MASTER

FORT ST. VRAIN EXPERIENCE REPORT

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Gas-Cooled Reactor Associates
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Introduction

The original intent of this report was to provide a preliminary evaluation of Fort St. Vrain operating experience with the addition of core region constraint devices (RCD). Installation of RCDs late in 1979 was accomplished to remedy core temperature fluctuations at high power-to-flow thresholds. An extensive amount of core testing was scheduled for mid-1980, which was to be the basis for this assessment. However, in order to allow the plant to operate in a stabilized manner at discrete power levels and in order to satisfy other nonrelated conditions, testing has been postponed to late 1980. An evaluation report will be provided at the appropriate time after core testing is completed. In the interim, it was perceived as beneficial to discuss and describe the RCDs and the nature of the application in eliminating temperature fluctuations. Familiarization with this approach will provide the reader with an understanding and foundation to comprehend the information produced from core testing. This report describes the RCDs, summarizes the engineering analyses supporting the design, and evaluates effects on fuel handling operations.

Background

During power operations in 1977, core temperature oscillations were observed in individual core region outlet temperatures above 53% power. While the average core outlet temperature remained essentially constant, discrete fluctuations were detected for certain power-to-flow threshold levels.

Significant effort was expended to explain this phenomenon analytically and to characterize the thermal-hydraulic nature using advanced computer techniques and an effective modeling program. Core flow and pressure distribution analyses suggest that static pressure differences occur when interblock gap spacing changes within the core geometry. Small pressure differentials acting over large surface areas of a particular region result in forces large enough to displace regions and/or reflector columns. The

subsequent change in flow distribution may cause thermal growth in adjacent columns of sufficient magnitude to displace the gaps again. These movements of regions and columns, accompanied by changes in flow profiles, provide an explanation for core region temperature fluctuations.

Design Description

Region constraint devices will interlock fuel regions at the top layer of the core and will prevent flow redistribution and maintain a constant interblock gap spacing at region boundaries. The RCDs will also limit changes in gap flows and minimize pressure differences across regions to nominal values. The mechanical interlock occurs at locations in the core where three regions intersect, resulting in a fully constrained, keyed top layer.

Table 1 lists the design criteria employed in the development of the device, and Figure 1 depicts placement of one RCD in three adjacent keyed elements. Each RCD consists of a central, triangular, 5-inch-thick carbon steel plate with an Inconel pin bolted to each corner. These pins engage into a fuel handling pick-up hole at the top of each fuel element and are cut to a half-round cross-section to permit movement through the 17-inch refueling penetration sleeve. Three dowels and a fuel element pick-up hole are provided at the top of the plate to provide for orientation, indexing, insertion, and removal by the fuel handling machine. Each RCD has a nominal weight of 200 lbs, a level within the range of handling machinery.

Region constraint devices are inserted and removed from the core using the existing fuel handling equipment with the following modifications:

- Changes in the fuel storage rack extension rails to permit stowage of RCDs.
- Replacement of the mechanical azimuthal drive stop to permit increased rotation.

Table 1
RCD Design Criteria

- With the RCDs installed, the stresses in involved core components will be less than yield under normal operating conditions and during an Operating Basis Earthquake (OBE).
- In the event of a .10g Design Basis Earthquake (DBE), the stresses in all components will not reach the ultimate strength of the material.
- The RCDs will remain intact and in place until removed by the fuel handling machine.
- Overall reactor performance is not affected by the presence of the RCDs.
- The RCDs will maintain nearly uniform gap flow areas across the core inlet.
- Materials are compatible with the reactor environment and with existing interfacing hardware (keyed plenum elements).
- The RCDs will be compatible with fuel handling equipment after minor changes are made to the grapple head.
- Since each RCD contacts a plenum element from three different regions, each RCD can be removed or installed from any one of the three respective reference penetrations; i.e., normal refueling operations are simplified if an RCD can be installed through one penetration and removed through another if desired.

FORT ST VRAIN REACTOR ,
REGION CONSTRAINT DEVICE
INSTALLATION

Figure 1

- Addition of two dowel holes to the grapple head to accommodate RCDs.

Performance Assessment

The effects of the RCDs on flows and pressure distribution were analyzed using a computer algorithm to model fluid performance at 100% power and rated mass flow from the circulators. For a given core geometry, RCDs will minimize bypass flow by preventing large gaps at the top of the core. While a ΔP occurs across regions adjacent to reflectors at lower axial levels, the resultant force acting towards the center of the core is suitably restrained by the device. Large ΔP values are not developed in the dynamic state, and the RCDs will also significantly reduce the potential for large inter-region static pressure differences.

Structural load is transferred through RCDs from fuel regions to hex reflector elements. This loading is then translated through hex reflector keying into the side reflector blocks and ultimately to the core barrel. Components with the highest stresses are reflector block keys, RCD bolts, and RCD pins. Structural evaluation indicates significant design margin for all components under normal operating conditions. Figure 2 shows a typical load transfer arrangement.

Normal operating loads consist of forces due to pressure gradients across regions and loads required to move regions to unfavored positions. A favored position is the slight leaning of a column that is caused by normal stack-up tolerances and irradiation shrinkage. Maximum normal operating loads occur at the perimeter of the core where cumulative forces from ΔP and gas flows are concentrated. The failure mode and bending stresses for block pins and keys are predominantly a shearing of threads. Table 2 lists and summarizes calculated loadings for all conditions and compares them to allowables.

TYPICAL REACTION CONTROL DEVICE

Fig. 2 Load Path Connection To Core Boundary By RCDs

PARTS LIST	
QTY	DESCRIPTION
1	TYPE I DO-217M-300-1
1	TYPE II DO-217M-300-1
1	TYPE III DO-217M-300-1
1	TYPE IV DO-217M-300-1
1	TYPE V DO-217M-300-1
1	TYPE VI DO-217M-300-1
1	TYPE VII DO-217M-300-1
1	TYPE VIII DO-217M-300-1
1	TYPE IX DO-217M-300-1
1	TYPE X DO-217M-300-1
1	TYPE XI DO-217M-300-1
1	TYPE XII DO-217M-300-1
1	TYPE XIII DO-217M-300-1
1	TYPE XIV DO-217M-300-1
1	TYPE XV DO-217M-300-1
1	TYPE XVI DO-217M-300-1
1	TYPE XVII DO-217M-300-1
1	TYPE XVIII DO-217M-300-1
1	TYPE XIX DO-217M-300-1
1	TYPE XX DO-217M-300-1
1	TYPE XXI DO-217M-300-1
1	TYPE XXII DO-217M-300-1
1	TYPE XXIII DO-217M-300-1
1	TYPE XXIV DO-217M-300-1
1	TYPE XXV DO-217M-300-1
1	TYPE XXVI DO-217M-300-1
1	TYPE XXVII DO-217M-300-1
1	TYPE XXVIII DO-217M-300-1
1	TYPE XXIX DO-217M-300-1
1	TYPE XXX DO-217M-300-1

Table 2

SUMMARY OF MAXIMUM LOADS AND STRESSES

Component		Normal Operation		OBE		DBE		Yield Stress (psi) @ 760°F
		Applied Load (lb)	Max. Stress (psi)	Applied Load (lb)	Max. Stress (psi)	Applied Load (lb)	Max. Stress (psi)	
Reflector Block Keys (shear in screw threads)		1,167	2,290	3,857	7,570	4,847	9,510	16,100 (SA-387 G22)
RCD Bolts (tension)	Interior	410	2,920	1,930	13,700	2,480	17,700	80,200 (SA-453-660)
	Boundary	1,167	6,550	3,557	20,000	4,437	24,900	
RCD Pins (bending)	Interior	410	24,200	1,930	114,000	2,480	134,000 *	134,000 (Inconel 718)
	Boundary	1,167	36,700	3,557	111,000	4,437	134,000 *	

* For these conditions, the outer fibers reach yield. The maximum moment the pin can carry before all of the fibers reach yield is 19,500 in-lb (hinge moment). The maximum DBE moment is 11,200 in-lb at the boundary and 11,800 in-lb in the interior.

Safety Analysis

The application of RCDs at Fort St. Vrain was evaluated for potential effects on plant safety to determine if employing RCDs invalidates previous analyses, assumptions, or conclusions presented in the FSAR. Moreover, subsequent analyses were performed to determine if the use of RCDs is a basis for the review of new events or unreviewed safety issues.

A systematic assessment of safety and transient analysis contained in the FSAR was executed. Highlights of this activity follow:

- Environmental Disturbances - Disturbances listed in the FSAR, except for earthquakes, directly affect only non-core-related equipment. RCDs are designed for seismic events.
- Reactivity and Transient Response - RCDs are inert in nature and do not affect power distributions, control rod performance or worth, shutdown margins, or nuclear kinetics.
- Shutdown Cooling - Since the nuclear and thermal-hydraulic characteristics are not significantly changed, this concern is not affected by RCDs.
- Loss of Forced Circulation - RCDs do not create flow disturbances which would invalidate core heatup analysis under this condition.
- Depressurization/Blowdown - RCDs cannot be lifted by pressure differentials or credible flow regimes; consequently, the internal missile generation event is not credible.

A comprehensive analysis of potential new concerns introduced by using RCDs was conducted. Highlights are as follows:

- The breaking of a lower pin and subsequent pin falling through the plenum and handling holes introduces negative reactivity less than 1% of the power produced by the element. This effect is not a safety concern.
- A loose RCD can cause only partial blockage of any of four inlet ports of an orifice valve. The corresponding reduction in flow rate is detectable and already governed by technical specifications and limiting conditions of operation.
- A failure of the RCD and fuel handling machine during shutdown activities is remedied by using special handling attachments to remove either elements with damaged handling holes or broken RCDs. No increase of risk is associated with any off-normal fuel handling operation.

Observations and Commentary

Current power operations at Fort St. Vrain have been sustained at power levels at or below 70% with no detectable core outlet temperature fluctuations. Several plant trips, shutdowns, and power ascension cycles have taken place with no abnormalities involving RCDs.

Future Fort St. Vrain reports will summarize and describe the extensive core tests planned to confirm the successful application of this innovative solution.