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PRE QUARTERLY PROGRESS REPORT

JULY – SEPTEMBER 1956

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

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PRE QUARTERLY PROGRESS REPORT

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ABSTRACT

A "Pyroprocessing Refabrication Experiment," to be located in close proximity to the Sodium Reactor Experiment Facility, will be utilized to determine the technical feasibility of remotely pyroprocessing and refabricating metallic uranium fuel materials. Irradiated SRE fuel will be processed to remove fission products, re-enriched, cast into slugs and remotely refabricated for further irradiation in SRE.

The PRE Program will consist of: a "cold" mockup phase of operations, in which equipment items will be designed and developed for remote operation and maintenance; a second phase of PRE Facility construction; an in-cell phase of "cold" operations in which the performance of all process, operating and maintenance equipment will be demonstrated in the PRE facility; and a final phase of "hot" in-cell operations, in which the complete process is applied to irradiated SRE fuel and the product returned to SRE for further irradiation.

The initial phase of "cold" mockup operations, a three-year period of design procurement, and development efforts, is under way. Major equipment items are being developed and either purchased or fabricated. When operated, modified, and tested, these equipment units will either serve as prototypes of actual process units, or will have been modified to such an extent as to be satisfactory for use in "hot" processing operations.

Space for the cold mockup facility has been allocated and plans have been drawn up for modifying the building enclosure to meet the requirements of the mockup unit. Performance and design specifications for various items of operating, maintenance, and processing equipment are being evaluated and several operating equipment units have been ordered.

Engineering studies involving inert gas purification, radiation damage, equipment components, and remote operating and maintenance techniques are in progress.

I. INTRODUCTION

A. PROPOSAL

It was proposed in NAA-SR-1670, "The Pyroprocessing-Refabrication Experiment" (PRE), that a fairly large scale experiment be undertaken to determine the technical feasibility of remotely pyroprocessing metallic uranium reactor fuel. It was proposed that samples of SRE fuel be reprocessed in a PRE facility located in proximity to the SRE site as shown in Fig. 1 in order to facilitate movement of radioactive fuel to and from the SRE.

The Pyroprocessing-Refabrication Experiment may be compared with the development of an entirely new and extremely complex machine prototype. This prototype system will be constructed with the specific idea that many components will be changed after trial runs.

The development in sequence comprises a cold mockup phase for equipment development, a phase of cold experiments in the PRE facility on the complete reprocessing cycle, and a hot operations phase in which irradiated SRE fuel will be processed. In the first or cold mockup phase, individual pieces of equipment will be designed, constructed, procured, operated, and modified for remote operation and maintenance. In the second phase, all of the individual pieces of modified equipment will be operated together in the PRE facility in a cold operational cycle simulating a complete processing cycle. In the third or hot operations phase, the entire "hot" or radioactive process will be integrated to demonstrate the technical feasibility of the PRE for irradiated SRE fuel.

B. OUTLINE OF OPERATIONS AND PROCEDURES

During the first three years of PRE operation a series of full scale, remotely-controlled experiments using manipulators, simulated cells (plywood mockup), periscopes, windows, etc., will be conducted at the Raymer facility of Atomics International. These experiments will be carried out in an air atmosphere instead of the inert atmosphere specified in NAA-SR-1670 for the decontamination cell. A tilt-pour induction furnace, a vacuum-induction furnace, mold disassembly equipment, slug cropping, dressing and inspection equipment,and a rod loader will all be mocked up in these first experiments. It will then be possible to study:

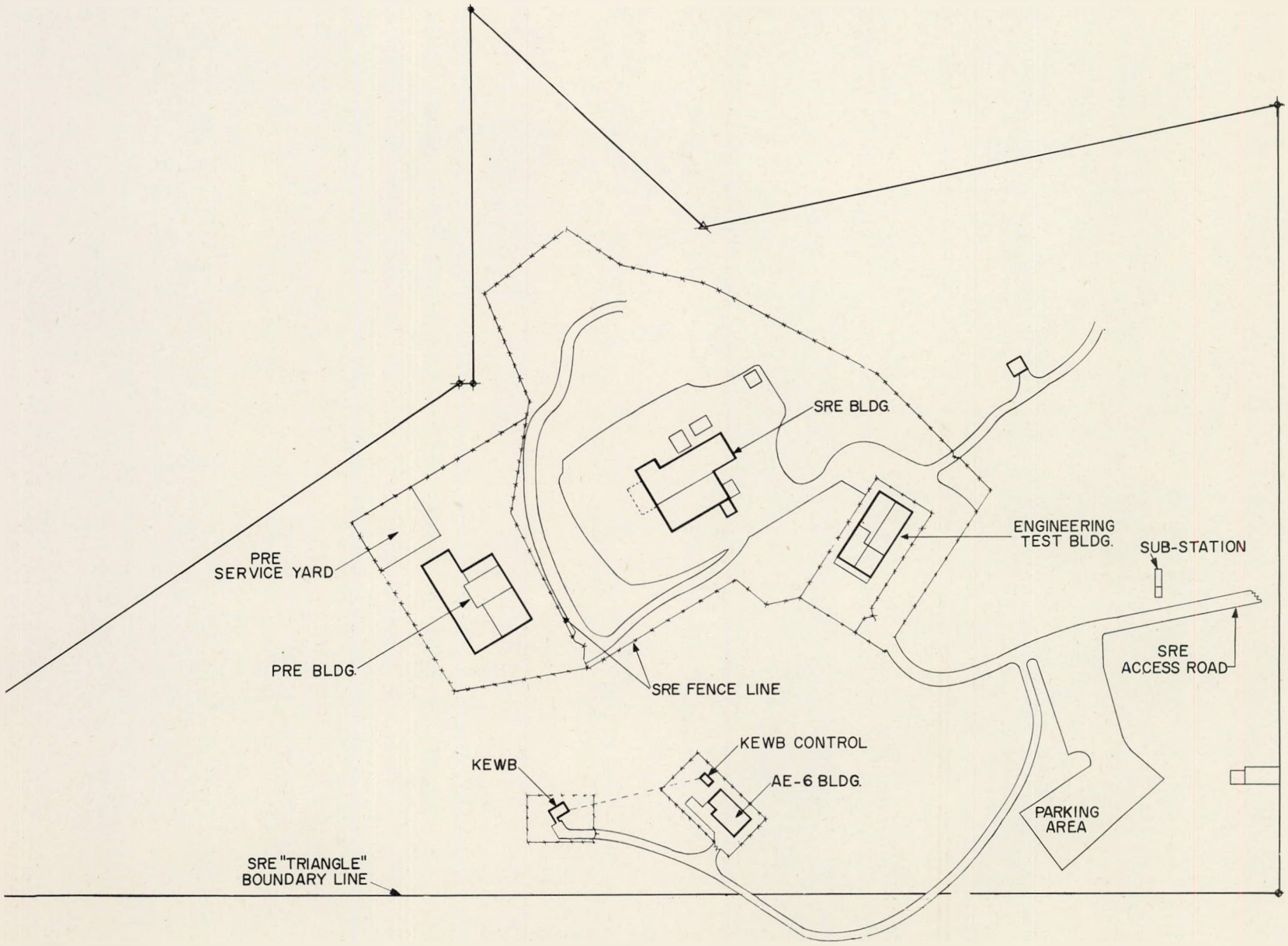

Fig. 1. PRE Site Location Plan

1. Remote loading of, operation of, and ingot casting from the tilt-pour (oxide slagging) furnace
2. Remote charging of this ingot into the vacuum casting furnace
3. Remote operation of the vacuum casting furnace
4. Remote disassembly of the casting molds
5. Remote cropping of the slugs from risers and the dressing of slugs to finished dimensions
6. Inspection of the slugs
7. Remote loading of slugs into fuel cans
8. SRE rod refabrication
9. Inspection of the refabricated rods

It is not likely that all of these experiments will be performed in the sequence listed.

A second series of experiments will be performed with the purpose of studying remote repair and maintenance of all process equipment and of the devices used to operate it (e. g. manipulators, cranes, etc.). Operation and maintenance of lighting and other mocked up cell utilities will be simulated.

It is not anticipated that the original equipment purchased for the mockup will be installed and used for "hot" operations in the PRE. It is probable that all of this equipment will be completely modified, changed, and/or adapted for remote operation and maintenance. If necessary, a second, or even a third model will be constructed for installation in the final PRE hot cells.

After the mockup has been in operation long enough to allow check out of all the major equipment units, design of the PRE building, hot cells and associated facilities will be undertaken. The facility will be completed as quickly as construction schedules permit. It is anticipated that this facility design phase of the program can begin late in the second year of operation. While the building design is under way, additional equipment components will be checked out in the mockup. While the building is under construction, the remote maintenance of the major equipment units will be studied, the final design of the equipment will be completed, and construction or purchase of equipment will be scheduled for installation in the PRE hot cells as soon as they are finished. A fairly long period of "cold" operation in the PRE facility will then be devoted to working out the "bugs" from the in-cell equipment and the facility. Before the facility is permanently contaminated

by introduction of irradiated SRE fuel slugs: a sequence of "cold" operations; followed by a sequence of tracer level operations, from receipt of fuel through completion of a refabricated fuel rod; and at least one cycle of remote maintenance operations will be completed.

C. FACILITY AND EQUIPMENT PROGRAMS

According to present plans the work to be undertaken will fall into the following categories:

1. Mockup Program - Full scale remotely operated equipment unit check-out facility

   a. Structure
   b. Crane
   c. Manipulators
   d. TV
   e. Periscope
   f. Tilt-pour furnace
   g. Vacuum furnace
   h. Lights

2. Building and Facilities

   a. Building
   b. Emergency power
   c. Cooling tower
   d. Generator room
   e. Decontamination room
   f. Waste disposal system
   g. Swimming pool waste storage

3. Cells and Services

   a. Cells #1, #2, and #3
   b. In-cell cranes
   c. Manipulators
   d. Periscopes
   e. Windows
   f. TV
   g. Atmosphere locks
   h. Quick disconnects
   i. Coolant system
   j. Cell lighting
   k. Inert atmosphere filling (Cell #2)
   l. Cell ventilation (Cells #1 and 3)

4. In-Cell Equipment

   a. Gas handling systems
   b. Vacuum furnace
   c. Tilt pour furnace
   d. Slug cropping and dressing
   e. Slug inspection
   f. Slug and waste transfer
   g. Tools (crane and manipulator attachments)
   h. Transfer and fuel can loader
   i. Rod loader, NaK filling, and sealing
   j. Rod inspection

k. Rod handling
l. Waste can sealing
m. Remote maintenance Equipment
n. Remote decontamination Equipment

5. Miscellaneous

a. Radiation damage control
b. Heat Transfer problems
c. Site selection and preparation
d. Instrumentation

Not all of the above categories are now being investigated. Some of them are prerequisite to others which, will therefore require consideration later in the program. This report will deal only with the work on which significant progress has been made during the past quarter.

II. PRE WORK IN PROGRESS

A. RAYMER FACILITY MOCKUP AND SHOP

An unrestricted area of approximately 1000 sq. ft. at the AI Raymer Facility has been allocated for the experimental mockup of PRE. An additional 2000 sq. ft. have been made available for desks, drafting tables, and work benches.

The present roof girder height is 11 feet above the cement floor. An additional 2 ft to 4 ft of ceiling height is available between the girders which are 20 feet apart. The proposed PRE equipment requires a greater vertical clearance for the crane service than is available; therefore, a section of the building roof, between two adjacent girders, will be raised and a cupola will be installed to provide adequate clearance. Design requirements for this modification, shown in Fig. 2, are now under consideration.

A cubic pit which covers half of the simulated cell area and which extends 10 feet below the mockup floor level is included in the design study of the building modification. This pit will house the mockup of the fuel rod loader and will permit installation of vacuum equipment below the floor level.

A 440 volt power line has been installed and a small machine shop has been set up in part of the mockup area. These will be utilized by both the SRE and PRE mockups.

1. Simulated Cell Structure - A cell area 20 by 10 ft has been designed and partly constructed at the Raymer Facility. Plywood and dimension lumber have been used to frame the cell, simulate the liner, and to simulate the 3 1/2 ft-thick cell wall.

2. Manipulators and Periscope - Specifications have been written, bids requested and received, and purchase orders placed for one pair of Mark VIII type, master-slave manipulators, and one thru-the-wall periscope. Deliveries of the manipulators and periscope are expected in mid-January 1957.

3. TV - Specifications for a closed circuit TV system which will be remotely operable and replaceable have been written and bids have been requested and reviewed. Some of the details of this system are still under consideration. Considerable future modification of this unit is anticipated during the evaluation of a satisfactory in-cell TV unit. Resistance to a relatively high ambient cell

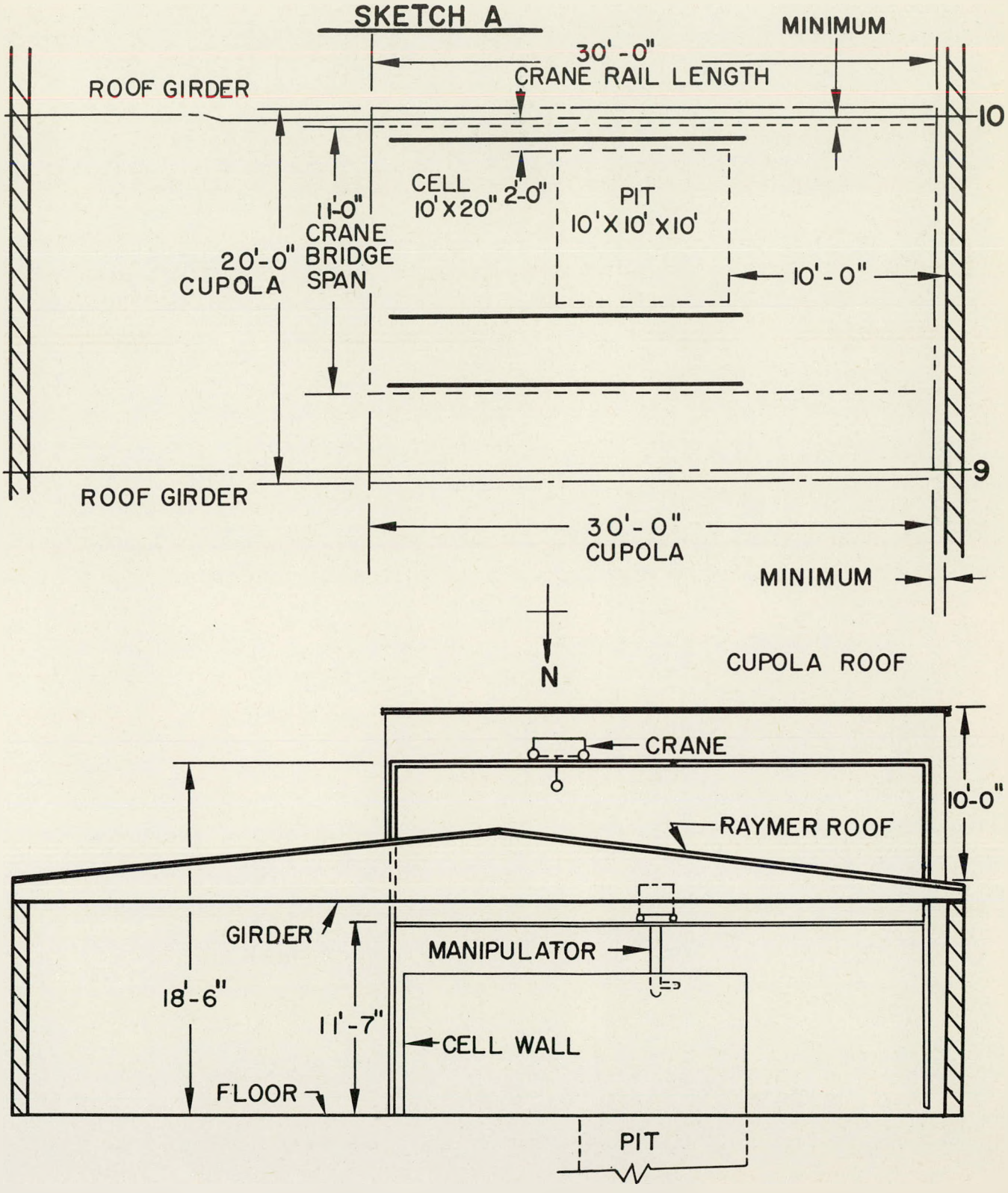

Fig. 2. Facility Modification for PRE Mockup

temperature and a high radiation field, good circuit stability, and good visual resolution are essential to the TV unit. Operation of process equipment from remote locations will be checked out in the mockup.

4. Bridge Crane for Mockup - Specifications for a remotely controlled crane were written and submitted for bids. The only bid received was reviewed and was found to be unsatisfactory because of several limitations on hook approach to the in-cell side and end walls. A close back approach is essential to eliminate dead spots in crane coverage of the cells. Reliability in operation and ease of maintenance are essential for the crane since contact maintenance will be impossible after the cells go "hot". The original specifications were revised and submitted to additional crane manufacturers for bids. One manufacturer has indicated that he will propose a pneumatically operated crane which appears to satisfy technical requirements.

5. Tilt-Pour Furnace - This furnace is the prototype for the oxide slagging furnace to be installed in the PRE process line for partial decontamination of SRE slugs by oxide slagging. Specifications for a tilt-pour, 50 lb (steel), induction furnace were written and submitted for bids. Several bids were received and reviewed. A unit will be selected for purchase and ordered as soon as the technical review is complete. This standard induction furnace will be operated remotely by crane and manipulators in the Raymer mockup to develop methods and techniques applicable to operation of the oxide slagging furnace in the PRE process cells. Ease of remote operation and maintenance is a governing requirement in the specification of this furnace for PRE.

6. Vacuum-Casting Furnace - This furnace is the prototype for the furnace in which partially decontaminated fuel will be re-enriched and centrifugally cast to make SRE slugs. Two quotations for a 50 lb (steel) bottom-tap vacuum induction furnace were received. Both appear to be reasonably close to the operational specifications submitted for bid. However, the designs are quite different. One utilizes a frozen metal seal while the second specifies a stopper rod for retaining the melt. No decision has been made on this piece of equipment. Technical comments are being prepared for each vendor on his submitted proposal. It is probably that both frozen seals and stopper rods will be mocked up before final design is completed.

7. Cell Lighting - Preliminary work was done on the cell lighting systems. Both sodium and mercury vapor lights were considered in terms of available

lumens per units, servicing problems, and heat removal. The lighting problem for PRE is unique in that lights must be serviced remotely because of radiological hazards in the cells. In addition, the cell atmospheres, particularly in the inert atmosphere processing cell, must be retained during light servicing. According to current plans the lights will be located in the cell roof behind a "non-browning" glass plate gasketed to the cell liner. This will maintain the integrity of the cell liner and thus retain the cell atmosphere during lamp changes. The lamp can be reached for removal through either a side or top plug in the cell wall. The relative merits of each configuration are being appraised. This lighting method imposes severe cooling problems since the lamps will be totally enclosed.

B. PRE BUILDING AND FACILITIES

Several preliminary floor plans were prepared and reviewed. Work on the building design was stopped at this point in order to concentrate more heavily on mockup equipment. A "cutaway" view of the proposed PRE building and facility is presented in Fig. 3.

C. IN-CELL EQUIPMENT DEVELOPMENT

1. Inert Gas Handling System - Work has begun on a gas purification system to be designed and constructed for operation during scheduled hot cell experiments using spent Hanford fuel. During this development study an attempt will be made to collect cesium-137, and other volatile fission products on a charged screen in close proximity to the melt during a vacuum furnace run.

In order to maintain an inert atmosphere in the PRE process cell, it will be necessary to remove from the inert gas atmosphere all moisture and oxidants which either leaked into the cell, outgassed from materials in the cell, or resulted from chemical reactions in the processing cycle. Consequently, a bleed stream of the process atmosphere will be exhausted through a decontamination system consisting of a filter, a liquid metal bubbler acting as a "getter", a heat exchanger, a positive displacement pump, a regenerative heat exchanger, and a low temperature trap for absorbing high boiling point impurities. A schematic flowsheet of this system is shown in Fig. 4. A filter housing and a liquid-metal gas bubbler are under construction for preliminary experimentation.

2. Cold-Short Fracturing of Uranium Slugs - In a series of experiments six uranium rods were broken at low temperatures by impact loading as shown in

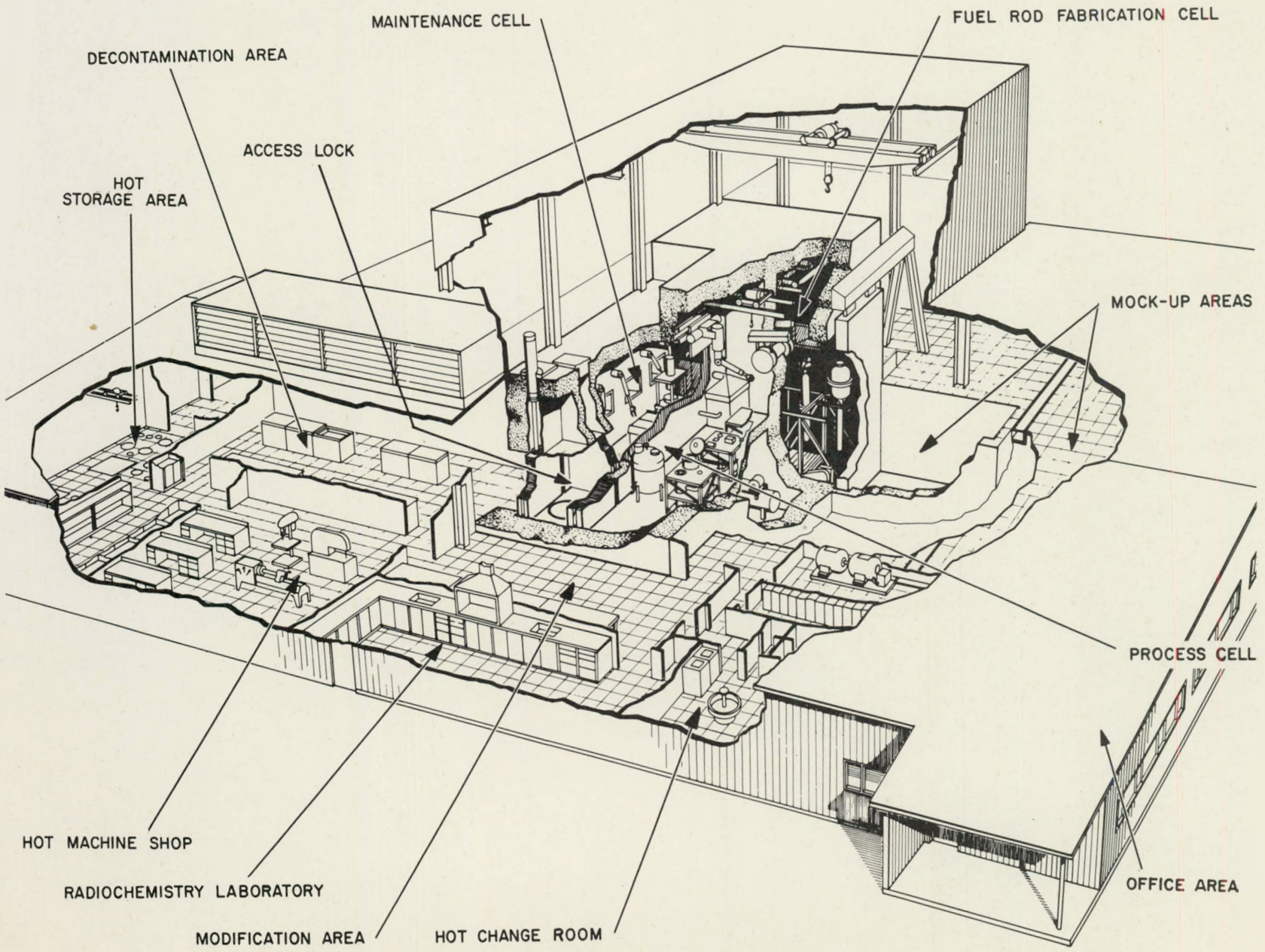

Fig. 3. Proposed PRE Facility (Cutaway View)

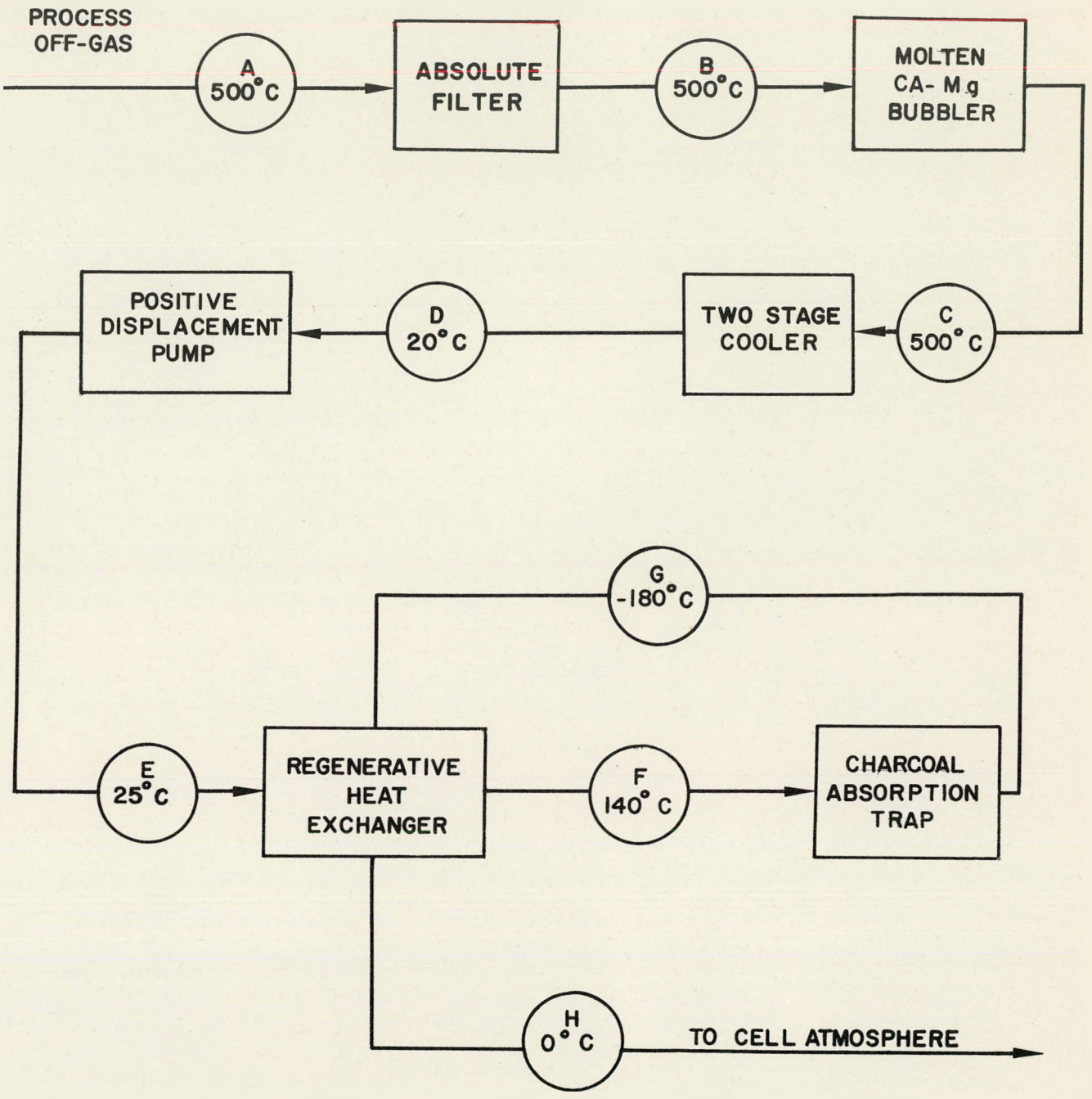

Fig. 4. Flowsheet of Inert Gas Purification System.

Fig. 5. These experiments were all of a preliminary nature and were performed using a small five-ton punch press. Slugs were broken at various reduced temperatures with and without notches. Notches were either precut or formed during impact loading on the "atuonotch" device shown in Fig. 5. The best breaks were achieved at temperatures below -130° C with a very small precut circumferential notch 0.005-in. deep. The progress of a typical break at -170° C of a 3/4-in. diameter slug provided with a 0.030-in. circumferential notch, and taking a tup penetration 1/8-in. deep is shown in Fig. 6. These photographs are successive frames of a high-speed movie film taken at 3000 frames per second. The broken ends were dressed to a plane surface, perpendicular to the long axis of the slugs, and within the tolerances specified for SRE slugs, by taking a 0.010-in. cut off the fractured end.

Difficulties were experienced in maintaining the required low temperatures for satisfactory cold-short fracturing. The problem of temperature control is now being resolved.

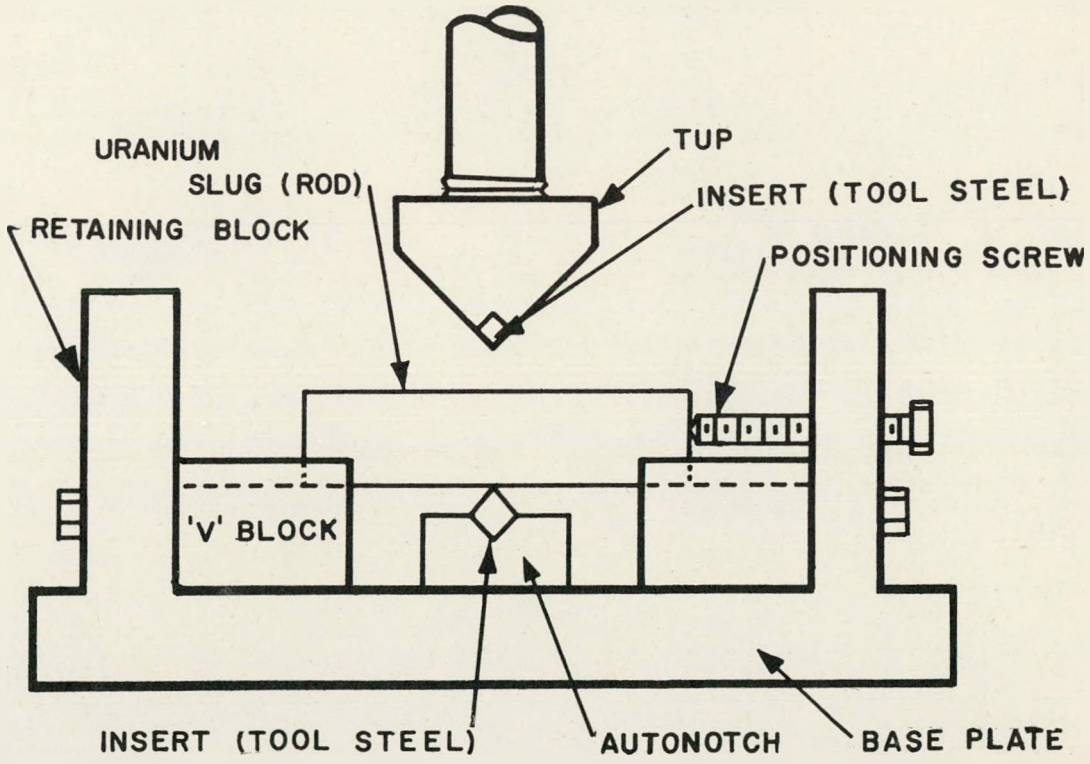

Fig. 5. Diagram of "Autonotch" (Impact Loading and Shearing Apparatus)

Fig. 6. High-Speed Photographs of Cold-Short Fracturing

The economic and technical aspects of facing the broken ends of uranium slugs are being studied. Both abrasive cut-off and electrical discharge machining techniques are being considered. Although the cost of the electrical discharge equipment is greater, the advantages of the technique such as control of in-cell contamination, greatly reduced process loss of expensive fuel materials, and reduced waste handling requirements may compensate for higher equipment cost.

3. Fuel Rod Loader - PRE-made fuel slugs will be loaded into stainless steel fuel cans and then fabricated into fuel rods for a recycle through the SRE. Several techniques by which the slugs can be clad and prepared for re-irradiation in the reactor are being evaluated. The primary requirement of each of these methods is the absolute exclusion of non-inert atmosphere from contact with the slugs during rod refabrication.

The original concept of fuel-rod transfer from the process cell utilized a magazine resembling a revolver barrel in principle. Radiation intensity calculations disclosed a potential problem with gasket and seal maintenance in such a device. Therefore, two feasible techniques are now being studied for slug transfer from the process cell to the refabrication cell. One method utilizes the original concept of a helium-filled magazine as presented in Fig. 7 to remove the slugs from the inert atmosphere of the process cell and to "lock" them into the inert atmosphere of the fuel rod fabricating device located in an air-filled cell. The second method uses an inter-cell transfer chute presented in Fig. 8, for loading and transfering the slugs from the inert atmosphere process cell directly into an inert-gas-filled SRE-type fuel can which may be subsequently placed in the fuel-rod fabricating device. The operating techniques involved in the two schemes are now being evaluated on the basis of preliminary designs of the equipment required for each method of fuel slug transfer. Mockup experiments are being devised to measure the diffusion of refabrication cell air into the loaded fuel rod during the movement of the loaded rod from the transfer chute to the rod fabrication device where it remains for NaK filling, capping, and sealing under reduced helium pressure. Equipment is being assembled for these experiments.

D. MISCELLANEOUS

1. Radiation Intensity Determinations - Calculations were made to determine the expected radiation intensities from irradiated fuel sources for various configurations of in-process materials. These calculations indicated that there

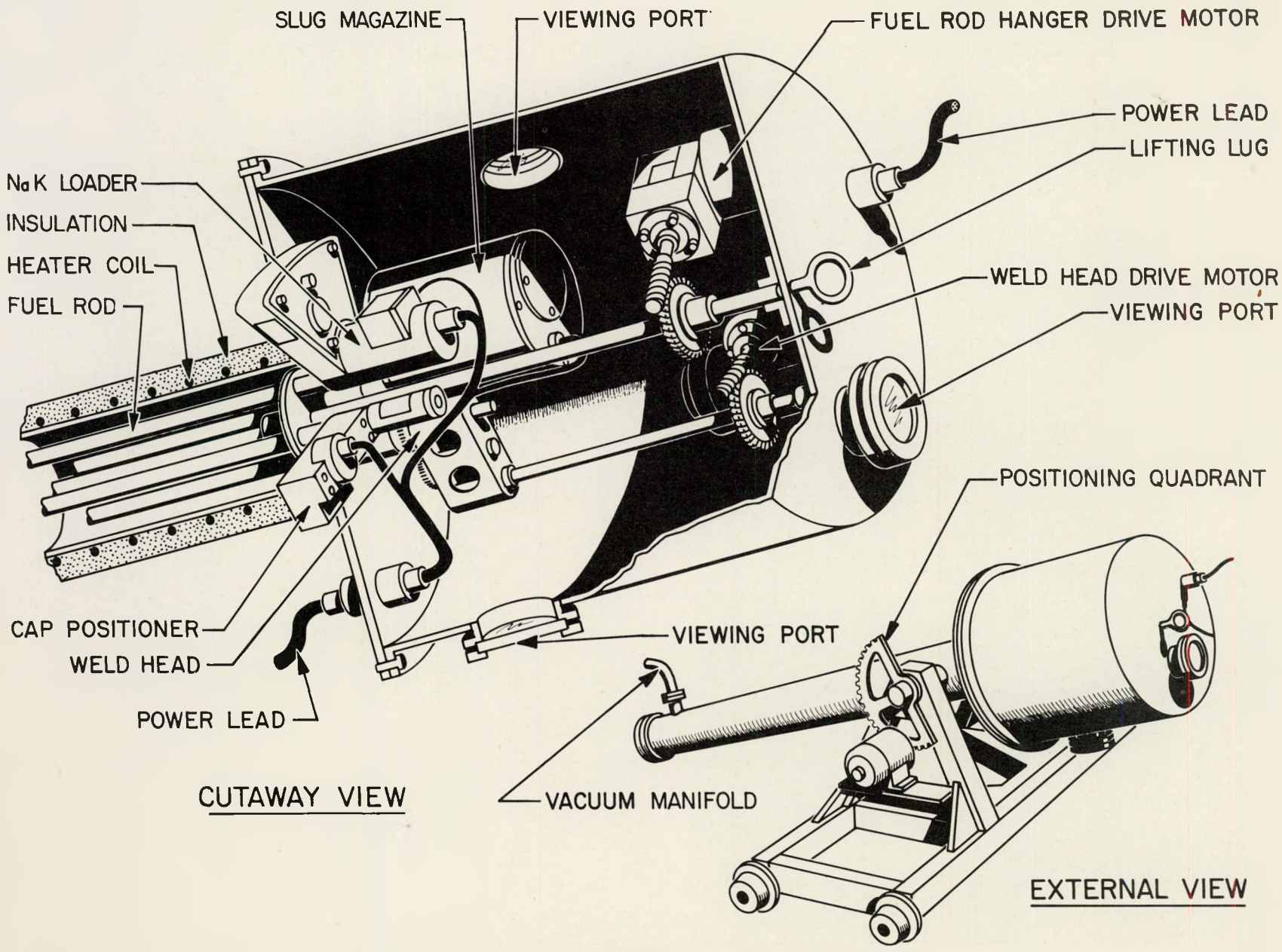

Fig. 7. Original Concept of Fuel Rod Loader

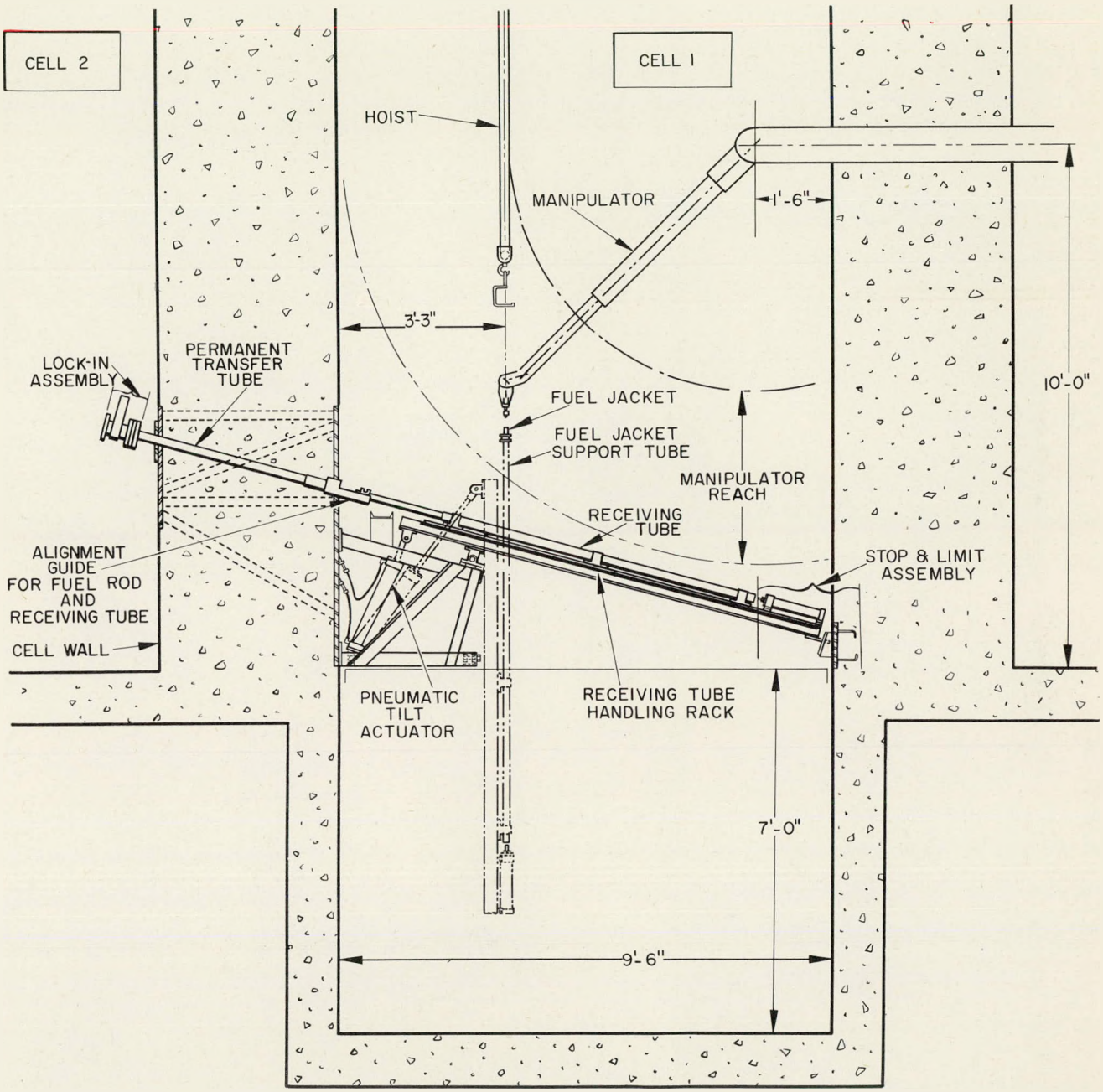

Fig. 8. Preliminary Layout for Inter-Cell Slug Transfer

may be two points in the fuel cycle where radiation will present serious problems. Multiple meltings in the tilt-pour slagging furnace will produce so much radiation-induced heat in the oxide-slagging crucible that cooling will be necessary at all time after the first few melts. It is possible that continued cooling may be required for a period of up to one year during storage of crucibles and waste materials.

III. PLANS FOR SECOND QUARTER

The major portion of the work planned for the next quarter comprises completion of the technical review and purchase of the following mockup equipment and/or services:

1. The tilt-pour furnace to be ordered for an expected 1 March 1957 delivery.
2. A vacuum furnace to be ordered for 15 May 1957 delivery.
3. Modifications of the Raymer Facility to house the mocked-up in-cell crane, to be completed by 1 January 1957. Crane installation will be completed shortly thereafter.
4. TV camera and monitor to be ordered for delivery during the last calender quarter of 1956. This will be installed and operated in the Raymer mockup.
5. Equipment for mockup of in-cell lighting which will be assembled and construction which will be initiated.

Continuation of experiments on collection of volatile gases and of fission products from vacuum furnace melts is planned. Results of these experiments will be correlated with those obtained for experimental melts now planned for the Vanowen hot cells. Future work will be done on expanding the techniques for cold-short fracturing of uranium slugs and on methods for slug preparation and inspection. Design work on hot cell layout, vacuum and gas-handling systems, access lock, fuel rod fabricator, and wire wrapper will continue. Detailing of the fuel rod fabricating device will begin and procurement of parts for assembly will be started as soon as a sufficient number of details are available. Further work will be done on investigation of in-cell lighting and on material handling. The problems associated with these in-cell services for PRE are unique in that once the cells become "hot" no contact maintenance will be possible, particularly in the process cell. Extreme care and forthought must, therefore, be exercised to permit servicing of lights, cranes, and manipulators from outside the cell.