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THORIUM-URANIUM RECYCLE FACILITY

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METALS AND CERAMICS DIVISION

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THORIUM-URANIUM RECYCLE FACILITY

John M. Chandler[1]

ABSTRACT

A Thorium-Uranium Recycle Facility (TURF) Pilot Plant was constructed at ORNL to provide the shielded and safely contained space in which to demonstrate processes and provide economic information for remote fuel cycle technology. The building is a three-story masonry structure and provides work areas and containment for four heavily shielded process cells, two shielded service cells, and an unshielded gloved maintenance area with attendant air lock. Special provisions were made for future conversion of these cells to inert atmosphere and for extinguishing cell fires. A special remote crane and manipulator system is provided for operation and maintenance.

INTRODUCTION

The Thorium Utilization Program at the Oak Ridge National Laboratory (ORNL) is directed toward the prudent and economical exploitation of thorium, especially through the development of suitable fuel cycle technology for thorium fueled reactors. A pilot plant to provide the shielded and safely contained space in which to demonstrate processes and provide economic information for all phases of remote fuel cycle technology was authorized by Public Law 88-72, dated July 22, 1963, in the requested amount of $7.275 million. The Thorium-Uranium Fuel Cycle Development Facility (TUFCDF), now named Thorium-Uranium Recycle Facility (TURF), was intended to be used initially to demonstrate the feasibility of remotely fabricating metal-clad fuel elements for water-cooled reactors, with flexibility to accommodate a remote fabrication line for graphite fuel

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[1]On loan from the Chemical Technology Division.

for gas-cooled reactors, if this proved desirable. Subsequently, it was planned to use the facility for the development of recycle methods for other fuel types. A graphite fuel development program is not only most desirable at this time; its need is indeed a reality, and it is the front-running fuel recycle project to be demonstrated in the TURF.

PROGRAM OBJECTIVES

We plan to conduct in TURF the tasks specified in the National HTGR Fuel Recycle Development Program Plan[2] prepared by Oak Ridge National Laboratory and Gulf General Atomic Company under the direction of the Division of Reactor Development and Technology, United States Atomic Energy Commission. The Program Plan objectives include the development, testing, and demonstration of conceptual processes. This provides technology and cost information essential to process evaluation and design, leading to the construction and operation of commercial plants for recycle of spent HTGR fuels.

At TURF we plan to conduct engineering-scale demonstration of chemical processing flowsheets and equipment useful for reconstituting HTGR fuel. Spent Fort St. Vrain Reactor fuel will be used to provide realism in our work. This demonstration work will include a head-end process in which the massive carbonaceous fuel blocks will be size reduced and burned to isolate the fissile ^{235}U-containing particles and the fertile particles containing ^{233}U and thorium from the massive carbonaceous block. Then the fissile and fertile particles are separated from each other to allow subsequent recovery and purification of the bred ^{233}U by solvent extraction.

The solvent extraction work will be conducted in the Building 3019 Acid Thorex Pilot Plant. This demonstration process will receive uranium and thorium feed material from the TURF burning operations. Purified ^{233}U nitrate product will be transported to TURF and transferred to the Refabrication Pilot Plant. Here the uranium solution is treated to

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[2] National HTGR Fuel Recycle Development Program Plan, ORNL-4702 (in press).

produce ceramic oxide microspheres containing ^{233}U and thorium. These oxide microspheres are coated with multiple layers of pyrolytic carbon and possibly an intermediate layer of silicon carbide (SiC). These coated particles are bonded together in the form of fuel sticks, which are then carbonized and inserted into pre-drilled holes in precision-machined hexagonal graphite blocks to complete the production of recycle HTGR fuel elements.

The recycle ^{233}U contains chemically inseparable ^{232}U, a contaminant produced primarily in the reactor by nuclear reactions of ^{232}Th. The ^{232}U daughter products ^{208}Tl and ^{212}Bi are strongly radioactive and emit gamma rays with energies of 2.62 and 2.2 MeV, respectively. So, for radiation safety in handling ^{233}U-^{232}U with the attendant high-energy gamma radiation, the process demonstration work is done remotely in the shielded cells of TURF. Makeup fuel containing ^{235}U particles and fertile thorium particles do not require heavy biological shielding, only alpha activity containment, and are prepared by existing commercial methods and charged to the in-cell processing equipment as finished coated microspheres or finished fuel sticks.

FACILITY DESCRIPTION

Work that began in 1960 led to the design and construction in 1967 of the TURF, as it is now known. In March 1962, criteria for the design of the Thorium Fuel Cycle Development Facility[3] were published. Title I design was completed in 1963 by Giffels and Rossetti, Inc., Detroit, Michigan, and by January 1965 they had completed Title II design work. Blount Brothers Corporation won the bid for $3,379,219 on April 13, 1965, to construct the facility, and by February 9, 1967, the TURF building was 94% complete. The following fall (1967) ORNL accepted the work and took occupancy.

The Thorium-Uranium Recycle Facility is shown in Fig. 1. Nearby facilities are the High Flux Isotope Reactor (HFIR), the HFIR office and

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[3]A. R. Irvine and A. L. Lotts, Criteria for the Design of the Thorium Fuel Cycle Development Facility, ORNL-TM-149 (March 2, 1962).

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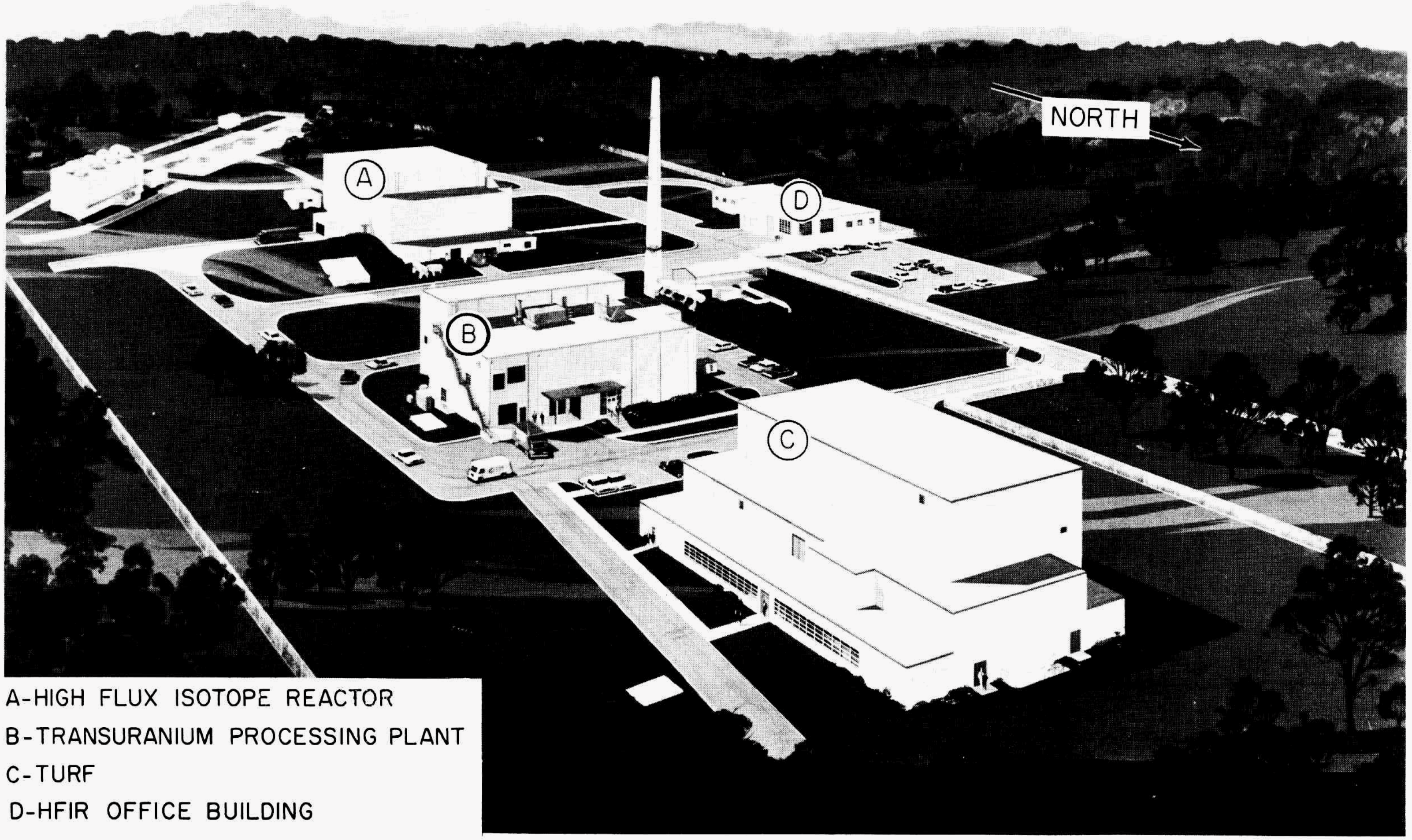

Fig. 1. Thorium-Uranium Recycle Facility and Nearby Buildings.

maintenance building, and the Transuranium Processing Plant (TRU). The TURF building is a three-story concrete block structure with partial basement. The building has an irregular shape, with an overall width of 124 ft, an overall length of about 162 ft, and a gross floor area of 32,950 ft^2, exclusive of hot cells.

Figure 2 is a first-floor plan view of the facility, showing the layout and major dimensions of the cell area. 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 that 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.

Hot Cell Description

The cell bank is pictured in Fig. 3 and consists of four process cells, heavily shielded with 5 1/2 ft of normal concrete, two shielded service cells, and an unshielded cell and air lock. The design of the individual process cell was determined by the nature of the operation to be performed in it. Chemical or burning operations are planned for cell G, whereas chemical and mechanical operations are planned for cells C and D. The operations in cell C will include sol-gel processes for sol forming, microsphere forming, drying, and firing to produce oxide microspheres. In cell D, mechanical operations will be conducted for coating the microspheres with multiple layers of pyrolytic carbon and possibly a silicon carbide intermediate layer. These coated microspheres will be examined, sorted, and characterized before they are bonded together with a carbonaceous binder and formed into cylindrical sticks, which then are carbonized and inserted into pre-drilled holes in precisely machined fuel blocks of the HTGR type. Also, in cell D these fuel elements will be assembled and transferred to cell E for final inspection and canning, preparatory to transfer to storage at TURF or to casks for shipment to the reactor.

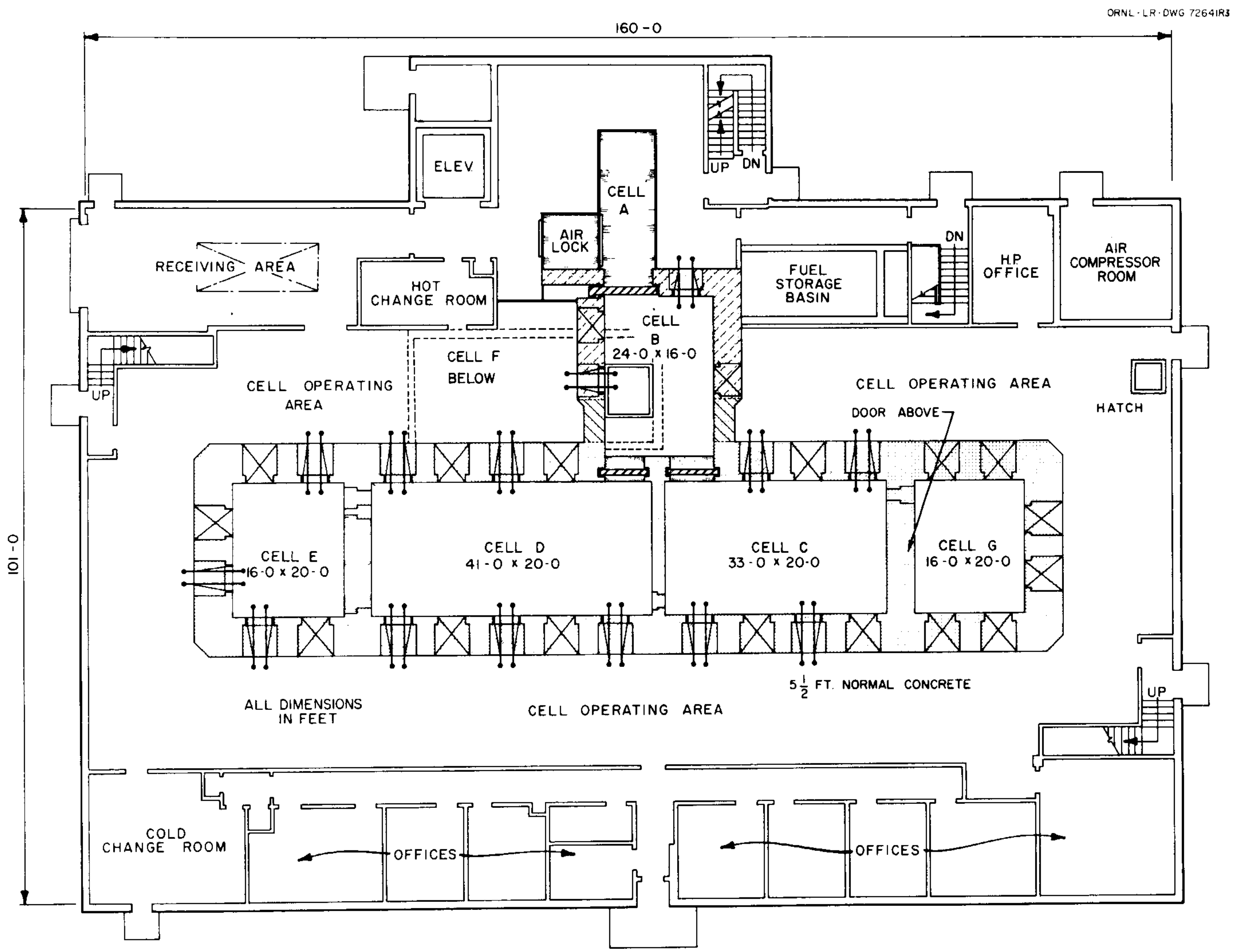

Fig. 2. First Floor Plan of TURF.

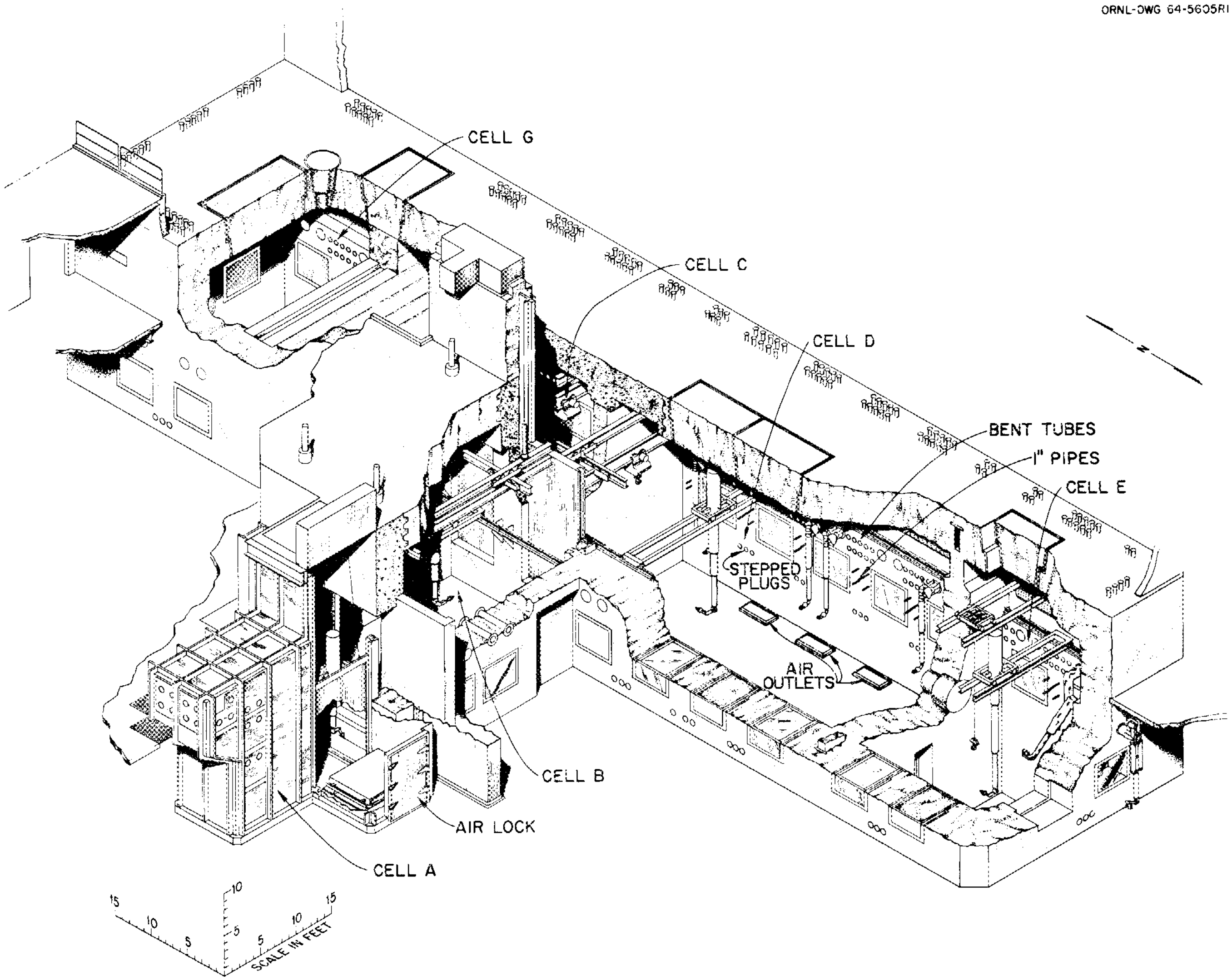

Fig. 3. TURF Cell Bank.

Figure 4 shows the length and elevation of the four process cells. They are arranged in a line and have a common width of 20 ft. Cells E and G are 16 ft long × 30 ft high. Cells C and D have a common height of 24 ft and lengths of 33 and 41 ft, respectively. Cell B, the 16-ft-wide × 23-ft 4-in.-long × 19-ft 1-in.-high decontamination cell, is located behind the two 12-in.-thick steel shielded doors and provides a radiation lock for large items that are being taken into or removed from cells C and D. Cell F, a lightly shielded (2-ft-thick) cell, is 15 ft 6 in. wide × 37 ft long × 13 ft 1 in. high and is located in the basement area with access through a hatch in the floor of cell B. Cell A, the gloved maintenance area, is unshielded and will be used for contact maintenance of equipment that has been partially decontaminated in cell B to reduce the penetrating gamma radiation to working levels. Cell A is 8 ft wide × 20 ft long and is located on the opposite side of cell B from cells C and D, as shown in Fig. 3, and is shielded from cell B by a 15-in.-thick steel shielded door. The air lock will allow transfer of moderately large (7 ft^3) items, weighing as much as 50 tons, into and from cell A without violating the hot cell containment.

All the shielded cells have stainless steel liners except cells E and F, which have epoxy coatings. Cell A, the unshielded gloved maintenance area, has epoxy coatings on the surfaces.

Operations and, generally, maintenance will be done by remote methods in all the shielded cells except E and G. Some personnel access for maintenance will be possible in cells B and F, where intermittent and lower levels of radioactivity are expected. This philosophy of remote operation demands simple, careful, and clever design of in-cell equipment if anything approaching trouble-free performance is to be expected.

Cell Services

Identical services are generally provided at 8-ft intervals around the perimeter of the cell bank. These services include a viewing window or a plugged opening into which a viewing window can later be

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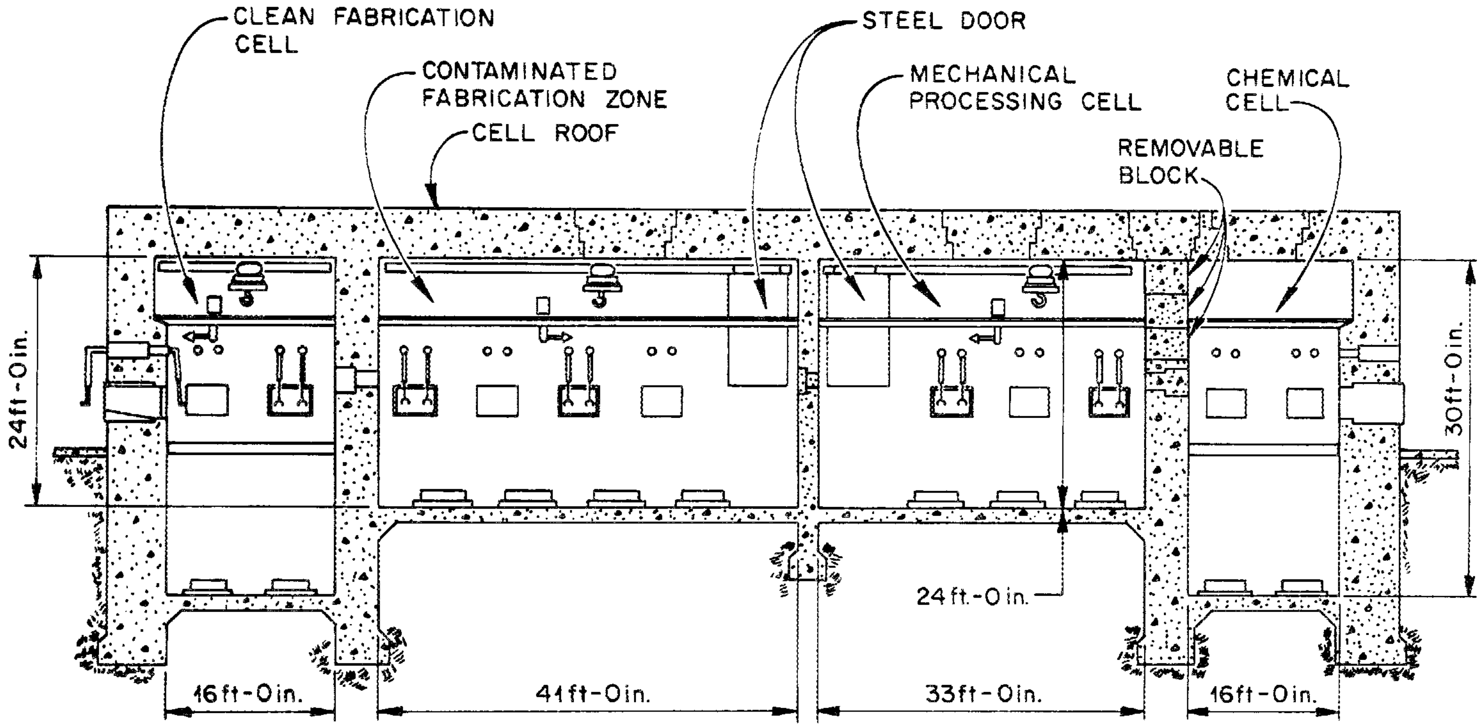

Fig. 4. Elevation Drawing of TURF Process Cells.

installed, master-slave manipulator sleeves, ten 4-in.-diam bent service sleeves, and five 1-in.-diam pipes embedded in the walls. The latter terminate atop the cell in a controlled area where connections can be made to utilities, reagent dispensers, or other in-cell services. In addition, each 8-ft cell module has three 6-in. × 8-in.-diam stepped sleeves through the shield wall for electrical service connections from the operating area, and there is one 4-in. × 6-in.-diam stepped plug for wiring to the two 1500-W in-cell lighting fixtures above each window.

In-Cell Crane and Manipulator Systems

The TURF has costly and complex in-cell handling equipment for carrying out the remote operation and maintenance. The crane system, as shown in Fig. 5, consists of two bridges, each having a net load capacity of 10 tons, two single-speed 5-ton-capacity hoists, and such other transfer bridges, and traction retrieval units as are necessary to move a crane bridge or hoist from cell A into cells B, C, and D and return without the necessity of personnel entry into the processing cells. Normally, one crane bridge with hoist will be located in cell C and another in cell D. However, both bridges and hoists could be used in a single cell.

An electromechanical manipulator system is provided to operate in cells A, B, C, and D on a set of rails installed about 9 ft below the in-cell crane system described above. Other electromechanical manipulators are located similarly in cells G and E. Cell F has only a crane rail and hoist, which operate only in that cell.

Other Features of TURF

Many other interesting and unique features of the TURF are described in the Safety Analysis.[4] A few examples are:

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[4]J. W. Anderson, S. E. Bolt, and J. M. Chandler, Safety Analysis for the Thorium-Uranium Recycle Facility, ORNL-4278 (May 1969).

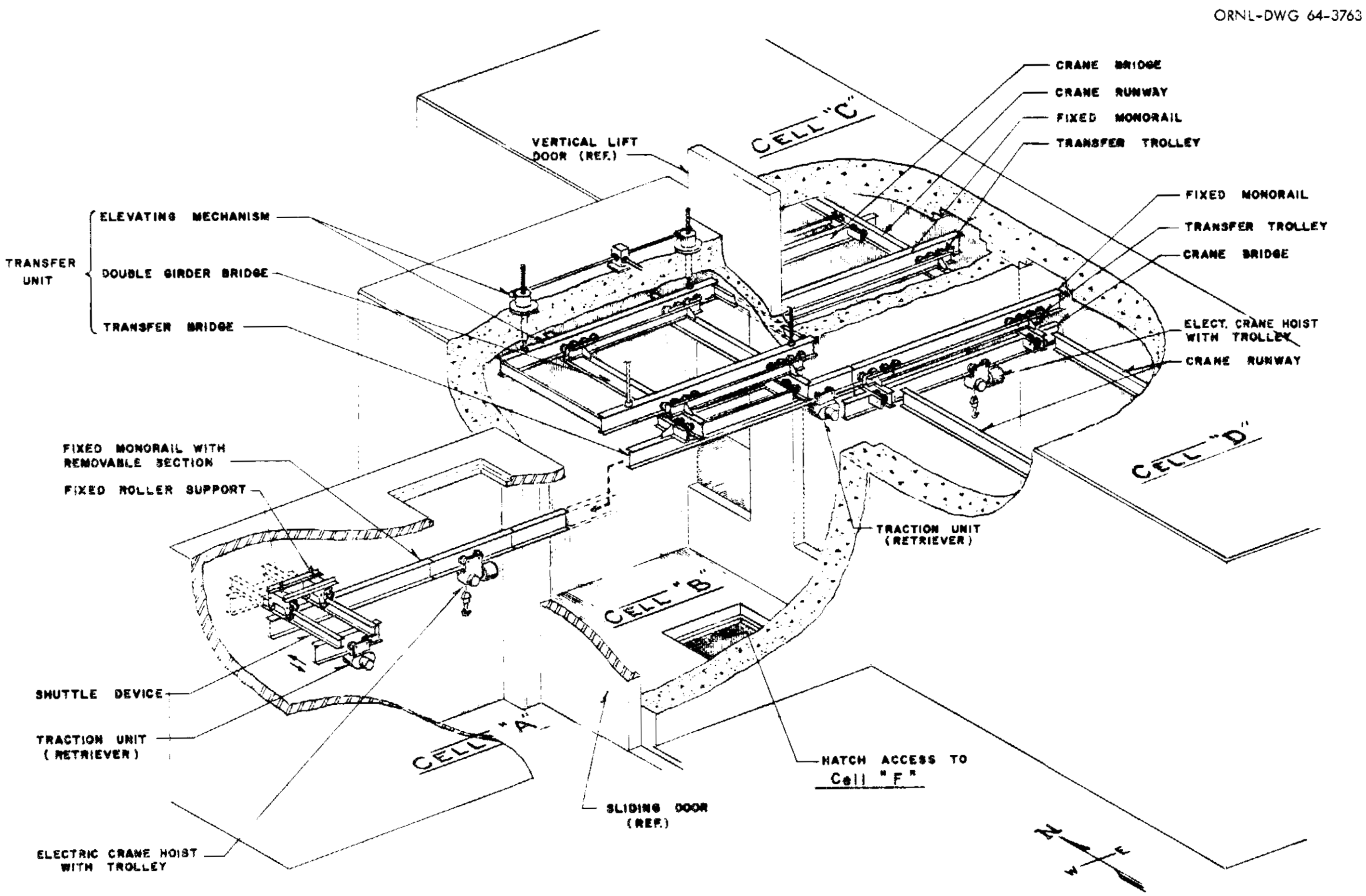

Fig. 5. In-Cell Crane System.

1. The viewing windows are copper tanks with glass ends, filled with zinc bromide solution.

2. The in-cell fire protection system uses gaseous carbon dioxide as the extinguisher. This system is quite unique, and much effort was expended perfecting it.

3. The vessel off-gas, the cell floor drainage, and other in-cell liquid wastes flow co-currently in common piping, which conveys these fluids to the underground pits housing the waste tanks and off-gas filters.

4. The cell ventilation system draws filtered air through diffusers located in the cell ceiling, down through the cell, and out through in-cell roughing filters, which remove droplets of dioctyl phthalate with an efficiency of 95%. The air then passes through large ducts to two banks of "absolute" filters and then is exhausted to the atmosphere through a 250-ft-high stack.

Initially, the cells will operate with an air atmosphere. Provisions are made for future addition of an inert gas cleanup and cooling system for all cells except cell E. Air inleakage to the cells is minimized by careful design of seals on the openings. This provides confinement of radioactivity as well as enabling future cell operation under an inert atmosphere.

TURF USAGE

One of the heavily shielded TURF cells now houses equipment to purify ^{252}Cf by removing the last traces of ^{244}Cm by ion exchange, isolate the ^{252}Cf, and package it for shipment. Very pure ^{248}Cm, as well as some ^{253}Es, has been prepared in TURF cell G by members of the Chemical Technology Division working on the Transuranium Program.

In the summer of 1968 cell G was used to prepare a charge consisting of $^{233}UF_4$ and ^{7}LiF for fueling the Molten Salt Reactor Experiment. This was prepared[5] by reducing UO_3 containing 39 kg U (35.6 kg ^{233}U) to UO_2 by

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[5] J. M. Chandler and S. E. Bolt, Preparation of Enriching Salt ^{7}LiF-$^{233}UF_4$ for Refueling the Molten Salt Reactor, ORNL-4371 (March 1969).

treatment with hydrogen, converting the $^{233}UO_2$ to $^{233}UF_4$ by hydrofluorination, and fusing the $^{233}UF_4$ with ^{7}LiF. A 500-g can of the $^{233}UO_3$ (with 222 ppm ^{232}U in the uranium) presented an exposure dose rate of about 300 R/hr at a distance of 2 ft. This salt was packaged in containers of assorted sizes suitable for conducting the initial critical experiment and later fueling the Molten Salt Reactor Experiment.[6]

During the above work in TURF, very high levels of alpha activity and very high gamma and neutron radiation levels were processed and handled without incident. This confirms the high degree of reliability and safety provided by the TURF, as expected from the design criteria.

SUMMARY

The Thorium-Uranium Recycle Facility (TURF) provides shielded and safely contained space in which to demonstrate the processes and provide economic information for all phases of remote fuel cycle technology. Initially, thorium-containing reactor fuel will be studied as we conduct our part of the National HTGR Recycle Development Program Plan.

The three-story masonry structure with a basement provides containment for four heavily shielded process cells, two shielded service cells, and an unshielded maintenance and air lock cell. The stainless-steel-lined process cells have all the usual hot cell features plus some unique ones, such as the gaseous CO_2 fire-protection system, provision for inert gas atmosphere, an integrated system for hot off-gas and hot liquid wastes, tanks filled with zinc bromide solution for viewing windows, and an up-to-date and elaborate in-cell crane and manipulator system.

The TURF is available now and ready for installation of process equipment that is to be tested and demonstrated in the HTGR fuel recycle program.

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[6] M. W. Rosenthal, R. B. Briggs, and P. R. Kasten, MSR Program Semiann. Progr. Rept. Feb. 28, 1969, ORNL-4396.

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