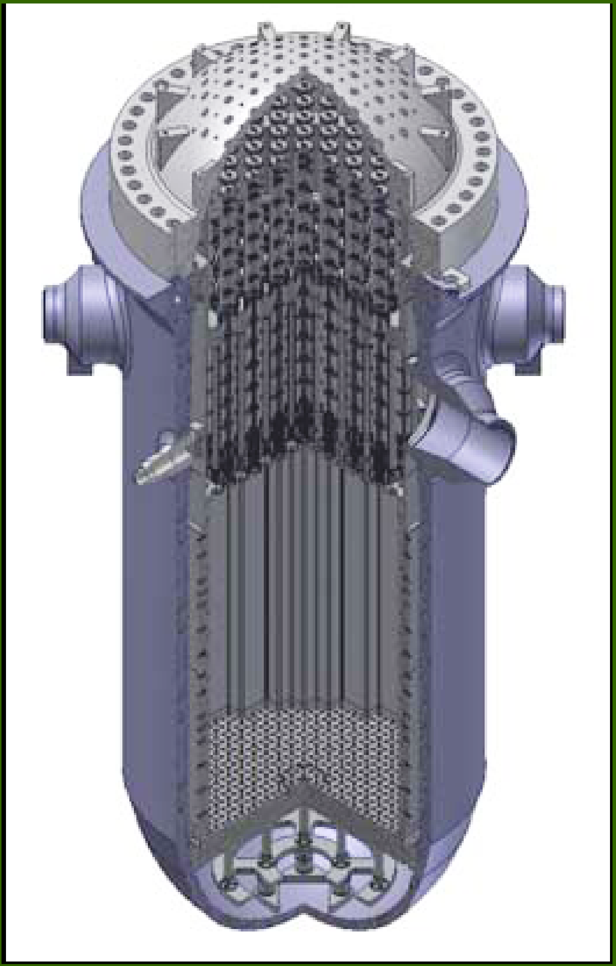
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Reactor Core & Vessel Design

AP1000 Technology Chapter 2.0

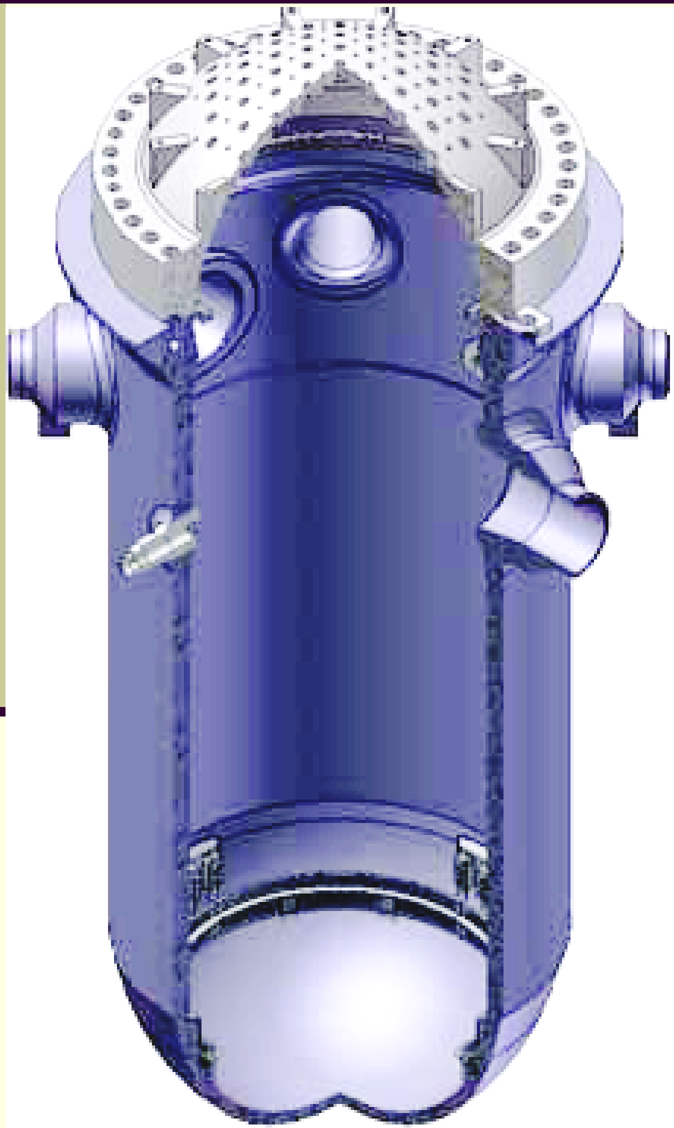


Human Resources Training & Development

Objectives

1. Describe the basic differences in the construction of the AP1000 reactor vessel from a standard three loop reactor vessel.
2. Describe the basic construction of an AP1000 fuel assembly.
3. Explain the difference in the construction of a rod cluster control assembly and a gray rod cluster assembly.

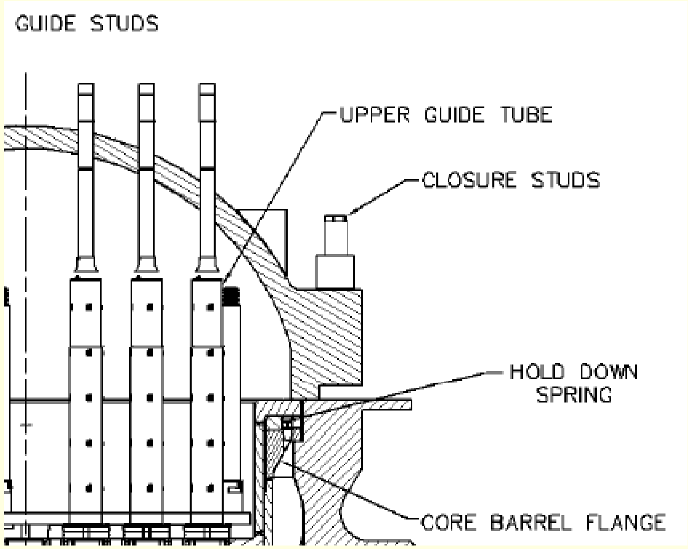
Reactor Vessel

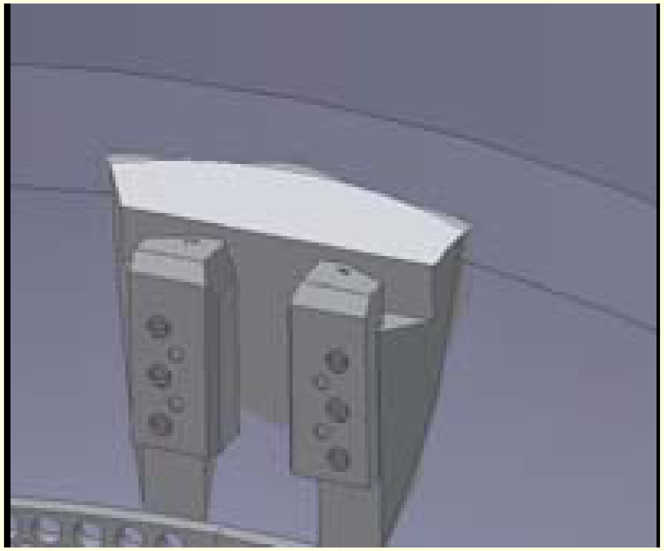


1. Reactor vessel is a modified three-loop Westinghouse reactor vessel.
   - because of two SGs with four RCP loop design,
   - direct vessel injection nozzles, and
   - 14 ft fuel assemblies.
2. ~40 feet long with an inner diameter of 159” in the core region.
3. Constructed of low alloy steel plates and forgings with a 0.22 inch SS internal clad.
4. There are no penetrations below the top of the core.
5. An integrated head package is used (more later)

Reactor Vessel Functions

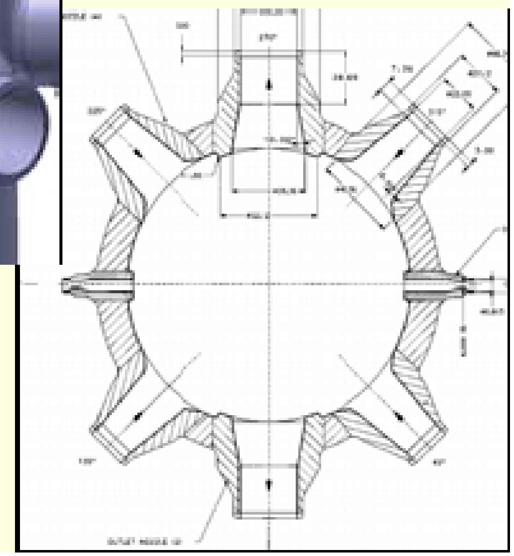
- Support the RV internals and core
  - Internal ledge, core barrel flange
  - Four core support pads on vessel align with core barrel keys to provide lateral support
- Locates and aligns RV internals
  - Radial key/keyway joints

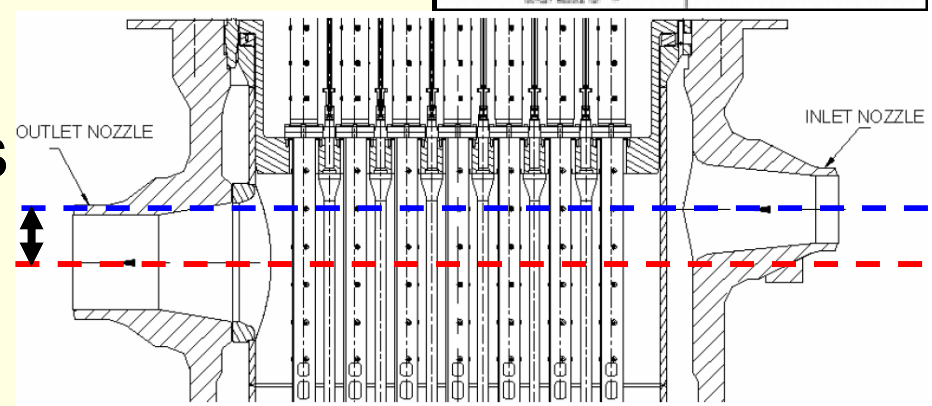




Reactor Vessel Functions (cont.)

- Directs coolant
  - 4-22“ cold leg inlet nozzles
  - Downcomer
  - 2-31” hot leg outlet nozzles
- Nozzles support and locate primary coolant loop piping
- Direct vessel injection safety feature
- Hot and cold leg nozzles are offset for RCP maintenance





Reactor Vessel Functions (cont.)

- Aligns and Supports
  - CRDM
  - Instrumentation
- Instrumentation tube and CRDM head adapters welded to closure head
  - Alloy 690 material
  - "J-groove" welds

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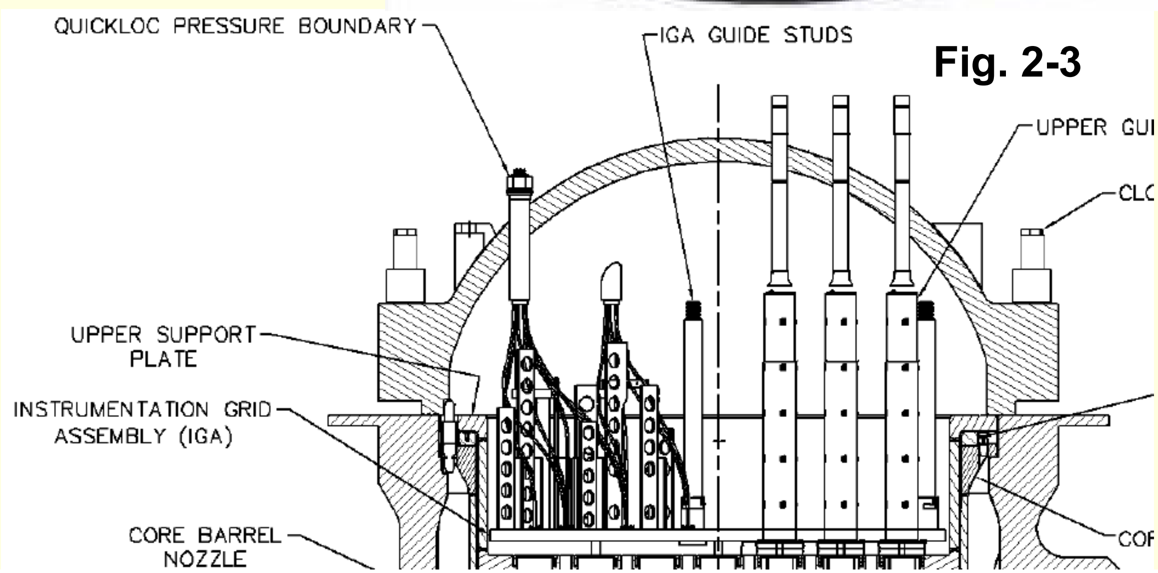


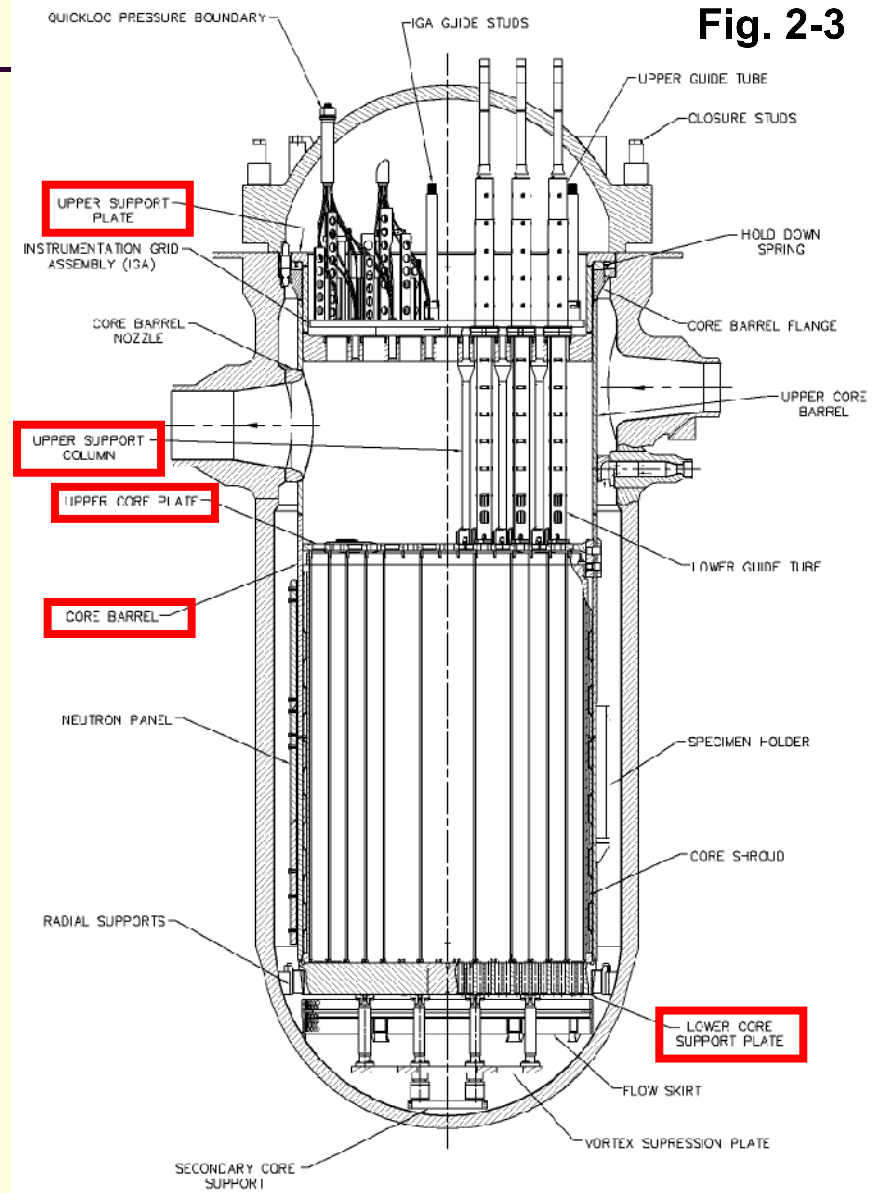
Fig. 2-3

*** There are fewer holes in the head for incore instrument penetrations than shown (details upcoming).**

Reactor Internals General Functions

- Provides support and alignment for fuel assemblies
- Accommodates differential thermal expansion
- Key components
  - Core barrel
  - Upper core support plate
  - Upper support columns
  - Upper core plate
  - Lower core support plate

Fig. 2-3



Reactor Internals General Functions (cont.)

- Directs reactor coolant to fuel assemblies
- Provides cooling flow to the reactor vessel head plenum
- Key components
  - Core barrel
  - Lower core support plate
  - Core shroud

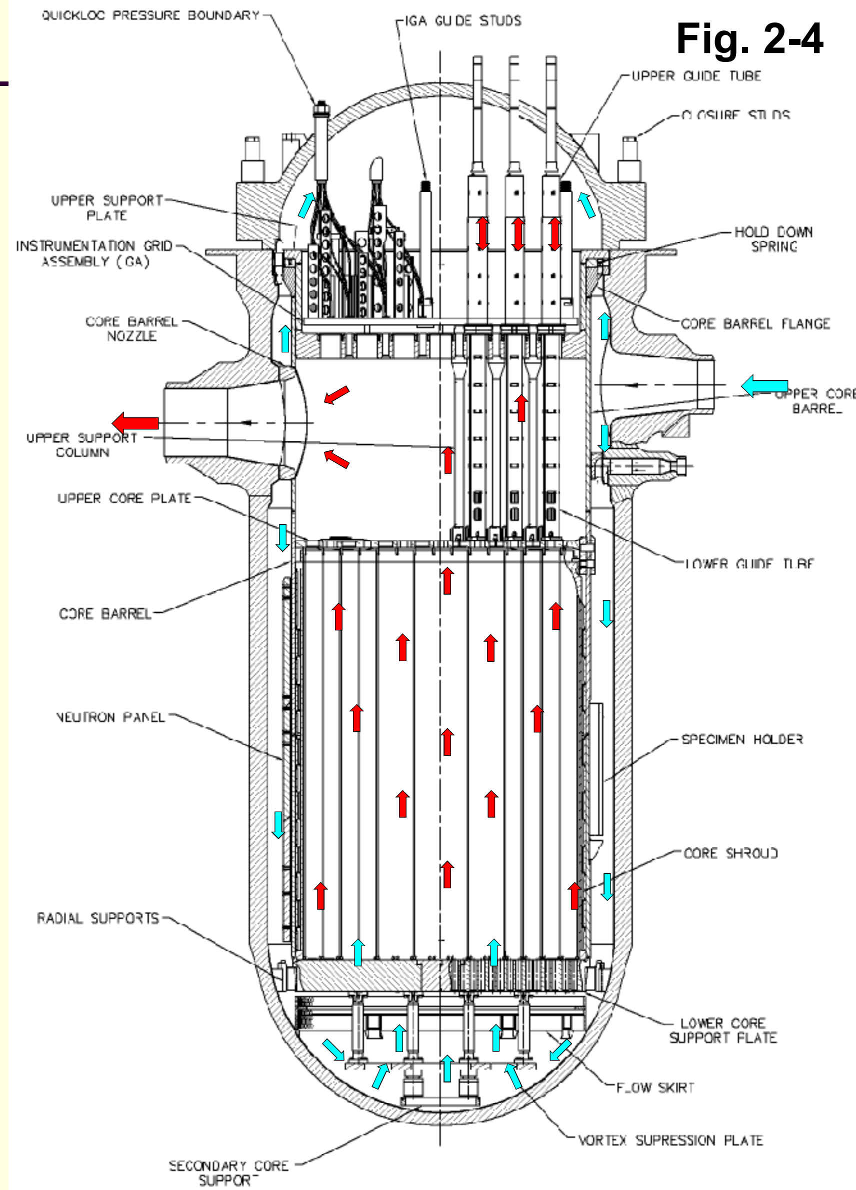
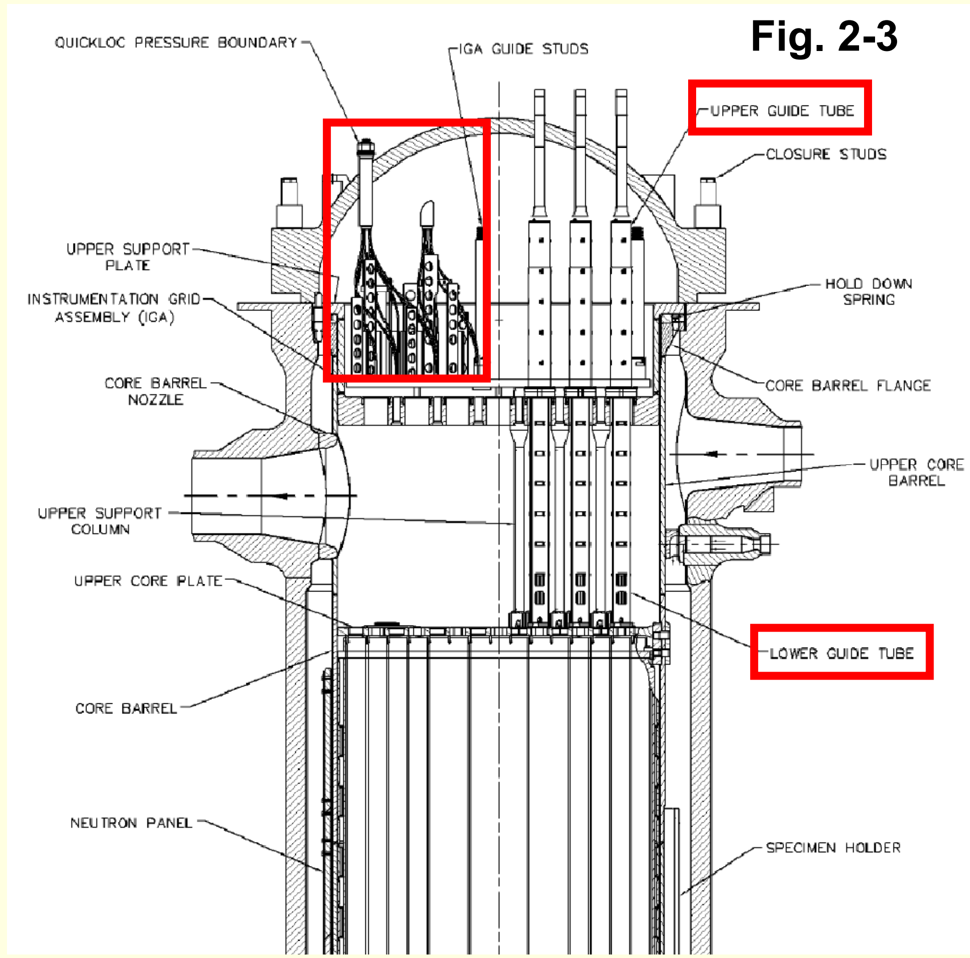


Fig. 2-4

Reactor Internals General Functions (cont.)

- Provides guidance for the RCCA control rods
- Key components
  - Upper and lower guide tubes
- Provides support and alignment for "top-mounted" incore instrumentation



Reactor Internals General Functions (cont.)

- Supports and orients the RV material surveillance capsules
- Key components
  - Irradiation specimen baskets
  - 3 azimuthal basket locations (135, 225, and 315 degrees)
  - 8 specimen capsules

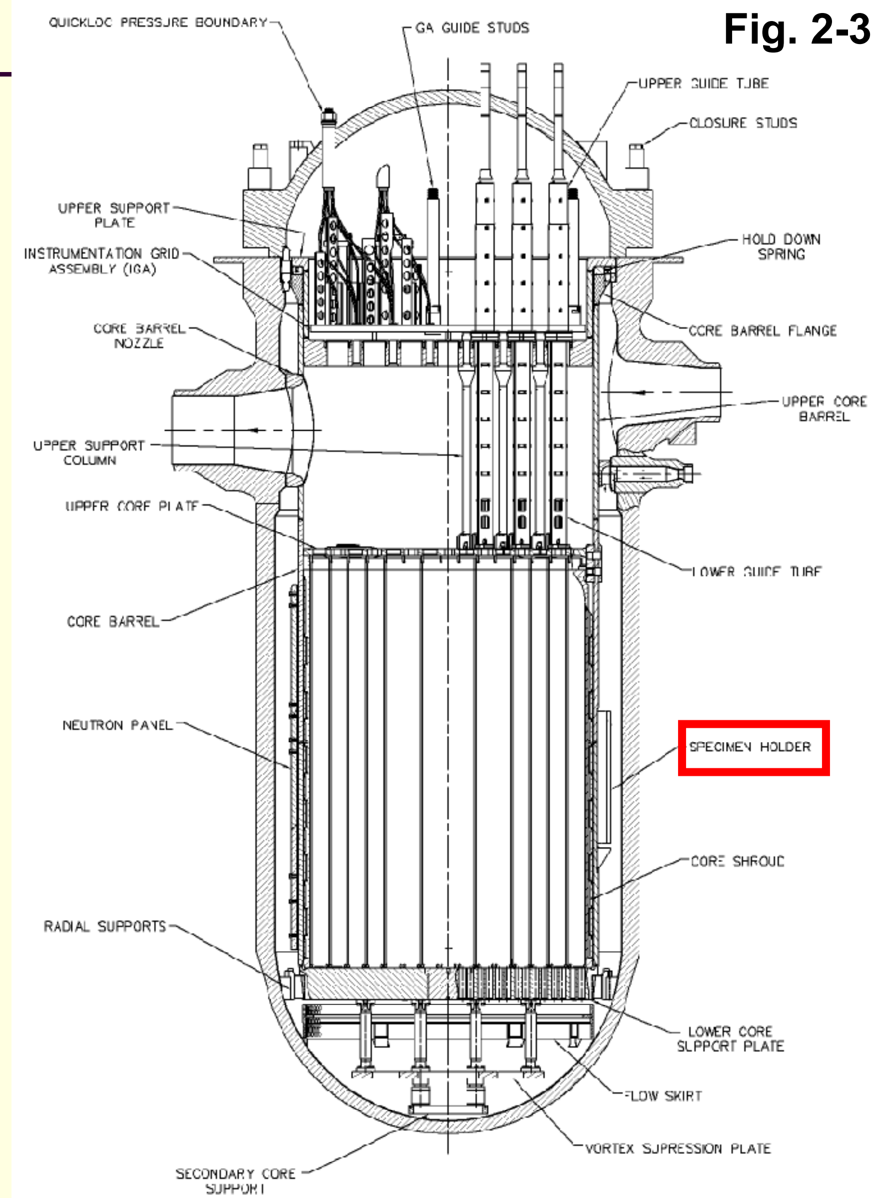


Fig. 2-3

Reactor Internals General Functions (cont.)

- Transmit loads from the reactor vessel internals to the RV
- Restricts rotational/ translational motion
  - Radial support keys engage clevis inserts in the RV
- Key components
  - Upper core support assembly
  - Radial keys
  - Lower core support plate
  - Secondary support structure

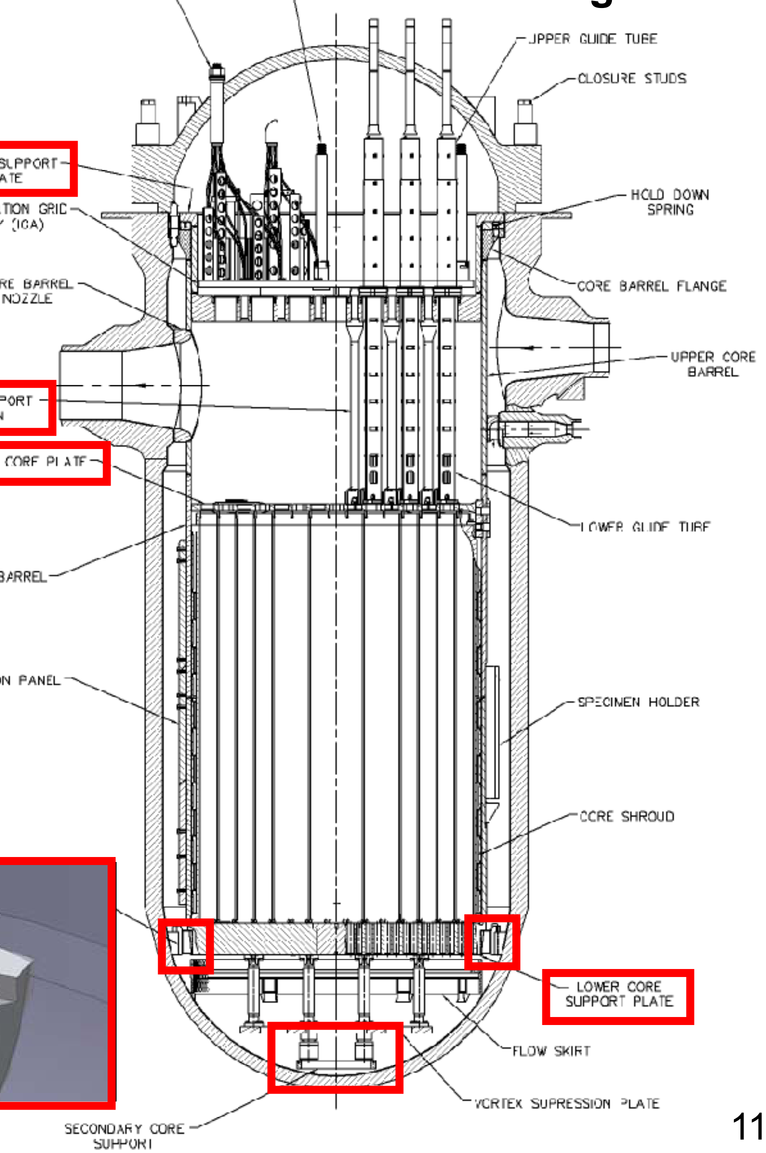
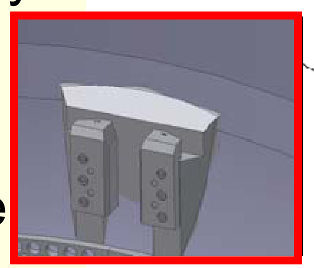


Fig. 2-3



Integrated Head Package (IHP)

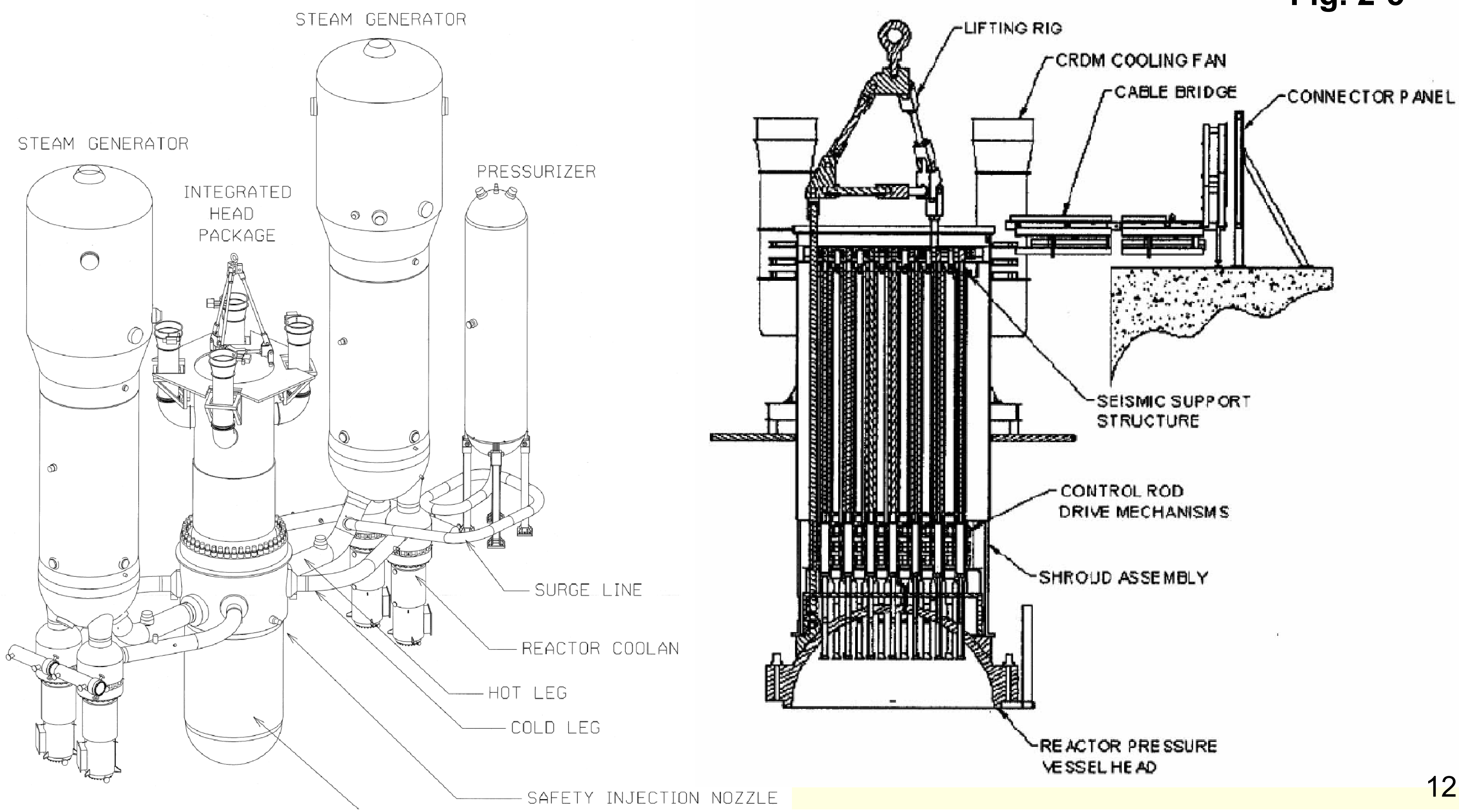


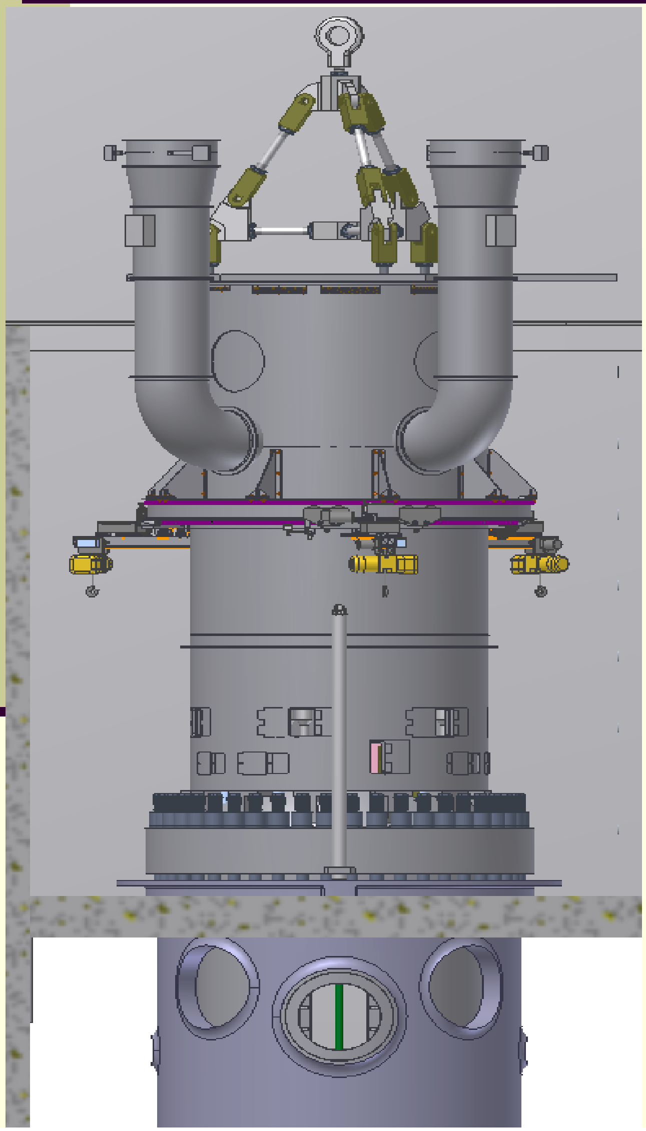
Fig. 2-5

IHP Basic Functions

- IHP combines several components into one assembly:
  - Lifting rig
  - Seismic restraint for CRDMs
  - Cooling for CRDMS
  - Support for head vent, electrical and I&C cables, including incore instrumentation cables & connectors
  - Support for vessel head stud tensioning
- Simplifies refueling the reactor

IHP Components

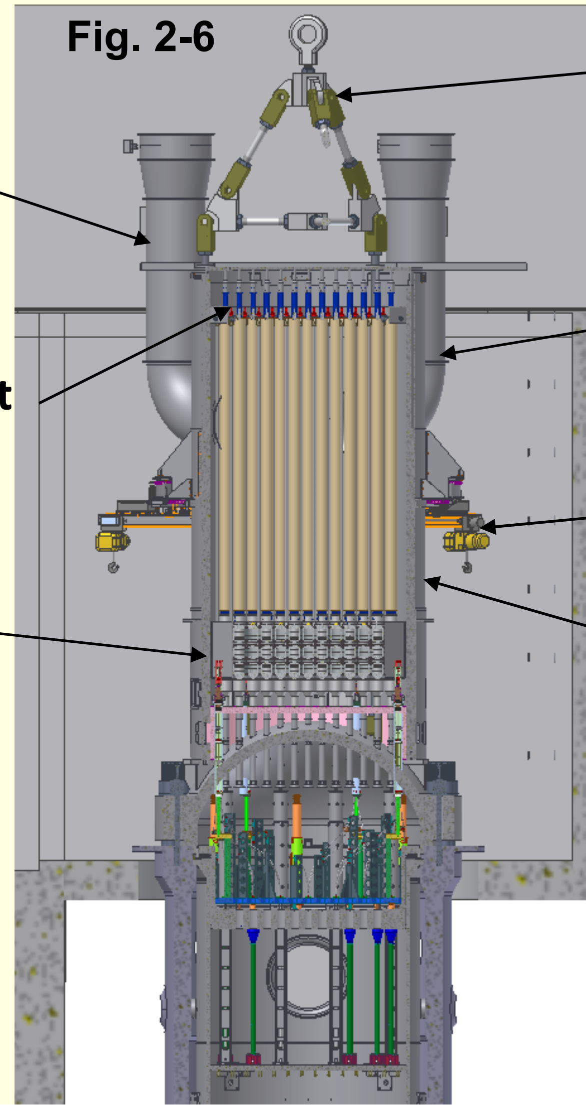
HRTD Human Resources Training & Development



CRDM Cooling Fans

Seismic Restraint For CRDMs

Quicklocs



Lift Rig

CRDM Cooling Duct

Stud Hoists

Shroud

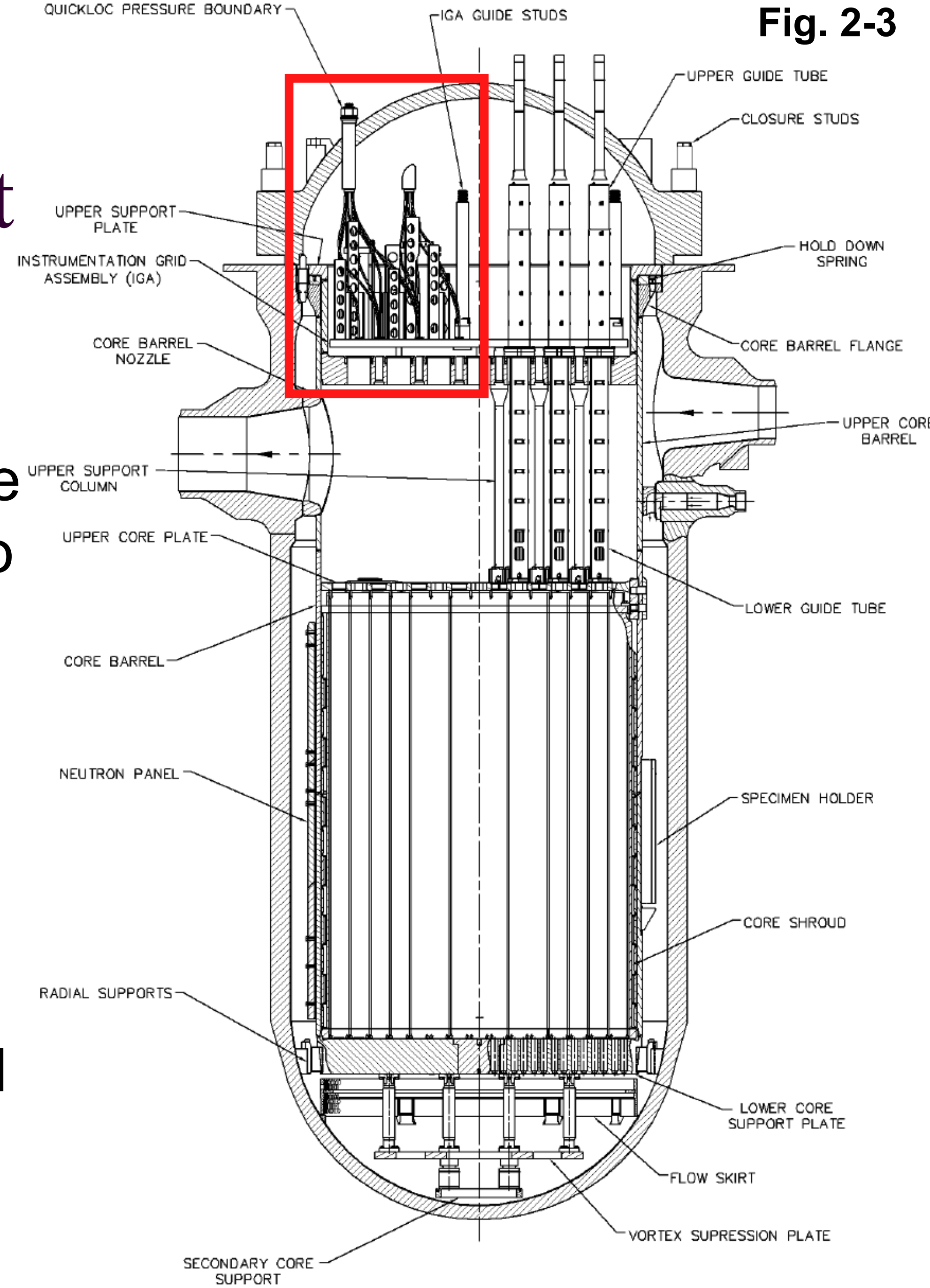
IHP Design Features

- Designed to support top-mounted fixed incore instrumentation (42 detectors)
  - Provides support for incore instrumentation cables & connectors
  - Detectors disconnected at Quickloc penetrations; detectors & guide tubes stay with upper internals during refueling (like later CE designs)
- Features to support 17-day refueling outage
  - Head electrical and I&C cables attached onto two connector panels with quick disconnects
  - Access doors for ICI,CRDM, and bare metal inspection of head

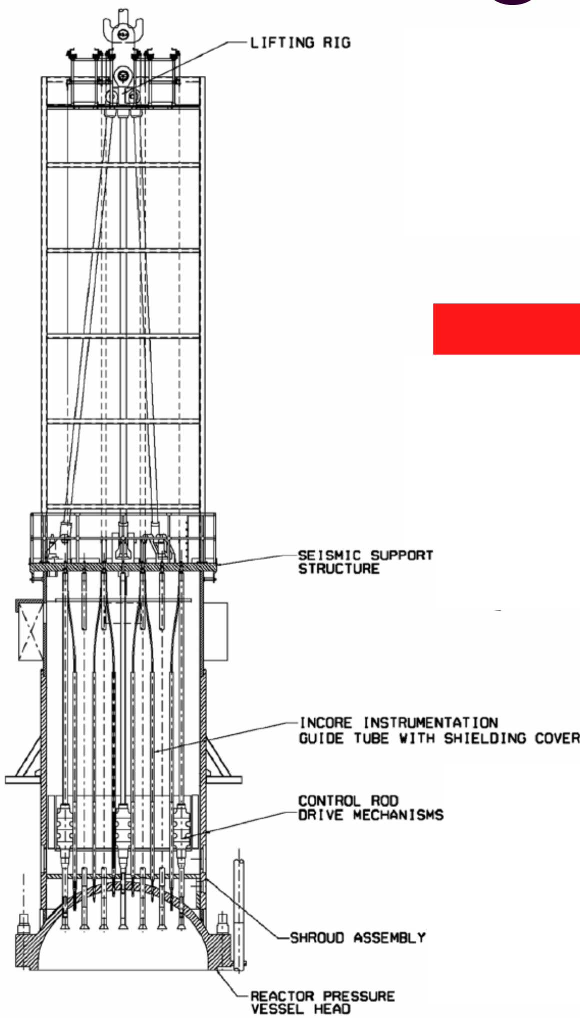
Incore Instrumentation Support

- With recent design change (DCD rev. 17), incore instrument guide tubes are collected into 8 “stalks” which terminate in Quickloc head penetrations.
- Incore instruments will stay with upper internals during refueling, thus no need for incore guide structures in IHP.

Fig. 2-3



Revised Integrated Head Package



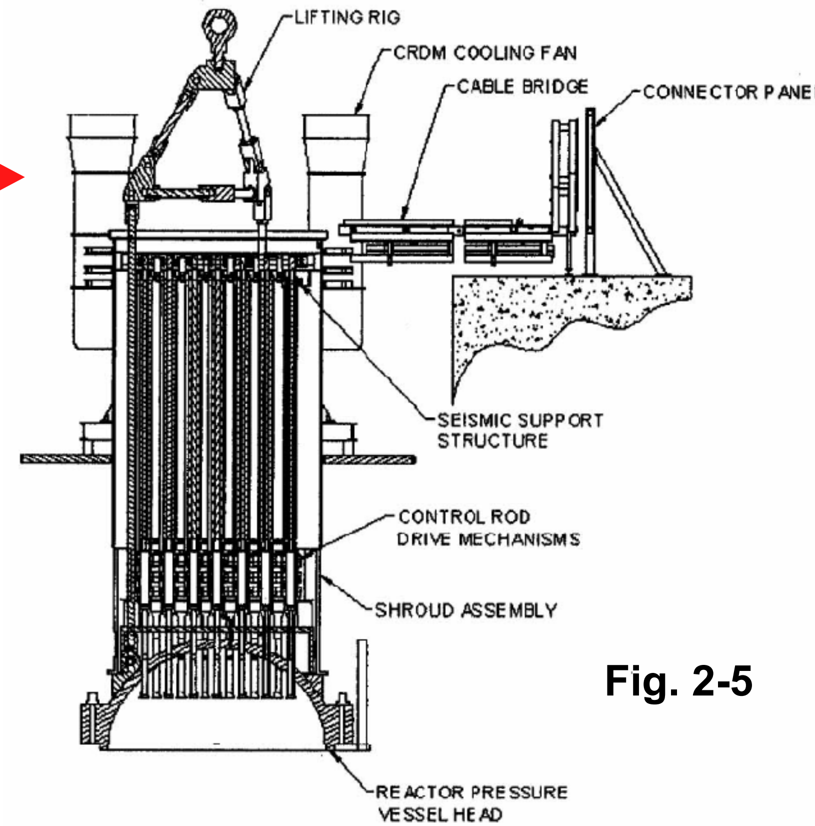


Fig. 2-5

With deletion of incore instrument guide tubes, IHP becomes shorter & lighter. CRDM cooling fans are now mounted directly on the IHP.

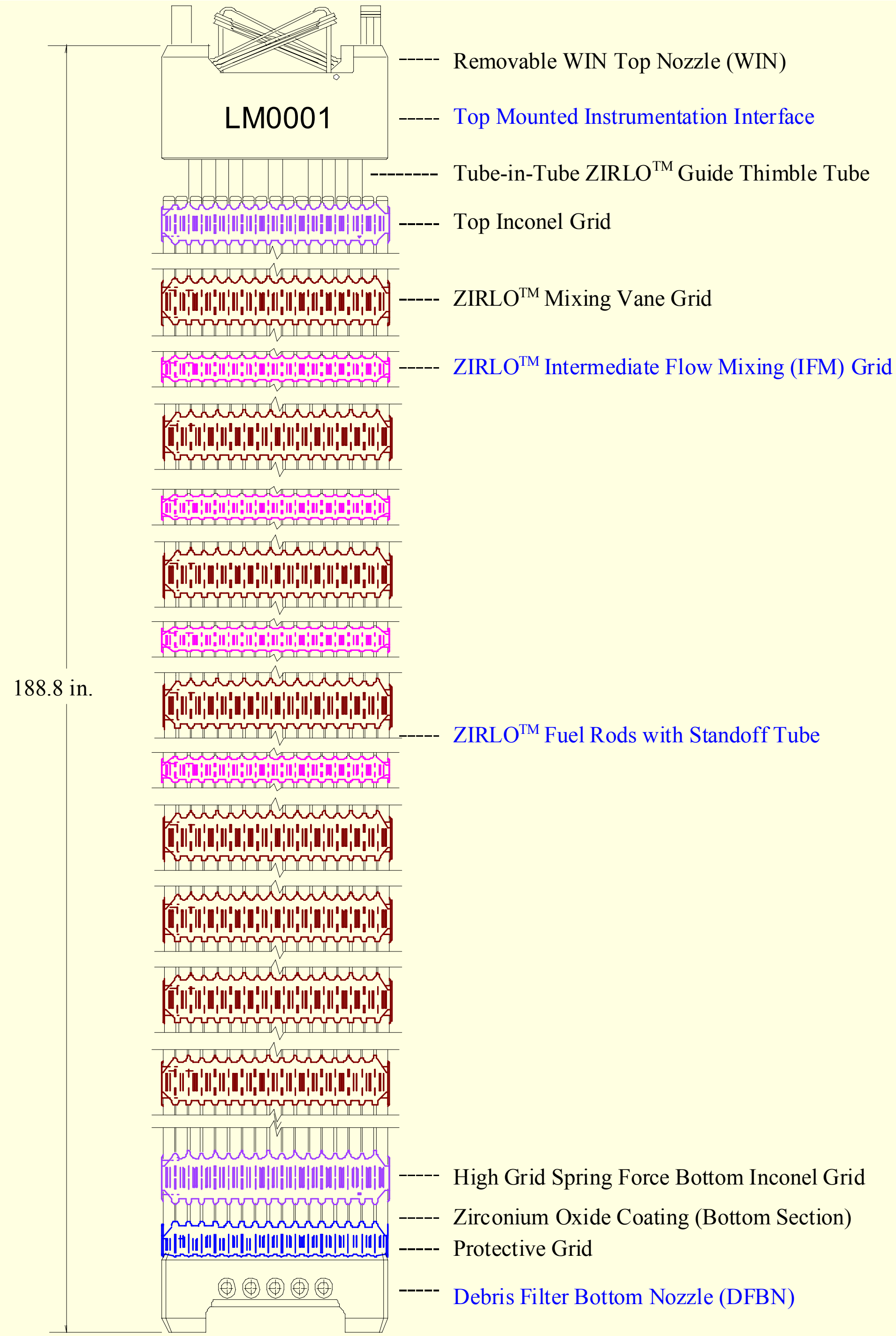
Core Design Features

- Standard 18-month reloads (510 EFPD) with capability to go to 24 months
- Core power density consistent with current operating plants
- Top-mounted <u>fixed</u> incore instrumentation
- Rod control system using gray rods for load changes
  - Boron changes limited to fuel depletion, startup and shutdown
- Rapid Power Reduction System
  - Allows full load rejection capability with only 40% steam dump

Fuel Assembly

- Based on current 17x17XL fuel in use worldwide

Fuel Assembly



Fuel Rod

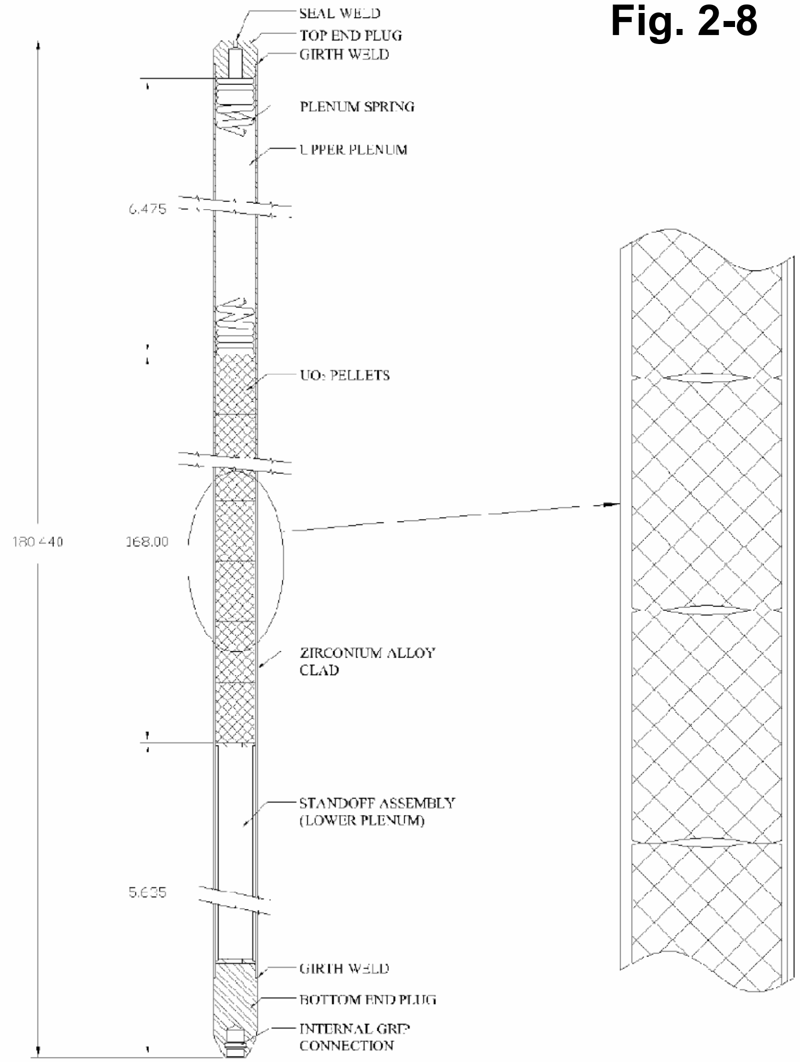


Fig. 2-8

Integral fuel burnable absorbers

- **boride-coated fuel pellets**

Or

- **fuel pellets containing gadolinium oxide mixed with uranium oxide**

Control Rods and Gray Rods

HRTD Human Resources Training & Development

- Control rods very similar to those in in current Westinghouse plants
  - 24 rodlets: Silver-indium-cadmium alloy encased in stainless steel tubes
  - 53 rod cluster control assemblies
- Gray rods (DCD): Similar to control rods in construction.
  - 12 of the 24 rodlets are SS
  - 12 rodlets are silver-indium-cadmium
  - 16 gray rod cluster assemblies
- Gray rods (WCAP-16943)*
  - 24 tungsten rodlets double encapsulated

*Change under NRC review

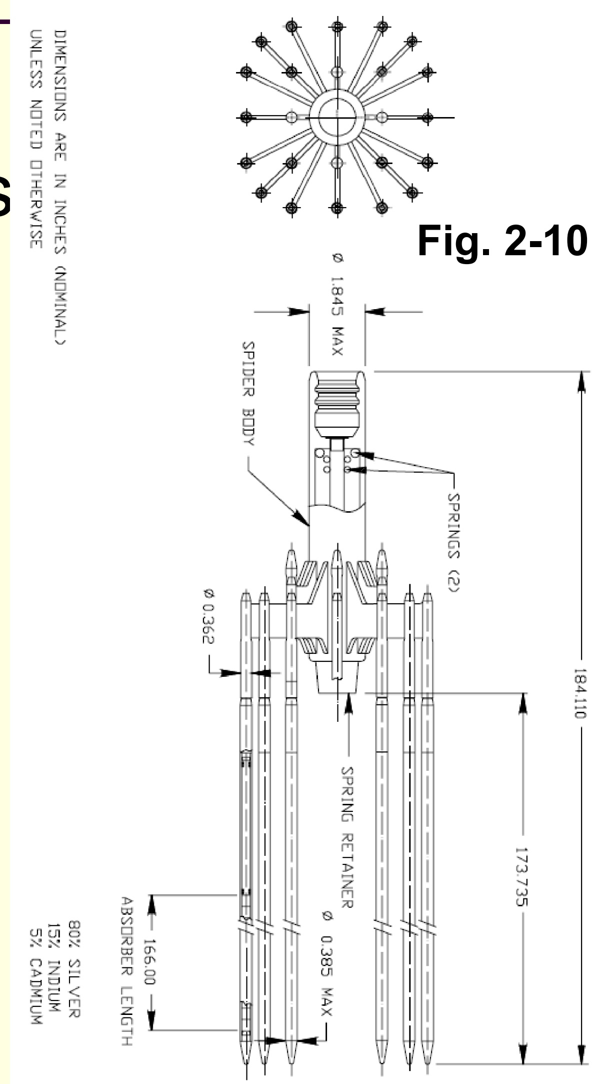


Fig. 2-10

MSHIM Operation

- The automated mode of control rod operation is referred to as mechanical shim (MSHIM).
- MSHIM operation eliminates the requirement for boron concentration change with power change.
- AP1000 operational boron change requirements are limited to startup, shutdown, and fuel depletion.
- MSHIM control strategy fully automated at power levels > ~30% (DCD rev. 16).

MSHIM Control Rod Functions

- MSHIM uses three separate sets of control rods for three unique reactivity control requirements:
  - “SD” Banks for rapid shutdown (Rx Trip)
  - “AO” Bank for axial power distribution control
  - “M” Banks for reactivity control associated with temperature, power level, and transient xenon changes

- The rod control system automatically modulates the AO bank to control axial power distribution simultaneous with MSHIM gray and control rod banks to maintain programmed RCS Tavg.

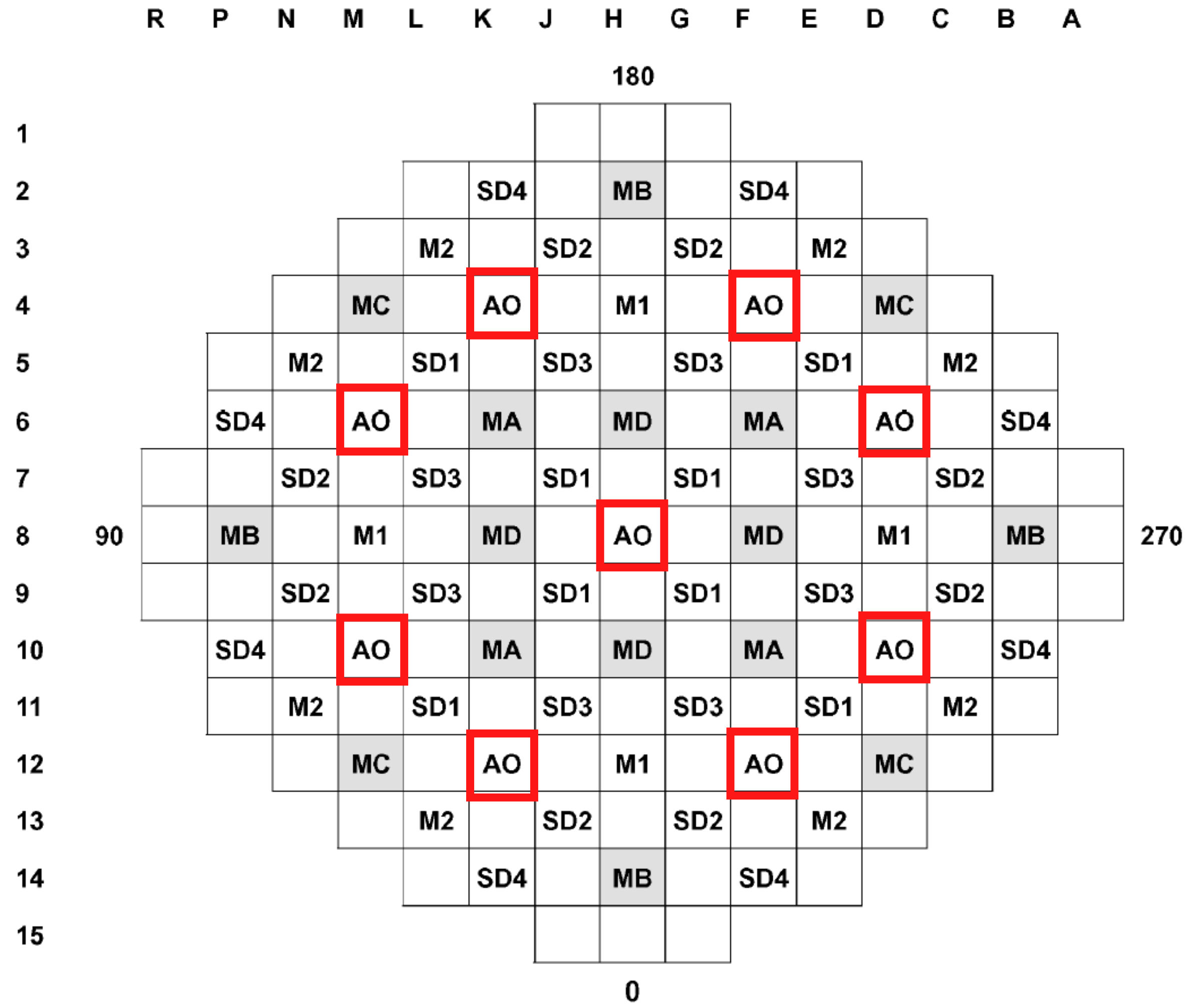


Fig. 2-14

Bank		Number of Clusters
MA	(MSHIM Gray Bank A)	4
MB	(MSHIM Gray Bank B)	4
MC	(MSHIM Gray Bank C)	4
MD	(MSHIM Gray Bank D)	4
M1	(MSHIM Black Bank 1)	4
M2	(MSHIM Black Bank 2)	8
AO	(A.O. Control Bank)	9
SD1	(Shutdown Bank 1)	8
SD2	(Shutdown Bank 2)	8
SD3	(Shutdown Bank 3)	8
SD4	(Shutdown Bank 4)	8
TOTAL		69

Gray Rod Position

AO Rod Position

Rapid Power Reduction System

- Reactor power control system designed to respond to a full load rejection without initiating a reactor trip.
- Load rejections requiring > 50% reduction of rated thermal power initiates the rapid power reduction system.
- System utilizes preselected control rod groups and/or banks which are intentionally tripped to rapidly reduce reactor power.

Questions?

Which one of the following is true concerning the Gray Rod Assemblies?

A. 24 Silver-indium-cadmium rodlets per assembly.

B. 53 total Grey Rod assemblies in the core.

C. 12 of the 24 Grey Rod assembly rodlets are stainless steel.

D. Grey Rod assemblies are 6 feet in length.

Which one of the following is NOT a feature of the AP1000 core and reactor vessel design?

A. **Four inlet nozzles, one for each RCP discharge pipe.**

B. **Two direct vessel injection nozzles.**

C. **Four outlet nozzles, one for each SG.**

D. **14-ft fuel assemblies.**