Fuel and Control Rods System

304B Chapter 2.2

Objectives

1. Recognize the purposes of the following:
   a. Nuclear Fuel
   b. Control Rods

Objectives

2. Summarize the function and physical arrangements of the following fuel assembly components:
    a. Fuel Pellets
    b. Fuel Cladding
    c. Fuel Rods
    d. Partial Length Fuel Rods
    e. Tie-Rods
    f. Water Rods
    g. Upper Tie Plate
    h. Lower Tie Plate
    i. Fuel Spacers
    j. Finger Springs
    k. Fuel Channel

Objectives

3. Summarize the function and physical arrangements of the following control rod components:
   a. Control Rod Blades
   b. Control Rod Rollers
   c. Velocity limiter
   d. Spud Coupler
   e. Lock Plug
   f. Valve Disc
   g. Control Rod Guide Tube

Objectives

4. Explain the following flow paths, including the purpose of that flow:
    a. control rod guide tube to fuel support piece
    b. channel flow
    c. bypass flow
5. Explain the following characteristics of the reactor fuel:
    a. fuel pellet composition
    b. enrichment variations
    c. burnable poisons

Objectives

6. Identify the common failure mechanisms of fuel and recognize the mitigating strategies for those mechanisms.
7. Explain why bottom entry control rods are used.
8. Explain the interrelationship that nuclear fuel assemblies have with the following systems:
   a. Reactor Pressure Vessel (RPV)
   b. Refueling And Vessel Servicing System
   c. Fuel Transfer System
   d. Spent Fuel Pool

Objectives

9. Explain the interrelationship that the control rods have with the following systems:
   a. Reactor Pressure Vessel (RPV)
   b. Control Rod Drive System (CRD)
   c. Fuel Transfer System
   d. Spent Fuel Pool
   e. Rod Worth Minimizer

Fuel Assembly Purposes

- Energy generation
- Fission Product Barrier
- Roller surface for control rods
- Distribution of water flow to the fuel assemblies and bypass regions

Control Rod Purposes

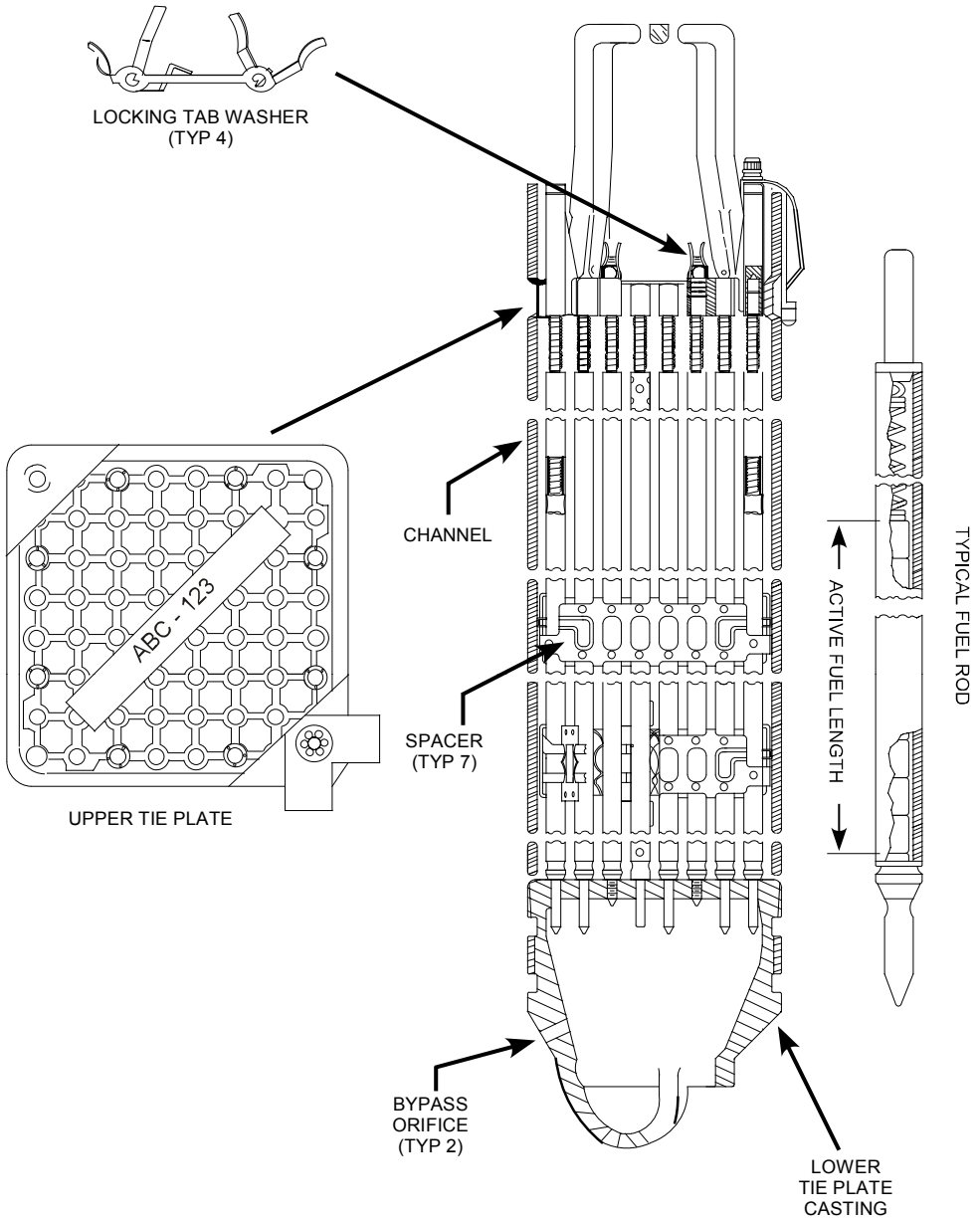
- reactor power control
- flux distribution to optimize core performance
- providing adequate shutdown margin to maintain the reactor sub-critical for all plant conditions
- in conjunction with the Rod Worth Minimizer (RWM) limits the reactivity effects of a dropped control rod

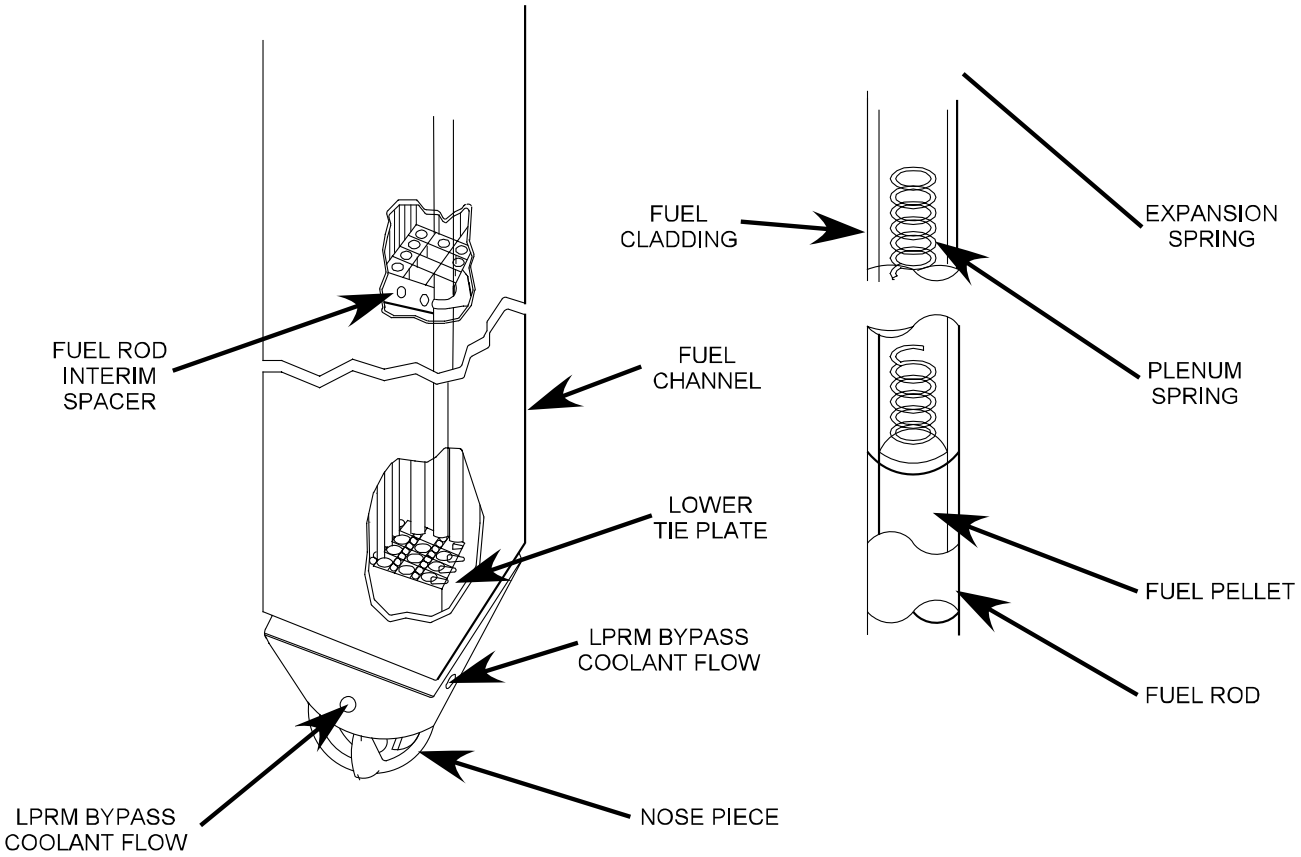
Fuel Assembly

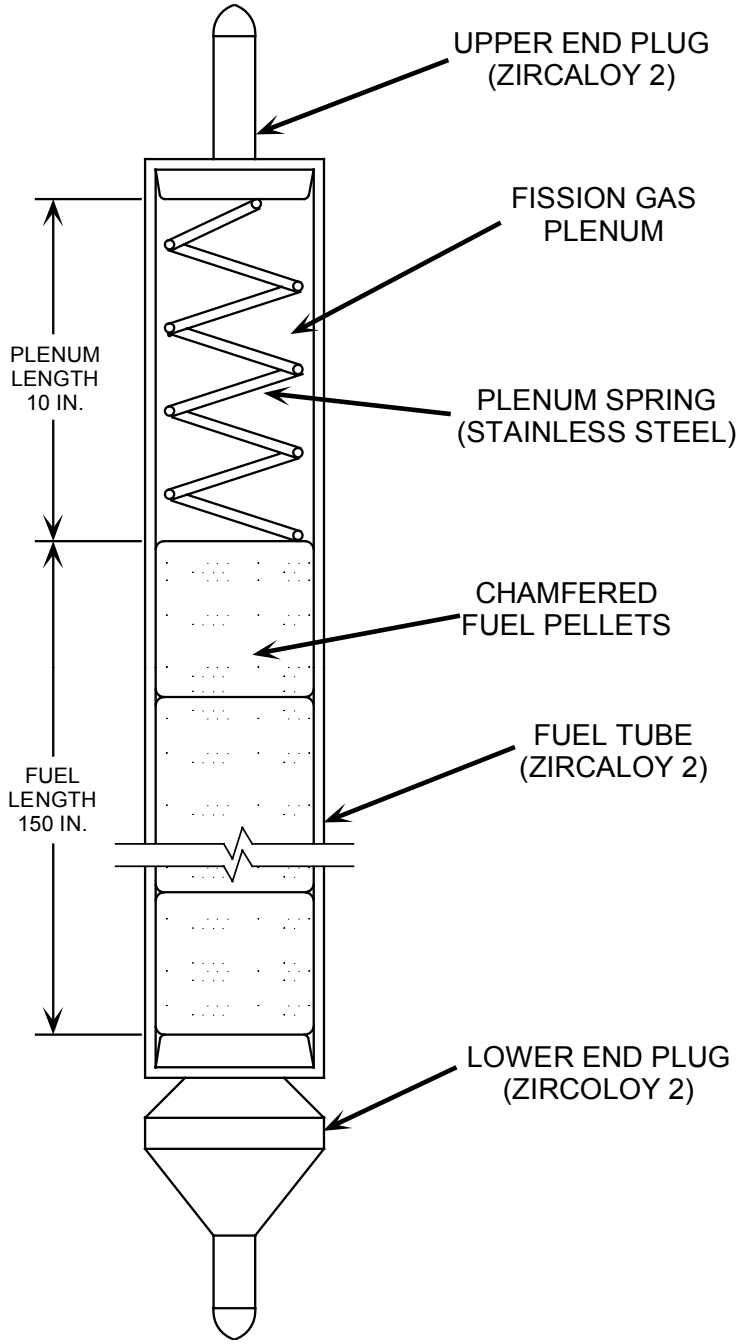
- Fuel pellets enclosed in a Zircaloy cladding to form fuel rods (the fuel rods are sometimes referred to as “pins”)
- Upper and lower tie-plates
- Fuel spacers
- Finger springs
- A channel that envelopes the fuel bundle

Fuel Assembly

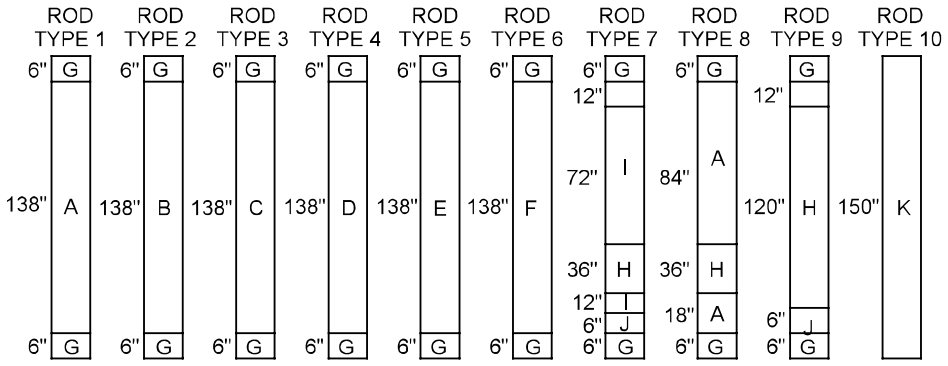
- Top Guide – Lateral Support
- Fuel Support Piece – Lateral & vertical support
- Weight translated to RPV bottom via control rod guide tube


LOCKING TAB WASHER
(TYP 4)
ABC - 123
UPPER TIE PLATE
CHANNEL
SPACER
(TYP 7)
BYPASS
ORIFICE
(TYP 2)
LOWER
TIE PLATE
CASTING
ACTIVE FUEL LENGTH
TYPICAL FUEL ROD


FUEL ROD
INTERIM
SPACER
FUEL
CHANNEL
LOWER
TIE PLATE
LPRM BYPASS
COOLANT FLOW
LPRM BYPASS
COOLANT FLOW
NOSE PIECE
FUEL
CLADDING
EXPANSION
SPRING
PLENUM
SPRING
FUEL PELLET
FUEL ROD


UPPER END PLUG
(ZIRCALOY 2)
FISSION GAS
PLENUM
PLENUM
LENGTH
10 IN.
PLENUM SPRING
(STAINLESS STEEL)
CHAMFERED
FUEL PELLETS
FUEL TUBE
(ZIRCALOY 2)
FUEL
LENGTH
150 IN.
LOWER END PLUG
(ZIRCOLOY 2)

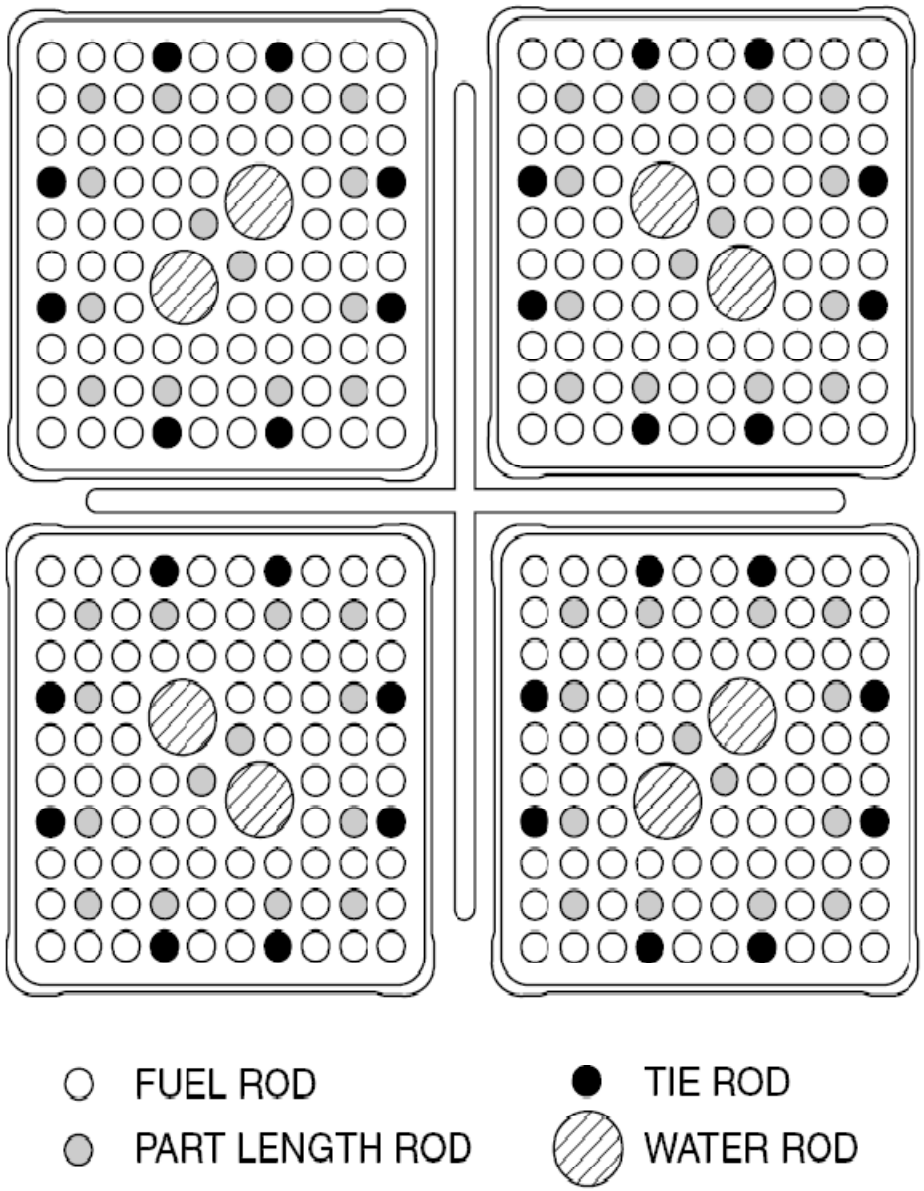
6	5	4	3	3	4	5	6
5	4	2	1	1	1	3	5
4	2	1	1	1	9	1	4
3	1	1	7	10	1	1	3
3	1	1	10	8	1	2	3
4	1	9	1	1	2	2	4
5	3	1	1	2	2	4	5
6	5	4	3	3	4	5	6

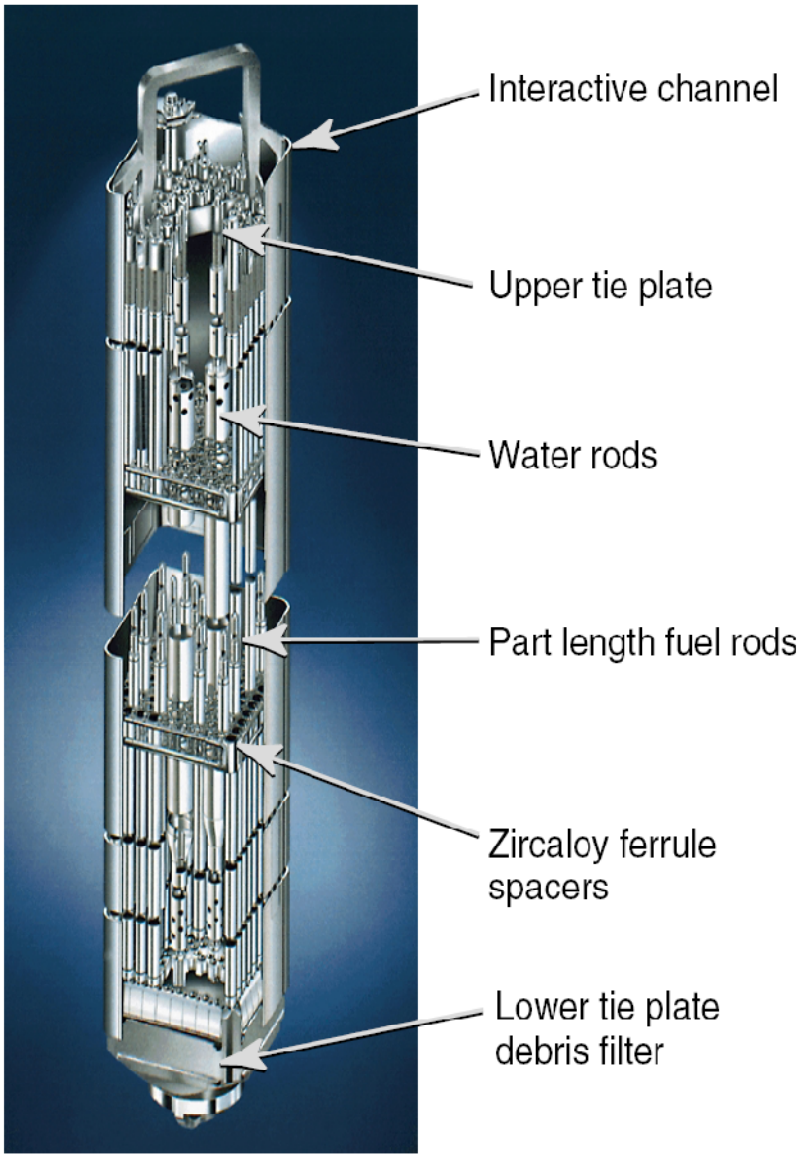


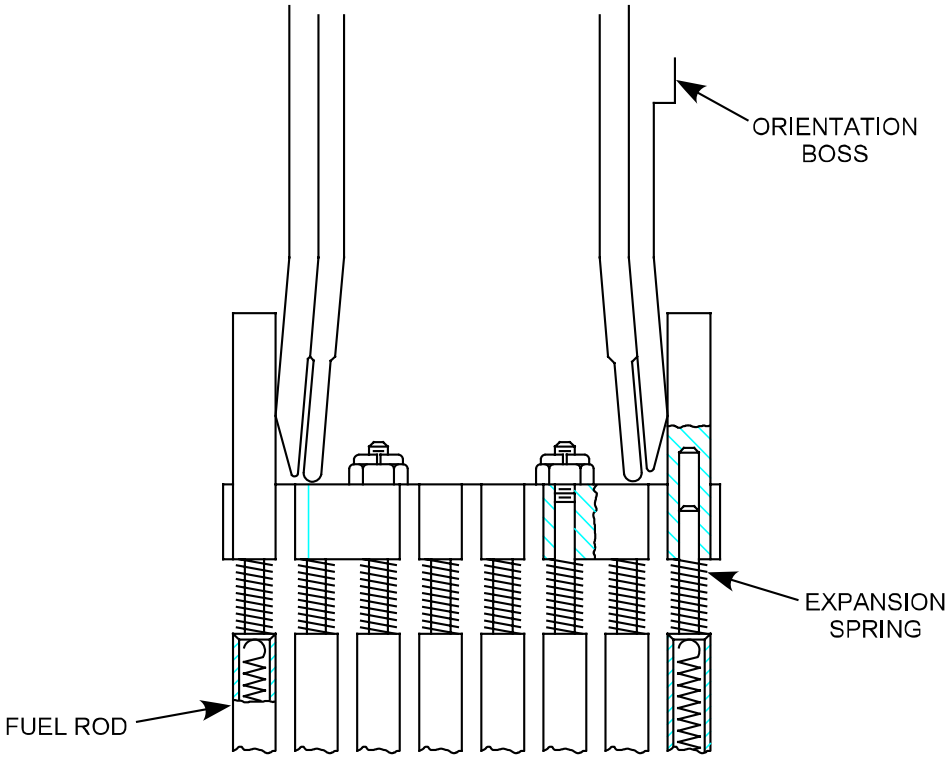
A. 3.00% U^{235}
B. 2.60% U^{235}
C. 2.20% U^{235}
D. 2.00% U^{235}
E. 1.70% U^{235}
F. 1.30% U^{235}
G. 0.711% U^{235}
H. 1.70% U^{235}, 5.0% Gd
I. 1.70% U^{235}, 4.0% Gd
J. 1.70%, 2.0% Gd
K. Water Rod

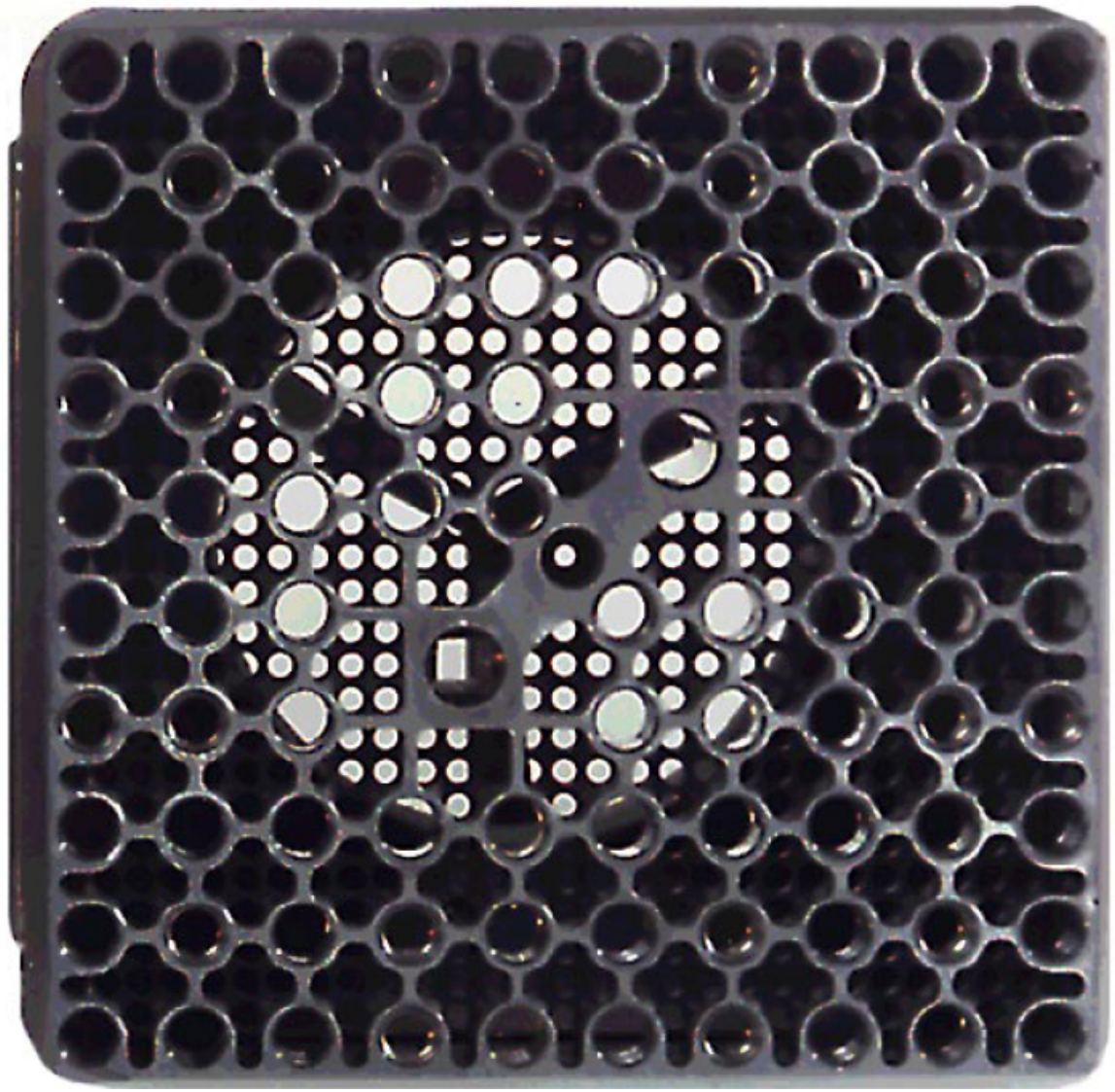
GE-14 Fuel Bundle

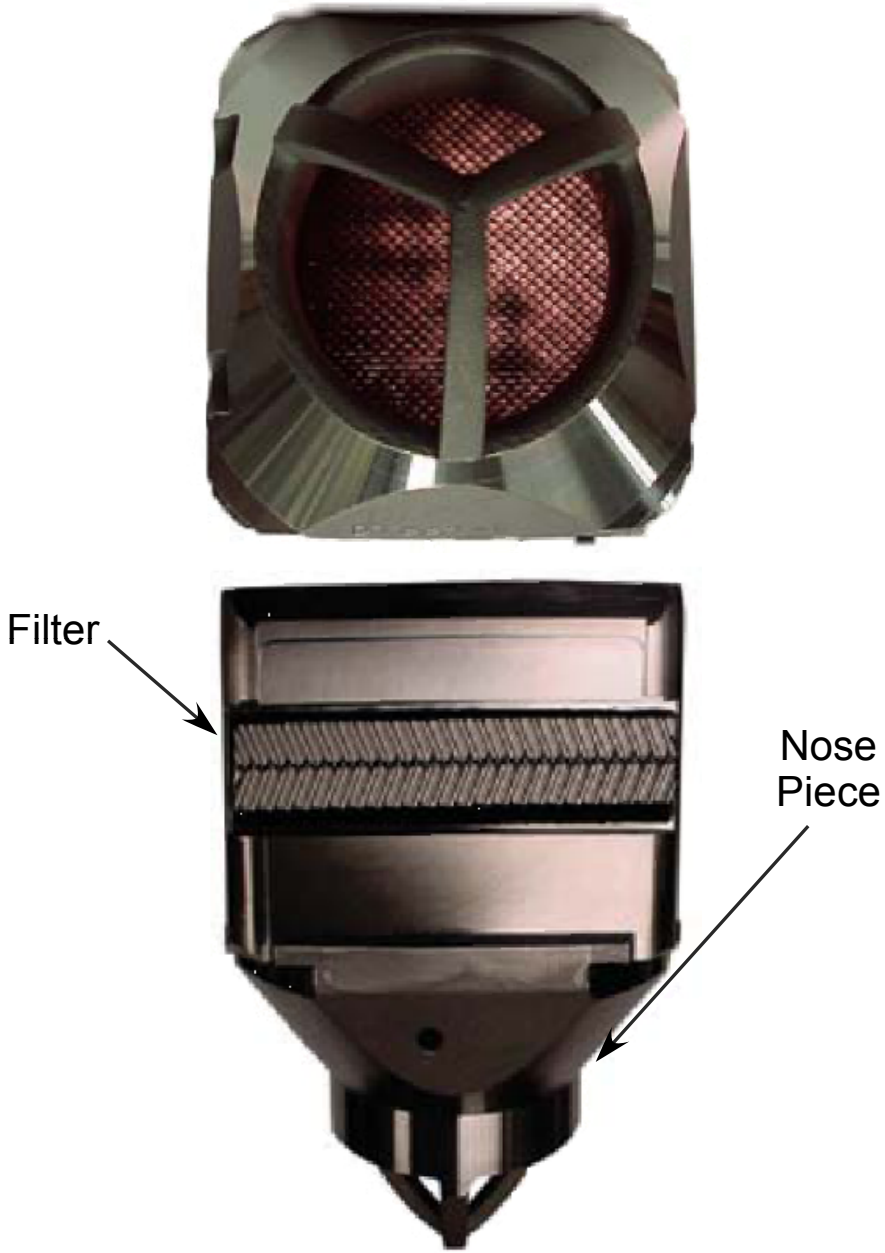
- A GE-14 fuel bundle (Figures 2.2-1 & 2) is comprised of four types of rods:
  - 70 standard fuel rods
  - 8 fuel tie rods
  - 14 partial length fuel rods
  - 2 Water rods

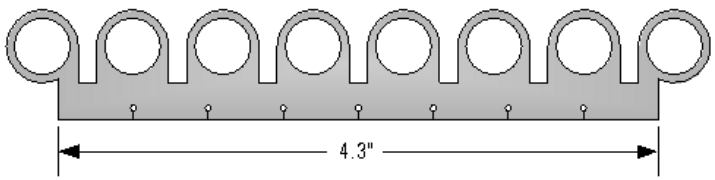

FUEL ROD
TIE ROD
PART LENGTH ROD
WATER ROD

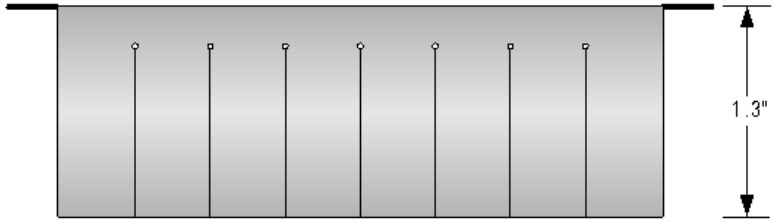

Interactive channel
Upper tie plate
Water rods
Part length fuel rods
Zircaloy ferrule spacers
Lower tie plate debris filter


ORIENTATION
BOSS
EXPANSION
SPRING
FUEL ROD

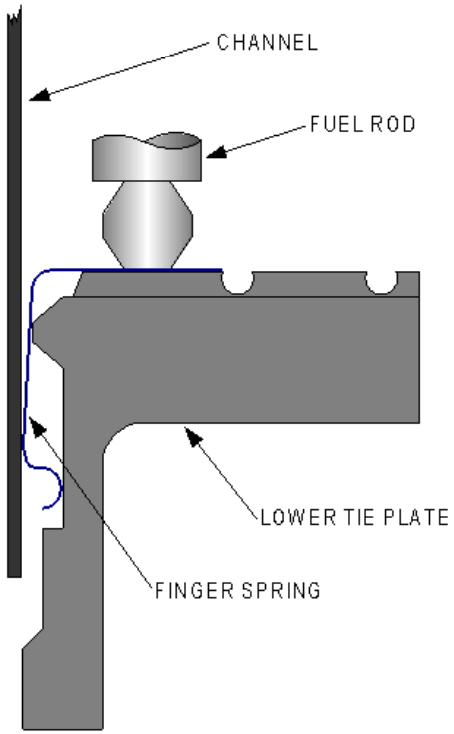



Filter
Nose
Piece



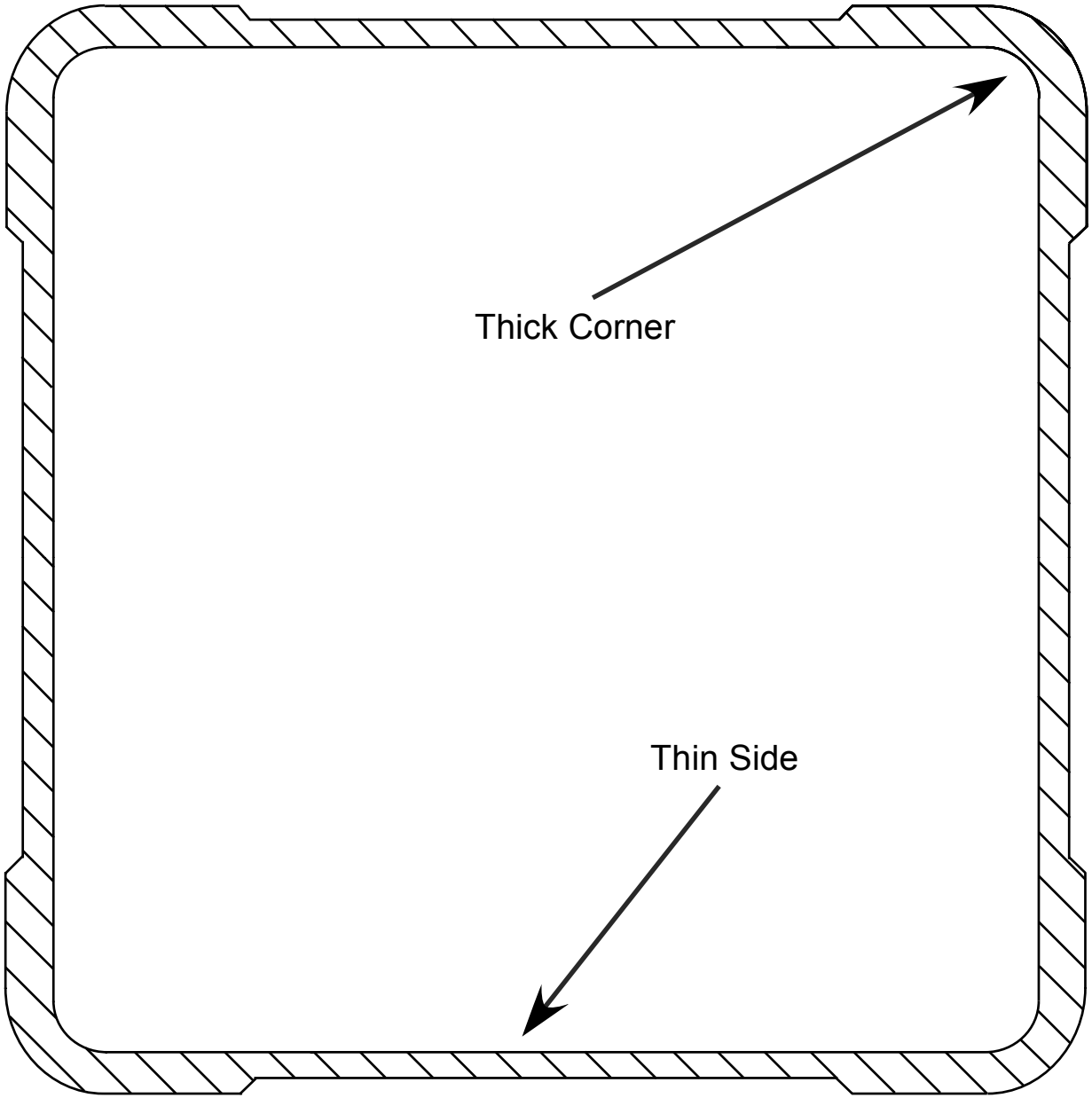


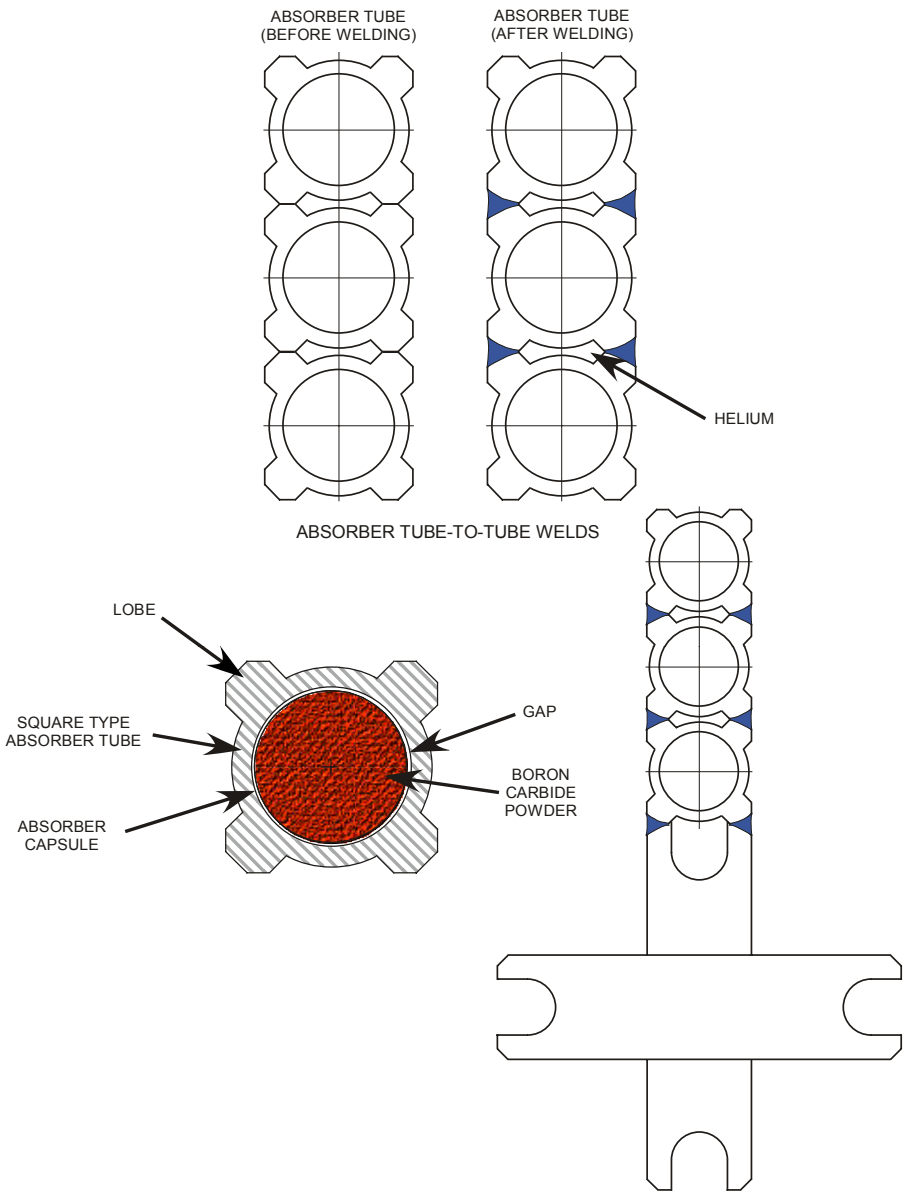
INCONEL X-750 (0.013 inches thick)



Fuel Channel

- A fuel channel (Figures 2.2-5 & 10) has several purposes:
  - Flow distribution
  - Bearing surface for the control rod blade rollers
  - Improved fuel bundle rigidity
  - Fuel rod protection during fuel handling
  - Acts as a heat sink during loss of coolant accident (LOCA) conditions

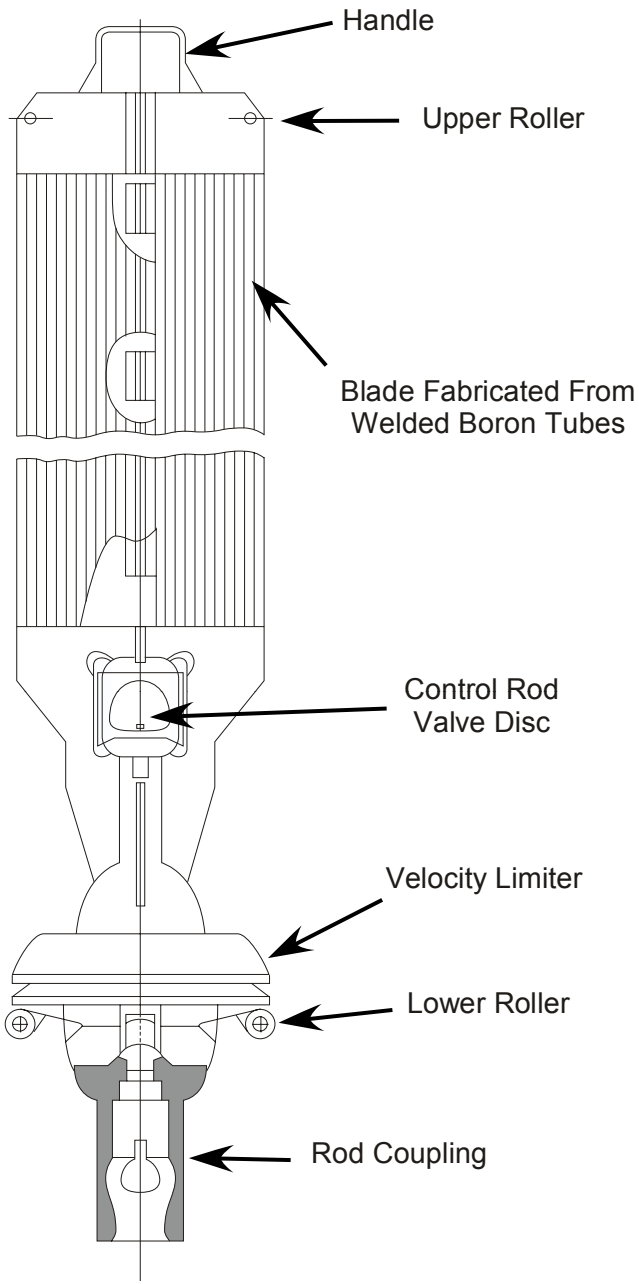

Thick Corner
Thin Side

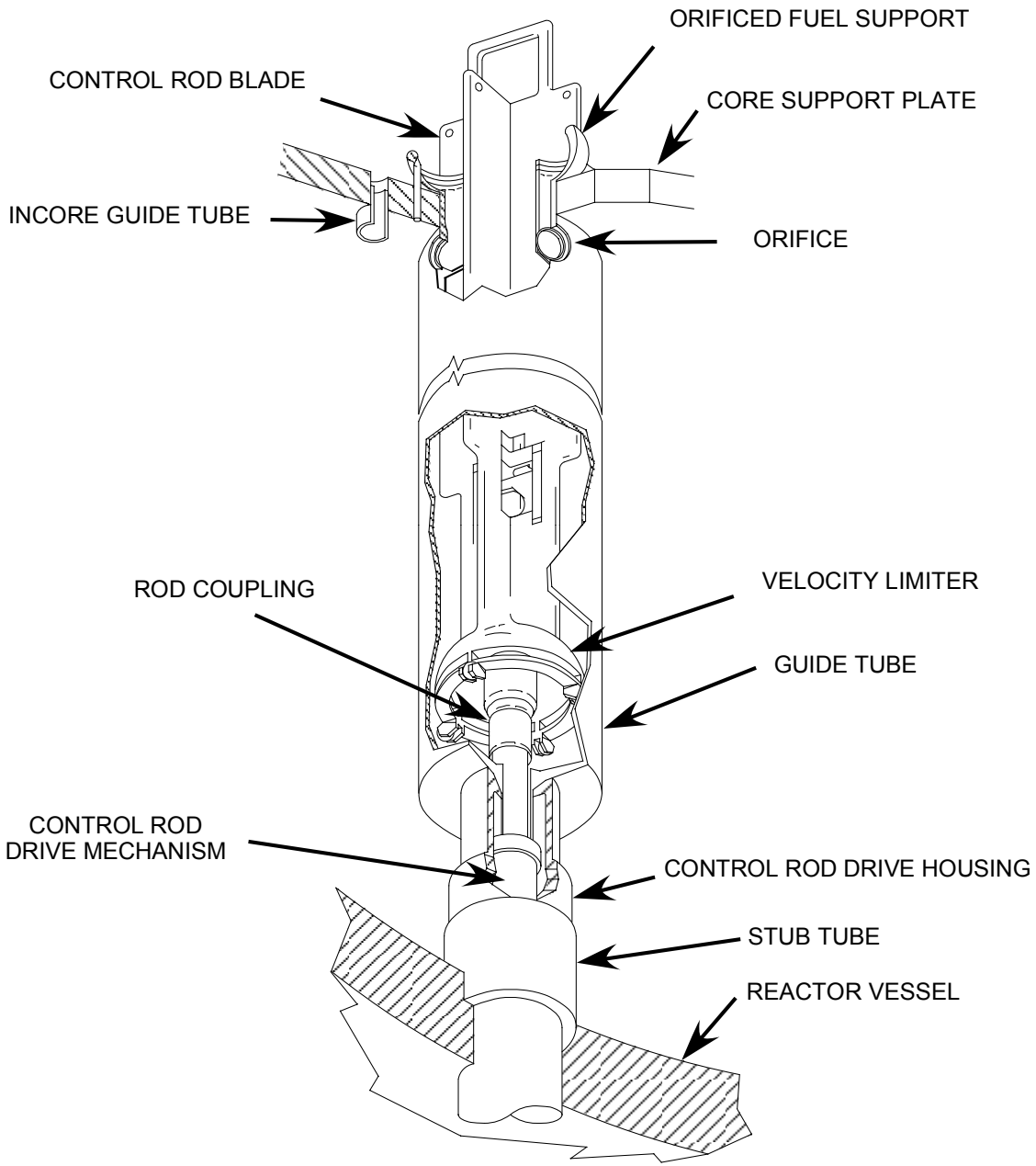

ABSORBER TUBE
(BEFORE WELDING)
ABSORBER TUBE
(AFTER WELDING)
HELIUM
ABSORBER TUBE-TO-TUBE WELDS
LOBE
SQUARE TYPE
ABSORBER TUBE
ABSORBER
CAPSULE
GAP
BORON
CARBIDE
POWDER

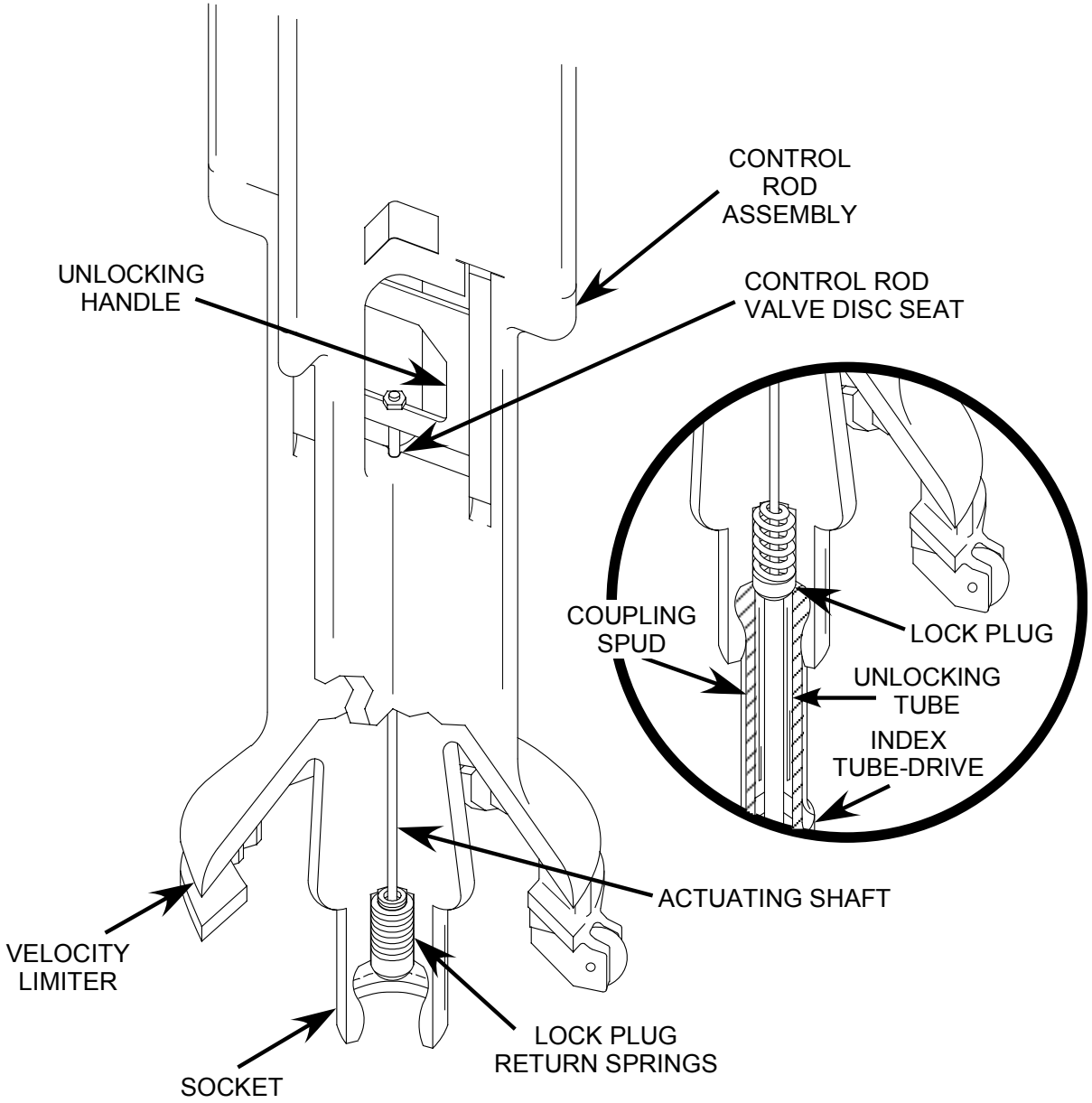
Control Rods

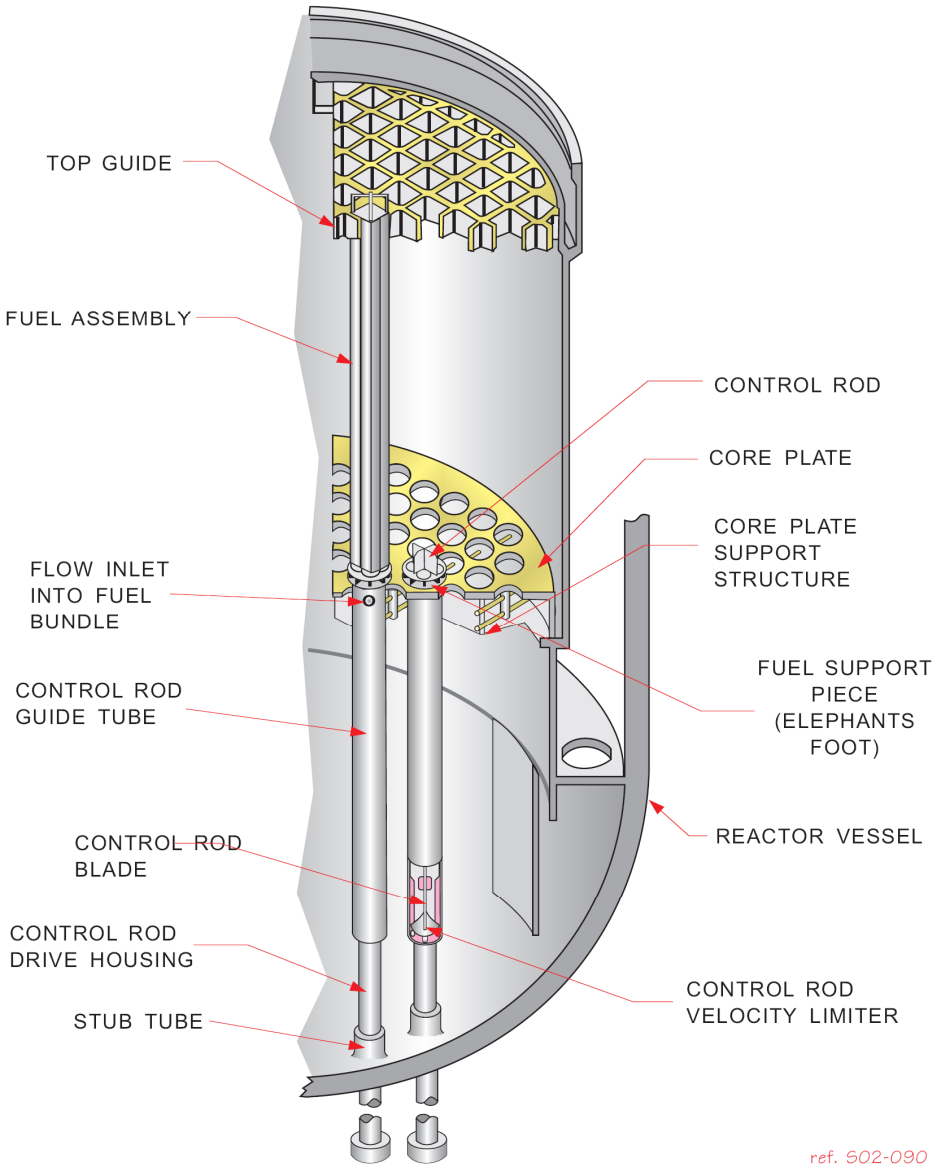
Rapid control rod insertion to avoid fuel damage

- Supports and positions a control rod
- Prevents its control rod from withdrawing as a result of a single malfunction
- Failure in one positioning device does not affect the operation of any other positioning device
- Rapid control rod insertion (scram) is locked to its control rod to prevent undesirable separation


Handle
Upper Roller
Blade Fabricated From
Welded Boron Tubes
Control Rod
Valve Disc
Velocity Limiter
Lower Roller
Rod Coupling


ORIFICED FUEL SUPPORT
CONTROL ROD BLADE
CORE SUPPORT PLATE
INCORE GUIDE TUBE
ORIFICE
ROD COUPLING
VELOCITY LIMITER
GUIDE TUBE
CONTROL ROD
DRIVE MECHANISM
CONTROL ROD DRIVE HOUSING
STUB TUBE
REACTOR VESSEL


CONTROL
ROD
ASSEMBLY
UNLOCKING
HANDLE
CONTROL ROD
VALVE DISC SEAT
COUPLING
SPUD
LOCK PLUG
UNLOCKING
TUBE
INDEX
TUBE-DRIVE
ACTUATING SHAFT
VELOCITY
LIMITER
LOCK PLUG
RETURN SPRINGS
SOCKET


TOP GUIDE
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CONTROL ROD
CORE PLATE
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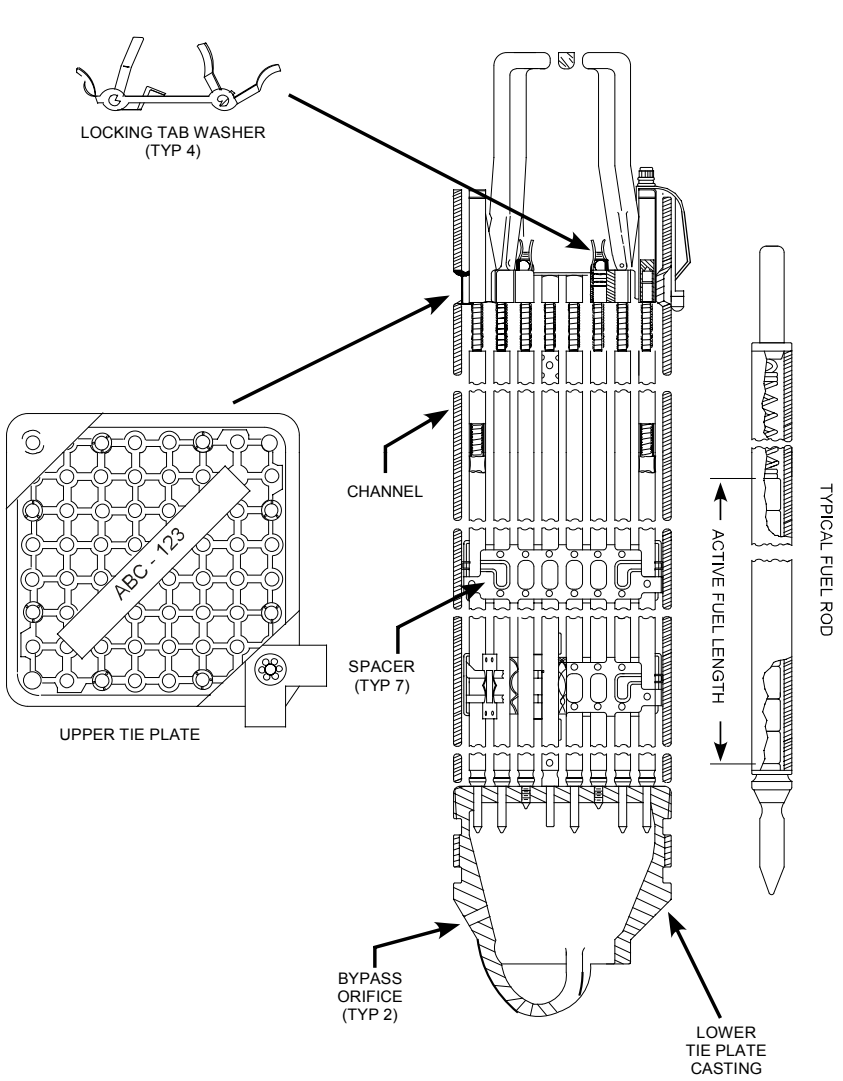
FLOW INLET INTO FUEL BUNDLE
FUEL SUPPORT PIECE (ELEPHANTS FOOT)
CONTROL ROD GUIDE TUBE
REACTOR VESSEL
CONTROL ROD BLADE
CONTROL ROD DRIVE HOUSING
CONTROL ROD VELOCITY LIMITER
STUB TUBE
ref. 502-090

Review


LOCKING TAB WASHER
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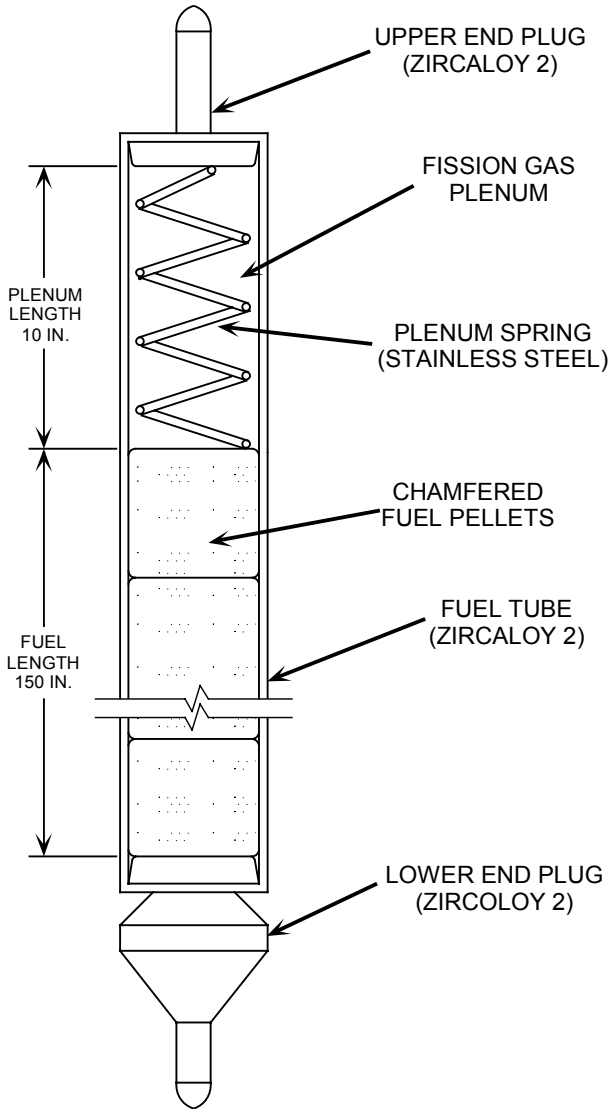
CHANNEL
ABC - 123
SPACER
(TYP 7)
UPPER TIE PLATE
BYPASS
ORIFICE
(TYP 2)
LOWER
TIE PLATE
CASTING
ACTIVE FUEL LENGTH
TYPICAL FUEL ROD


UPPER END PLUG
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FISSION GAS
PLENUM
PLENUM
LENGTH
10 IN.
PLENUM SPRING
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CHAMFERED
FUEL PELLETS
FUEL TUBE
(ZIRCALOY 2)
FUEL
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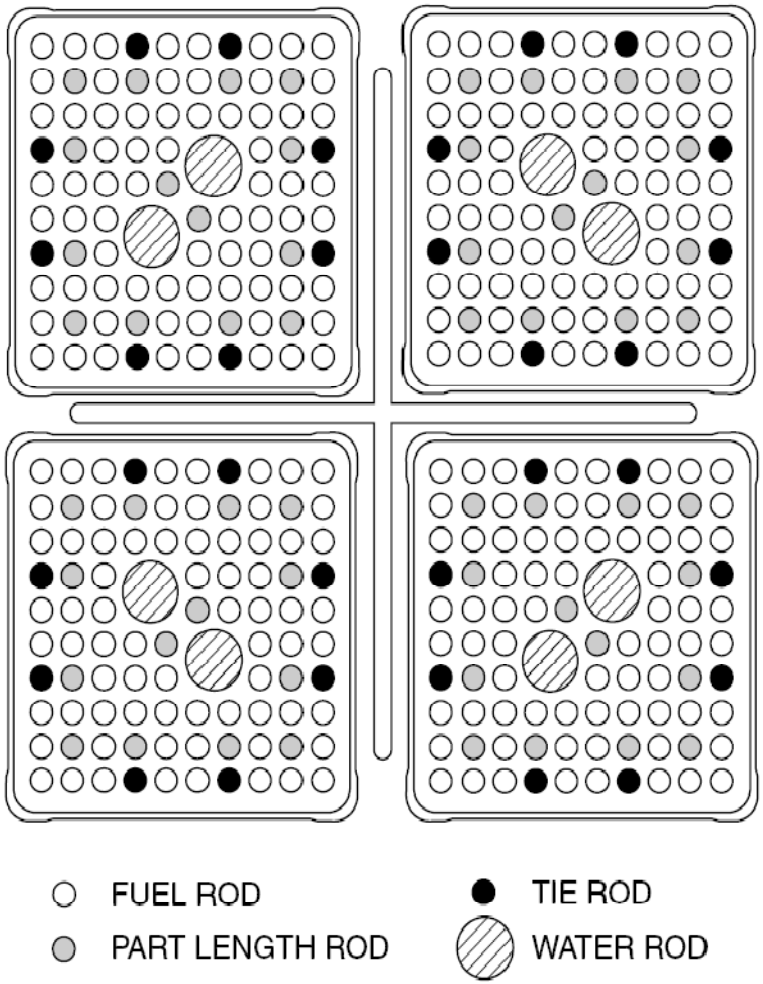
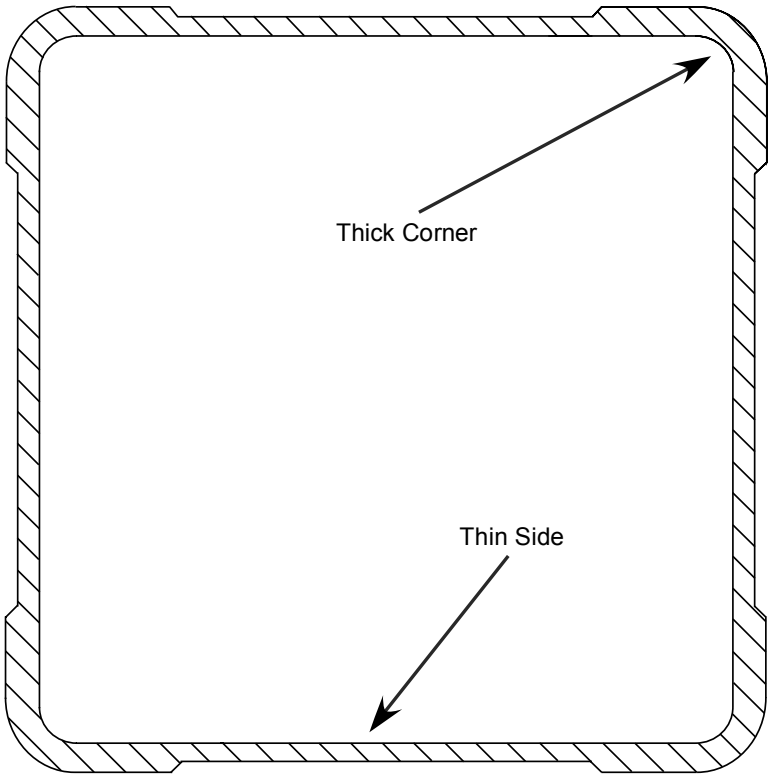
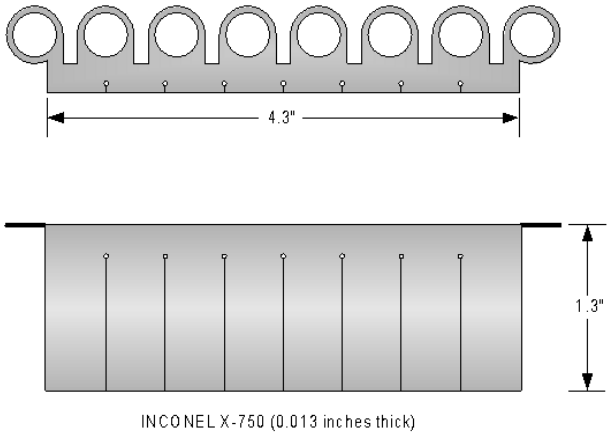
150 IN.
LOWER END PLUG
(ZIRCOLOY 2)

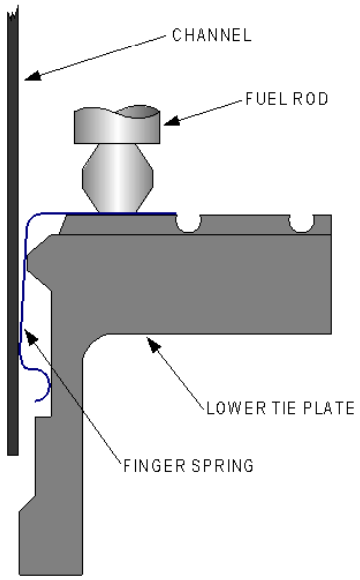
Review

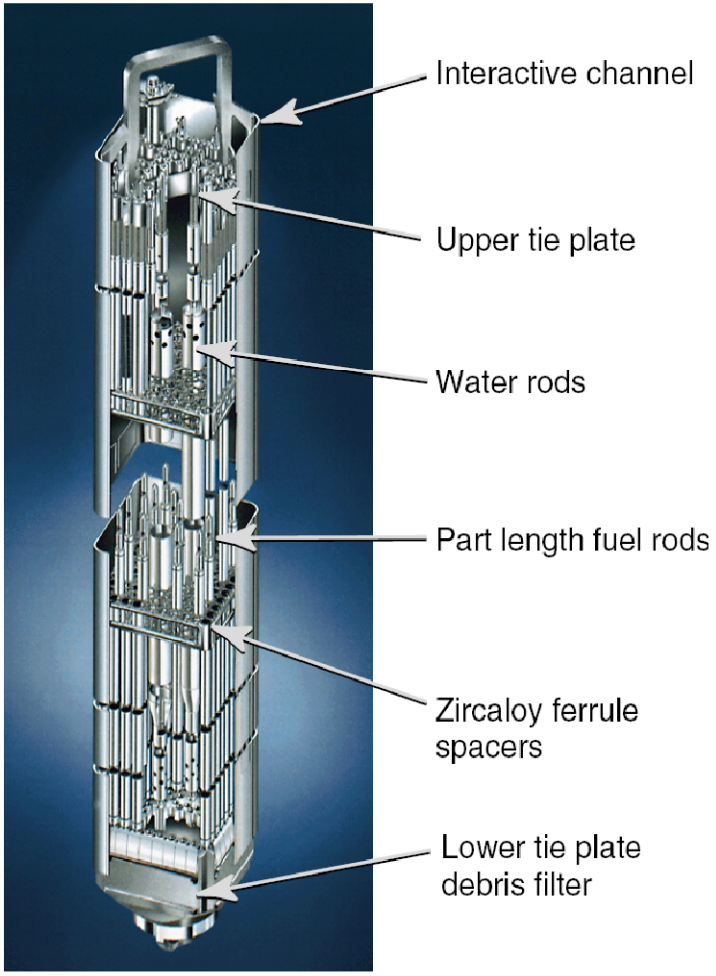

FUEL ROD
TIE ROD
PART LENGTH ROD
WATER ROD


Thick Corner
Thin Side

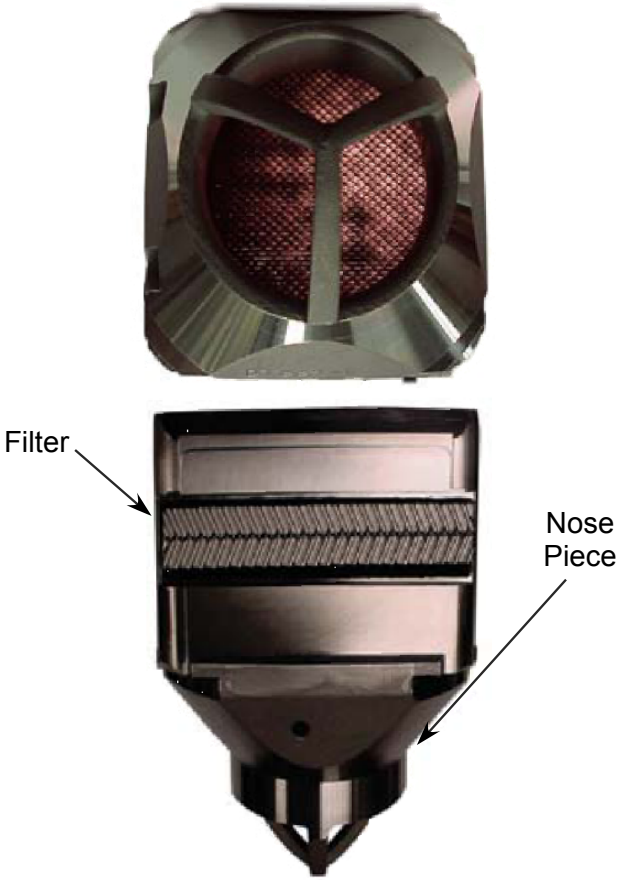
Review

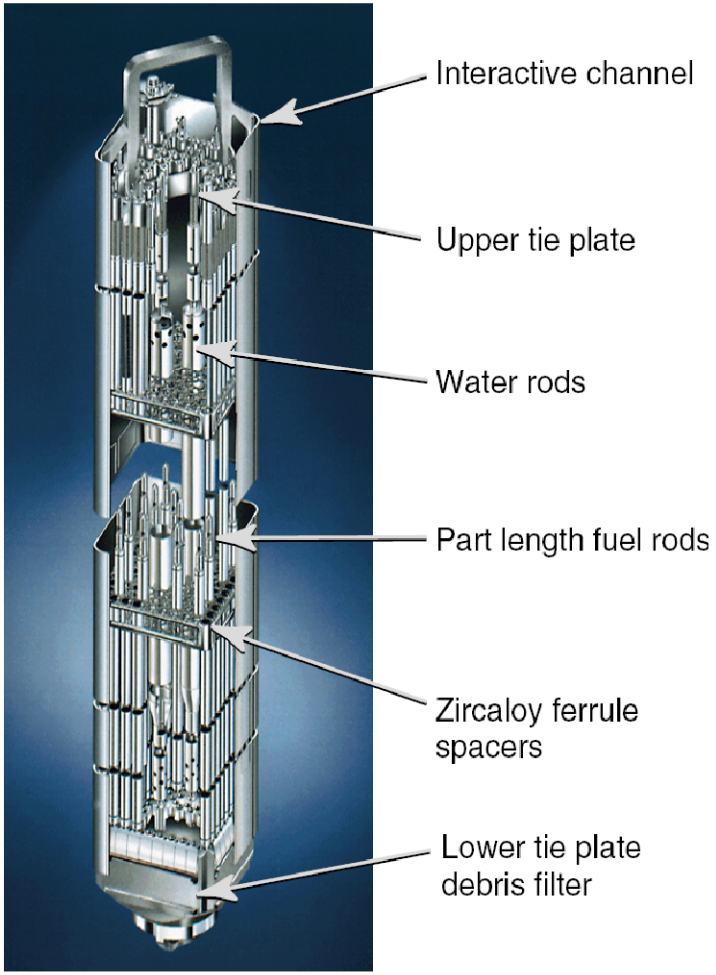

4.3"
1.3"
INCONEL X-750 (0.013 inches thick)


CHANNEL
FUEL ROD
LOWER TIE PLATE
FINGER SPRING


Interactive channel
Upper tie plate
Water rods
Part length fuel rods
Zircaloy ferrule spacers
Lower tie plate debris filter

Review


Filter
Nose
Piece


Interactive channel
Upper tie plate
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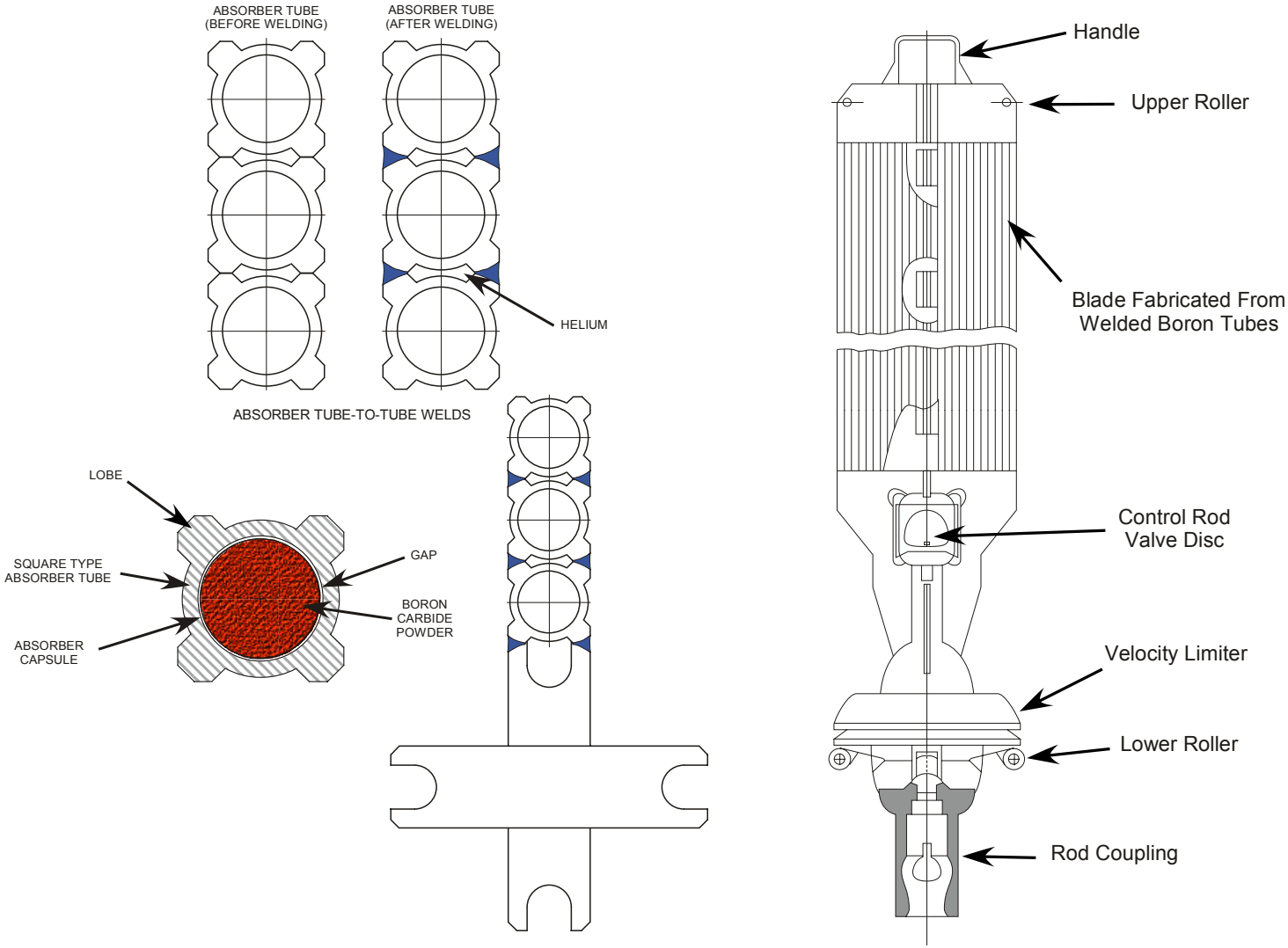
Zircaloy ferrule
spacers
Lower tie plate
debris filter

Review


ABSORBER TUBE (BEFORE WELDING)
ABSORBER TUBE (AFTER WELDING)
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SQUARE TYPE ABSORBER TUBE
ABSORBER CAPSULE
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Handle
Upper Roller
Blade Fabricated From Welded Boron Tubes
Control Rod Valve Disc
Velocity Limiter
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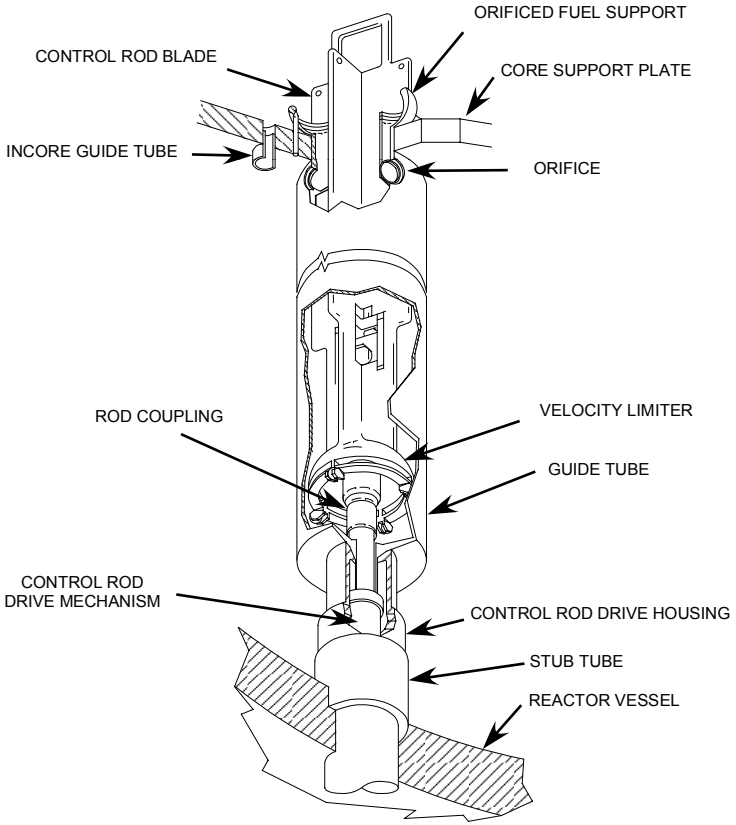
Rod Coupling

Review


ORIFICED FUEL SUPPORT
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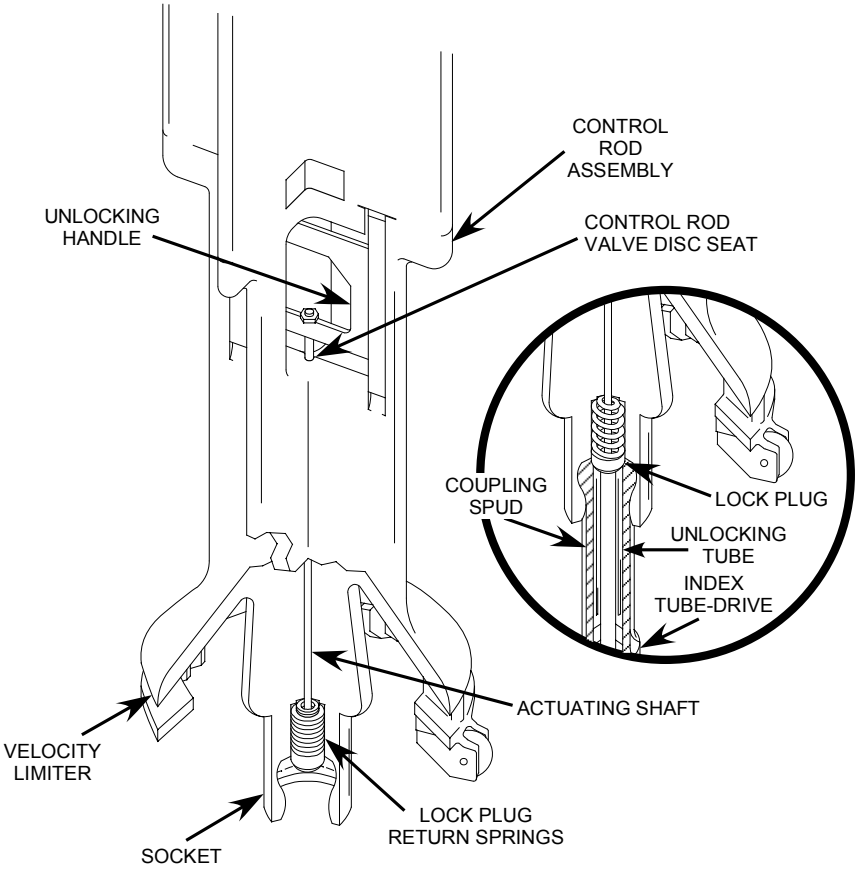
STUB TUBE
REACTOR VESSEL


CONTROL
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SPUD
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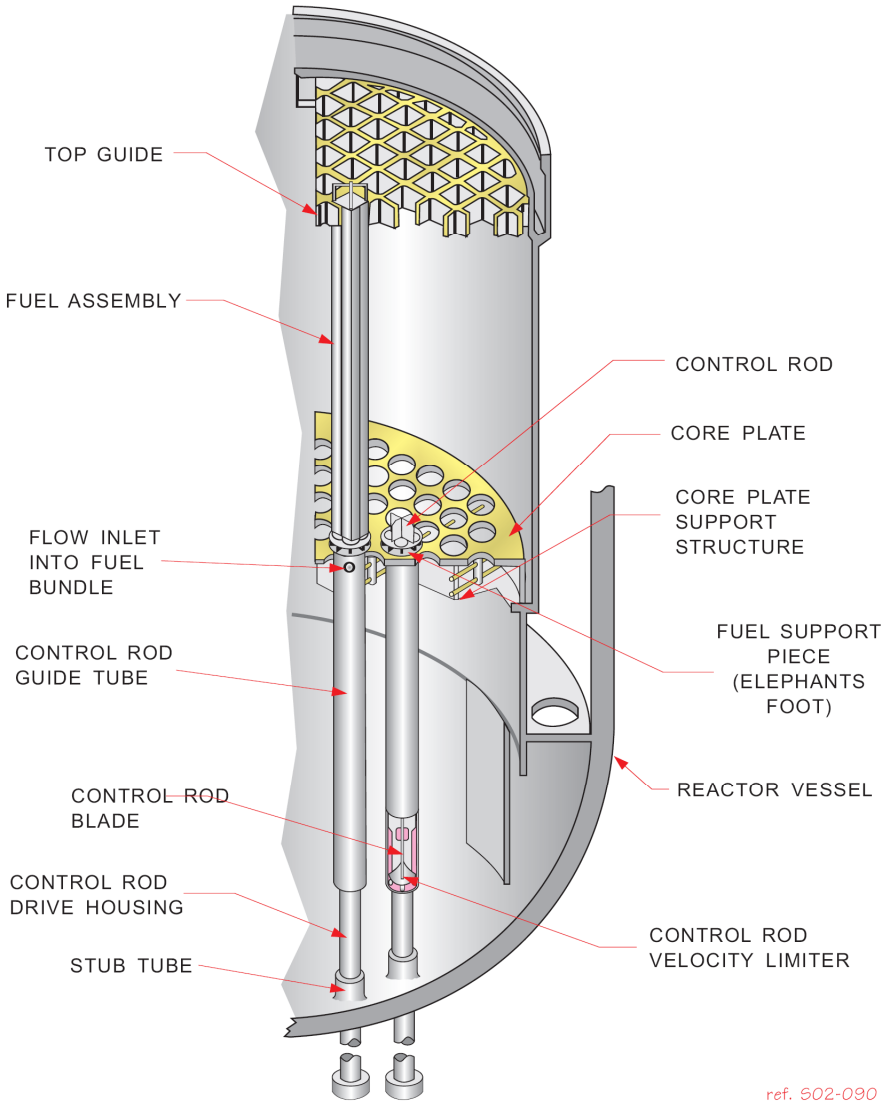
TOP GUIDE
FUEL ASSEMBLY
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FLOW INLET INTO FUEL BUNDLE
FUEL SUPPORT PIECE (ELEPHANTS FOOT)
CONTROL ROD GUIDE TUBE
REACTOR VESSEL
CONTROL ROD BLADE
CONTROL ROD DRIVE HOUSING
CONTROL ROD VELOCITY LIMITER
STUB TUBE
ref. S02-090

Bottom Entry Control Rods

- Less time remove and reinstall the reactor vessel head
- Remain operable when the reactor vessel head is removed
- Easier moisture removal and steam separation
- Limits reduced power production in upper core
- Axial power shaping to control local flux peaking
- Yields a more optimum fuel burnup
- Allow maximum use of water as a neutron shield

Flow Paths

- control rod guide tube to fuel support piece
- channel flow
- bypass flow

Fuel Failure Mechanisms

- Zircaloy-Hydriding
- Pellet-clad-interaction (PCI)
- Poor Water Quality
- Foreign material intrusion

System Interfaces

- RPV
- CRD
- Fuel Transfer System
- Refueling and Vessel Servicing System
- Spent Fuel Pool
- RWM

Objectives

1. Identify the system's purposes.
2. Explain how the system accomplishes its purposes.
3. Explain why some of the system lines are heat traced.
4. Identify the conditions that require initiation of the Standby Liquid Control System.
5. Identify the indications that can be used to verify initiation of the Standby Liquid Control System.

Objectives

1. Recognize the purposes of the following:
   a. Nuclear Fuel
   b. Control Rods

Objectives

2. Summarize the function and physical arrangements of the following fuel assembly components:
    a. Fuel Pellets
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Are there any questions?