EA02-025

TEXAS INSTRUMENTS, INC.'S 9/10/03 ATTACHMENT

REQUEST NO. 7

BOX 8

PART A-U

PART P

1999 3 18 3:17:26 PM MVC-FD91

Digital Mavica images

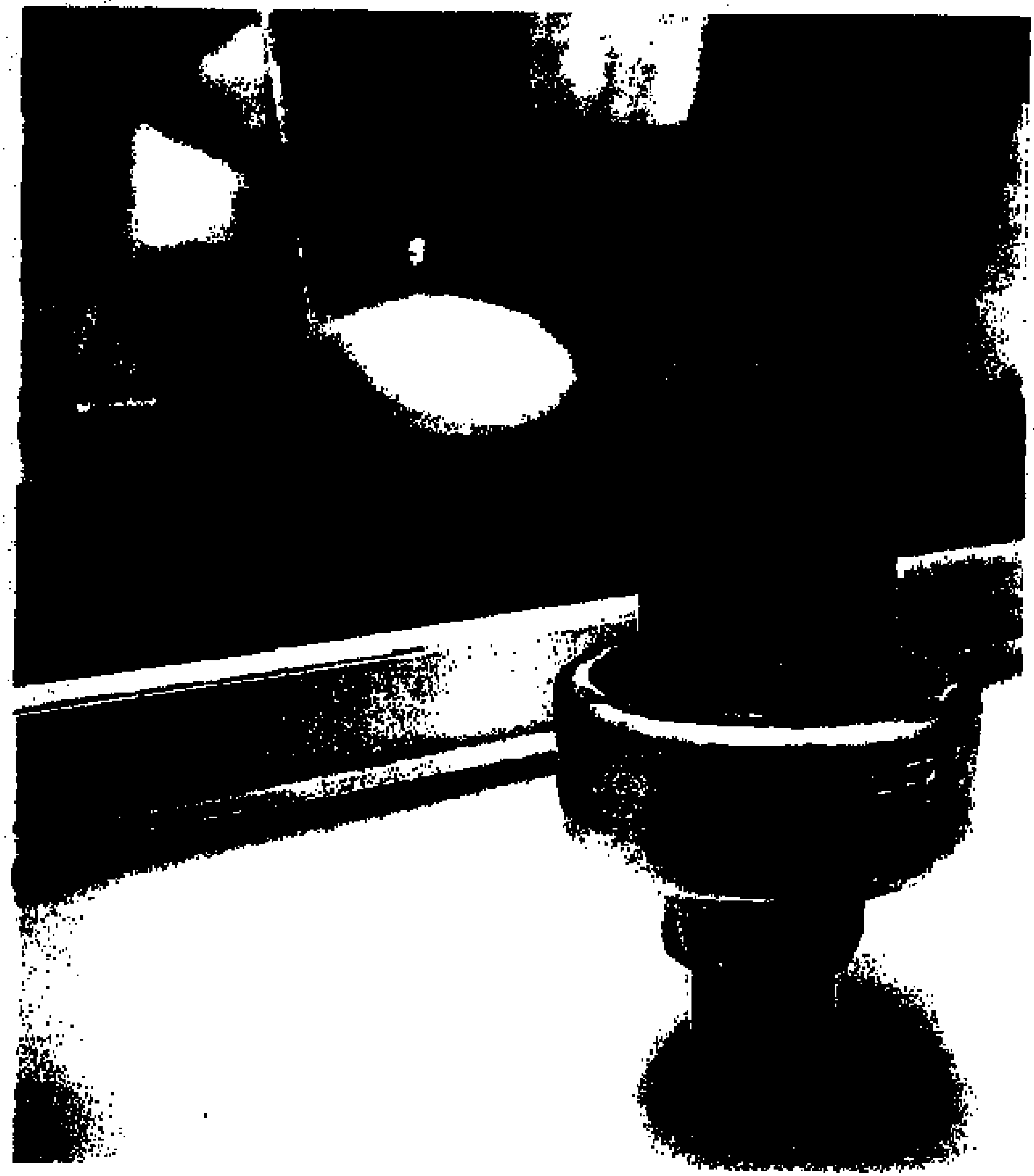
10 mavica images 133 Kbytes free

MVC-001X.JPG	1999	3	18	1:12:16	PM
MVC-002X.JPG	1999	3	18	1:12:48	PM
MVC-003X.JPG	1999	3	18	1:15:16	PM
MVC-004X.JPG	1999	3	18	1:24:42	PM
MVC-005X.JPG	1999	3	18	1:27:42	PM
MVC-006X.JPG	1999	3	18	1:29:02	PM
MVC-007X.JPG	1999	3	18	3:06:42	PM
MVC-008X.JPG	1999	3	18	3:10:28	PM
MVC-009X.JPG	1999	3	18	3:15:42	PM
MVC-010X.JPG	1999	3	18	3:17:26	PM

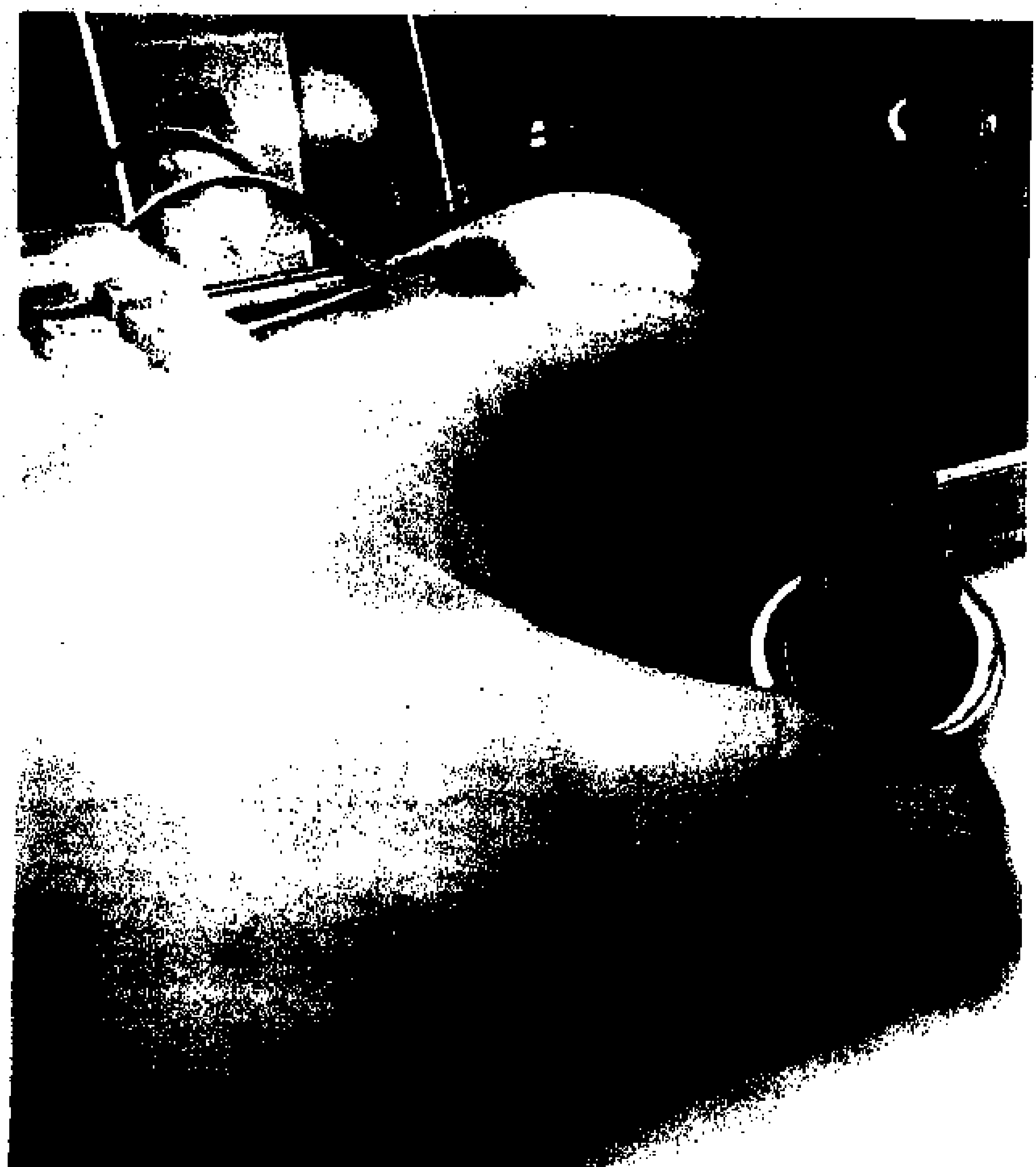
This document contains the following shortcuts:

Shortcut Text	Internet Address
MVC-001X.JPG	file:///F:/Disc%2036/MVC-001X.JPG
MVC-002X.JPG	file:///F:/Disc%2036/MVC-002X.JPG
MVC-003X.JPG	file:///F:/Disc%2036/MVC-003X.JPG
MVC-004X.JPG	file:///F:/Disc%2036/MVC-004X.JPG
MVC-005X.JPG	file:///F:/Disc%2036/MVC-005X.JPG
MVC-006X.JPG	file:///F:/Disc%2036/MVC-006X.JPG
MVC-007X.JPG	file:///F:/Disc%2036/MVC-007X.JPG
MVC-008X.JPG	file:///F:/Disc%2036/MVC-008X.JPG
MVC-009X.JPG	file:///F:/Disc%2036/MVC-009X.JPG
MVC-010X.JPG	file:///F:/Disc%2036/MVC-010X.JPG

TI-NHTSA 012924



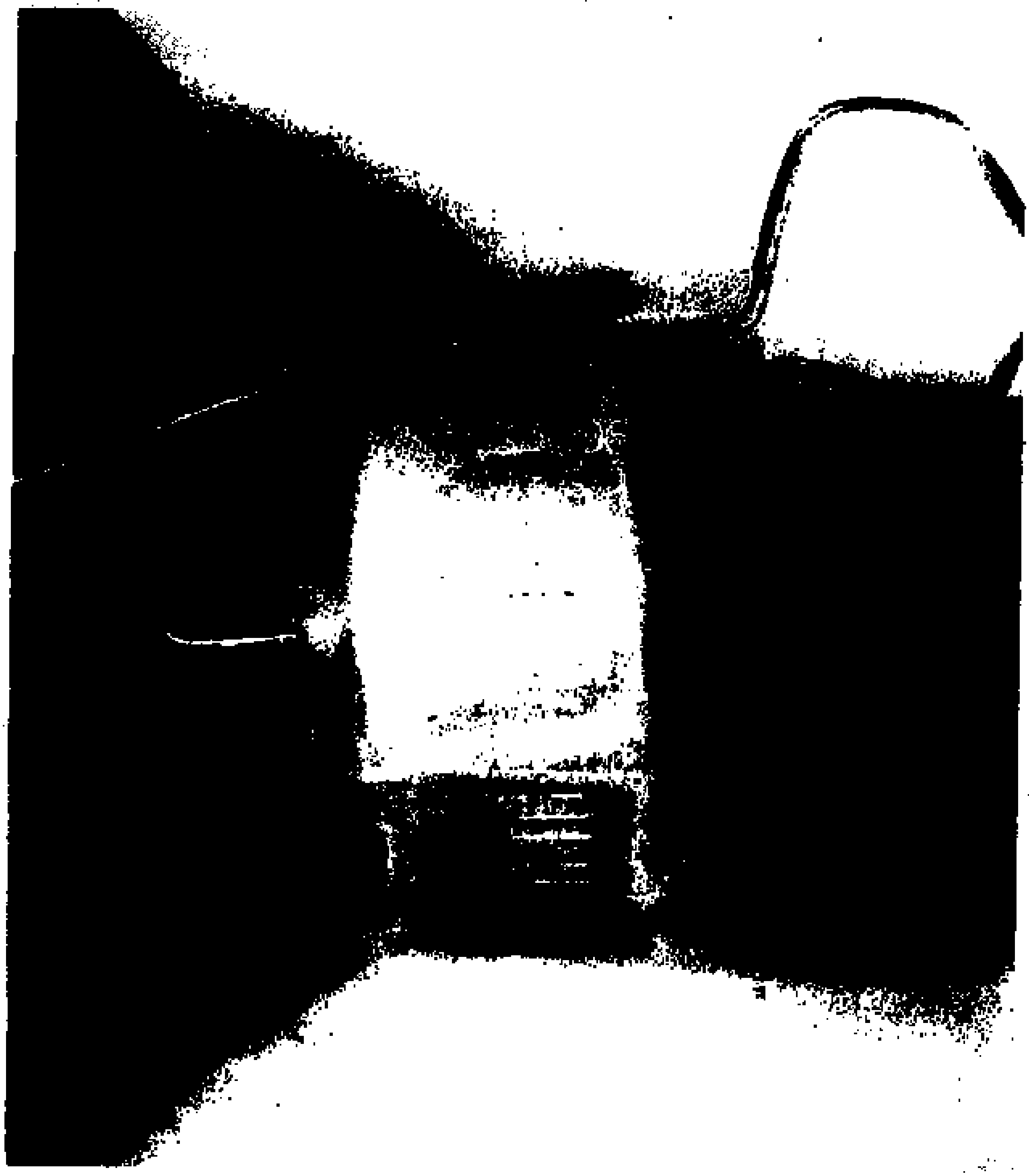
TI-NHTSA 012928



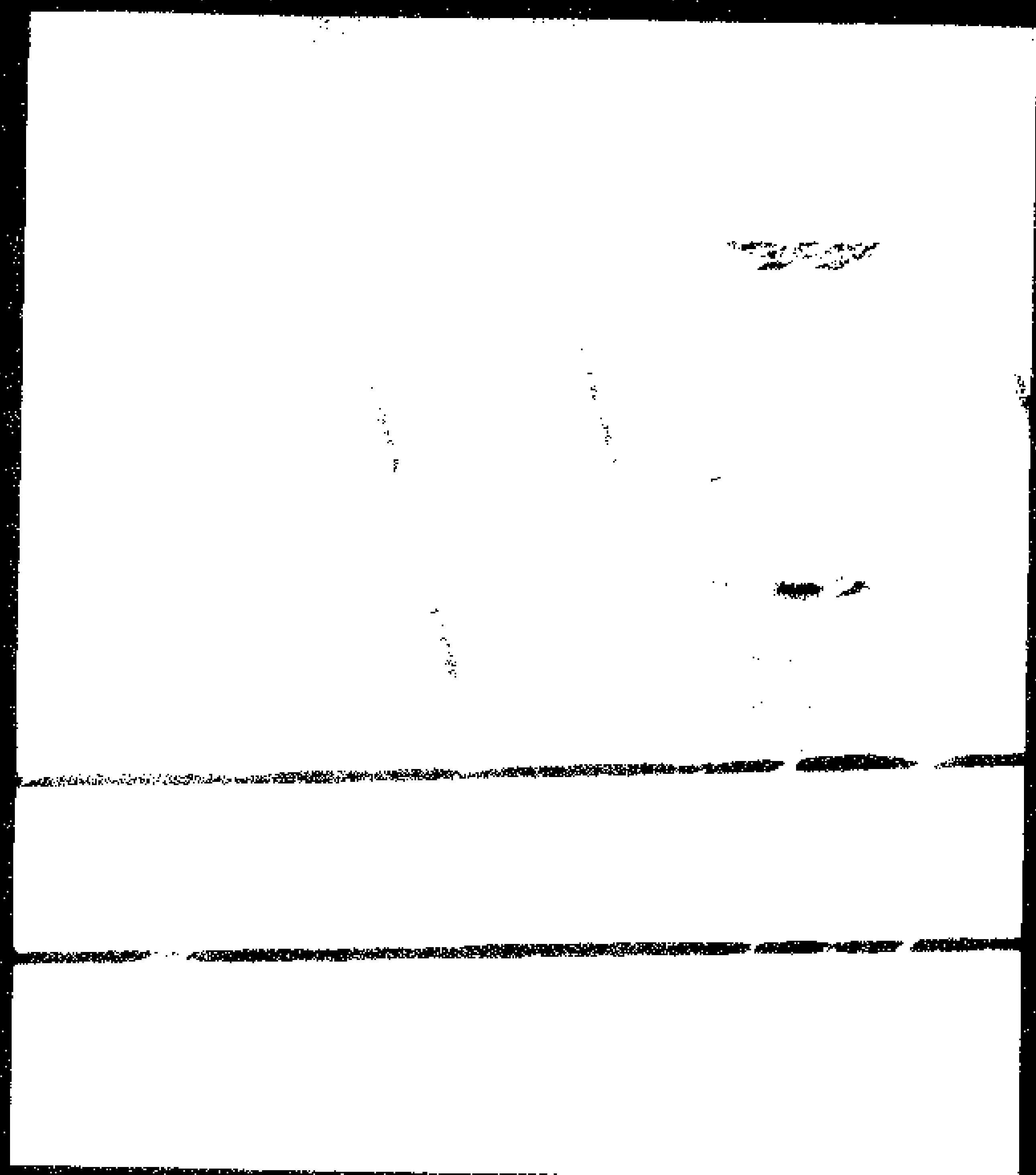
TI-NHTSA 012926

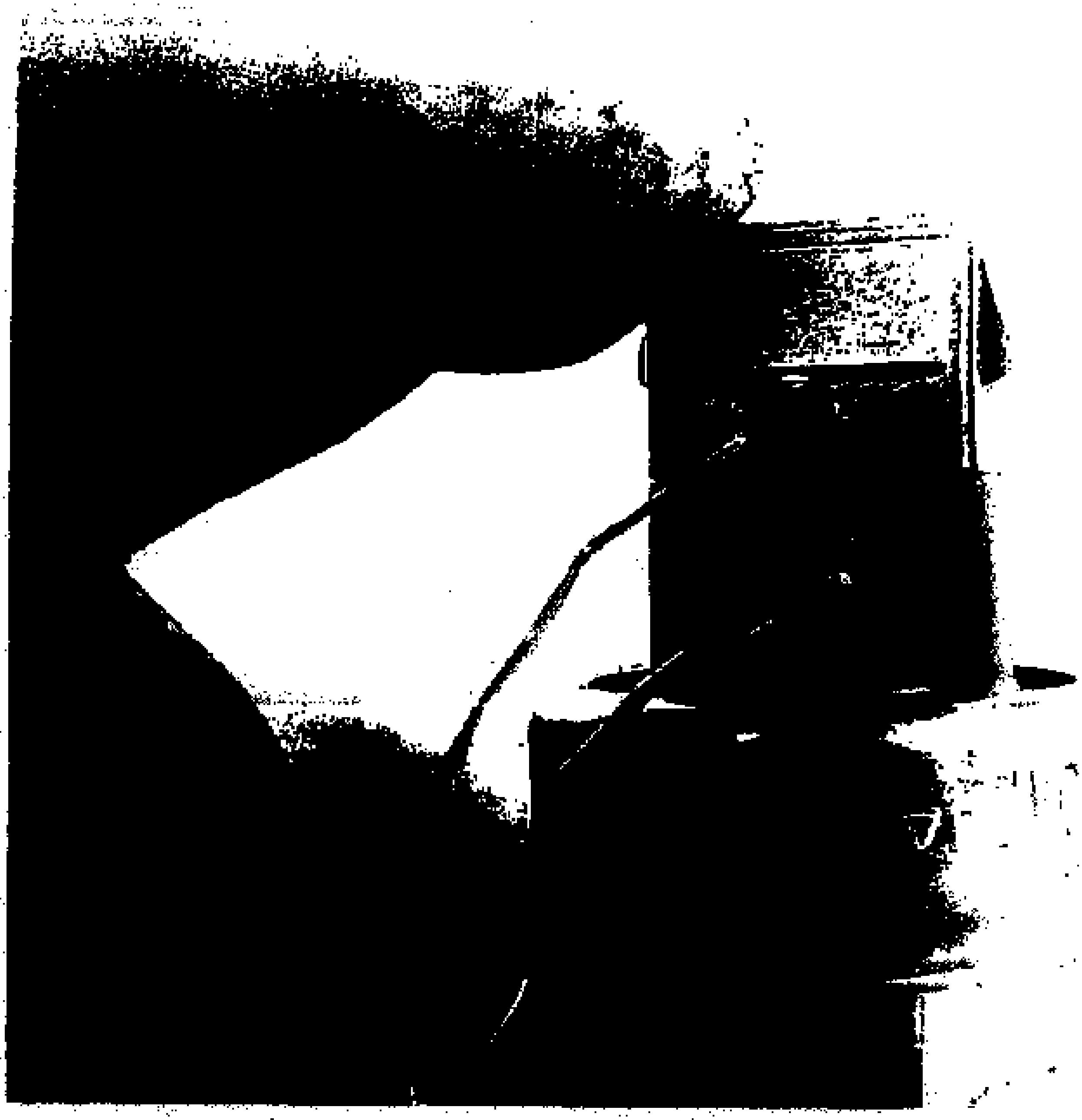
TI-NHTSA 012927

TI-NHTSA 012928

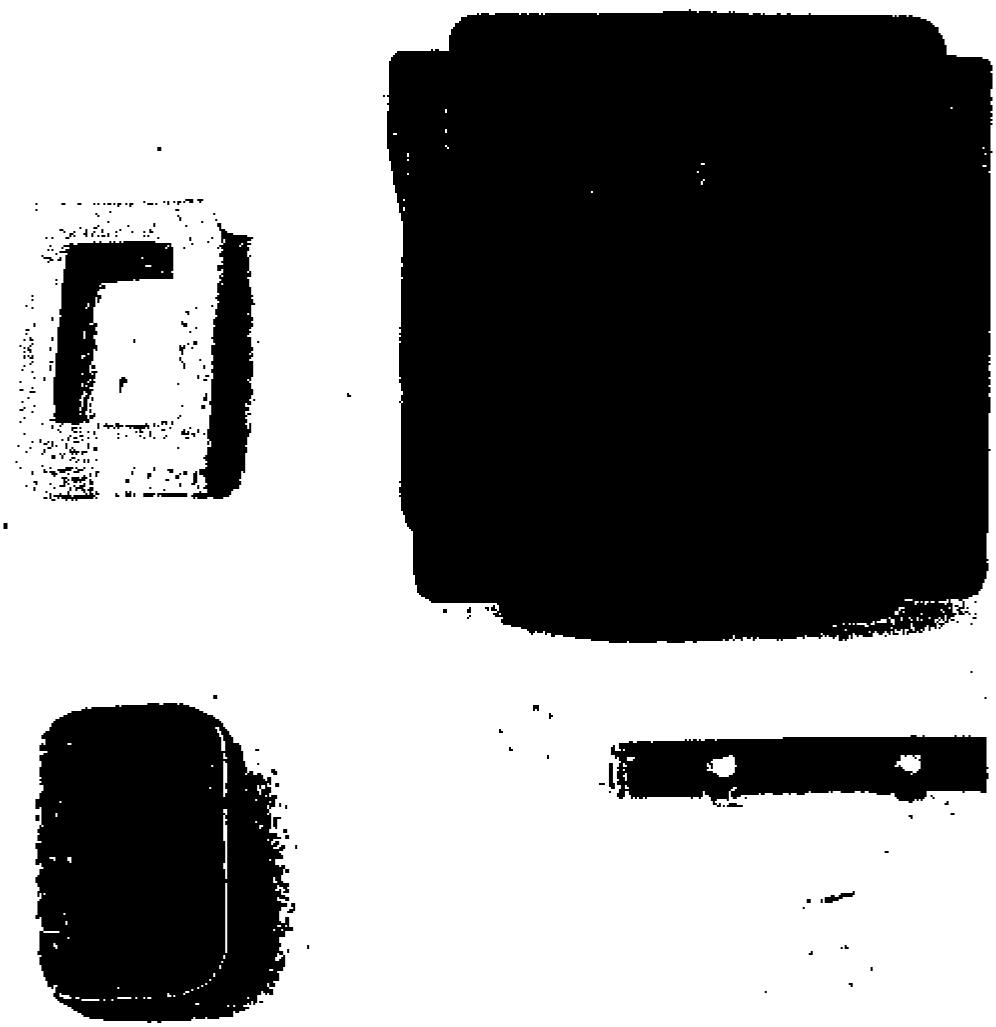


TI-NHTSA 012929





TI-NHTSA 012931



TI-NHTSA 012932

TI-NHTSA 012933

TI-NHTSA 012934

Weibull plots 2-1

3/17/99

Update
DOE 2

0%	leaks	5%	leaks
2-1	0	2-1	0
3-1	?	3-1	?
4-1	2	4-1	8 susp

725 K cycles completed | 425 K cycles compl.

TI-NHTSA 012936

Figure 1.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

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

○ Exponential
○ Lognormal
● Weibull

Time to failure	Suspended
[illegible]	
[illegible]	
[illegible]	
[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

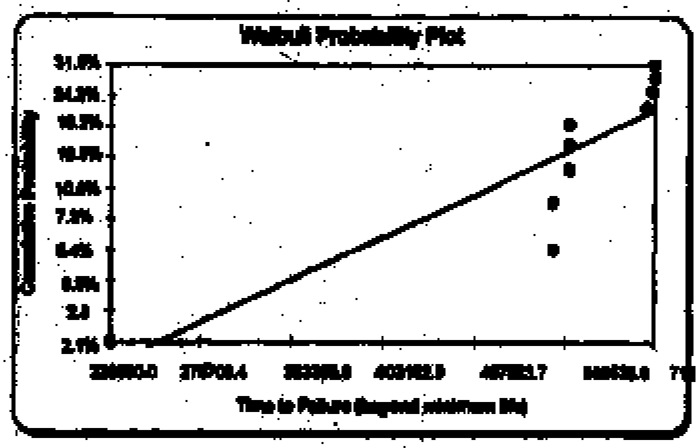
Minimum life: [illegible]

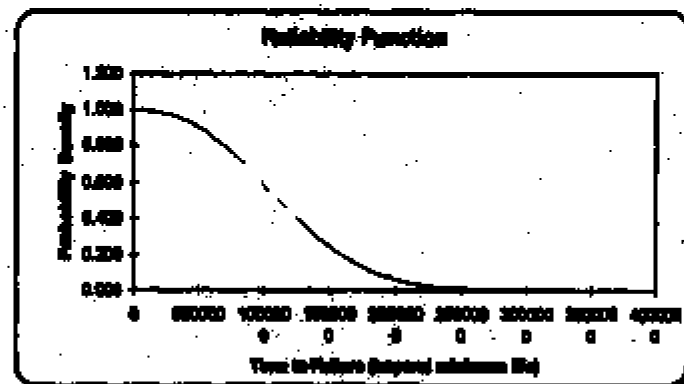
Time (cycles)	Reliability %
1000000	[illegible]

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

Calculated Outputs

α = [illegible]
β = 2.304
R^2 = 0.772





NOTES: 77P83-1 life test 720K cycle data point included in analysis

Test Date: 1/99

Figure 2.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

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

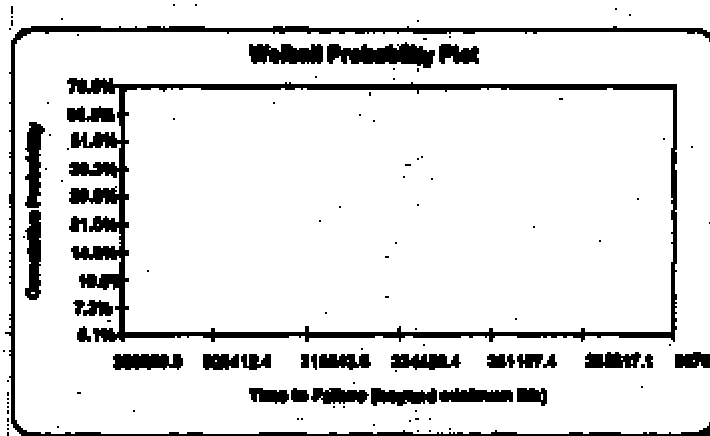
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	

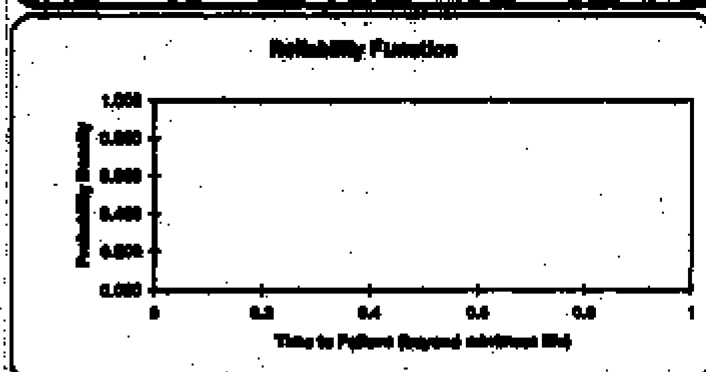
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]	[illegible]
[illegible]	[illegible]

Calculated Outputs

[illegible]





NOTES: DOE 1 Group 1: 77PSL3-1 (w/ snap) w/ 0% water in brake fluid.

Test Date: Start 2/26

Figure 2.

2 and 3 parameter WEIBULL FAILURE ANALYSIS

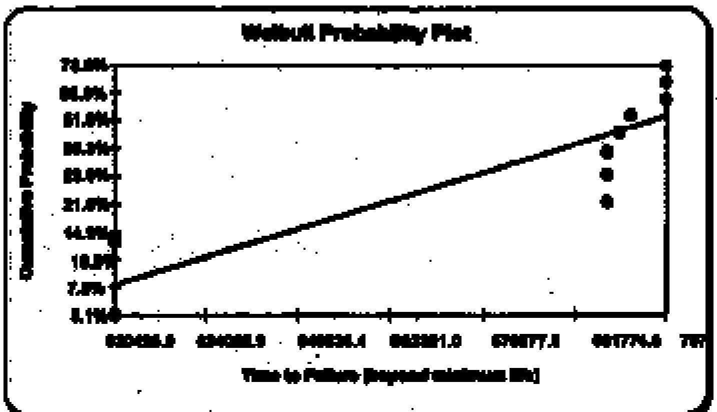
CLICK here to recalculate if failure data or "Minimum life" input value is altered

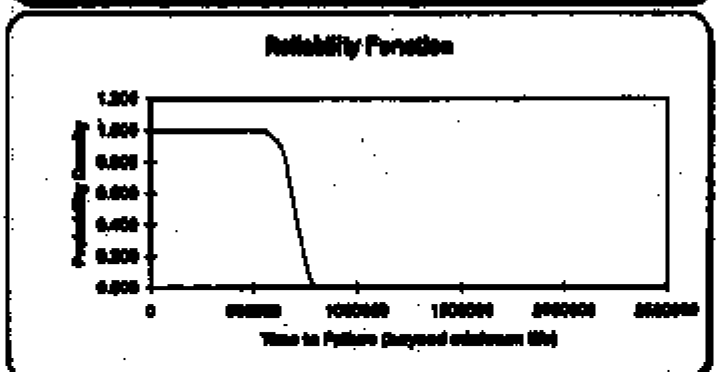
Time to failure	Suspended	Minimum life
[illegible]		[illegible]
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]		
[illegible]	[illegible]	
[illegible]	[illegible]	

[illegible]

Calculated Outputs

[illegible]





NOTES: DOE 1 Group 3: [illegible] w/ [illegible] water in brake fluid.

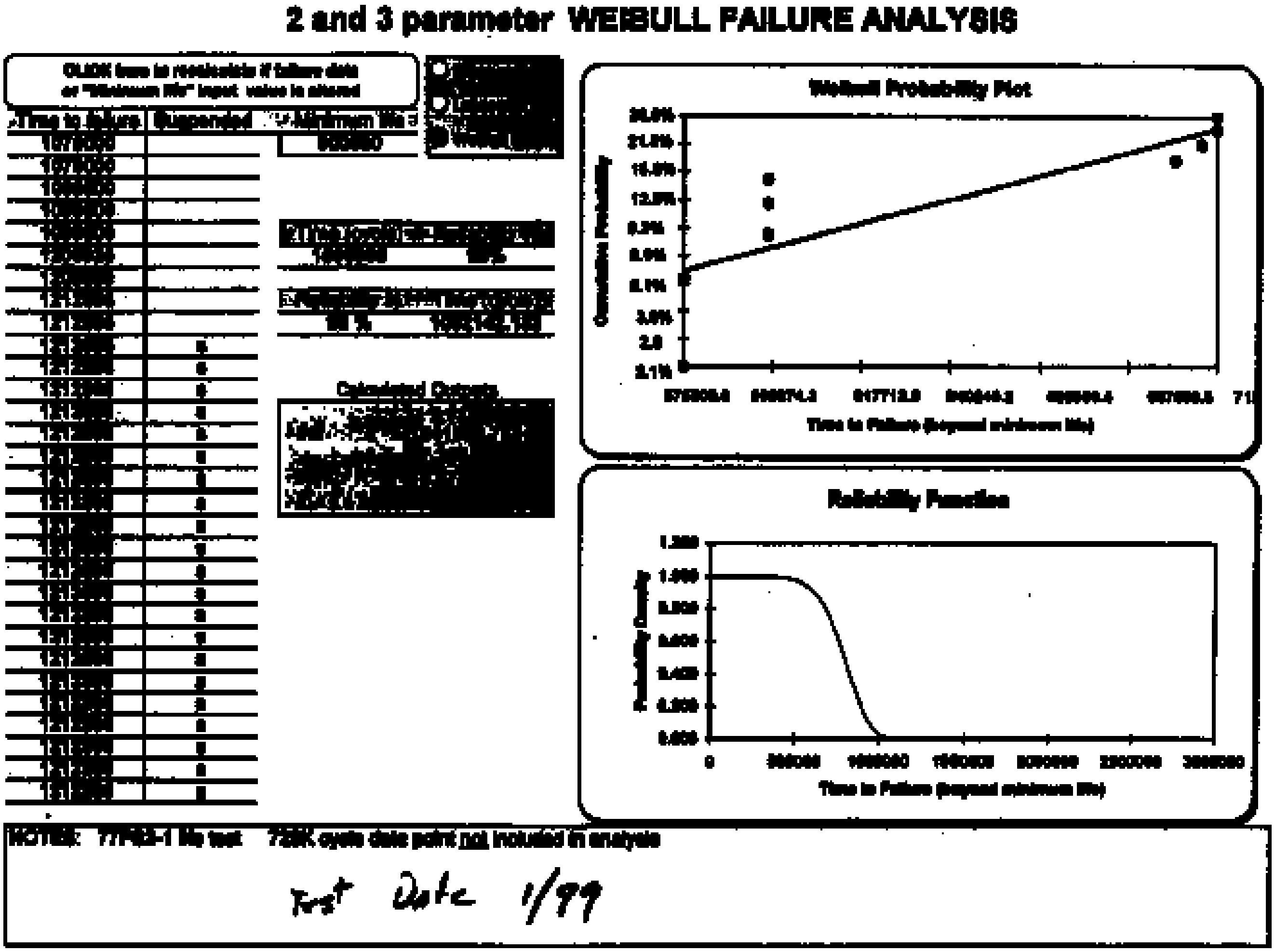
Test Date: 2/99

6

TI-NHTSA 012939

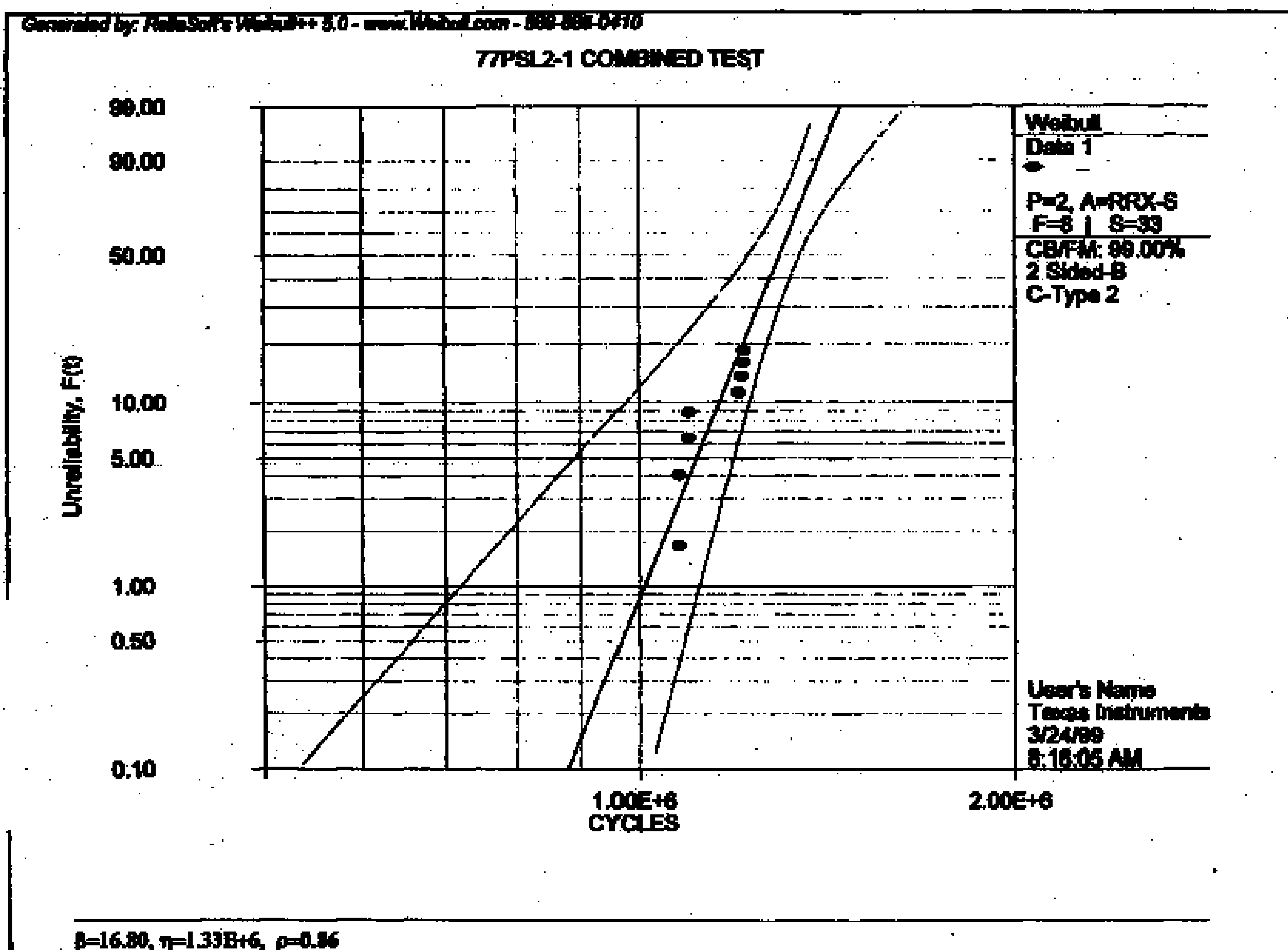
1 TI Proprietary Information: Attorney-Client Privilege Invoked

Figure 2.



TI-NHTSA 012940

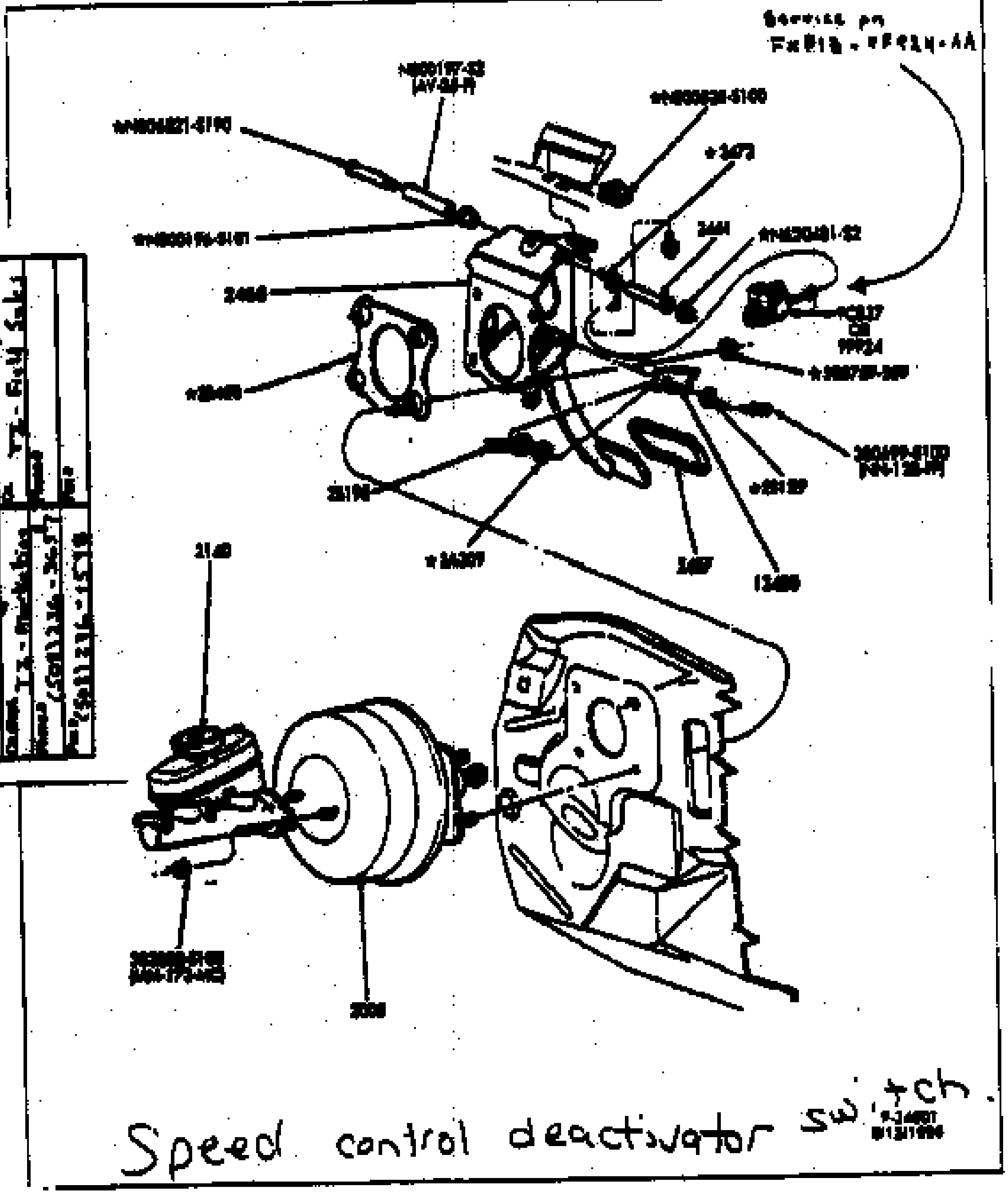
Plot of Data 1



1999 DT (Lincoln Town Car)

10 - Wheels, Brakes
BRAKES
Brake pedal and booster installation

* Speed Control
Deactivator Switch
Service pn
F[illegible]-AA



Post-it® Fax Note 7671
Date 3/10/99 pages 4
To Charlie Douglas
From Bob Sharpe
Co./Dept. TX - Field Sales
Phone # (508) 236-3617
Fax # (508) 236-1[illegible]18

CPD 2000 Version 11.04 -- January 1999

Amore, Alan

From: Dague, Bryan
Sent: Saturday, March 20, 1999 10:49 AM
To: Amore, Alan; Mulligan, Sean; Cambra, Lance
Subject: 77PS

Guys,

Just a short note to remind everyone what needs to get done this week:

Instrumented current/burn test:

- ~~Old BF~~
- Old BF w/water running 5%
- ~~Tap water~~
- ~~New BF~~
- 5% salt water and FR bases (probably 2 or 4 attempts will be needed → 24hr start 3/23

} Lance

The big report Sean is working on Sean

Long term BF and power soak needs to get started lance 3/22 start

We need to figure out why those 3-1 and 4-1 performed so poorly in the DOE Sean

I probably have missed something, but if you guys can get through all of the above stuff it will be a good week.

Good luck and keep me up to date via email and voice mail.

Regards,
Bry

TI-NHTSA 012943

Currey, Pat

From: Warner, Pam [pwarner@email.mc.ti.com]
Sent: Monday, March 22, 1999 7:55 AM
To: Watt, Jim
Cc: McGuirk, Andy

Ford 3_17_99.ppt

Jim,
Here are the foils I mentioned in my last message. I apologize that I forgot to send them.

<<Ford 3_17_99.ppt>>

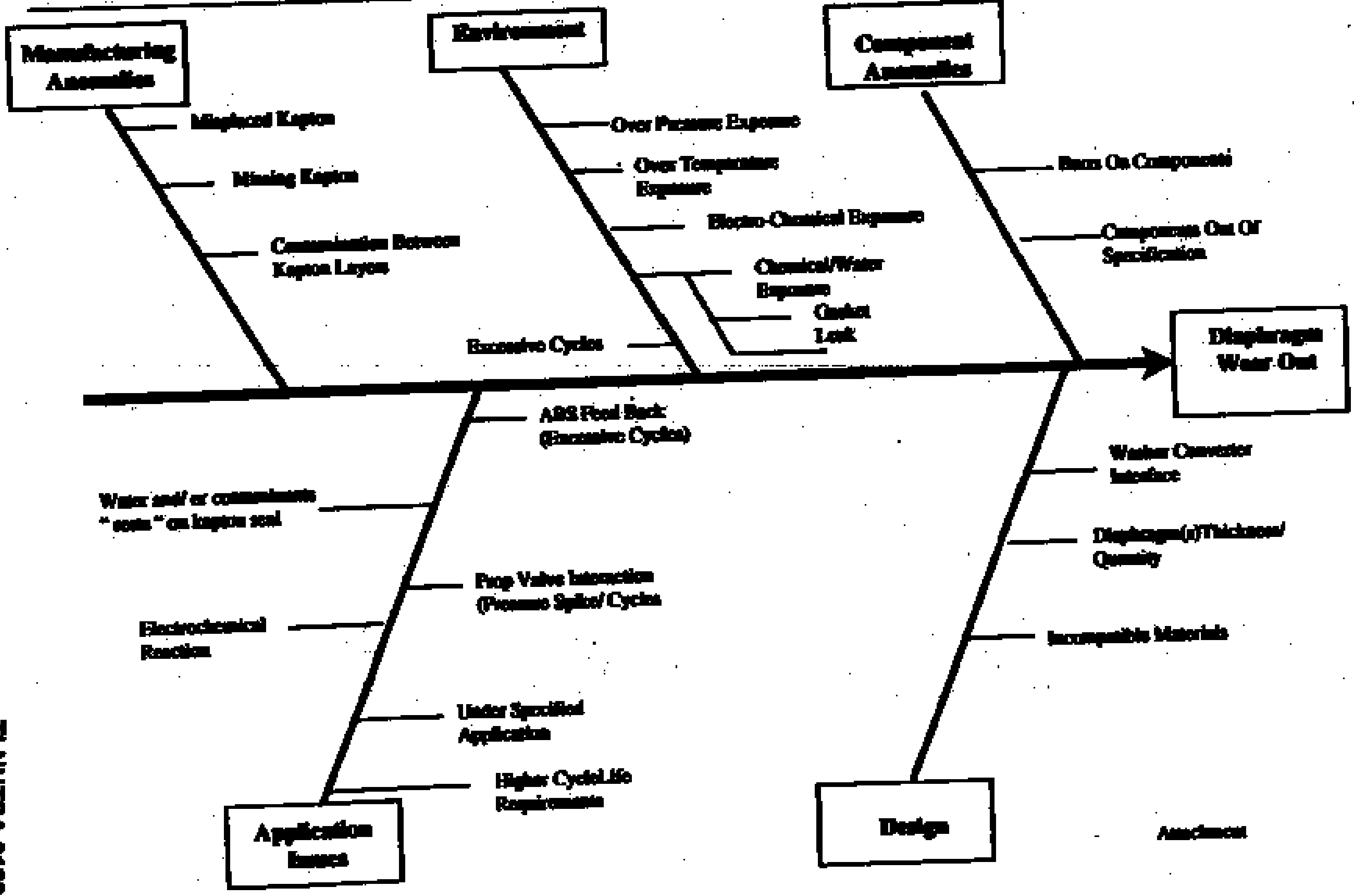
TI-NHTSA 012944

[redacted]

Brake Pressure Switch

Potential Thermal Event Theory Profile 3/24/99

Texas Instruments

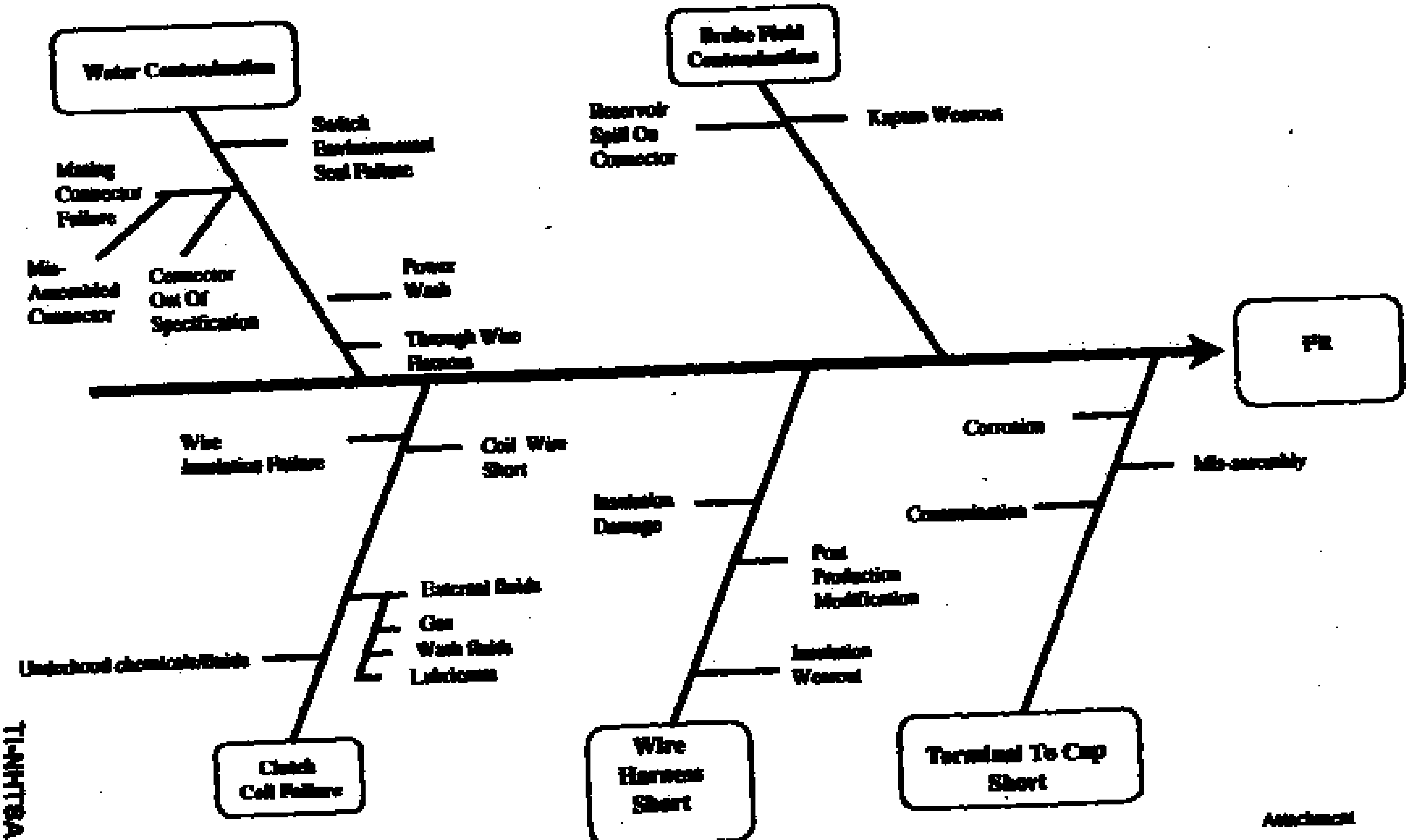


Attachment

TI-NHTSA 012846

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 3/24/99



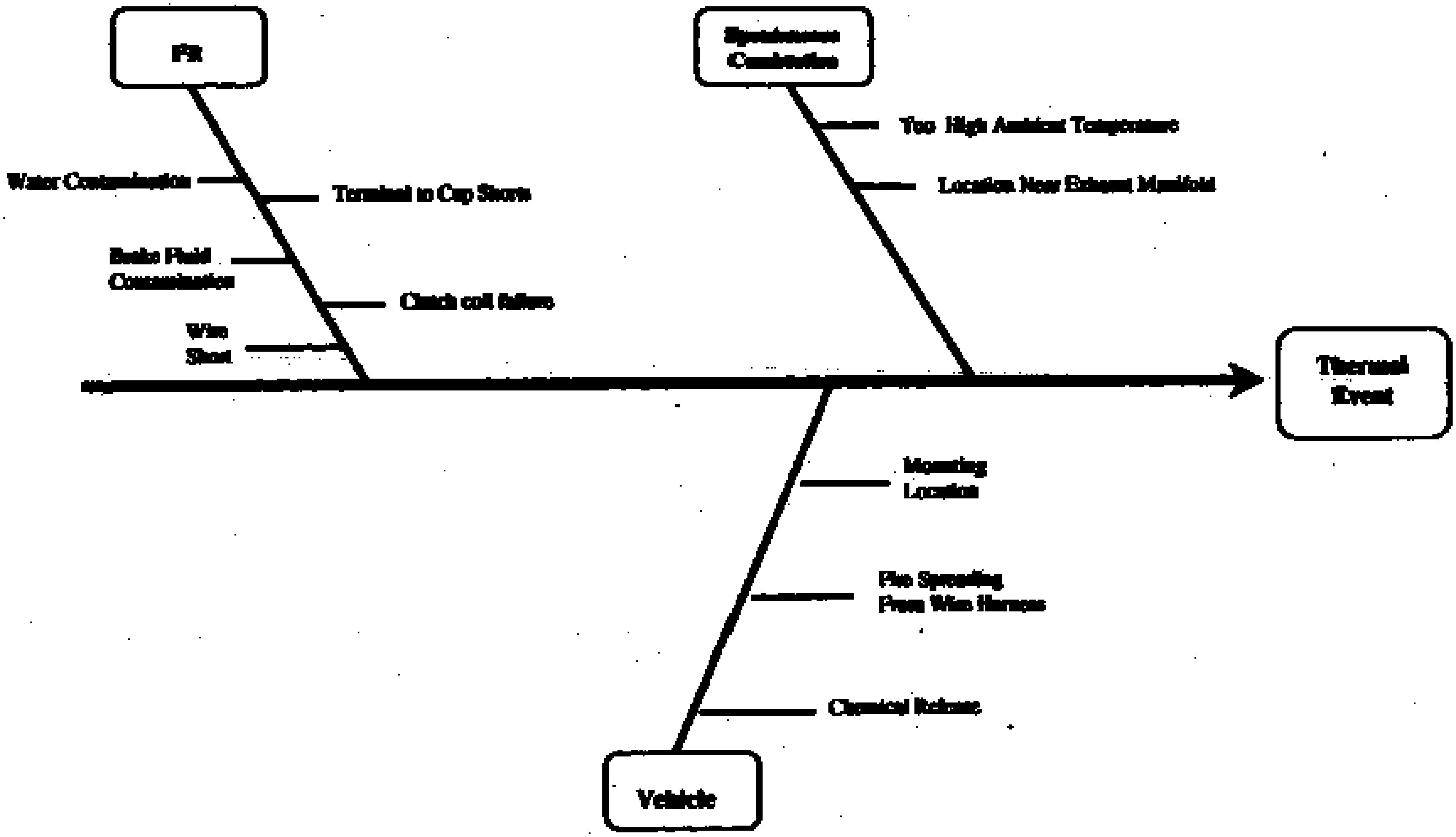
Attachment

C:/McGuire/99presentation

TI-NHTSA 012946

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 3/24/99



TI-NHTSA 012047

Attachment

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PS/99/12 REV A
3/22/99

77PS Ionic Rich Fluid Ingress Experiment

Abstract

This experiment has demonstrated that ionic rich fluid ingress into the electrical connector cavity of 77PS2-1 switches, while the switches are powered, can degrade switch components sufficiently to cause an undesired thermal event. Specifically, results show that an ionic rich fluid such as salt water is necessary to cause the level of corrosion necessary to cause an ignition.

(7) different test fluids were injected into the contact cavity of 77PSL2-1 switches for up to (24) hours with the switches powered at 14.5 Volts DC. Results have shown that brake fluid, (regardless of whether it is new or used, mixed with 5% water or without water), is not ionic enough to cause measurable corrosive effects on 77PSL2-1 switches. *over a (24) hour period. Tap water and rain water have been shown to be between (2) and (4) times as ionic as brake fluid. They have been shown to cause considerable corrosion in (24) hours or less.* It has also been shown that tap water with 5% NaCl is approximately (3) orders of magnitude more ionic than brake fluid and has caused corrosion that resulted in an ignition in less than (3) hours.

Purpose

This experiment was designed to simulate fluid ingress into the contact cavity of 77PSL2-1 switches at an accelerated rate. The intent was to quantify the corrosive effects of a matrix of fluids on the electrical components of 77PSL2-1 switches and correlate the results with specimens from the field. Once a correlation is established, a suspect fluid can be identified and the mode of ingress determined.

The test setup in this experiment was designed to emulate switch operating conditions as used in Ford applications. Each switch was mounted at a 45° angle, electrically wired to a Ford power steering clutch assembly and powered at 14.5 DC Volts.

Based on the operating environment of 77PS2-1 switches, (7) fluids were identified as possible ingress suspects. Each of these fluids was tested independently under the same operating conditions, using the same instrumentation.

Instrumentation

The following instrumentation was used to conduct this experiment.

DC Power supply.
VCR Camcorder .
HP34901A (20) channel multiplexer.
Data Acquisition System
(3) Shunts calibrated at 100 Amp = 100 mVolts.
Timer

Procedure

The following procedure was followed for the (7) fluids tested in this experiment, as shown in Table 1, below. Each fluid was tested independently and only one test was conducted at a time. A new switch was use for each fluid.

Table 1.

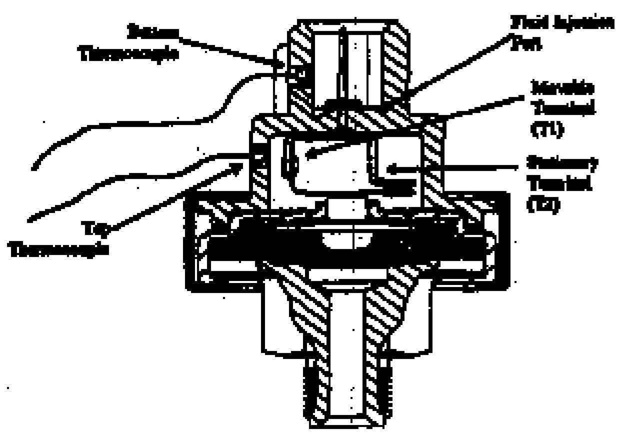
Fluid Tested	Test Duration (approximate)
Used Brake Fluid	24 hours
Used Brake Fluid with 5% Tap Water (by weight)	24 hours
New Brake Fluid	24 hours
New Brake Fluid with 5% Tap Water (by weight)	24 hours
Tap Water with 5% NaCl (by weight)	3 hours
Rain Water	3 hours
Tap Water	24 hours

A) Sample preparation.

A small hole was drilled through the base of a 77PSL2-1 switch, next to the terminal leads as shown in Figure 1, below. (This port facilitated injection of fluids into the contact cavity of the switch).

(2) holes were drilled into the side of the switch base, which did not penetrate through the base wall. A K-type thermocouple was placed in each hole as shown in Figure 1. The thermocouples were secured with epoxy.

Figure 1.



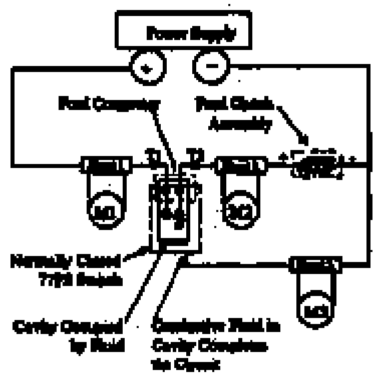
B) Switch Mount Setup

The switch was screwed to a metal test block, that was clamped in a vice at a 45° angle. (45° is the position of the switch in Ford applications). The switch was orientated such that the moveable terminal connector lead was located at the bottom of the switch. Figure 3 below, shows the switch mount setup in this experiment.

C) Wiring Setup

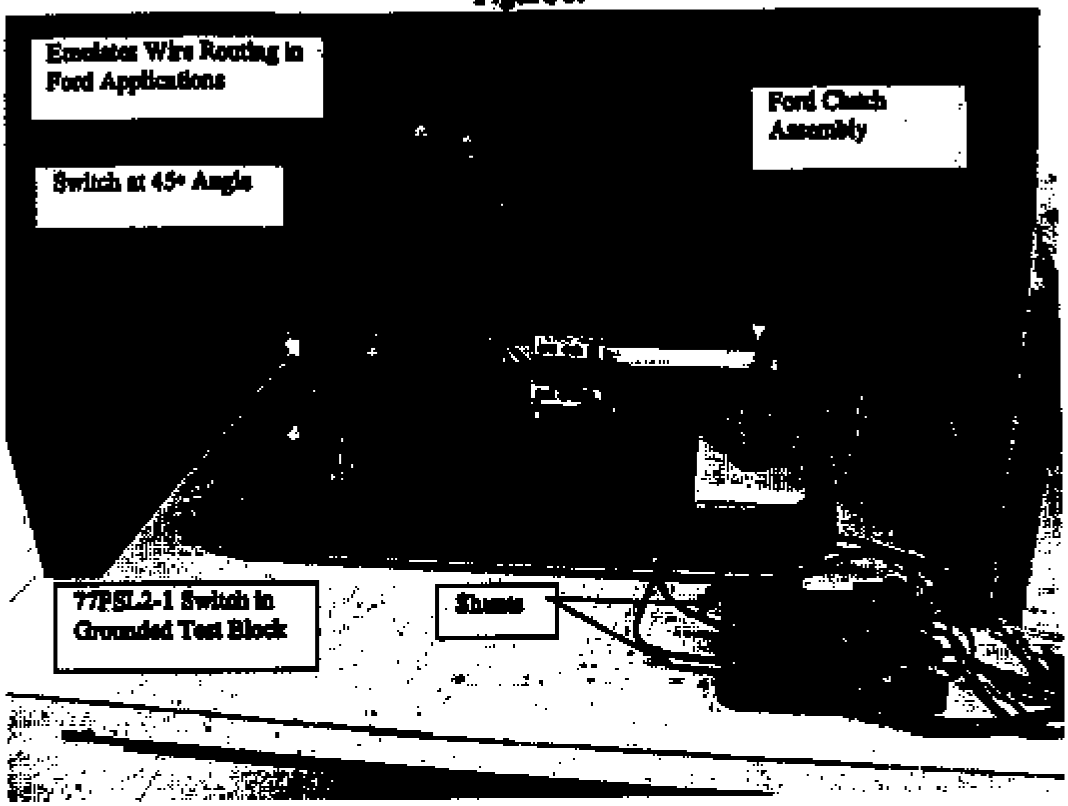
Figure 2 below, shows a wiring schematic of the test setup.

Figure 2.



Shunt 1 was connected between the power supply positive terminal and the pressure switch movable terminal through the Ford connector.
Shunt 2 was connected between the positive terminal of the Ford clutch assembly and the pressure switch stationary terminal via the Ford connector.
Shunt 3 was wired from the switch test block to the negative terminal of the power supply (also referred to as the Ground Voltage).
A Ford clutch assembly was connected in series with the pressure switch, represented as an inductive load in Figure 2, above.
A thermocouple was placed in the air gap of the Ford clutch assembly; between the coil and housing.
(See Figure 3 below, for a photo of the test setup used in this experiment).

Figure 3.



D) Test Procedure

A data acquisition system was used to record the following measurements:
Time (= clock time).
Seconds (= elapsed time in seconds).
Input current (= total current from power supply (M1 of Figure 2)).
Clutch current (= current through Ford Clutch Assembly (M3 of Figure 2)).
Hexport current (= current through fluid to grounded hexport (M2 of Figure 2)).
T1 voltage (= voltage at node T1).
T2 voltage = (voltage at node T2).
Ground voltage (= voltage at negative terminal of power supply).
Switch top temperature
Switch bottom temperature
Clutch temperature.
The test results were logged on an spreadsheet.

The sampling rate of the data acquisition system was adjusted for the duration of the particular test ((24) hour tests were set at a sampling interval of (10) minutes while (3) hour tests were set at a sample interval of (5) seconds).
14.5 Volts DC power was applied to the switch and the timer reset to zero.
(3) hour tests were video taped from the start of the test. (24) hour tests were not video taped.
Data acquisition began immediately after power was applied to the circuit.
After (10) minutes of running the switch dry, the contact cavity of the switch was injected with the test fluid.
The switch contact cavity was refilled several times during (3) hour tests but was not refilled during (24) hour tests. Fluid levels did not drop during the (24) hour tests; details are reported in the individual sections of this report.

E) Sample Disassembly

At the completion of each test, the switch was photographed (as necessary) and disassembled.
The internal components of the switch were photographed and observations were noted.

F) Sample Analysis

Each sample was submitted for analysis to determine chemical content and degree of corrosion. (Note: At the time of publishing, sample analyses were not available).

Data

The raw data sets obtained in this experiment are reported in the individual sections of this report.

Results

The hexport currents for the first (3) hours of all tests are shown in Figures 4 and 5 below. Figures 4 and 5 differ only in their scaling; Figure 5 is 15 Amps full scale while Figure 4 is 15 milli-Amps full scale. The large spikes that appear in these figures may be attributed to times when the connector was momentarily disconnected from the switch and reconnected to facilitate refilling of the switch cavity with fluid.

A (100) point moving average trendline was added to the 5% Salt Water data of Figure 4, to filter out data scatter and spikes that were recorded. The trendline of Figure 4 shows that the hexport current remained relatively steady at approximately ¼ Amps (average) for the first 100 minutes of the test. Over the following 60 minutes of the test, the hexport current steadily increased until it reached approximately 2 ½ Amps (average) at which point ignition occurred and the test was stopped. The hexport current data for the remaining fluids is (3) orders of magnitude below 5% Salt Water data and does not appear on the scale of Figure 4.

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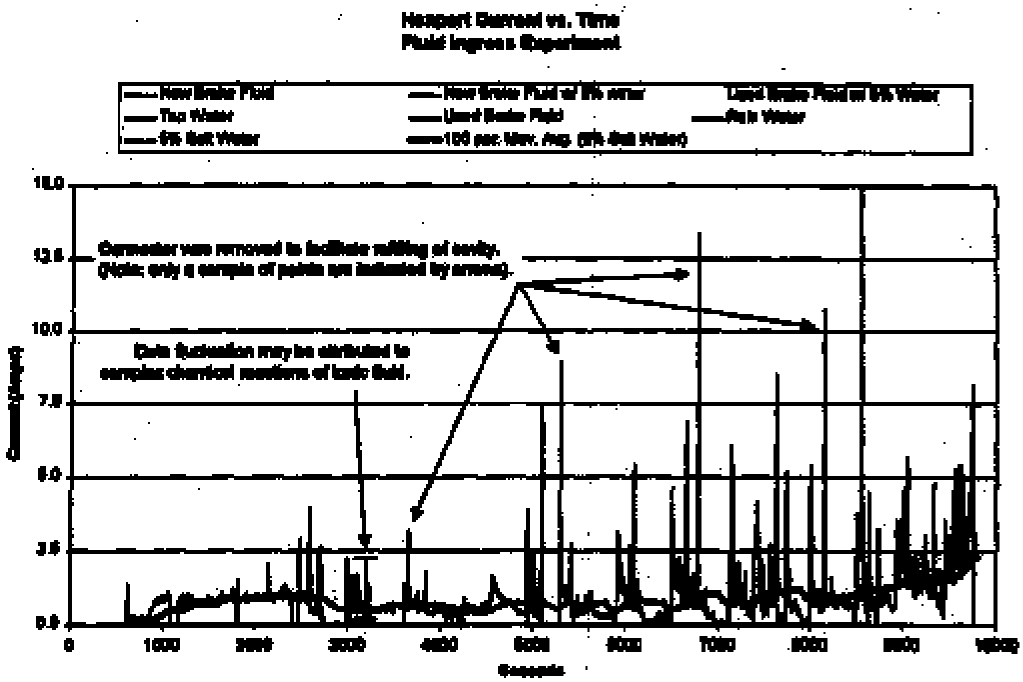
3/22/99

Figure 5 below, shows the hexport currents of all (4) brake fluid tests just above the noise floor at between 0 and 3 milli-Amps. Rain water and tap water hexport currents are (2) to (4) times higher than brake fluid hexport currents at 4 and 8 mAmps respectively.

Figure 4.



TI-NHTSA 012953

Figure 5.

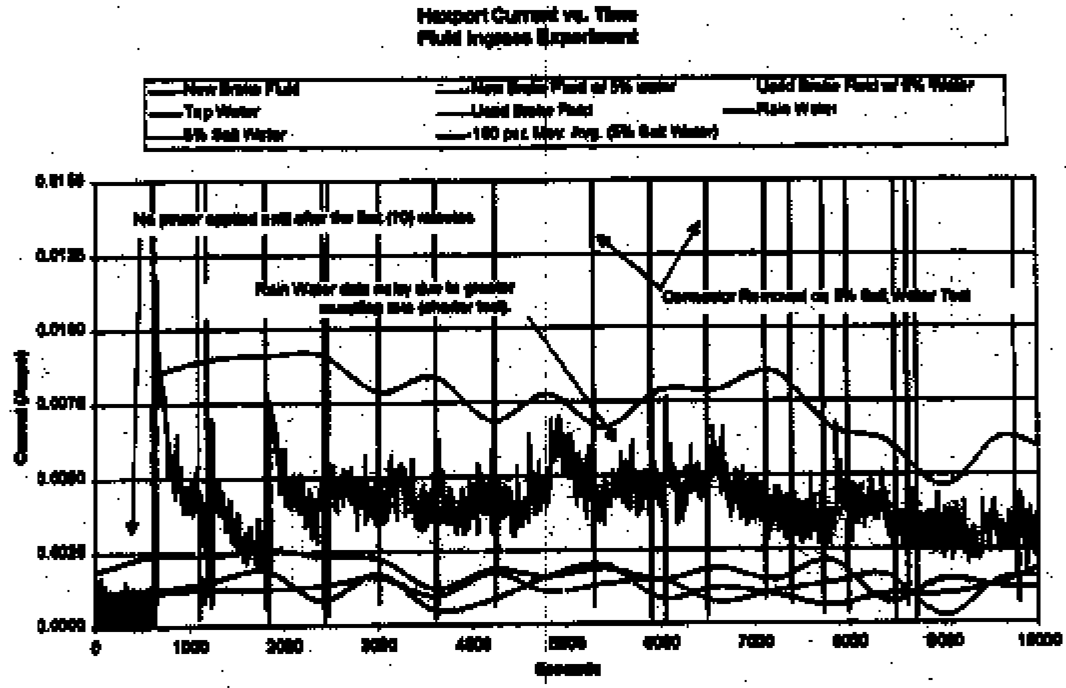


Figure 6 below, shows the hexport current for all (24) hour tests. This figure shows that the hexport current for all brake fluids, remains between 0 and 2 mAmps. It also shows that hexport current remains flat, indicating no ionization or buildup of corrosion.

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3/22/99

Figure 6.

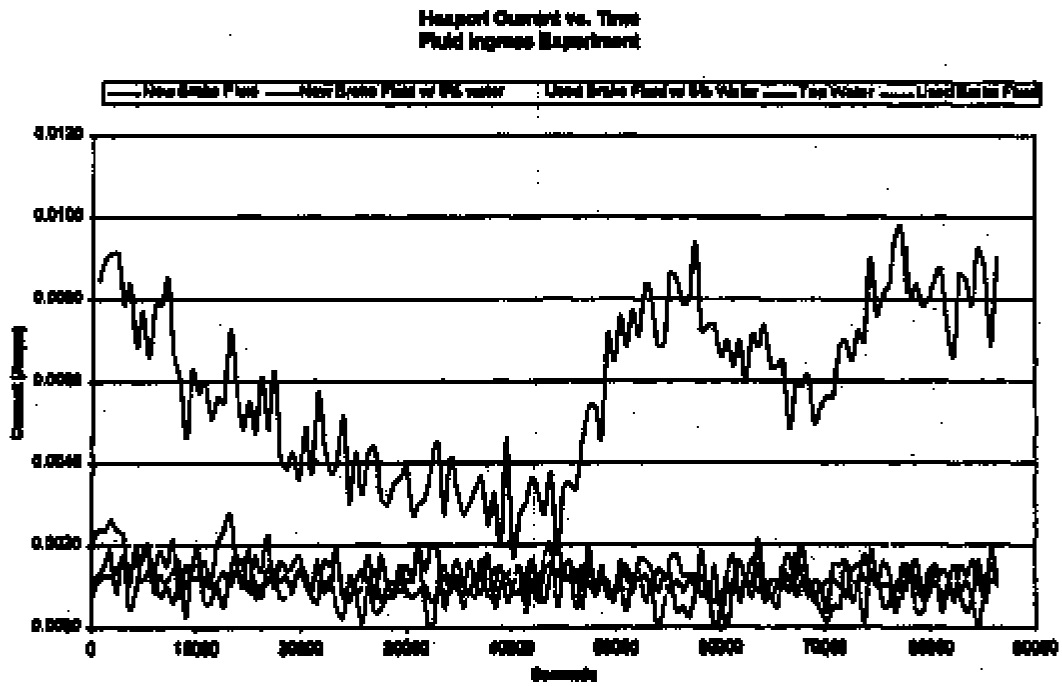

Figure 8.

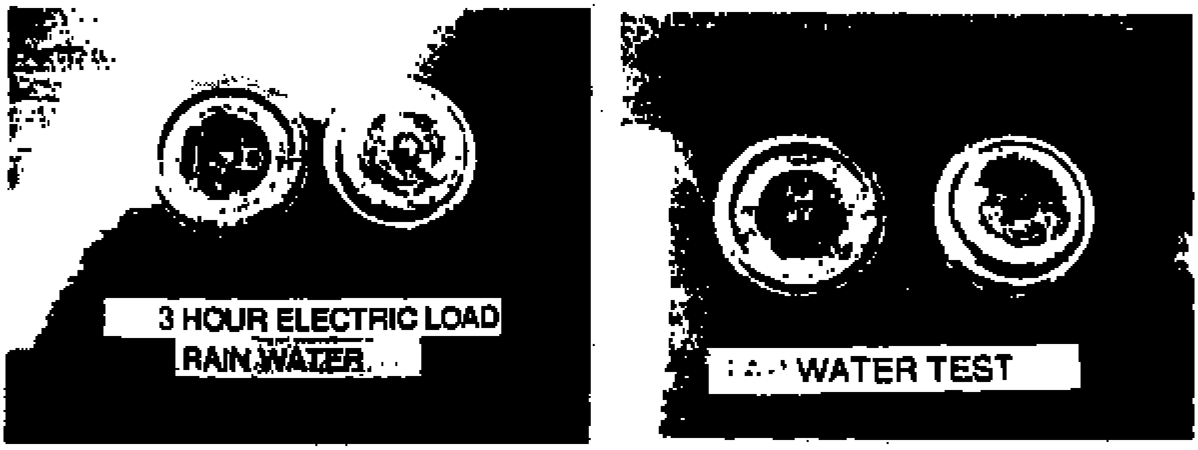

Figure 9.

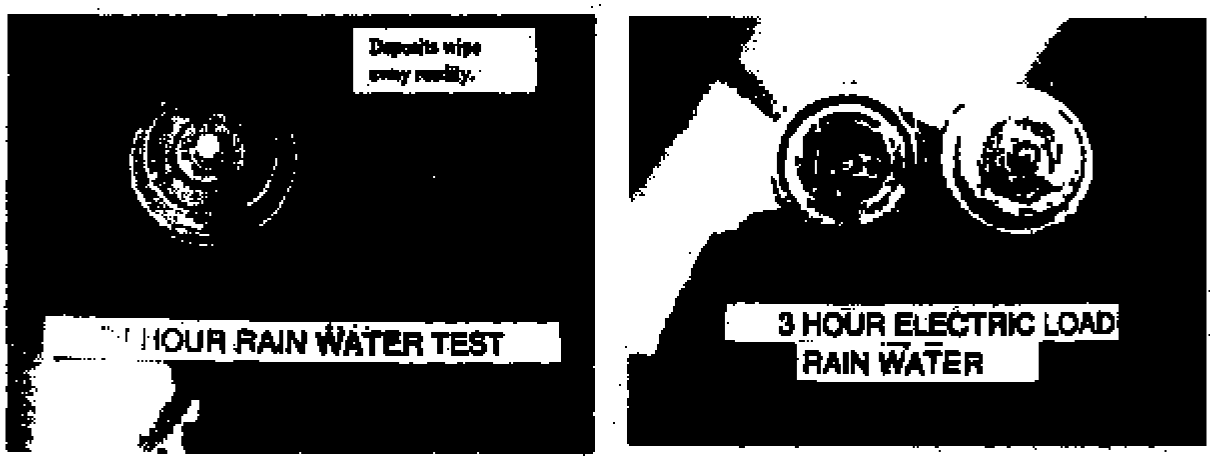

Figure 7 below, contains photos of switches from brake fluid experiments. The switch base of each sample is located on the left and the sensor assembly on the right, in each photo. Visual analysis of these switches indicates no corrosion of switch components. The black soot visible on the photos are deposits from ingredients and contaminants in the brake fluid. These deposits wipe off the switch with no effort.

Figure 7

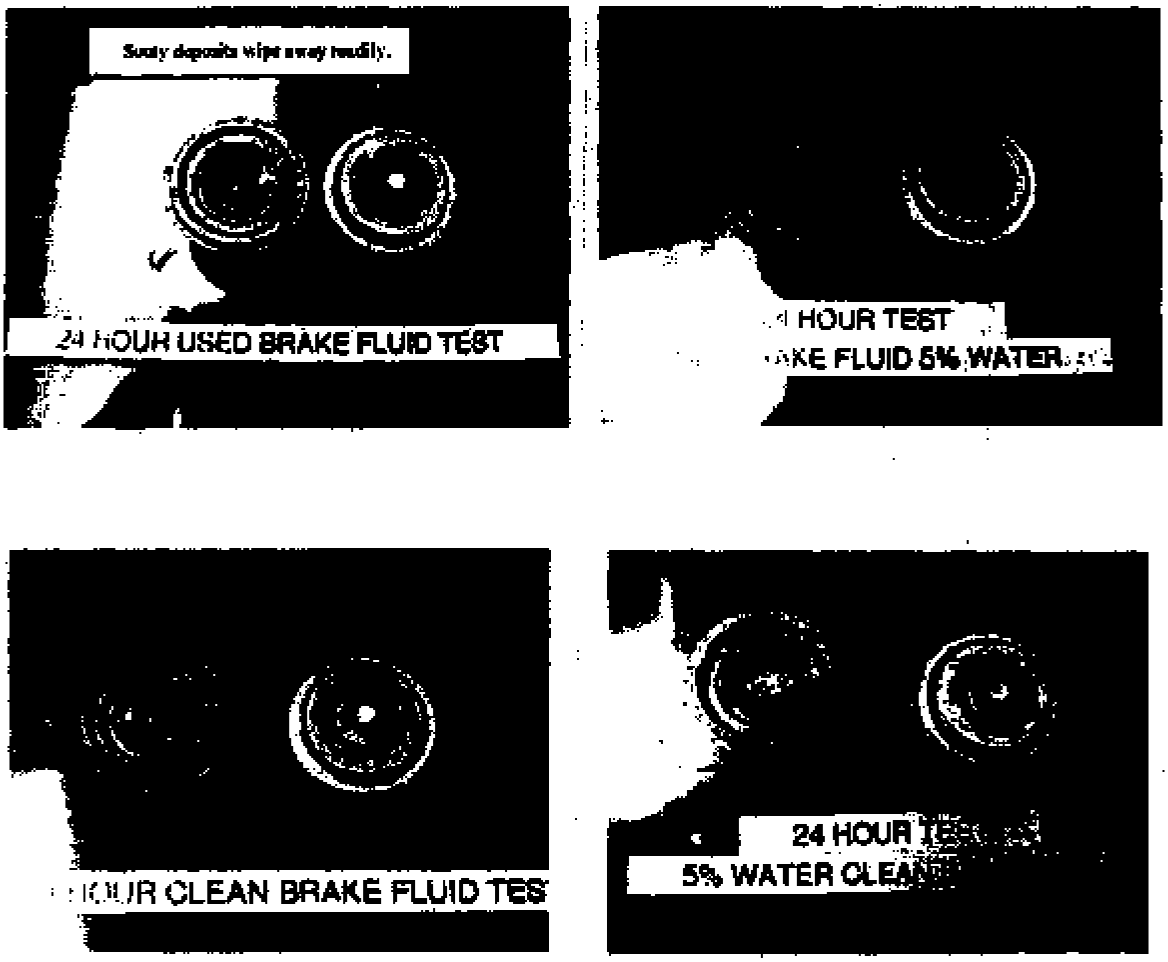

Figure 8 below, shows photos of switches from the tap water and rain water experiments. These photos show relatively high levels of corrosion.
An additional experiment was conducted in which a 77PSL2-1 switch was filled with rain water and allowed to sit without power for (24) hours. This switch is shown in Figure 9, below, alongside the rain water switch that was powered for (3) hours. The switch without power showed no sign of corrosion, indicating that ionization is the mo
Comparison of these switches shows that switch corrosion is caused by ionic degradation.

Figure 10, below, shows the internal cavities of the switch that was injected with 5% salt water. An extremely high level of corrosion is obvious. Based on these photos and the hexport current data for this switch (see Figure 3), it is obvious that as corrosion builds in the switch, an electric path from hot terminal leads to ground, is completed. Eventually sufficient current is drawn to the hexport body which results in an ignition.

Figure 10.

Conclusion

Based on the findings of this experiment, it has been concluded that ionic rich fluid ingress into the contact cavity of 77PSL2-1 switches can degrade switches sufficiently to cause a thermal event. 5% NaCl dissolved in tap water has caused ionic corrosion which resulted in a switch ignition.
The ionization level of brake fluid has been measured at approximately (3) orders of magnitude below 5% NaCl in water. Analysis of switch components tested with brake fluid has shown zero corrosion present. Based on these findings, brake fluid has been eliminated as a suspect fluid contributing to switch ignition.
Switches tested with tap water and rain water have shown levels of ionization (2) to (4) times higher than brake fluid and (2) orders of magnitude lower salt water. While corrosion is present, the levels are very low and further investigation is necessary before a conclusion can be made.

Steve, I brought this document along as far as I could. It needs some work but it is almost there.

I created a quick visual diagram as a suggestion as how we can display the information in an easily understood format. We may want to use it in along with the TI 77PS Test Synopsis. It shouldn't take more than 2-3 hours to get both items ready for presentation.

See you in the morning,

Sean

Sean,

Overall I think it is pretty good. See comments inside. Call me when you get in and we can discuss further.

Steve X3378

TI-NHTSA 012959

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PS/99/12 REV A
3/22/99

77PS Ionic Rich Fluid Ingress Experiment Report

Data
Results
Discussion
Conclusion

Section VII: New Brake Fluid With 5% Water Ingress Experiment
Data
Results
Discussion
Conclusion

Section IIX: Tap Water Ingress Experiment
Data
Results
Discussion
Conclusion

5% Salt

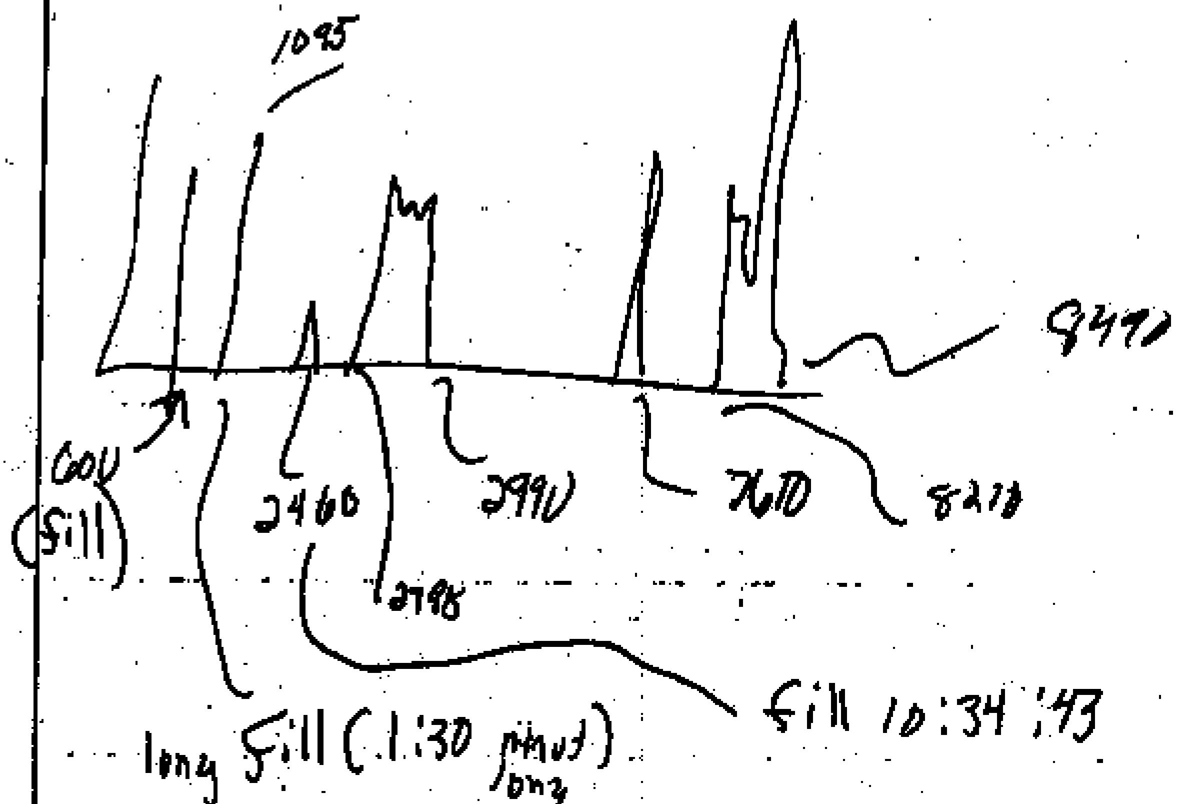
MVC-011L 2:10 Elapsed time = 12:12:32

Camera start time 10:02:

~~Test~~

Power Off Time Stamp (Excel) 9:54:38
First Fill 10:04 28

high R 600
1095
2460



Brake Fluid Samples

Sample	5% water date	k cycles	time	Sample	0% water date	k cycles	time
A1	3/12/99			B1	3/12/99		
A2	3/15/99	240		B2	3/15/99	450	
A3	3/16/99		1630	B3	3/17/99		1445
A4	3/17/99		1445	B4	3/18/99		1255
A5	3/18/99		1250	B5	3/19/99		900
A6	3/19/99		900	B6			

TI Proprietary Information: Attorney-Client Privilege Invoked
PS/99/12 Draft Copy: not for release
3/22/99

77PS Ionic Rich Fluid Ingress Experiment

Abstract

This experiment has demonstrated that ionic rich fluid ingress into the electrical connector cavity of 77PS2-1 switches, while the switches are powered, can degrade switch components sufficiently to cause an undesired thermal event. Specifically, results show that an ionic rich fluid such as salt water is necessary to cause a level electrolysis and buildup of ionic deposits necessary to induce ignition.

(7) different test fluids were injected into the contact cavity of 77PSL2-1 switches for up to (24) hours with the switches powered at 14.5 Volts DC. Results have shown that brake fluid, (regardless of whether it is new or used, mixed with 5% water or without water), is not ionic enough to cause measurable corrosive effects on 77PSL2-1 switches. Tap water and rain water stray currents have been measured at between (2) and (4) times that of brake fluids tested. There is some surface corrosion present on both the rain and tap water switches but little evidence to suggest a possible buildup over time. Further investigation on rain and tap water is required to draw any conclusions.

Purpose

This experiment was designed to simulate fluid ingress into the contact cavity of 77PSL2-1 switches at an accelerated rate. The intent was to quantify the corrosive effects of a matrix of fluids on the electrical components of 77PSL2-1 switches and correlate the results with specimens obtained from the field. Once a correlation is established, a suspect fluid can be identified and the mode of ingress determined.

The test setup in this experiment was designed to emulate switch operating conditions as used in Ford applications. Each switch was mounted at a 45° angle, electrically wired to a Ford power steering clutch assembly and powered at 14.5 Volts DC.

Based on the operating environment of 77PS2-1 switches, (7) fluids were identified as possible ingress suspects. Each of these fluids was tested independently under the same operating conditions, using the same instrumentation.

Instrumentation

The following instrumentation was used to conduct this experiment.

DC Power supply.
VCR Camcorder .
HP34901A (20) channel multiplexer.
Data Acquisition System
(3) Shunts calibrated at 100 Amp = 100 mVolts.
Timer

Procedure

The following procedure was followed for the (7) fluids tested in this experiment, as shown in Table 1, below. Each fluid was tested independently and only one test was conducted at a time. A new switch was use for each fluid.

Table 1.

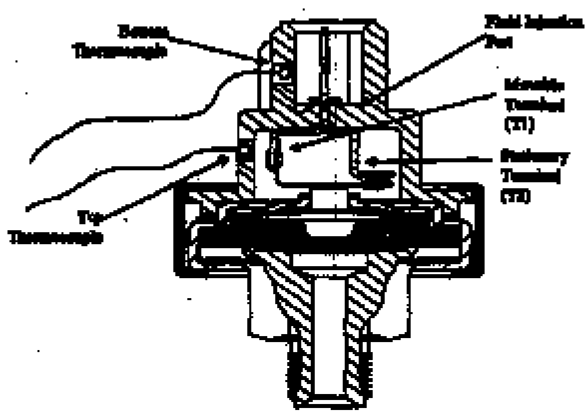
Fluid Tested	Test Duration (approximate)
Used Brake Fluid	24 hours
Used Brake Fluid with 5% Tap Water (by weight)	24 hours
New Brake Fluid	24 hours
New Brake Fluid with 5% Tap Water (by weight)	24 hours
Tap Water with 5% NaCl (by weight)	3 hours
Rain Water	3 hours
Tap Water	24 hours

A) Sample preparation.

A small hole was drilled through the base of a 77PSL2-1 switch, next to the terminal leads as shown in Figure 1, below. (This port facilitated injection of fluids into the contact cavity of the switch).

(2) holes were drilled into the side of the switch base, which did not penetrate through the base wall. A K-type thermocouple was placed in each hole as shown in Figure 1. The thermocouples were secured with epoxy.

Figure 1.



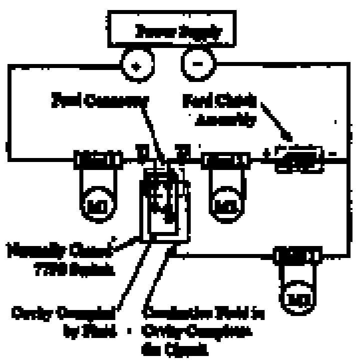
B) **Switch Mount Setup**

The switch was screwed to a metal test block, that was clamped in a vice at a 45° angle. (45° is the position of the switch in Ford applications). The switch was orientated such that the moveable terminal connector lead was located at the bottom of the switch. Figure 3 below, shows the switch mount setup in this experiment.

C) **Wiring Setup**

Figure 2 below, shows a wiring schematic of the test setup.

Figure 2.



Shunt 1 was connected between the power supply positive terminal and the pressure switch movable terminal through the Ford connector.
Shunt 2 was connected between the positive terminal of the Ford clutch assembly and the pressure switch stationary terminal via the Ford connector.
Shunt 3 was wired from the switch test block to the negative terminal of the power supply (also referred to as the Ground Voltage).
A Ford clutch assembly was connected in series with the pressure switch, represented as an inductive load in Figure 2, above.
A thermocouple was placed in the air gap of the Ford clutch assembly; between the coil and housing.
(See Figure 3 below, for a photo of the test setup used in this experiment).

The sampling rate of the data acquisition system was adjusted for the duration of the particular test ((24) hour tests were set at a sampling interval of (10) minutes while (3) hour tests were set at a sample interval of (5) seconds).
14.5 Volts DC power was applied to the switch and the timer reset to zero.
(3) hour tests were video taped from the start of the test. (24) hour tests were not video taped.
Data acquisition began immediately after power was applied to the circuit.
After (10) minutes of running the switch dry, the contact cavity of the switch was injected with the test fluid.
The switch contact cavity was refilled several times during (3) hour tests but was not refilled during (24) hour tests. Fluid levels did not drop during the (24) hour tests; details are reported in the individual sections of this report.

Different Δ fluid

E) Sample Disassembly

At the completion of each test, the switch was photographed (as necessary) and disassembled.
The internal components of the switch were photographed and observations were noted.

F) Sample Analysis

Each sample was submitted for analysis to determine chemical content and degree of corrosion. (Note: At the time of publishing, sample analyses were not available).

Data

The raw data sets obtained in this experiment are reported in the individual sections of this report.

Results

The hexport currents for the first (3) hours of all tests are shown in Figures 4 and 5 below. Hexport current is the current that travels from switch hot terminals to hexport body via the fluid medium. Figures 4 and 5 differ only in their scaling; Figure 5 is 15 amps full scale while Figure 4 is 15 milli-amps full scale. The large spikes that appear in these figures may be attributed to times when the connector was momentarily disconnected from the switch and reconnected to facilitate refilling of the switch cavity with fluid.

A (100) point moving average trendline was added to the 5% Salt Water data of Figure 4, to filter out data scatter and spikes. This trendline shows that hexport current remained relatively steady at approximately ¼ Amps (average) for the first 100 minutes of the test. Over the following 60 minutes of the test, the hexport current steadily increased until it reached approximately 2 ½ Amps (average) at which point ignition occurred and the test was stopped. The hexport current data for the remaining fluids is (3) orders of magnitude below 5% Salt Water data and does not appear on the scale of Figure 4.

Figure 5 below, shows the hexport currents of all (4) brake fluid tests just above the noise floor at between 0 and 3 milli-amps. Rain water and tap water hexport currents are (2) to (4) times higher than brake fluid hexport currents at 4 and 8 milli-amps respectively.

Figure 4.

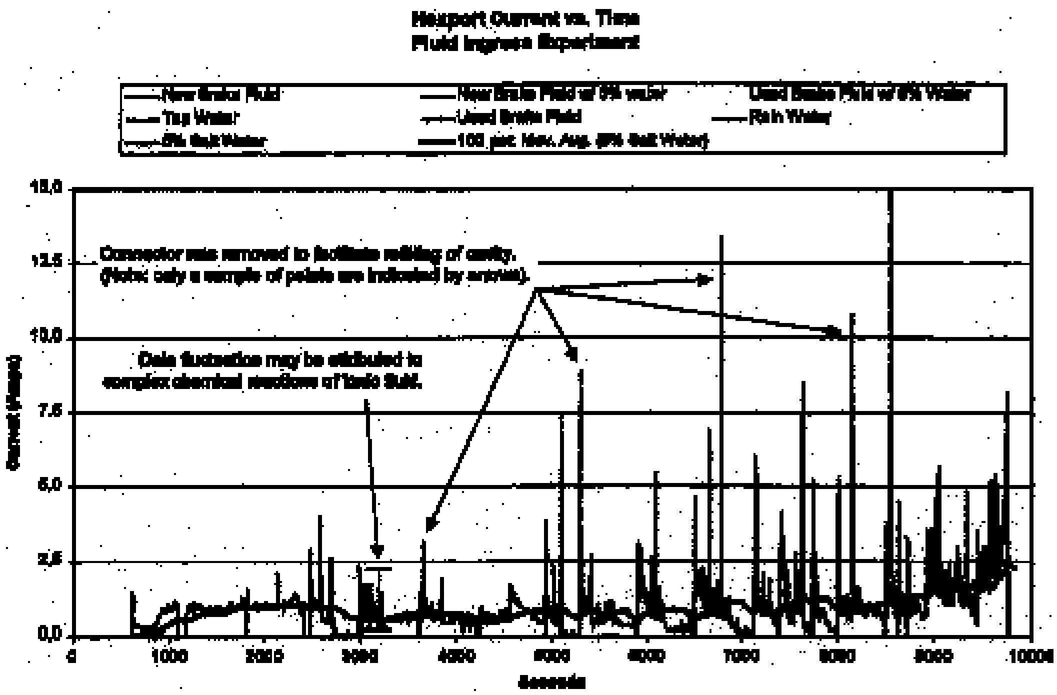


Figure 5.

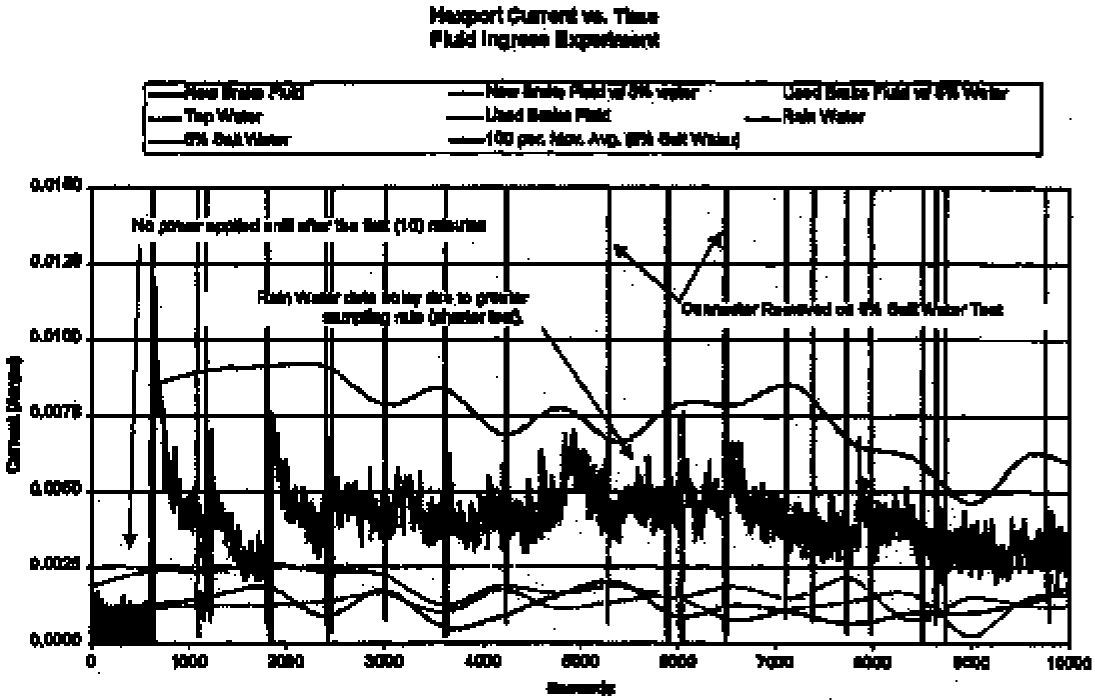


Figure 6 below, shows the hexport current for all (24) hour tests. This figure shows that the hexport current for all brake fluids, remains between 0 and 3 milli-amps. It also shows that brake fluid hexport currents remained flat, indicating no electrolysis or buildup of corrosion (as also indicated by inspection of internal components).

Figure 6.

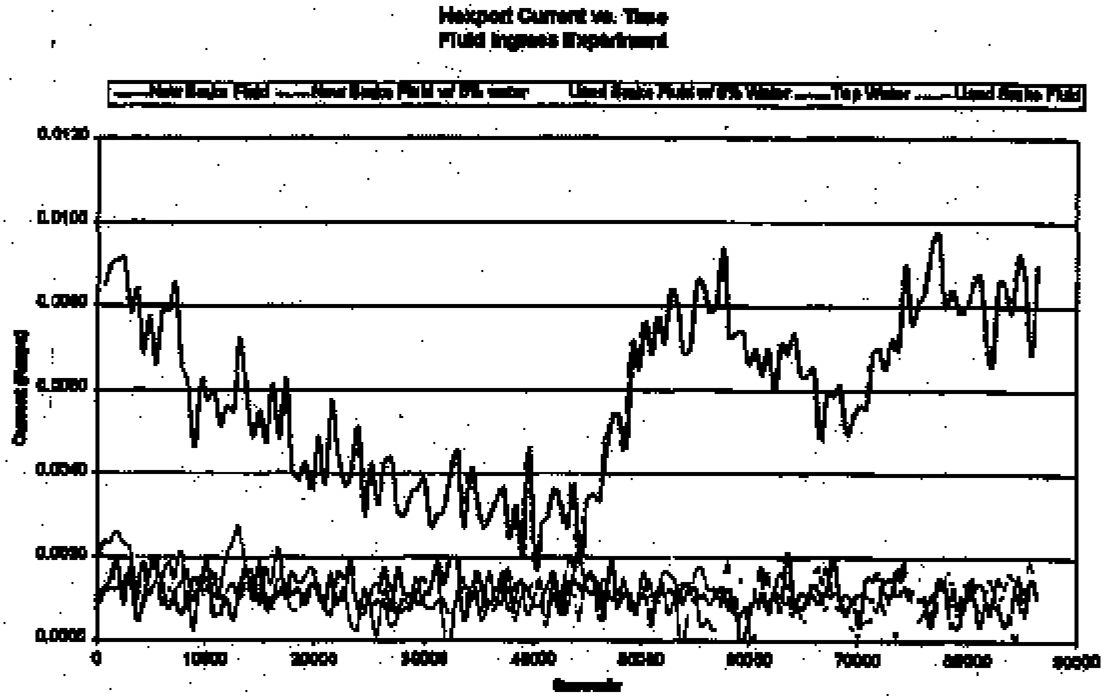

Hexport Current vs. Time
Fluid Ingress Experiment
Tap Water
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000

Figure 10, below, shows the internal cavitiy of the switch that was injected with 5% salt water. An extremely high level of corrosion and NaCl buildup is obvious. A chemical analysis on the corrosion was not available at the time of publishing. Based on these photos and hexport current data (see Figure 3), it is apparent that deposits from corrosion and NaCl build in the switch, create an electric path from hot terminal leads to grounded hexport body. As deposits increase, hexport current increases and internal elements heat up. A critical point is reached and ignition occurs.

Figure 10.

Conclusion

Based on the findings of this experiment, it has been concluded that ionic rich fluid ingress into the contact cavity of 77PSL2-1 switches can degrade switches sufficiently to cause a thermal event. 5% NaCl dissolved in tap water has caused electrolysis and NaCl buildup in 77PSL2-1 switches which has culminated in an ignition.
Less ionic fluids have not shown a buildup of corrosion to suggest an eminent ignition. Stray current levels in brake fluid tests, have been measured at approximately (3) orders of magnitude below 5% NaCl in tap water. Analyses of the brake fluid switches have shown no indications of corrosion. Based on these findings, brake fluid has been eliminated as a suspect fluid contributing to switch ignition.
Switches tested with tap water and rain water have measured stray current levels (2) to (4) times higher than brake fluid but (2) orders of magnitude lower than salt water. While corrosion is visible, the levels are very low. Further investigation is required.

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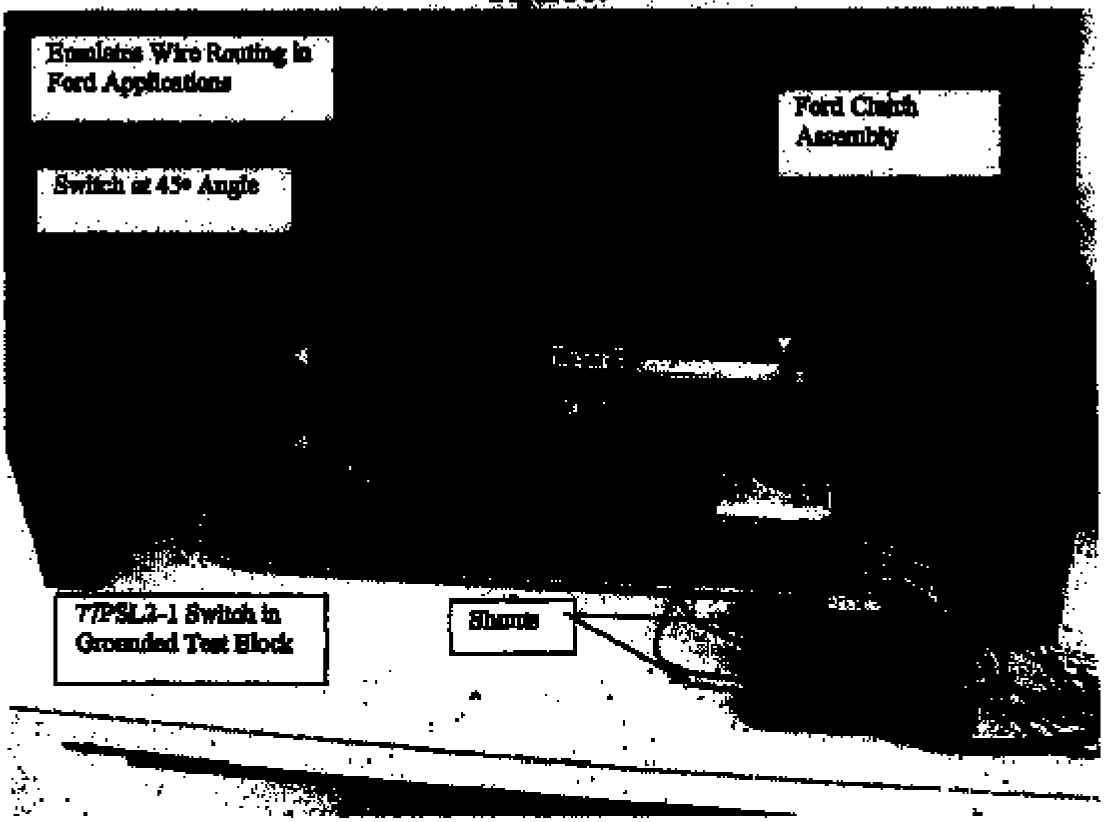
Figure 3.



D) Test Procedure

A data acquisition system was used to record the following measurements:
Time (= clock time).
Seconds (= elapsed time in seconds).
Input current (= total current from power supply (M1 of Figure 2)).
Clutch current (= current through Ford Clutch Assembly (M3 of Figure 2)).
Hexport current (= current through fluid to grounded hexport (M2 of Figure 2)).
T1 voltage (= voltage at node T1).
T2 voltage = (voltage at node T2).
Ground voltage (= voltage at negative terminal of power supply).
Switch top temperature
Switch bottom temperature
Clutch temperature.
The test results were logged on an spreadsheet.

Figure 8.

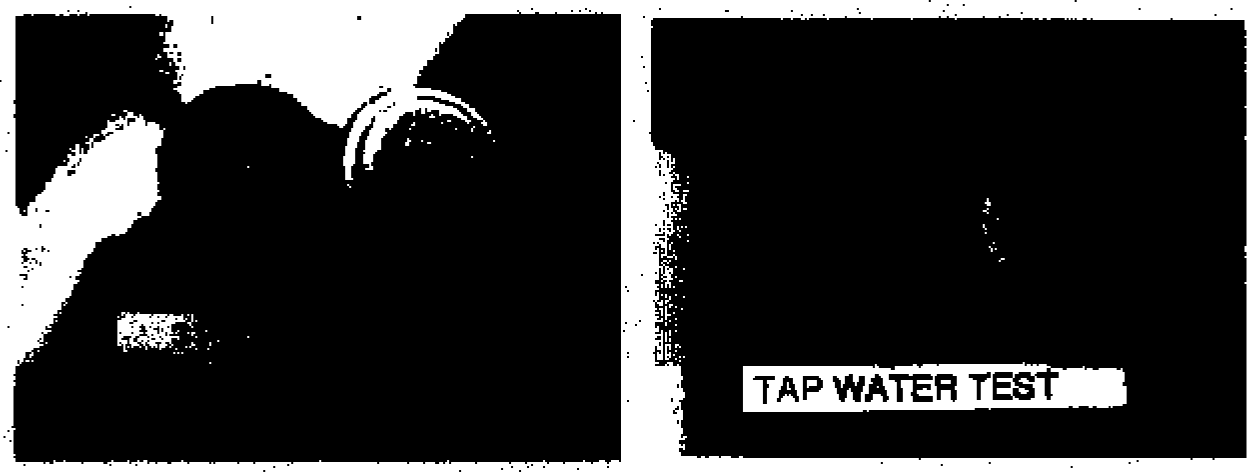


Figure 9.

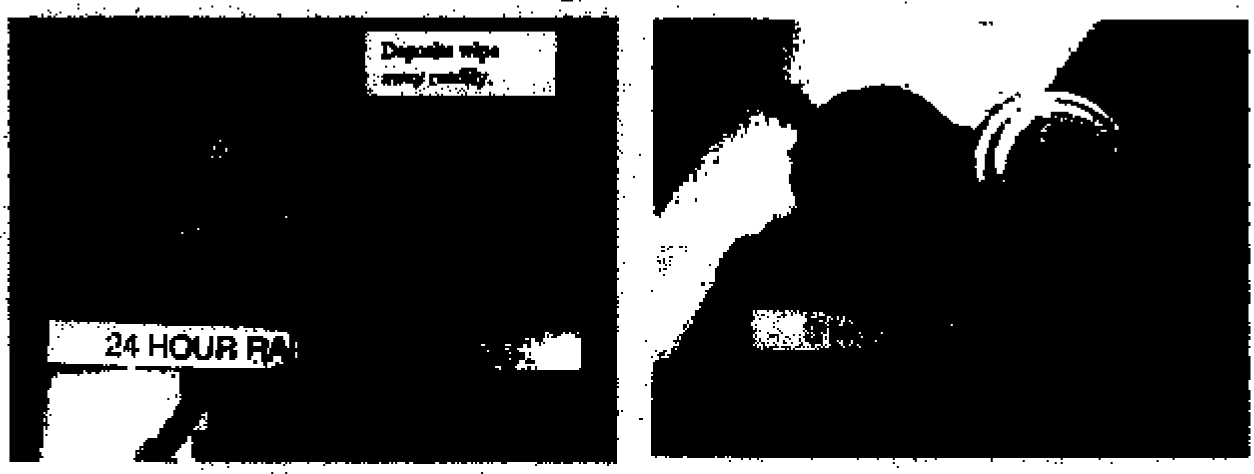


Figure 7 below, shows photos of the switches from brake fluid experiments. In each photo, the switch base is located on the left and the sensor assembly on the right. Visual analysis of these switches indicates no corrosion of switch components. The black soot visible on the photos are deposits from ingredients and contaminants in the brake fluid. These deposits wipe off the switch with no effort.

Figure 7

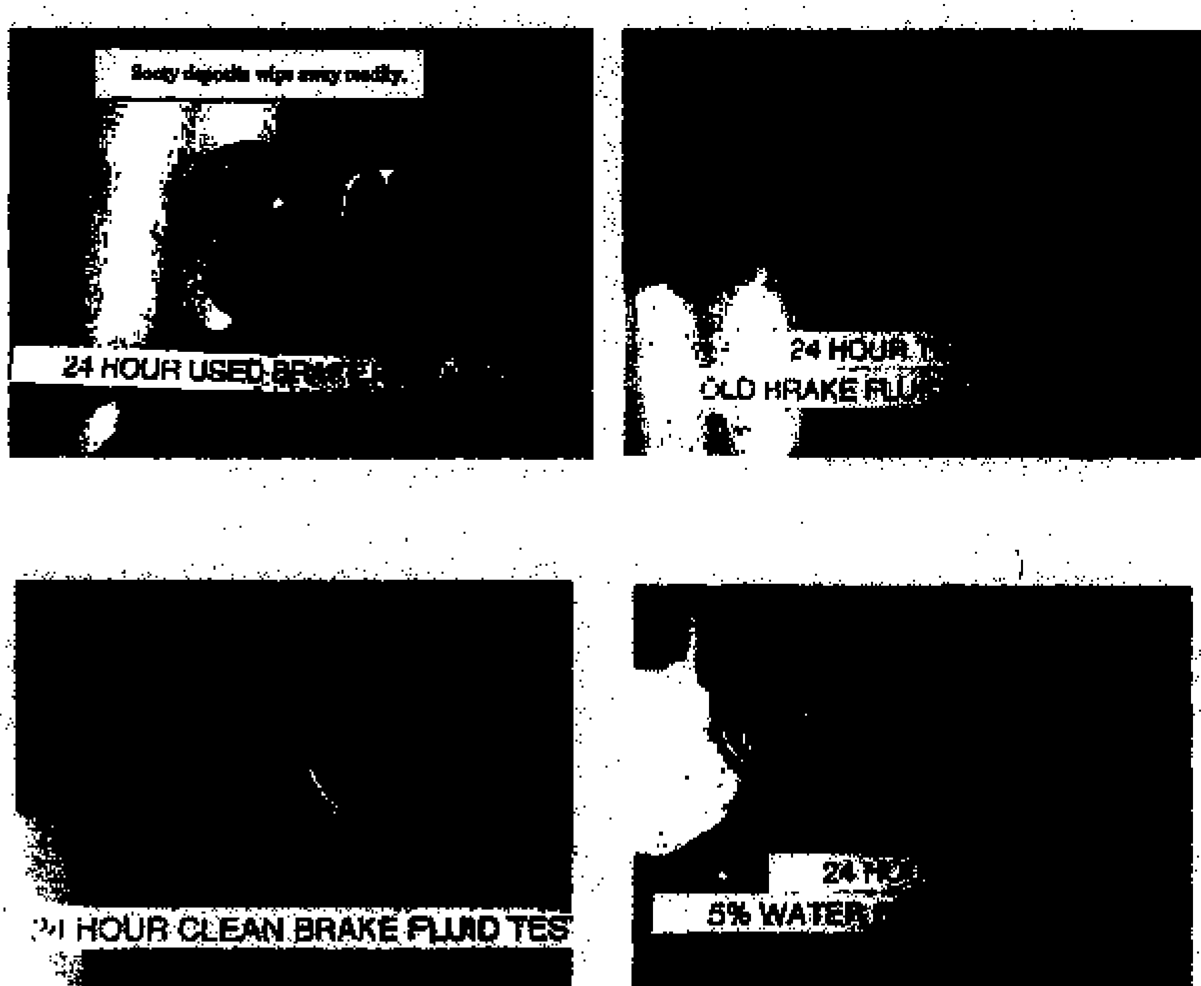


Figure 8 below, shows photos of switches from the tap water and rain water experiments. These photos show relatively high levels of surface corrosion.

An additional experiment was conducted in which a 77PSL2-1 switch was filled with rain water and allowed to sit without power for (24) hours. This switch is shown in Figure 9, below, alongside the rain water switch that was powered for (3) hours. The switch, without power, showed no sign of corrosion, indicating electrolysis as the mode of corrosion for the powered test.

RESISTIVITY OF PARTS?

1999 3 22 4:30:35 PM MVC-FD91

Digital Mavica images

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9 mavica images			120 Kbytes free	
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MVC-005X.JPG	1999	3 22	4:14:14	PM
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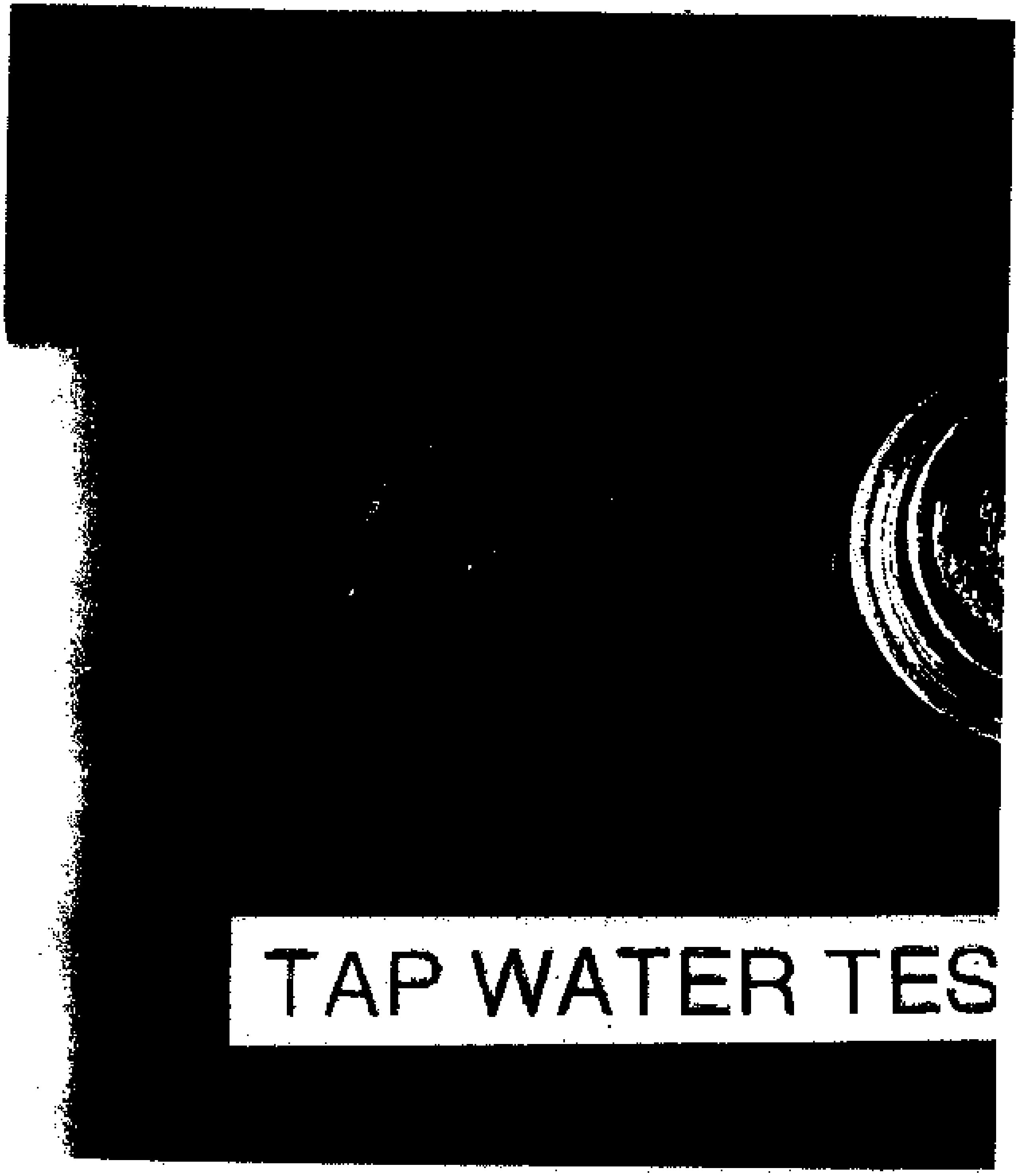

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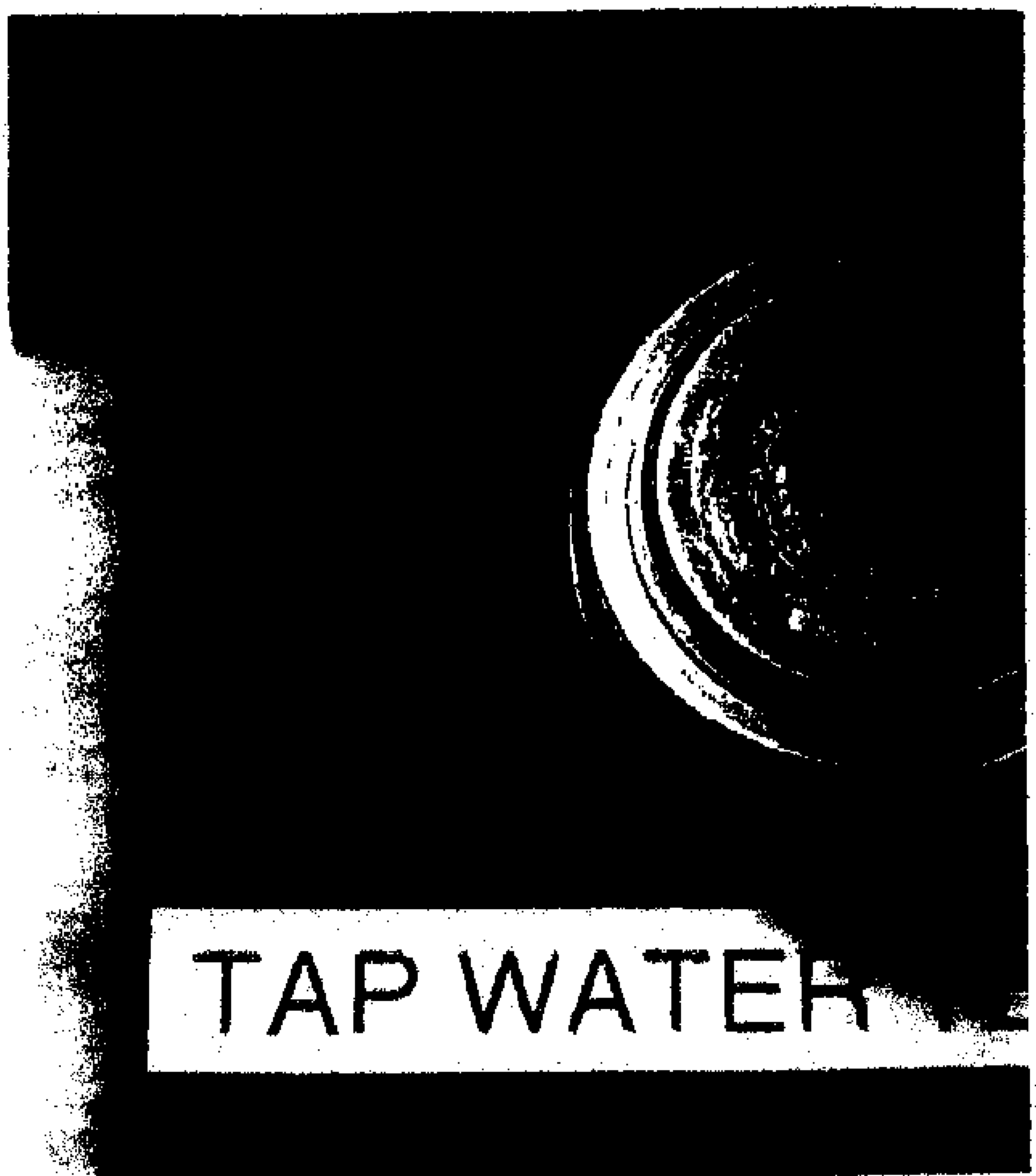

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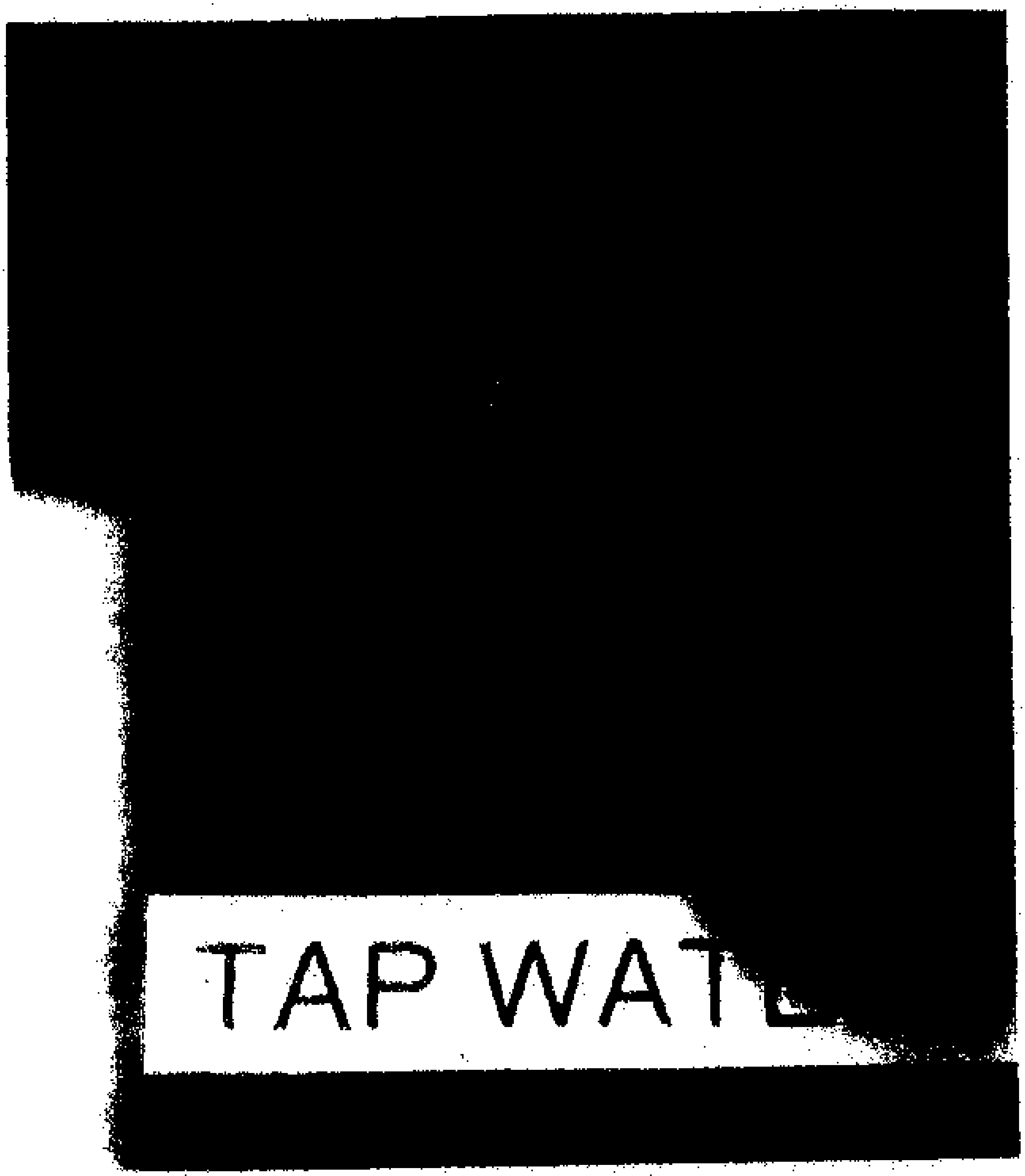

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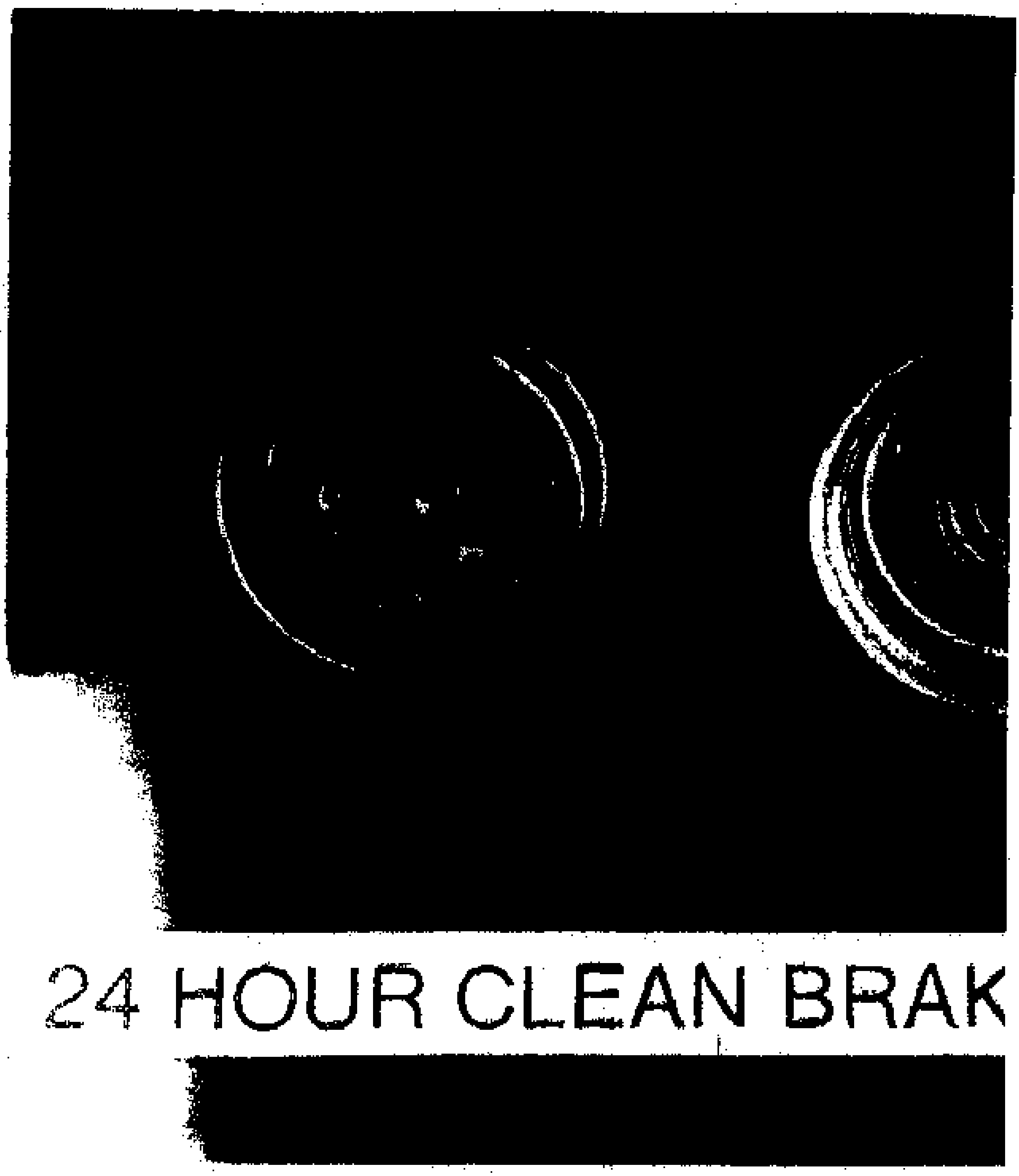

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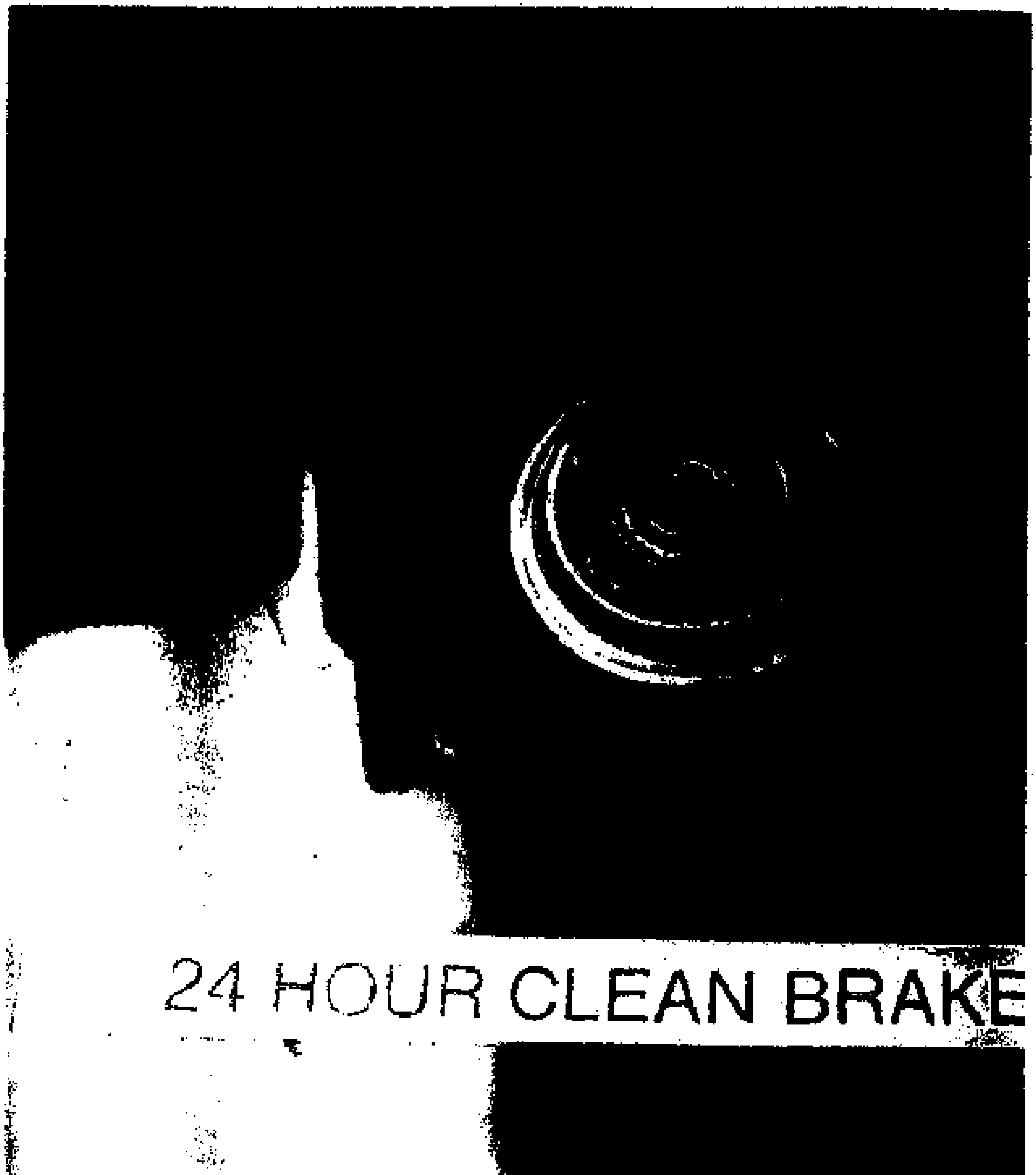

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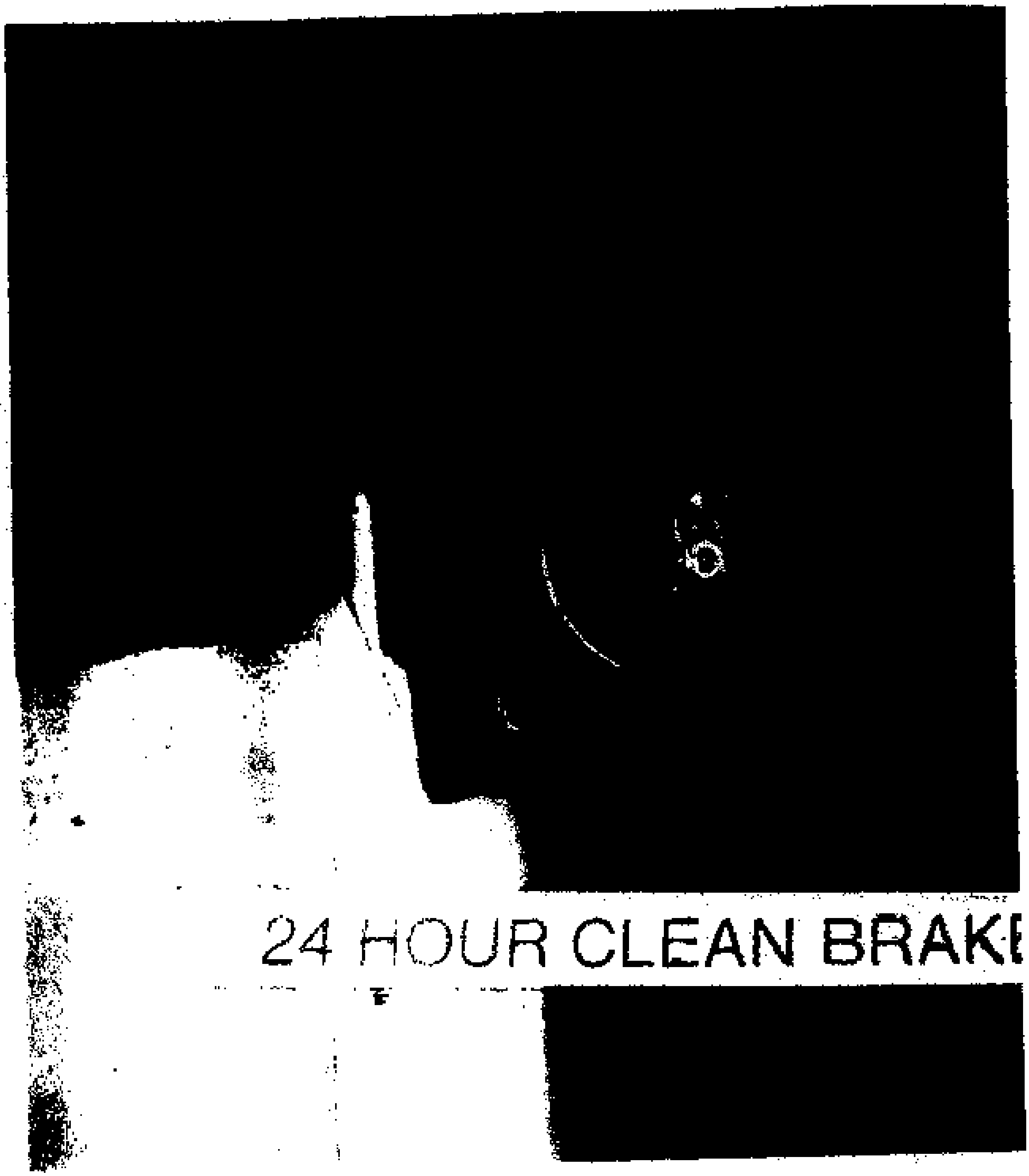
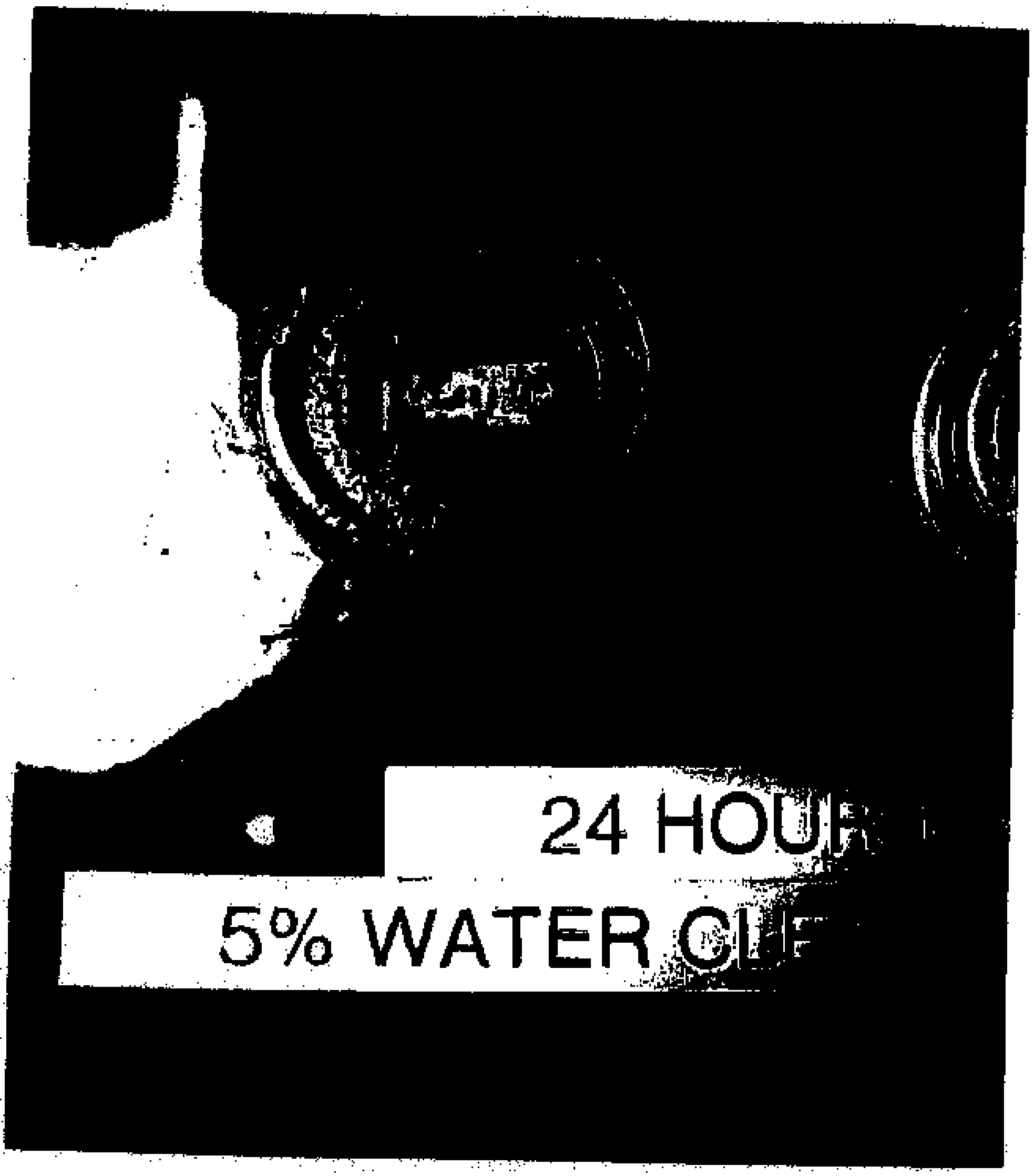

24 HOUR CLEAN BRAKE



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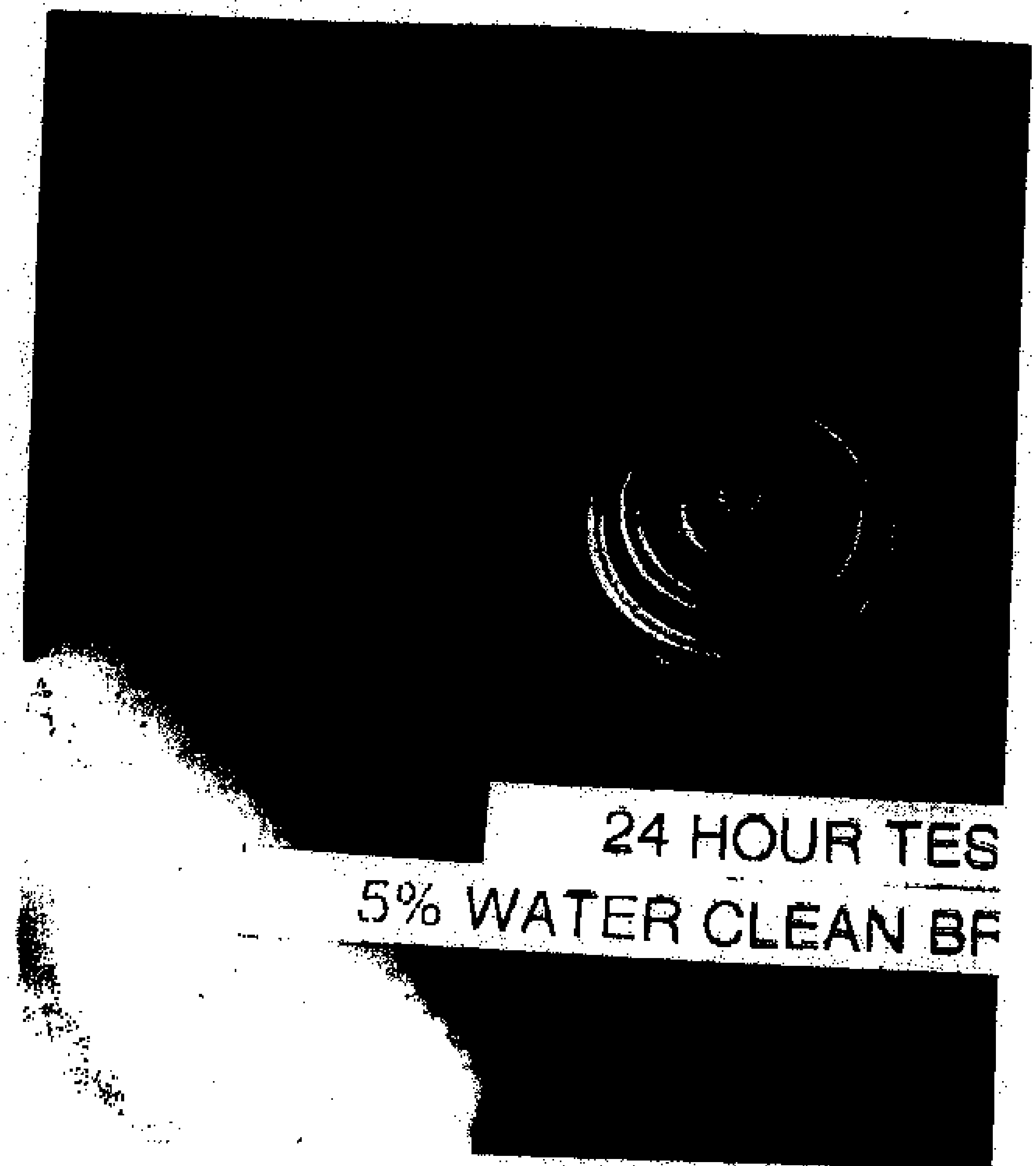
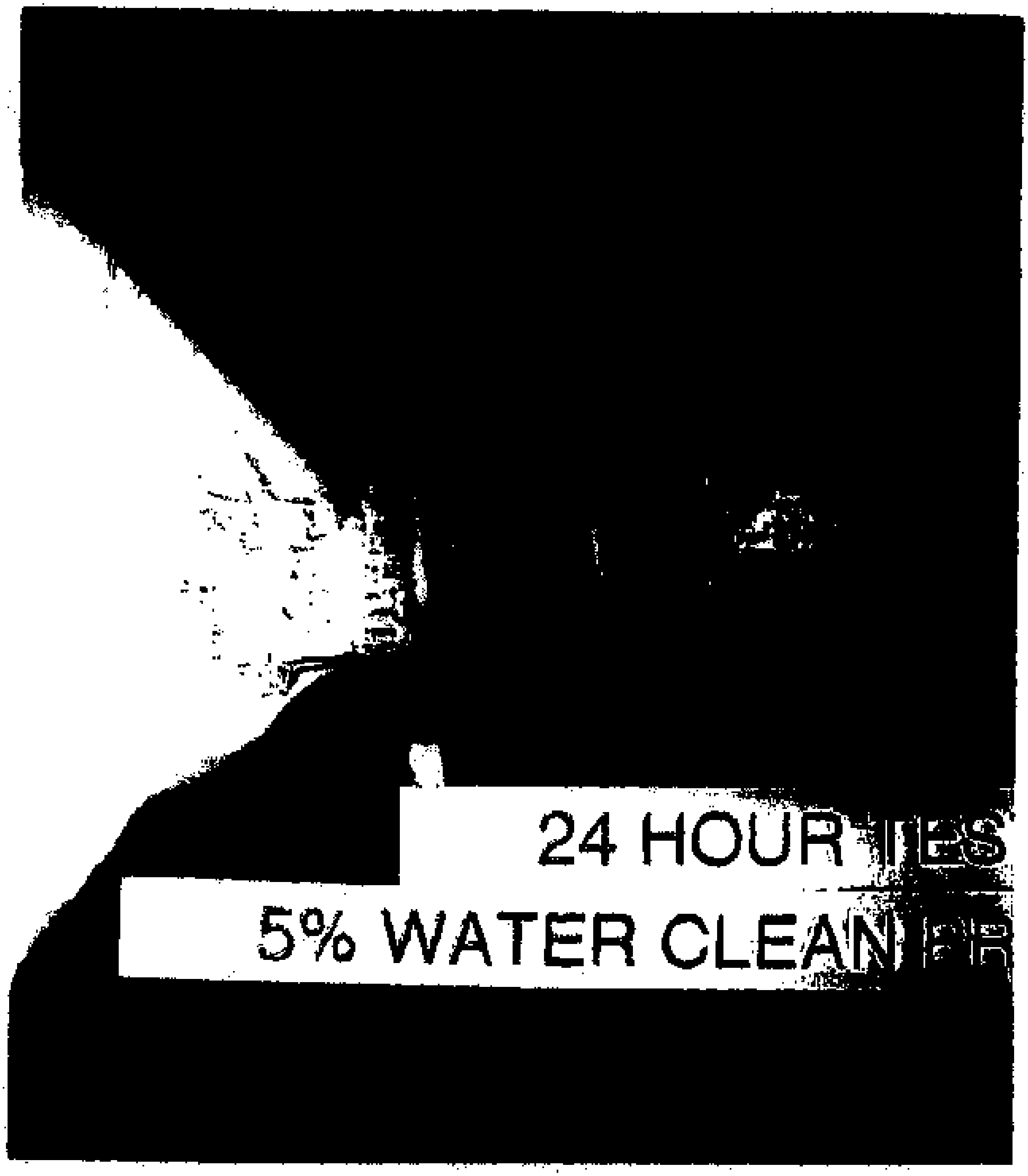

24 HOUR TES
5% WATER CLEAN BF



TI-NHTSA 012984

Ford Circuit Robustness to 77PS Ion Rich Fluid Ingress Experiment

Abstract

A 200 mAmp current limiting circuit design has been proposed for use with 77PS switches in Ford applications. (3) separate experiments were conducted to test the robustness of this design to ion rich fluid ingress into the electrical contact cavity of 77PS switches.
In experiment 1, a 77PS switch was powered in the proposed current limiting circuit, under worse case scenario conditions for (48) hours.
In experiment 2, a 77PS switch was powered in a non-current limiting circuit until the switch reached a state of impending ignition. (Impending ignition is defined as a condition where switch ignition would have occurred within (10) minutes had testing continued). The impending ignition switch was then powered in the proposed current limiting circuit for (18) hours.
In experiment 3, a resistive heater element was wrapped around the base of a switch. The maximum switch power, possible in the proposed circuit, was applied to the heater.
Results from these experiments clearly show that 77PS switches will not reach a state of potential ignition in the proposed circuit design. Results also show that even if a state of potential ignition was reached, there is not enough power in the proposed circuit design to nucleate an ignition.

Background

The proposed current limiting circuit design will replace the existing design used in specific Ford applications. Previous experiments have shown that electrolytic corrosion in 77Ps switches and high current draw in the existing circuit, are the principle factors leading to switch ignitions (see TI report PS/99/13). In previous experiments, 77PS switches were connected to the existing Ford circuit and subjected to ion rich fluid ingress. Electrolytic corrosion of components and the buildup of deposits bridged an electric path from hot switch terminals to the switch hexport ground. Current to the hexport ground slowly increased, causing a temperature rise in internal switch components which glowed red hot. Hexport current exceeded 2 Amps (average), critical conditions were reached and ignition resulted. A schematic of the proposed current limiting circuit is shown in Figure 1, below.

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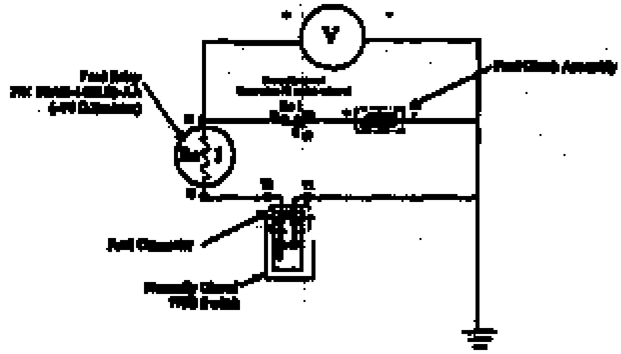
Figure 1

77PS Proposed Wiring Schematic

14.5 Volts DC (Ignition On)



The proposed circuit design will:
1) Limit current at the switch to 200 mAmps.
2) Limit power at the switch to 0.75 Watts.
3) Minimize the possibility of electrolytic corrosion through:
   A) Drastic reduction in time the switch is at a voltage potential above ground.
   B) Reduction in switch surface area exposed to a voltage potential above ground.

Table 1 below, illustrates the differences between the existing circuit design and proposed circuit design.

Table 1.

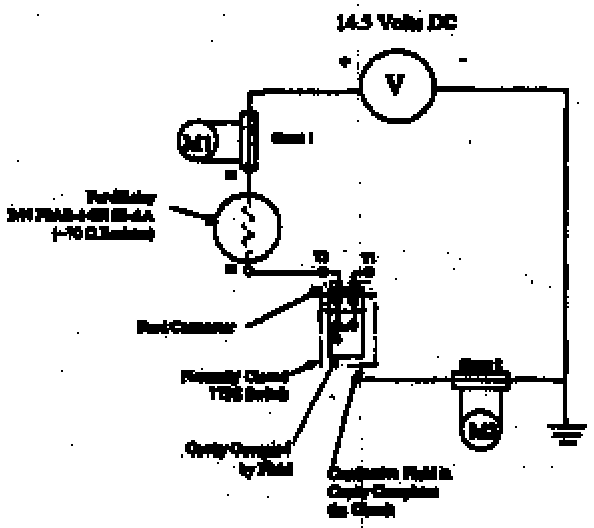
	Existing Design	Proposed Design
Maximum Switch Current	15 Amps	0.2 Amps
Maximum Switch Power	210 Watts	0.75 Watts
Switch Time at Full Voltage	Continuous	Brake On and Ignition On
Switch Surface Area at Full Potential	Maximum	Minimum

(3) experiment were designed and conducted to test the robustness of the proposed circuit design to ion rich ingress into 77PS switches.

<u>Experiment 1:</u> (48) Hour Current Limiting Circuit Test

A worst case scenario for electrolytic corrosion, in the proposed current limiting circuit, is a condition of high voltage potential at the stationary terminal of the 77PS switch. A high voltage condition exists only in an ignition on, brake on condition. Experiment 1 was conducted to validate the circuit design under worst case scenario conditions. A schematic of the test circuit is shown in Figure 2 below. To facilitate testing, the movable terminal (T1) was left floating and the switch left in the closed state. In this condition, the entire electrical contact is at the high voltage potential. This is a harsher test than the worst case scenario.

Figure 2.



Experiment 2: Impending Ignition

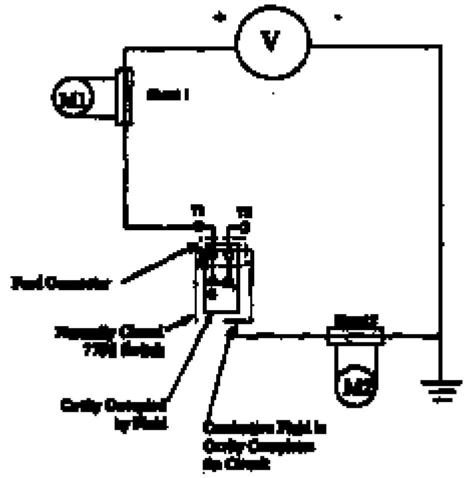
Experiment 2 was conducted to determine if there is enough power in the proposed circuit to nucleate an ignition. A 77PS switch was brought to impending ignition in the 15 amp circuit shown in Figure 3, below. (Previous tests on 77PS switches, in the 15 amp circuit, have resulted in switch ignitions). The impending ignition switch was removed from the 15 amp circuit and placed in the proposed 200 mAmp current limiting circuit (see Figure 2, above,) for (18) hours.

TI-NHTSA 012987

Figure 3.

15 Amp Circuit
Test Setup

14.5 Volts DC



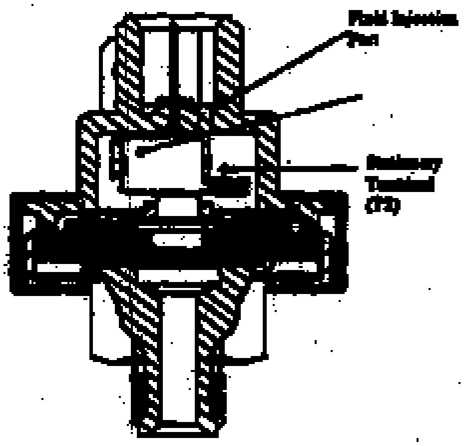
Experiment 3: Maximum Power Input

The proposed 200 mAmp current limit circuit design limits the power to the switch. Experiment 3 was conducted to test a worst case scenario, where maximum power is dumped into the switch. A resistive heating wire was used to emulate an electric bridge from hot switch terminals to hexport ground. The maximum power, possible in the proposed circuit design, was pumped into the heating element.

Procedure Experiment 1: (48) Hour Current Limiting Circuit Test

A fluid injection port was drilled through the base of a 77PSL2-1 switch, next to the terminal leads as shown in Figure 4, below. (This port facilitated injection of fluid into the contact cavity of the switch).

Figure 4.



The switch was screwed to a metal test block, which was clamped in a vise at a 45° angle. (45° is the position of the switch in Ford applications). The switch was orientated such that the moveable terminal connector lead was located at the bottom of the switch.

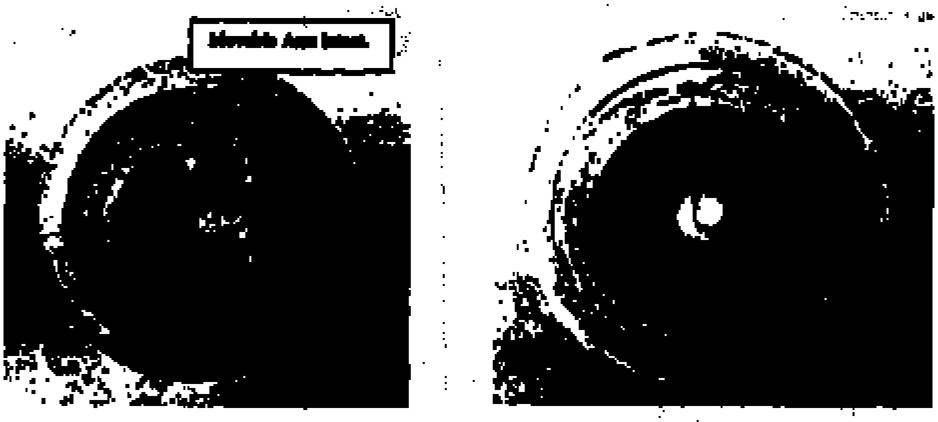
The switch was wired to the test circuit shown schematically in Figure 2, above.

The fluid level in the contact cavity of the switch was maintained for (48) hours.
The supply voltage and hexport current were monitored throughout the test.
At test completion, the switch was disassembled and observations recorded.

Results Experiment 1: (48) Hour Current Limiting Circuit Test

A steady current of 180 mAmps was measured to hexport ground, throughout the (48) hour test. The fluid level required replenishing only once. There was no activity noted throughout the test. Figure 5, below shows the disassembled switch at test completion. The photo on the left shows that the switch contact arm is fully intact. In the (15) Amp circuit, the contact arm would dissolve within (1) hour.

Figure 5.



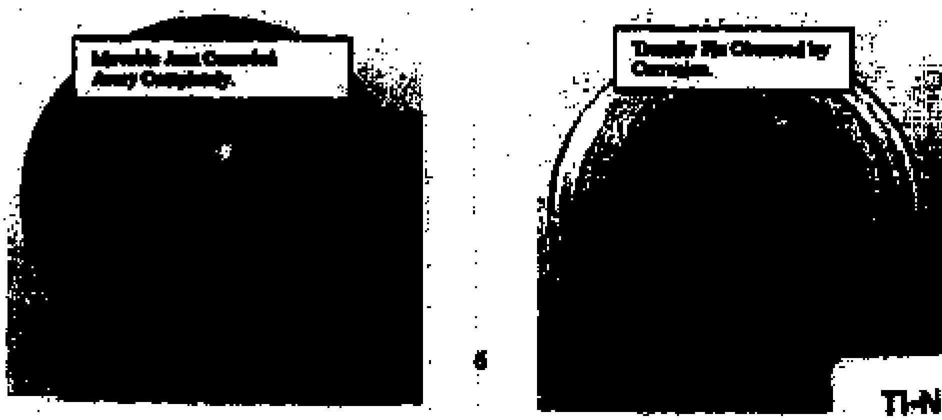
Procedure Experiment 2: Impending Ignition

A 77PSL2-1 switch was prepared and mounted as outlined in the Procedure for Experiment 1 in this report. The switch was wired to the test circuit, shown schematically in Figure 3, above.
The contact cavity of the switch was injected with several doses of a 5% salt water solution throughout the test. Switch conditions were monitored throughout the test. When conditions reached the point of impending ignition, (based on arcing and smoking) the switch was removed from the test setup and placed in the proposed current limiting circuit for (18) hours.
At test completion, the switch was disassembled and observations recorded.

Results Experiment 2: Impending Ignition

While wired in the 200mAmp circuit of Figure 2, above, the switch pulled 160 mAmps with slight fluctuations. The fluid level stated full throughout the test and no activity was observed. Figure 6, below, shows the disassembled switch used in the impending ignition experiment. The contact arm is completely corroded away and substantial deposits of corrosion has accumulated.

Figure 6.



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Procedure Experiment 3: Maximum Power Input

A small coil of resistive wire was wrapped around the base of a switch. The maximum power, possible in the proposed circuit design, was applied to the switch. Notes and observations were recorded.

In order to determine the maximum power possible in the proposed circuit, (2) Ford relays (P/N F0AB-14B192-AA) were characterized. The results are shown in Figure 7, below, which shows voltage verses current. The figure shows that the relay functions as a 70 Ω resistor over the operating range of interest.

Figure 7.

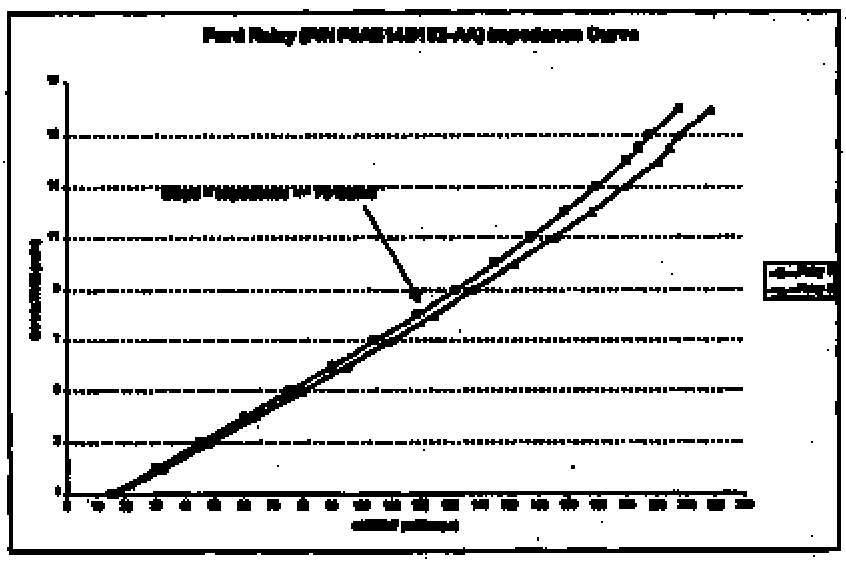


Figure 8.

The proposed circuit may therefore be approximated by (2) resistors in series, as show in Figure 8, above. Rrelay is the relay resistance and Rswitch is the switch resistance to hexport ground. Using Ohm's law, it can be shown that the power dissipated in the switch is given by Equation 1, below.

Equation (1)

$$P = (V^2)\frac{R_{switch}}{(R_{switch} + R_{relay})^2}$$

Where,
P = switch power
V = supply voltage
R_{switch} = switch resistance
R_{relay} = relay resistance

Equation (1) maximum occurs when dP/dRswitch = 0. Differentiating P with respect to R_{switch} yields equation (2).

Equation (2)

$$\frac{dP}{dR_{switch}} = (V^2)\left(\frac{R_{relay} - R_{switch}}{(R_{switch} + R_{relay})^3}\right)$$

Setting Equation (2) = to 0, maximum power occurs when Rswitch = Rrelay.
Substituting Rrelay for Rswitch in Equation (1) yields equation (3);

Equation (3) Maximum Switch Power = ¼ V^2 / Rrelay

Therefore, the maximum switch power possible in the proposed circuit is $(\frac{1}{4})(14.5)^2 / 70 = 0.75$ Watts.

Results Experiment 3: Maximum Power Input

0.75 Watts of power was applied to the heating element. The heating element had no effect on the switch which warmed but remained cool to the touch.

Conclusion

The robustness of the proposed current limiting circuit design has been proven. This experiment has demonstrated, in (3) separate experiments, that switch ignition will not occur in the proposed design. In laboratory experiments no switch ignition has occurred at less than 35 Watts of power applied to the switch (see TI report PS/99/13). The proposed design, reduces the switch potential power from 210 Watts in the existing design to 0.75 Watts. This experiment has shown that 0.75 Watts is not enough power to nucleate an ingition.

Curry, Pat

From:	Warner, Pam [pwarner@email.mc.ti.com]
Sent:	Tuesday, March 23, 1999 9:48 AM
To:	Arciniaga, Rosalie
Cc:	McGuirk, Andy
Subject:	FW: TESTLOG.xls

TESTLOG 3-17

Rose,
Here is the file Andy McGuirk would like you to make a foil of and also six black & white copies. Thanks for your help.

From: Dague, Bryan
Sent: Tuesday, March 16, 1999 4:37 PM
To: Warner, Pam; Rahman, Aziz
Cc: McGuirk, Andy; Beringhause, Steven
Subject: RE: TESTLOG.xls

<<TESTLOG 3-17>>

Andy,

Check it out to make sure the words are right and I did not miss anything.

See you at 7:00.

Bry

From: Rahman, Aziz
Sent: Wednesday, March 10, 1999 8:03 AM
To: Warner, Pam
Cc: McGuirk, Andy; Dague, Bryan; Beringhause, Steven
Subject: TESTLOG.xls

<<File: TESTLOG.xls>>

Pam,

For Andy's trip today.

Regards
Aziz.

TI-NHTSA 012994

Brake Pressure Switch Test Log, Updated [illegible]

Category	Test	Location	Test Parameters	Results Update
Lab Simulation [illegible]	1	TI	Various Levels of Brake Fluid, Water [illegible]	[illegible]
[illegible]			[illegible]	[illegible]
[illegible]			[illegible]	[illegible] Test Suspended.
				[illegible] Analysis in Progress.
	2	TI	Various Levels of Brake Fluid, Water.	[illegible]
			[illegible]	[illegible]
				Test Suspended.
	3	AVT	[illegible]	[illegible]
			[illegible]	[illegible] Test [illegible]
	4	AVT	[illegible]	[illegible]
			[illegible]	[illegible] Test suspended.
	5	AVT	[illegible]	[illegible]
			[illegible]	[illegible] Test suspended.
	5a	AVT	[illegible]	[illegible]
			[illegible]	Test suspended.
	6	TI	[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	Test [illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
	6a	TI	[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
				[illegible]
	6b	TI	[illegible]	[illegible]
			[illegible]	[illegible]
				[illegible]
				[illegible]
[illegible]	7	TI	[illegible]	[illegible]
[illegible]			[illegible]	Test [illegible]
[illegible]	8	TI	[illegible]	[illegible]
[illegible]	9	Control Labs	[illegible]	[illegible]
[illegible]	10	TI	[illegible]	Test in progress
[illegible]			[illegible]	
[illegible]				
			[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]

TI-NHTSA 012

Brake Pressure Switch Test Log, Updated [illegible]

			[illegible] being [illegible]. DOE is being [illegible].	
On-Vehicle Characterization of Pressure & Temperature Profile in Test Car	11	[illegible]	Monitor Pressure and Temperature at Switch Location for ABS and non-ABS braking events.	[illegible]
[illegible]	12	Control Labs	[illegible]	[illegible]
Characterization of [illegible] returned from field [illegible] & other sources	13	Control Labs	[illegible] chemical, metallurgical and [illegible] of returned switches	[illegible] complete. Analysis of [illegible] in progress.
Compatibility of Kapton with Brake fluid	14	Dupont	[illegible] changes in properties of Kapton with various % water in brake fluid	[illegible]
Evaluation of [illegible] Materials with improved [illegible]	15	TI	[illegible]	[illegible]

TI-NHTSA 012995

[illegible]

From:	Mulligan, Sean [[illegible]]
Sent:	Tuesday, March 23, [illegible] PM
To:	Sharpe, Robert
Cc:	Archinaga, Rosa
Subject:	Plots For Andy

5% salt water.xls | Ingress_master.xls | Used Brake fluid_5% water.xls | Used Brake fluid.xls | Tap_water.xls | Rain Water.xls

New_Brake fluid_5% water.xls | New_Brake fluid.xls

These are the excel files, Andy needs for tomorrow. Please contact me immediately when these are received. I will walk you through printing the appropriate files. (508) 236-2535.

5% Salt Water.xls contains the 5% Salt water plots. When you open this file the first (3) sheets: Hexport Current (20 Amps), (10 Amps) and (1.5 Amps) need to be color printed.

Ingress_master.xls has the other plots of interest. They are linked to all the remaining files which need to be opened before opening this file. I haven't figured out how to break the link so I hope this goes o.k. Once in Ingress_master.xls, the last (2) sheets need to be printed out: (Hexport Current (24 hrs) and Hexport Current (3 hrs).

<<5% salt water.xls>>
<<Ingress_master.xls>>
<<Used Brake fluid_5% water.xls>> <<Used Brake fluid.xls>> <<Tap_water.xls>> <<Rain Water.xls>> <<New_Brake fluid_5% water.xls>> <<New_Brake fluid.xls>>

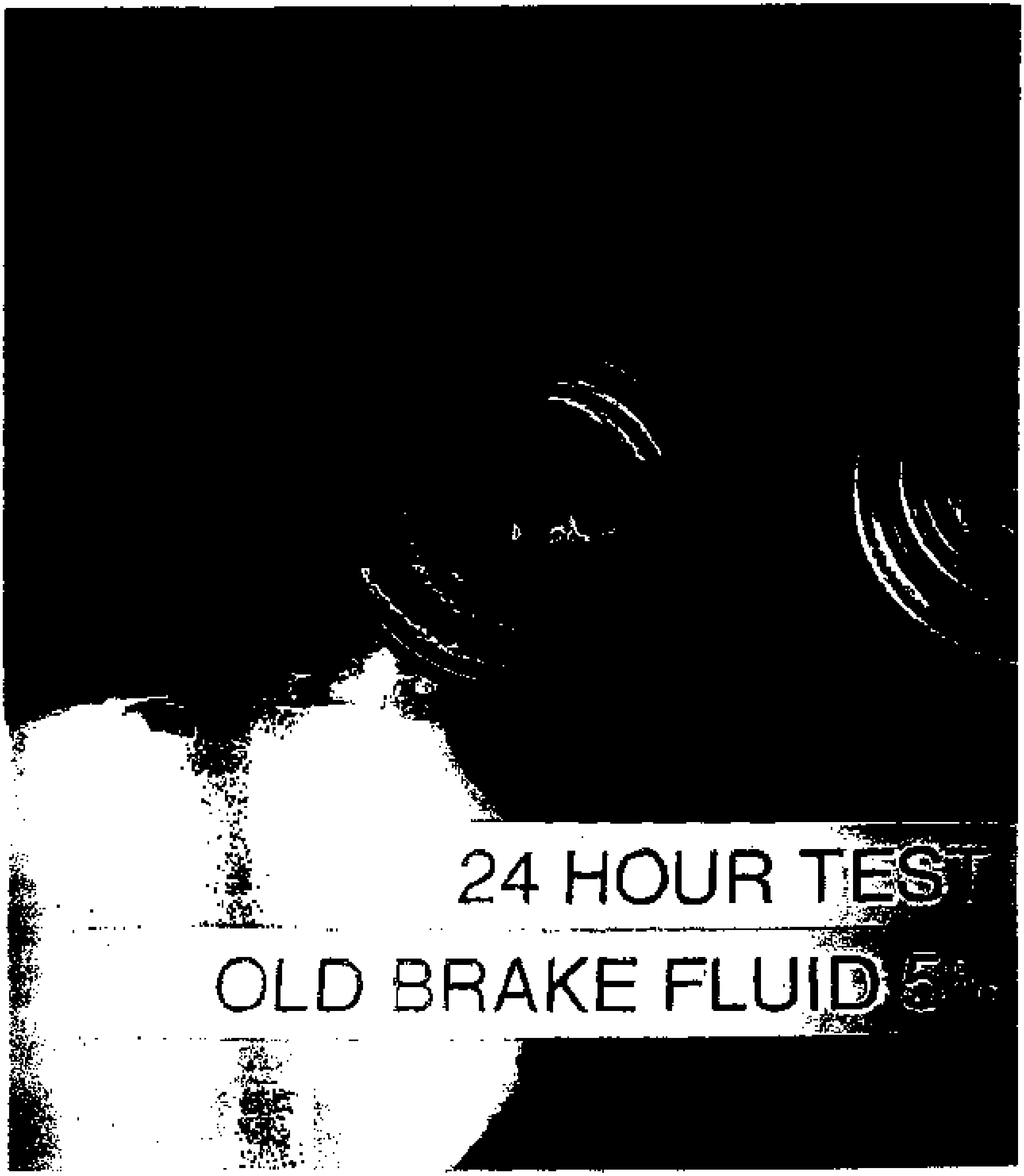
DRAWINGS AVAILABLE UPON REQUEST

1999 3 23 11:06:10 AM MVC-FD91

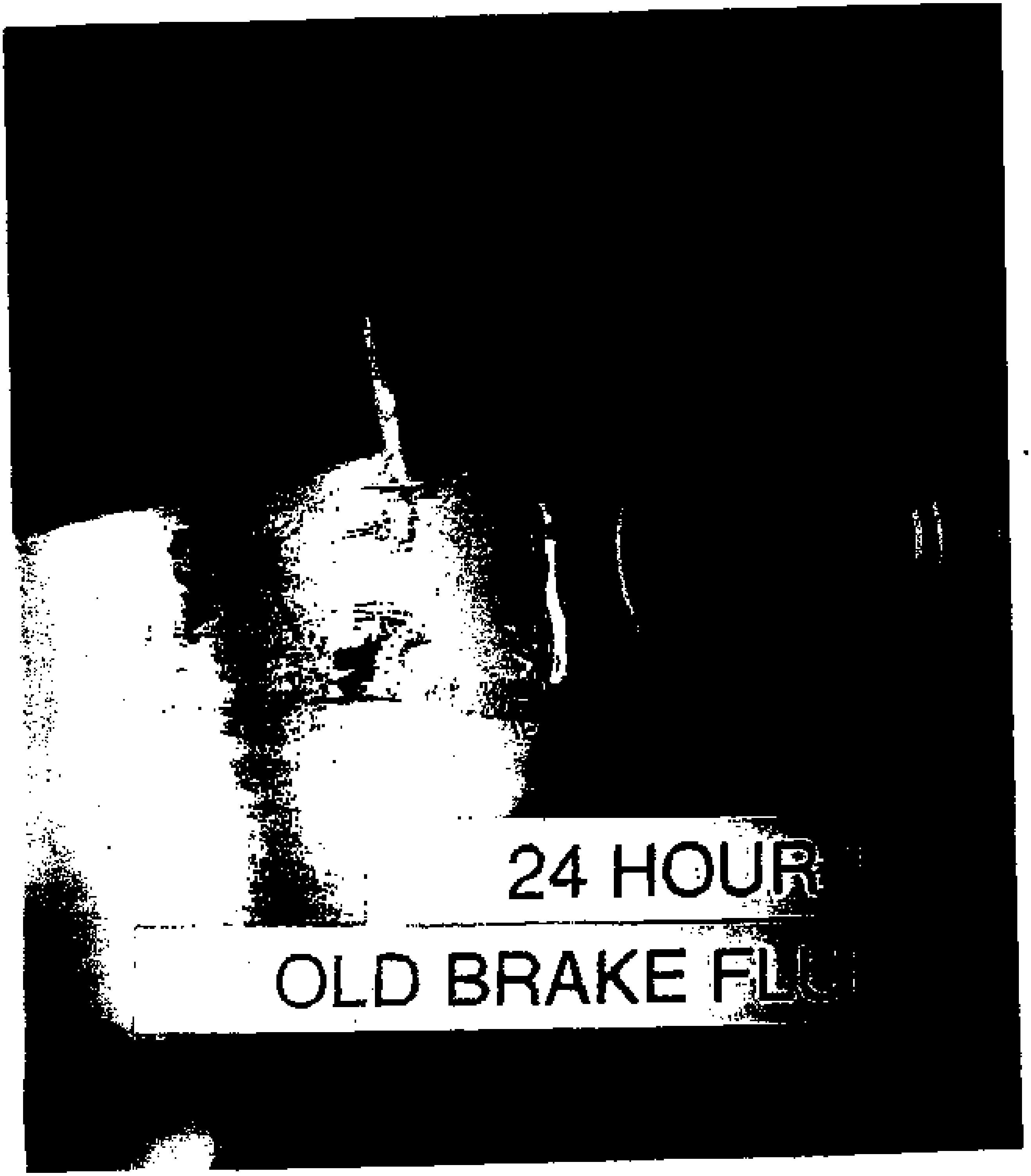
Digital Mavica images

3 mavica images	993 Kbytes free	CD12
MVC-001X.JPG	1999 3 23 11:05:48 AM	
MVC-002X.JPG	1999 3 23 11:06:00 AM	
MVC-003X.JPG	1999 3 23 11:06:10 AM	

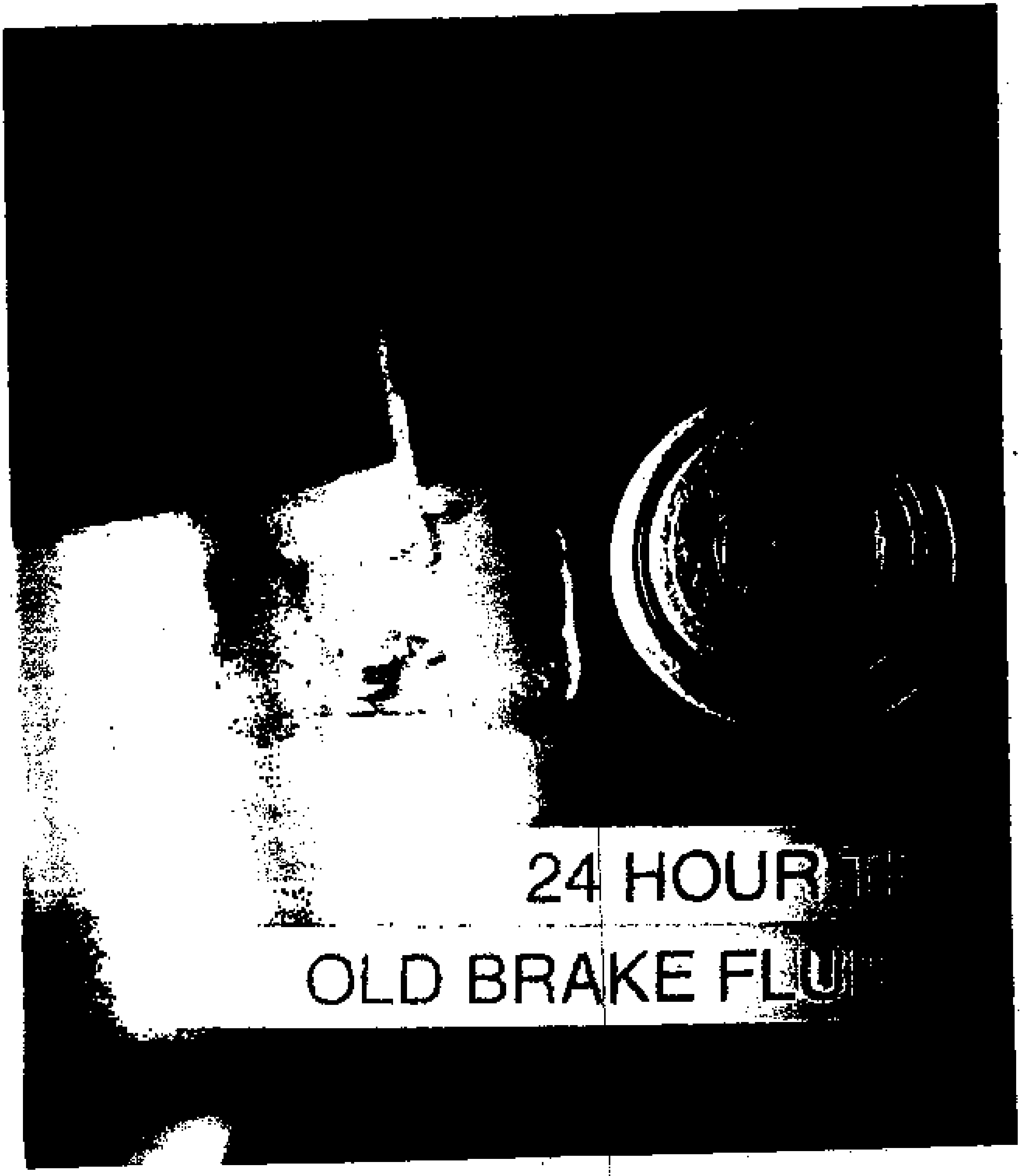
TI-NHTSA 013005



TI-NHTSA 013006



TI-NHTSA 013007



TI-NHTSA 013008

March 23, 1999

TEXAS INSTRUMENTS

FACSIMILE TRANSMITTAL

TO: Name: Rob Sharpe for Andy

Location: Detroit

Phone Number: (248) 305-5729

FAX Number: (248) 305-5734

FROM: Sean P. Mulligan
Mechanical Design
Precision Controls

TEXAS INSTRUMENTS MS 12-29

Phone Number: (508) 236-2535

FAX Number: (508) 236-3586

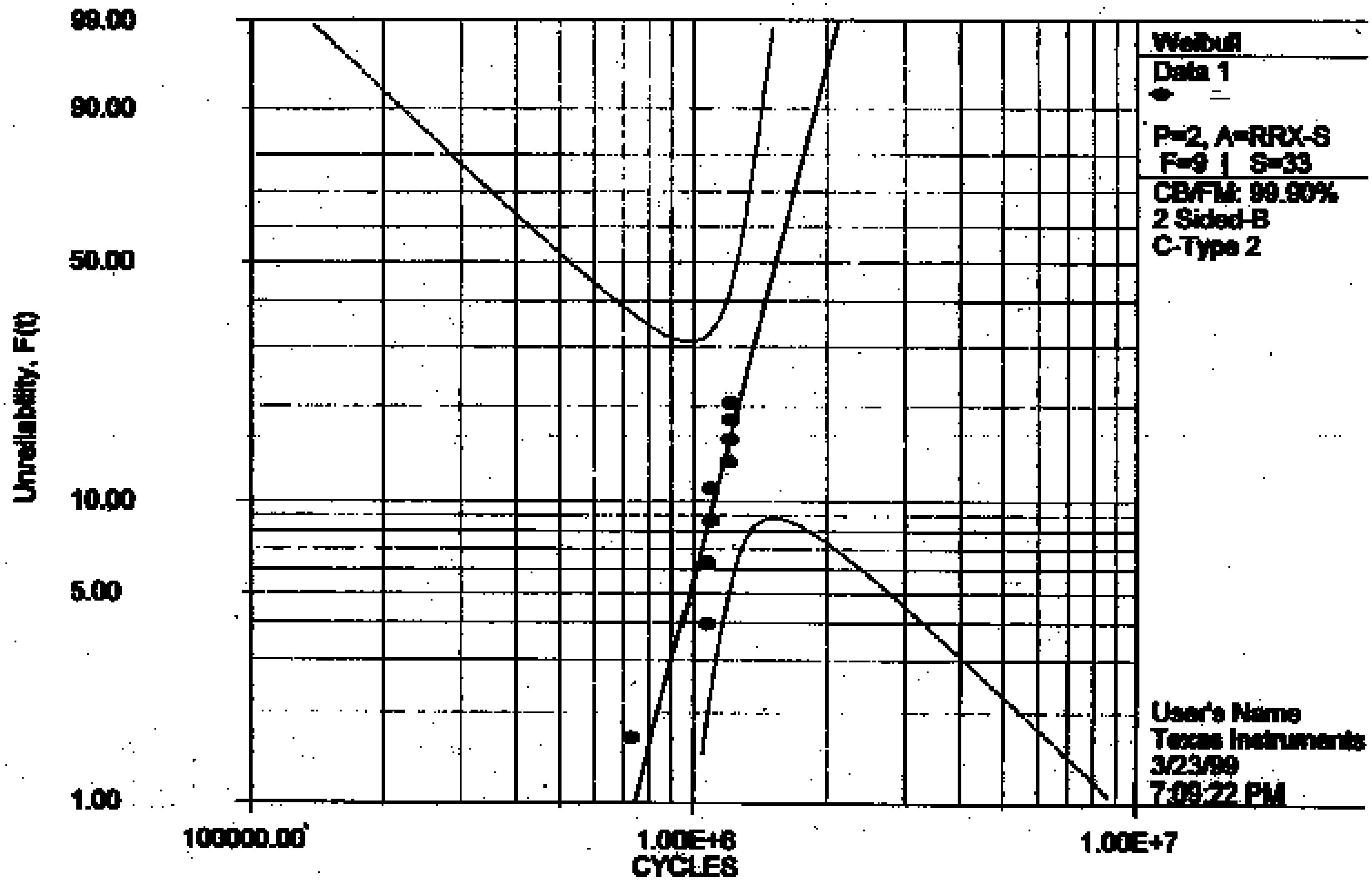
Total number of pages (including header page): 11

COMMENTS: For Andy,

Regarding the Weibull Analysis

TI-NHTSA 013009

77PSL2-1 COMBINED TEST



β=5.83, η=1.64E+6, ρ=0.91

Date: 3/23/99
User: User's Name
Company: Texas Instruments

User Input:

Mission End Time: = 500000
Confidence Bounds Used: 2-Sided

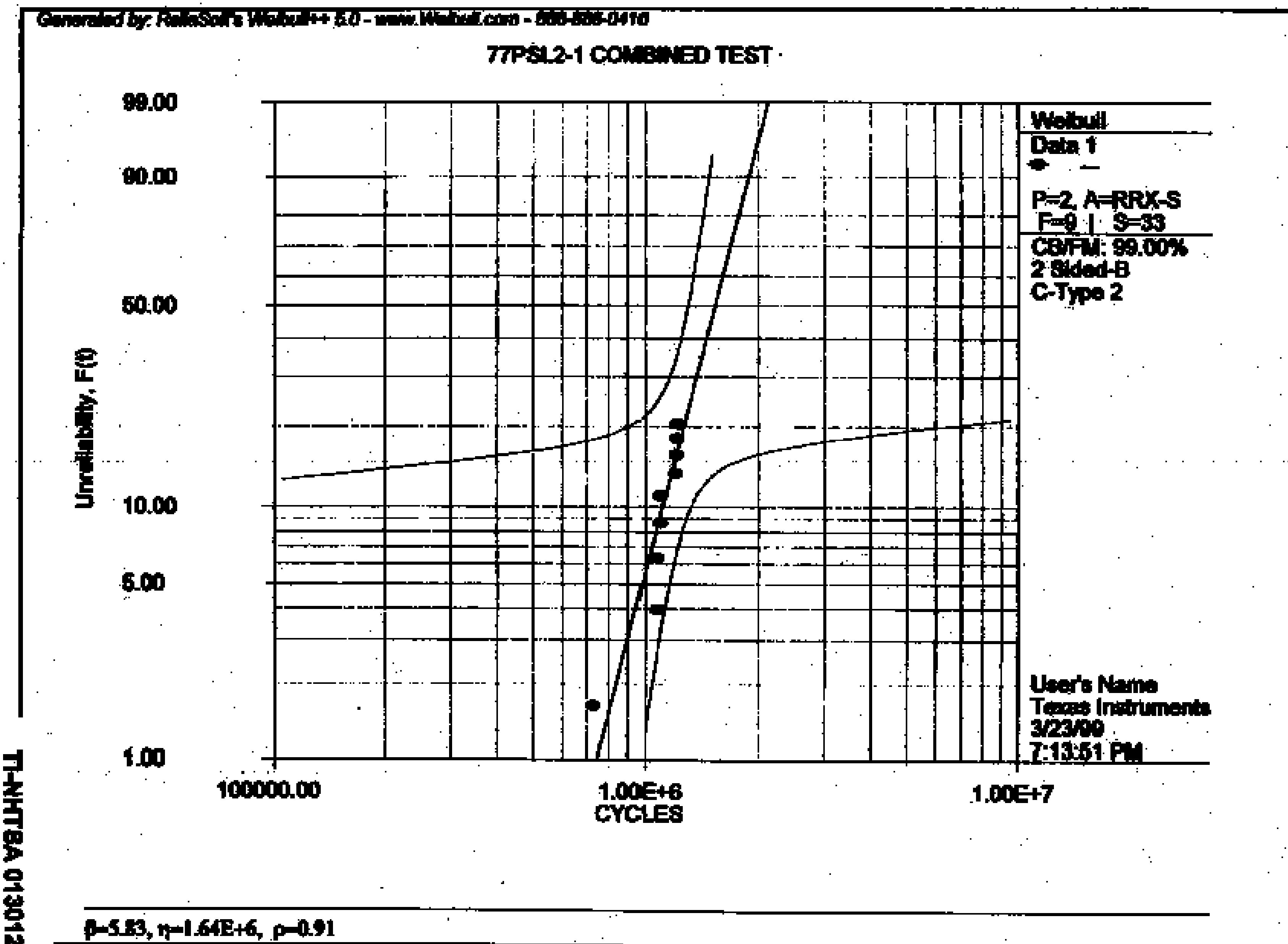
Confidence Level: = 0.999
On the parameters:
Lower=1.5762 Beta=5.5912 Upper=20.2886
Lower=10.8456E+5 Eta=16.3045E+5 Upper=24.6917E+5
Weibull++ Output :

Lower CL: = 0.4743
Reliability: = 0.9990
Upper CL: = 1.0000
Confidence: = 28 @ 0.999

ReliaSoft QCP End of Quick Results

TI-NHTSA 013011

Plot of Data 1



Date: 3/23/99
User: User's Name
Company: Texas Instruments

User Input:

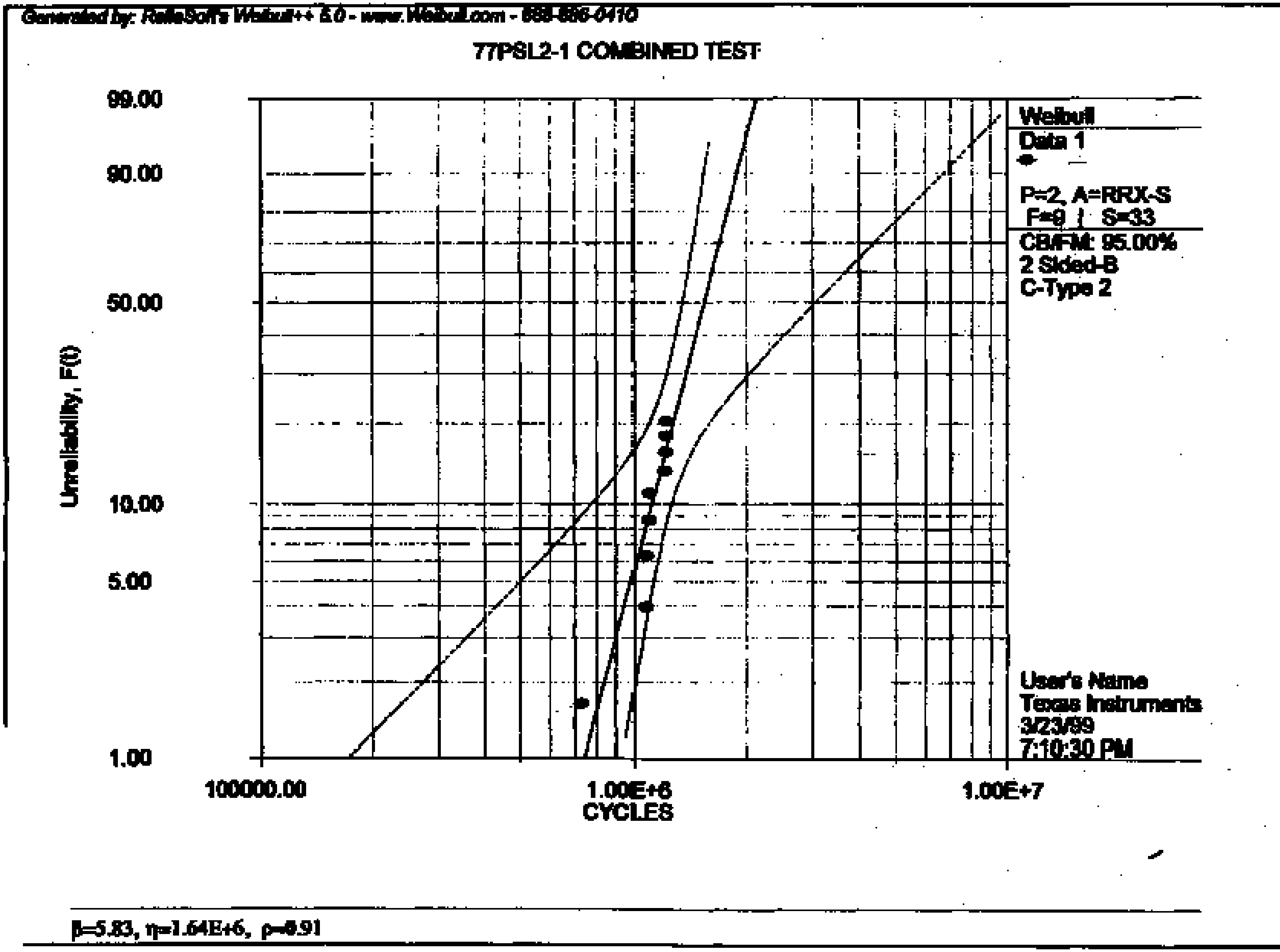
Mission End Time: = 500000
Confidence Bounds Used: 2-Sided

Confidence Level: = 0.99
On the parameters:
Lower=2.1973 Beta=5.8312 Upper=15.4748
Lower=11.8690E+6 Eta=16.3645E+6 Upper=22.6819E+6
Weibull++ Output :

Lower CL: = 0.8377
Reliability: = 0.9990
Upper CL: = 1.0000
Confidence: = 2S @ 0.99

ReliaSoft QCP End of Quick Results

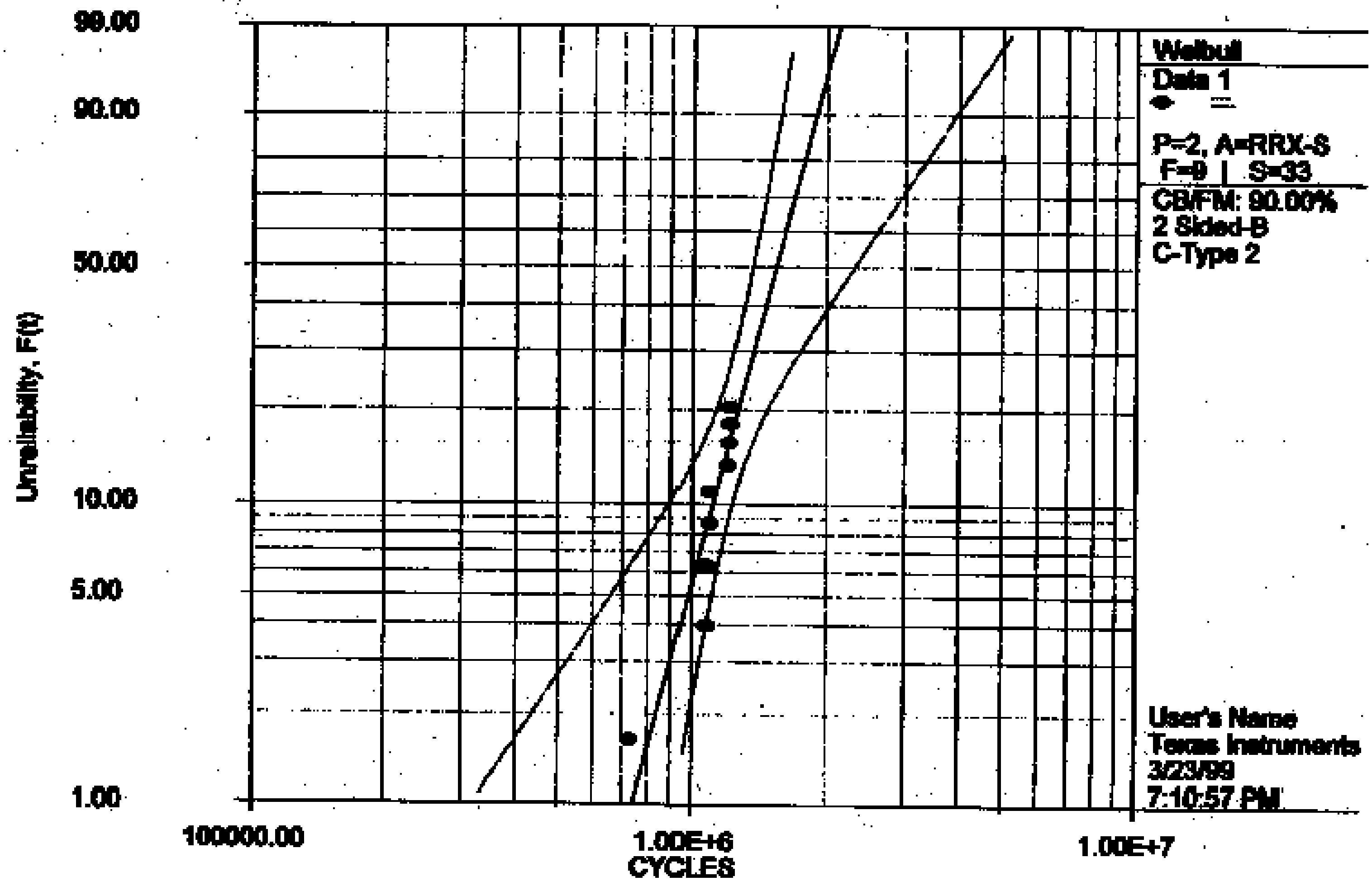
Plot of Data 1



TI-NHTSA 013014

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

77PSL2-1 COMBINED TEST



β=5.83, η=1.64E+6, ρ=0.91