U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No: 50-440/87027(DRS)

Docket No: 50-440 License No: NPF-58

Licensee: Cleveland Electric Illuminating Company
Post Office Box 5000
Cleveland, Ohio 44101

Facility Name: Perry Nuclear Power Plant, Unit 1

Inspection At: Perry Site, Perry, Ohio

Inspection Conducted: November 29 through December 4, 1987

NRC Augmented Inspection Team

Inspectors: Team Leader: R. D. Lanksbury 2/9/88 (Date)

Team Members: G. F. O'Dwyer 2/9/88 (Date)

S. D. Eick 2/9/88 (Date)

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S. D. Alexander 2/9/88 (Date)

Approved By: G. C. Wright, Chief
Operations Branch 2/9/88 (Date)

Inspection Summary

Inspection on November 29 through December 4, 1987 (Report No. 50-440/87027(DRS))
Areas Inspected: Special Augmented Inspection Team (AIT) inspection conducted in response to the Main Steam Isolation Valve (MSIV) closure failures of November 29, 1987, on Perry Unit 1, and related activities. The review

included root cause determination, safety significance, maintenance history, and broader industry implications.

Results: No violations or deviations were identified; however, the licensee has committed to additional and expanded surveillances of the MSIV's and maintenance activity practices in order to preclude subsequent similar failures.

EXECUTIVE SUMMARY

On November 29, 1987, the Perry Nuclear Power Plant was in the process of performing a Main Steam Isolation Valve (MSIV) fast closure operability check when the inboard MSIV in the "B" main steam line would not stay closed. The licensee was performing the operability checks as the result of commitments made due to previous problems with MSIV closures that occurred on October 29, 1987, and again on November 3, 1987. The operability check consisted of depressing the slow closure "test" push button and allowing the MSIV to fully close. The control switch was then placed in the "close" position and the "test" push button released. If the fast closure solenoid operated valve changes state per design, the MSIV will remain closed; if it fails to change state, the MSIV will reopen. The licensee unsuccessfully performed the above test a second time and then attempted to fast close the MSIV two times with no success. Subsequently, the licensee reported the failure to the NRC and commenced an orderly shutdown. Following the shutdown, licensee personnel and the Senior Resident Inspector made a drywell entry to observe the MSIV during a fifth closure attempt. During this test the valve stayed in the open position until the ASCO dual solenoid valve was gently tapped. The MSIV responded by closing with a normal stroke time. As a result of this event, Region III dispatched an Augmented Inspection Team (AIT) to the site the same day.

The licensee evaluated potential component failures and failure modes and from this, developed a carefully planned disassembly and troubleshooting program. As a part of this troubleshooting program the licensee disassembled the failed ASCO dual solenoid valve. The results of this disassembly and inspection revealed the presence of a sliver of foreign material and two smaller particles of foreign material in the "B" solenoid housing assembly. This material was later proven to be Ethylene Propylene Diene Monomer (EPDM) from one of the O-rings in the valve that was replaced as part of the corrective action to the November 3, 1987, event. No signs of other solenoid valve degradation were evident. The licensee evaluated the results of the troubleshooting program and concluded that the root cause of the failure of the MSIV to close was mechanical binding of the ASCO dual solenoid valve by the sliver of EPDM material. The mechanical binding resulted in the exhaust seat being held in an "energized" position even though the solenoids had been de-energized, and therefore, prevented the control air from being exhausted to atmosphere and prevented the MSIV from closing.

The AIT concluded that the root cause of the observed MSIV failure to stay closed on November 29, 1987, was a malfunction of the ASCO Model No. NP-8323A20E three-way dual solenoid valve caused by pieces of the body gasket (EPDM O-ring) falling into the "B" solenoid valve sub-assembly and ultimately interfering with the ability of the ASCO dual solenoid valve to shift to the de-energized position. The source of the body gasket material was deteriorated and degraded EPDM O-rings that were replaced as part of the November 3, 1987, event. This foreign material was introduced as a result of the maintenance activities by the licensee to rebuild the dual solenoid valve. The rebuild activity did not completely disassemble the "B" solenoid and therefore, the presence of the foreign material went undetected. The licensee subsequently replaced all eight MSIV dual solenoid valves with new ones. The plant was restarted on December 8. 1987.

Augmented Inspection Team (AIT) Report
50-440/87027

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2	Augmented Insepction Team (AIT) Charter
3	Main Steam Isolation Valve (MSIV) Cross Section
4	MSIV Control Unit Schematic Drawing
5	Cutaway Drawing of an ASCO 8323 Solenoid Valve
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I INTRODUCTION

A. Synopsis of Event

On November 29, 1987, while at approximately 80% power and in the process of performing a Main Steam Isolation Valve (MSIV) fast closure operability check, the inboard MSIV in the "B" main steam line at the Perry Nuclear Power Plant, Unit 1, would not stay closed. Each of the other seven MSIV's were successfully tested. The licensee was performing the operability checks as the result of commitments made due to previous problems with MSIV closure that occurred on October 29, 1987, and again on November 3, 1987 (see Augmented Inspection Team Report 50-440/87024). The operability check consists of depressing the slow closure "test" push button and allowing the MSIV to fully close. The control switch is then placed in the "close" position and the "test" push button released. If the fast closure, dual solenoid operated, valve changes state per design the MSIV will remain closed; if it fails to change state the MSIV will reopen. The licensee unsuccessfully performed the above test a second time and then attempted to fast close the MSIV two times with no success. Because of a previous commitment made by the licensee as a result of the past MSIV failures, the licensee reported the failure to the NRC and proceeded to shutdown the reactor to allow investigation of the event. Following the shutdown, licensee personnel and the Senior Resident Inspector made a drywell entry to observe the MSIV during a fifth closure test. During this test the MSIV again failed to close during the approximate three minute period in which the control switch was held in the "close" position. The dual solenoid operated valve was then gently tapped and the MSIV responded by closing in a normal stroke time (approximately 3 seconds). The MSIV was cycled one more time and exhibited a normal closing stroke time.

B. AIT Formation

Subsequent to the report of this event, Region III evaluated the data provided by the licensee on November 29, 1987, and determined that the criteria for an AIT existed. Assistance from the Office of Nuclear Reactor Regulation (NRR) was requested in several specialized areas including air systems and solenoid valves. This assistance was provided by Dr. H. L. Ornstein, Senior Reactor Engineer (AEOD) and S. D. Alexander, Reactor Engineer (NRR). In addition, Region III provided expertise in operations and plant maintenance by assigning G. F. O'Dwyer, Perry Plant Resident Inspector, S. D. Eick, Reactor Inspector, and R. D. Lanksbury, Reactor Inspector and Team Leader. Mr. Lanksbury and Ms. Eick arrived on site the evening of November 29, 1987, Dr. Ornstein arrived on November 30, 1987, and Mr. Alexander arrived on December 1, 1987. Concurrent with the AIT activities, Region III issued a Confirmatory Action Letter (CAL-RIII-87-24) which was received by the licensee on November 30, 1987. The CAL confirmed certain actions to be taken by the licensee in support of the AIT and also confirmed that the plant would not be restarted without the concurrence of the Regional Administrator or his designee. The CAL is Attachment 1 to this report.

C. AIT Charter

On November 30, 1987, a draft charter for the AIT was formulated with a list of preliminary questions to be pursued and the following list of general areas to be investigated:

- Failure of MSIV's to close/close within Technical Specification limits.
- Root cause(s).
- Interaction of previous maintenance/replacement activities to the event.
- Broader implications.
- Event reporting.

A finalized AIT Charter was issued on December 2, 1987. This Charter is Attachment 2 to this report.

D. Persons Contacted

Cleveland Electric Illuminating Company (CEI)

*A. Kaplan, Vice President, Nuclear Group
*F. R. Stead, Director, Perry Plant Technical Department (PPTD)
E. Riley, Director, Nuclear Quality Assurance Department (NQAD)
R. A. Newkirk, Manager, Technical Section, PPTD
V. K. Higaki, Manager, Outage Planning Section, Perry Plant Operations Department (PPOD)
W. E. Coleman, Manager, Operations Quality Section, NQAD
B. D. Walrath, Manager, Engineering Projects Support Section, Nuclear Engineering Department (NED)
D. R. Green, Manager, Electrical Design Section, NED
*E. M. Buzzelli, Manager, Licensing and Compliance Section, PPTD
S. J. Wojton, Manager, Radiation Protection Section, PPTD
K. R. Pech, Manager, Mechanical Design Section, NED
R. A. Stratman, Manager, Operations Department, PPOD
W. R. Kanda, Jr., Manager, Instrumentation and Control Section, PPOD
V. J. Concel, Lead System Engineer, Technical Section, PPTD
E. F. Parker, Supervisor, Mechanical Maintenance Quality Section, PPTD
P. J. Arthur, Nuclear Steam Supply System Lead, Technical Section, PPTD
G. A. Dunn, Supervisor, Licensing and Compliance Section, PPTD
S. W. Litchfield, Equipment Qualification Lead, Engineering Projects Support Section, NED
A. J. Polland, Lead Quality Engineer, Mechanical Maintenance Quality Section, NQAD

General Electric (GE)

T. R. McIntyre, Manager, Perry Engineering
R. S. Tunder, Senior Engineer, Plant Materials Technology

Automatic Switch Company (ASCO)

K. Thomas, Sales Engineer

Ricerca, Inc.

R. L. Cryberg, Manager, Analytical Services
W. R. Bramstedt, Group Leader, Analytical Services

*Denotes those attending the exit meeting on December 4, 1987.

In addition to the above, other members of the Perry staff and Ricerca staff were contacted by the AIT.

II DESCRIPTION - MSIV FAILURE TO CLOSE ON NOVEMBER 29, 1987

A. Narrative Description

On November 29, 1987, at approximately 1:57 a.m. (EST) while Perry Unit 1 was operating at approximately 80% power, the licensee performed a MSIV fast closure operability check in accordance with Surveillance Instruction (SVI) -C71-T0039, Revision 1, "Main Steam Line Isolation Valve Closure Channel Functional." The licensee was performing the operability checks as the result of commitments made due to previous problems with MSIV closure that occurred on October 29, 1987, and again on November 3, 1987, (see AIT Report 50-440/87024). The operability check consisted of depressing the slow closure "test" pushbutton and allowing the MSIV to fully close. The control switch is then placed in the "close" position and the "test" pushbutton released. If the fast closure, dual solenoid operated, valve changes state per design the MSIV will remain closed; however, if it fails to change state the MSIV will reopen. At approximately 2:39 a.m., inboard MSIV 1B21-F0022B was slow closed in accordance with SVI-C71-T0039, Step 5.1.36.b.b.. Upon reaching the fully closed position, the MSIV control switch was placed in the "closed" position and the "test" pushbutton released. The MSIV reopened indicating that the dual solenoid valve had not changed state. The operators verified that the solenoids had de-energized by observing their status lights in the control room. At 2:42 a.m. the operators again performed the slow closure operability check and again the MSIV reopened. Subsequently, they attempted to fast close the MSIV two separate times with no success. Based upon this the Unit Supervisor, at 2:45 a.m., declared MSIV 1B21-F0022B inoperable. Per a commitment made as a result of the October 29, 1987, and November 3, 1987, MSIV failures the licensee commenced an orderly reactor shutdown. At 3:32 a.m. the System Operation Center was informed of the intended plant shutdown and at 3:35 a.m. the licensee made a courtesy four hour Emergency Notification System (ENS) report on the failure of MSIV 1B21-F0022B. At 11:14 a.m. the reactor was scrammed and placed in Hot Shutdown. Following the shutdown, licensee personnel, accompanied by the Senior Resident Inspector (SRI), made a drywell entry to inspect the MSIV and observe it during a closure attempt. At 1:03 p.m. a third attempt to fast close MSIV 1B21-F0022B was made with no success. Personnel located at the MSIV verified, by monitoring the electrical terminals,

that the fast closure solenoids had de-energized. After holding the control switch in the "close" position for approximately three minutes the fast closure solenoid's valve body was gently tapped. MSIV 1B21-F0022B then closed in approximately three seconds. Technical Specification 3/4.4.7 requires that each MSIV close within a time frame of 2.5 to 5 seconds and Technical Specification 3/4.6.4 require that they close within 5 seconds. At 1:06 p.m. the operators opened and fast closed MSIV 1B21-F0022B one more time and observed that it operated properly. At 5:20 p.m. the reactor reached Cold Shutdown.

B. Sequence of Events and Operator Actions

At the AIT's request, a chronology of events related to the MSIV failure on November 29, 1987, was assembled by the licensee. The chronology, which includes MSIV performance data and operator actions, was verified to be accurate by AIT personnel through review of operating logs, condition reports, ERIS plots, Technical Specification Limiting Condition for Operation (LCO) tracking system documentation, and interviews with licensee operating personnel and staff. The chronology was as follows:

NOTE: All times are in Eastern Standard Time.

November 8, 1987	2048	Rebuild work on MSIV 1B21-F0022B complete per Work Order (WO) 87-9464
November 10, 1987	2324	MSIV 1B21-F0022B slow closed per System Operating Instruction (SOI)-B21, "Nuclear Steam Supply Shutoff, Automatic Depressurization, and Nuclear Steam Supply Systems (Unit 1)". MSIV control switch placed in the "close" position and test pushbutton released. MSIV verified to have remained closed indicating that the fast closure solenoids had de-energized and changed state. All accomplished in accordance with WO 87-9464, Revision 3. MSIV 1B21-F0022B fast closed per Surveillance Instruction (SVI)-B21-T2001, "MSIV Full Stroke Operability Test," as a retest for WO 87-9464. It closed satisfactorily in 3.2 seconds.
November 16, 1987	0535	Startup Test Instruction (STI)-B21-0025B, "Full MSIV Closure," was done at 96% power (all MSIV's fast closed satisfactorily including MSIV 1B21-F022B).
November 29, 1987	0157	Commenced SVI-C71-T0039, Revision 1, "Main Steam Line Isolation Valve Closure Channel Functional." All MSIV's cycled properly except MSIV 1B21-F0022B, which is described below.

0239	Slow closed MSIV 1B21-F0022B per SVI-C71-T0039. MSIV 1B21-F0022B reopened, indicating that the dual solenoid valve did not change state as required when the control switch was placed in the "close" position. Operators verified that the fast closure solenoids had de-energized.
0242	Slow closed MSIV 1B21-F0022B and again, the MSIV reopened. Operators verified that the fast closure solenoids had de-energized. Operators twice attempted to fast close MSIV 1B21-F0022B by placing the MSIV control switch in "close". The fast close solenoids de-energized but the valve did not close.
0245	Declared 1B21-F0022B inoperable and reactor shutdown commenced per a licensee commitment made following MSIV dual solenoid valve failures on November 3, 1987.
0332	Informed System Operations Center of intended plant shutdown.
0335	Made a courtesy 4 hour ENS report on failure of 1B21-F0022B to remain closed.
1114	Reactor taken to Hot Shutdown by scramming the reactor.
1303	After reactor shutdown, operators placed the control switch for MSIV 1B21-F0022B in "close" but the MSIV did not close. Personnel verified locally that the fast close solenoids had de-energized. Approximately 3 minutes after the switch was placed in "close", MSIV 1B21-F0022B's solenoid valve was gently tapped and it then closed properly in approximately 3 seconds.
1306	Operators opened and fast closed MSIV 1B21-F0022B, one more time, and it operated correctly.
1720	Reactor in Cold Shutdown.

III FAILURE MECHANISM ANALYSIS

After the event of November 29, 1987, the licensee convened a team of individuals from various departments including representations of Gilbert Associates (GAI) (the architect engineer), General Electric (G.E.), Automatic Switch Company (ASCO) (the solenoid valve vender), and Ralph A. Hiller Company (the control unit vendor). The charter of this team was to develop a list of components whose failures would fit the observed behavior of the MSIV. After developing this list, the known facts were used to evaluate the probability associated with each of the potential component failures. The team also evaluated the list of failures that had been developed as part of the root cause analysis performed as the result of the October 29 and November 3, 1987, events (see AIT Report 50-440/87024 for details). Their analysis concluded that the only component failure that fit the observed behavior was a failure of the ASCO Model NP-8323A20E three-way dual solenoid valve. The team next developed a list of potential failure modes of the ASCO dual solenoid valve and the corresponding probability of each of these modes. Their analysis yielded a total of eight (8) potential failure modes. Of these, two (2) were evaluated as likely and six (6) were evaluated as unlikely. The eight potential failure modes and their associated probabilities of causing the observed behavior are as follows:

* Improper disassembly or reassembly of dual solenoid valve during rebuilding
* One or both solenoid coil assemblies failed to reposition
  Poor instrument air quality
  Non-qualified seal elastomers
  Local high temperature deterioration of EPDM seal materials
  Blockage of the dual solenoid valve exhaust port with tape
  Degradation of O-ring lubricant
  Dual solenoid valve mounted at a 45° angle vs vertically as recommended by the vendor

* Likely failure

Subsequent to this analysis the licensee provided a written proposal for troubleshooting the MSIV to the AIT for concurrence. After evaluation and comment by the AIT a carefully planned disassembly and troubleshooting program was generated. In conjunction with the above, the AIT also independently evaluated potential failure modes for the MSIV's and concluded that the failure of the ASCO dual solenoid valve was the only reasonable choice.

IV INVESTIGATIVE EFFORTS

A. Main Steam Isolation Valves (MSIV's) Description

Two Main Steam Isolation Valves (MSIV's) are welded in a horizontal run of each of the four main steam line pipes; one valve is as close as possible to the inside of the drywell and the other is just outside the containment.

Attachment 3 shows a main steam line isolation valve. Each is a 26 inch, Y pattern, globe valve. The main disc or poppet is attached to the lower end of the stem. Normal steam flow tends to close the valve, and higher inlet pressure tends to hold the valve closed. The bottom end of the valve stem closes a small pressure balancing hole in the poppet. When the hole is open, it acts as a pilot valve to relieve differential pressure forces on the poppet. Valve stem travel is sufficient to give flow areas past the wide open poppet greater than the seat port area. The poppet travels approximately 90 percent of the valve stem travel to close the main seat port area; the last 10 percent of valve stem travel closes the pilot valve.

A 45 degree angle permits the inlet and outlet passages to be streamlined. This minimizes pressure drop during normal steam flow and helps prevent debris blockage. The valve stem penetrates the valve bonnet through a stuffing box that has two sets of replaceable packing. A lantern ring and leakoff drain are located between the two sets of packing. To help prevent leakage through the stem packing, the poppet backseats when the valve is fully open.

Attached to the upper end of the stem is an air cylinder that opens and closes the valve and a hydraulic dashpot that controls its speed. The speed is adjusted by a valve in the hydraulic return line bypassing the dashpot piston. Valve closing time is adjustable to between 3 and 10 seconds. The air cylinder is supported on the valve bonnet by actuator support and spring guide shafts. Helical springs around the spring guide shafts close the valve if air pressure is not available.

The valve is operated by pneumatic pressure and by the action of compressed springs. The control unit is attached to the air cylinder. This unit is shown on Attachment 4 and contains air control valves and solenoid operated valves. Part 4 of Attachment 4 is the main pilot control valve (dual solenoid valve). This valve consists of a valve body with a solenoid attached to either end (see Attachment 5). The dual solenoid valve provides control air to operate the four-way control valve (part 1) and the two-way control valve (part 3) and is used for opening and for fast closure of the MSIV. When both of the solenoids on the dual solenoid valve are energized the incoming solenoid air supply is directed through the valve body to shift the four-way control valve and the two-way control valve to the open position. In the open position the four-way control valve ports air through the three-way control valve (part 2) to the underside of the MSIV actuator piston while at the same time venting the over piston area of the MSIV actuator to atmosphere. With the two-way control valve in the open position the exhaust path through it to atmosphere is closed. For a fast closure of the MSIV both solenoids de-energize shutting off the control air to the four-way control valve and the two-way control valve and venting them both to atmosphere. When this occurs both valves will shift to the closed position. In the closed position the four-way control valve now directs air to the over piston area of the MSIV actuator and vents the under piston area to atmosphere. The two-way control valve now is in the closed position and also vents the under piston area of

the MSIV actuator to atmosphere. In this condition the MSIV is closed both by air pressure and by the helical valve springs.

Slow closure capability (used for test purposes) of the MSIV is accomplished through the use of the single solenoid valve (part 5). When the MSIV is open and the solenoid for the single solenoid valve is energized, air is directed to the three-way control valve (part 2) causing it to shift to the closed position. In this position the air that was directed to the under piston area of the MSIV actuator from the four-way control valve is stopped and a vent path for the under piston area is opened up through an air metering valve (part 9). The over piston area is still vented to atmosphere through the four-way control valve. In this configuration the air trapped in the under piston area is slowly bled off through the metering valve allowing the MSIV to slowly close.

Remote manual switches in the control room enable the operator to operate the valves. Operating air is supplied to the valves from the Instrument/Service Air System. An air tank (accumulator) between the control valve and check valve provides backup operating air.

B. Evaluation of Safety Significance

Based upon the absence of plant conditions requiring an automatic main steam line isolation, the failure of the MSIV to close would not have any immediate safety significance. Had a main steam line isolation been required, isolation of the "B" main steam line would have still occurred through the closure of the outboard MSIV, 1B21-F0028B, which showed acceptable stroke time during testing and no evidence of failure of the dual solenoid valve.

C. Operator Response

The AIT reviewed the event chronology discussed in paragraph II.B. against the requirements of the licensee's technical specifications as well as applicable operating and administrative procedures and determined that actions taken by operating personnel met the requirements. The licensee declared MSIV 1B21-F0022B inoperable, placed the reactor in Hot Shutdown within 12 hours, Cold Shutdown within 24 hours, and notified the NRC of the failure and shutdown pursuant to a licensee commitment made following the MSIV dual solenoid valve failures of October 29, 1987, and November 3, 1987. In addition, the licensee contacted the Senior Resident Inspector and made a courtesy ENS report. The AIT determined that this event was not immediately reportable pursuant to 10 CFR 50.72.

D. Troubleshooting Activities and Results

To determine the cause of the mis-operation of the MSIV control system, the suspect MSIV 1B21-F0022B ASCO dual solenoid valve was removed and disassembled. Prior to the removal of the dual solenoid valve, a visual examination and electrical checks were made to document the as-found conditions. No anomolies were noted. The

material conditions found in the ASCO dual solenoid valve and related air system were as follows:

1. Material Condition of the Affected Valve

The disassembly of the ASCO dual solenoid valve from MSIV 1B21-F0022B was observed. The dual solenoid valve had been rebuilt approximately one month earlier, with the exception of the "B" solenoid subassembly. At the time the corrective actions for the November 3, 1987, event were being implemented, the licensee only had three new dual solenoid valves available for replacing the eight being removed from the MSIV's. They were able to obtain sufficient rebuild kits to allow rebuilding the five remaining dual solenoid valves. The "B" solenoid subassembly was not rebuilt because it would have required cutting the "B" solenoid coil wires to gain access. Since the coil is not part of the rebuild kit this would have effectively ruined the dual solenoid valve and thus prevented its use. In addition, the licensee's determination of the root cause failure of the dual solenoid valves from the November 3, 1987, event did not include any malfunction related to the components contained within the "B" solenoid subassembly.

The licensee disassembled the dual solenoid valve with extreme care and in accordance with the approved procedure. All conditions found were recorded, including a photographic record. GE and ASCO representatives also observed the process closely and examined the parts. Each part was put in a container and marked for identification. When the "B" coil subassembly was disassembled, three pieces of foreign material were found on the top of the core (see Attachment 5). The three pieces of foreign material were stuck to the top of the core assembly and had to be peeled off. Visual, including microscopic, examination of the elastomer parts revealed no unusual wear or degradation. Internal moving parts and elastomers did have a thin coating of a material believed to be the standard silicone lubricant.

Other conditions noted were that: (1) the EPDM disc pads showed the characteristic seat impressions (but not the annular dimple observed on the failed solenoid valve's seats from the November 3, 1987, event), appeared shiny and, according to the ASCO representative, somewhat hardened as compared to new elastomers; (2) the Bisco Locaseal material used to seal the coil housing electrical lead conduit tubes had become activated indicating that the dual solenoid valves had been exposed to a neutron flux (core leakage and/or streaming paths). Perry personnel stated that all the inboard MSIV dual solenoid valves had activated Locaseal material which suggests that the normal neutron flux in the vicinity of them is fairly extensive during operation.

After completion of the disassembly and inspection of the MSIV 1B21-F0022B dual solenoid valve the dual solenoid valves for MSIV's 1B21-F0022C and 1B21-F0022D were disassembled and visually

examined (the 1B21-F0022C solenoid valve was previously rebuilt and the 1B21-F0022D solenoid valve was replaced with a new valve as a result of the November 3, 1987, event). The results of this inspection yielded similiar results to that discussed above for the 1B21-F0022B dual solenoid valve. The licensee also performed a dimensional analysis of the three solenoid valves, including measurement of spring constants. The results of this analysis were submitted to ASCO, who provided written certification that all measurements were within design tolerances. The AIT requested copies of the design drawings so that an independent review could be performed, however, ASCO refused to provide these drawings to the AIT or to the licensee.

General observations noted during the disassembly of the solenoid valves were as follows:

(1) The disassembly procedure referenced the procedure for maintenance of system cleanliness. Although no discrepancies were noted in this area, this procedure was not immediately available for reference.

(2) Contrary to ASCO installation instructions in Bulletin NP 8323, these dual solenoid valves are installed at approximately a 45 degree angle from vertical instead of vertical as prescribed and they are installed without a "street elbow" fitting in the exhaust port.

2. Laboratory Analysis of Particles Found in the Solenoid Valve

The licensee was able to obtain the services of a local laboratory, Ricerca Incorporated of Painesville, Ohio, to conduct sophisticated non-destructive, destructive, and consumptive analysis of samples which were obtained from the November 29, 1987, event.

On December 1, 1987, several members of the AIT accompanied Perry personnel to the Ricerca laboratory facility to discuss non-destructive and destructive testing of samples which were obtained from the early November valve refurbishing, as well as particle samples which were obtained from air-line discharge samples subsequent to the November 29 failure. A listing of the samples which were given to Ricerca for testing appears in Attachment 6.

The licensee and Ricerca were well equipped to initiate testing on short notice because of the background work and planning that had been done in order to analyze samples that had been obtained from the previous Perry MSIV failures (October 29 and November 3, 1987). Ricerca and Perry staff had spoken to knowledgable personnel at other organizations that had been involved in the laboratory analysis of samples obtained from ASCO solenoid valves that had failed at Brunswick (USNRC, Franklin Research Institute, CP&L Shearon Energy Center Laboratory).

One of the most substantial discoveries that Ricerca made was the finding of a particle "nucleation site" on the EPDM O-ring

which had been removed from the failed solenoid during [illegible]ly November 1987 refurbishment. This finding was made using a Zeiss universal stereo widefield optical microscope (SV-8) equipped with a source of indirect reflected light. Attachment 7 shows the particles that were found in the solenoid valve. Attachment 8 shows an O-ring that had been removed from the solenoid valve during the early November refurbishment. The suspected "nucleation site" of the largest particle is also shown on Attachment 8.

Using the aforementioned microscope and optical micrographs, the Ricerca staff was able to determine the nominal sizes of all 3 particles that had been recovered from the failed solenoid valve. The nominal dimensions of those particles are as follows:

	Length	Width	Depth
Particle 1	4.2 mm	0.8 mm	0.3 mm
Particle 2	0.6 mm	0.4 mm	0.1 mm
Particle 3	0.9 mm	0.3 mm	0.3 mm

Analysis of the particles, O-rings, discs, etc., was done using Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), Backscatter Electron Imaging (BEI), and for some samples, compression and hardness testing. The analysis and tests were conducted to enable comparison between unused off-the-shelf specimens and the materials that had been removed from the Perry plant subsequent to the November 3, 1987, event.

Molecular level examination of the three particles that were found in the solenoid valve and the EPDM O-ring, which were removed during the early November 1987 refurbishment, clearly showed that they were made of the same EPDM material. The spectral plots (EDS) obtained from the particles and the O-rings revealed the presence of: silicon (presumably from the silicon lubricant used in the valve assembly, either Parker Super O-lube used by CEI, or Dow Corning lubricant No. 550 oil used by ASCO); copper and zinc (the origin of which was presumably migration/contact from the solenoid valve's brass parts); and iron, nickel and chromium (also believed to have been introduced from contact with the solenoid valve's internal parts). The absence of large amounts of aluminum tends to discount the presence of desiccant (activated alumina).

Examination for any hydrocarbons associated with the particles and O-rings revealed the presence of only a few hydrocarbon groups. This is believed to have resulted from the elastomer's manufacturing, and to not be indicative of large scale oil intrusion (e.g., compressor oil) into the instrument air system. The analysis also found traces of other elements (lead, sulfur, calcium, potassium, chlorine) in the particles and O-rings. Those elements were believed to have been introduced in the elastomer during the manufacturing and/or curing process as trace metal catalysts and cross binding agents.

3. Analysis of Instrument Air System Air Quality

In order to assess the quality of the instrument air supplied to the MSIV control units, the licensee conducted instrument air system blow down and particle count tests on December 4, 1987. One AIT member witnessed the tests. Instrument air samples were obtained for three one minute duration blows at the 3/8" and 1 5/8" lines which lead to the MSIV 1B21-F0022B control unit. The three one minute samples from the 3/8" line had counts of 8, 6, and 5 particles which were 3 microns or less. There were no larger sized particles detected. The three one minute samples from the 1 5/8" line had counts of 35 and 40 particles which were 3 microns or less and counts of 1, 0, and 3 particles in the 3 to 10 micron range, with no larger sized particles detected.

The results of these tests indicate that on December 4, 1987, the instrument air system supplying MSIV 1B21-F0022B control unit had particle counts which did not meet the ISA 7.3 requirements but did meet the Perry nuclear plant's Final Safety Analysis Report commitment for air quality.

Ricerca analyzed many of the air samples that were obtained following the November 3, 1987, event. Analysis conducted included Infrared Spectroscopy (IR) for identification of organic compounds, particulate sizing, and gas chromatography for identification and quantification of condensable hydrocarbons. A listing of the samples that were examined is included as Attachment 6.

The air samples obtained as a result of the November 3, 1987, event from the supply lines connected to the dual solenoid valves and actuators of the failed MSIV's control units (samples designated as MSIV-4 through 7 and MSIV-12 through 19 on Attachment 6), contained particles in excess of 40 microns (see Section IV.D.2). The analysis of samples MSIV-5, 6, 13, 15 and 19 revealed the presence of fibrous materials. The licensee believed that the fibrous materials were the result of adverse sampling conditions in the drywell. Subsequent samples which used improved sampling techniques did not reveal any fibrous materials. In order to quantify particulate levels in the containment atmosphere that may have led to contamination of instrument air system samples, the licensee took containment air samples in the vicinity of the MSIV 1B21-F0022B control unit. The results of the particle count were as follows:

Size	Number of Particles
0 - 3 microns	815
3 - 10	116
10 - 20	35
20 - 30	15
30 - 40	7
> 40	7

Preliminary laboratory results of samples MSIV-4 through 7 and MSIV-16 and 17 characterized the particulates as three distinctly different types: white translucent, rust colored, and black metallic. Further analysis of those particulates has not yet been provided. A sub-sequent report characterized the majority of the particles greater than 40 microns from samples MSIV-4 through 7 and 12 through 19 as:

1) clear, crystalline-like
2) white, cloudy
3) dark

with relatively few metallic-like particles and fibers.

The licensee concluded that the majority of the fibers found were dust particles that were due to room air, as opposed to having the instru-ment air supply as their source. The licensee also alluded to the possibility that sample contamination could also have been a source of the large particles, however, there does not appear to be any strong basis to discount the instrument air system as the source of the particles.

The analysis also noted that instrument air samples MSIV-1 and 3 revealed the presence of silicone lubricant and partially degraded thread sealant, "Rectorseal," but did not reveal the presence of "Neverseeze" thread lubricant. Because the method used to obtain air samples MSIV 1 and 3 was "crude", it could not be definitively established that the silicone oil and the "Rectorseal" that were found in the samples had come from the instrument air system, as opposed to being residue which came from the fittings during the valve removal operation.

Two additional instrument air system samples, MSIV-10 and 11 were taken at the containment penetration on November 7, 1987. Those samples were analyzed for hydrocarbons, using gas chromatography. Both samples revealed hydrocarbon levels to be less than or equal to 0.1 part per million. One sample had no detectable hydrocarbons. The results indicated an absence of large scale hydrocarbon contamination of the instrument air system at the containment penetration (on November 7, 1987).

4. Licensee's Conclusions

The licensee evaluated the data gathered as a result of the troubleshooting program and concluded that the root cause of the failure on November 29, 1987, was a failure of the MSIV's ASCO dual solenoid valve. This failure was attributed to the binding of the "B" solenoid sub-assembly due to the presence of foreign material in the solenoid core assembly area. The source of the foreign material was attributed to a degraded O-ring from which a sliver of material separated and fell into the core assembly area. Since this portion of the solenoid was not previously disassembled during its refurbishment, its presence was not detected. The licensee also concluded that this root cause

appeared to be different than the root cause of the previous MSIV solenoid failures (October 29, 1987, and November 3, 1987).

V. RECENT EVENTS INVOLVING MSIV SLOW CLOSURE/FAILURE TO CLOSE

NRC Inspection Report No. 50-440/87024, Section V, discusses a number of events that have transpired, and their associated industry communication, within the industry over the past 15 to 20 years involving MSIV slow closures or failures to close. This report also discusses the failures of several MSIV's to close within the maximum allowable time as delineated in the Perry Technical Specifications. The Perry events were initiated when, on October 29, 1987, the Perry Nuclear Power Plant was in the process of completing their Startup Test Program and was performing stroke time testing of the MSIV's. During this testing the inboard valve in the "D" main steam line failed to close within the maximum value delineated in the facility technical specifications. Two other MSIV's also failed, including the outboard MSIV in the "D" main steam line. In all cases, subsequent stroke times for these three MSIV's were within acceptable values. The licensee initially declared the MSIV's inoperable. However, based on the acceptable stroke times achieved after the second try, later declared them operable. The licensee believed that the failures were the result of impurities in the MSIV actuator control unit and that the impurities had apparently been dislodged and/or expelled during MSIV operation. Plant operation and the Startup Test Program were continued with the stipulation that additional stroke time tests on the MSIV's, to confirm their operability just prior to the performance of the full reactor isolation startup test be performed. On November 3, 1987, while performing the additional stroke time testing of the MSIV's both the inboard and outboard MSIV's in the "D" main steam line again exhibited unacceptable stroke times. The licensee reported the failure of the two MSIV's to the NRC and commenced an orderly shutdown.

As a part of their troubleshooting program the licensee disassembled the MSIV actuator control units from the three MSIV's that had previously failed. The results of this disassembly and inspection revealed that the Ethylene Propylene Diene Monomer (EPDM) elastomers contained within the ASCO dual solenoid valves had been significantly degraded by exposure to high temperature and possibly hydrocarbons. An annular dimple was also observed on the seat material and resulted in part of the seat material being extruded into the exhaust orifice. This dimple, together with the deteriorated state of the seat material, indicated that the exhaust seat could be held in an "energized" position even though the solenoids had been de-energized, and would prevent the control air from being exhausted to atmosphere and therefore prevent the MSIV from closing.

The licensee subsequently replaced or rebuilt all eight MSIV dual solenoid valves. The plant was restarted on November 13, 1987, and the Startup Test Program, including the full reactor isolation startup test, was successfully completed.

One occurrence of an MSIV to close has occurred since the issuance of NRC Inspection Report No. 50-440/87024. This occurred at LaSalle, Unit 1 on December 17, 1987. The plant was in hot shutdown following a reactor scram resulting from a feedwater transient. The licensee was in the

process of closing the MSIV's to allow repair work of balance of plant equipment. The method being utilized to close the MSIV's consisted of pressing the "test" pushbutton to allow the MSIV to slow close, taking the hand switch to the "close" position, and then releasing the "test" pushbutton. Normally this would result in the MSIV staying closed, however, when this was done for MSIV 1B21-F0028C (outboard) it reopened. The licensee attempted to close the valve again but with no success. They also verified that the status lights for the dual solenoid valve's solenoids indicated that they had de-energized. Subsequent to the failure, the licensee removed and disassembled the ASCO dual solenoid valve. Examination of the valve internals revealed that the interfacing surfaces of the core assembly and the plugnut assembly (see Attachment 5) of the "B" solenoid had a yellowish, sticky, substance coating them. When the interfacing surfaces of these components were pressed together the core assembly would hang from the plugnut assembly with no support. No other anomalies were noted. This failure mode is consistent with a MSIV failure that occurred at Grand Gulf in 1985 (reported in Information Notice 85-17 and 85-17, Supplement 1) in which a similar substance was found coating the interfacing surfaces of the "B" solenoid core assembly and plugnut assembly. LaSalle subsequently replaced all eight MSIV dual solenoid valves.

VI AIT CONCLUSIONS

The root cause of the observed MSIV failure to close on November 29, 1987, was a malfunction of the ASCO Model NP-8323A20E three-way dual solenoid valve caused by pieces of the body gasket (Ethylene Propylene Diene Monomer (EPDM) O-rings) falling into the "B" solenoid valve sub-assembly and ultimately interfering with the ability of the dual solenoid valve to shift to the de-energized position. The source of the pieces of body gasket material were deteriorated and degraded EPDM O-rings that were replaced as part of the November 3, 1987 event (Inspection Report No. 50-440/87024). This foreign material was introduced as a result of the maintenance activities by the licensee to refurbish the dual solenoid valves. The "B" solenoid valve assembly was not completely disassembled during the refurbishment and therefore the foreign material was not detected. Subsequent to the valve's refurbishment the valve operated successfully four times. It is hypothesized that during the fifth operation one or more particles lodged between the core assembly and the wall (see Attachment 5) thereby preventing proper valve operation. The tapping of the valve probably loosened the particle(s) enough to allow the spring forces to overcome the static friction/binding forces caused by the particle(s) which may have been lodged between the sliding core and the stationary solenoid base sub-assembly.

All evidence collected during the investigation indicated that the event was caused by the failure of the ASCO dual solenoid valve to shift to the de-energized position. The evidence collected included the following:

a. The MSIV in question failed to stay closed during two slow closure operability checks and failed to close during three fast closure attempts.

b. On the fifth closure attempt the MSIV stayed open for the approximate

three minute period in which the control switch was held in the "close" position until the solenoid valve body was gently tapped. At that time the valve closed in a normal stroke time (approximately 3 seconds).

c. The design of the control unit is such that the simultaneous failure of more than one of the air control valves would be required to cause the observed failure.

The AIT also concluded that the licensee was very responsive to the event of November 29, 1987, and proceeded in a methodical, well thought out, approach to resolving the root cause of the event.

VII AIT RECOMMENDATIONS

A. The AIT recommends that the NRC take actions to assure that ASCO provides the NRC with pertinent information necessary to assure proper operation of such safety-related valves in accordance with plant safety analysis. Specific design, operation, and maintenance information should be obtained from ASCO. (It may be necessary to establish a special/vendor inspection team to ascertain some of the information which ASCO has been reluctant to provide.) Examples of such information include:

- Valve design specifications including acceptable tolerances on moving parts.
- Material specifications including shelf-life and inservice life expectancy.
- Design analysis including force analysis showing design margin for operation in the presence of "dirty air"
- Valve cycling frequency required to assure successful operation
- Maintenance of internal cleanliness during assembly/disassembly
- Sticking due to overheating caused by local hotspots from steam leaks and/or faulty/damaged/missing thermal insulation or inadequate HVAC
- Effects of these conditions on qualified life (EQ)
- Effects of prolonged exposure to neutron flux

b. The AIT recommends that the information notice discussed in Inspection Report 50-440/87024 to inform utilities of the recent MSIV failures be expanded to stress the merits of replacing safety-related solenoid operated valves rather than refurbishing them.

The information notice should also stress that it is important that if the option to rebuild the ASCO's is taken that it should be a complete rebuild to preclude a problem similar to that encountered at Perry on November 29, 1987.

VIII EXIT INTERVIEW

The AIT met with licensee representatives (denoted in Paragraph I.D.) informally throughout the inspection period and at the conclusion of the inspection on December 4, 1987, and summarized the scope and findings of the inspection activities.

The AIT also discussed the likely informational content of the inspection report with regard to documents or processes reviewed by the inspectors during the inspection. None of the areas expected to be contained in the report were identified by the licensee as proprietary. The licensee acknowledged the findings of the inspection.

IX STARTUP REVIEW

On December 4, 1987, the licensee met with members of the AIT and a representative of Region III management to discuss their plans for startup and to obtain NRC approval. As a result of this meeting the licensee committed to perform a number of actions both prior to startup and subsequent to startup. These commitments are detailed in a letter (PY-CEI/OIE-0296L) dated December 4, 1987, from Edelman, CEI, to Davis, NRC. The following is a summary of these actions:

A. Prior to Startup

1. Replace the ASCO dual solenoid valves on all eight MSIV's with new ASCO's.

2. Cycle all eight new ASCO dual solenoid valves a minimum of ten times as part of the retest activities.

B. Following Startup

1. Institute administrative controls for all future Class 1E ASCO solenoid valve work to require the use of new valves or the complete disassembly and cleanout to ensure that no particles are introduced during the rebuild process.

2. Complete the corrective actions previously discussed in a letter (PY-CEI/OIE-0289L) dated November 13, 1987, from Edelman, CEI, to Davis, NRC, with the following clarifications:

   a. The dual solenoid valve inspection discussed on page 5 of the enclosure will be performed during an outage of opportunity prior to the end of October 1988.

   b. The modified monthly slow closure surveillance test discussed on page 5 of the enclosure will be performed on a staggered basis as follows:

      (1) Until the January 4, 1988, outage, the test will be performed weekly, staggered between the inboard and outboard MSIV's.

      (2) For a one (1) month period following the January 4, 1988, outage this test will be performed once every two (2) weeks, again staggered between the inboard and outboard MSIV's.

On December 4, 1987, Region III released the licensee from CAL RIII-87-24 (Attachment 1) based on their corrective actions, commitments, and the preliminary results of the AIT inspection. Region III also concurred with the licensee's request to allow the plant to startup. The above was documented in a letter (Attachment 9) from Davis, NRC, to Edelman, CEI, dated December 8, 1987.

CONFIRMATORY ACTION LETTER

Attachment #1

NOV 30 1987

CAL RIII-87-24

Docket No. 50-440
Docket No. 50-441

The Cleveland Electric Illuminating
Company
ATTN: Mr. Murray R. Edelman
Vice President
Nuclear Group
Post Office Box 5000
Cleveland, OH 44101

Gentlemen:

This letter confirms the telephone conversation on November 30, 1987, between Mr. H. Miller of this office and Mr. A. Kaplan of your staff regarding the Main Steam Isolation Valve (MSIV) failure occurring at the Perry Nuclear Power Plant Unit 1 on November 29, 1987. With regard to the matters discussed, we understand that you will:

1. Take those actions necessary to ensure that complete documentary evidence of the "as found" condition of equipment being inspected is maintained.

2. Provide a step by step troubleshooting program to establish the root cause of the MSIV failure.

3. Not disturb any components that offer a potential for being the root cause including power sources, switches, solenoids, and the air system directly feeding the MSIVs until that action is approved by the leader of the NRC Augmented Inspection Team (AIT) which has responsibility for examining this matter. We recognize that, per our authorization of November 29, 1987, the air pack was removed from MSIV 1B21-F022B and the associated ASCO dual solenoid 3-way pilot valve was disassembled with the AIT team leader present.

4. Except as dictated by plant safety, advise the NRC AIT team leader prior to conducting any troubleshooting activities. Such notification should be provided soon enough to allow time for the team leader to assign an inspector to observe activities.

5. Submit to NRC Region III a formal report of your findings and conclusions within 30 days of receipt of this letter. You may extend the submittal date of the formal report requested in the NRC Confirmatory Action Letter dated November 4, 1987, to within 30 days of receipt of this letter.

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The Cleveland Electric Illuminating Company

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NOV 30 1987

We also understand that Perry Nuclear Power Plant Unit 1 will not be made critical without the concurrence of the Region III Regional Administrator or his designee.

Issuance of this Confirmatory Action Letter does not preclude the issuance of an order requiring implementation of the above commitments.

Please let me know immediately if your understanding differs from that set out above.

Sincerely,

Original signed by
A. Bert Davis

A. Bert Davis
Regional Administrator

cc: F. R. Stead, Manager, Perry Plant Technical Department
M. D. Lyster, Manager, Perry Plant Operations Department
Ms. E. M. Buzzelli, General Supervising Engineer, Licensing and Compliance Section
DCD/DCB (RIDS)
Licensing Fee Management Branch
Resident Inspector, RIII
Harold W. Kohn, Ohio EPA
Terry J. Lodge, Esq.
James W. Harris, State of Ohio
Robert M. Quillin, Ohio Department of Health
State of Ohio, Public Utilities Commission
R. Cooper, EDO
W. Lanning, NRR
F. Miraglia, NRR
G. Holahan, NRR
M. Virgilio, NRR
J. Partlow, NRR
K. Connaughton, SRI
J. Strasma, RIII
L. Sucharski, RIII
J. Taylor, EDO
J. Lieberman, OE

RIII	RIII	RIII	RIII	RIII	RIII	RIII	RIII	RIII	RIII
MMcBarger/jp	Knop	Forney	Wright	Miller	Berson	Grobe	Norelius	Paperiello	Davis
Virgilio/NRR									