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Technical Report

No. 13531

DEVELOPMENT OF AN ENGINE COOLANT THERMOSTATIC/PRESSURE SWITCH[1]

CONTRACT DAAE07-89-C-R082

May 1991

[1]Formerly referred to as Dual Level, High Coolant Temperature Warning Switch

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By _____

U.S. ARMY TANK-AUTOMOTIVE COMMAND
RESEARCH, DEVELOPMENT & ENGINEERING CENTER
Warren, Michigan 48397-5000

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Military vehicle engine cooling systems are frequently pressurized in order to raise the operating temperature of the coolant above the ambient boiling temperature. System pressure can be lost due to a defective radiator cap or any other pressure leak. Undetected loss of pressurization renders a vehicle unusable due to loss of coolant from boiling. Such engines are often equipped with a dashboard mounted over-temperature warning light which is activated by a thermostatic switch such as is described in MIL-S-12285. This type of switch does not provide warning of loss of pressurization.

This report describes the development of a thermostatic/pressure switch designed to warn of both coolant over-temperature conditions as well as loss of cooling system pressurization. The program involved the detailed design, qualification testing, and manufacture of preproduction thermostatic/pressure switches as well as preparation of a draft revision to MIL-S-12285.

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1.0 INTRODUCTION

This final report describes the development and testing of a thermostatic/pressure switch[1] by Index Industries for the U.S. Army Tank-Automotive Command (TACOM) under Contract DAAE07-89-R082. This device provides effective warnings of both over-temperature and under-pressurization of engine coolant systems. Included in the project was a detailed design effort, preproduction manufacturing, qualification testing, preparation of a draft military specification and in-vehicle application engineering.

[1] This switch was formerly referred to as the Dual Level, High Coolant Temperature Warning Switch.

2.0 OBJECTIVE

The contractual objectives were to accomplish the following:

- Finalize a production design of a thermostatic/pressure switch previously investigated as part of a Small Business Innovative Research (SBIR) contract with TACOM (ref. 1).
- Incorporate into the design the form and fit of the MIL-S-12285 thermostatic switches currently used in military vehicles (ref. 2).
- Include in the design both upper and lower temperature switching elements and a pressure switching element.
- Expand the over-temperature warning function to include a pressure sensing electrical interlock to activate the upper or lower temperature switching element depending on coolant pressure.
- Manufacture preproduction units designed to provide a warning whenever the coolant temperature is above 205^{o}F (when the cooling system pressure is less than 7 psig), and another warning whenever the coolant temperature is above 230^{o}F (regardless of cooling system pressure).
- Conduct qualification tests of preproduction units (ref. 3).
- Support in-vehicle testing of the devices and develop a retrofittable application to the M113 family of vehicles.
- Prepare a new specification or a modification to MIL-S-12285.

5.0 DISCUSSION

5.1 Mechanical/Electrical Design

The mechanical/electrical design challenge was to contain three switching elements (two temperature and one pressure) in the physical configuration which previously contained only one switching element. This was made feasible by the adaptation of a small, modular switching element which is used by Index Industries in its commercial temperature and pressure switch products. An important reliability feature of the design is the avoidance of internal conducting wires or electrical traces around the individual switching elements. The switch design, including a cut-away view of the stacking of the switching elements as well as a the switch circuit schematic is shown in Figure 5-1.

The probe diameter of the switch housing was increased from .610 inches as specified in MIL-S-12285D to .670 inches in order to accommodate 0.5 inch diameter internal switching elements. Index has manufactured over 750,000 coolant temperature switches with a .670 probe diameter with no reports of mechanical interference.

In order to assure precise switching pressures it was necessary to incorporate a hydrophobic vent into the design. This vent ensures that the internal reference pressure of the switch will be the same as atmospheric pressure and unaffected by the heating and cooling of the device.

The coolant pressure is sensed through a .050 inch diameter port in the bottom of the switch. This port size has been used in a wide variety of other pressure switches; accordingly, fouling of the port is considered unlikely.

Each of the three switching elements is designed to demonstrate snap action switching and therefore has switching hysterisis with a unique set point and reset point. Table 5-1 describes the parameters which relate to these unique set and reset points as well as the initial calibration requirement.

5.2 Functional Design Considerations

Most engine cooling systems are pressurized in order to (a) prevent coolant pump cavitation, (b) to allow the higher operating temperatures required for optimal engine performance and (c) to prevent coolant from boiling. The pressure in the coolant system is generated by the thermal expansion of the coolant and trapped air in the cooling system. System pressurization is usually controlled by a pressure relief valve incorporated into the radiator cap. Typical system pressures are in the 10 - 15 psig range.

Classical over-temperature warning systems consist of a thermostatic switch electrically connected to a warning lamp or a buzzer. The set point temperature of the switch is typically established at least 5-10^{0}F above the maximum expected operating temperature of the engine. Assuming that the cooling system is designed to pressurize to 10 psig, a typical operating temperature could be as high as 225^{0}F; in this instance, the over-temperature warning

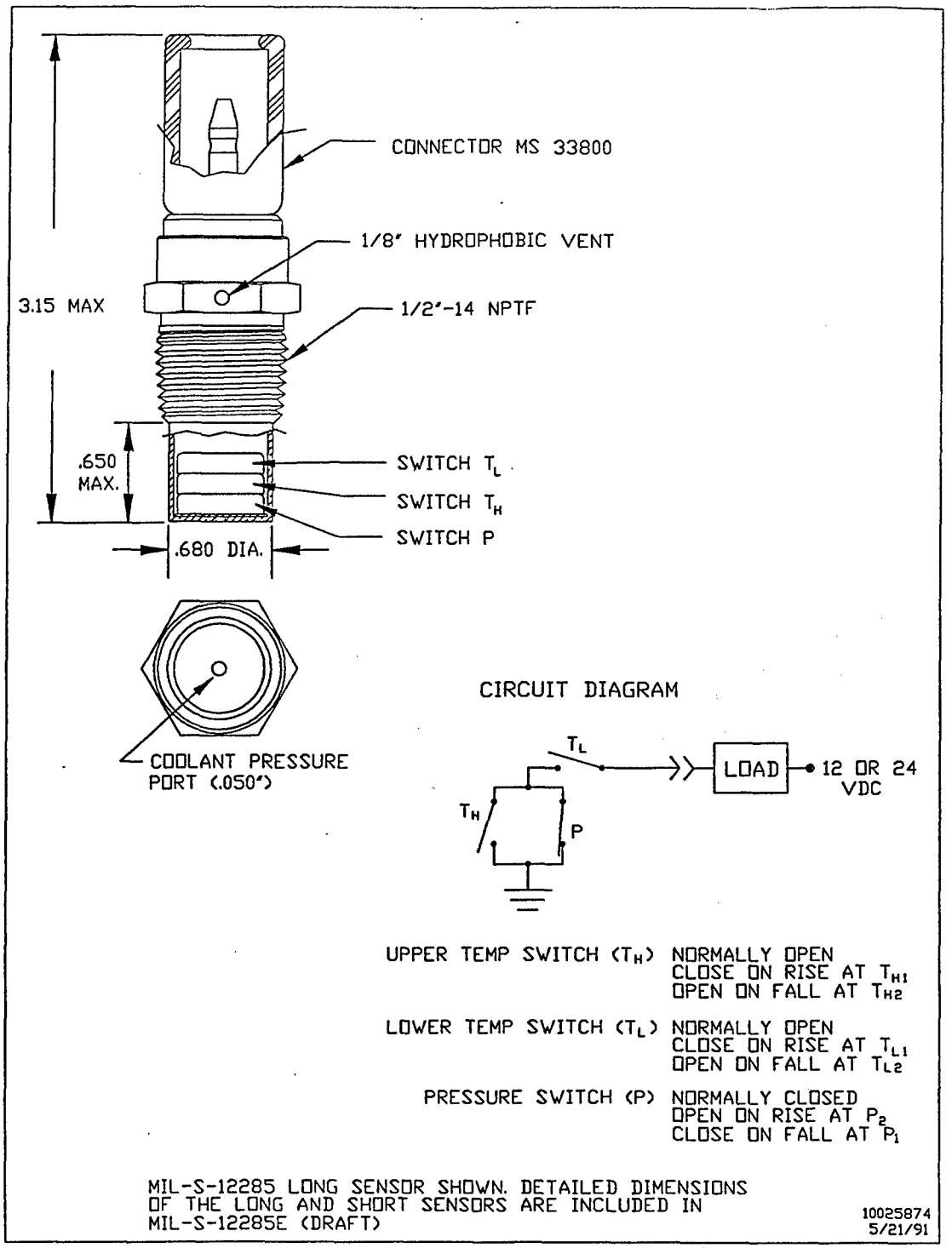


Figure 5-1. Thermostatic/Pressure Switch

Table 5-1 Switching Parameters and Initial Calibration Requirements

Switch Parameter	Related Condition	Parameter Description	Initial Calibration Requirement
P_1	none	Descending Setpoint Pressure	7.0 +/- 1.5 psig
P_2	none	Ascending Setpoint Pressure	P_1 + (2.5 psig max)
TL_1	$P < P_2$	Low Setpoint Temperature	205^0 +/- 3.6^0 F
TL_2	$P < P_2$	Low Reset Temperature	TL_1 - (15^0 F max)
TH_1	$P > P_1$	High Setpoint Temperature	230^0 +/- 3.6^0 F
TH_2	$P > P_1$	High Reset Temperature	TH_1 - (15^0 F max)

Table 5-2 Example of Cooling System Temperatures

Parameter	Temperature
Coolant Boiling Temperature (pressurized)	245°F
Coolant Pump Cavitation Temperature (pressurized)	235°F
Thermostatic/Pressure Switch High Setpoint	230°F
Maximum Specified Engine Operating Temperature	225°F
Coolant Boiling Temperature (unpressurized)	220°F
Coolant Pump Cavitation Temperature (unpressurized)	210°F
Thermostatic/Pressure Switch Low Setpoint	205°F

switch should be designed to activate at approximately 230°F. Such an over-temperature condition could occur under an excessive operating load or if a related cooling system component fails (thermostat valve, fan belt, coolant pump, fan, etc.).

If there is a cooling system fault such that pressurization is not achieved during engine warm-up, it is possible that the coolant will boil before an over-temperature warning is activated. This is because the maximum temperature of the unpressurized coolant (the boiling temperature) is less than the set point of the over-temperature warning switch. Similarly, if the coolant temperature is in the normal operating range (pressurized system) and cooling system pressure is rapidly lost, the coolant will instantly begin to boil causing a significant loss of coolant.

The thermostatic/pressure switches developed as a part of this effort are intended to warn of both excessive coolant temperature conditions and inadequate coolant system pressurization. The switch is comprised of an high temperature switching element, a low temperature switching element, a pressure switching element and case grounded, normally open electrical contacts. Closing of the electrical contacts by the switching elements activates a warning lamp or audio alarm. The functional switch design provides three types of cooling system warnings:

> Coolant over-temperature warning is provided whenever the coolant temperature is greater than the high setpoint temperature.
>
> Coolant over-temperature warning is provided whenever the coolant temperature is greater than the low setpoint temperature and the coolant system pressure is less than the descending pressure set point.
>
> Coolant system under-pressurization warning is provided whenever the coolant system pressure is less than the descending setpoint pressure and the coolant temperature is greater than the low setpoint temperature.

The switches developed under this contract had a high setpoint temperature of 230°F, a low setpoint temperature of 205°F, and descending setpoint pressure of 7 psig. Table 5-2 provides an example of how these setpoint temperatures would relate to a typical engine cooling system.

When applied to a typical diesel engine, the thermostatic/pressure switch operates as follows:

> Prior to starting a cool engine, the system pressure is zero psig. The over-temperature alarm remains off because the pressure is less than 7 psig and the coolant temperature is less than 205°F.

As the engine warms up, the thermal expansion of the coolant pressurizes the cooling system before the coolant temperature reaches 205°F. Unless there is a fault in the cooling pressurization system, the over-temperature alarm won't

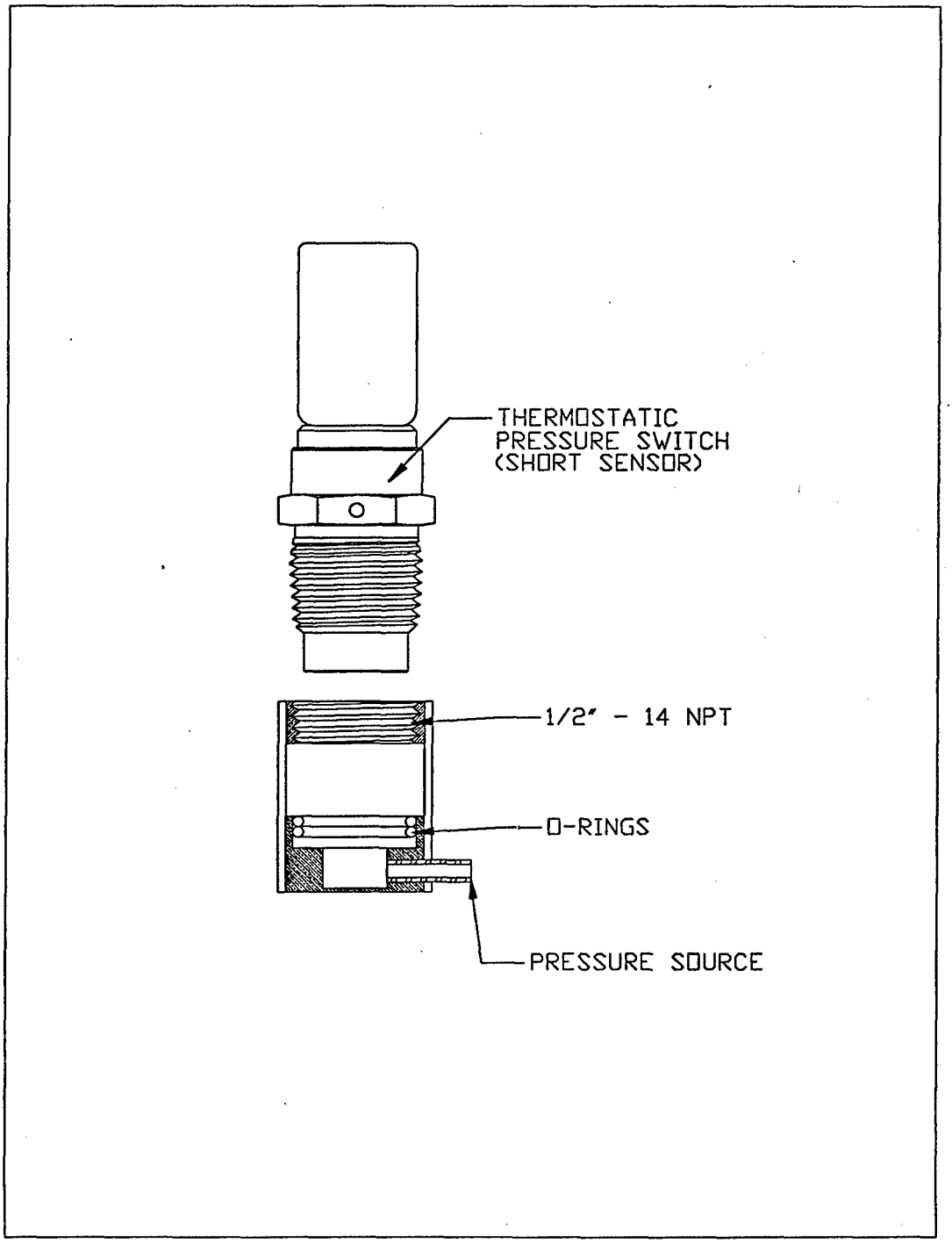


Figure 5-2. External Pressure Manifold

activate unless the coolant temperature exceeds 230°F.

If there is a fault in the pressurization system, the over-temperature alarm will activate if the engine temperature exceeds 205°F before the system pressure reaches the ascending setpoint pressure (approximately 8 psig). This provides warning of leaks in the cooling system during vehicle warm up and initial operation.

If the engine is operating at its maximum specified temperature of 225°F and subsequently loses cooling system pressurization, the 7 psig interlock will activate the low temperature (205°F) switching element causing the over-temperature alarm to activate. Continued operation of the vehicle is possible providing that the engine temperature is kept below the low switching temperature.

5.3 Manufacture of Preproduction Switches.

The switches were manufactured using components and tooling which were similar to that used for manufacture of Index commercial temperature and pressure switch products. The manufacturing challenge was to refine the sensor disc manufacturing processes to reliably achieve the desired temperature and pressure calibrations of the assembled switch.

One of the major differences in the manufacturing process was the need to apply both heat and pressure in order to calibrate the device. Rather than develop pressurized thermal baths, Index developed an externally mountable and submersible pressure manifold to facilitate individual switch calibration. (See Figure 5-2).

Two lots of preproduction thermostatic/pressure switches were manufactured. The initial lot was originally intended to be used for design refinement however due to the generally good performance of this lot, coupled with schedule constraints, it was decided to use these switches for the environmental exposure portions of the qualification test program. Because the disc manufacturing processes had not yet been fully refined, several of these switches were slightly out of calibration or near the tolerance limits for initial calibration. Use of these switches for the environmental portion of the qualification testing was appropriate because the primary performance criteria for these tests is based upon changes in calibration rather than absolute calibration values.

The second lot of switches were used for the initial calibration part of the qualification testing as well as for delivery to TACOM. The manufacturing process for the thermostatic/pressure switch involves manufacture and calibration of the individual switching elements followed by final assembly and testing of the complete unit. 100% of the switches are screened for initial calibration conformance. As shown in Table 5-3 the initial calibration data of the second lot of switches was excellent and validated that these devices are very producible using assembly personnel and tooling appropriate for manufacture of commercially equivalent products.

Table 5-3 Summary of Initial Calibration Data (Preproduction Lot)

Test Parameter	Mean Calibration	Standard Deviation	Calibration Requirement
TL_1	205.93	0.48	205 +/- 3.6°F
TL_2	193.08	1.83	TL_1 - (15°F max)
P_1	6.9	0.23	7.0 +/- 1.5 psig
P_2	8.3	0.70	P_1 + (2.5 psig max)
TH_1	231.6	0.65	230 +/- 3.6°F
TH_2	221.4	0.57	TH_1 - (15°F max)

5.4 Qualification Testing

5.4.1 Overview.

The purpose of the qualification testing was to demonstrate conformance to the test requirements specified in MIL-S-12285E (Draft). The test procedures and test requirements were derived from the existing MIL-S-12285D specification for thermostatic switches with appropriate adjustments made for the unique aspects of the thermostatic/pressure switch (ref. 3). The primary focus of the testing was to demonstrate that the devices would perform satisfactorily after exposure to a variety of severe environments and extended endurance testing. Satisfactory performance was determined by measuring changes in the calibration data before and after the testing.

Index Industries performed most of the testing in its laboratory and subcontracted the remaining tests to qualified test vendors. The qualification sample consisted of seven switches from the initial production lot which were identical to the twelve production configuration switches subsequently delivered to TACOM.

5.4.2 Abbreviated Test Description

Calibration. This test is the primary basis for initial quality conformance and is used to validate switch performance after various qualification tests.

High Temperature. This test required exposing the sample to elevated temperatures for one minute in a fluid bath at 150^{0} C.

Endurance. This test required exposure of the sample to repeated thermal and pressure cycles simulating lifetime actuation and non-actuation conditions.

Waterproofness. This test required that the sample be submerged in a saline solution for 1.5 hours and then be subjected to 15 hours of dry operation.

Vibration. This test required that the sample be subjected to a total of 9 hours of multi-axis vibration using specialized equipment capable of producing sweeps through the frequency range of 10 to 3500 Hz, at a peak of 50 g.

Fungus. This test required that the sample be exposed to a specified composite of fungus spores and then subjected to 90 days of continuous incubation.

Corrosion. This test required that the sample be subjected to 200 hours of salt spray in a controlled environment.

Shock. This test required that the sample be subjected to an impact of 100g, repeated ten times.

Table 5-4. Summary of Qualification Test Data

Parameter	Allowable Change	Minimum Change	Maximum Change	Mean Change	Standard Deviation
TL_1	+/-3.6°F	0.1	2.2	.53	.77
TL_2	+/-3.6°F	0.2	2.1	.04	1.32
P_1	+/-1.0 psig	0.0	0.8	.18	.31
P_2	+/-1.0 psig	0.0	0.6	.13	.26
TH_1	+/-3.6°F	0.0	0.6	.03	.32
TH_2	+/-3.6°F	0.2	1.1	.20	.64

Dielectric Withstanding. This test required that the sample be subjected to a potential of 440 volts rms between its terminal and case at a temperature of 180°F.

5.4.3 Qualification Test Results.

The qualification test program was successfully performed on the sample switches. There were no performance deficiencies and no required design changes. As shown in Table 5-4, the change in calibration after exposure to the various test environments was minimal and validates that the switch design is rugged, durable and reliable. Detailed descriptions of the testing and the corresponding results is contained in Appendix A. Vendor test reports are included in Appendix B.

5.5 In-Vehicle Testing

The contract originally required that Index support in-vehicle testing of the switches at the Yuma Proving Grounds. The contract was subsequently modified to require Index to provide support for the installation, form, fit, function testing of the switches on M113 vehicles at Ft Lewis, WA.

Index Industries engineers made approximately five field trips to Ft Lewis for this purpose. Cooperation by all TACOM and military personnel at Ft Lewis was excellent. While the focus of this application engineering task was upon the M113 family of vehicles, other vehicles evaluated included an M-923 five ton truck and an M-578 recovery vehicle.

The M-923 five ton truck had two cooling system problems. Initial examination revealed that the vehicle had an inoperative overtemp warning system because of a defective warning lamp; sensing of an over-temperature condition by the installed thermostatic switch would not have been displayed to the driver. The system did not have any type of a "lamp check" feature to automatically alert the driver of a burned out over-temperature warning lamp. After installing a thermostatic/pressure switch on an available 1/2" NPT port in the coolant manifold, the engine was started and allowed to warm up. Before the coolant reached the normal operating temperature, the thermostatic/pressure switch warned of an over-temperature condition indicating a pressurization problem. Subsequent investigation revealed that a defective radiator cap was preventing pressurization of the coolant system.

Most of the vehicles used for in-vehicle testing and application efforts were from the M113 family of vehicles with Detroit Diesel 6V-53 engines. Although they are equipped with temperature gauges, these vehicles do not have a warning signal such as a lamp or audio device to warn of engine over-temperature conditions. In contrast, the engine oil pressure condition is monitored by both a gauge and a warning light. TACOM requested that Index determine a method for applying the thermostatic/pressure switch to these vehicles on a retrofit basis.

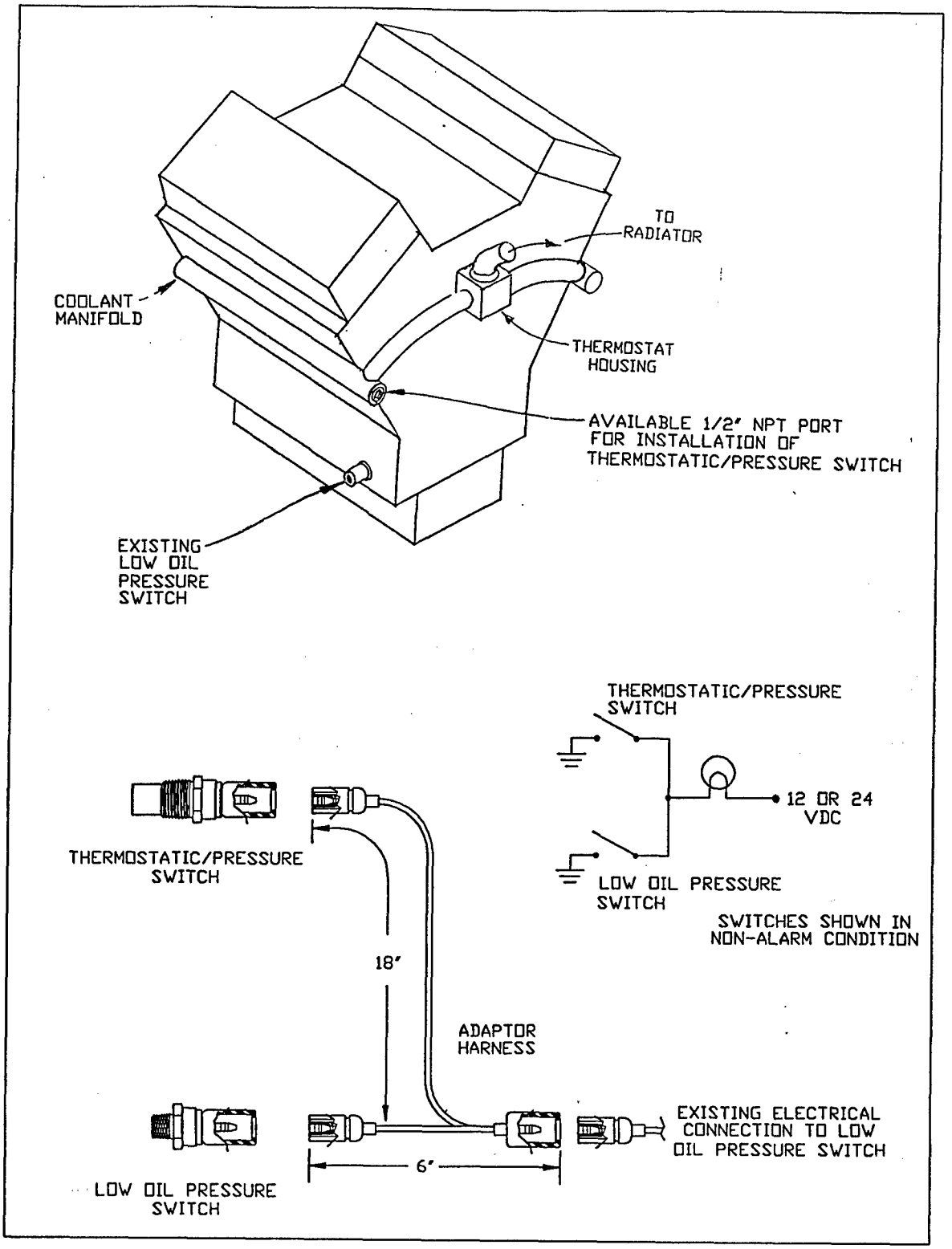


Figure 5-3. Adaptation to the M113 Vehicle

Two approaches were considered. The first approach was to simply install a thermostatic/pressure switch on the engine block and electrically connect it to a new warning lamp which would have to be installed on the instrument panel. This approach was discarded because of the difficulties of (a) adding a light to an overcrowded instrument panel, (b) accessing electrical power from the sealed wiring bundle, and (c) routing the new wiring through the firewall. A further consideration was that there would be no easy means for providing a "lamp check" to assure that the warning lamp was functioning prior to engine start. It should be noted that the low oil pressure warning lamp is automatically "lamp checked" whenever the ignition is turned on prior to engine start.

The second approach involved installing a thermostatic/pressure switch on the engine and electrically connecting it in parallel with the low oil pressure switch using a simple wire harness. This approach was selected for the following reasons:

The existing warning light can be used for multiple functions. Warning of low oil pressure, excessive coolant temperature or low coolant pressure is feasible since the installed temperature and pressure gauges can be used to ascertain the cause of the warning.

The low oil pressure warning system provides a reliable "lamp check" prior to each engine start.

The existing vehicle wire harness does not need to be modified.

The modification is simple and inexpensive. An eighteen inch wire harness with appropriate electrical terminations is designed to simply snap in place on the temperature switch and on the pressure switch.

The adaptation of the thermostatic/pressure switch to the M113 vehicle is shown schematically in figure 5-3. Subject to slight harness modifications, this approach can also be used to retrofit the thermostatic/pressure switch to the any other vehicle that has an available 1/2" NPT port in the engine coolant manifold and either an existing oil pressure or over-temperature warning system.

LIST OF REFERENCES

1. TACOM RD&E Center Technical Report No. 13257 Dual-Level, High-Coolant Temperature Warning Switch. Design, fabrication, and Test of Prototypes. Contract DAAE07-86-C-R071, April 1987.

2. MIL-S-12285D(AT) Military Specification, Switches, Thermostatic, 20 December, 1989.

3. Dual Level, High Coolant Temperature Warning Switch Qualification Test Plan, TACOM Contract DAAE07-89-R082, Data Item DI-A002, Submitted by Index Industries, 23 April 1990.

4. MIL-S-12285E (Draft) Military Specification, Switches, Thermostatic and Thermostatic/Pressure, Submitted by Index Industries, May 1991.

APPENDIX A

QUALIFICATION TEST PROCEDURES AND RESULTS

Background

The purpose of the testing was to determine conformance to the qualification test requirements specified in MIL-S-12885E (draft) for thermostatic/pressure switches. The primary purpose of the testing was to demonstrate that the devices performed satisfactorily after exposure to a variety of severe environments and extended endurance testing. Satisfactory performance was determined by measuring changes in the calibration data before and after the testing.

Index Industries performed most of the testing in its laboratory and subcontracted the remaining tests to qualified test vendors. The qualification sample consisted of seven switches which were identical to the twelve production configuration switches which were subsequently furnished to TACOM.

Abbreviated Test Descriptions

Calibration. This test is the primary basis for initial quality conformance and is used to validate switch performance after various qualification tests. Typically, each qualification test requires sample calibration before and after switch exposure to the specified environment.

High Temperature. This test involves exposing the sample to elevated temperatures for one minute in an instrumented, fluid bath at 150° C. .

Endurance. This test involves exposure of the sample to repeated thermal and pressure cycles simulating lifetime actuation and non-actuation conditions.

Waterproofness. This test requires that the sample be submerged in a saline solution for 1.5 hours and then subjected to 15 hours of dry operation.

Vibration. This test requires that the sample be subjected to a total of 9 hours of multi-axis vibration using specialized equipment capable of producing sweeps through the frequency range of 10 to 3500 Hz, at a peak of 50 g.

Fungus. This test requires that the sample be exposed to a specified composite of fungus spores and then subjected to 90 days of continuous incubation.

Corrosion. This test requires that the sample be subjected to 200 hours of salt spray in a controlled environment.

Shock. This test requires that the sample be subjected to an impact of 100 g, repeated ten times.

Dielectric Withstanding. This test requires that the sample be tested for its ability to withstand a potential of 440 volts rms between its terminal and case at a temperature of 180°F.

Qualification Testing Sequence

Qualification testing involved seven test samples which were tested in the order listed below:

Sample Number	MIL-S-12885E (Draft)[1] Paragraph	Test Sequence	Testing Agency
001	4.9.3	Calibration	Index[2]
	4.9.5	High Temperature	Index
	4.9.3	Calibration	Index
	4.9.6	Waterproofness	Index
	4.9.3	Calibration	Index
010	4.9.3	Calibration	Index
	4.9.11	Endurance	Index
	4.9.3	Calibration	Index
003	4.9.3	Calibration	Index
	4.9.10	Vibration	ESC[3]
	4.9.3	Calibration	Index
005	4.9.3	Calibration	Index
	4.9.7	Corrosion	ESC
	4.9.3	Calibration	Index
004	4.9.3	Calibration	Index
	4.9.9	Shock	ESC
	4.9.3	Calibration	Index
002	4.9.3	Calibration	Index
	4.9.4	Dielectric Withstanding	ESC
	4.9.3	Calibration	Index
008	4.9.3	Calibration	Index
	4.9.8	Fungus	Wyle[4]
	4.9.3	Calibration	Index

1 *MIL-S-12285E (Draft) see reference 4.*
2 *Index Industries, Bellevue, Washington.*
3 *Electronic Specialty Corporation, Vancouver, Washington.*
4 *Wyle Test Laboratories, El Segundo, California.*

Calibration Testing

Purpose. The purpose of the calibration test is to determine conformance to the performance specifications detailed in paragraph 4.9.3 of MIL-S-12885E (Draft). This test is the primary basis for initial quality conformance and is used to validate switch performance after various qualification tests.

Required Data and Performance. The calibration test requires that four temperature values and two pressure values be recorded. These values are based upon circuit closure, or warning light "on" conditions, and circuit opening, or warning light "off" conditions. Test samples are required to meet the initial calibration requirements specified in table A-II-1.

Testing Apparatus. The calibration test apparatus included mounting manifold, a fluid bath circulating through the manifold, a regulated, variable source of pressure, a 3 candlepower (cp), 24 volt indicating lamp connected to a 28 volt direct current (dc) source of electrical energy, and laboratory thermometers and pressure gauges.

Calibration Test Procedure.

1 The sample was mounted in such a position that the circulating fluid covered the tapered thread.

2 The sample was electrically connected through the indicator lamp to the voltage supply.

3 The initial bath temperature was set at a maximum of 195^{0} F and the manifold pressure maintained at zero psig.

4 The fluid bath temperature was set to increase at a rate no greater than 1^{0}F per minute until the indicator lamp illuminated. TL_1 was recorded.

5 The bath temperature was then maintained at 5^{0} F above TL_1 and the manifold pressure was increased until the indicator lamp turned off. P_2 was noted and recorded.

6 The manifold pressure was decreased until the indicator lamp turned off. P_1 was noted and recorded.

7 The manifold pressure was increased to P_2 (lamp off).

8 The bath temperature was increased at a rate no greater than 1^{0} F per minute until the indicator lamp turned on. TH_1 was noted and recorded.

9 The bath temperature was decreased at a rate no greater than 1^{0} per minute until the indicator lamp turned off. TH_2 was noted and recorded.

10 The manifold pressure was decreased to P_1 or less (lamp on).

11 The bath temperature was decreased at a rate no greater than $1^{o}F$ per minute until the lamp turned off. TL_2 was noted and recorded.

12 The recorded values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2 were compared with the applicable requirements specified in MIL-S-12285E (Draft).

Initial Calibration Requirements

Switch Parameter	Related Condition	Parameter Description	Initial Calibration Requirement
TL_1	$P < P_1$ psig	Low Setpoint Temperature	205^{o} +/- 3.6^{o} F
TL_2	$P < P_1$ psig	Low Reset Temperature	TL_1 - (15^{o} F max)
P_1	None	Descending Setpoint Pressure	7.0 +/- 1.5 psig
P_2	None	Ascending Setpoint Pressure	P_1 + (2.5 psig max)
TH_1	$P > P_2$ psig	High Setpoint Temperature	230^{o} +/- 3.6^{o} F
TH_2	$P > P_2$ psig	High Reset Temperature	TH_1 - (15^{o} F max)

Calibration Test Results

The following data are the initial calibrations of the twelve switches delivered to TACOM. As previously discussed in section 5.2, these units were used to satisfy the qualification test for calibration. All units satisfied the initial calibration requirement and therefore passed the calibration qualification requirement.

Serial Number	TL_1 (^{o}F)	P2 (psig)	P1 (psig)	TH_1 (^{o}F)	TH_2 (^{o}F)	TL_2 (^{o}F)	Results
01L	205.5	7.8	6.7	232.3	221.5	192.5	Passed
02L	205.3	9.3	7.1	232.3	221.3	193.5	Passed
03L	205.7	8.0	7.3	231.8	220.7	190.7	Passed
04L	205.8	7.7	6.9	232.1	222.1	191.9	Passed
05L	206.0	9.0	6.9	230.8	220.7	190.5	Passed
06L	205.3	7.6	7.0	232.0	221.2	190.9	Passed
07S	206.1	9.3	7.3	230.6	220.5	194.0	Passed
09S	205.5	8.0	6.9	231.0	222.1	194.8	Passed
10S	206.5	7.8	6.9	230.8	221.3	196.6	Passed
11S	206.5	9.3	6.9	231.9	221.7	193.7	Passed
12S	206.6	8.0	6.9	232.3	221.8	193.8	Passed
13S	206.3	7.8	6.8	231.5	222.1	194.0	Passed

High Temperature Testing

Purpose. The purpose of the high temperature test is to determine conformance to the high temperature exposure requirement of paragraph 4.9.5 of MIL-S-12285E (Draft).

Required Data and Performance. The high temperature test requires that a fluid bath be monitored at a temperature of 150° C (302° F) for a period of one minute. The sample calibration must not change by more than +/- (3.6°F) and +/- (1.0 psig) after high temperature exposure.

Testing Apparatus. This test involves use of a fluid bath capable of sustaining a temperature of 150° C (302° F).

Test Procedure.

1 The fluid bath temperature was established at 150° C (302° F). The sample was mounted in the bath such that the circulating fluid covered the tapered thread.

2 The sample was soaked for a period of one minute and then removed from the bath and re-calibrated. The recorded values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2 were compared with requirements specified in MIL-S-12285E (Draft).

High Temperature Test Results

The sample switch (TP-301-001) exhibited minimal calibration changes as a result of high temperature exposure and therefore passed the high temperature qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Allowable Change	Measured Change	Comments
TL_1 (°F)	204.0	204.1	+/-3.6	+0.1	Passed
TL_2 (°F)	190.5	188.5	+/-3.6	-2.0	Passed
P_1 psig	7.3	7.5	+/-1.0	+0.2	Passed
P_2 psig	9.5	9.5	+/-1.0	0.0	Passed
TH_1 (°F)	228.0	227.5	+/-3.6	-0.5	Passed
TH_2 (°F)	215.5	215.1	+/-3.6	-0.4	Passed

Notes (1) Prior to high temperature exposure
(2) After high temperature exposure

Vibration Testing

Purpose. The purpose of the vibration test is to determine conformance to the vibration exposure requirement of paragraph 4.9.10 of MIL-S-12285E (Draft).

Required Data and Performance. The vibration test requires monitoring of harmonic motion, acceleration, vibrational frequency, resonant frequencies, and calibration data. The sample calibration must not change by more than +/-3.6^{0}F and +/- 1.0 psig after exposure to vibration.

Testing Apparatus. The vibration testing was performed by Electronic Specialty Corporation of Vancouver, WA. A detailed description of the apparatus used is described in Appendix B. The vibration test requires instruments capable of detecting simple harmonic motion having a maximum amplitude of 0.03 inches and a peak of 50g, with an accuracy of +/- 10 percent for the amplitude. Vibrational frequency must also be monitored within the range of 10 to 3500 cycles per second (cps). Sensors must be capable of detecting resonant frequencies in excess of the applied vibration. The vibration source must be capable of generating automatic sweeps of the specified frequency range with a logarithmic rate of frequency change.

Procedure.

1 The test fixture was attached to the vibration source and the specified frequency range was scanned for points of resonance which could not be attributable to the sample.

2 The sample was mounted in the test fixture and electrically connected through the indicator lamp to the power source.

3 The frequency range of 10 to 3500 to 10 cps was scanned and points of resonance and their degree of criticality were recorded (for a definition of criticality of frequency see paragraph 6.4.3 of MIL-S-12285D). The complete vibrational cycle was completed within 20 +/- 2 minutes. This step was performed three times for each of the three mutually perpendicular axes at 50g acceleration. One critical frequency (750 Hz) was identified in the upright orientation.

4 The sample was vibrated in the upright orientation for two hours at 50g acceleration at 750 Hz.

5 The sample was vibrated at 50g in each of the other two orientations for two hours with the frequency cycled from 10 to 3,500 and back to 10 cps (20 minutes per cycle).

6 The sample was then re-calibrated and the data was compared to the initial values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2.

Vibration Test Results

The sample switch (TP-301-003) exhibited no intermittent operation, sticking of contacts or delay in functioning and exhibited minimal calibration changes as a result of vibration exposure and therefore passed the vibration qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Allowable Change	Measured Change
TL_1 (^0F)	204.5	205.1	+/-3.6	+0.6
TL_2 (^0F)	188.3	190.4	+/-3.6	+2.1
P_1 (psig)	7.0	7.8	+/-1.0	+0.8
P_2 (psig)	9.6	10.2	+/-1.0	+0.6
TH_1 (^0F)	233.0	233.0	+/-3.6	0.0
TH_2 (^0F)	216.3	217.4	+/-3.6	+1.1

Notes (1) Prior to vibration exposure
(2) After vibration exposure

Fungus Testing

Purpose. The purpose of the fungus test is to determine conformance to the fungus exposure requirement of paragraph 4.9.8 of MIL-S-12285E (Draft).

Required Data and Performance. The fungus test requires that the sample be subjected to the conditions detailed in MIL-F-13927A, method B, for a period of 90 days. Temperature and relative humidity inside the incubation cabinet will be maintained within 80^0 to 84^0 F and 96 to 100 percent, respectively. After exposure to ninety days of continuous incubation, the sample must conform to the initial calibration requirement.

Testing Apparatus and Procedure. The sample was exposed to the incubation environment by Wyle Test Laboratories of El Segundo, California. Initial and final calibration was performed by Index Industries. Refer to Appendix B for a detailed description of the testing apparatus and procedure.

Fungus Test Results

After exposure to ninety days of continuous fungus incubation, the sample switch (TP-301-008) calibrated in accordance with the initial calibration tolerance and therefore passed the fungus qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Requirement	Comments
TL_1 (^{0}F)	204.7	206.9	205 +/- 3.6	Passed
TL_2 (^{0}F)	189.3	191.0	TL_1 - (15 max)	Passed
P_1 (psig)	7.6	7.7	7.0 +/- 1.5	Passed
P_2 (psig)	9.9	9.9	P1 + (2.5 max)	Passed
TH_1 (^{0}F)	232.5	232.7	230 +/- 3.6	Passed
TH_2 (^{0}F)	216.1	216.3	TH_1 - (15 max)	Passed

Notes (1) Prior to fungus exposure
(2) After fungus exposure

Endurance Testing

Purpose. The purpose of the endurance test is to determine conformance to the endurance requirements of paragraph 4.9.11 of MIL-S-12285E (Draft).

Required Data and Performance. The endurance test was conducted by electrically connecting the switch in series with a 28 volt direct current (vdc) power source and a 3 candle power (cp) 24v lamp and cycling the temperature and pressure of the sample in the following sequence:

a. 2,500 cycles between 185^{0}F and 210^{0}F baths at 0 psig with an electrical lamp load.
b. 2,500 cycles at 210^{0}F with the pressure cycling between zero and 15 psig with an electrical lamp load.
c. 2,500 cycles between 210^{0}F and 235^{0}F baths at 15 psig with an electrical lamp load.
d. 25,000 cycles between 105^{0}F and 195^{0}F baths at 15 psig without an electrical load.

The sample calibration must not change by more than +/- 3.6^{0}F and +/- 1.5 psig after cyclic thermal and pressure exposure.

Testing Apparatus. The endurance test was performed using two temperature controlled oil baths, a transfer mechanism, cycle counters and a pressure manifold.

Procedure.

1 The sample was connected to the transfer mechanism and electrically connected through the indicator lamp to the 28 volt power source.

2 The sample was transferred between a 185^{0}F bath and a 210^{0}F bath for 2,500 cycles at a rate sufficient to produce "on and off" cycling of the indicator lamp.

3 While maintaining the sample in the 210^{0} F bath, the manifold pressure was cycled between zero and 15 psig for 2,500 cycles.

4 With the manifold pressure maintained at 15 psig, the sample was cycled between a 210^{0}F bath and a 235^{0}F bath for 2,500 cycles at a rate sufficient to produce "on and off" cycling of the indicator lamp.

5 With the manifold pressure maintained at zero psig and the sample disconnected from the electrical power source, the sample was cycled between a 105^{0}F bath and a 195^{0}F bath at a rate of one full cycle every two minutes for 25,000 cycles.

6 The sample was re-calibrated and the data compared to the recorded values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2.

Endurance Test Results

The sample switch (TP-301-010) exhibited minimal calibration changes as a result of endurance cycling and therefore passed the qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Allowable Change	Measured Change	Comments
TL_1 (^{0}F)	204.5	205.5	+/-3.6	+1.0	Passed
TL_2 (^{0}F)	190.5	190.7	+/-3.6	+0.2	Passed
P_1 (psig)	8.3	8.6	+/-1.0	+0.3	Passed
P_2 (psig)	10.3	10.7	+/-1.0	+0.4	Passed
TH_1 (^{0}F)	227.3	227.9	+/-3.6	+0.6	Passed
TH_2 (^{0}F)	213.0	213.5	+/-3.6	+0.5	Passed

Notes (1) Prior to endurance cycling
(2) After endurance cycling

Shock Testing

Purpose. The purpose of the shock test is to determine conformance to the shock requirement of paragraph 4.9.9 of MIL-S-12285E (Draft).

Required Data and Performance. The shock test involves subjecting the test sample to repeated impacts of 100g in accordance with MIL-STD-202, method 202. The sample calibration must not change by more than +/- 3.6^{o}F and +/- 1.0 psig after exposure to shock.

Testing Apparatus. The shock test was performed by Electronic Specialty Corporation, Vancouver Washington; A detailed description of the test apparatus and procedures are included in Appendix B. Initial and final calibration was performed by Index Industries.

Procedure.

1 The sample was mounted in a threaded fixture such that it is supported by the threaded portion of the switch body.

2 The fixture and sample were subjected to an impact acceleration in the vertical axis of 100g which was repeated 10 times.

3 The sample was re-calibrated and the data was compared to the initial recorded values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2.

Shock Test Results

The sample switch (TP-301-004) exhibited minimal calibration changes as a result of exposure to shock and therefore passed the qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Allowable Change	Measured Change	Comments
TL_1 (^{o}F)	203.7	203.8	+/-3.6	+0.1	Passed
TL_2 (^{o}F)	190.7	190.4	+/-3.6	-0.3	Passed
P_1 (psig)	6.8	6.6	+/-1.0	-0.2	Passed
P_2 (psig)	9.4	9.2	+/-1.0	-0.2	Passed
TH_1 (^{o}F)	233.5	233.4	+/-3.6	-0.1	Passed
TH_2 (^{o}F)	217.0	216.8	+/-3.6	-0.2	Passed

Notes (1) Prior to shock testing
(2) After shock testing

Corrosion Testing

Purpose. The purpose of the corrosion test is to determine conformance to the environmental exposure requirements of paragraph 4.9.7 of MIL-S-12285E (Draft).

Required Data and Performance. The corrosion test requires that the sample be subjected to a salt spray (fog) as specified in MIL-STD-202, method 101, with a test duration of 200 hours. The sample calibration must not change by more than +/- 3.6^{o}F and +/- 1.0 psig after exposure to salt spray.

Testing Apparatus. The Corrosion test was performed by Electronic Specialty Corporation, Vancouver Washington; A detailed description of the test apparatus and procedures are included in Appendix B. Initial and final calibration was performed by Index Industries.

Procedure.

1 The sample was exposed to salt spray (fog) as described in MIL-STD-202, method 101 for 200 hours.

2 The sample was calibrated and the data was compared with the initial calibration values for TL_1, P_1, P_2, TH_1, TH_2, and TL_2

Corrosion Test Results

The sample switch (TP-301-005) exhibited minimal calibration changes as a result of corrosive environment exposure and therefore passed the qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Allowable Change	Measured Change	Comments
TL_1 (^{o}F)	204.5	204.6	+/-3.6	+0.1	Passed
TL_2 (^{o}F)	189.6	189.0	+/-3.6	-0.6	Passed
P_1 (psig)	7.3	7.2	+/-1.0	-0.1	Passed
P_2 (psig)	9.8	9.8	+/-1.0	+0.0	Passed
TH_1 (^{o}F)	230.5	230.7	+/-3.6	+0.2	Passed
TH_2 (^{o}F)	215.5	215.0	+/-3.6	-0.5	Passed

Notes (1) Prior to corrosive environment exposure
(2) After corrosive environment exposure

Waterproofness Testing

Purpose. The purpose of the waterproofness test is to determine conformance to the environmental requirements of paragraph 4.9.6 of MIL-S-12285E (Draft).

Required Data and Performance. The waterproofness test requires that the sample be subjected to the conditions detailed in MIL-STD-1184, for Type II, Class 4 components. This involves one hour of submergence in a saline solution followed by thirty minutes of submergence while electrically connected to a 28 vdc power source and 3 cp lamp. After saline submergence, the sample switch must operate successfully for 15 hours and subsequently must calibrate in accordance with the initial calibration tolerance.

Testing Apparatus. The waterproofness test was performed using a container of the specified saline solution with sufficient depth to achieve a sample immersion of one inch below the surface. A 28 vdc power source and 3 cp lamp will be used to power the device while immersed. The endurance testing apparatus used for the endurance testing was then used to provide 15 hours of operation.

Procedure.

1 The sample was placed in the container of saline solution a minimum of one inch below the surface, at room ambient temperature (77^{0} +/- 15^{0} F), for a period of 1.0 hours.

2 The sample was electrically connected through the indicator lamp to the power supply and resubmerged in the saline solution for an additional 30 minutes.

3 The sample was removed and allowed to drain for a period of five minutes in its normal operating position.

4 The sample was then allowed to dry for five minutes and then operated for a period of 15 hours while attached to the electrical load.

5 The sample was re-calibrated and the data compared to the initial calibration requirement.

Waterproofness Test Results

After saline submergence and subsequent endurance cycling, the sample switch (TP-301-001) calibrated in accordance with the initial calibration requirement and therefore passed the waterproofness qualification test. Teardown inspection of the switch revealed that a minute amount of saline solution had seeped into the switch through the venting plug but that it had not impaired the operation of the switch.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Requirement	Comments
TL_1 (^{0}F)	204.0	203.8	205 +/- 3.6	Passed
TL_2 (^{0}F)	190.5	190.2	TL_1 - (15 max)	Passed
P_2 (psig)	9.5	9.5	P_1 + (2.5 max)	Passed
P_1 (psig)	7.3	7.3	7.0 +/- 1.5	Passed
TH_1 (^{0}F)	228.0	227.8	230 +/- 3.6	Passed
TH_2 (^{0}F)	215.5	215.3	TH_1 - (15 max)	Passed

Notes (1) Prior to saline submergence and subsequent endurance cycling
(2) After saline submergence and subsequent endurance cycling

Dielectric Withstanding Testing

Purpose. The purpose of the dielectric withstanding test is to determine conformance to the high voltage potential requirement detailed in paragraph 4.9.4 of MIL-S-12285E (Draft).

Performance. The dielectric withstanding test was performed in accordance with Mil-STD-202, method 301 by Electronic Specialty Corporation, Vancouver, Washington. Refer to Appendix B for a detailed description of the apparatus and procedures used. Index Industries performed the initial and final calibrations.

The general test requirement is that the switch must be maintained at a temperature of 25^0 +/- 5^0F while a potential of 440 volts root mean square (vrms) is applied to the sample between the switch terminal and the switch body (60 cycles per second alternating current).

After the voltage application, the sample must not show evidence of cracking, charring, burning, smoking or other damage. After high voltage exposure, the sample switch calibrated in accordance with the initial calibration tolerance

Procedure.

1 The sample was heated to a temperature of 180^0 +/- 5^0 F in an electric oven.

2 The switch terminal and body were connected to the voltage source

3 The voltage potential was increased to 440 volts at a uniform rate of approximately 440 volts rms per second.

4 The 440 volts rms potential was maintained for a period of 60 seconds, then decreased at the same rate to 0 volts.

5 The sample was then examined for evidence of cracking, burning, smoking or other damage.

7 The sample was recalibrated and the data compared to the initial calibration data for TL_1, P_1, P_2, TH_1, TH_2, and TL_2 .

Dielectric Withstanding Test Results

After the voltage application, the sample (TP-301-002) did not any show evidence of cracking, charring, burning, smoking or other damage; the sample switch calibrated in accordance with the initial calibration tolerance and therefore passed the dielectric withstanding qualification test.

Test Parameter	Initial Calibration[1]	Final Calibration[2]	Requirement	Comments
TL_1 (^0F)	204.0	204.3	205 +/- 3.6	Passed
TL_2 (^0F)	193.0	192.5	TL_1 - (15 max)	Passed
P_1 (^0F)	6.3	6.6	7.0 +/- 1.5	Passed
P_2 (^0F)	6.8	7.0	P1 + (2.5 max)	Passed
TH_1 (^0F)	226.4	226.4	230 +/- 3.6	Passed
TH_2 (^0F)	213.5	214.6	TH_1 - (15 max)	Passed

Notes (1) Prior to high voltage exposure
(2) After high voltage exposure

APPENDIX B

VENDOR TEST REPORTS

ELECTRONIC SPECIALTY CORP.
1 Northeast 13th Avenue, Post Office Box 3501, Vancouver, Washington 98685
Phone: (206) 574-5000
FAX: (206) 573-4635

CERTIFICATE OF TESTING

PREPARED FOR: Index Industries Inc. TEST REPORT NO.: 90-002
13205 SE 30th Street PURCHASE ORDER NO.: 3958
Bellevue, WA 98005 LOG NO.: 70848-00
Ph (206) 746-4049 DATE: 5-9-90

TEST SAMPLE(S): (4 pcs) # TP-301-002, 003, 004, 005
DATE RECEIVED: _____ TEST SPECIFICATIONS: Corrosion, Dielectric Shock, and Vibration testing of Index Industries Inc. P/N TP-301-XXX Per MIL-S-_____

THE ABOVE SAMPLE(S) WAS SUBJECTED TO THE FOLLOWING SEQUENCE OF TESTS AT ELECTRONIC SPECIALTY CORPORATION:

Corrosion TP-301-005

Dielectric TP-301-002

Shock TP-301-004

Vibration TP-301-003
" Rev. A. to reflect additional 6 hrs Vibration testing to satisfy total 9 hrs spec.
M. Olson 2-14-91

I certify that the above tests were performed by me or under my direct supervision, using test equipment in current calibration with tracibility to NBS standards.

PREPARED BY:	APPROVED BY:
SIGNATURE: Jon Rau	SIGNATURE: Maurice Olson
NAME: Jon Rau	NAME: Maurice Olson
TITLE: QC test technician	TITLE: Project Test Eng.

QUALITY CONTROL REPORT	DATE ISSUED	QCR-
SUBJECT Environmental testing of Index Industries Inc. P/N TP-301-XXX Per MIL-S-____	REVISION	90-002
	COGNIZANT GROUP	PAGE

DATA SHEET

TEST: Corrosion DATE: 5-5-90

DEVICE: Temperature/Pressure Switch

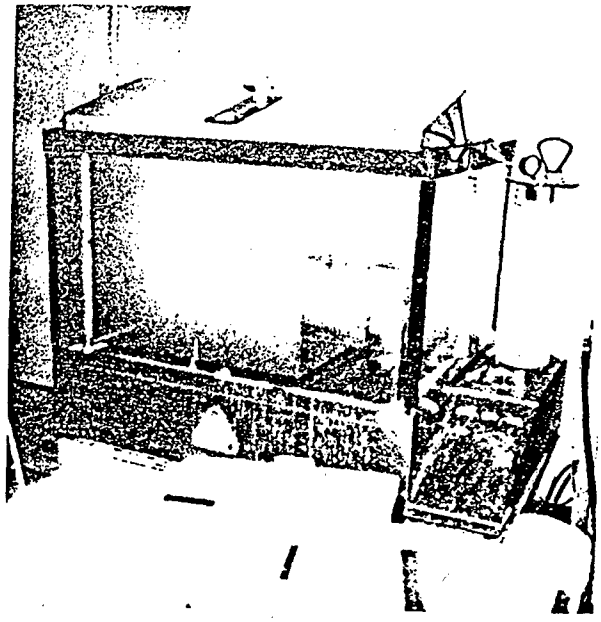
Test Procedure: Mil-Std-202, method 101, with test duration of 200 hrs. P/N TP-301-005

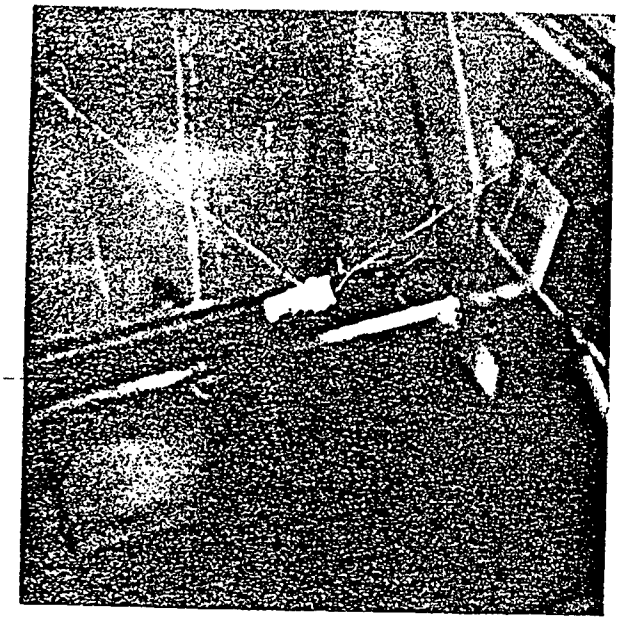
Prepare 5% NaCl (salt) solution by volume, and balance the pH to be between 6.5 and 7.2 at 93° to 97° F. The switch was suspended (see photo) in the salt spray unit ~~and~~ for 200 hrs. with wax string.

Start Salt Spray 4-27-90 3:00 pm
End Salt Spray 5-5-90 11:00 pm

Salt deposits were then removed by gently washing the switch in running water with a soft-hair brush.

M. Olson
5-9-90





Salt Spray Chamber, Switch Suspended in Chamber

QUALITY CONTROL REPORT	DATE ISSUED	QCR-
SUBJECT Environmental testing of Index Industries Inc. P/N TP-301-XXX Per MIL-S-____	REVISION	90-002
	COGNIZANT GROUP	PAGE

DATA SHEET

TEST: Dielectric DATE: 5-7-90

DEVICE: Temperature/Pressure Switch

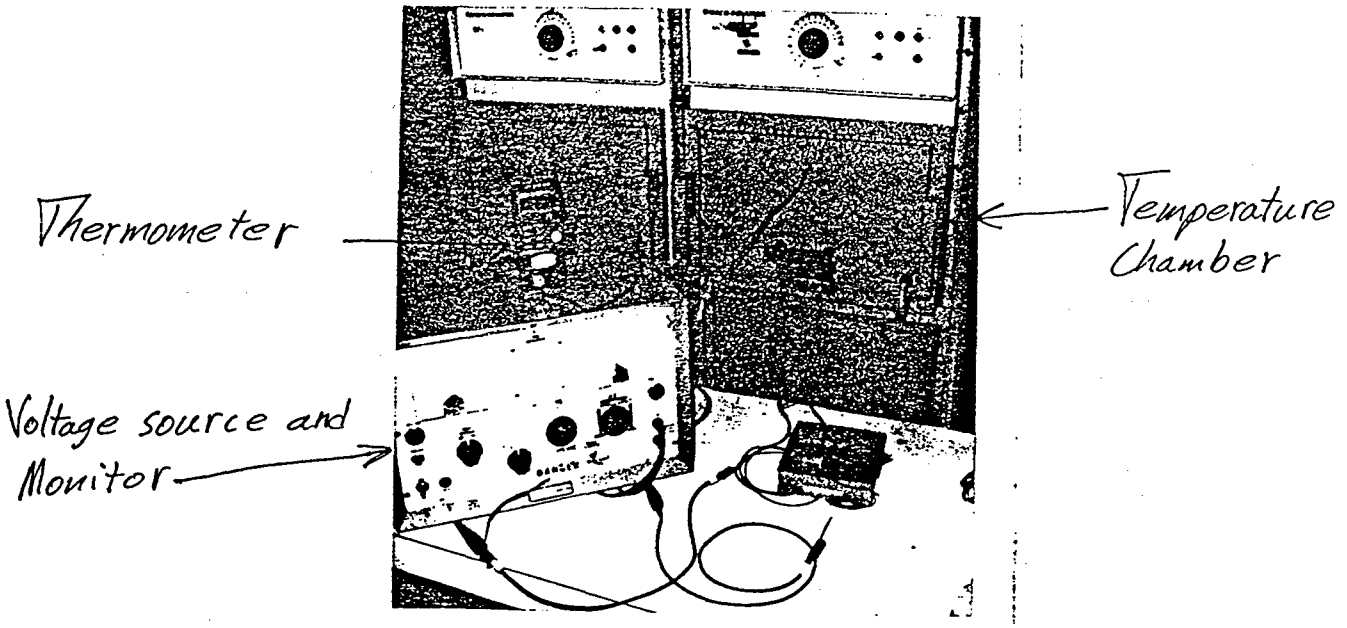
Test Procedure: Mil-Std.-202, method 301
P/N TP-301-002 was heated to 180°F for 30 minutes. Test voltage was applied to the switch terminal and body. The voltage was raised from 0 to 440 V in one second and maintained for 60 seconds then reduced to 0V in one second. The switch was then removed from the temperature chamber and examined.

Results: No breakdowns were detected during the 60 sec. test. No damage was observed after the switch was removed from the temperature chamber.

Jon Rau
5-9-90

ELECTRONIC SPECIALTY CORP.
14611 Northeast 13th Avenue Vancouver, Washington 98685

F 2411-2



Dielectric Test

QUALITY CONTROL REPORT	DATE ISSUED	QCR-
SUBJECT: Environmental testing of Index Industries Inc. P/N TP-301-XXX Per MIL-S-____	REVISION	90-002
	COGNIZANT GROUP	PAGE

DATA SHEET

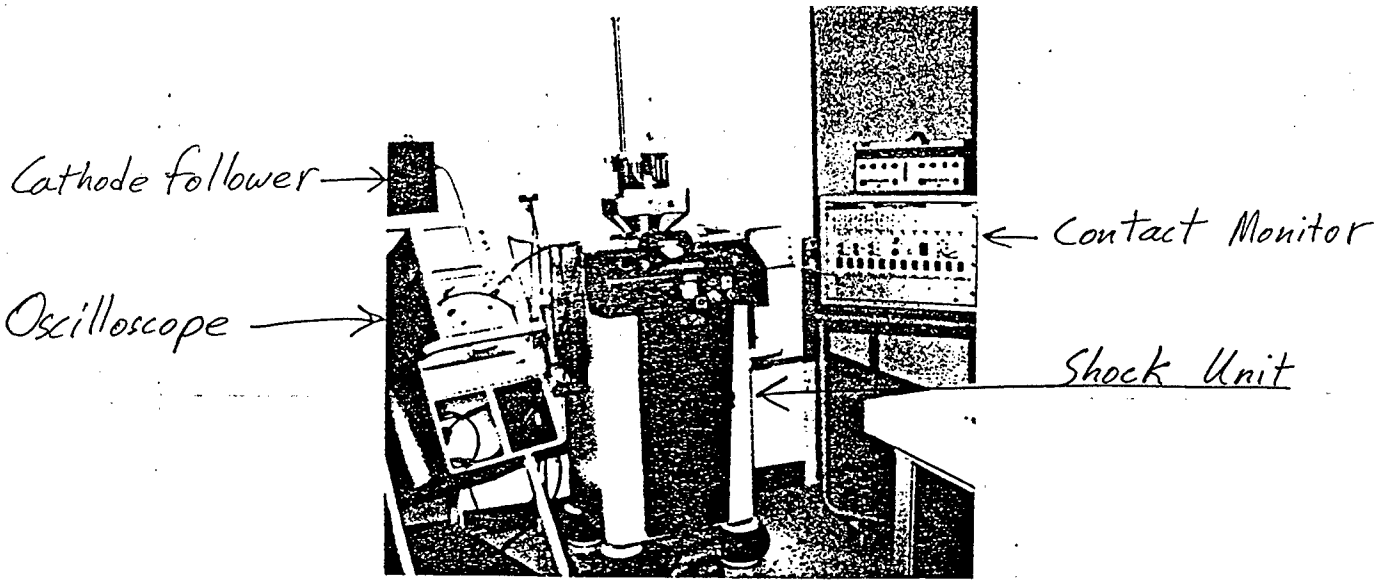
TEST: Shock. DATE: 5-4-90

DEVICE: Temperature/Pressure Switch

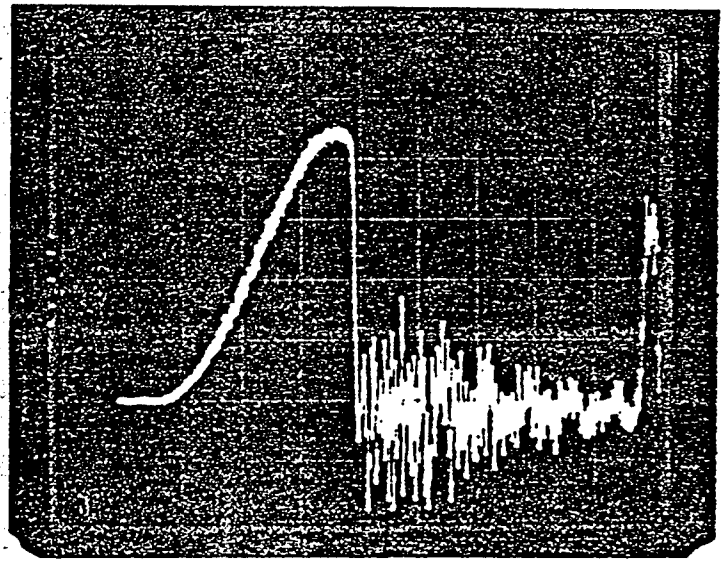
Test Procedure: Mil-Std-202F, method 213, P/N TP-301-004
The switch was shocked 10 times with a sawtooth pulse of 100 gravity units magnitude and 6 millisecond duration. The switch was monitored for contact closures in excess of 10 μsec. The switch was mounted in its normal operating position.

Results: No contact closures were detected.
No evidence of structural failure or other damage which might impair operation was found.

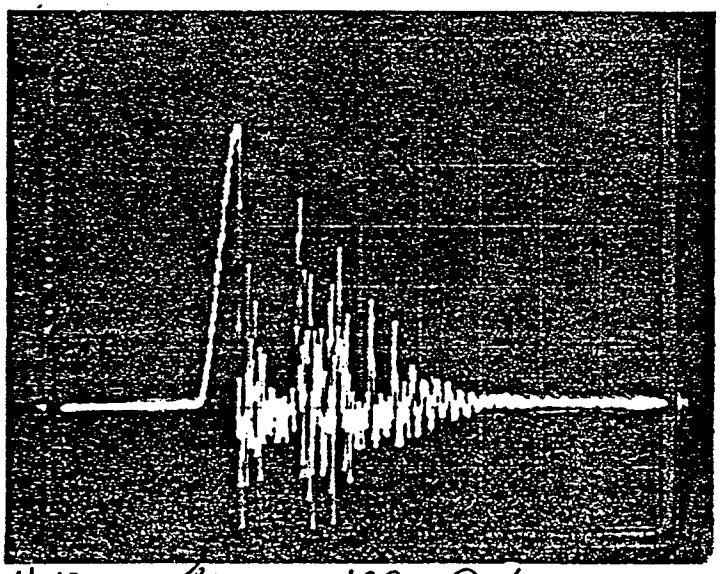
Jon Rau
5-9-90



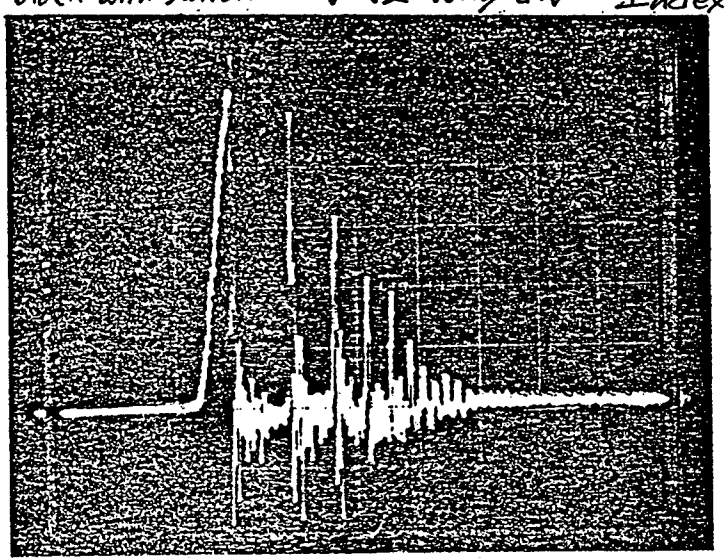
Shock Test Equipment



H 2 msec/div 100g @ 6 msec.
V .2 volts/div Index block with switch



H 10 msec/div 100g @ 6 msec
V .2 volts/div Index block with switch



H 10 msec/div 100g @ 6 msec
V .2 volts/div SS block empty.

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SUBJECT Environmental testing of Index Industries Inc. P/N TP-301-XXX Per MIL-S-____	REVISION	90-002
	COGNIZANT GROUP	PAGE 1

DATA SHEET

TEST: Vibration DATE: 5-4-90

DEVICE: Temperature/Pressure Switch.

Procedure: Mil-S-____. Amplitude of .03 in or 50g whichever is less. frequency of 10 to 3500 Hz.

P/N TP-301-003 was mounted to the test fixture provided by Index Industries.

Three, twenty minute scans from 10 Hz to 3500 Hz to 10 Hz using a logarithmic rate of change were made in mutually perpendicular axis. One critical frequency was found in the "A" or "normal" orientation (See attached form for orientation description) at 750 Hz

"A" orientation: 40 minute dwell at 750 Hz.
"B" orientation: 40 minutes of 20 minute logarithmic scan cycle.
"C" orientation: 40 minutes of 20 minute logarithmic scan cycle.

Results: No contact closures were detected during the 750 Hz dwell or during the "B" and "C" orientation sweeps with the monitoring equipment set to detect closures of 10 μsec or greater.

Jon Rau
5-9-90

QUALITY CONTROL REPORT	DATE ISSUED 2-13-91	QCR-
SUBJECT Environmental Testing of Index Industries P/N TP-301-XXX Per MIL-S-____	REVISION A	90-002
	COGNIZANT GROUP ESQC. Lab	PAGE 1A

DATA SHEET

TEST: Vibration (Additional 2 hrs/plane) 6 Hrs Total DATE: 2-13-91

DEVICE: Temperature/Pressure Switch

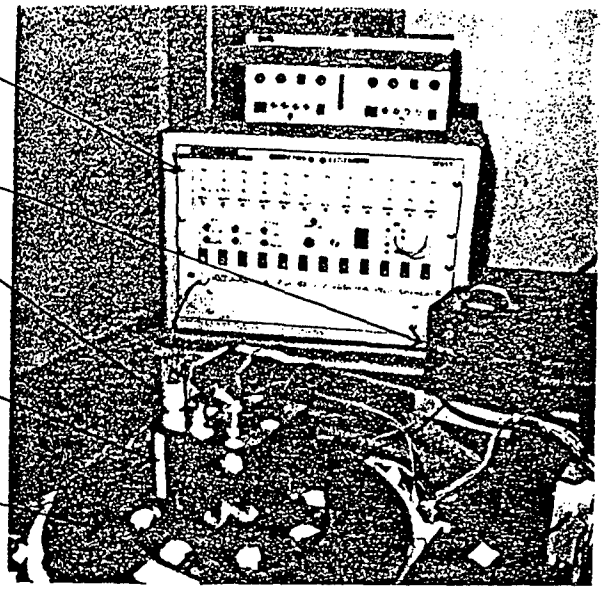
Procedure: MIL-S-____, Amplitude of 0.03 in. or 50g whichever is less, within frequency of 10 to 3500 Hz. P/N TP-301-003 was mounted to the test fixture provided by Index Industries.

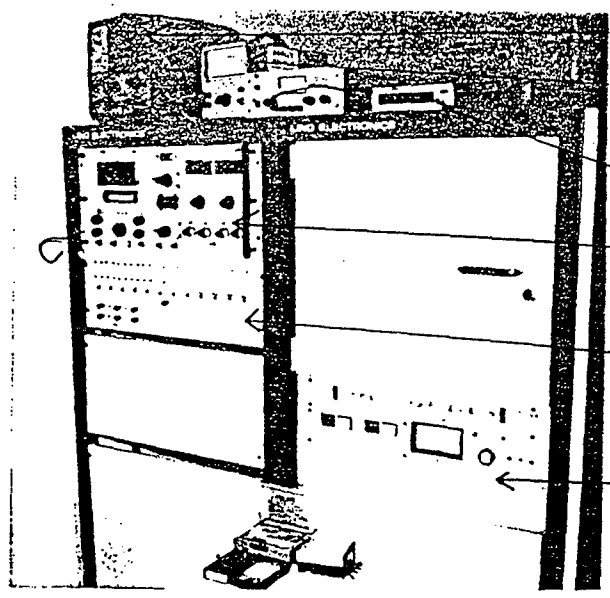
Six additional twenty minute Scans were performed in each of the 3 mutually perpendicular axis described on the Orientation description page, from 10 to 3500 to 10 Hz using a logrimathic rate of change.

"A" Orientation: 2 Hrs. of 20 min logarithmic Scan Cycle.
"B" Orientation: 2 Hrs of 20 min logarithmic Scan Cycle.
"C" Orientation: 2 Hrs of 20 min logarithmic Scan Cycle.

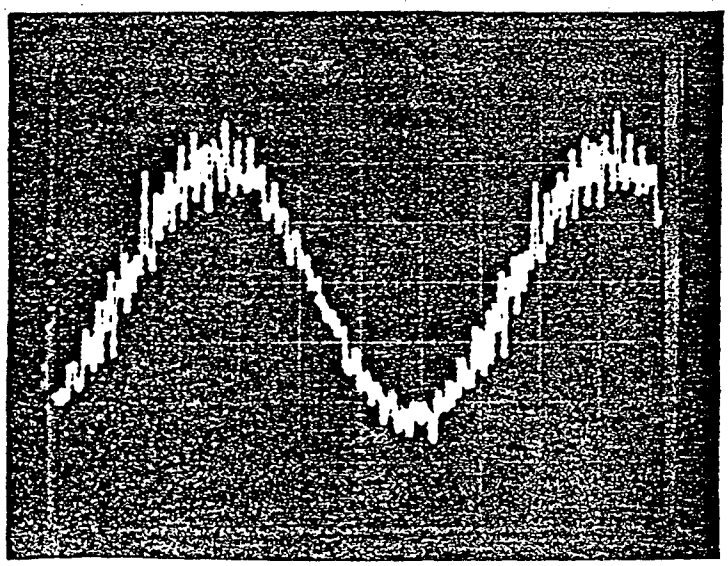
Results: No contact closures were detected during the total of 6 hrs / 2 hrs per A, B, & C axis orientations sweeps with the monitoring equipment set to detect closures of 10 usec or greater.

M. Olson
2-13-91





Vibrator Test

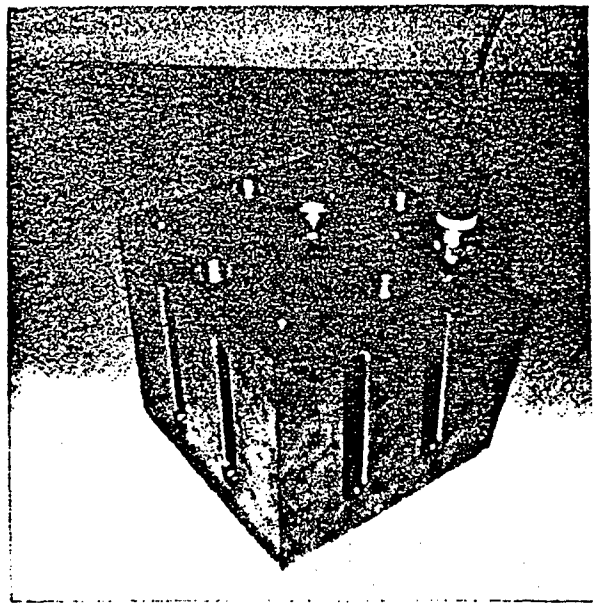


H .2 msec/div 750 Hz (critical frequency)

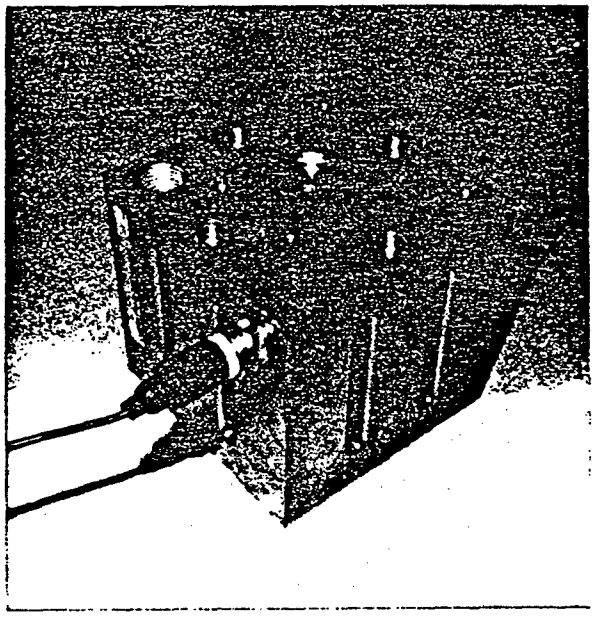
V 1 volt/div Index block with switch.

Orientation Description

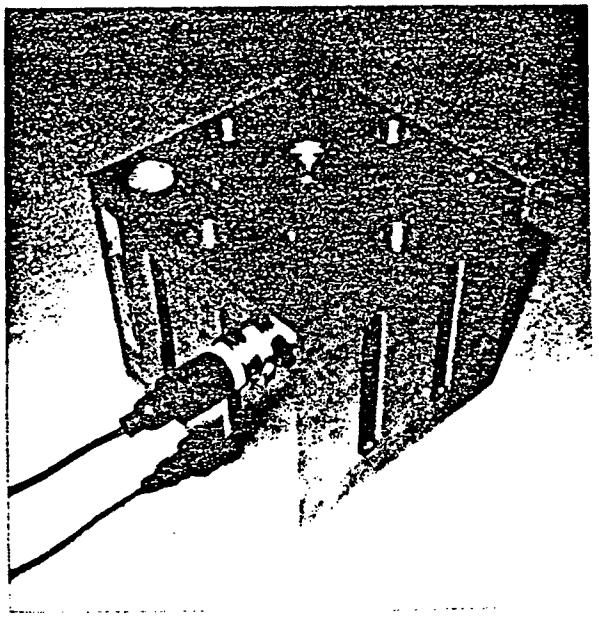
A or Normal



B (white dot up)



C (white dot to side)



ELECTRONIC SPECIALTY CORP.

14 1 Northeast 13th Avenue, Post Office Box 3501, Vancouver, Washington 98685

Phone: (206) 574-5000
FAX: (206) 573-4635

CERTIFICATE OF TESTING (CONT'D)

TEST EQUIPMENT LIST

TEST REPORT NO.: 90-002 DATE: 5-9-90

EQUIPMENT TYPE	MANUFACTURER	MODEL	E.S.I.D.	CALIB. DUE
Salt Spray	Associated Environmental Systems		189	Prior to test
pH Meter	VWR Scientific	49	02867	Prior to test
Dielectric	Slaughter Company	103-2.5E	02467	7-12-90
Temperature Chamber	Ransco Industries		02652	
Thermometer	Fluke	52	02898	9-5-90
Shock Machine	Avco	2	195	Prior to test
Accelerometer	Consolidated Electrodynamics Corp.	4-274-0001	01771	7-22-90
Cathode follower			0907	5-9-90
Oscilloscope	Tektronix	5223	02730	7-18-90
Verticle dual trace amp	Tektronix	5A38	02731	7-18-90
Digitizer time base/amp	Tektronix	5B25N	02732	7-18-90
Contact Monitor			02859	Prior to test
Vibrator Block	Index Industries	NA	NA	Prior to test
Vibrator	Ling Electronics	C390	199	Prior to Test
Console	"	SCO 100A	02685	" " "
Amplifier Control	"	SCO 100A	02684	" " "
Accelerometer (Control)	Endevco	2213E	02672	7-22-90
Accelerometer (Monitor)	Columbia	3031	02806	7-22-90
Frequency Counter	B&K Precision	1803	02869	8-22-90
Oscilloscope Ref.	Tektronix	5223	02730	7-18-90
Oscilloscope Mon.	Tektronix	T912	02626	8-23-90
VTVM	Hewlett Packard	400 FL	02221	11-3-90

ELECTRONIC SPECIALTY
DIVISION OF ELECSPEC CORPORATION

14511 Northeast 13th Avenue
Post Office Box 3501, Vancouver, Washington 98668-3501

(206) 574-5000
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TLX: 152-386

TEST EQUIPMENT LIST

Test Report No.: 90-CC2/1A Revised to reflect additional Lin. Vibration testing.
Date: 2-13-91

Equipment Type	Manufacturer	Model	ESID	Calib. Date	Calib. Due
Vibrator	Ling Electronics	C39K	199	Prior to test	—
Cond.	"	SCC 100A	02685	"	—
Amplifier Control	"	SCC 100A	02684	"	—
Accelerometer (control)	Endevco	2213E	02672	2-11-91	8-11-91
Accelerometer (Monitor)	Columbia	3031	02909	"	"
Frequency Counter	B+K Precision	1803	02869	8-23-90	2-23-91
Oscilloscope (Monitor)	Tektronix	T 912	02626	8-23-90	2-23-91
VTVM	Hewlett Packard	400FL	02721	11-2-90	5-2-91

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET REPORT NO. 50197

3 August 1990

Index Industries
13205 S.E. 30th Street
Bellevue, WA 98005

Attention: Bob Pierson
Test Title: Fungus Resistance
References: Your Purchase Order No. 4033
Wyle Laboratories Job No. D50197

Gentlemen:

This is to certify that the enclosed Test Data Sheets contain true and correct data obtained in the performance of the test program as set forth in your purchase order.

Where applicable, instrumentation used in obtaining this data has been calibrated using standards which are traceable to the National Institute of Standards and Technology.

Test Results:

One Dual Level Switch, P/N TP-301-008, S/N 170, was subjected to a Fungus Resistance Test in accordance with MIL-F-13927A, Class 1. A visual inspection of the specimen, as received, is presented in Data Sheet 1. The specimen completed the 90 day Fungus Resistance Test with no evidence of fungual growth, however, after 60 days some corrosion due to humidity was apparent. The test conditions are presented in Data Sheet 2. The Mycologist's report on fungus growth is attached hereto as Exhibit "A".

Encl: Data Sheets (2 Pages); Equipment List (1 Page); Exhibit "A" (1 Page)

STATE OF CALIFORNIA
COUNTY OF LOS ANGELES } S.S.

M. NAVID, GM EL SEGUNDO OPERATIONS, being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

M. Navid

SUBSCRIBED and sworn to before me this 6th day of AUG, 19 90

Karen K. Smith

OFFICIAL SEAL
KAREN K. SMITH
NOTARY PUBLIC - CALIFORNIA
Principle Office In
Los Angeles County
My Commission Expires April 8, 1994

DEPARTMENT Mechanical Systems

TEST ENGINEER S. Shih

TEST WITNESS

Not Applicable
DCAS-QAR VERIFICATION

QUALITY CONTROL N. Kiefer

DATA SHEET 1

Customer INDEX INDUSTRIES Job No. 50197

Date 4-25-90

Specimen DUAL LEVEL SWITCH

RECEIVING INSPECTION

No. of Specimens Received: ONE (1)

Record identification information exactly as it appears on the tag or specimen:

Manufacturer INDEX

Part Numbers TP-301-008

How does identification information appear: (name plate, tag, painted, imprinted, etc.)

ENGRAVED

Serial Numbers:* 170

Examination: Visual, for evidence of damage, poor workmanship, or other defects, and completeness of identification.

Inspection Results: There was no visible evidence of damage to the specimens unless noted below.

-0- NO MAJOR DAMAGE NOTED.

* If additional space is required for serial numbers, use an additional page, or reference first functional test data sheet (if applicable).

Inspected By W. ENG

Sheet No. 1 of

Approved [signature] Date: 4-25-90

W-614

QA Form Approval

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

DATA SHEET 2

TEST TITLE Fungus Resistance Test

CUSTOMER Index Industries Inc Job No. 50197
Specimen Dual Level Switch Date Started 4-25-90
Part No. TP-301-008 Serial No. 170 Date Comp. 7-25-90
Spec. Mil-F-13927A Class 1 Par. All Photo — Amb. Temp. Chamber

Procedure:

1-1 Device was installed into chamber with 4 cloth strips. Strips were placed around device at a distance of ≈ 2 to 3 inches. Cloth strips were used as controls to verify fungal growth.

1-2 Chamber was cycled in the following manner: 20 hours @ 80-85°F and a humidity of 93-97%, Then 4 hours @ 75-80°F and a humidity of 100%.

1-3 A mycological inspection was performed at 30, 60 and 90 days.

1-4 Test duration was 90 days.

Results:

1-1 Note mycologist's report IN EXHIBIT "A".

1-2 Signs of corrosion were noted due to humidity Not fungal growth.

Tested by W. Ehlers
Engineer S. Shih

W Y L E
Laboratories

EXHIBIT "A"

Report No. 50197
Page No. 5

Frank E. Swatek, Ph.D.
Industrial & Mycological Consultant
812 STEVELY AVENUE
LONG BEACH, CALIFORNIA 90815

DATE: 7-25-90

JOB NO. D 50197

CLIENT: Wyle Lab

ITEM: 1- Switch
Independantes

INVESTIGATION: Fungus resistance test in accordance with specification.

PROCEDURE: The unit was sprayed with a suspension of viable fungus spores in accordance with specification MIL-F-13927A. (June 1, 1967)

Spores from the following fungi were used:

Chaetomium globosum ATCC 6205
Aspergillus niger NLabs 386
Aspergillus flavus NLabs 380
Penicillium funiculosum NLabs 391
Aspergillus versicolor NLabs 432

The specimen was placed in the test chamber with an internal temperature of 86 ± 4° and a relative humidity of 95% ± 5%. This is accomplished by means of a heater immersed in water within the chamber which is controlled by a thermocouple placed in the chamber atmosphere, set to regulate the ambient temperature. At the end of 30,60,90 day period the unit was visually examined for the presence of fungus growth and/or material deterioration.

CONTROLS: 90 + % growth with sporulation of A niger.

RESULTS:

5-25-90
30 days — no growth on specimens (controls 100% growth)

6-25-90
60 days — no fungal growth on specimen (controls 100% also corrosion seen on metal due to humidity).

7-25-90
90 days — no fungal growth on specimen (Corrosion due to humidity. Controls very heavy sporulation.)

Test By: Charles E Swatek Ph.D.
(signature)

Pass Fungus Test

WYLE SCIENTIFIC SERVICES & SYSTEMS LABORATORIES GROUP

TEST Fungus Resistance Test

CUSTOMER Index Industries Inc. SPECIMEN Dual Level Switch JOB NO. 50197

PART NO. IP-301-008 S/N 170

TEST BY W. Ehlers WITNESS — DATE 7-26-90

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
Chamber	Mantec	N.A.	—	5090	N/A.	N/A.	—
Temp Recorder	Honeywell	153 K	0 to +200	3050	2-19-90	6-18-90	± 0.5%
Temp Recorder	Honeywell	153C	-100 to +200	7151	6-9-90	10-11-90	±0.5%

B-19

Report No. 50197 Page No. 4

W 614 C Q.C. Approval

SHEET OF

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