THE THORIUM-URANIUM RECYCLE FACILITY
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MASTER

ABSTRACT

The Thorium-Uranium Recycle Facility provides sufficient space and other facilities for the simultaneous testing and demonstration of two processes for the remote processing of fuel elements, fuel reconstitution, and refabrication into fuel assemblies. Process equipment will be located in two large remotely maintained cells, and two smaller directly maintained cells. An unshielded cell and a shielded service cell with a special remote crane and manipulator system are provided to achieve easy removal and installation of remotely maintained equipment. Special provisions have been made for future conversion of these cells to inert atmosphere, for replacement of the viewing window gas seal plates, and for extinguishing cell fires.

INTRODUCTION

The Thorium-Uranium Recycle Facility (TURF) is being constructed at Oak Ridge National Laboratory to aid in the development and demonstration of economic remote methods for reprocessing irradiated thorium based fuels and refabricating the fertile and fissionable material into fuel elements suitable for reuse in a power reactor. The methods to be developed in this facility are those involving remote handling, which will include those processes yielding minimal to intermediate decontamination. Previous work at ORNL in the Kilbrod facility^{1,2} has demonstrated the potential for such fabrication techniques on metal clad bulk (Th-U)O₂ sol-gel³ derived fuels under semi-remote conditions.

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The attractiveness of remote fabrication for thorium based fuels stems in part from the radioactivity of ^{232}U and its decay daughters which are always present to some degree in irradiated thorium. The effects of ^{232}U in the fissile product from irradiated thorium can be minimized by highly decontaminating the uranium just prior to fabrication, in which case direct fabrication techniques may be employed.⁴ However, this method is limited to the fabrication of fuel having relatively low ^{232}U content, and by the necessity to store the recycle thorium for a period of ten to fifteen years prior to its return to the fuel cycle. On the other hand, use of shielded remote fabrication methods will permit the use of simplified reprocessing methods yielding only modest decontamination factors, and will allow the thorium to be recycled immediately.

The TURF is designed for use in the development of a wide variety of processes for the several fuel types using the thorium cycle. It is intended to be useful over a long period with sufficient space to accommodate the equipment for processing and fabricating two diverse fuel assemblies simultaneously. Sufficient shielding is provided to protect personnel from radiation emanating from fuel assemblies which have been irradiated to the levels now anticipated in power reactors. While the equipment which can be installed in TURF may not be of full production size, it can be of adequate size, and sufficiently production-like in design, to allow collection of meaningful data relative to the economic feasibility of the various thorium fuel cycles.

The facility conceptual design was discussed earlier.⁵

This paper contains a general description of TURF, which is now under construction, and discusses in some detail certain of the more unusual features.

GENERAL DESCRIPTION

The building is a three story concrete block structure with partial basement. Figures 1, 2, and 3 show the layout and major dimensions of the three floors. The customary services and operating spaces are provided plus some additional features. Of interest among these features are an enclosed receiving area for incoming equipment and casks, a fuel storage basin at the first floor level, and a 50-ton building crane which can carry heavy loads from the receiving area to any point on the top of the cell bank as well as to the fuel storage basin. Most of the building is to be maintained at subatmospheric pressure in order that it may serve as a confinement barrier in the event of accidental release of radioactivity outside the cells.

The cell bank consists of four heavily shielded (5-1/2 ft normal concrete) process cells, two shielded service cells, and an unshielded cell and air lock shown in Fig. 4. The design of the individual process cell was determined by the nature of the operation to be performed therein. Chemical operations are planned for Cell G, whereas mechanical operations wherein only partial confinement of radioactive materials is attainable are planned for Cells C and D. These mechanical operations will include those which are incident to fuel reprocessing plus those which are required for fuel reconstitution and fuel element fabrication. Cell E will be used for fuel element fabrication and assembly operations which are subsequent to encapsulation of the fuel into tubes or other containment devices and removal of surface contamination from that device. The four process cells are arranged in a line and have a common width of 20 ft. Cells E and G are

Fig - First Floor Plan, A. R. Irvine - TURF

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Fig. 3 - Third Floor Plan, A. R. Irvine - TURF

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Fig. 4 - Cell Bank, A. R. Irvine - TURF

ORNL DWG 64 5605R1

each 16 ft. long by 30 ft. high. Cells C and D have a common height of 24 ft. and lengths of 33 ft. and 41 ft., respectively. Cell B is to provide a radiation lock for larger items which are being taken into or removed from Cells C and D and space for decontamination of equipment. Another shielded service area, Cell F, is located in the basement area, in part below Cell B; access is provided to Cell F by a hatch in the floor of Cell B. Cell F is to be used for storage of equipment. Of the shielded cells, all have stainless steel liners except Cells E and F. Cell A, which is unshielded, will be used for gloved and contact maintenance of equipment which has been partially decontaminated. The air lock will allow transfer of moderately large items into and from Cell A without violating the confinement barrier.

Identical services generally are provided at 8-ft. intervals around the perimeter. Among these services are a viewing window or a plugged opening into which a viewing window can later be installed, master-slave manipulator sleeves, ten four-inch diameter bent sleeves and three 6" x 8" diameter stepped sleeves through which services can be brought to the process equipment, five one-inch pipes which can be used to bring in fluids, radioactive waste drains, and two iodine quartz lamps. Other services which are provided, but not at 8-ft. intervals, are sleeves for future installation of periscopes, a small items entry tube, and a pneumatically operated solid sample removal device. Service penetration design remains basically unchanged from conceptual design.⁵

Maintenance generally will be by remote methods in all the shielded cells except Cells E and G. Cell G can be made common with Cell C by removing a portion of the wall between the two cells, at which time it will convert to remote maintenance. Some personnel access for maintenance will

be possible in Cells B and F because of the intermittent and lower levels of radioactivity in these two areas.

Access to the cells is attainable by a number of means. Access to Cells C and D for large equipment items is through the air lock, into Cell A, and thence through Cell B. A fifty-ton-capacity motorized transfer dolly system is provided to carry heavy objects from the air lock into Cell B. Plugged holes, for future installation of transfer ports are provided in the ceilings of Cells C, D, and G, in an external wall of Cell B, and in the dividing walls between Cells C and G, C and D, and D and E. An additional large shielded opening between Cells D and E is provided for future installation of a mechanism for transfer and cleaning of two different types of fuel elements simultaneously. The opening is designed for vertical transfer of rods up to ten feet in length. One or more entry points for small devices is provided for each shielded process cell. Pneumatically actuated transfer devices are provided for Cells C, D, and E. Access for installation and maintenance of large equipment items in Cells E and G is by means of a roof plug. Roof plugs are also provided for Cells C and D for use in installing very large equipment.

SPECIAL FEATURES

Cell Ventilation and Confinement of Radioactivity

Ventilation of all cells is by air drawn from the occupied areas of the building through "absolute" filters and thence through the cells on a once-through basis. In addition to the "absolute" filters on the cell air inlet, specially designed check valves are provided to prevent backflow of

gas from the cells to the occupied areas in the event of an accident resulting in an increase in cell pressure. The air leaving the cells is filtered at the point of exit by "dry" type filters having a 0.3 micron DOP efficiency of 95% and sufficient strength to resist differential pressures up to approximately 15 inches of water without failure, although the normal operating differential pressure will be of the order of one inch of water. After leaving the cell area the air will be filtered by two banks of "absolute" filters in series and then released to the atmosphere from a tall stack.

Although all the cells will operate initially with an air atmosphere, provisions are made for future addition of an inert gas cleanup and cooling system for all cells except Cell E. Seals on cell openings are all designed for minimum leakage, for reasons of confinement of radioactivity as well as to provide for future inert atmosphere operation.

In-Cell Crane and Manipulator Systems

The remote maintenance philosophy for Cells C and D depends entirely upon an in-cell crane system and an electro-mechanical manipulator system which operate in Cells A, B, C, and D. The crane system consists of two bridges having a net load capacity of 10 tons, two single-speed 5-ton capacity hoists, and such other bridges, traction units, etc., as are necessary to move a crane bridge or hoist from Cell A into Cells B, C, and D and to return it without the necessity for personnel entry into the process cells, even in the event of equipment failure as all moving parts of the crane system located in Cells C and D are remotely removable and replaceable. Fig. 5 is an isometric sketch of the major components of the in-cell crane system

Fig. 5 - In-Cell Crane System, A. R. Irvine - LURF

ORNL-DWG 64-3763 A

which operates in Cells A, B, C, and D. Under normal circumstances, one crane bridge with hoist will be located in Cell C and another in Cell D. To understand the functions of the system, let us assume that it is desired to bring an object from Cell D into Cell A: (1) The object is picked up by the hoist and the crane bridge and traversed to a point where it is centered in front of the door between Cells B and D; (2) the door between these two cells is then opened and the transfer bridge translated such that it butts against and mates with the crane bridge; (3) the crane hoist is actuated to move from the bridge in Cell D on to the transfer bridge; (4) the transfer bridge is translated such that no part of the bridge is in the door opening between Cells B and D and the door closed; (5) the sliding door between Cells A and B is opened and the transfer bridge mated with the fixed monorail in Cell A; and (6) the crane hoist is powered to run into Cell A. The crane bridges in Cells C and D are so arranged that, by means of a fixed monorail and a transfer trolley, they can be removed into Cell B and thence into Cell A. This is accomplished by raising and translating the transfer bridge to mate with a fixed rail in Cell C or D, and by using a traction unit normally stored in Cell A, to pull the crane bridge and transfer trolley onto the bridge in Cell B and thence into Cell A.

Electrification of the hoist on the bridges and on the fixed monorail in Cell A is by means of electric trolley pickups of a special design. The transfer bridge in Cell B obtains its power by means of a pendant cable whereas the bridges in Cells C and D get their power from a cable reel mounted on the bridge and remotely plugged into a receptacle on the wall of the appropriate cell. The bridges are designed to automatically plug into an electrical receptacle when a bridge is moved into position in either Cell C or D.

An electromechanical manipulator system is provided to operate on a set of rails in Cells A, B, C, and D some nine feet below the in-cell crane system just described. The principal parts of the manipulator system are shown pictorially in Fig. 6. The electrification method for the manipulator system is similar to that of the in-cell crane system except a cable system rather than trolley pickups is used between the bridge and carriage. Means are not provided for self movement of a manipulator bridge from cell to cell. Instead the manipulator bridge is so arranged that it can be picked up by two hoists operating on a single crane bridge and carried tightly coupled to that bridge from one cell to another. The manipulator unit is a Programmed and Remote Systems' model 3000 with a tube hoist having a travel of 13 ft. 6 in. and a net lifting capacity at the shoulder hook of 1000 lbs. Two electromechanical manipulators can be operated simultaneously in either Cell C or Cell D, whereas only one unit can be installed in Cell B. Operation of an electromechanical manipulator in Cell A is for maintenance purposes only.

A similar crane and manipulator with equivalent capacities are provided for Cell E; however, installation, removal, and maintenance is entirely by contact methods through the roof plug. A 5-ton-capacity crane system is also provided for Cell F. In this case, installation and removal of the bridge for maintenance is through the hatch in the floor of Cell B. Electrification of this crane system is again by cable reel from the wall to the bridge and electrical trolley pick-ups on the hoist carriage. No means of remote retrieval of a failed bridge in this cell is provided inasmuch as the radiation level will be relatively low and the probability of failure is reduced by both the lower radiation field and relatively low use rate.

Fig. 6 - Electromechanical Manipulator System, A. R. Irvine - TUF

Shielding Doors

Three steel shielding doors in this facility provide access between Cells A, B, C, and D. The door between Cells A and B weighs approximately 50 tons; is 15 in. thick, 7 ft. wide, and 17 ft. high; and moves horizontally on specially designed roller mounts. This door is operated by an electric motor driving two screws which are connected to the steel door. The other two doors weigh approximately 20 tons each; are 12 in. thick, 6 ft. wide, and 15 ft. high; and move vertically. These doors are also operated by electric motor driven screws which can move them from one extreme position to the other in eight minutes. They are so designed that failure of any of the mechanical parts will not necessitate entry into Cell B. Repairs can be made by removing a portion of the housing and replacing the faulty equipment with new parts.

All three doors are equipped with inflatable seals which effectively isolate the individual cells from each other. Replacement of these seals will be by contact methods.

Window Design

The viewing windows for the heavily shielded cells are of two different types: (1) lead glass and oil; and (2) a composite glass and zinc bromide window. The first type is to be used in openings in the high density (3.3 sp. gr.) concrete walls of Cell B, whereas the second type is used in openings in the normal concrete walls of the other cells. All windows consist of an embedded steel window form, a gas seal plate (sometimes called an alpha seal) on the radioactive side, and a tank containing the shielding media. The design of these windows is an outgrowth of several earlier designs.^{6,7,8,9,10} There are, however, two features which distinguish these windows from their

predecessors. They are; (1) the gas seal plate is replaceable from either the non-radioactive side or from the radioactive side, and (2) the zinc bromide window tanks are lined with copper clad steel plate instead of copper plate. The principal features of this window are shown in Fig. 7. This design will allow the maximum use of contact type operations in replacement of a gas seal plate at times when the activity level in the cell is relatively low and when leakage of air into the cells can be tolerated. If either of these conditions does not prevail at the time when a seal plate must be replaced, the plate may be replaced from the radioactive side by entirely remote means without exposure of personnel to radiation and with no leakage of air into the cell.

Cell Fire Protection

The fire protection system for a hot cell must meet requirements which are not usually encountered in normal fire protection systems. Many factors combined to render the more conventional water sprinkler system unacceptable for use in this cell bank. Carbon dioxide was the most desirable from the standpoint of nuclear safety, damage to equipment and disposal of fire extinguishing media; but experience in another facility at ORNL had shown problems with filter plugging by an accumulation of condensed moisture from the air, or of finely divided CO_2 particles. That problem is to be avoided in this facility by admitting only gaseous CO_2 into the cells.

In the TURF system (see Fig. 8) CO_2 is evaporated in the storage tank before withdrawal, superheated before passing into the gas distribution piping, and reduced to a controlled pressure before passing through limiting flow orifices. The CO_2 is stored in two large horizontal containers which

Fig. 7 - Viewing Window Construction, A. R. Irvine - TURF

hold approximately twice the amount of CO_2 that is needed for a discharge into the two largest cells. The evaporation of CO_2 in the vessels reduces the remaining liquid temperature to 0°F by the end of the second discharge. The pressure reducing valves, which are slightly modified standard units, serve as dual purpose selector and pressure reducing valves. Interlocks are provided for the control system to prevent overpressuring a cell with CO_2 . The control system is of somewhat intricate, though otherwise conventional, design. All the system components are tested and approved by a fire underwriter.

SUMMARY

The TURF will furnish versatile shielded space for carrying out an investigation of virtually any recycle problem associated with the thorium- ^{233}U fuel cycle. The facility contains a variety of different types of cells that allow operation and maintenance under several different philosophies. Sufficient space is available to simultaneously carry out all phases involved in the recycle of two different fuel elements.

Notable among the design features of the facility that permit such an ambitious undertaking are:

- (1) A cell ventilation system that provides for a high degree of confinement of radioactive particulate and for future conversion to an inert atmosphere.
- (2) An in-cell crane and manipulator system to be used for remote maintenance operations.
- (3) A more versatile gas seal plate design for the viewing windows.

- (4) Access to the cells by several different means, including large shielding doors.
- (5) A cell-fire protection system specially engineered for these cells to prevent plugging of exhaust filters and overpressuring of the cells.

Construction was started early in 1965 and is scheduled for completion in 1967.

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