EA02-025

TEXAS INSTRUMENTS, INC.'S

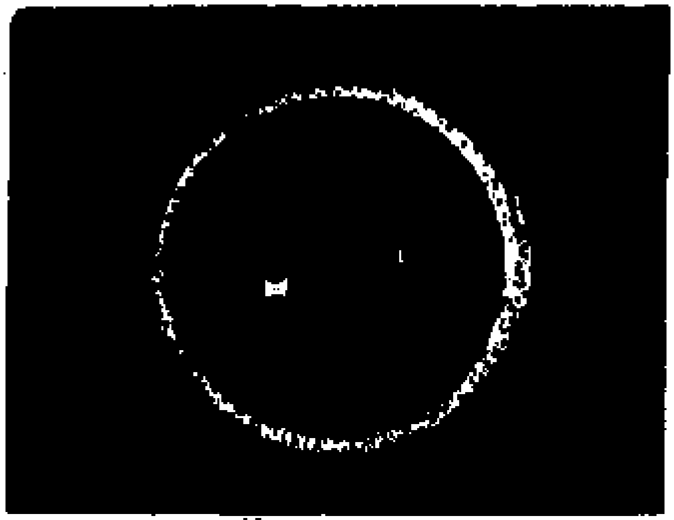
9/10/03

REQUEST NO. 7

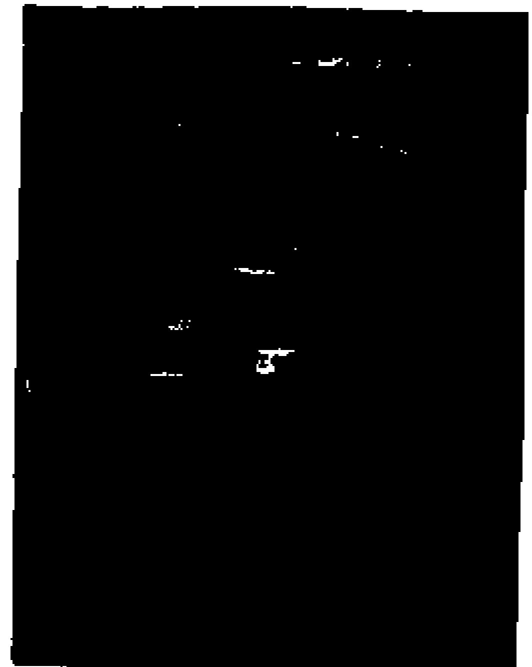
BOX 9

PART A – R

PART N



A35294



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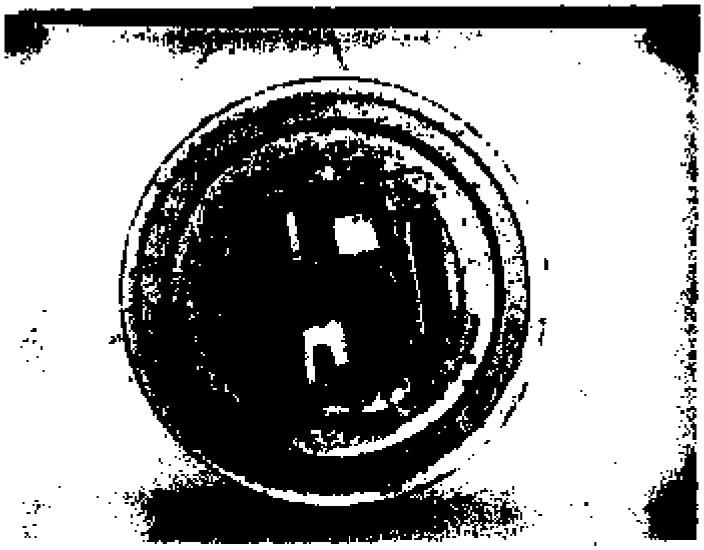
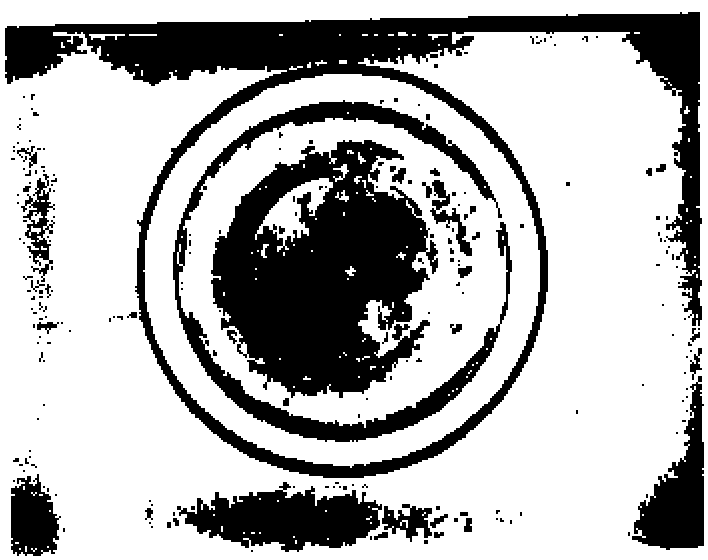
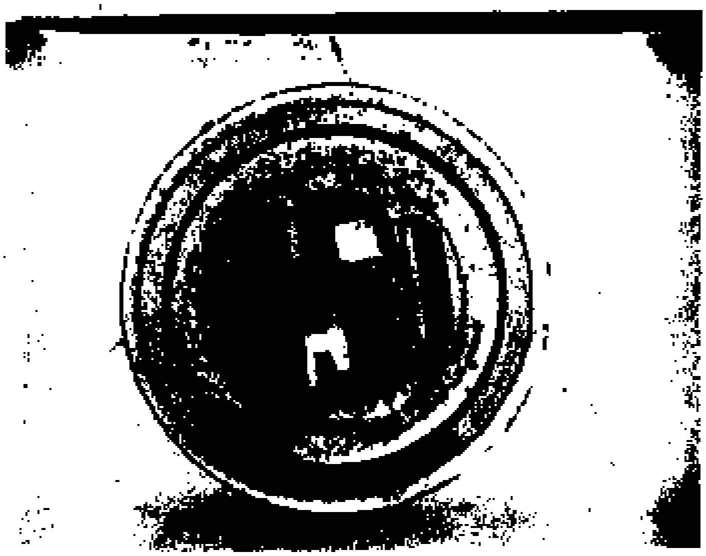
abar COLOR LABS

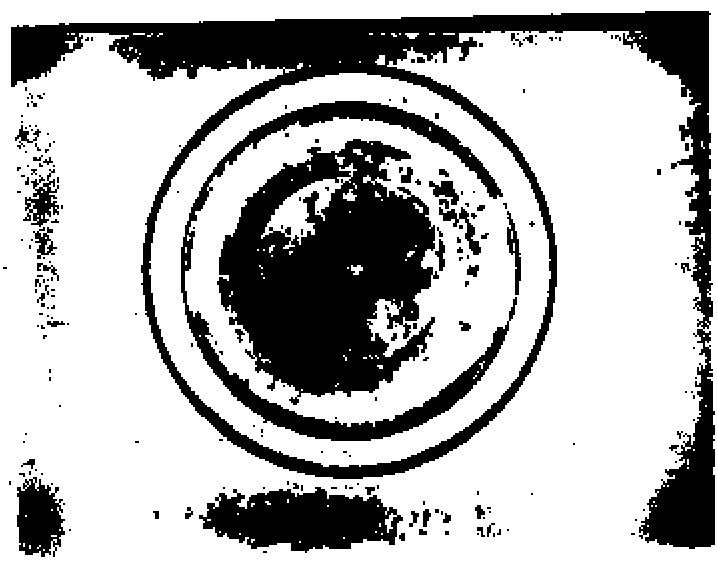
JEFF Di Domenico

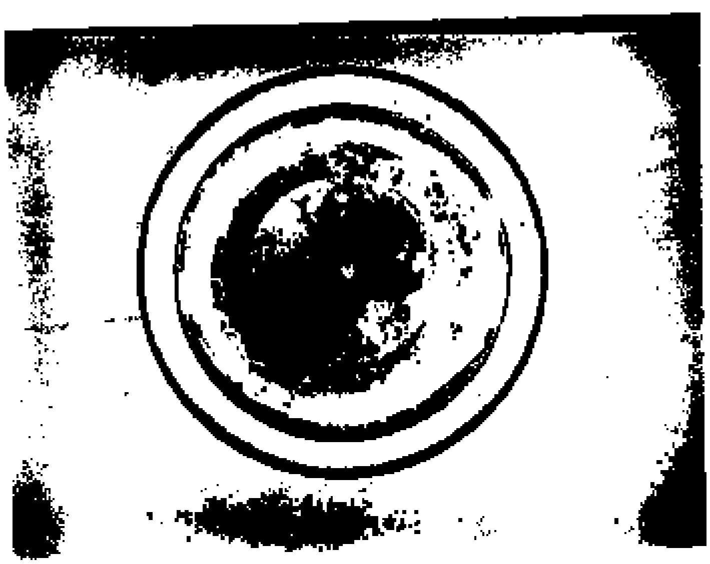
3144

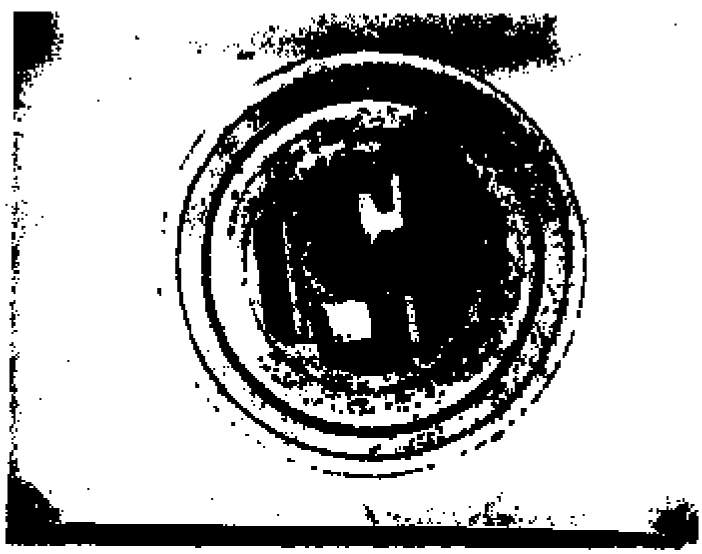


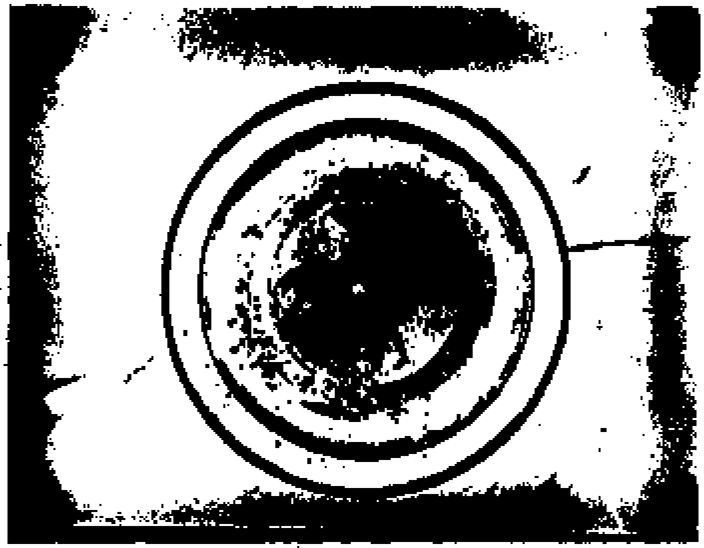


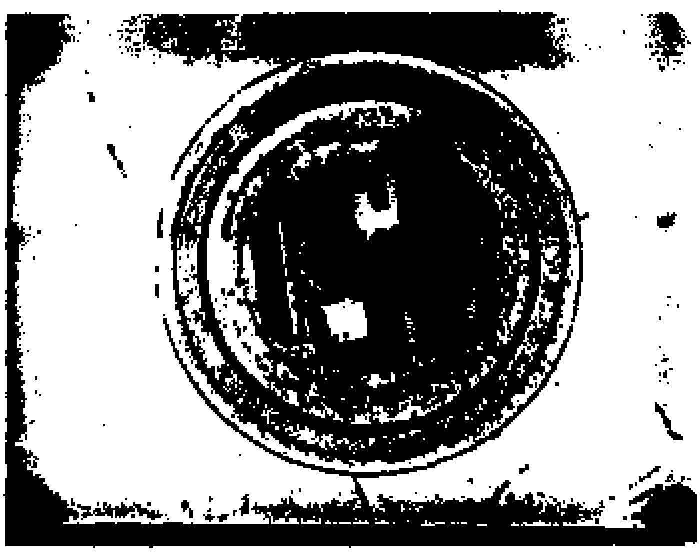


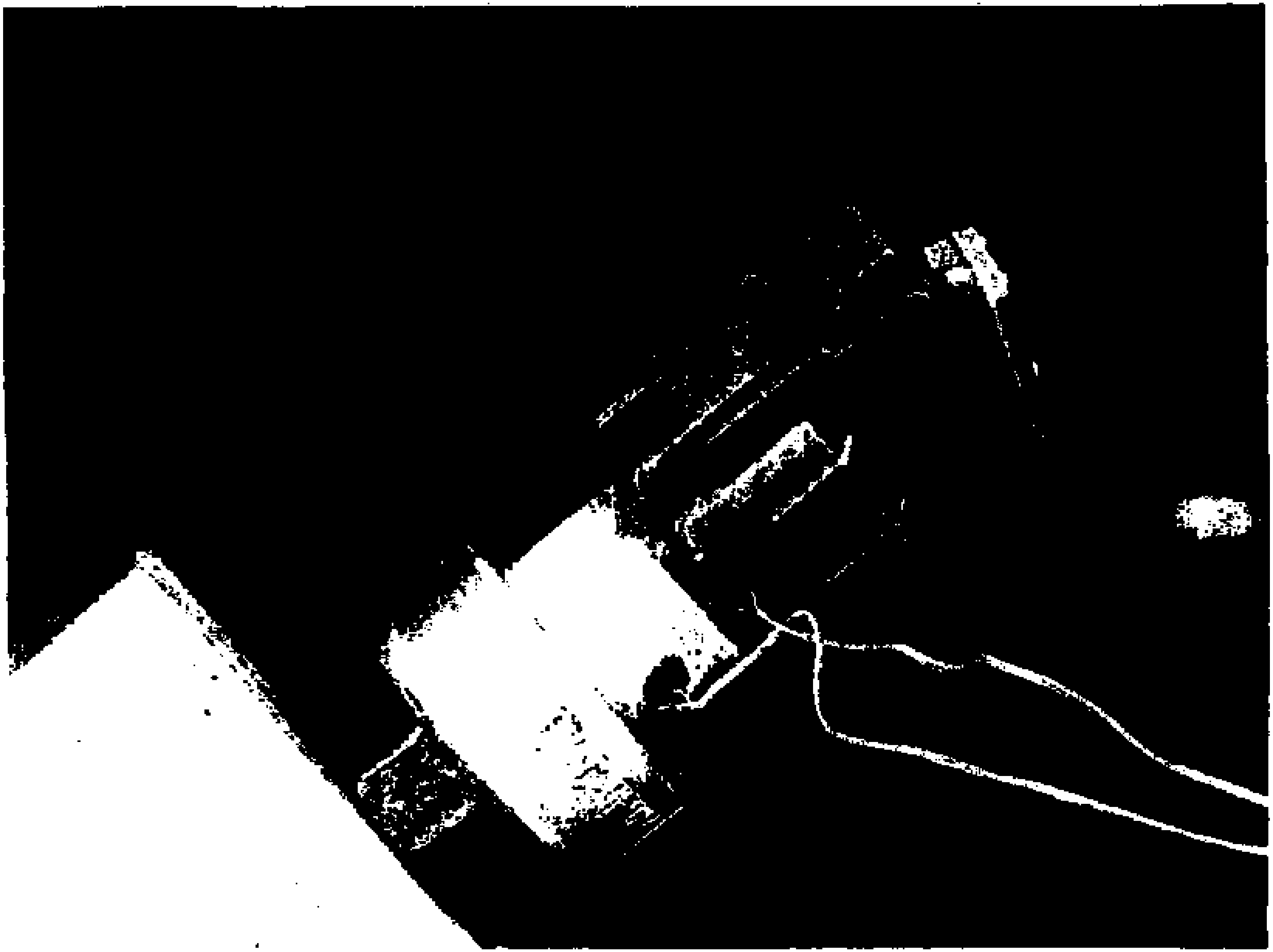


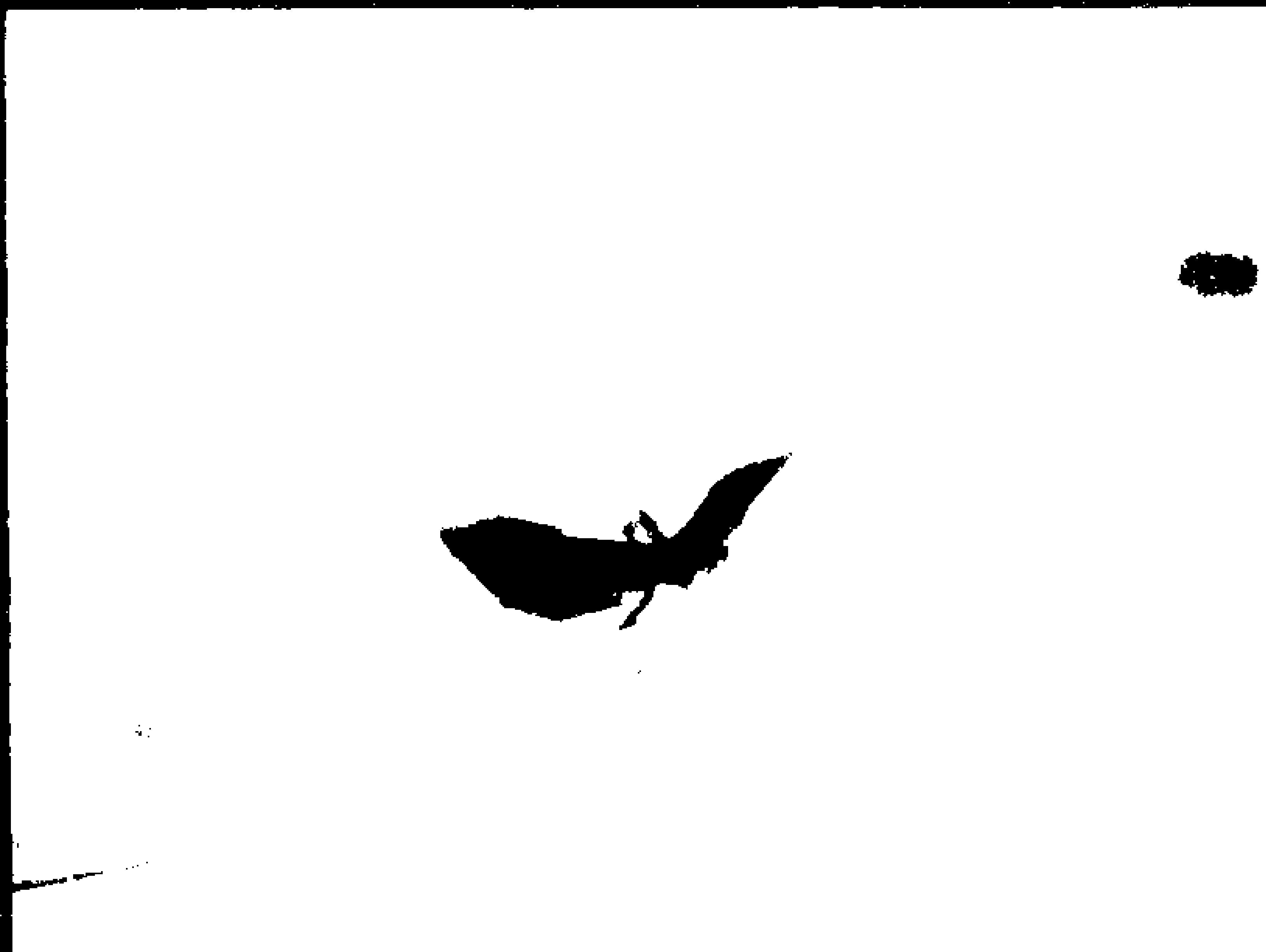












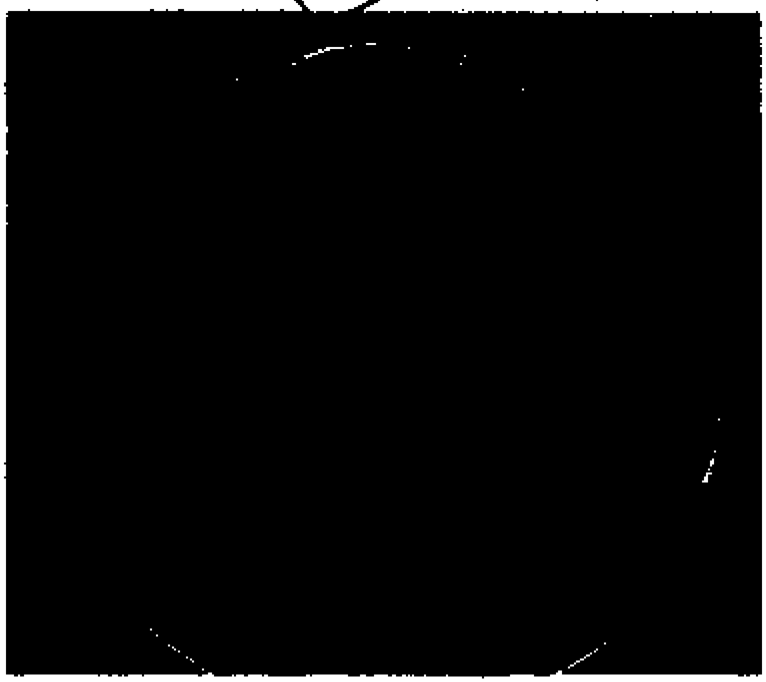
77PS Long Duration Brake Fluid Test
300 Hours at Continuous Power

C

D

77PS 5% NaCl in Water Test
(2) Hours at Continuous Power

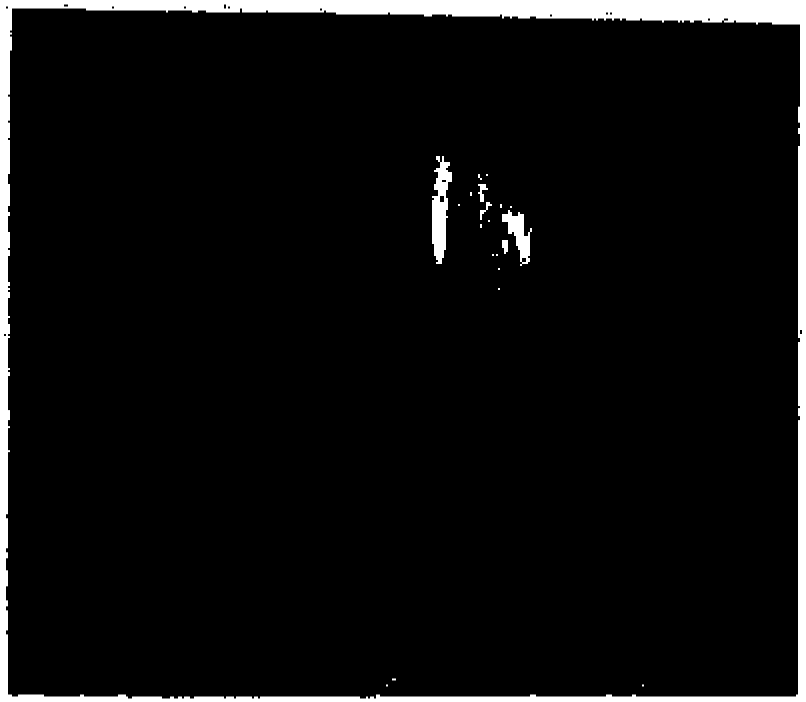
(A)



(B)

77PS Long Duration Brake Fluid Test
550 Hours at Continuous Power

E



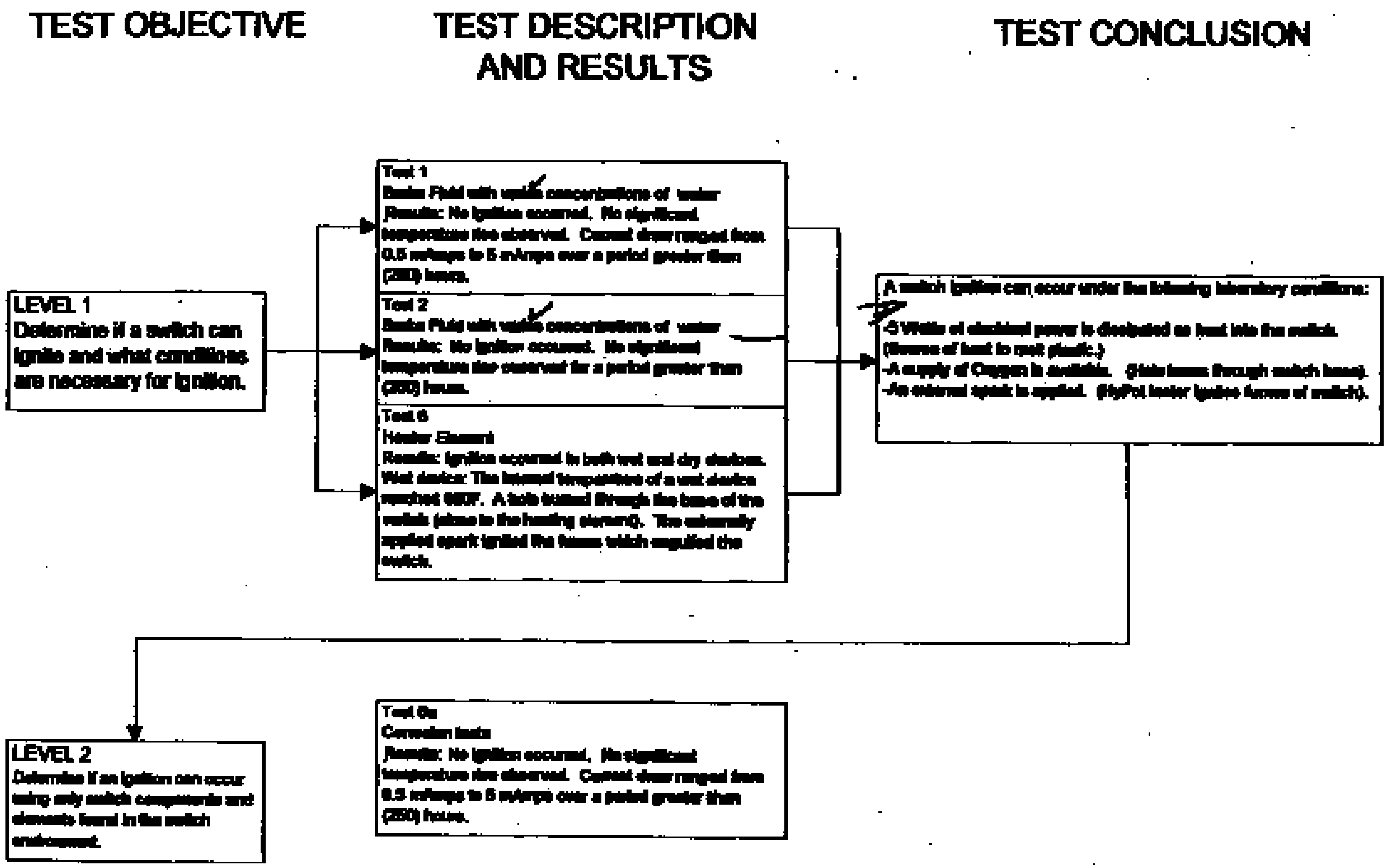
F

(6)

77PS Memphis Switch

TI-NHTSA 014812

TI-NHTSA 014513


TEST OBJECTIVE
TEST DESCRIPTION AND RESULTS
TEST CONCLUSION
LEVEL 1
Determine if a switch can ignite and what conditions are necessary for ignition.
Test 1
concentrations of water
Results: No ignition occurred. No significant temperature rise observed. Current draw ranged from 0.5 mAmps to 5 mAmps over a period greater than (250) hours.
Test 2
concentrations of water
Results: No ignition occurred. No significant temperature rise observed for a period greater than (250) hours.
Test 6
Heater Element
Results: Ignition occurred in both wet and dry devices.
A hole burned through the base of the switch (close to the heating element). The externally applied spark ignited the fumes which engulfed the switch.
A switch ignition can occur under the following laboratory conditions:
-5 Watts of electrical power is dissipated as heat into the switch. (Source of heat to melt plastic.)
-A supply of Oxygen is available. (Hole burns through switch base).
-An external spark is applied. (HyPot tester ignites fumes of switch).
LEVEL 2
Determine if an ignition can occur using only switch components and elements found in the switch environment.
Test 6a
Corrosion tests
Results: No ignition occurred. No significant temperature rise observed. Current draw ranged from 0.5 mAmps to 5 mAmps over a period greater than (250) hours.

Test 6a Results: A 5% NaCl in H_20 solution can corrode switch electrical components and cause an increase in electrical resistance. Repeated injections of the NaCl in H_20 solution, with the switch powered, can cause a switch ignition.

Tests 7, 8, 10 and 13b Results: Life cycle reliability DOE Diaphragm wear

Conclusion:

A switch ignition can occur under the following conditions:
5% NaCl in H_20 solution is injected, repeatedly, into contact cavity of a switch.
14 Volts is applied to the switch.
Hexport is grounded.
Current is limited at 15 Amps.

Level 3:

Objective:

Test 6b Objective: Understand the ignition process, determine the current path and establish a repeatable ignition method.

Results:

Test 6b Results: Multiple attempts at ignition, via injection of a 5% NaCl in H_20 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 method of switch ignition has been established. Based on hexport current measurements, the current path is from switch terminals to hexport body. When a NaCl in H_20 solution is repeatedly injected into contact cavity of powered switches, electrolytic corrosion and the build-up of deposits bridge an electric path from switch terminals to switch hexport body. When sufficient power is drawn through this bridge, 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:

Overall Objective: Compare and contrast variables influencing ignition using the established ignition method.

Test 13a Objective: Compare various fluids in the established ignition method.

Test 15 Objective: Compare the burn characteristics of various plastics as switch base material.

Test 15b Objective: Compare: 1) the probability of switch ignition in the vertical position verses a 45° orientation and 2) the probability of switch ignition as a function of rotational angle in the 45° orientation.

Results:

Test 13 Results: A switch filled with 5% NaCl in H_20 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 hexport current draw and showed no signs of corrosion.

Test 15 Results: Cellanex 4300 ignited 3 out of 5 attempts. Noryl ignited 2 out of 5 attempts. Zytel ignited 1out of 5 attempts. All using a NaCl and water solution

Test 15b Results: Switch ignitions have occurred in different rotational angles.

Conclusion: Brake fluid is not ionic enough to cause the electrolytic corrosion and buildup of deposits necessary to create an ignition. An ionic rich fluid such as NaCl in H_20 is necessary to create an ignition. ~~Zytel subjectively performs best in burn tests when compared with Cellanex 4300, Cellanex 3316 and Noryl.~~

what does this mean

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: To test proposed relay circuit.

Needs work

Results: (48) hours in worst case scenary.
(18) hours with impending burn switch.
Max power applied to heating element.

Discuss how much is max power

Conclusion: Cannot create an ignition in laboratory

Power is limited and not enough to create ignition

Test of switch on the edge of ignition?

Test 7 Objective: Determine if switches meet cycle life specification.

Test 15a Objective: Determine if long time switch exposure to brake fluid can lead to an ignition.

Results:

Test 6a Results: A 5% NaCl in H_2O solution can corrode switch electrical components and cause an increase in electrical resistance. Repeated injections of the NaCl in H_2O solution, with the switch powered, can cause a switch ignition.

Test 6c Results: Brake fluid with metal shavings does not conduct significant current.

Test 7 Results: Life cycle testing showed that switches exceeded cycle life specification.

Test 15a Results: Test is ongoing. Results to date show no increase in conductivity of both new and used brake fluid. After more than 350 hours of testing, current draw on each device is less than 20 mAmps.

Conclusion:

A switch ignition can occur under the following conditions:
5% NaCl in H_2O solution is injected into contact cavity of a switch.
14 Volts is applied to the switch.
Hexport is grounded.
Current is limited at 15 Amps.

Brake fluid with metal shavings is not conductive enough to create an ignition.

Switches meet engineering cycle life specification.

Long duration switch exposure to brake fluid has had no measurable effect on switches. After more than (350) hours of testing, current draw remains orders of magnitude below the levels needed to create ignition as simulated in laboratory experiments.

Level 3:

Objective:

Test 6b Objective: Understand the ignition process, determine the current path and establish a repeatable ignition method.

Results:

Test 6b Results: Multiple attempts at ignition, via injection of a 5% NaCl in H_20 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 has been established. Based on hexport current measurements, the current path is from switch terminals to hexport body.
When a NaCl in H_20 solution is repeatedly injected into the contact cavity of powered switches, electrolytic corrosion of the switch terminals 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:

Overall Objective: Compare and contrast variables influencing ignition using the established laboratory ignition method.

Test 13a Objective: Compare various fluids in the established ignition method.

Test 15 Objective: Compare the burn characteristics of various plastics as switch base material.

Test 15b Objective: Compare: 1) the probability of switch ignition in the vertical position verses a 45° orientation and 2) the probability of switch ignition as a function of rotational angle in the 45° orientation.

Results:

Test 13 Results: A switch filled with 5% NaCl in H_20 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 hexport current draw and showed no signs of corrosion.

TI-NHTSA 014521

Test 15 Results: When 5% 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 1out of 5 attempts.

Test 15b Results: Switch ignitions have occurred in different rotational angles.

Conclusion:

Brake fluid is not conductive enough to cause the electrolytic corrosion and necessary to create an ignition. Because of its' significantly higher conductivity, an ionic rich fluid such as NaCl in H_2O is necessary to cause an ignition. 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: To test proposed relay circuit.

Results:

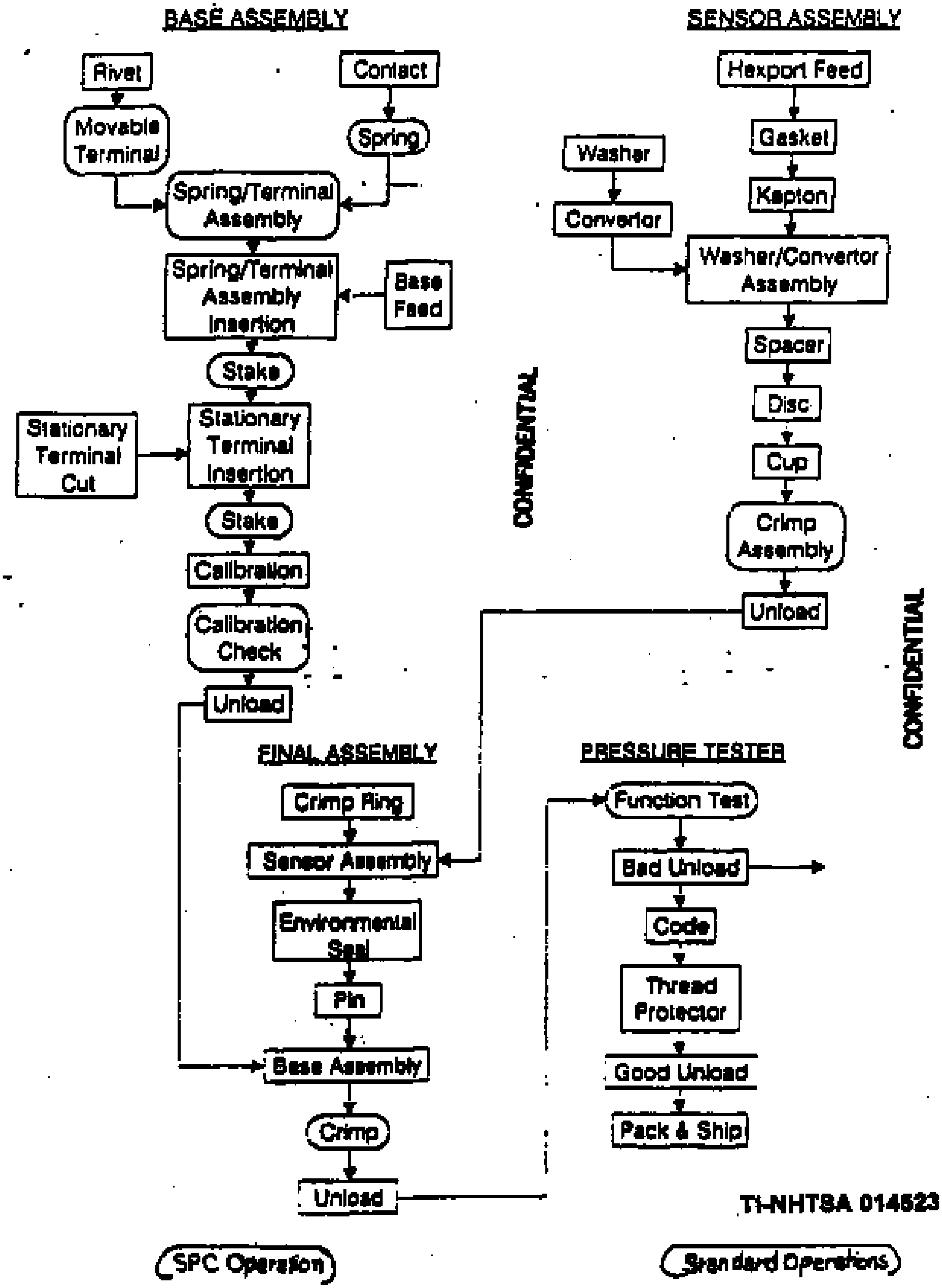
A switch was injected with 5%Nacl in H_2O solution and placed in a proposed current limiting circuit for (48) hours. The current draw remained constant at 180 mAmps throughout the test. There was no activity observed and the contact arm remained intact.
A switch was brought to an impending burn condition 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 placed in the proposed relay circuit for(18) hours where it drew 160 mAmps, showed no visible activity and did not result in a burn. 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 the switch and 0.75 Watts of power was dumped into the wire. The wire became warm to the touch but had no effect on the switch.

Conclusion:

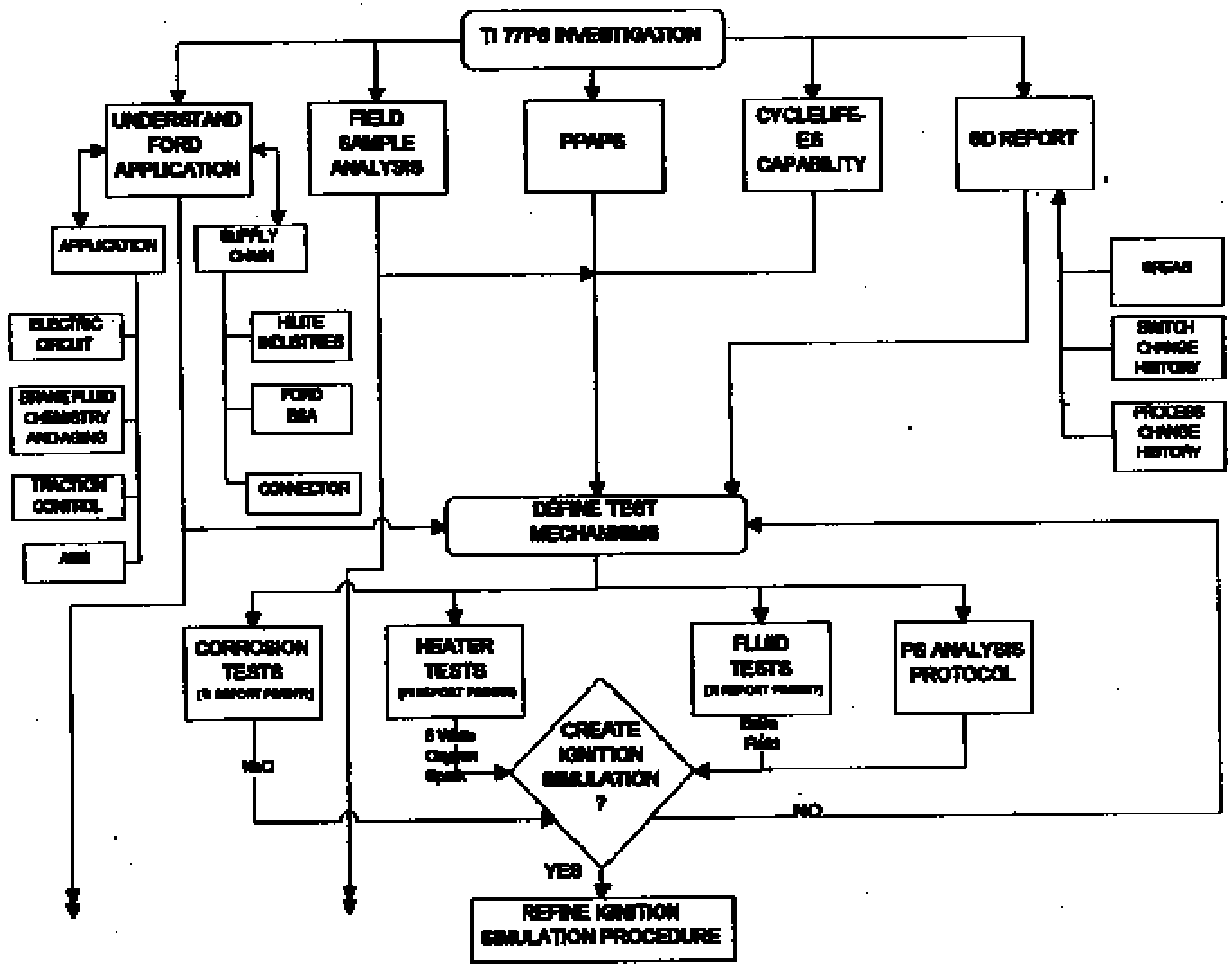
0.75 Watts, the maximum power in the proposed circuit design, is not enough power to cause electrolytic corrosion or significant switch terminal heating, which is necessary for ignition. In previous tests, using a resistor as the heating element, approximately 5 Watts of power was necessary to create and ignition. There is not enough power in the proposed circuit to create ignition.

FORD NEXT GENERATION SPEED CONTROL

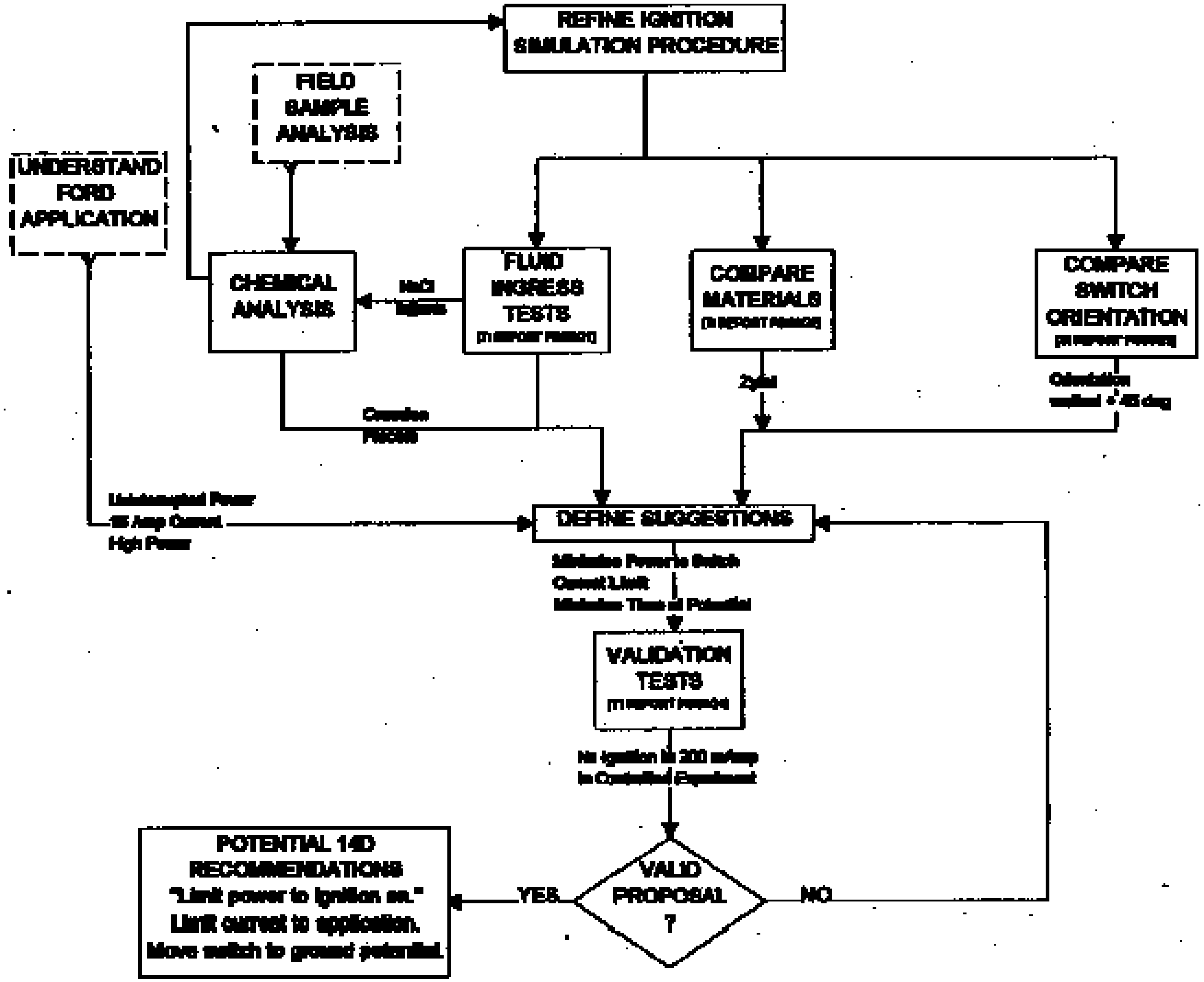
PROCESS FLOW CHART 77PSL2-1/2-3



TI-NHTSA 014523



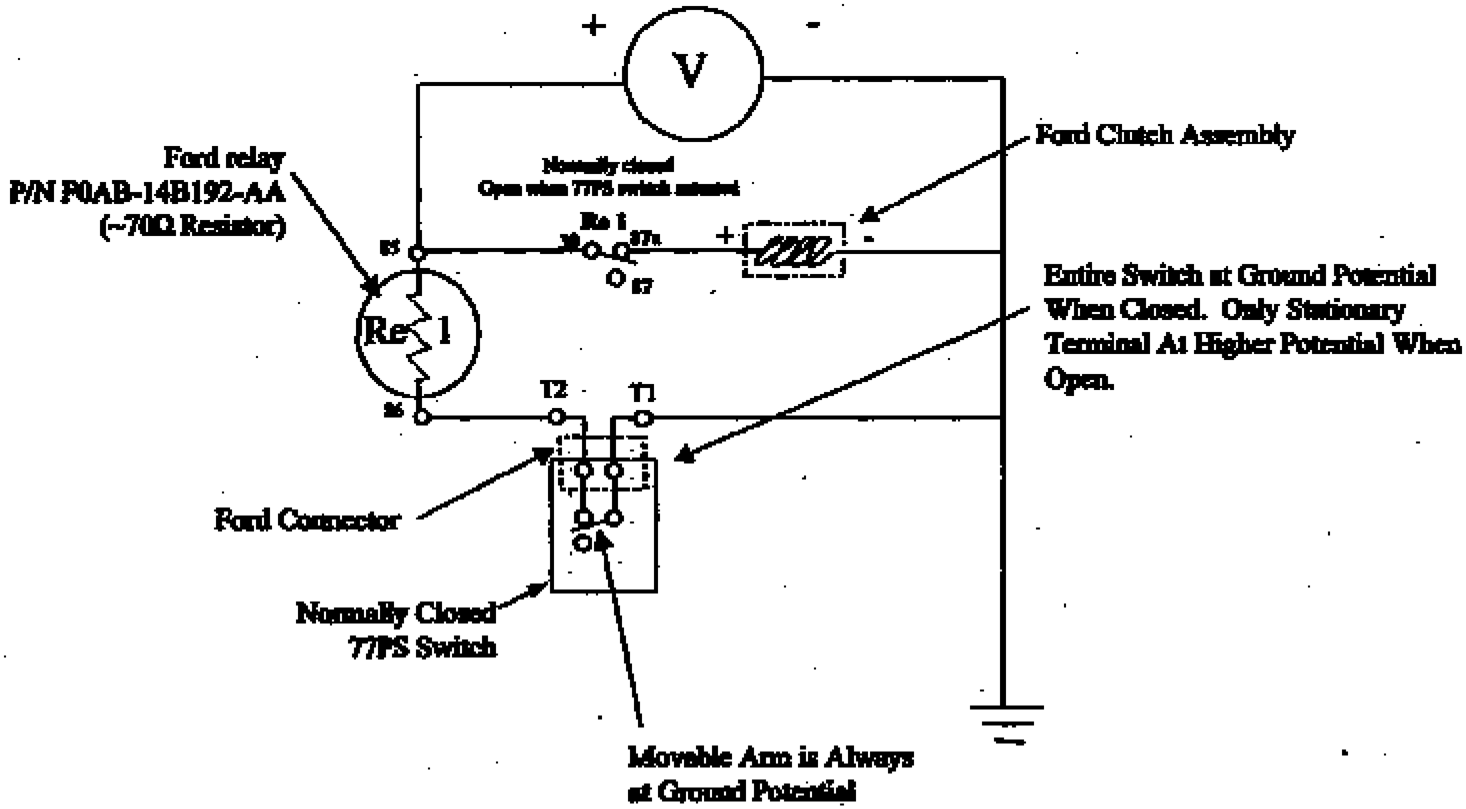
TI-NHTSA 014524



TI-NHTSA 014626

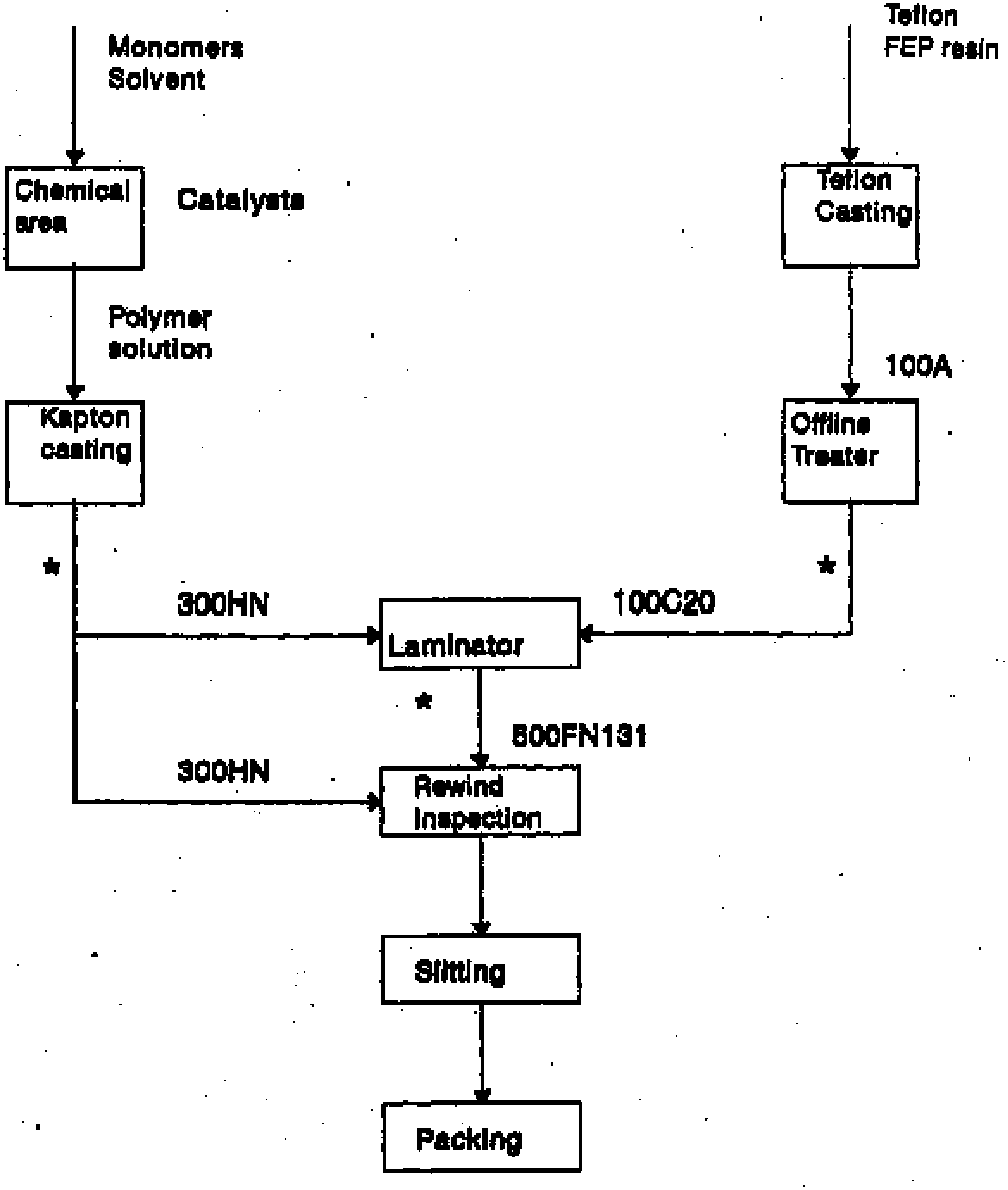
77PS Proposed Wiring Schematic

14 Volts DC



PROCESS FLOW

KAPTON 300HN, 500FN131

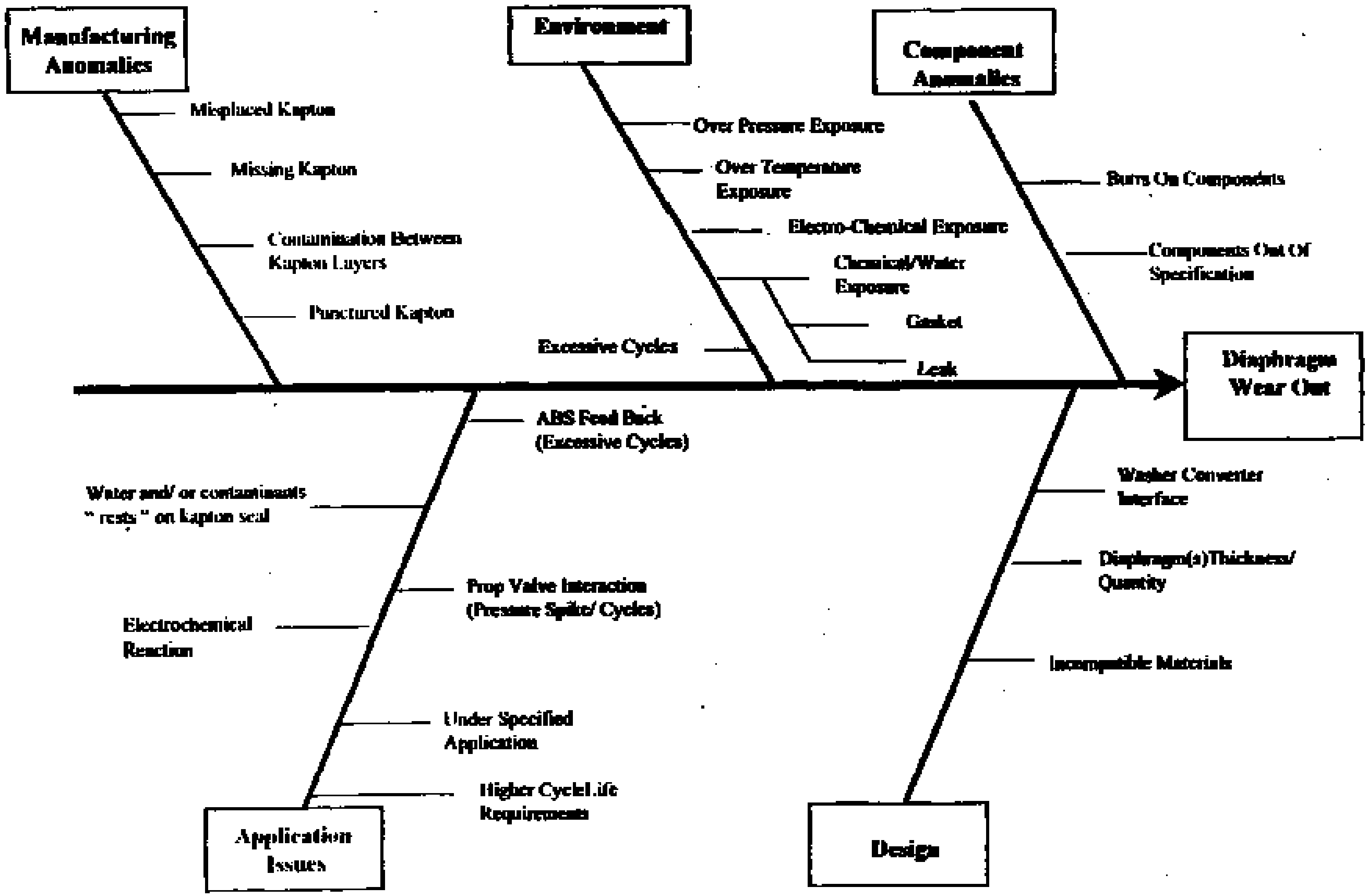


* At this point, samples of each mill roll are sent to the QC lab for testing and verification of conformance to specifications.

TI-NHTSA 014527

TEXAS INSTRUMENTS

Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series



TI-NHTSA 014828

Process Controls

Operation	Fault	Process Control	Control Method
Hexport Feed	Fails to Load Wrong/Mixed Hexport	100% Check with LVDT	Set-Up block
Gasket	Fails to Load Misplaced	100% reflective sensor check	Set-Up Masters SPC P-Chart
Kapton #1 & #2	Fails to Load One seal only Improperly cut seal	100% Continuity Check	SPC P-Chart
Kapton #3 (If Necessary)	Fails to Load Improperly cut seal	100% Continuity Check	SPC P-Chart
Washer	Fails to Load Upside down	100% Presence Check Orientation control on feed bowl	100% Pressure Test
Converter	Fail to load onto washer	100% Presence Check	100% Pressure Test
Spacer	Fails to Load	100% presence check with continuity probe	SPC P-Chart
Disc	Fails to Load Upside down Two Discs	100% Height probe	Operator set-up 100% Pressure Test
Cup Feed	Fails to Load	Height Probe	Operator set-up
Pre-Crimp	Trapped Disc	Low Pin Probe	SPC P-Chart
45 & 90 degree crimp	Fails to Crimp Improper crimp	Stroke made sensors	SPC X-Bar & R Poka-Yoke
Over Pressure	Drift over life Calibration Change	Minimum pressure gauge	Controlled by PLC
Unload good devices	Fails to unload good devices	Empty nest sensor	Controlled by PLC

TI-NHTSA 014629

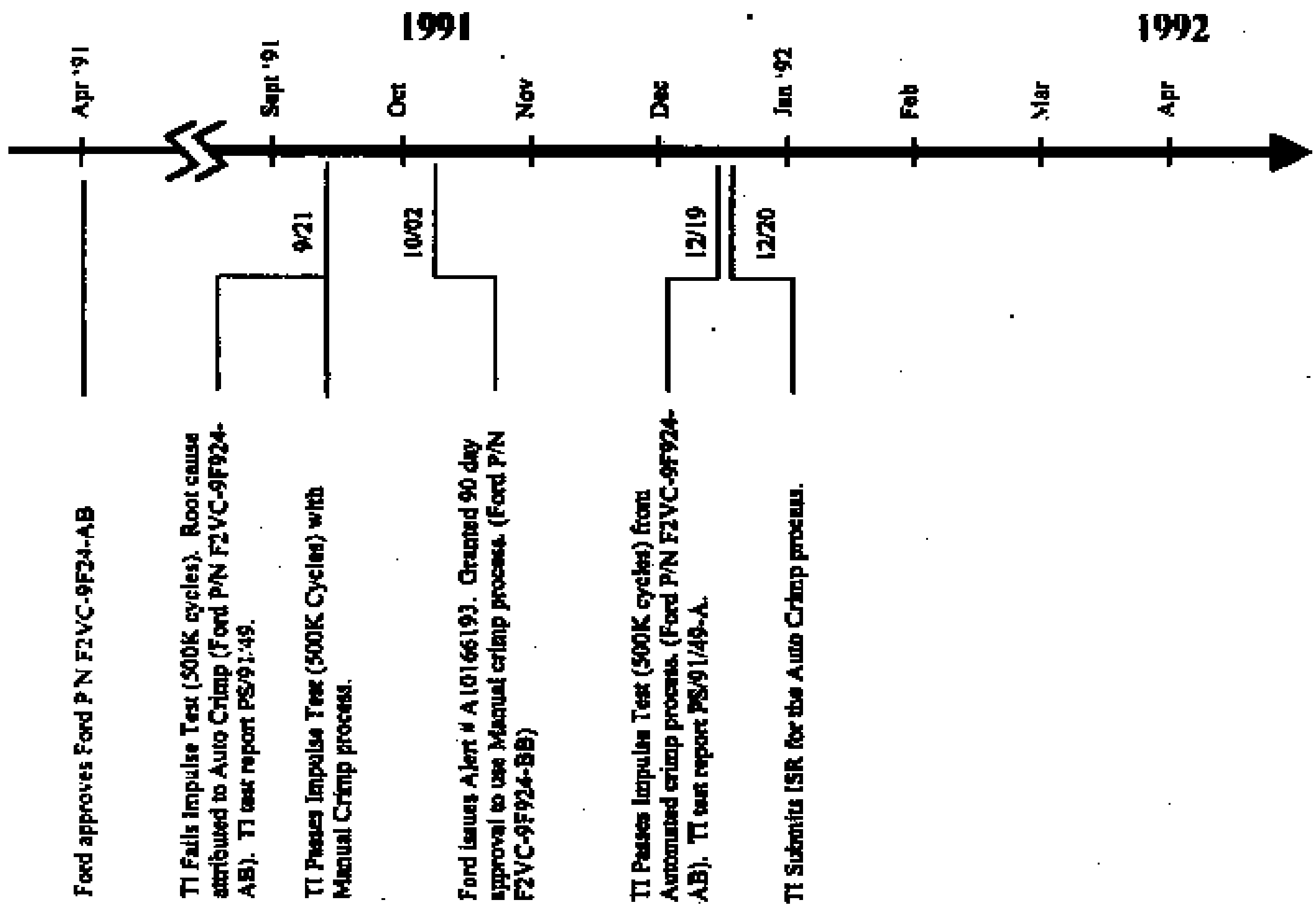
Process Controls

Operation	Fault	Process Control	Control Method
Assemble sensor & crimp ring in nest	Machine error Out of round sensor	100% height check	Controlled by PLC
Assemble Environmental seal & check	Missing seal Misplaced seal Multiple seals	100% height check	Controlled by PLC
Assemble Pin	Creep Calibration shift	100% Check with LVDT	SPC P-Chart
Assemble Base Assembly	Wrong base assembly. No base	100% part presence	SPC P-Chart 100% Pressure Test
Crimp Final Device	Wrong Crimp Height Wrong Crimp Diameter Torque	Crimp pressures Cylinder adjustments	SPC X-Bar & R Poka-Yoke SPC P-Chart
Function Test	Actuation Failure Release Failure Differential Failure	Actuation Masters Ramp Masters	SPC X-Bar & R SPC X-Bar & R
	Actuation Creep Release Creep Coarse Leak Millivolt Drop	Custome Pressure Tester	Vax System Program

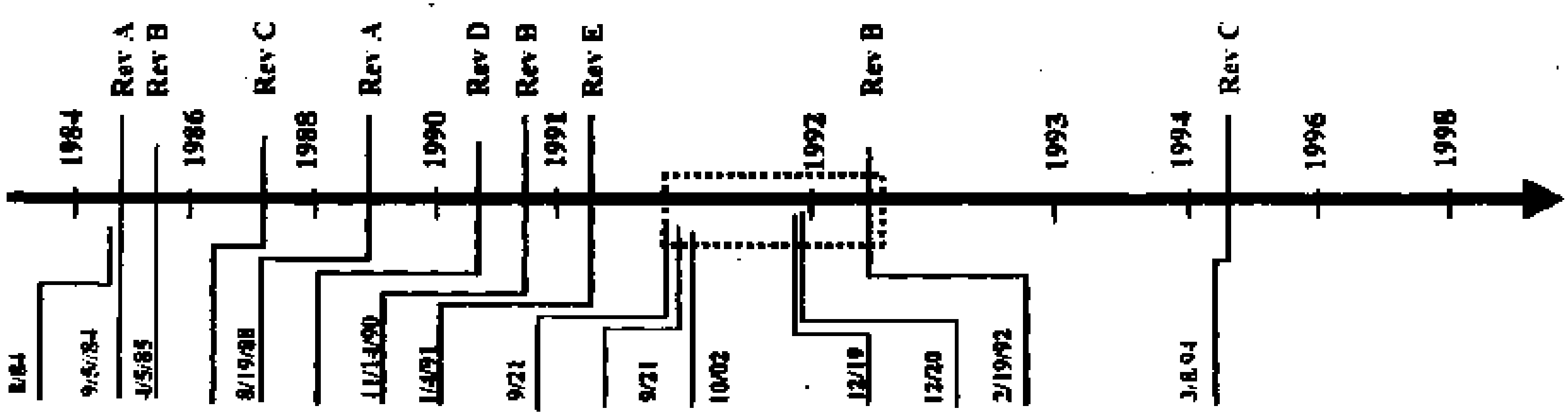
Texas Instruments

Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series

Timeline: F2VC-9F924-AB (TI P/N 77PSL2-1)



Timeline: Equipment / Process Evolution

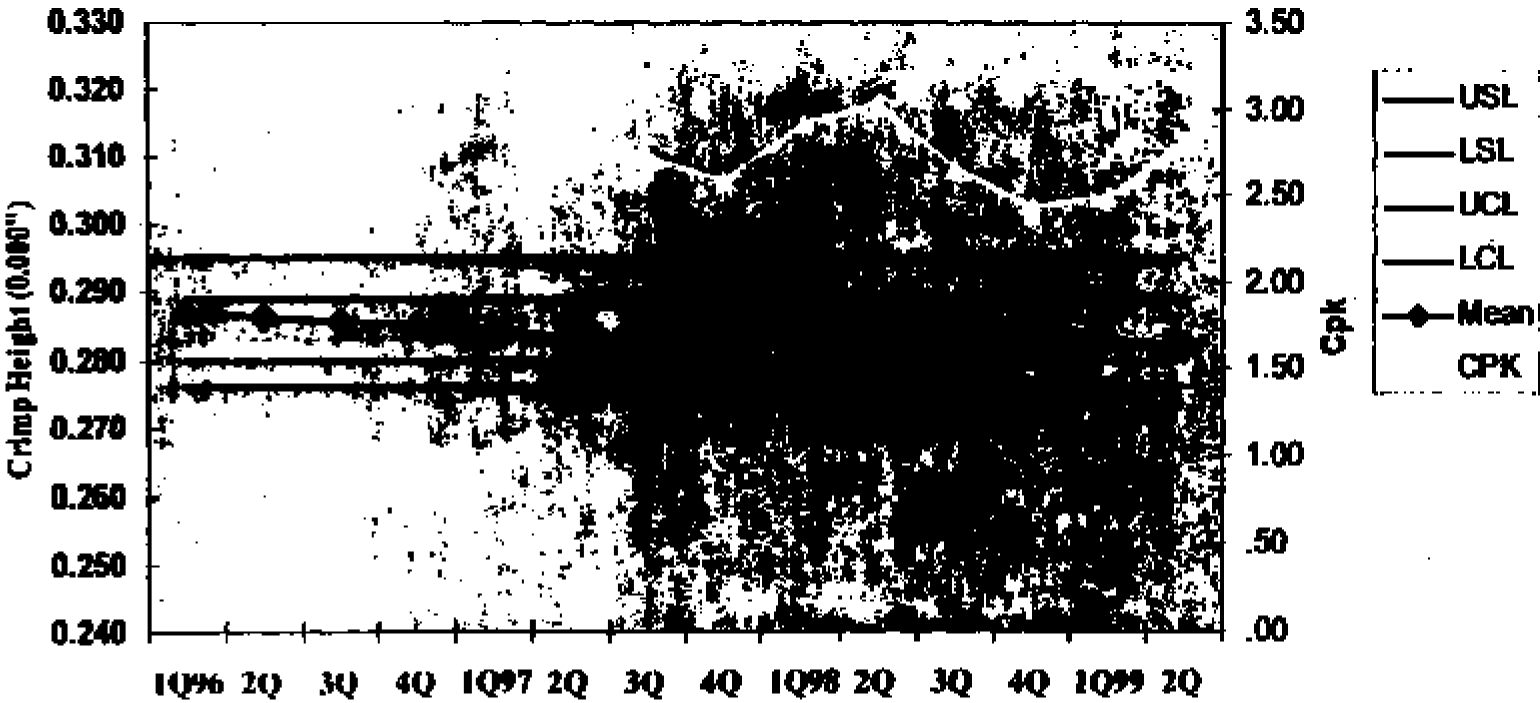


- AMI #2 (Sensor Assembly Machine) installed with attached Auto Crimp station
- Deleted PT=11, Gasket Load station
- Revised PT=12, add PT 34 - Gasket Probe
- Chgd cup feed. Chgd det as added 51,52 & det 38
- Added Over-Pressure Station to Crimp stations
- Revised sta 3,4,5,6,7,8,9.
- Replaced Auto Crimp indexer with a "CAMCO".
- Added 3rd Kapton Load Station for 77PS family
- TI Fails Impulse Test (500K cycles). Root cause attributed to Auto Crimp (Ford P/N F2VC-9F924-AB). TI test report PS/91/49.
- TI Passes Impulse Test (500K Cycles) with Manual Crimp process.
- Ford issues Alert # A101166193. Granted 90 day approval to use Manual crimp process. (Ford P/N F2VC-9F924-BB)
- TI Passes Impulse Test (500K cycles) from Automated crimp process. (Ford P/N F2VC-9F924-AB). TI test report PS/91/49-A.
- TI Submits ISR for the Auto Crimp process.
- Changed depth of hole to 1.380" from 1.250". Changed tool material to "D2 Tool Steel".
- Increased hub diameter from 0.750" to 0.800".

TEXAS INSTRUMENTS

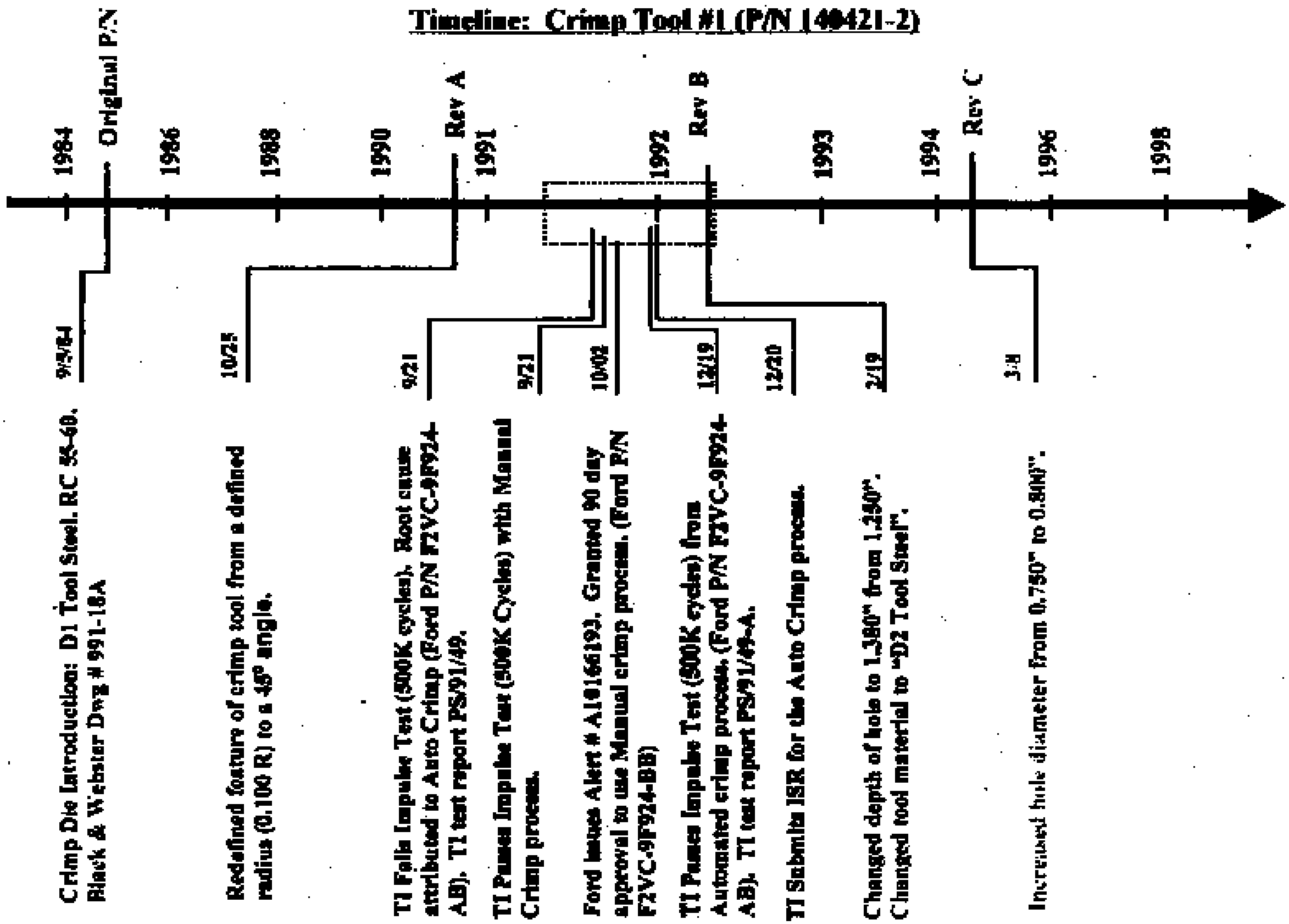
Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series

Crimp Height SPC History ('96 - Current)



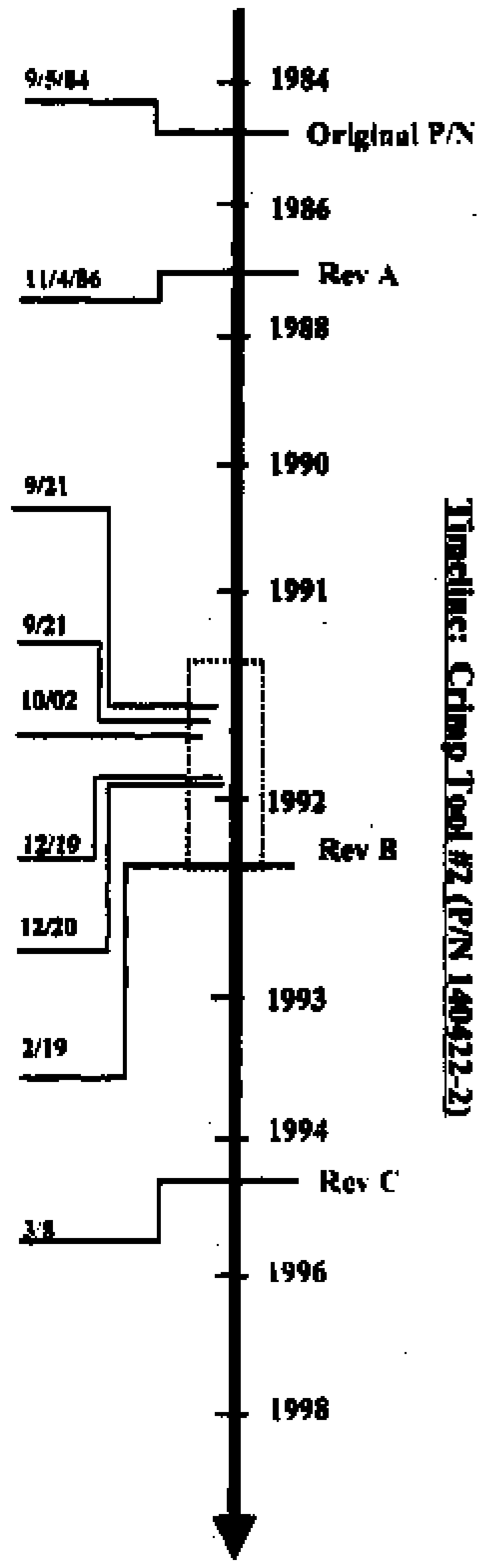
TI-NHTSA 014533

Timeline: Crimp Tool #1 (P/N 140421-2)



TI-NHTSA 014534

Timeline: Crimp Tool #2 (P/N 140422-2)



9/5/84 — Crimp Die Introduction: D1 Tool Steel, RC 55-60, Black & Webster Dwg # 991-18B

11/4/86 — Depth Change from 0.445" to 0.457", redefined feature of crimp tool from a defined radius to a 45° angle

9/21 — TI Fails Impulse Test (500K cycles). Root cause attributed to Auto Crimp (Ford P/N F2VC-9F924-AB). TI test report PS/91/49.

9/21 — TI Passes Impulse Test (500K Cycles) with Manual Crimp process.

10/02 — Ford issues Alert # A10166193. Granted 90 day approval to use Manual crimp process. (Ford P/N F2VC-9F924-BB)

12/19 — TI Passes Impulse Test (500K cycles) from Automated crimp process. (Ford P/N F2VC-9F924-AB). TI test report PS/91/49-A.

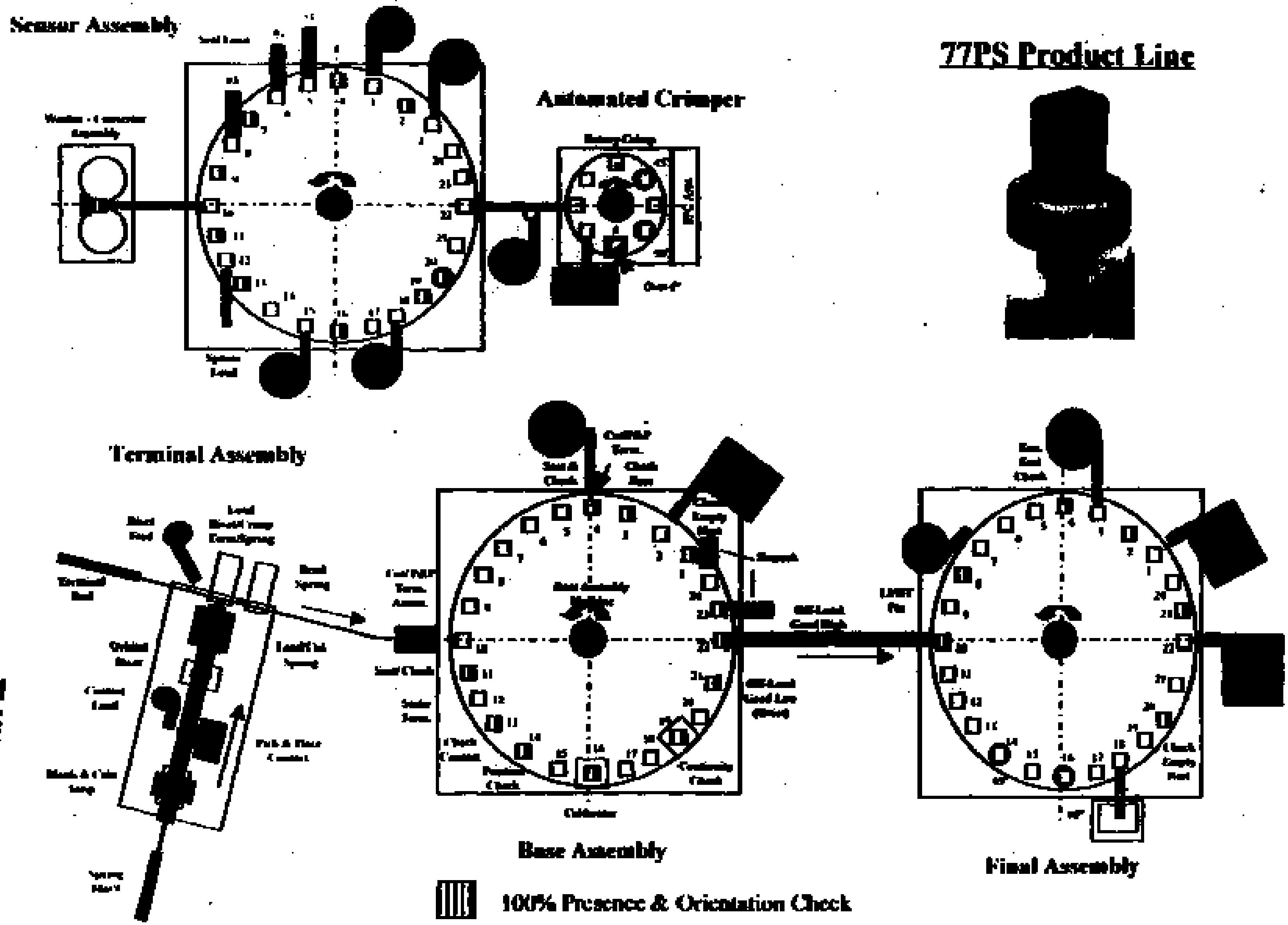
12/20 — TI Submits ISR for the Auto Crimp process.

2/19 — Added hole depth of 1.375", was not previously called out. Changed tool material to "D2 Tool Steel".

3/8 — Increased hole diameter from 0.750" to 0.800". Added note defining which surface to polish.

Texas Instruments

Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series



TI-NHTSA 014836

AMI Sensors & Checks

2) **Hexport Check**

- LVDT that measures the depth of the fluid path hole to determine if the correct hexport is being used.
- The part # and corresponding hexport are bar coded into the PLC.
- The fluid path hole of each hexport has a unique depth.
- The limits for each hexport are programmed into the PLC.
- The AMI stops on (1) fault.
- A master set up block is used to "0" out the LVDT.

4) **Gasket Check**

- 4 reflective sensors check to see if there is a gasket and that it is in place.
- None of the 4 is allowed to receive a reflection or the nest is called bad.
- The shift register is set bad on one fault, the AMI stops on two faults.
- There are 5 set-up masters to ensure the reflective sensors are in the correct positions.
- Under SPC control using a P-Chart.

7) **Kapton Check #1 & #2**

- 4 pogo pins are used to make a continuity check on the nest. The 4 pins must touch the 4 corners of the kapton (two corners of each piece) to ensure that two pieces are present.
- If one of the pogo pins goes to ground the nest is called bad.
- The shift register is set bad on one fault and the AMI stops on two faults.
- There is a set-up block to ensure the pins are in the correct position.
- Under SPC control using a P-Chart.

9) **Kapton Check #3**

- 2 pogo pins are used to make a continuity check. The 2 pins must touch the two corners of the third piece of Kapton to ensure the third piece has been placed in the nest.
- If one of the pogo pins goes to ground the nest is called bad.
- The shift register is set bad on one fault and the AMI stops on two faults.
- There is a set-up block to ensure the pins are in the correct position.
- Under SPC control using a P-Chart.

11) **Washer/Converter**

- The washer and converter are checked for part presence using a height probe sensor utilizing two micro switches. The height probe fixture comes down into the nest and if the micro switches are not broken the PLC indicates the parts are present. If the micro switches are broken the PLC assumes there are no components and calls the nest bad.

13) **Spacer Check**

- This station consist of three pogo pins, two continuity pins, and a hold down pin. The continuity pins come down and make contact with the spacer and if they do not go to ground the part is considered good. If there is a ground the part is considered bad.
  The shift register is set bad on one fault and the AMI stops on two faults.

16) **[illegible] Load Check**

This check is done with a LVDT. It is checking to make sure that there is not more than one disc, and the disc is not upside down.

19) **Cup Load Check**

- The cup is checked for part presence using a micro switch. The height check fixture comes down into the nest and if the micro switch is not broken the PLC believes there is a cup present. If the micro switch is broken the PLC believes there is no cup.
- The shift register is set bad on one fault and the AMI stops on two faults.

20) **Low Pin Check**

- The low pin check uses a LVDT to ensure the disc has not moved out of the converter and become trapped.

BAM Controls

3) **Base Presence**
- Uses a through beam to ensure a base has placed in the nest.

4) **Stationary terminal presence and position**
- Two micro switches are used to ensure there is a terminal present and it is the proper position.
- This station is also used to seat the terminal in the base cavity. If the terminal is not in place or in the wrong position the arm will travel too far and break the micro switches.

11) **Moveable terminal presence and position**
- Two micro switches are used to ensure there is a terminal present and it is the proper position.
- This station is also used to seat the terminal in the base cavity. If the terminal is not in place or in the wrong position the arm will travel too far and break the micro switches

13) **Check for contact**
- A reflective sensor is used to ensure a contact is in place.

14) **Part Presence**
- A through beam sensor is used to ensure there is a base in the nest before proceeding to the crimp station.

16) **Calibrate Base**
- This station sets the distance between the contact on the moveable arm and the stationary contact. This distance is predetermined and programmed into the PLC.

19) **Check Station**
- Checks to ensure the calibrator calibrated the base to the proper dimension. Measuring the distance until the contacts meet and continuity is made does this.

21) **Off-Load/Good Low**
- When running split lots the bases on the low end of the specification are off loaded at this station.

22) **Off-Load/Good High**
- When running split lots the bases on the high end of the specification are off loaded at this station.
- When running normal lots all bases are off loaded at this station or they are allowed to go directly into F.A.M.

23) **Rework**
- Any base that is not calibrated to the correct dimension and identified as so by the check station is off loaded at this station.

1) **Check Empty Nest**
- Uses a height probe and a micro switch to ensure the nest has been unloaded before loading another base into the nest.

TI-NHTSA 014538

FAM Controls

23) **Crimp Ring Presence**

- A height check probe is used to insure a part has been loaded. The height check fixture is attached to a micro switch and when the height check fixture comes down if the part is present the micro switch will not break contact. If it is not present it will break contact and send a signal to the PLC to stop the machine.

2) **Sensor Presence**

- A height check probe is used to insure a part has been loaded. The height check fixture is attached to a micro switch and when the height check fixture comes down if the part is present the micro switch will not break contact. If it is not present it will break contact and send a signal to the PLC to stop the machine.

4) **Environmental Seal Presence**

- A height check probe is used to insure a part has been loaded. The height check fixture is attached to a micro switch and when the height check fixture comes down if the part is present the micro switch will not break contact. If it is not present it will break contact and send a signal to the PLC to stop the machine.

8) **Pin Check**

- This station uses a LVDT to measure the height of the pin. The upper and lower limits of the pin size are loaded into the PLC and the machine stops if the measurement falls out of these limits.

10) **Base Presence**

- A height check probe is used to insure a part has been loaded. The height check fixture is attached to a micro switch and when the height check fixture comes down if the part is present the micro switch will not break contact. If it is not present it will break contact and send a signal to the PLC to stop the machine.

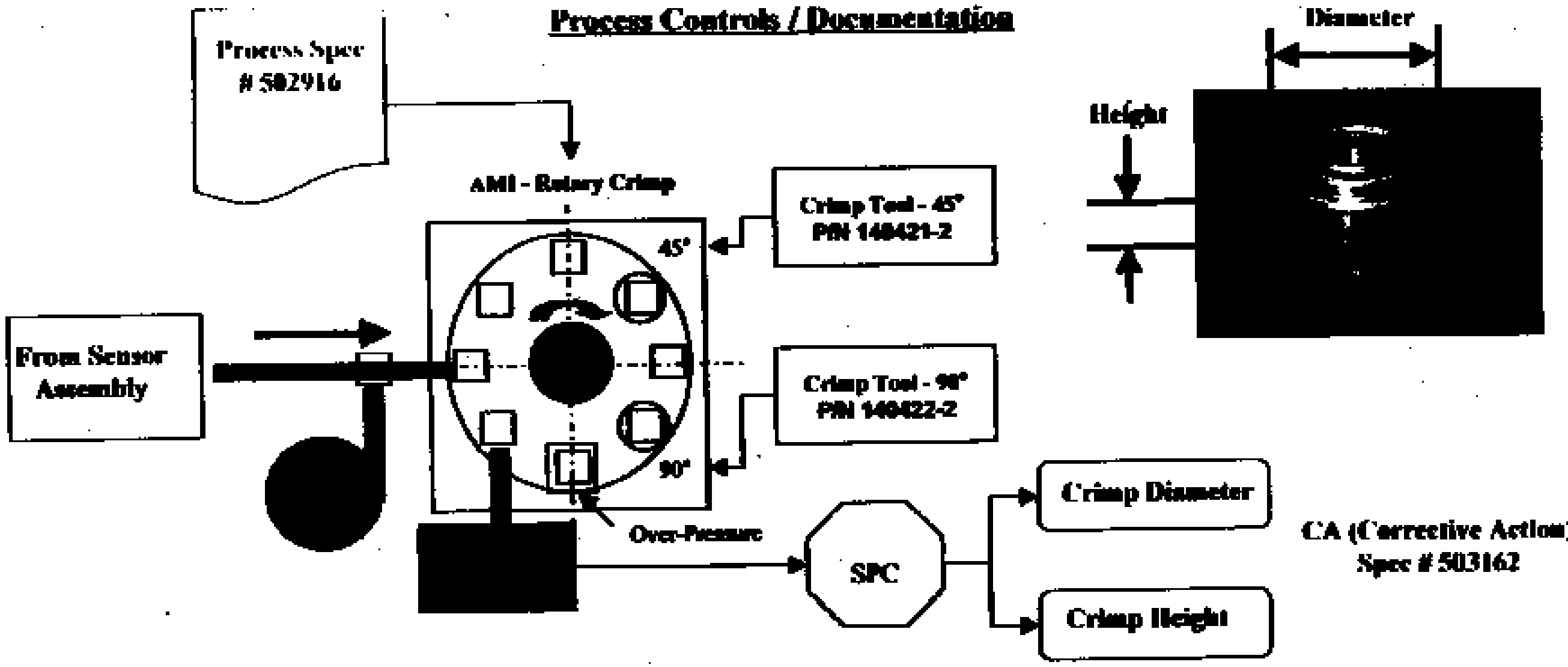
20) **Empty Nest Check**

- A height check probe comes down to check and make sure the nest is empty before loading another crimp ring into the nest.

Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series

TEXAS INSTRUMENTS

Process Controls / Documentation



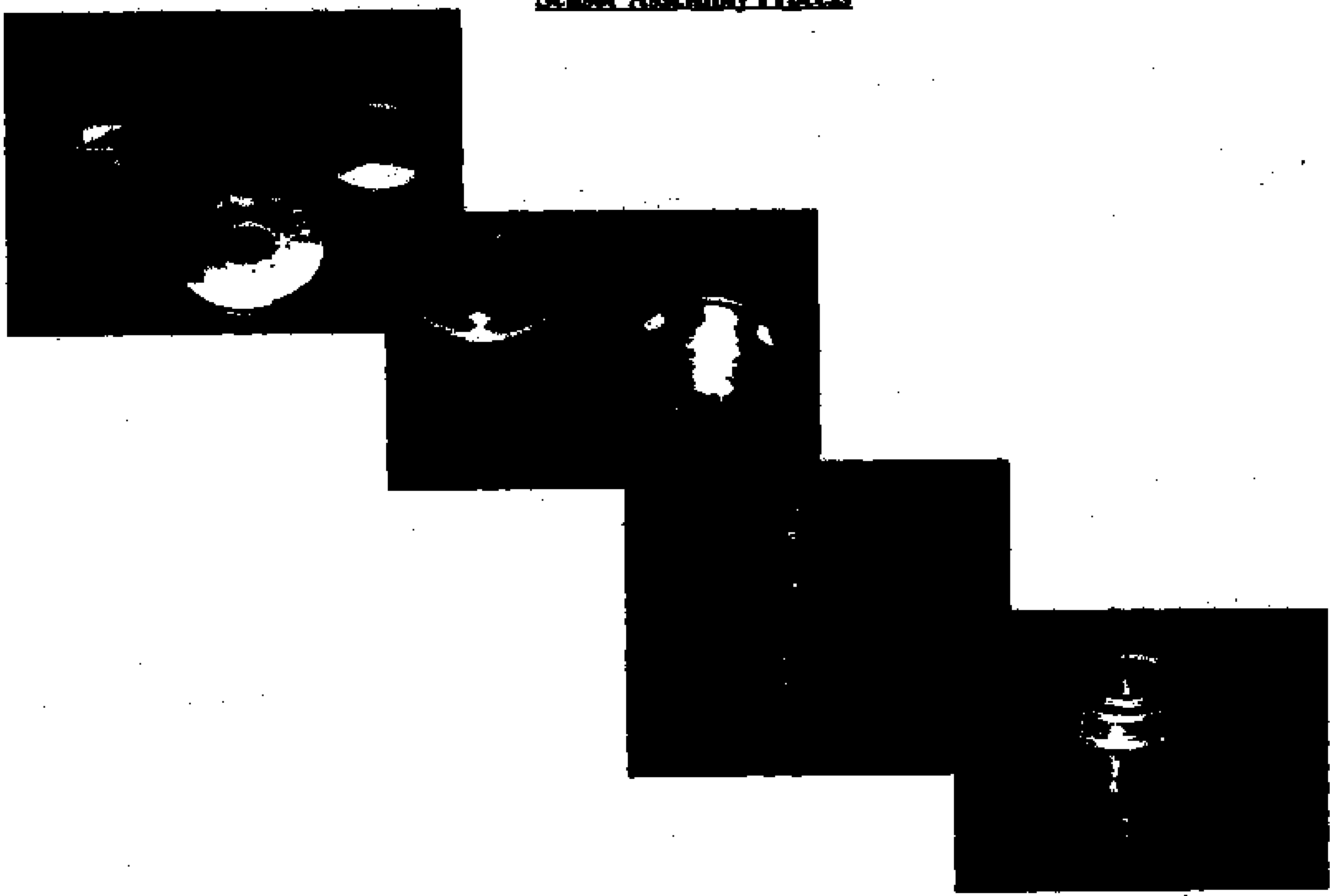
Crimp Logic / Sequence of Events:

- All tooling home
- Part presence sense
- Send cylinder down until down stroke sensor is activated
- Hold cylinder down
- Send cylinder home
- Repeat cycle

TEXAS INSTRUMENTS

Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series

Sensor Assembly Process



TI-NHTSA 014641

Texas Instruments

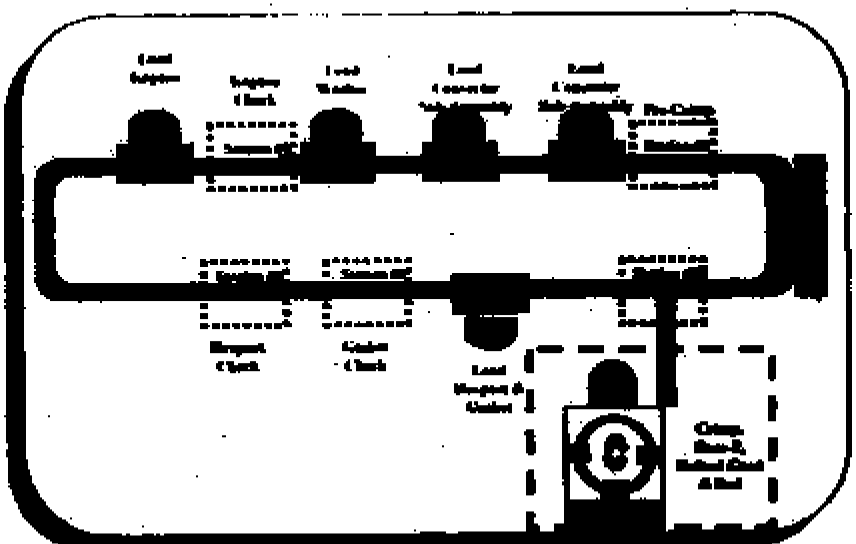
Ford - Electronic Speed Control Deactivation Pressure Switch
TI P/N 77PSL Series

Automatic vs. Hand Line Equipment

	Auto Crimper	Hand Line
Equipment Manufacturer	Black & Webster	Black & Webster
Load Method	Auto	Manual
Control Unit	5TI PLC	A/B PLC
Crimp Cylinders	American Cylinder	American Cylinder
Pressure Medium	Air	Air
Sensors (Up & Down)	Canfield Sensors	Canfield Sensors
Crimp Tool P/N:		
- 45°	140421-2	140421-2
- 90°	140422-2	140422-2
Process Controls Used:	Up & Down stroke sensors PLC control Over-Pressure Verification Crimp Height Crimp Diameter	Up & Down stroke sensors PLC control Over-Pressure Verification Crimp Height Crimp Diameter

TI-NHTSA 014642

Manual Sensor Assembly - TI Mexico

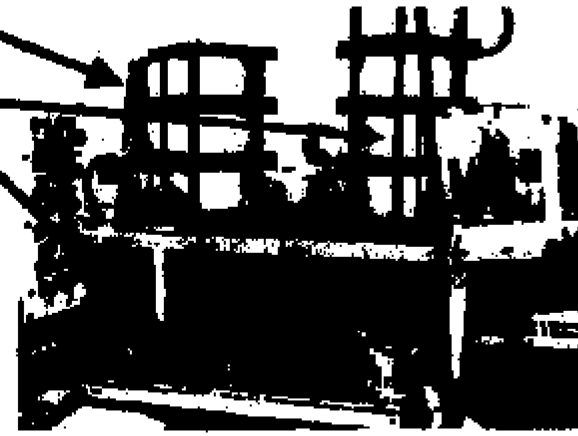


Hand Line - Crimp Equipment

45° Station

90° Station

Dial Nest: Operator loads pre-crimped sensor into nest



O-ring Station

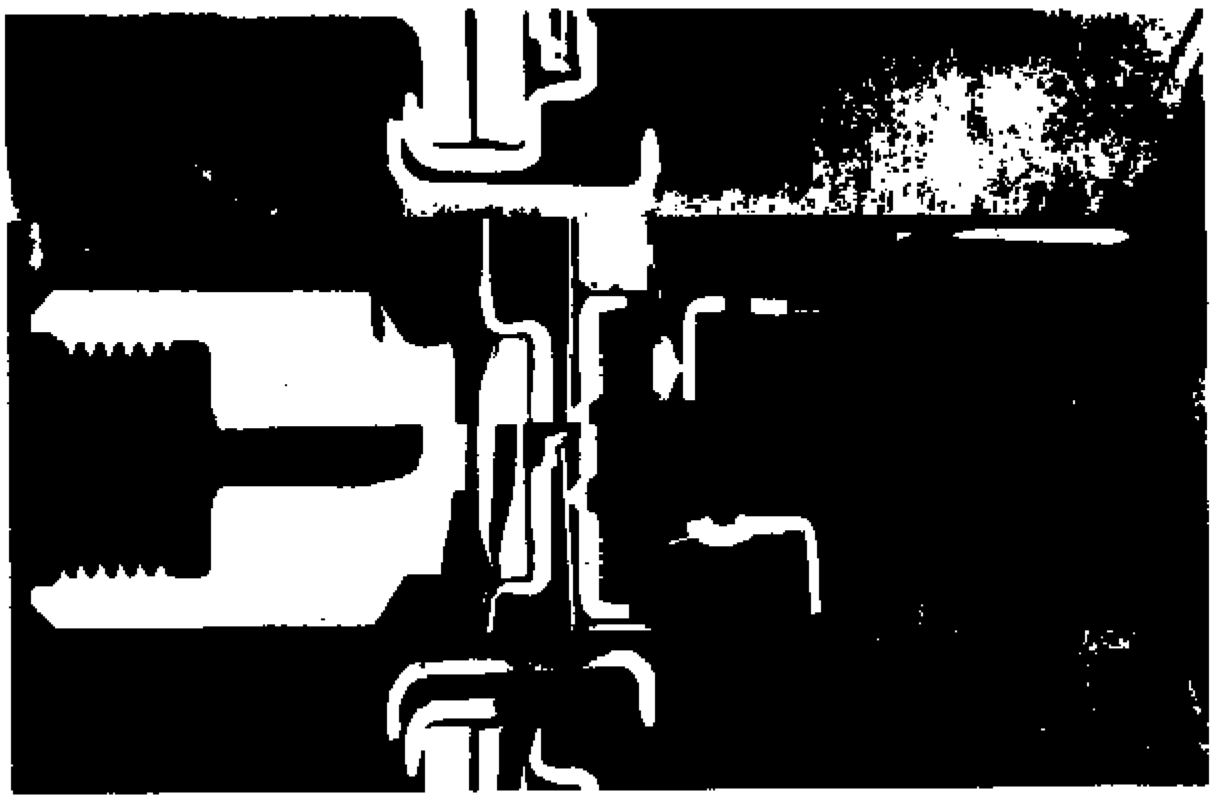
Operator Station - Operator places O-ring on sensor and feeds into sensor nest

Conveyor from Sensor Assembly Belt

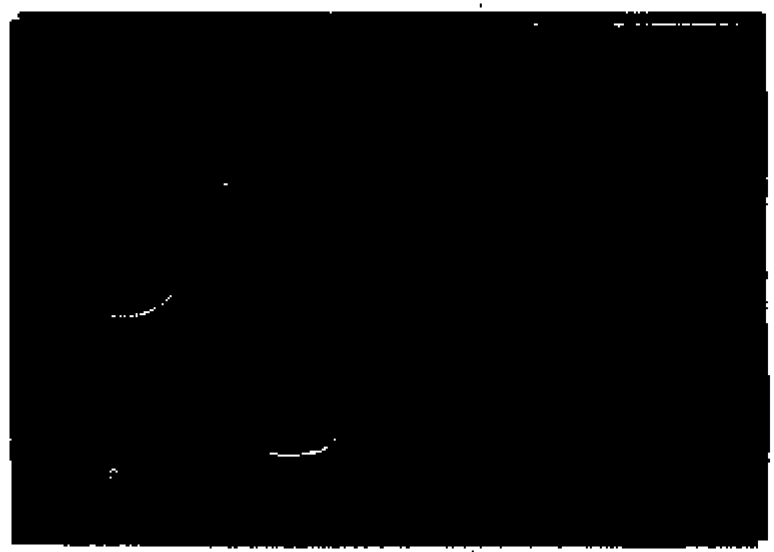
TI-NHTSA 014843

Automated Crimp Equipment

Switch X-Section



Low Cost
Automotive Pressure Switches



TI's pressure switches provide low cost, on/off controls for many automotive systems. The snap action disc reacts to changing pressure by reversing its curvature and activating electrical switch contacts.

Key Features Include:

- Designed for underhood environment
- Designed for line or pump mount applications
- Low weight
- Custom packaging for specific application needs
- Automotive temperature range of -30 to 125°C
- Normally open and normally closed contact logic
- Industry proven since 1984

Typical Applications

- A/C systems
- Power Steering Systems
- Cruise Control Systems
- Brake Systems
- Transmissions
- Suspension

Low Cost
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- Transmissions
- Suspension

DOE_tests.doc

Add Brake Fluid water content results

Proprietary Information: Attorney-Client Privilege Invoked

Report #

77PS Life Cycle DOE Test to Leakage

change all references to spacer → make washer

Abstract

The purpose of this life cycle test was to quantify the life expectancy of 77PSL2-1 (snap disc) and 77PSL4-1 (quiet disc) hydraulic pressure switches. (12) 77PSL2-1 and (12) 77PSL4-1 switches were pressure cycled to leakage with pure brake fluid. (12) 77PSL2-1 and (12) 77PSL4-1 switches were pressure cycled to leakage with brake fluid combined with 5% water. Upon leakage, the suspect switches were removed and the number of cycles recorded. Weibull Analyses were then performed on the data.
Due to results obtained in this test, an investigation was conducted to determine why (1) group of switches failed before the (3) other groups. The results of the investigation are also presented in this report.

Procedure

(48) 77PS switches were used as a test sample. There were (4) groups of switches as outlined at the bottom of Table 1, below. (2) switches from each group were loaded through clutch assemblies provided by Ford. All switches were placed in an oven where a temperature of 135°C was maintained. The switches were cycled from 2 psi to 1450 psi at a frequency of 2 Hz. When a leaky switch was detected, the test was suspended and the switches were allowed to cool to ambient temperature. Leaky switches were removed and the number of cycles noted. The remaining switches were brought back up to 135°C and testing resumed.

update from Ford_DOE_W...

Table 1
Cycles to leakage

Sample #	Group 1 (K cycles)	Group 2 (K cycles)	Group 3 (K cycles)	Group 4 (K cycles)
1	S	1175	1197	289
2	S	1181	1197	322
3	S	1192	1197	335
4	S	1192	S	335
5	S	1197	S	340
6	S	~~1235~~ 1199	S	376
7	S	S	S	380*
8	S	S	S	380*
9	S	S	S	380
10	S	S	S	387
11	S	S	S	387 [5]
12	S	S	S	387 [3]
Group 1: 77PSL2-1 (snap disc) w/ 0% water in brake fluid.				
Group 2: 77PSL4-1 (no snap disc) w/ 0% water in brake fluid.				
Group 3: 77PSL2-1 (snap disc) w/ 5% water in brake fluid.				
Group 4: 77PSL4-1 (no snap disc) w/ 5% water in brake fluid.				

Notes: "S" denotes sample did not leak.
*indicates switch was loaded through Ford clutch assembly.

TI-NHTSA 014548

Data

Summary:		
	Temperature:	135°C
	Pressure (low):	2 psi
	Pressure (high):	1450 psi
	Frequency:	2 Hz

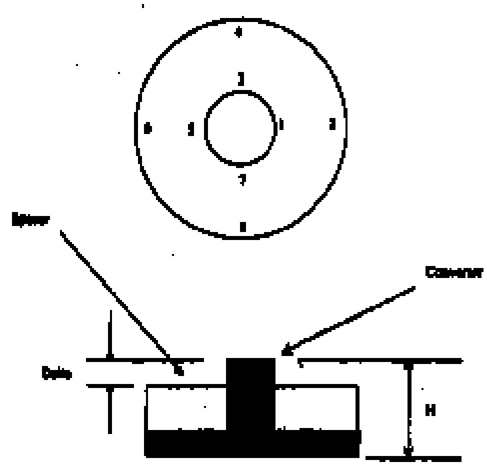
Table 1, above shows the number of cycles to failure (leakage) for each group. The table is incomplete as tests are ongoing.

Results

Weibull analysis: Weibull analyses were performed on the data obtained from Groups 2 and 4. The results are shown on Figures 1 and 2, respectively.
For each set of data entered into a Weibull Analysis, the set of parameters α, β and R^2 are determined. Values for the data used in this test may be seen in Figure 1. 1 and 2
α is the Characteristic Life which determines the spread of the distribution. The higher the number, the greater the spread.
β is the Shape Factor which determines the shape of the distribution curve.
R^2 is the Coefficient of Determination.

Leak analysis: As seen in Table 1, (10) leaks occurred in Group 4 well before any leaks occurred in the (3) other groups. An investigation was conducted to explain this unexpected result. It is suspected that premature leaks in Group 4 may be attributed to excessive stresses on the diaphragms of Group 4. Excess stress may be caused by height differences between the converter and spacer (see Figure 3, below). Measurements were made to compare the converter to spacer height differential of 77PSL2-1 switches to those of 77PSL4-1 switches.

Figure 3. converter_spacer ht



Converter to spacer height measurement Procedure:

The following samples were de-crimped and collected for measurement:
(3) 77PSL2-1 switches from the production line
(3) 77PSL4-1 switches from the production line
(4) 77PSL4-1 switches that leaked from Group 4 of the cycle test in this report.

The converter and spacer of each sample was removed. Each spacer was placed on its respective converter and placed on a level surface. A small pressure was applied to the spacer to keep it in good contact with the converter. A dial indicator was used to measure the height of the converter relative to the level surface. (See "H" in Figure 3 above). (8) measurements were made of the height of the spacer on the converter at the locations shown in Figure 3. Because test repeatability was a concern, each spacer/converter combination was measured (3) times. The spacer and converter were separated and randomly put back together between measurements. Raw data and further discussion are presented in Appendix A. The results are presented in Table 2, below.

Table 2.

	Delta	Standard Deviation
77PSL4-1 LEAKY SWITCHES		
322	0.0019	0.0006
335	0.0019	0.0006
348	0.0012	0.0004
380-3	0.0023	0.0004
77PSL4-1 FROM PRODUCTION LINE		
Sample 1	0.0016	0.0005
Sample 2	0.0014	0.0005
Sample 3	0.0020	0.0004
77PSL2-1 FROM THE LINE		
Sample 1	0.0031	0.0007
Sample 2	0.0033	0.0006
Sample 3	0.0028	0.0006

Delta is the distance the converter protrudes above the spacer (see Figure 3, above).
(Delta = Converter height – the average of all spacer heights measured for that sample).
Standard Deviation is the standard deviation of all spacer heights measured for that sample.

Conclusion

All 77PSL2-1 switches tested, (24), completed over 1,000,000 cycles without a leak when cycled with either pure brake fluid or with a brake fluid/ 5% water mix.

All 77PSL4-1 switches tested with pure brake fluid, completed over 1,000,000 cycles without a leak.

(10) 77PSL4-1 switches leaked before 400,000 cycles when tested with a brake fluid/ 5% water mix. It is suspected that these switches may have a less than optimum converter to

spacer height that puts an excessive strain on the diaphragm. Measurements have been made that tend to support this theory. Analysis of these switches and 77PSL2-1 switches (see Table 2 above) has shown that the converter on 77PSL2-1 switches protrudes above the spacer roughly 1/1000 to1.5/1000 of an inch more than on 77PSL4-1 switches. This difference may be enough to cause premature leaks. There seems to be no significant difference between 77PSL4-1 switches that have been life tested and those that are pulled from the production line.

There is a rather high standard deviation for measurements made on the converters and spacers. This may be attributed to variations in spacer and converter thickness' as well as measurement error. However, there is enough evidence to warrant further investigation.

Report Authored by Sean Mulligan

Figure 2.

G1_DOE.XLS

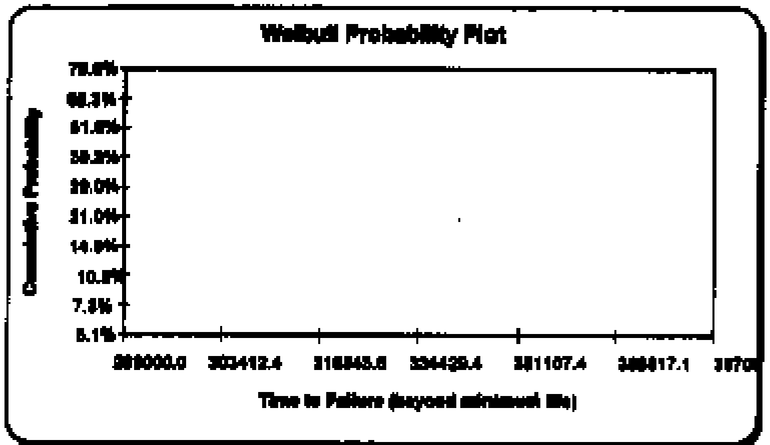
complete
printed 3/18/99

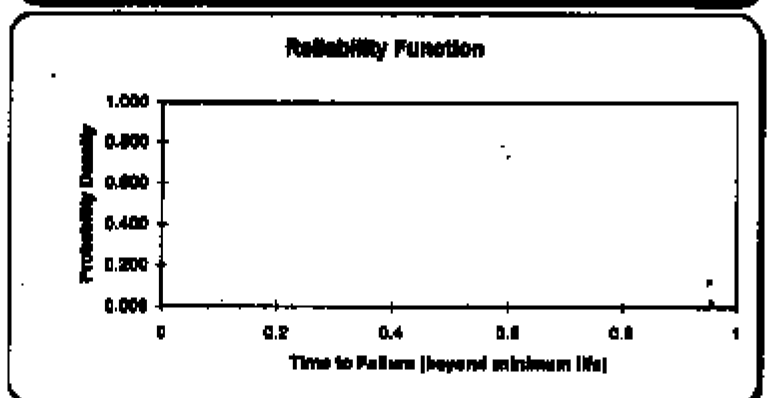
2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

1324428	6	300000
1324428	6	
1324428	6	
1324428	6	
1324428	6	1000000 #NUM!
1324428	6	
1324428	6	
1324428	6	
1324428	6	60 % #NUM!
1324428	6	
1324428	6	
1324428	6	

Calculated Outputs





NOTES: DOE 1 Group 1: 77PSL2-1 (w/ snap) w/ 0% water in brake fluid.

(6)

G2_00E.xls

2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

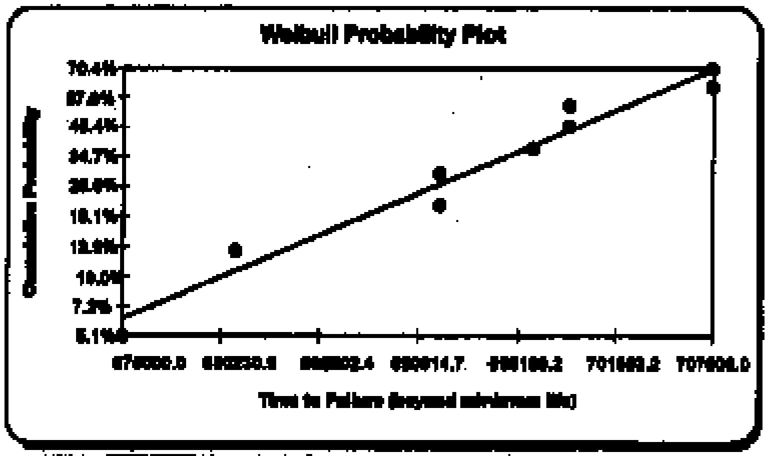
1170000	
1181000	
1182000	
1185000	
1197000	
1199000	
1199000	
1207000	
1207000	
[illegible]	0
[illegible]	0
[illegible]	0

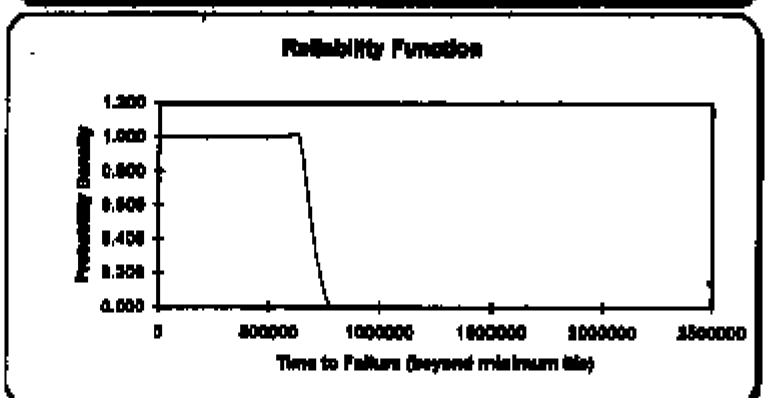
800000

1000000	100%

90 %	1182[illegible].705

Calculated Outputs





NOTES: DOE 1 Group 2: 77PSL4-1 (no snap) w/ 0% water in brake fluid.

Figure 2

G3_005.145

2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

1125430	
1125430	
1167000	
1167000	
1167000	
1180000	
1201000	
1207000	
1207000	
1207000	
1207000	6
1207000	1

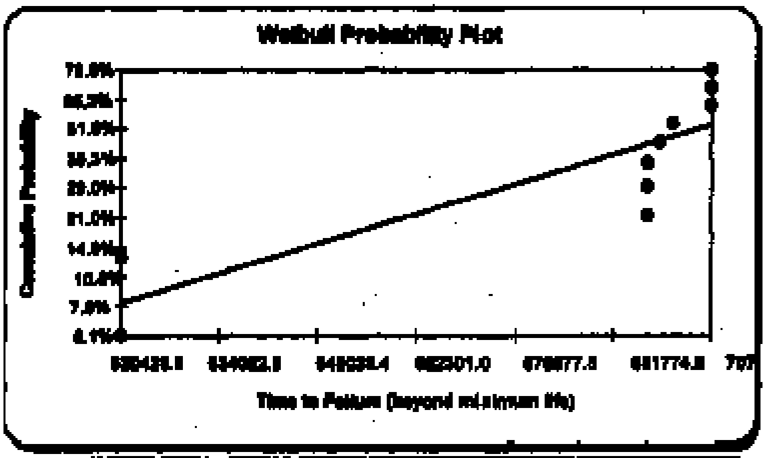
600000

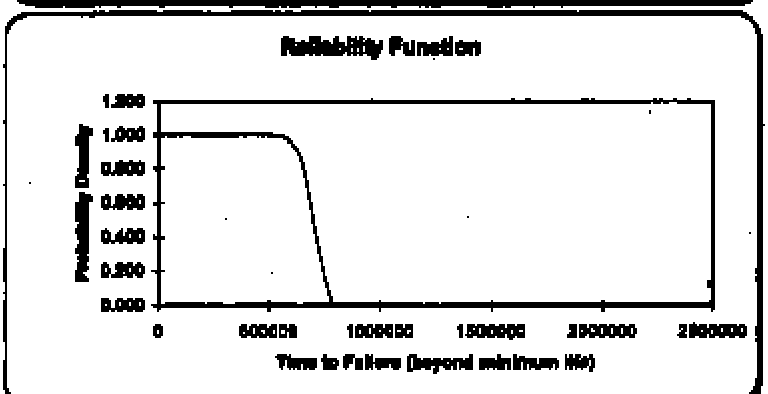
1000000	100%

95 %	1160231.501

Calculated Outputs

[illegible]





NOTES: DOE 1 Group 3: 77PSL2-1 (w/ snap) w/ 5% water in brake fluid.

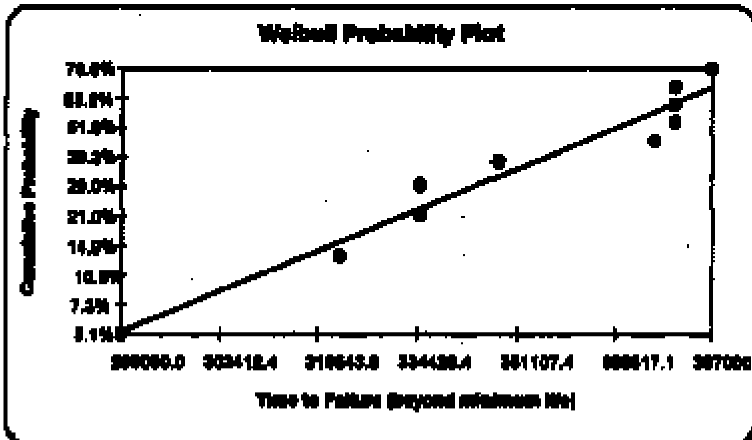
2 and 3 parameter WEIBULL FAILURE ANALYSIS

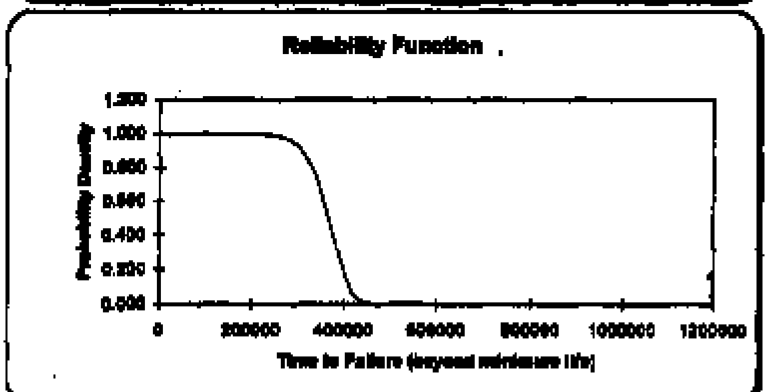
CLICK here to recalculate if failure data or "Minimum life" input, value is altered

2[illegible]000		0
3[illegible]2000		
3[illegible]000		
330000		
3[illegible]000		
379000		
[illegible]0000		
3[illegible]000		
3[illegible]000		
367000		
367000	0	
367000	0	

400000	0%
95 %	3[illegible]77[illegible]

Calculated Outputs





NOTES: DOE 1 Group 4: 77PSL4-1 (no snap) w/ 5% water in brake fluid.

Appendix A

Leak analysis: The following is an explanation of measurements made on converter and spacers heights of 77PS switches. (Refer to (4) spreadsheet pages included).

Explanation of Data pages. The first (2) pages of the spreadsheet that follows are the data pages.

Column 1: "switch #" is the name of the switch that was analyzed. (a number refers to number of cycles in thousands i.e. 322 = switch that leaked at 322,00 cycles)

Column 2: "H" is the converter height measurement.

Columns 3 – 10: are the locations where measurements were made on the spacer.

As you read down each column, the (3) sets of measurements made on each device is presented followed by an average for the three measurements and the standard deviation ("stdev.").

Explanation of Analysis pages. The last (2) pages of the spreadsheet that follows are the analysis pages.

Column 1: "AVE IN" is the average of the (4) inner measurements made on the spacer (locations 1, 3, 5, and 7).

Column 2: "stdev" is the standard deviation for the (4) inner measurements.

Column 3: "AVE OUT" is the average of the (4) outer measurements made on the spacer (locations 2, 4, 6, and 8).

Column 4: "stdev" is the standard deviation for the (4) outer measurements .

Column 5: "AVE TOT." is the average of all (8) measurements made on the spacer.

Column 6: "stdev" is the standard deviation for the (8) measurements made on the spacer.

Column 7: "Delta" is the converter height, H, minus the average height of all measurements made on the spacer, shown in bold in the "AVE TOT" column.

Column 8: "stdev." is the standard deviation of the "Delta" column.

Measurements.xls

77PSL4-1 LEAKY SWITCHES DATA

Measurement location

switch #	H	1	2	3	4	5	6	7	8
322	0.1846	0.1822	0.183	0.1827	0.1834	0.1824	0.1833	0.1821	0.183
	0.1846	0.1826	0.1836	0.1822	0.1828	0.1819	0.1824	0.1823	0.1828
	0.1846	0.1823	0.1832	0.1826	0.1832	0.1822	0.1821	0.183	0.1829
Average	0.1846	0.1824	0.1833	0.1825	0.1831	0.1822	0.1826	0.1825	0.1829
stdev.	0.0001	0.0002	0.0004	0.0003	0.0003	0.0003	0.0006	0.0005	0.0001
335	0.1848	0.1827	0.1822	0.1826	0.1819	0.1834	0.1838	0.1832	0.1833
	0.1847	0.1831	0.1829	0.1823	0.1815	0.1833	0.1831	0.1834	0.1836
	0.1848	0.1833	0.1831	0.1824	0.1815	0.1832	0.1831	0.1834	0.1838
Average	0.1848	0.1830	0.1827	0.1824	0.1816	0.1833	0.1833	0.1833	0.1836
stdev.	0.0001	0.0003	0.0005	0.0002	0.0002	0.0001	0.0004	0.0001	0.0002
348	0.1846	0.1831	0.1836	0.1831	0.1837	0.183	0.1838	0.183	0.1834
	0.1846	0.183	0.1836	0.1833	0.1839	0.1833	0.1841	0.1829	0.1833
	0.1846	0.1831	0.1837	0.1828	0.1834	0.183	0.1832	0.1832	0.1839
Average	0.1846	0.1831	0.1836	0.1831	0.1837	0.1831	0.1837	0.1830	0.1835
stdev.	0.0001	0.0001	0.0001	0.0003	0.0003	0.0002	0.0005	0.0002	0.0003
380-3	0.185	0.1828	0.1831	0.1825	0.1828	0.1824	0.1824	0.1828	0.1834
	0.185	0.1827	0.1835	0.1826	0.1828	0.1822	0.1823	0.1826	0.1832
	0.185	0.1827	0.1833	0.183	0.1836	0.1824	0.1824	0.1822	0.1826
Average	0.1850	0.1827	0.1834	0.1826	0.1831	0.1823	0.1824	0.1824	0.1829
stdev.	0.0000	0.0001	0.0002	0.0002	0.0005	0.0001	0.0001	0.0003	0.0004

77PSL4-1 FROM PRODUCTION LINE DATA

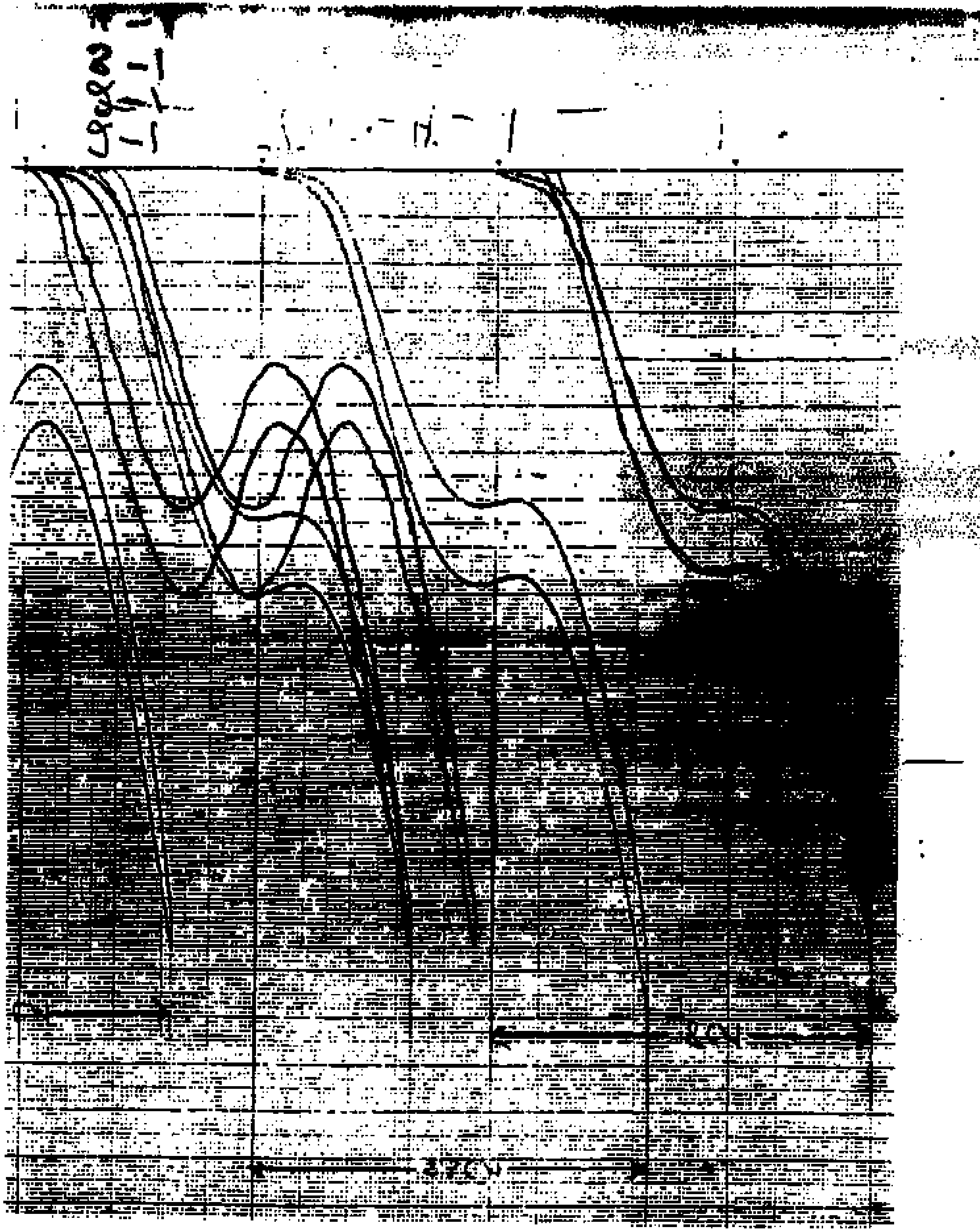
Measurement location

	H	1	2	3	4	5	6	7	8
sample 1	0.1857	0.1838	0.1853	0.1836	0.1838	0.1836	0.1839	0.1841	0.1847
	0.1856	0.1841	0.1852	0.1837	0.1845	0.1836	0.1838	0.1835	0.184
	0.1856	0.1836	0.1847	0.1842	0.1849	0.1837	0.184	0.1838	0.1841
Average	0.1856	0.1838	0.1851	0.1838	0.1844	0.1836	0.1839	0.1838	0.1843
stdev.	0.0001	0.0003	0.0003	0.0004	0.0006	0.0001	0.0001	0.0003	0.0004
sample 2	0.1855	0.184	0.1842	0.1836	0.1842	0.1836	0.1842	0.1841	0.1845
	0.1854	0.1841	0.185	0.184	0.1848	0.1843	0.1848	0.1838	0.1844
	0.1854	0.1838	0.1849	0.1834	0.1839	0.1834	0.1838	0.1832	0.1836
Average	0.1854	0.1840	0.1847	0.1837	0.1843	0.1838	0.1843	0.1837	0.1842
stdev.	0.0001	0.0002	0.0004	0.0003	0.0005	0.0006	0.0005	0.0005	0.0005
sample 3	0.185	0.1829	0.1832	0.1829	0.1827	0.1831	0.1839	0.1835	0.1839
	0.185	0.1829	0.1834	0.1825	0.1824	0.1827	0.1832	0.183	0.1831
	0.185	0.1827	0.183	0.1826	0.1822	0.1828	0.1832	0.183	0.1832
Average	0.1850	0.1828	0.1832	0.1827	0.1824	0.1829	0.1834	0.1832	0.1834
stdev.	0.0000	0.0001	0.0002	0.0002	0.0003	0.0002	0.0004	0.0003	0.0004

77PSL2-1 FROM THE LINE DATA

Measurement location

	H	1	2	3	4	5	6	7	8
sample 1	0.1885	0.1848	0.1847	0.1857	0.1866	0.185	0.1857	0.1845	0.185
	0.1884	0.1846	0.185	0.1842	0.1852	0.185	0.1854	0.1852	0.1862
	0.1883	0.1849	0.1869	0.1854	0.1862	0.1854	0.1858	0.1845	0.1851
Average	0.1884	0.1848	0.1855	0.1851	0.1860	0.1851	0.1856	0.1847	0.1854
stdev.	0.0001	0.0002	0.0011	0.0008	0.0007	0.0002	0.0002	0.0004	0.0007
sample 2	0.189	0.1853	0.1849	0.1854	0.1853	0.1852	0.1855	0.1862	0.1865
	0.189	0.1856	0.1847	0.1851	0.1854	0.1857	0.1855	0.1862	0.1862
	0.189	0.1853	0.1856	0.1858	0.1868	0.1856	0.1861	0.1859	0.1862
Average	0.1890	0.1854	0.1851	0.1854	0.1858	0.1855	0.1857	0.1861	0.1863
stdev.	0.0000	0.0002	0.0005	0.0004	0.0008	0.0003	0.0003	0.0002	0.0002
sample 3	0.189	0.1857	0.186	0.1862	0.1879	0.1859	0.1867	0.1858	0.1867
	0.189	0.1862	0.1865	0.1862	0.1877	0.1858	0.1863	0.186	0.1864
	0.1889	0.1859	0.1864	0.1858	0.1867	0.1859	0.1864	0.1863	0.1872
Average	0.1890	0.1859	0.1863	0.1861	0.1874	0.1859	0.1865	0.1860	0.1868
stdev.	0.0001	0.0003	0.0003	0.0002	0.0006	0.0001	0.0002	0.0003	0.0004



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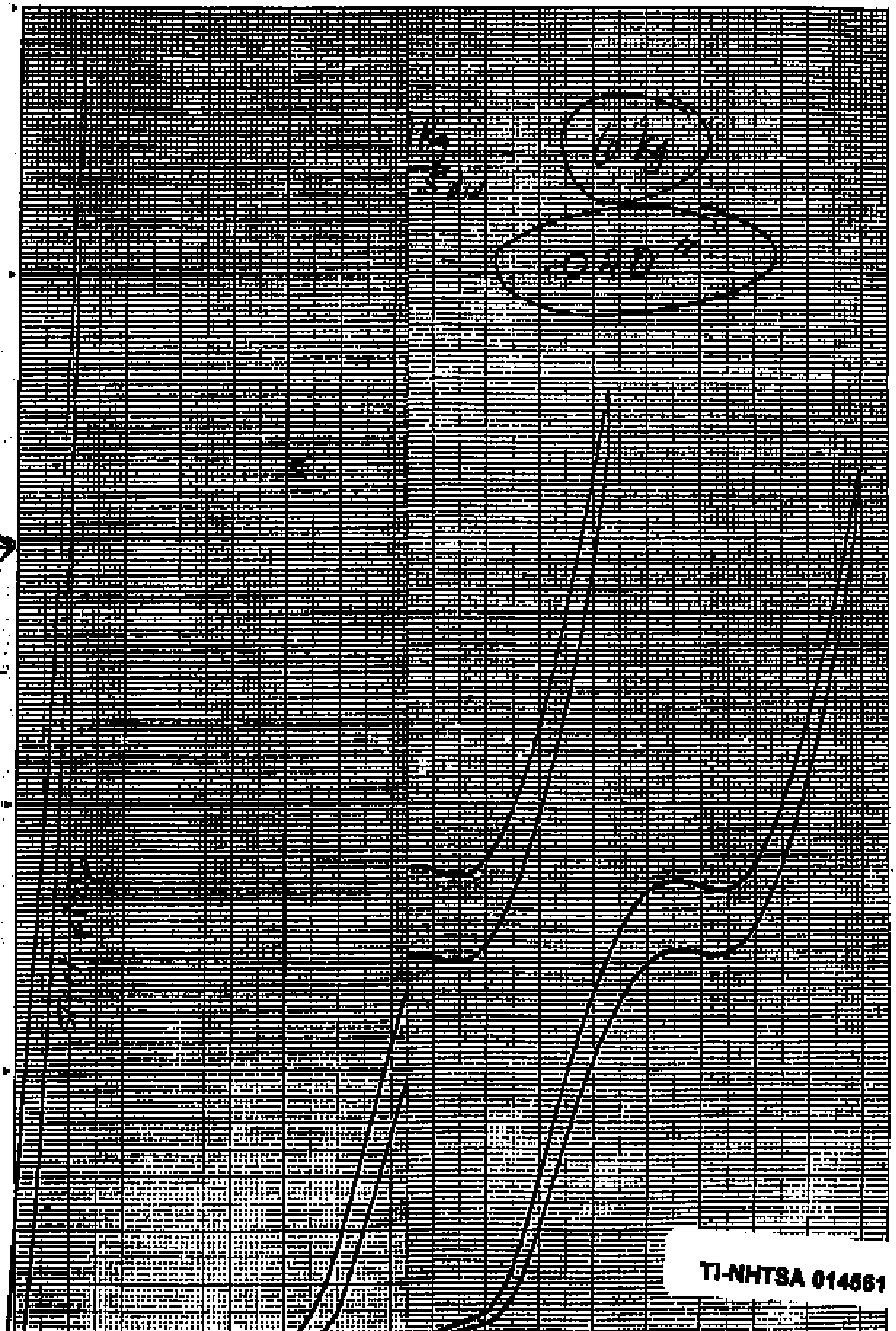
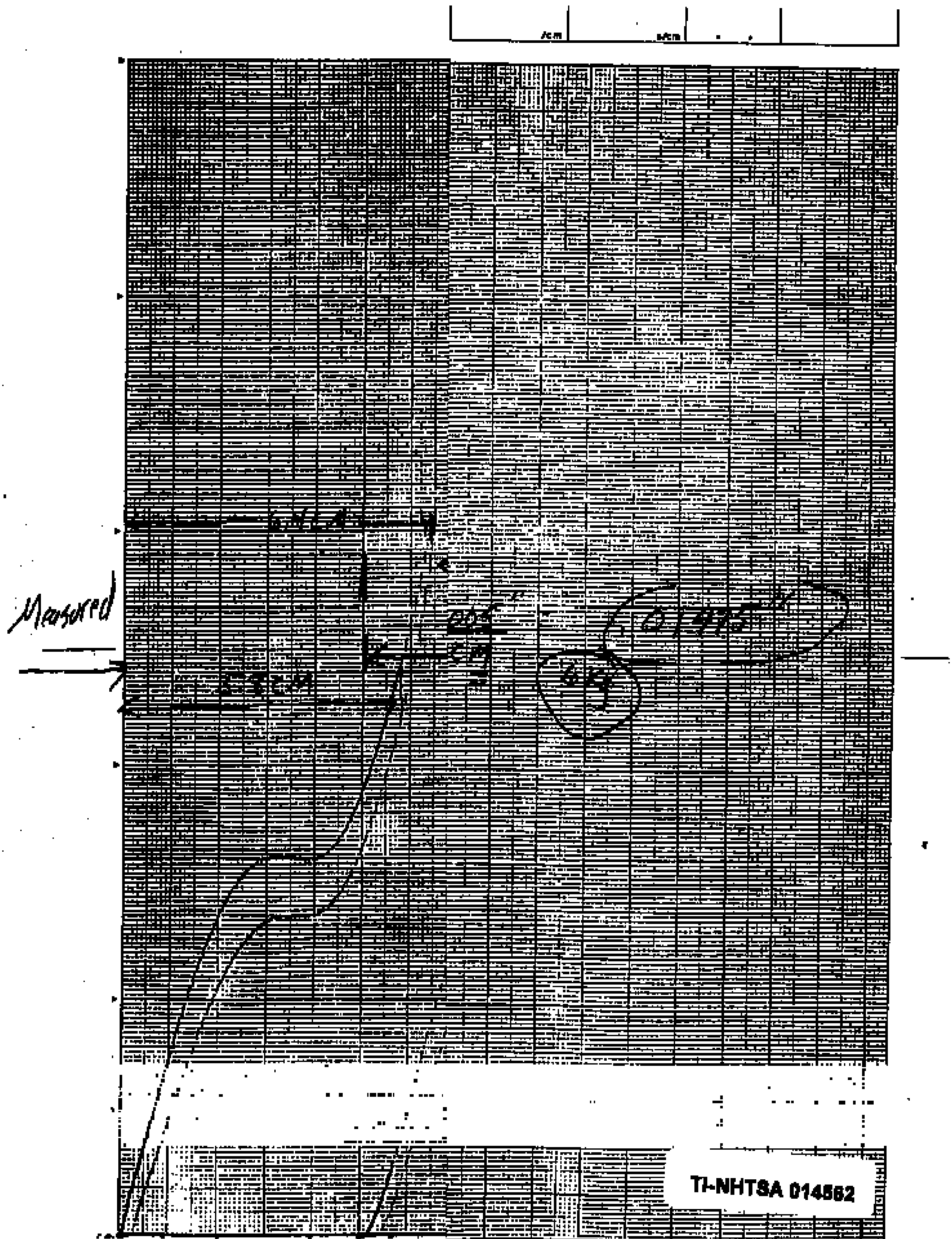
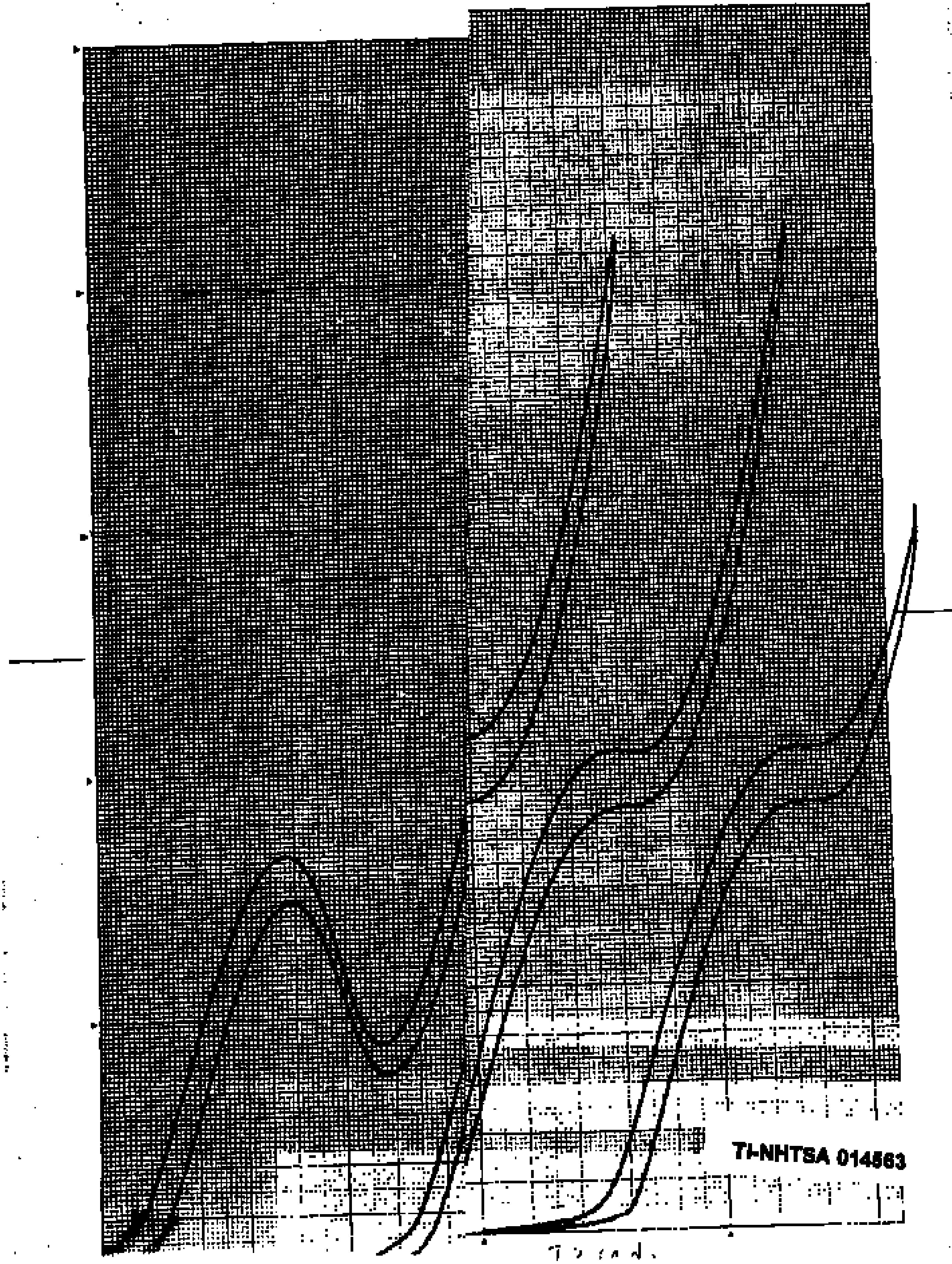



Measured

23/3/99



TI-NHTSA 014563

77PS Life Cycle DOE Test to Leakage

Abstract

The purpose of this life cycle test was to quantify the life expectancy of 77PSL2-1 (snap disc) and 77PSL4-1 (quiet disc) hydraulic pressure switches. (12) 77PSL2-1 and (12) 77PSL4-1 switches were pressure cycled to leakage with pure brake fluid. (12) 77PSL2-1 and (12) 77PSL4-1 switches were pressure cycled to leakage with brake fluid combined with 5% water. Upon leakage, the suspect switches were removed and the number of cycles recorded. Weibull Analyses were then performed on the data.
Due to results obtained in this test, an investigation was conducted to determine why (1) group of switches failed before the (3) other groups. The results of the investigation are also presented in this report.

Procedure

(48) 77PS switches were used as a test sample. There were (4) groups of switches as outlined at the bottom of Table 1, below. (2) switches from each group were loaded through clutch assemblies provided by Ford. All switches were placed in an oven where a temperature of 135°C was maintained. The switches were cycled from 2 psi to 1450 psi at a frequency of 2 Hz. When a leaky switch was detected, the test was suspended and the switches were allowed to cool to ambient temperature. Leaky switches were removed and the number of cycles noted. The remaining switches were brought back up to 135°C and testing resumed.

Table 1
Cycles to leakage

Sample #	Group 1 (K cycles)	Group 2 (K cycles)	Group 3 (K cycles)	Group 4 (K cycles)
1	S	1175	1197	289
2	S	1181	1197	322
3	S	1192	1197	335
4	S	1192	S	336
5	S	1197	S	348
6	S	1235	S	378
7	S	S	S	380*
8	S	S	S	380*
9	S	S	S	380
10	S	S	S	387
11	S	S	S	387*
12	S	S	S	387*
Group 1: 77PSL2-1 (snap disc) w/ 0% water in brake fluid.				
Group 2: 77PSL4-1 (no snap disc) w/ 0% water in brake fluid.				
Group 3: 77PSL2-1 (snap disc) w/ 5% water in brake fluid.				
Group 4: 77PSL4-1 (no snap disc) w/ 5% water in brake fluid.				

Notes: "S" denotes sample did not leak.
*indicates switch was loaded through Ford clutch assembly.

Data

Summary:	Temperature:	135°C
	Pressure (low):	2 psi
	Pressure (high):	1450 psi
	Frequency:	2 Hz

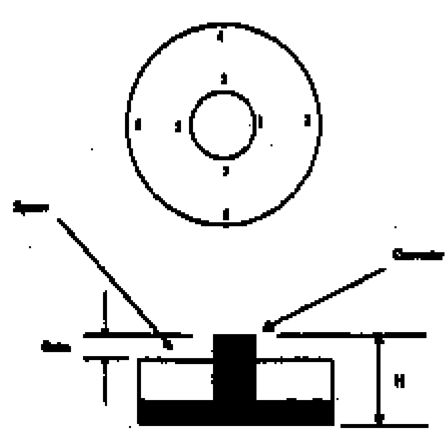
Table 1, above shows the number of cycles to failure for each group. The table is incomplete as tests are ongoing.

Results

<u>Weibull analysis</u>: Weibull analyses were performed on the data obtained from Groups 2 and 4. The results are shown on Figures 1 and 2, respectively.
For each set of data entered into a Weibull Analysis, the set of parameters α, β and R^2 are determined. Values for the data used in this test may be seen in Figure 2.
α is the Characteristic Life which determines the spread of the distribution. The higher the number, the greater the spread.
β is the Shape Factor which determines the shape of the distribution curve.
R^2 is the Coefficient of Determination.

<u>Leak analysis</u>: As seen in Table 1, (10) leaks occurred in Group 4 well before any leaks occurred in the (3) other groups. An investigation was conducted to explain this unexpected result. It is suspected that premature leaks in Group 4 may be attributed to excessive stresses on the diaphragms of Group 4. Excess stress may be caused by height differences between the converter and spacer (see Figure 3, below). Measurements were made to compare the converter to spacer height differential of 77PSL2-1 switches to those of 77PSL4-1 switches.

Figure 3.



Converter to spacer height measurement Procedure:

The following samples were de-crimped and collected for measurement:
(3) 77PSL2-1 switches from the production line
(3) 77PSL4-1 switches from the production line
(4) 77PSL4-1 switches that leaked from Group 4 of the cycle test in this report.

The converter and spacer of each sample was removed. Each spacer was placed on its respective converter and placed on a level surface. A small pressure was applied to the spacer to keep it in good contact with the converter. A dial indicator was used to measure the height of the converter relative to the level surface. (See "H" in Figure 3 above). (8) measurements were made of the height of the spacer on the converter at the locations shown in Figure 3. Because test repeatability was a concern, each spacer/converter combination was measured (3) times. The spacer and converter were separated and randomly put back together between measurements. Raw data and further discussion are presented in Appendix A. The results are presented in Table 2, below.

Table 2.

	Delta	Standard Deviation
77PSL4-1 LEAKY SWITCHES		
322	0.0018	0.0006
335	0.0018	0.0006
348	0.0012	0.0004
380-3	0.0015	0.0004
77PSL4-1 FROM PRODUCTION LINE		
Sample 1	0.0015	0.0006
Sample 2	0.0014	0.0006
Sample 3	0.0020	0.0004
77PSL2-1 FROM THE LINE		
Sample 1	0.0031	0.0007
Sample 2	0.0033	0.0006
Sample 3	0.0039	0.0006

Delta is the distance the converter protrudes above the spacer (see Figure 3, above).
(Delta = Converter height – the average of all spacer heights measured for that sample).
Standard Deviation is the standard deviation of all spacer heights measured for that sample.

Conclusion

All 77PSL2-1 switches tested, (24), completed over 1,000,000 cycles without a leak when cycled with either pure brake fluid or with a brake fluid/ 5% water mix.

All 77PSL4-1 switches tested with pure brake fluid, completed over 1,000,000 cycles without a leak.

(10) 77PSL4-1 switches leaked before 400,000 cycles when tested with a brake fluid/ 5% water mix. It is suspected that these switches may have a less than optimum converter to

spacer height that puts an excessive strain on the diaphragm. Measurements have been made that tend to support this theory. Analysis of these switches and 77PSL2-1 switches (see Table 2 above) has shown that the converter on 77PSL2-1 switches protrudes above the spacer roughly 1/1000 to1.5/1000 of an inch more than on 77PSL4-1 switches. This difference may be enough to cause premature leaks. There seems to be no significant difference between 77PSL4-1 switches that have been life tested and those that are pulled from the production line.
There is a rather high standard deviation for measurements made on the converters and spacers. This may be attributed to variations in spacer and converter thickness' as well as measurement error. However, there is enough evidence to warrant further investigation.

Report Authored by Sean Mulligan

Figure 1.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

○ Exponential
○ Lognormal
◉ Weibull

Time to failure	Suspended
288000	
332000	
338000	
338000	
348000	
378000	
380000	
380000	
380000	
387000	
387000	9
387000	8

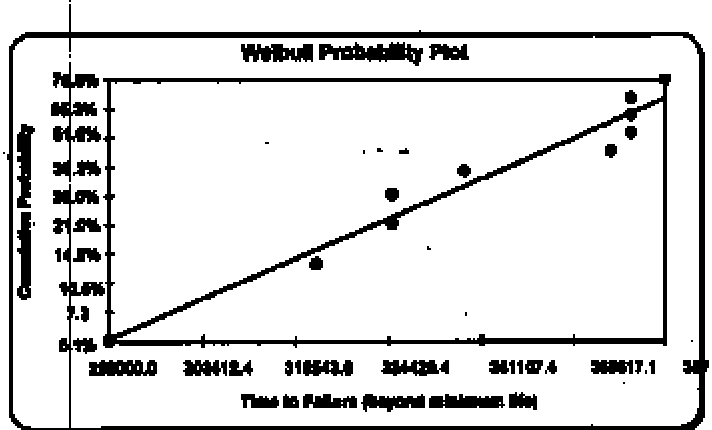
Minimum life
0

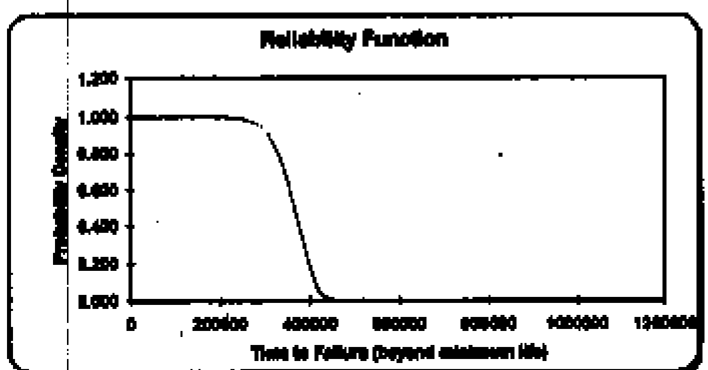
Time (cycle)	Reliability %
1000000	0%

Reliability %	Time (cycle)
99 %	287743.0016

Calculated Outputs

α = 386036.313
β = 10.676
R^2 = 0.963





NOTES: Group 4: 77PSL4-1 w/ 8% water in brake fluid

TI-NHTSA 014568

Figure 2.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

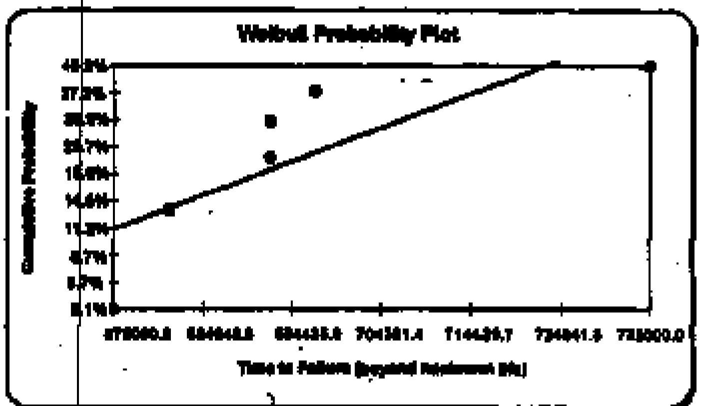
Time to failure	Suspended	Minimum life
1178000		[illegible]
1181000		
[illegible]		
[illegible]		
1187000		
[illegible]		
[illegible]	s	
[illegible]	s	
[illegible]	s	
[illegible]	s	
[illegible]	s	
[illegible]	s	

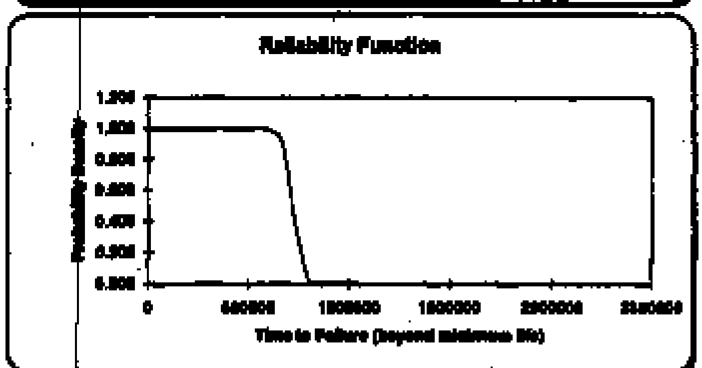
Time (cycles)	Reliability %
1000000	100%

Reliability %	Time (cycles)
90 %	[illegible]

Calculated Outputs

[illegible]





NOTES: Group 2: 77PSL4-1 (no snap) w/ 0% water

Appendix A

Leak analysis: The following is an explanation of measurements made on converter and spacers heights of 77PS switches. (Refer to (4) spreadsheet pages included).

Explanation of Data pages. The first (2) pages of the spreadsheet that follows are the data pages.

Column 1: "switch #" is the name of the switch that was analyzed. (a number refers to number of cycles in thousands i.e. 322 = switch that leaked at 322,00 cycles) .

Column 2: "H" is the converter height measurement.

Columns 3 – 10: are the locations where measurements were made on the spacer.

As you read down each column, the (3) sets of measurements made on each device is presented followed by an average for the three measurements and the standard deviation ("stdev.").

Explanation of Analysis pages. The last (2) pages of the spreadsheet that follows are the analysis pages.

Column 1: "AVE IN" is the average of the (4) inner measurements made on the spacer (locations 1, 3, 5, and 7).

Column 2: "stdev" is the standard deviation for the (4) inner measurements.

Column 3: "AVE OUT" is the average of the (4) outer measurements made on the spacer (locations 2, 4, 6, and 8).

Column 4: "stdev" is the standard deviation for the (4) outer measurements .

Column 5: "AVE TOT." is the average of all (8) measurements made on the spacer.

Column 6: "stdev" is the standard deviation for the (8) measurements made on the spacer.

Column 7: "Delta" is the converter height, H, minus the average height of all measurements made on the spacer, shown in bold in the "AVE TOT" column.

Column 8: "stdev." is the standard deviation of the "Delta" column

77PSL4-1 LEAKY SWITCHES

Measurement location

switch #	H	1	2	3	4	5	6	7	8
322	0.1846	0.1822	0.183	0.1827	0.1834	0.1824	0.1833	0.1821	0.183
	0.1845	0.1826	0.1838	0.1822	0.1828	0.1819	0.1824	0.1823	0.1828
	0.1846	0.1823	0.1832	0.1826	0.1832	0.1822	0.1821	0.183	0.1829
Average	0.1846	0.1824	0.1833	0.1825	0.1831	0.1822	0.1826	0.1825	0.1829
stdev.	0.0001	0.0002	0.0004	0.0003	0.0003	0.0003	0.0006	0.0005	0.0001
335	0.1848	0.1827	0.1822	0.1826	0.1819	0.1834	0.1836	0.1832	0.1833
	0.1847	0.1831	0.1829	0.1823	0.1815	0.1833	0.1831	0.1834	0.1836
	0.1848	0.1833	0.1831	0.1824	0.1815	0.1832	0.1831	0.1834	0.1836
Average	0.1848	0.1830	0.1827	0.1824	0.1816	0.1833	0.1833	0.1833	0.1835
stdev.	0.0001	0.0003	0.0005	0.0002	0.0002	0.0001	0.0004	0.0001	0.0002
345	0.1845	0.1831	0.1836	0.1831	0.1837	0.183	0.1838	0.183	0.1834
	0.1845	0.183	0.1835	0.1833	0.1839	0.1833	0.1841	0.1829	0.1833
	0.1845	0.1831	0.1837	0.1828	0.1834	0.183	0.1832	0.1832	0.1839
Average	0.1845	0.1831	0.1836	0.1831	0.1837	0.1831	0.1837	0.1830	0.1835
stdev.	0.0001	0.0001	0.0001	0.0003	0.0003	0.0002	0.0005	0.0002	0.0003
390-3	0.185	0.1826	0.1831	0.1826	0.1828	0.1824	0.1824	0.1829	0.1834
	0.185	0.1827	0.1835	0.1826	0.1826	0.1822	0.1823	0.1826	0.1832
	0.185	0.1827	0.1833	0.183	0.1838	0.1824	0.1824	0.1822	0.1826
Average	0.1850	0.1827	0.1834	0.1828	0.1831	0.1823	0.1824	0.1824	0.1829
stdev.	0.0000	0.0001	0.0002	0.0002	0.0006	0.0001	0.0001	0.0003	0.0004

77PSL4-1 FROM PRODUCTION LINE

Measurement location

	H	1	2	3	4	5	6	7	8
sample 1	0.1857	0.1838	0.1853	0.1835	0.1838	0.1836	0.1839	0.1841	0.1847
	0.1856	0.1841	0.1852	0.1837	0.1845	0.1836	0.1838	0.1835	0.184
	0.1856	0.1836	0.1847	0.1842	0.1849	0.1837	0.184	0.1836	0.1841
Average	0.1856	0.1838	0.1851	0.1838	0.1844	0.1836	0.1839	0.1838	0.1843
stdev.	0.0001	0.0003	0.0003	0.0004	0.0006	0.0001	0.0001	0.0003	0.0004
sample 2	0.1855	0.184	0.1842	0.1836	0.1842	0.1835	0.1842	0.1841	0.1846
	0.1854	0.1841	0.185	0.184	0.1848	0.1843	0.1848	0.1838	0.1844
	0.1854	0.1838	0.1849	0.1834	0.1839	0.1834	0.1838	0.1832	0.1836
Average	0.1854	0.1840	0.1847	0.1837	0.1843	0.1838	0.1843	0.1837	0.1842
stdev.	0.0001	0.0002	0.0004	0.0003	0.0005	0.0005	0.0005	0.0005	0.0005
sample 3	0.185	0.1829	0.1832	0.1829	0.1827	0.1831	0.1839	0.1836	0.1839
	0.185	0.1829	0.1834	0.1825	0.1824	0.1827	0.1832	0.183	0.1831
	0.185	0.1827	0.183	0.1826	0.1822	0.1828	0.1832	0.183	0.1832
Average	0.1850	0.1828	0.1832	0.1827	0.1824	0.1829	0.1834	0.1832	0.1834
stdev.	0.0000	0.0001	0.0002	0.0002	0.0003	0.0002	0.0004	0.0003	0.0004

77PSL2-1 FROM THE LINE

Measurement location

	H	1	2	3	4	5	6	7	8
sample 1	0.1855	0.1848	0.1847	0.1857	0.1866	0.185	0.1857	0.1846	0.185
	0.1854	0.1846	0.186	0.1842	0.1852	0.185	0.1854	0.1852	0.1862
	0.1853	0.1849	0.1869	0.1854	0.1862	0.1854	0.1858	0.1846	0.1851
Average	0.1854	0.1848	0.1859	0.1851	0.1860	0.1851	0.1856	0.1847	0.1854
stdev.	0.0001	0.0002	0.0011	0.0008	0.0007	0.0002	0.0002	0.0004	0.0007
sample 2	0.189	0.1853	0.1849	0.1854	0.1853	0.1852	0.1855	0.1862	0.1865
	0.189	0.1856	0.1847	0.1851	0.1854	0.1857	0.1856	0.1862	0.1862
	0.189	0.1853	0.1856	0.1858	0.1866	0.1856	0.1861	0.1859	0.1862
Average	0.1890	0.1854	0.1851	0.1854	0.1858	0.1855	0.1857	0.1861	0.1863
stdev.	0.0000	0.0002	0.0005	0.0004	0.0008	0.0003	0.0003	0.0002	0.0002
sample 3	0.189	0.1857	0.186	0.1862	0.1879	0.1859	0.1857	0.1865	0.1867
	0.189	0.1862	0.1865	0.1862	0.1877	0.1858	0.1863	0.185	0.1864
	0.1889	0.1859	0.1864	0.1858	0.1867	0.1859	0.1864	0.1863	0.1872
Average	0.1890	0.1859	0.1863	0.1861	0.1874	0.1859	0.1865	0.1860	0.1868
stdev.	0.0001	0.0003	0.0003	0.0002	0.0006	0.0001	0.0002	0.0003	0.0004

77PSL4-1 LEAKY SWITCHES

AVE IN	stdev.	AVE OUT	stdev.	AVE TOT.	stdev	Delta	stdev.
0.1824	0.0003	0.1832	0.0002	0.1828	0.0005	0.0019	0.0005
0.1823	0.0003	0.1830	0.0002	0.1826	0.0005		
0.1825	0.0004	0.1829	0.0003	0.1827	0.0004		
0.1824	0.0003	0.1830	0.0006	0.1827			
				0.0005			
0.1830	0.0004	0.1828	0.0003	0.1829	0.0006	0.0019	0.0006
0.1830	0.0005	0.1828	0.0006	0.1829	0.0007		
0.1831	0.0005	0.1828	0.0004	0.1830	0.0007		
0.1830	0.0004	0.1828	0.0006	0.1829			
				0.0006			
0.1831	0.0001	0.1836	0.0000	0.1833	0.0003	0.0012	0.0004
0.1831	0.0002	0.1837	0.0002	0.1834	0.0004		
0.1830	0.0002	0.1836	0.0002	0.1833	0.0004		
0.1831	0.0001	0.1836	0.0003	0.1834			
				0.0004			
0.1827	0.0002	0.1829	0.0002	0.1828	0.0003	0.0023	0.0004
0.1826	0.0002	0.1829	0.0002	0.1827	0.0004		
0.1826	0.0003	0.1830	0.0003	0.1828	0.0005		
0.1826	0.0002	0.1829	0.0006	0.1828			
				0.0004			

77PSL4-1 FROM PRODUCTION LINE

AVE IN	stdev.	AVE OUT	stdev.	AVE TOT.	stdev	Delta	stdev.
0.1838	0.0003	0.1844	0.0003	0.1841	0.0006	0.0015	0.0006
0.1837	0.0003	0.1844	0.0001	0.1841	0.0006		
0.1838	0.0003	0.1844	0.0002	0.1841	0.0006		
0.1838	0.0002	0.1844	0.0006	0.1841			
				0.0006			
0.1839	0.0002	0.1843	0.0002	0.1841	0.0005	0.0014	0.0005
0.1841	0.0002	0.1846	0.0002	0.1844	0.0004		
0.1835	0.0003	0.1841	0.0001	0.1838	0.0006		
0.1838	0.0003	0.1844	0.0006	0.1841			
				0.0005			
0.1831	0.0003	0.1834	0.0003	0.1833	0.0006	0.0020	0.0004
0.1828	0.0002	0.1830	0.0002	0.1829	0.0003		
0.1828	0.0002	0.1829	0.0002	0.1828	0.0003		
0.1829	0.0003	0.1831	0.0006	0.1830			
				0.0004			

77PSL2-1 FROM THE LINE

AVE IN	stdev.	AVE OUT	stdev.	ave tot	stdev	Delta	stdev.
0.1850	0.0005	0.1866	0.0006	0.1863	0.0007	0.0031	0.0007
0.1848	0.0004	0.1857	0.0004	0.1862	0.0007		
0.1851	0.0004	0.1860	0.0004	0.1858	0.0006		
0.1849	0.0004	0.1857	0.0007	0.1859			
				0.0007			
0.1856	0.0006	0.1866	0.0004	0.1866	0.0005	0.0033	0.0005
0.1857	0.0006	0.1866	0.0004	0.1858	0.0005		
0.1857	0.0003	0.1862	0.0001	0.1859	0.0006		
0.1856	0.0004	0.1857	0.0006	0.1867			
				0.0005			
0.1859	0.0002	0.1866	0.0002	0.1864	0.0007	0.0036	0.0006
0.1861	0.0002	0.1867	0.0002	0.1864	0.0006		
0.1860	0.0002	0.1867	0.0002	0.1863	0.0006		
0.1860	0.0002	0.1867	0.0006	0.1864			
				0.0006			

PS/99/07

77PS Life Cycle Test to Leakage

Abstract

The purpose of this life cycle test was to quantify the life expectancy of 77PS hydraulic pressure switches. A sample of switches was cycled under specified conditions until leakage occurred. Upon leakage, the suspect switch was removed and the number of cycles recorded. Weibull Failure Analyses were then performed on the data.

Procedure

(36) 77PS switches were used as a test sample. The switches were placed in an oven where a temperature of 135°C was maintained. The switches were cycled from 8 psi to 1500 psi at a frequency of 2 Hz. When a leaky switch was detected, the test was suspended and the switches were allowed to cool to ambient temperature. The leaky switch was removed and the number of cycles noted. The remaining switches were brought back up to 135°C and testing resumed.

Data

Summary:	Temperature:	135°C
	Pressure (low):	8 psi
	Pressure (high):	1500 psi
	Frequency:	2 Hz

Table 1. below, shows the raw data obtained.

Table 1.

Quantity of samples	Cycles to Leakage (*indicates switches did not leak to specified cycles)
1	728000
2	1075000
3	1095000
1	1200925
1	1208509
2	1212896
26	1212896*

Note: Some switches leaked at the same time; this is reflected in the above table where there are multiple quantities for the same cycles to leakage.

Figure 2.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

CLICK here to recalculate if failure data or "Minimum life" input value is altered

○ Exponential
○ Lognormal
◉ Weibull

Time to failure	Suspended
1076000	
1076000	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S
[illegible]	S

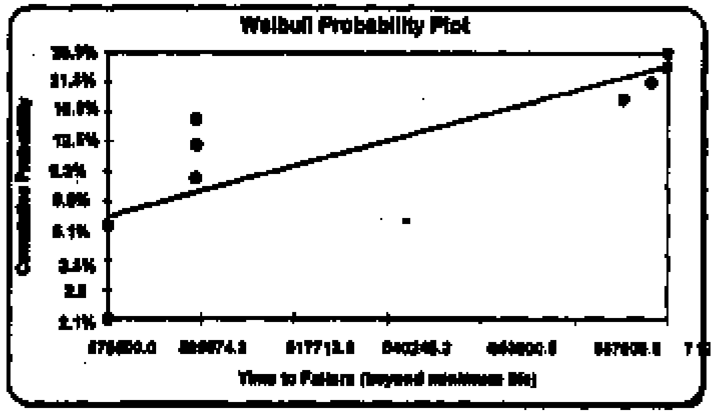
Minimum life
[illegible]

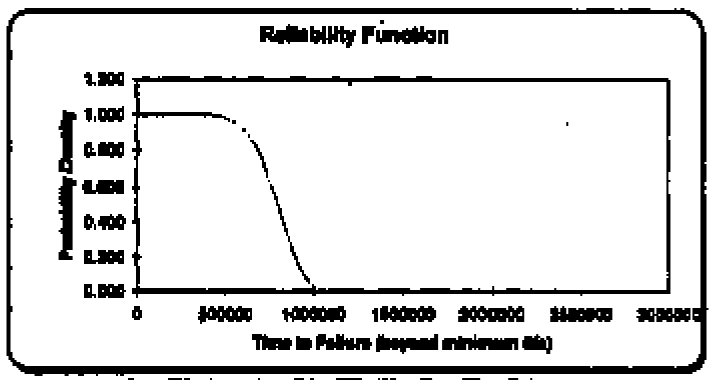
Time (cycle)	Reliability %
1000000	[illegible]

Reliability %	Time (cycle)
[illegible]	[illegible]

Calculated Outputs

α = [illegible]
β = [illegible]
R^2 = [illegible]





NOTES: 77PS 72?K cycle data point not included in analysis

TI-NHTSA 014680

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

Refer to Brake Pressure Switch Test Log.

Level 1:

Objective:

Overall objective: Determine if a switch ignition can occur in the laboratory and what conditions are required to create an ignition.

Test 1 Objective: Determine if switch ignition can occur under the following conditions:
Switch contact 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.

Test 2 Objective: Determine if switch ignition can occur under the following conditions:
Switch contact flooded with brake fluid mixed with varying amounts of % H_20.
14 volts applied to one terminal, second terminal connected to a 14 Ω resistor tied to ground. (1 Amp load across switch terminals).
Switch hexport electrically grounded.

Test 6 Objective: Determine if switch ignition can occur under the following conditions:
Heater element installed in contact cavity of the switch.
Power applied to the heating element until plastic base failure.

External spark applied to fumes from burn.
Brake fluid present in the contact cavity (wet device) and not present in the contact cavity (dry device).

Results:

Test 1 Results: No ignition occurred. No significant temperature rise observed. Current draw ranged from 0.5 mAmps to 5 mAmps over a period greater than (250) hours.

Test 2 Results: No ignition occurred. No significant temperature rise observed for a period greater than (250) hours.

Test 6 Results: Ignition occurred in both wet and dry 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 externally applied spark ignited the fumes which engulfed the switch.
Dry device: The internal temperature of a wet switch reached over 1000°F. The switch base flopped over. The externally applied spark ignited the fumes which engulfed the switch.

Conclusion:

A switch ignition can occur under the following laboratory conditions:

-5 Watts of electrical power is dissipated as heat into the switch for (15) minutes using a heating wire. (Source of heat to melt plastic)
-A supply of Oxygen is available. (Hole burns through switch base).
-An external spark is applied. (Hy-Pot tester ignites fumes of switch).

Brake fluid does not contribute to the ignition process

Level 2:

Objective:

Overall Objective: Determine if an 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.

Test 6c Objective: Determine if brake fluid with metal shavings is conductive enough to create an ignition.

TI-NHTSA 014582

Send test log w/ 6C update

Doug. Oberski

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: Refer to Test Log - - -

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

Level 1:

Objective:

Overall objective: Determine if a switch ignition ~~will~~ can occur in the lab and what conditions are necessary to create an ignition.

Test 1 Objective: Determine if switch ignition can occur under the following conditions:
Switch contact 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.

Test 2 Objective: Determine if switch ignition can occur under the following conditions:
Switch contact flooded with brake fluid mixed with varying amounts of % H_20.
14 volts applied to one terminal, second terminal connected to a 14 Ω resistor tied to ground. (1 Amp load across switch terminals).
Switch hexport electrically grounded.

Test 6 Objective: Determine if switch ignition can occur under the following conditions:
Heater element installed in contact cavity of the switch.
Power applied to the heating element until plastic base failure.
External spark applied to fumes from burn.

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Brake fluid present in the contact cavity (wet device) and not present in the contact cavity (dry device).

Results:

Test 1 Results: No ignition occurred. No significant temperature rise observed. Current draw ranged from 0.5 mAmps to 5 mAmps over a period greater than (250) hours.

Test 2 Results: No ignition occurred. No significant temperature rise observed for a period greater than (250) hours.

Test 6 Results: Ignition occurred in both wet and dry 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 externally applied spark ignited the fumes which engulfed the switch.
Dry device: The internal temperature of a wet switch reached over 1000°F. The switch base flopped over. The externally applied spark ignited the fumes which engulfed the switch.

Conclusion:

A switch ignition can occur under the following laboratory conditions:

-5 Watts of electrical power is dissipated as heat into the switch for (15) minutes (using a heater wire)
(Source of heat to melt plastic)
-A supply of Oxygen is available. (Hole burns through switch base).
-An external spark is applied. (Hy-Pot tester ignites fumes of switch).

Brake fluid does not contribute to the ignition process

Level 2:

Objective:

Overall Objective: Determine if an 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.

Test 6c Objective: Determine if brake fluid with metal shavings is conductive enough to create an ignition.

Test 7 Objective: Determine if switches meet cycle life specification.

~~Tests 8, 10 and 13b Objective: Characterize switches using a DOE.~~

Test 15a Objective: Determine if long time switch exposure to brake fluid can lead to an ignition.

Results:

Test 6a Results: A 5% NaCl in H_20 solution can corrode switch electrical components and cause an increase in electrical resistance. Repeated injections of the NaCl in H_20 solution, with the switch powered, can cause a switch ignition.

Test 6c Results: Brake fluid with metal shavings does not conduct significant current.

Test 7 Results: Life cycle testing showed that switches ~~met~~ exceeded cycle life specification. ~~First leak on [illegible] at 778,000 cycles.~~ [illegible]

~~Tests 8, 10 and 13b Results: DOE results under investigation.~~

Test 15a Results: Test is ongoing. Results to date show no increase in conductivity of both new and used brake fluid. After X hours current draw on all devices is less than 25mA.

Conclusion:

A switch ignition can occur under the following laboratory conditions:
5% NaCl in H_20 solution is injected into contact cavity of a switch.
14 Volts is applied to the switch.
Hexport is grounded.
Current is limited at 15 Amps.

Brake fluid with metal shavings is not conductive enough to create an ignition.

Switches meet engineering cycle life specification.

Long duration switch exposure to brake fluid has had no measurable effect on switches. ~~Brake fluid appears to be benign to the switch.~~ After X hours current draw is significantly below the required level need for switch ignition based on the laboratory test results

Level 3:

Objective:

Test 6b Objective: Understand the ignition process, determine the current path and establish a repeatable ignition method.

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Results:

Test 6b Results: Multiple attempts at ignition, via injection of a 5% 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:

laboratory

A repeatable method of switch ignition has been established. Based on hexport current measurements, the current path is from switch terminals to hexport body. When a NaCl in H_2O solution is repeatedly injected into contact cavity of powered switches, electrolytic corrosion of the switch terminals 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:

laboratory

Objective:

Overall Objective: Compare and contrast variables influencing ignition using the established ignition method.

Test 13a Objective: Compare various fluids in the established ignition method.

Test 15 Objective: Compare the burn characteristics of various plastics as switch base material.

Test 15b Objective: Compare: 1) the probability of switch ignition in the vertical position verses a 45° orientation and 2) the probability of switch ignition as a function of rotational angle in the 45° orientation.

Results:

Test 13 Results: A switch filled with 5% 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 hexport current draw and showed no signs of corrosion.

Test 15 Results: When 5% 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 1out of 5 attempts ~~, but the power required to reach ignition was higher than that of other materials tested.~~

Test 15b Results: Switch ignitions have occurred in different rotational angles.

Conclusion:

Brake fluid is not ~~ionic~~ conductive enough to cause the electrolytic corrosion and necessary to create an ignition. Because of its' significantly higher conductivity, an ionic rich fluid such as NaCl in H_20 is necessary to cause an ignition.
~~Zytel had a lower burn probably than other materials tested. It also took more power, thus higher temperatures, to ignite Zytel than other materials tested~~.
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: To test proposed relay circuit.

Results:

A switch was injected with 5%Nacl in H_20 solution and placed in a 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 intact.
A 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 placed in the proposed relay circuit for(18) hours where it drew 160 mAmps, showed no visible activity and did not result in a burn. 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 the switch and 0.75 Watts of power was dumped into 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 not enough power to cause ~~electrolytic corrosion~~ significant heating necessary for ignition. In previous tests, using a resistor as the heating element, approximately 5 Watts of power was necessary to create and ignition. There is not enough power in the proposed circuit to create ignition.