# 3.0 DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT AND SYSTEMS

## 3.1 CONFORMANCE WITH NRC GENERAL DESIGN CRITERIA

This section briefly outlines the General Design Criteria (GDC) applicable to the Reactor System of the Westinghouse Advanced Pressurized Water Reactor (WAPWR) per Title 10, Code of Federal Regulations, Part 50 (10CFR 50), Appendix A, "General Design Criteria for Nuclear Power Plants". As presented in this section, each criterion is listed to denote applicability to the Reactor System (see Table 3.1-1).

## TABLE 3.1-1

## GDC APPLICABLE TO THE REACTOR SYSTEM

| Criterion | Title |
|---|---|
| 1 | Quality standards and records |
| 2 | Design bases for protection against natural phenomena |
| 3 | Fire protection |
| 4 | Environmental and missile design bases |
| 5 | Sharing of structures, systems and components |
| 10 | Reactor design |
| 11 | Reactor inherent protection |
| 12 | Suppression of reactor power oscillations |
| 13 | Instrumentation and controls |
| 14 | Reactor coolant pressure boundary |
| 15 | Reactor coolant system design |
| 18 | Inspection and testing of electric power systems |
| 19 | Control room |
| 25 | Protection system requirements for reactivity control malfunctions |
| 26 | Reactivity control system redundancy and capability |
| 27 | Combined reactivity control systems capability |
| 28 | Reactivity limits |
| 29 | Protection against anticipated operational occurrences |
| 30 | Quality of reactor coolant pressure boundary |
| 31 | Fracture prevention of reactor coolant pressure boundary |
| 32 | Inspection of reactor coolant pressure boundary |

## 3.2 CLASSIFICATION OF STRUCTURES, COMPONENTS, AND SYSTEMS

Certain structures, components, and systems of the reactor system are important to safety because they:

a. Assure the integrity of the reactor coolant pressure boundary.

b. Assure the capability to shut down the reactor and maintain it in a safe condition.

c. Assure the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of 10CFR 100.

d. Contain or may contain radioactive material.

The purpose of this section is to classify structures, systems, and components according to the importance of the item in order to provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public. Table 3.2-1 delineates each of the items in the plant which fall under the above-mentioned categories and the respective associated classification that the NRC, ANS and industrial codes committees have developed. Each of the classification categories in Table 3.2-1 is addressed in the following sections.

The classification of specific piping runs and valves in these runs is provided in the system flow diagrams contained in this module. Instrumentation and electrical equipment required to shutdown the plant or mitigate an accident which is associated with the reactor system will be classified as IE (or Safety Class 3 per ANS 51.1) and identified in the appropriate module.

Additional information regarding the classification of structures, components, and systems is provided in RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".

### 3.2.1 Seismic Classification

Seismic classification criteria are set forth in 10CFR 100 and supplemented by Regulatory Guide 1.29.

All components classified as Safety Class 1, 2, or 3 (classifications are as defined by Reference 1), are seismic Category 1.

Seismic Category I structures, components, and systems are designed to withstand the Safe Shutdown Earthquake (SSE) and other applicable load combinations, as discussed in RESAR-SP/90 PDA Module 7, "Structural/Equipment Design". Seismic Category I structures are sufficiently isolated or protected from the other structures to ensure that their integrity is maintained.

### 3.2.2 System Quality Group Classification

The components are classified according to their importance to safety, as dictated by service and functional requirements and by the consequences of their failure. The quality assurance requirements and code requirements for the reactor system meet the intent of Regulatory Guide 1.26.

### 3.2.3 Safety Classes

Table 3.2-1 lists the safety class assigned to applicable systems and components in accordance with ANS 51.1 (Reference 1). The criteria (of Reference 1) are used in the plant design to provide an added degree of assurance that the plant is designed, constructed, and operated without undue risk to the health and safety of the public.

### 3.2.4 References

1. "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants", ANS-51.1, November 1983.

## TABLE 3.2-1

## CLASSIFICATION OF STRUCTURES, SYSTEMS, AND COMPONENTS FOR THE REACTOR SYSTEM

| System/Component | Location | Quality Group(b) | Safety Class(c) | Code(d) Classification | Principal Construction Codes & Stds | Seismic Category(e) | Quality Assurance(f) |
|---|---|---|---|---|---|---|---|
| Reactor Vessel | IC(a) | A | 1 | Class 1 | III(d) | 1 | WQCS-1 |
| Internals | IC | B | 3 | Class NG | III | 1 | WQCS-1 |
| Integrated Head | IC | C/D | 3 | Class NF | III | 1 | WQCS-2 |
| Package | | | | | | | |
| Cooling Shroud<br>Missile Shield<br>Lift Rod Assembly<br>Lift Rig Assembly<br>Cable Bridge Assembly<br>Cable Assembly<br>Seismic Support System | | | | | | | |
| CRDM Control Rods<br>Gray Rods | | | | | | | |
| Housing | IC | A | 1/2 | Class 1 | III | 1 | WQCS-1 |
| Displacer Rod Drive Mechanism | | | | | | | |
| Housing | IC | A | 1/2 | Class 1 | III | 1 | WQCS-1 |
| Reactor Core | | | | | | | |
| Fuel assembly | IC | NA | 3 | Class 2 | W design standard | 1 | WQCS-1 |
| Water displacer rod assembly | IC | NA | 3 | Class 2 | W design standard | 1 | WQCS-1 |
| Gray rod assembly | IC | NA | 3 | Class 2 | W design standard | 1 | WQCS-1 |
| Control rod assembly | IC | NA | 3 | Class 2 | W design standard | 1 | WQCS-1 |

(a) Inside containment
(b) Classification per Reg. Guide 1.26
(c) Safety classification per ANS 51.1
(d) ASME Section III, Division 1
(e) Classification per Reg. Guide 1.29
(f) WQCS-1 and WQCS-2 satisfy the requirements of 10CFR50 Appendix B

# 3.9 MECHANICAL SYSTEMS AND COMPONENTS

## 3.9.2 Dynamic Testing and Analysis

### 3.9.2.3 Dynamic Response Analysis of Reactor Internals Under Operational Flow Transients and Steady-State Conditions

The vibration characteristics and behavior due to flow-induced excitation are very complex and not readily ascertained by analytical means alone. Reactor components are excited by the flowing coolant which causes oscillatory pressures on the surfaces. The integration of these pressures over the applied area should provide the forcing functions to be used in the dynamic analysis of the structures. In view of the complexity of the geometries and the random character of the pressure oscillations, a closed-form solution of the vibratory problem by integration of the differential equation of motion is not always practical and realistic. The determination of the forcing functions as a direct correlation of pressure oscillations cannot be practically performed independently of the dynamic characteristics of the structure. The main objective is to establish the characteristics of the forcing functions that essentially determine the response of the structures. By studying the dynamic properties of the structure from previous analytical and experimental work, the characteristics of the forcing function can be deduced. These studies indicate that the most important forcing functions are flow turbulence and pump-related excitation. The relevance of such excitations depends on many factors, such as type and location of component and flow conditions.

### 3.9.2.4 Preoperational Flow-Induced Vibration Testing of Reactor Internals

The recommendations of Regulatory Guide 1.20 will be satisfied by conducting confirmatory pre- and post-hot functional examination of the reactor internals on the first plant with this type of design. This examination will emphasize the following areas:

A. All major load-bearing elements of the reactor internals relied upon to retain the core structure in place.

B. The lateral, vertical, and torsional restraints provided within the vessel.

C. The locking and bolting devices whose failure could adversely affect the structural integrity of the internals.

During the hot functional test, the internals are subjected to operating time at greater than normal full-flow conditions (four-pump operation). In addition, there is some operating time with only one, two, and three pumps operating.

Pre- and post-hot functional inspection results serve to confirm that the internals are well behaved. When no signs of abnormal wear or harmful vibrations are detected and no apparent structural changes take place, the four-loop core support structures are considered to be structurally adequate and sound for operation.

### 3.9.2.5 Dynamic System Analysis of the Reactor Internals Under Faulted Conditions

Analyses of the reactor internals for loads resulting from postulated pipe breaks(*) which result in loss-of-coolant accidents (LOCAs) are typically based on the time-history response of the reactor internals to hydraulic forcing functions applied simultaneously. The forcing functions are defined at points in the system where changes in cross-section or direction of flow may occur such that differential loads may be generated as a consequence of the pipe break(s). Because of the complexity of the system and the components, it may be necessary to use finite element stress analysis codes to provide more detailed information at various points.

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(*) See RESAR-SP/90 PDA Module 7, "Structural/Equipment Design" for the detailed application of Westinghouse revised pipe break criteria to the WAPWR design.

A digital computer program(1), which was developed for the purpose of calculating local fluid pressure, flow, and density transients that occur in pressurized water reactor coolant systems during a LOCA; or other evaluation methods will be used to evaluate the structural effects on the reactor internals of the pipe breaks postulated for the WAPWR(*). The results of these evaluations will be provided in the RESAR-SP/90 integrated PDA document.

### 3.9.2.6 Correlations of Reactor Internals Vibration Tests With Analytical Results

Consistent with the format and content guidelines of Regulatory Guide 1.70, Revision 3, this subsection will be provided in the FDA version of RESAR-SP/90.

## 3.9.4 Rod Drive Systems

### 3.9.4.1 Descriptive Information of the Control and Gray Rod Drive Systems

#### 3.9.4.1.1 Control Rod Drive Mechanism (CRDM) and Gray Rod Drive Mechanism (GRDM)

The control rod drive mechanisms (CRDM's) and gray rod drive mechanisms (GRDM's) are electro-mechanical devices located on the dome of the reactor vessel head. The CRDMs/GRDMs are coupled to the rod cluster control assemblies (RCCA's) and gray rod assemblies (GRA's), respectively, which are neutron absorbing components. Both electro-mechanical mechanisms are mechanically and electrically identical, but are attached to different reactivity control components. The CRDM and the GRDM are shown in Figures 3.9-1 and 3.9-2.

The primary functions of the CRDMs are to insert and withdraw the RCCAs in discrete steps or to hold the RCCA stationary within the core to control reactor power. The purpose of the GRDMs are to fully insert and fully withdraw the GRAs within the core for load follow and power maneuvering capability. In addition, the mechanism designs shall provide for rapid insertion of the RCCAs or GRAs to shut down the reactor.

The CRDM/GRDM is a magnetically operated jack which is an arrangement of three electromagnets which are energized in a controlled sequence by a power cycler to insert or withdraw RCCAs or GRAs in the reactor core in discrete steps. Rapid insertion of the RCCAs occurs when electrical power is interrupted.

The CRDM/GRDM consists of five separate subassemblies. They are the pressure vessel assembly, coil stack assembly, latch assembly, drive rod assembly and the hub extension assembly.

A. CRDM/GRDM Pressure Vessel Assembly

The pressure vessel assembly includes a latch housing/head adapter assembly and a rod travel housing which are connected by a threaded, seal-welded, maintenance joint which facilitates replacement of the latch assembly. The latch housing/head adapter assembly consists of a latch housing which is full penetration welded to a head adapter housing. The closure at the top of the rod travel housing is a threaded cap with a canopy seal weld for pressure integrity. This closure contains a threaded plug used for venting.

The head adapter housing is the pressure vessel component which penetrates the reactor vessel closure head and forms the connection between the reactor vessel head and the latch housing.

The latch housing is the lower portion of the pressure vessel and encloses the latch assembly. The rod travel housing is the upper portion of the pressure vessel and provides space for the drive rod assembly during its upward movement as the control rods are withdrawn from the core.

B. CRDM/GRDM Coil Stack Assembly

The coil stack assembly includes the coil housings, electrical conduit and connector, and three operating coils: the stationary gripper coil, the movable gripper coil, and the lift coil.

The coil stack assembly is a separate unit which is installed on the control rod drive mechanism by sliding it over the outside of the latch housing. It rests on a shoulder of the head adapter housing without mechanical attachment. Energizing the operating coils causes movement of the pole pieces and latches in the latch assembly.

C. CRDM/GRDM Latch Assembly

The latch assembly includes the guide tube, stationary pole pieces, movable pole pieces, and two sets of latches: the movable gripper latches and the stationary gripper latches.

The latches engage grooves in the drive rod assembly. The movable gripper latches are moved up or down in 5/8-inch steps by the lift pole to raise or lower the drive rod/hub extension assembly. The stationary gripper latches hold the drive rod/hub extension assembly while the movable gripper latches are repositioned for the next 5/8-inch step.

D. CRDM/GRDM Drive Rod Assembly

The drive rod assembly connects between the latch assembly and hub extension assembly and includes a coupling, drive rod, a disconnect button, a disconnect rod assembly, and a locking button.

The drive rod is machined with external grooves on a 5/8-inch pitch which receive the latches during holding or moving of the drive rod assembly. The coupling is threaded to the drive rod and provides the means for coupling to the hub extension assembly.

The disconnect button, disconnect rod assembly, and locking button provide positive mechanical locking of the coupling to the hub extension assembly and permits remote disconnection of the drive rod assembly.

E. CRDM/GRDM Hub Extension Assembly

The hub extension assembly extends between the drive rod assembly and the rod cluster control assembly (RCCA) or gray rod assembly (GRA). The hub extension assembly consists of a semi-permanent coupling, a locking sleeve, hub extension and coupling hub.

The coupling hub provides the capability of disconnecting the drive rod assembly from the hub extension assembly. The semi-permanent coupling attaches to the RCCA or GRA using a positively locked threaded joint. This joint is designed to be disconnected only for RCCA and GRA replacement.

The CRDM/GRDM is designed to release the drive rod/hub extension and RCCA or GRA during any part of the power cycler sequencing if electrical power to the coils is interrupted. When released from the CRDM/GRDM the drive rod/hub extension assembly and RCCA or GRA fall by gravity into a shutdown position.

The mechanisms are capable of raising or lowering a 400 lb load (which includes the drive rod/hub extension weight) at a rate of 45 in./min. Withdrawal of the drive rod/hub extension assembly and RCCA or GRA is accomplished by magnetic forces, while insertion is by gravity.

The mechanism internals are designed to operate in 650°F reactor coolant. The pressure vessel assembly is designed to retain reactor coolant at 650°F and 2500 psia. The three operating coils are designed to operate at 392°F with forced-air cooling required to maintain that temperature.

The CRDM/GRDM shown schematically in Figure 3.9-2, withdraw and insert an RCCA or GRA as shaped electrical pulses are received by the operating coils. An ON or OFF sequence, repeated by silicon-controlled rectifiers in the power programmer, causes either withdrawal or insertion of the RCCA and GRA. Position of the RCCA and GRA is measured by 42 discrete coils mounted on the rod position indicator coil stack assembly surrounding the rod travel housing. Each coil magnetically senses the entry and presence of the top of the ferromagnetic drive rod assembly as it moves through the coil center line.

During plant operation the stationary gripper coil of the control rod drive mechanism holds the RCCA in a static position until a stepping sequence is initiated, at which time the movable gripper coil and lift coil are energized sequentially.

The GRAs are either fully withdrawn of fully inserted during all phases of plant operation. Although the gray rod assemblies will be utilized in the fully withdrawn or fully inserted position, the design shall permit holding the GRA at any step elevation of the drive rod assembly travel.

#### 3.9.4.1.1.1 RCCA and GRA Withdrawal

The RCCA and GRA is withdrawn by repetition of the following sequence of events (Figure 3.9-2). The sequence, starting with the stationary gripper energized in the hold position, is as follows:

A. Movable Gripper Coil - ON

The latch-locking plunger raises and swings the movable gripper latches into the drive rod assembly groove. A nominal 0.055 inch axial clearance exists between the latch teeth and the drive rod.

B. Stationary Gripper Coil - OFF

The force of gravity, acting upon the drive rod/hub extension assembly and attached RCCA or GRA, causes the stationary gripper latches and plunger to move downward 0.055 inch until the load of drive rod/hub extension assembly and attached RCCA or GRA is transferred to the movable gripper latches. The plunger continues to move downward and swings the stationary gripper latches out of the drive rod assembly groove.

C. Lift Coil - ON

The 5/8-inch gap between the movable gripper pole and the lift pole closes, and the drive rod/hub extension assembly with attached RCCA or GRA raises one step length (5/8 inch).

D. Stationary Gripper Coil - ON

The plunger raises and closes the gap below the stationary gripper pole. The three links, pinned to the plunger, swing the stationary gripper latches into a drive rod assembly groove. The latches contact the drive rod assembly and lift it (and the attached RCCA or GRA) 0.055 inch. The 0.055 vertical drive rod assembly movement transfers the drive rod/hub extension assembly load from the movable gripper latches to the stationary gripper latches.

E. Movable Gripper Coil - OFF

The latch-locking plunger separates from the movable gripper pole under the force of a spring and gravity. Three links, pinned to the plunger, swing the three movable gripper latches out of the drive rod assembly groove.

F. Lift Coil - OFF

The gap between the movable gripper pole and lift pole opens. The movable gripper latches drop 5/8 inch to a position adjacent to a drive rod assembly groove.

G. Repeat Step

The sequence described above (items A through F) is defined as one step or one cycle. The RCCA or GRA moves 5/8 inch for each step or cycle. The sequence is repeated at a rate of up to 72 steps per minute, and the drive rod assembly (which has a 5/8 inch groove pitch) is raised 72 grooves per minute. The RCCA and GRA is thus withdrawn at a rate of up to 45 inches per minute.

### 3.9.4.1.1.2 RCCA and GRA Insertion

The sequence for RCCA and GRA insertion is similar to that for control rod withdrawal, except that the timing of lift coil ON and OFF is changed to permit the lowering of the RCCA and GRA. The sequence, starting with the stationary gripper energized in the hold position, is as follows:

A. Lift Coil - ON

The 5/8-inch gap between the movable gripper and lift pole closes. The movable gripper latches are raised to a position adjacent to a drive rod assembly groove.

B. Movable Gripper Coil - ON

The latch-locking plunger raises and swings the movable gripper latches into a drive rod assembly groove. A nominal 0.055 inch axial clearance exits between the latch teeth and the drive rod assembly.

C. Stationary Gripper Coil - OFF

The force of gravity, acting upon the drive rod/hub extension assembly and attached RCCA or GRA, causes the stationary gripper latches and plunger to move downward 0.055 inch until the load of the drive rod/hub extension assembly and attached RCCA or GRA is transferred to the movable gripper latches. The plunger continues to move downward and swings the stationary gripper latches out of the drive rod assembly groove.

D. Lift Coil - OFF

The force of gravity and spring force separate the movable gripper pole from the lift pole, and the drive rod/hub extension assembly and attached RCCA or GRA drop down 5/8 inch.

E. Stationary Gripper - ON

The plunger raises and closes the gap below the stationary gripper pole. The three links, pinned to the plunger, swing the three stationary gripper latches into a drive rod assembly groove. The latches contact the drive rod assembly and lift it (and the attached RCCA or GRA) 0.005 inch. The 0.055 inch vertical drive rod/hub extension assembly movement transfers the drive rod/hub extension assembly load from the movable gripper latches to the stationary gripper latches.

F. Movable Gripper Coil - OFF

The latch-locking plunger separates from the movable gripper pole under the force of a spring and gravity. Three links, pinned to the plunger, swing the three movable gripper latches out of the drive rod assembly groove.

G. Repeat Step

The sequence is repeated, as for RCCA or GRA withdrawal, up to 72 times per minute which gives an insertion rate of 45 inches per minute.

### 3.9.4.1.1.3 Holding and Tripping of the RCCAs and GRAs

During most of the plant operating time, the CRDM/GRDMs hold the RCCAs or GRAs withdrawn from the core in a static position. In the holding mode, only one coil, the stationary gripper coil is energized on each mechanism. The drive rod/hub extension assembly and attached RCCAs and GRAs hang suspended from the three latches.

If power to the stationary gripper coil is cut off, the combined weights of the drive rod/hub extension assembly and the RCCA or GRA (plus the stationary gripper return spring) are sufficient to move the latches out of the drive rod assembly groove. The RCCA or GRA falls by gravity into the core. The trip occurs as the magnetic field, holding the stationary gripper plunger half against the stationary gripper pole, collapses, and the stationary gripper plunger half is forced down by the weight of the stationary gripper return spring and the weight acting upon the latches. After the RCCA or GRA is released by the mechanism, it falls freely until the rods enter the dashpot section of the thimble tubes in the fuel assembly.

### 3.9.4.1.2 Applicable Control Rod and Gray Rod Drive System Design Specifications (CRDS/GRDS)

For those components in the CRDS/GRDS comprising portions of the reactor coolant pressure boundary (RCPB), conformance with the General Design Criteria and 10CFR 50, Section 50.55a is discussed in Sections 3.1 of RESAR-SP/90 PDA Module 7, "Structural/Equipment Design" and 5.2 of RESAR-SP/90 PDA Module 4, "Reactor Coolant System". Conformance with Regulatory Guides pertaining to materials suitability is discussed in Section 4.5 of this module and Subsection 5.2.3 of RESAR-SP/90 PDA Module 4, "Reactor Coolant System".

#### 3.9.4.1.2.1 Design Bases

Bases for temperature, stress on structural members, and material compatibility are imposed on the design of the reactivity control components.

#### 3.9.4.1.2.2 Design Stresses

The CRDS/GRDS is designed to withstand stresses originating from various operating conditions as summarized in Section 3.0 of RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".

#### 3.9.4.1.2.2.1 Allowable Stresses

For normal operating conditions Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code is used. All pressure boundary components are analyzed as Class 1 components.

#### 3.9.4.1.2.2.2 Dynamic Analysis

The cyclic stresses due to dynamic loads and deflections are combined with the stresses imposed by loads from component weights, hydraulic forces, and thermal gradients for the determination of the total stresses of the CRDS/GRDS.

### 3.9.4.1.2.3 Control Rod Drive Mechanisms (CRDMs)/Gray Rod Drive Mechanisms (GRDMs)

The CRDM/GRDM pressure housings are Class 1 components designed to meet the stress requirements for normal operating conditions of Section III of the ASME Boiler and Pressure Vessel Code. Both static and alternating stress intensities are considered. The stresses originating from the required design transient are included in the analysis.

A dynamic seismic analysis is required on the CRDM/GRDMs when a seismic disturbance has been postulated to confirm the ability of the pressure housing to meet ASME Boiler and Pressure Vessel Code, Section III, allowing stresses and to confirm its ability to trip when subjected to the seismic disturbance.

### 3.9.4.1.2.4 CRDM/GRDM Operational Requirements

The basic operational requirements for the CRDM/GRDMs are:

A. 5/8-inch step.

B. 148.75 inches travel.

C. 400 pounds maximum load.

D. Step in or out at 45 inches per minute (72 steps per minute)

E. Electrical power interruption initiating release of drive rod/hub extension assembly and attached RCCA or GRA.

F. Trip delay time of less than 150 milliseconds. Free fall of drive rod/hub extension assembly shall begin less than 150 milliseconds after power interruption, no matter what holding or stepping action is being executed, with any load and coolant temperature of 100°F to 550°F.

G. 40-year design life with normal refurbishment.

### 3.9.4.1.3 CRDM/GRDM Design Loads, Stress Limits, and Allowable Deformations

#### 3.9.4.1.3.1 Pressure Retaining Components

The pressure-retaining components are analyzed for loads corresponding to normal, upset, emergency, and faulted conditions. The analysis performed depends on the mode of operation under consideration. The scope of the analysis requires many different techniques and methods, both static and dynamic. Some of the loads that are considered on each component where applicable are as follows:

- Control rod trip (equivalent static load).
- Differential pressure.
- Spring preloads.
- Coolant flow forces (static).

- Temperature gradients.

- Differences in thermal expansion.

  - Due to temperature differences.
  - Due to expansion of different materials.

- Interference between components.

- Vibration (mechanically or hydraulically induced).

- All operational transients listed Subsection 3.9.1 of RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".

- Pump overspeed.

- Seismic loads (operating basis earthquake (OBE) and safe shutdown earthquake (SSE)).

- Forces due to postulated pipe breaks.

The main objectives of the analysis are to satisfy allowable stress limits, to assure an adequate design margin, and to establish deformation limits which are concerned primarily with the functioning of the components. The stress limits are established not only to assure that peak stresses will not reach unacceptable values but also to limit the amplitude of the oscillatory stress component in consideration of fatigue characteristics of the materials. Standard methods of strength of materials are used to establish the stresses and deflections of these components. The dynamic behavior of the reactivity control components has been studied, using experimental test data, dynamic analysis calculations and experience from operating reactors.

###### 3.9.4.1.3.2 Drive Rod Assembly and Hub Extension Assembly

All postulated failures of the drive rod/hub extension assemblies, either by fracture or uncoupling lead to a reduction in reactivity. If the drive rod assembly or hub extension assembly fractures at any elevation, that portion remaining coupled falls with and is guided by the RCCA or GRA. This always results in reactivity decrease.

#### 3.9.4.1.3.3 Latch Assembly and Coil Stack Assembly

##### 3.9.4.1.3.3.1 Results of Dimensional and Tolerance Analysis

With respect to the CRDM/GRDM system as a whole, critical clearances are present in the following areas:

A. Latch assembly - thermal clearances
B. Latch arm - drive rod clearances
C. Coil stack assembly - thermal clearances
D. Coil fit in coil housing

The following discussion defines clearances that are designed to provide reliable operation in the CRDM/GRDM in these four critical areas. These clearances, which were maintained from prior designs have been proven by life tests and actual field performance at operating plants.

A. Latch Assembly - Thermal Clearances

The magnetic jack has several clearances where parts made of Type 410 stainless steel fit over parts made of type 304 stainless steel. Differential thermal expansion is therefore important. Minimum clearances of these parts at 68°F is 0.011 inch. At the maximum design temperature of 650°F, minimum clearance is 0.0045 inch at the maximum expected operating temperatures of 550°F, minimum clearance is 0.0057 inch.

B. Latch Arm - Drive Rod Clearances

The CRDM/GRDM incorporates a load transfer action. The movable or stationary gripper latches are not under load during engagement, as previously explained, due to load transfer action.

Figure 3.9-3 shows latch clearance variation with the drive rod as a result of minimum and maximum temperatures. Figure 3.9-4 shows clearance variations over the design temperature range.

C. Coil Stack Assembly - Thermal Clearances

The assembly clearances of the coil stack assembly over the latch housing were selected so that the assembly could be removed under all anticipated conditions of thermal expansion.

At 70°F the inside diameter of the coil stack is 7.428/7.438 inches. The outside diameter of the latch housing is 7.38 to 7.39 inches.

Thermal expansion of the mechanism due to operating temperature of the CRDM/GRDM results in minimum inside diameter of the coil stack being 7.440 inches at 222°F and the maximum latch housing diameter being 7.426 inches at 650°F.

Under the extreme tolerance conditions listed above, it is necessary to allow time for a 70°F coil stack assembly to heat during a replacement operation.

D. Coil Fit in Core Housing

CRDM/GRDM and coil housing clearances are selected so that coil heatup results in a close to tight fit. This is done to facilitate thermal transfer and coil cooling in a hot CRDM/GRDM.

#### 3.9.4.1.4 CRDM/GRDM Performance Assurance Program

The ability of the pressure housing components to perform throughout the design lifetime as defined in the design specification is confirmed by the design analysis report required by the ASME Boiler and Pressure Vessel Code, Section III.

To confirm the mechanical adequacy of the fuel assembly, the CRDM/GRDM, guide tube and the RCCA, functional test programs will be conducted on a full scale test loop. The full scale prototype assembly will be tested under simulated conditions of reactor temperature, pressure, and flow (See Section 1.5).

It is expected that all CRDM/GRDMs will meet specified operating requirements for the duration of plant life with normal refurbishment.

Actual experience for similar designs in operating Westinghouse plants indicates excellent performance of CRDM/GRDMs.

All units are production tested prior to shipment to confirm ability of the CRDM/GRDM to meet design specification-operation requirements.

Each production CRDM/GRDM undergoes a production test as listed below:

| Test | Acceptance Criteria |
|---|---|
| Cold (ambient) hydrostatic pressure test | ASME Code, Section III |
| Confirm step length and load transfer (stationary gripper to movable gripper or movable gripper to stationary gripper) | Step length: 0.625 plus or minus 0.015 inch axial movement |
| | Load transfer: 0.055 inch nominal axial movement |
| Cold (ambient) performance test at design load - five full travel excursions | Operating speed: 45 inches per minute |
| | Trip delay: Free fall of drive rod assembly to begin within 150 milliseconds as verified by normal gripper latch opening times recorded during performance test. |

### 3.9.4.2 Displacer Rod Drive System

#### 3.9.4.2.1 Descriptive Information of the Displacer Rod Drive System

The displacer rod drive mechanism (DRDM) is a hydraulically operated, non-safety related device located on the dome of the reactor vessel head. The DRDM drivelines are coupled to water displacer rods (WDRs) which are non-neutron absorbing rods and have very little rod worth for controlling the reactor core. The primary DRDM function is to withdraw and insert WDRs in a full-in or full-out mode with no intermediate positioning and no rapid insertion requirements. The WDRs provide a means for controlling the amount of moderator in the reactor core.

The DRDM utilizes the reactor coolant system for an actuating pressure source. Internal to the DRDM are two pressure dropping and flow restricting devices. The first is the piston ring subassembly and the second is a flow orifice. External to the DRDM in the DRDM vent system is a third flow orifice. These devices establish defined pressure drops throughout the DRDM system resulting in performance control of the DRDMs.

A total of 88 DRDMs are utilized and controlled in groups of four DRDMs per bank. Each bank of DRDMs are connected by a hydraulic line (Figure 3.9-5).

DRDM bank separation and operational control is achieved by solenoid valves located on the integrated head package. One valve controls the bank to be operated, a second valve controls the flow to the RCDT system. Additional valves are included in the vent system to account for additional pressure drop needs in the event of a stuck rod and for insertion of makeup fluid bypassing the vent system manifold restrictor.

#### 3.9.4.2.2 Displacer Rod Drive Mechanism (DRDM)

The displacer rod drive mechanism consists of four subassemblies; the pressure housing, the internals cylinder, the rod position indicator support, and the drive rod assembly (Figure 3.9-6).

A. The DRDM pressure housing assembly is an integral pressure boundary composed of the following parts joined by full penetration welds; the reactor vessel head penetration tube, the center section, the top adapter, and the top cap.

The reactor vessel head penetration tube is the interface between the reactor vessel head and the DRDM. The tube accounts for a transition in outside diameter from 4.0 inches at the vessel head to 4.5 inches to mate with the center section.

The center section provides for the incapsulation of the internals cylinder. The length of both are dependent upon the drive line travel requirements.

The top adapter provides an internal shoulder for the support of the internals cylinder and provides internal threads for the lock plate and load plate which preload a metal O-ring seal between the pressure boundary and the internal cylinder. The internal threads also serve as the structural connection for the top cap. A canopy seal is used to seal the top adaptor and top cap joint.

The top cap provides for the transition from the ASME Class 1 pressure boundary to the Class 2 hydraulic vent system. A 1/4 inch through-hole fixtured with an equivalent 0.060 inch orifice is contained in the top cap.

B. The internals cylinder assembly includes the following parts; the cylinder, the lower latch support, the upper latch support, the latch, the latch pivot pins, torsion springs, and latch rivit pins.

The cylinder mates with the drive rod piston and piston rings to convert the delta pressure across the piston into a lift force. The length of the cylinder is dependant upon the driveline travel requirements.

The latch is housed in the upper and lower latch supports and is spring loaded to return to a fixed position. The latch interfaces with an extension on the drive rod called the spear.

C. The rod position indicator support assembly consists of a top plate, a support tube, and a cooling baffel can. The top plate provides for lateral restraint and shoulders on a ledge machined on the pressure housing top adapter. The supports tube provides for fixturing of the RPI detector coil and creates a stagnant air space around the pressure housing to reduce heat injection. The cooling baffel can directs cooling air down past adjacent control rod drive mechanism coil stacks to aid in cooling the CRDMs.

D. The drive rod assembly is the connecting link between the piston assembly and the WDRs. The assembly consists of two drive rod segments, the upper called the drive rod and the lower called the hub extension. Parts included are the spear, piston, piston rings, drive rod, coupling, disconnect rod, hub, hub extension, and semi-permanent coupling.

The lower drive rod section (hub extension) is designed for limited removals from the WDR assemblies. The upper section is designed for remote disconnects with no finite number of connects and disconnects.

The DRDM is capable of lifting 650 pound WDR assemblies at a nominal rate of 0.95 inches/second. The lift forces are generated by venting the DRDM resulting in a delta pressure across the piston. Insertion is by gravity.

Internals assembly and drive rod assemblies are designed to operate in 650°F reactor coolant. The pressure housing is designed to retain reactor coolant at 650°F and 2500 psia.

Position detection of the drive rod is achieved by two sets of three detector coils, one set located at the upper extent of the rod travel and the second set at the lower limit of rod travel. The rod position detection system sensor changes in the coil's magnetic field caused by the drive rod.

### 3.9.4.2.3 Displacer Rod Drive Operation

The normal WDR withdrawal operation is performed by selecting a group or bank of DRDMs. Assume group A of Figure 3.9-5. The steps for withdrawal are:

1. Open valve $S_2$
2. Open valve $S_{1A}$
3. Wait until full-out indication signal for group A
4. Close valve $S_{1A}$
5. Continue with next group if applicable
6. When all groups are withdrawn, close $S_2$

When both solenoid valves $S_{1A}$ and $S_2$ are open, a differential pressure is created across the piston and piston rings which causes the piston rings to heat and the drive rod to begin an upward motion. A travel limiter is located in the internals assembly lower latch support. A conical surface matching the drive rod piston is machined in the support. When the drive rod reaches the up position, the piston and support act as a valve disk and backseat shutting off flow from the DRDM. After all drive rods reach the stop position, the valves are closed (steps 4 and 6). The drive lines insert until the drive rod spear becomes captured in the latch.

WRD insertion is performed in a similar manner:

1. Open valve $S_2$
2. Open valve $S_{1A}$
3. Wait 30 seconds for all rods to reach the stop position
4. Close valve $S_2$
5. Open valve $S_4$
6. Wait until full-in indication signal for complete insertion
7. Close valves $S_4$ and $S_{1A}$

Steps 1, 2, and 3 raise all drive rods causing the spears to disengage the latches. Steps 4 and 5 minimizes the pressure differential across the piston and supplies reactor makeup water to fill the DRDM cylinder as the drive rods move by gravity into the core.

### 3.9.4.2.3.1 Design Bases

### 3.9.4.2.3.2 Design Stresses

The DRDM pressure boundary is a Class 1 component designed to meet the normal operating conditions for Section III of the ASME Boiler and Pressure Vessel Code. Static and alternating stresses originating from mechanical and system design transients are considered in the analysis.

In addition to normal operating conditions the pressure boundary is analyzed for report, emergency, and faulted conditions. Some of the loads considered are:

- o Differential pressures
- o Spring preloads
- o Seal preloads
- o Coolant flow forces
- o Component dead weights
- o Temperature gradients
- o Thermal expansions due to temperature fluxuations and different materials.
- o Vibrations mechanically or flow induced.
- o All operational transients listed in Subsection 3.9.1 of RESAR-SP/90 PDA Module 7, "Structural and Equipment Design".
- o Seismic loads, OBE (Operating Bases Earthquake) and SSE (Safe Shutdown Earthquake).
- o Forces due to postulated pipe breaks.

The analytical objectives are to satisfy the allowable stress limits and assure an adequate design margin for the components function. Stress limits are established not only to assure that peak stresses are acceptable but also to limit the oscillating stress amplitudes in consideration of materials fatigue characteristics.

#### 3.9.4.2.3.3 Allowable Stresses

Allowable stress limits and stress intensity ranges are defined by the ASME Code Section III for Class 1 components for the various operating conditions being considered.

#### 3.9.4.2.3.4 Dynamic Stresses

Stresses due to dynamic loads are combined with stresses imposed by component weights, hydraulic forces, and thermal gradients to define a total stress state for the DRDM.

#### 3.9.4.2.4 Displacer Rod Drive Operational Requirements

The basic operational requirements being performed by the DRDMs are as follows:

A. Full-in, Full-out travel
B. A nominal 148.75 inches of travel
C. 650 pound lift capabilities
D. Travel rate nominal 0.95 inch per second
E. No insertion (SCRAM) time requirement
F. 40 year design life on pressure boundary parts
G. 40 year design life on internals assembly and drive rod assembly with normal refurbishment of seals and wear parts.

## 3.9.5 <u>Reactor Internals</u>

### 3.9.5.1 Description

Figure 3.9-7 shows the WAPWR reactor internals design. This design is significantly different from existing Westinghouse designs due to the inclusion of the moderator control system to provide a spectral shift core design.

Basically, this new design requires that 2864 rodlets of 0.884 inches diameter be protected from flow forces when they are raised or lowered, with respect to the fuel assemblies, to control the reactor reactivity. In comparison, 1270 rodlets of 0.375 inches diameter are maneuvered in a standard Westinghouse four loop 17x17 plant. Three basic types of rod cluster assemblies are employed in the WAPWR design: 8 rodlet rod cluster control assemblies (RCCAs) that control reactivity and shutdown the reactor, 8 rodlet gray rod assemblies (GRAs) that are used for load follow maneuvering, and 22 and 24 rodlet water displacer rod clusters (WDRs) that provide the spectral shift feature.

Starting at the top of the vessel and listing major areas of the WAPWR reactor internals, the following areas are observed:

1) Calandria - in the same horizontal area as the vessel nozzles
2) Upper Internals - above the core
3) Lower Internals - location of the core, lower radial supports, etc.

The calandria is positioned within the upper internals barrel, which in turn is positioned inside the upper portion of the lower internals barrel, above the core. The calandria, upper internals barrel and lower internals barrel are supported by the reactor vessel ledge and are restrained against upward movement by the vessel head. The lower end of the internals is restrained against horizontal movement by radial supports located at the bottom of the lower internals barrel. The radial supports also perform the core drop energy absorption function.

### 3.9.5.1.1 Calandria

The calandria, shown in Figure 3.9-8, provides the means for turning the coolant flow from an axial (vertical) direction to a radial (horizontal) direction before exiting the reactor. The bottom plate of the calandria allows coolant to enter, while the top plate has passages only for the WDR and RCCA drive shafts. This effectively prevents flow at core outlet conditions from entering the vessel head region. The flow exits the calandria through the reactor vessel outlet nozzles. The drive shafts for the WDRs and RCCAs, pass through the calandria inside vertical tubes which extend between the top and bottom plates. These tubes protect the drive shafts against crossflow as the coolant flows around the outside of the tubes. The calandria tubes are aligned with the WDR and RCCA guide tubes of the upper internals to allow free passage of the drive shafts.

### 3.9.5.1.2 Upper Internals Assembly

The upper internals assembly is located above the core, in the region where the RCCAs, WDRs and GRAs are suspended when withdrawn from the core. This assembly consists of the inner barrel and upper core plate, WDR guides, RCCA guides and the related attachment hardware. The upper internals assembly is installed within the upper portion of the lower barrel. When the upper internals assembly is in place, 256 pins projecting from the underside of the upper core plate position the upper end of the fuel assemblies with respect to flow holes and other features in the plate. The WDR and RCCA guide columns are aligned with the upper core plate flow penetrations by pins projecting up similar to the fuel assemblies. Correct positioning and alignment of the fuel assemblies and rod guides allows free movement of the various rodlets. The WDR and RCCA spiders operate in the region above the upper core plate and do not pass through the core plate; only the rods themselves pass through. When fully withdrawn, the rods are suspended inside the rod guides from the mechanism drive rods. During operation, coolant flows up from the core through the upper core plate, through and around the rod guides and then into the calandria.

The rod guides are structures in the upper internals of the reactor which guide and support the rods when they are raised above the core full-in position. The rod guides' functions are identical to the guide tubes in existing Westinghouse PWRs, except that coolant flows inside of the guide instead of around the guide.

There is one guide structure for each type rod cluster. Eighty-eight box-type guide structures are used to guide seventy-six, 24-rod type WDRs and twelve, 22-rod type WDRs. Ninety-seven cruciform type guide structures are used to guide 69 RCCAs and 28 GRAs.

### 3.9.5.1.2.1 Water Displacer Rod Guide Structure

Figure 3.9-9 is a cross section of the WDR guide structure through the intermediate plate. The function of the WDR guide structure is to guide and support the WDRs as the coolant flows along the rods.

To minimize vibration and drag forces a continuous type WDR guide structure has been selected. The WDR guide structure consists of an octagonal shaped shroud (1)*, 0.160 inch thick, made from 304 stainless steel sheet metal. Alignment pins at the bottom plate (2) and at the top plate (3) are provided for alignment of the guide structure to the upper core plate and the bottom plate of the upper calandria. The external shroud is manufactured in two identical longitudinal halves. The interior of the guide structure consists of three modules. A bottom module consisting of the bottom plate, 16 "c"-tubes, 8 triangular shaped bars and one intermediate plate are all welded together to form a unit. The other two modules are all identical and similar to the bottom module with the only difference being that an intermediate plate is welded at each end of the structure.

### 3.9.5.1.2.2 RCCA Guide Structure

The function of the RCCA guide structure is to guide and support the control rods when they are raised above the core full-in position. Scram time, drag forces and sliding wear of the rod during insertion/withdrawal cycles are the most important requirement for this guide structure.

### 3.9.5.1.3 Lower Internals

The lower internals functions to support the core and attached internals structure. It provides a passageway for the reactor coolant. When the coolant enters the reactor vessel, it impinges on the side of the core barrel and is directed downward through the annulus formed by the gap between the outside diameters of the core barrel and the inside diameter of the vessel. The flow

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* Numbers in parentheses refer to numbers on drawings.

then enters the lower plenum area between the bottom of the lower core support plate and the vessel head and is redirected upward through the core. After passing through the core, the coolant enters the upper internals region, then radially out through the reactor vessel outlet nozzles. A small amount of flow is directed into the reactor vessel head area by nozzles and into the area between reflector enclosures and the inside diameter surface of the core barrel for cooling. The orificed flow holes in the lower core support plate, control and meter the flow through the core.

The lower internals consists of the following core support and internals structures.

#### 3.9.5.1.3.1 Core Barrel Assembly

The main functional requirement of the core barrel shown in Figure 3.9-10 is to provide support to the core and reflector assemblies, and provide directional control of reactor coolant flow.

Between the upper barrel attachment to the flange and lower barrel attachment to the weld ring, the barrel is joined with full circumferential full penetration welds in three axial segments.

#### 3.9.5.1.3.2 Radial Core Support Keys

The lower core support plate forging is restrained circumferentially by four uniformly spaced keys which are "T"-shaped. The radial keys are mounted on the underside of the lower support plate. The upright section of the "T" extends downward between clevis supports attached to the lower pressure vessel head. Limited motion is thus allowed in axial and radial directions for thermal growth but a controlled gap remains for transient conditions.

#### 3.9.5.1.3.3 Secondary Core Support

The radial core clevis support which is mounted to the lower pressure vessel head also includes the secondary-core support design features in addition to the feature of radial core restraint. The main purpose of the secondary core support structure is to absorb the impact loads of the core and the supporting structure during a core drop accident. The energy of impact is absorbed by an energy absorbing mechanism which consists of two solid compression cylinders radially spaced under the upright section of the radial key and shrunk into cylindrical recesses in the clevis support block. In this, the energy is absorbed by compressive deformation of the solid cylinders during core drop. The secondary core support is analyzed for the most severe condition, namely faulted, or Condition IV.

#### 3.9.5.1.3.4 Bottom Mounted Instrumentation

The bottom mounted instrumentation is the structure which guides and supports the flux thimbles that penetrate through the bottom of the reactor vessel. For the WAPWR plant, sixty-one thimble penetrations are guided into the core region by sixty-one butt type instrumentation guide columns. The upper end of each guide column is bolted to the lower core support plate and the lower end is bolted to either the upper or lower tie-plate. The body material utilizes standard bar stock with adoption of full penetration welded construction.

The critical areas of investigation for stress analysis are the guide columns, weldments and the bolts or structural fasteners. As such the bottom mounted instrumentation must withstand:

Coolant forces
Seismic forces
Dead weight
Thermal transients

#### 3.9.5.1.3.5 Head and Vessel Alignment Pins

The head-vessel alignment pins are located at four locations around the lower internals barrel flange and upper internals barrel flanges. The main body of the alignment pin measures 5.0 by 8.50 by 7.75 inches and is made of 304 stainless steel. The pins attach to, and extend above and below, the flange of the core barrel assembly; and function as the alignment mechanism for the reactor vessel head closure, upper internals assembly, lower internals assembly, and the reactor vessel. The portion of the pins extending below the flange engages pockets in the reactor vessel to provide alignment of the lower internals assembly to the reactor vessel. The portions of the pins extending above the flange engage the upper internals assembly and extend into pockets provided in the reactor vessel closure head, thereby insuring total alignment of all the assemblies. Minimal clearance is maintained between the pins and their engagement numbers in order to maintain functional alignment and to allow ease of assembly.

### 3.9.5.1.3.6 Hold Down Spring

The hold down spring consists of a conventional ring type structure. The hold down spring is preloaded when clamped in place between the upper and lower internals structures with the reactor vessel closure studs. The spring preload prevents movement of the upper and lower internals assemblies during normal operation and transients.

### 3.9.5.1.3.7 Upper Core Plate Guide Pins

The purpose of the upper core plate guide pins is to locate the upper core plate laterally with respect to the middle of the core barrel. The four equally spaced pins around the upper barrel, support the upper core plate in such a manner so that the plate is free to expand radially and free to move axially due to the temperature differences between the upper internals and the core barrel.

The bodies of the guide pins are Type 304 stainless steel. The mating surfaces are hard faced. The keyways in the upper core plate have inserts which are machined at assembly to obtain a customized clearance on each side of the guide pins. The surface which mates with the guide pins is also hard faced.

### 3.9.5.1.3.8 Irradiation Specimen Guides

The irradiation specimen guides are attached to the outside of the core barrel and contain irradiation specimens. These specimens are vessel material surveillance samples that are to be exposed to irradiation during reactor operation. At specific intervals during the design life of the reactor, a specimen will be removed from the container and the material samples will be treated to determine the irradiation effects on the reactor vessel. The irradiation specimens are provided a lead factor of 3.0 based on their radial, axial and azimuthal locations. This means that the fluence received by the specimens at the end of one year is the same as the fluence the vessel receives at the end of three years.

### 3.9.5.1.3.9 Safety Injection Nozzle Deflectors

The purpose of the safety injection nozzle deflectors is to guide the fluid direction downward after water from the safety injection nozzle is injected into the downcomer. The deflector is attached with three bolts to the barrel outside diameter in line with the outlet end of the safety injection nozzle. The safety injection nozzle centerlines are located between the centerlines of the hot leg and cold leg vessel nozzles and [ ] below the centerline of the hot leg and cold leg nozzles. (a,c)

### 3.9.5.1.3.10 Radial Reflector

The purpose of the radial reflector (Figures 3.9-11 and 3.9-12) is to improve the neutron economy of the core and to reduce the neutron fluence at the core barrel and reactor vessel. The radial reflector is composed of 48 separate modules, arranged circumferentially around the core. Each module is attached rigidly to the core barrel at its top end and pinned to the lower core support plate at its bottom end. Radial support pads are provided between the modular and the core barrel at each fuel assembly grid elevation to limit core bypass flow and provide radial support during seismic events. The modules are separated by a nominal (cold) gap of 0.050 inches and are free to expand individually in response to gamma heating and fluid system transients.

### 3.9.5.2 Design Loading Conditions

#### 3.9.5.2.1 Normal Conditions Transients (Operating Condition I)

1. RCP startup and shutdown
2. Plant heatup and cooldown
3. Unit loading and unloading between 0 and 15 percent of full power
4. Unit loading and unloading at 5 percent of full power/minute
5. Reduced temperature return to power
6. Step load increase and decrease of 10 percent of full power
7. Large step load decrease with steam dump
8. Steady state fluctuations
9. Load regulation
10. Boron concentration equalization
11. Feedwater cycling
12. Loop out of service
13. Refueling
14. Turbine roll test
15. Primary side leakage test
16. Secondary side leakage test
17. Core lifetime extension
18. Feedwater heaters out of service

#### 3.9.5.2.2 Upset Conditions Transients (Operating Condition II)

1. Loss of load
2. Loss of offsite power
3. Partial loss of flow
4. Reactor trip from low power
5. Reactor trip from full power
   Case A - with no cooldown
   Case B - with cooldown and no. S.I.
   Case C - with cooldown and S.I.
6. Inadvertent RCS depressurization

7. Inadvertent startup of an inactive loop
8. Control rod drop
9. Inadvertent safety injection actuation
10. Excessive feedwater flow
11. Cold overpressurization

#### 3.9.5.2.3 Emergency Conditions Transients (Operating Condition III)

1. Small loss of coolant accident (as defined in RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".)
2. Small steam line break
3. Small feedwater line break
4. Complete loss of flow
5. Sudden stoppage of flow

#### 3.9.5.2.4 Faulted Conditions Transients (Operating Condition IV)

1. Reactor coolant pipe break, i.e., large LOCA, (although not postulated for WAPWR; see RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".)
2. Large steam line break
3. Feedwater line break
4. Reactor coolant pump locked rotor
5. Control rod ejection
6. Steam generator tube rupture
7. Simultaneous steam line-feedwater line break

### 3.9.5.3 Design Bases

The design bases for the mechanical design of the reactor vessel internals components are as follows:

1. The reactor internals in conjunction with the fuel assemblies shall direct reactor coolant through the core to achieve acceptable flow distribution and to restrict bypass flow so that the heat transfer performance requirements are met for all modes of operation. In addition, required cooling

for the pressure vessel head shall be provided so that the temperature differences between the vessel flange and head do not result in leakage from the flange during reactor operation.

2. Provisions shall be made for installing incore instrumentation useful for the plant operation and vessel material test specimens required for a pressure vessel irradiation surveillance program.

3. The core internals are designed to withstand mechanical loads arising from the operating basis earthquake, safe shutdown earthquake, and pipe ruptures and meet the requirement of item 5 below.

4. The reactor shall have mechanical provisions which are sufficient to adequately support the core and internals and to ensure that the core is intact with acceptable heat transfer geometry following transients arising from abnormal operating conditions.

5. Following the design basis accident, the plant shall be capable of being shutdown and cooled in an orderly fashion so that fuel cladding temperature is kept within specified limits. This implies that the deformation of certain critical reactor internals must be kept sufficiently small to allow core cooling.

The basis for the design stress and deflection criteria is identified below.

### 3.9.5.3.1 Allowable Stresses

For normal operating conditions, Section III of the ASME Code is used as a basis for evaluating acceptability of calculated stresses. Both static and alternating stress intensities are considered.

It should be noted that the allowable stresses in Section III of the ASME Code are based on unirradiated material properties. In view of the fact that irradiation increases the strength of the Type 304 stainless steel used for the internals, although decreasing its elongation, it is considered that use of the allowable stresses in Section III is appropriate and conservative for irradiated internal structures.

The allowable stress limits during the design basis accident used for the core support structures are based on the ASME Code, Subsection NG, and the criteria for faulted conditions.

Internal structures are analyzed to meet the intent of the ASME Code in accordance with Subsection NG, Paragraph NG-3311(c). Stresses in the core support structure induced by interaction with internal structures are analyzed and shown to be in conformance with core support code limits. Design and construction for core support structures meet Subsection NG in full.

## 3.9.6 References

1. Takeuchi, K., et al., "Multiflex-A Fortran-IV Computer Program for Analyzing Thermal-Hydraulic-Structure System Dynamics," WCAP-8708-P-A, Volumes 1 and 2 (Proprietary) and WCAP-8709-A, Volumes 1 and 2 (Nonproprietary), February 1976.

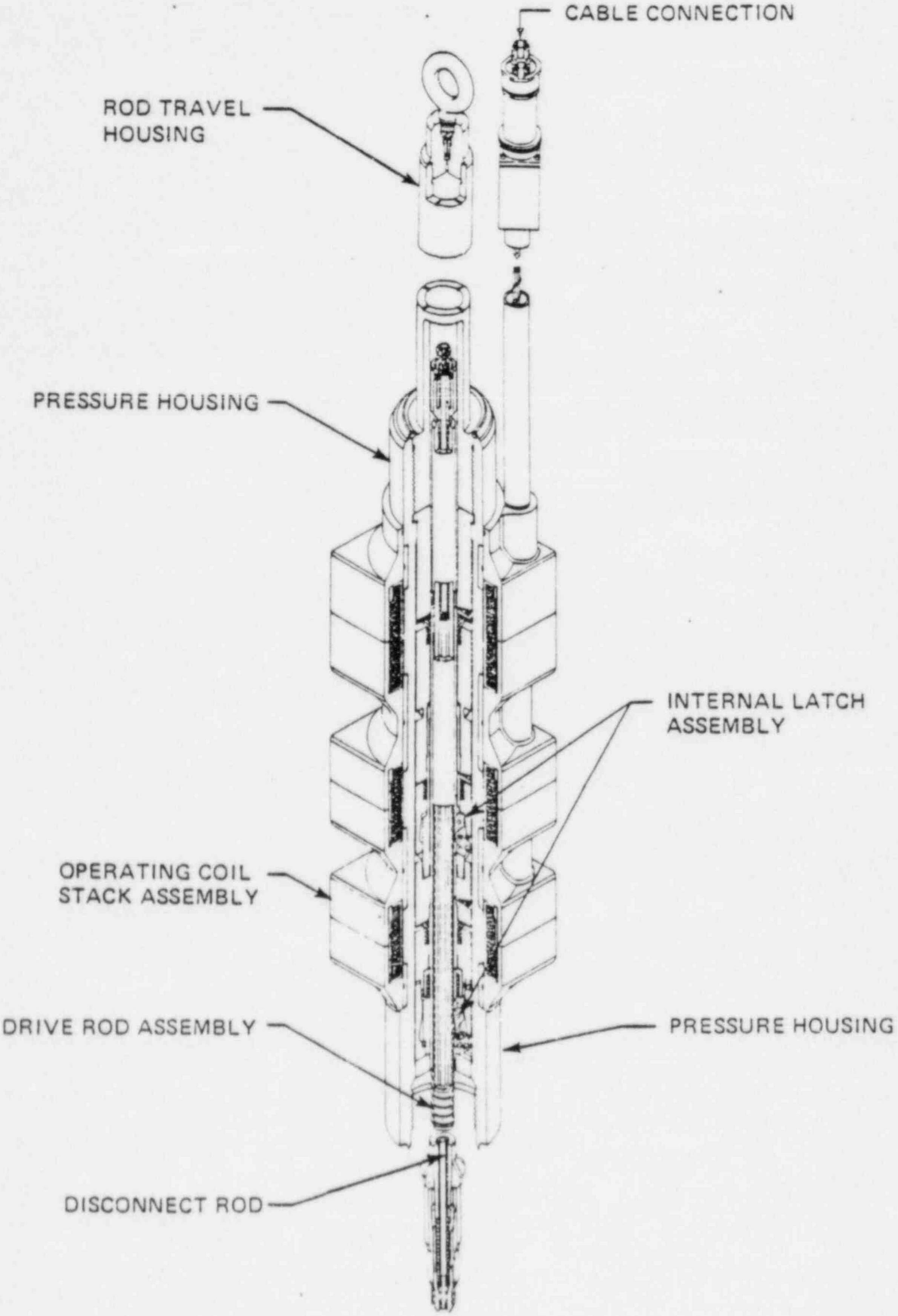


Figure 3.9-1 Typical Full-Length Control Rod Drive Mechanism

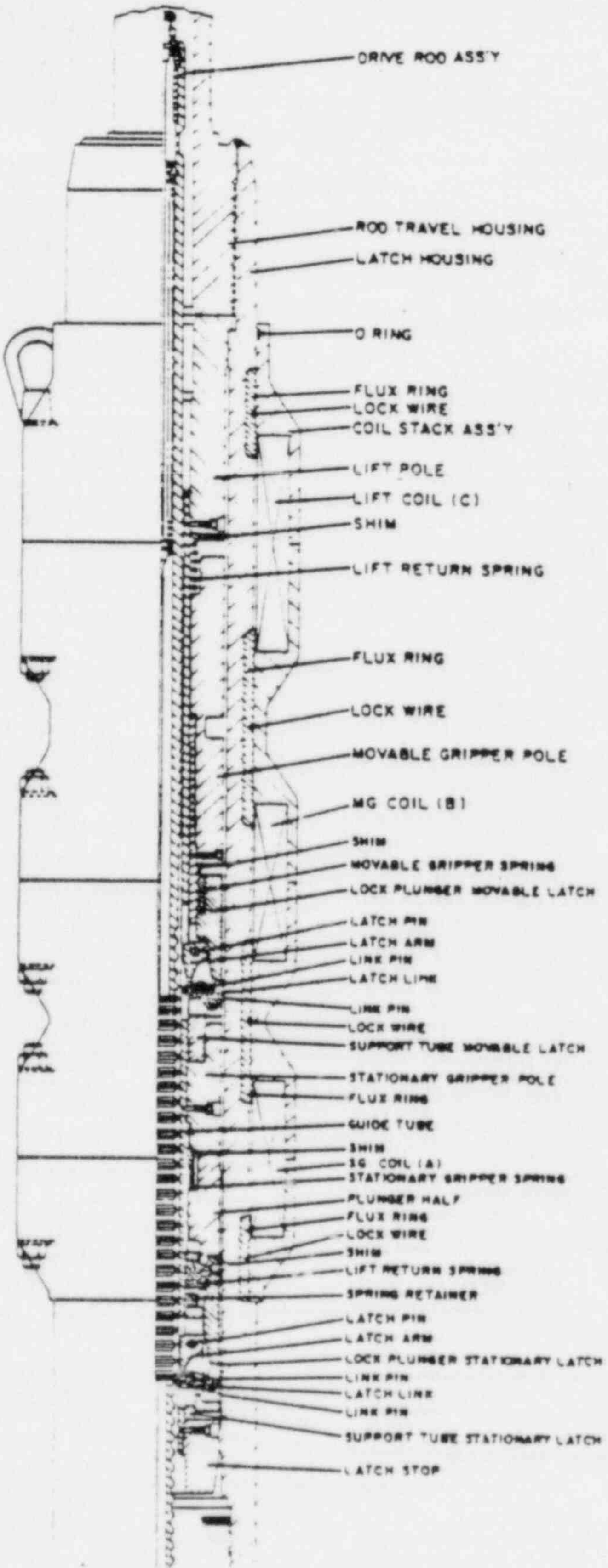
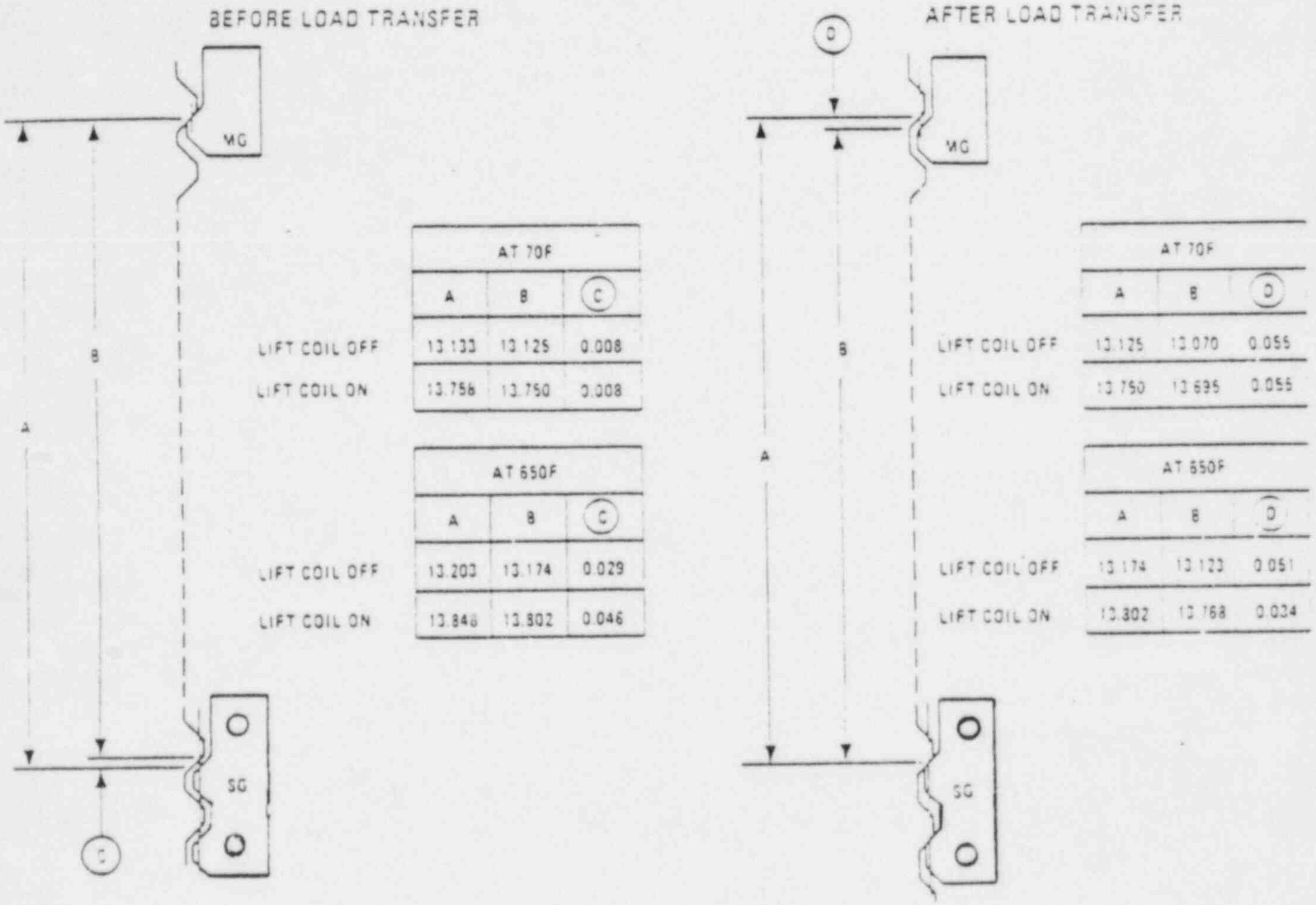


Figure 3.9-2 Typical Full-Length Control Rod Drive Mechanism Schematic



BEFORE LOAD TRANSFER

| | AT 70F | | |
|---|---|---|---|
| | A | B | ⓒ |
| LIFT COIL OFF | 13.133 | 13.125 | 0.008 |
| LIFT COIL ON | 13.756 | 13.750 | 0.008 |

| | AT 650F | | |
|---|---|---|---|
| | A | B | ⓒ |
| LIFT COIL OFF | 13.203 | 13.174 | 0.029 |
| LIFT COIL ON | 13.848 | 13.802 | 0.046 |

AFTER LOAD TRANSFER

| | AT 70F | | |
|---|---|---|---|
| | A | B | ⓓ |
| LIFT COIL OFF | 13.125 | 13.070 | 0.055 |
| LIFT COIL ON | 13.750 | 13.695 | 0.055 |

| | AT 650F | | |
|---|---|---|---|
| | A | B | ⓓ |
| LIFT COIL OFF | 13.174 | 13.123 | 0.051 |
| LIFT COIL ON | 13.802 | 13.768 | 0.034 |

Figure 3.9-3 Nominal Latch Clearance at Minimum and Maximum Temperatures

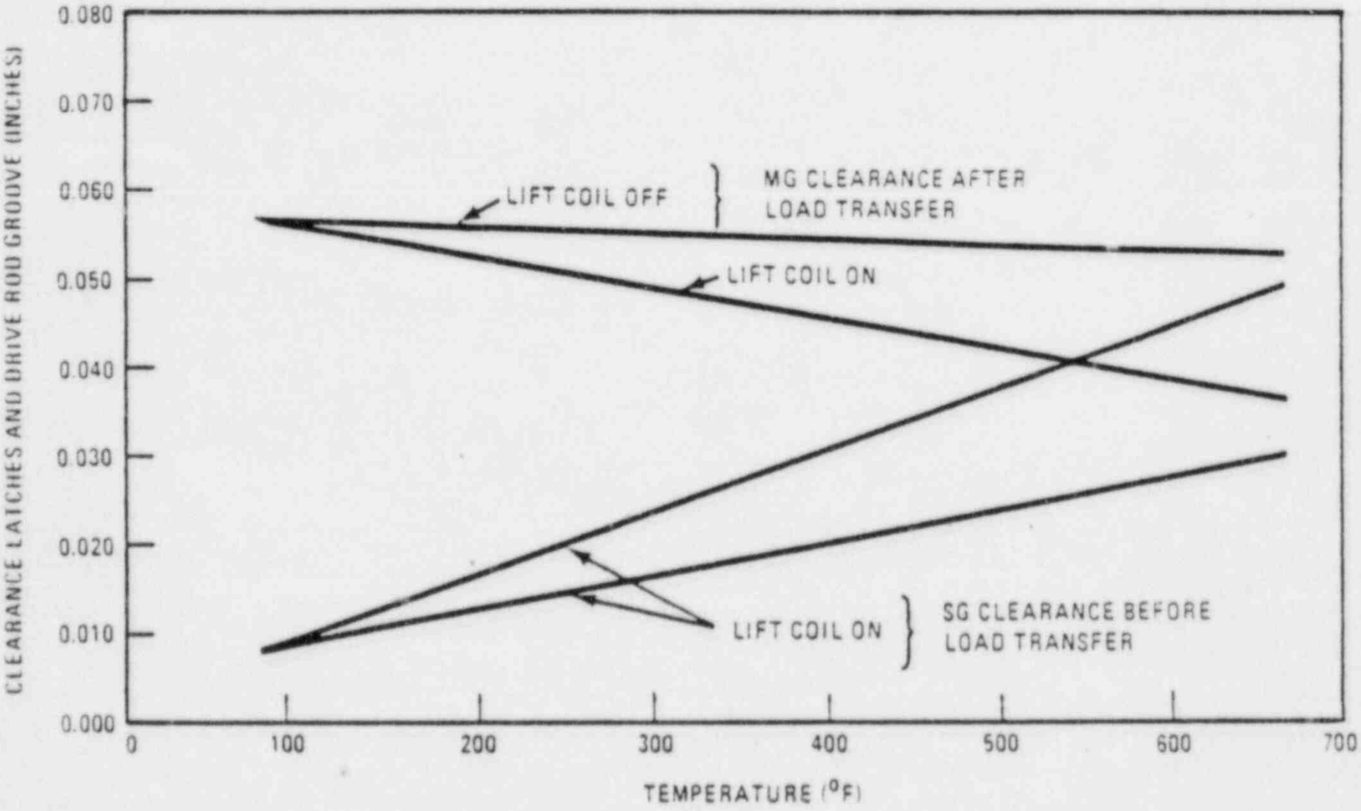


Figure 3.9-4 Nominal Control Rod Drive Mechanism Latch Clearnace Thermal Effect

(a,c)

Figure 3.9-5 DRDM Vent System

(a,c)

Figure 3.9-6 Displacer Rod Drive Mechanism

Figure 3.9-7 WAPWR Reactor Internals (General Assembly Layout) (PROPRIETARY)

(a,c)

Figure 3.9-8 Calandria Conceptual Design Layout

(a,c)

Figure 3.9-9 WDRC and RCCA Guide Structure Cross Section

(a,c)

Figure 3.9-10 Inner Barrel Conceptual Design Layout

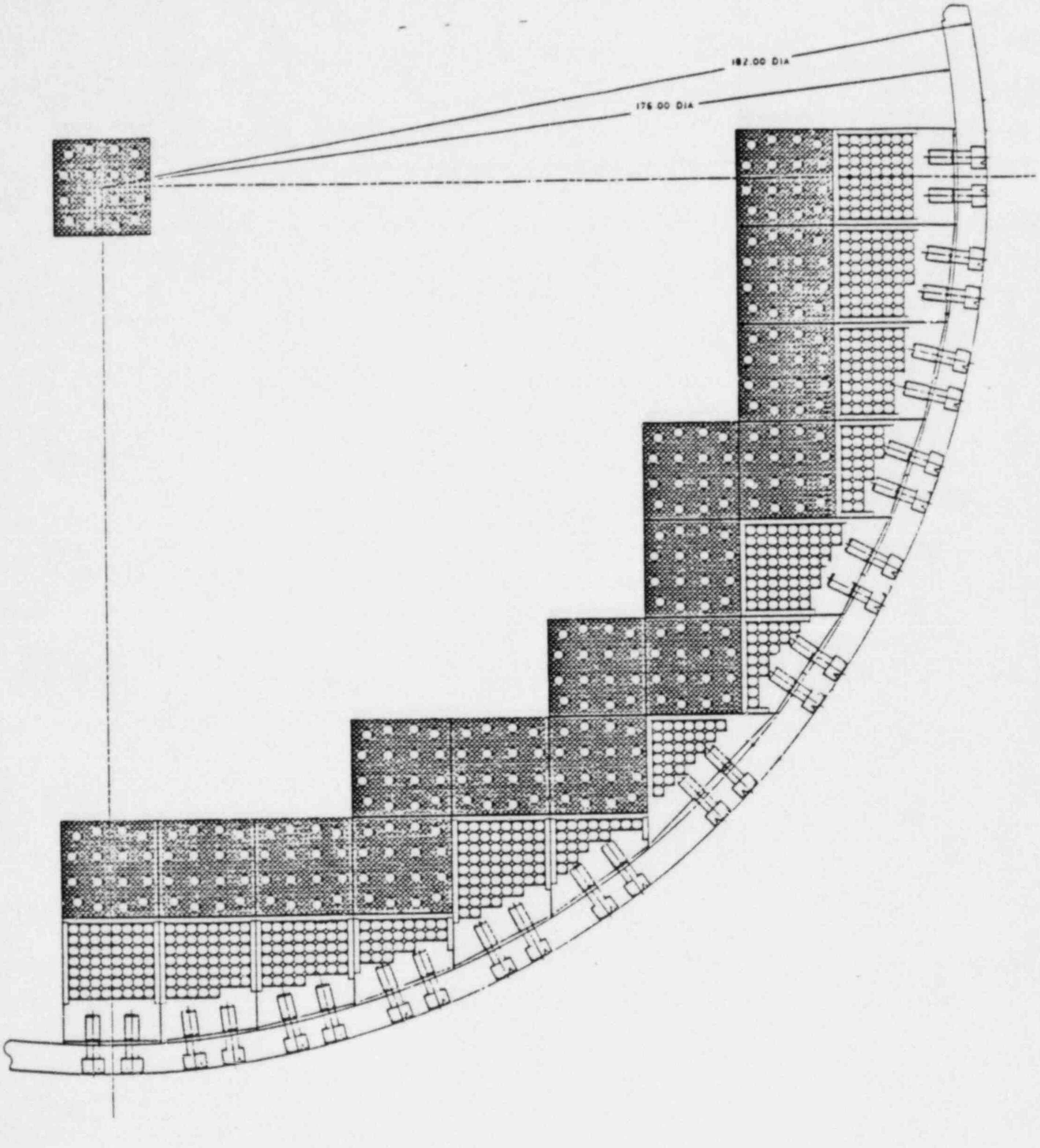


Figure 3.9-11 Radial Reflector Overall Plan View
(Quadrant)

Figure 3.9-12 Radial Reflector Module General Assembly (Typical)
(PROPRIETARY)