EG&G Idaho, Inc.

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INSERVICE TESTING EVALUATION OF CHECK VALVES AT THE ST. LUCIE UNIT 1 NUCLEAR STATION, DOCKET NO. 50-355

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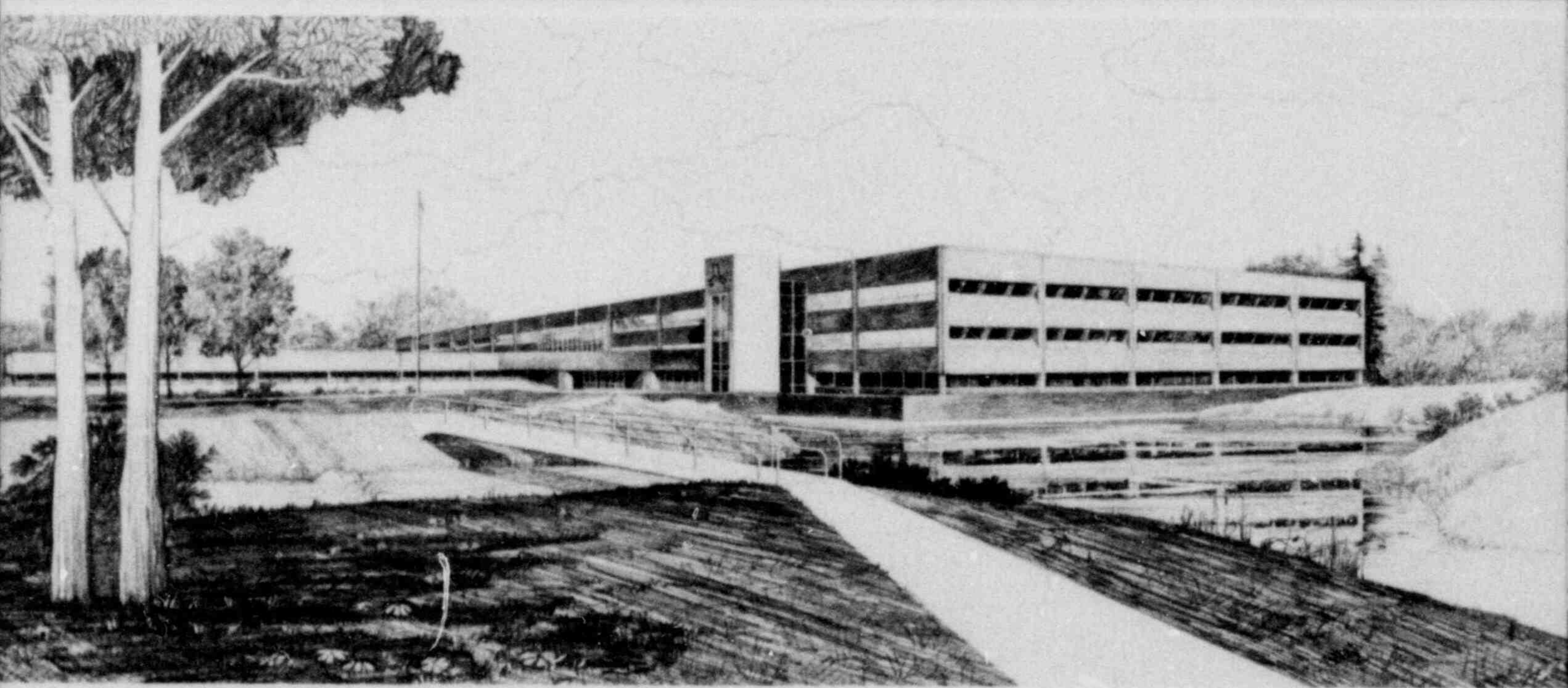
U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory



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Report No. EGG-EA-5097

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An evaluation to determine a meaningful testing frequency for check valves located in the containment spray headers, containment sump lines, SI tank outlet lines, emergency boration tank outlet lines, and charging lines at the St. Lucie Unit 1 Nuclear Station, Docket No. 50-355

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J. M. Fehringer
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INTERIM REPORT

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I. INTRODUCTION

The Florida Power and Light Company (FP&L) has requested specific relief from exercising valves VO-7192 and 7193, containment spray 10-inch header checks, VO-7129 and 7143, containment spray pumps 12-inch discharge checks, VO-7172 and 7174, containment sump 24-inch outlet checks, V-3215, 3225, 3235, and 3245, SI tank 12-inch outlet checks, V-2177 and 2190, emergency boration tanks 3-inch outlet checks, and V-2430, charging 2-inch line check, in accordance with the requirements of the ASME Code, Section XI, through the Summer 1975 Addenda for St. Lucie Unit 1 nuclear plant. FP&L has proposed to perform a maintenance inspection at 10-year intervals to verify full stroke operability of valves VO-7192, 7193, 7129, 7143, 7174, 7172, V-2177, 2190, and 2430 and a partial stroke exercise test during refueling outages for V-3215, 3225, 3235 and 3245.

At least one set of redundant valves, VO-7193 and VO-7143, containment spray A pump discharge and header checks, or VO-7129 and VO-7192, containment spray B pump discharge and header checks, must open to provide containment spray following a LOCA. At least one of the two redundant containment sump outlet check valves VO-7172 and VO-7174 must open to provide containment sump recirculation supply to the containment spray, low pressure safety injection, and high pressure safety injection pumps following a LOCA. At least three of the four redundant accumulator outlet checks valves V-3215, 3225, 3235 and 3245 must open to provide sufficient accumulator flow following a LOCA. At least one of the two redundant emergency boration tank outlet checks V-2177 and V-2190 must be open to provide a sufficient boric acid concentration following a LOCA. The common charging line check valve V-2430 must be open to provide sufficient flow following a LOCA.

No provisions have been incorporated into plant design for the inservice testing, full flow/full stroke exercising, of these valves. These valves, of course, are subject to the NRC's requirement for periodic testing discussed in Section II. This report summarizes an evaluation to: (1) determine the difficulty in periodically testing these check valves, and (2) provide the NRC

Probabilistic Staff with failure rate and failure mechanism information that will allow them to establish a meaningful testing interval for these valves. If no credible failure mechanism exists which can degrade or fail the valves, i.e., they are indeed independent, an infrequent testing schedule is justified.

An examination of Licensee Event Reports (LERs) pertaining to check valves, examination of specific valve manufacturer's drawings, and an actual visual examination of each valve installation were made in pursuit of the above information. This evaluation is described in Section III. The LERs were also used to determine an estimate of the random failure rate of the valves in their dominant modes of failure. These failure rate calculations are discussed in Section IV. Discussions regarding the difficulty of testing these valves is contained in Section V. EG&G Idaho, Inc., recommendations for testing methods and granting testing relief are contained in Section VI. All references are identified in Section VII.

II. PERIODIC TESTING REQUIREMENTS

In 1976 NRC notified all reactor operating utilities that the requirements contained within the ASME Code, Section XI, through the Summer 1975 Addenda would be imposed upon their valve and pump operability testing program. This notification stemmed from the NRC imposing the requirements contained within 10 CFR 50.55a(g) on in-service inspection.

One of the ASME code requirements states that check valves shall be full-stroke exercised once every three months unless operation is not practical during power operation. If the test is not practical, then a check valve may be part-stroke exercised during power operation and full-stroke exercised during each cold shutdown and refueling outage; and, in the case of frequent cold shutdowns, the check valve need not be exercised more often than once every three months.

III. EVALUATION

1. LICENSEE EVENT REPORTS

The LERs issued between January 1, 1972, and April 30, 1978, were reviewed to identify check valve failure modes and their associated failure mechanisms. The primary purpose of the review was to identify mechanisms that might cause a common mode failure of more than one valve. A common mode failure could be detrimental to the capability for providing long-term core cooling if multiple check valves failed to open. A listing of the failure modes and their identified failure mechanisms extracted from the LERs is provided in Table I.

2. FAILURE MODE AND EFFECTS ANALYSIS

A failure mode and effects analysis (FMEA) was performed on stainless steel, bolted bonnet, swing check valves to identify parts' failure modes that could prevent the valve from opening when required and mechanisms, particularly those mechanisms identified above, which might cause failure of those parts in the modes of interest. The FMEA was developed by reviewing the physical detail drawings of stainless steel, bolted bonnet, swing check valves. The results of the FMEA are summarized in Table II.

Mechanisms suspected in causing common mode failure of check valves were rust and boron crystal build up, particularly on the hinge pin, hinge, and seating surfaces. When borated water evaporates, boron crystals develop and were postulated to eventually prevent the valve from opening fully, or to directly restrict flow with the valve open or prevent proper seating causing excessive leakage. Actual examination of valve installations for V-2430, V-2177, V-2190, V-3215, V-3225, V-3235, V-3245, VO-7129 and VO-7143 revealed that neither side of the valve is exposed to air, therefore, evaporation at the valve does not take place and boron precipitation is not a problem. Actual examination of valve installations for VO-7192 and VO-7193 revealed that both sides of the valve are exposed to air only, therefore, evaporation and boron precipitation is not a problem. For valves VO-7172 and VO-71[illegible]4, actual examination of valve installations revealed that the containment sump side of these valves is periodically exposed to water and air while the

TABLE I

CHECK VALVE FAILURE MECHANISMS
IDENTIFIED WITHIN LERs

Reverse Leakage	Fail to Open	Fail to Close	External Leakage
Precipitates	Precipitates	Precipitates	Material Flaw
Debris	Debris	Debris	Faulty Gasket
Normal Wear	Pressure Transients	Burrs	Loose Nuts
Damaged or Fractured		Wear	Damaged or Fractured
Improper Seating			
Deformation			
Incorrect Assembly			
Material Flaw			

TABLE II

FAILURE MODE EFFECTS ANALYSIS
SYSTEM: ST. LUCIE UNIT 1 CHECK VALVES

	Part	Part Function	Part Failure Mode	Failure Mechanism	Effect on Valve Operation
1.	Body	Contains Coolant and Supports Disc	a) Fracture	a1) Stress a2) Flaw	a1) External Leakage a2) External Leakage
			b) Deformation	b) Incorrectly Installed	b) Fail to open due to binding of discs on hinge pin or reverse leakage due to poor mating of disc to seat ring.
2.	Seat Ring	Provides Seating Surface for Disc	a) Fails to Seat	a1) Scratched a2) Deposits a3) Foreign Material (rags, weld slag, dirt) a4) Excessive Disc to Seat Clearance	a1) Reverse Leakage a2) Reverse Leakage a3) Reverse Leakage or Fail to Close a4) Reverse Leakage
3.	Bonnet Cap	Contains Coolant	a) Fracture	a1) Stress a2) Flaw	a1) No effect since other studs position check valve. a2) Same as Above
4.	Bonnet Stud Nut and Bonnet Stud	Provides Means of Compressing Gaskets	a) Loose	a) Incorrect Tightning	a) No effect since other pairs of retaining nuts compress gaskets.
			b) Tight	b) Incorrect Tightning	b1) Fail to open due to deformation of valve body resulting in binding of disc or reverse leakage due to deformation of body resulting in poor mating of disc to seat ring. b2) External leakage due to deformation of gaskets.

TABLE '1 (Continued)

FAILURE MODE EFFECTS ANALYSIS
SYSTEM: ST. LUCIE UNIT 1 CHECK VALVES

	Part	Part Function	Part Failure Mode	Failure Mechanism	Effect on Valve Operation
5.	Bonnet Gasket	Prevents External Leakage	a) Leaks	a1) Deteriorates a2) Deformation	a1) External Leakage a2) External leakage due to incorrect compression of gasket when tightning nuts.
6.	Disc	Permits Flow in one Direction	a) Fractures	a1) Stress Flaw	a1) Reverse Leakage a2) Reverse Leakage
			b) Fails to Seat	b1) Deformation b2) Deposits b3) Scratched	b1) Reverse Leakage b2) Reverse Leakage b3) Reverse Leakage
			c) Fails to Open	c1) Deposits	c1) Fails to open due to deposits which prevent disc from moving.
				c2) Deformation	c2) Fails to open due to binding of disc.
7.	Disc Washer, Nut, Nut Pin	Mounts Disc to Hinge	a) Fractures	a1) Stress	a1) Disc is separated from hinge and obstructs flow.
				a2) Flaw	a2) Disc is separated from hinge and obstructs flow.
			b) Loose	b1) Incorrect	b1) Reverse leakage due to poor mating of disc to seat ring.
			c) Tight	c1) Incorrect Tightning	c1) No effect

TABLE II (Continued)

FAILURE MODE EFFECTS ANALYSIS
SYSTEM: ST. LUCIE UNIT 1 CHECK VALVES

Part	Part Function	Part Failure Mode	Failure Mechanism	Effect on Valve Operation
8. Hinge Pin, Hinge	Pivot Point for Disc	a) Fracture	a1) Stress	a1) Fails to open due to binding of disc or disc assembly partially plugs outlet of check valve.
			a2) Flaw	a2) Same as Above
		b) Does not Allow Disc to Swing	b1) Deposits	b1) Fails to open due to binding between disc and hinge pin.
			b2) Burrs	b2) Same as Above
		c) Excessive Play	c1) Normal Wear	c1) Reverse Leakage
9. Bracket, Stud	Mount Hinge Pin	a) Fracture	a1) Stress	a1) Hinge pin separated from valve body and disc abstructs flow. Reverse leakage due to poor mating of disc and seat ring.
			a2) Flaw	a2) Same as Above
		b) Loose	b1) Incorrect Tightning	b1) Fails to fully open due to binding between disc and valve body. Reverse leakage - poor mating of disc to seat ring.
		c) Tight	c1) Same as Above	c1) No effect

TABLE II (Continued)

FAILURE MODE EFFECTS ANALYSIS
SYSTEM: ST. LUCIE UNIT 1 CHECK VALVES

	Part	Part Function	Part Failure Mode	Failure Mechanism	Effect on Valve Operation
10.	Check Valve	Allows Flow in one Direction Only	a) Incorrect Assembly	a) Manufacturer Error	a1) Reverse Leakage a2) Fails to Open a3) Fails to Close
			b) Not Installed in Vertical Position	b) Installation	b1) Reverse L..kage (depending on disc weight)

downstream side is always exposed to water. The downstream side of the valve contains the hinge and hinge pin, therefore, evaporation and boron precipitation will not occur in this area and will not prevent valve opening. The maximum boric acid concentrations (~2200 ppm) are sufficiently low that boron precipitation from the solution is not likely for the temperature ranges these valves are exposed to (see Figure 1). Rust was found to be no problem because all valve materials are rust resistant.

The mechanism of debris appeared to be a likely candidate in causing common mode failure of check valves by restricting flow through the valve. Examination of each specific system indicated that debris, or the accumulation of debris large enough to cause valve binding, is prevented by system cleanliness requirements and the limited size of piping through which debris could be injected. Thus debris was judged to be no problem in restricting flow through these valves.

The examined LERs identified pressure transients as a possible mechanism which could cause common mode failures of check valves. The check valves being reviewed in this study are not normally subjected to these pressure transients by system function and design. However, a few cases of check valve damage resulting from large pressure transients and two phase flow have been recorded. The damage caused has been limited to disc and seating damage resulting only in reverse leakage failures. Thus, limiting differential pressures forcing these valves shut are not significantly large enough to result in valve damage that would preclude valve opening.

The FMEA identified a number of areas where incorrect check valve assembly or installation could result in common mode failures of check valves. These mechanisms could result in no coolant flow should the valves be installed in the reverse direction or in such a way to bind disc operation. Discussions with plant personnel, and a review of plant documents, indicated that each valve of concern was preoperational inspected and manually full stroke exercised in the direction required to fulfill its safety function. These tests were performed after each valve was installed in its respective system. In addition, examination of valve construction for swing check valves shows that disc binding is prevented by designing in a large tolerance area between the moving disc and the valve body.

IV. FAILURE RATE CALCULATIONS

For the following reasons, only experience failures identified within the LERs and the population associated with PWR check valves that contain borated water were obtained for calculating valve failure rates:

(1) All failure mechanisms that had resulted in a check valve failure to open were either due to rust deposits or the valve was subjected to large pressure transients which is not typical for the check valves of concern; that is, the valve materials are rust resistant and large pressure transients are nonexistent.

(2) Check valve population, a required value for calculating valve failure rates, was more easily obtained by counting the number of valves in borated systems than to count valves in all Class I, II, and III PWR and BWR systems.

The representative check valve population for a PWR reactor plant was determined by averaging the number of valves operating in Unit 1 and 2 of Zion and Calvert Cliffs. The average population was determined to be 64, where there were 61 and 66 valves in borated systems at Zion and Calvert Cliffs, respectively. This value was then multiplied by the total number of operating PWR months to obtain the accumulated check valve operating time for all plants. By also reviewing proposed pump and valve operability testing programs at these plants, it was determined that the average full or partial-flow test of a check valve occurs at the rate of 5.1 tests per year. This information was then used to calculate failure rates for the following modes of check valve failure: reverse leakage (RL), failure to open (FTO), failure to close (FTC), and external leakage (EL). For the purpose of these calculations, if no failure of a particular mode has been experienced then one failure was assumed. The following are the estimated failure rates:

$$\lambda_{RL} = 20 \text{ failures}/(123{,}328 \text{ months}) \times (720 \text{ hours/month}) = 2.25 \times 10^{-7} \text{failure/hr} \quad (1)$$

λ_{FTO} = 1 failure/51,984 demand = 1.9 x 10^{-5} failure/demand (2) (5)

λ_{FTC} = 1 failure/51,984 demand = 1.9 x 10^{-5} failure/demand (3) (5)

λ_{EL} = 5 failures/(123,328 months) x (720 hours/month) = 5.62 x 10^{-8} failure/hr (4)

Numbers in parenthesis refer to the following notes:

(1) Reverse leakage events are only reported in a LER if they violate the plant technical specification; thus, the calculated failure rate may be optimistic if small leakages, that do not violate technical specification requirements, are important. Also, the value for reverse leakage is slightly lower than the value of 3.0 x 10^{-7} failures per hour reported in the Reactor Safety Study (Reference 2).

(2) There were no cases of check valves that contained borated water failing to open, thus one failure was assumed. The failure rate value shown is therefore conservative.

(3) It was assumed that once a valve has been opened that the next valve operation is to the closed position. Therefore, it was assumed that the same number of demands are placed on the valve to close.

(4) The calculated value is approximately a factor of 5 higher than the value of 10^{-8} failures per hour reported in the Reactor Safety Study (RSS).

(5) To correlate the value reported in the RSS for check valve failure to operate with that identified above, both failure to open and close must be combined yielding a rate of approximately 3.7 x 10^{-5} failures per demand. This is approximately three times better than that reported in the RSS.

Table III provides a summary, by PWR reactor plant, of the experienced check valve failures identified in the LERs, the plant operating experience (months) and the approximate number of demands placed upon plant check valves to open from January 1, 1972, through April 30, 1978.

V. DIFFICULTY IN TESTING

Discussions with FP&L revealed that there were specific difficulties associated with performing full flow/full stroke exercise tests on these check valves. The following provides a summary of those difficulties as stated by FP&L and our determination, after visual examination, as to their validity:

(1) To perform a full flow test on valves VO-7192 and VO-7193, containment spray 10-inch header checks, and VO-7129 and VO-7143, containment spray pumps 12-inch discharge checks, FP&L states they would have to initiate full flow containment spray through each header and its respective nozzles resulting in 2700 gpm being sprayed over all equipment located inside the containment causing excessive damage to electrical equipment and lagging and an extensive clean up problem. We agree this test method is impractical.

FP&L has proposed to manually full stroke exercise these valves during maintenance inspections performed at 10-year intervals. This is a valid test method to ensure full stroke exercising of these valves. Alternative partial stroke exercising is discussed in Section VI.

(2) To perform a full flow test on valves VO-7174 and VO-7172, containment sump 24-inch outlet checks, FP&L would have to flood the containment sump to a level of approximately 14 feet resulting in excessive damage to electrical equipment and lagging and an extensive clean up problem. We agree this test method is impractical.

TABLE III

FAILURES ASSOCIATED WITH CHECK VALVES IN BORATED SYSTEMS
BETWEEN JANUARY 1, 1972 AND APRIL 30, 1978

Reactor Plant	Months Operation Between January 1, 1972 To April 30, 1978	Reverse Leakage Experience	Failure to Open Experience	Failure to Close Experience	External Leakage Experience	Operating Demands Per Plant
Arkansas 1	45	0	0	0	0	1224
Beaver Valley 1	24	0	0	0	0	653
Calvert Cliffs 1	43	0	0	0	2	1170
Calvert Cliffs 2	17	2	0	0	1	462
Cook 1	39	0	0	0	0	1061
Cook 2	1	0	0	0	0	27
Crystal River 3	15	0	0	0	0	408
Davis-Besse 1	8	1	0	0	1	218
Farley 1	9	0	0	0	0	245
Ft. Calhoun	57	0	0	0	0	1550
Ginna	76	2	0	0	1	2067
Haddam Neck	76	0	0	0	0	2067
Indian Pt. 1	35	0	0	0	0	952
Indian Pt. 2	59	1	0	1	0	1605
Indian Pt. 3	25	0	0	0	0	680
Kewaunee	50	0	0	0	0	1360
Maine Yankee	66	0	0	0	0	1795
Millstone 2	30	2	0	0	0	816
North Anna 1	1	0	0	0	0	27
Oconee 1	60	0	0	0	0	1632
Oconee 2	54	0	0	0	0	1468
Oconee 3	44	0	0	0	0	1197
Palisades	76	1	0	0	0	2067

TABLE III (Continued)

FAILURES ASSOCIATED WITH CHECK VALVES IN BORATED SYSTEMS BETWEEN JANUARY 1, 1972 AND APRIL 30, 1978

Reactor Plant	Months Operation Between January 1, 1972 To April 30, 1978	Reverse Leakage Experience	Failure to Open Experience	Failure to Close Experience	External Leakage Experience	Operating Demands Per Plant
Point Beach 1	76	0	0	0	0	2067
Point Beach 2	71	0	0	0	0	1931
Prairie Island 1	53	1	0	0	0	1442
Prairie Island 2	40	0	0	0	0	1088
Rancho Seco	43	0	0	0	0	1170
Robinson 2	76	0	0	0	0	2067
Salem 1	17	0	0	0	0	462
San Onofre 1	76	0	0	0	0	2067
St. Lucie 1	24	0	0	0	0	653
Surry 1	70	2	0	0	0	1904
Surry 2	62	3	0	0	0	1686
Three Mile Island 1	47	1	0	0	0	1278
Three Mile Island 2	1	0	0	0	0	27
Trojan	29	0	0	0	0	789
Turkey Point 3	66	2	0	0	0	1795
Turkey Point 4	59	0	0	0	0	1605
Yankee Rowe	76	0	0	0	0	2067
Zion 1	58	2	0	0	0	1578
Zion 2	52	0	0	0	0	1414
Total	1927 months*	20	0	1	5	51,841

*Assuming an average of 64 check valves per plant, the total operating time for the failure reporting period considered is obtained by multiplying 1927 months times 64 check valves yielding 123,328 total check valve months.

FP&L has proposed to manually full stroke exercise these valves during maintenance inspections performed at 10-year intervals. This is a valid test method to ensure full stroke exercising of these valves.

(3) To perform a full flow test on valves V-2177 and V-2190, emergency boration tanks 3-inch outlet checks, FP&L states they would have to inject highly borated water into the reactor coolant system that could result in power transients during power operations and extensive clean up requirements during cold shutdowns.

FP&L has proposed to manually full stroke exercise these valves during maintenance inspections performed at 10-year intervals. This is a valid test method to ensure full stroke exercising of these valves. Additional flow exercising tests are discussed in Section VI.

(4) To perform a reverse flow test on valve V-2430, charging line 2-inch check, FP&L states that plant modifications would be required.

FP&L has proposed to manually full stroke exercise this valve during maintenance inspections performed at 10-year intervals. This is a valid test method to ensure full stroke exercising of this valve.

(5) To perform a full flow test on valves V-3215, 3225, 3235, and 3245, SI tanks 12-inch outlet checks, FP&L states that plant modifications would be required.

FP&L has proposed to partial stroke exercise these valves during refueling outages using existing piping systems. Additional full stroke exercising is discussed in Section VI.

VI. RECOMMENDATIONS

In performing the FMEA, reviewing the LERs, and visiting the St. Lucie reactor plant, there were no identifiable failure mechanisms that could credibly prevent these valves from opening. Thus, the intended redundancy does not appear to be compromised.

It is our opinion that valves VO-7129 and 7143, containment spray pumps 12-inch discharge checks, can and should be partial stroke exercised ($\sim$150 gpm flow) by recirculating the CS pumps through the NaOH eduction lines during cold shutdowns and refueling outages. This partial stroke would verify that the valve discs move in the direction required to perform their safety function. It is also our opinion that a practical method of full flow testing valves VO-7192 and 7193, containment spray 10-inch header checks, and VO-7172 and 7174, containment sump 24-inch outlet checks, does not exist with present piping configurations. In addition, we agree with FP&L and feel that check valves VO-7129, 7143, 7192, 7193, 7172 and 7174 should have the bolted bonnet removed and the valve disc manually full stroke exercised at 10-year intervals to ensure proper full stroke valve operation.

It is our opinion that valves V-2177 and 2190, emergency boration tanks 3-inch outlet checks, can and should be full stroke/full flow exercised during refueling outages when power transients are not of concern and clean up time is available prior to plant start up.

It is our opinion that valve V-2430, charging line 2-inch check, cannot be flow verified shut with present piping configurations. The safety related function of this valve is to open. Valve full open is verified continuously during power operation by observing full charging system flow. In addition, we agree with FP&L and feel that check valve V-2430 should have the bolted bonnet removed and the valve disc manually full stroke exercised at 10-year intervals to ensure proper full stroke valve operation.

It is our opinion that valves V-3215, 3225, 3235, and 3245, SI tank 12-inch outlet checks, can and should be partial stroke exercised during refueling outages using the existing test lines. In addition, we feel these valves should have their bolted bonnets removed and the valve disc manually full stroke exercised at 10-year intervals to ensure proper full stroke valve operation.

All recommendations are made with the intent of most nearly meeting the requirements of the ASME Code Section XI without placing an unwarranted burden on the utility and without significantly reducing the level of plant safety.

VII. REFERENCES

1. To be provided by NRC.

2. "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants", WASH-1400, Nuclear Regulatory Commission, October 1975.