Westinghouse Electric Corporation
Atomic Fuel Department
Cheswick, Pennsylvania

Health Physics Manual
Revision II, October 1, 1960
Addendum 1, June 1, 1961

THORIUM AND ITS COMPOUNDS

The properties of uranium and thorium are not sufficiently dissimilar to warrant their separate treatment. As far as potential hazard is concerned, both natural uranium and thorium have substantially the same specific activity. Therefore, the handling procedures and techniques for thorium are the same as those used for uranium. Also the smear limit of 10 dpm/ft^2 for clean areas and 100 dpm/ft^2 for controlled or contaminated areas apply.

1. Air In Plant

The permissible air-borne concentration for natural thorium according to the National Bureau of Standards, Handbook 69, is 3.0×10^{-11} uc/cc for a 40 hour per week occupational exposure (66.0 dpm/m^3).

2. Air Outside of Plant

The maximum permissible concentration of uranium in air discharged to the environment is 1.0×10^{-12} uc/cc (2.2 dpm/m^3).

3. Waste Disposal

a. Liquids

Contaminated liquids from the Engineering Development Laboratory will meet the requirements of the AEC and the State of Pennsylvania Department of Health before being released to the sewer.

b. Solids

All solids contaminated with thorium must be kept separate from solids contaminated with uranium due to the accountability control.

L. P. Hackler

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Health Physicist

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WESTINGHOUSE ELECTRIC CORPORATION

Building 5-B
Atomic Fuel Department
Cheswick, Pennsylvania

NUCLEAR SAFETY CONTROL MANUAL

June 1, 1961

Index

I. Introduction

The Westinghouse Electric Corporation, Atomic Fuel Department Building 5-B, Cheswick, Pennsylvania, manufactures nuclear reactor core components using uranium in various forms such as:

1. Powder (UO_2, UC, UC_2, UN)
2. Pellets (UO_2, UC, UC_2, UN)
3. Pellet loaded tubes (fuel elements)
4. Bare metal and metal alloy
5. Clad plates or elements

This operation involves the receiving, storing, handling, and alloying depleted to highly enriched uranium.

It is the purpose of this manual to describe basic procedures and control methods used to insure against a criticality incident; to treat the subject broadly enough to cover most of our future needs and at the same time treat the individual methods sufficiently in detail so as to show that our present control methods are adequate in the matter of nuclear safety.

The basic philosophy of nuclear safety involves the limitation of contributing factors, such as, moderation, mass of U-235, container volume, concentration and/or density and geometry. A process or operation may be considered nuclearly safe if it requires at least two unlikely and unrelated accidents or errors to occur simultaneously to possibly cause a critical mass to be assembled.

II. Definitions

Brief definitions of some of the special terms used in this guide are given below. In a few cases, the terms may have rather special meanings with respect to nuclear safety as compared to other fields of nuclear technology.

Birdcage - A term used to refer to an outer container or framework surrounding and rigidly centering a vessel which actually contains fissionable material; the principle function of this "birdcage" is the maintenance of designated spacing between individual vessels containing fissionable material.

Core - The region containing the fissionable material in a reactor; sometimes refers to the fissionable material itself.

Criticality - The state of, or attaining the status of, a self-sustaining nuclear chain reaction.

Criticality Control - Efforts made to prevent a criticality incident; this usually requires the imposition of physical or administrative limitations, or both, to one or more the nuclear variables of a given system such that criticality is impossible so long as these limitations are maintained.

Criticality Zone - A well defined area where a specific or individual type of operation is performed. Boundaries of criticality zones are physically designated by yellow tape on the floor. Size is not a determining factor, since frequently one piece of equipment is one criticality zone.

Critical mass - The minimum mass of fissionable materialwhich can be made critical under a specific set of conditions.

Enrichment - The weight per cent of U-235 present in any amount of uranium; also referred to as U-235 assay.

Fissionable Material - Materials which, when asserbled in sufficient quality, can result in a chain reaction. Presently, only U-235, U-233, and Pu-239 are considered as fissionable materials.

Heterogeneous - A segregated or lumped distribution or arrangement of fissionable material and moderator which may be randomly or regularly spaced.

Homogeneous - A uniform distribution or dispersion of fissionable material and moderator.

H/U-235 Ratio - The ratio of the number of hydrogen atoms to the number of U-235 atoms in a core or assembly. Also a measure of the moderating characteristics of a core or assembly.

Interaction - The probability that an escaping neutron will enter another subcritical core [illegible]bly.

Maximum Permissible Value - The limiting value of one parameter or variable which will prevent criticality even though all other parameters are uncontrolled and may vary in any manner. This applies only for a single isolated system.

Moderation - A slowing down of neutrons from the high velocities (with correspondingly high energies) at which they are produced to "thermal" neutron velocities; (and corresponding energies) at which the probability of fission capture in U-235 nuclear is relatively large.

Moderator - A material having nuclear properties producing moderation (e.g., water, heavy water, carbon, etc.)

Multiplication Factor, K - The ratio of the number of neutrons present at a given time to the number present one neutron generation earlier in the absence of a neutron source. For criticality, K=1.

Nuclear Parameters - Those generalized factors which are inherent in the description of the nuclear safety of a core or assembly.

Poison - A non-fissioning material with neutron absorption cross-sections which are comparatively high with respect to other nuclear cross-sections of the same material or those of other material in the same system. (e.g., hafnium, boron, cadmium).

Reflection - The return to a core of neutrons escaping from the core.

Reflector - The property of being able to reflect neutrons back into a core or assembly. Good reflectors are also good moderators.

Slurry - A physical mixture containing fissionable material dispersed and suspended in liquid.

Solid Angle - The ratio of that portion of the area of a sphere which is enclosed by the conical surface forming the solid angle, to the square of the radius of the sphere.

Steradian - A unit of solid angle defined as that angle which is subtended by a surface area on the sphere numerically equivalent to the square of the radius. The total solid angle in space is 4π steradians.

Subcritical - Refers to an accumulation of fissionable material under such conditions that a nuclear chain reaction will not occur; a system with a multiplication factor K, of less than 1.

III. Responsibilities

Staff responsibility for nuclear safety has been established as shown on the following organization chart:

General Manager
AFD
I. G. Fox

Mgr. of Mfg.
Control
T. Sainsbury

Supervisor
Accountability
Health Physics &
Nuclear Safety
P. K. Morrow

Health Physics
Engineer
L. P. Hackler

Nuclear Safety
Engineer
H. W. King

The nuclear safety program is coordinated by the Supervisor of Accountability, Health Physics and Nuclear Safety. Serving in a staff capacity, his group provides:

A. Safe operating rules, limits and procedures for all use of fissile material.

B. Review and approval of designs for containers, equipment, etc., used for fissile material.

C. Review of new process methods, techniques, etc. to check for adequate means of criticality hazard control.

D. Assistance to line supervision on all problems involving nuclear safety.

E. Periodic audits of the nuclear safety program for adherence to established rules, procedures and limits.

Mr. E. C. Barnes, Manager, Radiation Protection, Westinghouse Atomic Power Group, will be available for consultation and assistance on WAFD criticality problems. He will aid in evaluating any special problems and will check the adequacy of established practices and procedures.

The responsibility for maintaining nuclear safety rests with the line supervision of the department or location having possession of the fissile material. These responsibilities include:

a. Assuring that nuclear safety controls and procedures are established for all operations and materials.

b. Education and training of employees.

c. Conducting periodic meetings with employees to re-emphasize nuclear safety and its control aids.

d. Adherence to established limits, rules and procedures of the nuclear safety program including maintenance of physical barriers, signs and other control aids.

e. Administering disciplinary action for violations.

f. Obtaining written approval from the Nuclear Safety Engineer prior to changes in methods, equipment, etc., which might affect nuclear safety.

IV. Basic Philosophy to Insure Nuclear Safety

A. Criteria

Several assumptions and rules are followed throughout this facility which are fundamental criteria for nuclear safety controls and as such are independent of the operation or process and do not vary.

1. Assumptions

   a. Intentional disregard of the nuclear safety program is not considered as a factor in designing controls and establishing safe practices.

   b. A process or operation may be considered nuclearly safe if it requires at least two unlikely and unrelated accidents or errors to occur simultaneously to possibly cause a critical mass to be assembled.

   c. All systems containing fissile material will be assumed to have reflection equivalent to that of a thick water reflector.

   d. Where moderation is possible, all systems containing fissile material will be assumed to have moderation equivalent to optimum water moderation.

   e. Water is the most likely and effective moderator or reflector to be found in the facility.

   f. Sufficient interaction between subcritical units of fissile materials may result in criticality.

   g. Nuclear poisons cannot be relied upon as a nuclear safety control but can be considered as an additional safety feature.

2. Rules

   a. Materials having good moderating or reflecting properties will not be stored in work areas, vaults or locations where fissile material is processed.

   b. No fissile material is to be left in the aisles.

   c. All fissile material will be kept in the vaults, approved storage area, or storage racks except when actually required for an operation.

   d. Where nuclear safety is dependent upon composition, positive segregation of materials of different composition must be assured at all times.

B. Maximum Permissible Values

The selection and proper use of maximum permissible values for nuclear safety control is dependent upon whether the system or equipment under evaluation can or cannot become moderated. It is assumed that a system can become moderated when the environmental conditions and the fissile material are of such a nature that a moderating material can possibly be

effectively introduced. When the exclusion of moderating material can be guaranteed either by the existing equipment and environment or by the fissile material itself, the system is treated as unmoderated.

Since hydrogen, as available in water, is the most probable moderating material, the degree of moderation is expressed as the ratic H/U, where H - represents the atoms of hydrogen and U the atoms of the fissile uranium isotope. A system having $H/U = 2$ is considered as an unmoderated system; when $H/U = 20$ the system is considered as moderated. When the ratio falls in the range of uncertainty, $2 < H/U < 20$, the smaller of the maximum permissible values (moderated or unmoderated) is selected for the control method.

The maximum permissible values for cylinder diameter, volume, slab thickness, and mass are obtained from K-1019 5th Revision Table XIII and XIV. The maximum permissible value for surface density of 150 gm. U-235/ft.^{2} is obtained from KAPL-A-CM-1, "Criticality Guide For The Knolls Atomic Power Laboratory".

1. Nuclear Isolation

    a. 12 inches of water or material of equivalent hydrogen content.

    b. 8 inches of concrete.

C. Safety Factors

In determining maximum permissible values for control of all fissile materials, certain minimum safety factors are applied to provide a degree of safety that will compensate for accidents and/or errors which could possibly occur during processing. These minimum safety

factors indicate the degree of safety which would be present after the ideal conditions of moderation and reflection had been attained. Under normal operating conditions the actual safety factors which are present far exceed those listed, since in most cases moderation is not present and reflection is only partial.

The following is a tabulation of the minimum safety factors which are present for the listed parameters assuming ideal conditions have been attained. These minimum safety factors are included in the maximum permissible values which were previously presented.

Parameter	Minimum Safety Factor
Diameter	1.1
Thickness	1.2
Volume	1.2
Mass	2.3
Surface Density	2.3

V. Nuclear Safety Control

Since the processing techniques for uranium oxide and uranium metal differ, the handling techniques also differ in order to provide the best possible nuclear safety in each operation. Therefore, only the Application of Maximum Permissible Values in Building 5-B are described in this manual. Nuclear safety control in Building 5-A and Building 4 and 5 are described in the Fuel Plate Manufacturing Facility, "Nuclear Safety Control Manual," which is classified as confidential material.

A. Application of Maximum Permissible Values for Building 5-B

1. Description

Figure (II) is a drawing showing the layout of Building 5-A and 5-B. Lines #1, #2, and #3 were designed to handle and store ceramic type fuel whose enrichement is 10 wt.% or less. Each of the three lines are identical and each contains the same type of machinery. Thus, three different enrichments can be processed at the same time without cross contamination. Ceramic-type fuel is manufactured by pressing pellets of various sizes and shapes from uranium oxide or other compounds using powder metallurgy techniques. These pellets are subsequently inserted into tubes which are then mounted into subassemblies and clusters.

Line #4 in the Commercial Reactor Facility is used exclusively for the manufacture of Westinghouse Testing Reactor (WTR) Fuel Elements. Nuclear safety control is the same as described in License SNM-338, Ammendment III, dated May 5, 1960.

Once the fuel is clad and there is no longer a contamination problem, the ceramic type fuel and fuel elements are taken into the Assembly Area, Figure (II). Here each component is inspected, assembled, and shipped to the customer.

2. Material Control

The courier is the only person permitted to move fissionable material to and from the vault, to transport or to give permission to transport material between criticality zones.

3. Lines #1, #2, and #3

a. Determination of Batch Size

Nuclear safety control during processing uranium oxide or other uranium compounds is by limiting the mass per criticality zone and by geometry. For example, the criticality batch size of 10.0 wt. % U-235 UO_2 powder is:

$$\frac{0.6 \text{ kgs. U-235}}{5.0\% \times 87.9\%} \times 2.2 \frac{\text{lbs.}}{\text{kgs.}} = 30 \text{ lbs. } UO_2$$

10

Why

This would be 15# if correct enrichment had been used

NOTE: 1. 87.9% UO_2 is uranium

2. Table 14, K-1019, 5th Revision* was used to determine the quantity of U-235 at 10.0 wt.%

Since the 0.6 kgs. U-235 has a 2.3 safety factor, this 30 pounds of UO_2 powder, double-batched and completely flooded is sub-critical.

Each of the four lines in the Commercial Reactor Facility is divided into criticality zones with a minimum spacing of one foot between zones. All criticality zones are physically defined through the use of yellow tape on the floor.

* Approval for the use of Table 14, K-1019, 5th Revision was granted by the AEC in a telegram from Mr. J. C. Delaney dated February 1, 1961.

b. Criticality Zones and Controls

The criticality zones and controls are:

Criticality Zone	Control
Ball Milling	Mass
Trays	Mass and slab geometry
Drying Oven	Mass and slab geometry
Granulator	Mass
Blender	Mass
Pellet Press	Mass
Sintering Furnace	Slab geometry
Centerless Grinder	Mass
Vault	Mass, slab, and cylinder geometry.

1. Ball Mills

Only one batch of UO_2 powder is permitted in each of the two ball mills. There is a twelve inch separation between each ball mill and each ball mill is identified as a criticality zone.

2. Trays

The product of each ball mill is distributed among several trays whose dimensions are 12 x 20 x $2\frac{1}{4}$ inches. Therefore, criticality control for UO_2 slurry is maintained by the $2\frac{1}{4}$ inch dimension of each tray. The number of trays filled by UO_2 from each ball mill depends on the enrichment since the batch size decreases as the enrichment increases. Thus,

if the product from the ball mill is distributed in four trays, then these four trays are considered as one batch size henceforth.

3. Despatch Oven

Trays filled with UO_2 slurry are placed in the despatch oven for drying. The despatch oven has an inside dimension of 30 inches deep, 42 inches high, and 48 inches wide. There are three shelves inside the oven with a 12 inch separation between each shelf. Criticality control in the Despatch Oven is one batch per shelf.

4. Granulator and Blender

Only one batch of material is permitted in the granulator zone and the blender zone at any one time. The granulator and blender are in adjacent criticality zones.

5. Pellet Press

Only one batch of material is permitted in the criticality zone containing the pellet press at any one time. The freshly pressed (green) pellets are collected in sintering boats or trays whose dimensions are 1.5 x 6 x 10 inches and stored in Vault 1-b. Criticality control is assured by the 1.5 inch dimension of the boats.

6. Sintering Furnace

Criticality control for material inside the Sintering Furnace is an infinite slab maintained by the 1.5 inch dimension of the sintering boats. The sintering boats are placed end to end or side by side, in the same plane.

7. Centerless Grinder

After sintering, pellets are moved in boat size batches to the grinder which is a criticality zone in itself. Here, the pellets are ground to their final dimensions, returned to the boats and stored in Vault 1-C. The contaminated water generated by grinding the pellets is first filtered by Delpark Filter Paper before being recirculated. The thickness of the contaminated water will never exceed a safe slab thickness as determined by the enrichment of the pellets being processed and from Table XIII, K-1019, 5th Revision. The safe slab thickness is maintained by an overflow pipe.

8. Loading Pellets Into Tubes

Finished pellets are taken from Vault 1-C, one tray at a time, to the tube loading area, Figure (II). Trays containing finished pellets are 1.5 inches deep, 6 inches wide and 10 inches long. The pellets are then inserted into tubes made of aluminum, stainless steel, etc., and sealed on the ends. Once the tubes are filled with pellets, they are placed in aluminum troughs, whose dimensions are 1.5 inches deep, 4 inches wide and will vary in length according to the over all length of each tube. The trough is filled with approximately 25 loaded tubes and placed on a movecart. Criticality is controlled by the 1.5 inch dimension of each trough.

4. Line #4

Manufacture of WTR Fuel Elements

See: Westinghouse Atomic Fuel Department
Special Nuclear Material License SNM-338
Ammendment III, Dated May 5, 1960

Criticality Control on the manufacture of Westinghouse Testing Reactor (WTR) Fuel Elements is the same as described in Ammendment III, dated May 5, 1960, except the entire operation will be moved into Line #4 of the Building 5-B.

5. Vaults

The storage vaults located in Lines #1, #2, and #3 of Building 5-B are identical Figure (1). Therefore, a complete description and evaluation will be made only on the vaults in Line #1.

a. Vault 1-A

Figure (1) depicts the storage vaults located in Line #1 and #2. Vault 1-A is used to store incoming UO_2 powder contained in standard 5 gallon cans. Each 5 gallon can contains one batch or less of UO_2 powder and is stored in ports as shown in Figure (2). See Appendix I-1 for solid angle calculations.

b. Vault 1-B

Vault 1-B is used to store the freshly pressed (green) UO_2 pellets that are waiting to go into the sintering furnace and the pellets waiting to go to the centerless

grinder. Both a 5 inch diameter column and a 3 inch slab are used for criticality control in Vault 1-B. See Figure (1) and Appendix I-2 for solid angle calculations.

c. Vault 1-C

Vault 1-C, Figure (3), is used to store finished UO_2 pellets where a 3 inch slab geometry is used for criticality control. See Appendix I-3 for solid angle calculations.

NOTE: Table XIII in K-1019, 5th Revision, is used to determine correct slab thickness for low enriched UO_2 being processed and stored.

d. Vault 4-A

Vault 4-A, Figure (4) and (5), is used exclusively to store Westinghouse Testing Reactor material such as enriched virgin uranium metal, ingots, fillers, plates, tubes, and scrap. The following shows how criticality is controlled in Vault 4-A.

Virgin Uranium	mass
Recyclable Scrap, Chips, Fines	5 inch I.D. columns
Plates, Ingots, Fillers	1.5"slab geometry
Tubes, Fuel Elements	horizontal columns

See Appendix I-4 for solid angle calculations.

6. Assembly Area

Criticality control in the Assembly Area is accomplished by the use of the infinite slab concept. This concept is based upon limiting the surface density of the enriched fuel. WAFD will

use a limit of 150 grams U-235 per square foot of floor area*. By keeping the U-235 surface density at 150 grams per square foot, the slab may have any length and width.

All fuel bearing material will be transferred via movecarts and will remain on the movecart unless it is required for an operation. Each machine or equipment operator will remove material from the movecart as needed. Once the operation on each piece of material is completed, he will return it to the movecart and the next piece taken. The quantity of fuel permitted on each movecart is such that 150 grams U-235 per square foot is not exceeded.

* KAPL - A-CM-1, April 23, 1958, states that 503 grams of U-235 per square foot of floor area is a safe limit. Therefore, WAFD has an additional safety factor of 3.3 over that used by Knolls Atomic Power Laboratory.

Appendix I

Solid Angle Calculations

1. Vaults 1-A, 2-A, 3-A

   a. Internal

Although the low enriched UO_2 powder is received and stored in standard 5 gallon containers, a 12 inch diameter sphere was assumed in the following solid angle calculations, see Figure 2. assumed

$$\Omega_1 + \Omega_2 + \Omega_{23} + \Omega_{24} = 4 \times 2\pi \ (1 - \cos\theta) = 8\pi \left[1 - \frac{76.0}{76.234} \right]$$
$$= 0.0778$$

$$\tfrac{1}{2}\Omega_4 + \tfrac{1}{2}\Omega_{25} = 2\pi(1 - \cos\theta) = 2\pi \left[1 - \frac{99.0}{99.181} \right]$$
$$= 0.0113$$

$$\Omega_5 + \Omega_{20} + \tfrac{3}{4}\Omega_7 + \tfrac{3}{4}\Omega_{22} = 3.5 \times 2\pi\,(1 \ \cos\theta) = 7\pi \left[1 - \frac{69.0}{69.2603} \right]$$
$$= 0.08352$$

$$\Omega_6 + \Omega_{21} = 2 \times 2\pi \,(\ 1 \ \cos\theta) = 4\pi \left[1 - \frac{48.0}{48.3735} \right]$$
$$= 0.09671$$

$$\Omega_8 + \Omega_{11} + \Omega_{15} + \Omega_{18} = 4 \times 2\pi\,(1 - \cos\theta) = 8\pi \left[1 - \frac{42.0}{42.4252} \right]$$
$$= 0.2537$$

$$\Omega_9 + \Omega_{10} + \Omega_{16} + \Omega_{17} = 4 \times 2\pi\,(1 - \cos\theta) = 8\pi \left[1 - \frac{24.0}{24.7388} \right]$$
$$= 0.7510$$

$$\Omega_{13} + \Omega_{14} = 2 \times 2\pi \ (1 - \cos \ \ ) = 4\pi \left[1 - \frac{20.0}{20.8805} \right]$$
$$= 0.5300$$

Ω Total = 1.85301 checked and OK based on [illegible] written

Ω_f = 0.1475

b. The storage rack across the aisle is a duplicate of the one just calculated. The closest sphere in this storage rack is at a distance of 48 inches. Instead of calculating the solid angle from each sphere in the storage rack across the aisle, the assumption was made that the interaction is from fifteen 12 inch diameter spheres all at the minimum distance of 48 inches.

Thus $\Omega = 15 \times 2\pi(1-\cos\theta) = 30\pi\left[\frac{48.00}{48.3735}\right]$ Ω = ~~1.05~~ ~~0.73~~ 2.58 OK

$= 0.7253$

Why

$$\Omega = \frac{0.7253}{4\pi} = 0.0577$$

adding the fractional angle from both storage racks

$$\Omega_f = 0.1475 + 0.0577$$
$$= 0.2052$$

Based on max control

2. Vaults 1-B, 2-B, 3-B

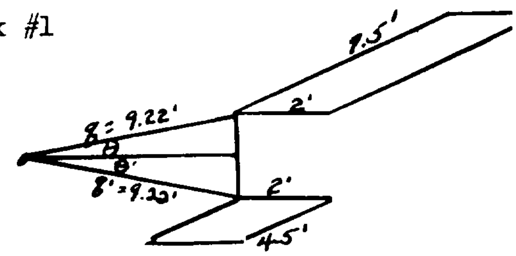
Vault 1-B contains two types of storage racks for storing green UO_2 pellets. One is a three inch slab, Figure (1) and Figure (3), and the other is an array of 5 inch I.D. columns as shown in Figure (1).

a. Solid Angle Calculations For Rack #2, Figure (I), (Internal)

$$= 2\left[4\sin^{-1}\frac{(a/2)\,(b/2)}{\sqrt{(a/2)^2 + (h)^2}\;\sqrt{(b/2)^2 + (h)^2}}\right]$$

$= 2.976$ where a = 1 foot = a/2
b = 4.5 feet = b/2
h = 2.25 feet

b. Adding the interaction from Rack #1



$$\Omega = \frac{ab\cos\theta}{q^2}$$

$$= 2\left[\frac{2(7.5)\ (0.9761)}{85}\right]$$

$$= 0.3445$$

$$\Omega' = 2\left[2\ \frac{(4.5)\ (0.9761)}{85}\right]$$

$$= 0.2067$$

$$\Omega_T = \Omega + \Omega' = 0.3445 + 0.2067$$

$$= 0.551$$

c. Interaction from 5 inch I.D. columns

$$\Omega_1 + \Omega_2 + \Omega_3 + \Omega_4 + \Omega_5 = 5\left[\frac{2\ DL}{h\sqrt{L^2 + h^2}}\right] \leftarrow \begin{cases} D = \frac{5}{12}' \\ L = 5' \\ h = 7 \end{cases}$$

$$= 0.3455$$

$$\Omega_6 + \Omega_7 + \Omega_8 + \Omega_9 + \Omega_{10} + \Omega_{11} + \Omega_{12} + \Omega_{13} = 8\left[\frac{2(0.416)(5)}{4\sqrt{16 + 25}}\right]$$

$$= 1.2980 \quad \begin{cases} D = \frac{5}{12}' \\ L = 5' \\ h = 4' \end{cases}$$

Total Solid Angle

$$\Omega_T = 2.976 + 0.551 + 1.2980 + 0.3455$$

$$= 5.17$$ see note on pg 22

$$\Omega_f = \frac{5.17}{4\pi} = 0.41162$$

3. Vaults 1-C, 2-C, 3-C

Vault 1-C has a 3-inch slab storage rack used to store finished UO_2 pellets, Figure (3).

$$\Omega = 2\left[4 \sin^{-1} \frac{(a/2)(b/2)}{\sqrt{(a/2)^2 + h^2}\ \sqrt{(b/2)^2 + (h)^2}}\right]$$

$$= 8\sin^{-1} \frac{7.5}{\sqrt{2.266}\ \sqrt{57.52}}$$

$$= 8 \sin^{-1} 0.65744$$

$$= 8\ (0.7126)$$

$$= 5.7$$

$$\Omega_f = \frac{5.70}{4\pi} = 0.454$$

must assume k_{eff} = 0.8 for geometri...

Fig 26 TID 7016 the allowable

solid angle is ~ 0.8

where ~~a~~ = 1 foot = a/2
~~b~~ = 7.5 feet = b/2
h = 1.125 feet

4. Vault 4-A

a. Highly Enriched Storage Rack (Internal)

Assuming mass control in the highly enriched storage rack, Figure (4), (5), and (6). Each port is 4" x 6" x 6" and a 6 inch diameter sphere is assumed.

$$\Omega_1 + \Omega_2 = 2 \times 2\pi\,(1-\cos\theta) = 4\pi\left[1 - \frac{19.0}{19.235}\right]$$

$$= 0.1535$$

$$\Omega_3 + \Omega_7 = 2 \times 2\pi\,(1 - \cos\theta) = 4\pi\left[1 - \frac{48.0}{48.0936}\right]$$

$$= 0.0245$$

$$\Omega_4 + \Omega_6 = 2 \times 2\pi\,(1 - \cos\theta) = 4\pi\left[1 - \frac{27.0}{27.2626}\right]$$

$$= 0.12108$$

$$\Omega_5 = 2\pi(1-\cos\theta) = 2\pi\left[1-\frac{18.0}{18.248}\right]$$

$$= 0.085408$$

$$\Omega_8 = 2\pi(1-\cos\theta) = 2\pi\left[1-\frac{66.0}{66.067}\right]$$

$$= 0.00641$$

$$\Omega_T = 0.3909; \quad \Omega_4 = \frac{0.3909}{4\pi} = 0.0312$$

OK

b. Interaction between 5" I.D. columns and Highly Enriched Storage Race, Figure (4), (5), and (6).

$$\Omega_3 + \Omega_4 = 2\left[\frac{2\ DL}{h\sqrt{L+h}}\right]$$

D = 0.5
h = 1.25
L = 12 ?

140

$$= \frac{4 \times 0.5 \times 12}{1.25\sqrt{(12)^2 + (1.25)^2}}$$

$= \cancel{1.592}$ 1.535

$$\frac{12}{\sqrt{144+30.25}} = 0.908$$

13.2

$$\Omega_1 = \frac{2DL}{h\sqrt{L+h}} = \frac{2 \times 0.5 \times 12}{5.5\sqrt{144+30.25}}$$

$= \cancel{0.16528}$ .161

D = 0.5
L = 12 ?
h = 5.5

$$\frac{6}{\sqrt{36+30.25}}$$ 0.737

8.15

$$\Omega_2 = \frac{2DL}{h\sqrt{L+h}} = \frac{2 \times 0.5 \times 12}{4\sqrt{144+16}}$$

$= \cancel{0.2372}$ 0.208

D = 0.5
L = 12 ?
h = 4

$$\frac{6}{\sqrt{36+16}}$$ 0.832

7.22

$$\Omega_T = 1.592 + 0.16528 + 0.2372$$

$$= 0.56168$$

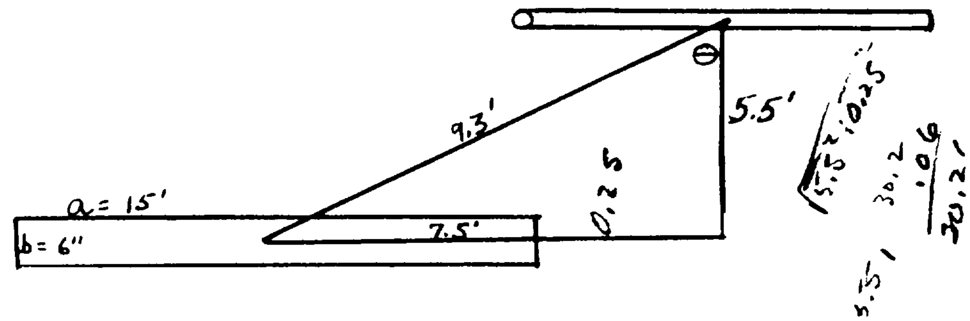
1.535
0.161
0.208
1.904

$$\Omega_F = \frac{0.56168}{4\pi}$$

$$= 0.04472$$

nix - mixing mass control with geometry control - geometry control would take precedence therefore Ω_T should be less ~~than~~ 0.8

c. Interaction between horizontal columns and six 1.5 slabs all at the minimum distance of 66 inches, Figure (4), (5), and (6).



$$\Omega_5' = \frac{15 \times 0.5 \left[\frac{5.5}{5.51}\right]}{5.51^2} = 0.246$$

$$\Omega_5 = \frac{ab \cos\theta}{q^2} = \frac{15 \times 0.5 \left[\frac{5.5}{9.3}\right]}{(9.3)^2}$$

$$\Omega_{3,4,5,6,7,8} \quad \cancel{= 0.0513} \quad 0.998$$

based on Fig 6 data

$$\Omega_f = \frac{0.0513}{4\pi} = 0.00408 \times 2 \times 6$$

$$= 0.0492$$

$$\Omega_1 + \Omega_2 = 2\left[\frac{2DL}{h\sqrt{L^2 + h^2}}\right] = \frac{4 \times 0.208 \times 15}{1.083\sqrt{(15)^2 + (0.083)^2}}$$

$$= 0.766$$

$$D = \frac{2.5}{12} = 0.208$$

$$L = 15$$

$$h = 1.104$$

$$\Omega_f = \frac{0.766}{4\pi} = 0.061$$

$$\Omega_T = 0.061 + 0.0492$$

$$= 0.11$$

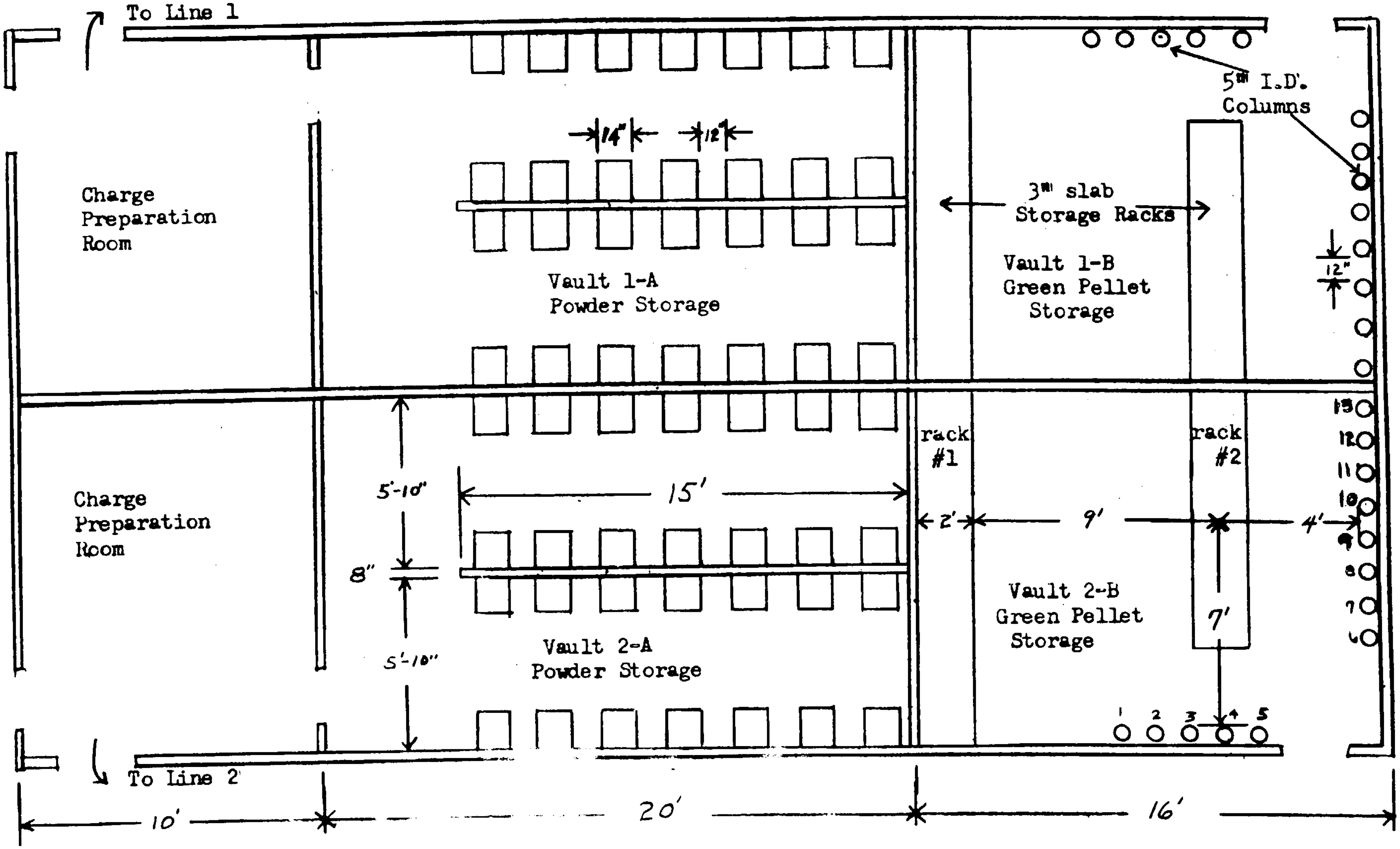
$$\Omega_{1,2} = \frac{4 \times 0.208}{1.104} \cdot \frac{7.5}{\sqrt{7.5^2 + 1.104^2}} = 0.745$$

$$56.2$$
$$1.2$$
$$\sqrt{57.4} = 7.58$$

0.99

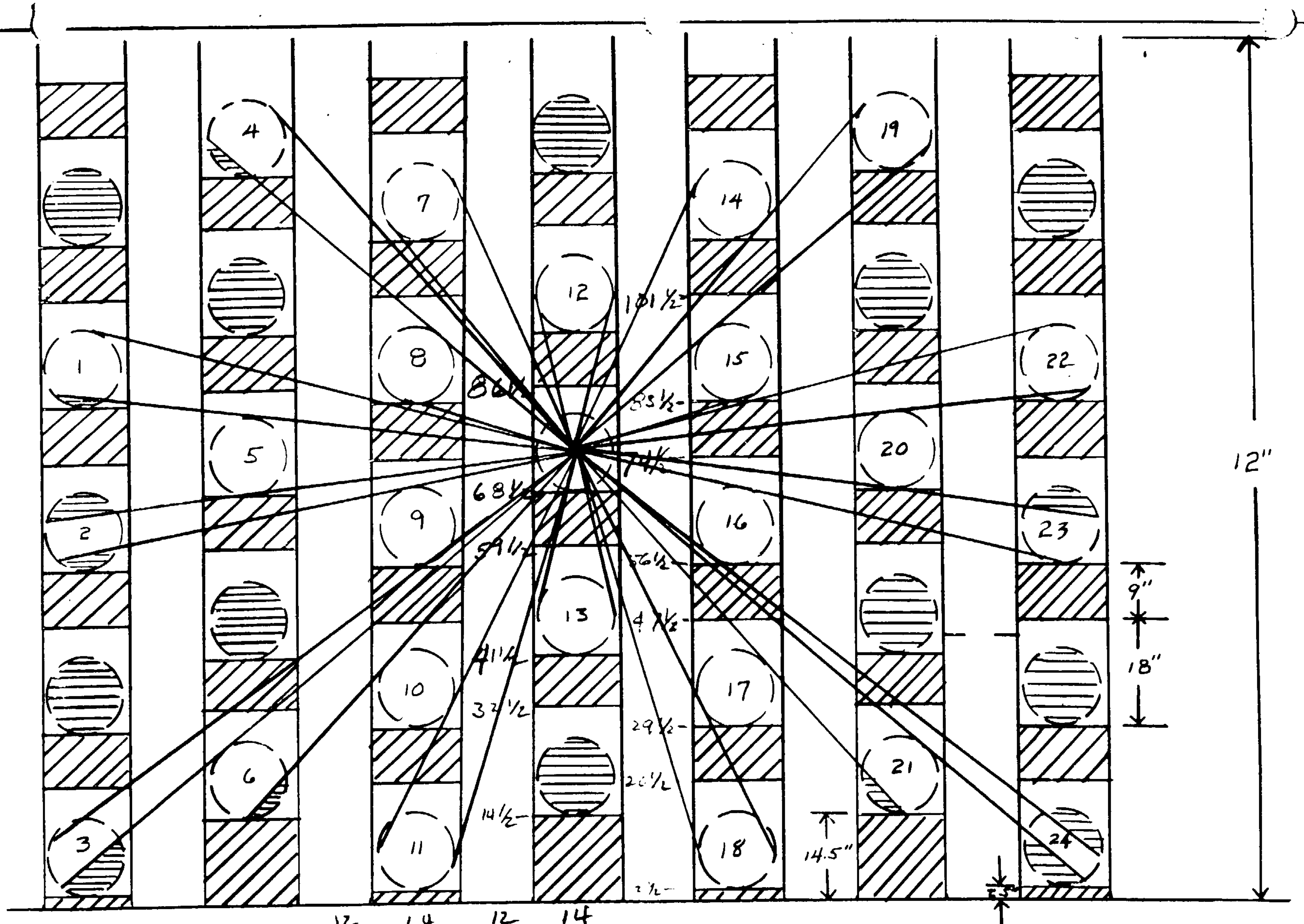
$$\Omega_T = \begin{array}{r} 0.998 \\ 0.745 \\ \hline 1.743 \end{array}$$

nix — Ω should be less than 0.8



NOTE: All walls in vaults are 8" solid concrete

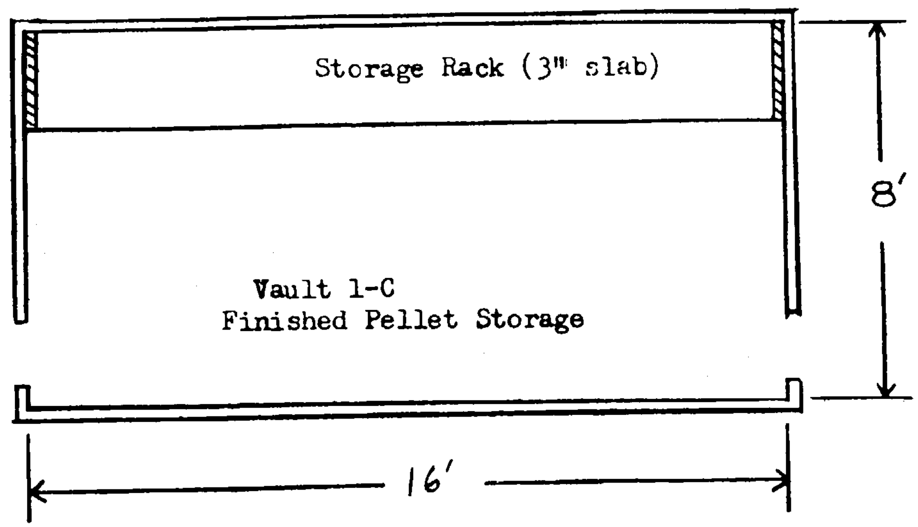
Fig. 1
Storage Vaults
Scale: 1" = 5' - 0"
6/15/61 LPH

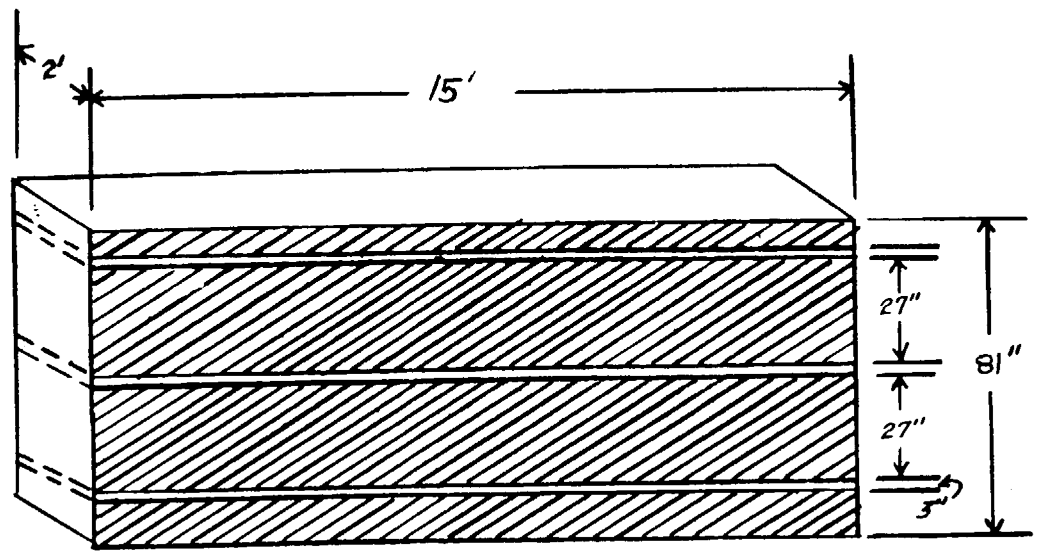


NOTE: All 5 gallon containers were assumed to be 12 inch diameter spheres for solid angle calculations.

Fig. 2
Powder Storage Vault
Scale: 1" = 2'- 0"

6-15-61 LPH





3" Slab Storage Rack

Fig. 3

Vault 1-C
Scale 1" = 4'- 0"
6-15-61 LPH

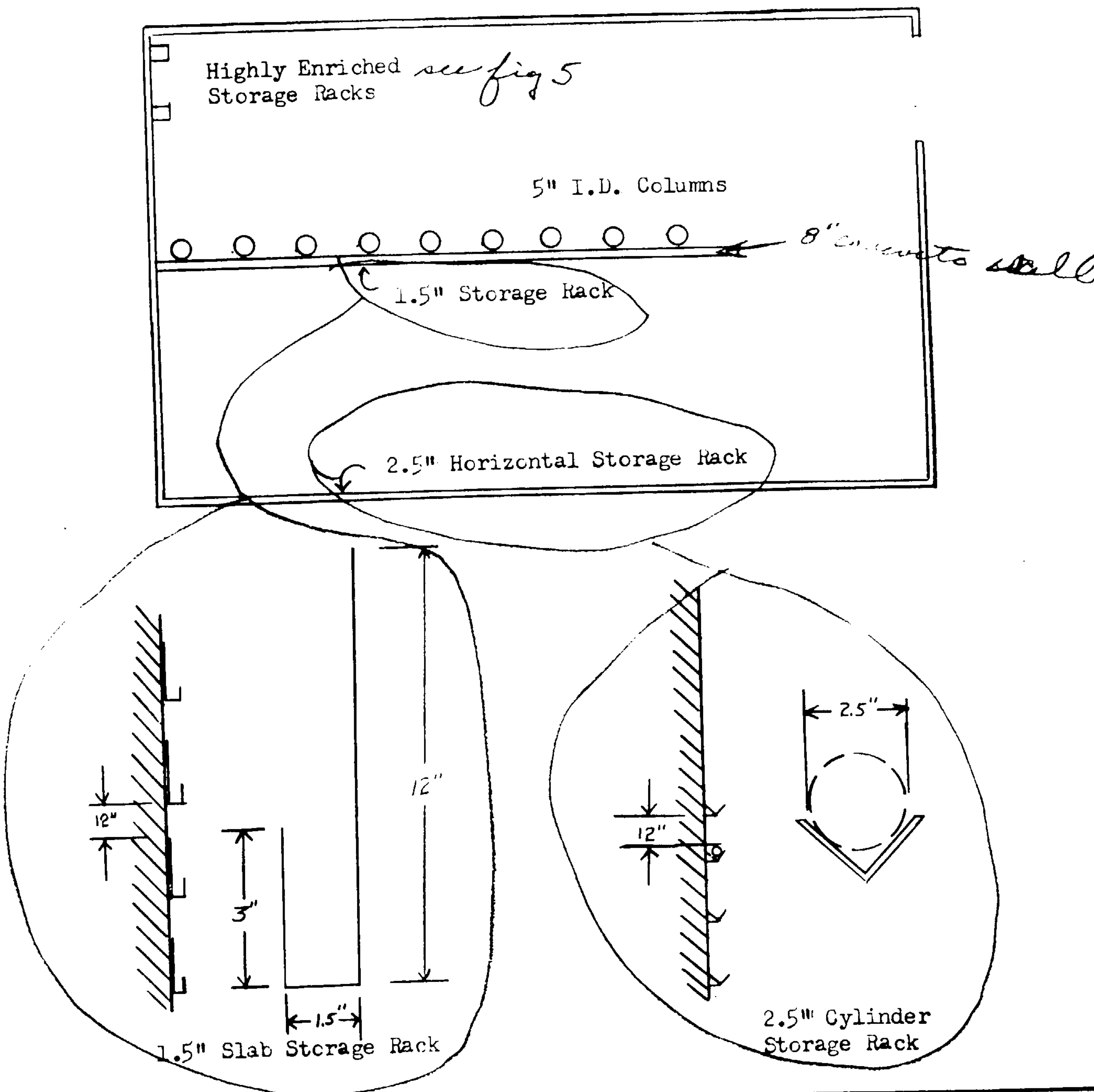
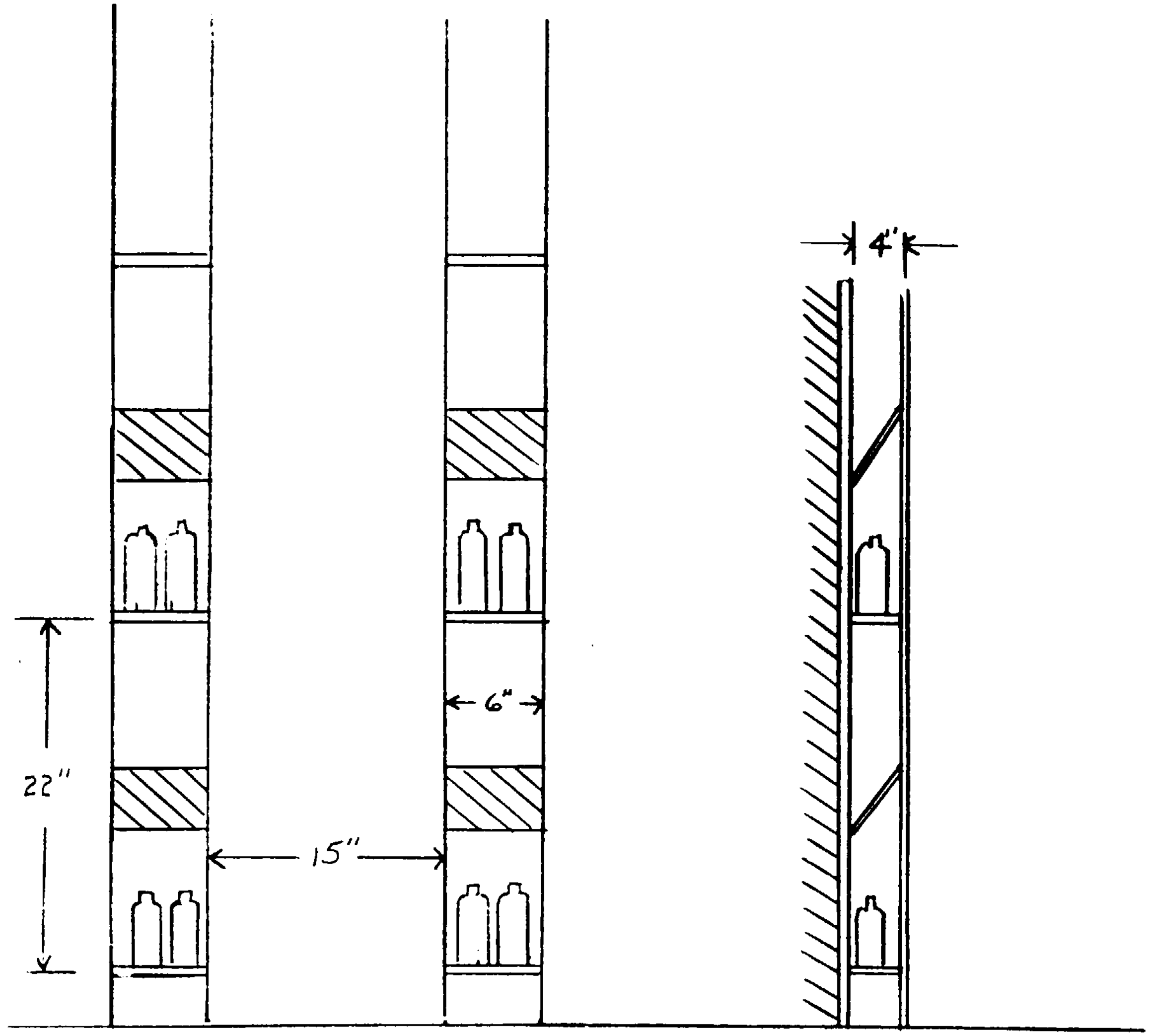


Fig. 4

Vault 4-A

Scale: 1" = 4'0"

6-15-61 LPH



Highly Enriched Storage Racks

Fig. 5

Vault 4-A

Scale: 1" = 1'0"

6-15-61 LPH

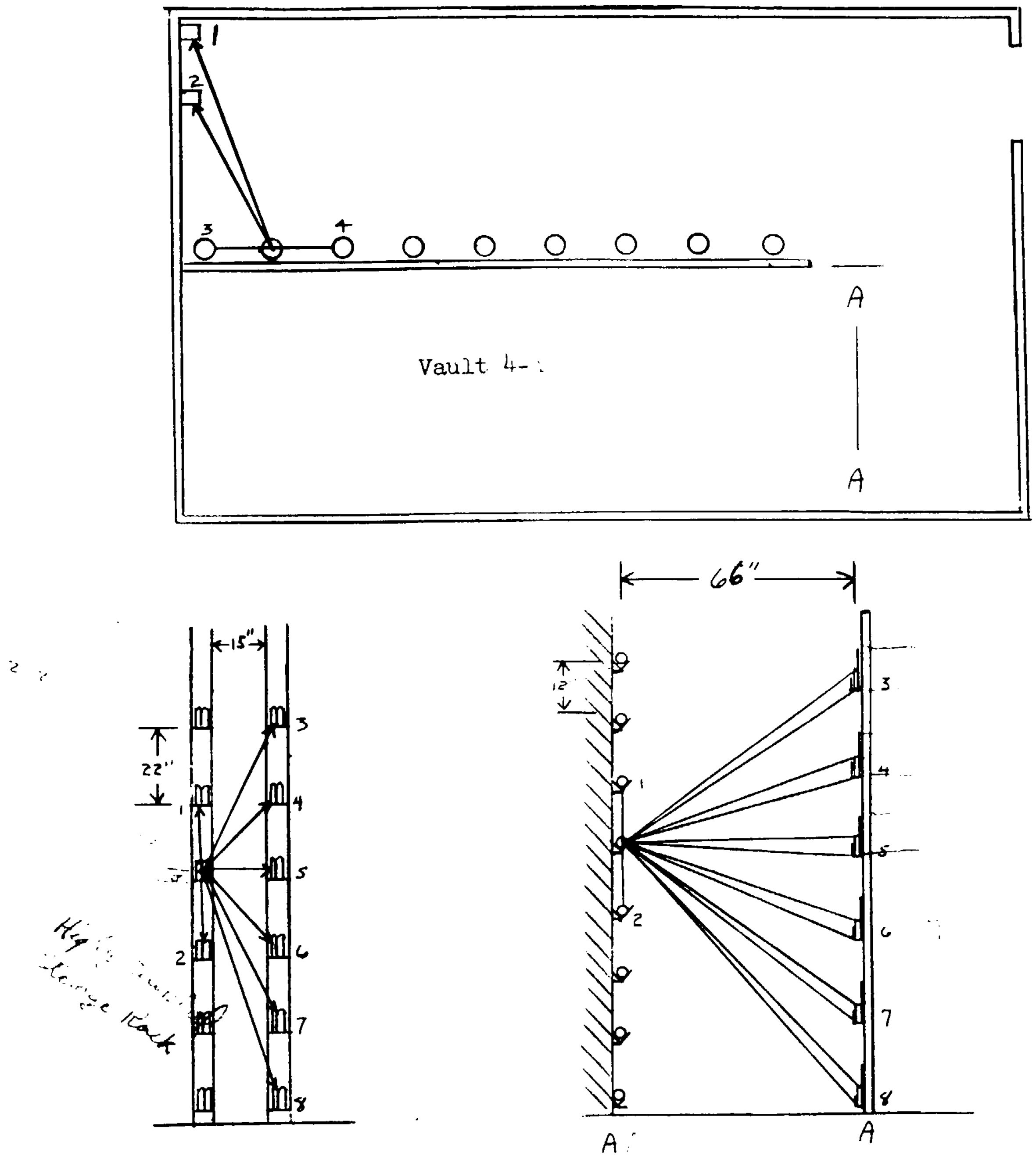


Fig. 6
Vault 4-A
Scale: 1" - 4'0"

6-15-61 LPH

WESTINGHOUSE ELECTRIC CORPORATION

ATOMIC FUEL DEPARTMENT

Cheswick, Pennsylvania

PLANT EMERGENCY PROCEDURES

INDEX

I. Forward

In the interest of plant safety and for protection of employees in particular, it may become necessary for all employees to evacuate the plant buildings in the event of a nuclear incident or other plant disaster. This manual has been prepared to describe the procedures used in the handling of criticality and radiation accidents. It shows the emergency organization including its various teams. Information is presented about the radiation alarms and monitors, communications, personnel monitors, area dosimeters and medical services.

II. Handling Radiation Emergencies

When a radiation incident occurs, the radiation detecting units will automatically activate the siren in the area where the incident occurred. Once this evacuation signal has been given the entire emergency procedure begins:

A. All persons in the areas where the sirens have been sounded will promptly leave the area and assemble at the Assembly Points.

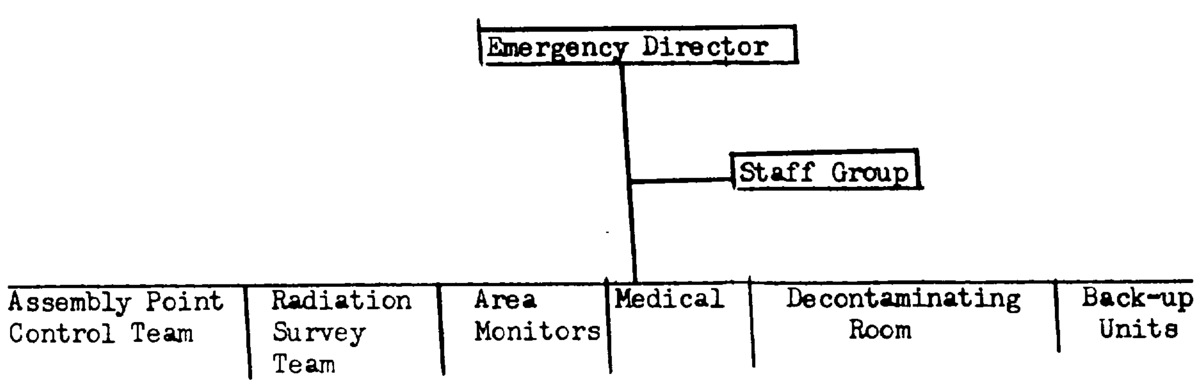
B. The Emergency Director and other designated persons will assemble at the Central Control Room. The general direction of the emergency actions will be handled from this point.

C. The various Emergency Units will assemble at their designated locations and start performing the duties assigned to them.

The following sections describe the duties of each unit individually, give names of personnel, and list the equipment used.

III. Emergency Procedure Organization

The administration of the Emergency Procedure is entirely under the direction of the Plant Emergency Director. The following organization has been established to insure proper integration of all phases of the Emergency Procedures.



Ex 6

IV. Emergency Units

1. Emergency Director

a. Names

	Plant Phones	Home Phones
I. G. Fox, Emergency Director #1	300-301	[redacted]
H. E. Grout, Emergency Director #2 or #3*	307	[redacted]
R. E. Bish, Emergency Director #2 or #3*	308	[redacted]
T. Sainsbury, Emergency Director #4	375-376	[redacted]

The above men will report immediately to the Central Control Room located at Industrial Relations (See Fig. I). The basic responsibility for handling a nuclear incident rests with one of the above men in the order named. The remaining ones may be called upon for advice and should remain in the Central Control Room.

* If the radiation emergency occurs in Buildings 4,5,or 5-A, Mr. H. E. Grout will be Emergency Director #2. When it occurs in Building 5-B, Mr. R. E. Bish will be Emergency Director #2.

b. Duties

The emergency director will:

(1) Make preliminary determination of extent, type, and location of incident.

(2) Issue instructions to emergency units.

(3) Co-ordinate activities of emergency forces and evaluate effectiveness, supplementing if necessary.

(4) Modify emergency plans as required and terminate the emergency actions in part or altogether when it is deemed safe to do so.

c. Equipment that is available in the Central Control Room located at the Industrial Relations Department (AED Budget)

1. Control Center Manual

2. Large layout drawing with plastic overlay and crayons for recording data.

3. Book of plant photographs

4. P.A. System

5. Two-way Radio

6. Telephones - the numbers are 292, 312, 313, 315, 316, and 317

7. List of personnel and their duties

2. Staff Group Assisting Emergency Director

EX 6

a.

Names	Plant Phones	Home Phones
Mr. W. E. Brown, General Foreman	342	[redacted]
L. P. Hackler, Health Physicist	328-431	[redacted]
E. P. Erath, Works Engineering	366	[redacted]
R. B. Barnhart*, Industrial Relations	315	[redacted]

b. The above men will remain in the Central Control Room to interpret data, assist in communications and provide help for the Director.

* Mr. Barnhart will handle communications. He will see that the emergency director has the necessary and sufficient information needed in order that all decisions made are the best ones possible. He will also see that all orders given by the emergency director are relayed to the proper Emergency Units.

Excl

3. Assembly Points Control Team

a. Names

Names	Plant Phones	Home Phones
J. A. Pelegrinelli #1	328-431	[redacted]
John H. Mohr #1	328	[redacted]
H. F. Andree, Jr. #2	328-431	[redacted]
R. Jezewski #2	429	[redacted]

b. Duties

These men will go directly to the Assembly Points (Fig. I). They will monitor for personnel contamination and radiation exposure, record readings and time: Refer people to decontamination station, medical point, or release them. Any object that produces radiation will be picked up and tagged, e.g., coins, knives, watches (other than radium dial watches), etc. Also "Personnel Statement Concerning Incident" data sheet will be issued to each employee.

c. Equipment

The following equipment is located at the Atomic Fuel Department Lobby and at the Receiving Department, Building 5 and will be picked up by the team members on their way out to the Assembly Points.

1. Radiation G.M. Survey Meters
2. Data Sheets
3. Pencils
4. Tags

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4. Radiation Survey Team

a. Names

Names	Plant Phones	Home Phones
P. F. Morrow	328	[redacted]
H. W. King, Jr.	328-431	[redacted]
L. A. Meierkord, Jr.		
W. Hardesty, Jr.	426	[redacted]

b. Duties

The Radiation Survey Team will:

1. Meet at West end of Building 3.
2. Establish that all personnel have evacuated the area and if the nuclear incident has or has not terminated.
3. From pre-planning and knowledge of the operations, map out a plan of how the reaction can be controlled.
4. Preserve data which would be of assistance in ascertaining the cause of the incident.
5. Establish and mark radiation boundary at 12½ mr/hr: advise emergency director of boundary.

   NOTE: The basic responsibility for deciding what to do in case of a nuclear incident rests with the emergency director, rather than with the Radiation Survey Team, although the latter may be called upon for advice.

c. Equipment - this equipment is located at the West end of Building 3.

1. Portable Radiation Survey Meters
2. Protective Clothing
3. Flashlights
4. Respirators
5. Signs stating: Danger
High Radiation Area
Stay Away

5. Area Monitors

Ex 6

a. Names

Names	Plant Phones	Home Phones
P. DiPasquale, #1	337	[redacted]
P. Bellomo, #1	337	[redacted]
D. Branzet, #2	335	[redacted]
B. Hawkins, #2	335	[redacted]

b. Duties

The Area Monitors will be equipped with G.M. Survey Meters and determine when all evacuated personnel are at a safe distance, to assist in controlling the crowd, and to permit no one to re-enter the building. Report all information to Central Control Room; such as injuries, number of employees who are being sent to Medical and to the Decontamination Point.

c. Equipment

This equipment will, with the Assembly Point Control Team, be located at the Atomic Fuel Department Lobby and at the Receiving Department Building 4 and 5 which will be picked up by the Team Members on their way out.

1. Two-way radio
2. G.M. Survey Meter

6. Decontamination Team (Pump Repair Facility)

Ex 6

a. Names

Names		Plant Phones	Home Phones
E. Dombroski	Pump Repair	BR 4-6353	[redacted]
S. Copeman	Pump Repair	BR 4-6353	[redacted]

b. Duties

The members of this team will report to Decontamination Room where they will recheck persons referred from the assembly points and arrange to scrub and issue clean clothes. Refer persons to medical point after recording "before" and "after" readings on the data sheet carried by each employee.

c. Equipment

1. G.M. Survey Meters
2. Clean Clothing
3. Towels
4. Decontaminating Agents

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7. Medical Point (Cafeteria)

a. Name	Plant Phone	Home Phone
Mrs. H. Westlake	272	[redacted]

b. Duties

1. Notify Dr. R. S. Ard, BRoad 4-5000, that a nuclear incident has occurred and to report at once to the Medical Point.

2. The medical personnel will activate appropriate receiving station (cafeteria) and make any necessary preparations at the dispensary for receiving patients.

3. Arrange for medical or clinical assistance procedures with the other groups.

    a. Citizen's General Hospital
    New Kensington, Penna.
    ED 7-3541

    b. Kuznicki Ambulance Service
    Cheswick, Pennsylvania
    BRoad 4-7080

4. Diagnose, treat, discharge, or arrange hospitalization.

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8. Back-up Units

A. Fire Unit

1. Name | Plant Phone | Home Phone

Lt. H. C. Lape, Fire Chief 316 [redacted]

There are several firemen on duty at all times.

2. Duties

a. In case of fire, they will act to control or extinguish the fire.

b. Invoke mutual assistance fire packs with other fire departments when such assistance is deemed necessary by the emergency director.

Harmar Fire Department BR 4-5454

c. Provide emergency lighting, water, first aid, as required at assembly points, decontaminating point and at medical point.

B. Guard Unit*

There are at least two guards on duty at WAFD at all times and one of these guards remains at the Atomic Fuel Lobby.

To provide protection to the guard on duty at the Atomic Fuel Lobby, a warning buzzer is connected to gamma detector #1 located in Building 4. Thus, if the radiation is sufficient to activate gamma detector #1, then the buzzer will be activated and the guard on duty will evacuate immediately and help control the crowd. However, if the buzzer does not sound, the guard will remain at his post and determine the location of the nuclear incident.

* See Off Shift Incident for emergency proceures if the nuclear incident occurs off shift.

a. Duties

1. Notify the other guard who will establish road blocks pending establishment of firm radiation boundaries.

2. Admit specialized staff and help from other sites by a simple recognition procedure.

E4 6

C. Industrial Relations

a. Names	Plant Phones	Home Phones
F. W. Steinle	317	[redacted]
R. B. Barnhart	312	[redacted]

1. Arrange for accurate and prompt reporting to the press and other media of information concerning the incident in accordance with Plant and Headquarters Emergency Communications Procedures.

2. Notify relatives of those who are being retained as a result of exposure, and arrange for visits if necessary.

3. Arrange for rest, refreshments, and food, as necessary for personnel who are required at the site for long periods of time. This particularly applies to those from other sites furnishing assistance.

E4 6

D. Specialized Assistance

a. Names	Plant Phones	Home Phones
E. C. Barnes (WAPD)	EX 1-2800 C-384	[redacted]
R. T. French (WAPD)	EX 1-2800 C-321	[redacted]
R. Catlin (WTR)	YU 2-3011 241	[redacted]
R. Kropp (Bettis)	HO 2-5000 6842	[redacted]

b. Duties

1. Contact the emergency director and find out what is known.

2. Assess the known data and situation; on the basis of this information, specify any additional precautionary measures.

3. Arrange for obtaining needed but unknown data.

4. Recommend action to the emergency director to end the reaction if necessary; provide on-the-spot advice in the safe correction of the situation; and obtain basic data as to the cause and effect for future guidance.

E. Receiving Department

1. Receiving Department employees will open the truck gate at the Southwest corner of the plant as they are leaving.

F. AEC Team

A team of AEC radiation experts are available at any time to aid in radiation emergencies. This team consists of 8-12 men and enough radiation equipment for each man. The AEC team is located at the Pittsburgh Naval Reactor Operations Office, Bettis Atomic Power Laboratory, Pittsburgh, Pennsylvania. The following are the names of men to call if this AEC team is needed:

E.4.b

a. Names	Plant Phones	Home Phones
Mr. L. D. Geiger	HO 2-5000 240	[redacted]
Mr. R. March	HO 2-5000 7575	[redacted]
Mr. W. Reese	HO 2-5000 6905	[redacted]

V. Radiation Detectors

The Radiation Detectors are connected in a multiple series circuit to obtain a coincidence feature that will necessitate two Radiation Detectors sensing the gamma radiation before the evacuation signal can be activated. This in no way impairs the speed or effectiveness of the system. It does, however, provide protection against false alarms.

Calculations show the compatibility and adequacy of the Radiation Detector locations with the coincidence features. A nuclear incident which will generate a radiation level of 300 rem per hour at one

foot from source at the incident was assumed in the final location and the number of Radiation Detectors needed. This is in accordance with 10CFR 70.24(1). 10 to 20 mr per hour has been set as the alarm level.

The Radiation Detectors used by Westinghouse Atomic Fuel Department are Model GA-2 designed and furnished by Nuclear Measurement Corporation of Indianapolis, Indiana. The following are some of the features of the Model GA-2 Radiation Detector.

A. The GA-2 is designed specifically to satisfy the requirements of Part 70.24.

B. The GA-2 scale goes from 0.05 to 50 mr/hr.

C. The response time of the Model GA-2 is less than ½ second.

D. The GA-2 cannot jam at high field intensities, short of melt down.

E. The Model GA-2 Radiation Detector is supplied with a small gamma source attached to the detector. The GA-2 indicates with this source approximately 0.08 mr/hr.

F. If a component failure occurs, the indicating meter will strike the lower contact, closing a relay which will light the amber light on the unit itself and at the monitor control panel located in the Atomic Fuel Lobby. The amber light indicates a failure either in the component itself or a power failure.

G. A bell and red lap indicate alarm level. The siren is connected to this same relay switch.

VI. Gamma Detector Locations and Evacuation Signal

Westinghouse Atomic Fuel Department has five types of fuel fabrication facilities; Buildings 4,5,5-A,5-B and Engineering Development Laboratory. With the exception of the Engineering Development Laboratory, which is located approximately 400 feet from the main plant, the four

facilities are adjacent to one another, see Figure (1). Each facility has individual Gamma Detectors and individual evacuation signals consisting of a siren or sirens in each facility. Thus, if a nuclear incident occurred in Building 5-A, the Gamma Detectors would, of course, activate the siren in this area and the employees would evacuate. The employees in Building 4 and 5 and Building 5-B will evacuate only if the radiation produced by the nuclear incident in Building 5-A is sufficient to trigger the siren or evacuation signal in these two buildings. Otherwise, they would remain on the job until it was determined that these employees should be evacuated as a safety precaution only. These employees would be monitored for radiation exposure and for contamination only after the employees in Building 5-A had been monitored.

In addition to the siren being activated automatically, they can also be activated manually. There is a manual control switch for each facility that can be operated from the Atomic Fuel Department Lobby. To operate the signal, simply break the glass with the small hammer attached to the signal box. The siren will then sound automatically.

To provide protection to the employees in the Atomic Equipment Department, a siren is installed inside these facilities. It will be connected to the Gamma Detector #1 located in Building 4. Thus, if the radiation is sufficient to activate Gamma Detector #1, then the sirens located in the Atomic Equipment Department and the main office will be activated. These employees will go and remain on the other side of the line located 100 feet from the fire brick wall, see Figure (I).

VII. Off Shift Incident

In order that the operating shift on duty can handle radiation emergencies for the first few minutes without specialized staff assistance from either our own or from other aides, the following emergency plans of the operating shift will be followed:

Ex. 6

A. Names

Names	Plant Phones	Home Phones
D. A. Dougherty - Second Shift	361	[redacted]
C. B. Crowther - Third Shift	361	[redacted]

B. Duties

1. Evacuate personnel from the area involved, and make any necessary operational changes.

2. Rope off or mark unsafe area to avoid unintentional re-entrance and exposure or contamination of personnel.

3. Cut off all power to the ventilation system.

4. Collect as much information about the situation as possible for the Emergency Director.

5. Call all members of the Radiation Emergency Teams and all off duty guards.

6. The guard on duty at the AED Lobby will administer first aid until relieved by the Medical Team. He will then perform his regular assigned emergency duties.

VIII. Required Notifications

If a nuclear incident occurred, the following would be notified immediately by the Industrial Relations Department:

1. Pittsburgh Naval Reactors Operations Office
   P.O. Box 1105
   Pittsburgh 30, Pennsylvania
   HOmestead 2-5000

2. New York Operations Office
   376 Hudson Street
   New York 14, New York
   YUkon 9-1000

3. Pensylvania Department of Health

a. C. L. Wilbar, Jr., M.D.
Secretary of Health
Office CE 8-5151 Ext. 3822
[redacted]
EX6

b. Karl M. Mason
Director, Bureau of Environomental Health
Office CE 8-5151 Ext. 852
[redacted]
EX6

c. Dick C. Heil
Office EXpress 1-2100 Ext. 618 or 619
[redacted]
EX6

4. Atomic Energy Commission
Washington 25, D. C.
HAzelwood 7-7800 Ext. 4593

IX. Instructions to Employees

Personnel in the area receiving the alarm will:

A. Immediately evacuate the building.

B. Leave at a fast pace and go to the designated assembly point.

C. Assist visitors and injured, if any, but do not delay in leaving.

D. Shut down predesignated operations which would be hazardous to leave unattended if means have been provided to do so without causing delay in evacuating.

E. Take radiation instruments held in readiness for such situations.

F. Try to account for your "buddy" and other persons in the area.

G. Remember what happened so you can inform emergency groups.

AFTER ARRIVAL AT ASSEMBLY POINT, PERSONNEL WILL:

A. Co-operate with local men in charge at the assembly point.

B. Get clothing and badge checked for radiation.

C. Complete questionnaire describing your actions and whatever you can about the incident.

D. Report immediately to the medical point if you feel nausea or if you vomit.

X. Exposure Determination

All employees have a 0.010" x 0.25" x 1" strip of indium foil in their identification badge. Thus if a nuclear incident occurs, these strips of indium foil will become radioactive by neutron bombardment. The Assembly Point Control Team will survey these identification badges and if they read above 0.5 mr/hr then the employee will be sent to the Medical Point at once.

Since most of the employees are not required to wear film badges, they (film badges) are placed at each exit and will be picked up by certain designated personnel and analyzed as soon as possible.

NOTE: The time and the intensity (mr/hr) that the indium foil was found to be radioactive must be recorded. Also, the time that the film badges were picked-up must be recorded.

PERSONNEL STATEMENT CONCERNING INCIDENT

Date of Incident ______________________ Time ______________ A.M. P.M.

Name ______________________________ Badge Number __________

Supervisor ____________________ Department ________________

Job Assignment ____

Where were you at time of incident? Building __________ (Show on map - reverse side)

How did you recognize or how were you informed of emergency? ______________

____

____

How soon did you leave your location after knowing of emergency? ________

What action did you take at the time of the incident if you did not leave immediately?

Specify particularly any actions to control emergency ______________

____

____

How did you leave the area? Walk Run (Mark route on map)

Did you see, hear, feel, or smell anything unusual? Describe ___________

____

____

Do you know where any of your co-workers were or what they were doing at time of incident? ____

____

Do you have other comments? _________________________________

____

____

Did this man's badge or any other object emit radiation?	Yes	No
Is this man's clothing contaminated?	Yes	No

If yes, go to decontamination point
Reading before _____ mr/hr; after _____ mr/hr decontamination.

Signed ____________________

Date ____________________

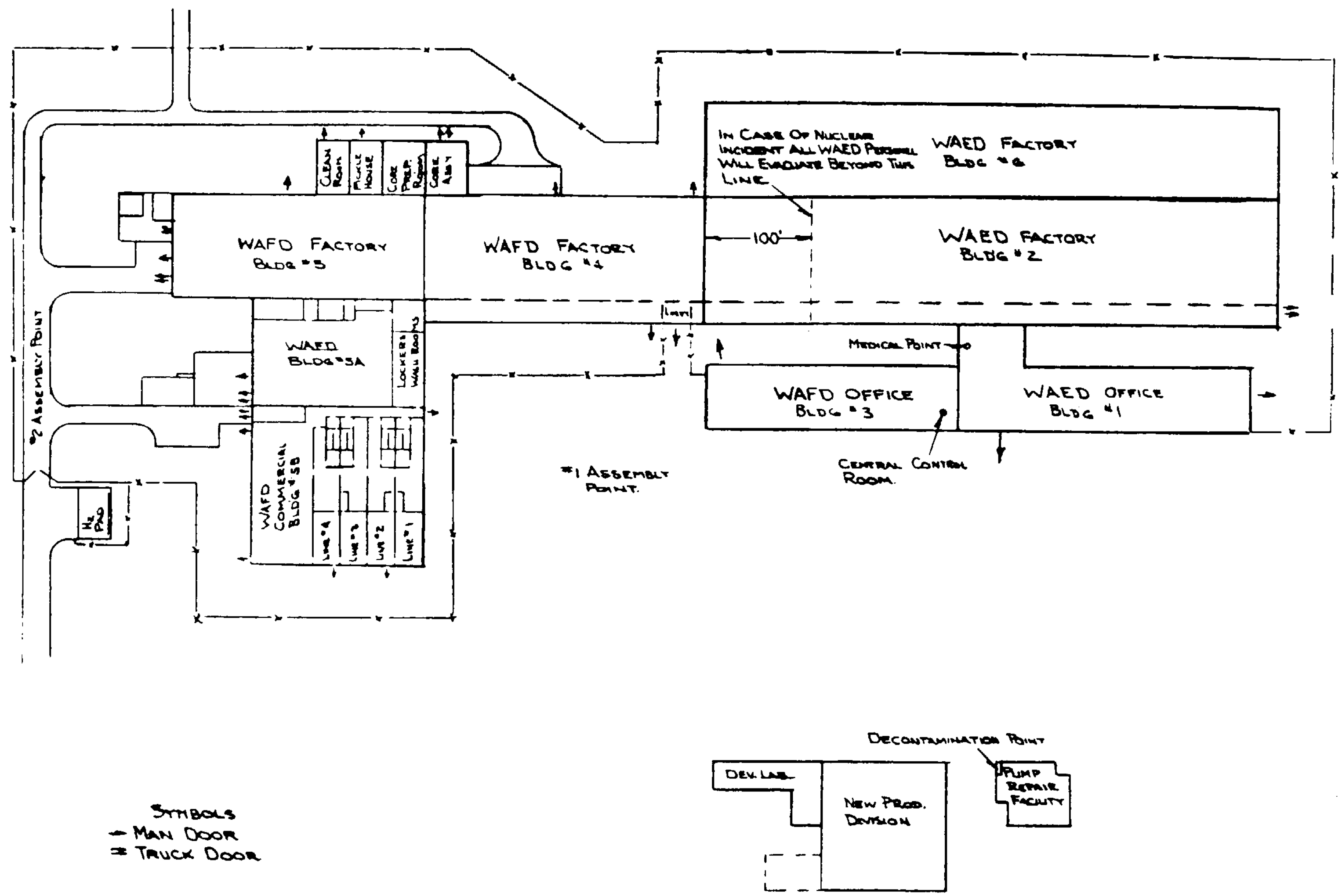

Figure I
Cheswick Site
Existing Buildings
Scale 1" = 100'

FEB.-109