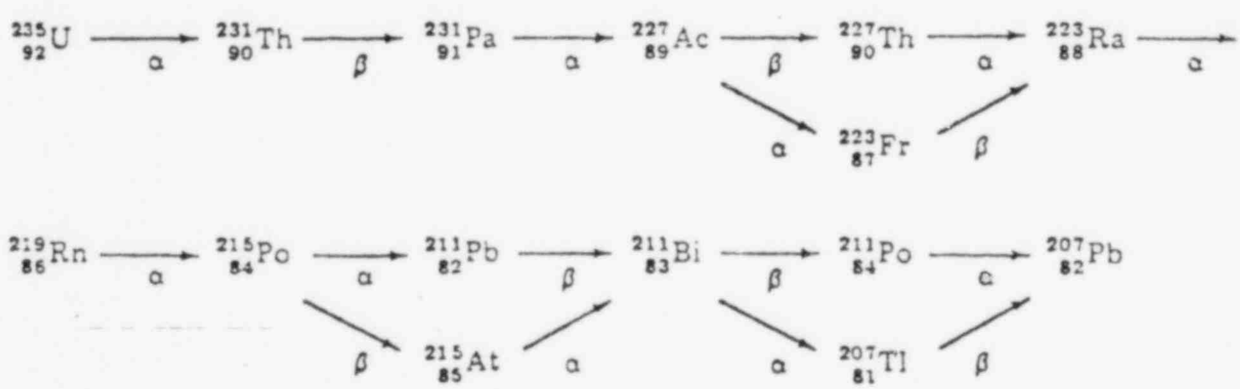
The Thorium Series



The Uranium Series



The Actinium Series



Thorium, Uranium, and Actinium Decay Chains