TMI-2 FUEL CANISTER AND CORE SAMPLE HANDLING EQUIPMENT USED IN INEL HOT CELLS[a]

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ABSTRACT

This paper describes the specialized remote handling equipment developed and used at the Idaho National Engineering Laboratory (INEL) to handle samples obtained from the core of the damaged Unit 2 reactor at Three Mile Island Nuclear Power Station (TMI-2). Samples of the core were removed, placed in TMI-2 fuel canisters, and transported to the INEL. Those samples will be examined as part of the analysis of the TMI-2 accident. The equipment described herein was designed for removing sample materials from the fuel canisters, assisting with initial examinations, and processing samples in preparation for detailed examinations. The more complex equipment used microprocessor remote controls with electric motor drives providing the required force and motion capabilities. The remaining components were unpowered and manipulator assisted.

INTRODUCTION

An important part of analyzing the accident at TMI-2 is examining selected samples from the damaged reactor core (1,2). In this paper, samples are defined as any preselected piece of the TMI-core received at the INEL in a fuel canister. Two methods were used to obtain samples of TMI-2 core material: (a) the "pick and place" method of removing distinct components from the rubble bed on top of the core and (b) core boring or drilling of cylindrical samples from the remaining core. Distinct core components are items that could be identified as to original location in the core and include partial fuel bundles from the upper core region, upper end fittings, control rod spiders, and miscellaneous small core parts (Fig. 1).

Fig. 1. Typical damaged upper end fitting from TMI-2 core.

Both types of samples were placed in special fuel canisters, design of which was based on the constraints resulting from the core conditions. It was with some difficulty that the damaged and distorted components were forced into canisters which provided a square cavity about 1/4 in. larger in width and breadth than a new fuel bundle.

The core bores, on the other hand, were drilled from the core and pushed up inside a split tube container inside a cylindrical bore casing which maintained the sample in a uniform cylindrical configuration. The core bores were held in the canisters in special dividers which separated and supported them, thus ensuring ease of insertion and removal (Fig. 2).

Both types of samples were placed in the specially designed fuel canisters using underwater remote means (not described herein), with video camera assistance. Visibility was limited by suspended particulate and microbial growth, inhibiting the selection and placement of samples in the canisters.

Fig. 2. TMI-2 core bore and casing being removed from shipping canister in TAN Hot Cell.

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The canisters holding these samples were then placed inside specially designed casks and transported by rail to the Test Area North (TAN) Hot Shop and Hot Cell at the INEL. The TAN area was selected for examining the samples because the TMI-2 core debris is being stored in the TAN pool, and the TAN facilities are the most suitable for canister handling. Upon arrival, the canisters were placed in a storage rack in the TAN pool. These operations were part of the overall TMI-2 core shipping, receipt, handling, and storage activity described in Refs. 3 and 4.

Handling and opening the canisters required specially designed equipment compatible with existing capabilities at TAN. Removal of samples also required specialized equipment. For these reasons, the fuel canister and core sample handling equipment was developed and used. The equipment was designed to be compatible with the TAN Hot Shop (THS) crane and electromechanical manipulators, and with the TAN Hot Cell (THC) electromechanical and master slave manipulators.

Equipment was provided to rotate the canisters from vertical to horizontal and back. Provisions were made to vent and open the canisters and later to close, seal, and fill them with inert gas. Tools were developed to remove TMI-2 core distinct components, which had been loaded randomly into canisters, and to pull core bores from other canisters. Equipment was provided to support the disassembly of partial fuel bundles. Novel tubular canisters were manufactured for transporting fuel rods, control rods, burnable poison rods, and core bores to other INEL Hot Cell facilities.

EQUIPMENT DESCRIPTION

The major assemblies of the fuel canister and core sample handling equipment are shown in Fig. 3, and components are individually described below.

- Laydown/Lifting Fixture - This is a strongback device used to handle the canisters in the TAN Hot Shop (THS). This fixture (Fig. 4) receives the canister in the vertical position; lowers it to horizontal; balances the canister during level horizontal lifting; adapts to the TAN Hot Cell (THC) transporter for moving the canister into and out of the THC; and raises the canister to vertical.

- Fuel Canister Vent and Drain Assembly - This is used to vent and purge combustible gases from the canisters and provides the inert gas for purging. It also is used to drain water

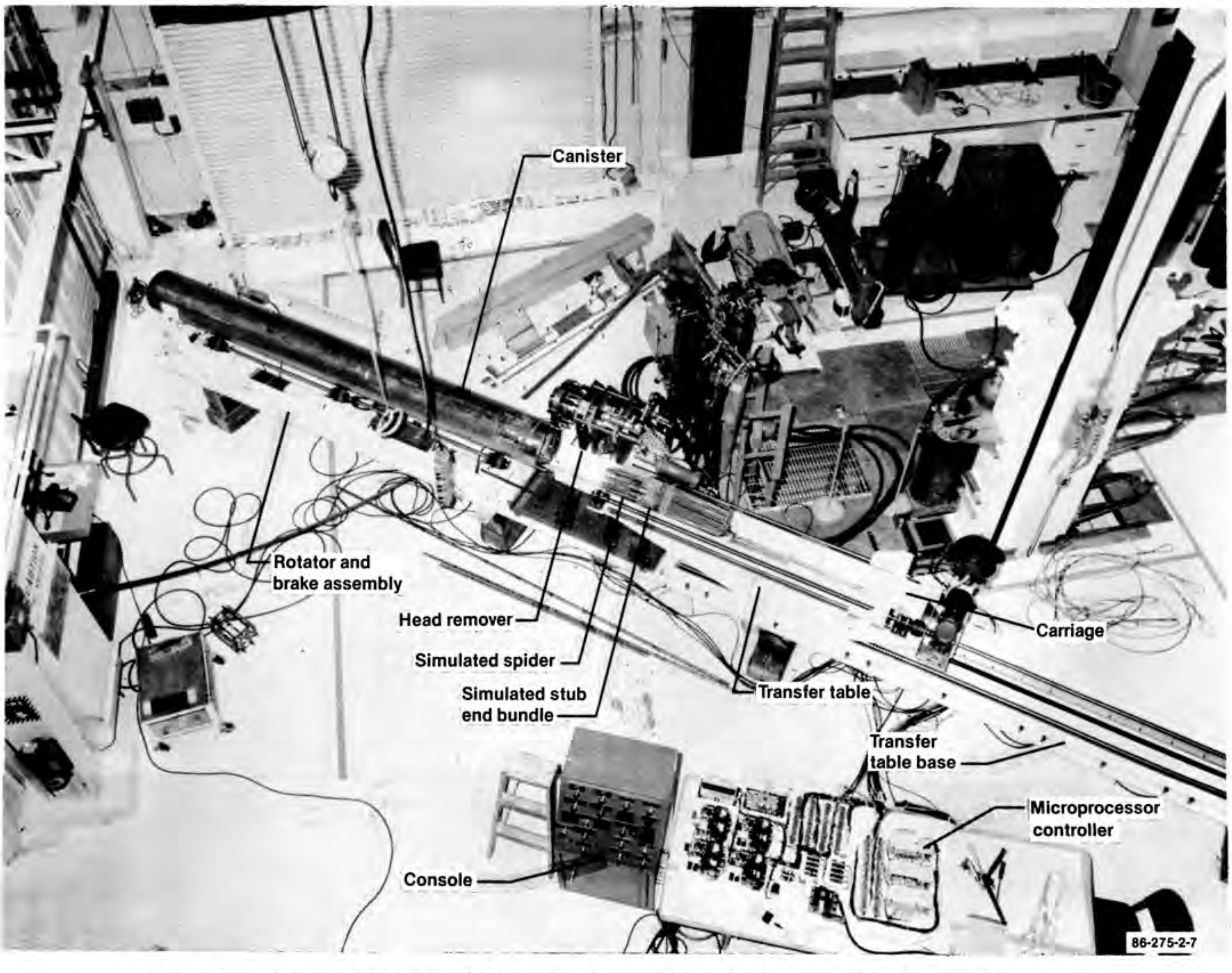

Fig. 3. Overall view of Fuel Canister and Core Sample Handling Equipment.

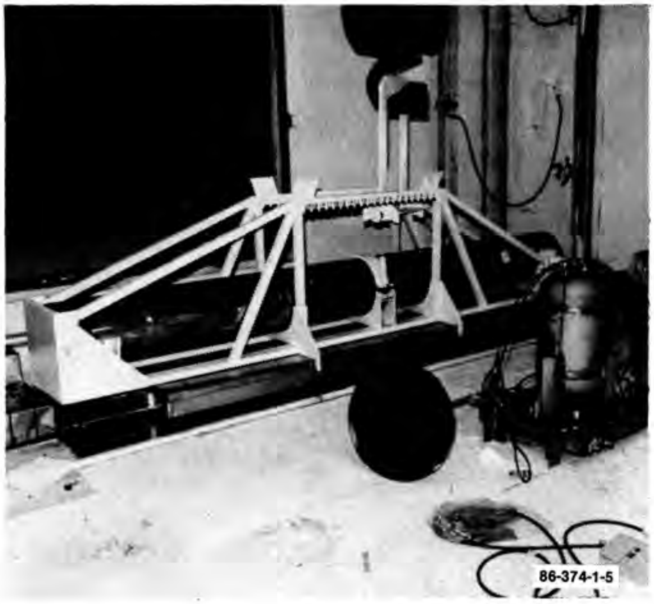

Fig. 4. Laydown/Lifting Fixture with fuel shipping canister on TAN Hot Cell transporter. Fuel canister vent and drain assembly can be seen in the right foreground.

from the canisters. The assembly connects to a canister with novel, manipulator-operated quick disconnects. The assembly is the pallet-mounted tank shown in Fig. 4. Hose-mounted disconnects are shown in the photograph.

- Head Removal Machine - This machine is comprised of the head remover, rotator and brake assembly, control console, and preprogrammed microprocessor controller (Fig. 3). The machine is used to detorque canister head bolts, remove and store the head, replace the head, and insert and torque the head bolts. The capacity is available to over-torque and break stuck bolts if required. Figure 5 shows the head remover holding a canister head in the retracted position, with a canister in place on the rotator and brake assembly. The white frame of the rotator and brake assembly supports the electrically-driven rotator wheels used to support and position the canister at the nut runners. The head remover is tilted away from the canister to the retracted position with a variable-speed, electric motor-driven actuator (Fig. 5). The head remover rides on Thomson rails in the two horizontal axes and is removed into and away from the canister with a variable-speed, electric motor-driven ball screw (Fig. 5). A drain pan is positioned under the head remover to catch and drain the water when the canister is opened. The standard torque (150 ft-lb) and overtorque (490 ft-lb) pneumatic nut runners are visible in Fig. 6 (black cylinders), as is the head grapple (white cylinder).

  The control console is shown in Fig. 7. Using the console-mounted controls, the head remover is lowered to align with the canister and moved forward to the canister head (Fig. 8). The canister is rotated to align the first bolt with the nut runner socket. The controls are switched to the automatic mode and the machine is started. The head removal is completed automatically by the microprocessor control console,

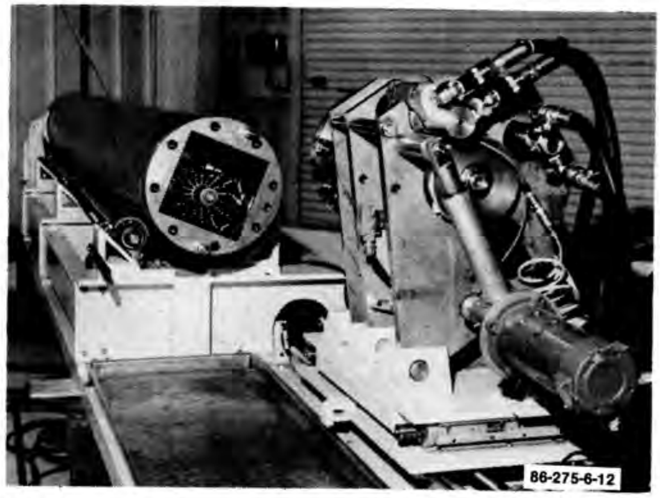

Fig. 5. Head Removal Machine in the retracted position. A canister is shown resting on the rotator. A simulated core component is positioned in the canister opening.

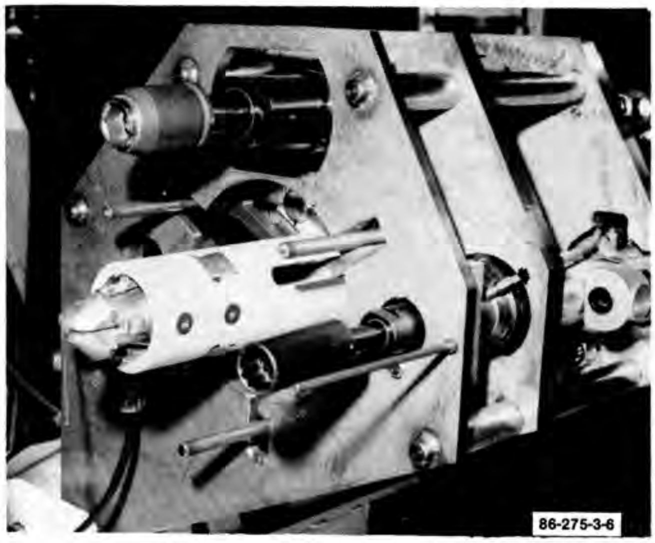

Fig. 6. A view of the Head Removal Machine showing canister head grapple and small and large nut runners.

Fig. 7. Control panel of Console.

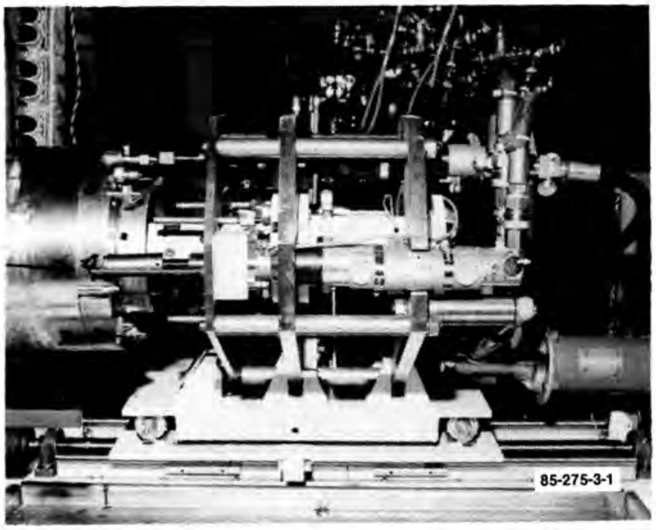

Fig. 8. View showing Head Remover aligned with canister. Note nut runner socket positioned on head bolt.

including detorquing the bolts and storing the head; however, the manual override control mode can be used if a bolt sticks.

- Transfer Table - This table (Figs. 3 and 9) is comprised of a Thomson rail-mounted ball screw-driven table upon which is mounted a Thomson rail-mounted ball screw-driven carriage. Both screws are driven by reversible electric motors controlled from the console. The 90-degree, V-shaped table fits the corner of the square opening of a canister. The carriage contains two hooks to attach extraction tools for withdrawing core bores, distinct components, or debris buckets from the canisters. The table is positioned against the open face of a canister, thus restraining the canister from moving while the canister contents are extracted onto the table. Both the carriage and table are used in reverse order to load materials into a canister.

- Extraction Tools - These were developed for use with the transfer table in withdrawing distinct components from canisters. Included are various hooks, tools and shovels (Figs. 10 and 11) and the video camera/tool crutch (Fig. 12). Those devices are manipulated into the canister with handles. Fig. 13 shows a hook tool being attached to a handle, using the tool clamp fixture and manipulator wrench.

- Video System - This system, used to visually monitor use of the extraction tools, consists of a Rees Model R93 radiation-resistant camera and remote control unit. The camera is mounted in a tubular carrier which mates with the video camera/tool crutch and allows a manipulator to slide the camera into position in a canister. A second camera without remote capabilities is manipulator-held, while a third is wall-mounted. The latter two provide overall viewing capabilities from above the equipment, an advantage not provided through the THC windows or by the Rees camera.

- Core Barrel Disassembly Machine - This consists of a Ridgid Model 1224 pipe threading machine modified for remote use. The control

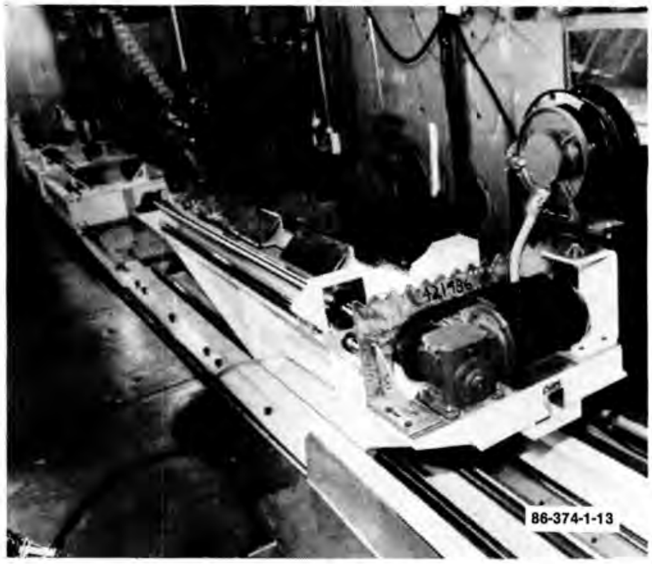

Fig. 9. View of Transfer Table located in TAN Hot Cell.

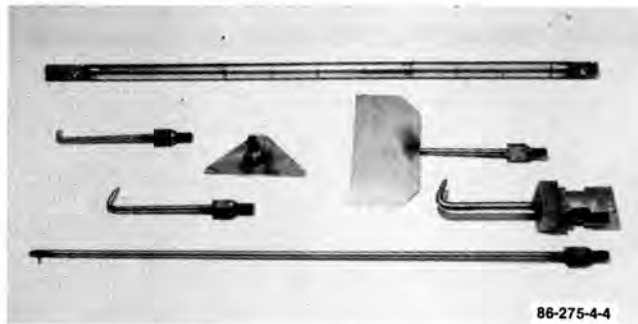

Fig. 10. Typical Extraction Tools used to remove core components from canisters. The tool handle is located in the uppermost part of photograph.

Fig. 11. V-shovel core component removal tool used to extract items from canisters.

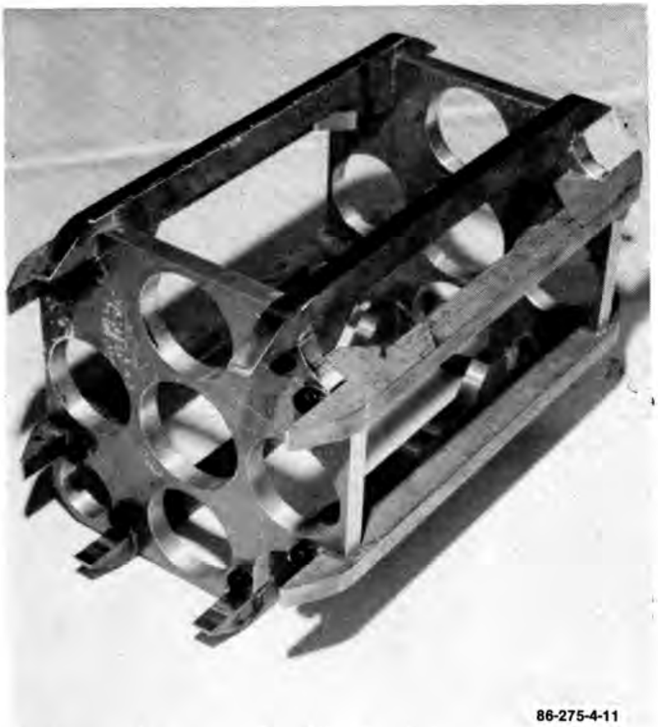

Fig. 12. The Video Camera/Tool Crutch used to position camera and tools in the canisters.

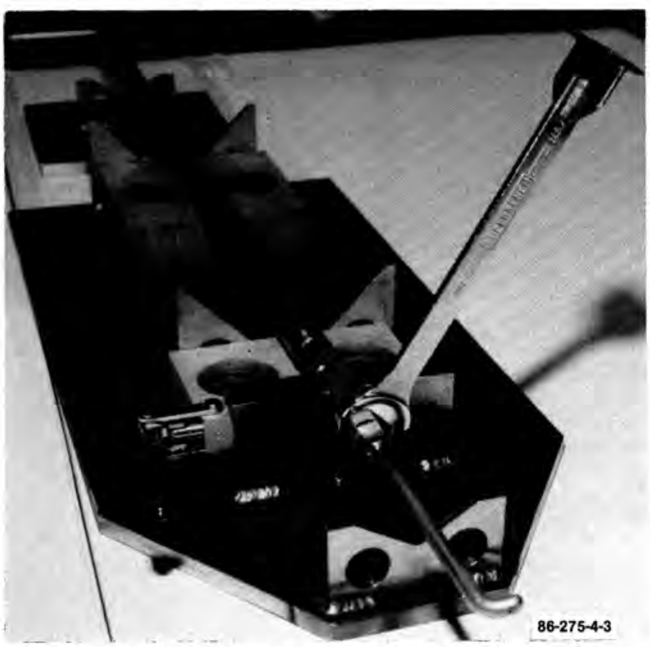

Fig. 13. Tool Clamp Fixture being used to install hook tool on handle.

switch is mounted on the control console, and removable pins replace the cutter wheel axle and pivot pin of the integral pipe cutter. The machine, with standard roller pipe cutter, is used with a master slave manipulator to cut the core barrel outer casing, as shown in Fig. 14. The cores were supported with modified, adjustable pipe support stands. A hand-held Milwaukee Model 6230 band saw, modified for manipulator handling and extended to use 53-3/4-in.-long blades, is employed to cut the upper split tube off the lower split tube and core sample.

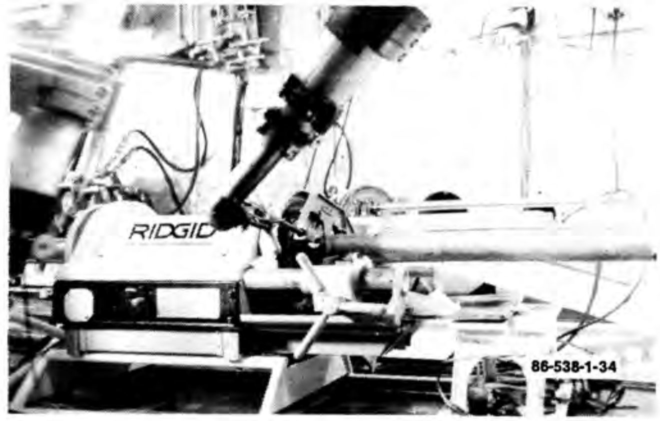

Fig. 14. The Core Barrel Disassembly Machine being used to cut outer casing from core barrel in TAN Hot Cell.

- Transport Tubes - These were developed for remote use by manipulators in order to contain the core samples and protect them during shipping and handling (Fig. 15). The tubular body diameter was selected to fit the sample (1-in. ID for fuel rods and 3-in. ID for core bores). One end is closed with a welded plug, while the other is closed with a rubber expanding plug adapted to manipulator operation.

INSTALLATION AND TRIAL OPERATION

Figure 16 is an overall view of the THC showing the cell windows and master slave manipulators on the left, one of two Parr 3000 electromechanical manipulators overhead, and the door from the THS in the background. A canister can be seen on the laydown/lifting fixture located on the transporter in the doorway. The head removal machine and transfer table are located opposite the windows.

The equipment was tested in trial operations out-of-cell using a canister and simulated core components. In Fig. 17, a simulated control rod spider assembly has been withdrawn by the carriage onto the transfer table, using a hook tool and handle. The crutch was used to support the hook tool and video camera holder. After several modifications, the system was installed in the THC. The system was again tested in trial operations using a dimensionally-accurate rejected fuel canister, an actual TMI-2 type upper end fitting, and several simulated core components, including a partial fuel bundle and control rod spider. Both trials were worthwhile in correcting some design and operational deficiencies while also providing technician training.

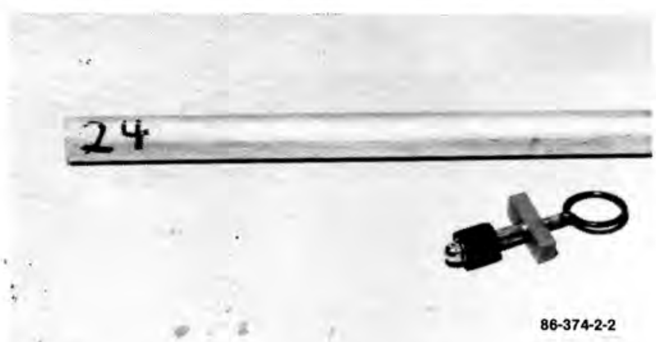

Fig. 15. Transport Tube and end plug used to ship fuel rods between INEL facilities.

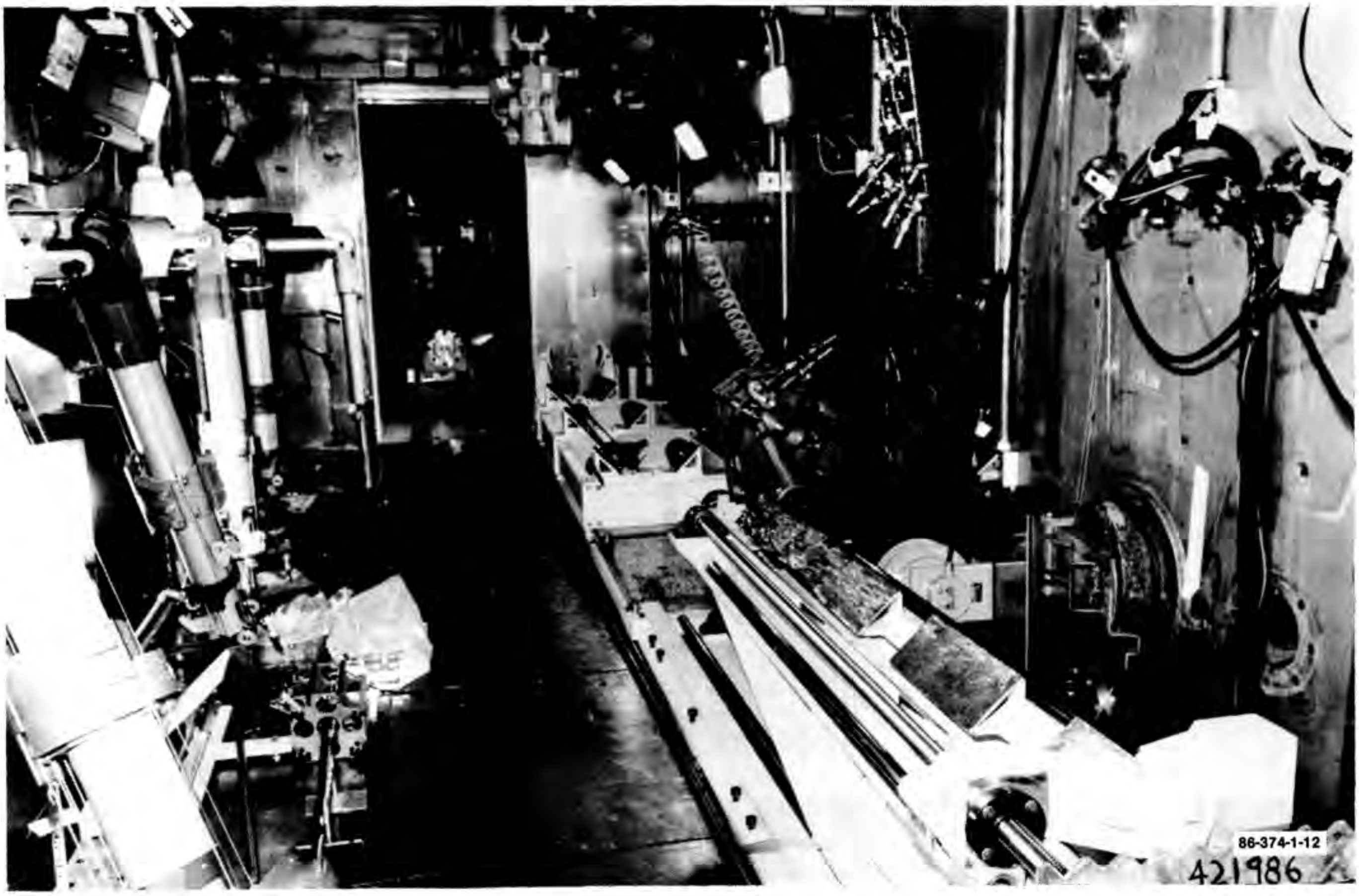

Fig. 16. Overall view of TAN Hot Cell showing Transfer Table and Head Removal Machine on the right, the Laydown/ Lifting Fixture with canister in the center, and the master slave manipulators on the left.

Fig. 17. View taken during trial operations showing hook tool aided by the video camera extracting a simulated control rod spider from a canister.

RESULTS

In late July 1986, canister D-141, containing selected distinct core component samples from TMI-2 was received at the INEL. The canister was transferred from the cask to the TAN pool, and later transferred from the pool to the THC entryway. The canister was lowered from the vertical to horizontal position, placed on the THC transporter, and moved into the THC using the laydown/lifting fixture. It then was placed on the rotator and brake assembly, where it was positioned for head removal. The vent and drain assembly was hooked up to the inlet and outlet connectors of the canister using the manipulator-operated quick disconnects, and the canister was vented, then drained of residual water. The head remover was used in conjunction with the rotator and brake assembly to remove the head bolts and swing the head away from the canister. The extraction tools were employed to pull, scoop, and pry the components from canister D-141 and later, components from canister D-153. The transfer table and carriage provided the pulling force. Tools and video cameras were positioned and manipulated with both master slave and electromechanical manipulators.

After extraction from the canisters, the components were photographed, examined visually, and placed in lead-lined 55-gal drums. The drums will be used for storage and on-site transport of selected components for subsequent examination. One partial fuel bundle was disassembled to remove fuel rods, control rods, and guide tubes for detailed study. The rods of interest were placed in transport tubes, while the remnants were put in a debris bucket and returned to the canister. The canister was returned to the pool for storage.

Core bores in canisters were received at the INEL in early August 1986 and were transferred into the THC. Each canister was opened, and the two core bores contained within were removed using a hook tool held by an electromechanical manipulator. The core bore canister dividers and other core bore tools remained in the canisters. The drill tools and casings were cut from the core bores using the core barrel disassembly machine and returned to the canisters. Upper casings and split tubes were cut off and disposed as dry, hot waste. Each core bore inside a lower split tube carrier was placed in a transport tube and transferred from the THC to the THS, where full-length isotopic and spectral gamma scans were performed. The core bores were transported to the Auxiliary Reactor Area (ARA) Hot Cell, where the split tubes were opened, and the core bores were examined visually, and photographed. Then sections were removed from the bores. Unused portions of the examined core bores, along with the split tubes, were returned to the canisters at the THC. The canisters were closed and returned to interim storage in the TAN pool.

The fuel canisters could not have been unloaded economically without using the equipment described herein. In fact, the equipment and operating personnel performed so well that several canisters were opened and drained to measure the total water contained within. It is possible that the closure and port seals of some canisters could develop leaks during the storage period. If canister seal leakage does occur, the equipment could be used to remove the closures and replace the faulty seals.

RECOMMENDATIONS

Experience gained from designing, testing, and operating the TMI-2 fuel canister and core sample handling equipment has resulted in identifying several important considerations applicable to complex hot cell equipment, in addition to the normal requirement to provide for servicing by manipulators. Those considerations are listed below.

- To reduce possible retention of contamination and enhance decontamination efforts, any cracks or crevices in the equipment should be sealed with either weld or caulk which is then painted.
- Bolted components and assemblies that have to be aligned and remain aligned should be dowel-pinned in final position.
- Thomson rails are recommended for mounting movable equipment where close alignment of linear motion is required, even though those rails are difficult to install properly.
- Limit switches provide a reasonable means of controlling travel of electrically-driven mechanical devices. It is recommended that those with operating arms (reeds) not be used because the arms are susceptible to undetected damage in a remote environment.
- Testing of equipment in trial operations, both hands-on and remote, should be a part of system testing in order to identify and eliminate design and operational flaws.
- Extensive training of operators is recommended for similar sophisticated, remote systems.

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