US-APWR
Fuel System Design Parameters List

Non-Proprietary Version

December 2007

Revision History

Revision	Page	Description
0	All	Original issued

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

Extensive irradiation experience of Mitsubishi fuel has shown its reliable performance. This reliable fuel design comes from the verified fuel design methodologies and the firm manufacturing capability. The fuel design, fabrication, the associated analysis methodologies and criteria are applied to the design and manufacture of the US-APWR fuel, consistent with NRC regulations and standards. The US-APWR fuel incorporates the latest design of Mitsubishi fuel, such as higher density pellet of 97%TD, gadolinia-uranium dioxide fuel with gadolinia of up to 10wt%, ZIRLO™* cladding, and the countermeasure design to debris fretting, grid fretting and incomplete control rod insertion.

This document provides the US-APWR fuel system design parameters related to "nuclear design", "thermal-hydraulic design", and "transient and accident analysis".

* ZIRLO™ is the trademark of the Westinghouse Electric Corporation.

Table of Contents

List of Tables iv
List of Figures v

1.0 INTRODUCTION 1-1

2.0 DESIGN PARAMETERS OF THE US-APWR FUEL SYSTEM 2-1

3.0 SUMMARY 3-1

List of Tables

Table 2-1 (1/2) The US-APWR Fuel System Design Parameters (Fuel Assembly) 2-2
Table 2-1 (2/2) The US-APWR Fuel System Design Parameters (Fuel Assembly) 2-3
Table 2-2 (1/2) The US-APWR Fuel System Design Parameters (Fuel Rod) 2-4
Table 2-2 (2/2) The US-APWR Fuel System Design Parameters (Fuel Rod) 2-5
Table 2-3 (1/2) The US-APWR Fuel System Design Parameters (In-Core Control Components) 2-6
Table 2-3 (2/2) The US-APWR Fuel System Design Parameters (In-Core Control Components) 2-7

List of Figures

Figure 2-1 Schematic Mitsubishi Fuel Assembly 2-8
Figure 2-2 Schematic Fuel Rod(1/2) 2-9
Figure 2-3 Schematic Fuel Pellet 2-9
Figure 2-4 Schematic Fuel Rod(2/2) 2-10
Figure 2-5 Schematic Rod Cluster Control Assembly 2-11
Figure 2-6 Schematic Burnable Absorber Assembly 2-12
Figure 2-7 Schematic Primary Neutron Source Assembly 2-13
Figure 2-8 Schematic Secondary Neutron Source Assembly 2-14

1.0 INTRODUCTION

This document provides the US-APWR fuel system design parameters related to "nuclear design", "thermal-hydraulic design", and "transient and accident analysis". The design inherits the reliable features which have been confirmed by the extensive irradiation experience of Mitsubishi fuel. The latest design features are adopted to the US-APWR fuel design, such as higher density pellet of 97%TD, gadolinia-uranium dioxide fuel with gadolinia of up to 10wt%, ZIRLO cladding, and the countermeasure design to debris fretting, grid fretting and incomplete control rod insertion.

2.0 DESIGN PARAMETERS OF THE US-APWR FUEL SYSTEM

The geometries and materials of the US-APWR fuel system including the following fuel system information and associated tolerances, are summarized in Table 2-1 to 2-3 and Figure 2-1 to 2-8.

- Type and metallurgical state of the cladding
- Cladding outside diameter
- Cladding inside diameter
- Cladding inside roughness
- Pellet outside diameter
- Pellet roughness
- Pellet density
- Pellet resintering data
- Pellet length
- Pellet dish dimensions
- Pellet grain size and open porosity
- Burnable absorber content
- Fuel column length
- Overall rod length
- Rod internal void volume
- Fill gas type and pressure
- Sorbed gas composition and content
- Spring and plug dimensions
- Fissile enrichment
- Equivalent hydraulic diameter
- Control rod descriptions, dimensions, and lifetime limits
- Fit of control rod interference with surrounding structure (e.g., guide tube)
- Burnable absorber rod and neutron source rod descriptions and dimensions

Table 2-1 (1/2) The US-APWR Fuel System Design Parameters (Fuel Assembly)

	Nominal	Tolerances	Note
Fuel Assembly			
Fuel rods array	17 x 17		
Number of fuel rods	264		
Number of control rod guide thimbles	24		
Number of in-core instrumentation guide tube	1		
Number of grid spacers	11		
Measure for trapping debris	Anti-debris bottom nozzle with built-in filter		
Material of Structural Parts			
Top/Bottom nozzle	Type 304 Stainless Steel		
Top nozzle holddown spring	Inconel -718 *		
Top/Bottom grid spacer	Inconel -718 *		
Intermediate grid spacer	Zircaloy-4		Recrystallized
Control rod guide thimble	Zircaloy-4		Recrystallized
In-core instrumentation guide tube	Zircaloy-4		Recrystallized
Sleeve between top nozzle and top grid spacer	Type 304 Stainless Steel		
Sleeve for intermediate grid spacers	Zircaloy-4		

* Inconel 718 is a nickel-chromium-iron Alloy 718.

Table 2-1 (2/2) The US-APWR Fuel System Design Parameters (Fuel Assembly)

	Nominal	Tolerances	Note
Geometry			
Overall fuel assembly length	[ ]*	[	
Maximum fuel assembly width	8.426 in.(214.02mm)		
Fuel rod pitch	0.496 in.(12.6mm)		
Equivalent hydraulic diameter	0.464 in.(11.78mm)		
Control rod guide thimble outer diameter (upper part)	0.482 in.(12.24mm)		
Control rod guide thimble inner diameter (upper part)	0.450 in.(11.43mm)		
Control rod guide thimble outer diameter (lower part)	0.429 in.(10.9mm)		
Control rod guide thimble inner diameter (lower part)	0.397 in.(10.08mm)		
In-core instrumentation guide tube outer diameter	0.482 in.(12.24mm)		
In-core instrumentation guide tube inner diameter	0.450 in.(11.43mm)	]	

* These values indicate the fuel assembly length except for the clamp height of the top nozzle.

Table 2-2 (1/2) The US-APWR Fuel System Design Parameters (Fuel Rod)

Fuel Rod	Nominal	Tolerances	Note
Overall rod length	181.5 in.(4610mm)	[	
Upper plenum length	6.77 in.(172mm)		
Lower plenum length	[		
Rod internal void volume	]		
Fill gas type and pressure	He gas [ ]		
Sorbed gas composition and content	–		
Active fuel length	165.4 in. (4,200mm)		
Outer diameter	0.374 in. (9.50mm)		
Rod design burnup	62,000 MWD/MTU	]	
Pellet			
Material	Sintered uranium dioxide(UO_2) Sintered gadolinia-uranium dioxide((U, Gd)O_2)		
Fissile enrichment (wt%U-235)	2.05/3.55/4.15	[	Region 1/2/3
Pellet diameter	0.322 in. (8.19 mm)		
Pellet length	0.453 in.(11.5mm)		
Pellet dish dimensions	[		Figure 2-3
Pellet chamfer dimensions	]		
Pellet roughness	–		
Pellet density	97%TD	]	
Pellet resintering data	[ ]		Not specified
Pellet grain size	–	[ ]	Not specified
Open porosity	[ ]		Typical value
Burnable absorber (Gd) content	Max10wt%	[ ]	

Table 2-2 (2/2) The US-APWR Fuel System Design Parameters (Fuel Rod)

	Nominal	Tolerances	Note
Cladding			
Material of cladding	ZIRLO		
Type and metallurgical state of the cladding	Cold Work Stress relieved		
Cladding outer diameter	0.374 in. (9.50mm)	[	
Cladding inner diameter	0.329 in. (8.36mm)		
Cladding thickness	–		
Cladding inside roughness	–	]	
Pellet spring and endplugs			
Upper plenum spring	[	[	
Lower plenum spacer volume		–	
Length of upper endplug		–	
Length of lower endplug	]	–	

Table 2-3 (1/2) The US-APWR Fuel System Design Parameters (In-Core Control Components)

	Nominal	Tolerances	Note
Rod Cluster Control Assembly			
Number of control rods per assembly	24		
Absorber material	Ag (80%)-In (15%)-Cd (5%)		
Upper absorber length	151.3 in.(3843mm)	[ ]	
Lower absorber length	[ ]		
Upper absorber outer diameter	0.341 in.(8.66mm)		
Lower absorber outer diameter	[ ]		
Cladding material	Type 304 Stainless Steel		
Cladding outer diameter	0.381 in.(9.68mm)	[ ]	
Cladding inner diameter	0.344 in.(8.74mm)		
Cladding thickness	–		
Design lifetime	15 years		
Burnable Absorber Assembly			
Number of absorber rods per assembly	Max. 24		
Absorber material	Borosilicate-Glass		
Absorber length	159.4 in.(4050mm)	[ ]	
Cladding material	Type 304 Stainless Steel		
Cladding outer diameter	0.381 in.(9.68mm)	[ ]	
Cladding inner diameter	0.344 in.(8.74mm)		
Cladding thickness	–		

Table 2-3 (2/2) The US-APWR Fuel System Design Parameters (In-Core Control Components)

	Nominal	Tolerances	Note
Neutron Source Assembly (Primary Neutron Source Assembly)			
Number of source rods per assembly	1		
Neutron source material	Californium 252		
Neutron source outer diameter	0.330 in.(8.38mm)	[ ]	
Neutron source length	1.5 in.(38mm)		
Cladding material	Type 304 Stainless Steel		
Cladding outer diameter	0.381 in.(9.68mm)	[ ]	
Cladding inner diameter	0.344 in.(8.74mm)		
Cladding thickness	–		
Neutron Source Assembly (Secondary Neutron Source Assembly)			
Number of source rods per assembly	4		
Neutron source material	Antimony–Beryllium		
Neutron source outer diameter	0.292 in. (7.42mm)	[ ]	
Neutron source length	88.0 in.(2235.2mm)	–	
Cladding material	Type 304 Stainless Steel		
Cladding outer diameter	0.381 in.(9.68mm)	[ ]	
Cladding inner diameter	0.344 in.(8.74mm)		
Cladding thickness	–		

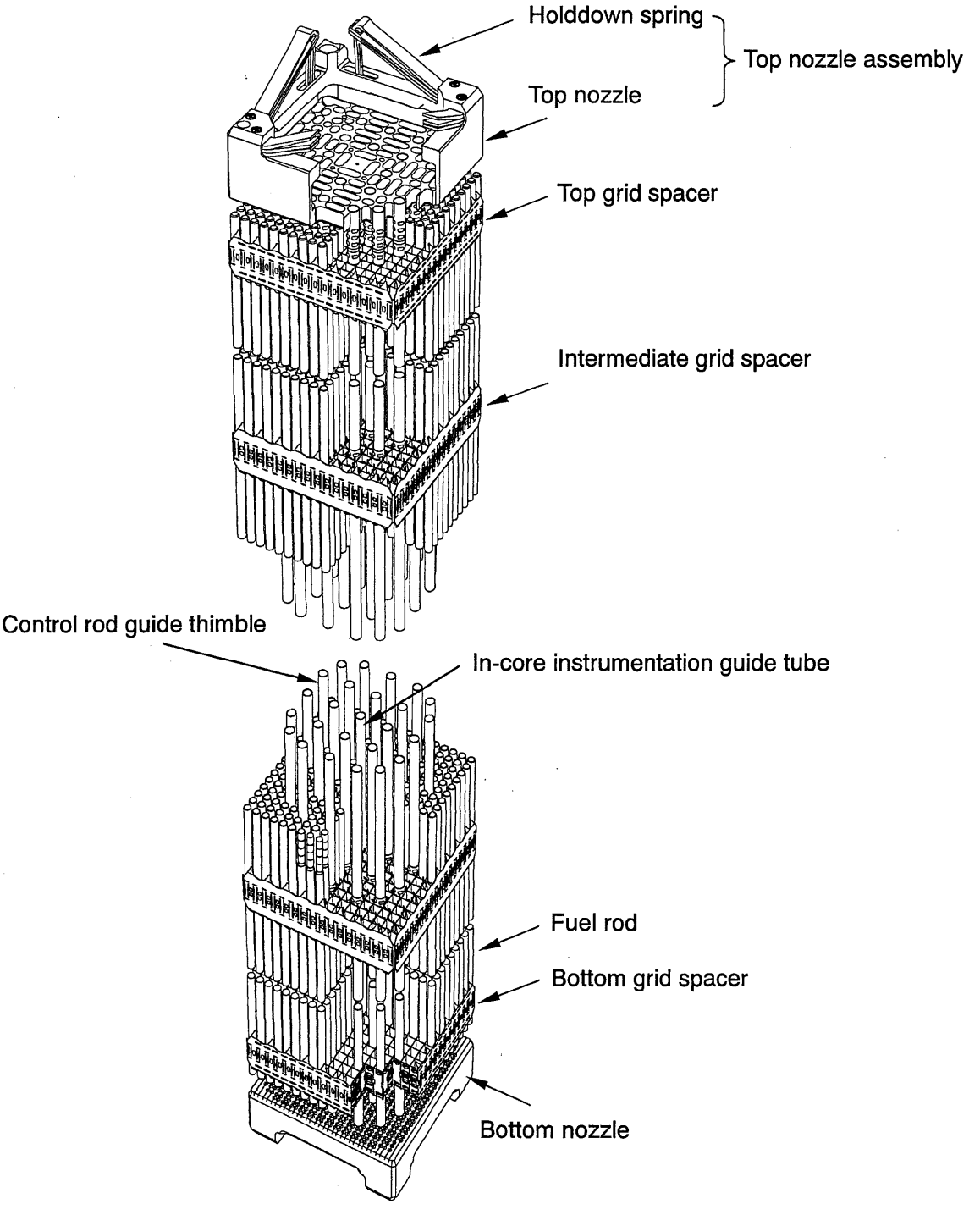


Figure 2-1 Schematic Mitsubishi Fuel Assembly

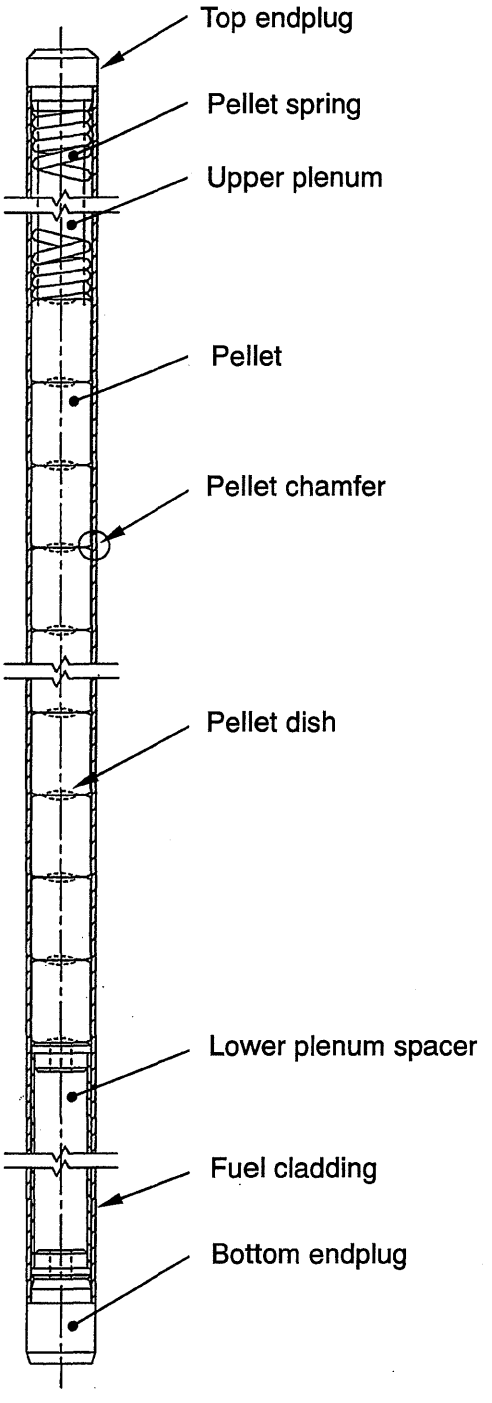


Figure 2-2 Schematic Fuel Rod (1/2)

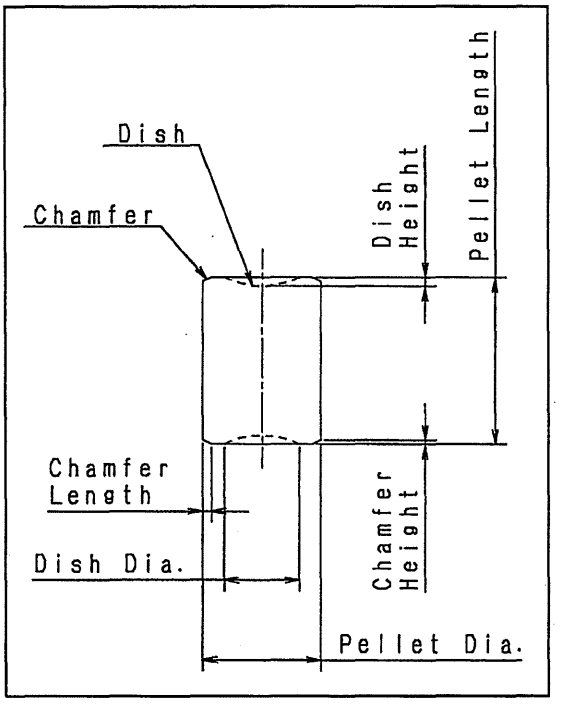
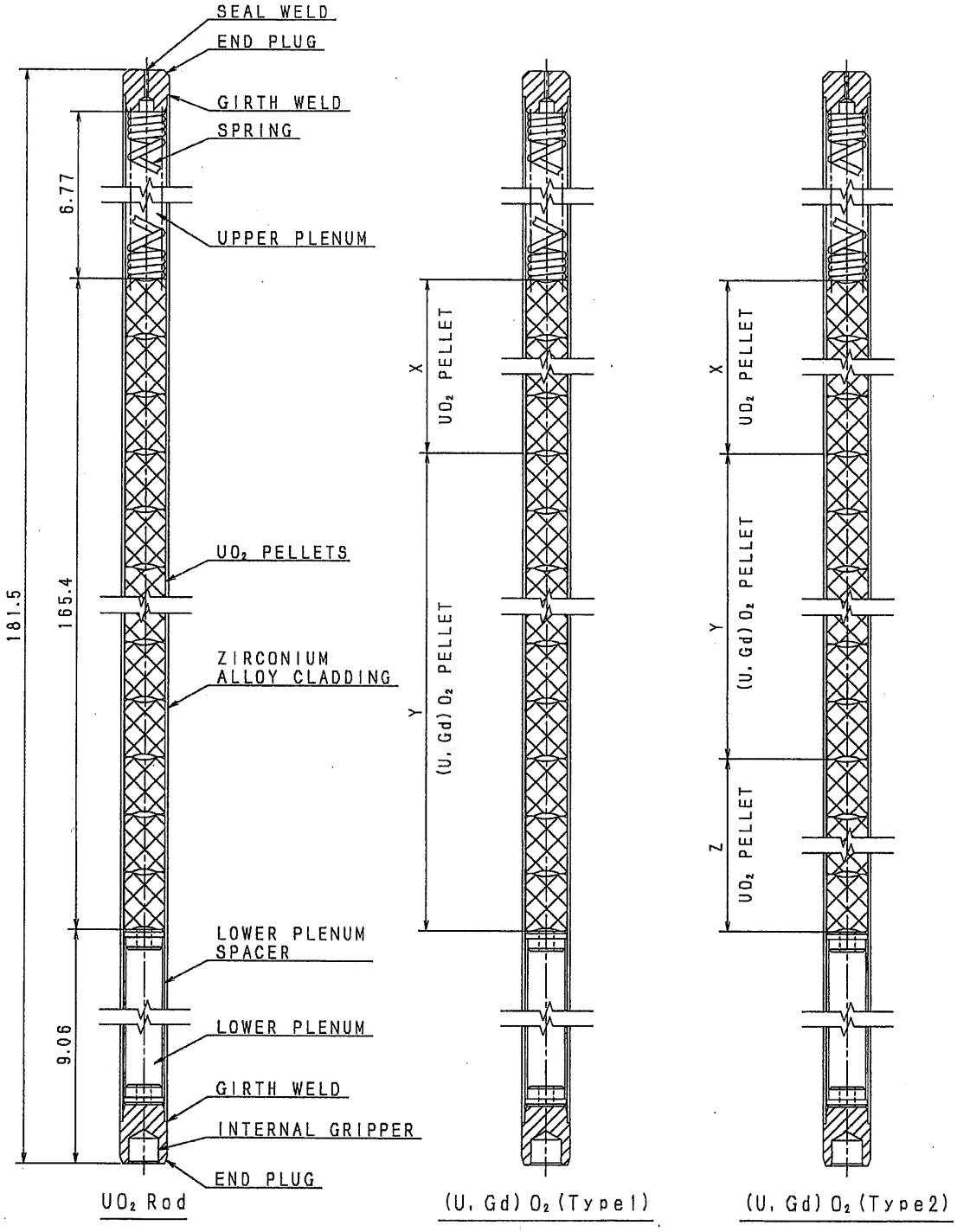


Figure 2-3 Schematic Fuel Pellet



X,Y,Z dimensions depend on core design.
Dimensions are in inches. (Nominal)

Figure 2-4 Schematic Fuel Rod (2/2)

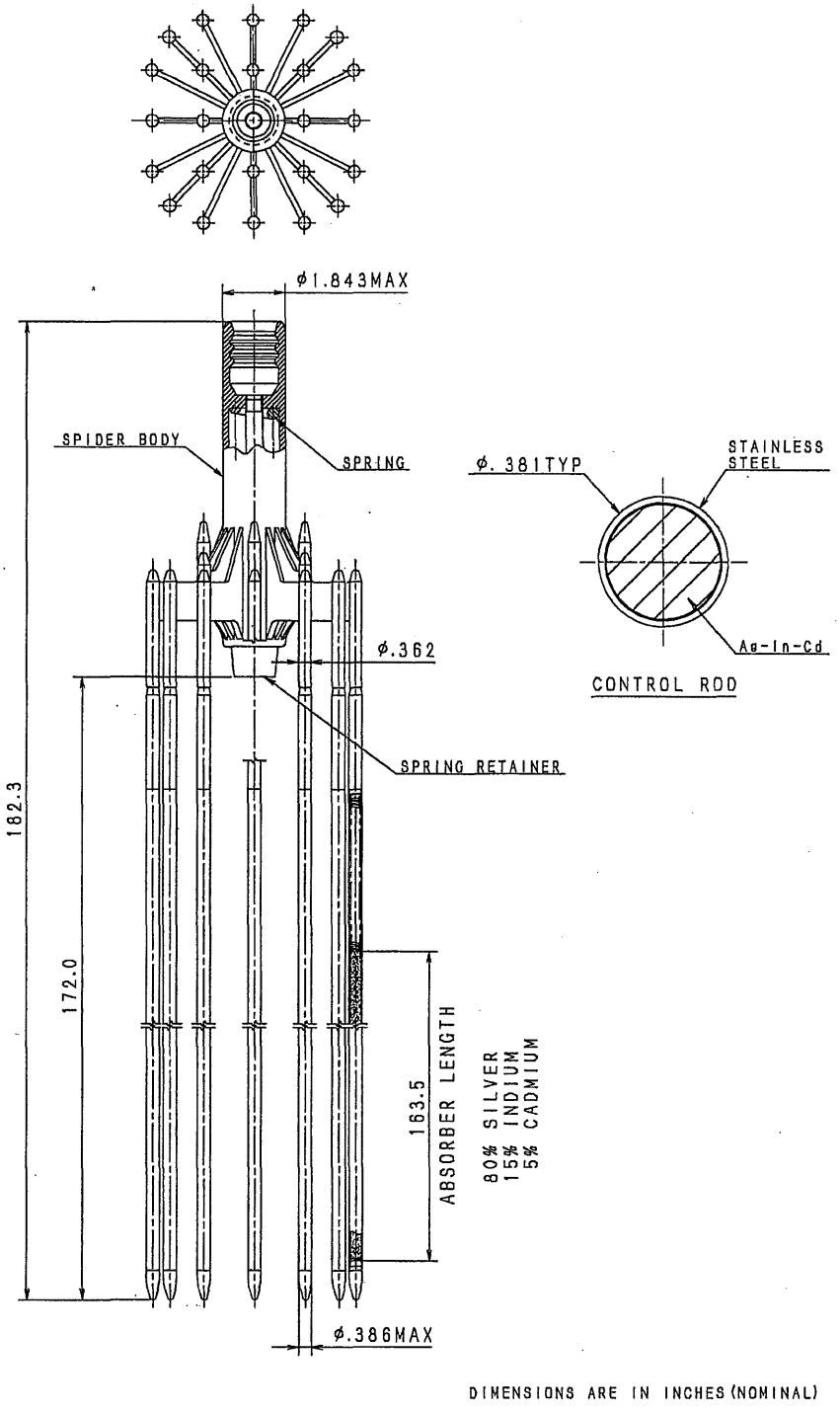


Figure 2-5 Schematic Rod Cluster Control Assembly

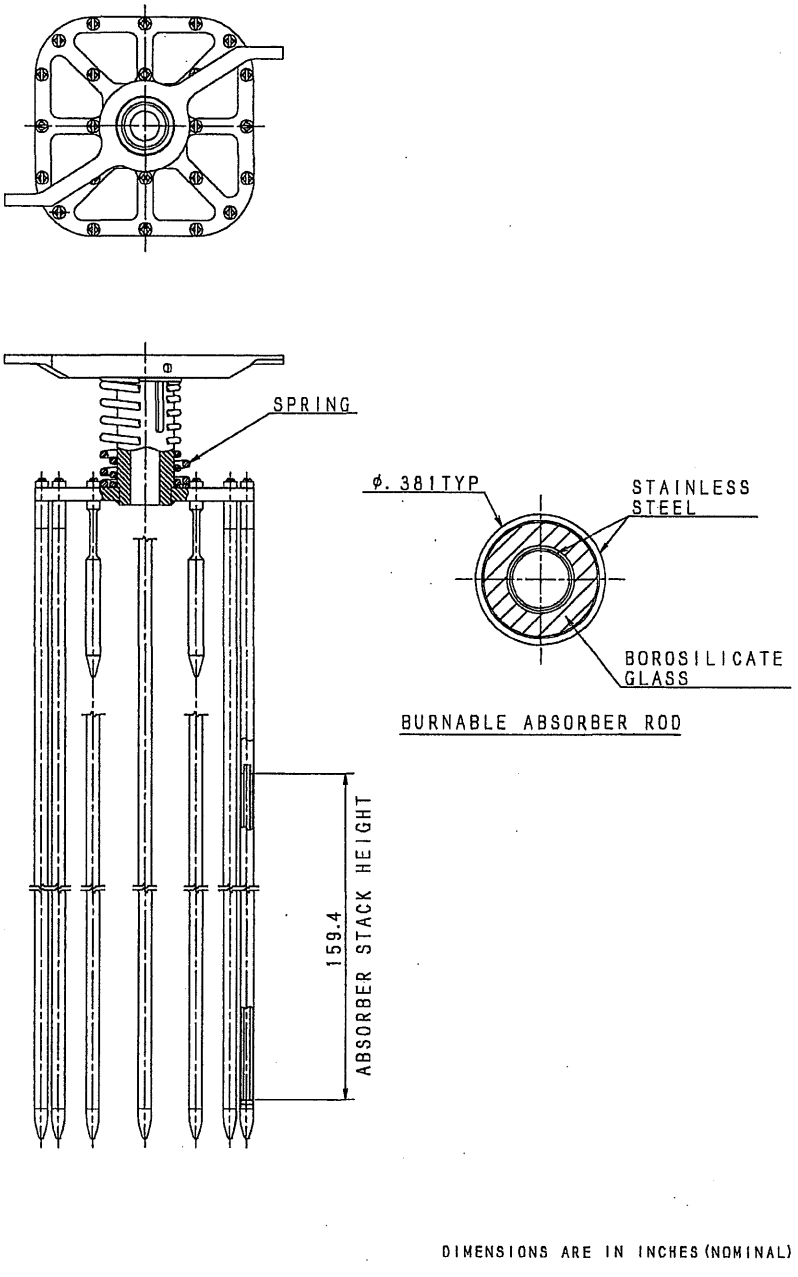


Figure 2-6 Schematic Burnable Absorber Assembly

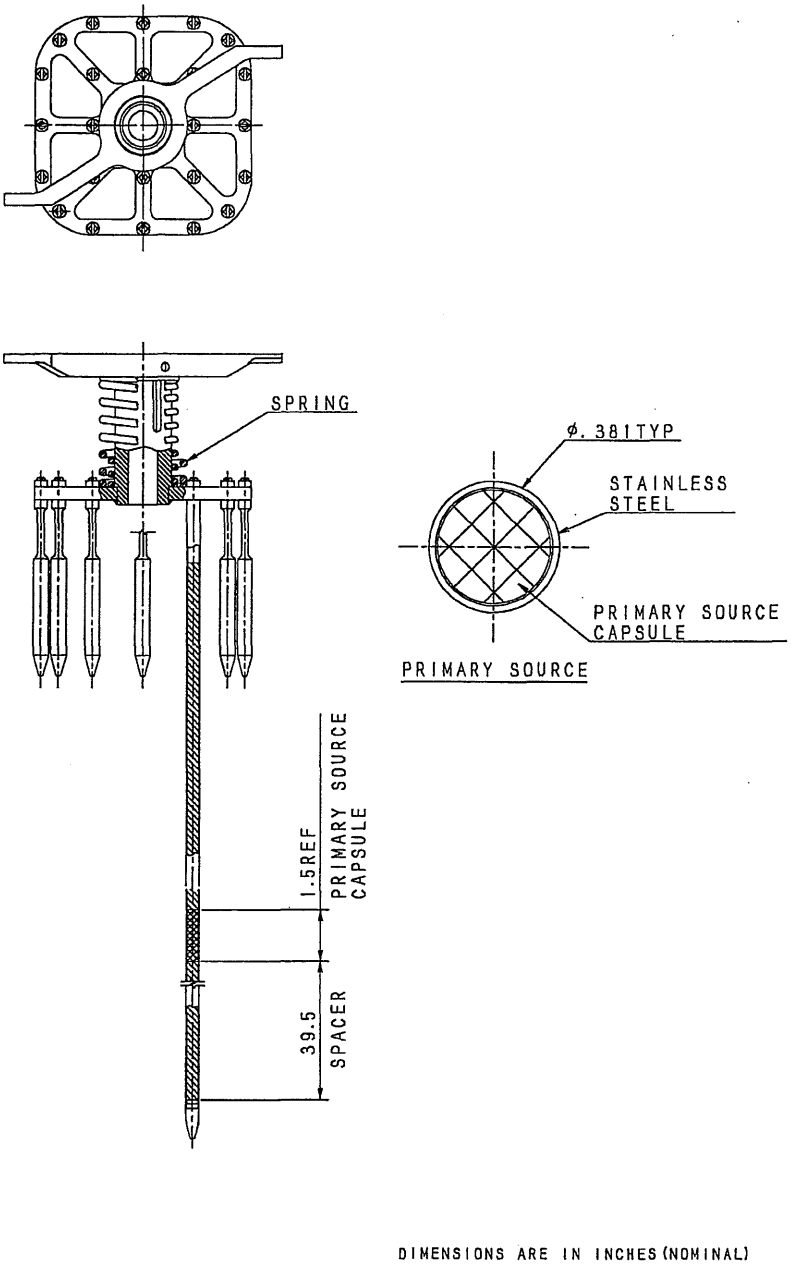


Figure 2-7 Schematic Primary Neutron Source Assembly

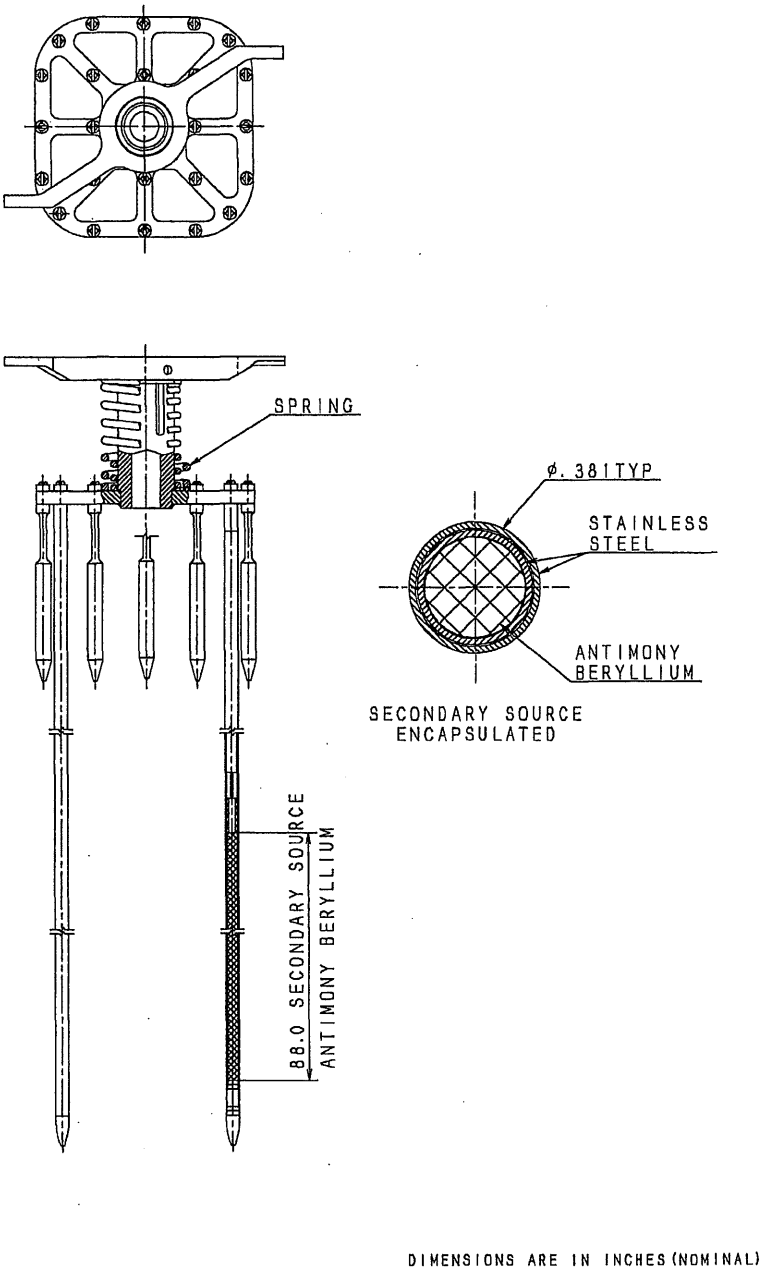


Figure 2-8 Schematic Secondary Neutron Source Assembly

3.0 SUMMARY

The fuel system design, fabrication, the associated analysis methods and criteria that have led to high reliability performance of Mitsubishi fuel system are applied to the design and manufacture of US-APWR fuel, consistent with NRC regulations and standards.

This document summarized the US-APWR fuel system design parameters related to "nuclear design", "thermal-hydraulic design", and "transient and accident analysis".