A VERTICAL SUBASSEMBLY ASSEMBLER-DISMANTLER
FOR THE FUEL CYCLE FACILITY

by

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ABSTRACT

A change in the program of Experimental Breeder Reactor II (EBR-II) from a power demonstration reactor to a fast-flux irradiation facility necessitated a corresponding change in the capabilities of the adjoining Fuel Cycle Facility (FCF) for handling irradiated subassemblies. A new vertical assembler-dismantler (VAD) capable of handling experimental subassemblies was designed, constructed, and installed in the FCF air cell to replace existing equipment for assembling and disassembling driver-fuel subassemblies. This machine was installed remotely with a minimum of interruption of normal cell activities. Performance of the new machine has met all design requirements adequately.

I. INTRODUCTION

The Fuel Cycle Facility (FCF) of Argonne National Laboratory, located within the National Reactor Testing Station, Idaho, is a two-cell complex consisting of a 700-ft² air cell and a 2200-ft² argon cell¹ (Fig. 1). This facility was designed to reprocess irradiated fuels from Experimental Breeder Reactor II (EBR-II) as part of the Liquid Metal Fast Breeder Reactor program of the Atomic Energy Commission. Construction of the facility was completed in 1963, and hot fuel handling was begun in late 1964. Since that time, more than 34,000 fuel elements have been processed. The reprocessing activities and the special-purpose equipment used in the FCF have been summarized in previous papers.²⁻⁵

Fig. 1. Plan of Fuel Cycle Facility.
Air Cell Is at Left, Argon Cell at Right.

During the past three years, the gradual conversion of the EBR-II from a power-demonstration complex to an experimental-irradiations facility has resulted in a corresponding change in the scope of activities of the adjacent FCF. Primary emphasis has shifted from fuel reprocessing to interim and final examinations of elements and capsules contained in special experimental subassemblies that have been irradiated in EBR-II. These examinations are made at selected times during the irradiation lifetime of the experiments to obtain data and to ensure the integrity of the experiments for further irradiation.

One of the results of this programmatic change was the need to replace the dismantling machine⁶ which had been designed for use with the EBR-II driver fuel. Needed was a more versatile machine that could be used to dismantle a variety of types of experimental subassemblies as well as the driver subassemblies. Many of the fuel capsules that were to be removed in dismantling would be reinserted in new subassemblies that would receive additional irradiation. Therefore, the capability of assembling a subassembly from irradiated fuel was included in the design of the new piece of equipment. The design for this machine also included the requirements that the fuel capsules not be inclined from the vertical, since this might disturb the sodium bond within the capsule and compromise postirradiation examination results. This machine, which could be used to both assemble and dismantle irradiated fuel subassemblies by totally remote means, was called the vertical assembler-dismantler (VAD).

II. DESCRIPTION OF EBR-II FUELED SUBASSEMBLY

The subassemblies that can be used in EBR-II consist principally of a hexagonal, or hex, can or tube surrounding a fuel section and welded to a top end fixture and a lower adapter. Figure 2 shows a typical subassembly.

Essentially all components of the subassembly except the fuel portions are made of Type 304 stainless steel. Two sizes of hex tubing can be used with mating pole pieces: one which is 2.29 in. across the flats, and one which is 1.908 in. across the flats. A variety of lower adapters may be used for special configurations. The overall length of the completed subassembly is 92 in.; the length of the hex tube is adjusted to maintain this length. The internal configuration of the fuel-support grid may be varied to hold 7, 19, 37, 61, or 91 fuel elements or capsules. A large

Fig. 2. EBR-II Fueled Subassembly

number of permutations of subassembly design can be, and have been, fabricated from combinations of these variables. All the subassemblies, however, can be dismantled by cutting the hex tube above the point where it is welded to the lower adapter. After the tube has been cut, the top end fixture and hex tube are withdrawn to expose the fueled section of the subassembly. The individual fuel elements then can be removed from the T-bar grid. Reassembly of a subassembly is essentially a reverse of this operation, except that the tube-cutting step is replaced with a spot-welding step. New lower hardware, including the lower adapter and attached T-bar grid, is placed in the equipment, and the fuel elements are inserted onto the T-bar grid. A new hex tube, which has been welded to a top end fixture, is slid over the fuel bundle and onto the lower adapter where it is spot welded in place.

III. DESIGN CRITERIA FOR THE VAD

The overall objective for the VAD is to assemble or disassemble all types of subassemblies that can be used in EBR-II. These operations must be done by totally remote methods, and the subassembly and capsules must not be inclined from the vertical during the operations. Within this overall objective, additional design criteria were:

(1) The machine had to be of modular design to facilitate remote installation in the FCF air cell with existing manipulation and viewing equipment. Except for small items inserted through a port, all materials entering the cell complex pass through 6-ft-dia floor plugs. A 5-ton weight limit is imposed by the capacity of the overhead cell crane.

(2) The use of complex mechanisms had to be avoided, and mechanical master-slave manipulators were to be used as much as possible. Experience with other cell equipment had indicated that complex mechanisms which had been provided to semi-automate operations and reduce operator effort very often did the opposite. (This reverse effect resulted primarily because of the difficulty in remotely adjusting and maintaining in-cell equipment for a prolonged period of operation.) Use of the overhead electromechanical manipulators or the crane to perform an operation had to be minimized, since these units serve other cell functions and are not always readily available.

(3) Radiation-resistant materials had to be used for all fixed components. Radiation levels as high as 10^5 R/hr were to be expected in the vicinity of the machine. Extensive testing by ANL of materials for their

radiation-resistant capabilities indicated that special electrical insulations, lubricants, and other materials of that type are required for efficient and prolonged operation of any in-cell equipment.⁷ Where usage of such materials was found to be impractical, simplified replacement procedures were substituted.

(4) Maximum temperature of the subassembly was not to exceed 600°F. Most subassemblies received from the reactor after a normal 15-day cooling period in the reactor storage basket generate up to 1000 to 2000 W of decay heat. To prevent damage to the fuel or cladding, a maximum temperature of 600°F was established until such time as the hex tube could be removed and the fuel-element bundle separated.

(5) The total time allowed for the normal disassembly or assembly of a subassembly was to be less than 8 hr. This figure was based on the requirements of a normal subassembly and on a normal one-shift work week at the FCF.

(6) Installation was not to require an extended shutdown of the FCF; such a shutdown was not considered possible because the FCF had to maintain a continuous supply of subassemblies for the reactor. Additionally, to facilitate remote installation and repair, the machine design had to incorporate features such as lifting handles, guide pins, and quick disconnects where appropriate.

IV. GENERAL DESCRIPTION OF THE VERTICAL ASSEMBLER-DISMANTLER

As shown in Fig. 3, the VAD consists of five major units attached to a vertical support structure or frame: the positional slide; the hex-tube cutter; the force boom; the fuel-element remover and loader (FERL); and the welder. An integral cooling system is incorporated. The machine is in the FCF air cell, with the support structure extending into a 6-ft-deep floor pit, as shown in Fig. 4. Master-slave manipulators installed at this station comprise one Model E and one Model F.*

For disassembly operations, the subassembly is lowered into the sleeve of the positional slide, and the force boom is rotated into position and clamped to the top end fixture of the subassembly. The elevation of the subassembly is adjusted to position the area of the hex tube to be cut

* Both are products of Central Research Laboratory, Red Wing, Minn.

Fig. 3. Pictorial View of the Vertical Assembler-Dismantler

Fig. 4. In-cell Positioning of Vertical Assembler-Dismantler

opposite the tube cutters; the cutters then are clamped around the hex tube. The entire subassembly is rotated to cut the tube around the periphery. The hex tube then is raised by the force boom to expose the fuel section; this section is retained on the grid and lower adapter, which remain clamped into the sleeve. The fuel elements are removed from the T-bar grid by master-slave manipulation (Fig. 5).

For assembly operations (see Fig. 6), adapter and fuel-support grid are supported in a sleeve of the positional slide, fuel elements are installed on the grid by master-slave manipulation, and the hex tube then is lowered over this fuel bundle by the force boom. The elevation of the subassembly is adjusted to position the desired weld area opposite the spot welders. The subassembly is rotated to position each face of the hex tube opposite the spot welder. The strength of the welds is tested by raising the force boom while the lower adapter remains clamped in the positional slide. The raising of the boom subjects the welds to a tensile force of 1800 to 2000 lb.

A more detailed description of the major components follows.

V. DESCRIPTION OF THE COMPONENTS OF THE VERTICAL ASSEMBLER-DISMANTLER

A. Frame or Support Structure

The VAD support structure is composed of two principal parts, the base and the E frame, which function together to support and guide the remaining components used for assembly and disassembly operations. The base section of the frame extends 6 ft into the floor pit and rests on the floor of the air cell on two support pads and four leveling screws. The E frame is bolted to the base; together they extend 11 ft 7 in. above floor level. Integral parts of the base and the E frame are two sets of guide rails to which the force boom and positional slide are attached. The servo-drive units for the force boom and positional slide are attached to the base and the E frame.

B. Positional Slide

The positional slide is mounted on one set of guide rails of the support structure. It not only supports the subassemblies held in the VAD, but does the following jobs besides: directs cooling air through an irradiated

Fig. 5. Removing Mark-IA Driver-fuel
Elements from the T-bar Grid

A

B

Fig. 6. Steps in Assembling a Driver-fuel Subassembly with the VAD.
(A) Inserting a Subassembly Lower Adapter into the Positional Slide of the VAD. (B) Rotating the Fuel-element Remover and Loader (FERL) into Position for Placement of Fuel Elements on the Subassembly T-bar Grid.
(contd on next page)

C

D

Fig. 6 (contd). Steps in Assembling a Driver-fuel Subassembly with the VAD. (C) Installing the Elements on the T-bar Grid, Using the FERL Guide and a Master-slave Manipulator. (D) Spotwelding the Hex Tube to the Lower Adapter.

subassembly to remove fission-product heat; houses the rotational drive and chuck for rotating the subassembly when cutting the hex tube during disassembly; raises or lowers the subassembly to various elevations; and serves as a support to which various jigs, fixtures, and clamps can be attached to aid in assembly or disassembly operations. Removable sleeves support the lower adapter of a subassembly. Sleeves of various sizes are used for different types of subassemblies.

C. Hex-tube Cutter

The hex tubing of the subassemblies is severed during the disassembly operation by a pneumatically operated cutting mechanism. The unit employs the same cutting technique as was successfully demonstrated on the original dismantling machine. Two pipe-cutting wheels are held against one side of the hex tube by a pneumatic cylinder, and a flat non-cutting wheel is held against the opposite side of the hex tube by a compression spring. When the subassembly is rotated, the cutting wheels perform in a manner similar to a conventional pipe cutter while following the irregular contour of the tubing.

The tube cutter is mounted on three ball casters and is moved about the work table by the master-slave manipulators. Although the cutter operates at a fixed elevation, the positional slide can raise or lower the subassembly so that a cut may be performed at any location on the 6-ft-long hex tubing.

D. Force Boom

The force boom is used to raise and lower the hex tube over the elements or capsules during the disassembly and assembly operations. A grapple contained within the unit grips the top end fixture of the subassembly. Both the tensile and compressive forces exerted by the grapple on the hex tube are measured by a load cell. The force boom is mounted on the second set of guide rails of the support structure. The boom can be extended to a height of 16 ft above the cell floor. This travel is required when processing subassemblies containing 60-in.-long capsules.

E. Fuel-element Remover and Loader (FERL)

The FERL was designed to aid the removal and loading of elements off of and onto the T-bar grid of the subassembly. The unit is operated by the master-slave manipulators. It consists of a wedge-and-clamp arrangement that removes or loads one row of elements at a time. The elements are moved between the T-bar grid and a loading plate by the wedge. The loading plate contains a rail network which is aligned with the grid rails and keeps the elements in order for positive identification. The elements are removed and installed on the loading plate individually by the master-slave manipulators.

F. Welder

During assembly operations, the lower end of the hex tube must be welded to the lower adapter of the subassembly. The welding technique is essentially the same as that employed on the original assembly machine. The unit contains two electrodes to weld opposite sides of the tube simultaneously. An argon-gas blanket is used to produce a wider spot weld and reduce the possibility of burning through the tube. A commercially available welding power supply with servo-current controllers* provides acceptable quality and repeatability of welds.

The welder is mounted on ball casters and is positioned around the subassembly by the master-slave manipulators. The welding heads are forced against the tubing by a pneumatic cylinder. Correct elevation of the weld location is provided by moving the entire subassembly up or down by the positional slide.

G. Cooling System

The forced-air (suction) cooling system used on the original dismantling machine has been adapted for use on the VAD. This system is connected to the air-cell cooling grapple, which transports subassemblies within the cell, and to three locations on the VAD. Axial cooling of the subassembly, through either the upper or lower end, is provided by cooling lines attached to the positional slide and the force boom. After the hex

* Product of Miller Electric Mfg. Co., Appleton, Wisconsin

tube has been removed, the element array is cooled by a center plenum connected to the cooling system. Up to 100 cfm of air can be directed axially through the subassembly while the hex tube is on. Approximately 120 cfm of air can be directed across the fuel bundle when the hex tube is not in place. A set of pneumatically operated valves is located in-cell to switch the cooling flow to any one of the required distribution lines.

VI. PRE-INSTALLATION TESTING

Before the VAD was installed in the air cell, it was assembled and tested in simulated cell conditions. This is a standard requirement for FCF equipment prior to in-cell installation and operation. The testing was performed within a specially designated area of the FCF which contains a work-station mockup. The mockup area consists of a simulated section of the cell wall and viewing window and is equipped with a pair of master-slave manipulators. An overhead bridge crane and electromechanical manipulator also are installed in the mockup area. Special requirements for the VAD tests included drilling a 2-ft-dia hole through the floor and installing the Model E and F manipulators in the mockup.

The obvious advantages of this type of testing include the demonstration that the equipment can be remotely installed and operated and the capability for making modifications or improvements as necessary before the equipment becomes contaminated. In addition, the training of operators and the preparation of operating manuals are much more effective when personnel have unrestricted access to the equipment.

During the testing period, a number of minor modifications of the VAD equipment were made. Dummy fuel and experimental subassemblies were assembled and disassembled repeatedly. Two experimental subassemblies to be irradiated in EBR-II were constructed in the VAD also.

VII. IN-CELL INSTALLATION

Concurrently with the mockup testing, a plan was formulated for installing the VAD in the air cell. This plan consisted of three phases: removal of the existing dismantling machine; modification of the work station; and installation of the VAD. All in-cell work had to be performed remotely because normal refabrication of fuel subassemblies was to continue in the air cell during this period.

A. Removal of Dismantling Machine

A step-by-step procedure was prepared, and plastic-lined wooden boxes were made to hold the components of the machine.

Two crews, working separate 8-hr shifts for one week, remotely disassembled and removed the old equipment. Each crew consisted of three technicians and one representative of Health Physics. One of the technicians, suited in protective clothing, guided the equipment into the boxes as it was lowered through the hatch in the cell floor and installed the box covers. No contamination spread outside the planned work area during the removal operations. Radiation levels on the surface of the equipment ranged from 50 mR/hr to 5 R/hr.

B. Modification of Work Station

After the dismantling machine had been removed, the work-station area was cleaned and modified for the VAD installation. The master-slave manipulators were replaced, and the distribution systems for electrical and pneumatic utilities were modified. The VAD was designed to use the existing utility control circuits; however, the number of circuits required was considerably less than used for the dismantling machine. As a result, many of the in-cell utility liners had to be removed remotely. The work station was prepared for the VAD installation in about a week.

C. Installation of the VAD

Following completion of the preoperational tests, the VAD was disassembled for transfer into the cell. The individual components were transferred into the air cell through the 6-ft-dia floor hatch and assembled remotely at the work stations as shown in Fig. 4. The entire operation was completed in about two weeks. Final checkout consisted of disassembling a dummy fuel subassembly and assembling a refabricated fuel subassembly.

The only difficulties encountered during the installation were in locating the VAD base into the floor pit. Attempts to level the base were unsuccessful, and it was discovered that the floor pit was not vertical. Remote measurements were made to determine the degree of tilt involved. The base was removed from the cell, modified, and then installed successfully.

VIII. OPERATING EXPERIENCE

Since being placed in operation in July 1967, the VAD has been in continual use except for brief periods of maintenance and repair. Operational availability to date has been 99%. Almost 250 subassemblies have been dismantled with the VAD, and 20 have been assembled. Until March 1969, the original assembly machine⁸ was kept in operation, and most subassemblies were assembled on that machine. However, the assembly machine must be removed to make way for additional special test equipment that will be installed, and all future irradiated subassemblies will be assembled on the VAD. Operational problems with the VAD have been remarkably few and all of them minor. As originally constructed, the lefthand drive counter used for reference location on the positional slide had gears and counterwheels made of plastic. Owing to the high radiation, these disintegrated rapidly. They have been replaced with metallic units.

Although not directly a machine problem, one operational difficulty of interest has developed. The capsules in a number of experimental and blanket subassemblies subjected to considerable burnup have swelled and distorted to the point where it has been extremely difficult to withdraw the hex tube from the capsule bundle after cutting the tube. To resolve this, a vertical hex-tube slitter was constructed. This slitter consists of a milling cutter wheel driven by a 1/2-in. portable drill motor through a speed reducer. The cutter assembly rests on the VAD table and clamps around the hex tube, which is positioned in the VAD. The hex tube is fed to the cutter wheel by the positional slide drive. Depth of cut is adjusted so that the tube may be cut without damaging the capsules inside.

Maintenance of the VAD consists of an occasional cleaning and adjusting of the spotwelding unit and replacement of the wheels of the hex-tube cutter. Although these operations can be done remotely in most cases, the individual components have been removed from the cell and manually serviced.

IX. CONCLUSIONS

The VAD has successfully demonstrated its ability to satisfy all the original design criteria in assembling and disassembling the EBR-II fuel and experimental subassemblies. The machine was developed on an accelerated schedule; about 18 months was required for design, fabrication,

and installation. The VAD has replaced both the original dismantling machine and the assembly machine and has released one complete work station for other activities.

The removal of the dismantling machine and installation of the VAD were performed remotely without shutting down the cell or curtailing other cell activities. This accomplishment was possible because of the modular construction of the equipment, a thorough pre-installation test program under simulated cell conditions, and an experienced cell-operating crew. It should be noted that all process and examination equipment in the FCF is required to be remotely installed and maintained.

Several factors probably have contributed to the low maintenance requirements of the VAD. First, many of the critical components are essentially second-generation designs based on components used on the original assembly and dismantling machines. Second, a great deal of FCF operating experience with remote operation of mechanical devices was available and was reflected in the design. Simplified mechanisms operated by the master-slave manipulators were selected instead of more-complex automated devices. Finally, the pre-installation testing of the machine revealed and permitted the correction of problem areas before the machine was contaminated.

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