General Information or Other (PAR) Event # 43663

Rep Org:	ABB INC (CBTS)	**Notification Date / Time:**	09/25/2007 10:17 (EDT)
Supplier:	ELECTROSWITCH CORP.	**Event Date / Time:**	09/25/2007 (EDT)
		Last Modification:	09/25/2007

Region:	1	**Docket #:**	
City:	FLORENCE	**Agreement State:**	Yes
County:		**License #:**	
State:	SC		

NRC Notified by:	TERENCE MALLOY	**Notifications:**	MEL GRAY	R1
HQ Ops Officer:	JOE O'HARA		BRIAN BONSER	R2
Emergency Class:	NON EMERGENCY		THOMAS KOZAK	R3
10 CFR Section:			CLAUDE JOHNSON	R4
21.21	UNSPECIFIED PARAGRAPH		PART 21 GROUP	

POTENTIAL FAILURE TO COMPLY WITH SPECIFICATION CONFIGURATION

Two Electroswitch P/N 70034K01 L-2 Auxiliary Switch Assemblies supplied to First Energy Perry Nuclear under purchase order #45151322 were taken from a spare parts inventory and were missing a spacer bushing (P/N 650311A39) that holds the rotary contact in position. First Energy Perry Nuclear reported this under OE25399. The absence of the bushing could allow the contact to move out of position, resulting in a loss of electrical contact. The presence or absence of the spacer cannot be determined from electrical or functional tests of the switch, because the electrical contact may not be displaced from its correct operating position.

The two nonconforming switch assemblies were not installed or placed in operation. Plant procedures require all switches to be opened and inspected prior to installation.

ABB has taken or is taking action to quarantine and physically inspect all available on-hand inventory, notify all customers, revise dedication procedures, and review historical procurement and customer records.

****

IE19

NRR

FAX

ABB Inc.
2300 Mechanicsville Road
Florence, SC 29501
843-413-4720
www.us.abb.com

To: Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Fax number: 301-816-5151

From: TERENCE MALLOY
Fax number: 843-413-4853

Date: 9/25/2007

Regarding: 10CFR Part 21 Notification

Phone number for follow-up:
(301) 415-6030/301-816-5100

The attached notification of failure to comply or existence of a defect and its evaluation is provided as specified by 10 CFR Part 21 para. 21.(d)(3)(i).

ABB

September 25, 2007

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001
FAX 301-816-5151

Subject: 10CFR Part 21 Notification of Deviation re. Electroswitch Corp. P/N 700034K01 L-2 Auxiliary Switch Assemblies

This letter provides notification of a potential failure to comply with specification configuration associated with Electroswitch P/N 700034K01 L-2 Auxiliary Switch Assemblies procured as a commercial grade item from Electroswitch and dedicated by ABB (CBTS). Information is provided as specified in 10CFR21 para. 21.21(d) (4).

1. Notifying activity: Thomas Rassau, Managing Director, ABB(CBTS), 2300 Mechanicsville Road, Florence, SC 29501
2. Identification of the Subject component: Electroswitch P/N 700034K01 Auxiliary Switch Assembly, identified as production lot 0516, procured as a commercial grade item.
3. (75) Switch assemblies underwent commercial grade dedication at the ABB (CBTS) Florence, SC facility in March & April, 2005 and were supplied to First Energy Perry Nuclear under their Purchase Order #45151322 (ABB SO #CCN3517).
4. Nature of the deviation: First Energy Perry reported two switch assemblies were taken from spare parts inventory that were missing a spacer bushing (P/N 650311A39) that holds the rotary contact in position. They also reported this under OE25399. Refer to Figure 1, below:

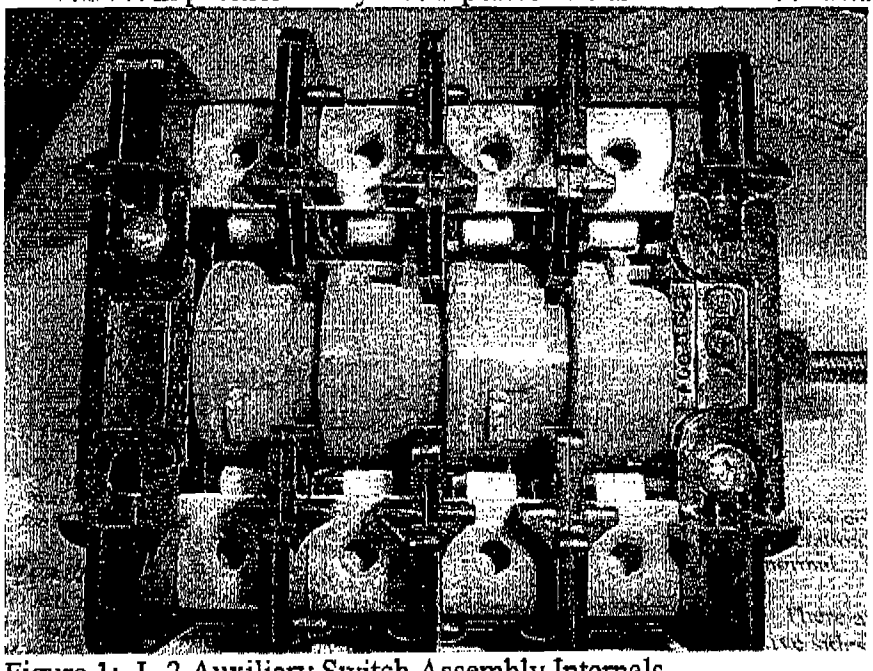

Figure 1: L-2 Auxiliary Switch Assembly Internals

ABB Inc.

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CIRCUIT BREAKER TECHNOLOGY SOLUTIONS

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The rotating assembly in the switch is made up of a shaft on which is mounted a series of electrical contacts in a molded plastic frame, with insulating spacer bushings positioning the contacts inside the frame. As the switch is rotated, the contacts will mate or break with the stationary contact terminals. Figure 1 shows that the spacer bushing is missing from the contact second from the left side. The absence of this bushing could allow the contact to move out of position, resulting in the loss of electrical contact, as depicted in Figure 1.

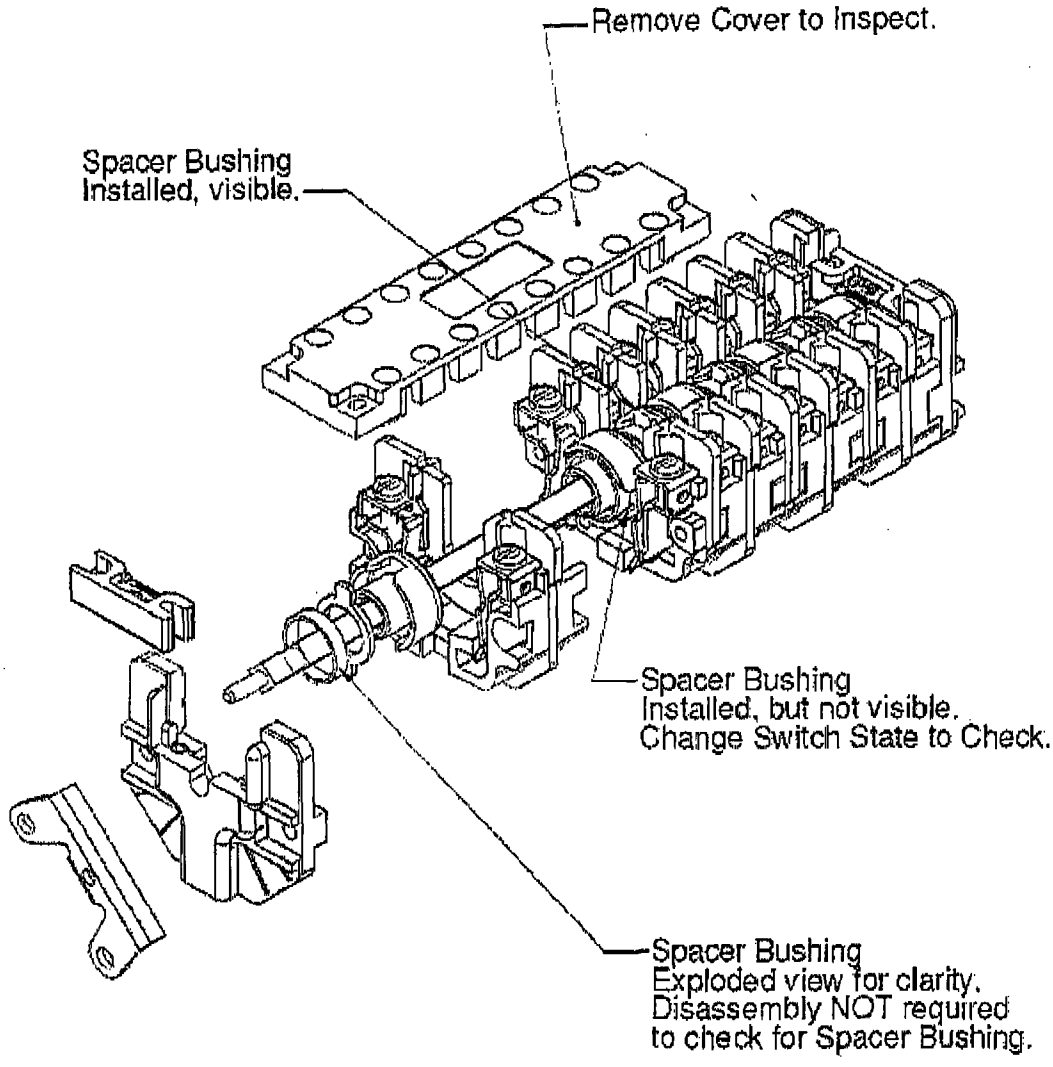
This style of L-2 auxiliary switch assembly is used on ABB HK, K-line, VHK, and VHKX Low Voltage and Medium Voltage circuit breaker assemblies. The auxiliary switches are used to provide 'a' and 'b' type contacts that are used in breaker control and trip circuitry, as well as other functions as determined by the operator. The presence or absence of the spacer bushing cannot be determined from electrical or functional tests of the switch, because the electrical contact may not be displaced from its correct operating position.

5. Initial report of the potential nonconformance was received from First Energy Perry Nuclear via email on August 13, 2007. The email reported that two 4-stage auxiliary switch assemblies were found to be missing spacers when taken out of inventory. These switch assemblies were procured in March and April 2005 from Electroswitch Corp, dedicated at ABB(CBTS), and shipped to First Energy under their Purchase Order #45151322.
6. (261) 4-stage auxiliary switch assemblies have been provided under (48) different Purchase Orders in the last seven years to activities subject to this regulation. Six- and eight-stage L-2 auxiliary switch assemblies have also been used and provided as safety-related components, which are designed and assembled in similar fashion as the 4-stage switch assemblies. Per Electroswitch, there are a total of (40) different switch part numbers in this series of switches. See Attachment 1 for a listing of all similar part numbers.
7. Corrective actions include:
    a. Quarantine and physical inspection of all available on-hand inventory for the presence of spacer bushings. Action complete; (133) 4-stage switch assemblies were visually inspected for the presence of the spacer bushings with no deficiencies noted (P/N 700034K01). (50) 8-stage switch assemblies were visually inspected for the presence of the spacer bushings with no deficiencies noted (P/N 700038K03). (26) 8-stage switch assemblies (all short contacts) were visually inspected for the presence of the space bushings, with one switch (date code 0729) missing one spacer bushing.
    b. Notification of the potential existence of this deviation to affected customers. (to complete 9/30/07)
    c. Revise dedication procedures to require physical inspection of the switch internals to confirm presence of the spacers. (complete 8/31/07)
    d. Review historical procurement and inspection records associated with the subject part and vendor. (Action complete – no previous defects were identified in the last seven years, out of (1585) units received for both commercial and safety-related applications. Electroswitch reported that no switches were returned in the last 12 years due to missing bushings.)
    e. Review historical records of customer field issues to determine if similar nonconformances were previously identified. (Action complete – no missing spacers were previously reported)

f. Follow-up with Electroswitch to determine how future escapes can be prevented and other actions warranted to prevent recurrence. (Action complete 8/31/07 – See Attachment 1)
g. Performance of Commercial Grade Survey at Electroswitch to determine if Electroswitch should remain on ABB (CBTS) Approved Vendor List. (Action complete 9/4/07 – three findings noted related to Calibration deficiencies, subcontracted Silver Plating Purchase Order discrepancies, and Nonconforming Material documentation.)
h. Electroswitch is modifying assembly routing instructions to perform a visual inspection of the switch internals prior to installing the switch cover. (Action to complete 9/30/07)
i. A test was performed to determine if a circuit breaker auxiliary switch assembly would fail if a spacer bushing was missing. Results of the testing are included in Attachment 2.

8. Based on the data provided by First Energy Perry Nuclear plant, the two nonconforming switch assemblies were not installed or placed in operation. Discussion with Perry System Engineer Mahmoud Nabavighadi indicated that Perry maintenance procedures require all switches to be opened and inspected prior to installation.
Because of the large variety of wiring configurations and usages of this switch, ABB (CBTS) cannot determine if the potential for a substantial safety hazard exists at this or any other licensee's facility if a similar nonconforming switch is identified, or whether any corrective actions should be taken. Licensees are requested to evaluate the history of inspections, maintenance practices, physical locations, failures, and system configurations where the switch assembly is used to determine whether the absence of the spacer would have been previously identified. If licensees wish to physically confirm the presence of the spacers, the internals of the switch assembly may be inspected by removing two screws on the face of the switch, removing the access plate, and visually sighting the spacers while rotating the switch 90 degrees to confirm all electrical contacts have a spacer present. See drawing, below:

ABB



Typical 8-Stage K-LineType L-2 Aux. Switch
4 & 6 Stage Switches similar.
HK & Switchgear Installations use alternate crank arm.

Very truly yours,

Thomas Rassau

Thomas Rassau
Managing Director

Attachments: 1. Electroswitch Report of Corrective Action Electroswitch response to SCAR 2007054.pdf
2. L-2 Spacer Bushing Test – ABB (CBTS) Engineering Report #1VAF200012D0022

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ELECTROSWITCH • SWITCHES & RELAYS
UNIT OF ELECTRO SWITCH CORP.

180 King Avenue
Weymouth, MA 02188
Telephone: (781) 335-5200
Fax: (781) 335-4253

Six Discipline Report of Corrective Action

Customer: ABB Florence Directed To: Terry Malloy

Switch Number: 700034K01

Date Code: 0515 Quantity: 2

Return Authorization Number: 2943 Date Received: 8/22/2007

Customer's Reference:

I. Customer Remarks:

Switches found to be missing spacers along the internal contacts, resulting in the potential for the switches to either jam or not operate correctly.

II. Problem Description:

After an evaluation of both subject switches, the customer's complaint was confirmed and it was further verified that one of the four required Nylon Insulating Bushings (part # 650311A39) had not been installed in each of the two switches.

III. Root Cause:

This discrepancy was not discovered during operational testing, as the Nylon Insulating Bushings are not fully visible to the inspector through the Molding Covers and the blade fingers maintained positive contact with the terminals during testing, which resulted in a positive continuity check. The root cause for this discrepancy is due to an assembly error of not installing the Nylon Insulating Bushings in the required locations.

IV. Interim Correction Action:

All remaining inventory (Qty 24) of part # 700034K01 (date code 0733) was evaluated to ensure proper assembly. No reoccurrence of this defect was found. In addition quality records were evaluated for the last 12 years to determine the return record for this series of switches (see attached list). Analysis of this data showed that no switches were returned for missing Nylon Insulating Bushings. Only 2 returns of this switch family in 12 years were returned for contacting issues (wrong contacts and wrong rotors installed). A general

assembler checklist concerning contacts, terminals, and rotors has been developed over the years to eliminate these types of defects.

I. **Permanent Corrective Action:**

Assemblers and Inspectors will be trained to a revised process that will be added to the manufacturing order (traveler) routing, which requires the switches to have all operational testing performed prior to installing the Molding Cover (part # 700071B00). This will allow the inspector to perform a detailed visual inspection to ensure that all internal elements of the switch have been installed. Upon final acceptance, the switches will then be sent back to the assembly department to have the Molding Covers installed. Effective date of this change is date code 0738.

II. **Verification:**

Quality assurance department will verify the proper assembly of this switch series during future production runs.

John [illegible]
Signature

QA Mgr.
Title

8/31/07
Date

QC Form 74 Rev. A

pg. 3 of 3

(CHESS) Item Classes K1 TO K1 ITEM HISTORICAL USAGE REPORT-BY ITEM NUMBER 8/30/07 13.22.35 PAGE 1
SWITCHES ONLY

O ITEM P NUMBER	DESCRIPTION	IT CL	TYP	CTC CD	F L	P B	U/M	STD LOT	ROUTING	STRICT
G 321987-303	TYPE L2 SWITCH W/ LEVER,6 CONT REV.A	K1	1		R		EA	1	3	5
G 321987-304	TYPE L2 SWITCH W/ LEVER,8 CONT REV.A	K1	1		R		EA	1	3	5
G 321987-306	TYPE L2 SWITCH W/ LEVER 10CONT REV.A	K1	1		R		EA	1	3	5
G 321987-308	TYPE L2 SWITCH W/ LEVER 12CONT REV.A	K1	1		R		EA	1	3	5
G 700034X01	TYPE L2 AUX SWITCH, 4 CONT DST REV.B	K1	1		R		EA	1	6	3
G 700034X02	TYPE L2 AUX SWITCH, 4 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700034X05	TYPE L2 AUX SWITCH, 4 CONTACT REV.B	K1	1		R		EA	1	6	3
G 700034X06	TYPE L2 AUX SWITCH, 4 CONT DST REV.B	K1	1		R		EA	1	6	3
G 700034X07	TYPE L2 AUX SWITCH, 4 CONT DST REV.B	K1	1		R		EA	1	6	4
G 700034X35	TYPE L2 AUX SWITCH, 4 CONTACT REV.B	K1	1		R		EA	1	6	3
G 700034X36	TYPE L2 AUX SWITCH, 4 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700036X01	TYPE L2 AUX SWITCH, 6 CONT DST REV.B	K1	1		R		EA	1	6	3
G 700036X06	TYPE L2 AUX SWITCH, 6 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700036X20	TYPE L2 AUX SWITCH, 6 CONTACT REV.B	K1	1		R		EA	1	6	5
G 700038X01	TYPE L2 AUX SWITCH, 8 CONT DST REV.B	K1	1		R		EA	1	6	3
G 700038X02	TYPE L2 AUX SWITCH, 8 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700038X03	TYPE L2 AUX SWITCH, 8 CONT REV.B	K1	1		R		EA	1	6	4
G 700038X15	TYPE L2 AUX SWITCH, 8 CONTACT REV.B	K1	1		R		EA	1	6	3
G 700038X15	TYPE L2 AUX SWITCH, 8 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700038X16	TYPE L2 AUX SWITCH, 8 CONTACT REV.B	K1	1		R		EA	1	6	4
G 700038X17	TYPE L2 AUX SWITCH, 8 CONTACT REV.B	K1	1		R		EA	1	6	3
G 700038X51	TYPE L2 AUX SWITCH, 8 CONT REV.D	K1	1		R		EA	1	6	3
G 700038X52	L2 SWITCH, 8 CONTACT REV.A	K1	1		R		EA	1	6	5
G 700038X53	L2 SWITCH, 8 CONTACT REV.D	K1	1		R		EA	1	6	
G 700040X10	TYPE L2 AUX SWITCH, 10 CONTACT REV.A	K1	1		R		EA	1	3	4
G 700040X11	TYPE L2 AUX SWITCH, 10 CONTACT REV.D	K1	1		R		EA	1	3	3
G 700040X20	TYPE L2 AUX SWITCH, 10 CONTACT REV.D	K1	1		R		EA	1	3	5
G 700040X21	TYPE L2 AUX SWITCH, 10 CONTACT REV.D	K1	1		R		EA	1	3	5
G 700044X10	TYPE L2 AUX SWITCH, 14 CONTACT REV.D	K1	1		R		EA	1	3	4
G 700044X11	L2 SWITCH 14 CONTACT REV.D	K1	1		R		EA	1	3	4
G 700044X12	L2 SWITCH, 14 CONTACT REV.A	K1	1		R		EA	1	3	5
G 700044X13	L2 SWITCH, 14 CONTACT REV.D	K1	1		R		EA	1	3	5
G 709757T09	TYPE L2 AUX SWITCH, 6 CONTACT REV-	K1	1				EA	1		
G 709757T10	TYPE L2 AUX SWITCH, 10 CONTACT REV-	K1	1				EA	1		
G 709757T11	TYPE L2 AUX SWITCH, 10 CONTACT REV-	K1	1				EA	1		
G 709757T12	TYPE L2 AUX SWITCH, 8 CONTACT REV-	K1	1				EA	1		
G 709956T07	TYPE L2 AUX SWITCH,6 CONTACT REV.A	K1	1		R		EA	1	3	4
G 709956T08	TYPE L2 AUX SWITCH, 8 CONTACT REV.A	K1	1		R		EA	1	3	4
G 709956T10	TYPE L2 AUX SWITCH, 10 CONTACT REV.A	K1	1		R		EA	1	3	4
G 709956T12	TYPE L2 AUX SWITCH, 10 CONTACT REVA	K1	1		R		EA	1	3	4

40 ITEMS SELECTED

ABB

Mechanical Life Test

Florence Engineering Test Lab

L-2 Spacer Bushing Test

September 12, 2007

Test Report No. 1VAF200012D0022

Terry Jernigan
Lab Technician, CBTS

Jason Pugh
Test Engineer, CBTS

John Webb
Engineering Manager, CBTS

ATTACHMENT 2

On September 6, 2007, the ABB Laboratory in Florence, S.C, began a series of tests to investigate possible change of state failures in type "L-2" auxiliary switches due to the absence of spacer bushings 650311A39 (or 650306A11, which it superseded).

1 Background

Perry Nuclear power plant reported that two switches, PN 700034K01, deviated from expected configuration in the fashion stated above. These switches, which had been received as nuclear safety related, were missing one of the spacer bushings in each of the two switches reported. With the spacer bushing absent, it is possible for the rotating contact to move axially along the rotor shaft until it no longer makes contact with the stationary contacts resulting in failure of the switch.

2 Test Setup

One K-Line K800 S circuit breaker complete with 125 VDC control voltage, a standard auxiliary switch 700034K06 for internal controls and an 8-stage 700038K01 were readied by removing the switch contact covers and removing select spacer bushings from the switch (the removed spacer bushings were varied from test to test). The breaker was wired per drawing 709494. The 'a' and 'b' contacts on 700038K01 were monitored individually so that the state of each contact could be recorded and analyzed. For labeling purposes, the contacts were referred to by their corresponding wire from drawing 709494. The breaker was cycled at a rate of approximately 1 Close-Open operation per minute. A 9VDC signal was sent through each of the contacts of the 8-stage switch and monitored through the use of a LabVIEW program.

Test Equipment: ELGAR SW 5250
Gage ID: ETE-0305
Last Cal: 1/4/2007
Cal. Due: 1/4/2008

2.1 Test 1 Setup and Results

For the first test, all of the spacer bushings were removed from the 8-stage switch [Switch 'A' Date Code 0516]. It was ensured that all contacts were properly aligned before the start of the test. Test 1 consisted of a run of 50 close and open operations of the breaker. **Image 1** shows the breaker and switch under test before the start of Test 1.

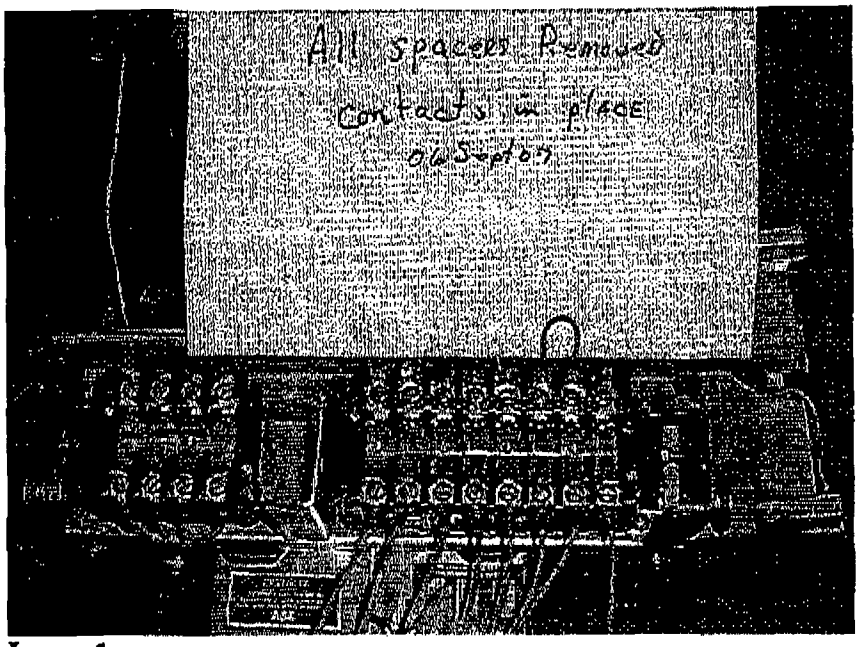

Image 1

The first failure occurred during the second cycle of the test, when contact 26 failed to register on the close and contact 20 and contact 32 failed to register on the open. The testing was paused to reset the 3 failed contacts. After two resets (with the last reset being after cycle 5 of the 50), contacts 20, 26, and 32 failed after the number of cycles as seen in **Table 1a**. Note that the blank spaces in Table 1 indicate there was no failure to register a change in state for the corresponding contact.

	Close	Open	Close	Open	Close	Open	Close	Open
	18	20	22	24	26	28	30	32
Resets	**Operations To Failure**							
1		2			2			2
2		2			2			2

Table 1a

It was then decided to refrain from resetting a contact after failure to analyze if a contact that had previously failed could indeed start properly registering the change of state once again.

The result of the remaining cycles of the test yielded the failures listed below in **Table 1b**. The failure on contact 30 resulted on the 15th cycle of the breaker. The failure of contacts 20, 26 and 32 occurred on the first open and close operation of the breaker after the second reset (above).

	Close	Open	Close	Open	Close	Open	Close	Open
	18	20	22	24	26	28	30	32
Resets	**Operations To Failure**							
3		1			1		15	1

Table 1b

None of the contacts which failed during the 50 cycles of the breaker ever came back to register the change of state properly. Once a contact failed to register, it continued to fail to register until manually reset. A picture of the four contacts, which failed, can be seen in **Image 2**.

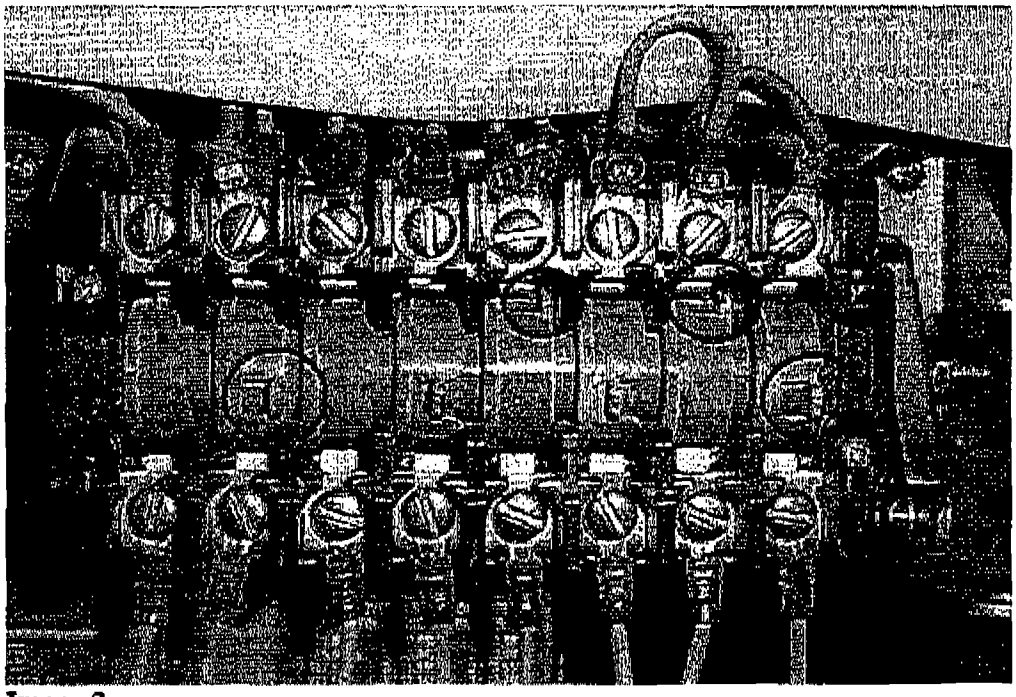

Image 2

2.2 Test 2 Setup and Results

For the second test, all spacers were again left out of the 8-stage switch and the breaker was tilted at an approximate 10-degree angle as seen in **Image 3**. This direction of this tilt was the direction that caused the contacts the greatest amount of movement axially away from the stationary contacts. The breaker ran for 50 cycles at this angle. There were no manual resets of the contact after a failure was registered.

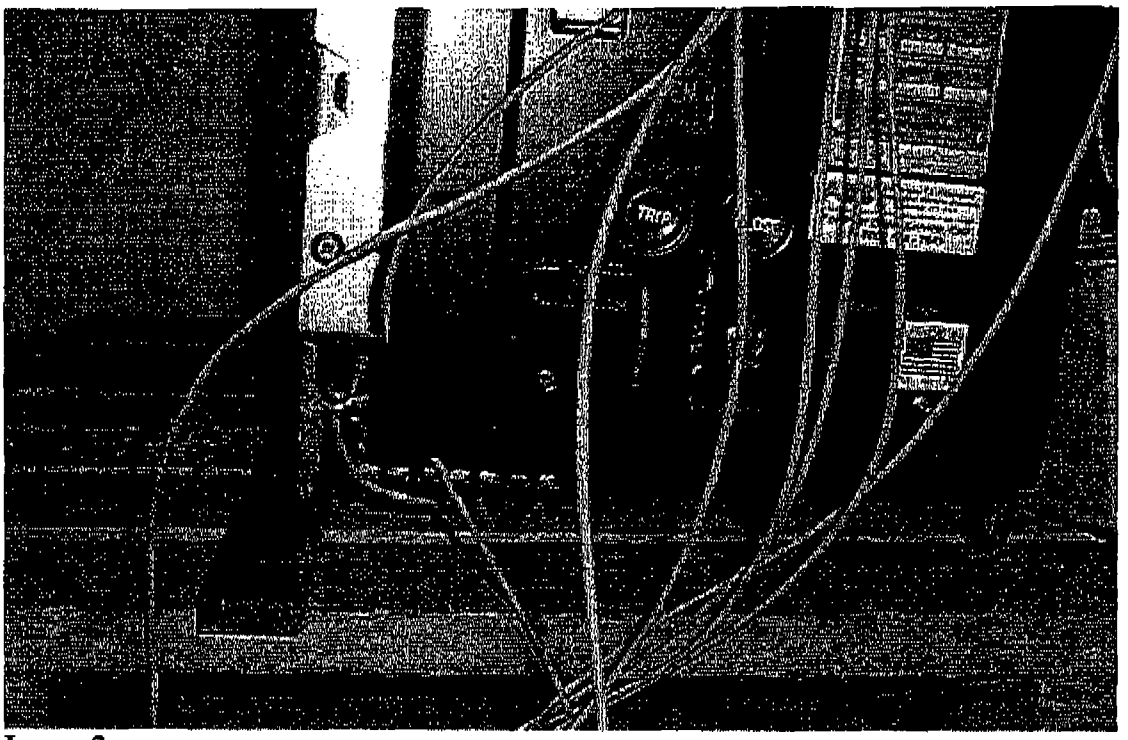

Image 3

Test two yielded 5 contacts that failed to register a state change. The number of operations before each contact failure occurred can be seen in **Table 2**. None of the contacts that failed ever returned to properly reporting a change of state during the run of 50 cycles.

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure							
	2	3		2		5	2

Table 2

Image 4 shows 4 of the 5 contacts that failed during test 2. The number 22 contact, 2nd from the left, is not properly aligned but due to the camera angle it cannot be seen as easily as the other 4. The rotating contacts can be clearly seen to have moved axially in the picture.

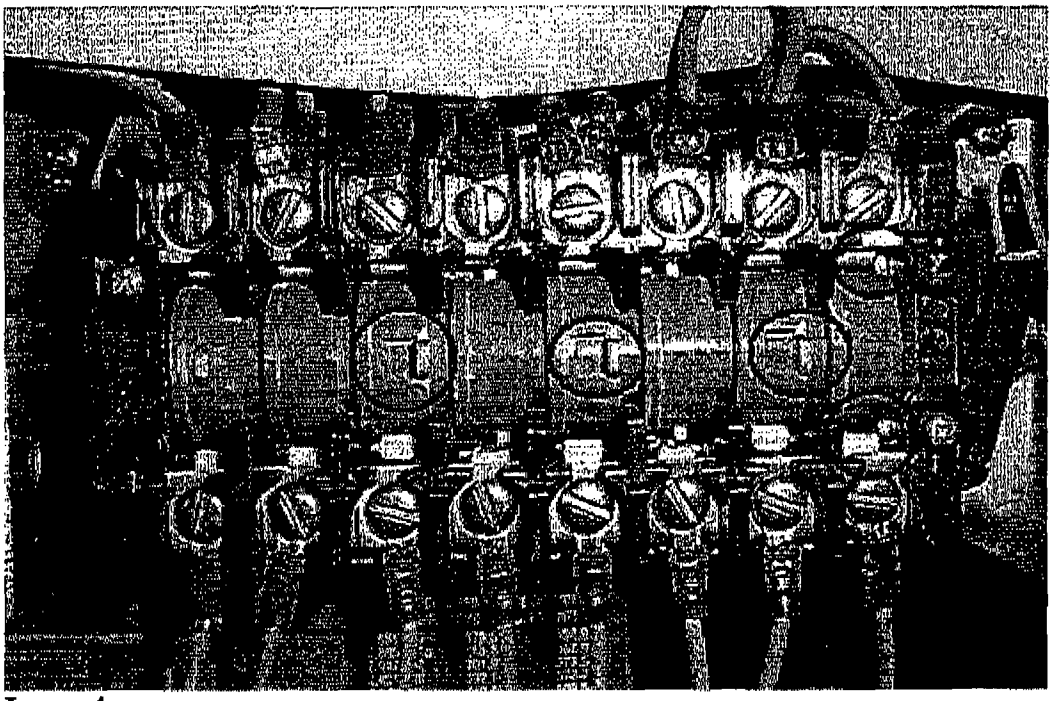

Image 4

2.3 Test 3 Setup and Results

The third test involved resetting all of the contacts to their properly aligned position. The breaker was then tilted to an approximate 10-degrees to simulate reasonable motion when maintenance is preformed upon the breaker. The angle was tilted in the direction to most likely cause the rotating contacts to move axially out of contact with the stationary contacts of the switch.

After tilting, the breaker was returned to a level position to run 100 cycles of open and close operations. No resets were performed once a contact failed. The results of this test appear in **Table 3.**

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure							
	2	5	4	2		9	2

Table 3

Image 5 reveals that rotating open contacts 20, 24, and 32 have indeed moved out of position and are no longer going to make contact.

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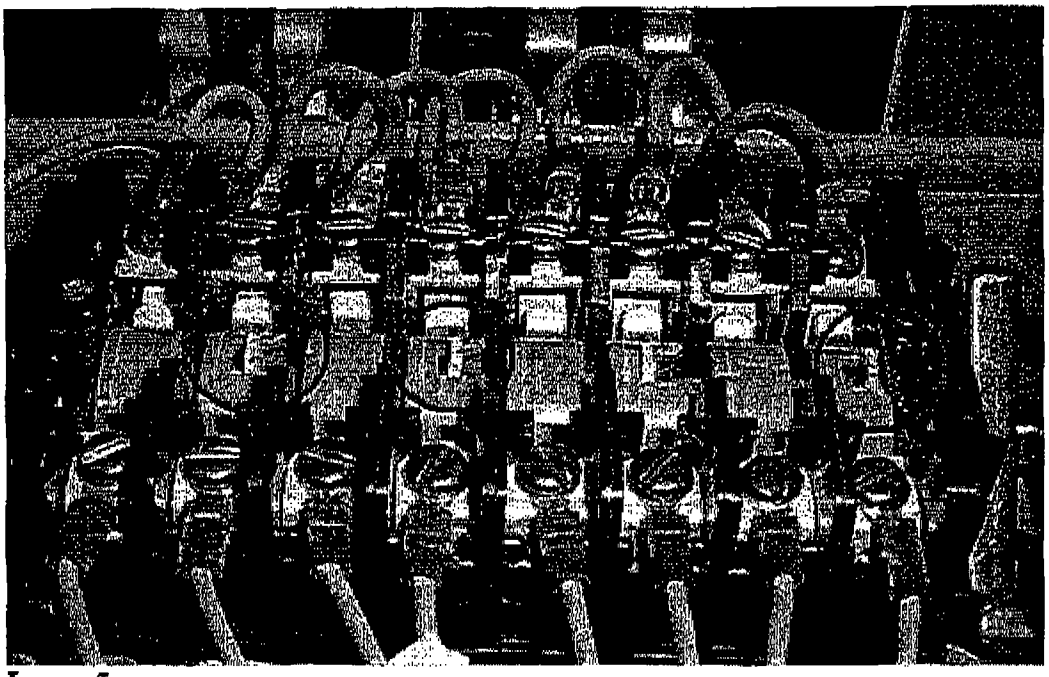

Image 5

Image 6 shows the other 3 close contacts, which have drifted as well.

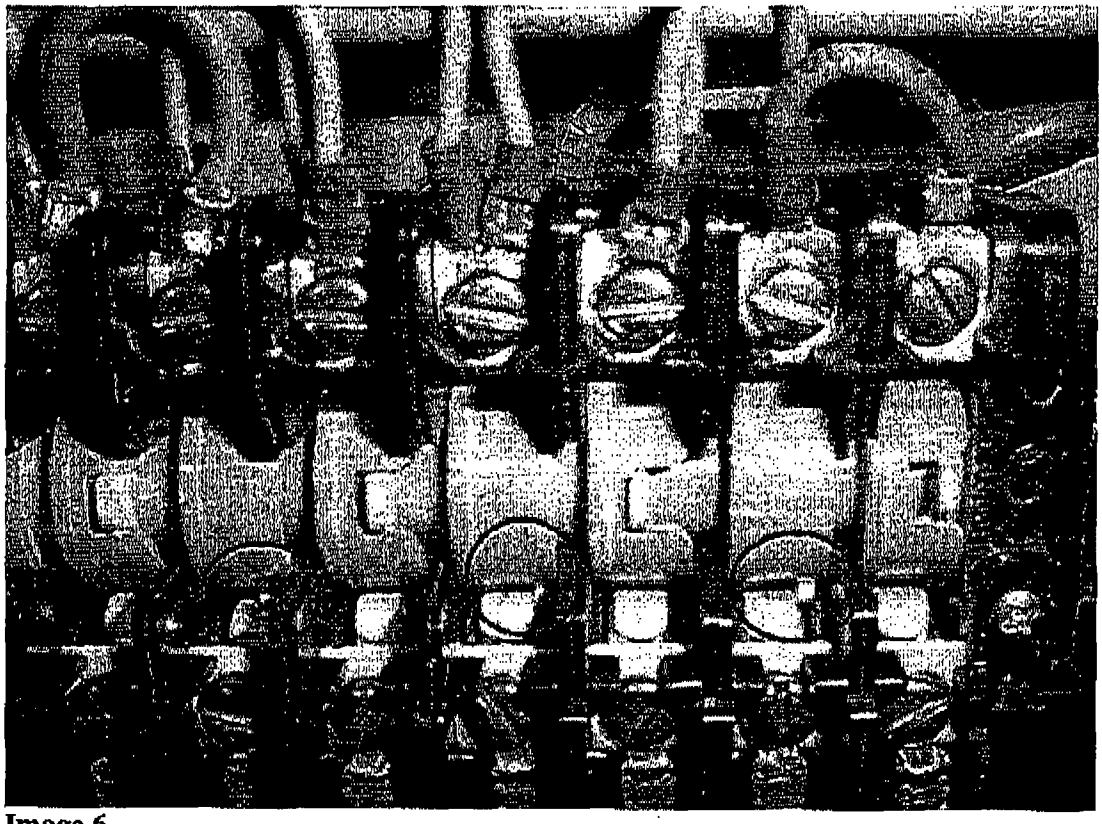

Image 6

None of the contacts, which had failed during this run of 100, ever moved back into a working position that properly signaled the breaker's change of state.

The contacts were reset and the same setup parameters of tilting the breaker approximately 10 degrees were again performed with another run of 100 open-close cycles. The results from this run are summarized in **Table 4.**

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure							
	2		4	3		4	2

Table 4

The same contacts failed in this run of 100 cycles as in the previous run, with the exception of contact 22 which did not fail in the second run of 100 cycles. Again, once a contact failed it never did properly register a state change of the breaker during any of the remaining cycles.

2.4 Test 4 Setup and Results

For the fourth test, the spacer bushing in the number 4 contact (third position to the left from the arm of the switch) of the 4-stage switch [Switch 'E', Date Code: 0546] was removed. This contact was monitored while 50 open-close cycles were performed on the breaker. The number 4 contact was the only contact being monitored during this test and after 50 operations; the number 4 contact never failed so an additional 50 operations were ran. The contact after 100 operations had moved slightly, but the rotating contact fit tightly enough in the grove of the assembly to prevent the contact from moving completely out of line as seen in **Image 7.**

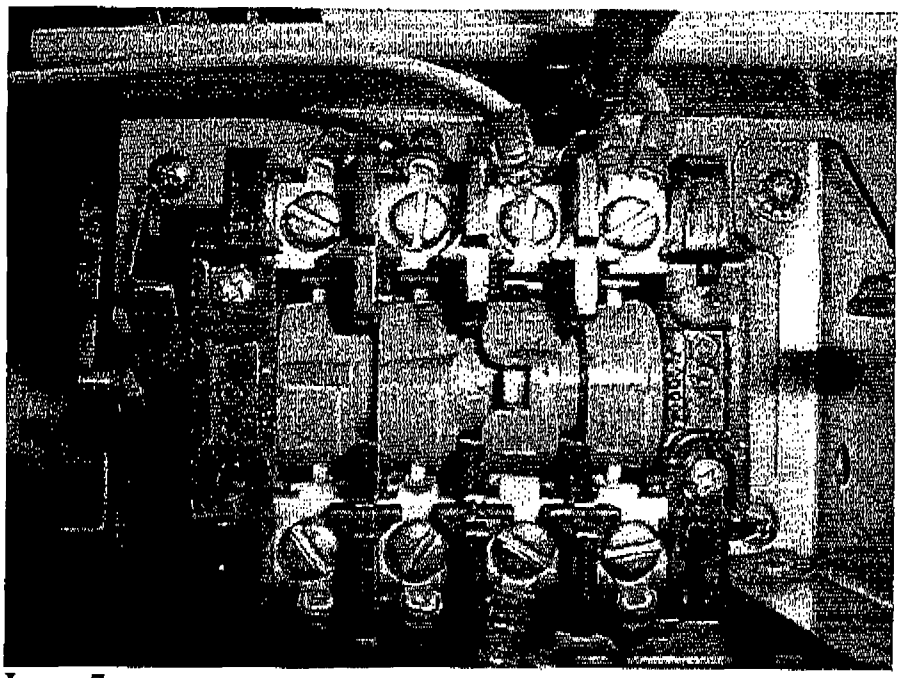

Image 7

2.5 Test 5 Setup and Results

Test number 5 involved the spacer bushings being replaced in the 8-stage switch except for contacts 18, 26, and 32. This test was intended to observe if the alignment of the contacts could be influenced by the existence or non-existence of spacers in adjacent contact barrels. After every few cycles, if any contact had failed, it was immediately re-aligned. This test ran for 50 close-open cycles and yielded the results in **Table 5**.

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure After Reset							
				2			6
				2			2
				5			2
				3			2
				1			2
				1			2
				8			2

Table 5

It is important to note that the only contacts capable of failing were contacts 18, 26, and 32. The other contacts had the spacers inserted to keep the alignment properly oriented.

2.6 Test 6 Setup and Results

For test number 6 all the spacer bushings were again removed and the actual contact barrels themselves were moved to different locations to gauge whether if the position of the failing contacts had any input on the results. The new order of the contacts with respect to the original order can be seen in **Table 6**.

Contact Positions	18	20	22	24	26	28	30	32
New Order	32	26	20	22	24	30	28	18

Table 6

The contacts were all properly aligned and 50 close-open cycles of the breaker were to be run. The contacts all passed the first close-open cycle, but the second cycle resulted in failure of all of the contacts due to mechanical failure of the switch itself. The switch can be seen in **Image 8** how it appeared after the testing was halted.

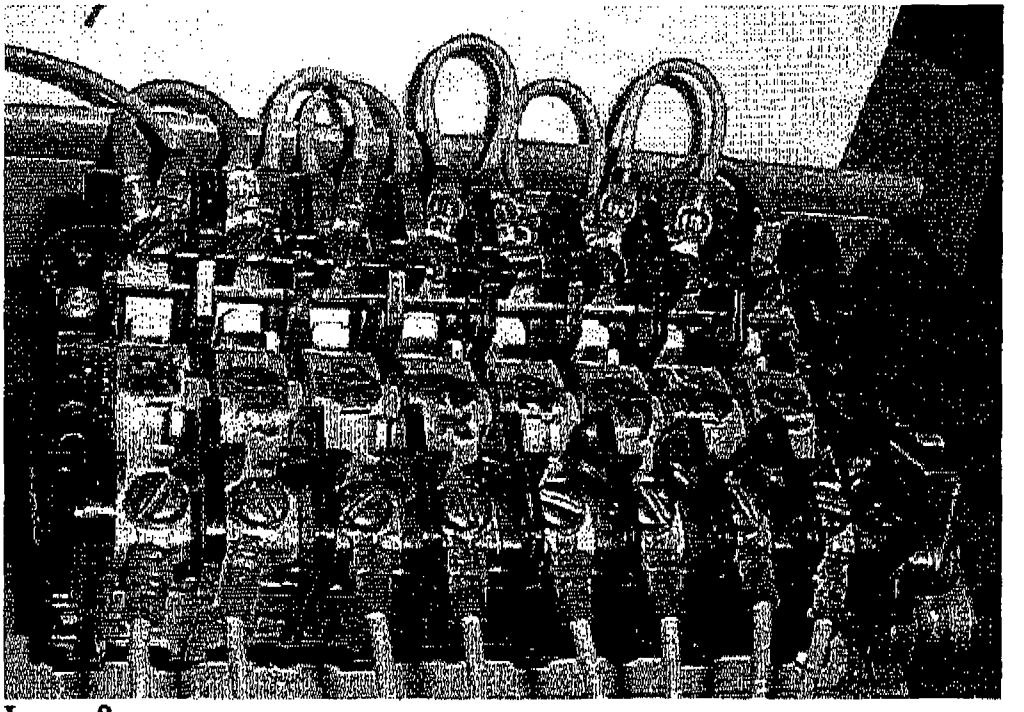

Image 8

The damage to the 32 contact bushing can be seen in **Image 9**. A plastic retaining notch that keeps the stationary contact from over-extending broke off due to contact with the rotating contact. This resulted in not only the retaining notch breaking off, but also the contact barrel itself sustaining damage that prevented the entire switch from rotating.

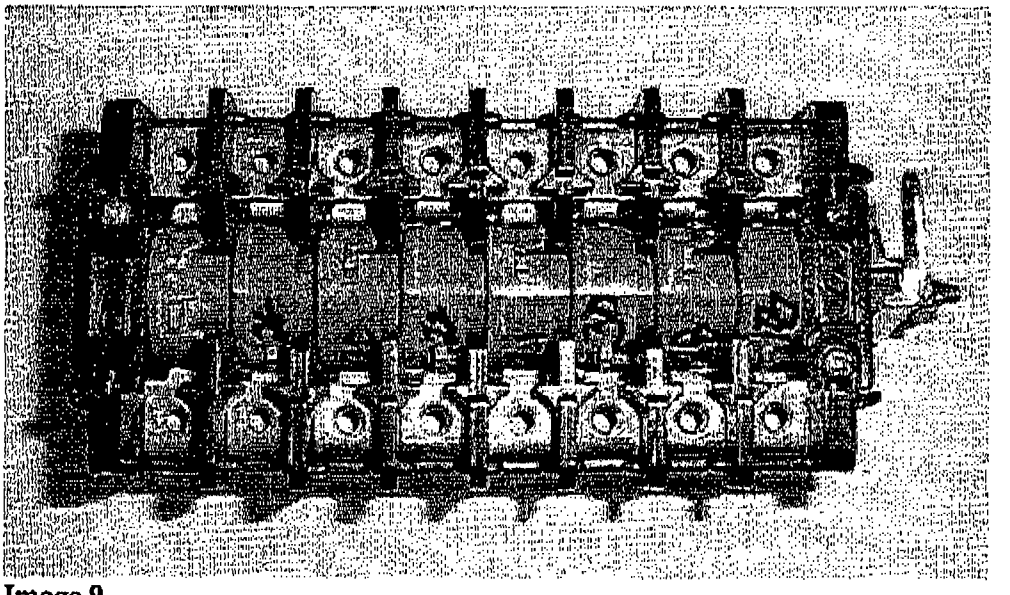

Image 9

It should also be noted, as in **Image 10**, the stationary contact retaining bosses had failed in other contacts as well.

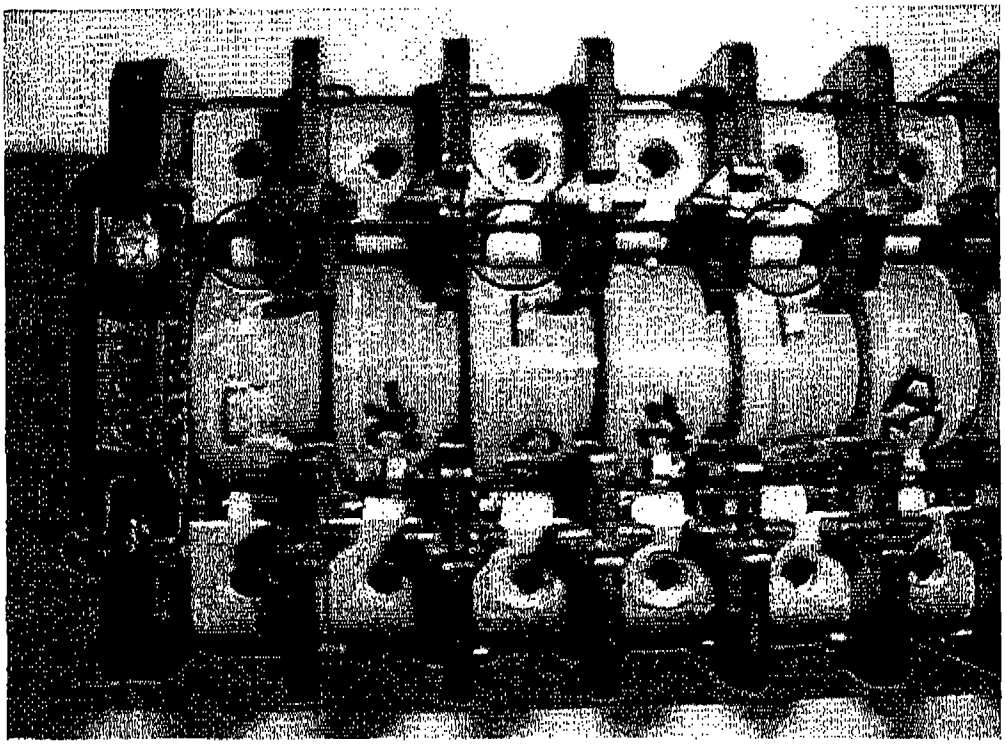

Image 10

2.7 Test 7 Setup and Results

In order to perform test number 7 the 8-state switch required replacement. A new switch [Date Code 0723] was installed and spacers were removed from contacts 20, 24, 30, and 32.

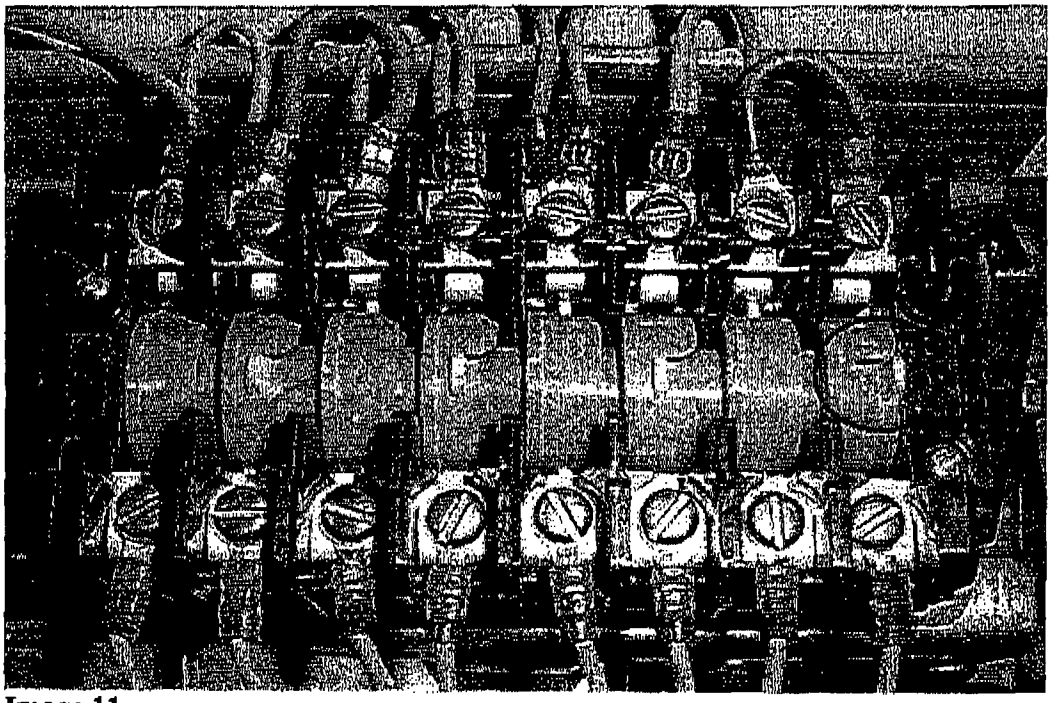

Image 11

The results of test number 7 have been compiled in **Table 7** below. The only contact that failed was contact 32 and it was re-aligned after every 10 cycles.

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure After Reset							
							2
							3
							2
							3
							2

Table 7

2.8 Test 8 Setup and Results

We continued to use the new switch to run test number 8. We removed all of the spacers from this switch and ran 100 cycles of close-open stopping to reset any failed contacts every 10 cycles. **Table 8** reflects how many close-open cycles it took for a contact to incorrectly determine the state change.

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure After Reset							
54		54					3
							3
							2
							1
							1
							1
							1
							2
							3

Table 8

It should be noted that three times contact 32 went back to making contact after not properly reading in the previous cycle. After registering for one full cycle, the contact always failed to read the change of state on the very next cycle.

2.9 Test 9 Setup and Results

For test number 9, we installed a new 8-stage switch [Date Code 0735] to further gain some more insight. The date code from the switch used was 0735. All of the spacer bushings were removed from the 8-way switch and 100 cycles of opening and closing the breaker commenced.

As can be seen from the information contained within **Table 9a**, only two contacts failed to make contact during the run of 100. They were contacts 22 and 26 and both failed immediately into the test.

Close	Open	Close	Open	Close	Open	Close	Open
18	20	22	24	26	28	30	32
Operations To Failure After Reset							
		2		1			

Table 9a

At some point within the first 5 cycles of this test, the contact which had slipped out of alignment, damaging the barrel casing of the 22-position switch. Below in **image 12** this damaged may be viewed.

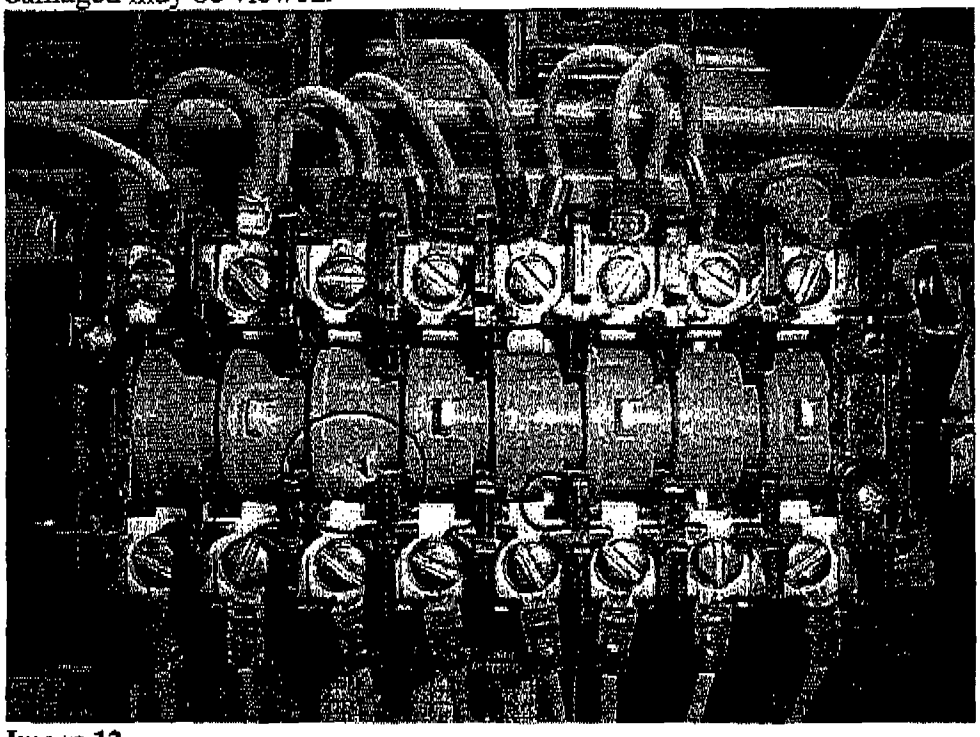

Image 12

The switch was again reset for a run of 50 cycles, with any switch that failed to register a change of state being reset every 10 operations. The data on **Table 9b** on the following page tabulates the number of resets and failures of each of the contacts.

The only switch, which failed during this additional run of 50 cycles, to work itself to a position of failing to report a state change was switch 22. This is the switch that had sustained damage at the start of the previous run of 100 cycles.

	Close	Open	Close	Open	Close	Open	Close	Open
Reset	18	20	22	24	26	28	30	32
	Operations To Failure After Reset							
1			2					
2			3					
3			2					
4			2					

Table 9b

It should be noted that the number 26 switch while out of position, continued making contact and never did fail to register a state change.

2.10 Test 10 Setup and Results

Since test number 9 had left us with a damaged switch, a fourth 8-way switch was installed on the breaker. The date code from this switch was 0620. The breaker ran for 50 close-open cycles with any failed contact being reset every 5 cycles of the breaker. **Table 10** contains the information from this test. From the test, two contacts, 20 and 26, failed repeatedly while contact 30 failed only once.

	Close	Open	Close	Open	Close	Open	Close	Open
Reset	18	20	22	24	26	28	30	32
	Operations To Failure After Reset							
1		7			3		17	
2		2			3			
3		4			3			
4		2			4			
5		2			2			
6		5			2			
7		2			3			
8		4			1			
9		2			2			
10		4			2			

Table 10

Image 13 below reveals the contacts that went out of position during this test. It should be noted that another switch barrel, of contact 26 suffered damage within the first 20 cycles of the test.

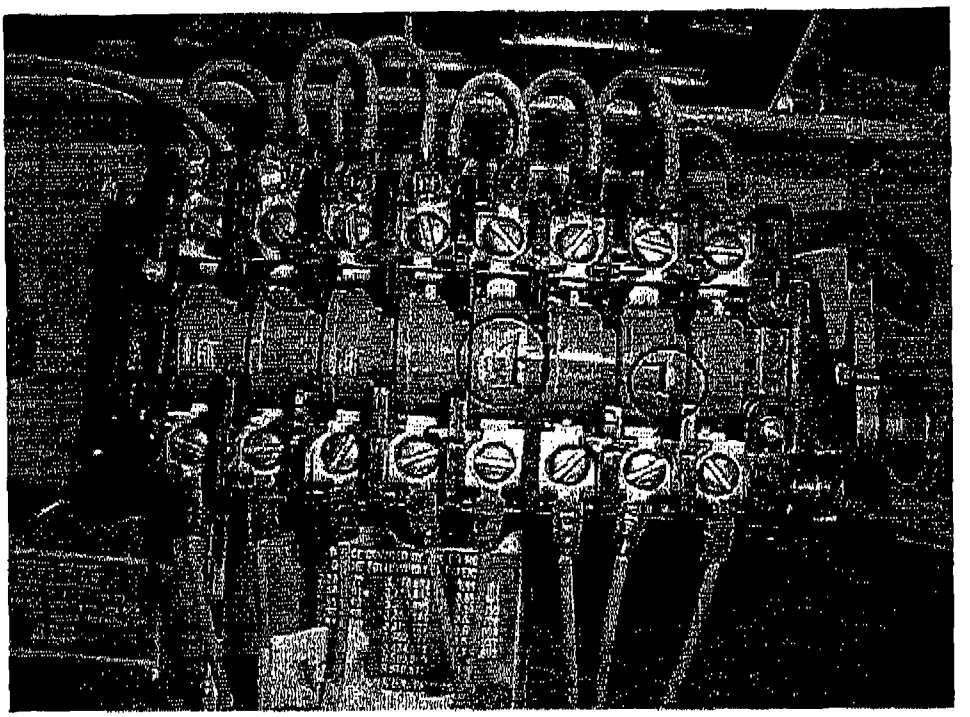

Image 13

2.11 Test 11 Setup and Results

The same breaker and switch was cycled close and then open 100 additional times without any resets to see if any contacts aside from 22 and 26 would fail or if contact 30 would indeed fail again. No additional contacts failed during this run and contact 30 did not fail to register a change of state. **Table 11** below records that contacts 22 and 26 were not reset and had no further opportunities to fail while contact 30, which had previously failed at 17 operations, did not fail through 17 subsequent operations.

	Close	Open	Close	Open	Close	Open	Close	Open
Reset	18	20	22	24	26	28	30	32
	Operations To Failure After Reset							
n/a			n/a		n/a			

Table 11

3 Analysis

3.1 Summary of Tests Performed:

3.1.1 Four 8-stage L-2 switches (700038K01) were tested with combinations of all or only a few of the spacer bushings removed.

3.1.2 One 4-stage L-2 Switch 700034K06 [b-b-a-b] which is the standard switch on all EO breakers also was tested with one spacer bushing removed.

3.1.3 Each contact was monitored individually and any failures to change position properly were recorded.

3.1.4 13 trials under 11 test setups were completed with various switches and combinations, either periodically resetting failed contacts or allowing the system to run continuously without pausing to reset failed contacts.

Note: Each assembly of the plastic rotating contact molding, brass contact, and spacer bushing (or missing spacer bushing) is herein referred to as a 'barrel'

3.2 Scoring:

3.2.1 Any contact which failed to proper record a change of state was scored as a failure. Although on extended runs without resetting some contacts were observed to register a closure after failing to close it was observed that contact was only marginal 'brushing' and not a return to a normal position. No contacts were scored as having returned to operability.

3.2.2 Each operation was a complete Close-Open cycle resulting in 2 repositioning of the switch; however since any 'a' or 'b' contact would only be measured as 'closed' in only 1/2 of the positions, each C-O cycle is considered one operation of a contact.

3.2.3 Each successful operation of a contact (as measured by indicating closed when it should be closed) is considered an opportunity to fail. Once a contact failed, until it was manually repositioned to its correct position, it was no longer scored as having an opportunity to fail. Thus, on a single trial, a contact which never failed had many opportunities to fail, but a contact which failed early in the trial would have had only one or two opportunities to fail.

3.2.4 During trials where a barrel had its spacer bushing present (to check if it affected adjacent barrels) there were no "opportunities to fail" recorded.

3.2.5 The measure of performance used for the balance of this document is "Failures per Opportunity", derived from the number of failures divided by the number of opportunities. The number of failures and number of opportunities is cumulative for any single 'barrel'.

3.3 Results:

33 individual contact 'barrels' were tested on four 8-stage and one 4-stage L-2 switches. All four 8-stage switches had different date codes.

Table 12 presents a summary of results scored by the methodology above:

3.3.1 There were 82 failures of 3762 opportunities (.022 F/O)

3.3.2 19 barrels experienced 0 failures out of 3004 opportunities (0 F/O)

3.3.3 8 barrels experienced 4 or fewer failures out of 590 opportunities, 15 total failures. (0.25 F/O)

3.3.4 6 barrels experienced 6 or more failures out of 168 opportunities. 67 total failures (0.40 F/O)

ABB

	Barrel	# Failures	# Opportunities	Failures per Opportunity
	E-4	0	50	0.000
	B-26	0	100	0.000
	B-28	0	100	0.000
	B-20	0	150	0.000
	B-24	0	150	0.000
	B-30	0	150	0.000
	C-18	0	150	0.000
	C-20	0	150	0.000
	C-24	0	150	0.000
	C-28	0	150	0.000
	C-30	0	150	0.000
	C-32	0	150	0.000
	D-18	0	150	0.000
	D-22	0	150	0.000
	D-24	0	150	0.000
	D-28	0	150	0.000
	D-32	0	150	0.000
	A-28	0	302	0.000
	A-18	0	352	0.000
0 Total	***19***	***0***	***3004***	***0.000***
	C-26	1	51	0.020
	B-18	1	54	0.019
	B-22	1	54	0.019
	D-30	1	117	0.009
1 Total	***4***	***4***	***276***	***0.016***
	A-24	2	110	0.018
	A-22	2	160	0.013
2 Total	***2***	***4***	***270***	***0.015***
	A-30	3	35	0.086
3 Total	***1***	***3***	***35***	***0.086***
	C-22	4	9	0.444
4 Total	***1***	***4***	***9***	***0.444***
	A-20	6	13	0.462
6 Total	***1***	***6***	***13***	***0.462***
	D-26	10	25	0.400
	D-20	10	34	0.294
10 Total	***2***	***20***	***59***	***0.347***
	A-26	13	36	0.361
13 Total	***1***	***13***	***36***	***0.361***
	B-32	14	29	0.483
	A-32	14	31	0.452
14 Total	***2***	***28***	***60***	***0.467***
Grand Total	***33***	***82***	***3762***	***0.093***

Table 12: Summary of Testing Results

3.4 Conclusions:

3.4.1 There is no apparent correlation between number of missing spacers in a switch, barrel position or contact function ('a' or 'b') to failure probability.

3.4.2 The entire population, including those barrels which never failed and those which did experience some failures do not present a normally distributed population.

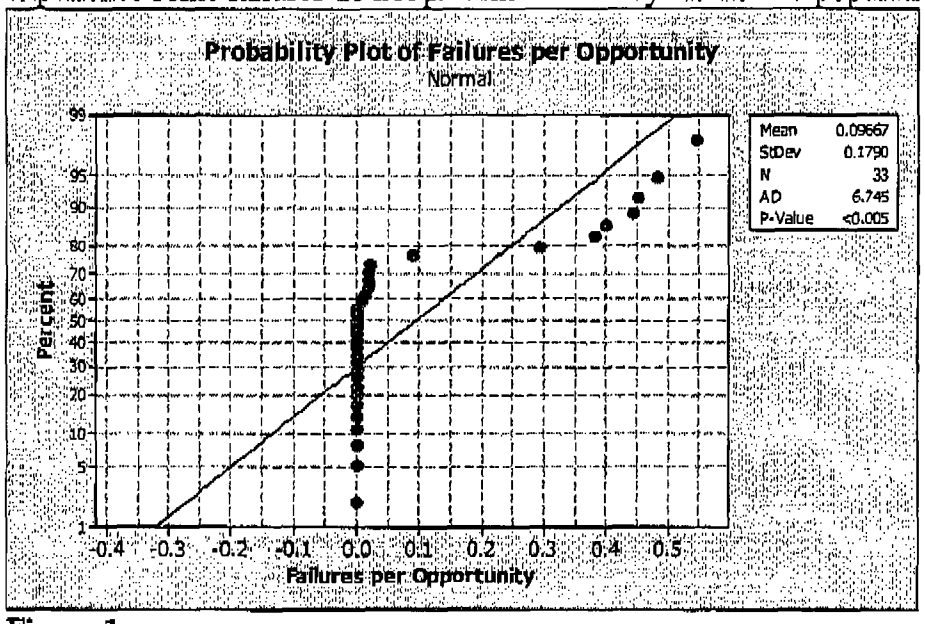

Figure 1

3.4.3 Excluding those 23 barrels which either never failed (57%) or only experienced a single failure, and taking only those 10 barrels which had more than one failure, the Failure per Opportunity measure presents a reasonable approximation of a normally distributed population. **Figure 2** Illustrates the distribution. Mean=0.312, Std. Dev.=0.199, P=0.07.

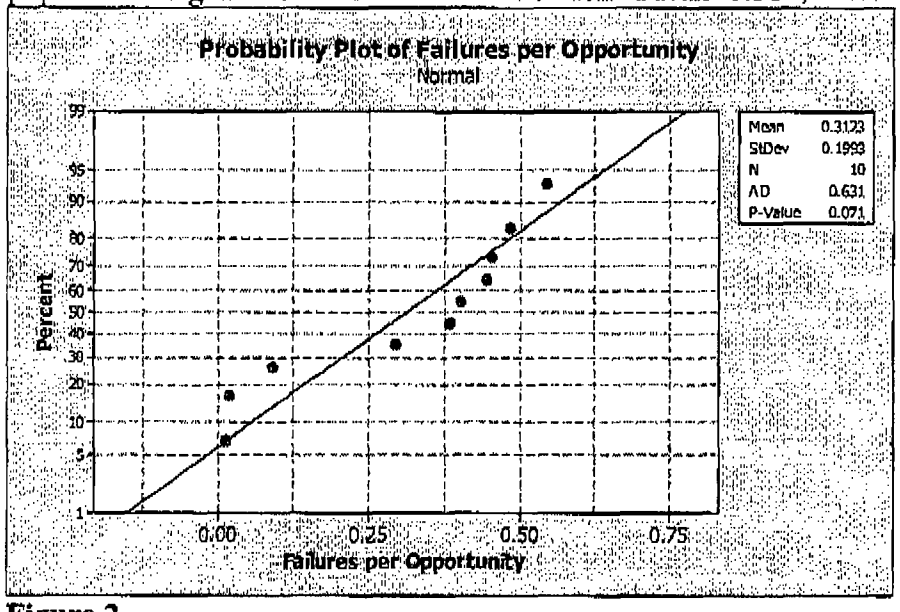

Figure 2

3.4.4 It must be remembered there are only 14 (failing) barrels sampled and of those, 4 have demonstrated only a single failure.

3.4.5 It has not yet been possible to gather a statistically significant sample of failing barrels.

3.4.6 Nevertheless, from the above data it can be determined that approximately 1/2 of all barrels which are missing a spacer will never fail. Examination of non-failing barrels has revealed that the fit of the contact on the rotating plastic molded part is sufficiently tight to hold the contact in place -- this was true even with the breaker slightly tilted (~10 degrees) in the direction which would cause the contact to fall out of the molding.

3.4.7 Overall, there is insufficient data to reliably predict performance of a barrel with a missing spacer, should it fall into the (approximately) half that do fail.
From the mean of 0.3, with a St. Dev. of 0.2, only a few St. Deviations exceed the physical limits of the system (one cannot have either negative Failures per Opportunity, nor >1 Failure per Opportunity). It should be noted that of the barrels with only one failure each, 2 failed at 54 operations, 1 at 17 operations and the other on the first operation with no other failures in up to 100 operations.

3.4.8 Further testing is not likely to prove useful because although most barrels which exhibited a tendency to fail did so quickly, there are still 3 (or 2 depending upon one's threshold) which did not fail until a reasonably high number of operations could be established. Even if further testing put all new failing barrels into the 'fail quickly' category, a very high number would have to be tested to reduce the 2 (or 3) noted barrels to statistical insignificance.

3.4.9 **Table 13** (attached on oversized 11" x 17" sheet) summarizes the collected data.

Trial	Test	A-18	B-20	A-22	B-24	A-26	B-28	A-30	A-32	B-18	B-20	B-22	B-24	B-26	B-28	B-30	B-32	C-18	C-20	C-22	C-24	C-26	C-28	C-30	C-32	D-18	D-20	D-22	D-24	D-26	D-28	D-30	D-32	E-4
1	1	50	3	40	50	1	50	13	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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2	2	50	3	3	50	3	50	5	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3	3	100	3	3	4	3	100	9	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4	3	100	3	100	4	3	100	8	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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6	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
7	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	84	[redacted]	84	[redacted]	[redacted]	[redacted]	[redacted]	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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10	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
11	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
12	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
13	8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1	11	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	100	100	1	120	1	120	100	120	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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# of Failures		0	3	7	2	13	9	3	14	1	0	1	3	3	9	0	10	0	0	1	0	1	0	0	0	0	13	3	3	13	9	1	0	0	Total #
# of Opportunities		362	13	159	193	38	302	29	19	54	150	54	153	103	208	130	28	150	150	9	150	51	150	150	150	150	34	53	53	25	158	117	150	50	3762
Failure/Opportunity		0	0.462	0.043	0.010	0.341	0	0.086	0.132	0.019	0	0.019	0	0	0	0	0.393	0	0	0.111	0	0.02	0	0	0	0	0.254	0	0	0.4	0	0.009	0	0	0.021