14. DESIGN INTEGRATION AND MAINTENANCE

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14. DESIGN INTEGRATION AND MAINTENANCE

14.1. INTRODUCTION

In principle, the engineering aspects of a D–^3^He reactor are less complicated than those of a D–T reactor because there is no tritium breeding blanket. The exceptions are the plasma-facing components, which are generally subjected to higher loads of energy and particles and those components that are subjected to disruption forces and energy and particle deposition. An additional advantage of a D–^3^He reactor is that the neutron yield of the reactor is low and, therefore, the lifetime of the fusion-power-core (FPC) components is not limited by the radiation lifetime. The main FPC components are the first wall, shield (which shields against neutron damage to the superconducting coils), divertor plates, toroidal- and poloidal-field (TF and PF, respectively) coil sets, associated support structures, coolant piping, and a set of kink-stabilization coils.

Although the radiation lifetime does not limit the lifetime of the FPC components of a D–^3^He reactor, the design integration and maintenance procedures closely resemble those of a D–T reactor. In general, the maintenance procedures should be limited to component replacement inside the reactor vault, with repairs to failed components being made outside the vault (Sec. 14.2). The ARIES-III FPC components and the reactor design are described in Sec. 14.3, and the procedures for removing the FPC components are presented in Sec. 14.4. Section 14.5 describes the difficulties associated with the need for a kink-stabilization coil system, and a summary with conclusions is given in Sec. 14.6.

14.2. THE MAINTENANCE SCHEME

In order to reduce the downtime of a reactor and thereby increase the availability, maintenance procedures for commercial fission-reactor power plants and other conceptual fusion-reactor designs [1] were reviewed in detail early in the ARIES reactor study. The design items that lead to drastic reductions in maintenance time for a fusion facility were identified as follow:

- Avoid the need to remove other components for access to the component that must be replaced.
• Make components structurally independent of any neighboring components that may be removed, which eliminates any need for temporary support.

• Minimize the number of welds to be cut and re-welded, eliminate complex welds, and provide easy access to components that require welding.

• Minimize the number of coolant supplies that have to be connected and disconnected, since leaks (especially at coolant joints) are major sources of failures.

• Minimize the number of connects/disconnects for electric power leads. Locate all power leads close to each other so that the appropriate jumpers can be removed simultaneously.

• Provide ample work and transport area for manipulators (or robots) and transport equipment. Locate ancillary equipment away from these areas.

• All components are subject to failure, hence, the procedure and the necessary tools for replacing every component should be included in the design.

• The reactor design and maintenance procedures should allow for modifying and upgrading components without impacting maintenance time and availability.

Most importantly, the maintenance approach for any reactor should be limited to component replacement inside the reactor vault, with repairs to failed components being made outside the vault.

To accommodate a component-replacement maintenance scheme, the FPC components must be modularized. Each module, however, should be as large as possible. This will keep the number of modules and the associated complexities (for coolant and electric supplies to each module) to a minimum.

For the ARIES-I reactor, the maintenance approach is to replace an entire FPC sector, including the associated TF coil. As a result, the associated piping can be bundled together, as can the electrical connects/disconnects. Thus, only a few connections have to be broken inside the reactor vault, allowing a large section to be replaced fairly rapidly. For this approach to succeed, each cryogenic component has its own cryostat, and a warm-to-cold interface was developed so that when a sector is to be moved, only its TF has to be warmed.

The ARIES-III maintenance scheme is different from that of ARIES-I in that the TF coils are designed to remain in place during maintenance in order to minimize thermal
cycling of the TF coils. Choosing this method allows a comparison to be made with the method used for ARIES-I, since both maintenance schemes are equally applicable to the ARIES-I and ARIES-III designs.

With the TF coils established as semi-permanent components, the size of a replaceable component is determined by the clearance between the TF coils. The next option affecting reactor design and layout is the choice between radial and vertical component-removal procedures. For a radial removal process, the outermost poloidal-field (PF) coils (weighing nearly 600 tonne each) have to be either raised or lowered to allow access to the vacuum vessel. Then, the vacuum vessel is opened and components are removed radially away from the center of the reactor. The alternative is a vertical lift scheme. Here, only the upper PF coils have to be lifted to gain access to the upper part of the vacuum vessel. Then, the vacuum vessel is opened at the top and components are lifted out.

The choice of a radial or vertical component-removal scheme has a significant impact on the reactor design and layout and on the reactor-room volume. The radial removal of tall components (such as the ~ 10.5-m-high ARIES-III shield) requires that the removal pathway be clear. This means that the toroidally continuous parts (PF coils, ring headers, and pipes) must be removed before FPC components can be withdrawn radially from the reactor and/or they should be located out of the removal path. The largest unobstructed removal area for a vertical lift is dictated by the clearance between adjacent TF coils. For ARIES-III, this requires that component (e.g., the inboard first-wall and shield module) cross-section dimensions be smaller than 0.81 m by 0.8 m. Although, this will lead to a larger number of modules for vertical removal, a smaller unobstructed removal path will be required compared to a radial removal scheme. The other issue is the extra room needed for component replacement. For ARIES-III, vertical lift requires a minimum clearance of 11 m (to accommodate the ~ 10.5-m-high shield), while a ~ 5-m clearance is required for the radial component-removal scheme.

While certain features of radial and vertical component-removal schemes can be deduced a priori, detailed layout of the FPC (including location of ring headers, coils, support, etc.) is required in order to make a sound judgment on the choice between radial and vertical removal. Therefore for the ARIES-III reactor, a vertical component-removal scheme has been adopted as the reference, and the radial component-removal scheme will be explored in the context of the ARIES-II and ARIES-IV designs. Then, a comparison of the maintenance procedures for all the ARIES designs will provide a basis for comparing and evaluating the different maintenance schemes.
14.3. REACTOR CONFIGURATION

The ARIES-III reactor has an aspect ratio of 3 with plasma major and minor radii of, respectively, 7.5 m and 2.5 m. The reactor is 13-m high and has a diameter of 26 m (Fig. 14.3-1). Typical component dimensions are given in Table 14.3-I. The primary structural material of the ARIES-III reactor is reduced-activation ferritic steel; the divertor is made entirely of tungsten; the first wall is coated with 1-mm-thick layer of beryllium to enhance synchrotron-power reflection; and the coolant is organic.

14.3.1. Fusion Power Core

The ARIES-III reactor is cooled with organic coolant. Since the temperature of the organic coolant is limited to about 450°C, advanced structural material is not required. Low-activation ferritic steel is, therefore, selected as the structural material.

The ARIES-III fusion power core comprises 20 superconducting TF coils, a bucking cylinder, 14 superconducting PF coils, a vacuum vessel, an integrated first wall and shield, a double-null divertor, 3 neutral-beam ducts, and radio-frequency (RF) antennas (Fig. 14.3-1). A detailed description of the ARIES-III first-wall and shield mechanical design is given in Sec. 12.5. The divertor design is detailed in Sec. 10.3. The ARIES-III reactor requires 10 helically wound, kink-stabilization coils (see Sec. 14.5), which are located between the vacuum vessel and the shield.

Figure 14.3-2 is an elevation view showing a cross-sectional cut through a TF coil of the ARIES-III reactor. The TF magnets produce an on-axis field of 7.8 T (maximum field on the coil is 14 T). The ferromagnetic structure (the shield) is utilized to reduce the ripple from the TF coil. (If this turns out to be ineffective, either the number of TF coils or the dimensions of the outboard leg of the TF coils should be increased.) The design of the outboard first-wall and shield module is driven by the surface heat load, which is very high for any D-3He reactor. Additionally, the second stability plasma pushes the plasma axis toward the outboard first wall. To reduce the peak surface heat load of 2.8 MW/m² on the outboard first wall, the outboard plasma scrape-off-layer thickness at the mid-plane is increased to 90 cm (from ~10 cm) by “bulging” the first wall outward (see Fig. 14.3-2). This reduces the maximum heat flux from 2.8 MW/m² to 1.86 MW/m². Figure 14.3-3 shows the planer view through the equatorial plane of the ARIES-III FPC.

The bucking cylinder has vertical recesses in its outer wall in which the straight leg of each of the TF-coil cryostats rests. The reactor inboard and outboard integrated
14.3. REACTOR CONFIGURATION

Figure 14.3.1. Cutaway view of ARIES-III showing the FPC components.
Table 14.3-I.
Major Dimensions (m) of the ARIES-III Reactor Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucking cylinder</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>9.2</td>
</tr>
<tr>
<td>Bore radius</td>
<td>3.32</td>
</tr>
<tr>
<td>Radial depth</td>
<td>0.46</td>
</tr>
<tr>
<td>Toroidal-field coil</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>12.2</td>
</tr>
<tr>
<td>Width</td>
<td>1.49</td>
</tr>
<tr>
<td>Radial depth</td>
<td>0.34</td>
</tr>
<tr>
<td>Mid-plane toroidal span</td>
<td>8.3</td>
</tr>
<tr>
<td>Outboard first wall and shield</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>9.78</td>
</tr>
<tr>
<td>Width</td>
<td>0.81</td>
</tr>
<tr>
<td>Radial depth</td>
<td>0.83</td>
</tr>
<tr>
<td>Inboard first wall and shield</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>10.5</td>
</tr>
<tr>
<td>Width</td>
<td>0.34</td>
</tr>
<tr>
<td>Radial depth</td>
<td>0.68</td>
</tr>
<tr>
<td>Divertor</td>
<td></td>
</tr>
<tr>
<td>Poloidal length</td>
<td>1.2</td>
</tr>
<tr>
<td>Inboard toroidal length</td>
<td>1.6</td>
</tr>
<tr>
<td>Outboard toroidal length</td>
<td>1.8</td>
</tr>
</tbody>
</table>
first wall and shield are each divided toroidally into 80 modules, with each of the upper and lower divertor plates sectioned into 20 pie-shaped modules. Every TF coil is, thus, associated with 4 inboard and 4 outboard shield modules and 1 upper and 1 lower divertor modules (Fig. 14.3-4). Between adjacent TF coils, there is an upper access port for vertical maintenance of the inboard and outboard shields and of the upper divertor module. The divertor pumping ducts are located between the TF coils at the bottom of the reactor. A second (lower) access port, located at a bifurcated end of the divertor pumping duct, serves two purposes: (1) removal of the lower divertor module without having to disassemble any other component, and (2) access for connecting/disconnecting inboard and outboard first-wall and shield modules.
14.3.2. Auxiliary Heating and Current-Drive Systems

Other vacuum-vessel penetrations include the RF heating launchers and the neutral-beam ducts. About 200 MW of RF heating is required during start-up. Twenty 10-MW RF antennas are aligned above the mid-plane in two rows of 10 each. The antennas span the width of four outboard first-wall and shield modules. The 20 RF-antenna coaxial power-supply lines are 10 cm in diameter and are located above the mid-plane close to the upper maintenance ports (Fig. 14.3-1).

To provide adequate control of the current-density profile, two neutral-beam systems, which are located in a single building, are stacked vertically but with different tangency radii. (A detailed description of the neutral-beam system is given in Section 6.4.) Three neutral-beam ducts will penetrate the reactor building. One beam (150 MW at 1 to 3 MeV) is centered at the reactor mid-plane with a tangency radius of 9.06 m; it has a tapered duct; and the width and height at the first wall are, respectively, 0.47 m and 1.95 m. The other two beams (each 30 MW at 3 to 6 MeV) are centered at the mid-
Figure 14.3-4. Section of the ARIES-III FPC showing a TF coil and associated components.
plane with tangency radii of 7.64 m and 8.25 m; the affiliated ducts are square (0.45 m × 0.45 m). The outboard shield modules that lie in the path of the neutral beams are tailored to accommodate the angled neutral-beam ducts. Three actively cooled beam dumps are located on the first wall opposite each of the ducts: the 150-MW beam dump is 1.2-m thick × 0.47-m high × 1.95-m wide; the two 30-MW beam dumps are also 1.2-m thick but are 0.45-m high × 0.5-m wide.

14.3.3. Ring Headers

The shape of the vacuum vessel does not follow the outline of the shield modules in that there is an ~1.2-m gap between the upper and lower extremities of the outboard shield and the vacuum vessel (Fig. 14.3-2). This gap is utilized to house several ring headers.

All of the ARIES-III reactor components are cooled with the same organic coolant, and all components have the same inlet and outlet temperatures, which minimizes the required number of coolant loops. The ARIES-III power-conversion system consists of four steam-generator and turbine loops. Coolant is supplied to all FPC components through toroidally continuous ring headers. There are eight ring headers: two each for the outboard and inboard shields and two each for the lower and upper divertors (see Fig. 14.3-2). These toroidally continuous ring headers are fed through four major supply-and-return coolant pipes. This configuration increases coolant-supply reliability in case one of the four major coolant supplies is interrupted. To minimize the number of vacuum-vessel penetrations, all ring headers are located within the vacuum vessel. Consequently all component connects/disconnects are also inside the vacuum vessel. Corresponding to a coolant velocity of 10 m/s, the four major supply pipes are 1.20 m in diameter; ring headers of the outboard and inboard shields have diameters of, respectively, 0.40 m and 0.30 m; and the divertor ring headers require diameters of about 0.23 cm. The diameters for the connecting pipes from the appropriate ring headers to the components are 6 cm and 9 cm, respectively, for the inboard and outboard shield modules, and 10 cm for the divertor modules.

14.3.4. Disruption Considerations

A major design criteria is that the reactor should survive plasma disruptions. The reactor components have to withstand the disruption-induced forces while plasma-facing
components are subjected to extremely high thermal loads. The consequences of disruptions are much more severe for a D–³He reactor than for a D–T reactor because the plasma current is typically 3 to 5 times larger and the thermal stored energy in the plasma in 10 to 20 times greater.

In ARIES-III, the neighboring shield modules are electrically connected, both to provide a passive stabilizing shell against the kink mode and to distribute the disruption forces on the massive shield. The disruption-induced forces are, however, distributed more or less uniformly in the shield. Preliminary analysis has shown that the massive ARIES-III shield design is capable of absorbing disruption-induced forces. However, detailed analysis is needed to confirm the location and magnitude of the forces and to determine whether or not these forces are localized, especially on or near the fragile first-wall region.

The high thermal loads on plasma-facing components can cause the evaporation of surface layers during a disruption. It is estimated (Sec. 10) that a full-power disruption would cause a 3.6-mm-thick layer of tungsten to evaporate (the ARIES-III divertor can withstand only one such disruption). Another disruption-related concern is the survivability of the beryllium coating on the first wall. Since the coating can survive only one disruption, a repair method for the first-wall coating is necessary. In situ re-coating is clearly favored over replacing damaged first-wall and shield modules. The technology for remote plasma-spraying techniques has already been demonstrated (see Sec. 12.3 for a detailed description of Be plasma spraying), and it can be accomplished by introducing a plasma-spray gun through a lower-divertor access port.

14.3.5. Reactor Building

The reactor building has a 1-m-thick, cylindrical concrete wall with a radius of about 26 m. The building should be at least 30-m high to allow for a 13-m clearance above the reactor for assembly and maintenance procedures (see Sec. 14.4). To minimize the reactor building dimensions, the vacuum pumps are located in a pump room beneath the reactor room with ducts leading directly through the floor. Primary coolant supply- and-return pipes are also routed the floor. The reactor building is penetrated by neutral beams originating from one side only.
14.4. MAINTENANCE PROCEDURES

The components of the FPC are lifted vertically through a top access port in the vacuum vessel. The largest and heaviest removable component is an outboard first-wall and shield module (~54 tonne). Two of the three upper PF coils need to be lifted for access to the upper vacuum-vessel maintenance ports (see Fig. 14.4-1). These two PF coils, which weigh ~210 and ~52 tonne, share the same cryostat and support structure (weighing ~50 tonne). A 350-tonne-capacity crane mounted on rails above the reactor would be sufficient to lift these coils and their cryostat as a unit (total weight of ~320 tonne). This crane, however, will not be adequate for reactor assembly, because the bucking cylinder and the vacuum vessel weigh, respectively, ~726 and ~592 tonne. These components

Figure 14.4-1. The first step in the ARIES-III maintenance procedure in order to access the FPC components. Shown are the lifted upper PF coils, associated cryostats, and support structure as a unit (total weight is ~320 tonne).
must be assembled inside the reactor room: the vacuum vessel can be prefabricated in sections that are welded together, and the bucking cylinder can be manufactured into identical pie-shaped sections that, which butted against each other, form the cylinder. Since each TF coil weighs ~90 tonne, it can be moved by the maintenance crane. Although the largest PF coils weigh close to ~600 tonne, the PF coils could be assembled on site, and they do not have to be moved during maintenance operations.

The shield and divertor modules are sized to fit through the outboard space between two adjacent TF coils. (Typical module dimensions are listed in Table 14.3-I.) To remove the inboard or outboard shields or the upper divertor modules, an upper access port must be opened; the lower divertor modules can be removed through the vacuum duct.

A 10-cm gap exists between the inboard shield and the vacuum vessel, which is necessary for appropriate stand-offs for support of the shield and for 10 helically wound, 1-cm-thick, normal-conducting control coils. At the mid-plane, the gap between the outboard shield and the vacuum vessel is also 10 cm. However, the outboard gap gradually widens poloidally to approximately 1.2 m at the upper and lower extremities of the module (Fig. 14.3-2). Because this 10-cm gap is insufficient for accessing the lower ring headers from the top maintenance port, a small lower access port was incorporated into the divertor duct. Through this port, connects/disconnects for all of the inboard and outboard shield and lower divertor-plate are accomplished. After a component is disconnected, it can be lifted through the upper maintenance port.

The vertical-lift maintenance scheme makes use of the gaps between the lower extremities of the outboard shield modules and the vacuum vessel. The ring headers of the upper divertor are elevated above the inboard shield so that access to other FPC components is not obstructed. The inboard-shield ring headers are located at the bottom of the vessel below the shield so that the divertor pumping duct is not blocked. The lower gap between vacuum vessel and shield is used to house the outboard first wall and shield and the lower-divertor ring headers, which are situated slightly above the vacuum pumping ducts. The lower divertor modules can, therefore, be removed from the vessel through the lower divertor port without having to disassemble any other component.

It may become necessary to re-coat the first wall with a 1-mm-thick Be layer. In situ re-coating of the first wall requires the removal of one of the lower divertor-plate modules to allow access for a remote-controlled plasma-spray gun.

The major steps involved in accessing and removing FPC components are listed below and illustrated in Figs. 14.4-1 through 14.4-5. (Note: When performed in the reverse order, these removal steps become the reassembly steps.)
Figure 14.4-2. Three steps in the ARIES-III maintenance procedure. Step A: removing upper and lower access ports (the lower access port can be removed independently of any other maintenance step); Step B: disconnecting the divertor modules; Step C: removing the divertor modules.

A. Upper Divertor Replacement

1. Lift the upper PF-coil structure (Fig. 14.4-1).
2. Remove the upper maintenance port (Fig. 14.4-2, step A).
3. Disconnect the divertor module from its ring headers (see Fig. 14.4-3 for header locations).
4. Slide the divertor module over the upper tip of the outboard shield towards the port (Fig. 14.4-2, step B).
5. Tilt the divertor module and lift through the top port (Fig. 14.4-2, step C).
Figure 14.4-3. View of a section of the ARIES-III FPC, depicting details of the lower divertor module, inboard (IB) and outboard (OB) first-wall and shield modules, and associated ring headers.

B. Lower Divertor Replacement

1. Remove lower access port (Fig. 14.4-2, step A).

2. Disconnect the divertor module from its ring headers (see Fig. 14.4-3 for header locations).

3. Slide the divertor module between lower tip of the outboard and inboard shields towards the port (Fig. 14.4-2, step B).

4. Tilt the divertor module to fit diagonally through the lower port (Fig. 14.4-2, step C).
Figure 14.4-4. View of the ARIES-III outboard first-wall and shield module, lifted. The module is simply lifted out through the upper access port (the outboard-shield ring headers have to be disconnected through access gained from the lower port).

C. Outboard First-Wall and Shield Module Replacement

1. Lift the upper PF-coil structure (Fig. 14.4-1).

2. Remove upper and lower maintenance ports (Fig. 14.4-2, step A).

3. Disconnect the outboard module from the ring headers (see Fig. 14.4-3 for header locations).

4. Lift outboard shield module through the top port (Fig. 14.4-4).
D. Inboard First-Wall and Shield Module Replacement

1. Lift the upper PF-coil structure (Fig. 14.4-1).

2. Remove upper and lower maintenance ports (Fig. 14.4-2, step A).

3. Disconnect and remove the lower and upper divertor modules (Fig. 14.4-2, steps B and C) and the outboard shield (Fig. 14.4-4).

4. Disconnect the inboard module from ring headers and tilt the module towards the access port (Fig. 14.4-5, step A).

5. Lift the inboard shield module through the top port (Fig. 14.4-5, step B).

![Diagram of inboard shield module](image)

**Figure 14.4-5.** Two steps in the ARIES-III maintenance procedure for the inboard shield modules. Step A: inboard module disconnected from its ring headers (which can only be accessed through the lower port); Step B: removal of the inboard shield module.
The last two (C and D) require a toroidal rotation of those inboard and outboard shield modules that are not aligned with the top access port before they can be lifted out of the vessel.

It is expected that the divertor target will require far more frequent maintenance and replacement than any of the first-wall and shield modules. Access ports, ring headers, and other components are arranged to permit direct access and removal of the divertor target without interference from other components.

14.5. KINK-STABILIZATION COILS

The ARIES-III reactor requires 10 coils for feedback stabilization of kink modes (Sec. 4.5). These coils must be wound helically around the torus as close as possible to the plasma. The coils are made of copper and are 1-cm thick and 60-cm wide. They are located between the shield and the vacuum vessel (Fig. 14.3-1). Each coil makes one full turn around the torus both toroidally and poloidally. Figure 14.5-1 shows the complete helical coil set. The coils are grouped in four sets, one of which is shown in Fig. 14.5-2. The sections are electrically insulated from each other, as are the coils within a section (Fig. 14.5-2). However, geometrically opposing coils within a section are joined electrically through connectors that run poloidally along the edges of each section. Figure 14.5-2 also highlights one coil pair and illustrates the connectivity circuit and the poloidal-connection braces between 2 of the 10 coils. All five opposing coil-sets per section are similarly joined. The connecting braces are bundled to lie on top of each other. Every coil circuit in each section must have its own leads (i.e., five leads per section). The cut through the coils at the outboard face (Fig. 14.5-1) shows the location of these leads.

The FPC location of the helical kink-stabilization coils can be seen in Fig. 14.3-1. The coils interfere with component removal regardless of whether a radial or a vertical scheme is chosen. Since sections of the coil that lie in the component movement path have to be removable, an elaborate coil design (where virtually each coil would be sectioned in several places) would be necessary. The sectioning has to occur at the top vacuum-vessel access port and also at the lower-divertor access port. Furthermore, each coil must have its own cooling circuit. The complications arising from the helically wound, kink-stabilization coils seem very difficult, if not almost insurmountable, with the present physics requirements and engineering design.
Figure 14.5-1. View of the ARIES-III feedback kink-stabilization coils. Shown are the 10 helically wound (one complete turn both toroidally and poloidally) control coils with the associated breaks, connecting braces, and lead cuts.
Figure 14.5-2. View of one set of the ARIES-III feedback kink-stabilization coils. One coil pair, its connectivity circuit, and its poloidal-connection braces are also highlighted.

14.6. SUMMARY AND CONCLUSIONS

For the ARIES-I reactor, the maintenance approach is to replace an entire FPC sector, including the associated TF coil. As a result, the associated piping can be bundled together, as can the electrical connects/disconnects. Thus, only a few connections have to be broken inside the reactor vault, allowing a large section to be replaced fairly rapidly. For this approach to succeed, each cryogenic component has its own cryostat, and a warm-to-cold interface was developed so that when a sector is to be moved, only its TF has to be warmed.

The ARIES-III maintenance scheme is different from that of ARIES-I in that the TF coils are designed to remain in place during maintenance in order to minimize thermal cycling of the TF coils. Choosing this method allows a comparison to be made with the method used for ARIES-I, since both maintenance schemes are equally applicable to the ARIES-I and ARIES-III designs. Furthermore, a vertical component-removal scheme has been adopted as the reference for the ARIES-III reactor. The radial component-removal
scheme will be explored in the context of the ARIES-II and ARIES-IV designs. Then, a comparison of the maintenance procedures for all the ARIES designs will provide a basis for comparing the different maintenance schemes.

The design integration activities of the ARIES-III reactor study have resulted in a reactor component layout that minimizes the number of vacuum-vessel penetrations by placing the coolant ring headers inside the vacuum vessel. The reactor inboard and outboard integrated first wall and shield are each divided toroidally into 80 modules, with the upper and lower divertor plates each sectioned into 20 pie-shaped modules. Between adjacent TF coils, there is an upper access port for vertical maintenance of the inboard and outboard shields and of the upper divertor module. The divertor pumping ducts are located at the bottom of the reactor between the TF coils. A bifurcated divertor pumping duct, also at the bottom of the reactor, serves as an access port to the lower divertor plate and also provides adequate room for performing connect/disconnect actions on the inboard and outboard shield modules. The upper divertor-plate piping network is elevated above the inboard shield so that access to other FPC components is not obstructed. Minor first-wall re-coating can be performed in situ by utilizing remote-controlled plasma-spray equipment already in service. Access to the vacuum vessel from the top requires lifting the upper two PF coils, including their cryostat and support structure.

The requirement for a kink-stabilization coil set wound helically around the torus, however, proved to be very difficult to fulfill. These coils not only have complicated connectivity requirements, but they also obstruct maintenance access paths to FPC components. As such, each coil has to be sectioned in several places. Design of a multi-sectioned coil and its associated coolant circuits may prove to be an insurmountable obstacle.
REFERENCES