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EVALUATION OF TMI-2 PRESSURE SWITCHES NM-PS-1454 AND NM-PS-4174

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ABSTRACT

Two pressure switches used to actuate alarms in the Three Mile Island Unit 2 Reactor Building Nitrogen Manifold System were selected for investigation on the basis of specific critical criteria. They were subjected to in situ electrical tests, removal, and detailed examination at the Idaho National Engineering Laboratory (INEL). One unit exhibited no anomalies during in situ testing and survived the accident and subsequent handling, shipping, and storage with no apparent problems. The other unit, however, exhibited an anomaly during in situ testing but appeared to have been mishandled, obscuring its true condition upon removal and rendering analysis of the anomaly impossible. Both units showed evidence that contaminated air entered the switch enclosure, and the second unit also showed evidence of a significant incursion of moisture, possibly from hot-water spraying during the Reactor Building gross decontamination experiment, causing corrosion. Except for the corrosion to the second switch, however, the two units suffered no significant degradation as a result of the accident or from subsequent containment in the post-accident environment.

On the basis of the findings, it is recommended that specific attention be paid to the way in which moisture would be prevented from entering the switch compartment.

SUMMARY

NM-PS-1454 and NM-PS-4174 are two pressure switches in the Reactor Building Nitrogen Manifold System. They monitor the nitrogen pressure in system headers in the Reactor Building, and if their alarm setpoints are exceeded, they signal the control room through the Radwaste Panel Annunciator. NM-PS-1454 monitors the supply header pressure and trips when pressure exceeds 150 psig. NM-PS-4174 monitors the 20 psig distribution header pressure and trips when the pressure drops below 1.5 psig.

The units were selected for investigation on the basis of specific critical criteria, which are spelled out later in this report, and were subjected to in situ electrical tests, removal, and detailed examination at the Idaho National Engineering Laboratory (INEL). NM-PS-1454 exhibited no anomalies during in situ testing and survived the accident and subsequent handling, shipping, and storage with no apparent problems. NM-PS-4174, however, exhibited an anomaly during in situ testing; its normally open (NO) contact was measured as closed even though the pressure was essentially zero. Such a condition should have resulted in an open contact. Unfortunately, this unit appears to have been mishandled, obscuring its true condition upon removal and rendering analysis of the anomaly impossible.

Furthermore, NM-PS-4174 experienced a significant incursion of moisture, possibly from hot-water spraying during the Reactor Building gross decontamination experiment, causing corrosion. NM-PS-1454 experienced no such incursion of moisture. Except for the corrosion to the one switch, however, the two units suffered no significant degradation as a result of the accident or from subsequent containment in the post-accident environment.

In conclusion, specific attention should be paid to the way in which moisture would be prevented from entering the switch compartment.

ACKNOWLEDGMENTS

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EVALUATION OF TMI-2 PRESSURE SWITCHES NM-PS-1454 AND NM-PS-4174

INTRODUCTION

The accident at Three Mile Island Unit 2 (TMI-2) has provided an opportunity to evaluate instruments that have been exposed to such unusual conditions as direct radiation, radioactive contamination, moisture, and high humidity with elevated temperatures and pressures.

There are approximately 11 pressure switches located in the Reactor Building. The selection of units to be evaluated was based on obtaining the most data to: (a) improve qualification standards, (b) assess adequacy of existing standards, (c) improve future designs, (d) assess vulnerability of other existing plants that use similar equipment, and (e) better understand the TMI-2 accident itself. The selection of units was limited for practical and operational reasons. For example, certain units were inaccessible or extremely difficult to remove from the Reactor Building, or they were essential to maintaining the plant in a safe condition and thus could not be taken out of service.

A priority-one classification was assigned by the Instrumentation and Electrical Equipment Survivability Planning Group to the following types of equipment:

- Class 1E or potential Class 1E equipment
- Reactor control equipment
- Equipment needed to understand the accident
- Equipment thought to be especially sensitive to the environment and therefore useful for establishing design criteria
- Equipment thought to be especially useful in assessing instrument damage or representative of important generic features.

In situ testing was performed, and pressure switches NM-PS-1454 and NM-PS-4174 were removed from the Reactor Building. These units, commonly used in nuclear power plants and representative of the other units in the TMI-2 Reactor Building, were selected because of their accessibility and because they could be removed without danger to maintaining the plant in a safe condition. Both of the units were mounted on Instrument Rack 432 (Figure 1), located at the 347-ft elevation, which was well above the high water mark in the Reactor Building.

An alarm annunciator in Panel 302B (Radwaste) outside the Reactor Building has displays for "N_2 GAS 100 # SUPPLY...PRESS HI," tripped by opening a normally closed (NC) contact in NM-PS-1454 at 150 psig increasing pressure, and for "N_2 GAS 20 # SUPPLY...PRESS LO/HI," tripped by either opening a normally open (NO) contact in NM-PS-4174 at 1.5 decreasing pressure or opening an NC contact in NM-PS-4175 at 150 psig increasing pressure. Any alarm trip in this annunciator transmits a single alarm signal to an annunciator in the control room. The switches of the two units were connected separately by approximately 720 ft of cable to this annunciator. Neither the switch contacts nor the annunciator responses were recorded continuously with a strip chart recorder or data logger. Therefore, no permanent records exist to determine how they performed during or after the accident or if and when they may have failed. Limited information is available from technician and operator log books. According to records, the units were factory calibrated in 1974 and calibration checked in February 1977 after their installation (see Appendix A). There was no reported failure or degradation of these units during or after the accident, and the anomaly in NM-PS-4174 was discovered only during in situ testing.

The units are Static "O" Ring Pressure Switches manufactured by SOR Inc., Olathe, Kansas (see Figures 2, 3, 4, and 5). The pressure sensing element of the switch is a force balance piston-actuated assembly sealed by a flexible diaphragm and an O-ring that is static. There are only three wetted parts in this arrangement: a pressure port, the diaphragm, and the O-ring. Media pressure on the area of the piston counteracts the force of the range spring (adjustable by the adjusting nut) and moves the piston

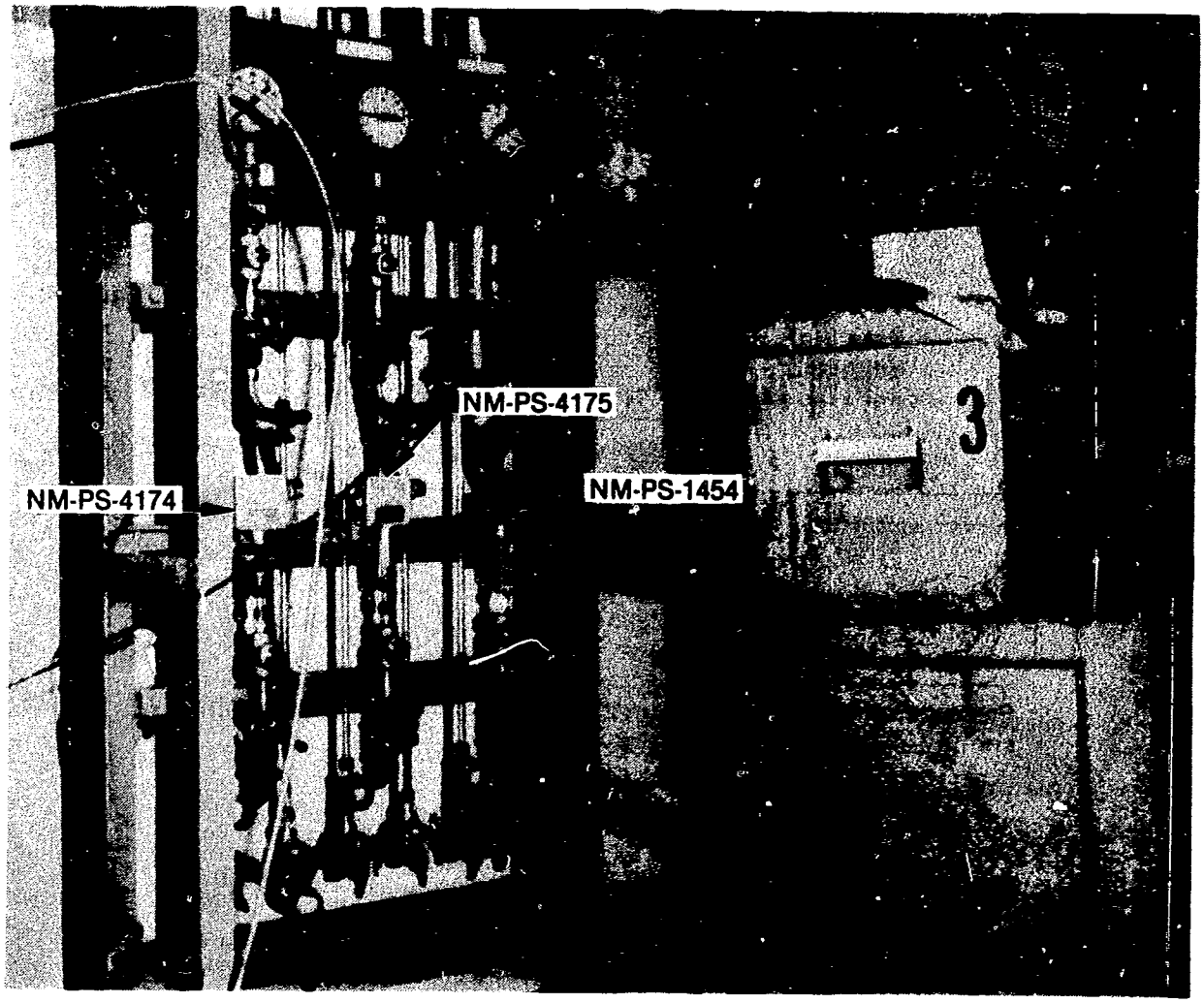
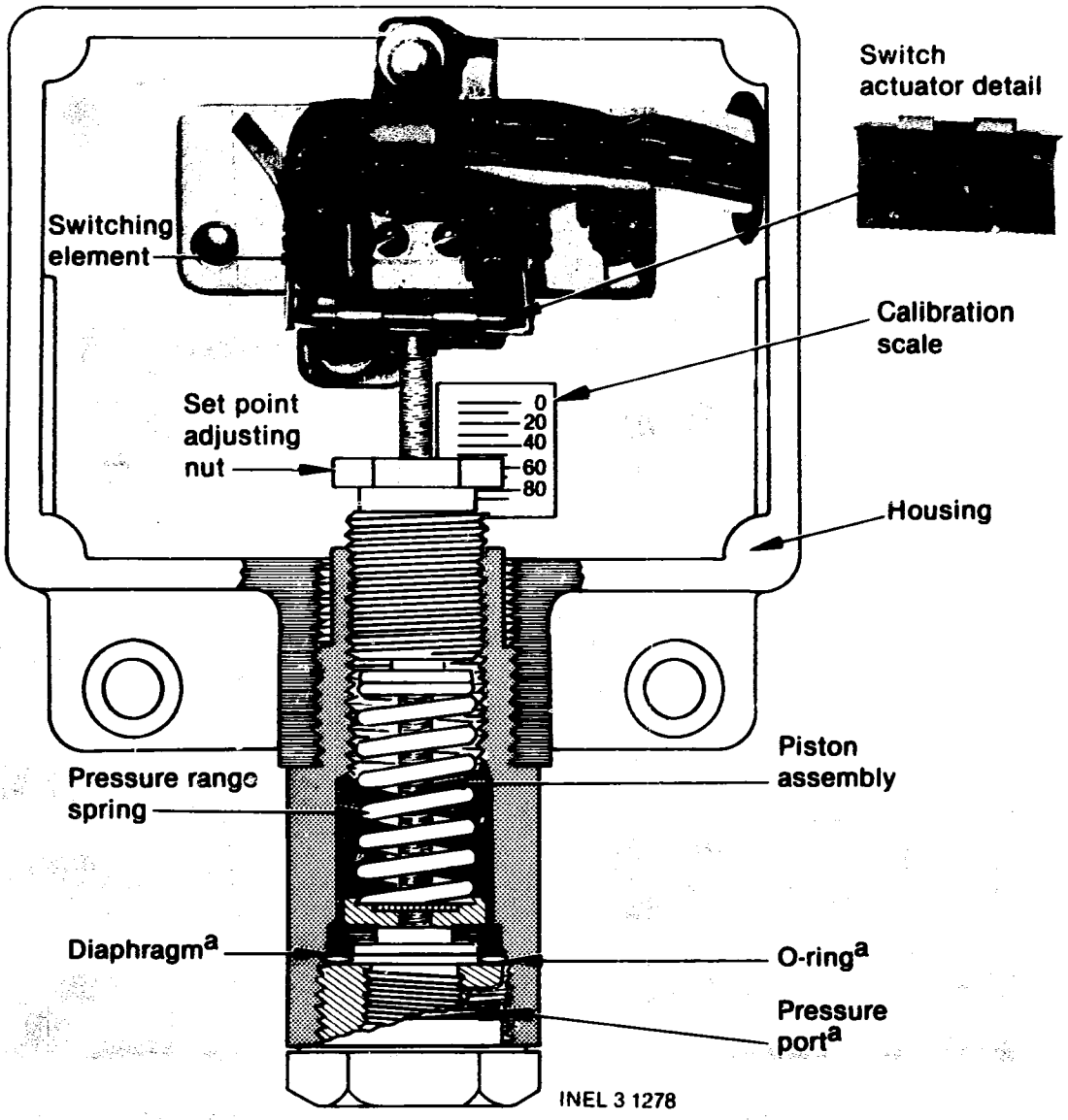


Figure 1. Instrument Rack 432 at the 347-ft elevation, showing pressure switches NM-PS-1454, NM-PS-4174 and NM-PS-4175.



a. Wetted parts

Figure 2. Cutaway view of a Static "O" Ring Pressure Switch.

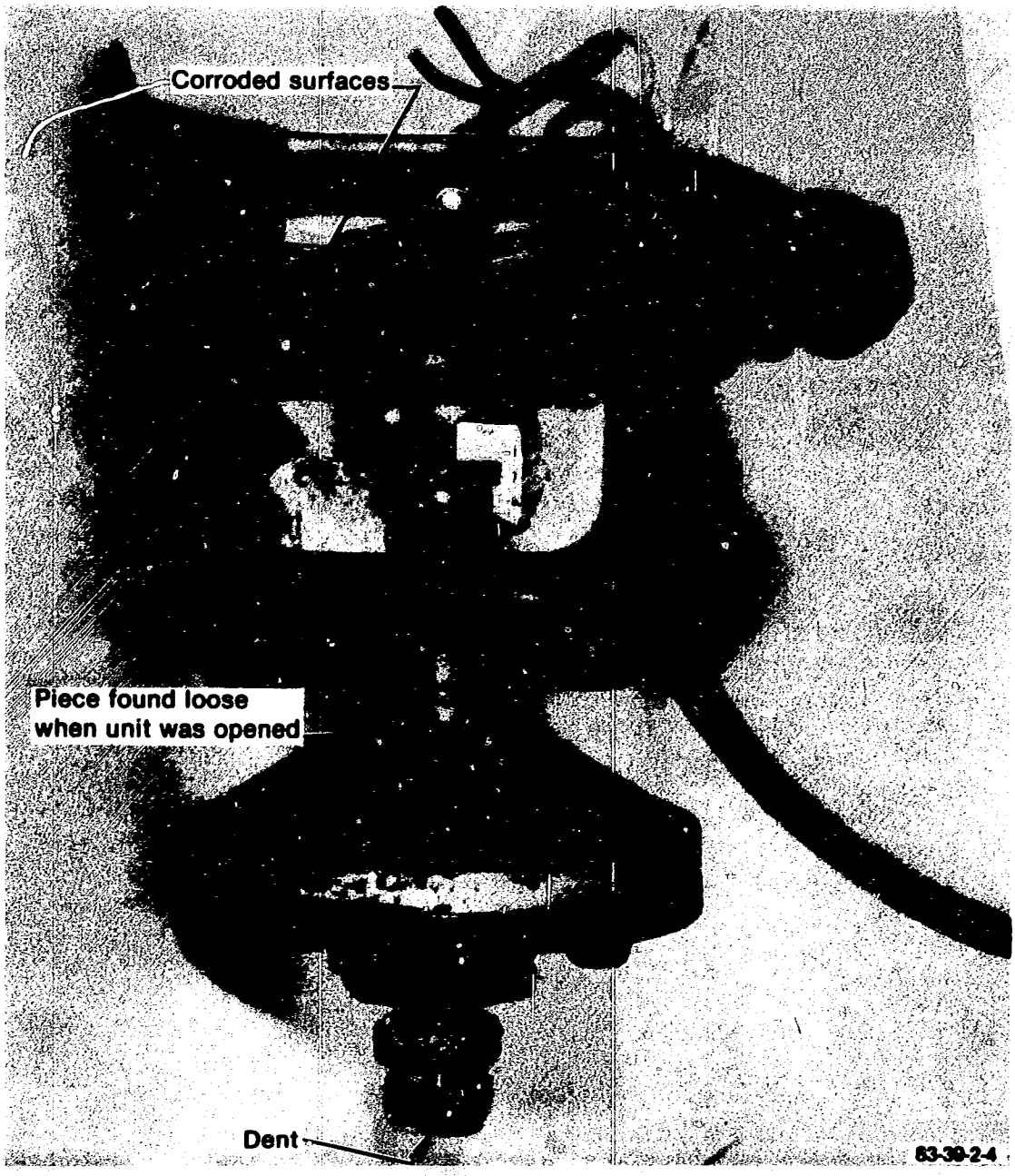


Figure 3. Pressure switch NM-PS-4174 interior.

Figure 4. Pressure switch NM-PS-1454 exterior.

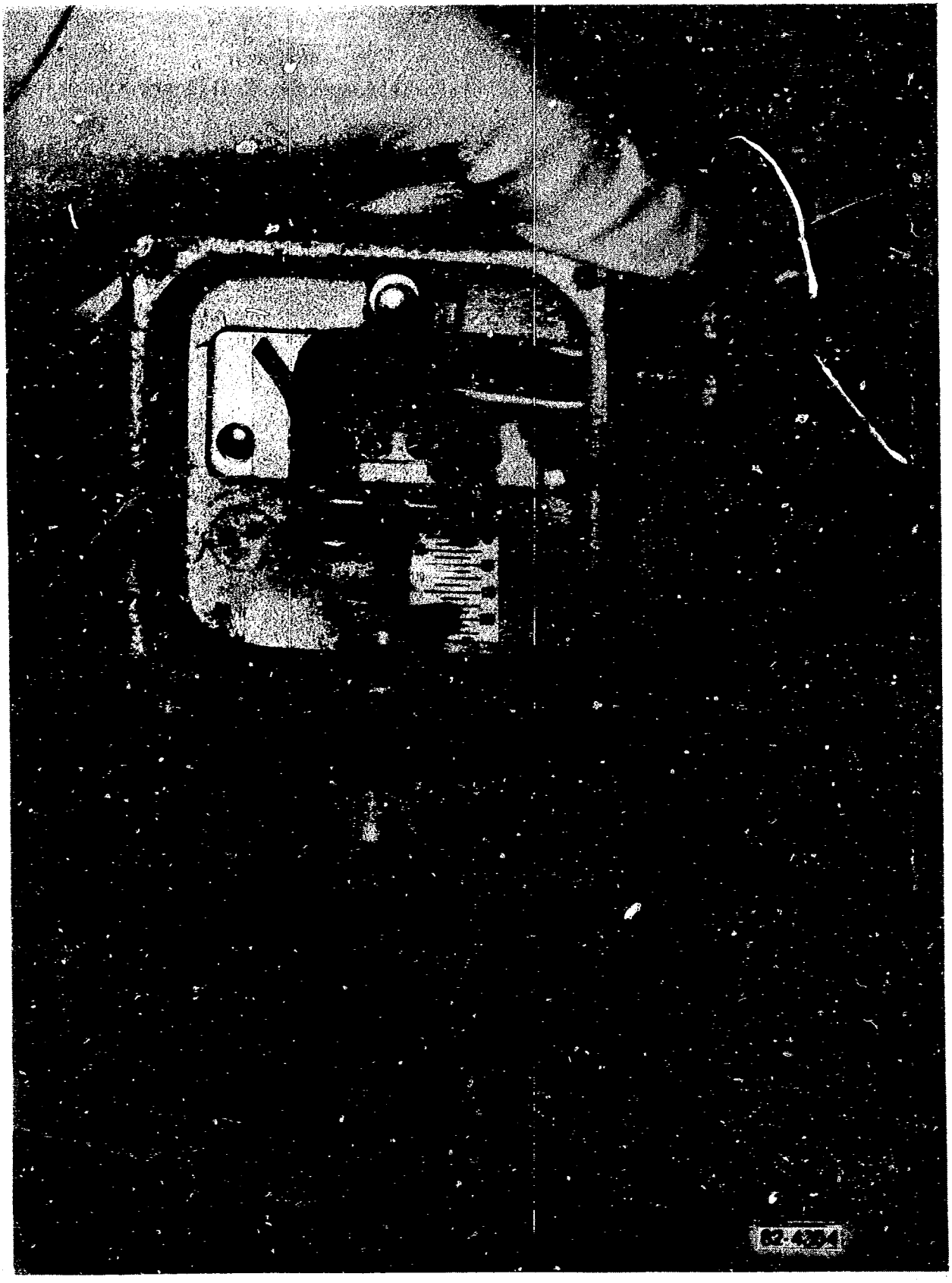


Figure 5. Pressure switch NM-PS-1454 interior.

shaft a few thousandths of an inch to actuate the electrical snap-action switching element.

Pertinent characteristics of NM-PS-1454 and NM-PS-4174 are summarized in Table 1.

TABLE 1. CHARACTERISTICS OF NM-PS-1454 AND NM-PS-4174

Characteristic	Instrument NM-PS-1454	Instrument NM-PS-4174
Model	6N-AA45-CSSX	12N-AA4-CSSX
Serial Number	73-10-1116	76-3-1145
Calibrated Range	6.6 to 280 psig	0 to 6.6 psig
Output	2 Form C Contacts	2 Form C Contacts
Rating	11A-1/4 HP @ 125/250 VAC 5A-30 VDC	11A-1/4 HP @ 125/250 VAC 5A-30 VDC
Body	Aluminum (copper free) (painted)	Aluminum (copper free) (unpainted)
Trip Setpoint	150 psig (increasing)	1.5 psig (decreasing)
Reset Point	142 psig (decreasing)	1.65 psig (increasing)
Dead Band	7.5 to 18 psig	0.15 to 0.3 psig

PRESSURE SWITCH REMOVAL

Pressure switches NM-PS-1454 and NM-PS-4174 were removed from the Reactor Building in August 1981 and September 1982, respectively. Since the units were radioactively contaminated, they required special handling, storage, and shipping. The units were packaged in double plastic bags, boxed, and then packed in vermiculite in metal barrels and stored at TMI until they were shipped to the INEL, where they were again stored until examination and testing began in January 1983. Because NM-PS-4174 was removed a year later than the other pressure switch, it was exposed longer to the Reactor Building environment, allowing it to suffer the effects of hot-water spraying during the Reactor Building gross decontamination experiment.

EVALUATION

The basic approach to pressure switch evaluation is described below:

1. Perform in situ testing, then remove assembly from containment and ship to laboratory.

2. Perform visual inspection and record any apparent discrepancies, anomalies or other pertinent observations. Determine internal radiological contamination.

3. If a unit appears to be functional and in situ tests reveal no apparent discrepancies, perform calibration tests similar to pre-accident measurements (pressure versus output), duplicating the pre-accident setting as closely as practicable without making adjustments and then comparing pre- and post-accident measurements. Also, check hysteresis and repeatability at minimum and maximum settings; measure contact resistance, voltage drop, and temperature rise at full load current; measure insulation resistance; determine operating forces; and conduct a high voltage dielectric withstand test.

4. Where discrepancies or failures exist, attempt to determine the cause of the discrepancies through nondestructive means.

5. Document all activities associated with the examinations, providing photographs for reference.

6. Use measurement equipment which is calibration certified.

7. Analyze data and report results.

8. Store the units for possible future action.

In Situ Testing at TMI-2

All in situ tests were conducted from outside the Reactor Building. Access to the units was not permitted, nor was the variation of input pressure to the units.

Specifically, the in situ tests consisted of (a) the measurement of the interconnecting cables' resistance and capacitance/inductance and (b) time domain reflectometery (TDR) of the interconnecting cables.

In Situ Test Results

In situ tests of NM-PS-1454 were made in November 1981, and tests of NM-PS-4174 were made first in November 1981 and again in May 1982, following the gross decontamination experiment.

Resistance measurements indicated closed circuits of approximately 2 ohms each, a normal value for wires with a closed switch at the end. TDR measurements showed no cable anomalies and indicated that the circuit closures were at the device locations.

Both sets of in situ test data for NM-PS-4174 indicated that this unit probably was not operational because the NO contact remained closed even when the system was depressurized. However, because the system could not be pressurized or depressurized, in situ tests could not determine functional operability of either unit.

Examination of Pressure Switches at the INEL

The examination of each unit, with a few exceptions, will be discussed separately. The units were radioactively contaminated; therefore, special handling procedures were required, i.e., personnel were required to wear protective clothing, and work was performed in controlled areas in

accordance with appropriate safe work practices. The units were examined and tested in a laboratory fume hood that was equipped to accept radioactively contaminated components.

The purpose of the examination was to determine the extent of radiological contamination, as well as determine the physical conditions, mechanical responses to applied forces, electrical characteristics, and degradation of elastomeric materials. Detailed data were obtained through these tests and examinations before any parts were significantly disturbed.

For radiological characterization, smear samples were taken from several exterior locations, the switch enclosure interior, and the (interior) parts of the pressure cell, and counted using Tennelec and Ortec counter/scaler equipment.

To establish their physical conditions, the instruments were visually examined at various stages of disassembly.

Mechanical response testing comprised complete instrument response to the application of pressure to the pressure cell and (separately) electrical switch moving part motions in response to force applied directly to the switch.

Tests to determine electrical characteristics dealt with contact resistance and voltage drop, ac/dc overload, contact temperature rise at full load ac current, and switch case insulation resistance and dielectric withstand capability.

Evaluation of elastomeric materials was based solely on the comparison of tensile strength measurements of the O-rings and diaphragms that were removed from the units and of new replacement parts.

Examination of NM-PS-4174

Radiological Observations. The exterior smear survey shows 30,000 to 190,000 disintegrations per minute (dpm) gross beta and gamma radiation (see Figure 6). The interior of the switch enclosure shows 10,000 dpm, indicating contaminated water or air had entered the enclosure. Cover plate gamma spectrum analysis and full smear count results are presented in Table 2.

Visual Observations. The bolts holding the flanged pressure port assembly together had a heavy coating of rust; all other surfaces were lightly corroded. Table 3 provides a detailed comparison of visual observations of both switches externally and internally. (See also Figure 7.)

The interior of the switch enclosure portion of NM-PS-4174 was clean but appeared to have had moisture in it at one time, as evidenced by the corrosion of ferrous metal parts (see Figure 3). The water that caused this corrosion may have been from the hot-water spraying of the Reactor Building during the gross decontamination experiment. The cover gasket appeared to be in good condition, so it is likely that water entered the enclosure through the conduit or its associated fittings.

After pressure cell response tests and certain electrical tests were conducted, the pressure cell was disassembled and examined. There was evidence of water presence on the plunger disk and the upper side of the diaphragm, further supporting the conclusion that water had entered the enclosure.

The unit appears to have been damaged in handling. There is a dent in the pressure fitting, and the switch actuation plate was adrift in the switch enclosure. The actuation plate was reinstalled prior to mechanical characterization.

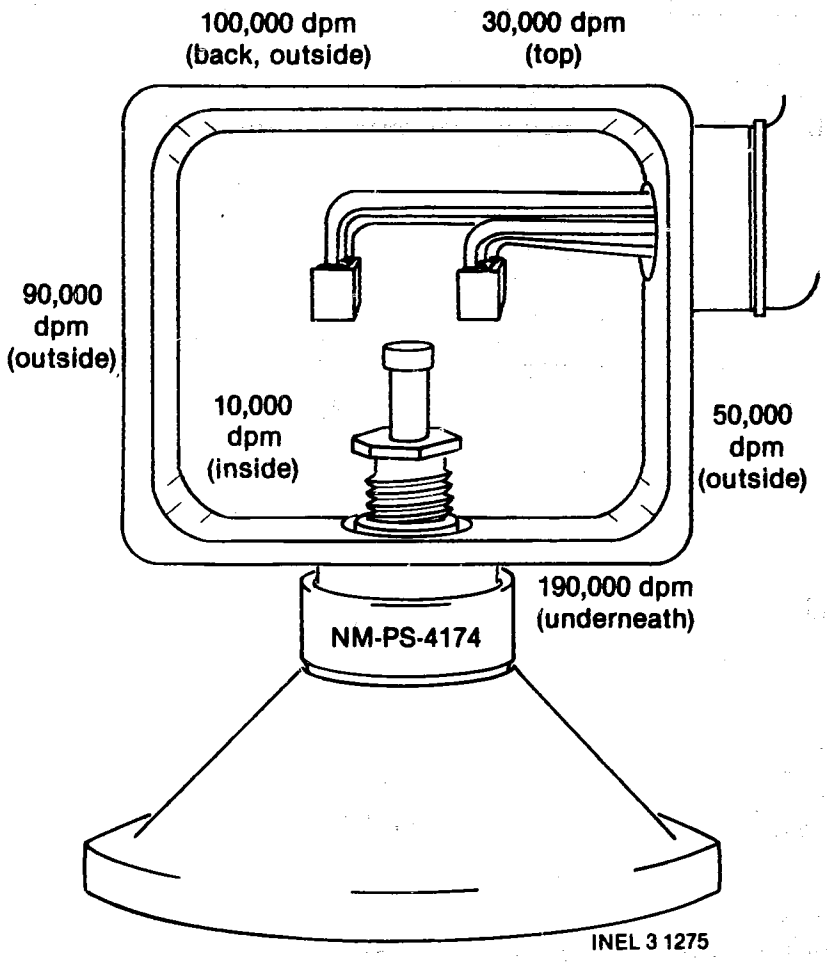


Figure 6. Contamination smear sites for NM-PS-4174.

TABLE 2. RADIOLOGICAL FINDINGS

Isotope Activity of Cover Switch Plate

	NM-PS-4174		NM-PS-1454	
	μCi	$\mu Ci/cm^2$	μCi	$\mu Ci/cm^2$
Cs-134	0.9 ± 0.09	0.012 ± 0.001	0.8 ± 0.08	0.011 ± 0.001
Cs-137	11 ± 1	0.15 ± 0.01	10 ± 1	0.14 ± 0.01

β, γ Activity of Externals and Internals
(in disintegrations per minute)

	NM-PS-4174	NM-PS-1454
Switch Enclosure		
External	30,000/190,000[a]	12,000/400,000[a]
Internal	10,000	16,000
Pressure Cell		
Housing	810	--
End Cap	--	310
Inside	--	30
Diaphragm		
Back Side	230	<200
Pressure Side	1,450	910
Plunger		
Top Surface	270	--
Face (Pressure Side)	290	--
Plunger & Spring Assembly	--	<200
Stem Hole	<200	--
Conduit		
Outside	84,000	68,530
Inside	1,210	11,650
Bolts	24,000	--

a. Minimum/maximum.

TABLE 3. PHYSICAL OBSERVATIONS

NM-PS-4174	NM-PS-1454
External	
o Unpainted	o Painted; clean
o Corrosion widespread --Light brown over most of aluminum housing --Conduit fitting heavily rusted --All bolts on diaphragm cover heavily rusted; rust spread on to cover by each bolt	o Corrosion insignificant --One cover bolt heavily rusted --Conduit fitting heavily rusted --I.D. plate fasteners rusted
o Damaged --Dent in pressure fitting	o No visible damage
Internal	
Switch Enclosure:	
o Clean	o Clean; like new
o Rust on all ferrous parts	o No corrosion
o Rust particles and metal chips adhering to housing wall by setpoint adjusting nut	
o Switch actuator plate completely detached (later reinstalled without difficulty)	o No damage
o Gasket intact	o Gasket intact
Pressure Cell:	
o Water marks on both sides of plunger disk and on upper side of diaphragm	o No comments

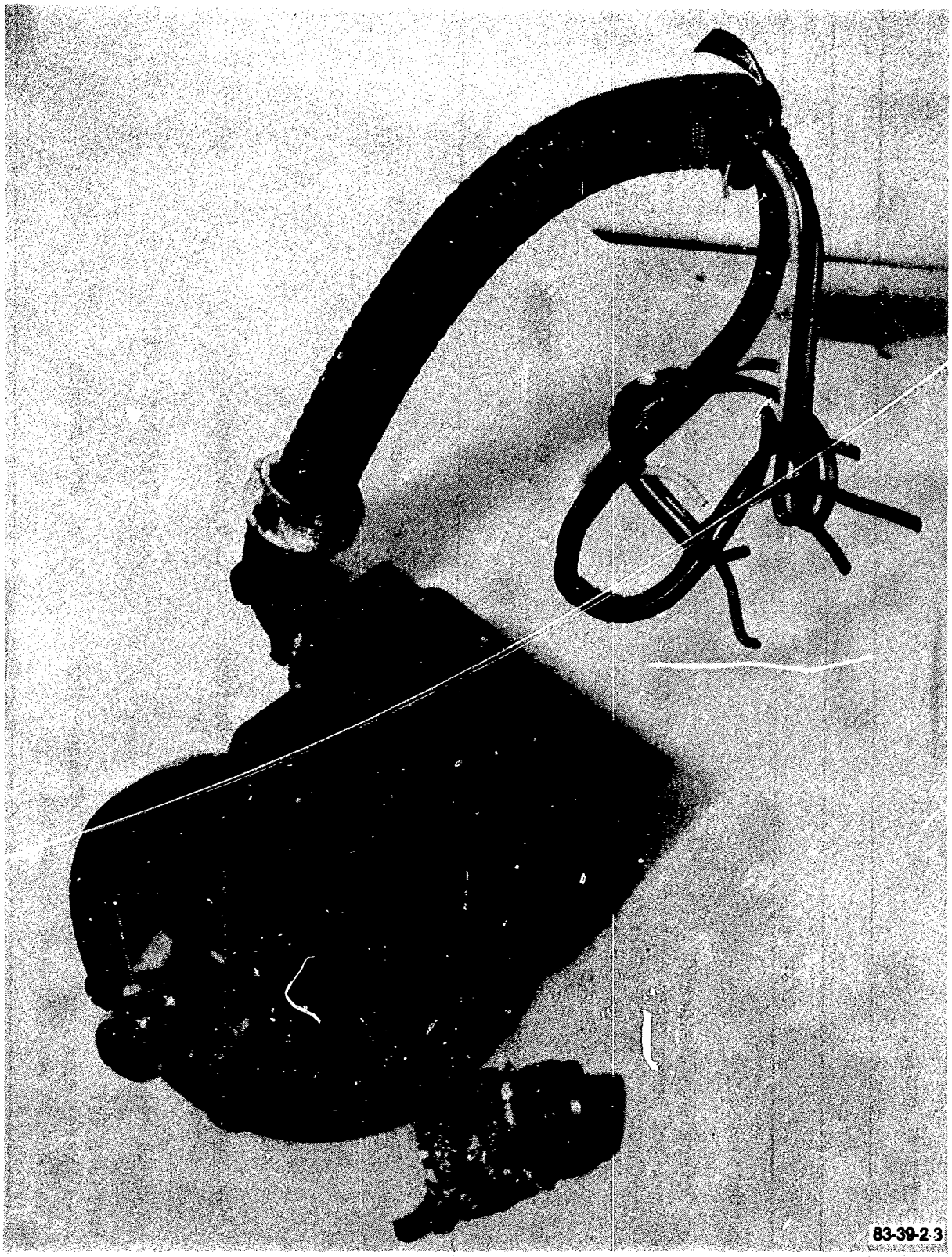


Figure 7. Pressure switch NM-PS-4174 exterior.

Mechanical Characterization.

Pressure Response Characterization--Upon initial observation, the trip pressure was within 0.05 psig of the startup setting (see Table 4). Post-overload testing showed an even smaller difference of 0.03 psig, except on the right switch (not used in the plant circuitry), which exhibited an average difference of 0.11 psig. Reset value was 0.165 psig lower than the startup value, again except for the right switch, which was 0.11 psig higher. These values are within the manufacturer's dead band specifications. The significant difference between the post-overload responses of the left and right switches may be explained by the mechanical damage suffered and the subsequent reassembly under poorer than factory assembly line conditions.

Minimum and maximum settings exhibited a good repeatability of 0.02 (minimum) to 0.06 (maximum) psig (see Tables 5 and 6).

Switch Operating Forces--The switch operating forces were reasonably close to vendor's tolerance. Results are shown in Table 7. (Also see Figure 8 for the mechanical characteristics of the switch.)

Electrical Characterization. During the previous mechanical operations, the NO switch contact, which was reported as closed during in situ tests, appeared to be functioning correctly. However, the NC contact and the right hand switch exhibited open circuit, or high contact resistance, behavior until subjected to the high currents of the dc and ac overload tests. This is typical of switch contacts exposed to plant atmosphere and not used for long periods of time. Results are shown in Table 8. Actual contact resistance and voltage drop, shown in Table 9, are acceptable. Temperature rise at full load ac current is within vendor's tolerance and is shown in Table 10.

TABLE 4. INITIAL OBSERVATION OF LEFT AND RIGHT SWITCH SETTING/RESPONSE FOR PRESSURE SWITCHES NM-PS-4174 AND NM-PS-1454

		Trip[a] (psig)				Reset[b] (psig)			
	Switch	Min	Max	Avg	R[c]	Min	Max	Avg	R
NM-PS-4174 Data									
Startup	Left	--	--	1.65	--	--	--	1.5	--
Initial Test	Left	1.58	1.61	1.6	0.03	1.31	1.36	1.335	0.05
	Right[d]	--	--	4.91	--	--	--	2.7	--
Post-Overload	Left	1.60	1.65	1.62	0.05	1.35	1.37	1.363	0.02
	Right	1.70	1.77	1.76	0.07	1.50	1.63	1.61	0.13
NM-PS-1454 Data									
Startup	Left	--	--	150	--	--	--	142	--
Test	Left	152.6	153.7	153.2	1.1	143.0	144.0	143.55	1.0
	Right	153.2	155.0	154	1.8	143.6	145.1	144.3	1.5

a. Achieved by increasing pressure.

b. Achieved by decreasing pressure.

c. Repeatability (difference between minimum and maximum).

d. Right switch malfunctioned after first reading.

TABLE 5. MINIMUM SETPOINT HYSTERESIS/REPEATABILITY FOR PRESSURE SWITCHES NM-PS-4174 AND NM-PS-1454

		Trip[a] (psig)				Reset[b] (psig)			
	Switch	Min	Max	Avg	R[c]	Min	Max	Avg	R
NM-PS-4174 Data									
Vendor Calibration	Left	0.16	0.16	--	0	0.05	0.05	--	0
	Right	0.16	0.16	--	0	0.05	0.05	--	0
Initial Test	Left	0.47	0.45	0.455	0.02	0.24	0.30	0.28	0.06
	Right[d]	--	--	--	--	--	--	--	--
Post-Overload	Left	0.48	0.51	0.5	0.03	0.29	0.30	0.30	0.01
	Right	0.63	0.67	0.655	0.04	0.48	0.50	4.487	0.02
NM-PS-1454 Data									
Vendor Calibration	Left	7.9	7.9	--	0	6.6	6.6	--	0
	Right	7.9	7.9	--	0	6.6	6.6	--	0
Test	Left	10.0	10.3	10.07	0.3	7.3	7.6	7.55	0.3[e]
	Right	10.3	10.6	10.46	0.3[f]	7.9	8.0	7.98	0.1[g]

a. Achieved by increasing pressure.
b. Achieved by decreasing pressure.
c. Repeatability.
d. Right switch nonoperational.
e. Repeatability differential reduced to a constant of 0.1 for last five readings.
f. Repeatability differential reduced to a constant of 0.2 for last five readings.
g. Repeatability differential reduced to a constant of 0.0 for last five readings.

TABLE 6. MAXIMUM SETPOINT HYSTERESIS/REPEATABILITY FOR PRESSURE SWITCHES NM-PS-4174 AND NM-PS-1454

		Trip[a] (psig)				Reset[b] (psig)			
	Switch	Min	Max	Avg	R[c]	Min	Max	Avg	R
NM-PS-4174 Data									
Vendor Calibration	Left	6.3	6.3	--	0	6.05	6.05	--	0
	Right	6.3	6.3	--	0	6.05	6.05	--	0
Initial Test	Left	5.63	5.65	5.64	0.02	5.28	5.31	5.30	0.03
	Right[d]	--	--	--	--	--	--	--	--
Post-Overload	Left	5.67	5.69	5.68	0.02	5.29	5.30	5.295	0.01
	Right	5.99	6.00	6.0	0.01	5.59	5.61	5.6	0.02
NM-PS 1454 Data									
Vendor Calibration	Left	279.5	280	--	0.5	272	272.5	--	0.5
	Right	279.5	280	--	0.5	272	272.5	--	0.5
Test	Left	272	275	272.6	3[e]	265.1	267 4	265.76	2.3[f]
	Right	272.5	276	273.25	3.59	266	268.5	266.5	2.5[h]

a. Achieved by increasing pressure.
b. Achieved by decreasing pressure.
c. Repeatability.
d. Right switch nonoperational.
e. Repeatability differential reduced to a constant of 0.1 for last five readings.
f. Repeatability differential reduced to a constant of 0.6 for last five readings.
g. Repeatability differential reduced to a constant of 0.3 for last five readings.
h. Repeatability differential reduced to a constant of 0.3 for last five readings.

TABLE 7. ACTUATING FORCES

Function	Manufacturer's Specification	NM-PS-4174		NM-PS-1454	
		Left Switch	Right Switch	Left Switch	Right Switch
Operate	3 to 5 oz	3.8 oz	2.8 oz	3.8 oz	3.8 oz
Release	1 oz min	2.8 oz	1.95 oz	2.75 oz	2.75 oz
Differential Travel	0.004 in. max	0.003 in.	0.001 in.	0.0015 in.	0.002 in.
Over Travel	0.005 in. min	0.016 in.	0.015 in.	0.0165 in.	0.018 in.

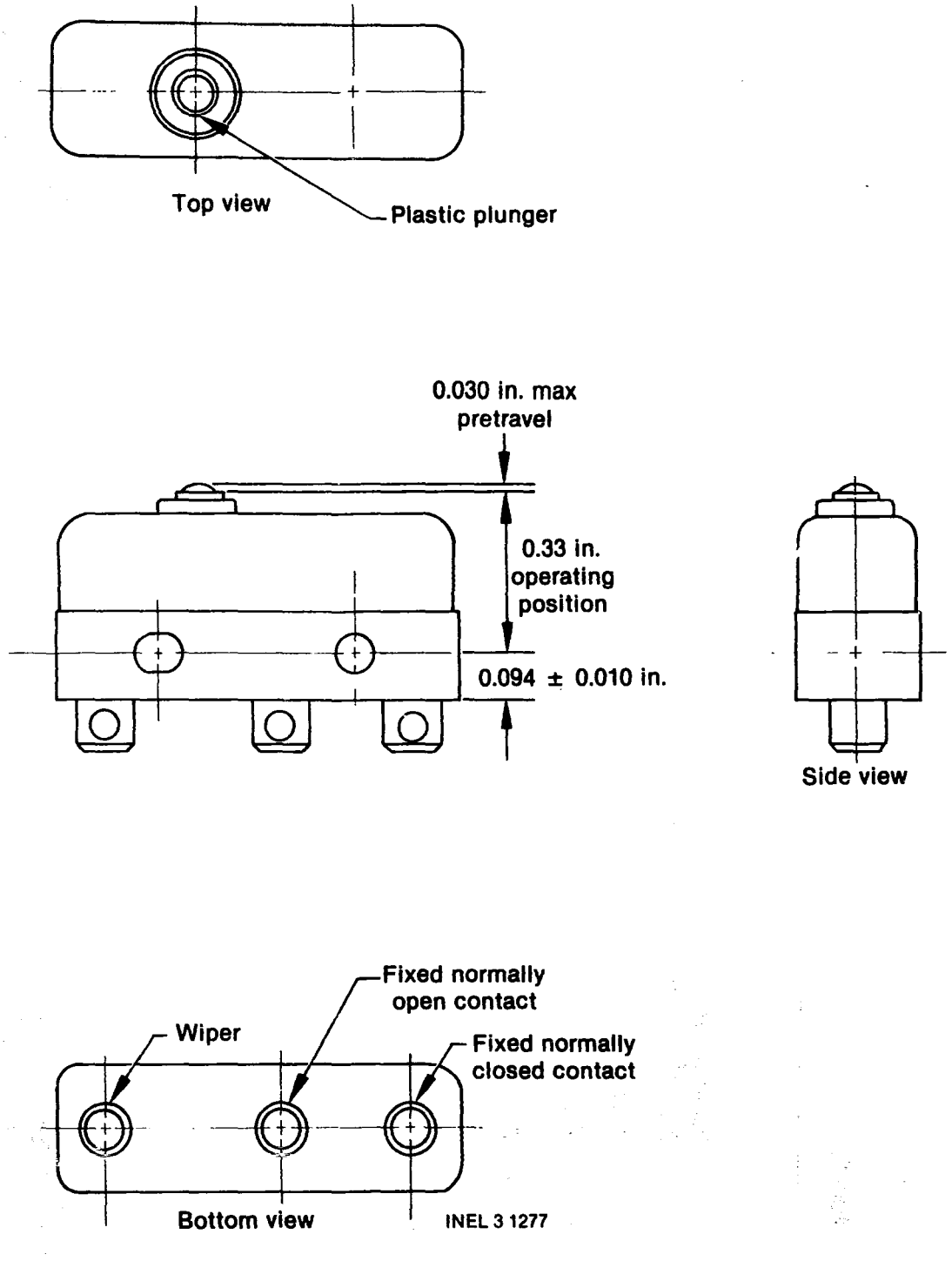


Figure 8. Switch mechanical characteristics showing distance of movement upon activation.

TABLE 8. NM-PS-4174 SWITCH CONTACT ANOMALY PATTERN

Test	Left Switch				Right Switch			
	Normally Open Contact		Normally Closed Contact		Normally Open Contact		Normally Closed Contact	
	Deactuated	Actuated	Deactuated	Actuated	Deactuated	Actuated	Deactuated	Actuated
1. In Situ	NOP-C[a]	NT[b]	NT	NT	NT	NT	NT	NT
2. Visual Inspection								
Before Repair	--[c]	--	--	--	--	--	NOP-O[d]	--
After Repair	--	--	NOP-O	--	--	--	NOP-O	--
3. Min Setpoint Check	--	--	NOP-O	--	--	NOP-O	NOP-O	--
4. Max Setpoint Check	--	--	NOP-O	--	--	NOP-O	NOP-O	--
5. Contact Resistance	--	--	NOP-O	--	--	NOP-O	NOP-O	--
6. DC Overload	--	--	--[e]	--	NT	NT	NT	NT
7. AC Overload	NT	NT	NT	NT	--	--[e]	--	--
8. Repeat 3, 4, 5	--	--	--	--	--	--	--	--

a. Nonoperating--NO contact is closed when not actuated or NC contact stays closed when not actuated.

b. Not tested.

c. Dashes indicate test was conducted, but no anomaly was found.

d. Nonoperating--NO contact stays open when actuated or NC contact is open when not actuated.

e. Recovered after first cycle of operation.

TABLE 9. CONTACT RESISTANCE AND VOLTAGE DROP FOR PRESSURE SWITCHES NM-PS-4174 AND NM-PS-1454

		Left Switch		Right Switch	
		Normally Open Actuated	Normally Closed Unactuated	Normally Open Actuated	Normally Closed Unactuated
NM-PS-4174					
Initial Test	Resistance	0.051Ω	High[a]	High[a]	High[a]
	Drop	25.55 mV	--[b]	--	--
Post DC Overload	Resistance	0.066Ω	0.058Ω	NT[c]	NT
Post AC Overload	Resistance	NT	NT	0.075Ω	0.059Ω
NM-PS-1454					
Initial Test	Resistance	0.060Ω	0.059Ω	0.056Ω	0.056Ω
	Drop	30.0 mV	29.95 mV	28.3 mV	28.45 mV
Post DC Overload	Resistance	0.056Ω	0.066Ω	NT	NT
Post AC Overload	Resistance	NT	NT	0.050Ω	0.040Ω

a. Unrepeatable.

b. Not able to measure.

c. Not tested.

TABLE 10. TEMPERATURE RISE IN °C at 11 AMPS (MAXIMUM ALLOWABLE 30°C)

		NM-PS-4174		NM-PS-1454	
		Left Switch	Right Switch	Left Switch	Right Switch
Unactuated	Common Contact	21.9	21.8	22.99	14.61
	Normally Closed Contact	20.9	21.1	20.67	15.88
	Normally Open Contact	13.1	11.6	10.61	11.82
Actuated	Common Contact	25.5	23.3	22.51	19.28
	Normally Closed Contact	8.1	9.2	7.63	7.33
	Normally Open Contact	24.3	21.95	23.76	17.75

Examination of NM-PS-1454

Radiological Observations. A smear survey of the switch exterior shows 12,000 to 400,000 dpm gross beta and gamma radiation (see Figure 9). The interior of the switch enclosure shows 16,000 dpm, indicating contaminated air had entered the enclosure. Cover plate gamma spectrum analysis and full smear count results appear in Table 2.

Visual Observations. There was no significant corrosion of the instrument itself (see Table 3). However, one cover screw, the instrument tag fasteners, and the conduit fitting were heavily rusted.

The interior of the switch enclosure portion of the assembly was clean, displayed no visible evidence of moisture entry, and could be characterized as looking like new. The cover gasket appeared to be in good condition.

After pressure cell response tests and certain electrical tests were conducted, the pressure cell was disassembled and examined. No unusual conditions were noted.

Mechanical Characterization.

Pressure Response Characterization--Upon initial observation, the trip pressure for the contact used in plant circuitry was an average 3.2 psig above the startup setting (see Table 4). Reset value was an average 1.55 psig above the startup setting. These values are within the manufacturer's dead band specifications.

Minimum and maximum settings exhibited a good repeatability of 0.0 (minimum) to 0.6 (maximum) psig after the first few operations (see Tables 5 and 6).

Switch Operating Forces--The switch operating forces were within vendor's tolerance. Results are shown in Table 7.

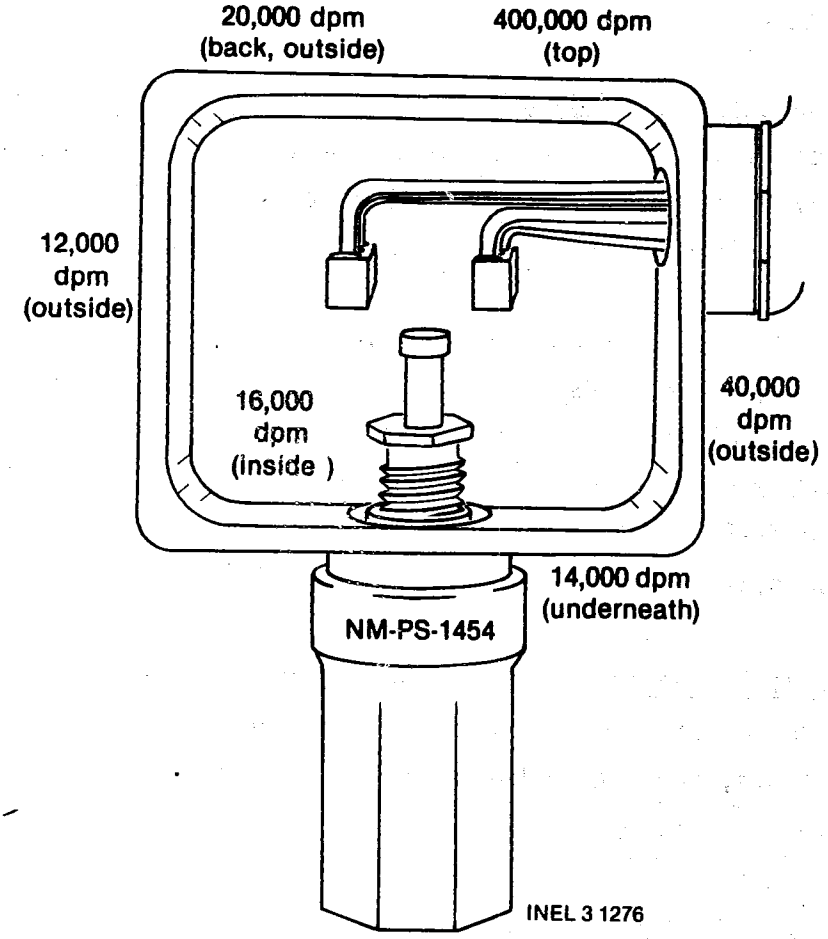


Figure 9. Contamination smear sites for NM-PS-1454.

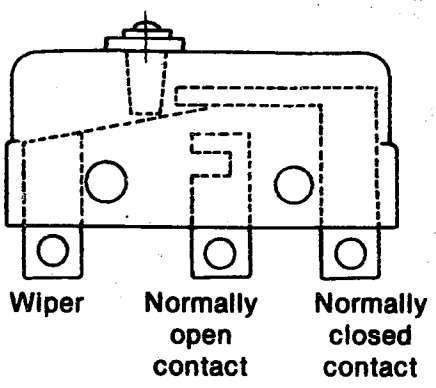
Electrical Characterization. Contact resistance and voltage drop, shown in Table 9, are acceptable. Temperature rise at full load is within vendor's tolerance and is shown in Table 10.

Common Findings

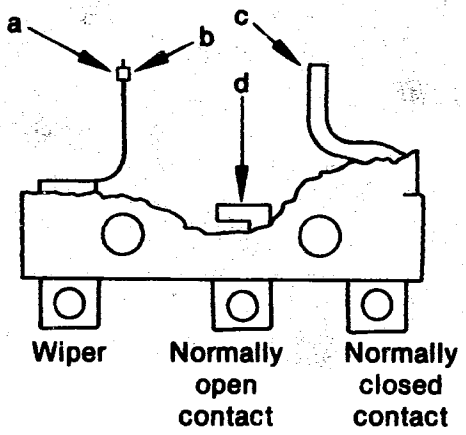
Insulation Resistance and Dielectric Voltage Withstand. For both instruments, the insulation resistance of the microswitches was very good at 10^{10} ohms or greater, and the switches successfully withstood application of 1,000 VAC in each of several connection configurations.

AC/DC Overload. Scanning electron microscope photographs of the right switch (ac overload) of NM-PS-4174 showed evidence of marked contact pitting (see Figures 10 and 11). Consequently, this right switch is considered unacceptable for further use. The left switch (dc overload) of both NM-PS-4174 and NM-PS-1454 showed evidence of contact arcing, but pitting appeared to be minimal (see Figures 10, 12, and 13).

Elastomeric Evaluation. The data presented in Table 11 show that little or no degradation due to irradiation had occurred in the elastomers of the instruments, indicating that the radiation dose received was less than 10^6 rad.



"X-ray" view of assembled switch.

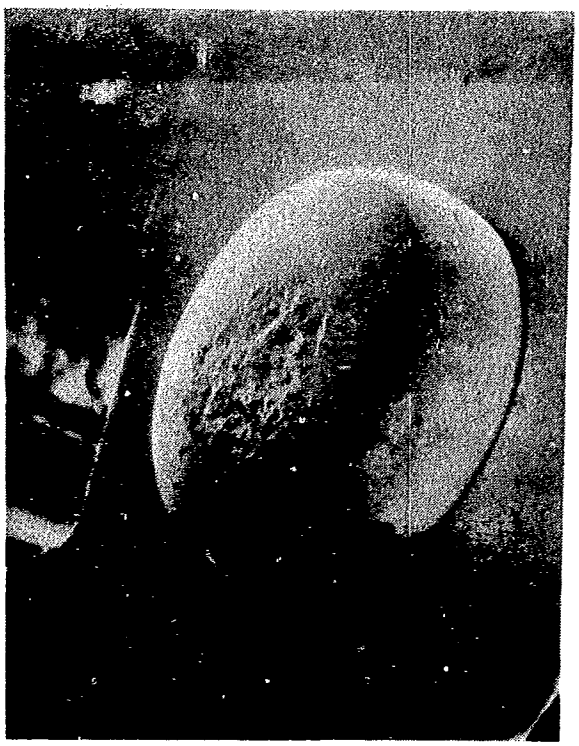


Switch contacts bent for scanning electron microscope examination.

INEL 3 1274

a. Wiper normally closed contact.
b. Wiper normally open contact.
c. Fixed normally closed contact.
d. Fixed normally open contact.

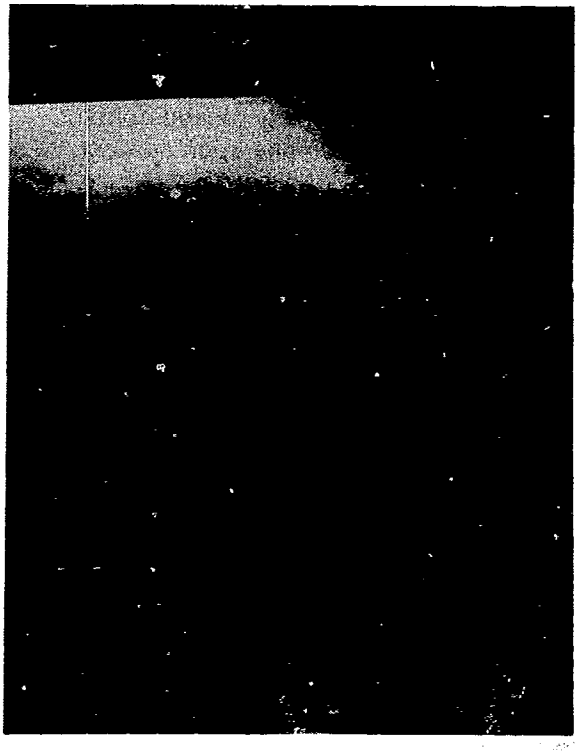
Figure 10. Approximate direction of scanning electron microscope photographs, as indicated by arrows above. (Footnotes correspond with views in Figures 11, 12, and 13.)



Wiper normally closed contact
(angle a)

Fixed normally closed contact
(angle c)

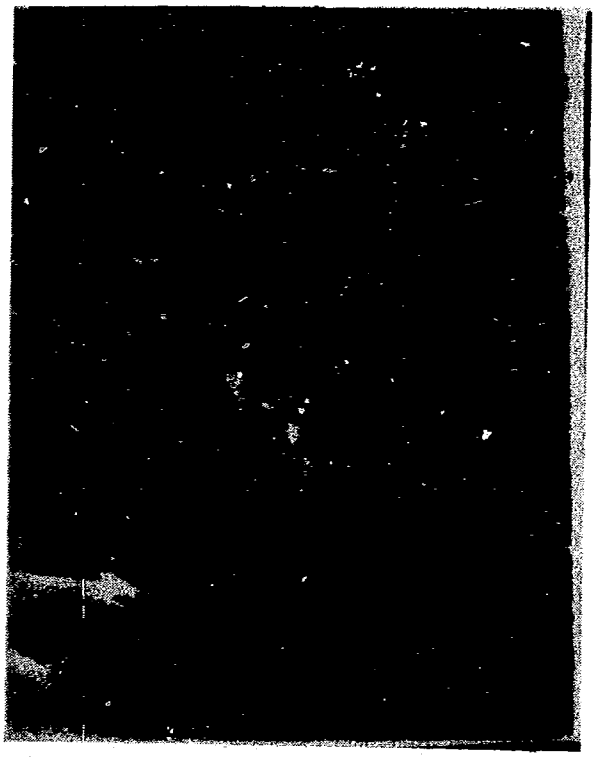
Wiper normally open contact
(angle b)



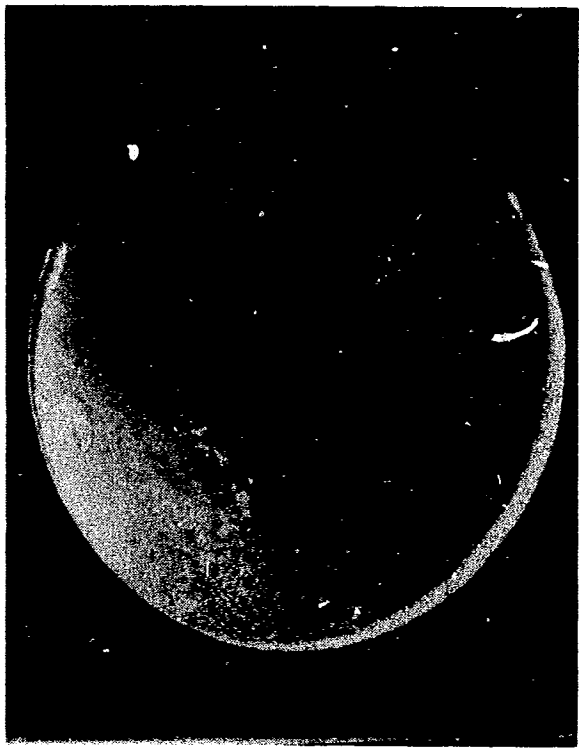
Fixed normally open contact
(angel d)

Figure 11. Scanning electron microscope photographs of NM-PS-4174 right switch taken at the angles shown in Figure 10, post ac overload. (None of these contacts saw plant service.)

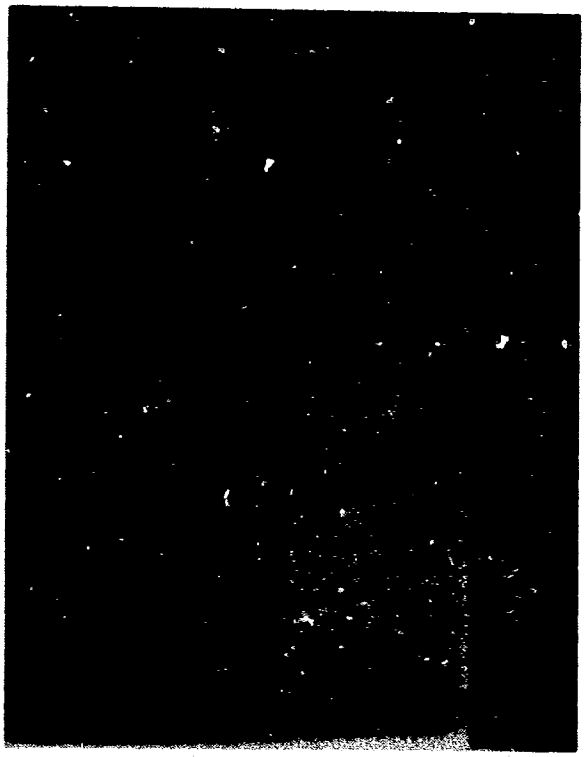
Wiper normally closed contact
(angle a)



Fixed normally closed contact
(angle c)

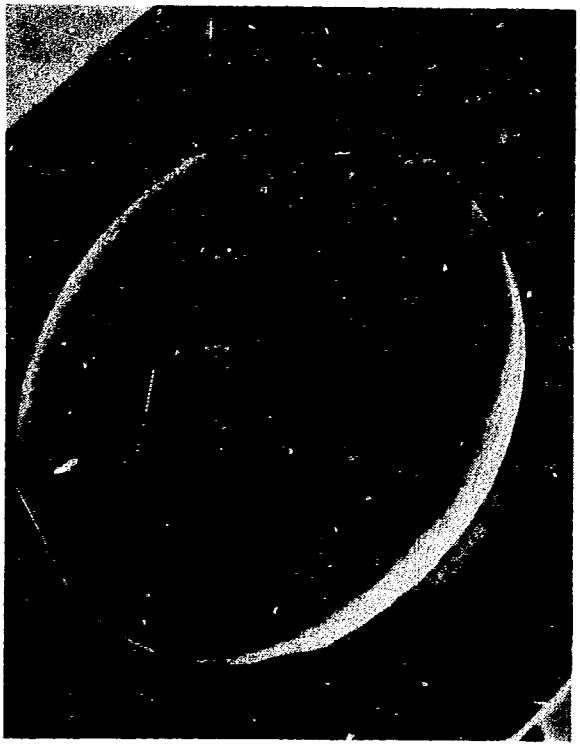


Wiper normally open contact
(angle b)

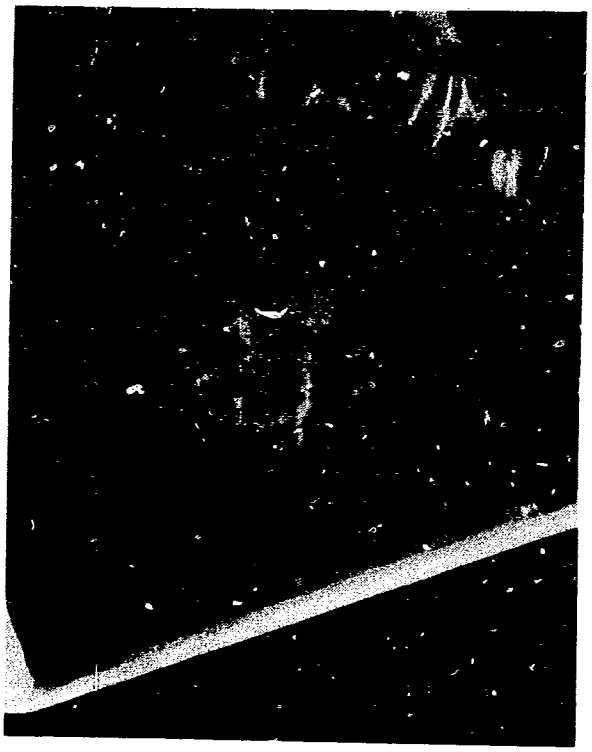


Fixed normally open contact
(angel d)

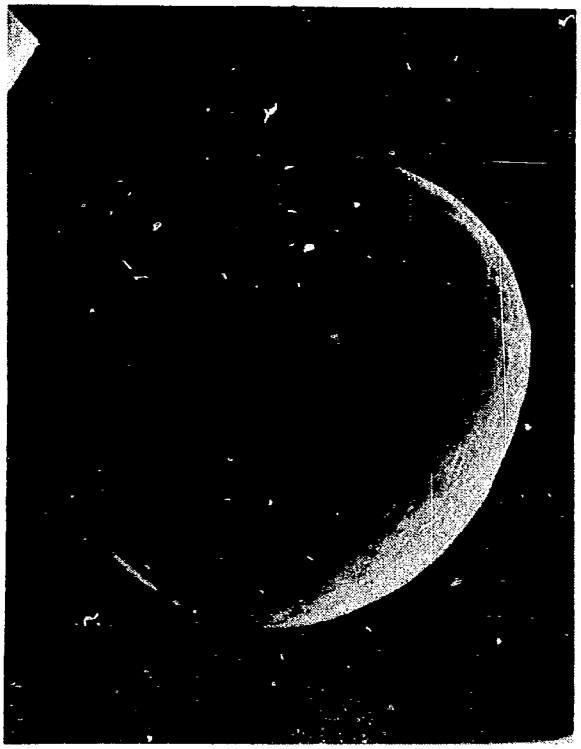
Figure 12. Scanning electron microscope photographs of NM-PS-4174 left switch taken at the angles shown in Figure 10, post dc overload.



Wiper normally closed contact
(angle a)



Fixed normally closed contact
(angle c)



Wiper normally open contact
(angle b)

Fixed normally open contact
(angel d)

Figure 13. Scanning electron microscope photographs of NM-PS-1454 left switch taken at the angles shown in Figure 10, post dc overload.

TABLE 11. ELASTOMER TENSILE TEST DATA

Instrument	Number of Tests	Break Point Average (lbs)	Standard Deviation (lbs)	Elongation Average (%)	Standard Deviation (%)
O-Rings					
NM-PS-4174 (Low Pressure)	4	28.88	0.3	268	16.84
NM-PS-1454 (High Pressure)	2	10.65	2.55	310	82.20
Replacement Pressure Switch (High Pressure)	2	12.35	1.63	264	62.23
Replacement O-Ring (Low Pressure)	8	18.31	1.31	207	24.10
Replacement O-Ring (High Pressure)	3	9.40	0.92	229	44.06
Diaphragms[a]					
NM-PS-4174 Silicon Rubber (Cloth Reinforced)	4	8.30	3.26	330	36.10
BUNA N	4	5.58	1.07	422	180.00
NM-PS-1454 Silicon Rubber (Cloth Reinforced)	2	4.78	0.45	277	0
BUNA N	2	7.73	0.30	209	5.66
Replacement Switch					
Silicon Rubber (Cloth Reinforced)	2	6.85	0.21	342	22.6
BUNA N	2	6.55	1.06	350	56.6

a. Diaphragm test samples were 0.20 in. wide.

CONCLUSION AND RECOMMENDATION

Tests and evaluations confirmed that if moisture is prevented from entering the switch compartment, switches of this type are well suited for the Reactor Building service for which they were installed.

Therefore, it is recommended that instruments such as these pressure switches be carefully sealed when installed to prevent the incursion of moisture.

APPENDIX A
STARTUP DATA AND VENDOR CALIBRATION DATA

T.M.I. UNIT NO. 2
INST. CAL. DATA SHEET

J.O. 9459-02

INST. NO. NM-PS-4174

SER. NO. 76-3-1145

SYSTEM Nuclear Plant N2 Manif. FUNCTION RB N2 Hdr. Below NM-V-142

LOCATION RB2 RK-432 MOD OR TYPE SOR 12N-AA4-CSSX

TOLERANCE NA % OF SPAN SPECIAL DATA

RANGE .2- psig	REFERENCE DATA Spec. 46
OUTPUT NA	B&R Dwg. 2036, 2083-3
ACTION OOD at 1.5 psig	P/I SOr Bull.

CALIB.									
1	Opens on decrease at 1.5 psig								
2	Reset at 1.65 psig								
3									
4									
5									

REMARKS ECM 4261

REVIEWED BY Q. C.
K. Conner 2/11/77
Q. C. ENGINEER DATE

MAXIMUM ERROR IN PERCENT OF SPAN NA

PERFORMED BY MLH/RDC/GH/EB DATE 2/10/77

EVIEWED BY [signature] DATE 2-11-77
UE&C INST. SUP.

ACCEPTED BY RT Carlson DATE 6-24-77
UE&C START-UP

9

TEST EQUIPMENT

W&T # 2
Simpson E27

T.M.I. UNIT NO. 2
INST. CAL. DATA SHEET

J.O. 9459-02

INST. NO. NM-PS-1454

SER. NO. 73-10-1116

SYSTEM Nuclear Plant N2 Manif. FUNCTION N2 Supply Press. Alm. Sw

LOCATION RB2 RK-432 MOD OR TYPE SOR 6N-AA45-CSSX

TOLERANCE NA % OF SPAN SPECIAL DATA

RANGE 10-275 psi	REFERENCE DATA Spec. 46
OUTPUT. NA	B&R Dwg. 2036, 2083-3
ACTION OOI at 150 psig	P/I SOR Bull.

CALIB.									
1	Opens on increase 150 psig								
2	Reset 142 psig								
3									
4									
5									

REMARKS

K Hoover 2/11/77

MAXIMUM ERROR IN PERCENT OF SPAN NA

PERFORMED BY MLM/RDC/GH DATE 2/10/77

REVIEWED BY DATE 2-11-77
UE&C INST. SUP.

ACCEPTED BY DATE 2-24-77
UE&C START-UP

TEST EQUIPMENT

Heise 2647
Simpson E27

TABLE A-1. FINAL TEST AND CALIBRATION DATA FOR NM-PS-1454 AND NM-PS-4174[a]

	NM-PS-1454		NM-PS-4174	
Test[b]	Switch Element No. 1 (psig)	Switch Element No. 2 (psig)	Switch Element No. 1 (psig)	Switch Element No. 2 (psig)
Max Pressure Applied	--	--	25	25
Initial Cycle				
Min Setpoint, Increasing	7.9	7.9	0.16	0.16
Min Setpoint, Decreasing	6.6	6.6	0.05	0.05
Reset at Min	1.3	1.3	0.11	0.11
Second Cycle				
Min Setpoint, Increasing	7.9	7.9	0.16	0.16
Min Setpoint, Decreasing	6.6	6.6	0.05	0.05
Reset at Min	1.3	1.3	0.11	0.11
Min Setpoint Increasing Repeatability	0.0	0.0	0.0	0.0
Min Setpoint Decreasing Repeatability	0.0	0.0	0.0	0.0
Initial Cycle				
Max Setpoint, Increasing	280.0	280.0	6.3	6.3
Max Setpoint, Decreasing	272.5	272.5	6.05	6.05
Reset at Max	7.5	7.5	0.25	0.25
Second Cycle				
Max Setpoint, Increasing	279.5	279.5	6.3	6.3
Max Setpoint, Decreasing	272.0	272.0	6.05	6.05
Reset at Max	7.5	7.5	0.25	0.25
Max Setpoint Increasing Repeatability	0.5	0.5	0.0	0.0
Max Setpoint Decreasing Repeatability	0.5	0.5	0.0	0.0

a. Data taken from Manufacturer's Calibration Data Sheet (TMI-2 Quality Assurance File) and certified to be within the design requirements stated on the applicable specification document.

b. Manufacturer's test procedure: (a)pressure to be increased from 0 psig to actuation value, (b) increase pressure to maximum available for test gauge chosen for range, and (c) proceed from top to bottom as shown, increasing and decreasing pressure for sequence as required.