EA02-025

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

REQUEST NO. 7

BOX 8

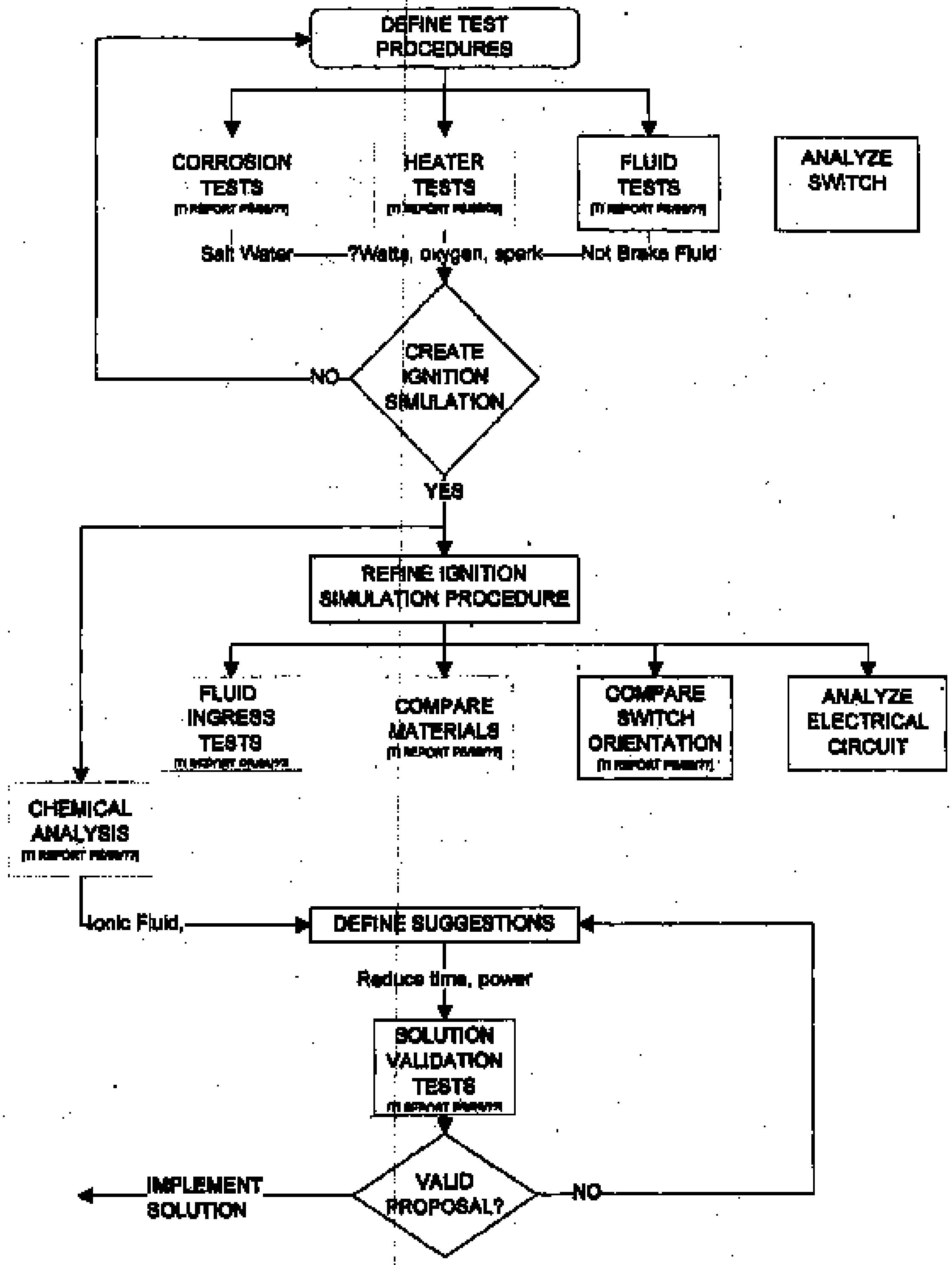
PART A-U

PART U

Currey, Pat

From: Mulligan, Sean [smulligan@email.mc.ti.com]
Sent: Sunday, April 25, 1999 11:50 AM
To: McGuirk, Andy
Subject: Document3

<<Doc3.doc>>



TI-NHTSA 013376

Currey, Pat

From: Mulligan, Sean [smulligan@email.mc.ti.com]
Sent: Sunday, April 25, 1999 6:19 PM
To: McGuirk, Andy

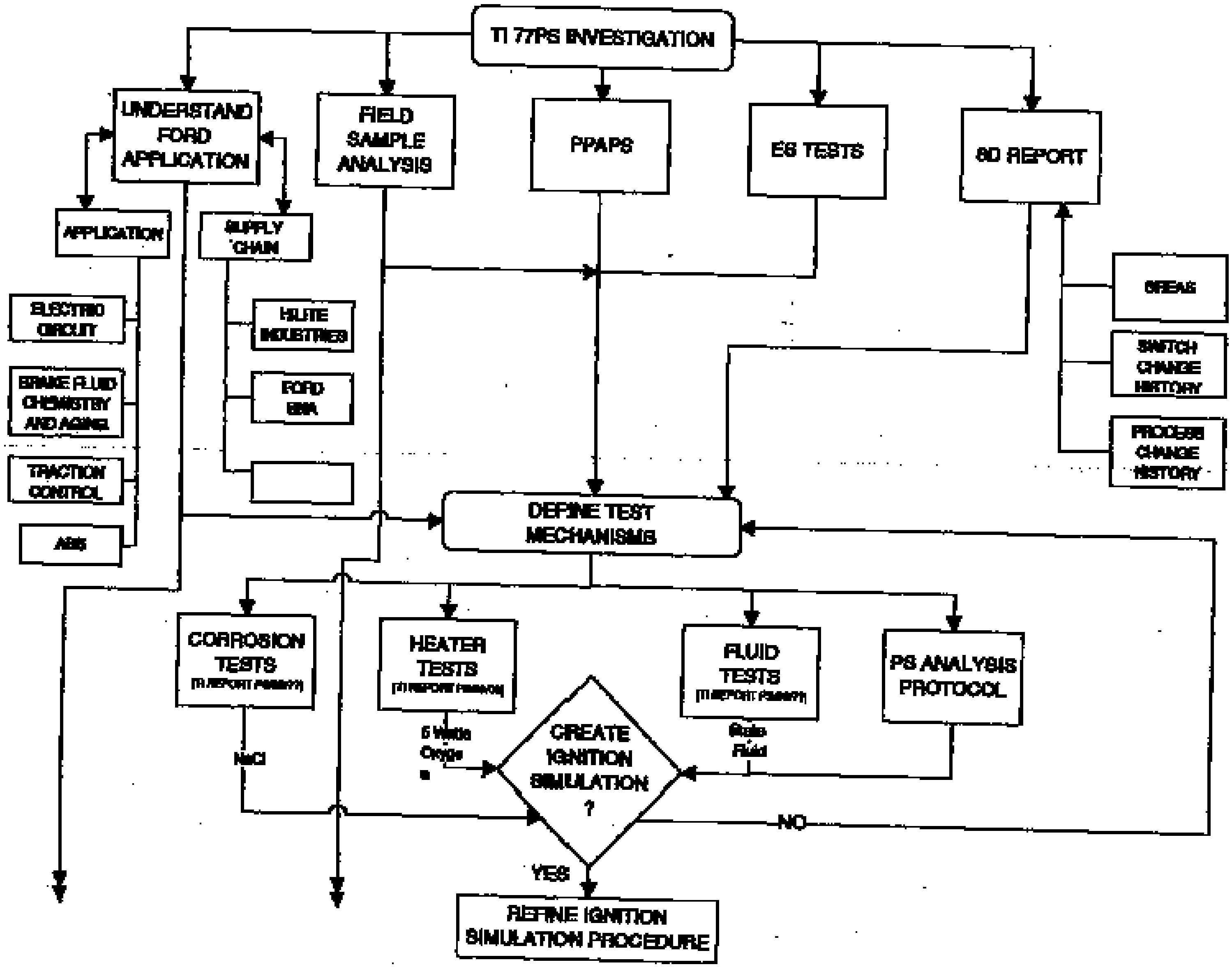
77P8flow_2.ppt

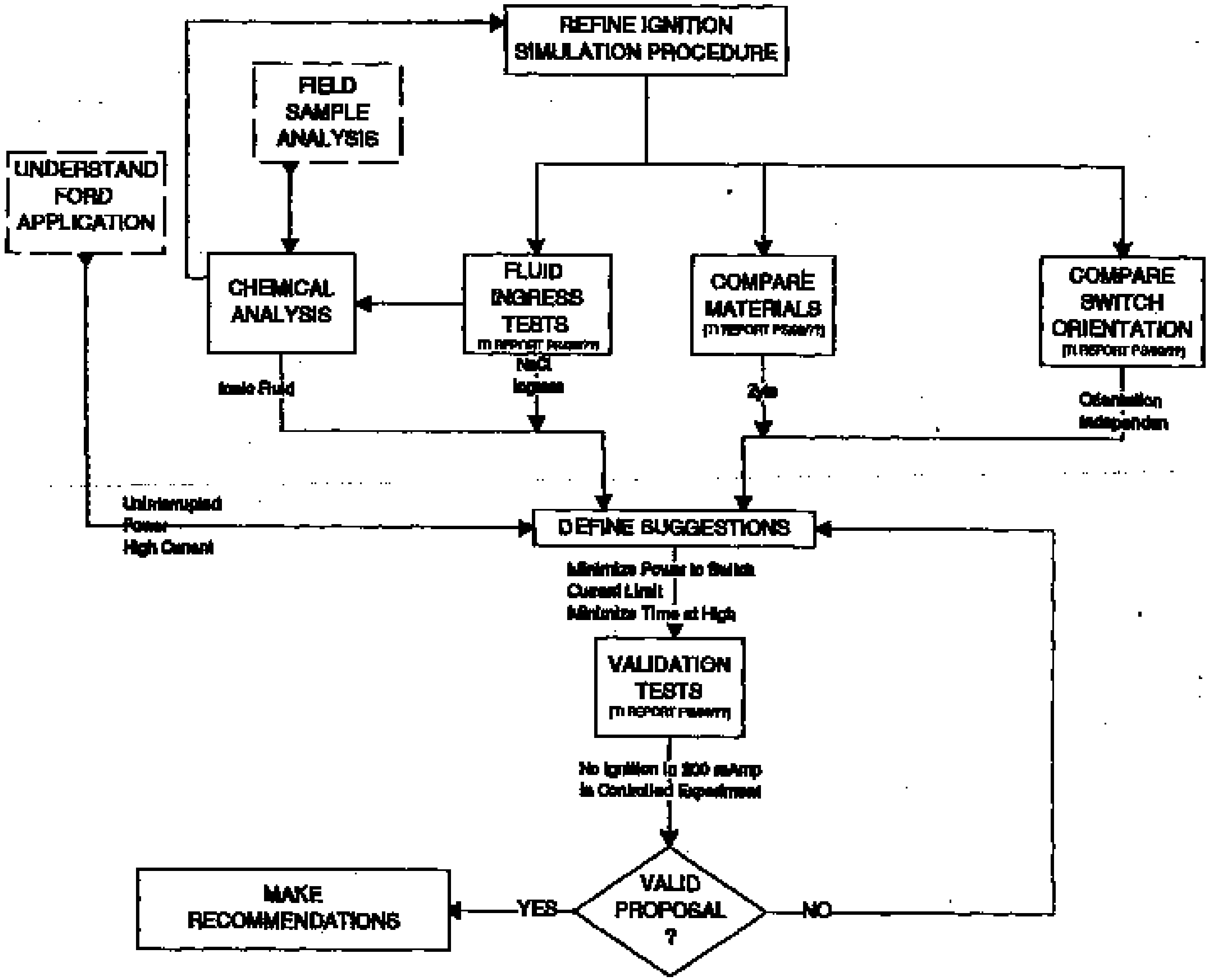
<<77P8flow_2.ppt>>

All the best,

Sean P. Mulligan

Phone (508) 236-2535
Fax (508) 236-3586


TI 77PS INVESTIGATION
UNDERSTAND FORD APPLICATION
FIELD SAMPLE ANALYSIS
PPAPS
ES TESTS
8D REPORT
APPLICATION
SUPPLY CHAIN
ELECTRIC CIRCUIT
BRAKE FLUID CHEMISTRY AND AGING
TRACTION CONTROL
ABS
HILITE INDUSTRIES
FORD
SWITCH CHANGE HISTORY
PROCESS CHANGE HISTORY
DEFINE TEST MECHANISMS
CORROSION TESTS
HEATER TESTS
FLUID TESTS
PS ANALYSIS PROTOCOL
NaCl
5 Watts
CREATE IGNITION SIMULATION ?
NO
YES
REFINE IGNITION SIMULATION PROCEDURE



TI-NHTSA 013379

GROUP NUMBER

DEVICE #

	G1	G2	G3	G4	G5	G6
1			*A 44503		297283	243000
2					297348	281012
3						266712
4						297283
5						305241
6						
7	-					
8						
9						
10						

CYCLES

*A=Estimated total cycles are indicated number plus 425000

Note:

G1=77PSL2-1 IN 100% BRAKE FLUID
G2=77PLS3-1 IN 100% BRAKE FLUID
G3=77PSL4-1 IN 100% BRAKE FLUID
G4=77PSL2-1 IN 5% WATER/ 95% BRAKE FLUID SOLUTION
G5=77PSL3-1 IN 5% WATER/ 95% BRAKE FLUID SOLUTION
G6=77PSL4-1 IN 5% WATER/ 95% BRAKE FLUID SOLUTION

Long-duration Brake Fluid Test Powered

To date:

(6) samples

2 Used Brake fluid → < 1/10 m Amp

4 New Brake Fluid → 1.3 - 17 m Amps steady

No samples required refilling

Converter / Washer Measurements

From line today — Washer — ID

,2960 ± 5/10,000	same washer different place
,2965 + 5/10,000	same washer
,2965	Repeatable

Converter

,2890 ± 5/10,000

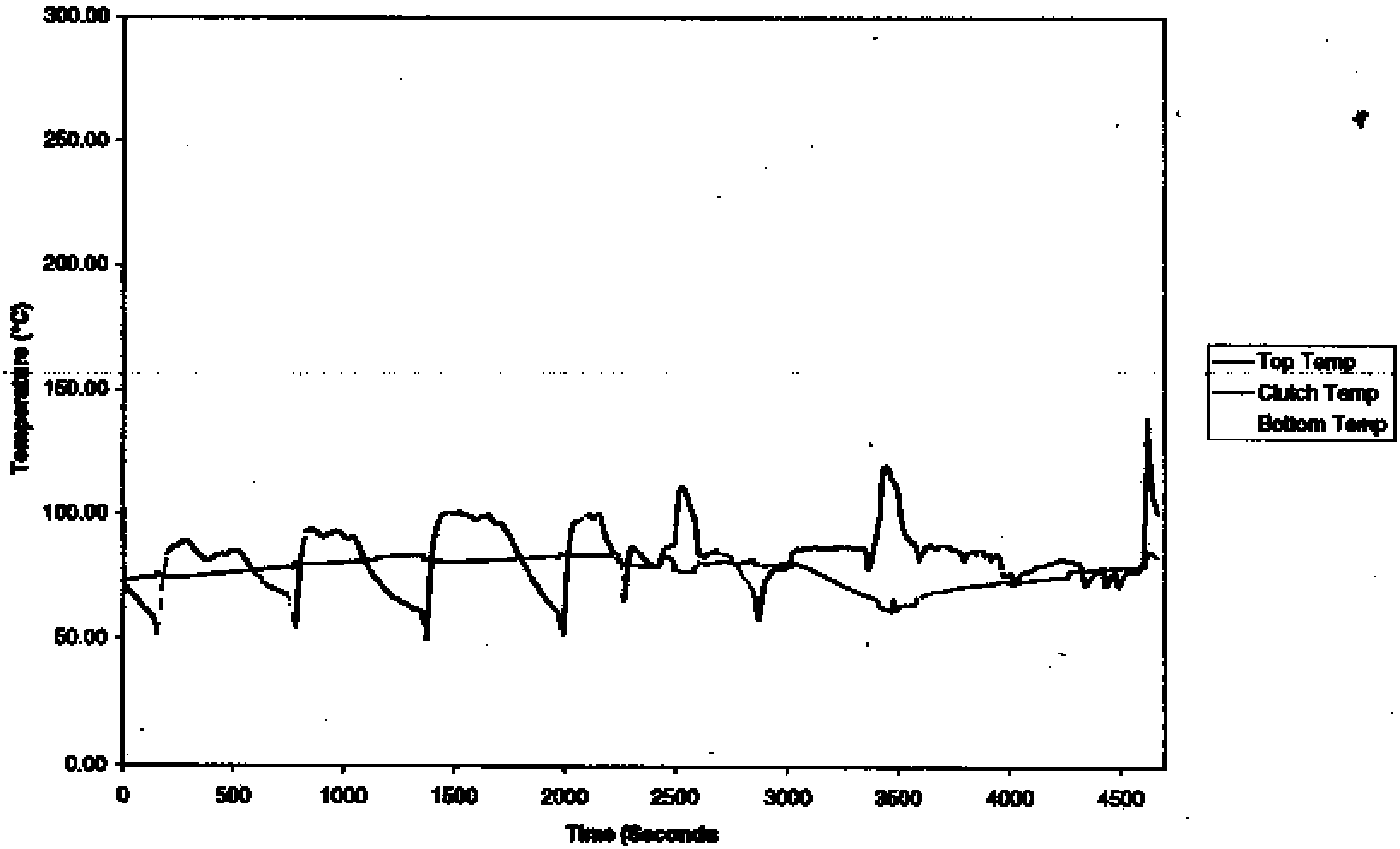
[redacted]

,2990 ± 5/10,000

,2590 ± 0

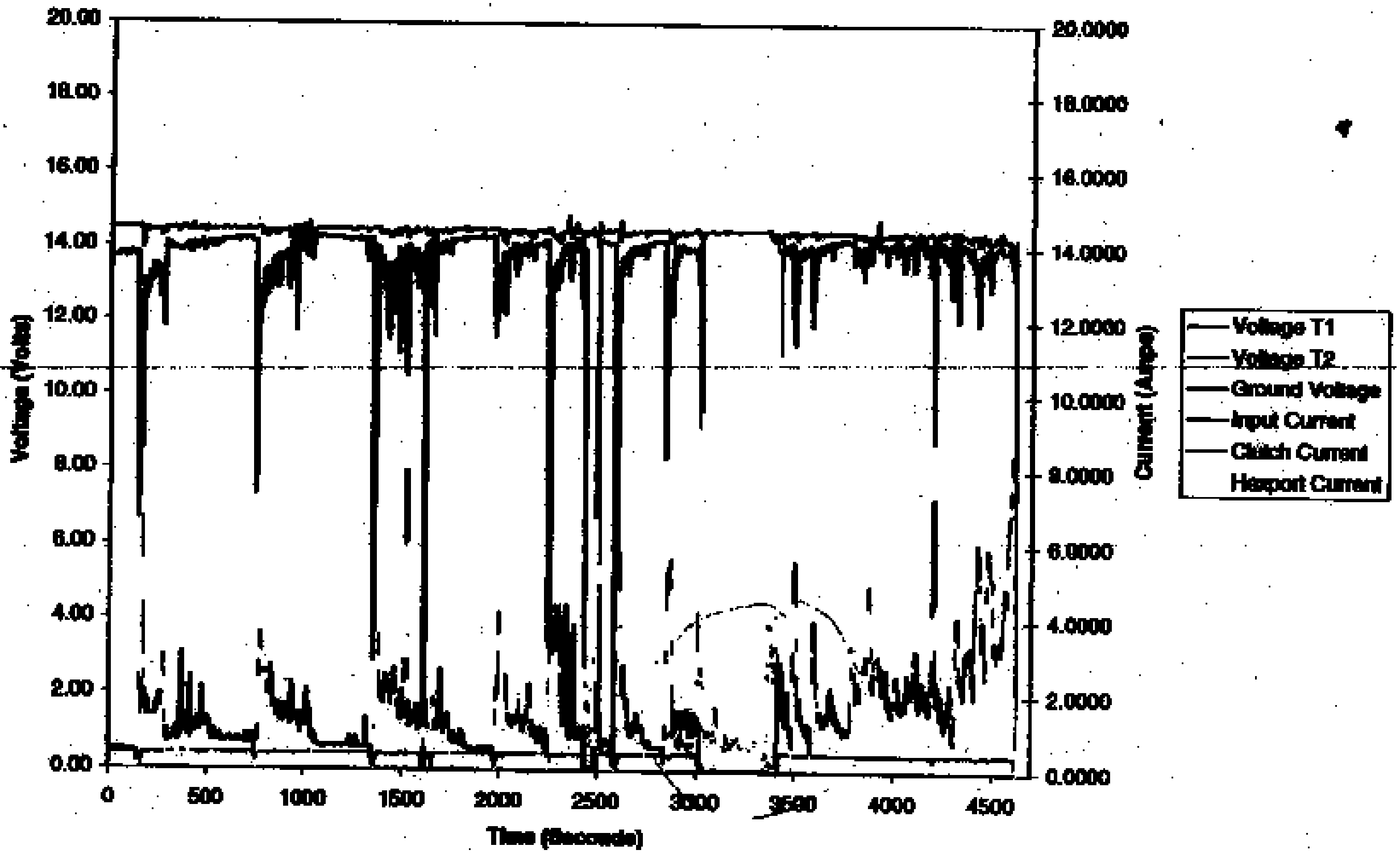
Converter ,2905

11:22AM to 12:39AM Temperature



TI-NHTSA 013383

11:22AM to 12:39PM



TI-NHTSA 013384

Currey, Pat

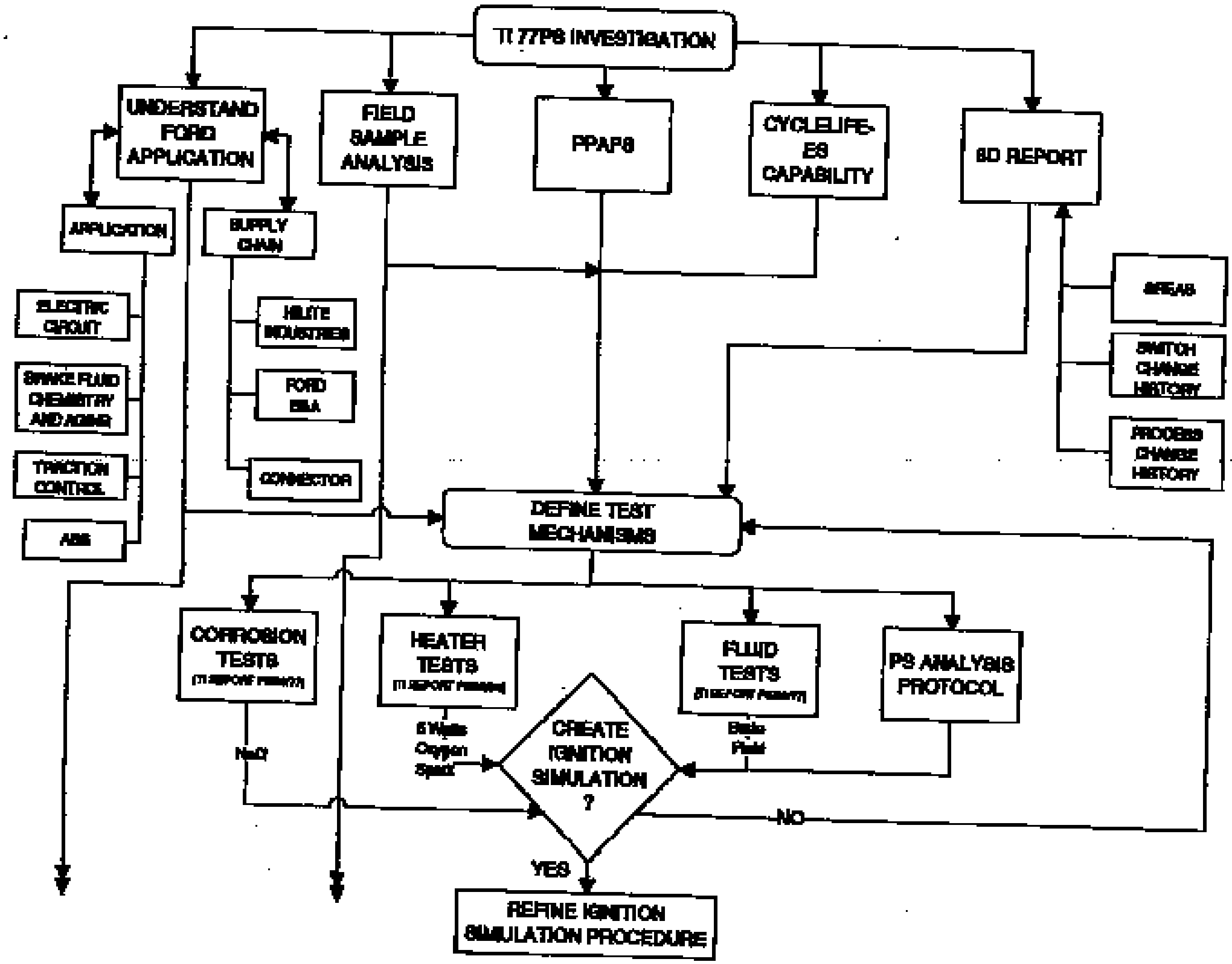
From: Mulligan, Sean [smulligan@email.mc.ti.com]
Sent: Sunday, April 25, 1999 6:49 PM
To: McGuirk, Andy

<<77PSflow_2.ppt>> <<TESTLOG 4-25.xls>>

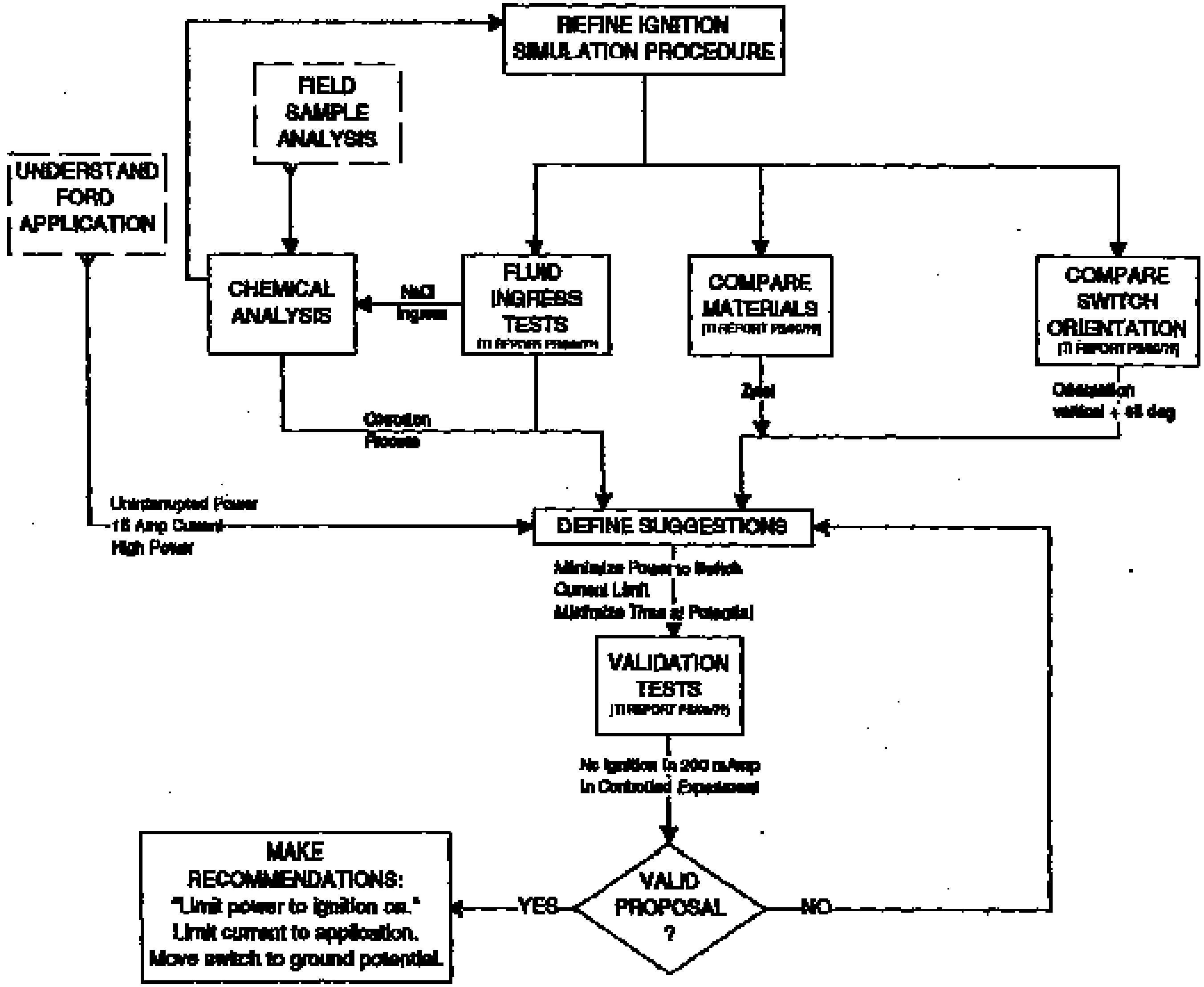
All the best,

Sean P. Mulligan

Phone (508) 236-2535
Fax (508) 236-3586



TI-NHTSA 013386



TI-NHTSA 013367

Brake Pressure Switch Test Log, Updated 3/10/[illegible]

Category	Test	Location	Test Parameters	Results Update
Lab Simulation of Potential Ignition in Switch	1	TI	Vary water concentrations in "new" Brake Fluid 14Vdc to one terminal, hexport grounded Water Conc. 0%, 4%, 6%, 10%, 75%	300+ hours, Current draw in the [illegible] to [illegible] range Fluid has discolored No Significant Temperature Rise. Test Suspended Internal Analysis suspended
	2	TI	Vary water concentrations in "new" Brake Fluid 1 Amp through switch terminals	300+ hours. Constant temperature No significant temperature rise with load Test Suspended
	3	A/T	"new" Brake Fluid in Switch. 24 VDC to one terminal. Hexport Grounded	> 300 hours [illegible], max current 7mA No significant change with time. Test ongoing
	4	A/T	"new" Brake Fluid in Switch, 24 VDC to one terminal. Hexport Grounded, Ambient at 150 C	[illegible] hours into test max current [illegible] No significant temperature rise with time. Test suspended
	5	A/T	"new" Brake Fluid in Switch, 14 Amps through switch terminals	Temperature rise of 20 C above room temp Delta T reached steady state at 20 C. Test completed
	5a	A/T	"new" Brake Fluid in Switch approx. [illegible] Amps through Switch Terminals	Temperature rose to approx. 270 F. No smoke. No ignition. Test suspended
	6	TI	[illegible] into Switch [illegible] With Fluid & Dry [illegible] [illegible]	[illegible] See attachment Test complete [illegible] Smoke observed at [illegible] F. [illegible] F
	6a	TI	Create leaker by [illegible] [illegible] water solution, [illegible] between [illegible] and hexport	One out of 13 devices [illegible] Others [illegible] It took about [illegible] hours to [illegible] The [illegible] device [illegible]
	6b	TI	[illegible] test to understand repeatability and current path	Switch [illegible] solution into switch Current path is through hexport. See slide and notes. Additional test [illegible]
Life Cycle Reliability of Pressure Switch	7	TI	0-1000 psig pressure pulses at 1[illegible]C per [illegible]	First leak observed at 7[illegible] cycles Test Completed. See attached Weibull Chart
[illegible] Wear	8	TI	0-1000 psig pressure pulses at 1[illegible]C	Parts with [illegible] cycles, [illegible]
[illegible] at Lab Condition	9	Central Labs	Field returns, [illegible]	Parts in Central Labs, [illegible]
[illegible]	10	TI	Vary water concentrations in "new" Brake Fluid 12 amp + 12 [illegible] at 6% water in [illegible] 12 amp + 12 [illegible] at 6% water in [illegible]	Test [illegible] Suspended at 1.3 million cycles with no leaks observed [illegible] suspended at 1.3 million cycles with 3 leaks observed at 1.3M. [illegible] suspended at [illegible] cycles to assess leakage [illegible]

[illegible]	11	A/T?	[illegible]	[illegible]
[illegible]	11a	TI	[illegible]	Test complete [illegible]
[illegible]	12	Control Labs	[illegible]	[illegible]
[illegible]	13	Control Labs	[illegible]	[illegible]
[illegible]	11a?	TI	[illegible]	Test complete [illegible]
[illegible]	[illegible]	TI	[illegible]	[illegible]
[illegible]	14	[illegible]	[illegible]	[illegible]
[illegible]	15	TI	[illegible]	[illegible]
[illegible]	16a?	TI	[illegible]	Test in progress [illegible]
[illegible]	11b	TI	[illegible]	Test complete [illegible]
[illegible]	16	TI	[illegible]	Test complete [illegible]

Brake Pressure Switch Test Log, Updated 3/10/99

Test			Relay switch to [illegible] [illegible] in (15) Amp	Insufficient energy in circuit to create or [illegible] [illegible] ignition in [illegible]
			circuit then place in relay circuit for (10) hrs.	Heater element was warm to the touch.
			Input max. circuit power into heater on switch.	

TI-NHTSA 013390

Carrey, Pat

From: McGuirk, Andy [a-mcguirk@email.mc.ti.com]
Sent: Monday, April 26, 1999 6:05 AM
To: Warner, Pam
Subject: FW:

77PSflow_2.ppt   TESTLOG 4-25.xls

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

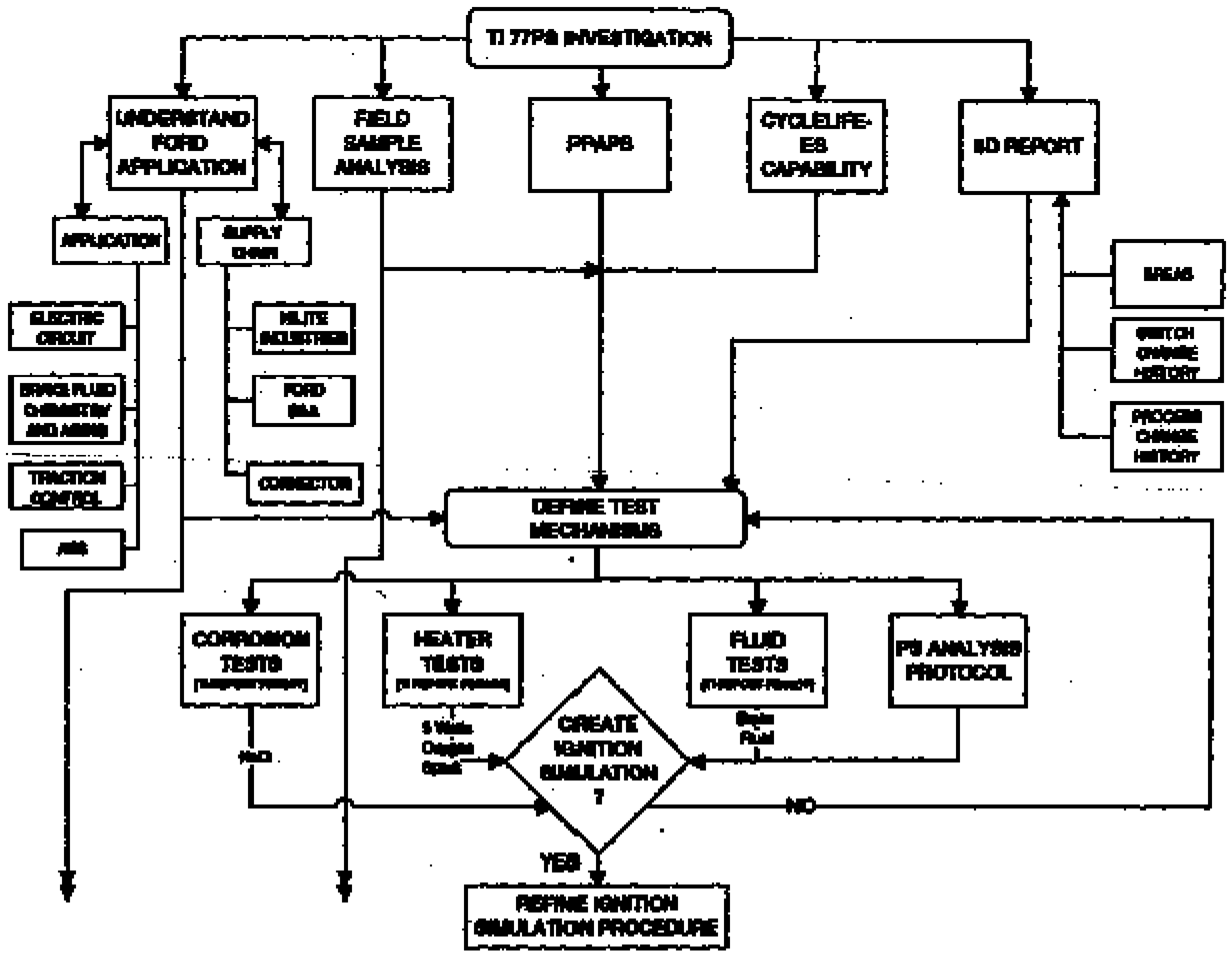
From: Mulligan, Sean
Sent: Sunday, April 25, 1999 7:49 PM
To: McGuirk, Andy

<<77PSflow_2.ppt>> <<TESTLOG 4-25.xls>>
All the best,

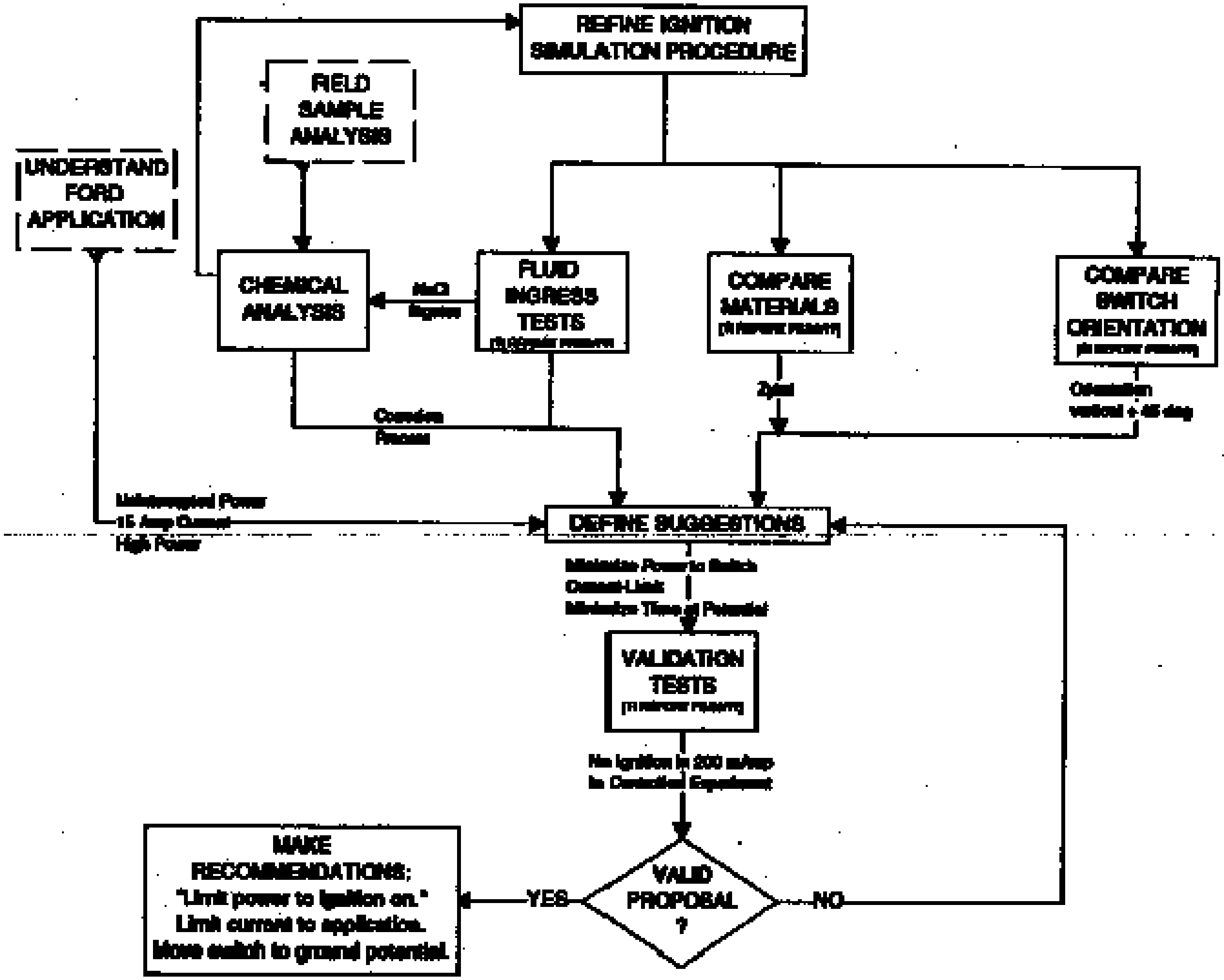
Sean P. Mulligan

Phone (508) 236-2535
Fax (508) 236-3586

TI-NHTSA 013391



TI-NHTSA 013392



TI-NHTSA 013393

Brake Pressure Switch Test Log, Updated 3/16/99

Category	Test	Location	Test Parameters	Results Update
Lab Simulation	1	TI	Vary water concentrations in "used" Brake Fluid	300+ hours, Current down to the [illegible] mA range
of Potential Ignition			14Vdc to [illegible], Hexport grounded	Fluid has discolored
in Switch			Water Cycle: [illegible]	No Significant Temperature Rise. Test Suspended.
				Internal Analysis suggested
	2	TI	Vary water concentration in "used" Brake Fluid	700+ hours. Constant temperature
			1 Amp through switch terminals	No significant temperature rise with time
				Test Suspended
	3	AVT	"used" Brake Fluid in Switch, 24 VDC to [illegible] terminal. Hexport Grounded	+ 300 hours [illegible] current [illegible]
				No significant change with time. Test ongoing
	4	AVT	"used" Brake Fluid in Switch, 24 VDC to [illegible] terminal. Hexport Grounded, Ambient at 100 C	[illegible] current [illegible]
				No significant temperature rise with time. Test suspended
	5	AVT	"used" Brake Fluid in Switch, 10 Amps through switch terminals	Temperature rose to 30 C above ambient temp
				[illegible] steady state at 30 C. Test suspended
	5a	AVT	"used" Brake Fluid in Switch approx. 30 Amps through Switch Terminals	Temperature rose to approx. 370 F [illegible]
				Test suspended
	6	TI	[illegible] Switch	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
	6a	TI	Create leaks by [illegible]	One out of 11 [illegible]
			[illegible]	[illegible]
			[illegible]	[illegible]
				[illegible]
	6b	TI	[illegible]	[illegible]
			[illegible]	[illegible]
				[illegible]
				[illegible]
[illegible] Cycle [illegible] Pressure Switch	7	TI	[illegible] at 130C	Fluid leak observed at [illegible] cycles
			[illegible]	Test Completed [illegible]
Diaphragm Wear	8	TI	[illegible] at 130C	[illegible]
Field vs Lab Degradation	9	Central Labs	Field [illegible]	[illegible] at Central Labs [illegible]
Range Of Exposure [illegible]	10	TI	Vary water concentrations in "new" Brake Fluid	Test Report [illegible]
[illegible]			[illegible]	[illegible]
[illegible] Diaphragm Wear			[illegible]	[illegible]
[illegible] test				[illegible]
				[illegible]
On-Vehicle Characterization	11	AVT	Measure Pressure and Temperature	Test at AVT [illegible]
of Pressure & Temperature			[illegible] Locations for [illegible]	
Profile in Town Car			[illegible]	

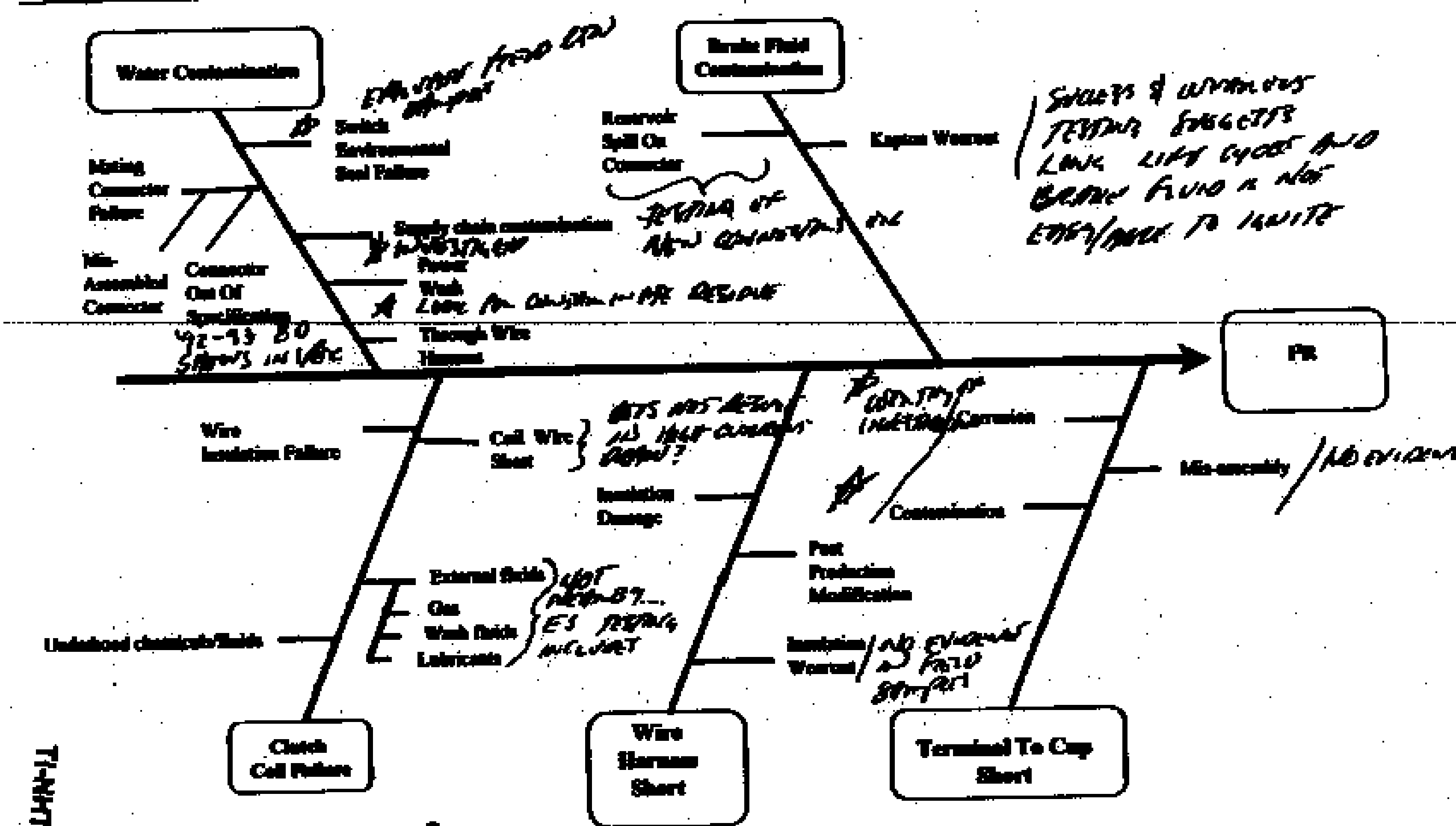
Brake Pressure Switch Test Log, Updated [illegible]

Brake fluid analysis Used fluid at master cylinder	11a	TI	[illegible]	Test complete [illegible]
Spark Arc Study	12	Control Labs	[illegible]	[illegible]
[illegible]	13	Control Labs	[illegible]	[illegible]
Fluid Ingress Tests	13a	TI	[illegible]	Test complete [illegible]
Design Of Experiments (D) Repeat of test 10	13b	TI	[illegible]	Test completed. [illegible]
Compatibility of Kapton with Citric Acid	14	Dupont	[illegible]	[illegible]
Evaluation of Plastic Materials with improved Corrosion	15	TI	[illegible]	Test completed [illegible]
Long duration brake fluid ingress test	16a	TI		Test in progress. [illegible]
Evaluation of Switch Orientation	16b	TI	[illegible]	Test complete. [illegible]
Relay Circuit Test	20	TI	[illegible]	Test complete. No leakage. [illegible]

TEXAS INSTRUMENTS

Brake Pressure Switch
Potential Thermal Event Theory Profile 4/26/99

[redacted]

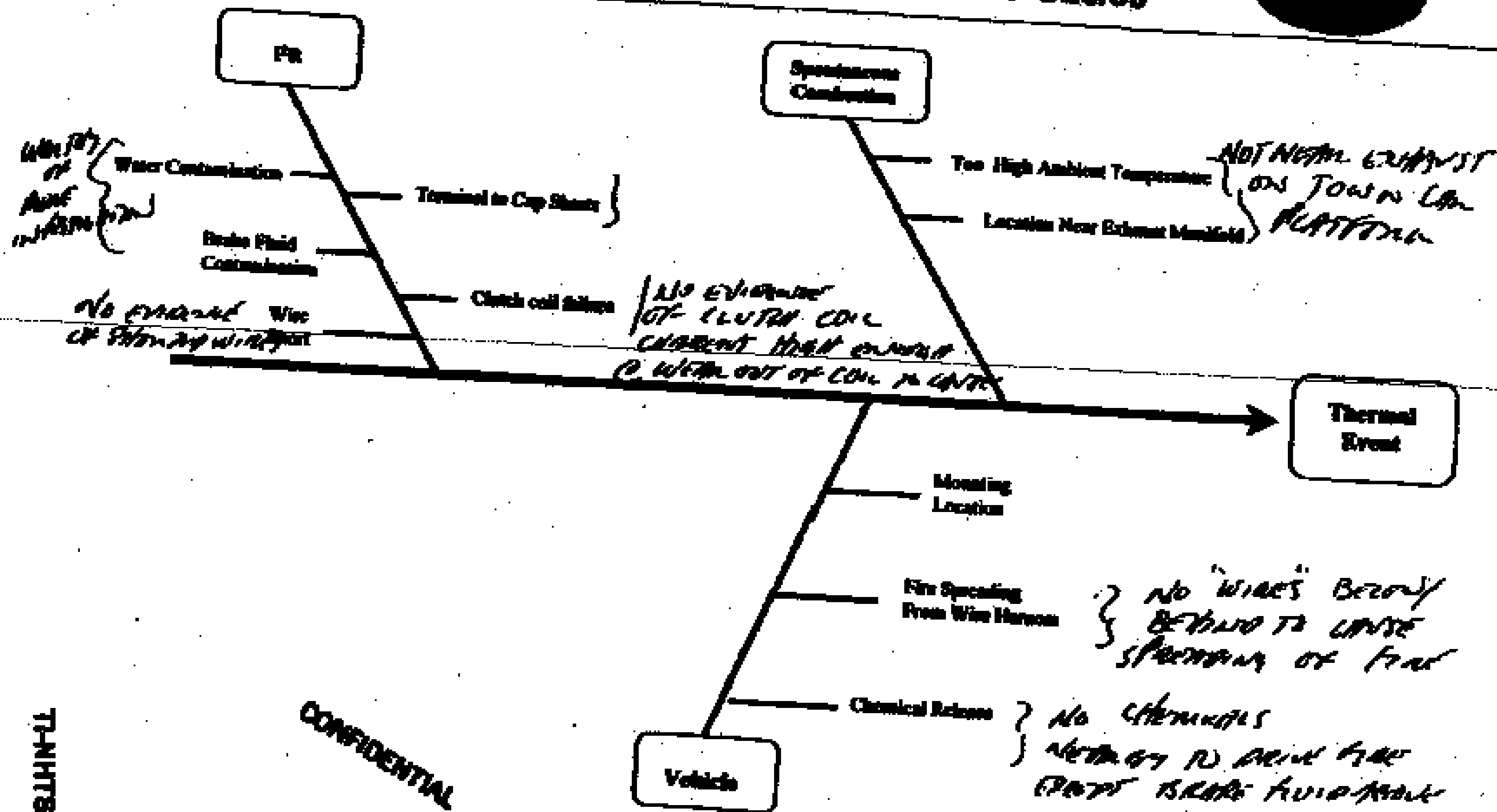


CONFIDENTIAL

Texas Instruments

Brake Pressure Switch
Potential Thermal Event Theory Profile 4/26/99

[redacted]



CONFIDENTIAL

TI-NHTSA 013397

Brake Pressure Switch Test Log, Updated 4/26/99

Category	Test	Location	Test Parameters	Results Update
[illegible]ulation [illegible]dental Ignition [illegible] Switch	1	TI	Vary water concentrations in 'new' Brake Fluid 14Vdc to one terminal, hexport grounded Water Conc. 0%, [illegible], 6%, 10%, 76%	250+ hours, Current draw in the 0.5mA to 5mA range Fluid has discolored. No Significant Temperature Rise. Test Suspended. Internal Analysis suspended.
	2	TI	Vary water concentrations in 'new' Brake Fluid 1 Amp through switch terminals	250+ hours. Constant temperature. No significant temperature rise with time Test Suspended.
	3	AVT	'new' Brake Fluid in Switch, 24VDC to one terminal. Hexport Grounded	> 300 hours into test, max current 7mA No significant change with time. Test ongoing
	4	AVT	'new' Brake Fluid in Switch 24 VDC to one terminal. Hexport Grounded, Ambient at 100 C	18 hours into test max current 5mA No significant temperature rise with time. Test suspended.
	5	AVT	'new' Brake Fluid in Switch, 15 Amps Through switch terminals	Temperature rise of 20 C above room temp Delta T reached steady state at 20 C. Test suspended.
	5a	AVT	'new' Brake Fluid in Switch approx. 50 Amps through Switch Terminals	Temperature rose to approx. 270 F. No smoke. No ignition Test suspended.
	6	TI	Build heater elements into Switch. Heat to failure, include sparking. With Fluid & Dry Pure 'new' brake fluid with metal shavings 5% brake fluid solution	2 tested. Smoke observed, ignition observed on part w/heater See attachment Test complete Brake fluid in cavity slows down heat build-up Smoke observed at 575 F. Base melts and falls off at 800 F
	6a	TI	Create heater by corroding spring arm Salt water solution, 14V between spring and hexport	One out of 15 devices increased resistance to 5 ohms. Others either very low resistance or megaohms It took about 100 hours to reach the 5 ohm stage. The 5 ohm device ignited under conditions similar to test 6.
	6b	TI	Re-run ignition test to understand repeatability and current path.	Switch ignition with repeated 5% water solution into switch Current path is through hexport. See plots and video. Additional test include [illegible]

TI-NHTSA 013998

			used brake fluid w/ 5% H_2O	
			new brake fluid	
			new brake fluid w/ 5% H_2O	
[illegible]				
Design Of Experiments (2) Repeat of test 10	13b	TI	Vary water concentrations in 'new' Brake Fluid 10 amp + 20 quiet switches w/ 0 % water in BF 10 amp + 20 quiet switches w/ 5 % water in BF	Test suspended. Analysis in process to assess test fixturing.
[illegible]				
Compatibility of Kapton with Oxalic Acid	14	Dupont	Characterize change in properties of Kapton with various % oxalic acid in brake fluid.	Report expected from Dupont by 5/3/99.
[illegible]				
Evaluation of Plastic Materials with Improved [illegible]	15	TI	Assess properties and moldability of different grades of plastic resin with additives to improve plastic part performance	Test suspended. Celanese and Nand ignited 3/5 and 2/5 trials ZYTEL samples tested 1/5 ignitions
[illegible]				
[illegible] duration brake fluid [illegible] test.	15a	TI		Test in progress. (15) days to date. Used brake fluid current dropped off to <1/10 mAmp. New brake fluid hotpot current remains low
[illegible]				
[illegible] of Switch [illegible]	15b	TI	Assess ignition sensitivity to switch orientation. Test vertical upside 45 degree. Test rotational sensitivity.	Test complete. Ignition is independent of switch orientation. simulated switch ignition can occur in vertical or 45 degree angle. Ignition appears not sensitive to switch rotational alignment.
[illegible]				
[illegible] Circuit	16	TI	Repeat test 13a in Ford relay circuit for (48) hrs. Bring switch to impending ignition in (15) Amp circuit then place in relay circuit for (15) hrs. Input max. circuit power into heater on switch.	Test complete. No ignition. Corrosion rate drastically reduced. Insufficient power in circuit to create or move toward ignition in lab Heater element was warm to the touch.

DOT

on going

Brake Pressure Switch Test Log, Updated 4/26/99

				DOE
Life Cycle Reliability	7	TI	0-1400 psig pressure pulses at 135C	First leak observed at 728,000 cycles.
of Pressure Switch			per LS	Test Completed. See attached Weibull Chart.
Diaphragm Wear	8	TI	0-1400 psig pressure pulses at 135C.	Parts withdrawn every 200k cycles, characterized for wear — wear
Field vs Lab Correlation	9	Central Labs	Field returns, from dealer lots, junkyards	Parts in Central Labs, see Ford spreadsheet
Design Of Experiments (1)	10	TI	Vary water concentrations in 'new' Brake Fluid	Test Report being written investigation continues. — DOE
Evaluating Factors			12 snap + 12 quiet switches w/ 0 % water in BF	Suspended at 1.3 million cycles with no leaks observed.
Effecting Diaphragm Wear			12 snap + 12 quiet switches w/ 5 % water in BF	Snap samples suspended at 1.3 million cycles with 2 leaks
Impulse test				observed at 1.3M. Quiet samples suspended at 500k cycles to
				assess failuring anomalies.
On-Vehicle Characterization	11	AVT	Monitor Pressure and Temperature	Test at AVT.....see Ford charts...>500k in car?
of Pressure & Temperature			at Switch Location for ABS and non-ABS	
Profile in Town Car			braking events.	
Brake fluid analysis	11a	TI	Analyze used brake fluid at the master cylinder	Test complete.
Used fluid at master cylinder.			(UMC), used brake fluid at the caliper (UCA)	UMC: Cu = 415 (ug/ml), Fe = 5.6 (ug/ml), Cr = 0.08 (ug/ml), 1.1 %H2O.
			and new brake fluid (NEW) for metal and water	UCA: Cu = 592 (ug/ml), Fe = 5.h (ug/ml), Cr = 1.9 (ug/ml), 1.1 %H2O.
			content.	NEW: Cu = <0.01 (ug/ml), Fe = 0.92 (ug/ml), Cr = <.01 (ug/ml), 0.3 %H2O.
Spark /Arc Study	12	Central Labs	Determine if arc/spark forms in switch	Equipment set-up in progress at Central Labs.
			using clutch loads and high speed video.	TI Experimented with no 'significant' sparks observed
			Use dry switches as well as switches with	
			various brake fluid water mixes.	
Characterization of	13	Central Labs	Characterize electrical, mechanical	Data log and analysis procedure set up complete.
switches retrieved from field			and chemical aspects of returned switches	Analysis of switches in progress.
junkyards & other sources				
Fluid Ingress Tests	13a	TI	Repeat ignition simulation with different fluids.	Test complete.
#14			(3) hour tests:	5% NaCl sample resulted in an ignition.
		(1)	5% NaCl in tap water	All brake fluid samples drew less than 3 mAmps. No corrosion
		(1)	tap water	visible on brake fluid samples.
		(1)	rain water	Rain water and tap water samples drew <10 mAmps and showed
		(1)	(48) hour tests:	some signs of corrosion.
		1	used brake fluid	Chemical anlysis in process.

TI-NHTSA 013400

Epstein, Sally

From: Mulligan, Sean [smulligan@[illegible]]
Sent: Wednesday, April 28, 1999 12:45 PM
To: Sharpe, Robert
Subject: For Andy McGuirk

<<objective_results_conclusions_2.doc>>

All the best,

Sean P. Mulligan

Phone (508) 236-2535
Fax (508) 236-3586

TI 77PS Test Synopsis Draft 4/28/99

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

Level 1 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_2O.
14 volts applied to one terminal, second terminal electrically floating. (No electrical load across switch terminals).
Switch hexport electrically grounded.

Results: (8) samples were tested total:
(2) with 4% H_2O in brake fluid.
(2) with 6% H_2O in brake fluid.
(2) with 10% H_2O in brake fluid.
(2) with 75% H_2O in brake fluid.

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

TI-NHTSA 013402

- Test 2

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

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

Conclusion: A one amp load through switch terminals can not ignite brake fluid in the contact cavity of switches.

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

Results: (2) dry devices were tested and (1) wet device was tested. Ignition occurred in all devices.
Wet device: The internal temperature of a wet device reached 660°F. A hole burned through the base of the switch (close to the heating element). The externally applied spark ignited the fumes which engulfed the switch.
Dry device: The internal temperature of a dry 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:
A heating element is installed in the switch contact cavity.
5 watts of power is applied to the heating element.
An external spark is applied to fumes.
Brake fluid does not contribute to the ignition process

TI-NHTSA 013403

Level 2: 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.

Results: (1) out of (15) samples tested increased resistance to 5Ωs. 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.

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.

- Test 6c

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

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

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

- Test 7

Objective: Determine if switch meets cycle life specification.

Results: Tests made first quarter of 1999 show that switches exceed cycle life specification.
In the first quarter of 1999, a total of (42) 77PSL2-1 snap switches were impulse tested to over 1,000,000 cycles with only (1) leak below 1,000,000 cycles which occurred at 728,000 cycles. A Weibull analysis of fist quarter, 1999 tests showed 99.9% reliability at 500,000 cycles at 95% confidence level.

Conclusions: First quarter, 1999 tests confirm findings of impulse tests made during the period between 1991 and 1992. During that period, (6) impulse tests on 144 devices of 57PS and 77PS construction, had no leaks when tested to

500,000 cycles. A Weibull analysis of first quarter, 1999 tests, showed 99.9% reliability at 500,000 cycles at 95% confidence level. Switches meets cycle life specification.

- Test 15a

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

Results: Test is ongoing. (6) samples are being tested. (4) samples contain new brake fluid and (2) samples contain old brake fluid. 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: 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: Understand the ignition process, determine the current path and establish a repeatable ignition method.

- Test 6b

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

Results: Multiple attempts at 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: Compare and contrast variables influencing ignition using the established laboratory ignition method.

- Test 13a

Objective: Compare various fluids in the established ignition method.

Results: The following fluids were tested.
(1) NaCl in H_20.
(1) tap water
(1) rain water
(1) used brake fluid
(1) used brake fluid with 5% H_20
(1) new brake fluid
(1) new brake fluid with 5% H_20
The 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.

Conclusion: Brake fluid is not conductive enough to cause the electrolytic corrosion and necessary current draw 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.

- Test 15

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

Results: When 5% NaCl in H_20 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.

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

- Test 15b

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

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

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

Level 5 Objective:

Test 16

- Objective: Test proposed relay circuit.

Results: (1) switch was injected with 5%Nacl in H_2O solution and placed in the proposed current limiting circuit for (48) hours. The current draw remained constant at 180 mAmps throughout the test. There was no activity observed and the contact arm remained intact.
(1) switch was brought to an impending burn condition using the established burn method. An impending burn is a condition where a corrosive resistance has built up in the switch and an ignition is imminent. The switch was then placed in the proposed relay circuit for(18) hours where it drew 160 mAmps, showed no visible activity and did not result in an ignition.
Because the proposed relay circuit acts as a resistor which limits current to the switch, the maximum power to the switch is limited to .75 Watts. A resistive wire was wrapped around the base of (1) switch and 0.75 Watts of power was 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 an ignition. There is not enough power in the proposed circuit to create ignition.

Brake Pressure Switch Test Log, Updated 4/29/99

Category	Test	Location	Test Parameters	Results Update
ab Simulation	1	TI	Vary water concentrations in 'new' Brake Fluid	250+ hours, Current draw in the 0.5mA to 5mA range
f Potential Ignition			14Vdc to one terminal, hexport grounded	Fluid has discolored.
a Switch			Water Conc: 4%, 6%, 10%, 75%	No Significant Temperature Rise. Test Suspended.
				Internal Analysis suspended.
	2	TI	New Brake Fluid	250+ hours. Constant temperature.
			1 Amp through switch terminals	No significant temperature rise with time
			14Vdc to one terminal, hexport grounded	Test Suspended.
	3	AVT	new' Brake Fluid in Switch, 24 VDC to one	> 580 hours into test, max current 7mA
			terminal. Hexport Grounded	No significant change with time. Test ongoing
	4	AVT	new' Brake Fluid in Switch, 24 VDC to one	16 hours into test max current 5mA
			terminal. Hexport Grounded, Ambient at 100 C	No significant temperature rise with time. Test suspended.
	5	AVT	new' Brake Fluid in Switch, 16 Amps	Temperature rise of 20 C above room temp
			Through switch terminals	Delta T reached steady state at 20 C. Test suspended.
	5a	AVT	new' Brake Fluid in Switch approx. 60 Amps	Temperature rose to approx. 270 F. No smoke. No ignition
			through Switch Terminals	Test suspended.
	6	TI	Build heater elements into Switch.	2 tested. Smoke observed, ignition observed on part w/heater
			Heat til failure, include sparking.	See attachment
			With Fluid & Dry	Test complete
				Brake fluid in cavity slows down heat build-up
				Smoke observed at 676 F, Base melts and falls off at 800 F
	6a	TI	Create heater by corroding spring arm	One out of 15 devices increased resistance to 5 ohms.
			Salt water solution, 14V between spring	Others either very low resistance or megaohms
			and hexport	It took about 100 hours to reach the 5 ohm stage.
				The 5 ohm device ignited under conditions similar to test 6.
	6b	TI	Re-run ignition test to understand	Switch ignition with repeated 5% water solution into switch
			repeatability and current path.	Current path is through hexport.
				See plots and video.

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	8c	TI	Pure 'new' brake fluid with metal shavings	Additional test include tap water, old BF, new BF and other. Metal shavings do not contribute significantly to brake fluid conductivity
Life Cycle Reliability of Pressure Switch	7	TI	0-1450 psig pressure pulses at 185C for ES	First leak observed at 728,000 cycles. Test Completed. See attached Weibull Chart.
Diaphragm Wear	9	TI	0-1450 psi pressure pulses at 150C	Parts withdrawn every 200k cycles, characterized for wear
[illegible] vs Lab [illegible]	9	Central Labs	Field returns, [illegible]	Parts in Central Labs, see Ford spreadsheet
Design Of Experiments (1) Evaluating Factors Effecting Diaphragm Wear Impulse test	10	TI	Vary water concentrations in 'new' Brake Fluid 12 snap + 12 quiet switches w/ 0 % water in BF 12 snap + 12 quiet switches w/ 5 % water in BF	Test Repeat being written Investigation continues. Suspended at 1.3 million cycles with no leaks observed. Snap samples suspended at 1.3 million cycles with 2 leaks observed at 1.3M. Quiet samples suspended at 500k cycles to [illegible]
On-Vehicle Characterization of Pressure & Temperature Profile in Town Car	11	AVT	Monitor Pressure and Temperature at Switch Location for ABS and non-ABS braking events.	Test at AVT.....see Ford charts...>600k in car?
Brake fluid analysis Used fluid at master cylinder.	11a	TI	Analyze used brake fluid at the master cylinder (UMC), used brake fluid at the caliper (UCA) and new brake fluid (NEW) for metal and water content.	Test complete. UMC: Cu = 415 (ug/ml), Fe = 5.6 (ug/ml), Cr = 0.08 (ug/ml), 1.1 %H2O. UCA: Cu = 582 (ug/ml), Fe = 5.5 (ug/ml), Cr = 1.9 (ug/ml), 1.1 %H2O. NEW: Cu = <0.01 (ug/ml), Fe = 0.02 (ug/ml), Cr = <.01 (ug/ml), 0.3 %H2O.
Spark /Arc Study	12	Central Labs	Determine if [illegible] forms to [illegible] using [illegible] loads and high speed video. Use dry switches as well as switches with various brake fluid water [illegible].	Equipment set-up in progress at Central Labs. TI Experimented with no 'significant' sparks observed
Characterization of switches returned from field [illegible] & other sources	13	Central Labs	Characterize electrical, mechanical and chemical aspects of returned switches	Data log and analysis procedure set up complete. Analysis of switches in progress.
Fluid Ingress Tests	13a	TI	Repeat ignition simulation with different fluids. (3) hour tests:	Test complete. 5% NaCl sample resulted in an ignition.

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			5% NaCl in tap water	All brake fluid samples drew less than 3 mAmps. No corrosion
			rain water	visible on brake fluid samples.
			(24) hour tests:	Rain water and tap water samples drew <10 mAmps and showed
			tap water	some signes of corrosion.
			used brake fluid	Chemical anlysis in process.
			used brake fluid w/ 5% H_2O	
			new brake fluid	
			new brake fluid w/ 5% H_2O	
Design Of Experiments (2)	13b	TI	Vary water concentrations in 'new' Brake Fluid	Test suspended. Analysis in process to assess test fixturing.
Repeat of test 10			10 snap + 20 quiet switches w/ 0 % water in BF	
			10 snap + 20 quiet switches w/ 5 % water in BF	
Compatibility of Kapton	14	Dupont	Characterize change in properties of Kapton	Report expected from Dupont by 5/3/99.
with Oxalic Acid			with various % oxalic acid in brake fluid.	
Evaluation of Plastic	15	TI	Assess properties and moldability of different	Test suspended.
Materials with Improved			grades of plastic resin with additives	Celanese and Noryl ignited 3/5 and 2/5 trials
Parameters			to improve plastic part performance	ZYTEL samples tested 1/5 ignitions
Long duration brake fluid	15a	TI	(4) samples with new brake fluid	Test in progress. (15) days to date.
ingress test.			(2) samples with used brake fluid	Used brake fluid current dropped off to <1/10 mAmp.
				New brake fluid hexpod current remains low
Evaluation of Switch	15b	TI	Assess ignition sensitivity to switch orientation.	Test complete. Ignition is independent of switch orientation.
Orientation			Test vertical versus 45 degree.	simulated switch ignition can occur in vertical or 45 degree angle.
			Test rotational sensitivity in 45 deg. orientation.	Ignition appears not sensitive to switch rotational alignment.
Relay Circuit	16	TI	Repeat test 13a in Ford relay circuit for (48) hrs.	Test complete. No ignition. Corrosion rate drastically reduced.
Test			Bring switch to impending ignition in (15) Amp	Insufficient power in circuit to create or move toward ignition in lab
			circuit then place in relay circuit for (18) hrs.	Heater element was warm to the touch.
			Input max. circuit power into heater on switch.	

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77PS FORD

TEST

DISKS

Disc

photos {
1 5% NaCl H2O Test
2 " "
3 5% NaCl H2O Burn Internal/External
4 Rain water 24 hr → Tap water Powered
5 Used Brake Fluid Test
}
6 Excel USED Brake Ingress Test
7 Excel New Brake w/ 5% H2O Ingress
8 Excel Clean Brake Ingress
9 Excel Tap water Test
10 Photos 5% H2O, Clean BF, Clean BF, Tap water
11 Excel used Brake w/ 5%
12 Photos Used Brake w/ 5%
13 Excel FR_ 5% 5% Salt Data
14 Excel FR_2 5% Salt Data
15 Photos FR_2 No Burn but Connector
16 Photos FR_2
17 Noryl Burn Test 1 HP-DAQ Data
18 Noryl Burn Test 1 Fluke DAQ Data
19 Noryl Burn Test 2 photos
20 Noryl Burn Test 2 photos
21 Noryl Burn Test 2 HP DAQ Data
22 Noryl Burn Test 2 Fluke DAQ Data
23 Vertical Burn Photos Disk_1
24 Vertical Burn Photos Disk_2
25 48 hour Relay photos
26 Impending Burn photos
27 Pumping Tests (?)
28 Thermo cycle Dunk Test
29 Zytel-Burn Test photos Disk_1
30 Zytel-Burn Test photos Disk_2
31 Zytel - Burn Test Data_1 Excel
32 Zytel - Burn Test Data_2 Excel
33 Zytel - Burn Test photos Disk_3
34 Long duration M1 #5 photos
35 Long duration M2 #5 photos

APT pressure sensors 4/29/99
PN 3CP2-1

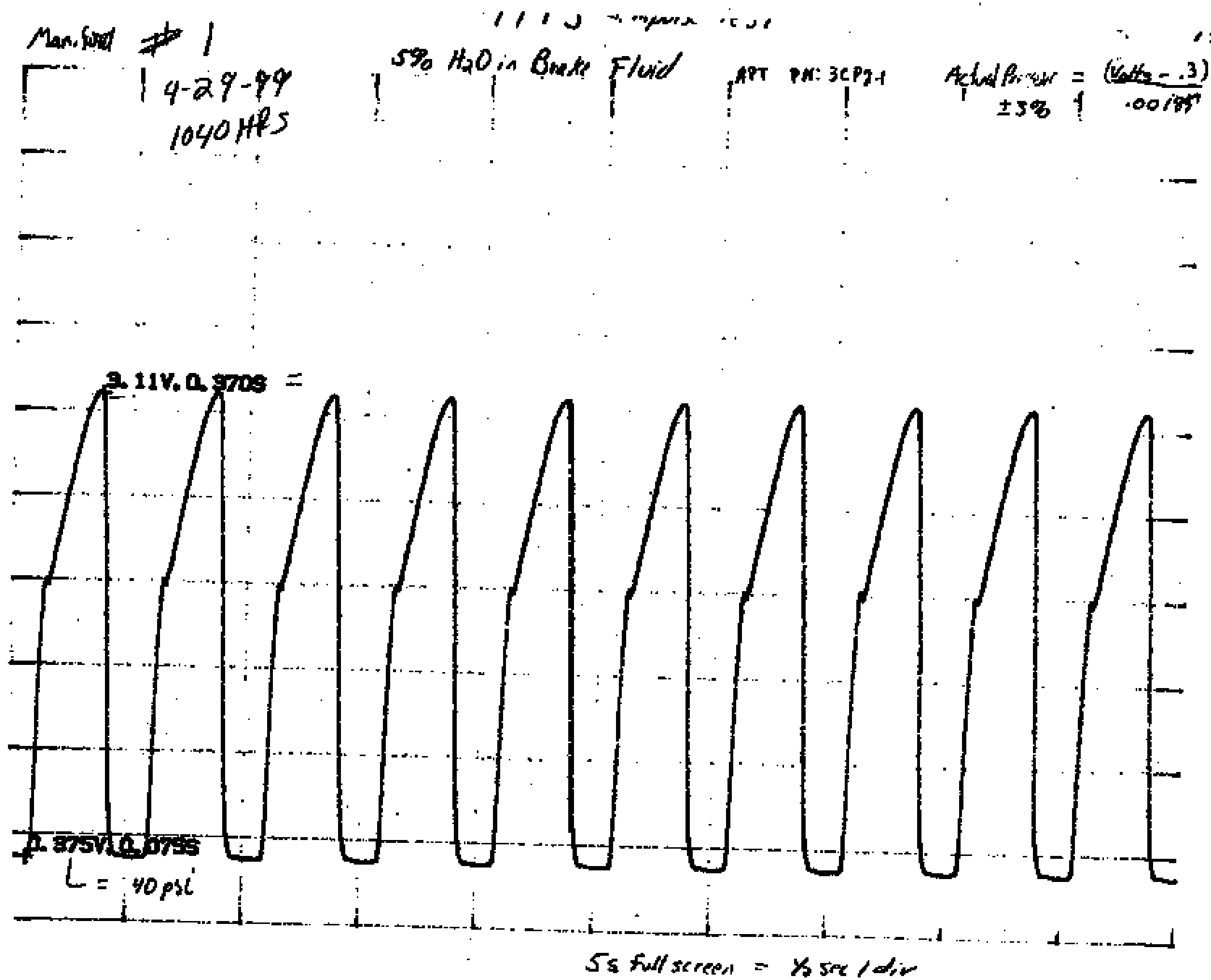
Pressure = $\frac{(Volts - .3)}{.00199}$

For Impulse test
Low pressure = 0 - 40 psi
High pressure = 1450 ± 50 psi

∴ Lower Voltage Range = .30 - .372
$V = (40)(.00199) + .3 = .372$

Higher Voltage Range = 2.932 ⟶ 3.120
$(1400)(.00199) + .3 = 2.932$
$(1500)(.00199) + .3 = 3.12$

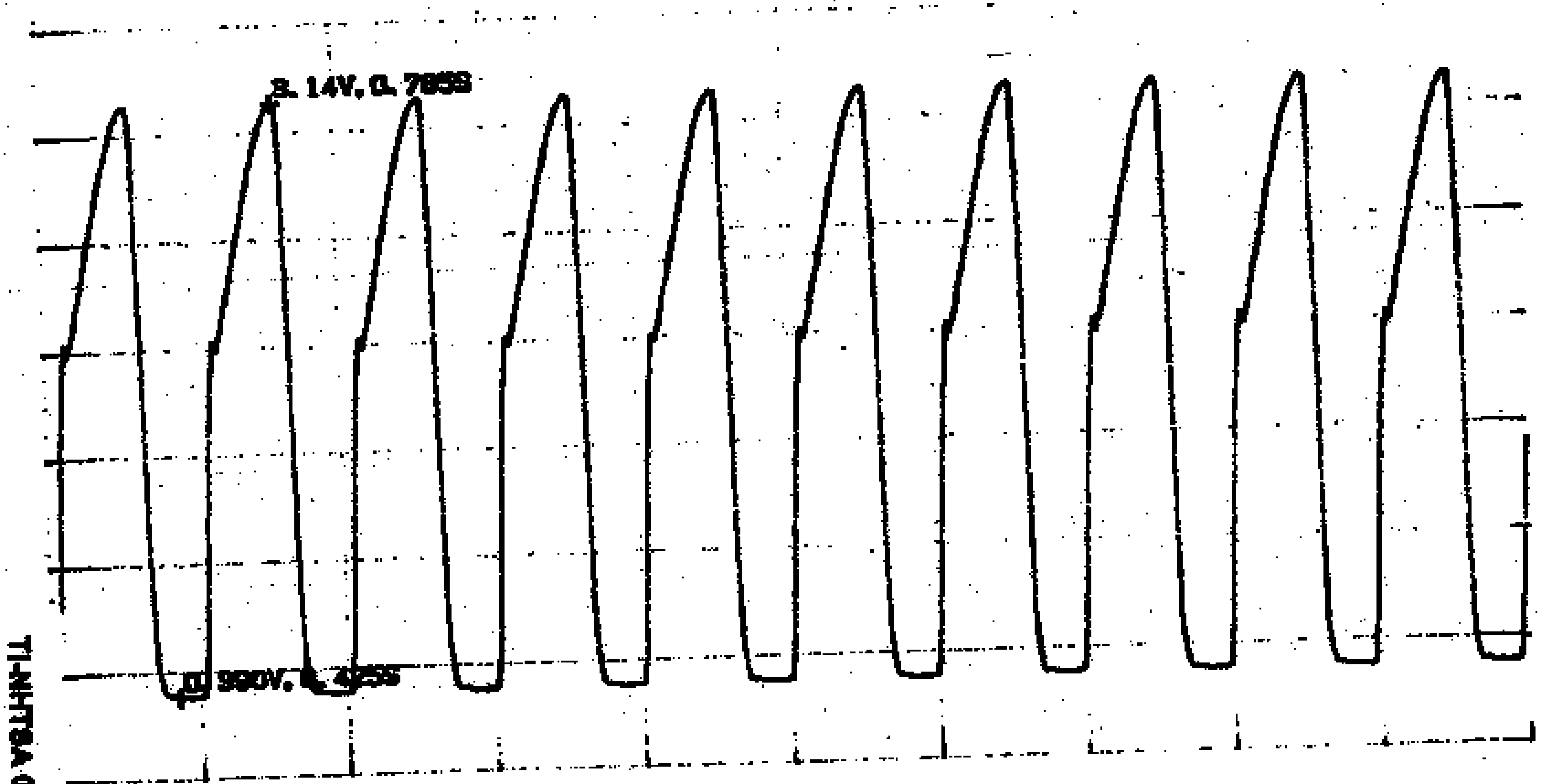
TI-NHTSA 013413


Manifold # 1
4-29-99
1040 Hrs
5% H_2O in Brake Fluid
APT PN: 3CP2-1
Actual Pressure = (Volts - .3) / .00199
±3%
3.11V, 0.970S
0.875V, 0.075S
L = 40 psi
5s full screen = ½ sec/div

A-

Manifold #2
4-29-99
1041 HRS

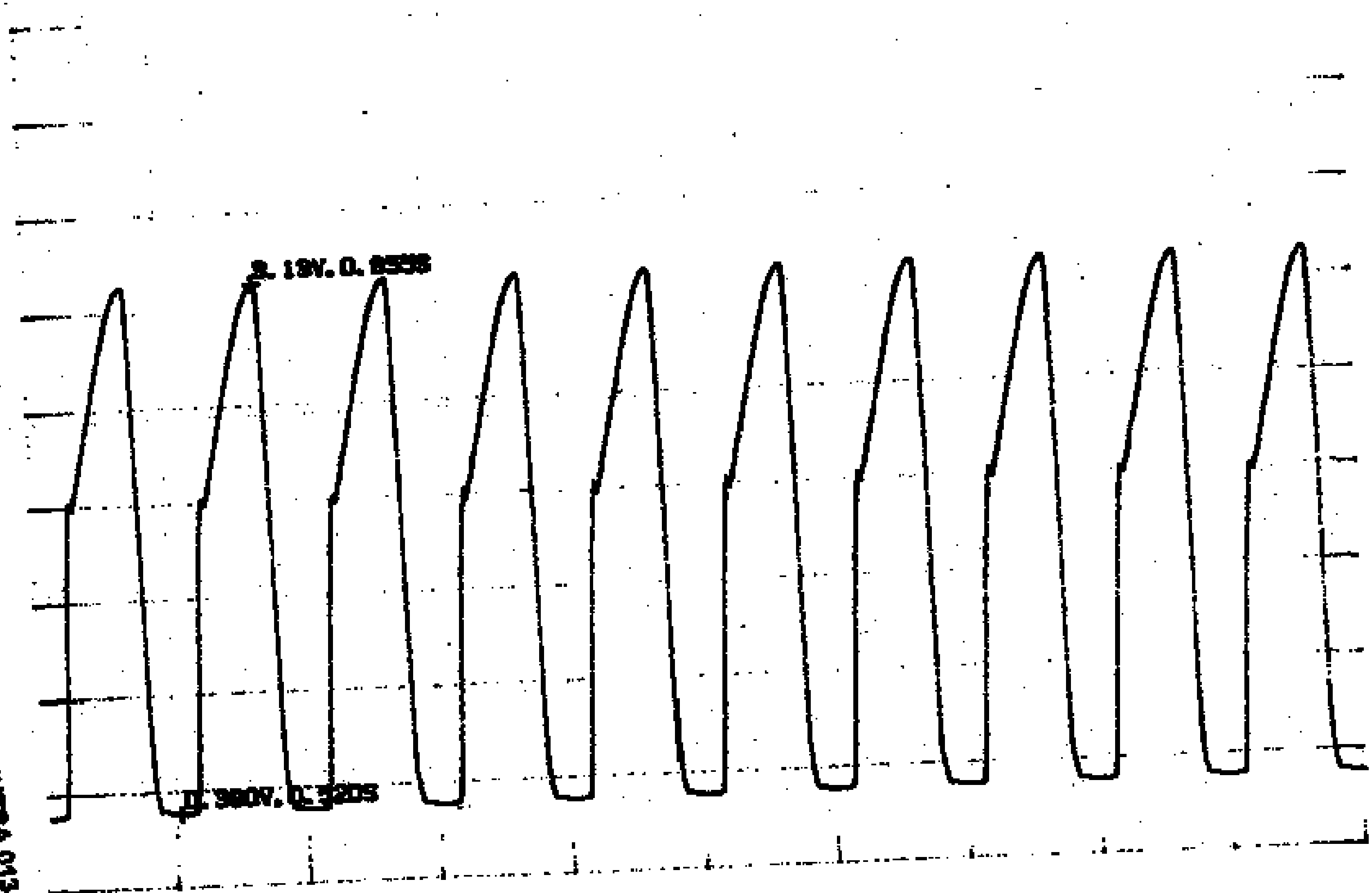
APT PN 3CP2.1



A-

Man. J #3
4-29-99
1043H89

APT PN: 3CP2-1



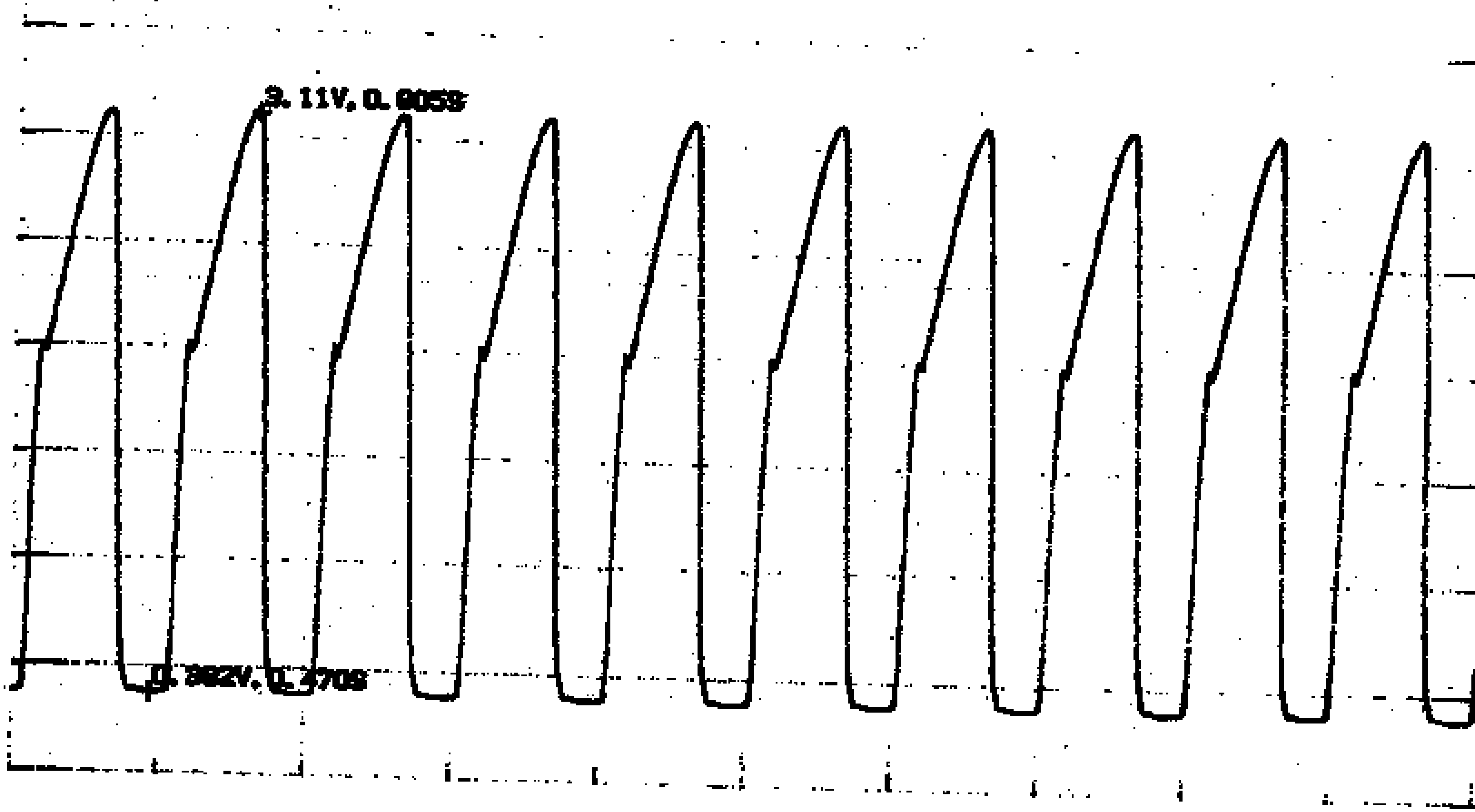
TI-NHTSA 013416

Manifold #4

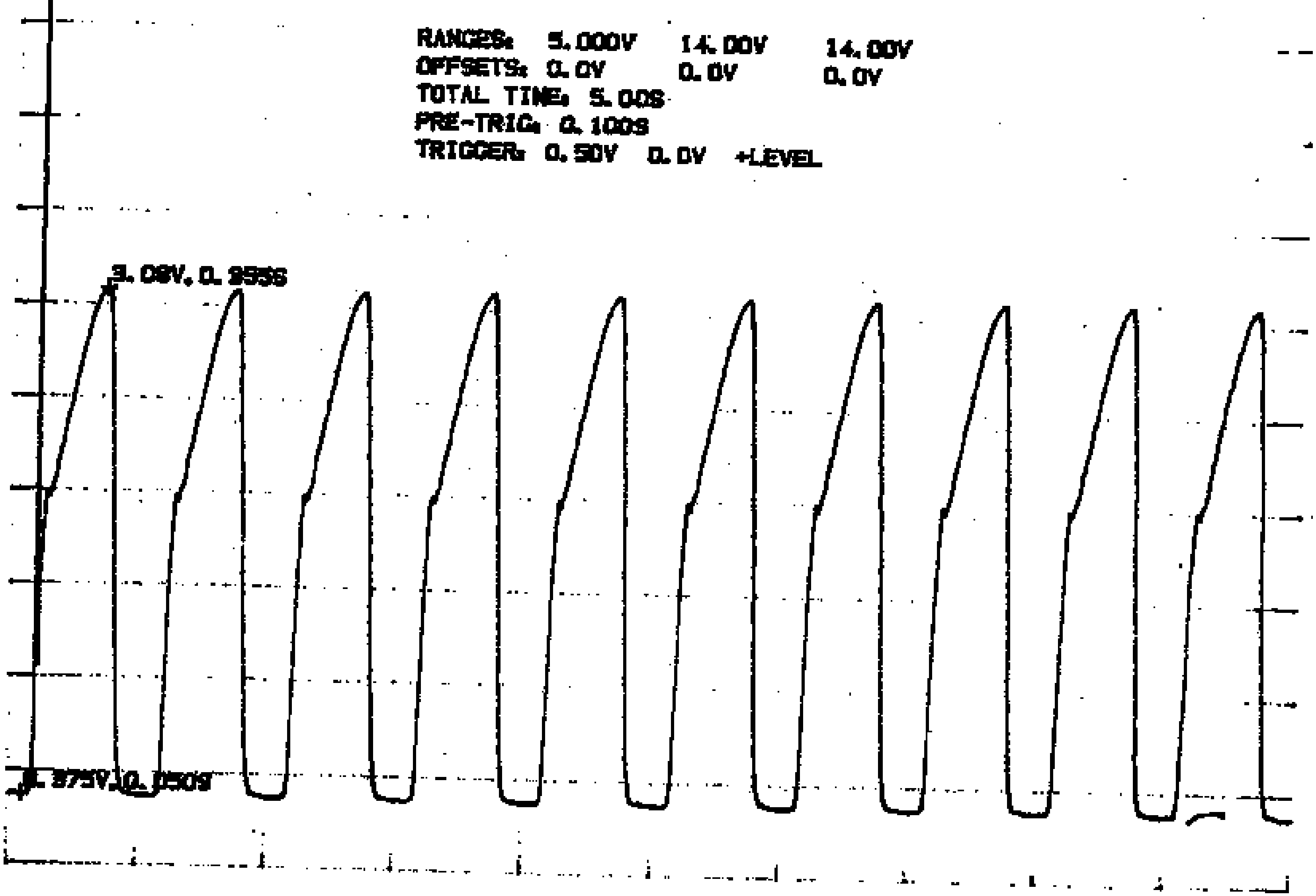
A-

4-29-99
1046HRS

APT PN: 3CP2-1



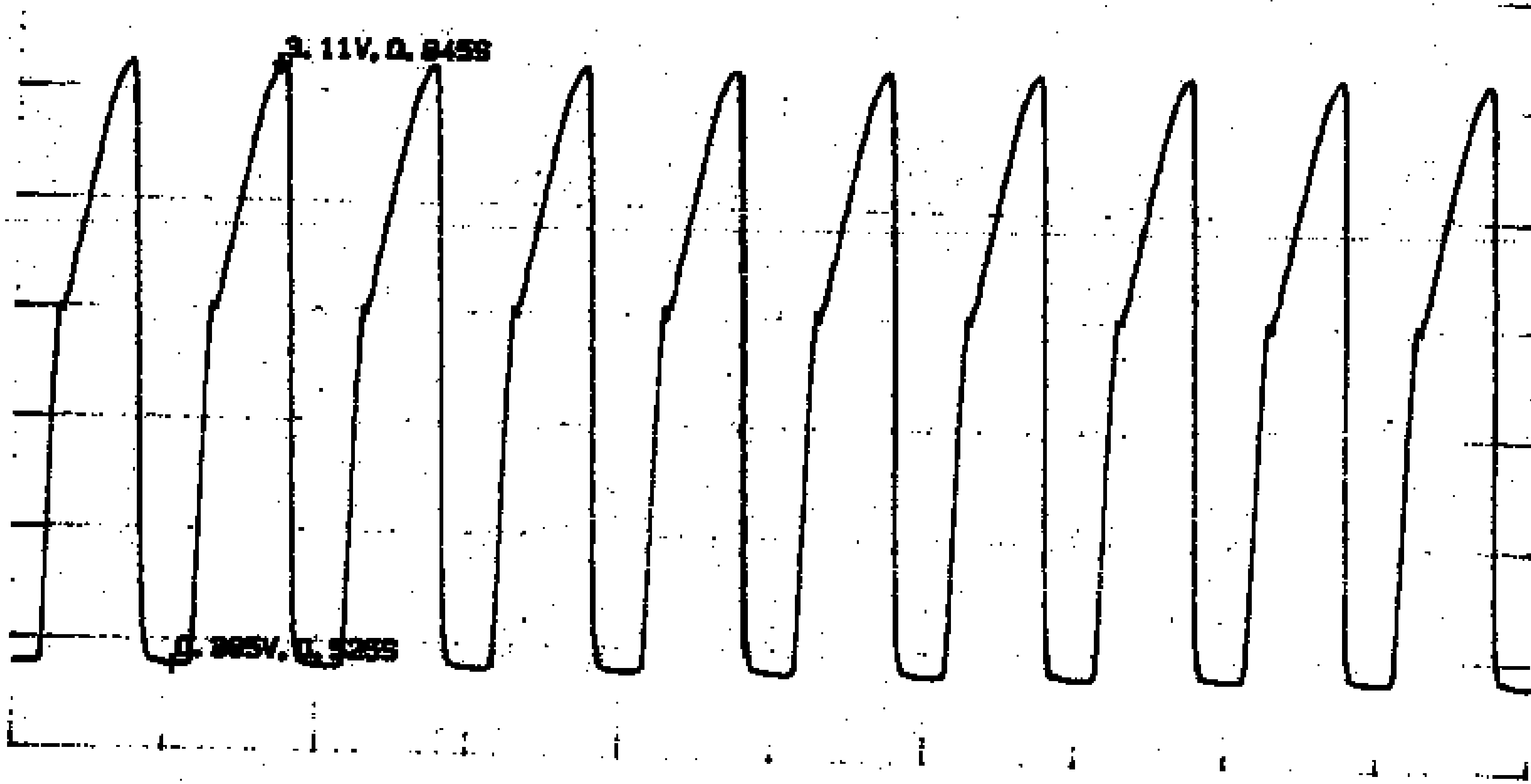
#1
4/29
1620 HRS



#2

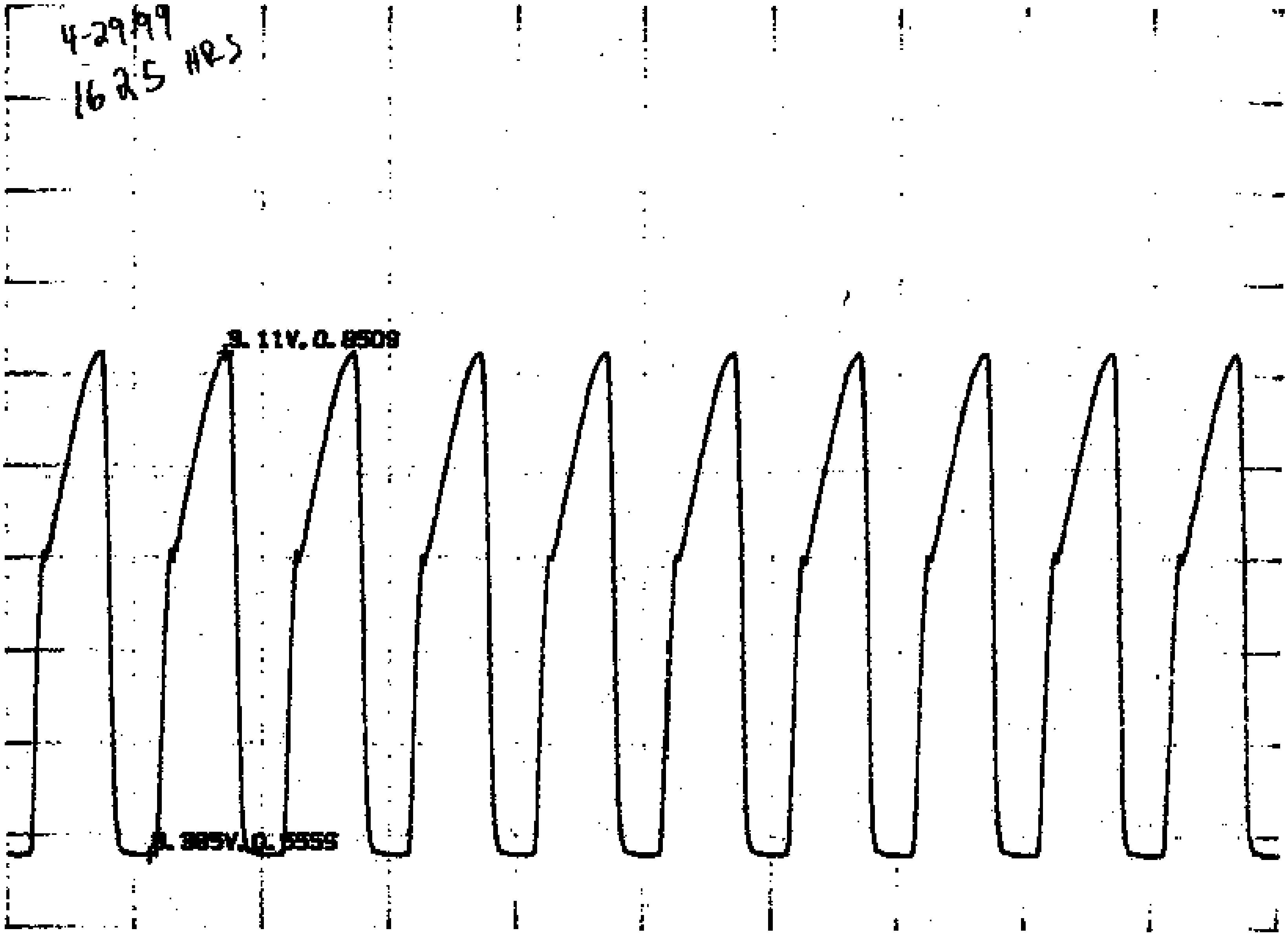
9/29/94
1623 HRS

RANGES: 5.000V 14.00V 14.00V
OFFSETS: 0.0V 0.0V 0.0V
TOTAL TIME: 5.00S
PRE-TRIG: 0.100S
TRIGGER: 0.50V 0.0V +LEVEL



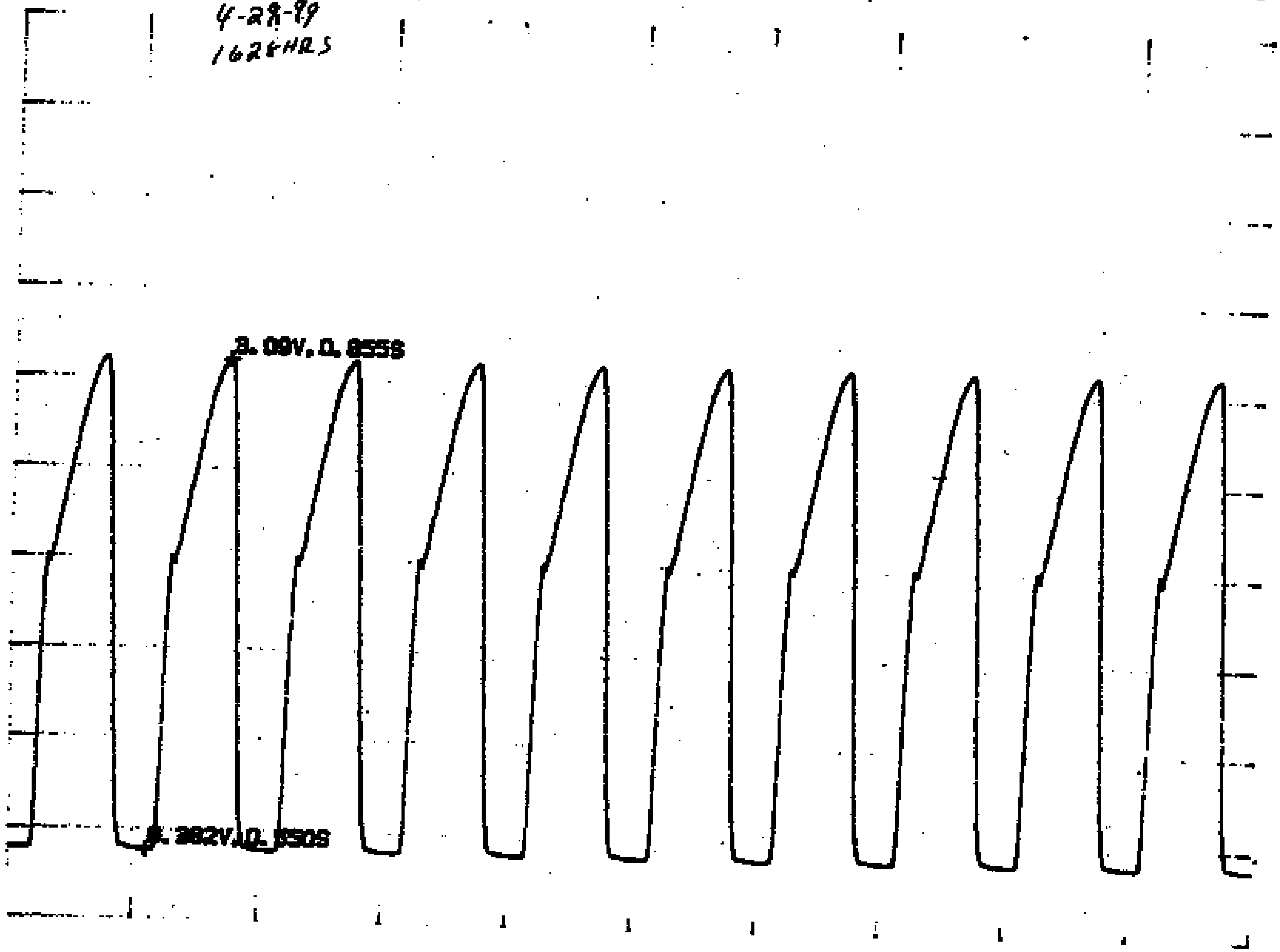
#3
4-29-99
1625 HRS

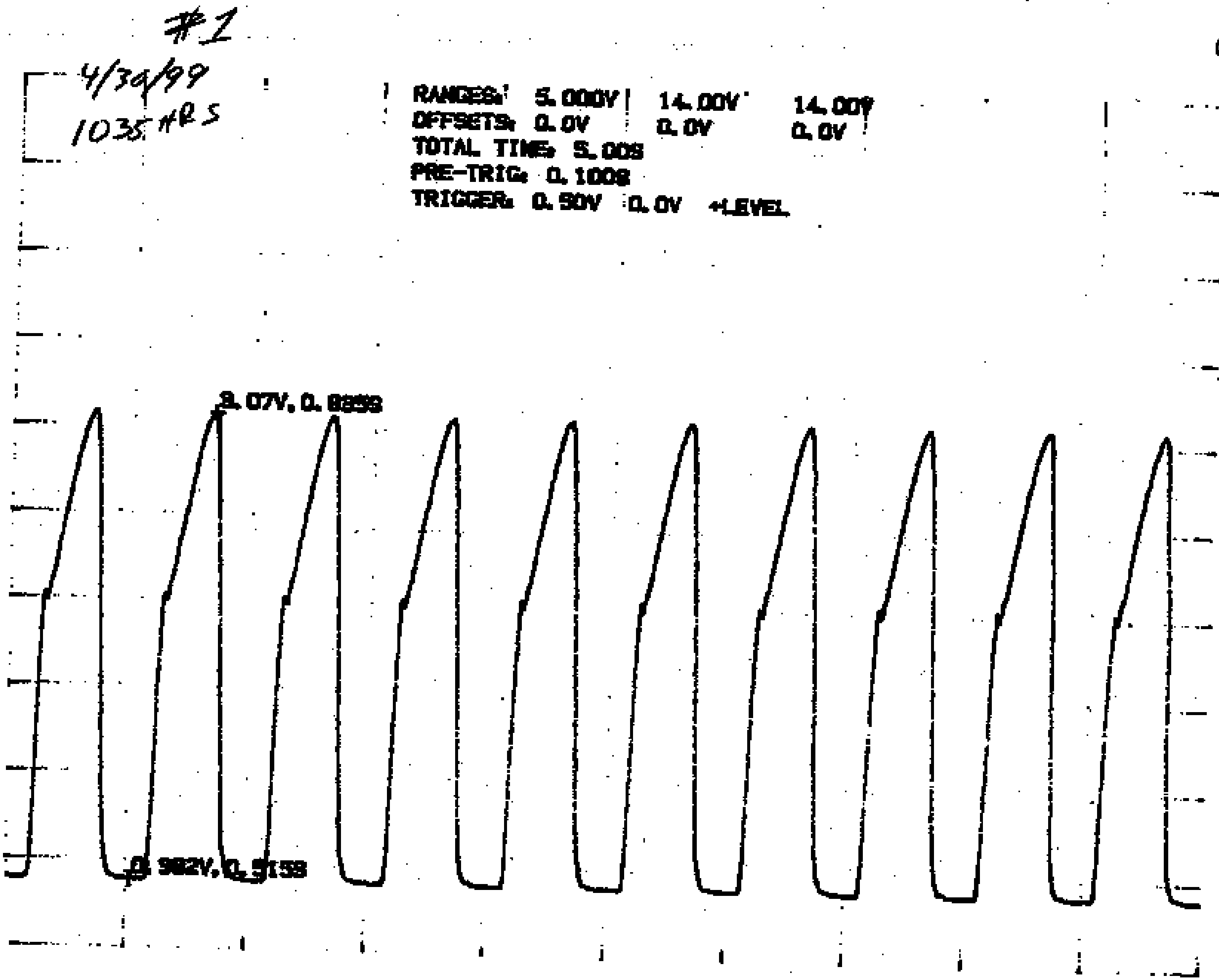
B



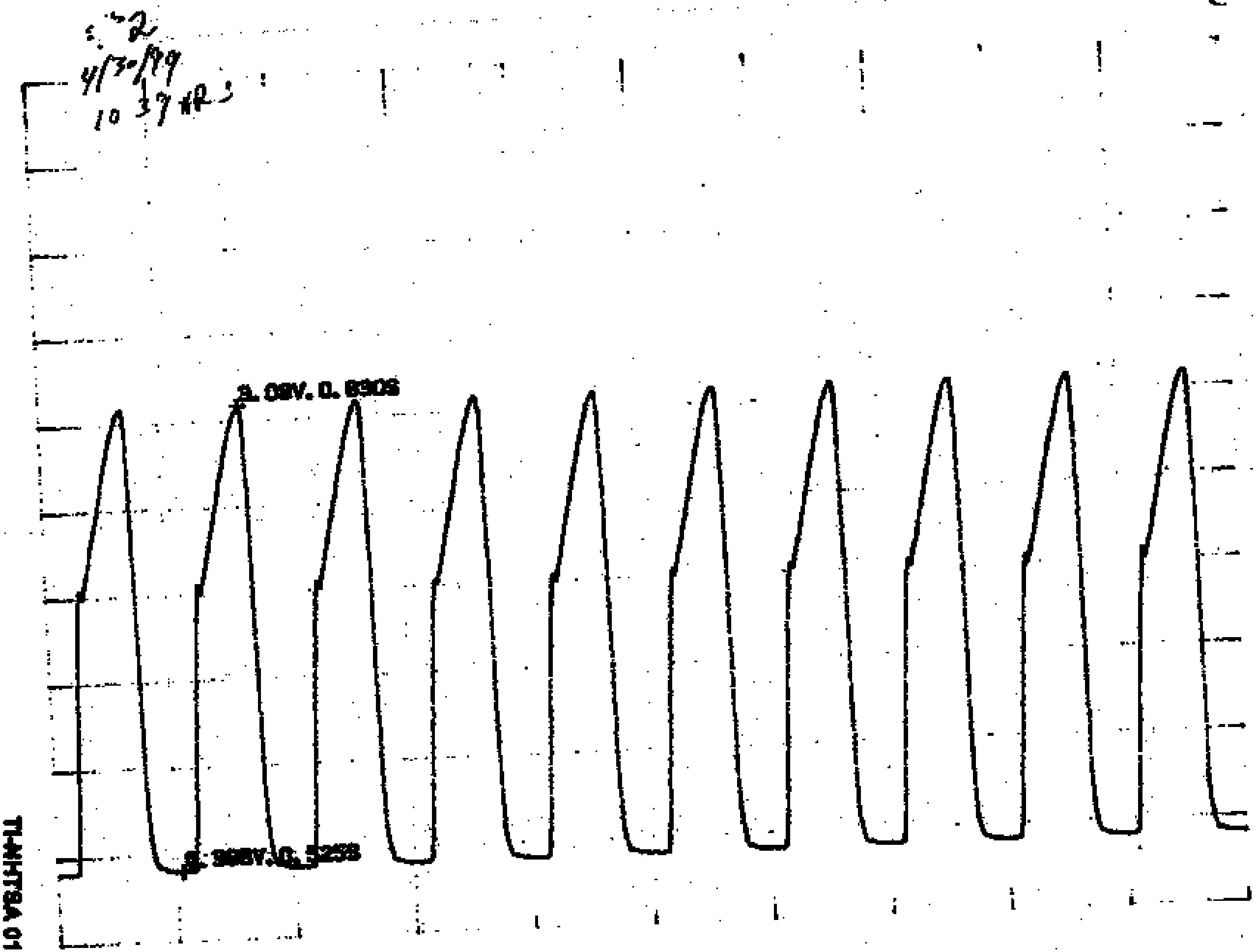
#4
4-28-99
1626HRS

B-4



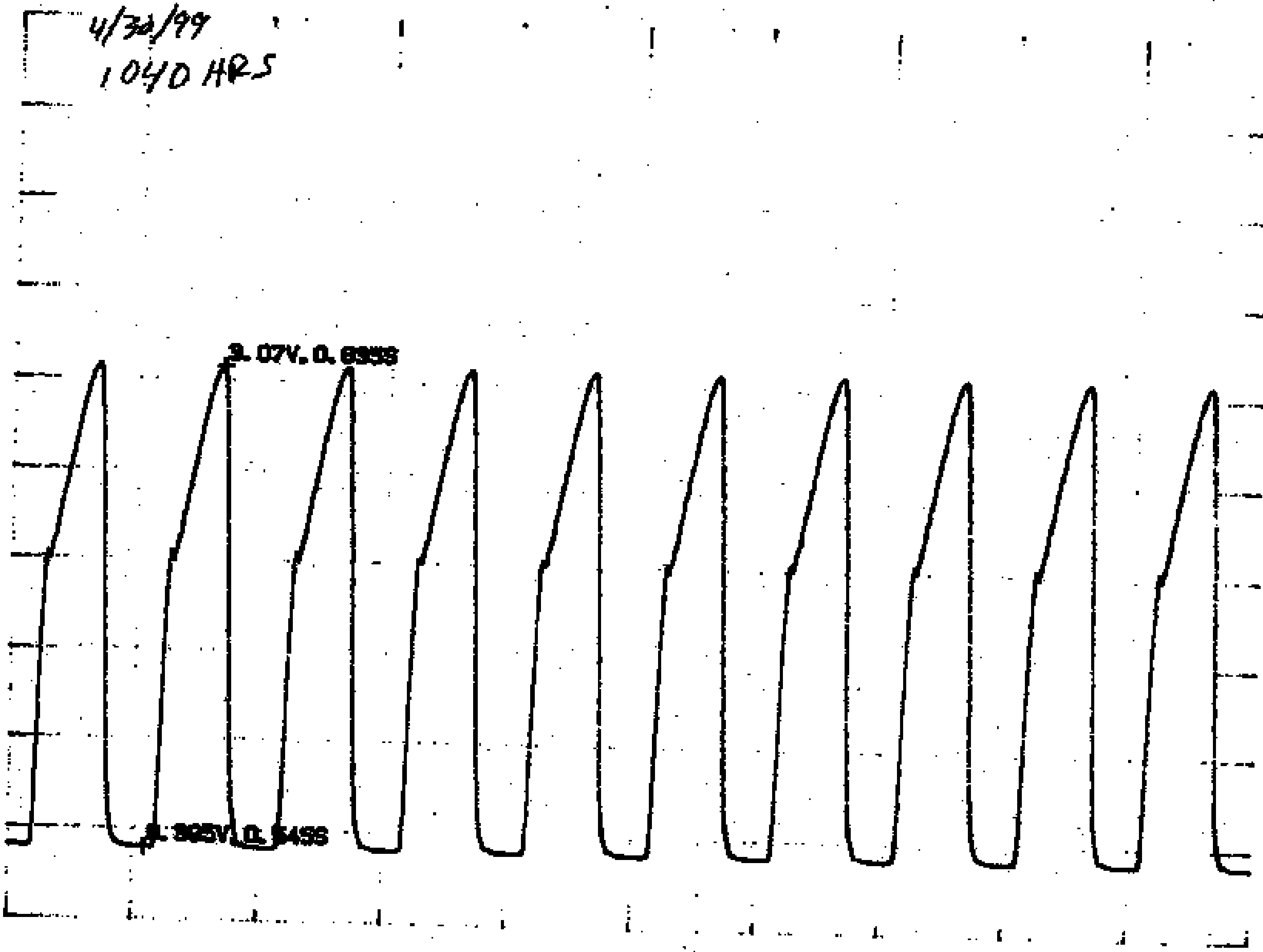


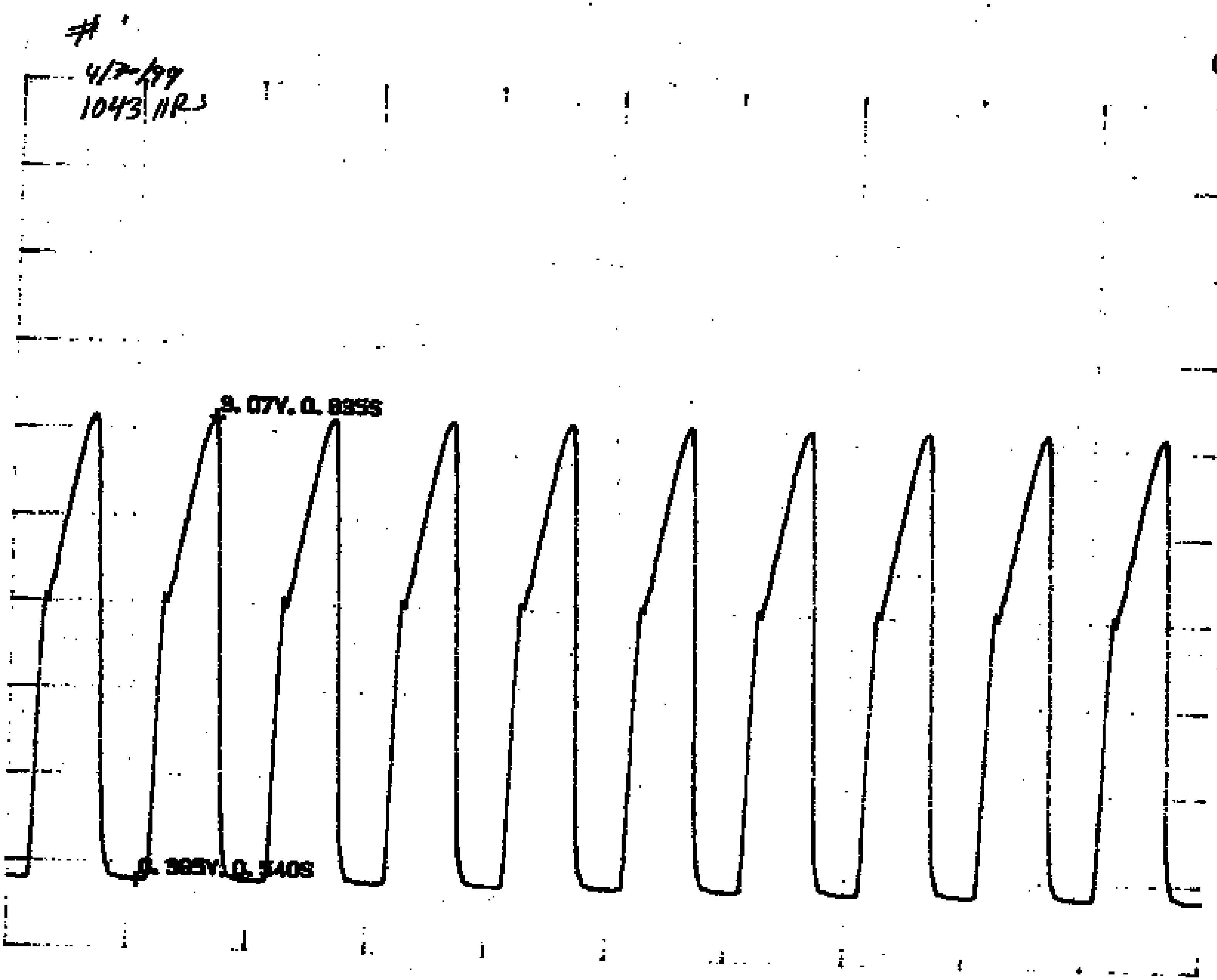
TI-NHT8A 013422



TI-NHTSA 013423

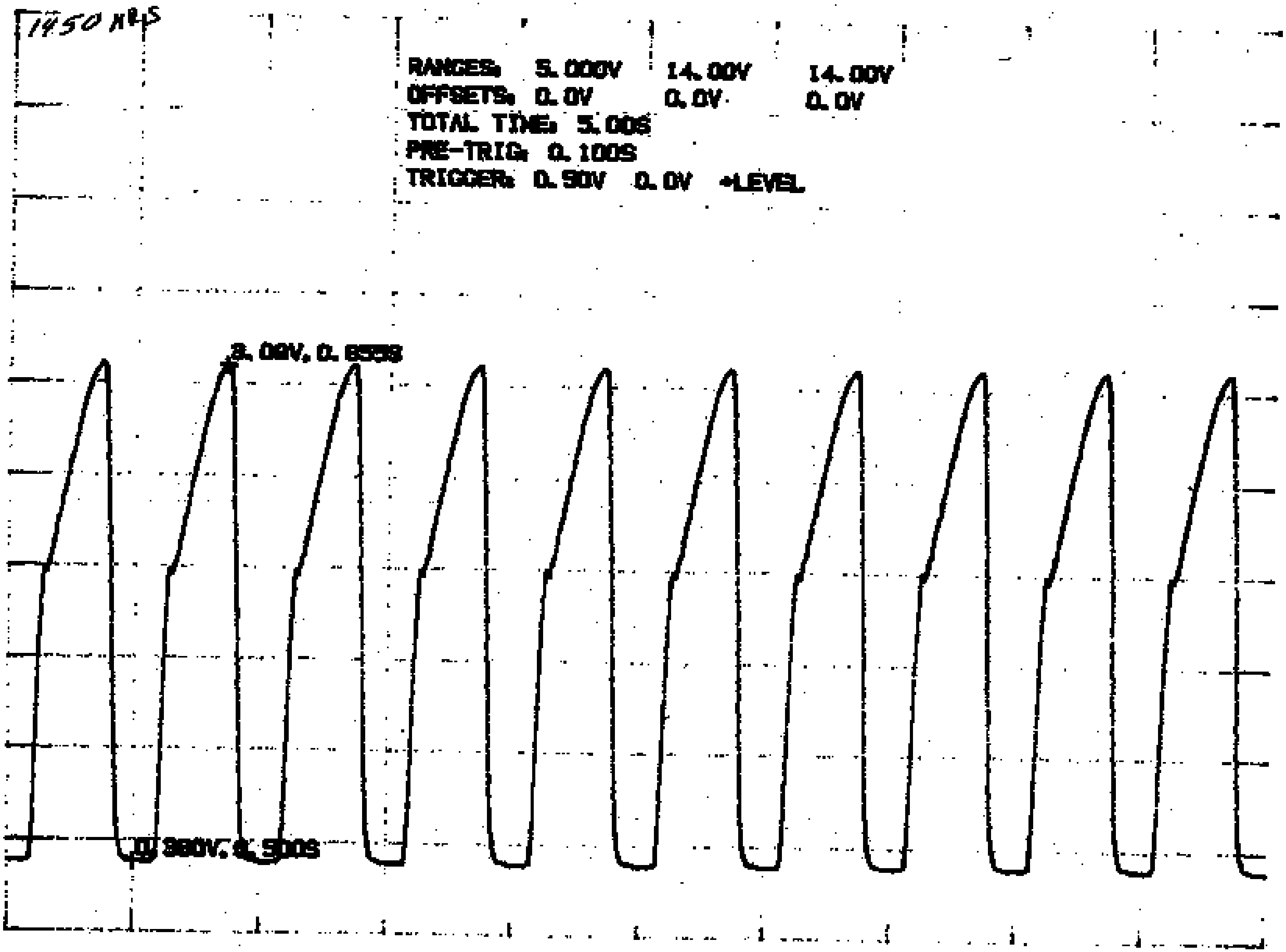
#3
4/30/99
1040 HRS




#1
1043
9.07V, 0.835S
0.385V, 0.540S

#1
4/24/94
1450 RPS

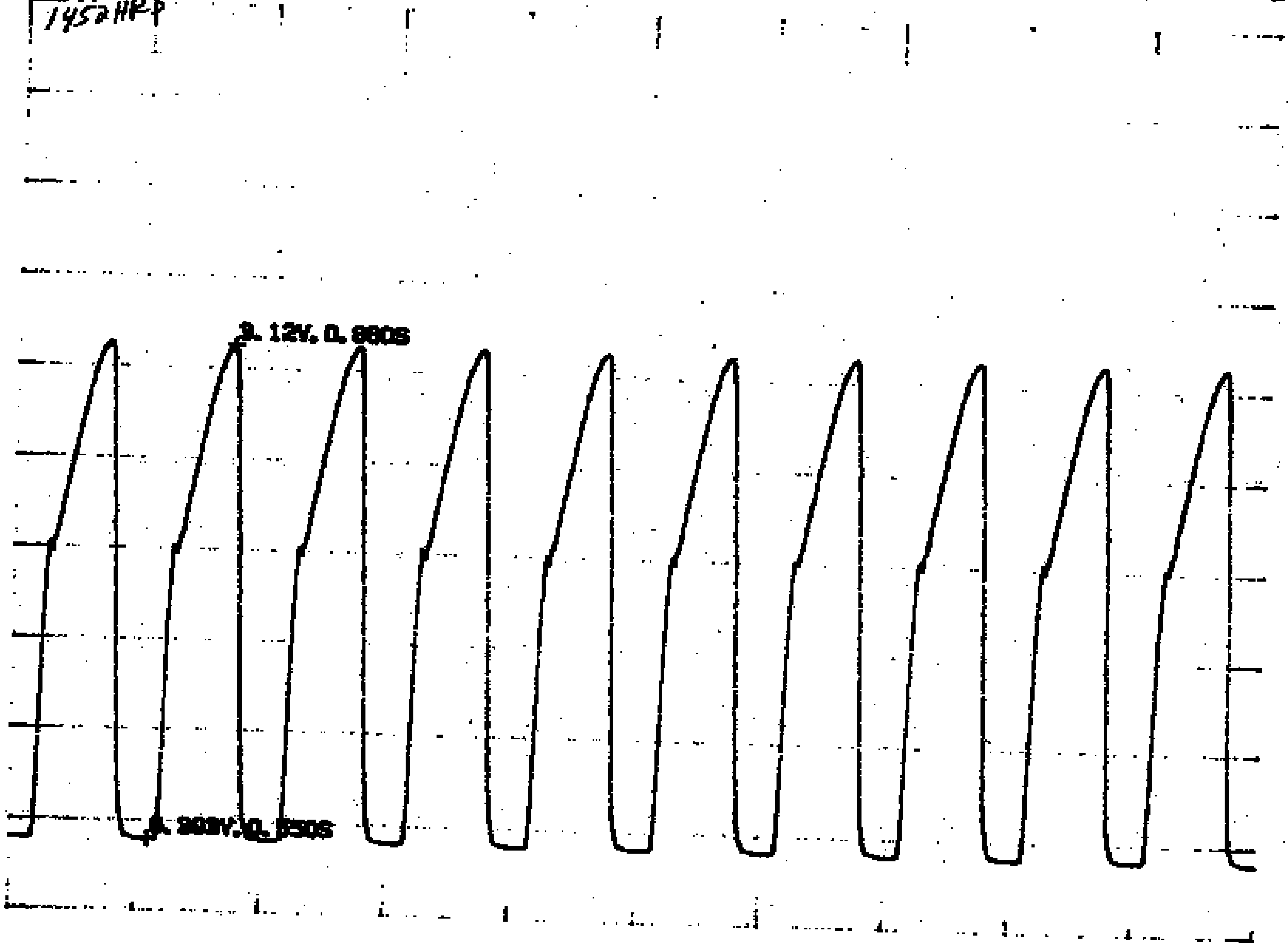
D-



TI-NHTSA 013426

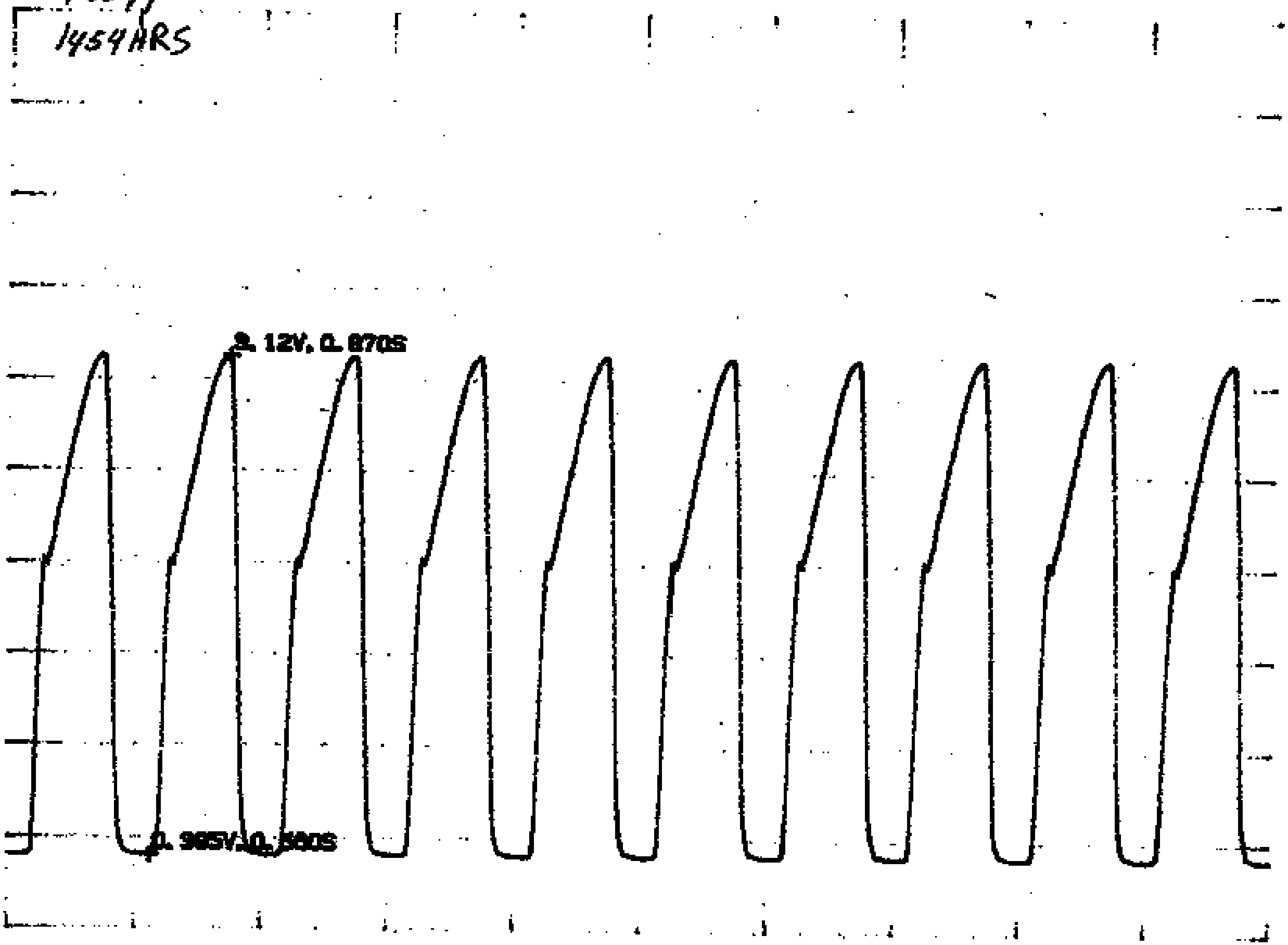
#2
4/20/99
1452 HRS

D



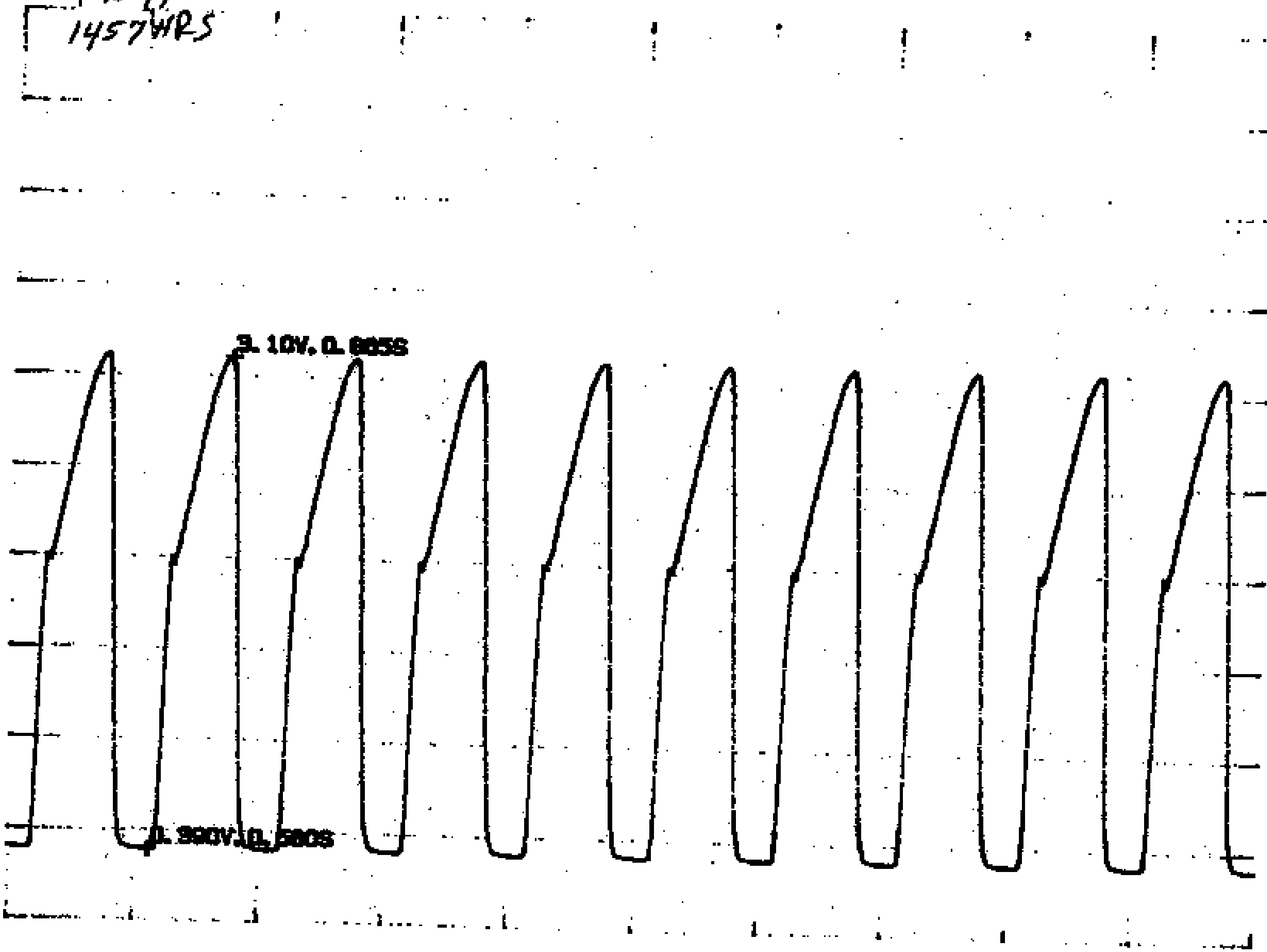
4-30-99
1454 HRS

D-



7
4-30-94
1457 HRS

0-



TI-NHTSA 013429