SUSQUEHANNA UNIT 1 REACTOR MODE SWITCH FUNCTIONAL TESTING AND WEAR CHARACTERISTICS EVALUATION

FIRL Final Report
F-A5898

Prepared for

Pennsylvania Power and Light Company
2 North Ninth Street
Allentown, Pennsylvania 18101

February 10, 1984

50-387

Franklin Institute Research Laboratory, Inc.
20th and Race Streets, Phila., Pa. 19103 (215) 448-1000

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1. SUMMARY

FIRL Report No.	Report Title:
F-A5898	Susquehanna Unit 1 Reactor Mode Switch Functional Testing and Wear Characteristics Evaluation
Conducted and Reported by:	Conducted for:
Franklin Institute Research Laboratory, Inc. Twentieth and Race Streets Philadelphia, PA 19103	Pennsylvania Power and Light Company 2 North Ninth Street Allentown, Pennsylvania 18101
Report Date:	Period of Test Program:
February 10, 1984	September 30, 1983 through January 30, 1984

Objective:

The objective of the test program was to determine if the defects found in the unmodified version of the Susquehanna Unit 1 reactor mode switch had been corrected in the modified version and to verify that no new deficiencies had been created. In addition, the wear characteristics of the switch were to be determined and the mechanical life of the switch estimated.

Equipment Tested:

A four-position reactor mode switch, specified by General Electric Company (GE) Drawing No. 195B9497P009, and manufactured by Gould, Drawing No. 7003-207, Revision B was tested. The switch has modular construction and a key handle.

Elements of Program:

A receipt inspection and functional tests were performed to verify proper switch operation prior to testing. The switch was then subjected to 3000 mechanical cycles interspersed with functional tests to estimate the mechanical life of the switch. Following the cycling, the switch was disassembled and the internal components were inspected for wear.

Conclusions:

The modified mode switch performed significantly better than the unmodified switch that failed in service at Susquehanna Unit 1. During testing, an open circuit condition occurred during six switch cycles; after 1800 cycles, a tendency for a false detent to occur was recognized, which could allow inappropriate contacts to be closed. FIRL concluded that the most probable cause of the open circuit condition was a loose particle of plastic material from manufacture becoming temporarily lodged on contact surfaces and preventing closing of the circuit. Additional cleanliness during assembly should reduce the probability of open circuit conditions. FIRL concluded that the mechanical life of the switch should be limited to 1000 cycles.

2. BACKGROUND

This report describes the testing of the modified version of the reactor mode switch for Susquehanna Unit 1. The modifications to the switch were made in response to a failure of the switch that occurred on March 22, 1983. At that time, while the reactor was in hot shutdown, the reactor mode switch was placed in the start-up position to allow a surveillance test to be performed. Following the completion of the surveillance test, the mode switch handle was turned to the shutdown position, which should have actuated all four channels of the reactor protection system (RPS). However, when the switch was placed in the shutdown position, RPS channel "B" failed to actuate. This failure prompted the issuance of a Licensee Event Report (LER) and a Nonconformance Report (NCR), which are included in Appendix A of this report.

On April 4, 1983, Pennsylvania Power and Light Company (PP&L) requested Franklin Institute Research Laboratory, Inc. (FIRL) to test the failed unmodified reactor mode switch and determine the cause of the failure (FIRL Project 5818-001). FIRL tested the switch and performed an internal inspection. The resulting report* regarding the unmodified mode switch concluded:

> "...significant irregularities were found among the cam shaft parts. Large design clearances resulted in imprecise operation of the cam followers, and the general construction of the switch allowed nonuniform rotation of the cam shaft. The cumulative effects of these factors resulted in erroneous operation of the switch."

Subsequent to Project 5818-001, the manufacturer (Gould) and the supplier (General Electric) modified the mode switch.

On September 30, 1983, PP&L requested FIRL to determine if the previous defects of the mode switch had been corrected and to verify that no new deficiencies had been created as a result of the modifications made to the switch.

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*FIRL Report F-A5818-1, Susquehanna Unit 1 Reactor Mode Switch Failure Modes and Mechanisms, April 29, 1983.

During functional testing of the first three test samples of the modified mode switch, several anomalies occurred. Each time, the manufacturer, supplier, and PP&L agreed upon a solution to eliminate the problem. A chronology of events and a discussion of all switch modifications are presented in Appendix B and Section 4.2, respectively. This report focuses upon the final version of the modified switch that was tested and mechanically cycled.

3. OBJECTIVE

The objective of the test program was to determine if the defects found in the unmodified Susquehanna Unit 1 reactor mode switch had been corrected and to verify that no new deficiencies had been created. In addition, the wear characteristics of the switch were to be determined and the mechanical life of the switch estimated.

4. DESCRIPTION OF TESTED SPECIMENS

4.1 SWITCH CONSTRUCTION

The modified reactor mode switch tested by FIRL was received enclosed in an isolation can, which is described below. This switch was assigned FIRL Specimen No. 5898-004 (see Section 4.2 for a discussion of other specimens). The lead wires were harnessed together and extended from the conduit openings on the bottom of the isolation can. The switch was specified by General Electric Company (GE) and was manufactured by Gould, Inc. Table 1 lists the identification information that was found on the switch and isolation can. No model number could be identified for this component. In lieu of a model number, the GE "drawing" number (195B9497P009) is used as the prime identifier. This number identifies the GE design drawing (195B9497) and a unique part number (P009). This number can be found on the GE sticker located on the rear separator of the mode switch. The operating handle for the switch is a removable key. The key number is 401, which is stamped on the shank of the key.

During receipt inspection, the mode switch isolation can was removed to obtain the identification information presented in Table 1. No damage was visible on the exterior of the switch, and it appeared that the switch was constructed of the same self-extinguishing polycarbonate as the unmodified Susquehanna Unit 1 mode switch.

The isolation can consists of three pieces: a front and bottom section, a top and side section, and a rear cover piece. During service, the isolation can completes the electrical and fire separation between the four sets of safety circuits attached to the switch. The can is made of aluminum and fits snuggly over the barriers that separate the switch sections (see Figure 1). The front and bottom section of the can contains the conduit connections and the wiring harness stress relievers. The stress relievers are wire ties connected to the inside of the bottom section of the isolation can. The purpose of the stress relievers, as stated by GE, is to prevent the application of inadvertent stress to the terminals of the switch, which are connected directly to the stationary contacts of the switch.

Table 1. Mode Switch Identification Information

Description of Identifier	Identifier
1. GE Material ID Tag (taped to isolation can)	"N" No. N9001 "T" No. TALGH8 Dwg. No. 188C8035G001 Rev. 0/0 Mode Switch Safety-Related Item Stock TALGH8-001 GE 518 12/20/83
2. GE Sticker (inside left of isolation can)	TC No. 374 Dwg. No. 195B9496001 83143 TAHKC9 Rev. 03
3. GE Sticker (inside right of isolation can)	188C3085G001 Rev. 0/0 TALGH8-001 Safety-Related Item GE 518 518 12/20/83
4. Key Number (on shank of key handle and cylinder)	401
5. GE Sticker (inside isolation can rear coverplate)	GE4 195B9487G001 TAKHB9 Rev. 06 10/27/83
6. Gould Sticker (on top of switch)	No. H33SS3X1 ("SS" appears double struck)
7. Printed Stamp (on top of switch)	1283-02
8. GE Sticker (inside isolation can)	TC No. 83145 TAHKA9 Rev. 07 12/19/83 ...2391* ...488G003*
9. GE Sticker (on rear fire barrier of the switch)	Plus ECN NJ45962

*Partial numbers. Remainder of number is covered by the stress relief nut of the wiring harness.

Table 1 (Cont.)

	Description of Identifier	Identifier
10.	GE Sticker (on rear fire barrier of the switch)	PO No. WD265001 Date 8350 Insp. 043 Rev. 03 Drawing 195B9497P009
11.	GE Sticker (on rear fire barrier of the switch)	PO No. Except IR RAJ185
12.	Printed Stamp (on rear switch segment)	27

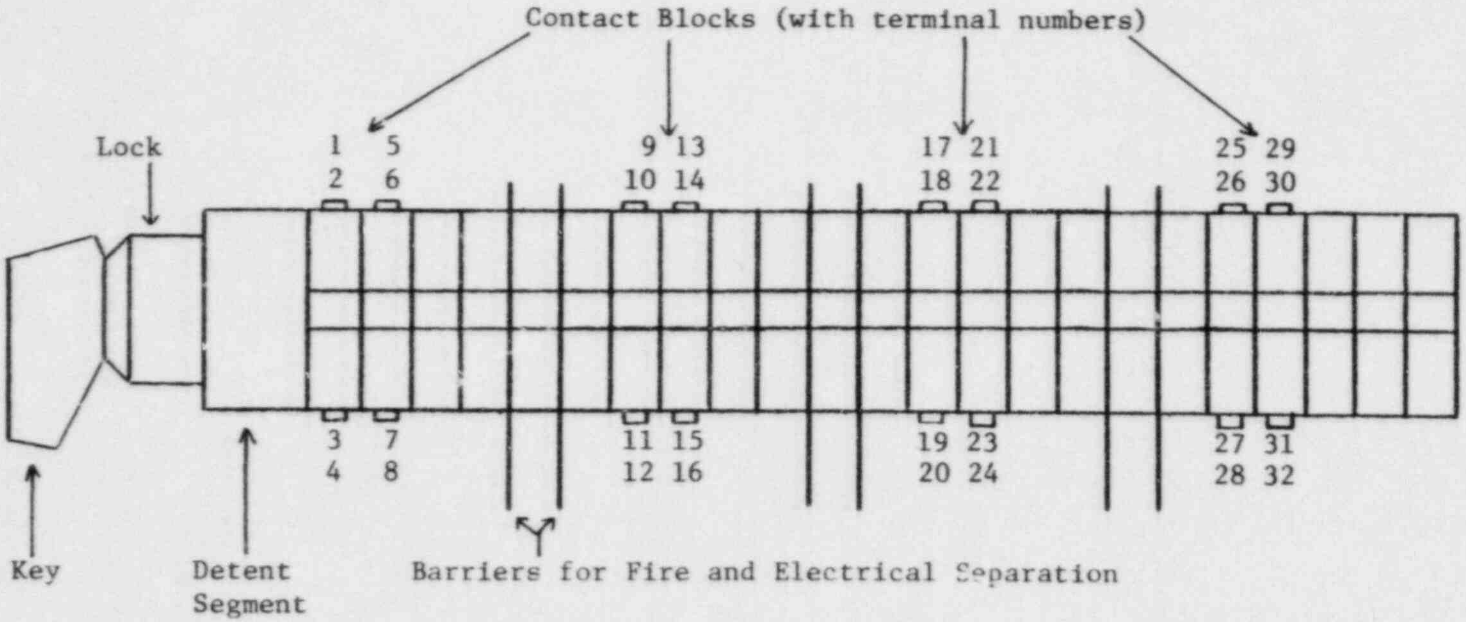

Figure 1. Mode Switch Outline (Side View)

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The reactor mode switch uses modular construction; see Figures 1 and 2. At the front of the switch is a four-position key-operated lock, a detent mechanism, and a stop plate that prevents turning the handle past the two extreme positions. To the rear of the lock and detent are 8 contact blocks interspaced with 14 spacer blocks. The contact blocks contain the electrical contacts. The spacer blocks contain no contacts and are used for additional separation of four groups of contact blocks. Each block has a nominal depth of 0.475 in. Attached to the final block is a plastic backplate.

The switch is divided into four sections by six metal separator plates. (Two separators sandwiching a spacer block are used to divide each set of adjacent contact sections.) In the center of each section, there are two contact blocks, each of which contains an upper and lower electrically independent single pole switch, as shown in Figure 2. A cam follower that moves in and out of the block as the contact closes and opens is visible on the top and on the bottom of each contact block. Four wiring terminals are present on each contact block, two for each single pole switch in the contact block. These wiring terminals have been fixed to the contact block segment by the use of an epoxy.

Each block of the switch is attached to the block in front of it by two screws that pass through the mounting holes shown in Figure 2. The cam shaft is made of plastic, and each block of the switch contains an individual section of the shaft which plugs into other sections of the shaft contained in adjacent blocks. Thus, the cam shaft consists of 22 sections (one in each block). A torsion bar assembly runs through the entire length of the switch from the lock to the rear cover. Each cam shaft section consists of a molded plastic shaft onto which a disk is fitted. In the contact block segments, the disks are shaped to serve as cams that open and close the contacts. Each cam shaft section slides onto the torsion bar assembly in the following sequence: contact block, cam shaft segment, contact block, etc.

4.2 DISCUSSION OF MODE SWITCH MODIFICATIONS

At the conclusion of FIRL Project 503I-A5818-001, after having received the results of the testing and inspection, the manufacturer and supplier

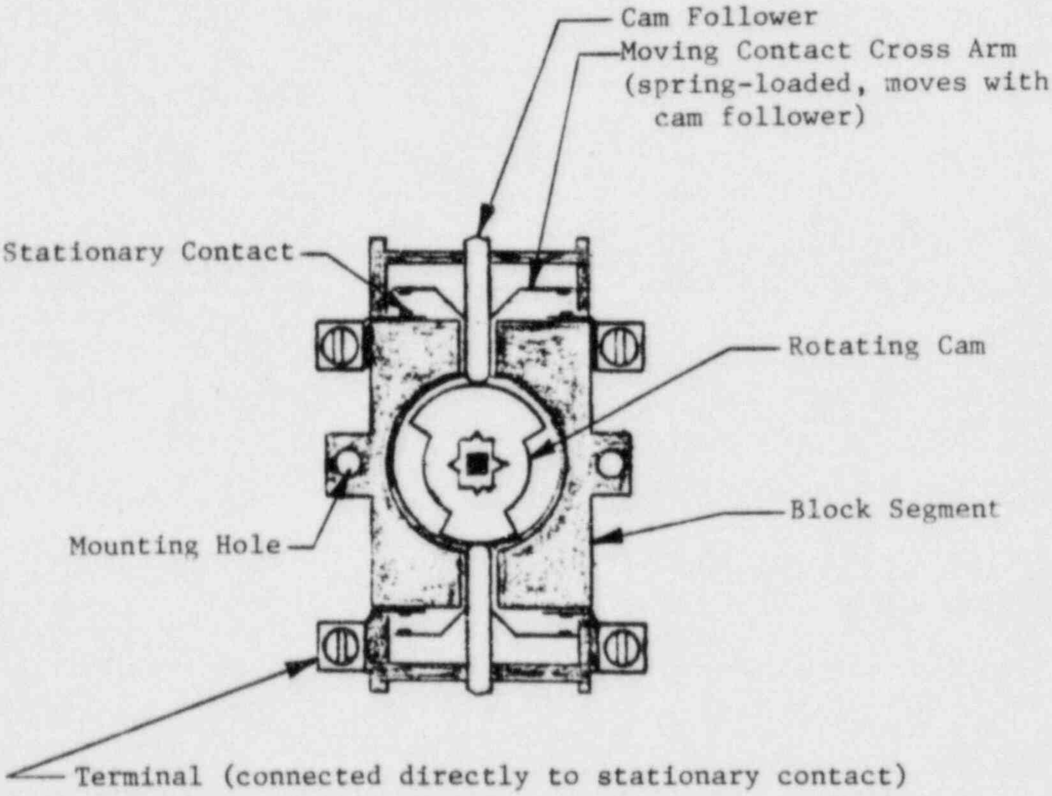

Figure 2. Contact Block (shown with contact cover removed and all contacts open)

evaluated the switch and proposed and implemented several changes. These proposed changes included reducing the manufacturing and design tolerances, adding a metal torsion bar or shaft which extends through the length of the switch, making cams of similar function more uniform, rounding the cam follower edges, and color coding cams of similar function. The first new style mode switch received by FIRL (FIRL Specimen No. 5898-002, so numbered to correspond to a GE "switch number") arrived in a damaged condition. The key was bent approximately 45 degrees, and the rear cover plate was cracked. This damage was a result of the mode switch having been shipped in a box with the key handle inserted in the cylinder of the nose piece. Because the switch was returned without having been tested to General Electric (San Jose, CA) per PP&L request, it was not possible to verify that the design changes had been implemented.

The second mode switch (FIRL Specimen No. 5898-001) passed the receipt inspection (i.e., no visual indication of damage from shipment and no apparent indications of manufacturing defects). The key handle did have a 5-degree bend, but this did not appear to be significant to the operation of the switch. During the execution of initial functional tests, the switch failed to meet the acceptance criteria. Contact (7, 8) closed in switch position 3 (REFUEL). This contact should be closed only when the switch is in position 4 (SHUTDOWN). A non-quality assurance (QA) disassembly was performed at PP&L's request, and it was found that the red cam which operates contact (7, 8) had been installed backwards during manufacture. This switch was also returned to GE per PP&L request. Gould subsequently modified the switch by placing an "O" on the reverse side of each cam to prevent a recurrence of this problem.

A third mode switch was brought to FIRL by GE (FIRL Specimen No. 5898-003) and passed the receipt inspection. GE and Gould representatives witnessed receipt inspection and functional testing. During the functional testing, contacts (15, 16) and (7, 8) closed in switch position 3. Both of these contacts should be closed only in switch position 4. This condition could be obtained with only a slight counterclockwise overtravel during switch rotation and depended upon the position of the stationary contact and wiring terminal. (The stationary contacts of this switch and its predecessors were not firmly fixed in place and were free to move approximately 1/16 in with respect to the moving contacts [see Figure 2]. The stationary contact is directly coupled to the wiring terminal. Therefore, depending on the position of the lead wires, the stationary contact could be pushed toward or away from the moving contact with the switch open. In the closed position, the play in the stationary contact was always overcome by the moving contact, assuring closure of the contacts.) Both Gould and GE stated that they believed the switch mounting used by FIRL to be the cause of the extraneous contact closures. For this and all previous tests, the switch had been firmly held in a horizontal position on a laboratory table. The manufacturer and supplier insisted that Specimen No. 5898-003 be tested in a manner which simulates the actual in-service condition (i.e., mounted in a panel angled at 42 degrees with an isolation can and wiring harness installed). PP&L agreed to this test change, and FIRL constructed the mounting fixture. (It should be noted that FIRL at no time considered the misoperation of the switch to be attributable to the test method.) Prior to testing FIRL Specimen No. 5898-003 in the test fixture, the switch was again modified by Gould/GE. An improved torsion bar assembly was installed and an "e"-ring was removed after PP&L approval was obtained for the modification. The new torsion bar had smaller tolerances with respect to the detent mechanism aperture and removed much of the play in the switch. The "e"-ring is a clip that was used to hold the torsion bar in the lock assembly. When the torsion bar was changed from a short stub that only connected to the beginning of the plastic cam shaft to a shaft that extended the entire length of the switch, the "e"-ring became unnecessary. After modifying the switch, functional testing was performed with the switch mounted in the test fixture. During this procedure, it was found that the isolation can, which GE brought for the test, did not fit because a lateral support member was located incorrectly and there were no countersunk holes in the front of the isolation can. PP&L, GE, and Gould agreed to test the switch without the isolation can. All wiring was approved by PP&L and GE prior to commencing the functional test. During this functional test, Switch No. 5898-003 again failed to meet the acceptance criteria when the switch was in position 3. Again, contacts (15, 16) and (7, 8) closed in position 3. An exact reason for the problems could not be identified. The switch was returned to GE in San Jose, CA.

At the time of the above functional tests, the following modifications were proposed by Gould and GE to resolve the anomalies: fixing the external contacts with epoxy, milling the cam surfaces (more accurate than punching), shortening the switch by removal of blank contact blocks, and epoxying the cams to the shaft. When the replacement mode switch was received (FIRL Specimen No. 5898-004), Gould stated that only the first two proposed solutions had been implemented. In addition, the switch was already wired and installed in an isolation can when it arrived at FIRL. The wiring included stress reliefs that fixed the wires to the inside of the isolation can. Complete functional and mechanical cycling tests were performed on Specimen No. 5898-004.

From the original mode switch which failed at Susquenhanna Unit 1 on March 22, 1983 to the switch being evaluated in this report (FIRL Specimen No. 5898-004), the following modifications were performed:

- cam follower surfaces were rounded
- like cams were made more uniform
- like cams were color coded (red and green)
- a steel torsion bar/shaft that extends through the switch was added
- the design and manufacturing tolerances were reduced
- an "O" was placed on the reverse side of all cams to assure proper installation
- an improved torsion bar/shaft was installed to remove play
- the "e"-ring was removed
- cam surfaces were milled (non-verifiable by FIRL)
- the external contacts were fixed in place with epoxy
- strain relief was added to external wiring of the switch.

All of these modifications have contributed to the improvement in switch construction, operation, and performance.

5. DISCUSSION OF TEST PROCEDURES

5.1 INITIAL FUNCTIONAL TESTING PROCEDURE

The reactor mode switch was wired to a lamp array as shown in Figure 3. With the mode switch in position 1 (see Figure 4), the circuit was energized. The status (on or off) of the indicating lamps was recorded. Using a smooth motion that minimized any overtravel or undertravel, the switch was rotated counterclockwise. Lamp status was recorded at each switch position. After data were obtained for position 4, another set of data was recorded as the switch was rotated clockwise. A complete cycle consisted of rotating the switch from position 1 (RUN) to position 4 (SHUTDOWN) and back to position 1. This contact position verification test* was repeated while rotating the switch handle unevenly to determine the effects of slight over- and undertravel of the switch handle.

Acceptance criteria for the contact position verification test are identified in Table 2. This information was derived from PP&L drawing number 8856-M1-C72-5(3)-9 of the reactor protection system (RPS). If an abnormal condition (such as data that differ from the acceptance criteria) was observed at any point during the course of the testing, a description of the condition was noted on the data sheet and the abnormal condition was fully evaluated prior to continuation of the testing.

The mode switch is designed to meet a reactor protection system requirement of a "make-before-break" switching logic. This requirement dictates that contacts of the switch position being entered be closed before the contacts of the previous switch position open. An eight-channel stripchart recorder** was used during the make-before-break tests to monitor contact positions. Toggle switches were used to allow the monitoring of 16 sets of contacts on the eight-channel recorder (Figure 3). Table 3 provides the toggle switch settings for each eight-contact set. The mode switch was cycled using both fast (2 to 3

*Section 5.2 provides a more complete description of this and other functional tests performed on the mode switch.

**A complete list of test instruments is contained in Appendix C.

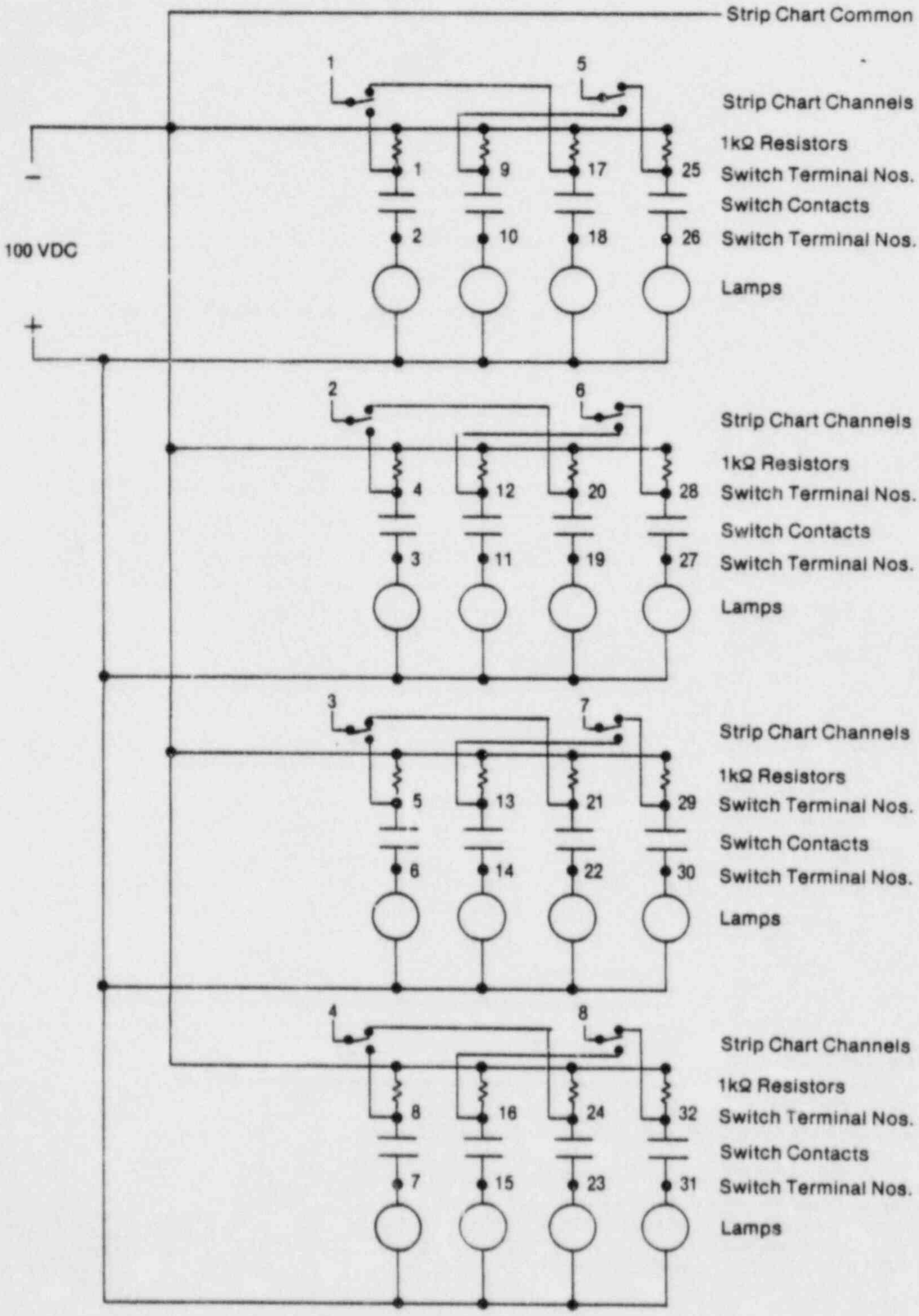

Figure 3. Functional Test Setup for Mode Switch

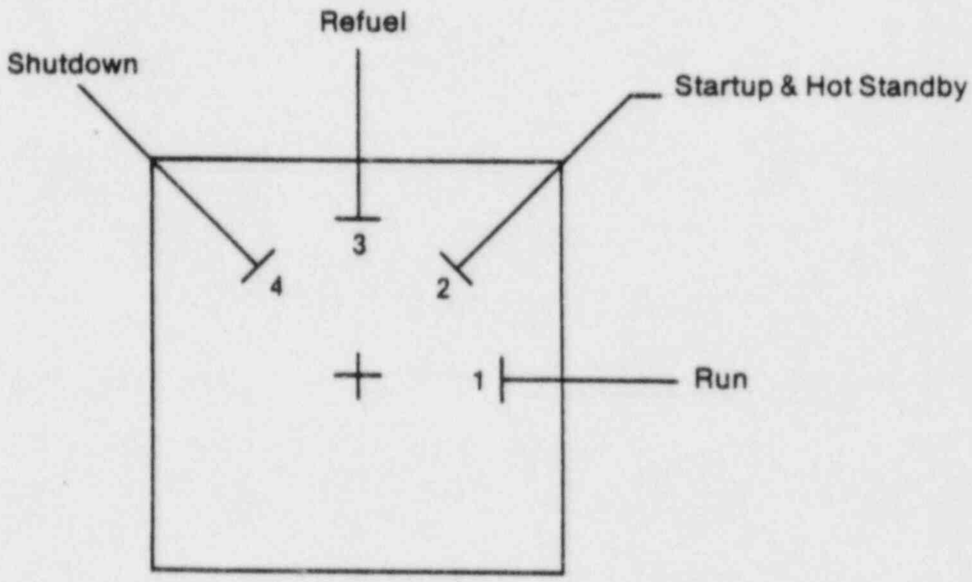

Figure 4. Switch Key Position

Table 2. Acceptance Criteria for Functional Test

Contacts marked with "X" must be closed and contacts marked "0" must be open for each indicated switch position.

Contact Terminals	Switch Positions 1	2	3	4
1, 2	X	0	0	0
9, 10	X	0	0	0
17, 18	X	0	0	0
25, 26	X	0	0	0
3, 4	0	X	0	0
11, 12	0	X	0	0
19, 20	0	X	0	0
27, 28	0	X	0	0
5, 6	0	0	X	0
13, 14	0	0	X	0
21, 22	0	0	X	0
29, 30	0	0	X	0
7, 8	0	0	0	X
15, 16	0	0	0	X
23, 24	0	0	0	X
31, 32	0	0	0	X

For lamps, X = ON; 0 = OFF

Table 3. Toggle Switch Settings for "Make-Before-Break" Test

Switch Arrangement 1

Channel No.	Switch Position	Contact Terminal No.
1	Down	1, 2
2	Down	3, 4
3	Down	5, 6
4	Down	7, 8
5	Up	25, 26
6	Up	27, 28
7	Up	29, 30
8	Up	31, 32

Switch Arrangement 2

Channel No.	Switch Position	Contact Terminal No.
1	Up	17, 18
2	Up	19, 20
3	Up	21, 22
4	Up	23, 24
5	Down	9, 10
6	Down	11, 12
7	Down	13, 14
8	Down	15, 16

seconds) and slow (5 to 6 seconds) cycling speeds. The mode switch was also cycled, from position 4 to position 2 to position 1 and back to position 4 using a fast cycling speed. This test was used because the results of the original mode switch tests showed that the greatest amount of angular shaft deviation occurred during this style of switching cycle.

5.2 MECHANICAL CYCLE TESTING PROCEDURE

While mounted in a test fixture, the reactor mode switch was cycled 3000 times to simulate the wear that would occur during the anticipated life of the switch. Periodically during this cycling, specific functional tests were performed to verify switch operability. Three specific tests were performed: a contact verification test (static test), a make-before-break test (dynamic test), and a "snap-action" test. These three tests are described below:

1. Contact verification test (static test): This test is a verification that all contacts of the switch assume their proper open or closed position for each switch position. Using the lamp array, the switch is cycled once and the lights in each of the switch positions are observed to see if they meet the acceptance criteria shown in Table 2. Pass/fail data were recorded.

2. "Snap-action" test: This test is a verification that normal operator switching action will not result in the switch "hanging-up" in mid-position. It also verifies correct contact opening or closing in each of the switch positions. Using the lamp array, the switch is cycled through each position, the operator's hand is removed from the switch handle as soon as the normal switch snap occurs, and verification of the switch handle and contact position is made. Contact acceptance criteria are shown in Table 2. Pass/fail data were recorded. Fifty switch cycles were performed in each snap-action test.

3. Make-before-break test (dynamic test): The make-before-break test used periodically during mechanical cycling is the same as that described in Section 5.1. The resulting charts were reviewed to determine acceptability of switch make-before-break operation.

   Note: A cycle consists of a uniform rotation of the switch from position 1 (RUN) to position 4 (SHUTDOWN) and back to position 1.

These tests were performed as outlined below:

1. Cycles 0-1000 - Snap-action test prior to any cycling
   - Contact verification test every 50 cycles (not including the 1000th)
   - Make-before-break test every 200 cycles (not including the 1000th)

2. After cycle 1000 - Contact verification test
   - Make-before-break test
   - Snap-action test
   - Contact verification test

3. After cycle 1500 - Contact verification test

4. After cycle 2000 - Contact verification test
   - Make-before-break test
   - Snap action test

5. After cycle 2500 - Contact verification test

6. After cycle 2995 - Contact verification test

7. After cycle 3000 - Make-before-break test
   - Snap-action test

Both the testing and the intervals at which each test was performed were prescribed by PP&L. In addition, the lamp array was monitored continuously during all cycling.

5.3 INTERNAL INSPECTION PROCEDURE

The reactor mode switch was disassembled one segment at a time. Measures were taken to identify all parts so that the switch could be reassembled later if necessary. During disassembly, a descriptive record was kept of any abnormalities found in the parts, operation, and construction. Contact block cam segments were compared, and differences and irregularities in the segments were recorded. Any indication of wear was also noted. Photographs were taken of the internal parts and structure of the switch, showing both normal and abnormal conditions.

Criti‹ .. measurements were made of the each contact block. These measurements included the gap between the cam follower and guide, the diameters of the cam shaft and shaft guide aperture, and the degree of the radial twisting of the cam shaft.

5.4 WEAR CHARACTERISTICS EVALUATION PROCEDURE

To determine the wear characteristics of the mode switch, similar measurements were made on both the cycled reactor mode switch components and new spare mode switch parts, and comparison of these measurements was made.

6. DISCUSSION OF TEST RESULTS

6.1 INITIAL FUNCTIONAL TEST RESULTS

Mode switch Specimen No. 5898-004 and its isolation can were mounted in the test panel, and the switch was wired to the test circuit. Fifty switch cycles were executed by moving from position 1 to position 4 and back to position 1. Although the procedure did not require the monitoring of the switch during this initial cycling, the lamp array was used to observe the switch operation.* The switch had a solid feel and a positive switching action; however, some play was noticeable in the lock assembly. No closing of extra contacts occurred, even with slight overtravel and undertravel of the switch handle.

The make-before-break switch logic was monitored and recorded on an eight-channel stripchart recorder. A make-before-break time overlap was found for all contacts in both directions of switch rotation. However, this overlap was short (approximately 1 millisecond) for most contacts when changing from position 4 to position 3 and from position 3 to position 2. The time overlaps for the other transfers averaged about 2 to 3 milliseconds. In no case during functional testing did a break-before-make condition arise. No improper operation of the switch occurred during the initial functional testing.

6.2 MECHANICAL CYCLE TESTING

The lamp array was used to monitor contact positions throughout the mechanical cycling tests. During cycle 17 of the first snap-action test, the lamp for contact (19, 20) failed to light when the mode switch was rotated from position 3 to position 2, indicating that an open circuit condition had occurred. The following actions were taken to investigate the possible cause of this anomaly:

- o The bulb on the lamp array corresponding to contact (19, 20) was tightened; contact (19, 20) still indicated open.

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* FIRL monitored the lamp array whenever the switch was cycled throughout the entire test program.

- o The power supply was increased from 100 Vdc to 115 Vdc; contact (19, 20) still indicated open.
- o The bulb was replaced with a bulb that was proven to be working; contact (19, 20) still indicated open.
- o Cycle 17 was completed by moving the mode switch to position 1.
- o During cycle 18, contact (19, 20) was closed while the switch was moved from position 1 to position 2 but open when the switch was moved from position 3 to position 2.
- o Cycle 19 was performed. Contact (19, 20) closed properly in both the counterclockwise and clockwise directions.

After cycle 25, contact resistance measurements were taken. The readings for contacts (19, 20) and surrounding contacts were within the same range. The 50 cycles of the snap-action testing were completed without recurrence of the anomaly.

While the mode switch was moved slowly from position 2 to position 1 on cycle 572, contact (25, 26) failed to close. The first three investigative actions used during cycles 17 and 18 were repeated. Contact (25, 26) remained open. A contact resistance measurement verified that the contacts were open and that the test circuit was not the cause of the problem. Testing was stopped and PP&L was notified of the two anomalies. PP&L requested that FIRL attempt to repeat the anomaly. Contact (25, 26) again failed to close when moving from position 2 to position 1. PP&L directed that the testing continue and that further anomalies continue to be fully documented.

The anomaly occurred again during cycles 576 and 580. Contact (25, 26) failed to close when the switch was moved from position 2 to position 1. No other open contact anomalies occurred during the remainder of the 3000 switch cycles performed.

Several other observations were made concerning the mode switch. After approximately 1600 cycles, the mode switch began to make squeaking noises, primarily in the clockwise direction. These noises were probably attributable to a plastic-to-plastic rubbing of rotating switch internals.

A hesitation in the switch motion began to occur after approximately 1800 cycles. The problem occurred only when the mode switch was moved from position 4 to position 3 or from position 1 to position 2. It appeared as though a false detent was forming. Contact (7, 8) would remain closed when the switch was in the false detent position and the key handle seemed to be in position 3. The false detent position could only be obtained when using a slow actuation motion. In the false detent position, the key handle could not be removed. Both false detents became more noticeable as the cycling continued.

Following completion of the cycling, the make-before-break test stripcharts were reviewed. As with the initial make-before-break test performed during functional testing, make-before-break time overlap existed for all contacts in both switch rotation directions. The changes from position 4 to position 3 and from position 3 to position 2 showed a 1 millisecond time overlap. The other contacts had a 2 to 3 millisecond average time overlap. At no time was a break-before-make condition be observed.

6.3 INTERNAL INSPECTION AND SPARE PARTS INSPECTION

6.3.1 Internal Inspection of Mode Switch

Before the mode switch was disassembled, the isolation can was removed. No noticeable debris was present inside the isolation can. The lead wires were removed from the switch, and it was discovered that ring lugs were used for the connectors. None of the switch terminals were found to be loose.

The switch was then disassembled segment by segment until the first contact block segment was reached [contacts (29, 30), (31, 32), red cam]. While moving the switch from position 4 to position 3 and watching the cam-to-cam follower action, it was determined that the "hang-up" or false detent condition occurs when the cam follower does not ride up the entire slope of the cam surface but rather sticks just before reaching the outer cam surface. In Figure 2, this can be visualized as a counterclockwise rotation of the cam until the top contacts are closed and the leading slope of the cam is driving the lower cam follower and contacts to the open position. When this cam was removed, it was noted that the slope surfaces appeared to be rough. Likewise, the first green cam contact block [contacts (25, 26), (27, 28)] exhibited a similar false detent when the mode switch was being moved from position 1 to position 2. Its cam also had rough slope surface conditions. As disassembly progressed, it was not possible to produce the false detent condition. The spring force in the detent mechanism was sufficient to overcome the summation of remaining cam edge friction.

Inspection of the [(29, 30), (31, 32)] contact block segment showed that it had "flashing" (excess material which remains after the injection molding process) trimmed from the cam shaft aperture. The removal of the flashing appeared as if it had been accomplished with a knife. (Further disassembly revealed that contact block segment [(9, 10), (11, 12)] also had flashing removed in a similar manner.) When segment [(29, 30), (31, 32)] was opened, a small piece of plastic was found; however, the location or place of origin inside the segment prior to opening the segment could not be determined. This piece of plastic was placed in the cam follower to cam follower guide gap in an attempt to produce a binding which would account for the open contact anomaly (see Section 6.2). No binding occurred.

Further disassembly of the switch revealed that there was no evidence of slot wear on any of the segments. No wear was evident on any of the cam followers. Cam follower (7, 8) was found to be rough and porous. This piece seemed to be poorly molded as opposed to damaged in use. In any event, it did not affect switch operation.

Other measurements were made on the switch segments. Angular range measurements in each switch position at various contact block segments were performed. The average angular range measurements for this mode switch were between ±2 to 3 degrees. The unmodified mode switch that had failed in service varied ±10 degrees. This is a significant improvement. The majority of the handle play is located at the coupling shaft (plastic) to torsion shaft (metal) connection. The torsion shaft to detent mechanism connection was tight and the detent mechanism was found to be working properly.

The width of the cam follower gap was found to be less than that of the original mode switch that had failed in [illegible]. This represents an improvement and reduces the tendency [illegible] follower/contact arm cocking, which was cause for concern in the [illegible]tch. (See Section 6.4 for measurements.) The average cam [illegible]ures on the modified mode switch are slightly larger than those [illegible]odified mode switch. This, combined with smaller average cam shaft di[illegible]ers, produces a larger clearance in the new switch.

Each cam was viewed with the optical comparator, and an enlarged tracing of both the front and back of each cam was prepared. A comparison of like cams using the optical comparator showed very good uniformity of shape. It was also noted that all cams had an "O" stamped on the reverse side of the cam. The slopes of both green and red cams appeared to be rough and the corners rounded slightly. A further microscopic analysis confirmed this observation and also showed that partially loosened or flaking material was present on these surfaces. The roughness appears to be caused by punching or machining of the cams at time of manufacture. The loosened and flaking material appears to be caused by the rubbing of the cam follower on the cam slopes, which scrapes the areas already weakened by the machining. The scraped material flakes after repeated rubbing; however, the flakes appear to remain attached to the cams. It should be noted that these flakes are microscopic in size and do not result in significant wear areas.

6.3.2 Mode Switch Spare Parts Inspection

Four spare mode switch parts were received (FIRL Speciment Nos. 5898-005A, B, C, D): a detent mechanism, a contact block segment (complete with contact arms, springs, and followers), a red cam, and a green cam.

Measurements similar to those on the used switch internals were recorded for the spare contact block segment. Flashing had been removed from the cam shaft aperture; however, no pieces of debris were discovered in the segment. The detent mechanism had a slight coating of lubricant on both ball bearings. Enlarged tracings of the front and back of each cam were prepared. The slope surfaces of the cams were rough. Both cams had an "O" stamped on one side.

While performing the microscopic inspection of the spare cams and some cams from the tested switch, a small flake of plastic* was removed from a red cam slope surface from the tested switch. To determine whether or not the flake of insulating material could cause the open contact anomaly, further testing was undertaken. Using the spare contact segment, the flake was carefully placed on the contact surface and the segment was wired in series with a light. Depending on the placement of the flake, the contacts could be open or closed circuited with the contacts in the closed position. The nature of the moving contact is such that it does not always touch the stationary contact in the same place; therefore, at times it rested on the flake and at others proper contact was made. With the flake causing an open condition, even an increase in voltage to 170 Vdc (the peak on the 120 Vac waveshape), did not cause the contacts to conduct. Another observation was made while applying a lifting force to the follower simulating that which would be applied by a cam in rotation. It was found that the contacts could be open with one direction of simulated cam rotation and closed in the other. These results were repeatable with the segment in any orientation.

After completion of the above tests, the tested mode switch was reassembled. However, prior to installing the last contact block segment [contacts (29, 30), (31, 32)], two small pieces of plastic that were cut from the edge of the spare segment were placed inside (one each on contacts 30 and 32). This test was performed to determine if flashing material could also be a source of the open circuit conditions. Prior to the completion of assembly, the contacts were verified to be open. The block was installed and assembly completed. In the horizontal position, the switch was cycled; in position 3, contact (29, 30), which had previously been verified to be open circuited, was now closed. The switch was placed in position 4 and contact (31, 33) remained open. The switch was cycled between positions 3 and 4 four more times. Each time contact (31, 32) remained open, although the light did blink on momentarily, indicating that the contacts had closed for an instant.

*The dimensions of the flake were measured with a scanning electron microscope (SEM). The length was 1.5 mm, the width was 0.72 mm, and thickness was 0.127 mm.

The circuit polarity was reversed and the switch completely cycled three times. Contact (31, 32) remained open in position 4. The switch was then inclined to 45°, and after the fifth complete cycle, contact (31, 32) closed in position 4, indicating that the particle of plastic had moved off of the contact. The switch was partially disassembled and both pieces of plastic were removed. The mode switch was reassembled and removed from the test circuit.

6.4 WEAR CHARACTERISTICS EVALUATION

The wear characteristics of the mode switch were evaluated by comparing the mode switch parts after 3000 cycles to the new spare mode switch parts.

The widths of the spare cam followers (0.155 in) fall within the range (0.154 in to 0.157 in) of the used cam followers. There was little indication of wear on the followers or in the cam follower guides on the cycled switch. The cam follower gap of the spare segment (0.012 to 0.013 in upper, 0.018 in lower) falls within the range of the used segments (0.006 in to 0.015 in upper, 0.011 in to 0.025 in lower). The gaps are sufficiently large to prevent cam follower binding but still allow for slightly cocking to occur.

The relative size of the cam shaft aperture in the contact block segment was reasonably uniform. The used segments ranged from 0.479 in to 0.485 in; the spare segment measured 0.479 in. There were no signs of wear on the apertures or on any portion of the cam shaft. It was also noted that the three segments whose cam shaft apertures measured 0.479 in (two used segments, one spare segment), were the three segments that had flashing removed from the aperture surface. This trimming process is a potential source of debris in the switch.

Both detent mechanisms were in good shape. The lubricant was no longer visible in the used mechanism. The fiber insert which provides the female connection for the torsion shaft showed no sign of wear.

Both used and new cams had rough slope surfaces and material flaking was evident on the used cams. This material flaking is potential source of debris in the switch. However, no indication of such debris was found in the switch at disassembly. The used green cams were very close in size and shape to the spare green cam as viewed with the optical comparator. However, the spare red cam was different from the red cams used in the switch. As illustrated in the optical comparator tracing (Figure 5), three of the four slopes match well. The fourth slope on the used red cam is steeper and its corresponding upper dwell is longer than the spare red cam. Some minor wear was evident on cycled switch cams. The wear occurred on the high spots of the rough slope surfaces and on the cam edges.

6.5 ESTIMATION OF MODE SWITCH MECHANICAL LIFE

During functional testing and mechanical cycling of mode switch Specimen No. 5898-004, the switch was cycled approximately 3200 times. During the mechanical cycling, the switch began to exhibit a potential for retaining position in false detent locations between positions 4 and 3, and between positions 2 and 1. In these false detent positions, contacts could close that were supposed to be open. The handle of the switch had to be turned slowly to attain these false detent positions. The false detent would probably not occur if the switch were operated at normal rates of rotation. However, since the false detent was recognized during testing, the possibility of occurrence during plant operation exists. To avoid this condition, which appears to be wear-related, and to account for manufacturing variation from switch to switch, the mechanical life should be limited to a value substantially less than 1800 cycles, the point at which the false detent first occurred during testing. Based on judgment, FIRL recommends a mechanical life of no more than 1000 cycles.

The above recommendation assumes that the open contact anomalies that occurred during the mechanical cycling test are acceptable during plant operation or that such conditions can be eliminated. During testing, an open circuit condition occurred six times during 3200 cycles. If an instance of an open contact is not acceptable and such conditions cannot be eliminated, the switch would not be acceptable for service. The condition appears to be related to loose insulating material from manufacture of the switch lodging on a contact surface at random times. The time of first occurrence during actual

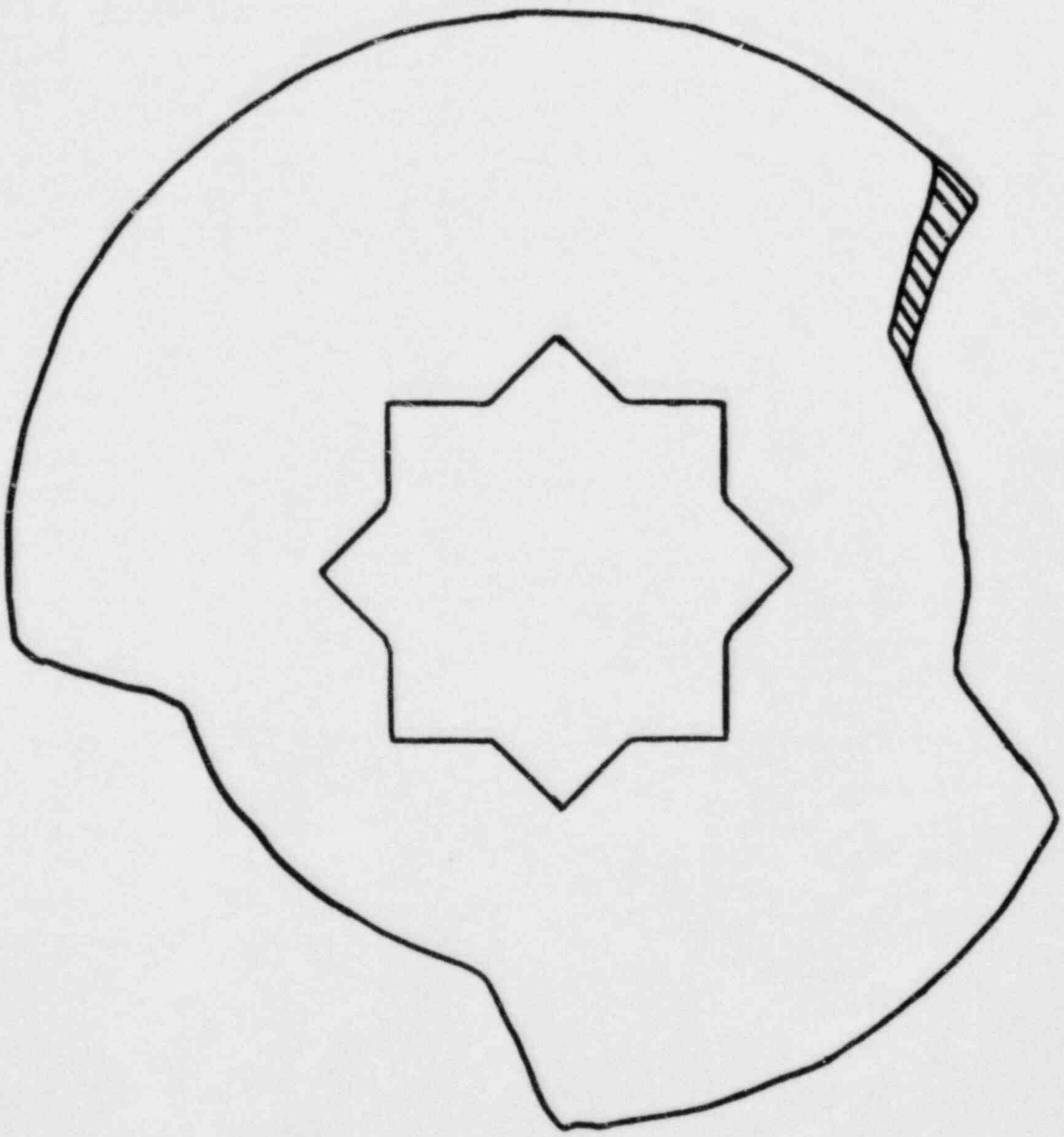

Figure 5. Comparison of Red Cam [(29, 30), (31, 32)] and Spare Red Cam

operation cannot be estimated; on the tested switch, it occurred after 17 cycles of mechanical testing. The potential for open contacts can be reduced by taking additional steps during manufacture to assure that no loose plastic fragments remain in the switch when assembled. Although the source of insulating fragments may have been from flaking of material from cam slopes, FIRL discounts the cams as a source of the insulating material because the flakes remained attached to the cams and no evidence of this material was evident in the segments during disassembly. The one fragment of insulating material found in the switch during disassembly appeared to be flashing material from a contact block segment.

7. CONCLUSIONS

The modified mode switch, FIRL Specimen No. 5898-004, performed significantly better than did the unmodified mode switch from Susquehanna Unit 1, and the problems discovered during the testing of the unmodified switch have been resolved. In particular, the following modifications account for the majority of the improvement in the operation of the switch:

- o increased uniformity between like cams produced a better switching action
- o epoxying the stationary contacts to the contact block segment widened the distance between stationary and moving contacts when the switch is in the open position
- o increasing the thickness of the torsion shaft assembly reduced the clearances in the detent mechanism and consequently reduced the angular play in the switch
- o reducing the gap between the cam follower and its guide reduced cam follower cocking.

Two potential problems were noted during mechanical cycling. These were the occurrence of an open contact six times during the 3200 cycles of operation and a tendency for a false detent to occur after 1800 cycles, which could allow extra contacts to be closed. The most probable cause of the open contact condition is small particles of plastic material from switch construction lodging on a contact surface. Another possible source of the plastic particles is from flaking of cam slope surfaces; however, flaking is considered to be a low probability source because the flakes were found to be attached to the cams and were not accumulating in the switch sections.

The effect of the false detent condition is to limit the number of cycles allowable for the switch during in-plant use. Under the assumption that an occasional open contact condition is acceptable or can be eliminated by additional cleanliness during manufacture, FIRL concludes, based on engineering judgment, that the mechanical life of the switch should be limited to no more than 1000 cycles. This limit is recommended to account for variations in manufacture from switch to switch, and to preclude the tendency for a false detent condition to occur.

8. RECOMMENDATIONS

Based on its testing of the reactor mode switch and evaluation of the wear characteristics, FIRL makes the following recommendations.

1. Provided that a random occurrence of an open contact condition is acceptable during operation, the mechanical life of the switch should be limited to 1000 cycles.

2. To reduce the likelihood of open contact conditions, the manufacturer should be requested to take extra care in removing extraneous plastic particles from the switch segments during assembly.

3. To further reduce the possibility of a false detent condition during plant operation, the reactor operators should be informed that the mode switch key handle cannot be removed from the switch if the switch is in the false detent position. Key removal should be used as a means of verifying correct switch position.

APPENDIX A

PENNSYLVANIA POWER AND LIGHT
LICENSEE EVENT REPORT AND NONCONFORMANCE REPORT

Franklin Institute Research Laboratory, Inc.
A Subsidiary of The Franklin Institute
20th and Race Streets, Phila., Pa. 19103 (215) 448-1000

Pennsylvania Power & Light Company
Two North Ninth Street • Allentown, PA 18101 • 215 / 770-5151

March 23, 1983

Mr. R.C. Haynes
Regional Administrator, Region I
U.S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, PA 19406

SUSQUEHANNA STEAM ELECTRIC STATION
LICENSEE EVENT REPORT 83-043/01P-0
ER 100450 FILE 841-23
PLA- 1590

Dear Mr. Haynes:

This transmission confirms the verbal notification of March 22, 1983, by D.J. Steffenauer to J.G. McCann of your staff, concerning the failure of the "D" channel of the reactor protection system to actuate when the reactor mode switch was turned from startup to shutdown. The reactor was in Operating Condition 2, hot shutdown, when this occurred. The mode switch had been placed in the startup position to allow a surveillance to be performed on the scram discharge volume vent valves.

This condition is considered reportable in accordance with Technical Specification 6.9.1.8.a.

H. W. Keiser
Superintendent of Plant-Susquehanna

cc: Director, Office of Inspection & Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Director, Office of Management & Program Control
U.S. Nuclear Regulatory Commission
Washington, DC 20555

PP&L

NONCONFORMANCE REPORT

1. NCR NO. 83-234	2. NO. TAGS 1

NOTE: INSTRUCTIONS FOR COMPLETING NCR ARE ON REVERSE SIDE

3. ITEMS DESCRIPTION/LOCATION
Reactor Mode Selector Switch
(S1) on 1C651

Tag Location: On switch (switch located in Elec.Maint.)

4. DWG/SPEC/PART/REV. NO.
8856-M1-C72-22(10)-3

5. SYSTEM NO. 58

6. UNIT NO. 1

7. SUPPLIER/CONTRACTOR/SECTION
GE

8. NONCONFORMING CONDITION

Contacts 13 & 14 and contacts 29 & 30 on switch S1 operate intermittently when S1 is placed into the shutdown mode resulting in a half scram in lieu of a full scram. This renders the quality of switch S1 on 1C651 as indeterminate.

9. REPORTED BY
S.Poole
SIGNATURE [signature] DATE 5/23/83

10. DISPOSITION
☒ CORRECT CONDITION
☒ DETERMINE CAUSE
☐ PREVENT RECURRENCE

11. STOP WORK
☐ YES ☒ NO
MANAGER—NQA N/A DATE

12. ISSUED BY [signature] 5/23/83
SUPERVISOR—QC DATE

13. RESPONSIBILITY
☒ PLANT STAFF SECTION PENG ☐ NPE ☐ OTHER

14. DISPOSITION
☐ REWORK ☐ REJECT ☐ USE-AS-IS ☐ REPAIR ☐ OTHER

SIGNATURE DATE

15. REPORTABILITY EVALUATION
☐ NOT REPORTABLE
☐ REPORTABLE SIGNATURE DATE

16. DISPOSITION APPROVAL
SECTION HEAD DATE

17. NPE APPROVAL
SIGNATURE DATE

18. DISPOSITION RESULTS/ACTION TAKEN

19. QC ACCEPTANCE
SUPERVISOR - QC DATE

20. TREND CODE 2E

FORM NDI-QA-8.1.5 A, REV. 0

APPENDIX B

CHRONOLOGY OF PROJECT EVENTS

Franklin Institute Research Laboratory, Inc.
A Subsidiary of The Franklin Institute
20th and Race Streets, Phila., Pa. 19103 (215) 448-1000

Susquehanna Unit 1 Reactor Mode Switch Functional Testing

Chronological List of Events
(Mode Switch Procedure Execution Documentation)

Date	Test Specimen	Description of Event
9-30-83	--	PP&L service order issued.
9-30-83	--	FIRL received old style reactor mode switch (which had been previously tested by FIRL), a segment of the new style switch, and a "GE Cam Switch Assembly" drawing in order to facilitate test preparations.
10-20-83	5898-002	First new style reactor mode switch received from PP&L.
10-21-83	5898-002	MSP No. 1 - Receipt Inspection Procedure (QAP 7-4, Revision 0) executed.* Inspection found key handle bent (45°) and rear cover plate cracked. Client notified.
10-21-83	5898-002	NRC No. 5898-NCR-01 issued.**
10-21-83	5898-002	Switch returned to GE-San Jose per client request in telephone communication (Corrective Action Report CAR No. 5898-CAR-01 prepared; replied to and signed by client on 11-7-83).***
10-24-83	5898-001	Second new style reactor mode switch received from GE.
10-24-83	5898-001	MSP No. 1 (QAP 7-4, Revision 0) executed. Inspection found key handle bent 5°. No other apparent damage.
11-2-83	5898-001	MSP No. 2 - Functional Test Procedure (QAP 14-5, Revision 0) executed. Anomaly in switch operation occurred. Closure of contact [7,8] in position 3. Client notified.

*MSP = Mode Switch Procedure; QAP = Quality Assurance Procedure
**NCR = Nonconformance Report
***CAR = Corrective Action Request

Susquehanna Unit 1 Reactor Mode Switch Functional Testing

Date	Test Specimen	Description of Event
11-3-83	5898-001	NCR No. 5898-NCR-02 issued.
11-3-83	5898-001	CAR No. 5898-CAR-01 issued to PP&L.
11-4-83	5898-001	CAR No. 5898-CAR-02 prepared.
11-4-83	--	MSP No. 2-NQA (QAP 14-6, Revision 0) issued.
11-7-83	5898-001	Demonstration of switch anomaly for GE, Gould, and PP&L representatives. Switch disassembled. One red cam found to be installed backwards.
11-7-83	5898-001	Second new style reactor mode switch returned to GE per CAR No. 5898-CAR-02 disposition.
11-7-83	--	Received revised "GE Cam Switch Assembly" drawing, Revision A (Green and Red Cam I.D.) from Gould (hand-delivered).
11-18-83	5898-003	Third new style reactor mode switch received by FIRL. Hand-carried by GE-San Jose personnel.
11-18-83	5898-003	MSP No. 1 (QAP 7-4, Revision 0) executed. Switch in good condition.
11-18-83	--	Received revised "GE Cam Switch Assembly" drawing, Revision B from Gould per letter dated 11-16-83. "O" on back of cam to assure correct installation.
11-18-83	5898-003	MSP No. 2 (QAP 14-5, Revision 0) executed. GE and Gould present for testing, but PP&L was not present. During step 4.11 (switch handle rocking), an anomaly was observed. Contacts [7,8] and [15,16] could be closed in position 3 on slight overtravel. The Project Engineer notified PP&L.
11-18-83	5898-003	NCR No. 5898-NCR-03 issued.
11-18-83	5898-003	CAR No. 5898-CAR-03 issued.

Susquehanna Unit 1 Reactor Mode Switch Functional Testing

Date	Test Specimen	Description of Event
11-21-83	5898-003	Demonstration of switch anomaly for GE, Gould, and PP&L representatives. Fact finding for PP&L to make further determination of problem and possible solutions. GE stated that problem would disappear if test fixture resembled the actual plant installation.
11-21-83	5898-003	PP&L signed NCR No. 5898-NCR-03.
11-21-83	5898-003	PP&L replied to and signed CAR No. 5898-CAR-03. Switch to be retested in different test fixture with isolation can and wiring harness installed.
11-30-83	5898-003	CAR No. 5898-CAR-03 re-issued to PP&L due to change in PP&L reply (test to be performed without isolation can).
11-30-83	5898-003	Testing of reactor mode switch in simulated in-plant test mounting fixture. Prior to testing, the switch was modified by GE/Gould. A new shaft was installed and the internal e-ring was removed.
11-30-83	5898-003	MSP No. 2-2 - Functional Test Procedure (QAP 14-8, Revision 0) executed. Isolation can did not fit the switch. Switch wired without can. All parties approved wiring before testing. During step 4.9 of MSP No. 2-2, the anomaly reoccurred. Contacts [7,8] and [15,16] closed in position 3. After non-QA disassembly by Gould and reassembly using a different segment body for contact [15,16], the anomaly was still present. Contact [23,24] could also be closed at this time. PP&L stopped test.
11-30-83	5898-003	PP&L signed NCR No. 5898-NCR-04.
11-30-83	5898-003	CAR No. 5898-CAR-04 issued.
11-30-83	5898-003	PP&L released switch to GE/Gould for redesign and retesting.

Susquehanna Unit 1 Reactor Mode Switch Functional Testing

Date	Test Specimen	Description of Event
12-21-83	5898-004	Fourth new style reactor mode switch received by FIRL. This switch was modified by GE/Gould and all changes were approved by PP&L prior to receipt by FIRL. Switch arrived with an isolation can and lead wires installed.
12-21-83	5898-004	MSP No. 1 (QAP 7-4, Revision 0) executed. Switch was in good condition. Isolation can cover removed/replaced during inspection.
12-21-83	5898-004	MSP No. 2 (QAP 14-5, Revision 0) executed. Switch performed satisfactorily.
1-9-84	5898-004	MSP No. 4-1 (QAP 14-10, Rev. 0), "Mechanical Life Test," begun. Anomaly noted on Cycles 17 and 18. Contact [19,20] failed to close. Client notified. Similar problem occurred with contact [25,26] on cycle numbers 572, 573, 576, and 580. Also noted was a "hanging up" in the switch while moving the switch from position 4 to position 3. It appears that wear has created a false detent. A similar, but much less severe, situation occurs while moving from position 1 to position 2.
1-11-84	5898-004	MSP No. 4-1 completed. No other problems occurred. "Make-before-break" switch logic occurred correctly.
1-12-84	5898-004	MSP No. 3-1 (QAP 12-2, Rev. 0), "Disassembly and Inspection," begun. Initial inspection included removal of isolation can and search for cause of anomaly noted in MSP No. 4-1. Angular range measurements taken.
1-13-84	5898-005	Reactor mode switch spare parts received from GE via Federal Express
1-17-84	5898-004	MSP 3-1 completed. All data taken and optical comparator tracings of each cam made.

Susquehanna Unit 1 Reactor Mode Switch Functional Testing

Date	Test Specimen	Description of Event
1-17-84	5898-004	MSP 5 (QAP 7-5, Rev. 0), "Reactor Mode Switch Spare Parts Receipt Inspection and Measurement," executed. Optical comparator tracings of each cam received made and measurements made on the segments received.
1-24-84	5898-004 5898-005	MSP 6 (QAP 14-10, Rev. 0), "Reactor Mode Switch Wear Characteristics Evaluation," begun. Permission to perform additional testing requested by FIRL.
1-25-84	5898-004 5898-005	PP&L decided not to proceed with additional cycling.
1-25-84	5898-004 5898-005	MSP 6 completed. No significant wear evident. Spare RED cam is of a different shape than used RED cams. Anomaly that occurred during MSP 4-1 was probably caused by a piece of non-conducting debris on the contact suface. The machined cam surface and the trimmed cam shaft aperature are considered the most likely sources of the debris. During further testing with a small plastic chip the anomaly was repeated. Client notified of completion of all procedures.

APPENDIX C

LIST OF TEST INSTRUMENTS

APPENDIX C

LIST OF TEST INSTRUMENTS

A. Calibrated Equipment

1. Hewlett Packard
   8-channel Strip Chart Recorder
   Sanborn Model 7700
   Serial No. 421-7400
   Calibration Date: 11-9-83
   Range: 1 mV/division - 1000 mV/division
   Chart Speed: 0.25 mm/second - 100 mm/second

2. Sorenson (A Division of Raytheon)
   Power Supply
   Model M5 DCR150-3B
   Serial No. 1179
   U.S. Equipment Rental No. 70257
   Performance Check by: U.S. 10 on 8-24-83
   Input: 103-127 V
   50-63 Hz
   8.5 amps
   Output: 0-150 Vdc
   0-3 amp dc

3. Fluke
   Digital Multimeter
   Model 8800A
   Serial Number 36076
   Calibrated: 5-31-83

B. Other Test Equipment

1. Test circuit containing:

   a. eight 3-position toggle switches

   b. 16 lights

   c. eight 10-contact terminal strips

2. Test mounting fixture:

   -constructed of wood and aluminum
   -angled 42° from the horizontal
   -mounting plate per GE specification

3. Starret micrometer

4. Snap-on feeler gages, Model FB-300A

5. Mitutoyo telescoping gages, Mod l H Code NO. 155-903

6. Optical Corporator