4713

ISOMEDIX

Re: Control # 50985

November 15, 1974

Mr. Douglas M. Collins
Directorate of Licensing
Atomic Energy Commission
Washington, D.C. 20549

Dear Mr. Collins:

This is in answer to your letter of October 25, 1974, requesting additional details regarding amendment to our Byproduct Material License #29-05364-01. The numbered items correspond to the numbers in your letter.

1. Enclosure 1, drawing #100618, shows additional details of the pool, biological shield, floor, location of voids and location of support systems, including air filter banks, water filter system, source hoist mechanism, etc. Key items are numbered 1,2,3, etc., and will correspond with further discussions of other points in your letter.

The location of the ventilation system is as shown in Drawing 100168, with roughing and absolute filters located at #11. The motor and fan are located on the roof north of the irradiator, above the 1000 square foot Pre-Irradiation Holding Area (Drawing SK42394) previously

COPIES SENT TO REGULATORY OPERATIONS

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127.

submitted .Exhaust air is evacuated to the atmosphere above roof level. As a result of consultations with manufacturers, we intend to reduce the proposed irradiation room air flow from a rate of 20 air changes per hour to 10 air changes per hour or approximately 1,000 cfm. We estimate this rate is sufficient to reduce ozone concentration to permissable limits during the 2-3 minute time period required to lower the source and enter the radiation chamber. If, upon entering the radiation chamber under these conditions, noticeable ozone concentrations are detected, our entrance procedures will be revised to require the operator to wait for an additional specified time before entering the irradiator.

2. A copy of the calculations of expected radiation levels on the outside of the shield is attached as Enclosure 2.

The only deliberate void in the shield is a 12"x12" duct located at #1, Drawing 100618. The duct rises vertically for a distance of 52", bends 90° to the east for a distance of 44", then bends 90° to the north and exits the shield. The minimum concrete thickness in a direct line from the source to the outside wall is more than 60", and the minimum thickness after one scatter is 42".

Additional concrete thickness above normal roof level (#2, Drawing 100618) is gained by placement of solid cement blocks over the vertical portion of the duct. The calculated dose rate at that point, with 10^6 curies, is 8.5 mr/hr. With the initial loading of 200,000 ci, dose rate is about 2 mr/hr. Calculations are in Enclosure 3.

There is also a 12" wide, 6" deep pipe trench running below floor level, as shown at #9, Drawing 100618. It is exposed to the source between the time the source breaks water until it clears the bottom of the 12" thick floor. This is a distance of about 12". Since the source rack is over 36" high, about 1/3 of its activity will "see" the hole during transit. The beam must travel through 16" of concrete supporting the inner chamber wall, be scattered at a 45° angle, and travel down the labyrinth and exit below the floor surface. Except for the water-filled pipes in the trench, a portion of the trench under the north wall of the labyrinth will be blocked with a length of 32" of 16" long concrete blocks, with lead wool packed into voids around the pipes (#10, Drawing 100618). With 10^6 curies, a sub floor level transient dose rate at the outer (north) edge of the wall and below floor

surface is expected to be less than 4 mr/hr. This area is a normal storage area. Calculations are in Enclosure 4.

In the roof, slightly off-set from the vertical source rack, are three-three inch holes. (#16, Drawing 100618) Two source rack guide cables are attached in the two end penetrations to plugs shown in Enclosure 5. In the center plug (Enclosure 6) are two 3/8" holes, through which 1/8" stainless steel source rack cables pass, which raise or lower the source. A fixture on the roof of the cell, directly over this plug supports lead bricks 9" (or more) in thickness to attenuate possible radiation leakage. (Item #13 on Drawing 100618). Additional shielding can be added if needed.

There are no electrical penetrations. Wiring travels through the labyrinth.

The shielding calculations are regarded as a guide and basis for initial design parameters. In placing the facility into operation, the following procedure will be followed:

A source of approximately 50,000 curies of cobalt will be

loaded into the source rack and raised to the irradiate position. A complete survey of the facility will be made, with special attention being given to measuring dose rates at key points, including the maze entrance door, the roof above vent stack, all penetrations and the pipe trench. Walls will be surveyed for possible voids. The cement shield is built so that localized shielding, in the form of solid cement blocks, can be added at virtually any point, either inside or outside of the primary shielding. If a "hot spot" is found, such shielding will be added to bring dose rates into design specifications.

Following this test, the source will be increased to 200,000 curies (the extent of the initial cobalt-60 order) and the entire procedure repeated.

Results of such surveys with appropriate action taken, will be maintained for future reference in source upgrading, and for appropriate inspection.

3. The "Step 1" source assembly is somewhat changed from our earlier plan. The source module frame (rack) is now identical for Steps 1,2 and 3, and is shown on Drawing 100615, Enclosure 7. In the Step 1 mode, three source

modules will be stacked in the 75" height of the frame (Sheet 2, Drawing 100615). In Step 2 operation, the source modules will be loaded into the three 38" sections of the frame. Product to be processed in "Step 1" is placed in a circular configuration around the source up position, and the source then raised to the expose position. There is no automated product shuffle system in this mode of operation. A metal guard, in the form of steel bars extending from floor to ceiling, surrounds the source and source holder to prevent product from contacting and possibly restricting movement of the source plaque.

4. A sketch of the "Step 2" package shuffle system is shown in Enclosure 8. Movement of the product "tote" boxes is via pneumatic cylinders and elevators, with none of the pushing being done in a direct line to the source.

The tote boxes travel on rollers which roll in the direction of movement, and the boxes are contained along their base and top by steel channels which maintain the designated direction of travel. Enclosure 9 shows the method of operation of the shuffle system. The location of the source relative to the system is shown in Enclosure 8.

The entire system, with minor modifications for flexibility, is quite similar to the AECL-type shuffle system installed in our Chicago facility, and licensed in our -02 license. The vertical steel guards described for the Step 1 operation will be removed for Step 2 operations.

Source modules are as shown in Enclosure 10, Drawing 100619. The modules, in turn, are placed in the source rack, which all becomes the source plaque.

5. We have not completed the detailed design of the "Step 3" system. The purpose of this system is to bring the product from outside the irradiation chamber into the shuffle system. The request to operate in this mode should be deleted from the present application. We will submit supplementary information on this system at a later time.

6. Except for the small space required to permit the source to rise from the pool, the remainder of the opening will be covered with metal planking. During all source handling operations, when portions of the planking are removed, a metal railing will be placed across the pool to prevent personnel from inadvertently falling into the pool.

7. The inside of the pool is painted with a rubber-based swimming pool paint resistant to acids, salt water, fresh water, and alkali. The paint is designed for use on interiors of concrete with water. The trade name of the paint is "PUR-POOL" and is available from the PUR-All Paint Products Company, Inc.

8. The water treatment system is a Model PBS-13 available from the W.J. Westaway Company, Ontario, Canada. It is a two bed demineralizer with carbon filter. It is capable of maintaining the water at purity levels suggested by the cobalt-60 supplier (AECL). The most critical parameter is water conductivity which can be maintained at less than 10 micromhos. The unit is equipped with a conductivity monitor for constant readout of this parameter. Water flow rate is 10 gallons per minute which will yield a pool water turnover approximately every 5 days. Water is pulled from the pool through a floating skimmer into the treatment system and returned to the pool through a pipe in the pipe trench. Location of the water treatment system, piping, etc., is shown at #8, Drawing D100618.

9. The water level control, makeup water input, and low level alarm system are located in the pool as shown at

#3, 4 & 5 in Drawing 100618.

Makeup water will begin to be added when the level drops approximately 2 1/2 inches below normal level, and the low level alarm will sound when the level is approximately six inches below normal level.

Signals to activate the low level alarm signal, or to open and close the water valve, are generated by floats. A magnetic float travels up or down a hollow steel tube which contains an electric sensing element, which is triggered by the magnetic field. The sensing element then triggers the solenoid. The units are stainless steel Gems Level Switches, Model LS 1950.

Makeup water is added through a pipe whose open end is above pool level, to avoid the possibility of backflow into the municipal water system.

Additional water can be added in an emergency via a fire hose located near the labyrinth entrance, shown at #14 in Drawing 100618.

10. There is no water holdup system associated with the

primary pool. Disposal of the water, or emptying of the pool, can be done only by altering the water treatment system, hence, there cannot be an inadvertant emptying of the pool.

11. It will be possible to open the maze door from the inside to allow egress at any time by a person trapped inside the shield.

12. The source hoist and lowering system is as shown on SK100620, Enclosure 11. Source movement is accomplished by a double acting pneumatic cylinder, whose location is at #12 in Drawing D100618. A stainless steel aircraft closed loop cable travels from the cylinder toward the ceiling, then horizontally to a roller above the center 3" plug over the source, and through the plug into the pool, where both ends are secured to the source rack. Movement of the cylinder in one direction, pulls the source down, and in the other direction, pulls the source up.

The pneumatic cylinder is enclosed, but has a transparent cover so that its stroke position can be readily seen. This provides another means for the operator to determine the source rack position relative to the full up or down position.

13. As noted in Item 12, movement of the source into the storage pool is via a double acting pnuematic cylinder. The source rack is subjected to a positive pull from this cylinder during retraction into the pool. As noted elsewhere (Items 3 and 4), there is physical constraint between product and source in all modes of operation. However, there is sufficient strength in the source rack and sufficient pull from the cylinder, if need be, to permit the crushing of a typical box of product which might somehow come in contact with the source rack.

If needed, additional leverage on the source down cable can be applied at any point along the cable. We are unable to visualize a realistic situation in which it will not be possible to physically retract the source with force, if need be.

14. See Drawing Sk42374, Enclosure 3 to our August 8 Supplement. The non-restricted storage area in the middle bay is generally open storage space, of a warehouse nature. Placement of the cask would normally be against the North wall of the Isomedix area, away from any personnel traffic pattern ("Pre-Irradiation Holding Area"). The area North of the wall is warehouse area with raw material

storage on pallets, and the area is only seldom inhabited.

There is also a locked wire caged area on a portion of the north wall. It is normally used for product quarantine, but could be available for cask storage if deemed necessary by the RPO. ("Quarantine", 320 ft^2).

The restricted area behind the hot cells is basically open, and normally is roped off (dotted line on drawing) from the rest of the area. In this case it is possible to lock a large sliding door between the rear of the hot cell and the adjacent bay (to the East) and prevent access from that direction.

If a loaded cask is placed in either area for temporary storage, the cask lid will be chained and locked to the base of the cask to prevent its being opened.

The RPO may, at his descretion, choose to store the cask at the bottom of the 20' pool located behind the Hot Cells.

15. The proposed sealed source leak test procedure (section

14.3.2) was recommended by the source manufacturer, AECL, and has been their recommended procedure for several years. Isomedix is currently licensed under its -02 amendment to utilize this procedure in its Chicago facility, which is a total operation very similiar to the proposed installation. Evidence of a leaking source will also be apparant from the monitoring of the resin bed and filter banks as proposed, or from monthly wipe tests of the cell interior, and monthly monitoring of the absolute filter. The relatively large volume of water in this pool (approx. 70,000 gallons) would not, we feel, provide as sensitive an analysis as the proposed wipe test procedure.

16. The industrial waste drain referenced leads to a closed septic system. The plant and surrounding area are not yet serviced by a municipal sewer system, although connection to such a system is proposed by the Township (Hanover) at some point in the near future. Your comment regarding concentrations is noted and understood.

This concludes the discussion related to your specific questions. In addition, we would like to add one add-

itional procedure, and request an additional man be added as an operator.

Add 13.10.7 Transferring sources from Hot Cell Pool to Labyrinth Irradiator.

1. Remove cover grating of Hot Cell Pool, erect guard rail and lower underwater lights.
2. Place sources to be transferred into source basket. (This is done underwater in pool behind hot cell 2).
3. Move all source baskets in pool to wall closest to hot cells (north end of pool).
4. Using overhead crane, lower cask into pool.
5. Place source basket in cask.
6. Place lid on cask.
7. Raise cask slowly to pool surface. RPO is required to be present and monitor radiation levels.
8. Raise cask above pool surface. Survey for radiation levels. If level is above 10 mr/hr at any surface, lower into pool and reduce number of sources in cask. If radiation levels are below 10 mr/hr, secure lid with nuts and bolts.
9. Raise cask out of and away from pool.

10. Remove guard rail and replace grating on top of pool.

11. Use procedure in 13.10.2 to transfer cask into Labyrinth Irradiator.

Add Mr. John Hollis as an authorized user to conduct service irradiation activities in the Labyrinth Irradiator. His qualifications follow:

a. He has had (to date) three months of supervised on-the-job training in and around hot cell service irradiation activities, which together contain approximately 300,000 curies of cobalt-60.

b. He has received the training outlined in para. 14.6.2, August 8, Supplement, with other proposed operators, has reviewed and is familiar with Operating Procedures as outlined in para. 13.1[illegible]

c. By the time the unit becomes operational, he will be totally familiar with its details of operation. He is a qualified electrician, licensed by the State of New Jersey, and will physically install the electrical system of the irradiator. Thus, he will be especially familiar with the safety system, which is basically electro-mechanical.

d. During his employment at Isomedix, he has proven himself to be highly mature, reliable and dependable. In the judgment of the RPO, he meets the qualifications of the proposed position.

It is our understanding that you may decide to make an on-

site inspection of the irradiator prior to authorizing operations. We believe the system will be operational by mid-December 1974, and we will aprise you of the actual date a week or more in advance. We assume it would be appropriate to issue a license with a provision that operations could not begin until after the aforementioned inspection is completed. A license number would enable us to complete administrative arrangements for source shipment with the Canadian Government, so that actual shipment could be made on short notice following your final authorization.

Very truly yours,

George R. Dietz
President

GRD:dp

enclosures

ENCLOSURES

1. Drawing 100618
2. AECL Shielding Calculations
3. Vent Duct Shielding Calculations
4. Pipe Trench Shielding Calculations
5. Guide cable plug assembly
6. Center plug assembly
7. Source Rack Assembly (2 sheets) (Drawing 100615)
8. Package Shuffle System Concept
9. Product Flow Diagram
10. Source Module (Drawing 100619)
11. Source Hoist Mechanism (SK 100620)

SHIELDING CALCULATIONS
FOR
PROPOSED
COBALT 60 IRRADIATOR

ISOMEDIX INC.
PARSIPPANY, N.J.

R. Chu
August 27, 1974

ATOMIC ENERGY OF CANADA LIMITED
COMMERCIAL PRODUCTS
OTTAWA, CANADA

Received with letter dated 11/15/74

Encl 2

Shielding Calculations

The biological shield for the irradiator is shown on Drawing B700001-047. The shield is designed to attenuate the radiation from a 1,000,000 curies Cobalt 60 plaque source within the design levels shown in Table 1. The radiation leakage levels were selected on the basis that under normal working conditions no person in the vicinity of the irradiator receives more than an average of 10.0 mrem per week or a maximum of 500.0 mrem per year. This is the exposure level recommended by the International Commission on Radiological Protection (1) for individual members of the public.

Primary Shielding

The transmission of Cobalt 60 gamma radiation in concrete is shown in Figure 1A, 1B. The exposure rate from a 1 curie point source of Cobalt 60 is 1.3×10^3 mR/h at 1 metre and varies inversely with the square of the distance. Concrete thickness for the primary shielding was determined by calculating the maximum exposure rate outside the shielding wall for a point source and correcting for source geometry and absorption within the source plaque. Some sample calculations are given below.

1. Maximum field outside external wall parallel to source plaque:

   Concrete thickness = 72 in (1.83 m).

   Transmission = 2.7×10^{-9}.

Distance from source plane to exterior surface of wall = 14 ft (4.27 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{4.27}\right)^2 \times 2.7 \times 10^{-9} = 0.19 \text{ mR/h}.$$

Self absorption factor and geometry factor for transforming point source calculation to that for a 36.0 in (0.91 m) high plaque source = 0.8.

Maximum exposure rate = 0.15 mR/h.

This is below the design average radiation level of 0.25 mR/h.

2. Direct transmission to personnel access door:

Oblique concrete thickness = 64 in (1.63 m).

Transmission = 2.5×10^{-8}.

Assume point source at center of source plaque.

Distance from source to door = 25 ft 9 in (7.85 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{7.85}\right)^2 \times 2.5 \times 10^{-8} = 0.53 \text{ mR/h}$$

Self-absorption and geometry factor 20° from plane of source plaque = 0.4

Maximum exposure rate = 0.21 mR/h

This is below the design radiation level of 0.25 mR/h.

3. Maximum field on roof:

Concrete thickness = 64 in (1.63 m).

Transmission = 2.5×10^{-8}.

Assume point source at center of source plaque.

Distance from source to roof = 10 ft 8 in (3.25 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{3.25}\right)^2 \times 2.5 \times 10^{-8} = 3.08 \text{ mR/h.}$$

Self absorption and geometry factor for vertical source plaque = 0.3.

Maximum exposure rate = 0.92 mR/h.

This is below the design maximum radiation level of 2.0 mR/h. Additional attenuation provided by oblique transmission through concrete will reduce the average radiation levels in the access adjacent to the primary shielding to less than 0.25 mR/h with a capacity source of 1,000,000 curies of Cobalt 60.

Maze Design

Accurate calculations of the exposure rate and energy spectrum at points along a concrete maze are difficult to perform. At present detailed calculations of the exposure rate attenuation in concrete mazes have been confined to two-legged concrete ducts (2). The amount of work required for detailed calculations for mazes with more than one right-angle bend becomes prohibitive and maze designers must either rely on measurements to determine exposure rates at the entrance of a maze with several legs or must make order of magnitude estimates using purely empirical formulae.

Maze entrances for industrial irradiators designed by AECL are based on both calculations and measurements. The radiation incident upon the maze walls due to singly-scattered radiation is calculated by dividing the scattering areas into small segments and calculating the amount of single-scattered radiation from each segment. The exposure rate from the small scattering area A (Figure 2) is given by:

$$D = \frac{D_o \alpha (E_o, \theta_o, \theta, \phi) A \cos\theta}{r_1^2 \quad r_2^2}$$

where

$\alpha (E_o, \theta_o, \theta, \phi)$ is the differential expsoure albedo,

A is the area of the scattering surface,

D_o is the exposure rate at one unit length from the source,

E_o is the initial energy of the gamma rays from the source.

Values of the differential expsoure albedo,

$\alpha(E_o, \theta_o, \theta, \phi)$ have been calculated by Raso (3) using the Monte Carlo method. Using the Raso data, Chilton and Huddleston (4) developed the following semi-empirical equation for the differential exposure albedo

$$\alpha(E_o, \theta_o, \theta, \phi) = \frac{C(E_o) \quad K(\theta_s) \quad 10^{26} + C^1 \ (E_o)}{1 + \cos\theta_o / \cos\theta}$$

where $C(E_o)$ and $C^1(E_o)$ are constants for a given energy

$K(\theta_s)$ is the Klein-Nishina differential energy scattering coefficient,

θ_s is the angle through which the radiation is scattered and is given by $\cos\theta_s = \sin\theta_o \sin\theta \cos\phi - \cos\theta_o \cos\theta$

For Cobalt 60 gamma rays, E_o = 1.25 Mev

C(1.25 Mev) = 0.0665

C^1(1.25 Mev) = 0.107

The calculated values of the differential exposure albedo for Cobalt 60 gamma rays have been verified by measurements at AECL.

The energy of the singly-scattered radiation is given by:

$$E = \frac{E_o}{1 + \frac{E_o}{0.511}(1 - \cos\theta_s)}$$

The required thickness of the maze walls required to attenuate the singly-scattered radiation of energy, E, to below the design levels are calculated and corrections for lower energy multiply-scattered radiation are made using information obtained from measurements of the radiation fields in and around mazes built by AECL.

For maze walls where no singly-scattered radiation is incident and the maximum radiation energy is due to doubly-scattered radiation, an estimate of the incident doubly-scattered exposure rate is obtained by calculating the scatter from one wall surface to another surface and then to the maze wall. The energy of the gamma rays impinging on the second area is assumed to be the energy of a gamma ray having one Compton scatter at the centre of the first area and going to the centre of the second area. For the second scatter the parameters $C(E_o)$ and $C^1(E_o)$ are approximated by

$C(E_o) = 0.0561\ E_o^{0.574}$ and $C^1(E_o) = 0.0122\ E_o^{-0.683}$.

Again, corrections for lower energy multiply-scattered radiation are made from measurement data.

Detailed measurements of radiation fields inside mazes have been performed by AECL for two shielded room facilities in Ottawa, the irradiator at St. Hilaire, Quebec, and the Ethicon Medical Products Sterilizing Irradiator in Somerville, New Jersey. In addition, surveys of the exterior radiation fields

TABLE 1			
LOCATION	OCCUPANCY	EXPOSURE RATE (mR/h)	
Control Area	40.0 hrs/wk.	2.0 max.*	0.25 average
Machine Room	40.0 hrs/wk.	2.0 max.	0.25 average
Roof	40.0 hrs/wk.	2.0 max.	0.25 average
External Walls	40.0 hrs/wk.	2.0 max.	0.25 average
Pool Surface (Source Lowered)	40.0 hrs/wk.	2.0 max.	0.25 average

* Maximum exposure rate in any small area adjacent to shield.

EXPOSURE RATE TABLE

are performed on every industrial irradiator built by AECL. These extensive measurements confirm that the recommended maze shielding provides adequate protection.

References

1. "Recommendations of the International Commission on Radiological Protection", (Adopted September 17, 1965), ICRP Publication 9, London; Pergammon Press 1966.
2. J.M. Chapman and C.M. Huddleston, "Dose Attenuation in Two-Legged Concrete Ducts for Various Gamma-Ray Energies", Nuclear Science and Engineering, 25, 66 (1966).
3. D.J. Raso, "Monte Carlo Calculations on the Reflection and Transmission of Scattered Gamma Rays", Nuclear Science and Engineering, 17, 411 (1963).
4. A.B. Chilton and C.M. Huddleston, "A Semi-empirical Formula for Gamma Rays on Concrete", Nuclear Science and Engineering, 17, 419 (1963).

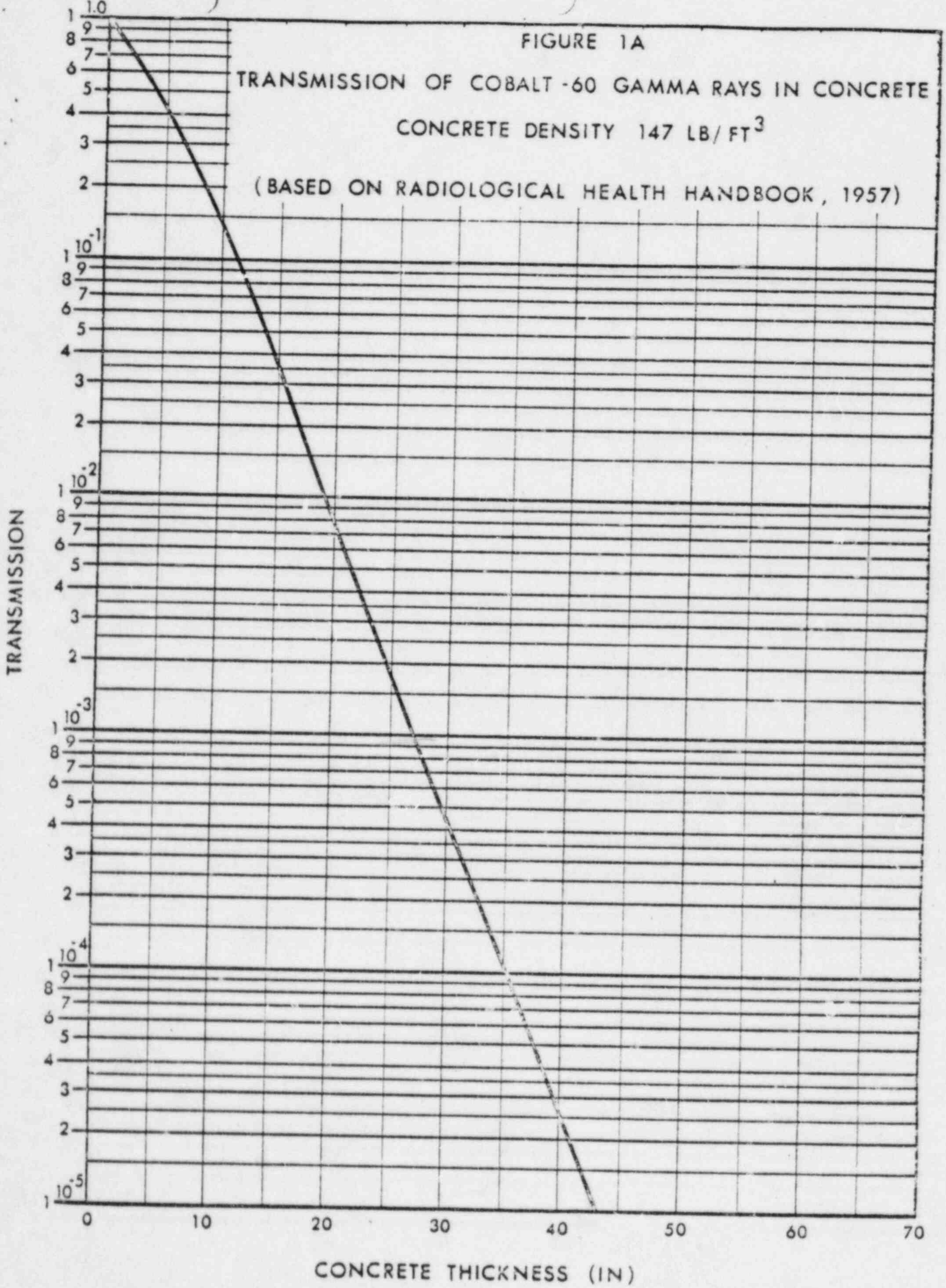


FIGURE 1A
TRANSMISSION OF COBALT-60 GAMMA RAYS IN CONCRETE
CONCRETE DENSITY 147 LB/FT^3
(BASED ON RADIOLOGICAL HEALTH HANDBOOK, 1957)
TRANSMISSION
1.0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
10
20
30
40
50
60
70
CONCRETE THICKNESS (IN)

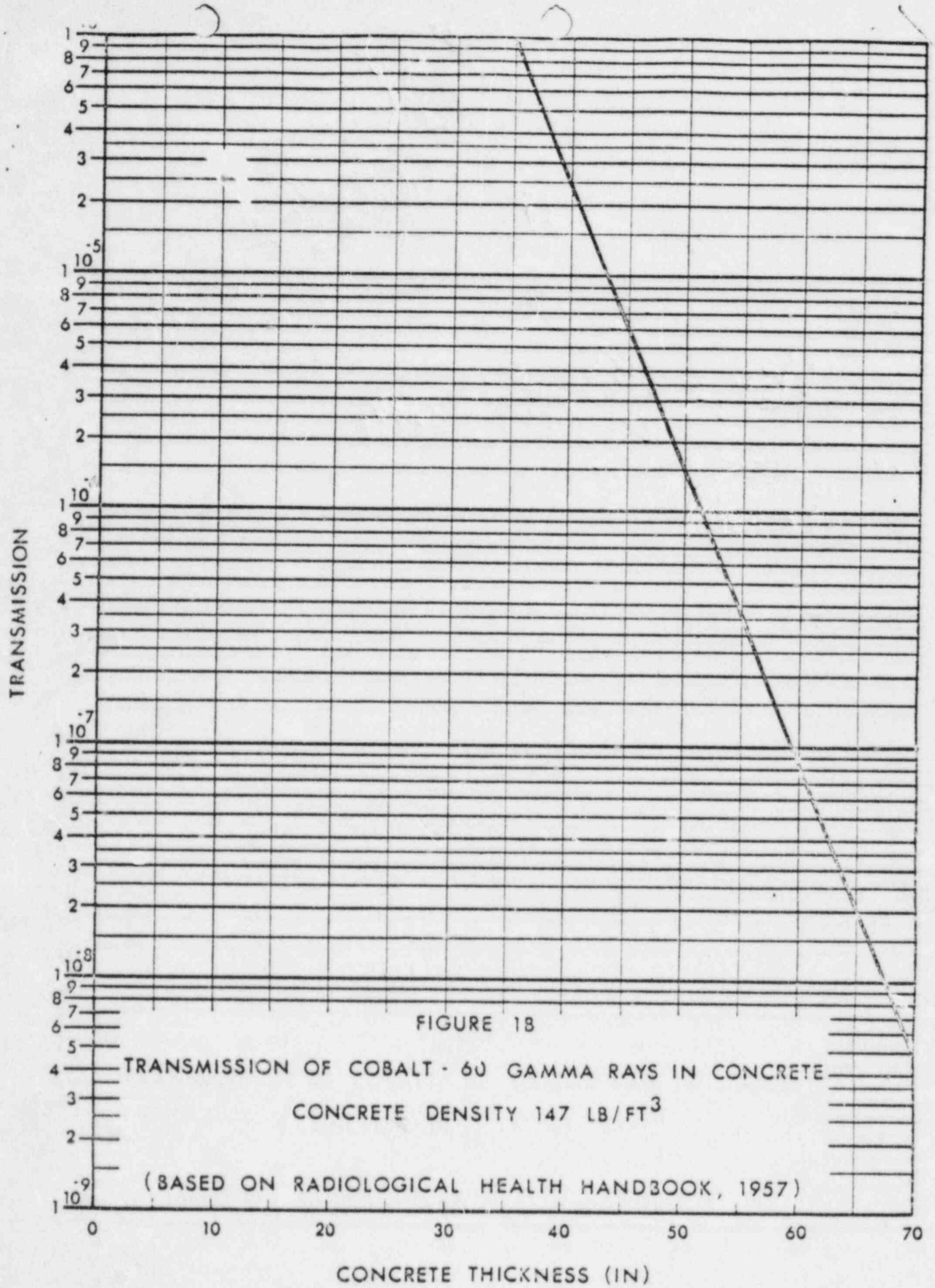


FIGURE 18

TRANSMISSION OF COBALT - 60 GAMMA RAYS IN CONCRETE

CONCRETE DENSITY 147 LB/FT^3

(BASED ON RADIOLOGICAL HEALTH HANDBOOK, 1957)

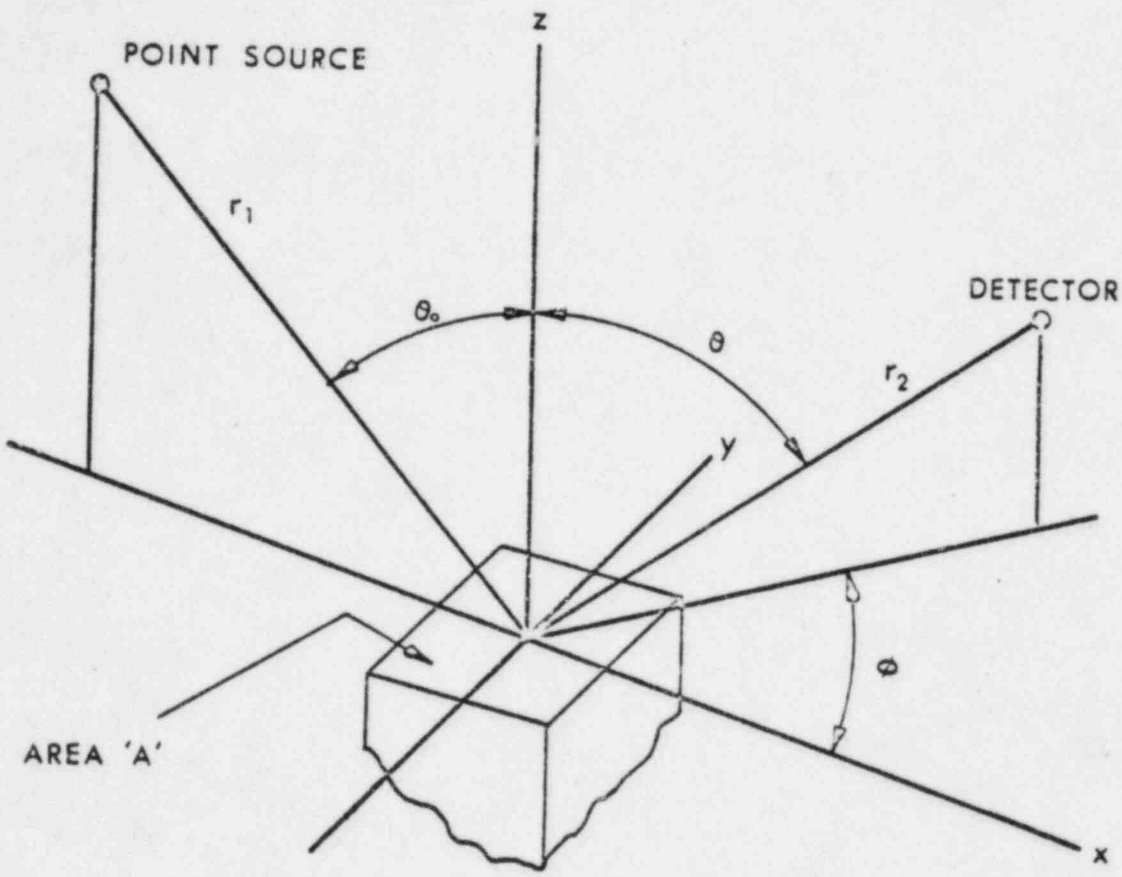


FIGURE 2
SCATTERING OF GAMMA RAYS
FROM SURFACE

Dose Rate over Vertical Portion of Ventilation Duct.

E_o = 1.25 Mev ; Scatter Angle $\theta_s = 45^\circ$

$$E = \frac{E_o}{1 + \frac{E_o}{.511}(1-\cos\theta_s)}$$

E = .73 Mev.

Total source = 1×10^6 ci.

Self absorption + geometry factor = 0.5

Total distance, source center to top of shielding = 6.79 meters

Transmission factor (42" cement) = 6×10^{-7}

Dose rate = $1\times10^6 \times 1.3 \times 10^3 \times \left(\frac{1}{(6.79)}\right)^2 \times 6\times10^{-7} \times 0.5$ = 8.5 mr/hr

Rec. with letter 11/15/74

ENCL 3

Dose Rate at North End of Pipe Trench (Sub floor level)

$E_o = 1.25$ Scatter Angle, $\theta_s = 45^o$

from $E = \dfrac{E_o}{1+ \frac{E_o}{.511} (1-\cos \theta_s}$, E = .73 Mev.

$1/3 \times 10^6$ ci is unshielded during transit.

Total distance = 8.7 meters

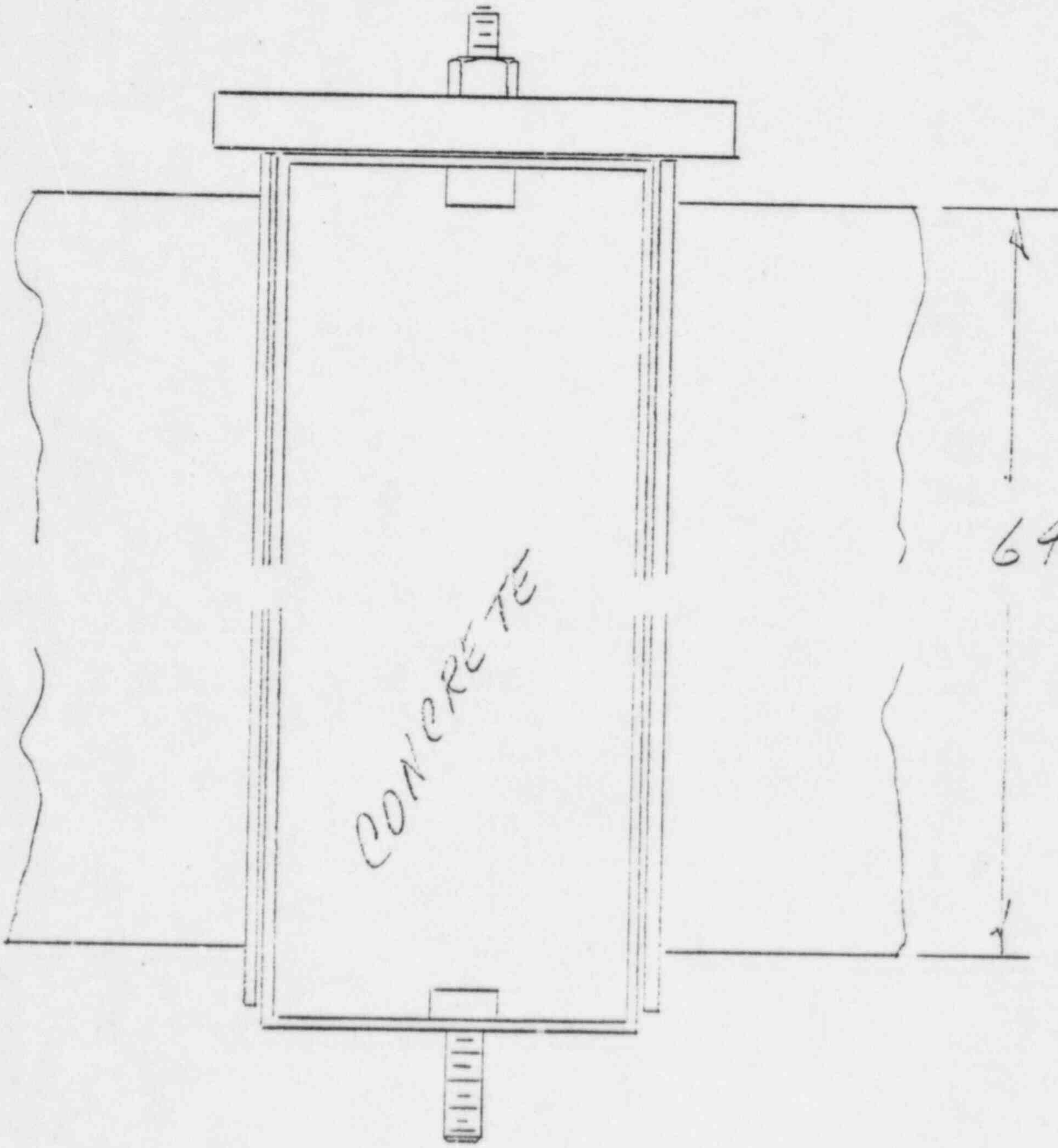
Transmission factor for 42" concrete = 6×10^{-7}

Dose = $1/3\ 10^6 \times 1.3 \times 10^3 \times \left(\frac{1}{(8.7)}\right)^2 \times 6 \times 10^{-7} = 3.4$ mr/hr

(Note: This is a transit, sub -floor level dose rate in a steel covered trench. Use 2 lengths of cement block, 32", although 24" is sufficient).

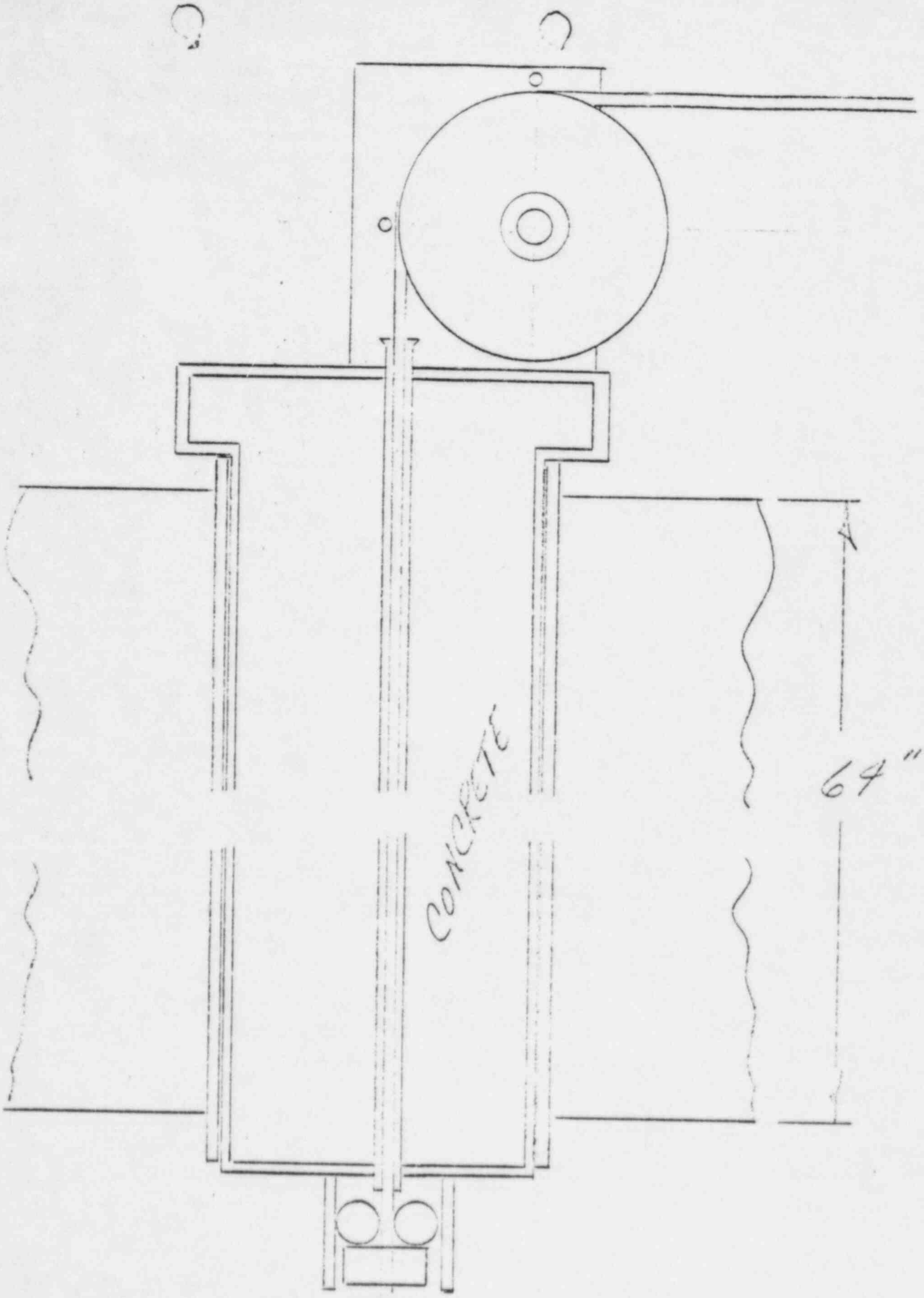
Rec with letter 11/15/74

Encl 1



GUIDE CABLE PLUG ASSY rec with letter 11/15/74

ENCL 5



CENTER PLUG ASSY.

rec. with letter 11/15/74

ENCL 6

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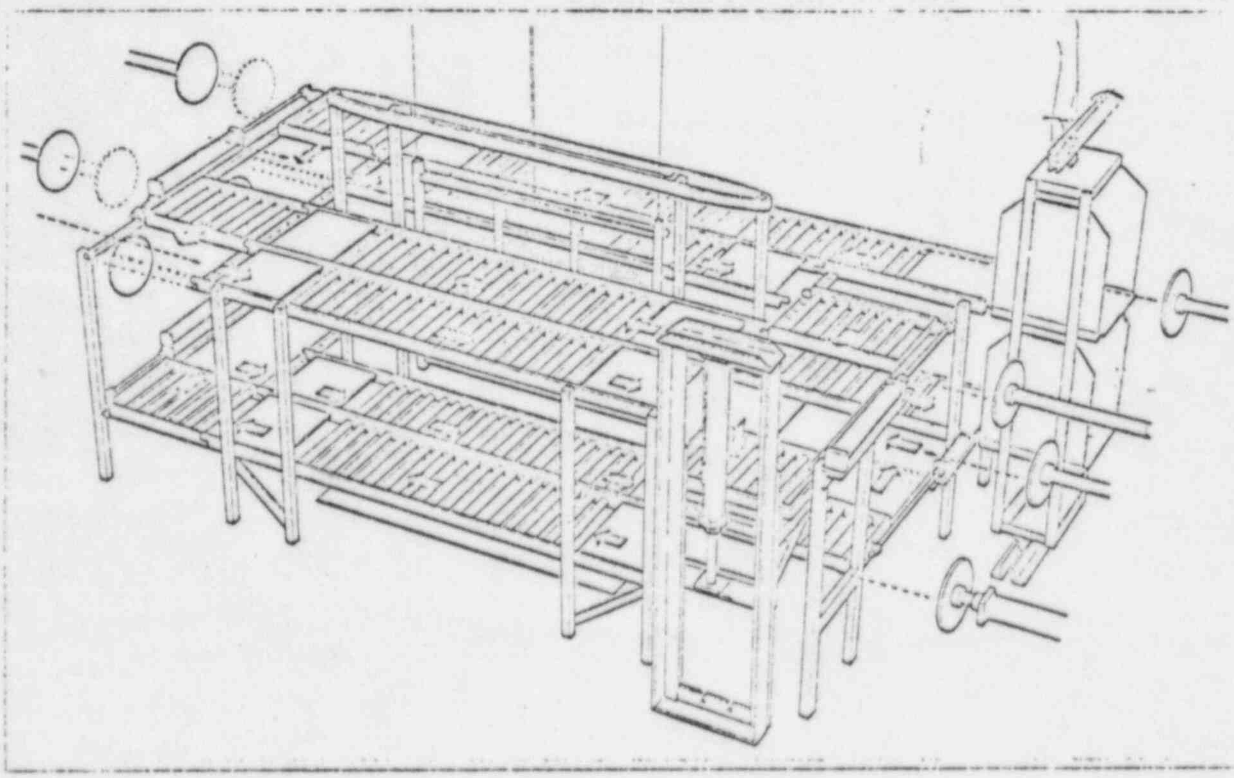
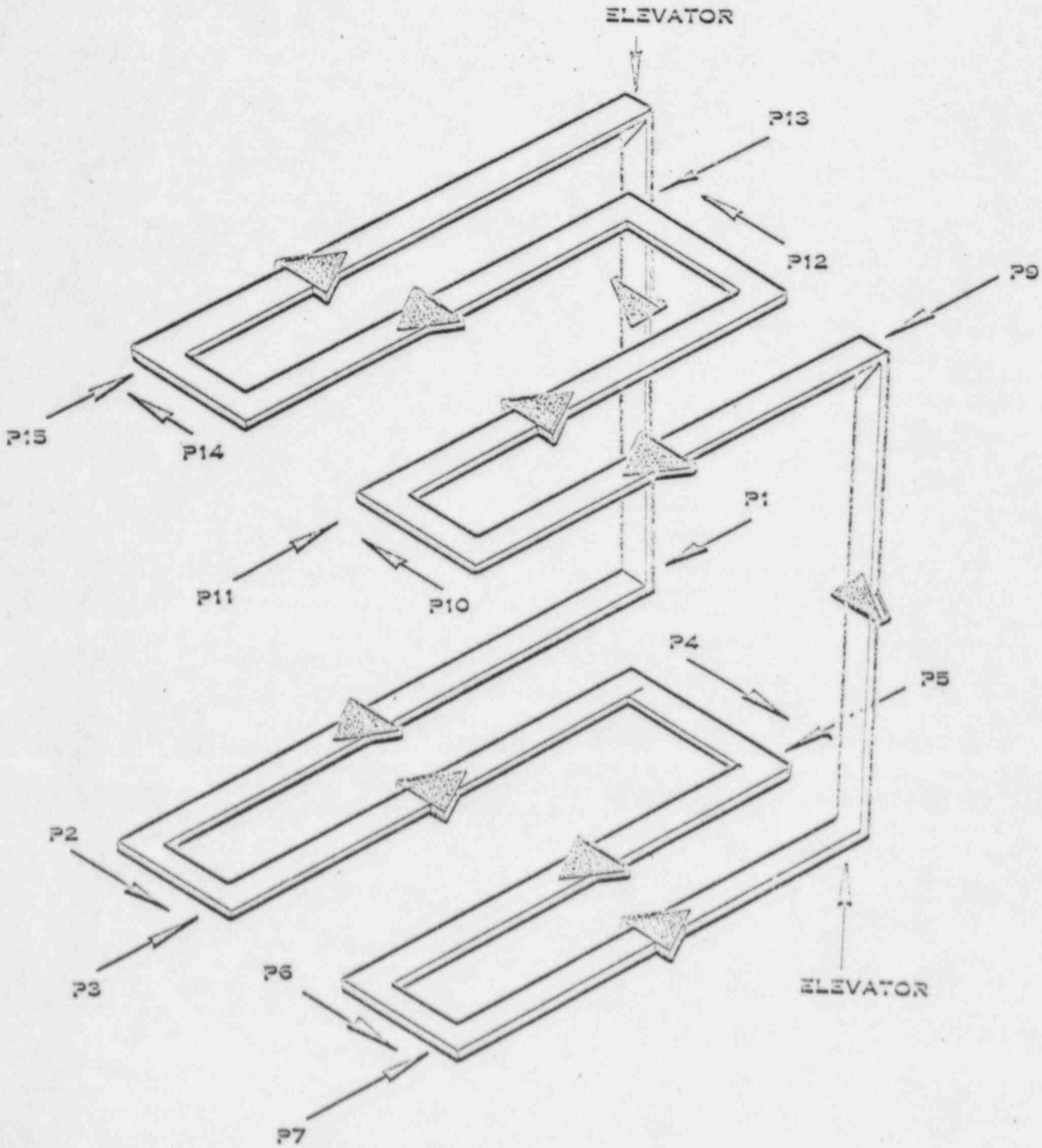


PACKAGE SHUFFLE SYSTEM
CONCEPT

Rec. with letter dated 11/15/74

Encl. B



PRODUCT FLOW DIAGRAM

Rec. with letter dated 11/15/78

ENCL 9

4713

Re: Control # 50985

ISOMEDIX

November 15, 1974

Mr. Douglas M. Collins
Directorate of Licensing
Atomic Energy Commission
Washington, D.C. 20549

Dear Mr. Collins:

This is in answer to your letter of October 25, 1974, requesting additional details regarding amendment to our Byproduct Material License #29-05364-01. The numbered items correspond to the numbers in your letter.

1. Enclosure 1, drawing #100618, shows additional details of the pool, biological shield, floor, location of voids and location of support systems, including air filter banks, water filter system, source hoist mechanism, etc. Key items are numbered 1,2,3, etc., and will correspond with further discussions of other points in your letter.

The location of the ventilation system is as shown in Drawing 100168, with roughing and absolute filters located at #11. The motor and fan are located on the roof north of the irradiator, above the 1000 square foot Pre-Irradiation Holding Area (Drawing SK42394) previously

submitted .Exhaust air is evacuated to the atmosphere above roof level. As a result of consultations with manufacturers, we intend to reduce the proposed irradiation room air flow from a rate of 20 air changes per hour to 10 air changes per hour or approximately 1,000 cfm. We estimate this rate is sufficient to reduce ozone concentration to permissable limits during the 2-3 minute time period required to lower the source and enter the radiation chamber. If, upon entering the radiation chamber under these conditions, noticeable ozone concentrations are detected, our entrance procedures will be revised to require the operator to wait for an additional specified time before entering the irradiator.

2. A copy of the calculations of expected radiation levels on the outside of the shield is attached as Enclosure 2.

The only deliberate void in the shield is a 12"x12" duct located at #1, Drawing 100618. The duct rises vertically for a distance of 52", bends 90° to the east for a distance of 44", then bends 90° to the north and exits the shield. The minimum concrete thickness in a direct line from the source to the outside wall is more than 60", and the minimum thickness after one scatter is 42".

Additional concrete thickness above normal roof level (#2, Drawing 100618) is gained by placement of solid cement blocks over the vertical portion of the duct. The calculated dose rate at that point, with 10^6 curies, is 8.5 mr/hr. With the initial loading of 200,000 ci, dose rate is about 2 mr/hr. Calculations are in Enclosure 3.

There is also a 12" wide, 6" deep pipe trench running below floor level, as shown at #9, Drawing 100618. It is exposed to the source between the time the source breaks water until it clears the bottom of the 12" thick floor. This is a distance of about 12". Since the source rack is over 36" high, about 1/3 of its activity will "see" the hole during transit. The beam must travel through 16" of concrete supporting the inner chamber wall, be scattered at a 45° angle, and travel down the labyrinth and exit below the floor surface. Except for the water-filled pipes in the trench, a portion of the trench under the north wall of the labyrinth will be blocked with a length of 32" of 16" long concrete blocks, with lead wool packed into voids around the pipes (#10, Drawing 100618). With 10^6 curies, a sub floor level transient dose rate at the outer (north) edge of the wall and below floor

surface is expected to be less than 4 mr/hr. This area is a normal storage area. Calculations are in Enclosure 4.

In the roof, slightly off-set from the vertical source rack, are three-three inch holes. (#16, Drawing 100618) Two source rack guide cables are attached in the two end penetrations to plugs shown in Enclosure 5. In the center plug (Enclosure 6) are two 3/8" holes, through which 1/8" stainless steel source rack cables pass, which raise or lower the source. A fixture on the roof of the cell, directly over this plug supports lead bricks 9" (or more) in thickness to attenuate possible radiation leakage. (Item #13 on Drawing 100618). Additional shielding can be added if needed.

There are no electrical penetrations. Wiring travels through the labyrinth.

The shielding calculations are regarded as a guide and basis for initial design parameters. In placing the facility into operation, the following procedure will be followed:

A source of approximately 50,000 curies of cobalt will be

loaded into the source rack and raised to the irradiate position. A complete survey of the facility will be made, with special attention being given to measuring dose rates at key points, including the maze entrance door, the roof above vent stack, all penetrations and the pipe trench. Walls will be surveyed for possible voids. The cement shield is built so that localized shielding, in the form of solid cement blocks, can be added at virtually any point, either inside or outside of the primary shielding. If a "hot spot" is found, such shielding will be added to bring dose rates into design specifications.

Following this test, the source will be increased to 200,000 curies (the extent of the initial cobalt-60 order) and the entire procedure repeated.

Results of such surveys with appropriate action taken, will be maintained for future reference in source upgrading, and for appropriate inspection.

3. The "Step 1" source assembly is somewhat changed from our earlier plan. The source module frame (rack) is now identical for Steps 1,2 and 3, and is shown on Drawing 100615, Enclosure 7. In the Step 1 mode, three source

modules will be stacked in the 75" height of the frame (Sheet 2, Drawing 100615). In Step 2 operation, the source modules will be loaded into the three 38" sections of the frame. Product to be processed in "Step 1" is placed in a circular configuration around the source up position, and the source then raised to the expose position. There is no automated product shuffle system in this mode of operation. A metal guard, in the form of steel bars extending from floor to ceiling, surrounds the source and source holder to prevent product from contacting and possibly restricting movement of the source plaque.

4. A sketch of the "Step 2" package shuffle system is shown in Enclosure 8. Movement of the product "tote" boxes is via pneumatic cylinders and elevators, with none of the pushing being done in a direct line to the source.

The tote boxes travel on rollers which roll in the direction of movement, and the boxes are contained along their base and top by steel channels which maintain the designated direction of travel. Enclosure 9 shows the method of operation of the shuffle system. The location of the source relative to the system is shown in Enclosure 8.

The entire system, with minor modifications for flexibility, is quite similar to the AECL-type shuffle system installed in our Chicago facility, and licensed in our -02 license. The vertical steel guards described for the Step 1 operation will be removed for Step 2 operations.

Source modules are as shown in Enclosure 10, Drawing 100619. The modules, in turn, are placed in the source rack, which all becomes the source plaque.

5. We have not completed the detailed design of the "Step 3" system. The purpose of this system is to bring the product from outside the irradiation chamber into the shuffle system. The request to operate in this mode should be deleted from the present application. We will submit supplementary information on this system at a later time.

6. Except for the small space required to permit the source to rise from the pool, the remainder of the opening will be covered with metal planking. During all source handling operations, when portions of the planking are removed, a metal railing will be placed across the pool to prevent personnel from inadvertently falling into the pool.

7. The inside of the pool is painted with a rubber-based swimming pool paint resistant to acids, salt water, fresh water, and alkali. The paint is designed for use on interiors of concrete with water. The trade name of the paint is "PUR-POOL" and is available from the PUR-All Paint Products Company, Inc.

8. The water treatment system is a Model PBS-13 available from the W.J. Westaway Company, Ontario, Canada. It is a two bed demineralizer with carbon filter. It is capable of maintaining the water at purity levels suggested by the cobalt-60 supplier (AECL). The most critical parameter is water conductivity which can be maintained at less than 10 micromhos. The unit is equipped with a conductivity monitor for constant readout of this parameter. Water flow rate is 10 gallons per minute which will yield a pool water turnover approximately every 5 days. Water is pulled from the pool through a floating skimmer into the treatment system and returned to the pool through a pipe in the pipe trench. Location of the water treatment system, piping, etc., is shown at #6, Drawing D100618.

9. The water level control, makeup water input, and low level alarm system are located in the pool as shown at

#3, 4 & 5 in Drawing 100618.

Makeup water will begin to be added when the level drops approximately 2 1/2 inches below normal level, and the low level alarm will sound when the level is approximately six inches below normal level.

Signals to activate the low level alarm signal, or to open and close the water valve, are generated by floats. A magnetic float travels up or down a hollow steel tube which contains an electric sensing element, which is triggered by the magnetic field. The sensing element then triggers the solenoid. The units are stainless steel Gems Level Switches, Model LS 1950.

Makeup water is added through a pipe whose open end is above pool level, to avoid the possibility of backflow into the municipal water system.

Additional water can be added in an emergency via a fire hose located near the labyrinth entrance, shown at #14 in Drawing 100618.

16. There is no water holdup system associated with the

primary pool. Disposal of the water, or emptying of the pool, can be done only by altering the water treatment system, hence, there cannot be an inadvertant emptying of the pool.

11. It will be possible to open the maze door from the inside to allow egress at any time by a person trapped inside the shield.

12. The source hoist and lowering system is as shown on SK100620, Enclosure 11. Source movement is accomplished by a double acting pneumatic cylinder, whose location is at #12 in Drawing D100618. A stainless steel aircraft closed loop cable travels from the cylinder toward the ceiling, then horizontally to a roller above the center 3" plug over the source, and through the plug into the pool, where both ends are secured to the source rack. Movement of the cylinder in one direction, pulls the source down, and in the other direction, pulls the source up.

The pneumatic cylinder is enclosed, but has a transparent cover so that its stroke position can be readily seen. This provides another means for the operator to determine the source rack position relative to the full up or down position.

13. As noted in Item 12, movement of the source into the storage pool is via a double acting pnuematic cylinder. The source rack is subjected to a positive pull from this cylinder during retraction into the pool. As noted elsewhere (Items 3 and 4), there is physical constraint between product and source in all modes of operation. However, there is sufficient strength in the source rack and sufficient pull from the cylinder, if need be, to permit the crushing of a typical box of product which might somehow come in contact with the source rack.

If needed, additional leverage on the source down cable can be applied at any point along the cable. We are unable to visualize a realistic situation in which it will not be possible to physically retract the source with force, if need be.

14. See Drawing Sk42374, Enclosure 3 to our August 8 Supplement. The non-restricted storage area in the middle bay is generally open storage space, of a warehouse nature. Placement of the cask would normally be against the North wall of the Isomedix area, away from any personnal traffic pattern ("Pre-Irradiation Holding Area"). The area North of the wall is warehouse area with raw material

storage on pallets, and the area is only seldom inhabited.

There is also a locked wire caged area on a portion of the north wall. It is normally used for product quarantine, but could be available for cask storage if deemed necessary by the RPO. ("Quarantine", 320 ft^2).

The restricted area behind the hot cells is basically open, and normally is roped off (dotted line on drawing) from the rest of the area. In this case it is possible to lock a large sliding door between the rear of the hot cell and the adjacent bay (to the East) and prevent access from that direction.

If a loaded cask is placed in either area for temporary storage, the cask lid will be chained and locked to the base of the cask to prevent its being opened.

The RPO may, at his descretion, choose to store the cask at the bottom of the 20' pool located behind the Hot Cells.

15. The proposed sealed source leak test procedure (section

14.3.2) was recommended by the source manufacturer, AECL, and has been their recommended procedure for several years. Isomedix is currently licensed under its -02 amendment to utilize this procedure in its Chicago facility, which is a total operation very similiar to the proposed installation. Evidence of a leaking source will also be apparant from the monitoring of the resin bed and filter banks as proposed, or from monthly wipe tests of the cell interior, and monthly monitoring of the absolute filter. The relatively large volume of water in this pool (approx. 70,000 gallons) would not, we feel, provide as sensitive an analysis as the proposed wipe test procedure.

16. The industrial waste drain referenced leads to a closed septic system. The plant and surrounding area are not yet serviced by a municipal sewer system, although connection to such a system is proposed by the Township (Hanover) at some point in the near future. Your comment regarding concentrations is noted and understood.

This concludes the discussion related to your specific questions. In addition, we would like to add one add-

itional procedure, and request an additional man be added as an operator.

Add 13.10.7 <u>Transferring sources from Hot Cell Pool to Labyrinth Irradiator</u>.

1. Remove cover grating of Hot Cell Pool, erect guard rail and lower underwater lights.
2. Place sources to be transferred into source basket. (This is done underwater in pool behind hot cell 2).
3. Move all source baskets in pool to wall closest to hot cells (north end of pool).
4. Using overhead crane, lower cask into pool.
5. Place source basket in cask.
6. Place lid on cask.
7. Raise cask slowly to pool surface. RPO is required to be present and monitor radiation levels.
8. Raise cask above pool surface. Survey for radiation levels. If level is above 10 mr/hr at any surface, lower into pool and reduce number of sources in cask. If radiation levels are below 10 mr/hr, secure lid with nuts and bolts.
9. Raise cask out of and away from pool.

10. Remove guard rail and replace grating on top of pool.

11. Use procedure in 13.10.2 to transfer cask into Labyrinth Irradiator.

Add Mr. John Hollis as an authorized user to conduct service irradiation activities in the Labyrinth Irradiator. His qualifications follow:

a. He has had (to date) three months of supervised on-the-job training in and around hot cell service irradiation activities, which together contain approximately 300,000 curies of cobalt-60.

b. He has received the training outlined in para. 14.6.2, August 8, Supplement, with other proposed operators, has reviewed and is familiar with Operating Procedures as outlined in para. 13.10.

c. By the time the unit becomes operational, he will be totally familiar with its details of operation. He is a qualified electrician, licensed by the State of New Jersey, and will physically install the electrical system of the irradiator. Thus, he will be especially familiar with the safety system, which is basically electro-mechanical.

d. During his employment at Isomedix, he has proven himself to be highly mature, reliable and dependable. In the judgment of the RPO, he meets the qualifications of the proposed position.

It is our understanding that you may decide to make an on-

site inspection of the irradiator prior to authorizing operations. We believe the system will be operational by mid-December 1974, and we will aprise you of the actual date a week or more in advance. We assume it would be appropriate to issue a license with a provision that operations could not begin until after the aforementioned inspection is completed. A license number would enable us to complete administrative arrangements for source shipment with the Canadian Government, so that actual shipment could be made on short notice following your final authorization.

Very truly yours,

George R. Dietz
President

GRD:dp

enclosures

ENCLOSURES

1. Drawing 100618
2. AECL Shielding Calculations
3. Vent Duct Shielding Calculations
4. Pipe Trench Shielding Calculations
5. Guide cable plug assembly
6. Center plug assembly
7. Source Rack Assembly (2 sheets) (Drawing 100615)
8. Package Shuffle System Concept
9. Product Flow Diagram
10. Source Module (Drawing 100619)
11. Source Hoist Mechanism (SK 100620)

SHIELDING CALCULATIONS
FOR
PROPOSED
COBALT 60 IRRADIATOR

ISOMEDIX INC.
PARSIPPANY, N.J.

R. Chu
August 27, 1974

ATOMIC ENERGY OF CANADA LIMITED
COMMERCIAL PRODUCTS
OTTAWA, CANADA

Shielding Calculations

The biological shield for the irradiator is shown on Drawing B700001-047. The shield is designed to attenuate the radiation from a 1,000,000 curies Cobalt 60 plaque source within the design levels shown in Table 1. The radiation leakage levels were selected on the basis that under normal working conditions no person in the vicinity of the irradiator receives more than an average of 10.0 mrem per week or a maximum of 500.0 mrem per year. This is the exposure level recommended by the International Commission on Radiological Protection (1) for individual members of the public.

Primary Shielding

The transmission of Cobalt 60 gamma radiation in concrete is shown in Figure 1A, 1B. The exposure rate from a 1 curie point source of Cobalt 60 is 1.3×10^3 mR/h at 1 metre and varies inversely with the square of the distance. Concrete thickness for the primary shielding was determined by calculating the maximum exposure rate outside the shielding wall for a point source and correcting for source geometry and absorption within the source plaque. Some sample calculations are given below.

1. Maximum field outside external wall parallel to source plaque:

   Concrete thickness = 72 in (1.83 m).

   Transmission = 2.7×10^{-9}.

Distance from source plane to exterior surface of wall = 14 ft (4.27 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{4.27}\right)^2 \times 2.7 \times 10^{-9} = 0.19 \text{ mR/h.}$$

Self absorption factor and geometry factor for transforming point source calculation to that for a 36.0 in (0.91 m) high plaque source = 0.8.

Maximum exposure rate = 0.15 mR/h.

This is below the design average radiation level of 0.25 mR/h.

2. Direct transmission to personnel access door:

Oblique concrete thickness = 64 in (1.63 m).

Transmission = 2.5×10^{-8}.

Assume point source at center of source plaque.

Distance from source to door = 25 ft 9 in (7.85 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{7.85}\right)^2 \times 2.5 \times 10^{-8} = 0.53 \text{ mR/h}$$

Self-absorption and geometry factor 20° from plane of source plaque = 0.4

Maximum exposure rate = 0.21 mR/h

This is below the design radiation level of 0.25 mR/h.

3. Maximum field on roof:

Concrete thickness = 64 in (1.63 m).

Transmission = 2.5×10^{-8}.

Assume point source at center of source plaque.

Distance from source to roof = 10 ft 8 in (3.25 m).

Exposure rate due to point source of 1,000,000 curies of Cobalt 60 =

$$1.3 \times 10^3 \times 1.0 \times 10^6 \times \left(\frac{1.00}{3.25}\right)^2 \times 2.5 \times 10^{-8} = 3.08 \text{ mR/h.}$$

Self absorption and geometry factor for vertical source plaque = 0.3.

Maximum exposure rate = 0.92 mR/h.

This is below the design maximum radiation level of 2.0 mR/h. Additional attenuation provided by oblique transmission through concrete will reduce the average radiation levels in the access adjacent to the primary shielding to less than 0.25 mR/h with a capacity source of 1,000,000 curies of Cobalt 60.

Maze Design

Accurate calculations of the exposure rate and energy spectrum at points along a concrete maze are difficult to perform. At present detailed calculations of the exposure rate attenuation in concrete mazes have been confined to two-legged concrete ducts (2). The amount of work required for detailed calculations for mazes with more than one right-angle bend becomes prohibitive and maze designers must either rely on measurements to determine exposure rates at the entrance of a maze with several legs or must make order of magnitude estimates using purely empirical formulae.

Maze entrances for industrial irradiators designed by AECL are based on both calculations and measurements. The radiation incident upon the maze walls due to singly-scattered radiation is calculated by dividing the scattering areas into small segments and calculating the amount of single-scattered radiation from each segment. The exposure rate from the small scattering area A (Figure 2) is given by:

$$D = \frac{D_o \, \alpha \, (E_o, \theta_o, \theta, \phi) \, A \cos\theta}{r_1{}^2 \quad r_2{}^2}$$

where

$\alpha (E_o, \theta_o, \theta, \phi)$ is the differential expsoure albedo,

A is the area of the scattering surface,

D_o is the exposure rate at one unit length from the source,

E_o is the initial energy of the gamma rays from the source.

Values of the differential expsoure albedo,

$\alpha(E_o, \theta_o, \theta, \phi)$ have been calculated by Raso (3) using the Monte Carlo method. Using the Raso data, Chilton and Huddleston (4) developed the following semi-empirical equation for the differential exposure albedo

$$\alpha(E_o, \theta_o, \theta, \phi) = \frac{C(E_o) \quad K(\theta_s) \quad 10^{26} + C^1 \ (E_o)}{1 + \cos \theta_o / \cos \theta}$$

where $C(E_o)$ and $C^1(E_o)$ are constants for a given energy

$K(\theta_s)$ is the Klein-Nishina differential energy scattering coefficient,

θ_s is the angle through which the radiation is scattered and is given by $\cos \theta_s = \sin \theta_o \sin \theta \cos \phi - \cos \theta_o \cos\theta$

For Cobalt 60 gamma rays, $E_o = 1.25$ Mev

$C(1.25 \text{ Mev}) = 0.0665$

$C^1(1.25 \text{ Mev}) = 0.107$

The calculated values of the differential exposure albedo for Cobalt 60 gamma rays have been verified by measurements at AECL.

The energy of the singly-scattered radiation is given by:

$$E = \frac{E_o}{1 + \frac{E_o}{0.511} (1 - \cos \theta_s)}$$

The required thickness of the maze walls required to attenuate the singly-scattered radiation of energy, E, to below the design levels are calculated and corrections for lower energy multiply-scattered radiation are made using information obtained from measurements of the radiation fields in and around mazes built by AECL.

For maze walls where no singly-scattered radiation is incident and the maximum radiation energy is due to doubly-scattered radiation, an estimate of the incident doubly-scattered exposure rate is obtained by calculating the scatter from one wall surface to another surface and then to the maze wall. The energy of the gamma rays impinging on the second area is assumed to be the energy of a gamma ray having one Compton scatter at the centre of the first area and going to the centre of the second area. For the second scatter the parameters $C(E_o)$ and $C^1(E_o)$ are approximated by

$C(E_o) = 0.0561\ E_o^{0.574}$ and $C^1(E_o) = 0.0122\ E_o^{-0.683}$.

Again, corrections for lower energy multiply-scattered radiation are made from measurement data.

Detailed measurements of radiation fields inside mazes have been performed by AECL for two shielded room facilities in Ottawa, the irradiator at St. Hilaire, Quebec, and the Ethicon Medical Products Sterilizing Irradiator in Somerville, New Jersey. In addition, surveys of the exterior radiation fields

are performed on every industrial irradiator built by AECL. These extensive measurements confirm that the recommended maze shielding provides adequate protection.

References

1. "Recommendations of the International Commission on Radiological Protection", (Adopted September 17, 1965), ICRP Publication 9, London; Pergammon Press 1966.
2. J.M. Chapman and C.M. Huddleston, "Dose Attenuation in Two-Legged Concrete Ducts for Various Gamma-Ray Energies", Nuclear Science and Engineering, 25, 66 (1966).
3. D.J. Raso, "Monte Carlo Calculations on the Reflection and Transmission of Scattered Gamma Rays", Nuclear Science and Engineering, 17, 411 (1963).
4. A.B. Chilton and C.M. Huddleston, "A Semi-empirical Formula for Gamma Rays on Concrete", Nuclear Science and Engineering, 17, 419 (1963).

TABLE 1

LOCATION	OCCUPANCY	EXPOSURE RATE (mR/h)	
Control Area	40.0 hrs/wk.	2.0 max.*	0.25 average
Machine Room	40.0 hrs/wk.	2.0 max.	0.25 average
Roof	40.0 hrs/wk.	2.0 max.	0.25 average
External Walls	40.0 hrs/wk.	2.0 max.	0.25 average
Pool Surface (Source Lowered)	40.0 hrs/wk.	2.0 max.	0.25 average

* Maximum exposure rate in any small area adjacent to shield.

EXPOSURE RATE TABLE

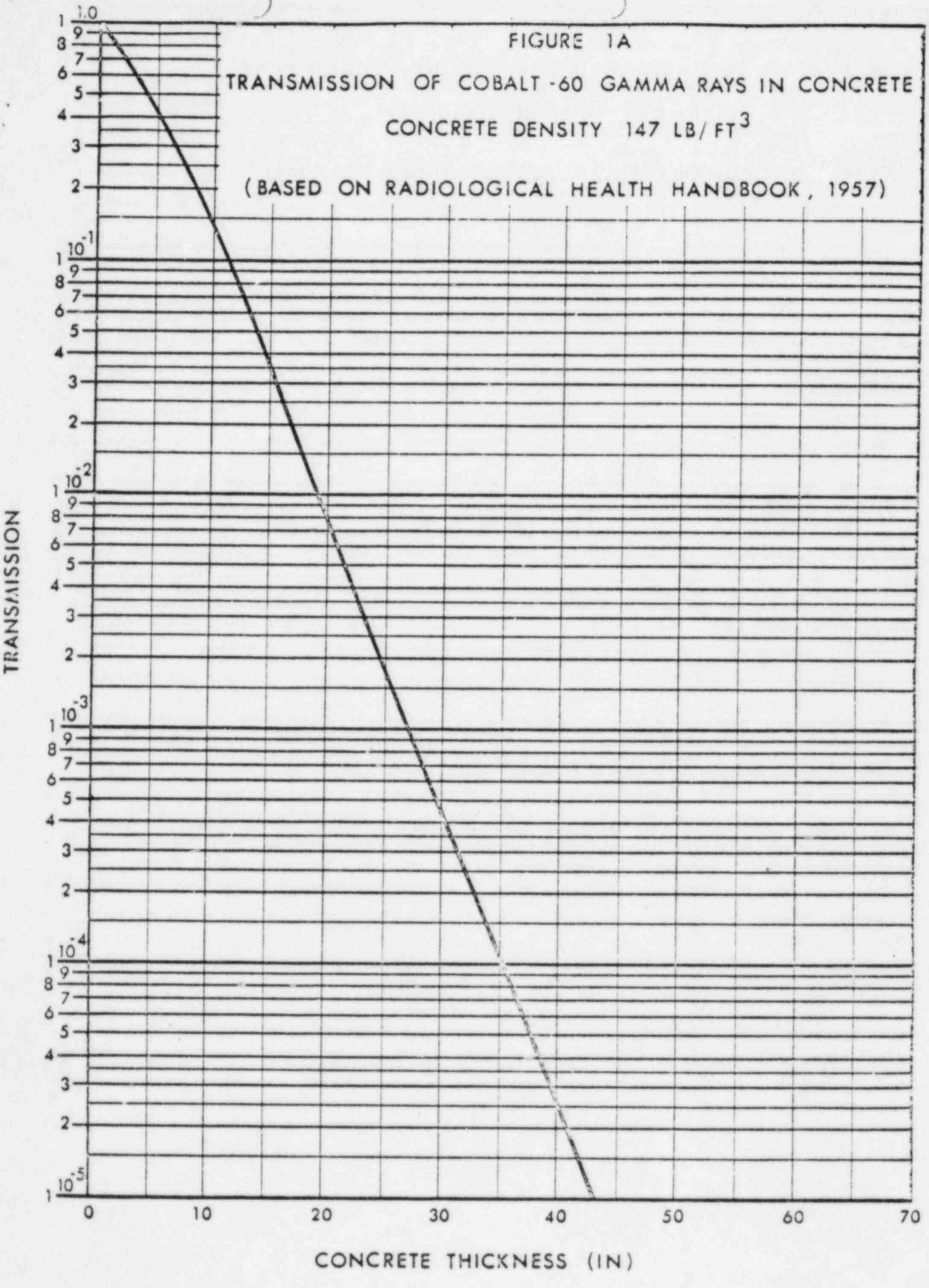


FIGURE 1A

TRANSMISSION OF COBALT-60 GAMMA RAYS IN CONCRETE

CONCRETE DENSITY 147 LB/FT^3

(BASED ON RADIOLOGICAL HEALTH HANDBOOK, 1957)

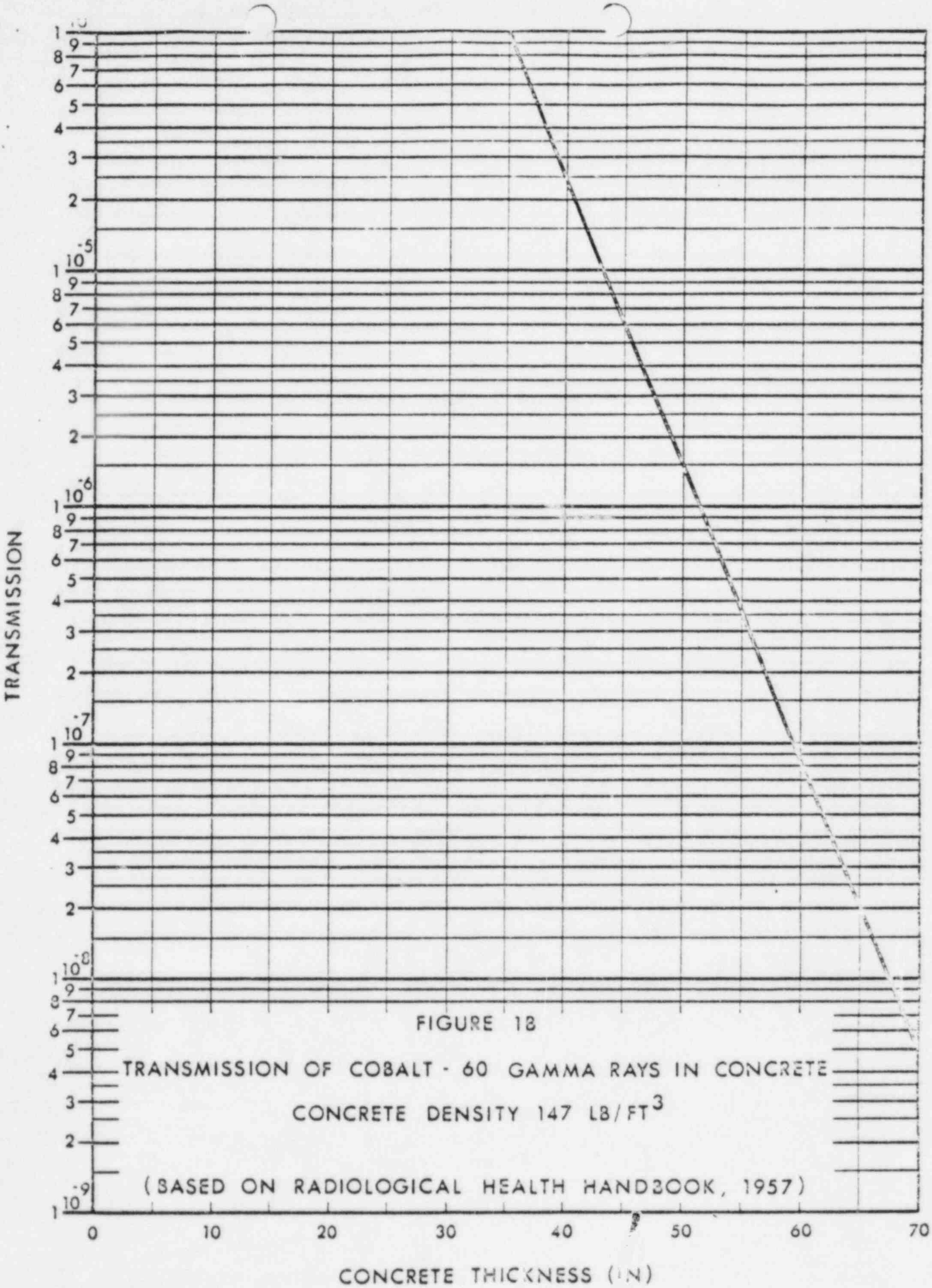


FIGURE 18

TRANSMISSION OF COBALT - 60 GAMMA RAYS IN CONCRETE

CONCRETE DENSITY 147 LB/FT^3

(BASED ON RADIOLOGICAL HEALTH HANDBOOK, 1957)

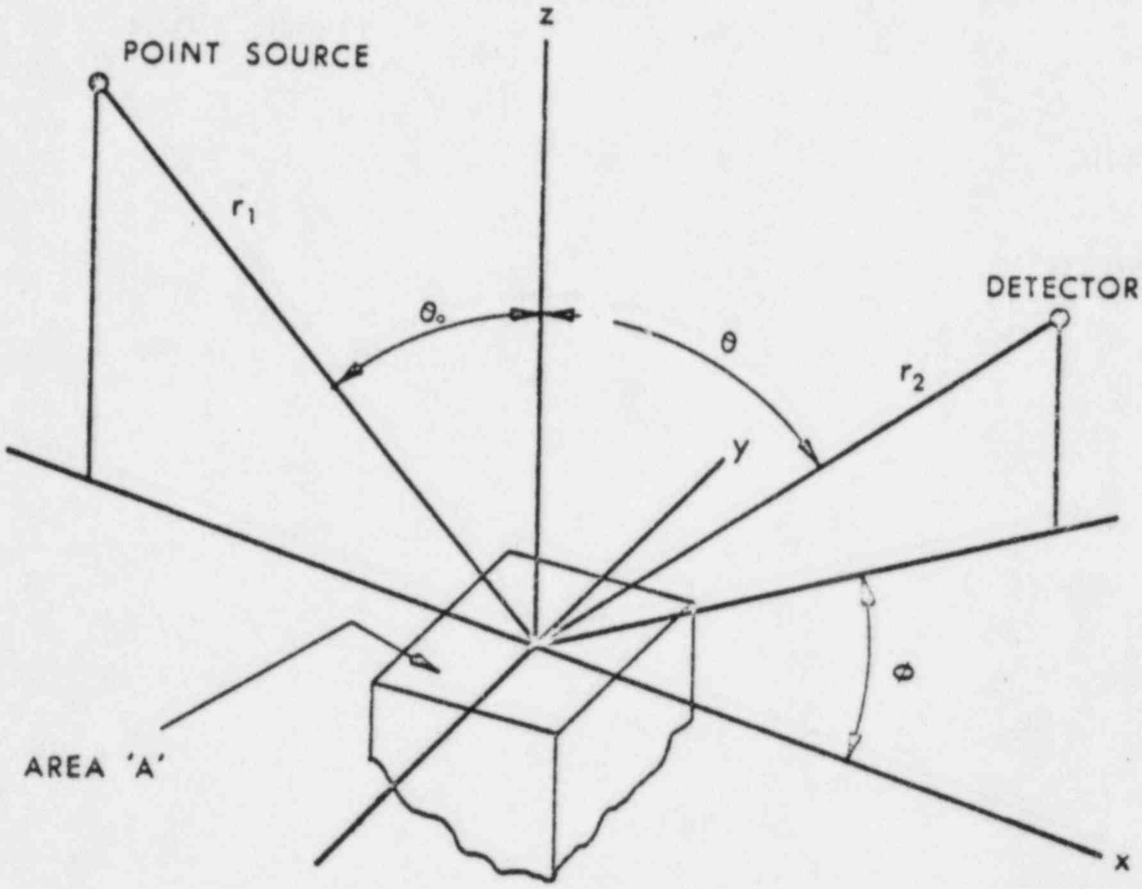


FIGURE 2
SCATTERING OF GAMMA RAYS
FROM SURFACE

Dose Rate over Vertical Portion of Ventilation Duct.

E_o = 1.25 Mev ; Scatter Angle $\theta_s = 45^o$

$$E = \frac{E_o}{1 + \frac{E_o}{.511}(1-\cos\theta_s)}$$

E = .73 Mev.

Total source = $1x10^6$ ci.

Self absorption + geometry factor = 0.5

Total distance, source center to top of shielding = 6.79 meters

Transmission factor (42" cement) = $6x10^{-7}$

$$\text{Dose rate} = 1x10^6 \times 1.3 \times 10^3 \times \left(\frac{1}{6.79}\right)^2 \times 6x10^{-7} \times 0.5 = 8.5 \text{ mr/hr}$$

Encl. 2

Dose Rate at North End of Pipe Trench (Sub floor level)

$E_o = 1.25$ Scatter Angle, $\theta_s = 45^o$

from $E = \dfrac{E_o}{1+\frac{E_o}{.511}(1-\cos\theta_s}$, E = .73 Mev.

$1/3 \times 10^6$ ci is unshielded during transit.

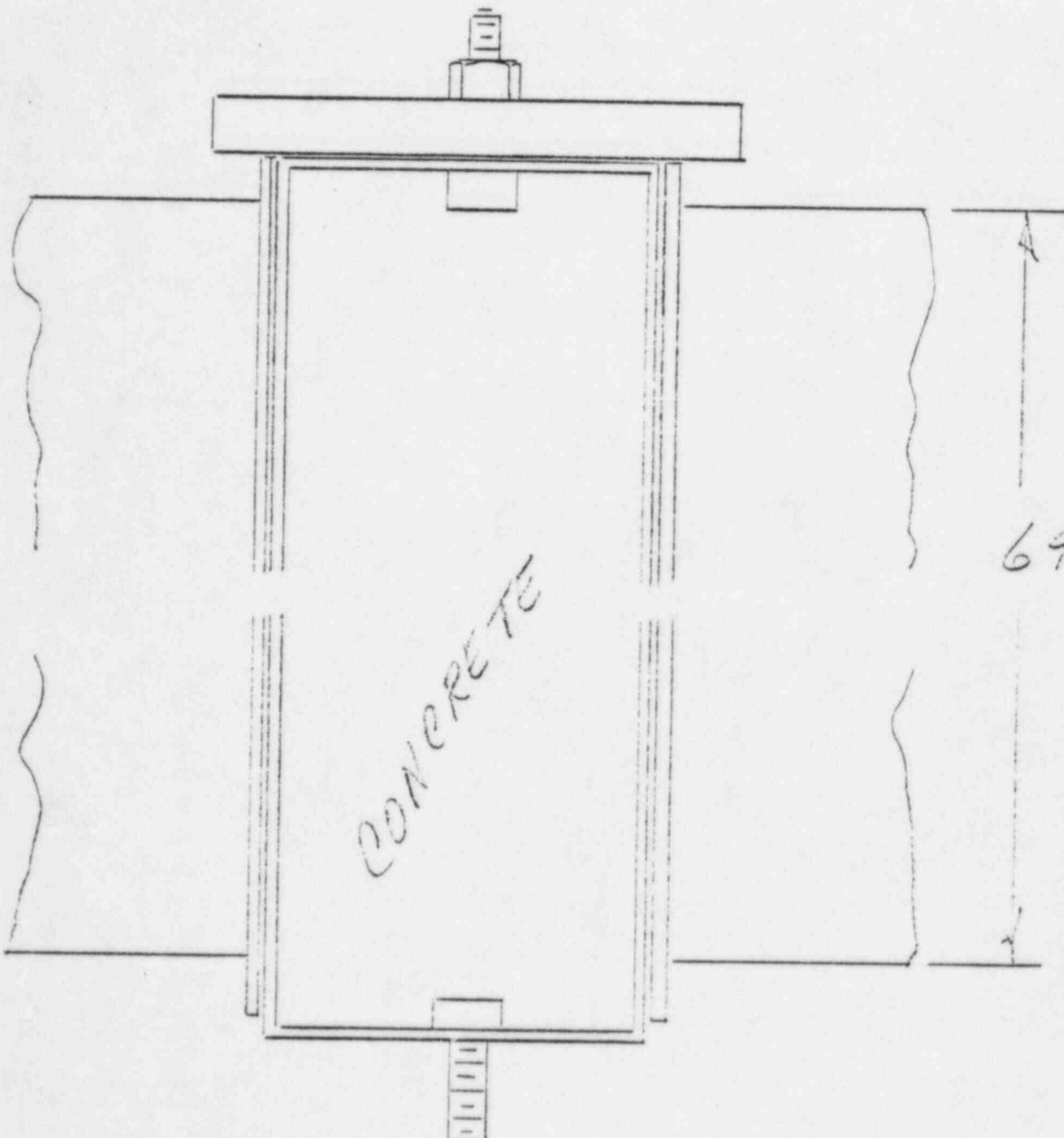
Total distance = 8.7 meters

Transmission factor for 42" concrete = 6×10^{-7}

Dose = $1/3\ 10^6 \times 1.3 \times 10^3 \times \left(\frac{1}{(8.7)}\right)^2 \times 6 \times 10^{-7}$ = 3.4 mr/hr

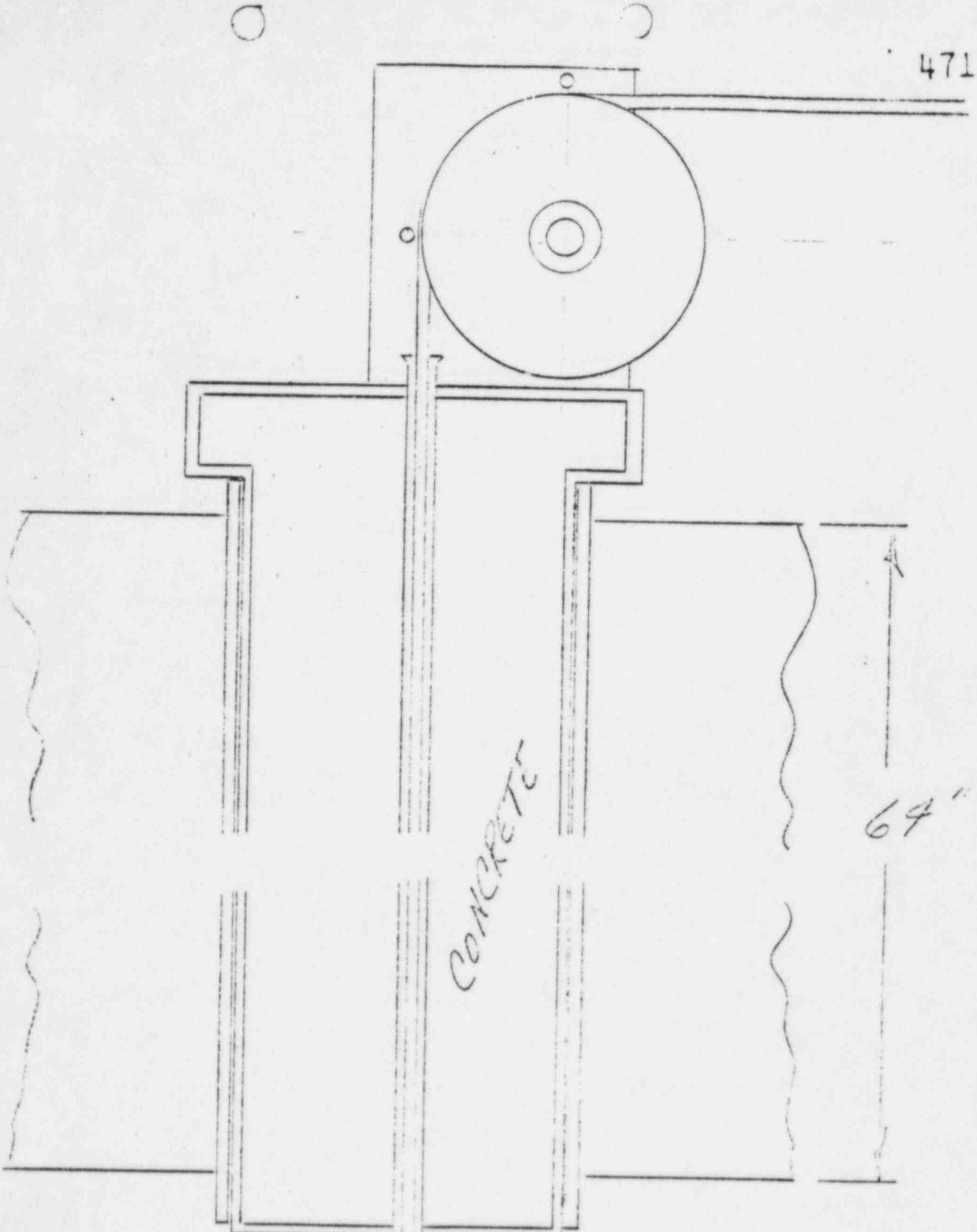
(Note: This is a transit, sub -floor level dose rate in a steel covered trench. Use 2 lengths of cement block, 32", although 24" is sufficient).

ENCL 4



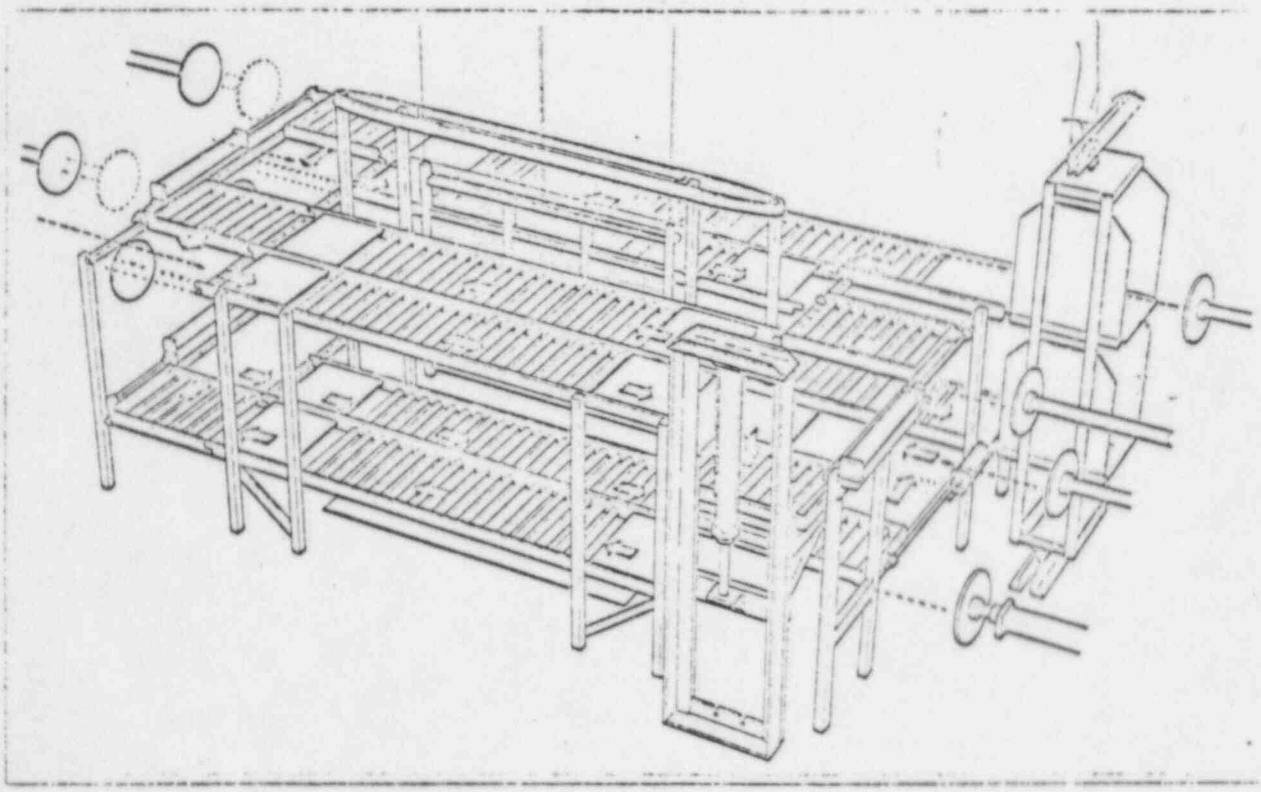
GUIDE CABLE PLUG ASSY

ENCL 5

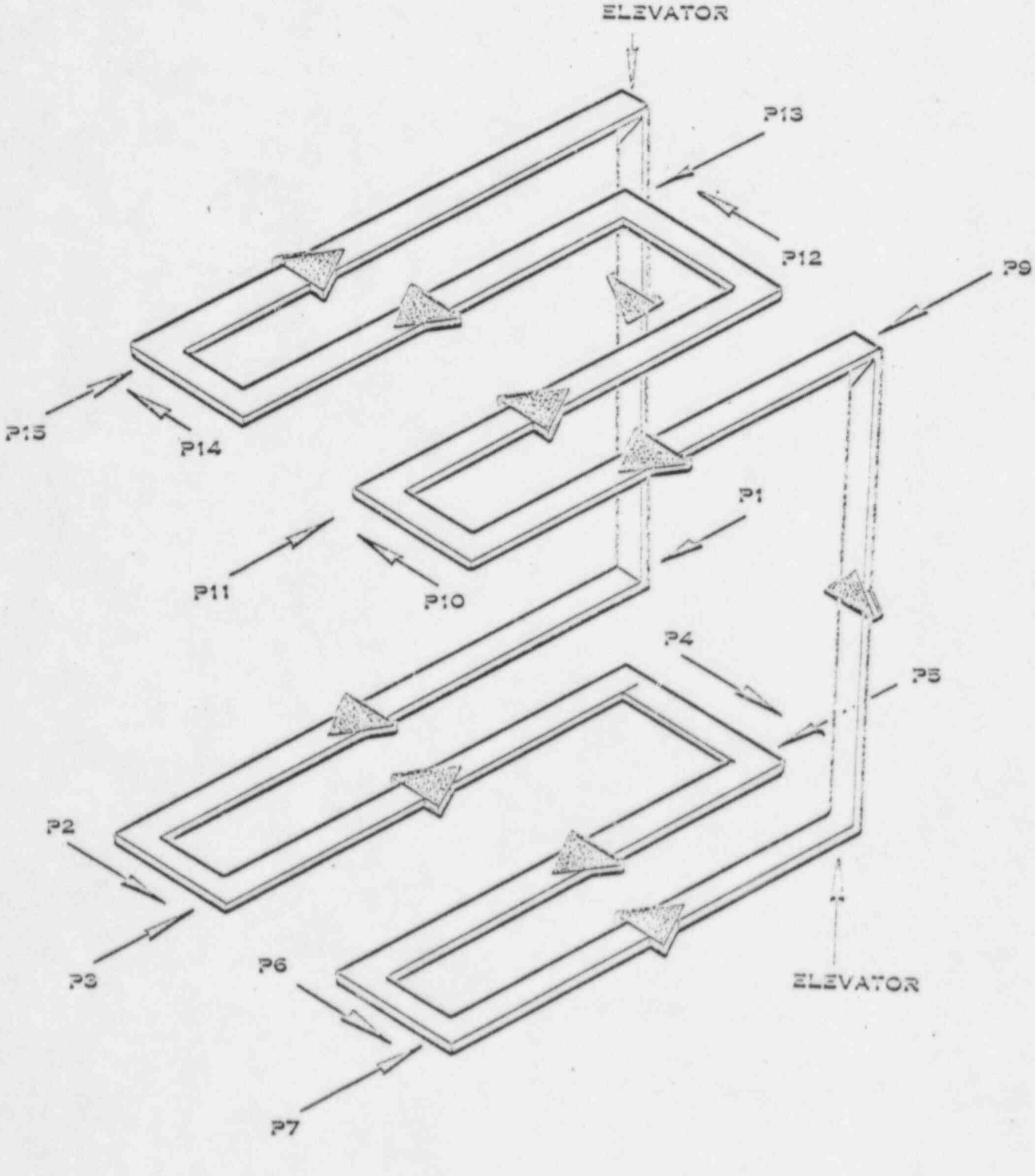


CENTER PLUG ASSY

ENCL 6



PACKAGE SHUFFLE SYSTEM
CONCEPT



PRODUCT FLOW DIAGRAM

Encl 9