CONF-820609--44

REMOTE MAINTENANCE EQUIPMENT FOR THE FUSION ENGINEERING DEVICE*

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ABSTRACT

Tokamak design studies for the past five years have emphasized the importance of device maintenance by developing configurations based strongly on component disassembly. These configuration-oriented considerations have not, however, addressed the means by which a component is replaced, namely the maintenance procedures and the equipment needed. A detailed study of the replacement of a torus sector is the basis for identifying the stepwise maintenance procedures and the major equipment needed to accomplish this task. The replacement scenario is described in six stages, along with the requirements for general purpose and special purpose equipment.

INTRODUCTION

The Fusion Engineering Device[1] (FED) is a configuration which is representative of next generation D-T tokamaks. It embodies key maintenance problems associated with future fusion reactors, namely those of handling large, radioactive components. In this context, the FED can be used as a model for defining the requirements for maintenance equipment, as well as for developing these equipment concepts. To present this material, the disassembly scenario leading to the replacement of a torus sector has been chosen. The ten torus sectors are among the largest and heaviest components making up the tokamak. Table 1 is a list of the characteristics of the major FED components, and Fig. 1 is a view of the device with one of the sectors removed.

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract W-7405-eng-26 with the Union Carbide Corporation-Nuclear Division.

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SECTOR REPLACEMENT SCENARIO

The development of this scenario assumes that peripheral components (i.e., test modules, pumped limiter, ICRH, ECRH) remain installed in the sector during its removal. For simplicity, sector replacement can be viewed as a two-part scenario consisting of sector removal and subsequent replacement using a spare or the repaired sector. Each of these has three stages of operation described in Tables 2 and 3.

Sector Removal

General device shutdown is the first stage and consists of de-energizing the coils, draining and storing the torus coolant, a bakeout of the torus for detritiation, and the preparation of maintenance equipment. Based on the present understanding of these procedures, 64 hours is required, which is greater than the 24-hour shutdown period necessary for personnel access to the device. Therefore, contact maintenance is permitted to assist in the setup of remote equipment and to accomplish tasks which are more efficiently done hands-on.

Disassembly of the sector interfaces is Stage 2. It consists of removing structural attachments between the sector and the support spool/frame, cutting the vacuum flange, uncoupling coolant and electrical connections and removing pipe assemblies, decontaminating the duct and the sector, removing the pump duct, and installing shield plugs over duct openings.

Removal of particulate matter eroded from the first wall surfaces of the sector prior to its removal is a measure which will minimize the potential contamination resulting from debris falling out of the sector during its extraction. This operation, as well as the installation of local shield plugs, will enhance recovery back to contact operations before the sector is removed.

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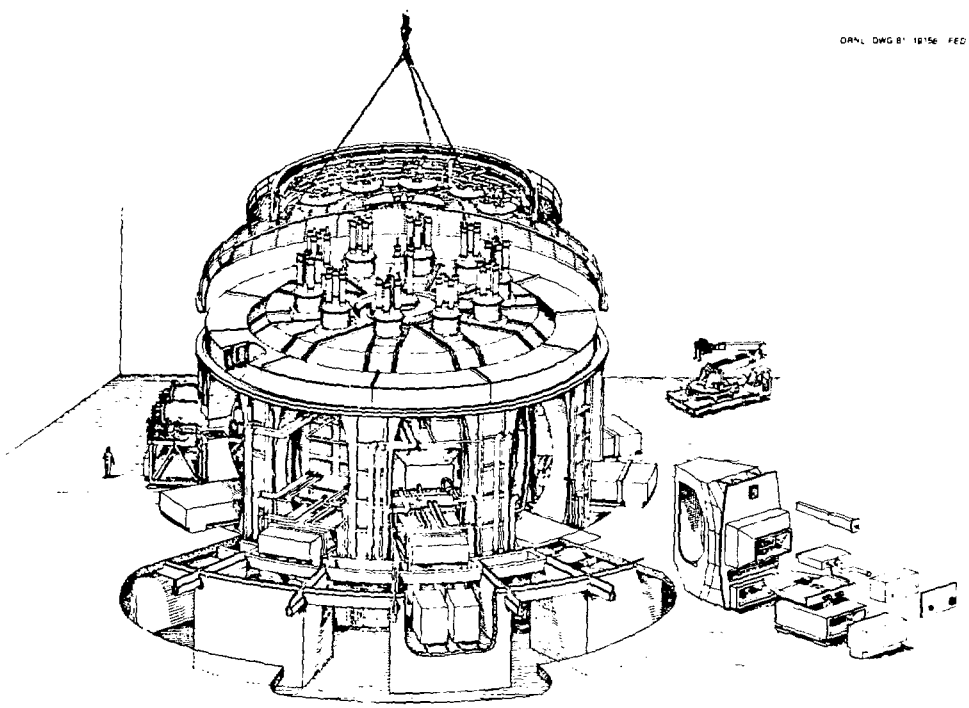
Table 1. Characteristics of major FED components

Component	Quantity	Size (m)	Weight (tonne)	Major maintenance equipment
Torus Sector	10	7 × 5 × 4	375	Special transporter, O/H crane, remote welder
Limiter Module	10	4 × 3 × 0.5	30	Special transporter, O/H crane
Pump System	20	2.5 × 2 × 1.5	<10	General purpose manipulator, O/H crane
ICRH Launcher	4	3.3 × 2.5 × 1.3	<10	Special transporter, O/H crane
O/H Solenoid	1	12 × 3 dia.	350	O/H crane
EF Coil #2	1	19 dia.	300	O/H crane
EF Coil #3	1	19 dia.	450	Jacking system
EF Coils #1, 4	1	3.9 dia., 3.1 dia.	90	Special purpose manipulator
TF Coil	10	10.6 × 7.2 (clear bore)	200	Special fixtures, O/H crane
Fuel Injector	2	6 × 3 dia.	<20	General purpose manipulator, O/H crane



FED REFERENCE CONFIGURATION
DIMETRIC VIEW

Fig. 1

1 General Device Shutdown

- De-energize coils
- Drain & store torus coolant water
- Bakeout torus using hi-temp N_2 gas
- Lower torus temperature
- Prepare maintenance equipment

} 3 h
18.5/24 h
18.5 h

64 h

2 Disassemble Sector Interfaces

- Remove struct. bolts (44-2 1/2 cm)
- Cut vac. flange (22 m)
- Uncouple coolant lines

Lines	Connects	Diam (cm)
2	4	30
1	2	20
6	12	8
1	2	10
4	8	15

- Uncouple waveguide

1	2	3

- Uncouple coax (combination electrical & coolant)

1	2	20

- Remove lines in window area
- Cut vac. flange of duct elbow
- Remove elbow to storage
- Install floor cover plate over open duct
- Cut vac. flange of duct
- Roll back duct; remove to storage

3 Sector Removal

- Install sector handling device* and lock into position
- Engage extraction mechanism to sector
- Pull sector onto handling device
- Extract handling device and sector
- Attach contaminant collector to sector
- Lift sector and transport to hot cell air lock

Equipment - Stage 1

- General device shutdown does not require the use of maintenance equipment; the procedures listed are automated and executed from the control room
- Preparation of maintenance equipment consists of removing equipment from storage and placing it in reactor cell during the 18.5-h cooldown phase

Equipment - Stage 2

- General purpose mobile manipulator
- Debolting tool (2-1/2 cm bolts)
- Track-mounted cutter
- Nut runner for "Grayloc" type couplings
- Lifting slings for pipe sections
- O/H crane(s)

Equipment - Stage 3

- General purpose manipulator
- O/H crane(s)
- Sector handling device

*Sector handling device has provisions for containing contaminated debris.

Table 2. Sector Removal Procedures and Equipment

4 Sector Replacement

- Visually inspect floor area and open bay for particulate matter
- Decontaminate open bay and floor area
- Transport repaired sector to handling device
- Engage extraction mechanism to sector
- *Roll handling device and sector into window area
- Lock handling device into position
- Push sector into its final position in torus
- Inspect vacuum flanges and bolt holes for alignment
- Remove sector handling device
- Install structural bolts (44-2 1/2 cm)
- **Weld vacuum seal (22 m)
- Inspect floor area; decontaminate as required

5 Assemble Sector Interfaces

- Install shielded duct; weld vacuum flange (8 m)
- Remove floor cover plate
- Install duct elbow; weld flanges (8 m, 8 m)
- Leak check all welded flanges (22 m, 8 m, 8 m, 8 m)
- †Position lines, connect couplings

Lines	Connections	Diam (cm)
2	4	30
1	2	20
6	12	8
1	2	10
4	8	15

- Same for waveguide

1	2	3

- Same for ICRH coax assembly

1	2	20

- Leak check each coupling by pressurizing systems with tracer gas
- Check work area around sector for contaminated debris; cleanup as required

6 General Device Startup

- Final inspection by maintenance personnel
- Remove maintenance equipment to storage
- Circulate coolant in sector
- Activate torus pump system
- Recondition plasma chamber using bakeout, discharge cleaning, etc.
- Energize coils
- Begin reactor operations

Equipment - Stage 4

- CCTV (general purpose mobile manip.)
- Decon vacuuming device
- Radiation monitoring device
- General purpose mobile manipulator
- O/H crane crane
- Sector handling device
- Bolting tool
- Track-mounted welder

Equipment - Stage 5

- O/H crane
- Portable remote viewing
- Track-mounted welder
- ††Leak detection equipment
- General purpose mobile manipulator
- Decontamination equipment

Equipment - Stage 6

- O/H crane

*Sector alignment onto handling device is provided by guidelines; final alignment is provided by guide tracks which support the handling device.
**Vacuum seal flange on sector is prepared in hot cell.
†Lines are preassembled into holding fixture.
††Pump down torus to base pressure; use tracer gas analyzer at sector pump system for vacuum test; use tracer gas analyzer at coolant couplings.

Table 3. Sector Replacement Procedures and Equipment

Removing the sector is the third stage and is shown schematically in Fig. 2. It consists of installing the sector handling device, engaging the mechanisms of that device, extracting the sector out of the window area, attaching the contaminant collector to the sector, and transporting the sector to the hot cell using the overhead crane.

Also shown in Table 2 is a listing of the major equipment needed in each of the three stages.

Sector Replacement

Sector replacement is Stage 4 of the total scenario. It consists of inspection and decontamination of the open torus and the adjacent floor area, transporting the repaired sector from the hot cell to the sector handling device, positioning the sector into the torus, inspecting vacuum flanges and bolt holes for alignment, removing the sector handling device, installing structural attachments, welding the sector seal, and inspecting the floor area and decontaminating as required. If a shield plug is installed into the sector at the duct opening, personnel access to the sector is possible.

Stage 5 is reassembly of all of the sector interfaces and final vacuum testing. It consists of installing the shielded duct and welding the flange joint, installing the duct elbow and welding those two flange joints, leak checking all three joints, installing all of the pipe assemblies and connecting couplings, leak testing the couplings, general inspection and radiation check and cleanup as required. Many of the operations during this stage can be assisted by personnel. Continuous radiation monitoring will be required before and during these manned operations.

General device startup is the sixth and final stage. It consists of a final inspection by maintenance personnel, removal of maintenance equipment to storage, circulating coolant in the sector, starting up the torus pump system, reconditioning the plasma chamber, energizing the coils, and finally reactor plasma startup.

Table 3 also includes a listing of the major equipment needed during each stage. It is the same equipment shown in Table 2, with the addition of leak detection equipment.

GENERAL PURPOSE AND SPECIAL PURPOSE EQUIPMENT

General purpose maintenance equipment is that which is not dedicated to any particular operation and can be used to accomplish more than one task. The Mobile Manipulator System (MMS) is an example of general purpose equipment. It is capable of limited lifting, uses various end-effector tools, and can perform inspection and equipment setup.

Special purpose maintenance equipment is that which is dedicated to a specific task or function. The Sector Handling Device (SHD) is an example of equipment dedicated to a specific task, namely the extraction of the torus sector. The remote cutter/welder is another example, although it is not limited to sector removal and can be used on any flange which is designed to accommodate this equipment.

Table 4 is a listing of the major equipment identified from the sector replacement scenario, along with relevant comments. It is worth noting here that for the replacement of a single sector, there is no requirement for more than one unit of any equipment listed. The consideration of multiple sector replacement may require duplicating some of the equipment. This could be determined by doing a cost-benefit analysis which assesses potential machine downtime saved.

General Equipment Requirements

A preliminary listing of equipment requirements is presented below. They are general in nature and must be supplemented with functional requirements and operating requirements in order to provide a basis for conceptual equipment designs.

Materials of fabrication:

1. In general, non-magnetic materials are preferred and should be considered where they do not have a significant impact on the cost of the equipment design. Non-magnetic materials are a requirement for small tools (i.e., wrenches) used in the reactor building.

2. All materials should exhibit resistance to degradation from gamma radiation. This is especially true for the use of organic substances.

3. Materials should be reasonably impermeable to tritium wherever practical.

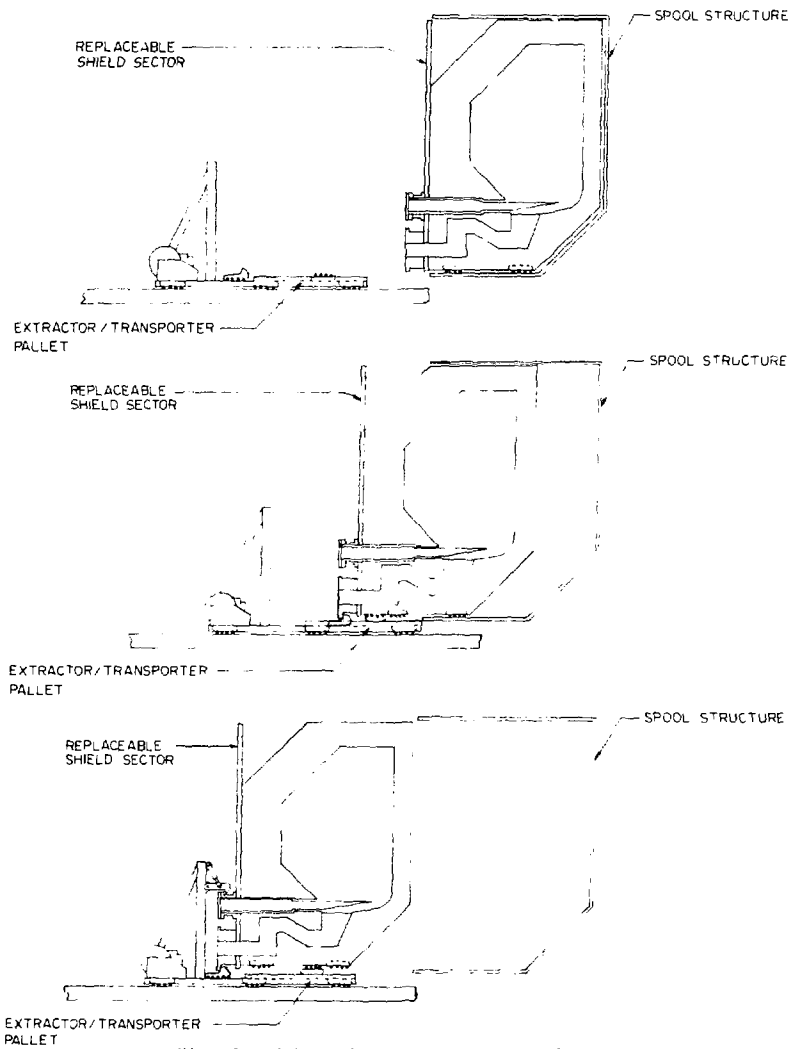


Fig. 2. Schematic representation of a sector removal

4. Materials should be resistant to chemicals used for cleaning and decontamination.

Surfaces and finishes:

1. All equipment surfaces must be smooth, having at least a mill-quality finish. Ferritic materials may require coatings to protect their surfaces from corrosion and oxidation.

2. Inaccessible equipment surfaces are to be avoided to ease cleaning and inspection.

3. Penetrations into the maintenance equipment for its moving parts, modular interfaces, and umbilicals must be sealed.

Equipment assembly

1. Components which make up the maintenance equipment should be modular with full access to all modules for maintenance and disassembly.

2. The equipment assembly or its modular components should be capable of glovebox repair when hands-on repairs are not possible.

Table 1. Maintenance Equipment for the Removal of One Sector

Item	Comments
Mobile manipulator system	• Used in all six stages of sector replacement • It interfaces directly with the equipment having an asterisk (*)
Floor-mounted manipulator system	• Located behind the TF coil[a]
*Bolt removing tool	• Pneumatically driven
*Nut-runner	• For coolant couplings
Cutter/welder system	• Track mounted
*Lifting slings	• For lifting pipe assemblies
Overhead cranes	• 50-tonne capacity and 500-tonne capacity
Sector handling device	• Provisions for containment of contaminated debris
*Portable CCTV	• General viewing and inspection
*Leak detection equipment	• Inspection of flanges and couplings
*Decontamination equipment	• Portable vacuuming system

[a] This device was among the general purpose maintenance equipment identified at the FED Maintenance Equipment Workshop held in January and March 1981 (re ORNL/TM-7769). There does not appear to be any advantage in using this equipment instead of the mobile manipulator for sector removal.

SUMMARY AND CONCLUSIONS

Assessing various disassembly scenarios is a way of determining which maintenance equipment is needed to replace tokamak components. The replacement of a torus sector was used to identify general purpose and special purpose major equipment by evaluating six stages of operations. For the replacement of one sector, the duplication of equipment was shown not to be a requirement. Other component replacements will be evaluated in order to expand the list of required equipment; similar work for the TF coil has already been started.

The equipment listed in Table 4 seems to indicate that the development of maintenance equipment concepts can be accomplished using present technology which has been adapted to the particular needs of the tokamak. If the development of this equipment is coupled to a reactor configuration which is designed at the outset for maintainability, viable approaches and systems can be developed for maintenance.

REFERENCES

1. D. Steiner, et al., "Fusion Engineering Device Design Description," ORNL/TM-7948, Oak Ridge National Laboratory (1981).

2. L. S. Masson, et al., "Pre-Conceptual Design Requirements and System Description for FED Frame Seal Welder and Cutter," EGG-EI5786, Idaho National Engineering Laboratory (March 1981).

3. P. Sager, et al., "Proceedings of FED Remote Maintenance Equipment Workshop," ORNL/TM-7769, Oak Ridge National Laboratory (1981).