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# PRE QUARTERLY PROGRESS REPORT
## OCTOBER – DECEMBER, 1956

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

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# PRE QUARTERLY PROGRESS REPORT
## OCTOBER – DECEMBER 1956

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# ABSTRACT

PRE* is a fuel reprocessing experiment directed to development of a low cost fuel decontamination and refabrication process for metallic uranium. During FY 1957 the major objective is designing and equipping a cold mock-up to perform mechanical operations and study material transfer and handling of process metal simulating uranium fuel.

Detailing has begun on a device for remote refabrication of fuel rods from processed slugs. The device will be built for remote operation in the cold mock-up during FY 1958.

A tilt-pour induction furnace and a vacuum centrifugal casting furnace will be ordered shortly for cold mock-up operation. Work on design of devices for remote dimensional inspection of cast slugs is proceeding.

Master-slave manipulators, periscope, and closed-circuit TV have been ordered for the cold mock-up. A rectilinear manipulator and shielding window will be ordered. A pneumatic crane will be installed in the mock-up to simulate in-cell material handling problems such as material transfer, furnace operation, light service and maintenance, and manipulator removal for servicing. The vacuum Access Lock is being designed. A cold mock-up of at least one door will be designed and built to test the seals.

Radiation intensity from various PRE sources has been calculated. Curves are given for calculated radiation levels from slug-loading mechanisms, from drossing crucibles, atmosphere filters freeze-out traps for removal of xenon and krypton, processed fuel ingots, and processed fuel rods. Radiation level at the Access Lock door has been calculated as well as leakage through cracks at the cell doors. Activity from fission products released in melting has been calculated.

A prototype gas-handling system simulating the system to be used in purifying the Process Cell atmosphere is being designed and built. Equipment for testing inflatable seals for atmosphere containment is being assembled.

*Pyroprocessing-Refabrication Experiment Ref. NAA-SR-1670 June 29, 1956.

# I. INTRODUCTION

## A. GENERAL OBJECTIVE

PRE is a fuel reprocessing experiment directed to the development of a low cost fuel decontamination and refabrication plan for metallic uranium fuel. High temperature techniques are to be used for the partial decontamination, re-enrichment and recasting of uranium fuel followed by refabrication of the uranium slugs into fuel rods suitable for re-irradiation in SRE.

## B. MOCK-UP EFFORT

In the first phase of the PRE program, a "cold mock-up" will be designed, constructed, and operated to develop process equipment and techniques for the remote operation and maintenance of this process equipment. This phase of the program will be stressed during FY 1957, 1958, and 1959. The PRE facility design and construction will begin in late FY 1959 or early in FY 1960 based on the experience gained during the cold mock-up phase.

In the first part of the mock-up program, a plywood structure simulating process hot cells will be built and operated. It will be necessary to modify the available building by elevating a portion of the building roof to accommodate a prototype in-cell crane. It will also be necessary to sink a pit into the floor, in which the fuel rod refabrication device can be installed for remote operation and the associated below-cell equipment can be simulated in its normal relative position. It is planned to equip the mock-up with a pneumatic crane, Mark VIII manipulator, rectilinear manipulator, periscope and TV for remote viewing of operations, and a shielding window.

Major pieces of process equipment will be designed and constructed or purchased, then tested and modified in the mock-up before designing the final equipment for eventual in-cell installation and hot operation. A decontamination furnace for oxide drossing of fission products, a vacuum furnace for re-enrichment and centrifugal casting of fuel slugs, an electrical discharge machine for cutting and facing the ends of cast slugs, and a rod refabrication device for loading and sealing fuel rods will all be designed and fabricated or procured, operated, and modified in the cold mock-up.

C. FISCAL YEAR 1957 OBJECTIVES

The major objectives during FY 1957 include:

1) Complete modification of the available facility to house the cold mock-up. This is scheduled for completion during the third quarter of FY 1957.
2) Complete construction of the mock-up enclosure and equipment with Mark 8 master-slave manipulators, TV camera and monitor, periscope, crane and crane-ways to service the mock-up rectilinear manipulator, and shielding window. The rectilinear manipulator and the shielding window are scheduled for ordering in FY 1957 with delivery by second quarter FY 1958. All other items are scheduled for delivery and installation during the fourth quarter of FY 1957.
3) Initiation of study and design of major items of process equipment to be operated including:
    a) Vacuum centrifugal casting furnace
    b) Electrical discharge cutting machine for cutting anf facing cast slugs
    c) Cast slug inspection devices
    d) Drossing furnace charging device
    e) Drossing furnace ingot mold
    f) Vacuum furnace centrifugal casting molds
    g) Lighting mock-up
    h) Fuel rod refabricator
    i) Fuel slug transfer system between cells
    j) Wire wrapping systems for fuel rods
    k) Vacuum lock and turn-table
4) Initiation of the preparation of specifications for procurement of process equipment.
5) Completion of the assembly and initiation of operation of equipment available for delivery during the fiscal year. A prime objective is the development of techniques for remote operation, repair, and maintenance. It is expected that the decontamination furnace will be installed in the mock-up during the last quarter of FY 1957. The vacuum furnace and molds will be ordered with delivery expected early in FY 1958.

The rod refabrication device will be detailed and constructed during the remainder of FY 1957 and FY 1958 for operation and modification during FY 1958.

6) Initiation of development work in connection with the inert gas processing system using off-gas from Vanowen hot cell experiments. In this work a prototype gas-handling system will be studied to develop criteria for design of the PRE hot gas handling system. Collection of volatile fission products and methods of gettering with reactive metals will be investigated. This development work will continue into FY 1958 and permit design and specification of the PRE gas handling system during the latter half of FY 1958. Inflatable seals will be tested and developed during FY 1957 and early 1958 to contain the atmospheres in the PRE process cells.

## II. PRE PROGRESS

### A. PRE SITE AND FACILITY (D. Janeves)

The proposed site of PRE has been described previously[1]. An exploration of the proposed site is in progress for the purpose of analyzing building costs and establishing design criteria for the facility. A geophysical survey using seismic reflection methods has been reported by an outside soil engineering consultant. According to his report bed-rock surface lies fifteen to twenty-six feet below the existing ground surface. Bed-rock contours dip gently to the northwest, permitting advantageous location of the PRE building on a bed-rock foundation with a minimum of rock excavation. This study is proceeding into the next fiscal quarter.

Preliminary layouts of the site and of the main building enclosure for the PRE have been completed. These layouts are being utilized for operational and component design studies.

The sub-cell vault space has been studied with respect to the shielding requirements of each auxiliary equipment unit to be located therein. Maintenance and replacement requirements of the inert gas purification system, vacuum pumping systems, and heat exchangers are being analyzed.

## B. PRE HOT CELL STRUCTURE (D. Janeves)

Preliminary layouts of floorplans for the process cell and the fabrication cell have been made and inter-cell lock geometries are being studied. The location of transfer locks affects the location of some major equipment items and consequently controls the locations of utility plumbing to the adjacent equipment areas.

A general lay-out of in-cell equipment for the process cell has been developed. Some preliminary and conceptual details of in-cell functional equipment have been studied in order to determine basic dimensional clearances required between associated pieces of in-cell equipment and fixed or thru-wall facilities of the cell structure. The location and number of cell face windows have been based on the requirements as indicated by in-cell equipment lay-out details.

## C. MOCK-UP STRUCTURE (D. J. Stoker)

In order to simulate the proposed PRE cells and mock-up the proposed equipment and operations, further modifications of the building facility are necessary. It has been decided to install the mock-up crane in a high bay area so a rectilinear manipulator can be installed and serviced by the crane. A pit will be provided so that fabrication cell equipment can be mocked-up. The pit will simulate the basement under the process cell and maintenance cell where vacuum equipment and high frequency equipment will be placed. It is intended to use twenty feet of the high bay for cell mock-up and ten feet either for equipment preparation or for other tasks such as mock-up of roof plugs, lighting, manipulator maintenance, and crane removal.

The detail design and construction specifications for the Raymer modifications have been completed. Firm bids on this modification are being solicited and approval to proceed has been requested from the AEC.

## D. FABRICATION CELL

1. Fuel Rod Refabrication (D. Janeves) - The Fuel Rod Fabrication device, has been modified to facilitate in-cell operations. The baseplate of the bell jar hasbeen enlarged to permit the vacuum exhaust port to be located therein. This arrangement simplifies the in-cell operational requirements involving crane and manipulator useage. Pneumatic actuators for the operation of the NaK loading component, chill-block locating device, fuel rod cap-inserting component, and

cap-to-tube welding unit are located above the top plate of the bell jar housing and work through vacuum seals in the top plate. Vacuum pumping and out-gassing heater requirements have been determined for the unit. The control and instrumentation requirements have been investigated and panel designs are now being made. A visual check-out was made on a simulated fuel rod fabricator unit to determine optimium height and location of the viewing port of the fuel rod fabricator unit with respect to the shielding window.

In-cell height dimensions will be determined on the basis of the remote handling requirements for vertical removal of the semi-completed fuel rod from the fuel rod fabricator.

2. Wire Wrapping and Rod Inspection (D. Janeves and N. P. Grisanti) - The fuel rod cluster now used in SRE consists of one central rod and six circumferentially disposed rods. Each of the six outside rods is wrapped along its length with a helicoid of wire to space the rods from one another and provide passages for flow of sodium coolant past the rods in the primary coolant loop of the reactor. In PRE the filled and sealed fuel rod must be wire wrapped remotely before its return to SRE for reclustering and reuse in the reactor.

The experimental development of a remotely operable and remotely maintainable device for installing the spacing wires on PRE-fabricated fuel rods is progressing. Concurrently, inspection devices are being investigated to determine the integrity of the cap-to-tube welds and of the stainless steel-NaK-uranium bond throughout the completed fuel rod. This is now done by cyclographic inspection of the filled and sealed fuel rod before wire wrapping. The possibility of eliminating wire wrapping in PRE by using prewrapped fuel rod tubes is being studied.

## E. PROCESS CELL

1. Cell Ambient Temperature - Temperature calculations were made for the process cell utilizing a wall cooling system. The cooling pipes are welded to the steel liner of the cell. The case of wall cooling only and the case of both wall and ceiling cooling were considered. The cell included two 30 kw induction furnaces and five 3 kw mercury vapor lamps. Calculations were made for various spacings between the pipes and for various water flows from four equal sources. With wall cooling pipes only, a pipe spacing of 6 inches and water velocity of 3 ft/sec resulted in the lowest cell temperature of 157° F. With cooling pipes in

the walls and ceiling, combination of pipe spacing of 6 inches and water velocity of 3 ft/sec resulted in the lowest cell temperature of 141° F. In the above calculations, various assumptions were made as to the cell materials, cell linings, wall thickness, and cell dimensions.

2. Tilt-Pour Furnace for Oxide Drossing (J. L. Ballif) - Bids have been requested for delivery by March of an induction furnace for simulating oxide drossing. Design has started on a device for charging slugs into this furnace by remote control. This will be done in the cold mock-up.

The physical configuration of this furnace is now fairly well fixed. The crucible will be about 5 in. ID x 10 in. deep. The coil will be about 8 inches nominal diameter and the space between the crucible and coil will be filled with alumina. This assembly will be supported by a Transite box about 24 inches on edge with the crucible lip near the upper edge. A double trunnion pouring arrangement will be used with the pouring trunnion center line passing through the crucible spout to permit pouring directly over the mold center even though the mold is about 6 inches to 8 inches away from the crucible lip in the melting position. This coil-crucible unit will be supported about 1-1/2 feet above the base with the tilting mechanism below and to the rear of the unit.

3. Vacuum Furnace (J. R. Foltz, and D. J. Stoker) - A vacuum induction furnace of 50 lb (steel) capacity is necessary for re-enrichment of partially decontaminated fuel, bottom pouring, and centrifugally casting slugs for refabrication. Bids on this furnace were submitted by two vendors. After review of these bids and discussions with vendors' representatives, certain modifications were made to the requirements outlined in our preliminary specification. These will form the basis for a new specification now being prepared. In this new specification a centrifugal casting unit will be included as required rather than optional equipment. Flanges will be turned after welding and surface finish will be improved to facilitate decontamination of the furnace whenever it becomes necessary.

4. Preparation of Finished Slugs (J. Guon) - In work reported earlier[1] a five-ton punch press was used for cold-short fracturing of 3/4-inch diameter uranium slugs. Since this press was too small for the development work now in progress a 15 ton punch press has been set up to continue the earlier work. Mold stripping devices suitable for remote operation have been fabricated and will be

tested using cold or tracer level uranium castings and the manipulators in the east cave at the Vanowen facility.

An inspection fixture suitable for remote operation with manipulators has been laid out to check dimensions of the finished slugs. This fixture can check for length (6.000 ± 0.010 in.), bow (0.003 in. maximum single throw wrap in the 6 inch length), and diameter (0.750 ± 0.002 in.) at any point along the slug length.

A specification has been written, quotations requested, and bids received from several concerns for a remotely operated electrical discharge slug cut-off machine. Vendors' response indicated that a specially-designed high-cost machine was necessary to meet the preliminary specification; therefore, a new specification relaxing most of the more stringent remote control specifications was written and new quotations requested. The new specification permits purchase of a standard commercial machine to be modified at Atomics International for remote operation after study in the cold mock-up.

## F. HOT CELL SUPPORTING SERVICES

### 1. Material Handling (N. P. Grisanti, and G. P. Streechon)

a. In-cell cranes - The present concept of in-cell cranes for PRE fabrication and maintenance cells envisions standard top riding bridge cranes modified for remote operation, repair, and maintenance. An in-cell crane for the process cell may also be a modified standard crane but other alternates such as combination jib-and-bridge cranes and out-of-cell motor arrangements of an in-cell crane have been considered.

(1) Studies of Crane Environment - A somewhat exaggerated assumption of the radiation sources likely to be present in the process cell was made in order to arrive at an estimate of the flux intensities at the crane location. The sequences of operations in the process cell were scrutinized to establish crane traffic patterns and determine probable radiation damage to crane components. Probable radiation exposure in normal crane operation amounts to $7 \times 10^6$ roentgens in a period of three years operation. This means that replacement of insulation and lubricants need not be made more frequently than every three years in normal operation. The problem is less severe in the fabrication and the maintenance cells where radiation intensity is less than in the process cell.

Until empirical data become available an operating temperature of 250° F has been assumed for the ambient temperature in which the crane operates. This estimate is based on calculations for a crane position directly under the cell lights. Other positions would probably result in ambient temperatures between 160° F and 200° F.

(2) The Modified Standard Crane - The modified standard crane may be either electric or air driven. Plans for experimental operation of an air crane in the mock-up have been adopted because of the inherent sensitivity of control and radiation resistance of an air-powered crane. If installation complications or reliability factors prove the air crane to be less practical than the electrical, in spite of other advantages over the electrically powered crane, environmental conditions of the process cell will allow use of an electric crane with glass-insulated electrical components and high-temperature lubricants.

Modifications of the standard crane consist of trimming crane hardware, reorienting major crane components to get better than standard side and end approaches, and devising methods of component assembly for maximum ease of remote dismantling. Without modification standard cranes would cover less than 40 per cent of the cell floor area.

(3) Manipulator - Crane Configurations (Alternate) - Because of the nature of process cell functions, several arrangements for in-cell crane facilities have been evaluated. In one possible configuration a special crane is mounted on a bridge together with a manipulator. Two such bridges, each with a manipulator and crane would be used in the cell to give adequate cell area coverage. This arrangement allows an appreciably lower cell height but may complicate cell operations or increase maintenance. This arrangement has the advantage of avoiding crane service interruption if one crane or manipulator fails. A disadvantage is that another device must be used to remove the manipulator from its bridge for necessary servicing which is estimated to be as frequent as every two or three weeks. Studies of this arrangement will continue through the mock-up stage to evaluate more thoroughly the significance of these various advantages and disadvantages.

(4) Out-of-Cell Motor Concept - Although the radiation hazard evaluation described above suggests that a conventional crane may be practical

for in-cell application, a limited amount of effort has been devoted to conceptual investigations of in-cell cranes whose radiation-vulnerable components are installed outside the cell. Such a system, if practical, would minimize the radiation problem.

Preliminary studies have indicated that this concept appears feasible for the bridge and trolley drives, but is intricate for the hoist drive. If its intricacies impair reliability or ease of maintenance, a conventional in-cell-powered hoist would be more practical. If maintenance procedures and facilities must be contrived for an in-cell-powered hoist, a conventional trolley can be serviced by the same facilities. This leaves the bridge drive as the one most practical for adaptation to out-of-cell power. Since any in-cell crane must have a manual override in the event of crane failure under load, studies of out-of-cell-powered trolley-and-bridge are to be continued.

Investigations of out-of-cell powered in-cell cranes have followed two approaches. One utilizes a chain and sprocket drive while the other incorporates ball bearing lead screws*. In either approach a Saginaw fitting and splined shaft transmit power to the trolley and hoist along the crane runway. When the trolley power reaches the bridge through the splined shaft it is transmitted through gearing to either a chain drive or lead-screw. Since the hoist drum is stationary with respect to the bridge, hoist power is transmitted directly from its splined shaft through a gear box to the drum.

(5) Crane and Manipulator Maintenance - The shielding and maintenance problems associated with through-wall or through-roof removal and replacement of crane units, rectilinear manipulators, and lighting assemblies are so large as to prescribe the use of some method of in-cell servicing and removal through the Access Lock. One technique, which seems to be both feasible and moderately simple in execution, involves the use of "sky hooks" through the cell roof. These "sky hooks" are steel rods sliding through snug steel sleeves cast into the concrete roof shield. The sleeves are sealed against the cross diffusion of atmospheres on opposite sides of the roof by the use of O-ring seals which could be contact-maintained outside of the cell. Since the steel rod provides more than adequate shielding, the out-of-cell seals should have satisfactory service lives.

*A nut incorporating ball bearings in its threads - manufactured by Saginaw Steering Division, General Motors Corporation.

The "sky hook" is made up of four or five foot lengths of rod which are screwed together and present, at all times, a smooth cylindrical surface to the O-ring seal. The bottom section of the "sky hook" serves as a support for the in-cell clamping device to engage with a crane unit or manipulator and a roof plug when not in use. Should the replacement of this plug section be required at any time, either the clamping device could be removed from it and attached to the next section of the extension rod or the clamp and plug unit could be replaced in-cell with an identical assembly brought in through the Access Lock. The plug section of a "sky hook" support for a light assembly could contain an insulated co-axial conduit and permit contact maintenance of lighting circuitry outside of the shielded facility. In such an installation, no lighting conduit would be subjected to unusual radiation and in-cell servicing of the lights would be limited to the replacement of the luminaires. Preliminary drawings of a roof tube assembly and "sky hook" for lifting a top-riding crane, manipulator, or bridge assembly from its support and lowering it to the cell floor are shown in Fig. 1.

Preliminary layouts of manipulator and crane configurations for an in-cell mock-up have been made simulating the proposed configuration for in-cell crane installation shown in Fig. 2.

b. Heavy Duty Manipulators - Preliminary bids for a mock-up recti-linear manipulator have been solicited from several vendors. Functions of in-cell heavy-duty manipulators are listed below:

1) Precise positioning of equipment
2) Equipment adjustment
3) Crane hook attachments and adjustments
4) Assembling and disassembling equipment
5) Handling slugs, sprues, and risers
6) Disassembly and reassembly of molds
7) Loading, closing, opening, and unloading furnaces
8) Positioning and servicing TV units
9) Servicing lighting fixtures
10) Operating vacuum cleaners
11) Operating sampling devices

Manipulator requirements to perform the necessary functions are:

1) Two arms, each with an approximate lifting capacity of 500 to 750 lbs. and a capacity for applying 150 ft-lb. of torque
2) Traverse the complete cell length and width
3) Be rectilinear in operation
4) Be remotely removable from the cell for maintenance

Study of manipulator functions and requirements lead to the conclusion that the process cell will require the installation of two heavy-duty rectilinear manipulators. These manipulators must be installed in-cell in such a way that all component parts can be removed from the cell by utilizing the in-cell crane. Mounting of the crane on a separate bridge above the manipulator bridge permits use of the crane for manipulator service and allows the crane to cover nearly the entire cell floor area. However, this results in increased cell height and volume with resultant difficulties of enlarging cell structure, building a high bay, cell atmosphere maintenance, and visual access to the lights and crane in the top of the cell. Alternate methods of crane and manipulator mounting are under consideration.

2. Inter-Cell Material Transfer - Work is continuing on the development of a controlled-atmosphere slug transfer chute between the process cell and the fabrication cell. In this equipment, PRE-made uranium fuel slugs would be transferred from the inert atmosphere of the process cell into a stainless steel SRE fuel tube located in the air atmosphere of the fabrication cell. During the transfer of slugs the fuel rod tube contains the process cell atmosphere. After the transfer is completed the tube is evacuated and purged before back-filling with argon to prevent contact with an oxidizing atmosphere during the transfer of the rod from the slug transfer chute to the rod refabrication device. Experiments are now in progress to determine the diffusion problems connected with the inert gas-air system in the transfer of the slug-loaded, argon-filled fuel rods into the rod refabricating device.

3. Access Lock - Analysis of the "demand load" on major equipment units showed that the large out-of-cell overhead crane serving the high-bay area would see only intermittent use. Since the shielded steel doors in the access lock and between the maintenance cell and the fabrication cell do not exceed the load

capacity of this crane, it is feasible to omit the three hydraulic hoist mechanisms proposed for the access lock doors and use the high-bay crane for this operation. Since this crane had previously been considered as a standby unit for overriding an inoperative hydraulic unit on a lock door, no new operational requirements would be imposed on the crane and three heavy mechanical units would be eliminated. The exclusion of these devices from the structure would reduce the maintenance requirements of the facility and the structural support requirements of the shielded cell unit.

The design and layout of the access lock has been undertaken. Since permanently-installed rails over the lock door sill would interfere with vacuum operation of the lock, it is necessary to design extension rails to carry a transfer dolly from the cells to the inside of the lock.

Various configurations of in-cell rail extension are being considered. It is desirable to minimize in-cell maintenance requirements, hence any configurations requiring additional actuating mechanisms are being considered only for in-lock installation. Since in-lock mechanisms are accessible for contact maintenance, they serve as an excellent proving ground for the development of remotely operable equipment. In-cell rail installations should utilize either the crane or a mechanical linkage with an out-of-cell actuator for positioning the rails to span the gap over the open access lock door frame.

4. Lighting and Viewing (G. Gustovich)

a. Cell Lighting - In an earlier concept of in-cell lamp installation[1], lights were to be relamped either through side-wall or roof plugs with non-browning glass gasketed to the cell liner to maintain the integrity of the in-cell atmospheres. Further studies of this configuration were made with respect to cooling requirements and radiation hazards to personnel during relamping operations or in the event of accidental rupture of the sealing glass plate covering the lamp. Adequate in-cell illumination requires five 3 kw mercury lamps in the decontamination cell.

Calculations revealed that luminaire cooling is essential to prevent breaking of the cover glass by thermal stresses when 3 kw mercury lamps are totally enclosed. Lower voltage lamps were not considered because of the larger number required for adequate cell illumination and the additional apertures required in the cell lining.

Calculation of the expected radiation hazard during removal of a sidewall or roof plug for lamp servicing has led to de-emphasis on this lamp configuration. A concept of in-cell lamp mounting with service of lamps accomplished by use of "sky hooks" has been substituted. Maximum safety, reliability and utilization of existing service devices appears to be offered by in-cell lamp installations.

b. Lighting Mock-up Tests - The new concept of in-cell lighting installations provide a basis for all tests to be performed in the mock-up. Chromel-alumel thermocouples have been made at the AI Standards Laboratory for use in various temperature tests. The following material and equipment were purchased for Raymer mock-up tests:

1) 3 kw mercury lamp
2) 3 kw lamp luminaire
3) ballast transformer for 3 kw lamp
4) magnetic starter
5) safety switch and box
6) 1/4 inch commercial plate glass
7) volt-ohm-meter
8) 3 kw lamp terminals for Dean-Plate (cooler-type) luminaire
9) high temperature 1000-volt electrical wire
10) other required miscellaneous items

Tests have been planned to substantiate calculations of lighting level requirements and heat removal. Quotations have been requested on the fabrication of a cooler-luminaire made from commercial Dean Plates. This luminaire may replace the commercial luminaire in that it serves a dual purpose as both lamp reflector and heat-removal system. This luminaire is to be used for the various temperature tests to be performed in the Raymer mock-up.

Various types of seals have been investigated for through-roof lamp installations. A combination rubber and organic seal with liquid metal (gallium or mercury) will be tested in a mock-up installation. The light mock-up will utilize a 3 kw mercury lamp in a small enclosure for determining lamp restarting time and other characteristics necessitating the use of an ultra-violet absorber for protection of personnel. A plate glass has been purchased to provide protection.

c. TV and Periscope - Purchase orders have been placed for a standard periscope and closed-circuit TV for remote viewing of mock-up operations. Delivery of the closed-circuit television unit is expected in the early part of January, 1957. Tests to be performed on the television unit have been partially summarized. Preliminary mock-up tests and operational tests will extend through the next six months. Considerable modification work will be necessary to install or improve the following items:

1) helium cooling system
2) camera radiation shield
3) remote lens changing
4) electrical disconnect operations
5) mobile or stationary camera support stands
6) investigation of electronic camera components for resistance to radiation
7) camera remote control mechanism

Since the mock-up facility will not be available for actual cell mock-up tests in the next quarter, these tests will be initiated in the fourth fiscal quarter.

d. Windows - Cell windows are being further evaluated for performance, size, and availability. Experimental observations utilizing the SRE hot cells have indicated that the horizontal centerline of the PRE windows should be approximately five feet above the coplanar floors of the cells and the operating galleries. The spacing of windows in the cell faces will depend on the layout of in-cell equipment. These correlated geometries are being studied.

A window will be purchased for use in the mock-up and eventual installation in the PRE facility at Santa Susana.

5. Emergency Power Supply - A preliminary survey has been made on the emergency power system equipment requirements. Basic requirements were presented for a normal power supply, diesel-generator supply, and battery-operated motor-generator supply. Minimum outage-time requirements would determine whether or not a motor-generator set should be used in conjunction with a diesel-generator set. The outage-time is based upon the continuous

operation requirements for the decontamination equipment. The primary critical loads are the drossing furnace ventilation system, the vacuum and drossing furnace coil cooling system, and general cell equipment such as lights, crane, and manipulator.

Preliminary survey included the emergency power diesel-generator set, battery-operated M-G set, instrumentation, controls, switchgear, water cooling tower, battery equipment, equipment location, building location, and other pertinent data.

Additional information included the estimation of approximate loads required for lighting and power for cell use and general building lighting and power requirements. Further determination of loads will be made after the completion of all mock-up tests.

6. In-Cell Radiation Instrumentation (G. Gustovich) - A preliminary report has been initiated on the problems associated with radiation detection devices to be used in the PRE cells. Up to date information was compiled on the various type of gamma and beta activity and the range of incident energies anticipated from the melting of irradiated fuel slugs.

Continuance of this investigation has been prolonged into the next fiscal quarter. The problems to be investigated in a preliminary survey include: radiation measurements, radiation counters, radiation detection devices, operating life, wiring techniques, temperature effects on probe and cables, ranges of instrument operation, replacement of in-cell detection devices, types of gamma and beta detectors, continuous accumulated radiation, recording mechanisms, detection probes in transfer lock and cells No. 1 and 3, number of detection devices required in each cell, in-cell calibration of instruments, covers for probes to avoid particulate contamination, and numerous other details involved in radiation instrumentation as applicable to our unique operating conditions.

## G. HOT CELL AUXILIARY PROCESSES

### 1. Radiation Control (S. Berger)

a. Radiation Intensity from Various Sources in PRE - In the basic design of any high level hot cell, such as the process cell of the PRE, the foremost problems are the magnitude of the expected radiation intensity and radiation damage. The process cell which is by far the "hottest" of the PRE cells, either contains or has associated with it, the following major sources of radiation:

1) The incoming spent fuel which is assumed to be in the form of three-slug magazines
2) The melting crucible containing 50 slugs
3) The glass wool filter which removes cesium, iodine, 10 per cent of the barium, and 10 per cent of the strontium
4) The freeze out trap which contains the volatile fission products xenon and krypton
5) The oxide dross (consisting essentially of rare earth compounds) lining the crucible wall
6) The processed fuel ingot
7) The processed fuel rod

Radiation intensities from each of these sources at various distances, and thermal heating power as a function of cooling time after one melt and after successive melts have been calculated and results are shown in Fig. 3 through 18. The most intense source of radiation is the drossing crucible containing the dross of 10 melts. These values will be important in determining if any external cooling is necessary in disposing of these crucibles as waste.

The basic assumptions used in making these calculations were that the average thermal flux in the fuel was $1 \times 10^{13}$ $n/cm^2$-sec see Table I, and that the fuel had been in the reactor for a period of 300 days at a reactor power level of 20 megawatts.

A careful examination of the accompanying curves reveals several interesting facts. For example, the 10, 30, and 100 day cooling curves for the processed fuel are much closer together than for the unprocessed fuel. This is due to the fact that at 10 days cooling about 50 per cent of the gamma activity is in the 0.75 Mev range, at 30 days cooling about 70 per cent, and at 100 days cooling over 90 per cent is in the 0.75 Mev range. Of the fission products emitting gammas in the 0.75 Mev range, the major portion (at 10 days cooling) of the activity is due to the transient equilibrium set up between 65 day zirconium and 40 day niobium. These elements stay with the uranium in the processed fuel.

In determining the radiation intensity due to the oxide dross, it was assumed that the wall attenuated by a factor $e^{-\mu t}$, where "t" is the wall thickness, and "$\mu$" is the absorption coefficient. This is a pessimistic assumption by a factor of about 2 since the gamma rays generally go through a thickness greater than "t".

The thermal heating power on the glass wool filter has not been included in these curves since the value is relatively low. After the first melt, allowing for a 10 day cooling period, the heating power is only about 30 watts and this would build up to approximately 100 watts after 10 to 15 melts. If a cooling of several weeks is allowed for the glass wool filter (decay of $I^{131}$) the value of 100 watts drops down to 10 watts which is due entirely to 37 year cesium.

b. Radiation Intensities From Proposed Slug Loading Mechanisms - After the spent fuel has been processed and cast into slugs, these slugs will be loaded into new rod assemblies. Two slug loading mechanisms have been proposed other than the slug transfer chute described above.

The two proposed mechanisms are clip type magazines containing 24 or 48 processed slugs or cylindrical or revolving barrel type mechanisms containing 12 processed slugs. Radiation intensities for each mechanism are shown in Fig. 19 through 20.

A careful comparison of these curves indicates that there is no significant difference between the two mechanisms as far as radiation intensity is concerned.

c. Radiation Level at the Process Cell Access Lock Door - The access lock chamber leads into the process cell through a vertically-rising 1-1/2-foot-thick steel door. The door will be sealed by inflatable seals on both the process cell side and the access lock side of the door. This is to insure that the inert atmosphere is maintained in the cell and that the escape of gaseous and particulate activity is kept to an absolute minimum.

These seals being organic are susceptible to radiation damage and an estimate of their expected life in the high radiation field was required. The following assumptions were made in order to determine the worst possible radiation level at the seals.

1) All spent fuel was cooled less than 10 days.

2) The drossing crucible had been used nine previous times and contained its tenth melt.

3) The vacuum furnace contained a 50 kg ingot.

4) All photons were scattered at an angle of 90°.

5) Four slugs of processed fuel are situated two feet from the door.

The total allowable exposure for natural rubber which has a tolerable dosage before breakdown of $6 \times 10^7$ roentgens is approximately four years.

d. Scattered Radiation Leakage Through Cracks - In calculating the amount of radiation intensity getting out between the access lock door and its jamb with no steps in the door, the following assumptions were made:

1) No source of radiation is in direct line with the cracks or interface.

2) The scattered radiation comes from the drossing furnace which has been used for ten previous melts.

3) Only single scatterings from the floor, ceiling, and back wall are considered.

Figure 21 shows the radiation intensity as a function of crack size measured at the interface on the access lock side of the door.

It may be concluded that by keeping the crack size under 1/8 inch, little or no shielding would be required. However, this presupposes that there are no direct line sources of radiation. To be completely protected against the possibility of radiation hazard from a "hot" source in line with the interface, the door should be imbedded into the concrete both at the floor level and at the sides; however, no steps are considered to be essential.

e. Volatile Fission Products - Calculations have been carried out to determine the quantitative amounts of volatile fission products released per melt of spent fuel. These values will be used to determine the size of the inert gas-handling system and the frequency of replacement for various components.

The basic assumptions upon which the calculations were made are as follows:

1) Each melt represents 50 slugs of spent fuel.

2) These slugs have been in the reactor for 300 days at 20 megawatts.

3) Cooling time is not significant since the volatile elements are composed to a large extent of either stable or long lived isotopes.

Table II summarizes these results. Figure 22 shows the activity in curies of each volatile fission product as a function of cooling time.

f. Cell Shielding Requirements - The shielding requirements for the PRE hot cell walls have been checked by the shielding unit of the General Engineering Section and found to be within the accepted AEC tolerances. However, the recent lowering of the recommended permissible dosage by AEC requires a re-examination of local standards and this may be reflected in a slight increase in shielding thickness.

2. Hot Basement - A preliminary study was made to determine the space requirements of the various equipment pieces which are proposed to be installed in the basement beneath the process cell and the maintenance cell. It is thought that this basement will be a limited access area and will contain potentially radioactive mechanical equipment (ventilation blowers and vacuum pumps), potentially radioactive process equipment (cell ventilation filters and inert gas purification equipment), and equipment which has to be located immediately adjacent to hot cell equipment (e.g., the induction furnaces, high-frequency electrical gear).

A partial equipment layout was made which indicates that the basement size now proposed is adequate. The area will be compartmentalized to avoid possible cross contamination and shield those equipment pieces believed to be the most radioactive. The basement includes two complete gas purification trains as described in the last quarterly report[1]. High-frequency gear is located in the basement close to the cells.

3. Cell Atmosphere System - A literature survey has begun to determine the process conditions and equipment design criteria for purifying inert atmospheres contaminated with oxygen, nitrogen, hydrogen and radioactive cesium, iodine, krypton, and xenon.

Design of a prototype system to be installed adjacent to the Vanowen hot cave has been initiated. This system will process off-gas from drossing furnace operations and will serve as the pilot plant for the PRE inert gas purification system.

A Gast rotary oil-less Model 1550 air pump, has been procured and will be tested to determine its characteristics when pumping helium. It is expected that the pump will have to be canned in order to be used for pumping radioactive gas.

a. Cesium Collection - A theory has been advanced that the cesium coming off the uranium melt during drossing furnace operation is in the form of an ion, probably a cation. To check this theory an electrostatic precipitator has been suggested as a possible means of trapping the cesium. A stainless steel wire screen supported top and bottom by lavite insulation rings was built as the precipitator. A negative potential of 600 volts is supplied to the screen. The screen will be installed and tested during the first run at the Vanowen hot cave. It can operate either in a vacuum at reduced voltage or in an inert gas atmosphere.

b. Reactive Metal Gettering - Materials have been obtained for preliminary experiments on a low melting alloy of calcium, magnesium, and barium. This is one of several proposed liquid metals for chemical purification of the cell atmosphere for water, oxygen, nitrogen, and hydrogen. A lithium base alloy with sodium and lead will also be checked.

c. Atmosphere Containment - A literature survey was made on methods of sealing various cell openings to contain the contaminated atmospheres. No information was found on the use of inflatable seals in vacuum or inert atmosphere work. However, considerable work on vacuum seals has been done at KAPL.[2,3,4,5,6] This information along with permeability data from other sources[7,8] permitted an evaluation of the problems to be expected in all seals except those in the doors of the access lock. This is summarized below:

1) Neoprene gaskets and "O" rings will be satisfactory for all static seals (except in a few high radiation fields) provided they are properly restrained and used in pairs with a pump-out monitoring space between.
2) Natural rubber can be substituted for neoprene in some of the extreme radiation fields.
3) Soft metal (aluminum or copper) can be used in other locations in the extreme radiation field.
4) Reciprocating shaft seals and rotating shaft seals similar to the design described by Heywood[5] using a liquid metal between

neoprene and other elastomers will be adequate for all uses anticipated in the process cell. The diffusion through inflatable neoprene seals for the door to the access lock has been estimated and found to be quite low. However, because no information has been found on performance of this seal, a mock-up test program has been started.

Two inflatable neoprene seals have been obtained and a test apparatus is being constructed to evaluate the leakage rate of these and similar seals.

## III. PLANS FOR THIRD QUARTER

1) During the third quarter modifications to the building facility to house the cold mock-up will be initiated for completion early in the fourth quarter. Mock-up crane erection will begin and the crane will be installed.
2) Detailing of the fuel rod refabrication device will continue and fabrication and assembly of components will begin.
3) Investigation of using pre-wrapped fuel rod tubes will continue.
4) Delivery of the tilt-pour induction furnace is expected early in the fourth quarter. During the third quarter design of remote charging devices will continue and fabrication of components will begin.
5) The vacuum-casting furnace will probably be ordered for first quarter FY 1958 delivery.
6) Construction of a slug inspection device will be initiated.
7) A rectilinear manipulator and shielding window will be ordered for the cold mock-up.
8) Work on the prototype gas-handling system will continue using off-gas from Vanowen hot cave melting runs.
9) Mock-up of inflatable seals for containment of cell atmospheres will be completed and tests initiated to determine the applicability of these seals to vacuum operation.
10) The inclusion of a plutonium recovery step in the flow sheet was considered as an alternate step in the PRE proposal. Study of the possibility of plutonium recovery, in the PRE hot cells will begin.

## TABLE I
## MAXIMUM-MINIMUM FUEL ELEMENT POWER FOR SRE

| | | |
|---|---|---|
| I. Reactor (37 clusters) | 20 Mw | |
| A. Center Cluster | 650 kw | |
| 1. Center Rod | 56 kw | |
| a. Max slug | 6.1 kw, | $\phi = 1.2 \times 10^{13}$ nv |
| b. Min slug | 3.3 kw, | $\phi = 6.4 \times 10^{12}$ nv |
| 2. Outside Rod | 99 kw | |
| a. Max slug | 11 kw, | $\phi = 2.1 \times 10^{13}$ nv |
| b. Min slug | 5.8 kw, | $\phi = 1.1 \times 10^{13}$ nv |
| B. Outside Cluster | 502 kw | |
| 1. Center Rod | 43 kw | |
| a. Max slug | 4.7 kw, | $\phi = 9.1 \times 10^{12}$ nv |
| b. Min slug | 2.5 kw, | $\phi = 4.8 \times 10^{12}$ nv |
| 2. Outside Rod | 77 kw | |
| a. Max slug | 8.4 kw, | $\phi = 1.6 \times 10^{13}$ nv |
| b. Min slug | 4.5 kw, | $\phi = 8.7 \times 10^{12}$ nv |

Note: Calculated from data in NAA-SR-1517

## TABLE II

## VOLATILE FISSION PRODUCTS - BASED ON ONE 50 kg MELT

| Element | No. of Moles | Volume (cc at STP) | GMS | Per Cent Radioactive | 1/2-Life |
|---|---|---|---|---|---|
| Xe* | 0.12 | 2600 | 16 | 1 | 5 days |
| Kr† | 0.025 | 560 | 2.1 | 8 | 10 years |
| Cs** | 0.090 | 2000 | 12 | 33 | 33 years |
| I †† | 0.0020 | 45 | 0.26 | 10 | 8 days |

| * Xenon | † Krypton | ** Cesium | †† Iodine |
|---|---|---|---|
| $Xe^{131}$(Meta-stable) | $Kr^{83}$(Stable) | $Cs^{133}$(Stable) | $I^{127}$(Stable) |
| $Xe^{132}$(Stable) | $Kr^{84}$(Stable) | $Cs^{135}$(Stable) | $I^{129}$(Stable) |
| $Xe^{133}$(Active) | $Kr^{85}$(Active) | $Cs^{137}$(Active) | $I^{131}$(Active) |
| $Xe^{134}$(Stable) | $Kr^{86}$(Stable) | | |
| $Xe^{136}$(Stable) | | | |

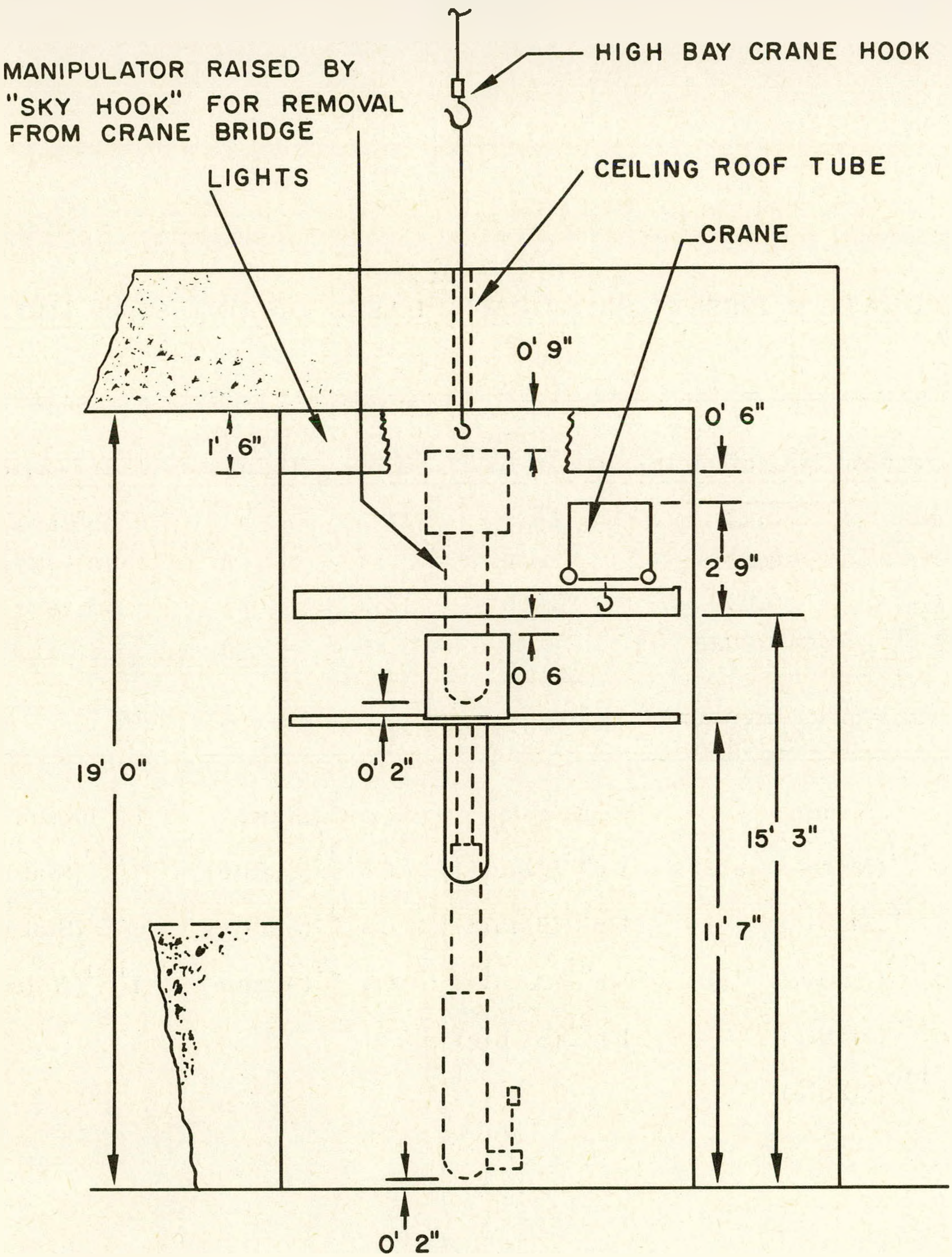


Fig. 1. Schematic Roof Tube Installation

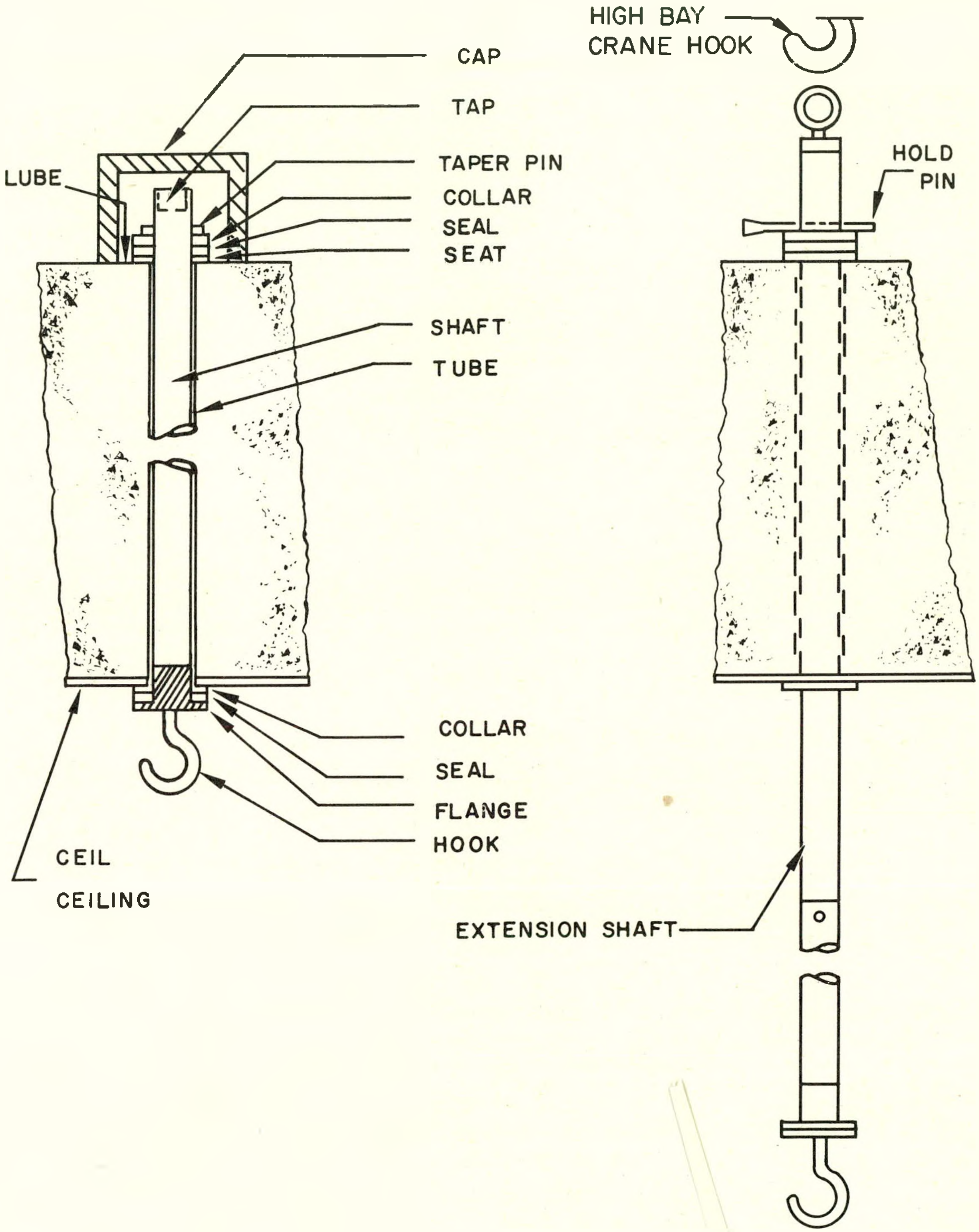


Fig. 2. Proposed Configuration of Crane and Manipulator

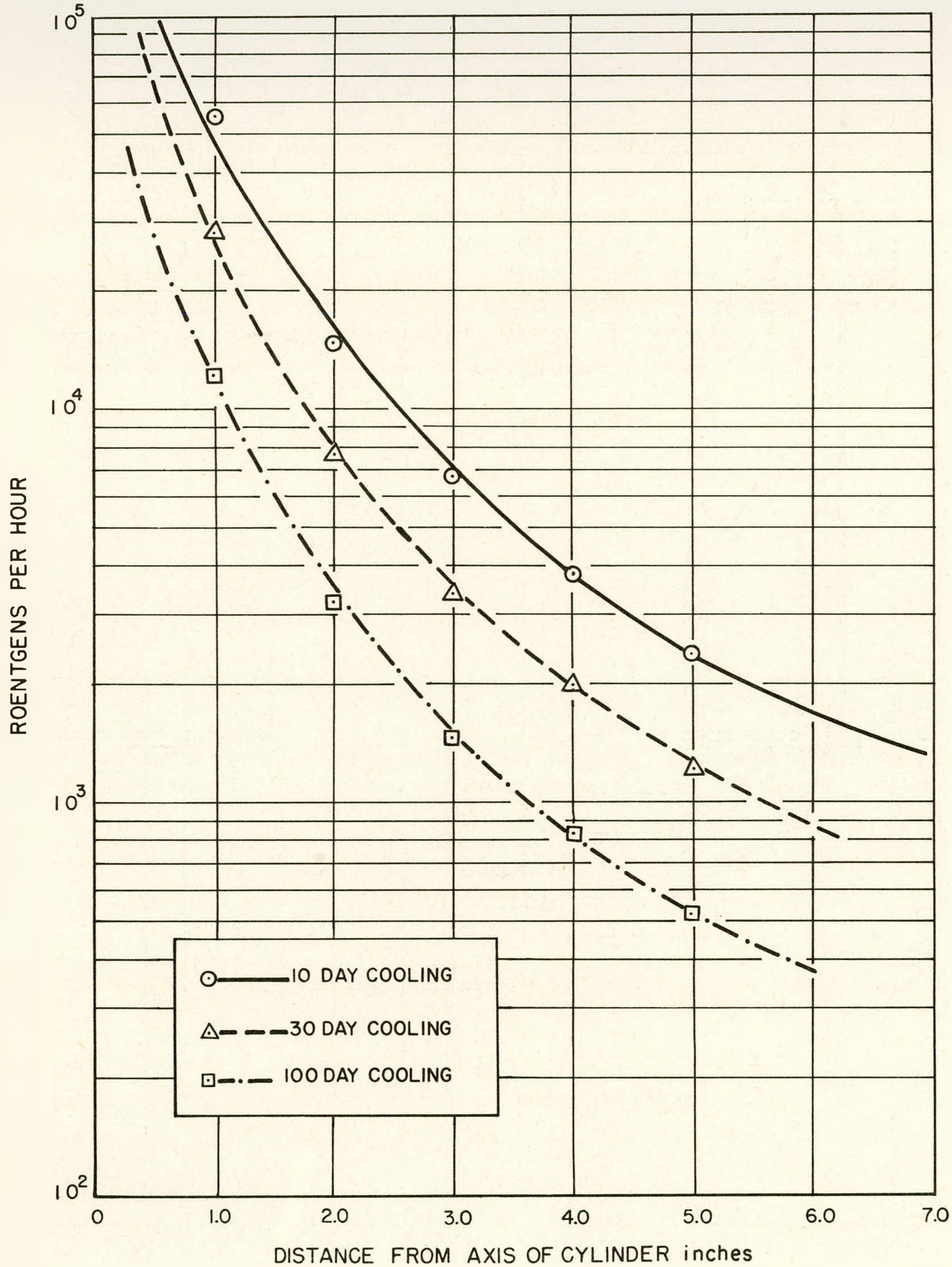


Fig. 3. Radiation Intensity on the Central Axis of a Cylindrical Slug Magazine (Condition: Spent elements after 300-day in-pile operation at 20 Mw, $\phi = 2.1 \times 10^{13}$ nv.)

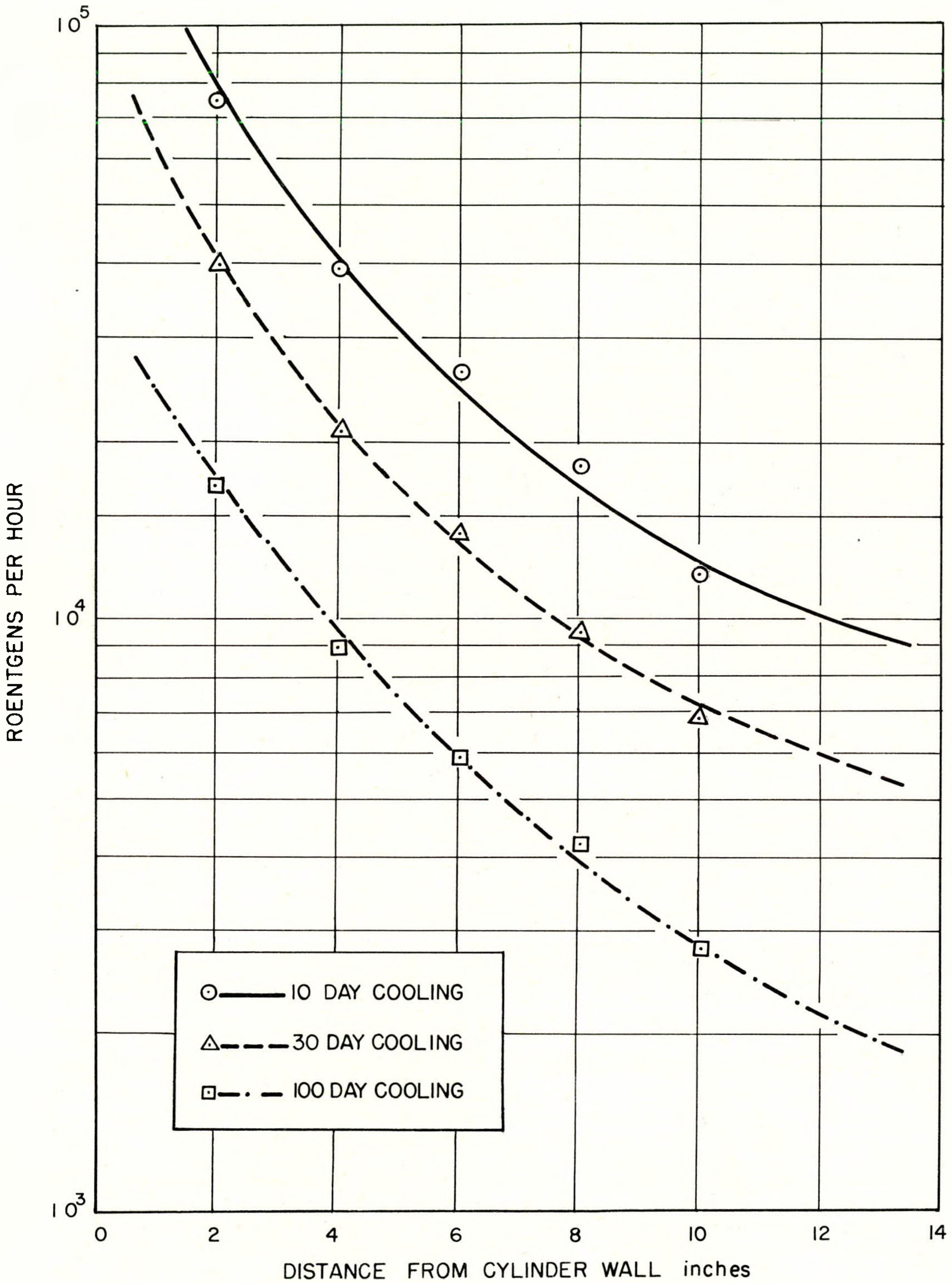


Fig. 4. Radiation Intensity on Mid-Plane (Condition: Spent elements after 300-day in-pile operation at 20 Mw, $\phi = 2.1 \times 10^{13}$ nv.)

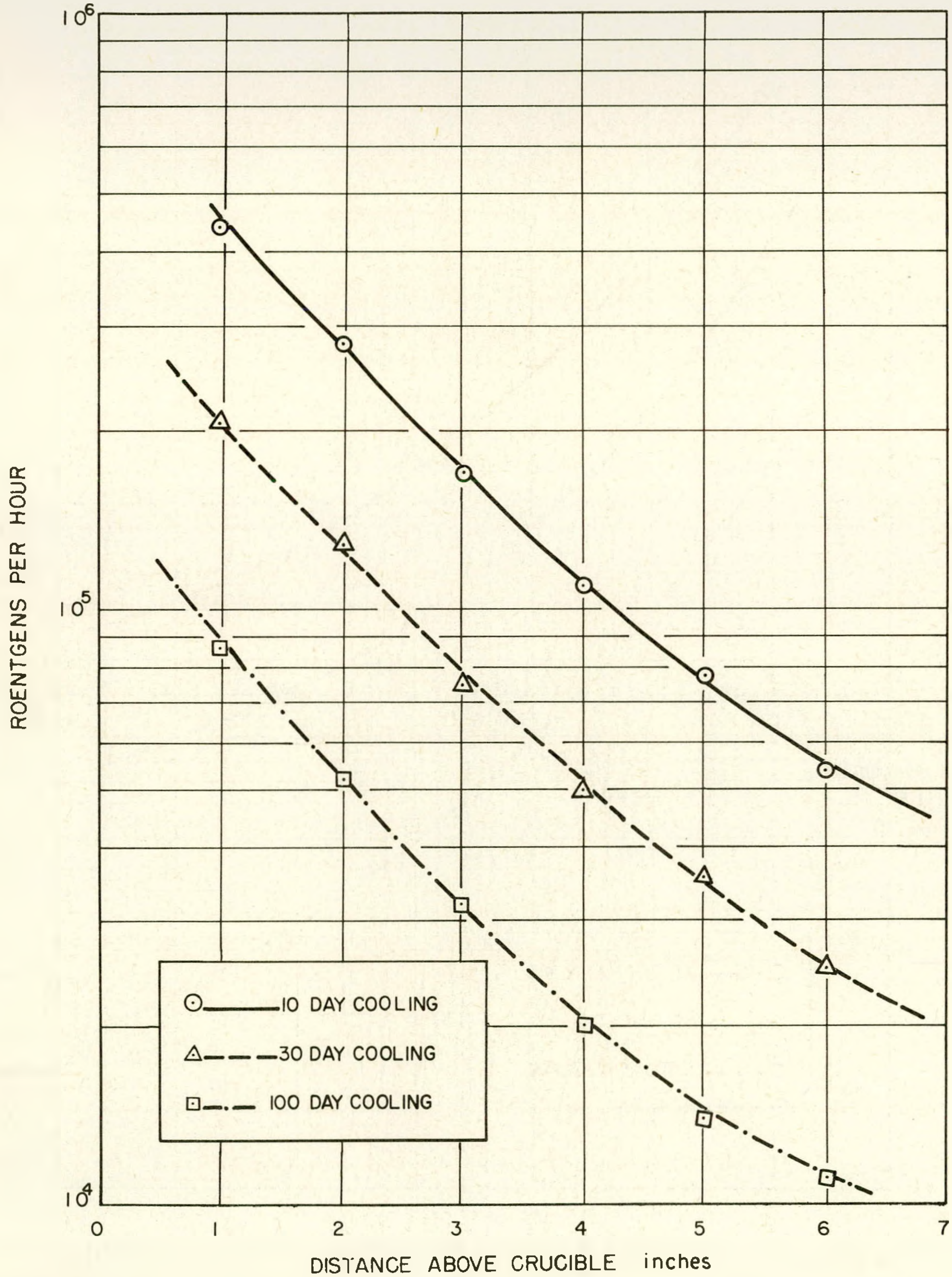


Fig. 5. Radiation Intensity on Central Axis of an Oxide Drossing Crucible (Condition: 50 slugs after 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$ nv.)

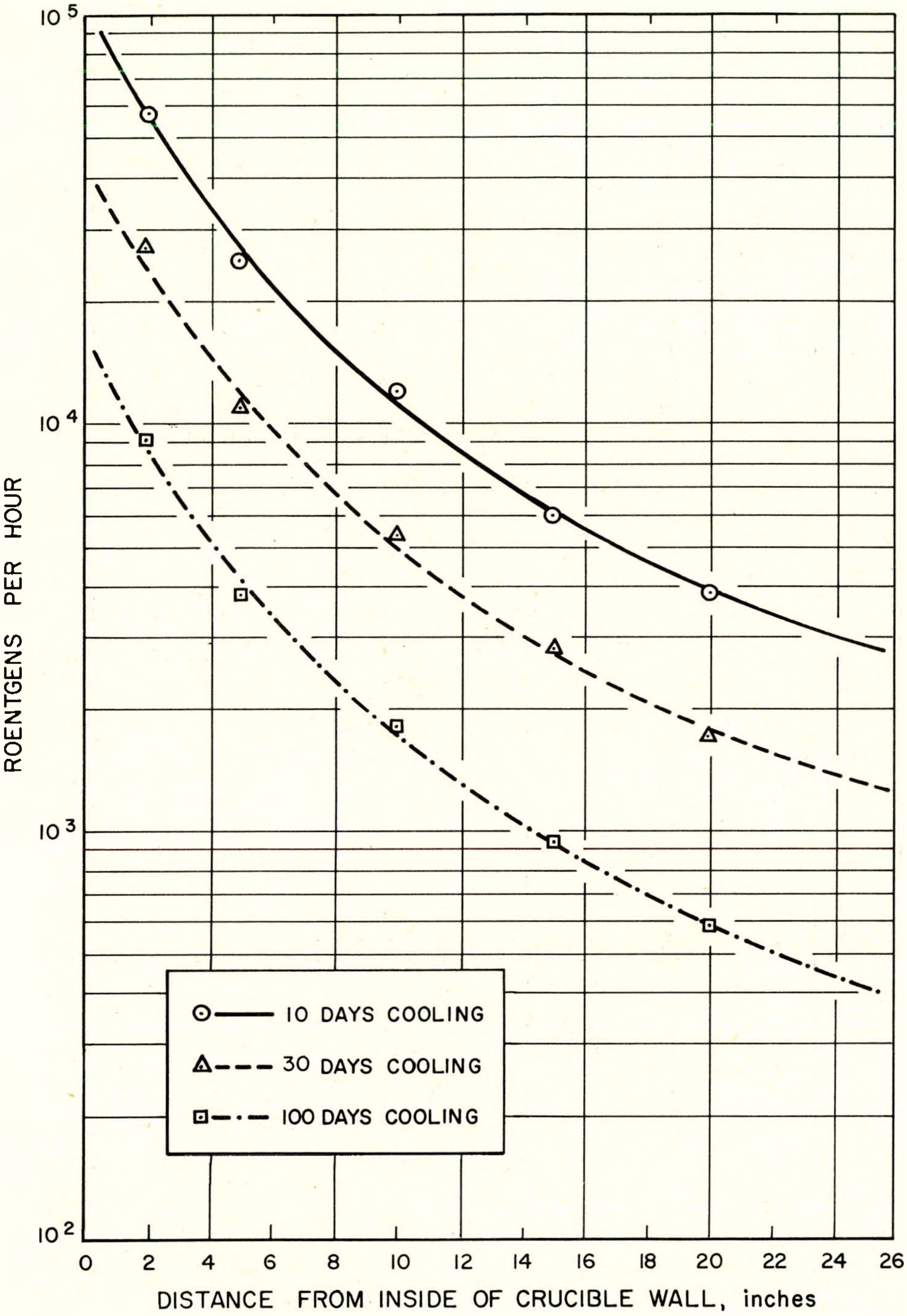


Fig. 6. Radiation Intensity on Mid-Plane of an Oxide Drossing Crucible (Condition: 50 slugs after 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$ nv.)

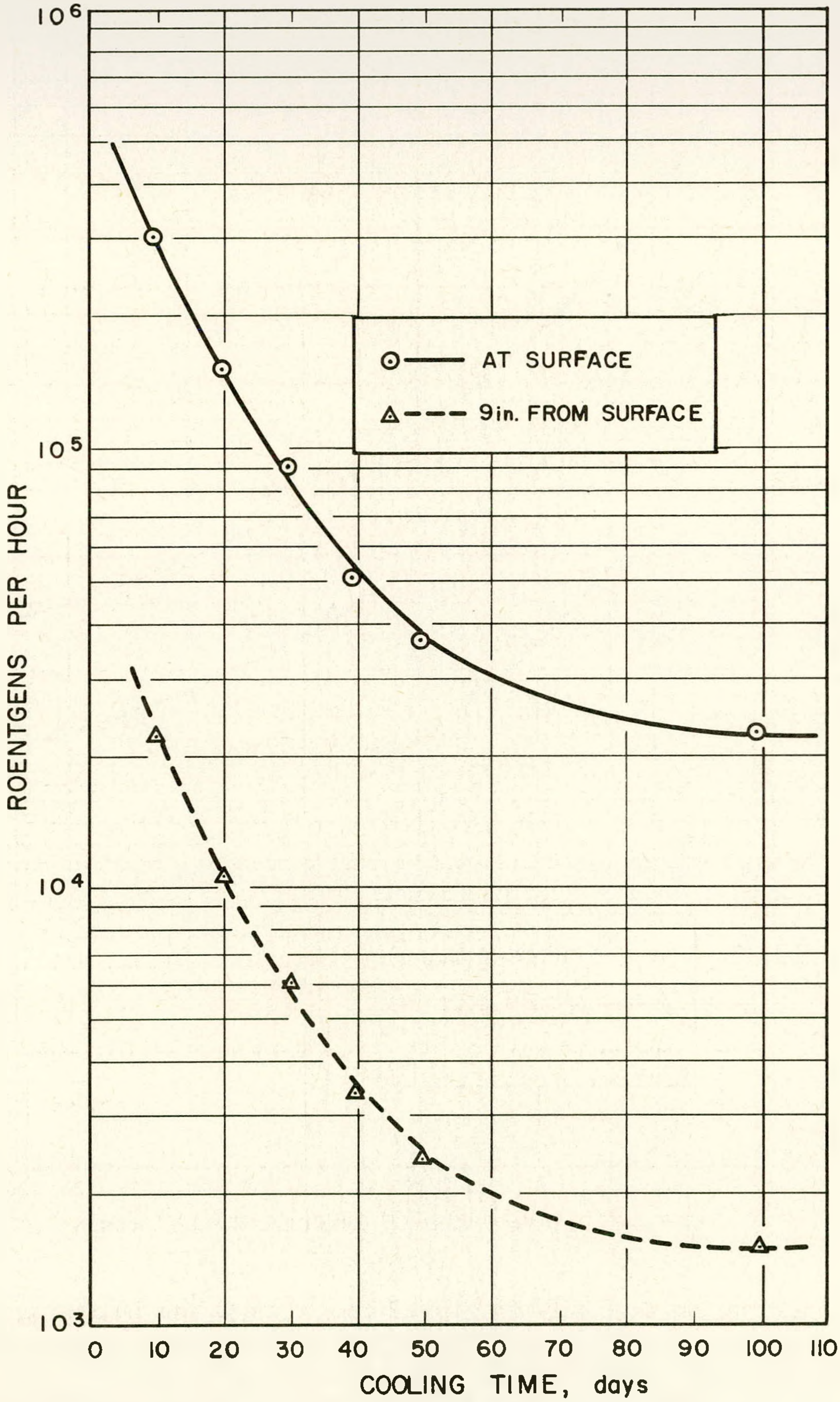


Fig. 7. Radiation Intensity From a Fiberglass Filter (Condition: After first melt. 300-day in-pile operation at 20 Mw, $\phi$ = $1.7 \times 10^{13}$)

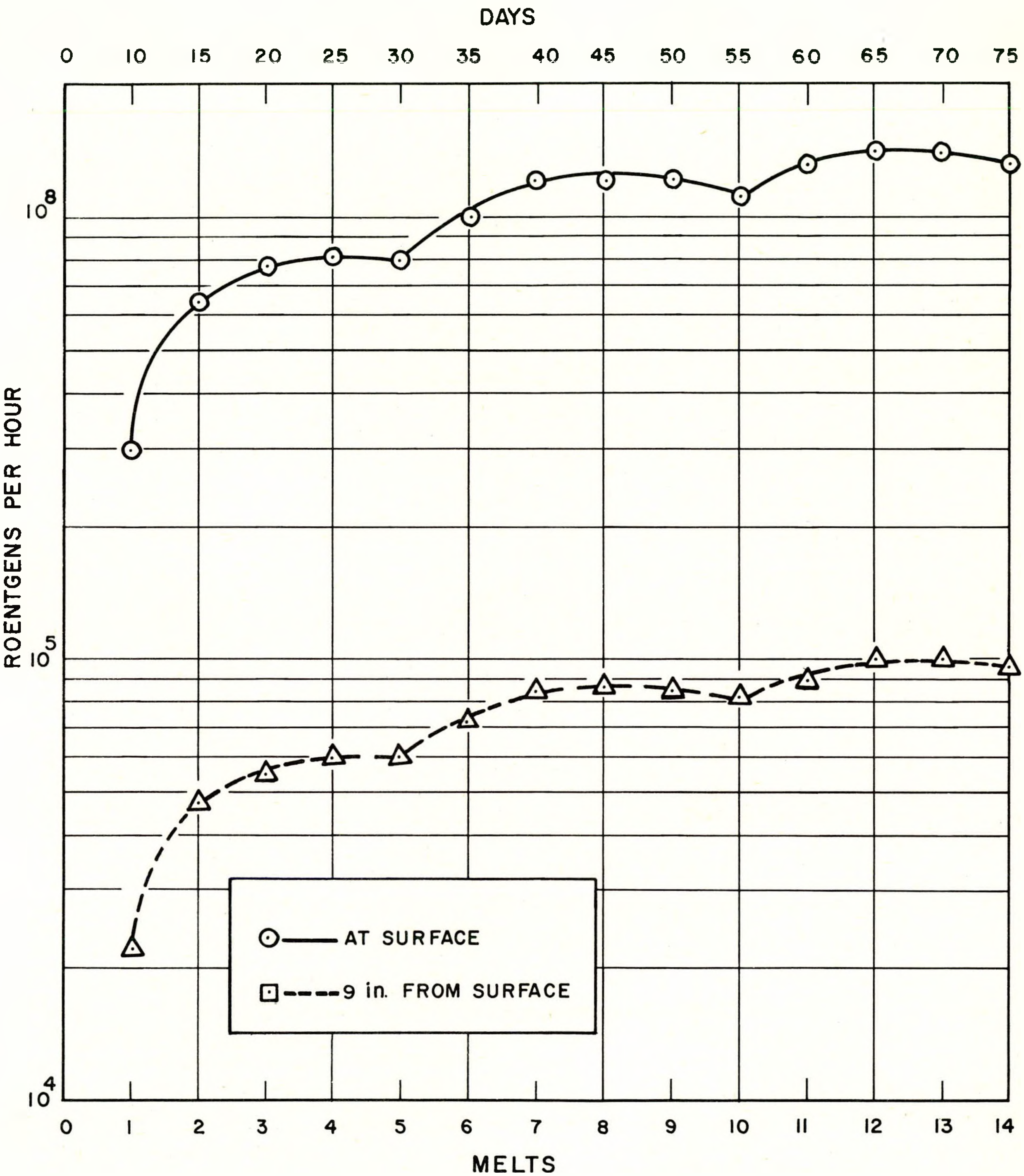


Fig. 8. Buildup of Radiation Intensity From Fiberglass Filters (Condition: After 300-day in-pile operation at 20 Mw, 3 clusters, five melts, removed every 25 days. $\phi = 1.7 \times 10^{13}$)

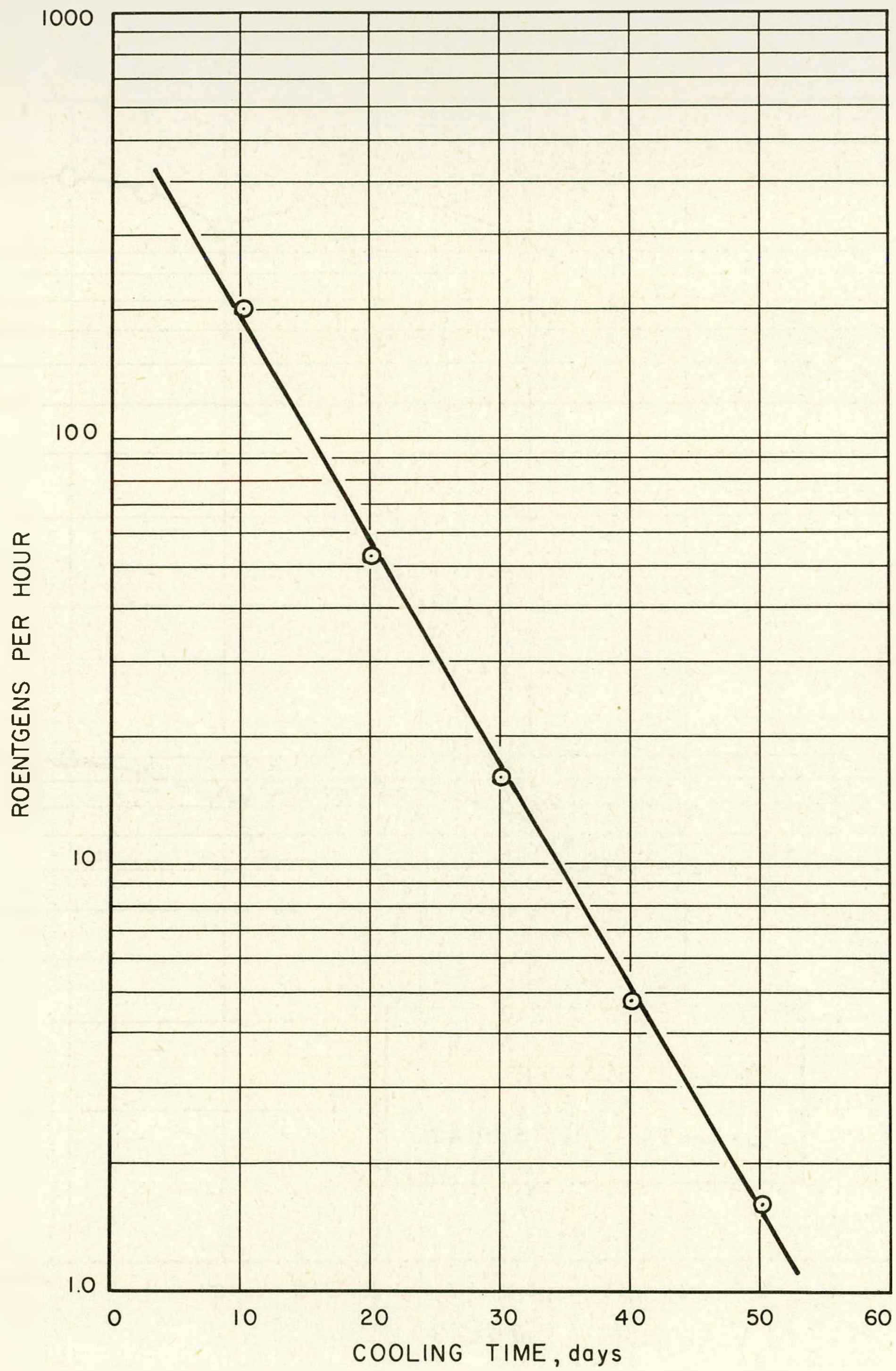


Fig. 9. Radiation Intensity From a Freeze-out Trap (Condition: After 300-day in-pile operation i.e., after first melt, at 20 Mw, $\phi$ = 1.7 x $10^{13}$)

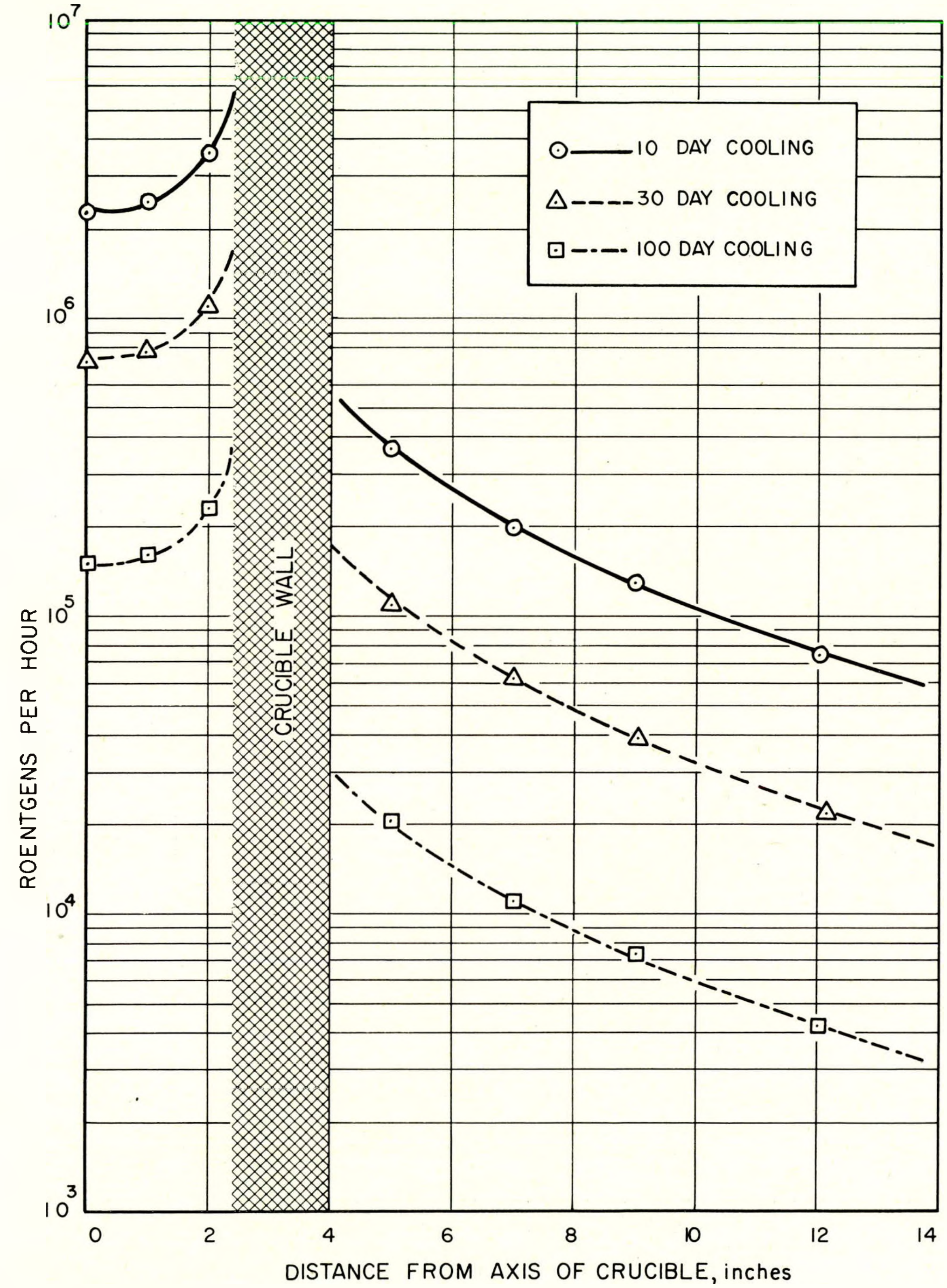


Fig. 10. Radiation Intensity Outside Oxide Drossing Crucible (Condition: Due to oxide dross after 300-day in-pile operation at 20 Mw, $\phi$ = 1.7 x $10^{13}$ nv.)

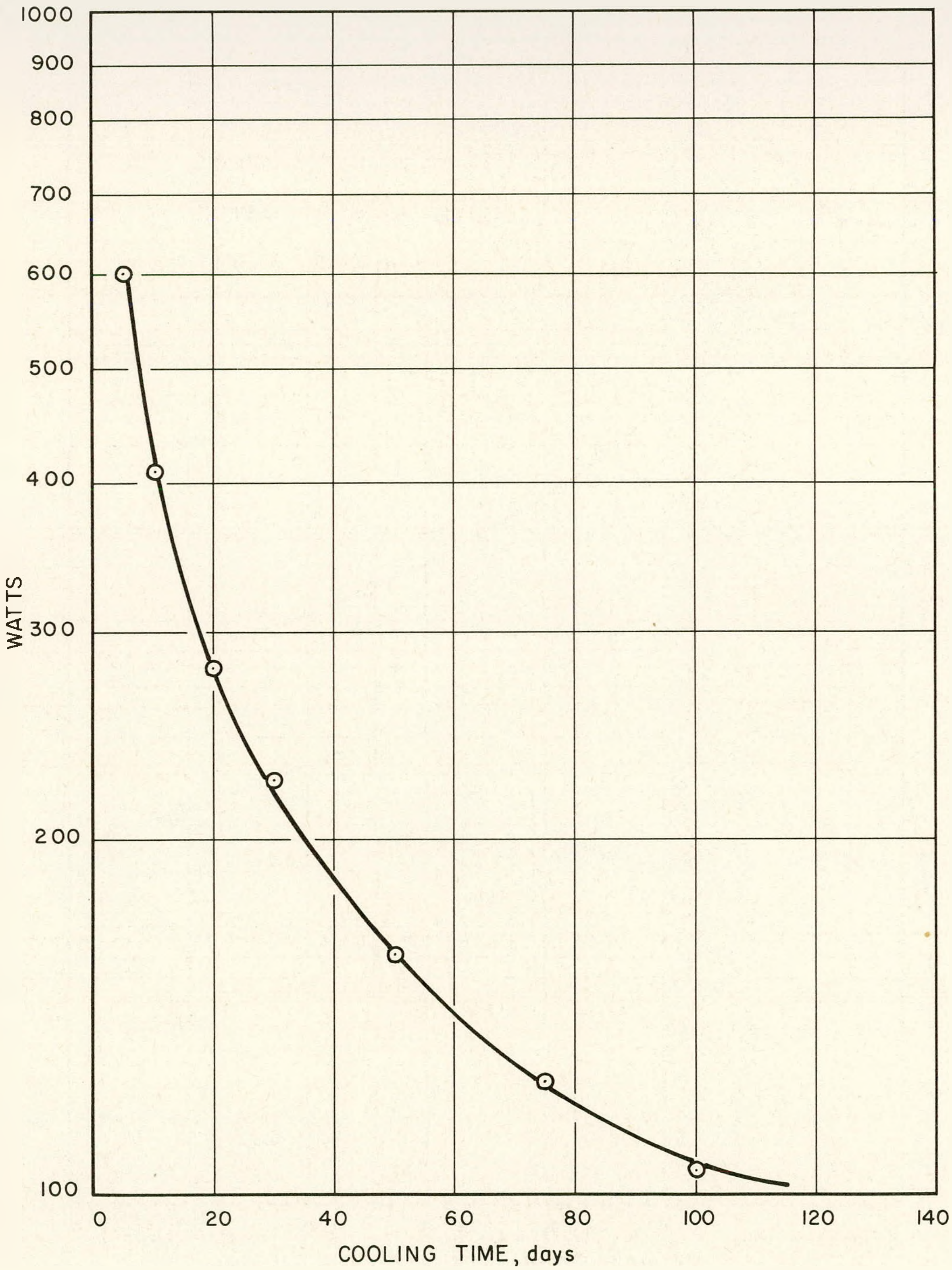


Fig. 11. Thermal Power of an Oxide Drossing Crucible (Condition: Due to oxide dross of one melt after 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$)

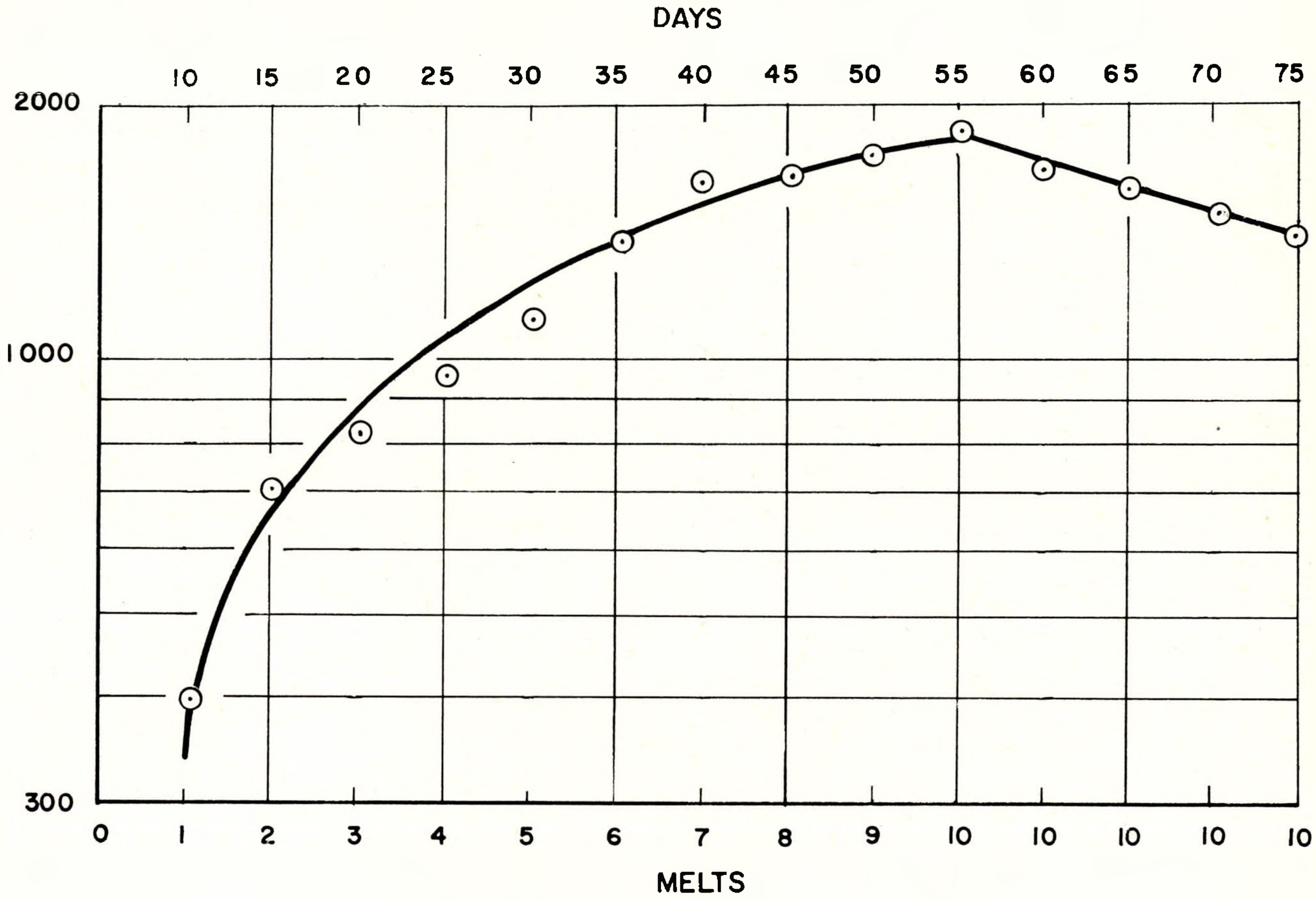


Fig. 12. Buildup of Thermal Power of an Oxide Drossing Crucible (Condition: After 300-day in-pile operation at 20 Mw, 3 clusters, five melts, removed every 25 days. $\phi = 1.7 \times 10^{13}$)

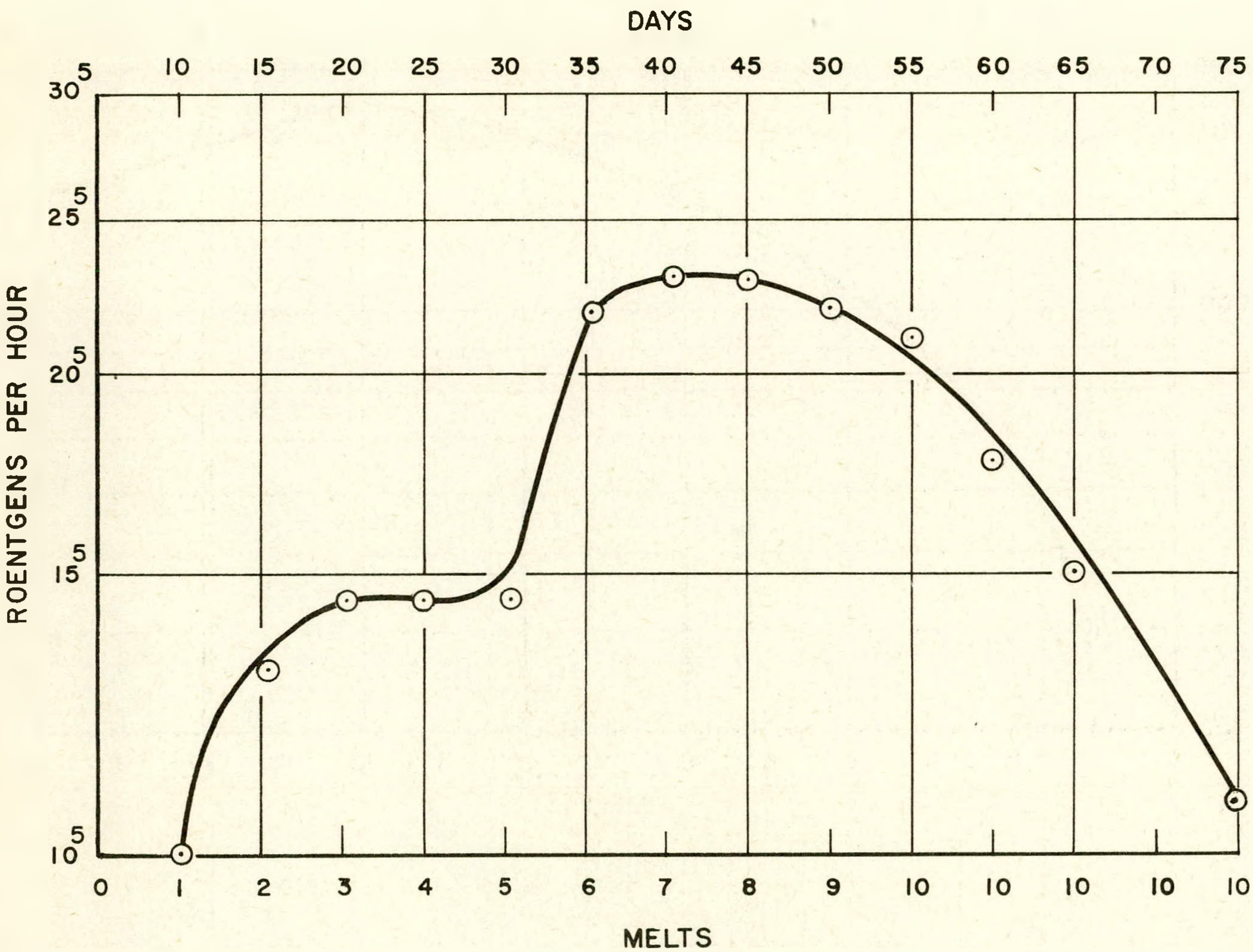


Fig. 13. Buildup of Radiation Intensity of an Oxide Drossing Crucible (Condition: Due to oxide dross after 300-day in-pile operation at 20 Mw, 3 clusters, five melts, removed every 25 days. $\phi = 1.7 \times 10^{13}$)

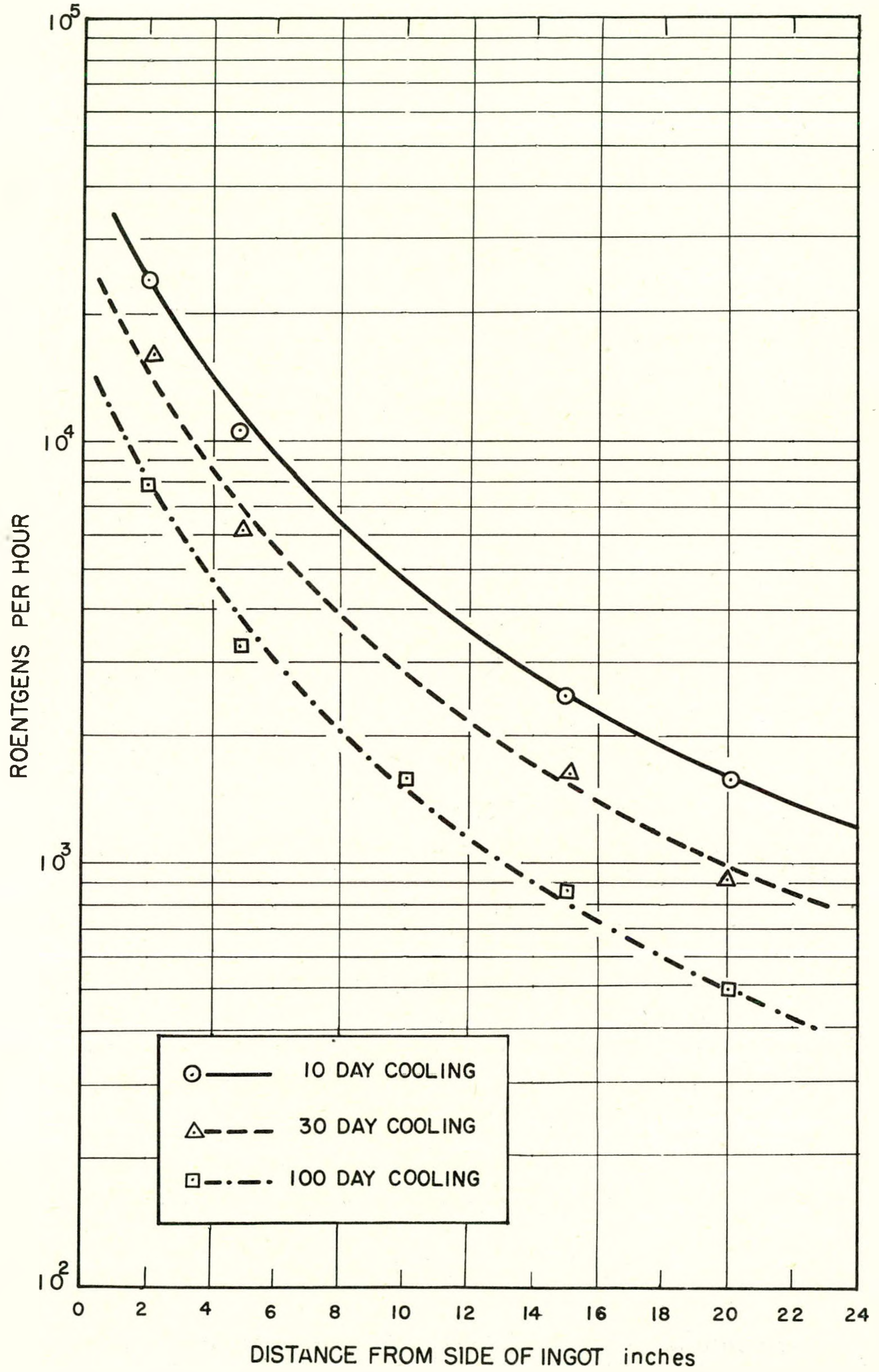


Fig. 14. Radiation Intensity on the Mid-Plane of a Processed Ingot
(Condition: After 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$)

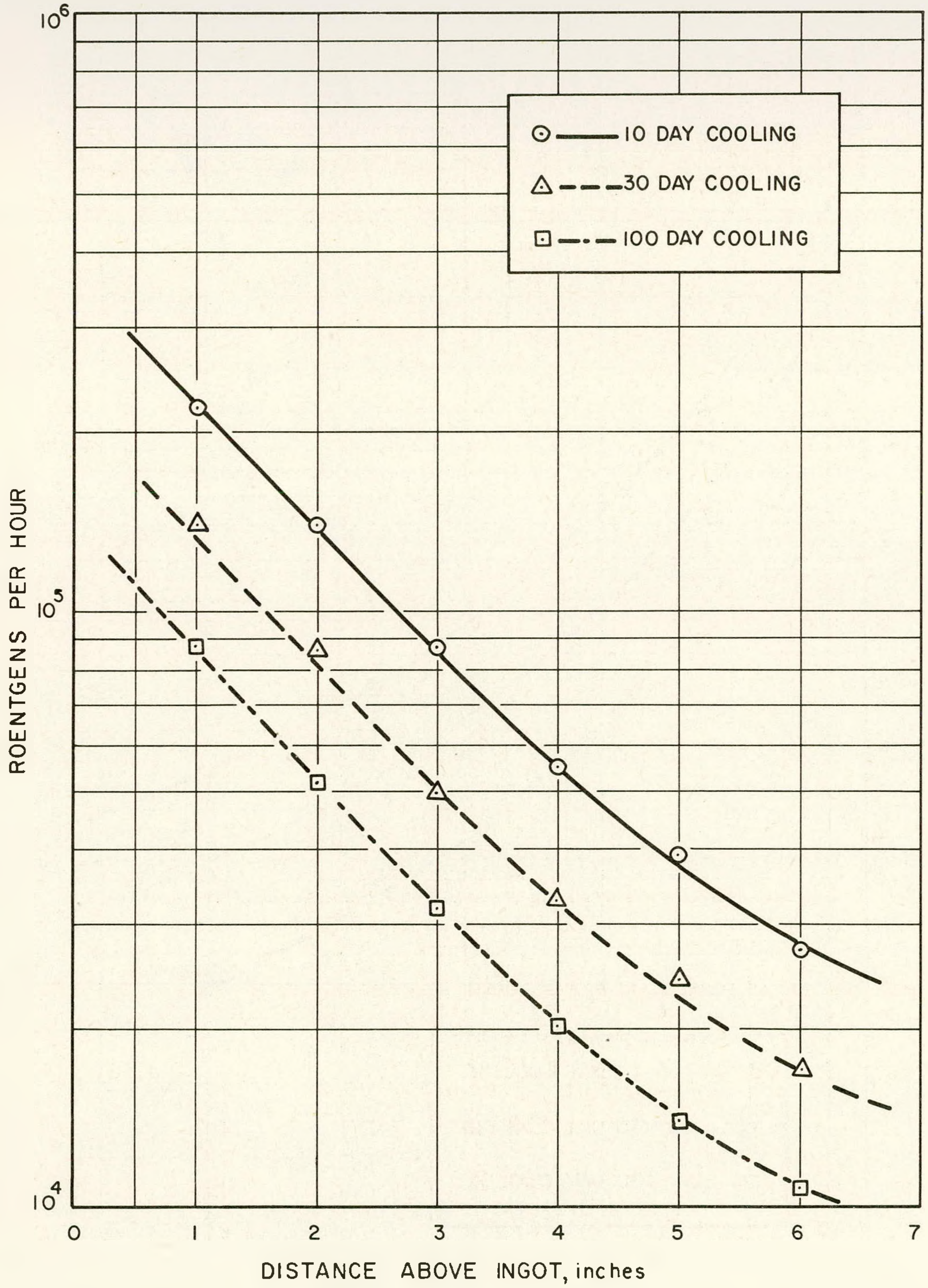


Fig. 15. Radiation Intensity on the Central Axis of a Processed Ingot (Condition: After 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$)

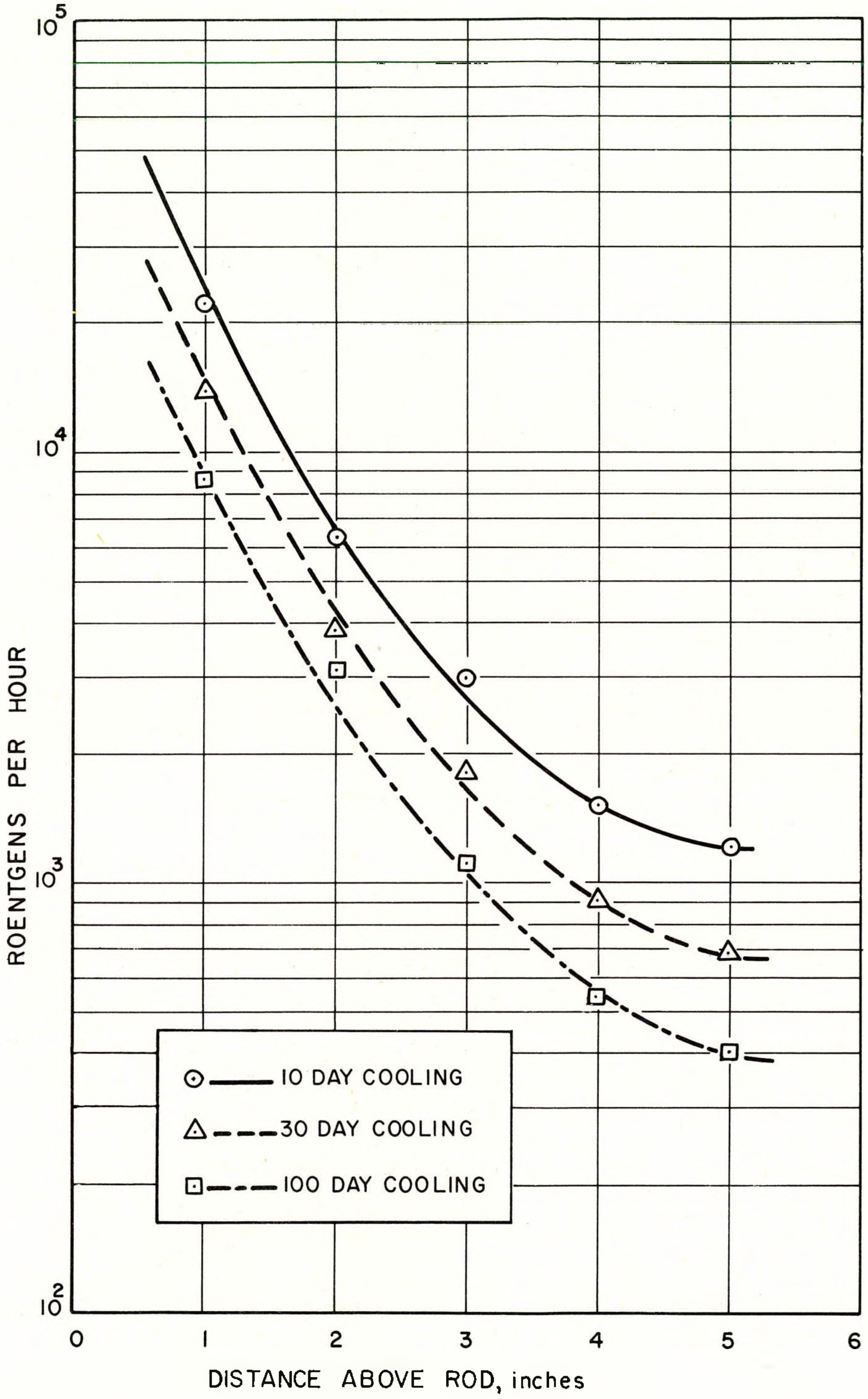


Fig. 16. Radiation Intensity on the Central Axis of a Processed Fuel Rod (Condition: After 300-day in-pile operation at 20 Mw, $\phi = 1.7 \times 10^{13}$)

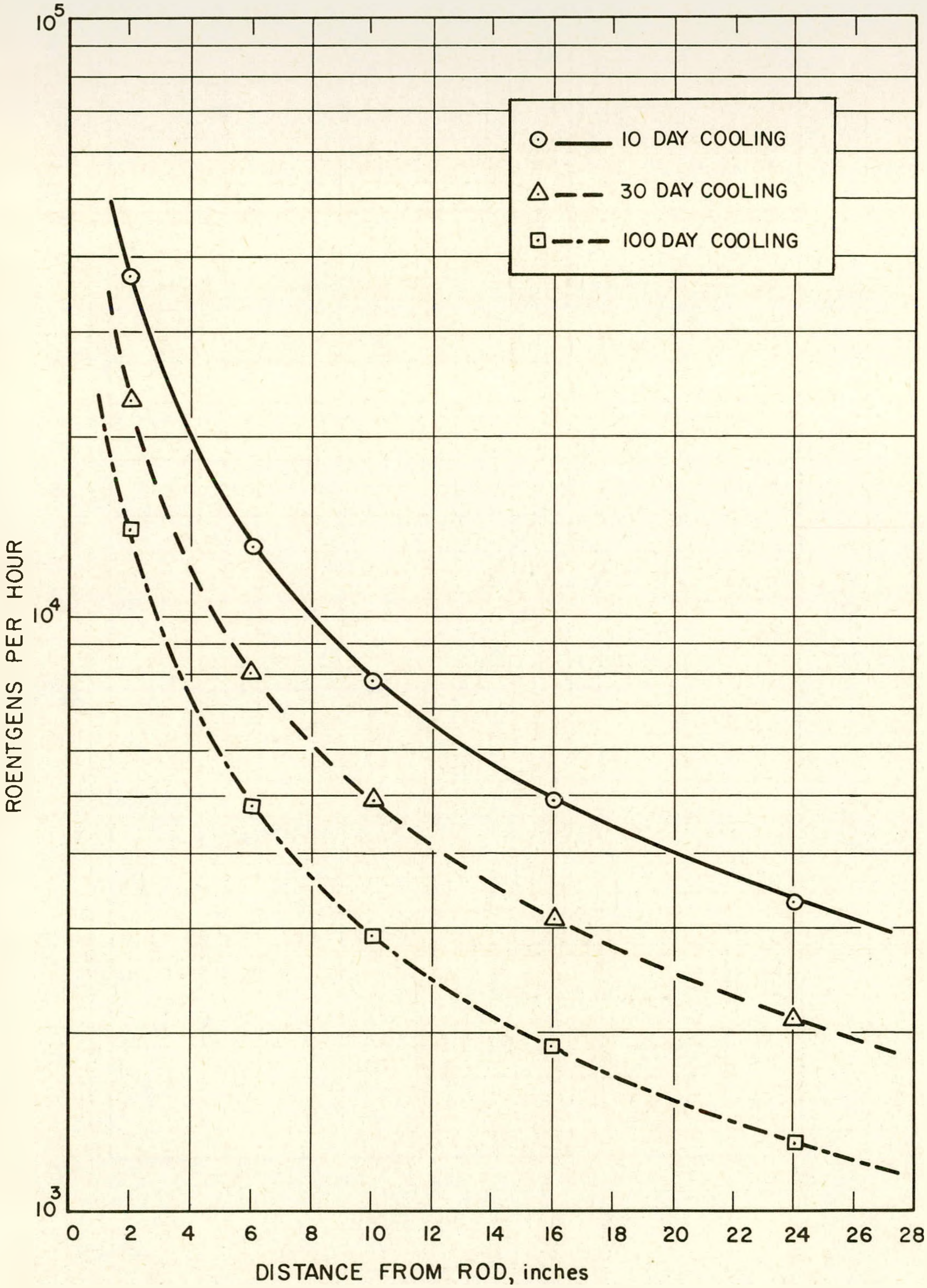


Fig. 17. Radiation Intensity on the Mid-Plane of a Processed Fuel Rod (Condition: After 300-day in-pile operation at 20 Mw, $\phi$ = $1.7 \times 10^{13}$)

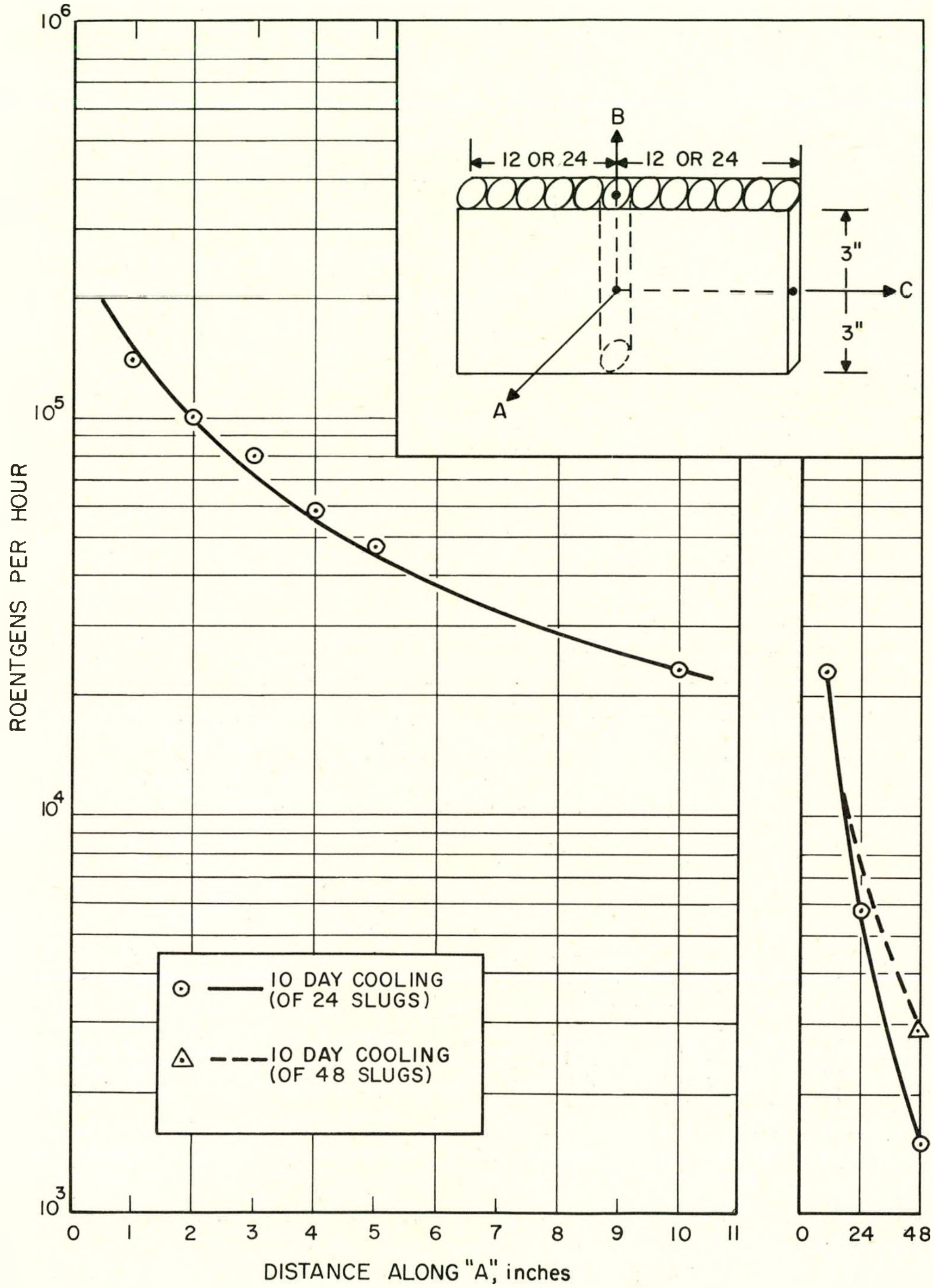


Fig. 18a. Radiation Intensity From a Clip-Type Slug Magazine (Condition: After 10-day cooling following operation for 300 days at 20 Mv, $\phi$ = 1.7 x $10^{13}$)

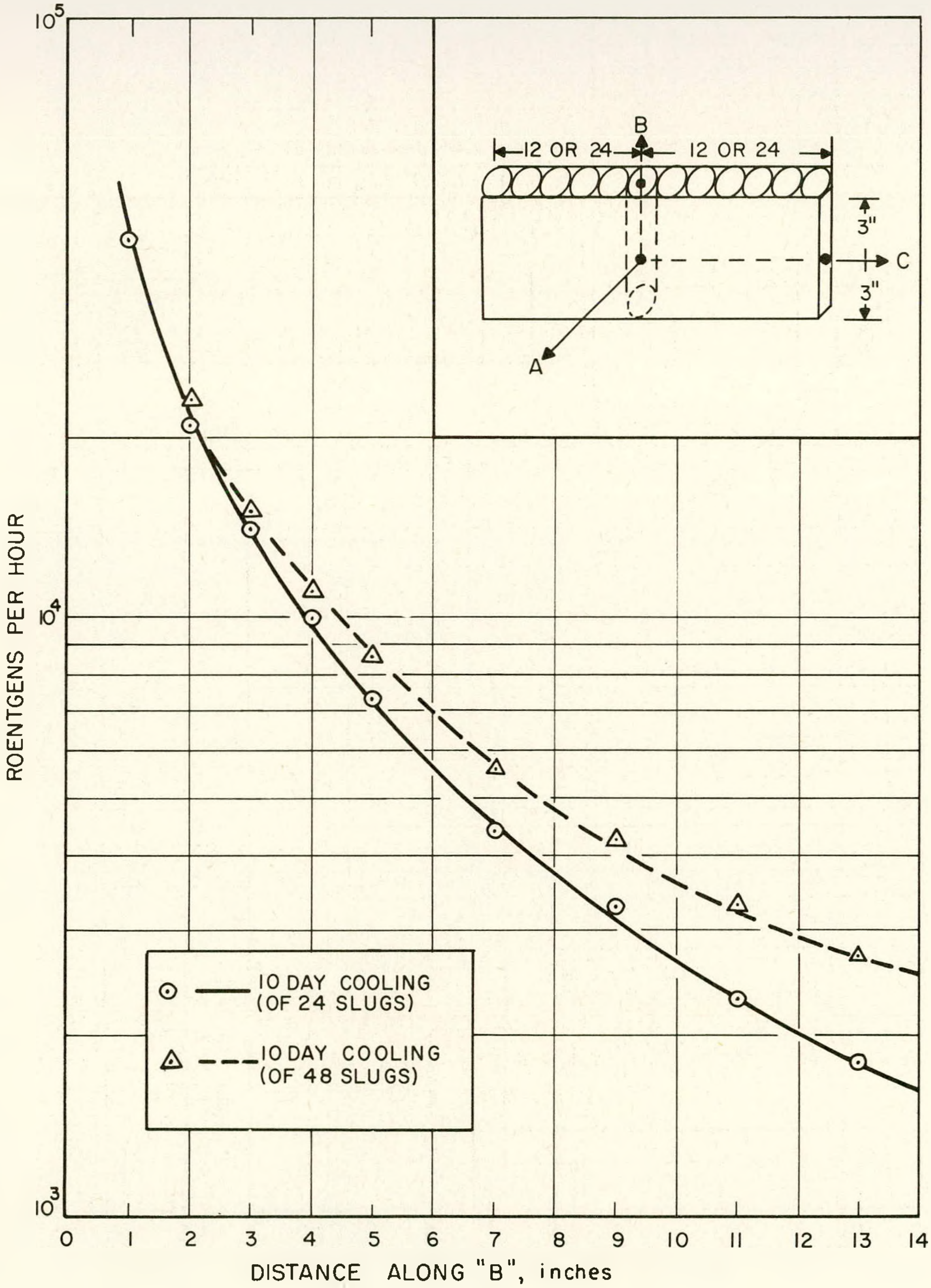


Fig. 18b. Radiation Intensity From a Clip-Type Slug Magazine (Condition: After 10-day cooling following operation for 300 days at 20 Mw, $\phi = 1.7 \times 10^{13}$)

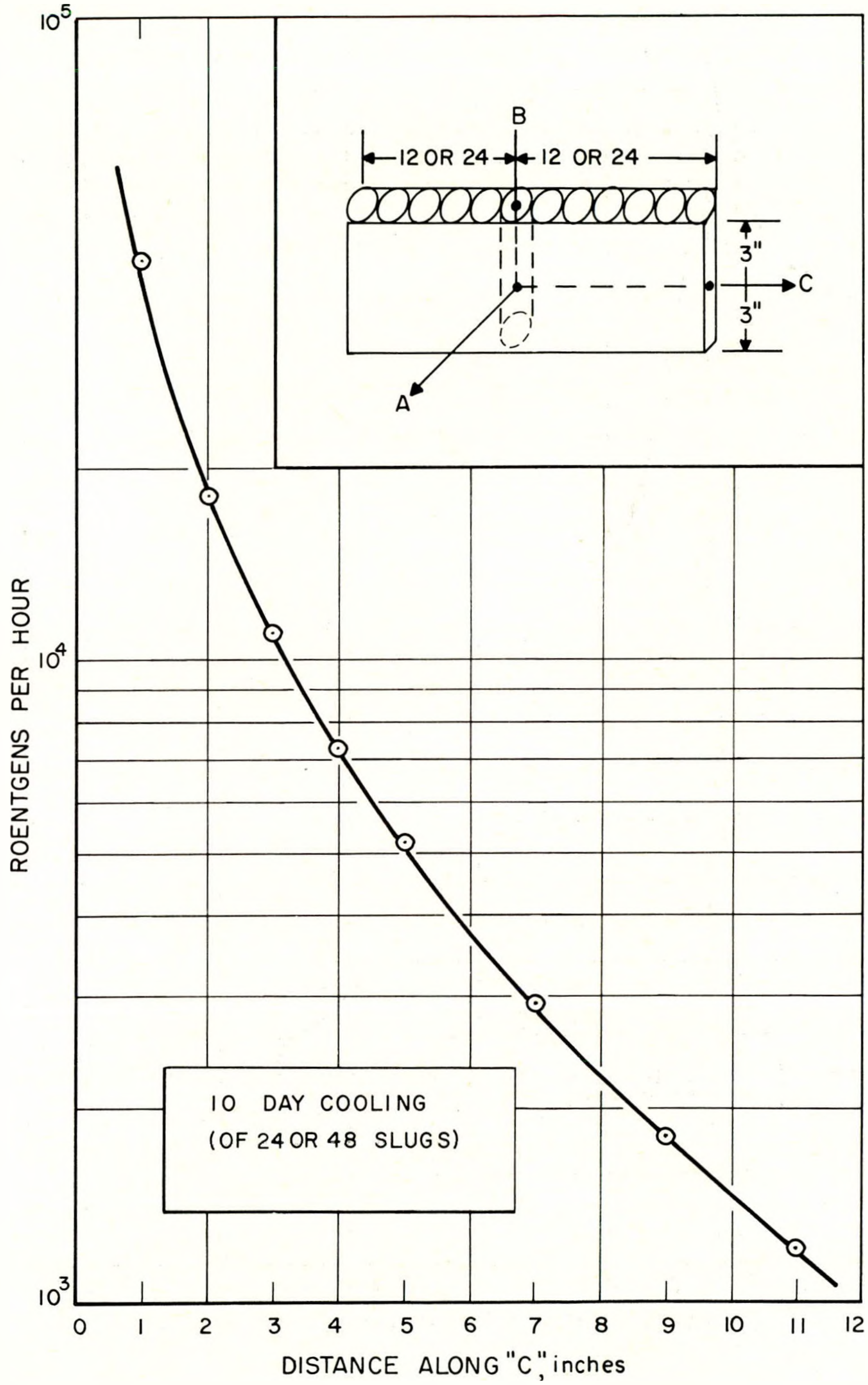


Fig. 18c. Radiation Intensity From a Clip-Type Slug Magazine (Condition: After 10-day cooling following operation for 300 days at 20 Mw, $\phi$ = 1.7 x $10^{13}$)

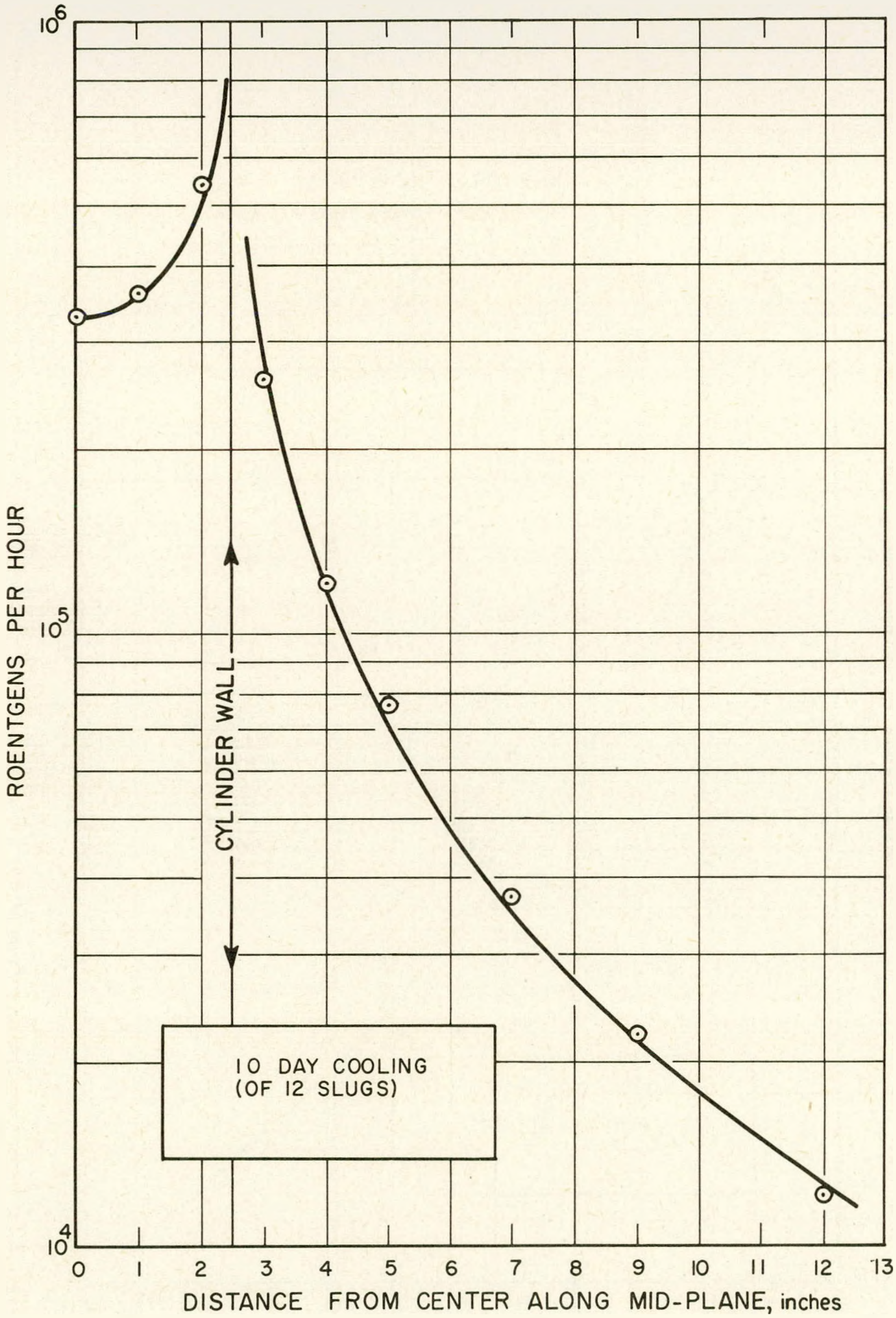


Fig. 19. Radiation Intensity on the Mid-Plane of a Cylindrical Slug Magazine (Condition: After 10-day cooling following operation for 300 days at 20 Mw, $\phi = 1.7 \times 10^{13}$)

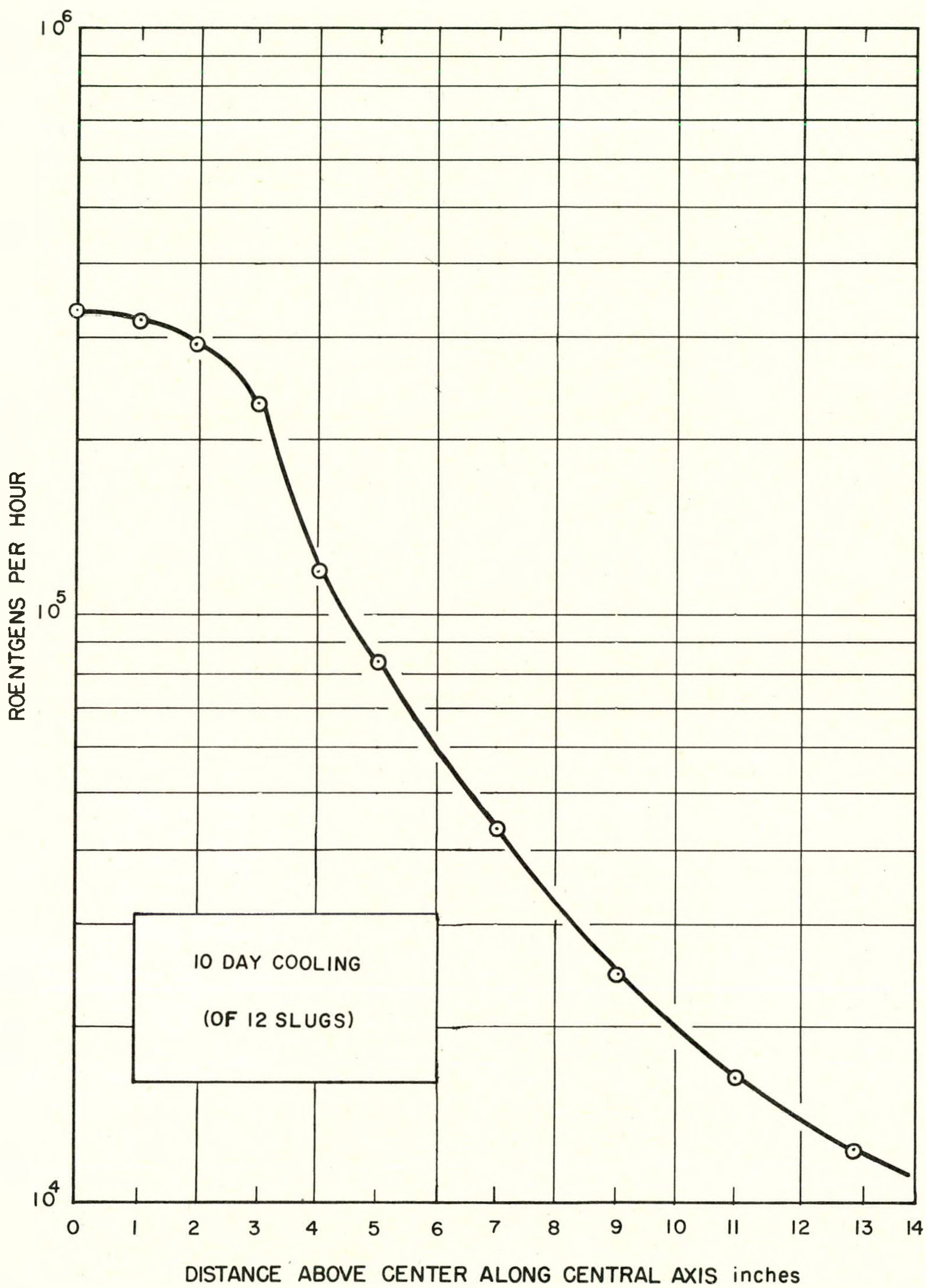


Fig. 20. Radiation Intensity on the Cylindrical Axis of a Cylindrical Slug Magazine (Condition: After 10-day cooling following operation for 300 days at 20 Mw, $\phi = 1.7 \times 10^{13}$)

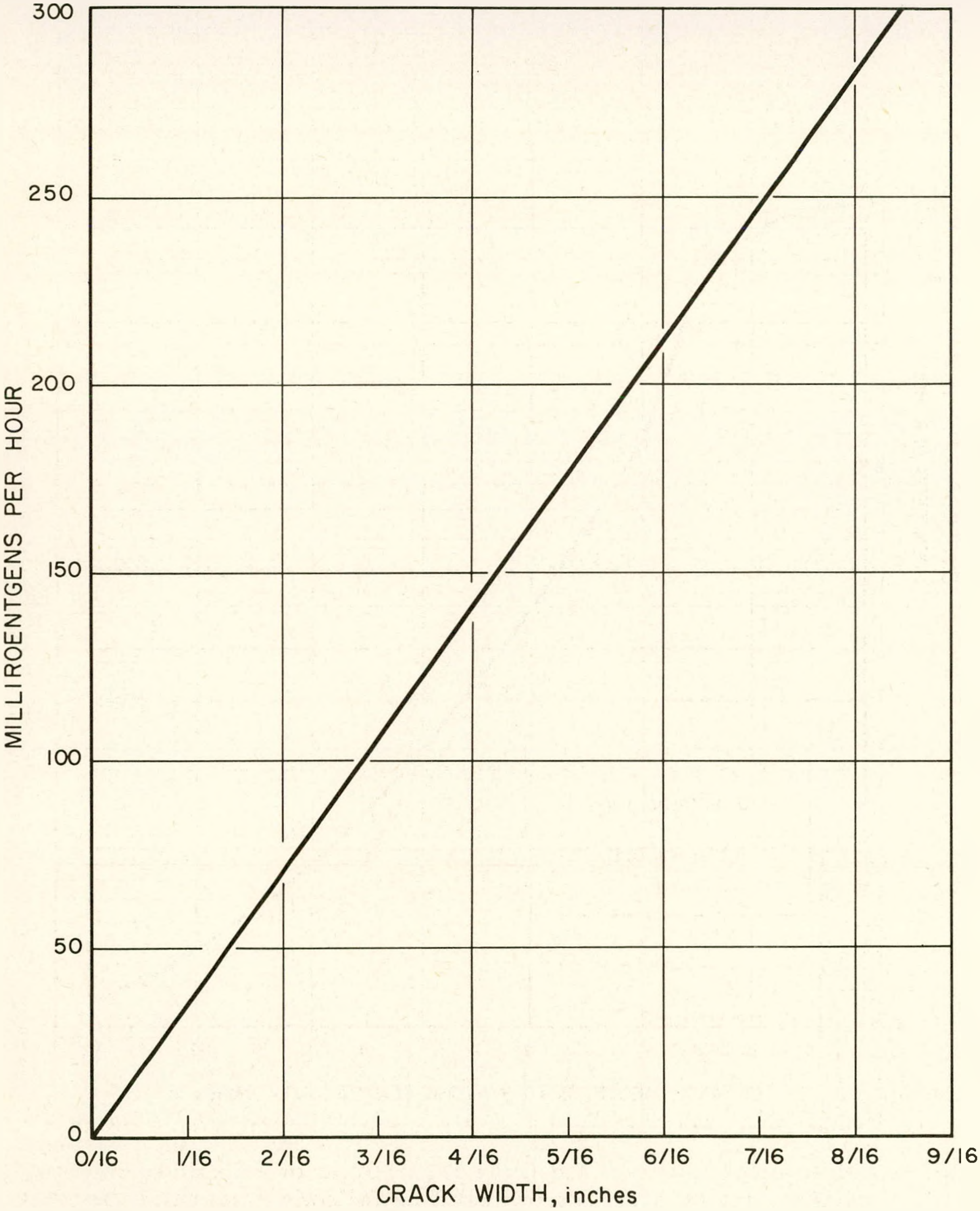


Fig. 21. Scattered Radiation Through the Access Lock Door

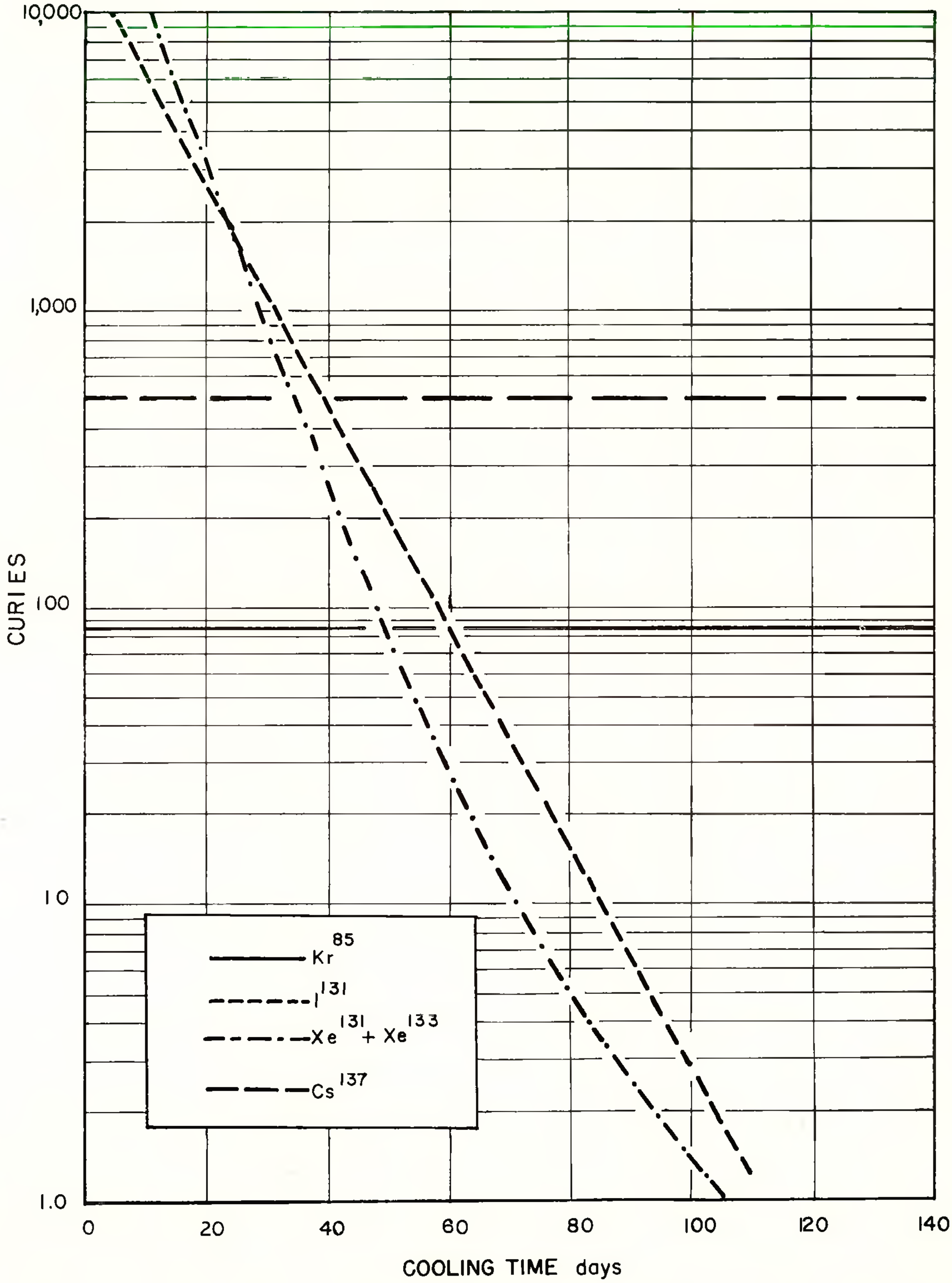


Fig. 22. Activity of Volatile Fission Products

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