4. REACTOR

4.1 SUMMARY DESCRIPTION

4.1.1 REACTOR SYSTEM

The reactor system, listed below, has been removed from service. It no longer has a Design Basis, Licensing Basis, or operational function. Although this system has been removed from service, it may still contain fluids, gases or other hazards such as energized circuits, compressed air, radioactive material, etc. Equipment may not have been physically removed from the plant. See General Arrangement Drawings, P&IDs, and One Line diagrams for current plant configuration.

STRUCTURES/SYSTEMS/COMPONENTS	STATUS
Reactor	Removed from Service
Control Element Drive Mechanism (CEDM)	Removed from Service
Vibration and Loose Parts Monitoring (VLPM)	Removed from Service

4.1.2 FUEL AND ASSOCIATED COMPONENTS

The fuel (fuel rods, poison rods, assemblies) and Control Element Assemblies (CEAs), are partially removed from service. SONGS has permanently ceased operation and removed all nuclear fuel and CEAs from both unit's reactor vessels. The irradiated fuel assemblies and CEAs are being stored in the spent fuel pool (SFP) and in the Independent Spent Fuel Storage Installation (ISFSI) until they are is shipped offsite. As a result, fabrication and in-core operational related information about the nuclear fuel and CEAs has been deleted. A general description of the fuel and CEAs remains in the DSAR.

4.2 FUEL DESIGN

4.2.1 DESCRIPTION AND DESIGN

This subsection summarizes the mechanical design characteristics of the fuel and associated components. Typical mechanical design parameters are presented in Table 4.2-1 and a typical fuel assembly is presented in Figure 4.2-1.

4.2.1.1 Fuel Assemblies

A fuel assembly consists of 236 UO_2 fuel, Urania-erbia fuel and poison rods, five control element guide tubes, 11 fuel rod spacer grids, upper and lower end fittings, and a holddown device. The outer guide tubes, spacer grids, and end fittings form the structural frame of the assembly.

The fuel spacer grids maintain the fuel rod array by providing positive lateral restraint to the fuel rod but only frictional restraint to axial fuel rod motion. The grids are fabricated from preformed Zircaloy or Inconel strips (the bottom spacer grid material is Inconel) interlocked in an egg crate fashion and welded together. Each cell of the spacer grid contains leaf springs and arches. The leaf springs press the rod against the arches to restrict relative motion between the grids and the fuel rods. The perimeter strips contain features designed to prevent hangup of grids during fuel movement.

The ten Zircaloy-4 spacer grids are fastened to the Zircaloy-4 guide tubes by welding, and each grid is welded to each guide tube at eight locations, four on the upper face of the grid and four on the lower face of the grid, where the spacer strips contact the guide tube surface. The lowest spacer grid (Inconel) is not welded to the guide tubes due to material differences.

Of the ten Zircaloy-4 grids, six are designated the HID-1 or HID-1L design and four are designated the HID-2 or HID-2L design. The higher-strength HID-2 or HID-2L grids are located along the mid-length of the fuel assembly.

The upper end fitting is an assembly consisting of two cast 304 stainless steel plates, five machined posts and five helical Inconel X-750 springs, which attaches to the guide tubes to serve as an alignment and locating device for each fuel assembly and has features to permit lifting of the fuel assembly. The lower cast plate locates the top ends of the guide tubes and is designed to prevent excessive axial motion of the fuel rods.

The springs are of conventional coil design having approximately 14 active coils. The spring material was fabricated in accordance with AMS 5699E.

The upper cast plate of the assembly, called the holddown plate, together with the helical compression springs, comprise the holddown device

The lower end fitting is a single piece stainless steel casting consisting of a plate with flow holes and four support legs, which serve as alignment posts.

The four outer guide tubes have a widened region at the upper end, which contains an internal thread. Connection with the upper end fitting is made by passing the male threaded end of the guide posts through holes in the lower cast flow plate and into the guide tubes. When assembled, the flow plate is secured between flanges on the guide tubes and on the guide posts. The connection with the upper end fitting is locked with a mechanical crimp. The center guide tube and each outer guide tube has, at its lower end, a welded Zircaloy-4 fitting. This fitting has a female threaded portion, which accepts a stainless steel bolt, which passes through a hole in the fuel assembly lower end fitting, to secure it. This joint is secured for the outer guide tubes with a stainless steel locking ring tack welded to the lower end fitting in four places. For the center guide tube, the threaded portion and the nut itself are welded.

The central guide tube inserts into a socket in the upper end fitting and is thus retained laterally by the relatively small clearance at this location. The upper end fitting socket is created by the center guide tube post which is threaded into the lower cast flow plate and tack welded in two places. There is no positive axial connection between the central guide tube and the upper end fitting.

The fuel assembly design enables reconstitution, i.e., removal and replacement of fuel and poison rods, of an irradiated fuel assembly. The fuel and poison rod lower end caps are conical shaped to ensure proper insertion within the fuel assembly grid cage structure; the upper end caps are designed to enable grappling of the fuel and poison rod for purposes of removal and handling. Threaded joints which mechanically attach the upper end fitting to the control element guide tubes will be properly torqued and locked during service, but may be removed to provide access to the fuel and poison rods.

Markings provided on the fuel assembly upper end fitting enable verification of fuel enrichment and orientation of the fuel assembly. Identical markings are provided on the lower end fitting to ensure preservation of fuel assembly identity in the event of upper end fitting removal. Additional markings are provided on each fuel rod during manufacturing to distinguish between fuel enrichments and burnable poison rods, if present.

Starting with Cycle 16 Lead Test Assemblies (LTA) from AREVA and Westinghouse were used in the SONGS 2 and 3 reactor cores. These LTA had the same dimensions as the resident fuel assemblies including grid locations. The LTA have similar characteristics important for handling and storage as the resident fuel. The AREVA fuel cladding and guide tubes were made of AREVA proprietary material, M5, instead of the ZIRLO^{TM} material of the resident fuel.

4.2.1.2 Fuel Rods

The fuel rods consist of slightly-enriched UO_2 or (U, Er) O_2 cylindrical ceramic pellets, a round wire Type 302 stainless steel compression spring, and may contain alumina spacer discs (removed for Batch P fuel), all encapsulated within a ZIRLO^{TM} or Zircaloy-4 tube seal welded with Zircaloy-4 end caps. The fuel rods are internally pressurized with helium during assembly.

During the manufacturing process, each fuel rod is marked in order to facilitate a means of maintaining a record of pellet enrichment, pellet lot and fuel stack weight.

The fuel cladding is cold worked and stress relief annealed ZIRLO^{TM} or Zircaloy-4 tubing 0.025-inch thick

The UO_2 and (U, Er) O_2 pellets are dished at both ends. The density of the UO_2 in the pellets is about 10.47 g/cm^3, which corresponds to 95.5% of the 10.96 g/cm^3 theoretical density (TD) of UO_2. The density of the (U, Er) O_2 in the pellets is about 10.44 g/cm^3, which corresponds to 95.8% of the 10.90 g/cm^3 theoretical density of (U, Er) O_2. However, because the pellet dishes and chamfers constitute about 1.5% of the volume of the pellet stack, the average density of the pellet stack is reduced to about 10.315 g/cm^3 and 10.289 g/cm^3 for the UO_2 and (U, Er) O_2, respectively. This number is referred to as the "stack density."

The compression spring located at the top of the fuel pellet column maintains the column in its proper position during handling and shipping.

4.2.1.3 Burnable Poison Rods

A small number of fixed burnable neutron absorber (poison) rods may remain in selected fuel assemblies. They replace fuel rods at selected locations. The poison rods are mechanically similar to fuel rods, but contain a column of burnable poison pellets instead of fuel pellets. The poison material is alumina with uniformly-dispersed boron carbide particles. The balance of the column consists of alumina pellets, with the total column length the same as the column length in fuel rods. The burnable poison rod plenum spring is designed to produce a smaller preload on the pellet column than that in a fuel rod because of the lighter material in the poison pellets.

Each burnable poison rod assembly includes a serial number and visual identification mark. The serial number is used to record fabrication information for each component in the rod assembly. The identification mark is unique to poison rods and provides a visual check on the pellet boron content during fuel bundle fabrication.

4.3 Control Element Assembly Description and Design Figures

The San Onofre Units 2 and 3 have three different types of CEAs: full-length five-element, full-length four-element, and part-length five-element. Each CEA interfaces with the guide tubes of one fuel assembly, with the exception of the four-element CEA, which straddles two adjacent fuel assemblies. Part-length CEAs are differentiated from full-length CEAs by the following identifying features:

CEA Type	Engraved Identification Number (on Spider)	Grooves on Control Rod
Full-length	1, 2, 3, etc. (1-in. high)	None, smooth OD
Part-length	A, B, C, etc. (1-1/2-in. high)	One per rod

The control elements of a full-length CEA consist of an Inconel 625 tube loaded with a stack of cylindrical absorber pellets. The absorber material consists of boron carbide (B_4C) pellets, with the exception of the lower portion of all full length CEAs, which contain silver-indium-cadmium (Ag-In-Cd) alloy cylinders.

Each full-length control element is sealed by welds, which join the tube to an Inconel 625 nose cap at the bottom, and an Inconel 625 end fitting at the top. The end fittings, in turn, are threaded and pinned to the spider structure, which provides rigid lateral and axial support for the control elements. The spider hub bore is specially machined to provide a point of attachment for the CEA extension shaft.

The control elements of a part-length CEA consist of solid Inconel 625 over the bottom section of their length, an Inconel 625 tube open to the reactor coolant over the next section and a sealed chamber containing B_4C pellets in the top section. See Table 4.2-1 for dimensions.

The lower ends of the four outer fuel assembly guide tubes are tapered gradually to form a region of reduced diameter.

Table 4.2-1 (Sheet 1 of 2)
MECHANICAL DESIGN PARAMETERS

Spacer Grids And Fuel Rods

Spacer Grid		
Type	Leaf spring	
Material	Zircaloy-4	
Number per assembly	10 (6 HID-1 and 4 HID-2)	
Weight each, lb	3.6 HID-2 1.8 HID-1	
Bottom Spacer Grid		
Type	Leaf spring	
Material	Inconel 625	
Number per assembly	1	
Weight each, lb	2.6	
Weight of fuel assembly, lb	1,500	
Outside dimensions		
Fuel rod to fuel rod, inches	7.972 x 7.972	
Fuel Rod		
Fuel rod material (sintered pellet)	UO_2	$(U,Er)O_2$
Pellet diameter, inches	0.3255	
Pellet length, inches	0.390	
Pellet density, g/cm^3	10.47	10.44
Pellet theoretical density, g/cm^3	10.96	10.90
Pellet density (% theoretical)	95.5	95.8
Stack height density, g/cm^3	10.315	10.289
Clad material	Zircaloy-4 or ZIRLO™	
Clad ID, inches	0.332	
Clad OD, (nominal), inches	0.382	
Clad thickness, (nominal), inches	0.025	
Diametral gap (cold, nominal), inches	0.0065	
Active length, inches	150.0	
Plenum length, inches	9.138	
Fuel rod pitch, inches	0.506	
Fuel rod array arrangement	16 x 16	

Table 4.2-1 (Sheet 2 of 2)
MECHANICAL DESIGN PARAMETERS

Control Rods (Control Element Assemblies)

Control Element Assembly (CEA)	Full Length	Part Length
Number/Absorber Elements per ass'y	79/5 element CEAs	8/5 element CEAs
	4/4 element CEAs	
Type	Cylindrical rods	Cylindrical rods
Clad material	Inconel 625	Inconel 625
Clad thickness, inches	0.035	0.035
Clad OD, inches	0.816	0.816
Diametral gap, inches	0.009	0.009
Poison		
Material	B_4C/Ag In Cd/Inconel	Inconel/H_2O/Spacer/B_4C
Length, in.		
5 element CEAs	136/12.5/0.6	76.4/55/2/16
4 element CEAs	126.5/12.5/10.13	
B_4C Pellet		
Diameter, inches	0.737	0.737
Density, % of theoretical density of 2.52 g/cm^3, nominal	73	73
Weight % boron, minimum	75	75
Finger Array Dimensions		
5 element CEAs, inches	4.050 x 4.050	4.050 x 4.050
4 element CEAs, inches	4.050 x 4.130	

NOTE: This table presents typical nominal values to provide familiarity with the Mechanical Nuclear Fuel Design.

Figure 4.2-1
FUEL ASSEMBLY TYPICAL