EA02-025

TEXAS INSTRUMENTS, INC.'S

9/10/03

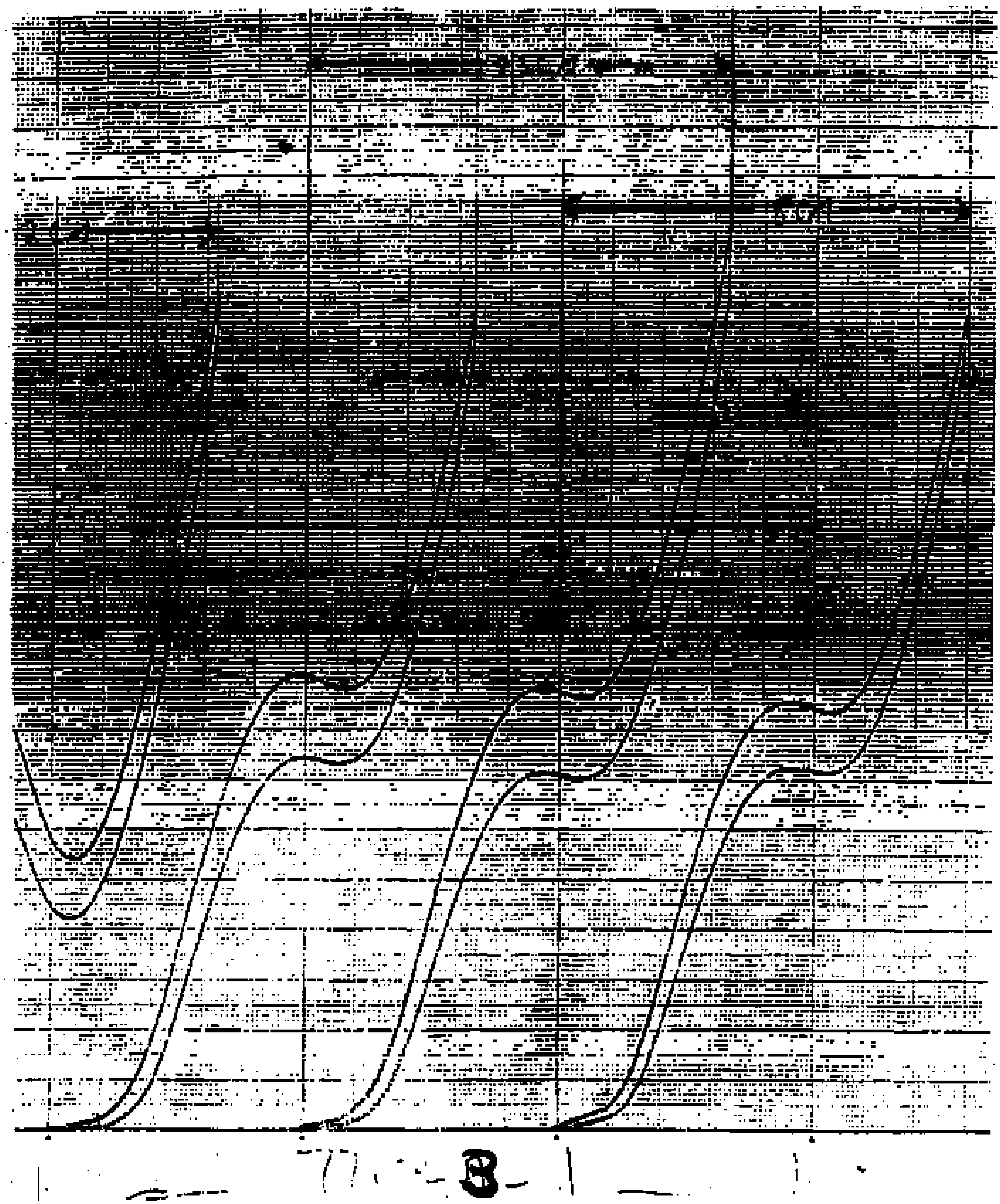
REQUEST NO. 7

BOX 9

PART A – R

PART H

DRAWINGS AVAILABLE UPON REQUEST



TI-NHTSA 014050

Hyd[illegible]

[illegible] [illegible] [illegible]

FORCE [illegible]

WASHER

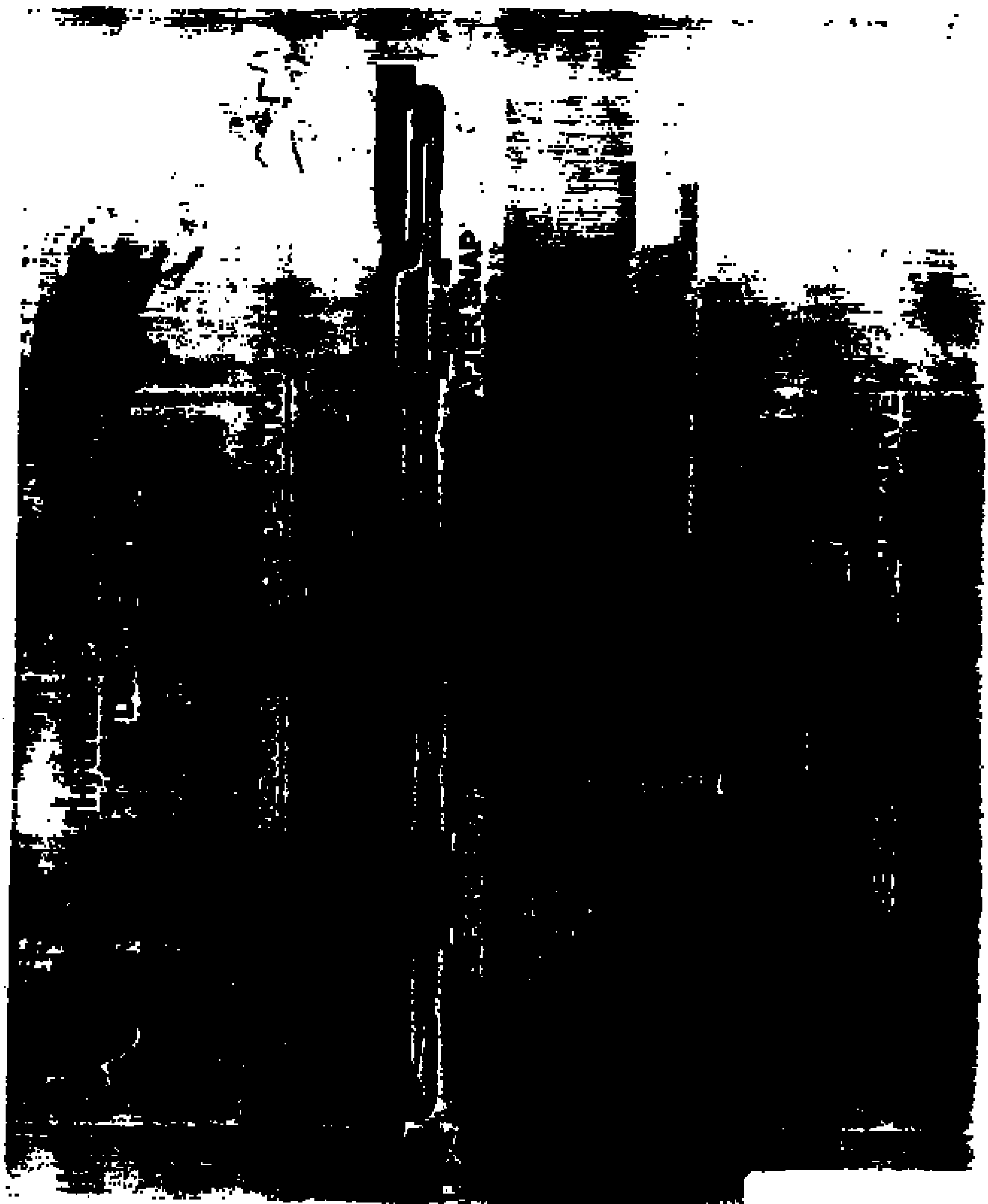
[illegible]MER

DISK

[illegible]

FORCE [illegible] [illegible] EFF[illegible]

EFFECTIVE [illegible] DESIGN
AND [illegible]

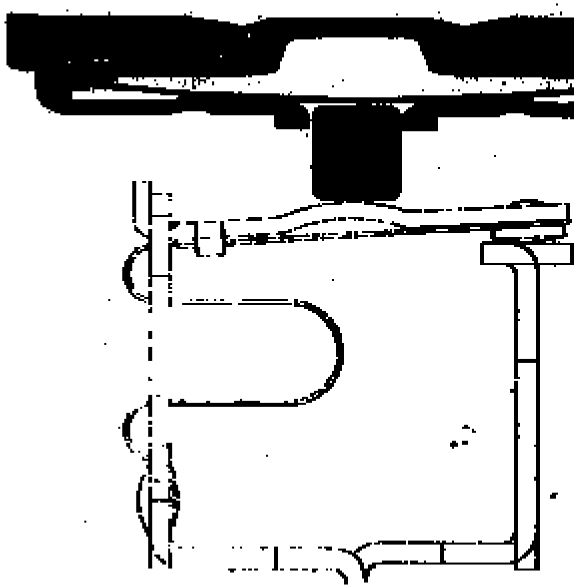


TI-NHTSA 014063

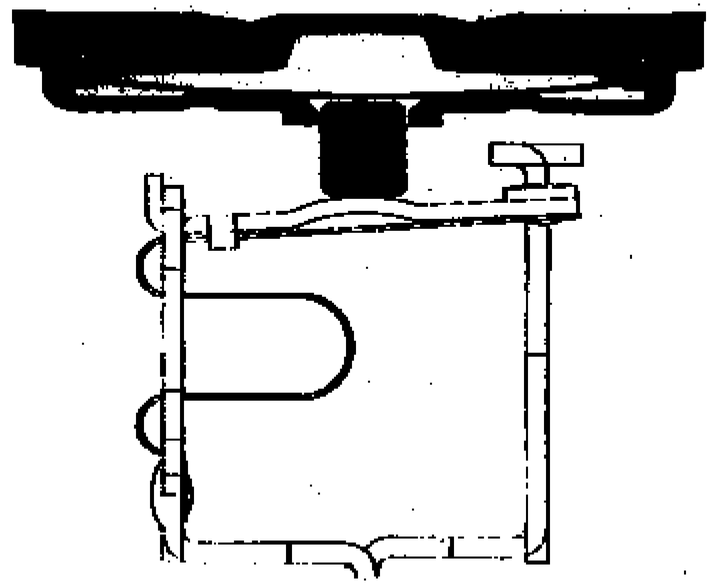
Hydraulic Pressure Switches
Design Overview

PRESSURE SWITCH LOGIC

NORMALLY CLOSED



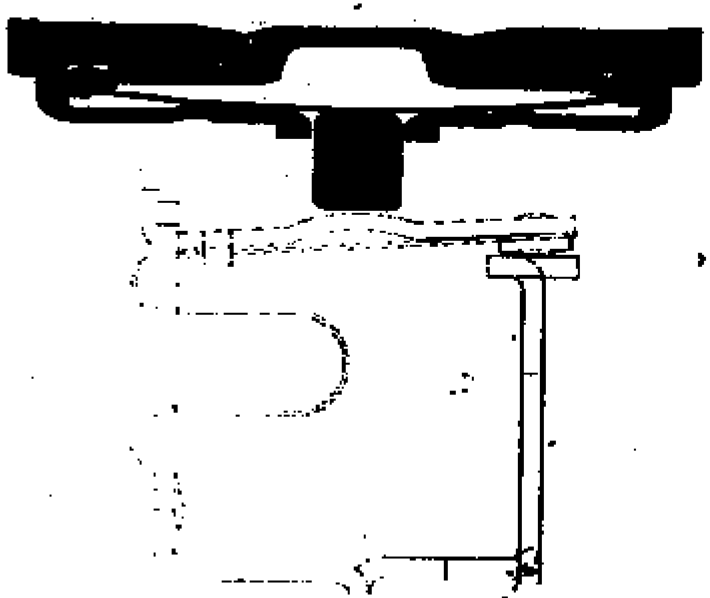
NORMALLY OPEN



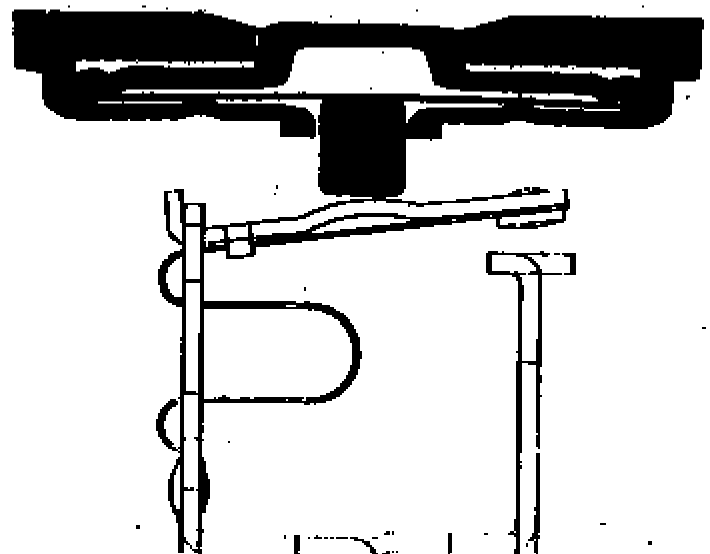
Hydraulic Pressure Switches
Design Overview

USING DISC MOTION TO MAKE / BREAK CONTACTS

BEFORE SNAP

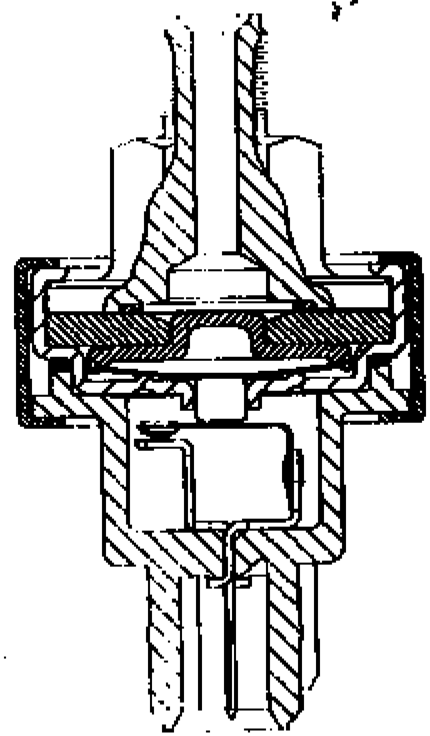


AFTER SNAP

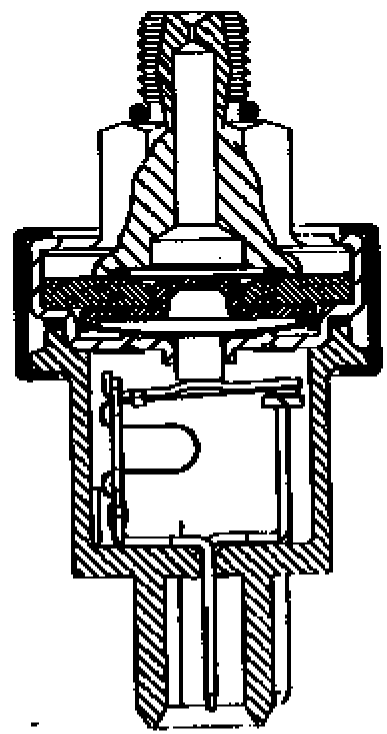


Hydraulic Pressure Switches
Design Overview

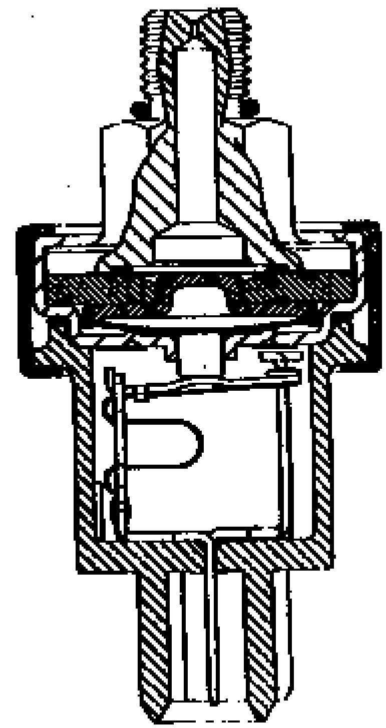
PRESSURE SWITCH ASSEMBLIES



L - SHAPED SPRING
NORMALLY CLOSED



S - SHAPED SPRING
NORMALLY CLOSED



S - SHAPED SPRING
NORMALLY OPEN

SNAP SENSOR CHARACTERISTIC CURVES

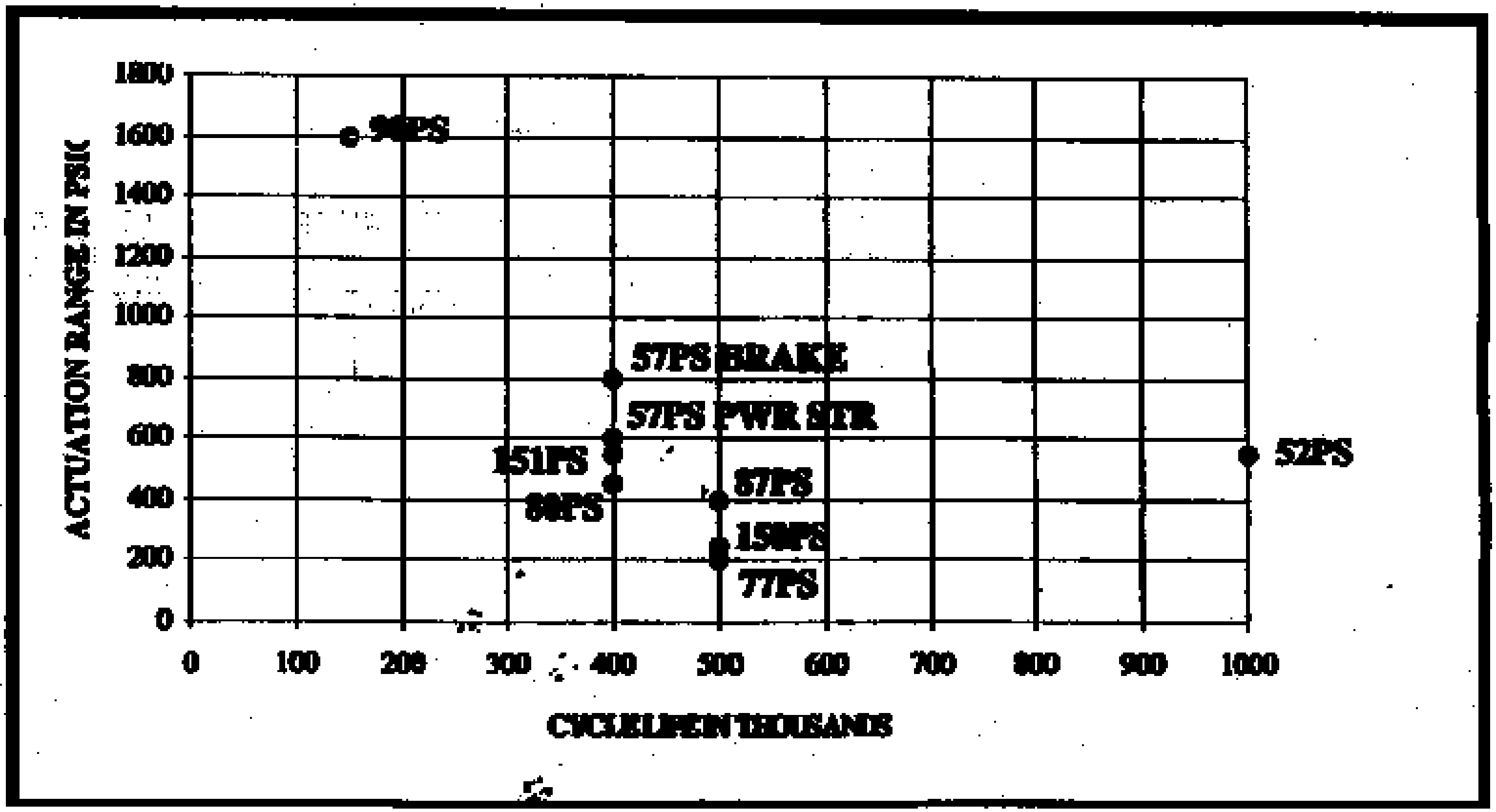
Hydraulic Pressure Switches

Design [illegible]

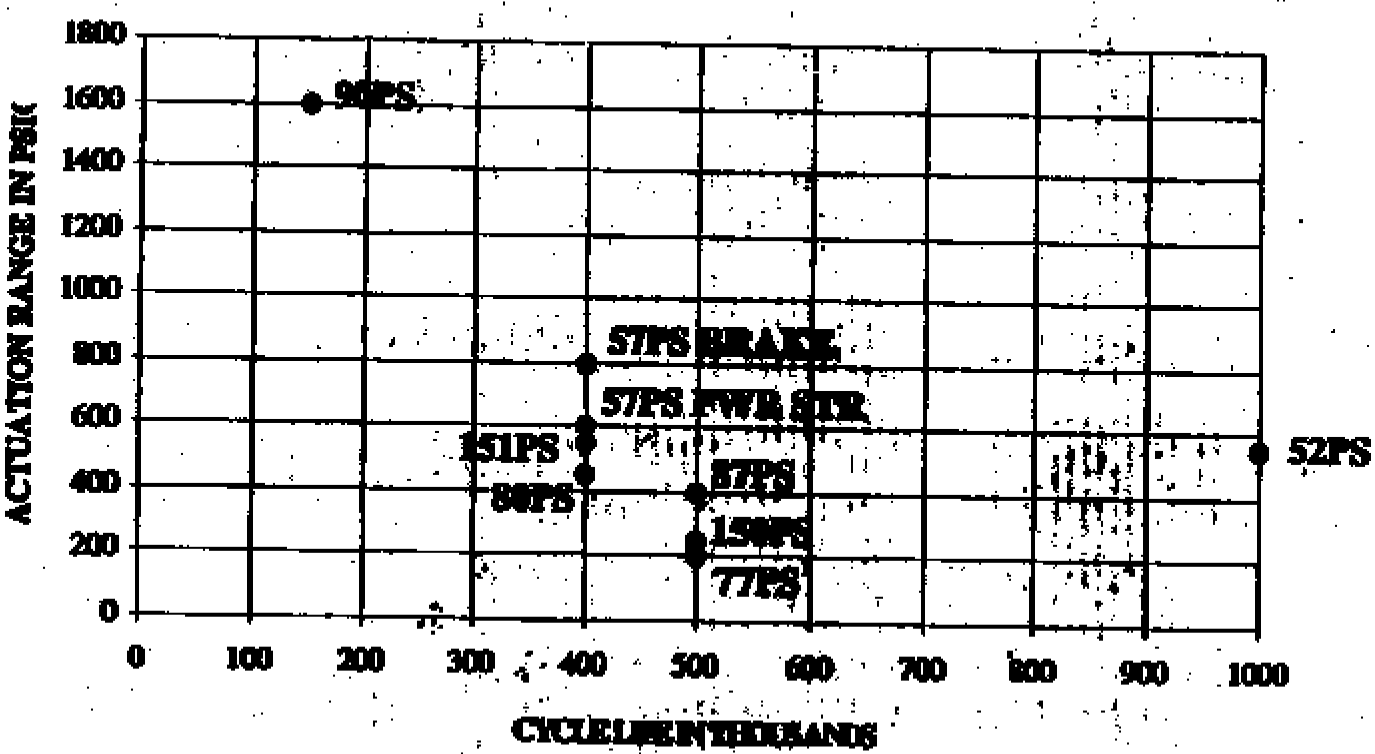
25 Jun 99 BJD [illegible]

TI-NHTSA 014067

Hydraulic Pressure Switches
Design Overview



Hydraulic Pressure Switches Design Overview



25 Jun 99 BJD 05/00357 HPSdesign.ppt

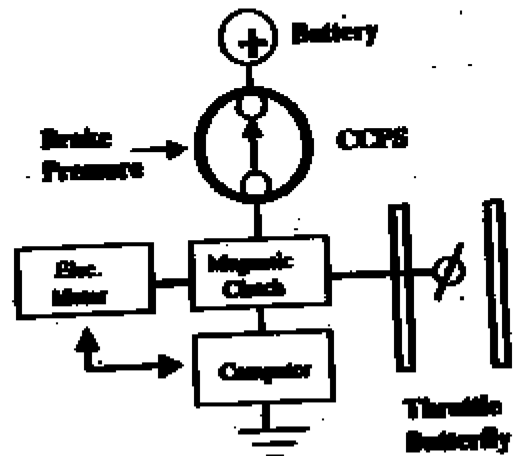
TI-NHTSA 014089

Texas Instruments

Automotive Sensors & Controls
Cruise Control Pressure Switch

Overview

- The CCPS is a redundant safety device designed for use in a vacuum-less electronic cruise control system.
- Functionally, it replaces the present vacuum dump valve by de-energizing a clutch which connects the throttle to an electronic actuator.
- It is plumbed into the brake line. When the driver applies pressure to the brake pedal, the normally-closed switch opens, disconnecting the actuator from the throttle butterfly.



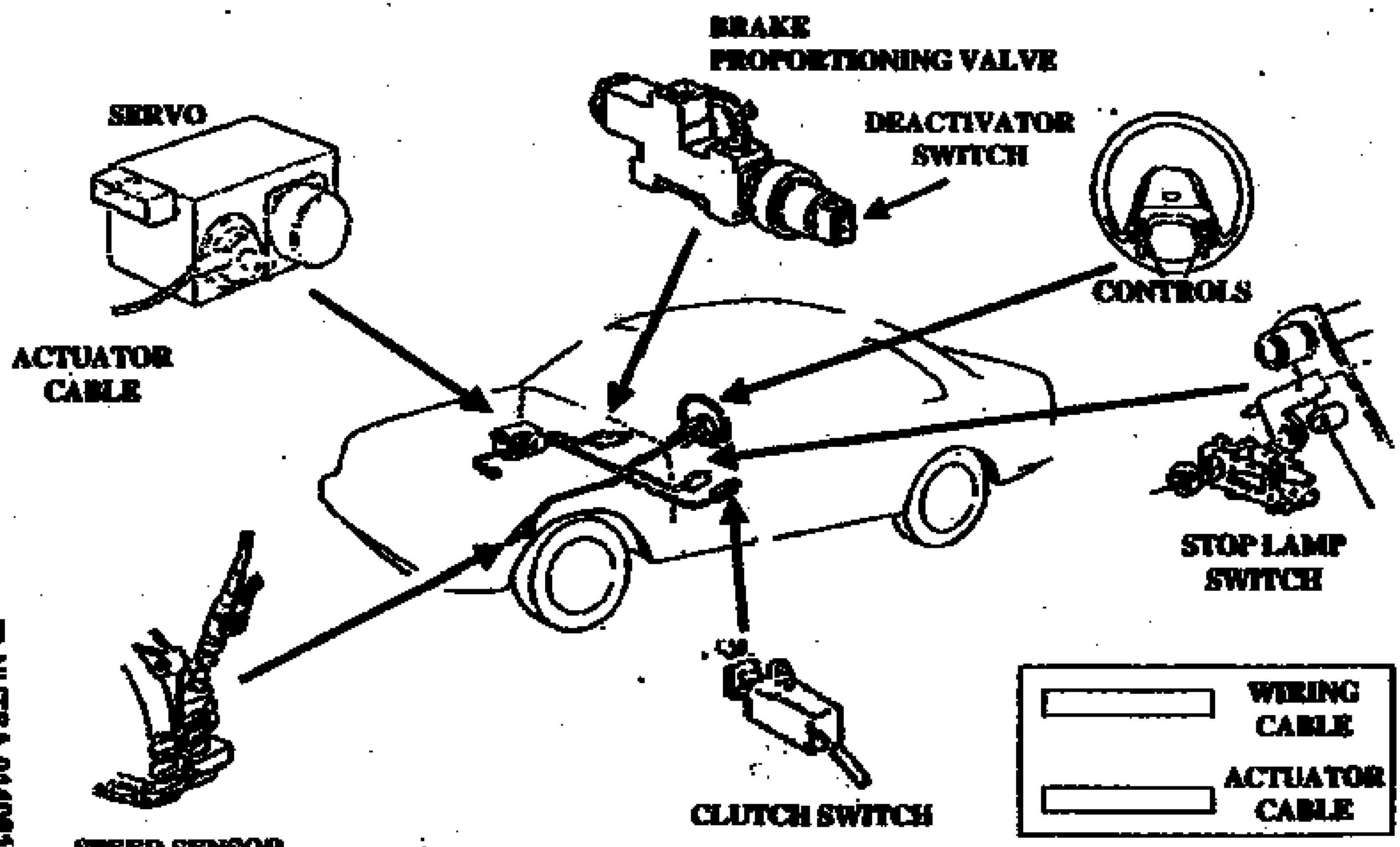
Specifications

Actuation:	125 PSI +/- 35
	250 PSI +/- 50
Release:	20 PSI min
	40 PSI min
Burst:	7000 PSI
Proof:	3000 PSI
	4000PSI
Cycles:	500K, 0 - 1450 PSI, 2 Hz
Voltage:	Battery
Current:	0.75 AMP Inductive

Texas Instruments

Automotive Sensors & Controls
Cruise Control Pressure Switch

1991 Next Generation Speed Control System



TI-NHTSA 014081

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 6/02/99

Lab Experiment-5% NaCl/H_2O and Continuous Power

- Contact arm (Cu) corrodes - chemical analysis shows presence of Na, Cl, Cu, and O on the cup surface

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 6/02/99

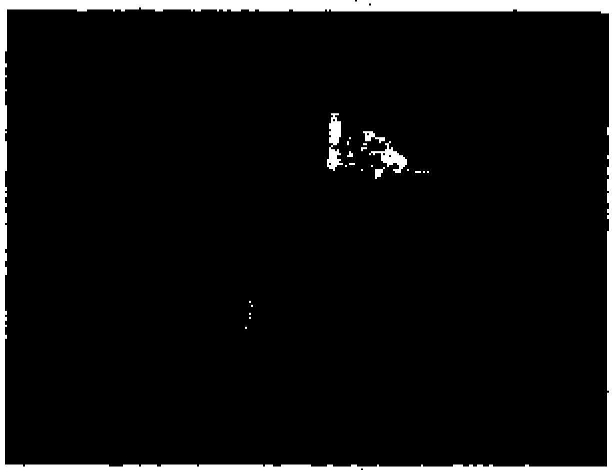
Lab Experiment- "New" Brake Fluid and Continuous Power (300 hours)

- **Contact arm (Cu) corrodes - chemical analysis shows presence of Cu, C, and O on the cup surface.**

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 6/02/99

Lab Experiment "New" Brake Fluid and Continuous Power (550 hours)



- Contact arm (Cu) corrodes - chemical analysis shows presence of Cu, C, and O on the cup surface.

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 6/02/99

Memphis Switch Analysis

- Chemical analysis reveals K, S, Cu, C, and O.

TI 77PS Test Synopsis

This document is a synopsis of tests conducted by Texas Instruments during the 77PS investigation. The intent of this document is to highlight test findings which drove the investigation to its current state. Throughout the investigation, several tests were conducted with the same objective. When each objective was met, efforts were refocused to obtain a new level of understanding and to establish a new set of objectives. As such, tests have been categorized into (5) levels, representing the level of knowledge obtained from the group of tests conducted. Each level is listed below with a short description of the objective:

Level 1: Create a laboratory switch ignition without any restrictions on methods.
Level 2: Create a laboratory switch ignition using only conditions found in the switch operating environment.
Level 3: Understand the laboratory ignition mechanism.
Level 4: Compare factors contributing to laboratory ignition.
Level 5: Evaluate recommendations.

Refer to <u>Brake Pressure Switch Test Log</u>.

Level 1 Objective: Determine if a switch ignition can be created in the laboratory.

- Test 1

Objective: Determine if switch ignition can occur under the following laboratory conditions:

Switch contact cavity flooded with brake fluid mixed with varying amounts of % H_20.
14 volts applied to one terminal, second terminal electrically floating. (No electrical load across switch terminals).
Switch hexport electrically grounded.

Results: (8) samples were tested total:
(2) with 4% H_20 in brake fluid.
(2) with 6% H_20 in brake fluid.
(2) with 10% H_20 in brake fluid.
(2) with 75% H_20 in brake fluid.

No ignition occurred. No significant temperature rise observed in all samples. Current draw ranged from 0.5 mAmps to 5 mAmps over a period greater than (250) hours.

TI-NHTSA 014066

- Test 2

Objective: Determine if switch ignition can occur under the following laboratory conditions:

Switch contact flooded with brake fluid.
14 volts applied to one terminal, second terminal connected to a 14 Ω resistor which is tied to ground. (1 Amp load across switch terminals).
Switch hexport electrically grounded.

Results: (2) samples were tested. No ignition occurred. No significant temperature rise observed for a period over (250) hours.

Conclusion: A (1) Amp load through switch terminals did not ignite brake fluid in the contact cavity of switches.

- Test 6

Objective: Determine if switch ignition can occur under the following laboratory conditions:

Heater element installed in contact cavity of the switch.
Power applied to the heater element until plastic base melts.
Spark generated in contact cavity of switch.
Brake fluid present in the contact cavity (wet device) and absent in the contact cavity (dry device).

Results: (2) dry devices were tested and (1) wet device was tested. Ignition occurred in all devices.
Wet device: The internal temperature of a wet device reached 660°F. A hole burned through the base of the switch (close to the heating element). The applied spark ignited the fumes in the contact cavity of the switch and engulfed the base material of the switch.
Dry device: The internal temperature of a dry switch reached over 1000°F. The switch base flopped over. The applied spark ignited the fumes in the contact cavity of the switch and engulfed the base material of the switch.

Conclusion: A switch ignition can occur under the following laboratory conditions:

Heater element installed in the switch contact cavity.
5 watts of power dissipated in heating element.
Spark generated in the contact cavity of the switch.

Brake fluid did not contribute to the ignition process.

TI-NHTSA 014067

Level 2: Objective: Determine if a laboratory ignition can occur using only switch components and elements found in the switch environment.

- Test 6a

Objective: Determine if corrosive degradation of switch electrical components can cause an increase in electrical resistance (and thus a source of heat) in the switch, which may lead to an ignition.

Results: (1) out of (15) samples tested increased resistance to 5 Ωs. A solution of 5 wt. % NaCl in H_20 can corrode the electrical components of the switch and cause an increase in electrical resistance. Repeated injections of the solution of 5 wt. % NaCl in H_20 into the contact cavity of a switch, with the switch continuously powered at 14 Volts, can cause an ignition.

Conclusion: A switch ignition can occur under the following laboratory conditions:

A solution of 5% NaCl in H_20 is injected into contact cavity of a switch.
Continuous 14 Volt power applied to the switch.
Hexport is grounded.
Current is limited at 15 Amps.

- Test 6c

Objective: Determine if brake fluid with metal shavings is conductive enough to create an ignition.

Results: (3) devices with various size metal particles were tested. No significant current increase detected.

Conclusion: Metal shavings did not significantly increase conductivity brake fluid. Current levels measured were well below levels necessary to create an ignition.

- Test 7

Objective: Determine if switch meets cycle life specification.

Results: Tests conducted during the first quarter of 1999 show that switches exceed cycle life specification.
In the first quarter of 1999, a total of (42) 77PSL2-1 snap switches were impulse tested to over 1,000,000 cycles with only (1) leak below 1,000,000 cycles, which

occurred at 728,000 cycles. A Weibull analysis showed 99.9% reliability at 500,000 cycles at 95% confidence level.

Conclusions: Switches meet cycle life specification. First quarter, 1999 tests confirm impulse test findings made during the period between 1991 and 1992. During that period, (6) impulse tests on 144 devices of 57PS and 77PS construction, had no leaks when tested to 500,000 cycles. A Weibull analysis of first quarter, 1999 tests, showed 99.9% reliability at 500,000 cycles at 95% confidence level.

- Test 15a

Objective: Determine the long term corrosive effects of brake fluid on the electrical components of switches which are continuously powered at 14 Volts.

Results: Test was suspended after 550 hours of testing. (6) samples were tested with continuous 14 Volts power. The contact cavity of (4) switches contained new brake fluid and (2) switches contained old brake fluid. Switches with old brake fluid drew very little hexport current and showed a decrease in hexport current over time to less than 1/10 mAmp. Samples with new brake fluid showed an increase in hexport current to over 20 mAmps toward the end of the 550 hours of testing. Analyses of (1) sample with new brake fluid and (1) sample with old brake fluid revealed electrolytic corrosion of the contact arm of both switches. There was a much lower level of corrosion in the sample with used brake fluid than the sample with new brake fluid.

Conclusion: Brake fluid in the contact cavity of switches, which are at 14 Volts continuous power for over 500 hours, can cause electrolytic corrosion of the switch contact arm and an increase in hexport current.

- Test 17

Objective: Quantify the long term corrosive effects of new brake fluid on the electrical components of switches under the following laboratory conditions:

Contact cavity of switch flooded with new brake fluid.
Switches at continuous 14 Volts power.
Switches subjected to vibration for (1) hour per day.
Switches subjected to 100°C for (1) hour per day.

Results: Test suspended after (312) hours. (50) samples tested. The average hexport current draw after (312) hours is 1.9 mAmps with a standard deviation of 1.8 mAmps. These results are consistent with results previously found in Test 15a at the 300 hour point.

TI-NHTSA 014089

Conclusion: New brake fluid in the contact cavity of switches, has not caused an increase in hexport current after (312) hours at continuous 14 Volts power.

Level 3: **Objective:** Understand the laboratory ignition process, determine the current path and establish a repeatable ignition method.

- Test 6b

Objective: Understand the ignition process, determine the current path and establish a repeatable ignition method.

Results: Multiple attempts at laboratory ignition, via injection of a solution of 5 wt. % NaCl in H_2O into the contact cavity of switches, has resulted in a repeatability rate of approximately 50%. Plots of hexport current verses time show an increase in current until the point of ignition.

Conclusion: A repeatable laboratory method for switch ignition was established. Based on hexport current measurements, the current path is from switch terminals to hexport body.
When a solution of 5 wt. % NaCl in H_2O is repeatedly injected into the contact cavity of powered switches, electrolytic corrosion of the switch terminal results in an increase in terminal resistance. When sufficient power is drawn through the corrosive resistance, switch elements heat up and begin to glow red hot. A hole burns through the switch base and ignition occurs. There is arcing visible throughout the corrosion process which may provide the spark necessary for ignition.

Level 4: **Objective:** Compare and contrast variables influencing ignition using the established laboratory ignition method.

- Test 13a

Objective: Compare various fluids in the established ignition method.

Results: The following fluids were tested.
(1) NaCl in H_2O.
(1) tap water
(1) rain water
(1) used brake fluid
(1) used brake fluid with 5 wt. % H_2O
(1) new brake fluid
(1) new brake fluid with 5 wt. % H_2O
The switch filled with 5 wt. % NaCl in H_2O resulted in an ignition when average hexport current exceeded 2.5 Amps. Switches that were filled with tap water and rain water drew less than 10 mAmps over a (3) hour test and showed little signs of

corrosion. Switches filled with a matrix of new and used brake fluids, with water and without water, all drew less than 3 mAmps bexport current draw and showed no signs of corrosion over the (24) hour test.

Conclusion: Brake fluid is not conductive enough to cause the electrolytic corrosion and necessary current draw to create an ignition within a 3 hour lab test. Because of its' significantly higher conductivity, an ionic rich fluid such as NaCl in H_2O can cause an ignition in a 3 hour lab test exposure..

- Test 15

Objective: Compare the ignition characteristics of various plastics as switch base material.

Results: When 5 wt. % NaCl in H_2O was injected into switches with different base materials, the following results were obtained: Cellanex 4300 ignited 3 out of 5 attempts. Noryl ignited 2 out of 5 attempts. Zytel ignited 1 out of 5 attempts.

Conclusions: All plastics tested can ignite using the established laboratory ignition method.

- Test 15b

Objective: Determine if switch ignition can occur in the vertical position and 45° orientation. Determine if switch ignition can occur and at different rotational angles in the 45° orientation.

Results: Switch ignitions can occur in both the vertical and 45° orientation using the established laboratory ignition method.

Conclusion: Switch ignition does not appear to be sensitive to vertical orientation verses 45° orientation nor to rotational angle in the 45° orientation.

Level 5 Objective:

Test 16

- Objective: Test proposed relay circuit.

Results: (1) switch was injected with a solution of 5 wt. % Nacl in H_2O and placed in the proposed current limiting circuit for (48) hours. The current draw remained constant at 180 mAmps throughout the test. There was no activity observed and the contact arm remained mostly intact.
(1) switch was brought to an impending burn condition using the established burn method. An impending burn is a condition where a corrosive resistance has built

up in the switch and an ignition is imminent. The switch was then placed in the proposed relay circuit for(18) hours where it drew 160 mAmps, showed no visible activity and did not result in an ignition.
Because the proposed relay circuit acts as a resistor which limits current to the switch, the maximum power to the switch is limited to .75 Watts. A resistive wire was wrapped around the base of (1) switch and 0.75 Watts of power was dissipated in the wire. The wire became warm to the touch but had no effect on the switch.

Conclusion: 0.75 Watts, the maximum power in the proposed circuit design, is insufficient to cause substantial electrolytic corrosion or significant switch terminal heating, which is necessary to create an ignition. In previous tests, using a resistor as the heating element (see Test 6), approximately 5 Watts of power was necessary to create an ignition.

TI-NHTSA 014072

Brake Pressure Switch Test Log, Updated 6/29/99

Category	Test	Location	Test Parameters	Results Update
Lab Simulation	1	TI	Vary water concentrations in 'new' Brake Fluid	250+ hours, Current draw in the 4.7mA to 5mA range
of Potential Ignition			14Vdc to one terminal, hexport grounded	Fluid has discolored.
in Switch			Water Conc: 4%, 6%, 10%, 75%	No Significant Temperature Rise. Test Suspended.
				Internal Analysis suspended.
	2	TI	New Brake Fluid	250+ hours. Constant temperature.
			1 Amp through switch terminals	No significant temperature rise with time
			14Vdc to one terminal, hexport grounded	Test Suspended.
	3	AVT	new' Brake Fluid in Switch, 24 VDC to one terminal. Hexport Grounded	> 300 hours into test, max current 7mA
				No significant change with time. Test suspended
	4	AVT	new' Brake Fluid in Switch, 24 VDC to one terminal. Hexport Grounded, Ambient at 100 C	16 hours into test max current 6mA
				No significant temperature rise with time. Test suspended.
	5	AVT	new' Brake Fluid in Switch, 10 Amps Through switch terminals	Temperature rise of 20 C above room temp
				Delta T reached steady state at 20 C. Test suspended.
	5a	AVT	new' Brake Fluid in Switch approx. 50 Amps through Switch Terminals	Temperature rose to approx. 270 F. No smoke. No ignition
				Test suspended.
	6	TI	Build heater elements into Switch.	3 tested. Smoke observed, ignition observed on past wheeler
			Heat till failure, include sparking.	See attachment
			(1) w/ solution of Brake Fluid and 6 wt. % H_2O	Test complete
				Brake fluid in cavity slows down heat build-up
				Smoke observed at 675 F, Base melts and falls off at 800 F
	6a	TI	Create heater by corroding spring arm	One out of 15 devices increased resistance to 5 ohms.
			Salt water solution, 14V between spring	Others either very low resistance or magnetized
			and hexport	It took about 100 hours to reach the 5 ohm stage.
				The 5 ohm device ignited under conditions similar to test 6.
	6b	TI	Re-run ignition test to understand	Switch ignition with repeated 5% water solution into switch
			repeatability and current path.	Current path is through hexport.
				See plots and video.
				Additional test include tap water, old BF, new BF and other.
	6c	TI	Pure 'new' brake fluid with metal shavings	Metal shavings do not contribute significantly to brake fluid

Epstein, Sally

From:	McGuirk, Andy [a-mcguirk@email.mc.ti.com]
Sent:	Tuesday, June 29, 1999 3:56 PM
To:	Epstein, Sally
Subject:	FW: Ford foil

Andy.ppt

AUTOMOTIVE SENSORS AND CONTROLS QRA MANAGER
34 FOREST ST M/S 23-05
ATTLEBORO, MA 02703
TEL : (508) 236-3080
FAX : (508) 236-3745
MOBILE: (508) 208-6119
PAGE: (800) 467-3700 PIN 604-2044

From: McGuirk, Andy
Sent: Tuesday, June 01, 1999 12:49 PM
To: Beringhause, Steven; Prola, Stephen
Subject: FW: Ford foil

Maybe for your use ?

AUTOMOTIVE SENSORS AND CONTROLS QRA MANAGER
34 FOREST ST M/S 23-05
ATTLEBORO, MA 02703
TEL : (508) 236-3080
FAX : (508) 236-3745
MOBILE: (508) 208-6119
PAGE: (800) 467-3700 PIN 604-2044

From: Wellman, Stacey
Sent: Thursday, May 20, 1999 11:27 AM
To: Warner, Pam
Cc: Sharpe, Robert; McGuirk, Andy
Subject: Ford foil

At the request of Andy McGuirk, I am sending the following attachment to you:

<<Andy.ppt>>

Regards,
Stacey

TI-NHTSA 014074

NA Hydraulic Switch History

Time Period:	'83	'87	'90	'91	'98	'99
Application:	Power Steering	Power Steering Suspension	Power Steering Suspension Transmission	Power Steering Suspension Transmission Cruise	Power Steering Suspension Transmission Cruise Clutch	Power Steering Suspension Transmission Cruise Clutch
Fluid:	Power Steering Fluid →	→	→	→	→	→
		Brake Fluid →	→	→	→	→
			Transmission Fluid →	→	→	→

- TI has some 16 years and 130 million units accumulated experience in hydraulic applications using multiple fluids
- TI has some 12 years of brake system application experience working with brake fluids

C:\McGuire\[illegible]

TI-NHTSA 014076

TEXAS INSTRUMENTS **Brake Pressure Switch**
Potential Thermal Event Theory Profile 5/20/99 [redacted]

AGENDA

- CONTRIBUTING FACTORS AND ROBUST DESIGN DIALOGUE
- OVERVIEW TIME LINE
- SYSTEM OVERVIEW
    - SWITCH AND CONNECTOR
- IS / IS NOT TABLE
- CAUSE AND EFFECT DIAGRAMS
- THEORIES
    - BRAKE FLUID IGNITION
    - PLASTIC IGNITION
- TEST RESULTS
- CONTRIBUTING FACTORS AND ROBUST DESIGN DIALOGUE
- ROBUST DESIGN ALTERNATIVES

[illegible] Attachment

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

[redacted]

1. Connector Seal to P/S

2. Power continuously available
   A. Operator notifications

3. Switch orientation/location

4. Current limit / fuse

5. Hexport isolation

6. Plastic ignition robustness
   A. Nearby fuels

7. Kapton seal of P/S

8. Environmental seal of P/S

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

OVERVIEW OF CONCERN TIME LINE

OCT/NOV 98	DEC '98	JAN '99	FEB '99	FEB '99	MAR '99	APR '99	May '99
NHTSA initiates investigation	Supply chain dialogue	Core team momentum	TI Eng'r at Ford	Brake fluid fails to ignite	H20 corrosion ignites plastic	Ford NHTSA responds	Deploy results

[illegible]

Attachment

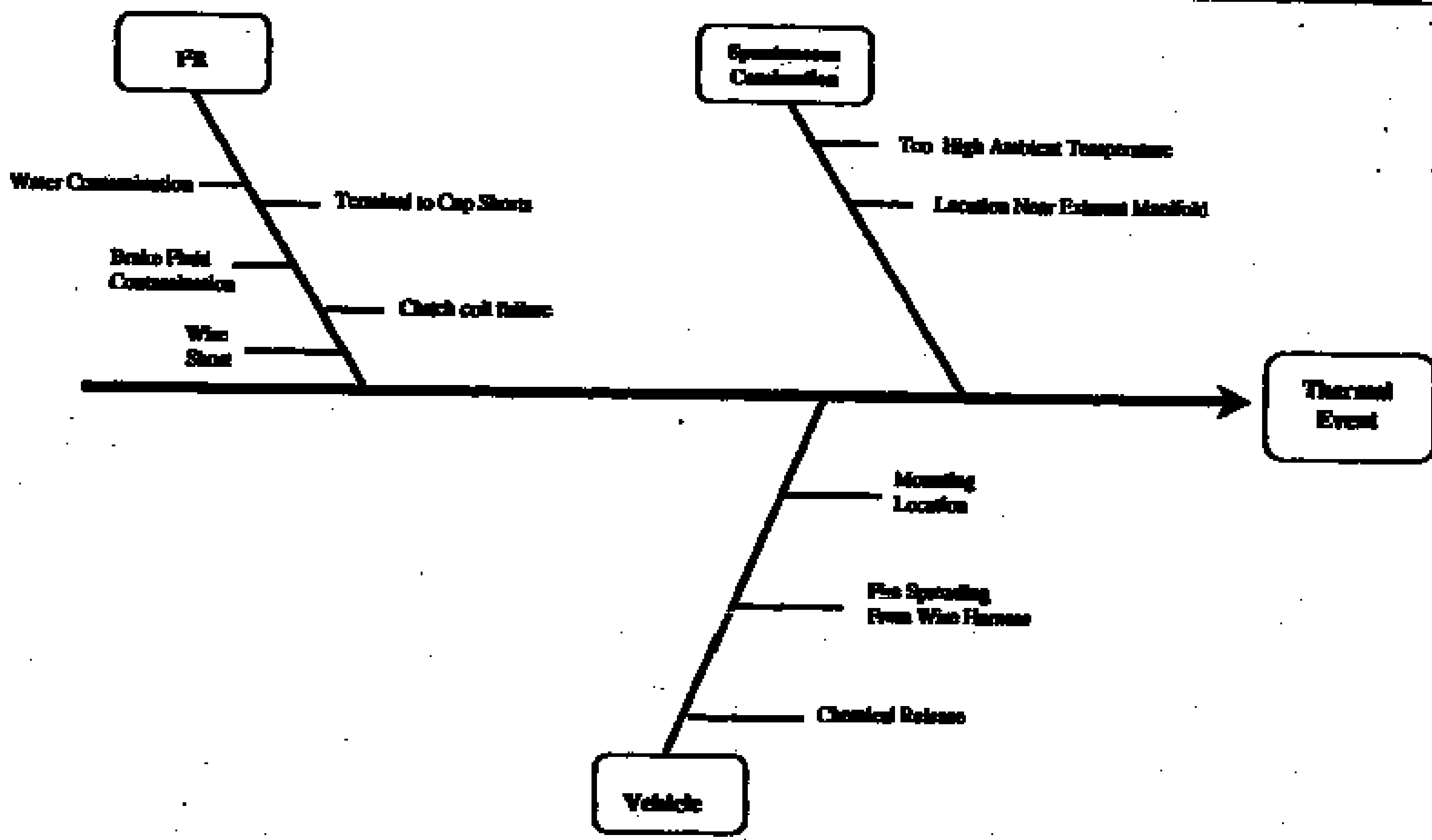
TI-NHTSA 014078

Brake Switch Overview

- Mounted under hood…14 inches under master cylinder
- Mounted on proportional valve at frame of vehicle
- Switch oriented approximately 25 degrees off vertical (connector up)
- Switch controls speed control…normally closed, opens at 130 psi
- Continuously powered by battery 15 amp connection

Texas Instruments

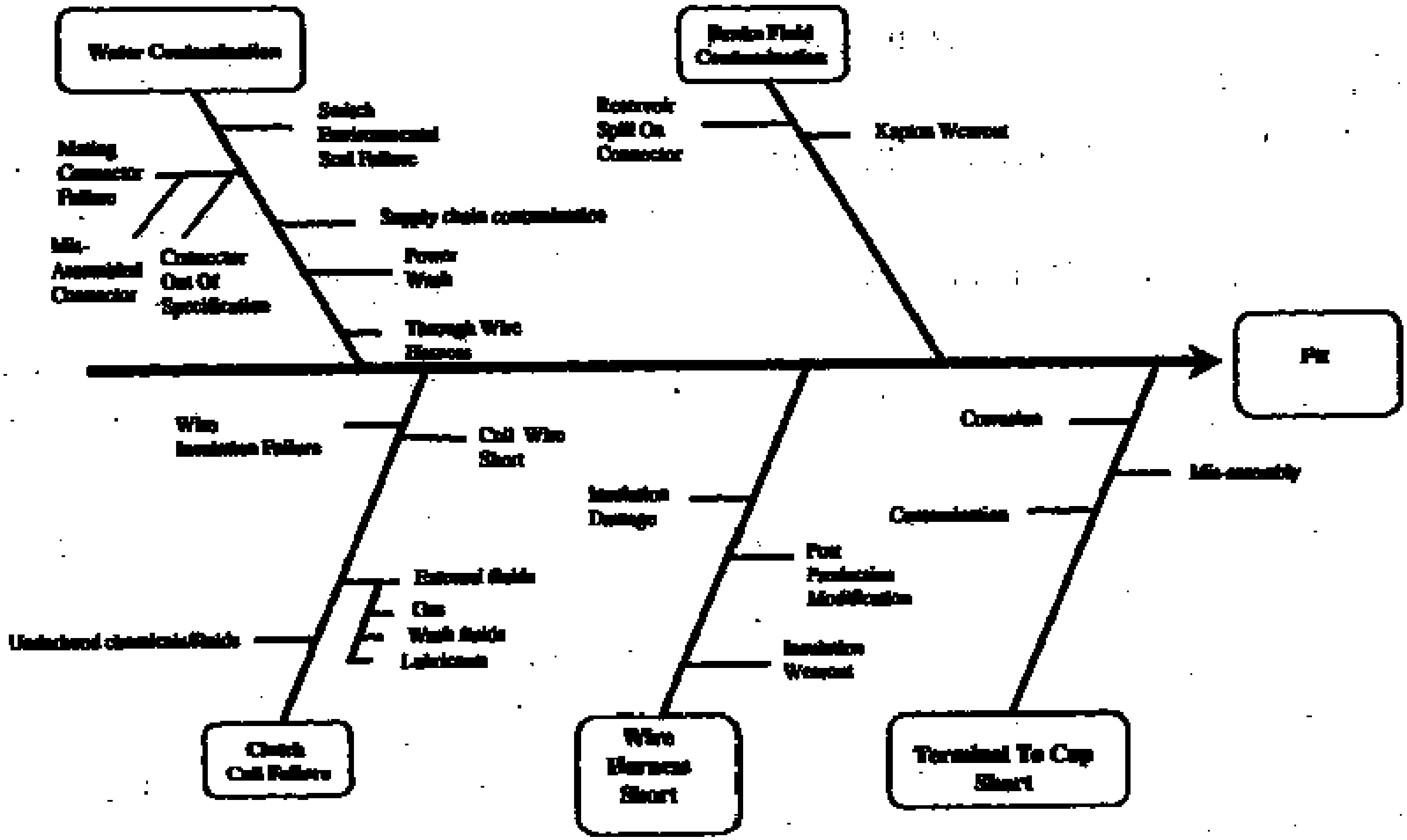
Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99



Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

[redacted]

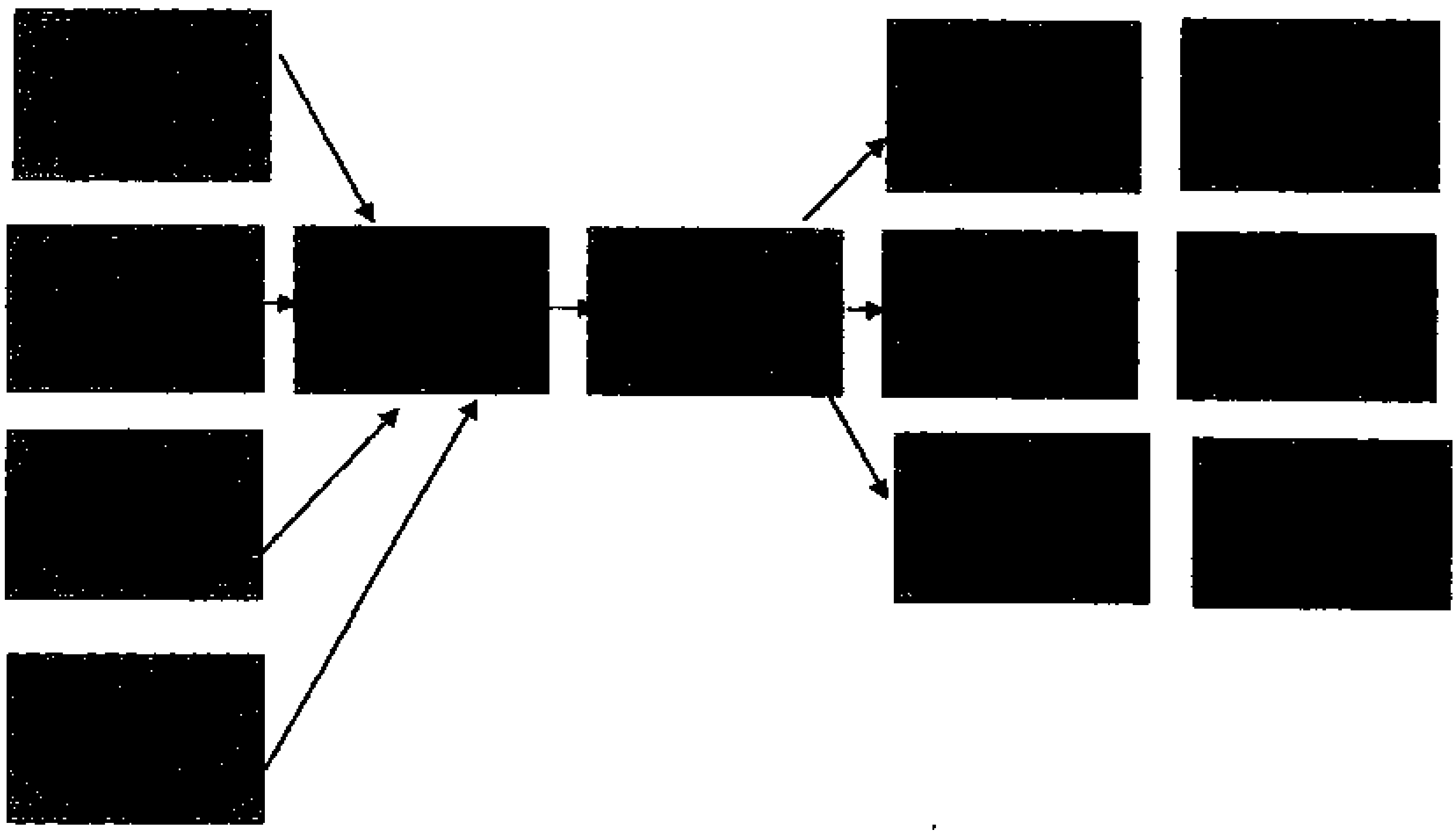


Attachment

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

REFINED BRAKE FLUID IGNITION THEORY
POSSIBLE CAUSE THEORIES
"FEB '99 FOCUS"



Attachment

TI-NHTSA 014082

Excel spreadsheet

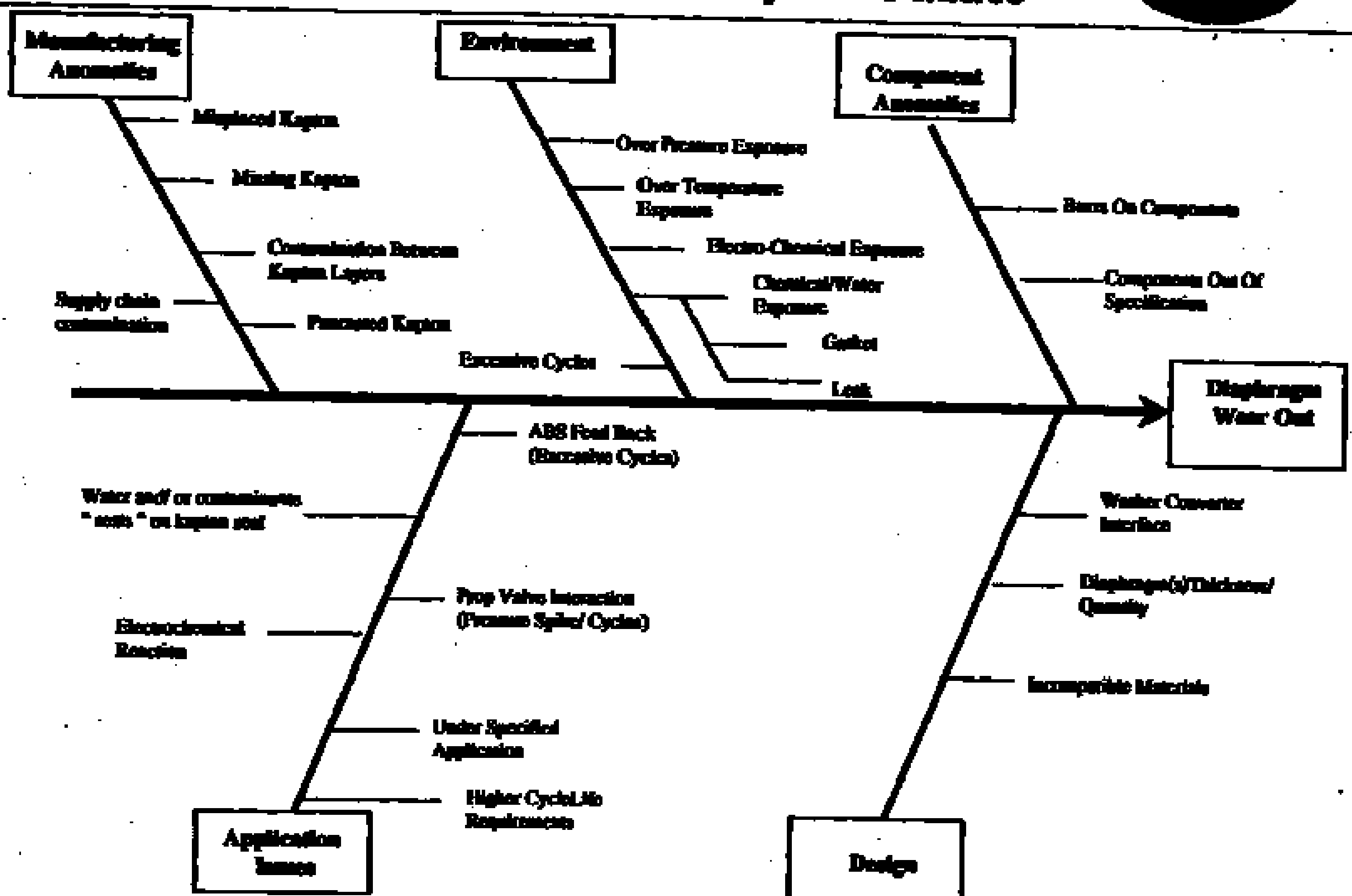
TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

- TI and Ford not successful in creating ignition with "new" brake fluids

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99



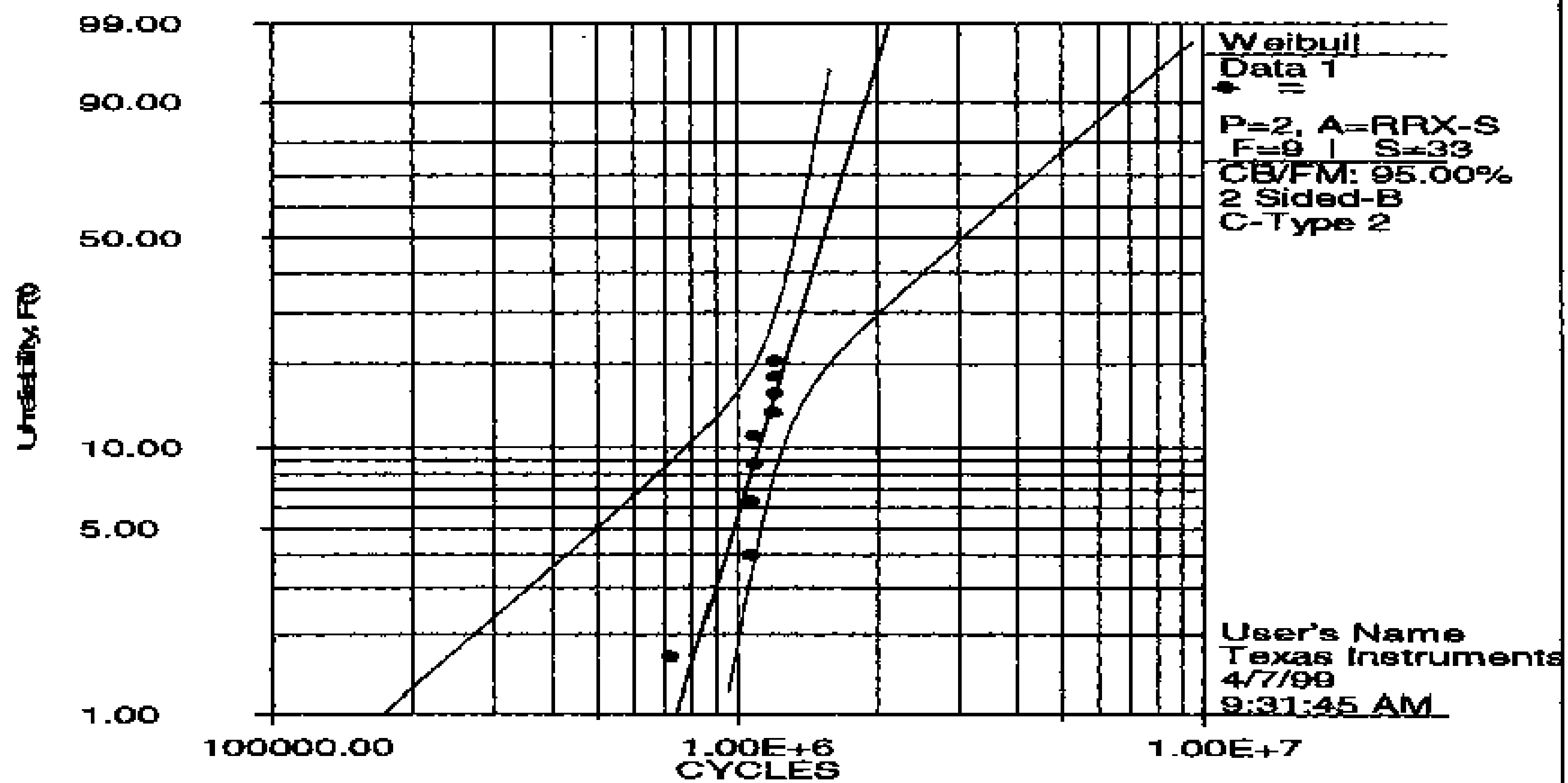
Attachment

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

Generated by: ReliaSoft's Weibull++ 5.0 - www.Weibull.com - 888-886-0410

77PSL2-1 COMBINED DATA



β=5.83, η=1.64E+6, ρ=0.91

C:\McGuirk\99presentations\Ford

Attachment

TI-NHTSA 014086

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

- "Town Car" switch meets accelerated/simulated life cycle specification shown by "success" and "end-of-life" testing

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

PROCESS FLOW DIAGRAM
"CORROSION" POTENTIAL CAUSE FLOW ANALYSIS

[redacted] → [redacted] → [redacted] → [redacted] → [redacted]

↓

[redacted] ← [redacted] ← [redacted] ← [redacted] ← [redacted]

↓

[redacted] → [redacted]

TI-NHTSA 014088

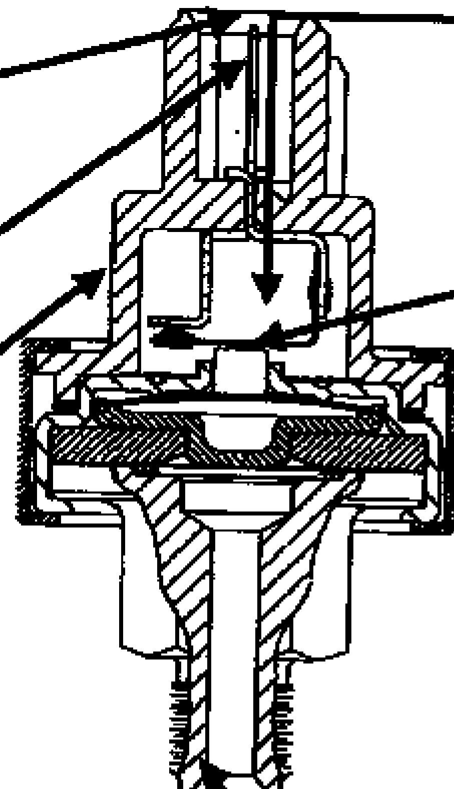
TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

5. High current flow to case through water and ionic contamination

2. 12V Battery source to drive corrosion and provide energy

6. Plastic connector melts. Once it opens, oxygen enters the switch cavity. Arm terminal/corrosion becomes "RED HOT" igniting the plastic



1. Water and "ionic" contamination (e.g. NaCl or cleaner) enters the switch cavity

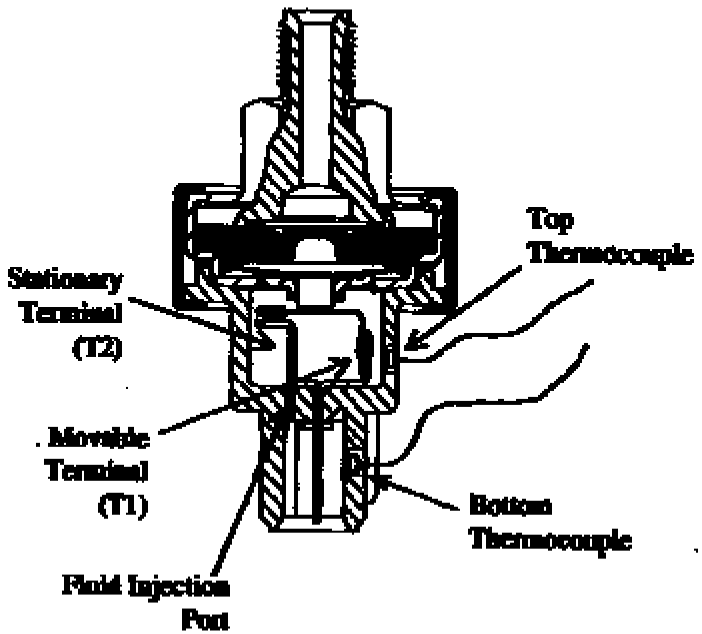
4. Contact arm& terminal corrosion increases resistance (acts like heater wire).

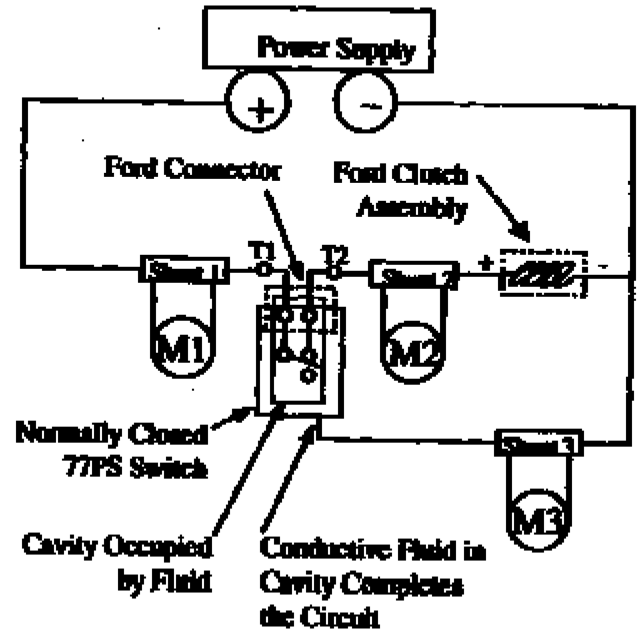
3. Hexport grounded accelerates corrosion

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

5% Salt Water Ingress Experiment
Test 1





TI Report PS/99/12
03/15/99

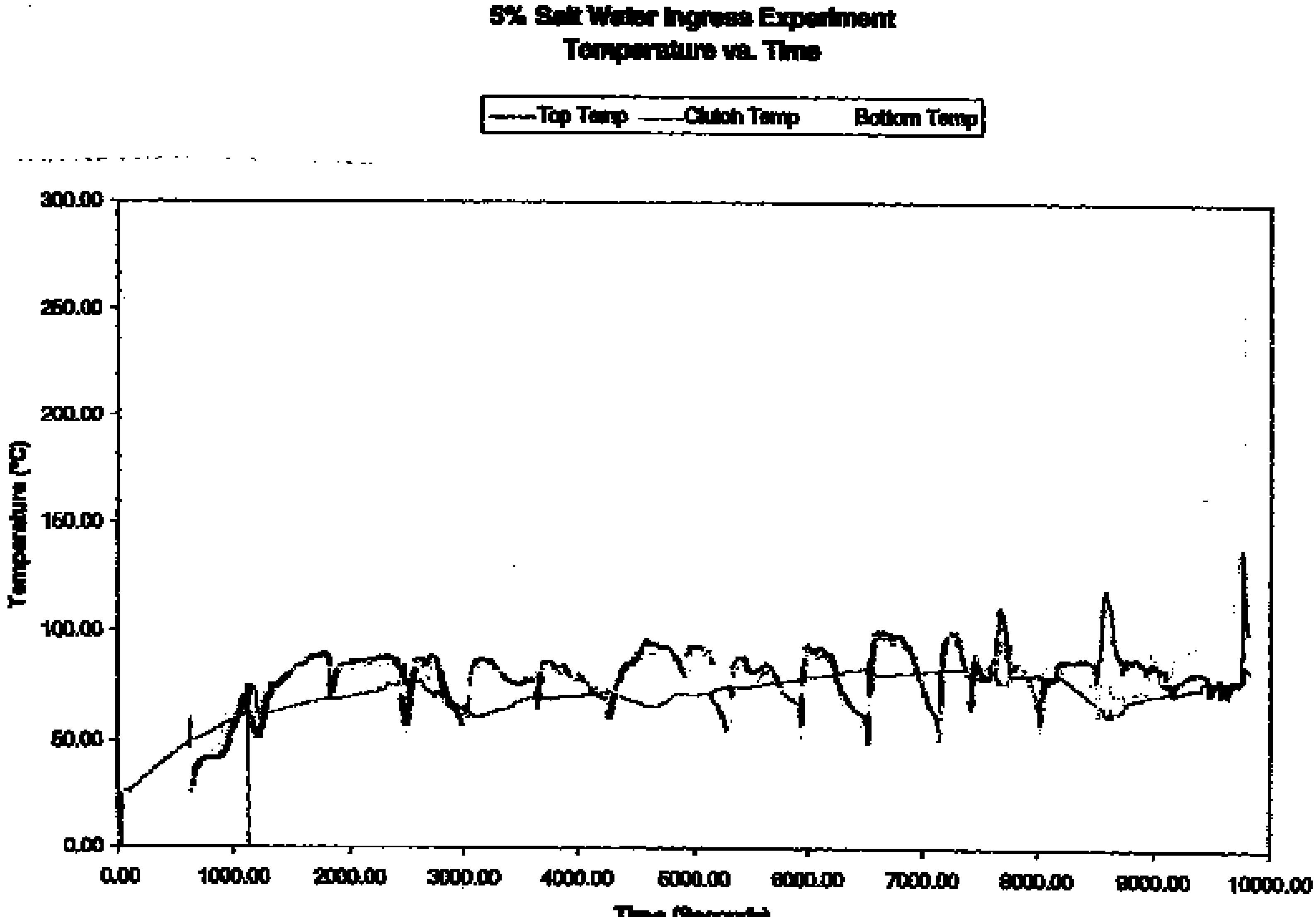
Test 1: Figure 1 and Figure 2.

Attachment

TI-NHTSA 014080

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

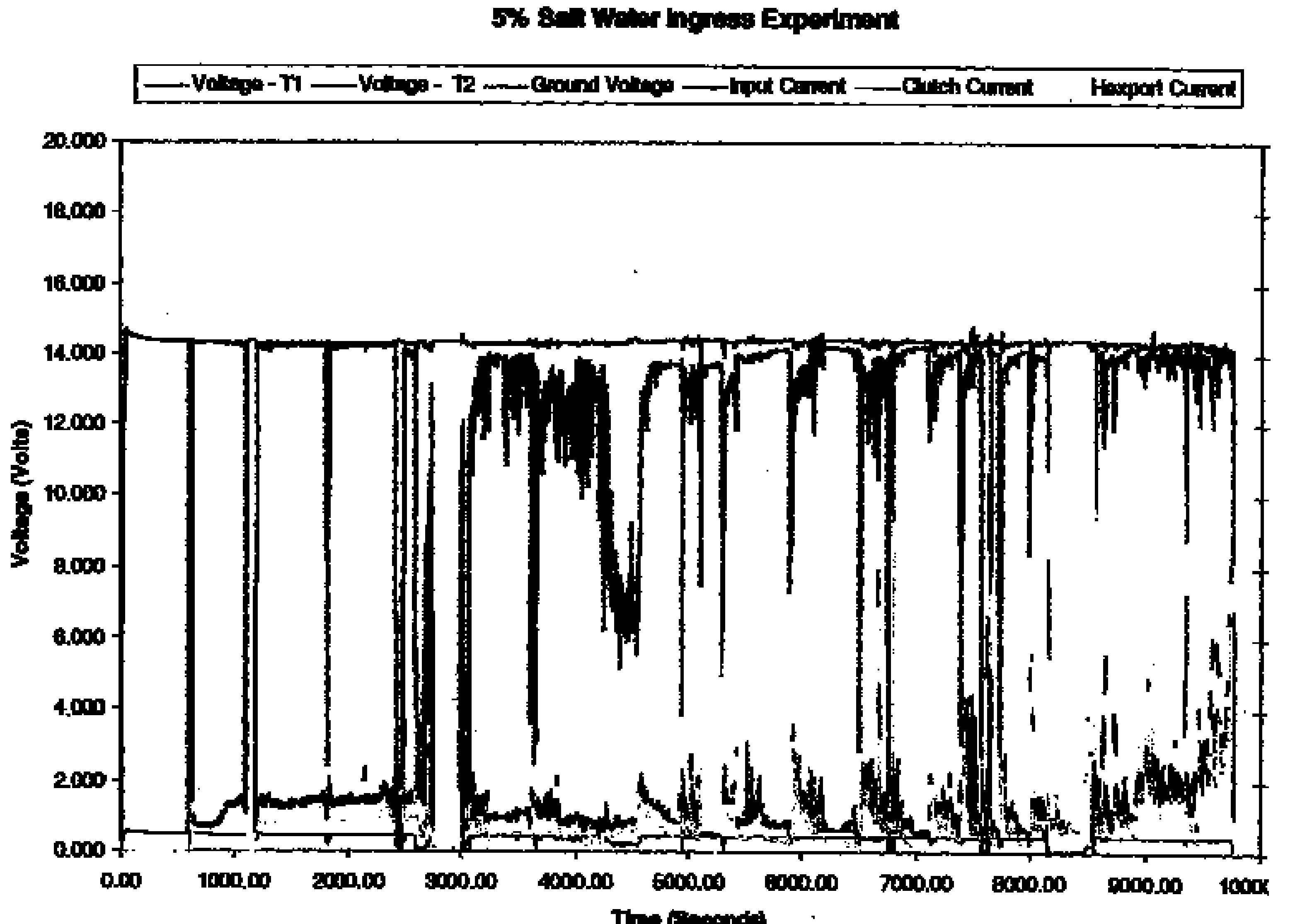


INTENTIONAL IGNITION CREATED THRU TI FLUID INGRESS LAB TEST PS/99/13' Attachment

TI-NHTSA 014091

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99



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TI-NHTSA 014092

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

77PS
45° Orientation in 15 Amp Circuit
5% Salt Water Ingress

Cellanex 4300 Base

Cellanex 3316 Base

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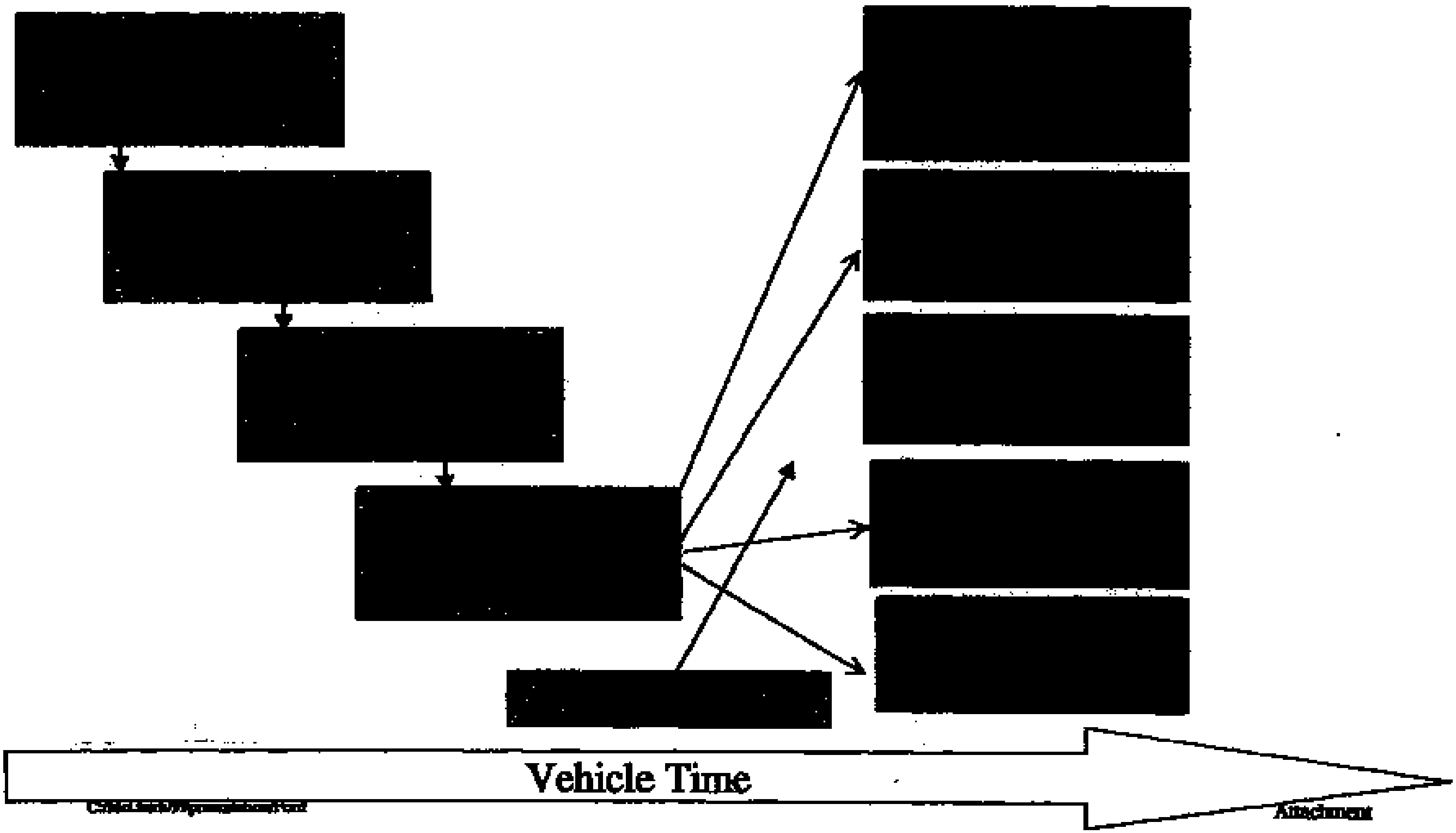
Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

"Corrosion" potential cause time line
Theory Time Line

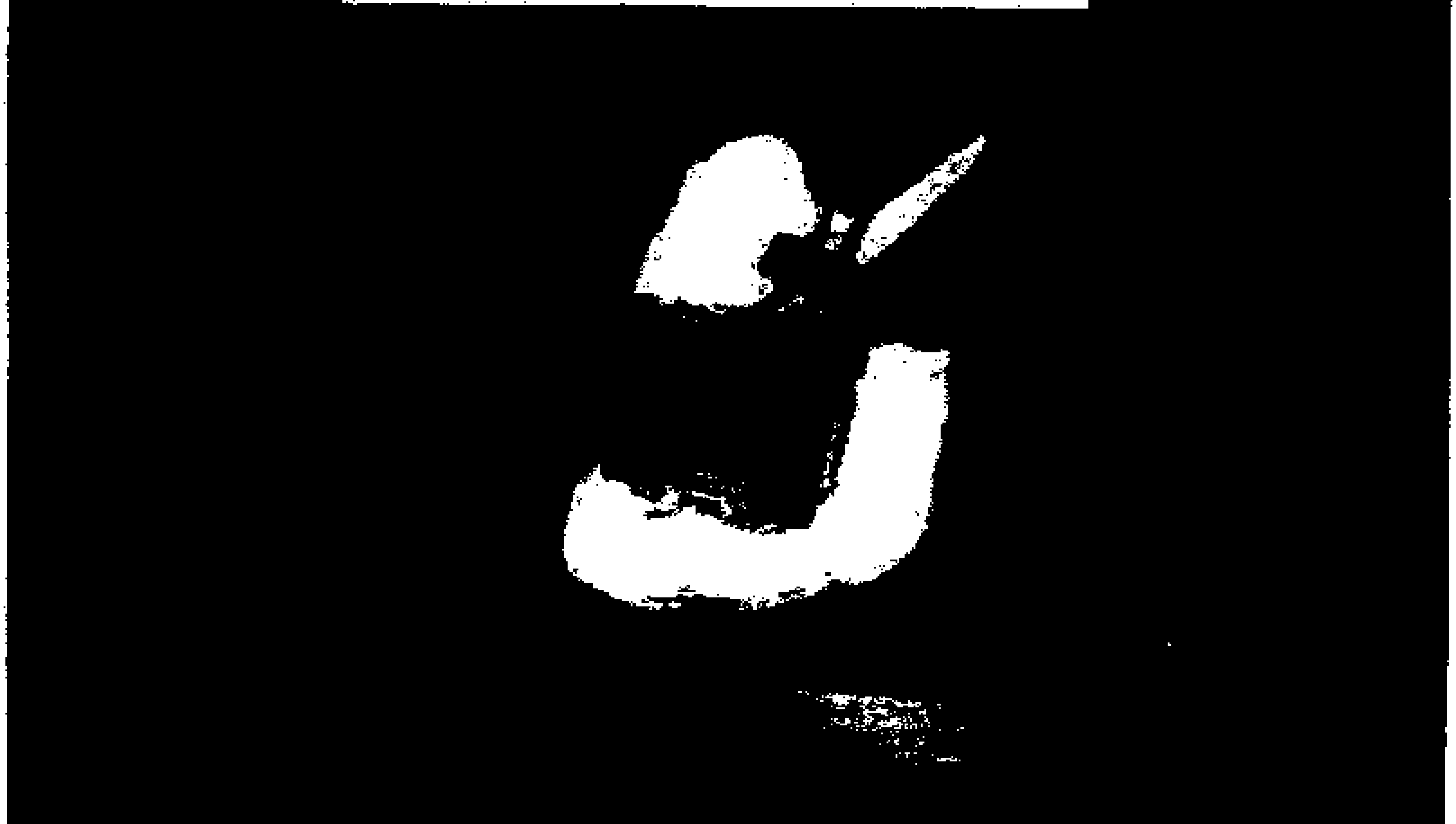


Attachment

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

77PS Cellanex 4300 Base
Vertical Orientation in 15 Amp Circuit
5% Salt Water Ingress



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TI-NHTSA 014085

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

PROCESS FLOW DIAGRAM
"CORROSION" POTENTIAL CAUSE FLOW ANALYSIS

[redacted]

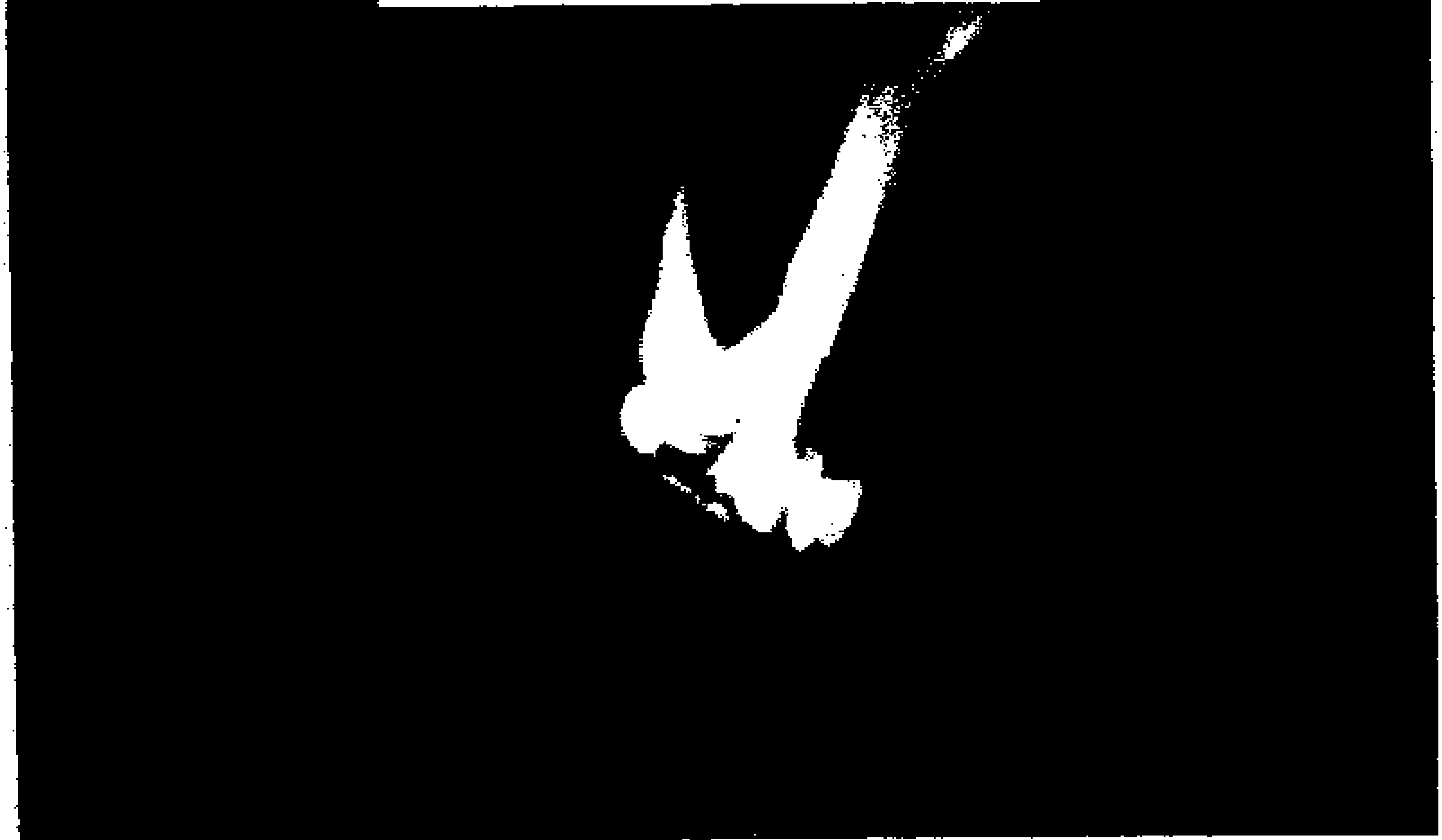
Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

77PS Noryl Base

45□ Orientation in 15 Amp Circuit

5% Salt Water Ingress

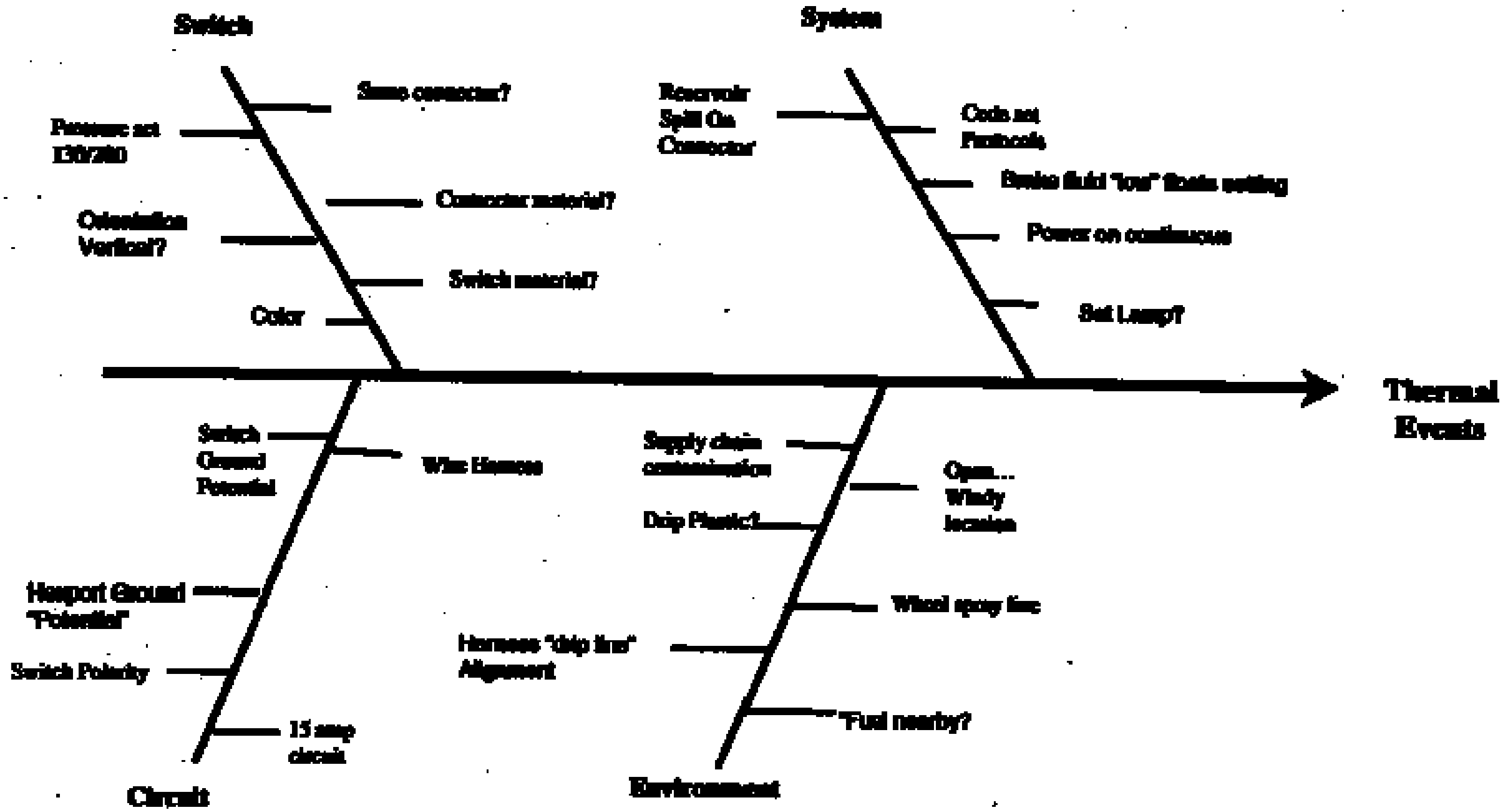


INTENTIONIAL IGNITION CREATED THRU TI FLUID INGRESS LAB TEST PS/99/13 Attachment

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

ECONOLINE VS. TOWN CAR P/S



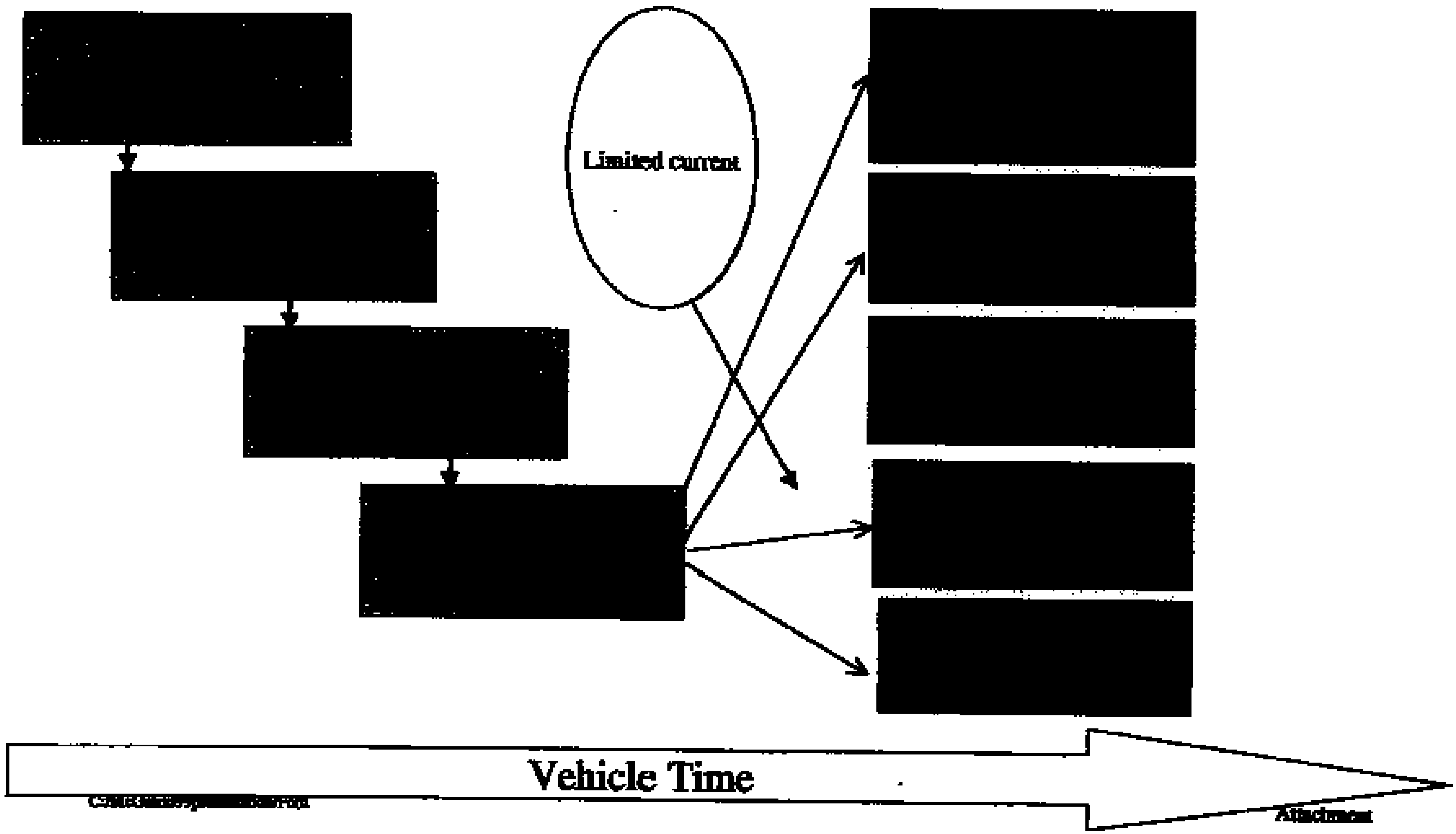
Attachment

TI-NHTSA 014098

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

"Corrosion" potential cause time line
Theory Time Line

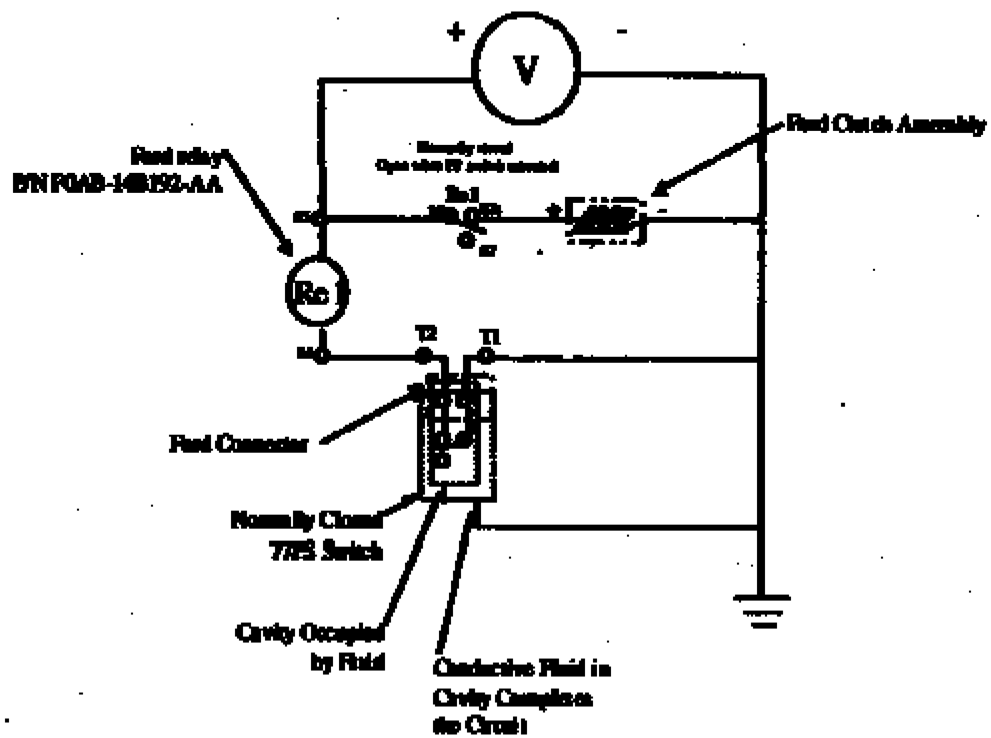


TI-NHTSA 014099

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

77PS Proposed Wiring Schematic

14 Volts DC

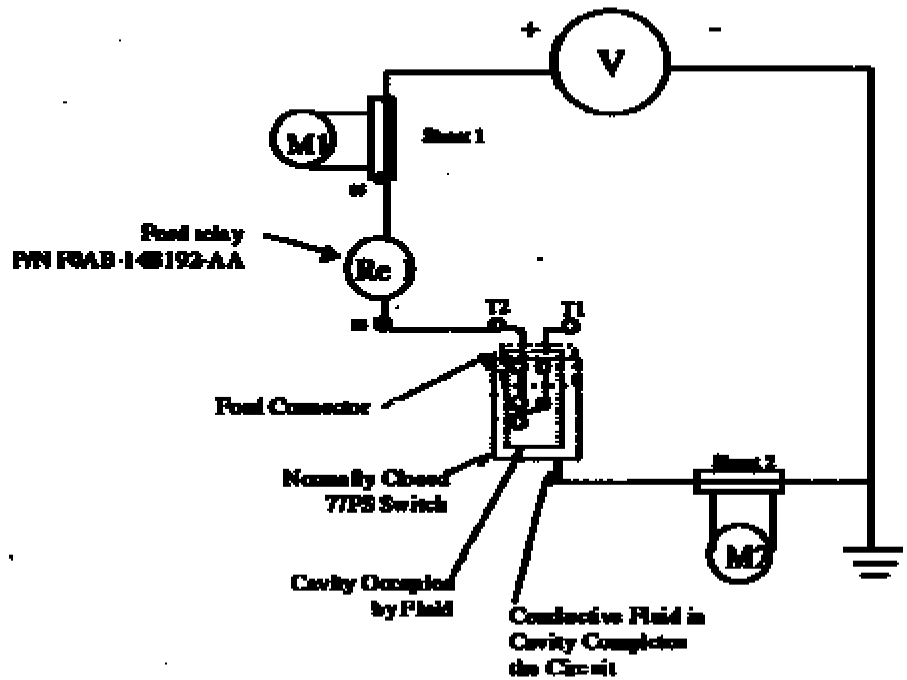


Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

200 mAmp Current Limit Circuit
Test Setup

14.5 Volts DC



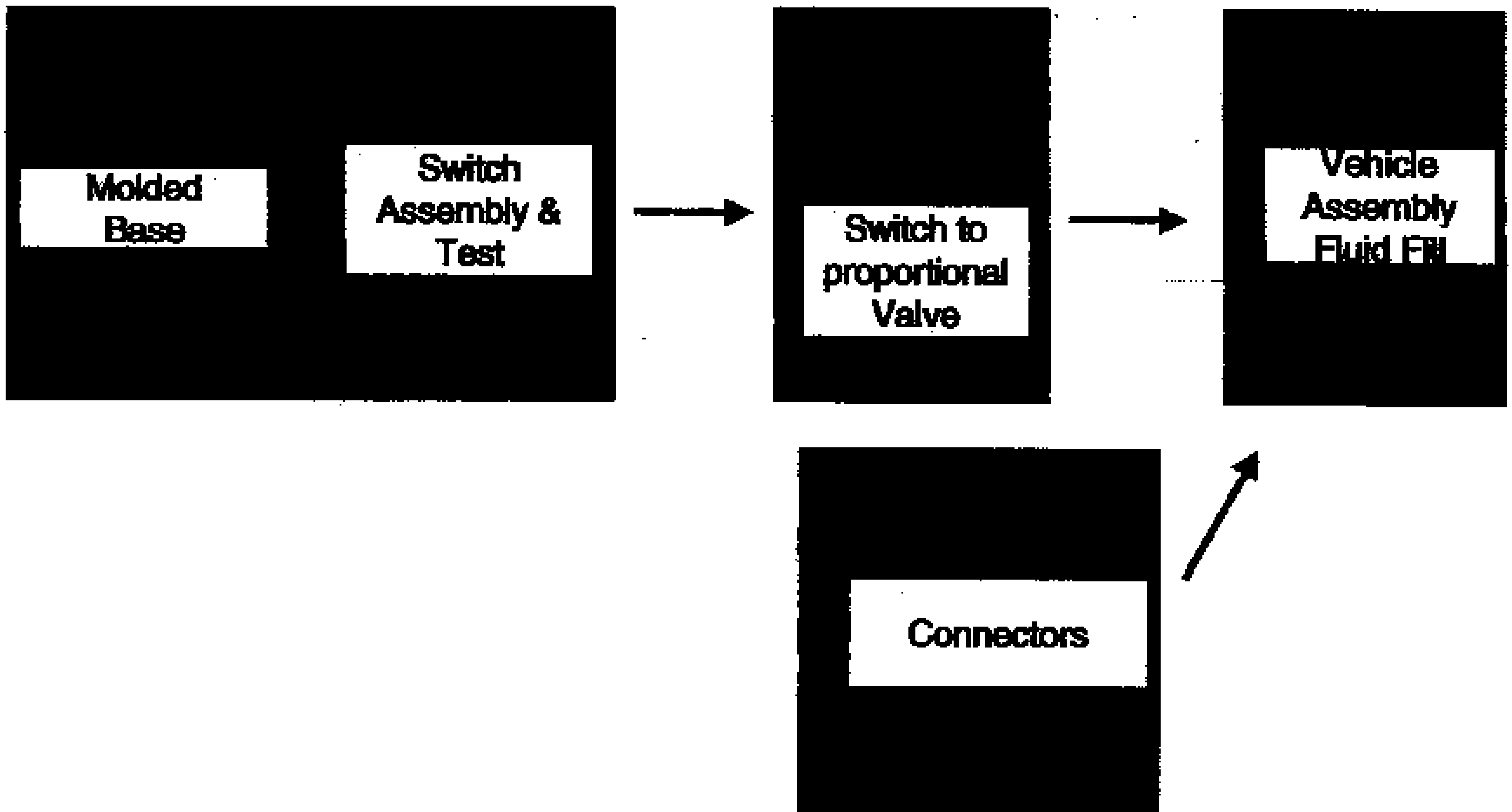
Worst case scenario is when the switch is actuated, which puts T2 at full voltage.
To facilitate testing, TI is floating which keeps TI and T2 at full voltage but limits current draw to .2 Amps (This test is harsher then worst case scenario).

TI-NHTSA 014101

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

See low current stuff from sean

PRESSURE SWITCH "FLOW DIAGRAM"
('92, '93, TOWN CAR)



Texas Instruments

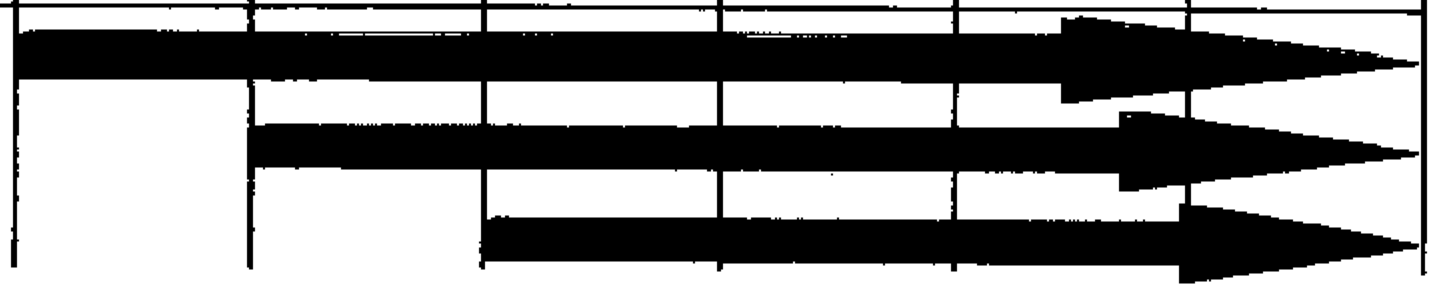
Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

[redacted]

NA Hydraulic Switch History

Time Period:	'83	'87	'90	'91	'98	'99
Application:	Power Steering	Power Steering Suspension	Power Steering Suspension Transmission	Power Steering Suspension Transmission Cruise	Power Steering Suspension Transmission Cruise Clutch	Power Steering Suspension Transmission Cruise Clutch

Fluid:



- TI has some 16 years and 130 million units accumulated experience in hydraulic applications using multiple fluids
- TI has some 12 years of brake system application experience working with brake fluids

TI-NHTSA 014104

Brake Pressure Switch

Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

Today's Date: UPDATED 04/21/99

Scope or Effect Description

1. Operational Definition (Problem Statement): TOWN CAR UNDERHOOD FIRES			
2. Description	IS	IS NOT	Get Information
WHAT	Town Car MY '92, '93, '94	Crown Victoria? Grand Marquis? TB Super Coupe? MY '91, '95, 96 ? '92, '93 Expedition?	COMPARE PLATFORMS
	FIRES… - Electrical pressure switch - Connector - Servo system - Electrical Distribution	Not only pressure switches	COLLECT/TEST OTHER SYSTEM COMPONENTS FOR "SYNERGY" COMPARE VEHICLE OPTIONS FOR SYNERGY
	SYSTEM ISSUES… - Cruise inoperative - Locked in park - Heat inoperative - Brake lights inoperative - Discharged battery - Door locks? - Hazard lamps?	Other circuits	COMPARE WARRANTY
WHERE	Driver side hood Mid-fire height in engine compart.	Passenger side hood Dash – pass compartment Not high in engine comp.	EVALUATE HEAT SOURCES
		Not low in engine comp.	
WHEN	1-24 hours after parking Ignition off After 4-5 years After XXX miles	Not while driving Not while ignition on Not before 3 years ? Not before YYY miles	EVALUATE POWER AND HEAT AND WIND SOURCES REVIEW MILES
	After AAA switch cycles	Not Before BBB cycles	
HOW BIG	149 cases / 222k units "candle size" flame	Not all cars ? Not "explosion"	COMPARE PLATFORMS READ FIRE RPTS
	Several pressure switches	Not all underhood fires Not all pressure switches	PARETO UNDERHOOD

Attachment

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

Attachment

Texas Instruments
Automotive Sensors & Controls
8D Report

Customer Title: [illegible] Thermal Events		Open Date: [illegible]	
T.I. CAR Report Number: CAR [illegible]		Updated: 4/21/99	
Status Date:	Vehicle: Lincoln	Part Name: Electric Speed Control Deactivation Pressure Switch	
	Model: Town Car	Part No: [illegible]	
	Plant: Various		

1. Team & Background
[illegible] — A. [illegible]
A. McGuirk — C. Douglas
G. Baker — T. Rowland

2. Problem Description:
Under hood car fire

3. Containment Action(s):	% Effectiveness	Implementation Date
Under review, considering disabling speed control system.		

4. Root Cause: See attachment 1, IS - IS NOT Table.	% Contribution:
(Theories of 3/15/99) • Water enters pressure switch thru connector • Continuous power drives corrosion • Corrosion creates high resistance • Resistance creates local heating • Several sequences over time (?) • Local heating ignites pressure switch and connector plastic • [illegible]	Unknown

5. Chosen Permanent Corrective Actions See attachment 2,3,4	Verification:	% Effectiveness:
Under Review: • [illegible] • Connector cover • Create ground fault protector • Improve connector seal • Eliminate constant power • Change [illegible] orientation • [illegible] power reduction • Modify plastic parameters • Optimize polarity • Move to ground potential	TBD by lab experiments	Unknown

6. Implemented Permanent Corrective Actions:	Implementation

7. Action(s) to Prevent Recurrence:	Implementation
Eliminate constant power, reduce power to function need, [illegible] electrical function.	

8. Congratulate Team	Close Date:	Reported By:	A. McGuirk
		Dept. Name:	QRA Manager
		Telephone No.:	[illegible]

[illegible]

TI-NHTSA 014106

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

77psi3-1		GROSS QTY		COMPLETE	COMPLETE	BEGIN	IMPACT	COMMENTS/CONCERNS
COMPONEN	DESCRIPTIO	REQUIRED	SUPPLIER	1MK	2MK	PARTIAL	TO TI	
27405-1	CONVERTER	2,040,000	KF BASSLE	10 WKS	18 WKS	2 WKS	NONE	ADD OVERTIME/MATERIAL AVAILABILITY
27639-1	WASHER / A	2,040,000	DEMASTER	10 WKS	18 WKS	2 WKS	NONE	MATERIAL AVAILABILITY
27713-1	CUP 77PS	2,040,000	VALENTINE	6 WKS	10 WKS	1 WK	NONE	RAW MATERIAL AVAILABILITY
36656-27	57PS	2,040,000	DISC DEPT	12+ WKS	24 WKS	3 WKS	TOOL $?	POSSIBLE CAPACITY ISSUE
36900-1	HEXPORT 77	2,040,000	ELCO	10 WKS	25 WKS	3 WKS	NONE	RAW MATERIAL AVAILABILITY
74224-1	KAPTON	204	EI DUPONT	2 WKS	2 WKS	2 WKS	NONE	
27225-1	KAPTON ST	1,102	EI DUPONT	3 WKS	3 WKS	2 WKS	NONE	
74353-1	GASKET	2,040,000	JBL PARKER	8 WKS	18 WKS	3 WKS	NONE	ELIMINATE CORES WILL INCREASE DEL. BY 10%
36898-1	STATIONAR	2,040,000	KF BASSLE	10 WKS	16 WKS	2 WKS	NONE	ADD OVERTIME/MATERIAL AVAILABILITY/ REELS
26744-1	CONTACT-S	2,040,000	DERRINGER	4 WKS	9 WKS	1 WK	NONE	MATERIAL AVAILABILITY
36897-1	MOVABLE T	2,040,000	KF BASSLE	10 WKS	18 WKS	2 WKS	NONE	ADD OVERTIME/MATERIAL AVAILABILITY/REELS
27716-1	BECU ISSU	440	BRUSHWELL	1 WK	2 WKS	1 WK	NONE	NONE
74916-1	RIVET	2,040,000	JOHN HASS	8 WKS	11 WKS	4 WKS	NONE	RAW MATERIAL AVAILABILITY
46516-2	PRESSURE S	2,040,000	INTMOLDIN	14 WKS	32 WKS	4 WKS	NONE	RAW MATERIAL CHANGEOVER/PRESS CAPACITY
74076-143	CERAMIN PI	2,040,000	PARATECH	7 WKS	15 WKS	2 WKS	NONE	
74247-4	BLUE O'RING	2,040,000	JBL PARKER	8 WKS	10 WKS	2 WKS	NONE	ELIMINATE CORES WILL INCREASE DEL. BY 10%
74797-1	CRIMP RING	2,040,000	VALENTINE	6 WKS	10 WKS	1 WK	NONE	RAW MATERIAL AVAILABILITY
74668-1	RED THREA	2,040,000	MARK IV CA	3 WKS	6 WKS	1 WK	NONE	
77PS	SWITCH		TI	7/15,8/1,8/15	250K/MONTH			7 day weeks, thru summer vacations, 'add' plastic mold

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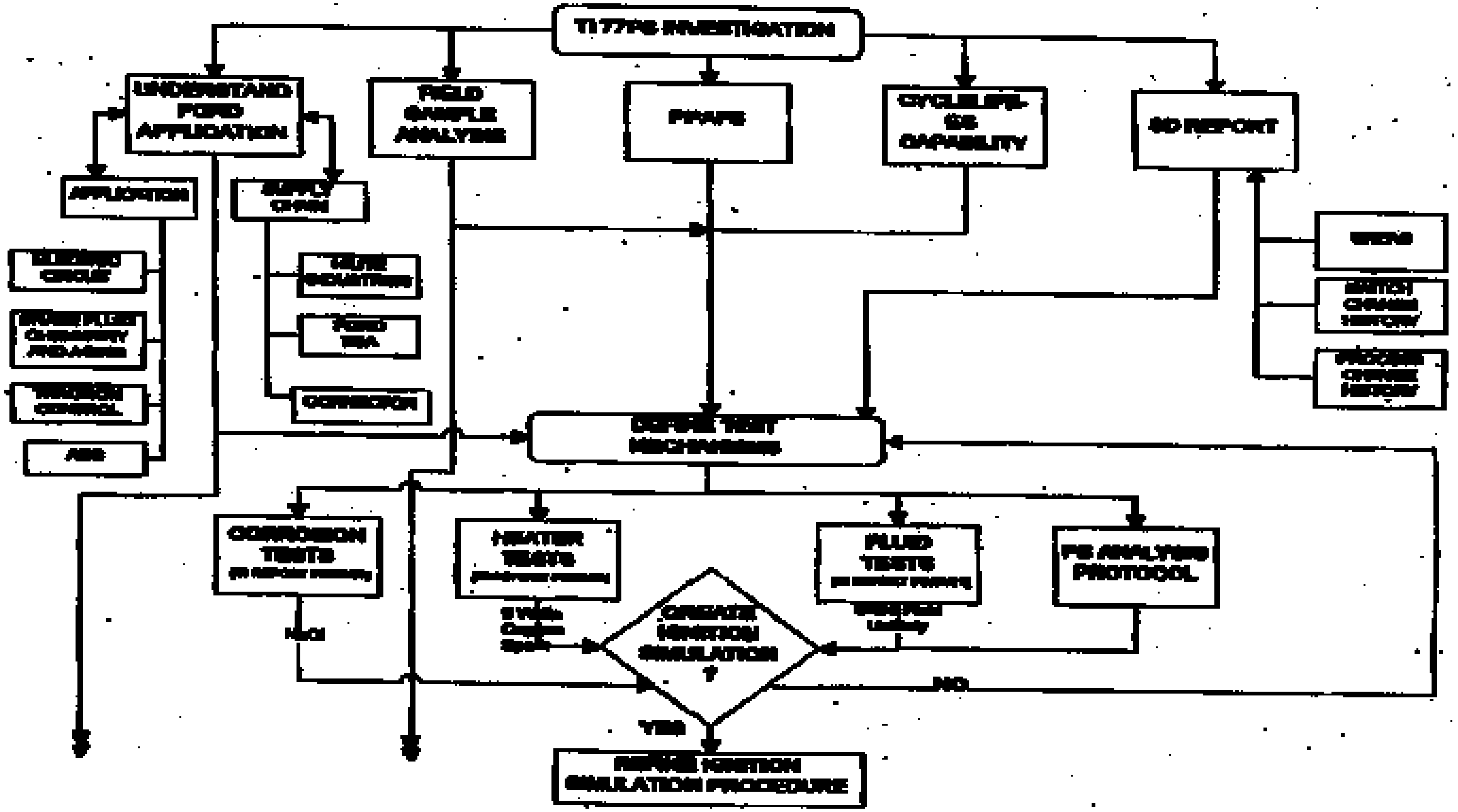
Attachment

TI-NHTSA 014107

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

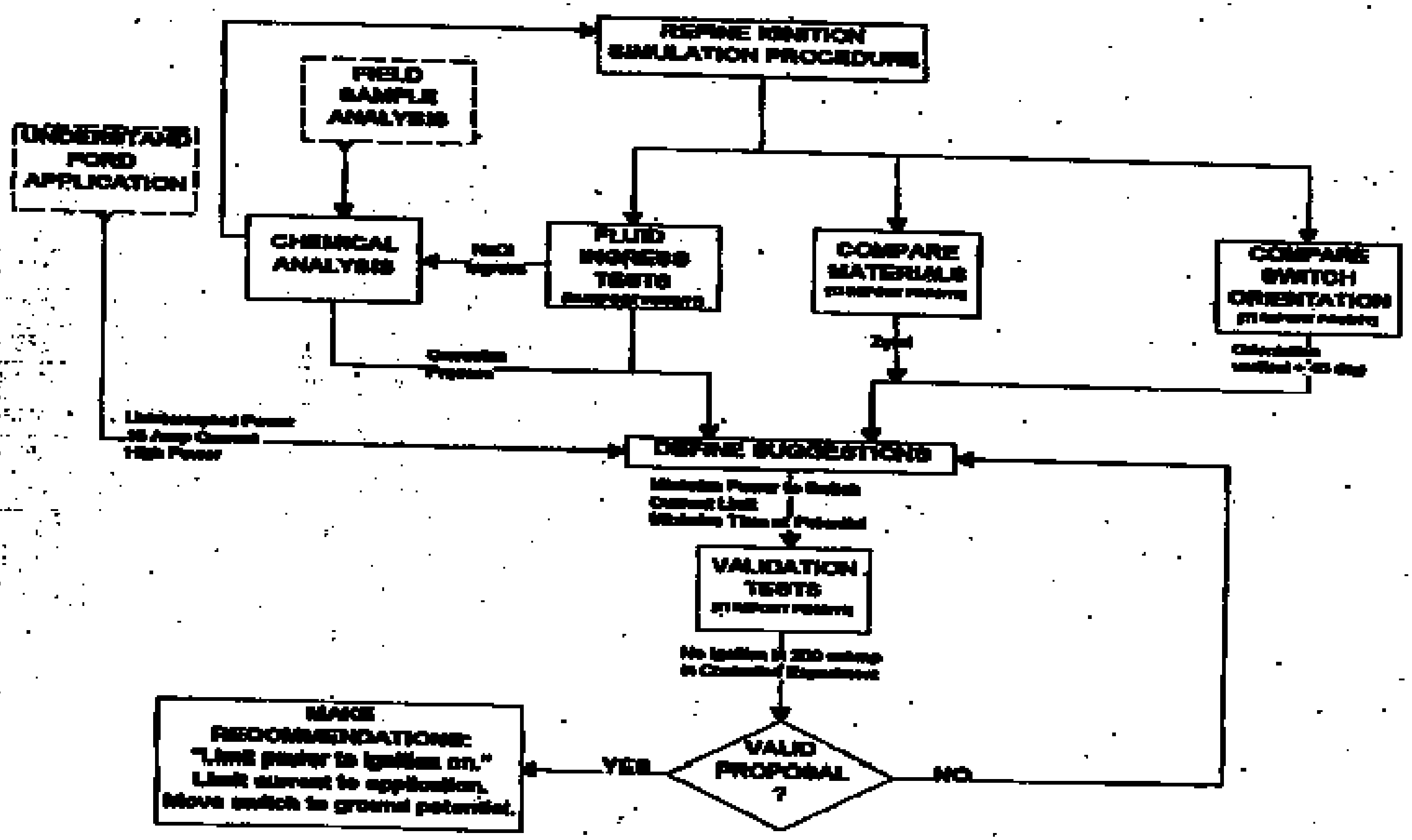


TI-NHTSA 014108

Attachment

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99



Attachment

TI-NHTSA 014109

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

Category	Test	Location	Test Parameters	Results Update
Lab Simulation	1	TI	Vary water concentrations in "new" Brake Fluid	250+ hours. Current draw in the 0.5mA to 5mA range
of Potential Ignition			14Vdc to one terminal, hexport grounded	Fluid has discolored.
in Switch			Water Conc: 4%, 6%, 10%, 70%	No Significant Temperature Rise. Test Suspended.
				Internal Analysis suspended.
	2	TI	New Brake Fluid	250+ hours. Constant temperature.
			1 Amp through switch terminals	No significant temperature rise with time
			14Vdc to one terminal, hexport grounded	Test Suspended.
	3	AVT	"new" Brake Fluid in Switch, 24 VDC to one	> 300 hours into test, max current 7mA
			terminal. Hexport Grounded	No significant change with time. Test ongoing
	4	AVT	"new" Brake Fluid in Switch, 24 VDC to one	16 hours into test max current 5mA
			terminal. Hexport Grounded, Ambient at 150 C	No significant temperature rise with time. Test suspended.
	5	AVT	"new" Brake Fluid in Switch, 16 Amps	Temperature rise of 30 C above ambient.
			Through switch terminals	Delta T reached steady state at 30 C. Test suspended.
	5a	AVT	"new" Brake Fluid in Switch approx. 60 Amps	Temperature rose to approx. 270 F. No smoke. No ignition
			through Switch Terminals	Test suspended.
	6	TI	Build heater elements into Switch.	3 tested. Smoke observed, ignition observed on part w/heater
			Heat till failure, include sparking.	See attachment
			With Fluid & Dry	Test complete
				Brake fluid in cavity slows down heat build-up
				Smoke observed at 475 F. Base melts and falls off at 600 F
	6a	TI	Create heater by corroding spring arm	One out of 15 devices increased resistance to 5 ohms.
			Salt water solution, 14V between spring	Others either very low resistance or [illegible]
			and hexport	It took about 160 hours to reach the 5 ohm stage.
				The 5 ohm device ignited under conditions similar to test 6.
	6b	TI	Re-run ignition test to understand	Switch ignition with repeated 5% water solution into switch
			repeatability and current path.	Current path is through hexport.
				See slides and video.
				Additional test include tap water, old BF, new BF and other.

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Attachment

TI-NHTSA 014110

Brake Pressure Switch

Potential Thermal Event Theory Profile 5/20/99

TEXAS INSTRUMENTS

	6c	TI	Flow "wear" brake fluid with metal shavings	Metal shavings do not contribute significantly to brake fluid conductivity.
Life Cycle Reliability of Pressure Switch	7	TI	0-1450 psig pressure pulses at 150C [illegible]	First leak observed at [illegible] cycles. Test Completed. See attached Weibull Chart.
Diaphragm Wear	8	TI	0-1450 psig pressure pulses at 120C	[illegible]
Field vs Lab Correlation	9	Control Labs	Field returns, [illegible]	Parts in Control Labs, see Ford presentation.
Design Of Experiments (1) [illegible] Factors [illegible] Diaphragm Wear [illegible]	10	TI	Vary water concentrations in "new" brake fluid 12 snap + 12 [illegible] w/ 0 % water in BF 12 snap + 12 [illegible] w/ 5 % water in BF	Test Report being [illegible]. Suspended at 1.2 million cycles with no leaks observed. [illegible] suspended at 1.2 million cycles with 2 leaks observed at 1.[illegible]. [illegible] suspended at [illegible] cycles to [illegible].
On-Vehicle Characterization of Pressure & Temperature Profile in Test Car	11	AVT	Monitor Pressure and Temperature at the [illegible] Location for ABS and non-ABS braking events.	Test at AVT ... see Ford charts ... [illegible]?
Brake fluid analysis Used fluid at master cylinder.	11a	TI	Analyze used brake fluid at the master cylinder (UMC), used brake fluid at the calipers (UCA) and new brake fluid (NBF) for metal and water content.	Test complete. UMC: Cu = [illegible], Fe = [illegible], Cr = [illegible], 1.1 [illegible] UCA: Cu = [illegible], Fe = [illegible], Cr = 1.0 [illegible], 1.1 [illegible] NBF: Cu = <.01 [illegible], Fe = [illegible], Cr = <.01 [illegible], 0.[illegible]
Spark Gap Study	12	Control Labs	Determine if spark [illegible] [illegible] high [illegible]. [illegible] brake fluid [illegible].	Equipment set up in progress at Control Labs. [illegible] observed.
Characterization of [illegible]	13	Control Labs	[illegible]	Data [illegible]. Analysis of [illegible] in progress.
Field [illegible]	14a	TI	[illegible] [illegible] [illegible] tap water [illegible] [illegible] [illegible] used brake fluid used brake fluid w/ 3% H_2O new brake fluid new brake fluid w/ 3% H_2O	Test complete. [illegible] All brake fluid [illegible]. No corrosion [illegible]. [illegible] showed some signs of corrosion. Chemical analysis in progress.

C:\[illegible]

Attachment

TI-NHTSA 014111

Texas Instruments

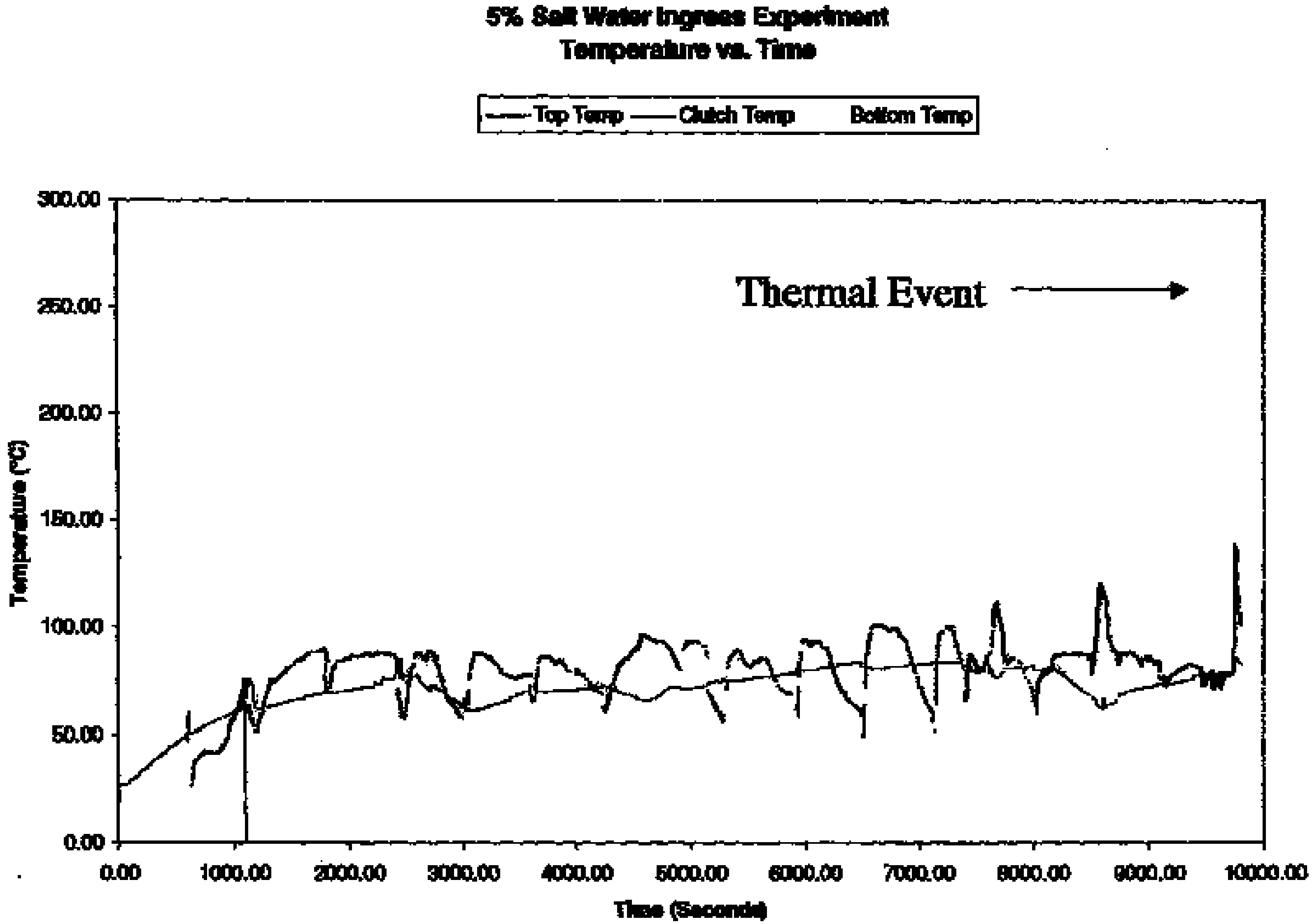
Brake Pressure Switch
Potential Thermal Event Theory Profile 5/20/99

Compatibility of Kapton	14	Dupont	Characterize change in properties of Kapton	Compatibility of Kapton	14	Dupont	Characterize change in properties of Kapton
with Oxalic Acid			with various % oxalic acid in brake fluid.	with Oxalic Acid			with various % oxalic acid in brake fluid.
Evaluation of Plastic	15	TI	Assess properties and moldability of different	Evaluation of Plastic	15	TI	Assess properties and moldability of different
Materials with Improved			grades of plastic resin with additives	Materials with Improved			grades of plastic resin with additives
Parameters			to improve plastic part performance	Parameters			to improve plastic part performance
Long duration brake fluid	15a	TI	(4) samples with new brake fluid	Long duration brake fluid	15a	TI	(4) samples with new brake fluid
Ingress test.			(2) samples with used brake fluid	Ingress test.			(2) samples with used brake fluid
Evaluation of Switch	15b	TI	Assess ignition sensitivity to switch orientation.	Evaluation of Switch	15b	TI	Assess ignition sensitivity to switch orientation.
Orientation			Test vertical versus 45 degree.	Orientation			Test vertical versus 45 degree.
			Test rotational sensitivity in 45 deg. orientation.				Test rotational sensitivity in 45 deg. orientation.
Relay Circuit	16	TI	Repeat test 10a in Ford relay circuit for (48) hrs.	Relay Circuit	16	TI	Repeat test 10a in Ford relay circuit for (48) hrs.
Test			Bring switch to impending ignition in (15) Amp	Test			Bring switch to impending ignition in (15) Amp
			circuit then place in relay circuit for (15) hrs.				circuit then place in relay circuit for (15) hrs.
			Input max. circuit power into heater on switch.				Input max. circuit power into heater on switch.

TI-NHTSA 014112

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/6/99

Texas Instruments



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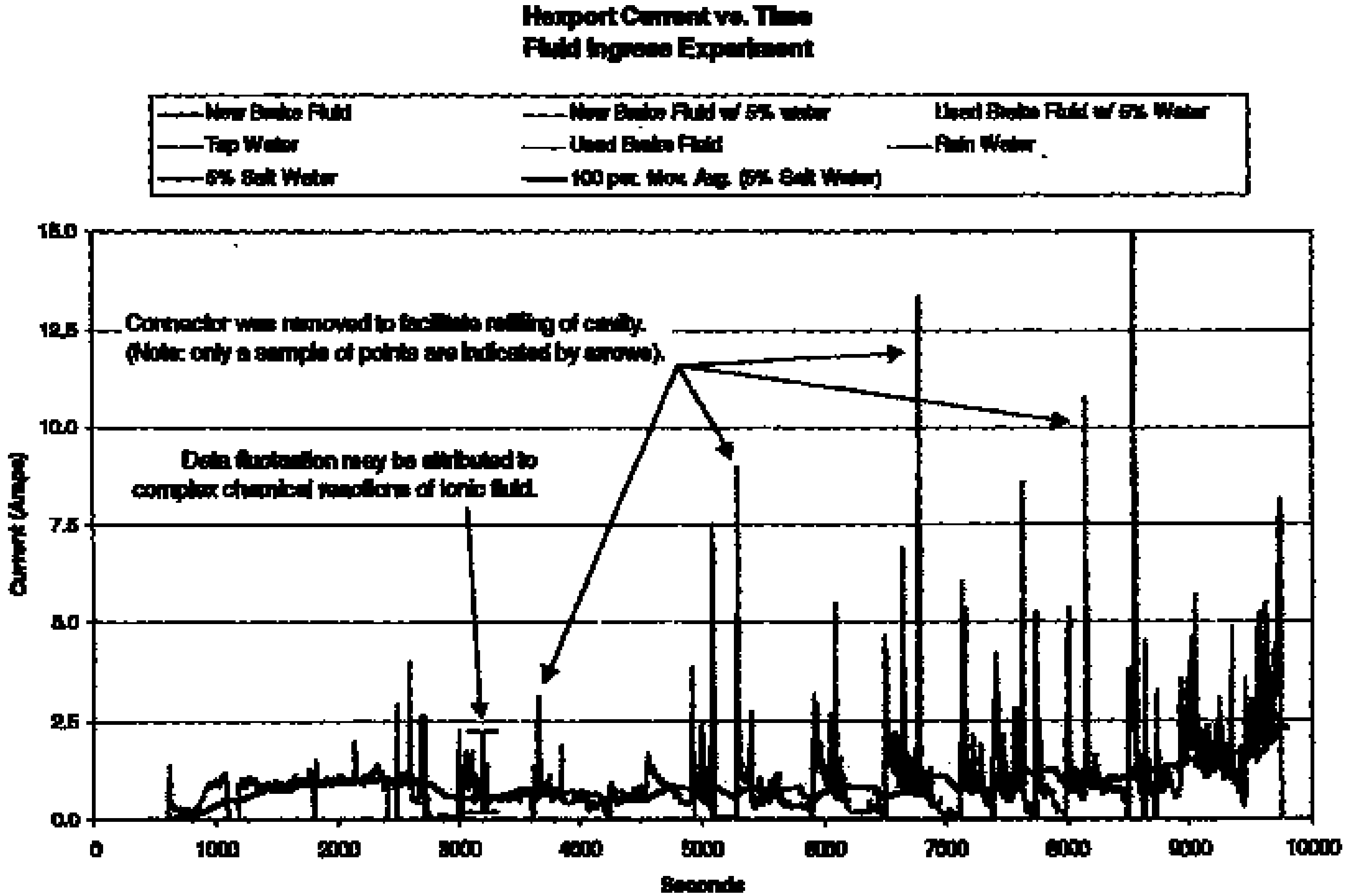
TI-NHTSA 014113

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 5/6/99



INTENTIONAL IGNITION CREATED THRU TI FLUID INGRESS LAB TEST

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