NASA TECHNICAL MEMORANDUM

NASA TM-82439

SOLID ROCKET BOOSTER THRUST VECTOR CONTROL V-2 OFF-NOMINAL TESTING

By Boris Pagan
Structures and Propulsion Laboratory

August 1981

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

(NASA-TM-82439) SOLID ROCKET BOOSTER THRUST VECTOR CONTROL V-2 OFF-NOMINAL TESTING Technical Report, Sep. - Jul. 1980 (NASA) 178 p HC A09/MF A01 CSCL 21H

N81-31283

Unclas
G3/20 27429

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM-82439	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Solid Rocket Booster Thrust Vector Control - V-2 Off-Nominal Testing		5. REPORT DATE August 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Boris Pagan		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, DC 20546		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This report was prepared by the Propulsion Control Branch, Structures and Propulsion Laboratory.

16. ABSTRACT

This report presents the results of the V-2 off-nominal test sequence performed on the Space Shuttle solid rocket booster thrust vector control (SRB TVC) subsystem by the Marshall Space Flight Center, Huntsville, Alabama. These tests were performed between September 1979 and July 1980, per paragraph 10, SE-019-098-2H, SRB TVC Overall Systems Test Requirements.

A discussion of the overall TVC subsystem performance is presented. In addition, test objectives, detail results, and data are included for general information.

17. KEY WORDS	18. DISTRIBUTION STATEMENT Unclassified-Unlimited

19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 178	22. PRICE NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

INTRODUCTION

The purpose of this report is to present a summary of the off-nominal phase V-2 certification testing results conducted on the SRB TVC subsystem, dedicated to the technical evaluation of this flight system.

The TVC subsystem (figure 1) was subjected to 19 off-nominal test conditions. This test sequence consisted of: 8 burp starts (APU fuel locked tests), 30 hot firings (27 completed), 14 GN_2 spin tests, and 3 servicing-passive system tests (actuator off-null, and FSM pressure decay tests). Hot firing time totalled 3560 sec (26 starts) for rock system, and 3993 sec (30 starts) for tilt system. GN_2 spin time reached 1989.5 sec (10 starts) for rock system, and 2183.5 sec (13 starts) for tilt system. Table 2 presents a summary of the V-2 off-nominal test sequence.

The actuator gimbal programs used in the off-nominal tests were B (GN_2 spins only), C2, D, and N*. Figures 2 through 5 show the profiles used in all these runs.

Table 1 presents the part and serial numbers for the hardware employed in the tests.

In summary, the TVC subsystem operated nominally in response to the given commands and test conditions. All objectives were accomplished with no component or system malfunction encountered.

TABLE 1

HARDWARE IDENTIFICATION
V-2 OFF NOMINAL TESTING

Hardware Configuration: Verification Hot Firing Assembly

Drawing No.: 13A10180, Rev. A

Components:	P/N	System A S/N	System B S/N
APU	13A10010	102	101
Hydraulic Pump	13A10038	156850	156843
Hydraulic Manifold	13A10037	004	005
Hydraulic Reservoir	13A10036	0008	0005
Actuator	16A03000	004	002
FSM	13A10009-1	004	005
FIV	13A10041	0002	0001
Check Valve/ Filter Assembly	13A10042	009	010
Quick Disconnects (15 of them)	13A10050	-	-
Hand Valves	20M85007-1	-	-

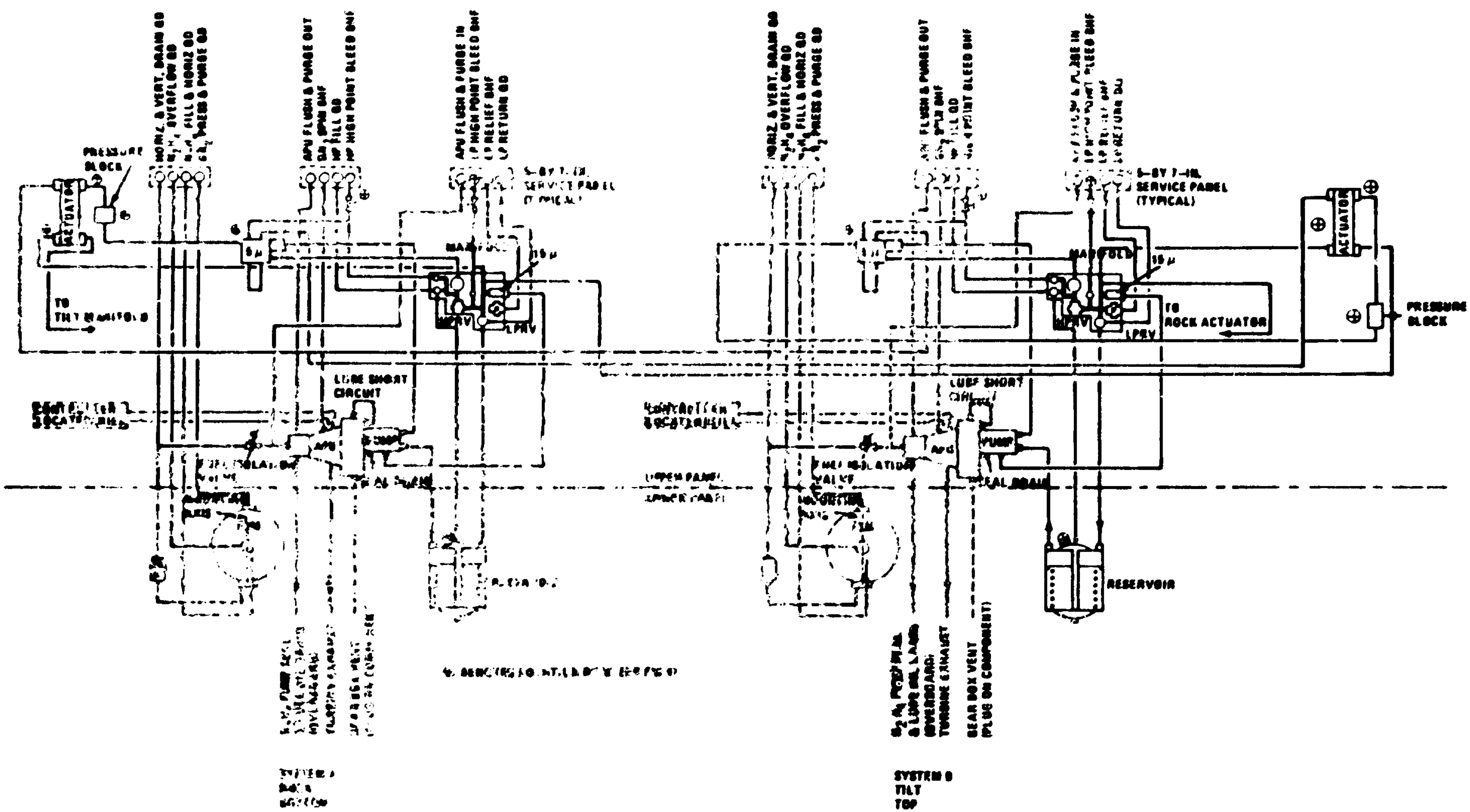


FIGURE 1

THRUST VECTOR CONTROL (TVC) SUBSYSTEM SCHEMATIC

TABLE 2
SUMMARY OF V-2 OFF-NOMINAL TESTING

TEST NO	DATE	DURATION (SEC) A	DURATION (SEC) B	PROGRAM	REMARKS
277A	9/13-9/24	11 DAYS			FSM PRESSURE DECAY TEST
277	9/24/79	–	–	–	APU LOCKED FUEL TEST 1
278	9/24/79	–	–	–	APU LOCKED FUEL TEST 2
279	9/24/79	–	–	–	APU LOCKED FUEL TEST 3
280	9/24/79	–	–	–	APU LOCKED FUEL TEST 4
281	9/24/79	–	–	–	APU LOCKED FUEL TEST 5
282	9/24/79	–	–	–	APU LOCKED FUEL TEST 6
283	9/24/79	–	–	–	APU LOCKED FUEL TEST 7
284	9/24/79	–	–	–	APU LOCKED FUEL TEST 8
285	9/25/79	73	75	N*	LOW RESERVOIR LEVEL TEST 1; ABORT–ELECTRONICS PROBLEM
286	9/25/79	160	160	N*	LOW RESERVOIR LEVEL TEST 1
287	9/25/79	160	160	N*	LOW RESERVOIR LEVEL TEST 2
288	9/28/79	160	160	N*	HIGH RESERVOIR LEVEL TEST 1
289	9/28/79	160	160	N*	HIGH RESERVOIR LEVEL TEST 2
290	10/4/79	[30 MINUTES]		N*	ACTUATOR DRIFT TEST IN OFF–NULL POSITION
291	10/5/79	160	160	N*	LOW FSM PRESSURE TEST 1
292	10/5/79	160	160	N*	LOW FSM PRESSURE TEST 2
293	10/11/79	160	160	N*	LOW FSM PRESSURE TEST 3
294	10/11/79	160	160	N*	LOW FSM PRESSURE TEST 4
295	10/12/79	160	160	N*	GN_2 SPIN PORT LEAK TEST
296	10/12/79	160	160	N*	LOW FSM PRESSURE TEST 5
297	10/16/79	160	160	N*	BLEED VALVE LEAK TEST
298	10/26/79	105.5	146	N*	HYDRAULIC HIGH PRESSURE RELIEF VALVE TEST

TABLE 2 (CONTINUED)
OFF NOMINAL TESTING (CONT'D)

TEST NO.	DATE	DURATION (SEC) A	DURATION (SEC) B	PROGRAM	REMARKS
P037-314	5/8/80	60	60	NA	LOW PRESSURE GN_2 SPIN
P037-315	5/9/80	24.5	14.5	B	HIGH PRESSURE GN_2 SPIN. ABORTED DUE TO ELECTRONIC AND FACILITY PROBLEM
P037-316	5/13/80	57	87.5	B	HIGH PRESSURE GN_2 SPIN. ABORTED DUE TO HYDRAULIC RESERVOIR LEVEL LOW CAUSED BY AIR IN THE HYDRAULIC SYSTEM
P037-317	5/13/80	300	300	B	HIGH PRESSURE GN_2 SPIN SUCCESSFUL
P037-318	5/15/80	20	20	C2	CHECKOUT TEST FULL DURATION SUCCESSFUL
P037-319	5/23/80	160	160	D	NOMINAL RUN FULL DURATION
P037-320	5/20/80	160	160	D	LOW RESERVOIR LEVEL TEST (10 PCT BOTH SYSTEMS) FULL DURATION
P037-321	5/22/80	300	300	B	HIGH PRESSURE GN_2 1000 PSIG GN_2 SPIN PRESSURE
P037-322	5/22/80	300	300	B	HIGH PRESSURE GN_2 1000 PSIG GN_2 SPIN PRESSURE
P037-323	5/22/80	300	300	B	HIGH PRESSURE GN_2 1000 PSIG GN_2 SPIN PRESSURE
P037-324	5/22/80	300	300	B	HIGH PRESSURE GN_2 1000 PSIG GN_2 SPIN PRESSURE
P037-325	5/22/80	300	300	B	HIGH PRESSURE GN_2 1000 PSIG GN_2 SPIN PRESSURE
P037-326	6/2/80	–	46	–	HIGH PRESSURE GN_2 SPIN TO VERIFY HYDRAULIC PUMP COMPENSATOR SETTING AT 3850 PSIG. TEST ABORTED, HIGH PRESSURE RELIEF VALVE IN HYDRAULIC SYSTEM RELIEVED AND THE GN_2 SPIN PRESSURE WAS NOT ENOUGH TO CARRY THE ADDITIONAL LOAD
P037-327	6/2/80	–	4.5	–	SAME AS IN TEST P037-326
P037-328	6/2/80	–	67	–	HIGH PRESSURE GN_2 SPIN TO SET COMPENSATOR TO 3850 PSIG–SUCCESSFUL
P037-329	6/2/80	–	160	D	SIMULATE A COMPENSATOR FAILURE IN THE BACK–UP MODE (TILT APU AT 110 PERCENT MODE)
P037-330	6/4/80	160	160	D	SIMULATE A COMPENSATOR FAILURE AT 100 PCT TURBINE SPEED
P037-331	6/4/80	–	104	–	GN_2 SPIN AT 1000 PSIG TO SET THE COMPENSATOR BACK TO 3250 PSIG
P037-332	6/9/80	160	160	D	KSC FLIGHT COUNTDOWN SIMULATION: NOMINAL PARAMETERS FULL DURATION
P037-333	6/19/80	142	142	D	KSC FLIGHT COUNTDOWN SIMULATION: MAXIMUM PARAMETERS. TEST ABORTED DUE TO PROCEDURE MISTAKE: PREFILTRATION VALVE IN ACTUATOR WAS LEFT OPEN. NO ANOMALIES OR COMPONENT FAILURE WERE ENCOUNTERED
P037-334	6/19/80	160	160	D	KSC FLIGHT COUNTDOWN SIMULATION: MAXIMUM PARAMETERS
P037-335	6/19/80	160	160	D	KSC FLIGHT COUNTDOWN SIMULATION: MINIMUM PARAMETERS

TABLE 2 (CONTINUED)
OFF NOMINAL TESTING (CONT'D)

TEST NO	DATE	DURATION (SEC) A	DURATION (SEC) B	PROGRAM	REMARKS
P037-336	6/23/80	15	15	C2	RECYCLE TEST
		160	160	D	
P037-337	6/23/80	10	10	–	HYDRAULIC BYPASS VALVE FAILED OPEN. TEST ABORTED, HYDRAULIC PRESSURE LOW CUTOFF WAS ACTIVE DURING RUN
		160	160	–	HYDRAULIC BYPASS VALVE FAILED OPEN
P037-341	7/15/80	40	–	–	GN_2 SPIN AT 1000 PSIG TO SET COMPENSATOR AT 3900 PSIG (ROCK HYDRAULIC PUMP)
P037-342	7/15/80	152.5	152.5	D	HOT FIRING COMPENSATOR FAILURE SIMULATION AT 3900 PSIG
P037-343	7/16/80	–	160	D	ACTUATOR OFF-NULL TEST
P037-344	7/16/80	–	33	–	PCSC FAILURE SIMULATION
P037-345	7/16/80	–	40	–	ACTUATOR OFF-NULL TEST RERUN
P037-346	7/22/80	12 HOURS		–	FSM PRESSURE DECAY TEST 2

B1 GIMBAL PROGRAM

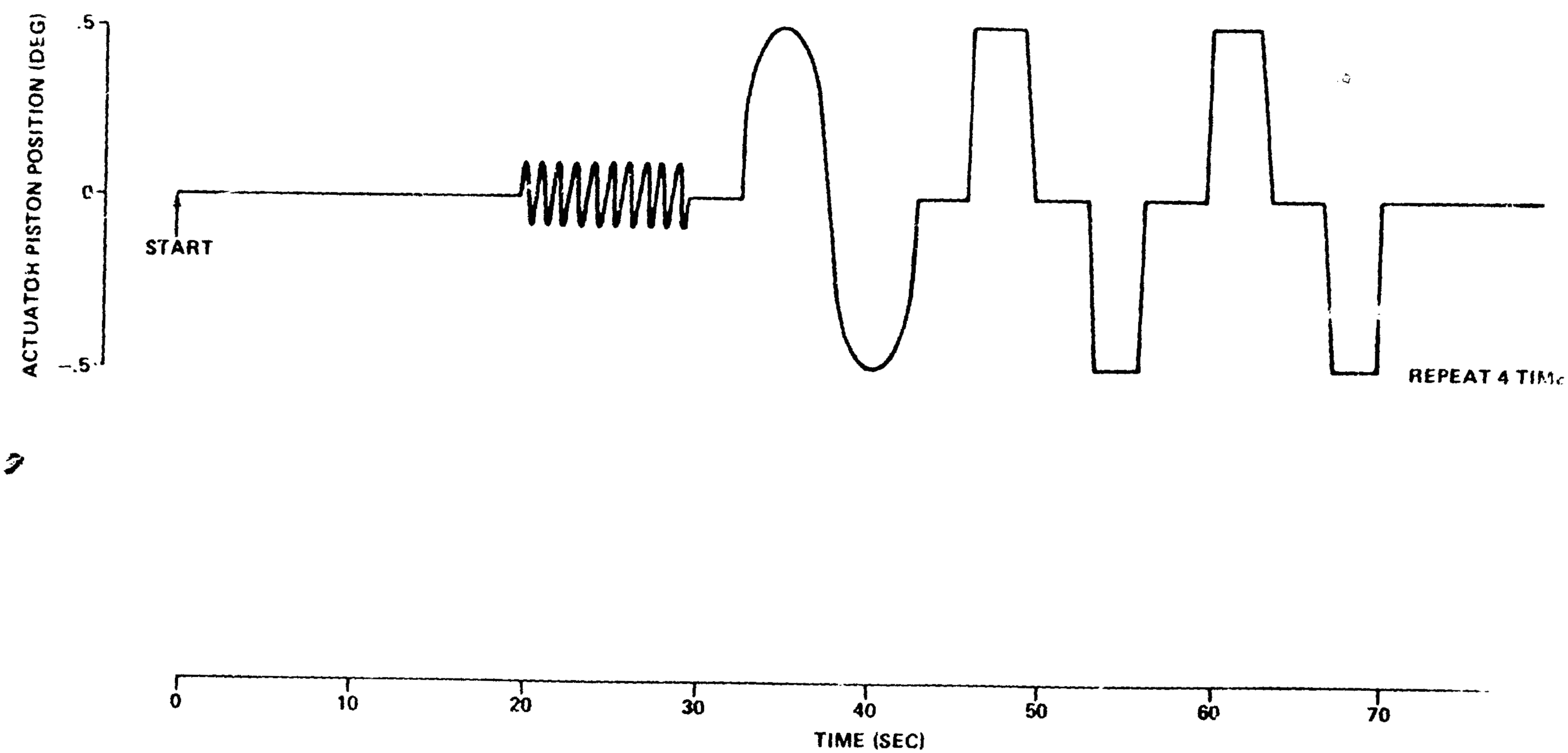


FIGURE 2

C2 GIMBAL PROGRAM
(KSC CHECKOUT PROFILE)

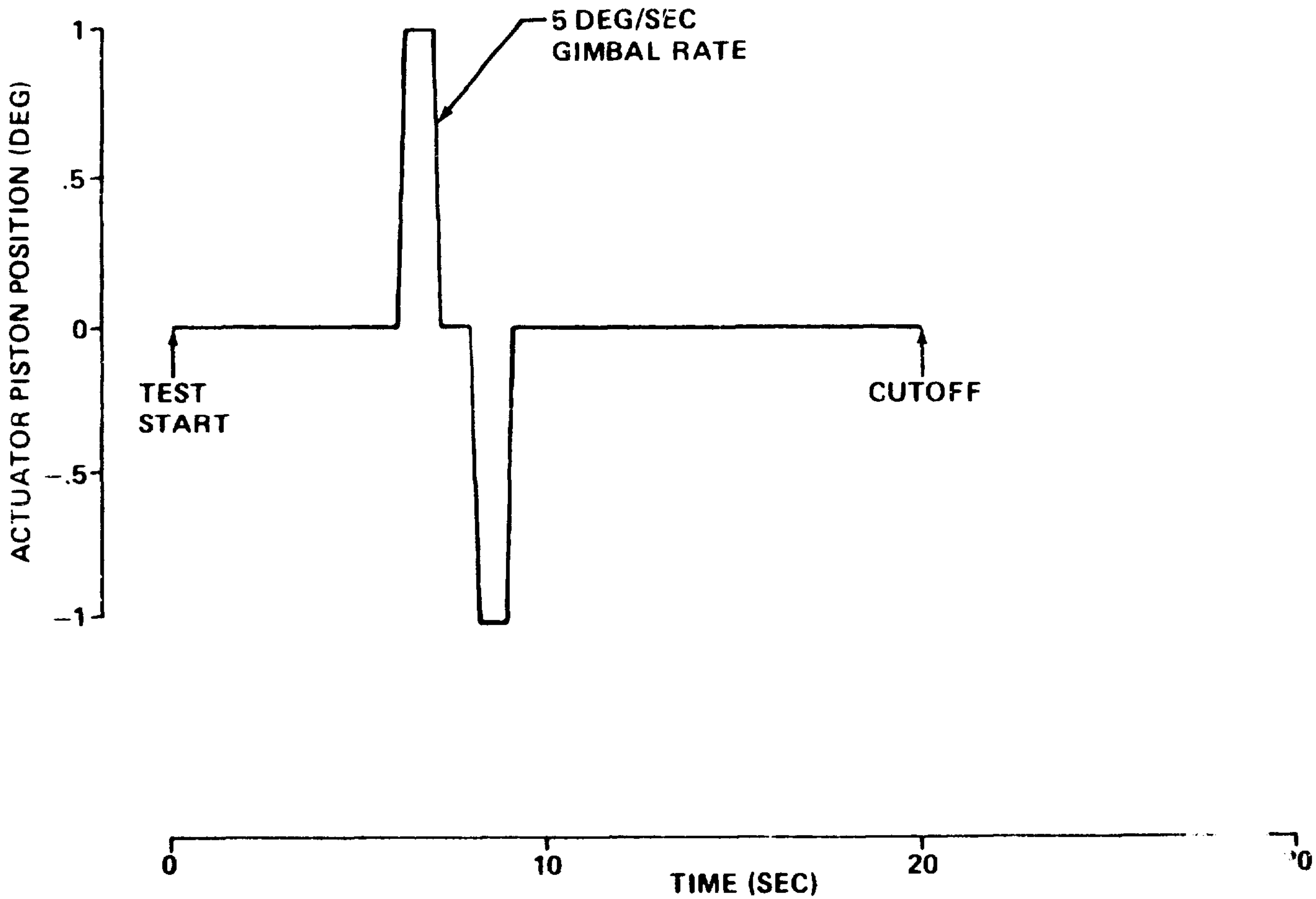
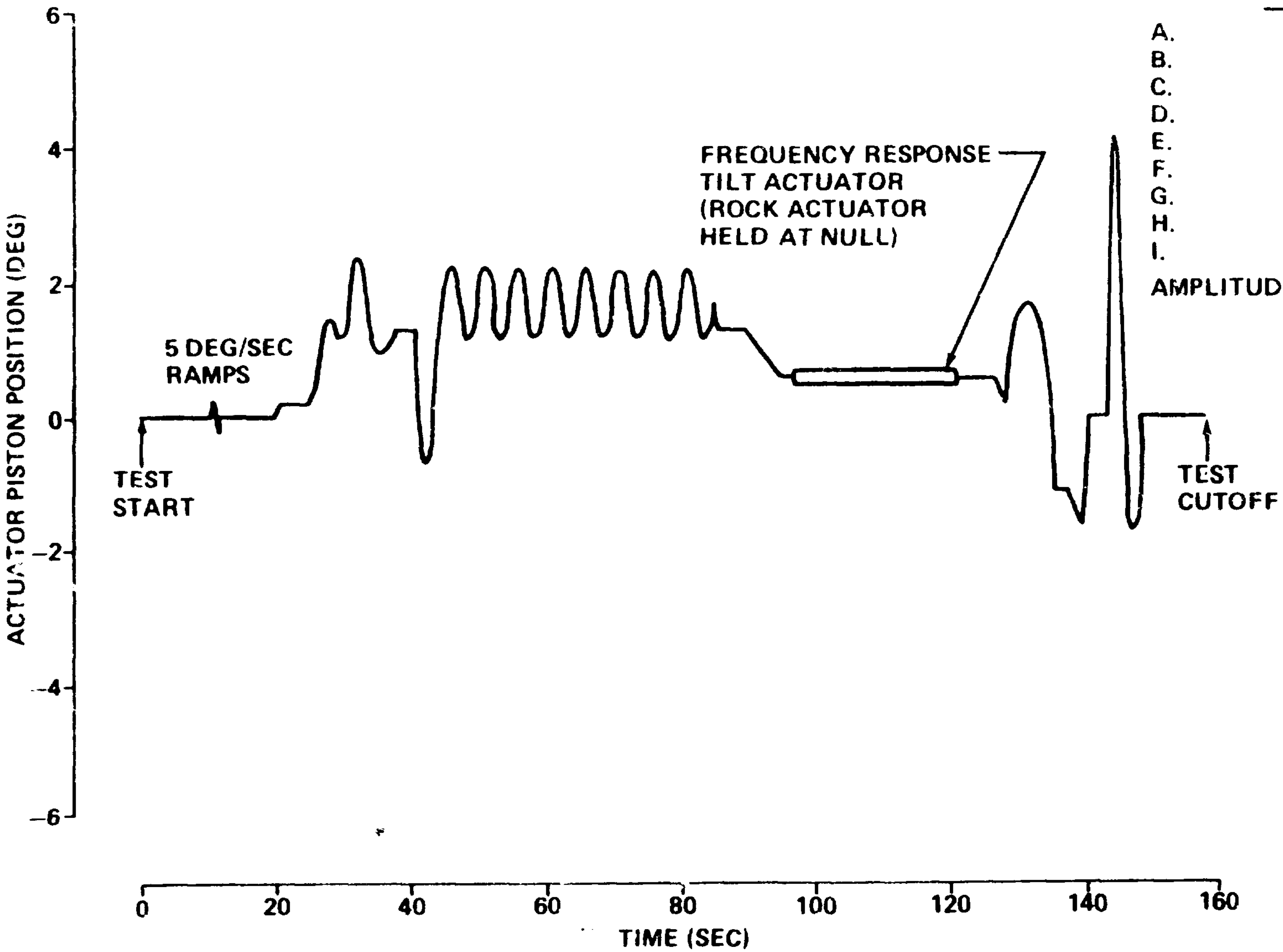


FIGURE 3

N* GIMBAL PROGRAM



FREQUENCY RESPONSE (SINE WAVE)

	FREQUENCY (Hz)	CYCLES
A.	16	24
B.	12	18
C.	10	15
D.	8	12
E.	4	8
F.	2	5
G.	1	4
H.	.5	2
I.	.2	1

AMPLITUDE ± .25 DEGREES

FIGURE 4

D GIMBAL PROGRAM

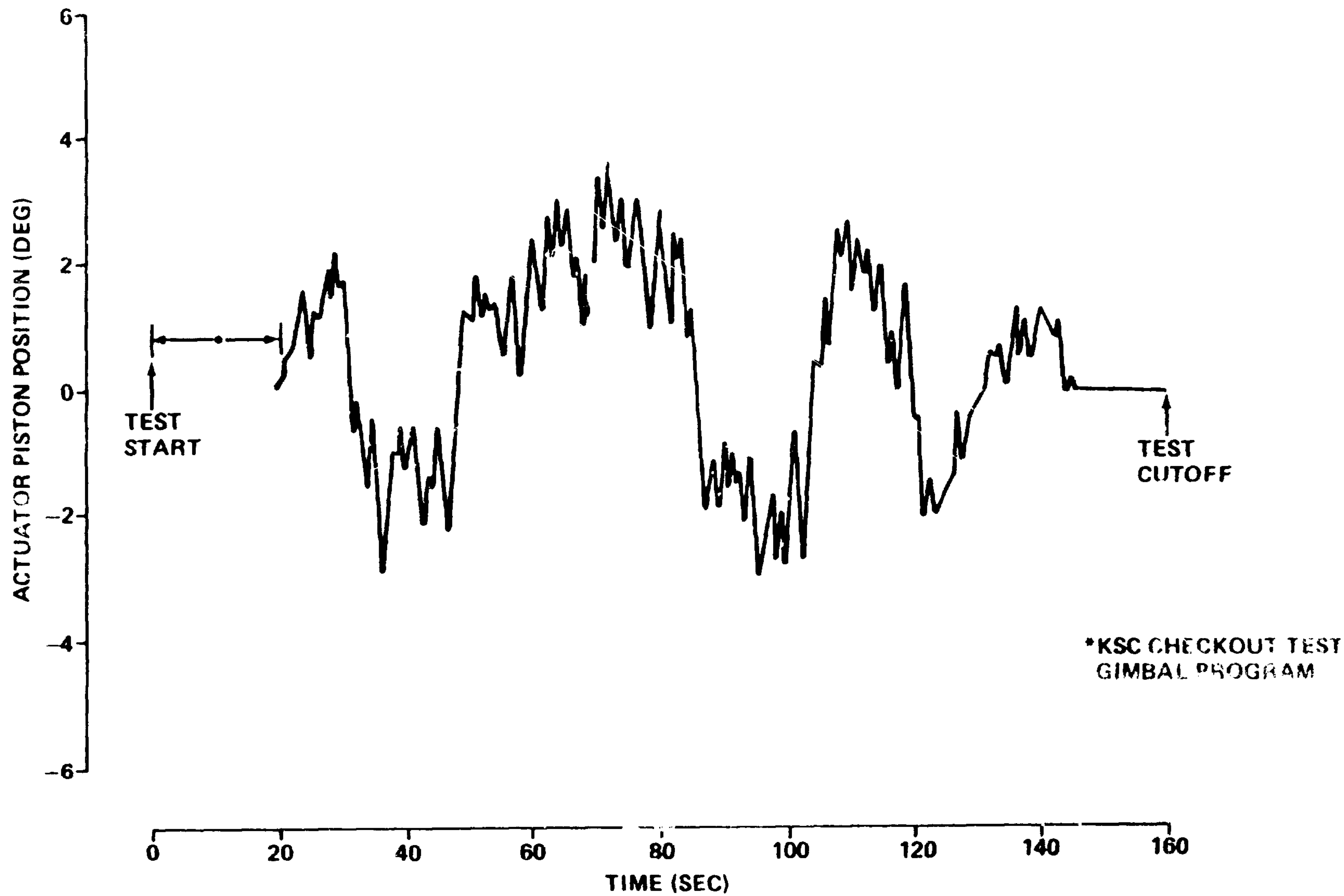


FIGURE 5

FUEL SYSTEM PRESS.RE DEC.Y TEST 1

OBJECTIVE

To demonstrate the standby capacity of the fuel system.

To obtain the GN_2 pressure variations due to temperature changes inside the fuel system.

RESULTS

The fuel system (FSM and associated lines between the service panel and the fuel isolation valve) was pressurized to 400 +0/-25 psia for 11 days. The data obtained from the test demonstrates the ability of the fuel system to contain the above pressure level for the 9-day standby period prior to the Shuttle launch. (See table 3.) This data also reflects the temperature-pressure relationship. (See figures 6 and 7) No insulation was used in the FSM; therefore, the temperature readings in the N_2H_4 bottle compare favorably with the ambient temperature. Hardware from the verification configuration V-2 was used for this test; consequently, the line routing in the fuel system was slightly different to the flight configuration. Table 4a shows the pressure variations at a constant temperature (68°F) for different days. Table 4b also shows the pressure variations at 75°F.

TABLE 3

FUEL SUPPLY MODULE PRESSURE DECAY TEST

DAY	TIME	ROCK FSM		TILT FSM	
		PRESSURE (PSIG)	TEMP (^{o}F)	PRESSURE (PSIG)	TEMP (^{o}F)
9/13/79	12:30 PM	385	76	377	75
	1:30 PM	382	75	375	75
	2:30 PM	384	76	375	75
	3:30 PM	384	76	378	75
9/14/79	8:30 AM	375	68	361	67
	9:30 AM	375	68	358	67
	10:30 AM	377	68	367	68
	11:30 AM	377	69	364	68
	12:30 PM	NA	NA	NA	NA
	1:30 PM	380	71	365	70
	2:30 PM	381	72	367	70
	3:30 PM	380	72	368	70
9/17/79	8:30 AM	375	68	363	68
	9:30 AM	375	68	360	67
	10:30 AM	375	67	359	67
	11:30 AM	377	67	364	67
	12:30 PM	376	66	362	66
	1:30 PM	376	67	366	66
	2:30 PM	377	67	364	66
	3:30 PM	377	67	365	66
9/18/79	8:30 AM	372	65	352	64
	9:30 AM	373	65	359	65
	10:30 AM	376	65	355	65
	11:30 AM	376	66	359	65
	12:30 PM	377	66	363	66
	1:30 PM	377	67	365	NA
	2:30 PM	378	67	366	67
	3:30 PM	378	66	366	67

TABLE 3 (CONTINUED)

FUEL SUPPLY MODULE

PRESSURE DECAY TEST

DAY	TIME	ROCK FSM PRESSURE (PSIG)	ROCK FSM TEMP (°F)	TILT FSM PRESSURE (PSIG)	TILT FSM TEMP (°F)
9/19/79	8:30 AM	377	63	368	73
	9:30 AM	NA	NA	368	74
	10:30 AM	380	70	374	75
	11:30 AM	383	72	373	75
	12:30 PM	384	73	375	76
	1:30 PM	385	75	374	77
	2:30 PM	386	76	376	78
	3:30 PM	387	76	378	78
9/20/79	8:30 AM	375	68	360	68
	9:30 AM	377	69	363	68
	10:30 AM	377	69	365	68
	11:30 AM	378	70	367	69
	12:30 PM	378	70	366	69
	1:30 PM	378	70	366	70
	2:30 PM	378	70	365	70
	3:30 PM	378	71	366	70
9/21/79	8:30 AM	382	74	368	73
	9:30 AM	382	75	368	74
	10:30 AM	384	75	374	75
	11:30 AM	386	76	373	75
	12:30 PM	386	77	375	76
	1:30 PM	387	78	374	77
	2:30 PM	388	79	376	78
	3:30 PM	389	80	378	78
9/24/79	8:30 AM	378	64	363	62
	9:30 AM	378	65	366	NA

TABLE 4A
FUEL SYSTEM PRESSURE DECAY TES[illegible]
PRESSURE AT 68°F

DAY	ROCK SYSTEM	TILT SYSTEM
9/14/79	375	367
9/17/79	375	363
9/19/79	377	NA
9/20/79	375	363

TABLE
FUEL SYSTEM PRESSURE DECAY TEST 1
PRESSURE AT 75°F

DAY	ROCK SYSTEM	TILT SYSTEM
9/13/79	384	375
9/19/79	386	373
9/21/79	386	373

TEMPERATURE VS PRESSURE
FSM PRESSURE DECAY TEST 1
ROCK SYSTEM

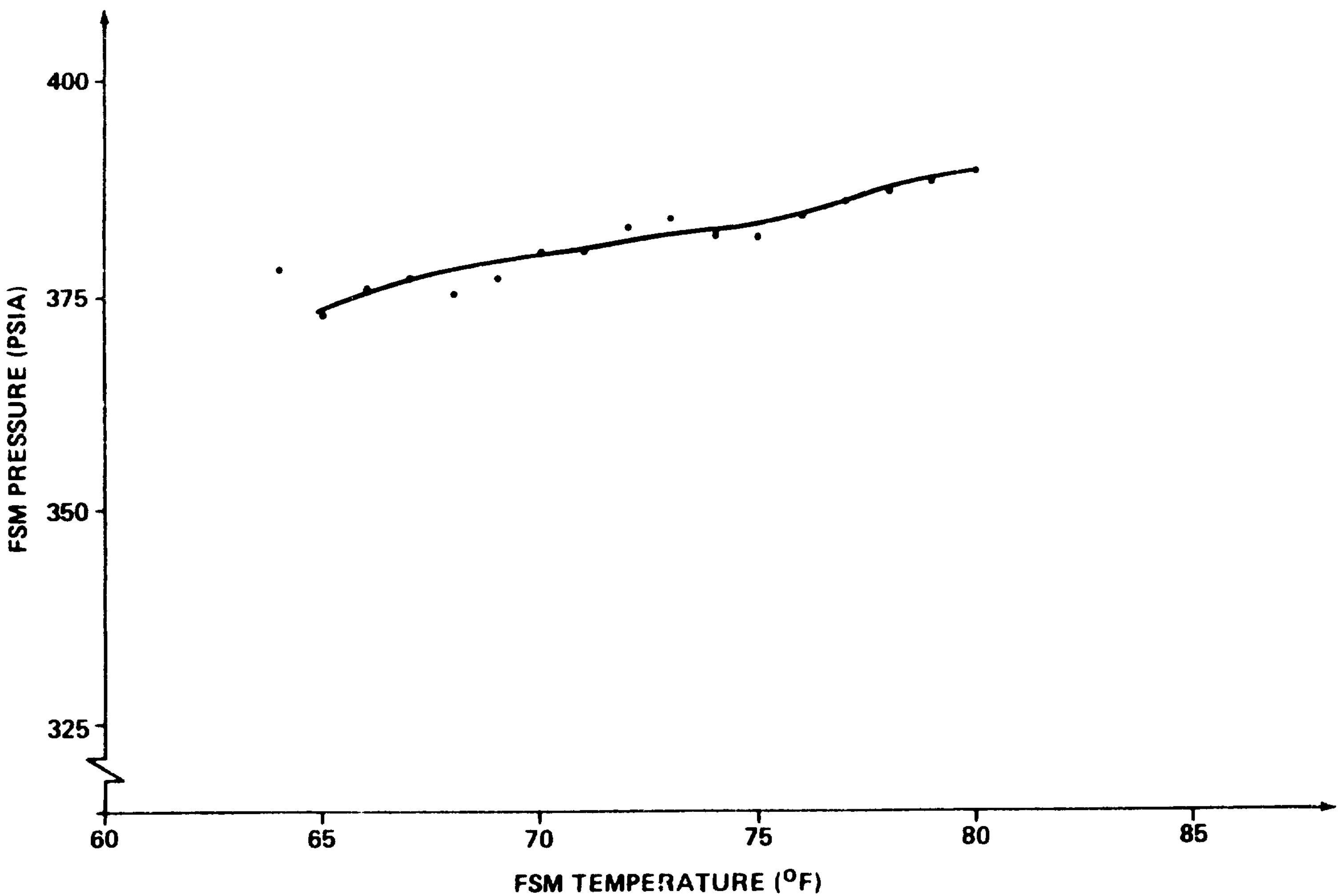


FIGURE 6

TEMPERATURE VS PRESSURE
FSM PRESSURE DECAY TEST 1
TILT SYSTEM

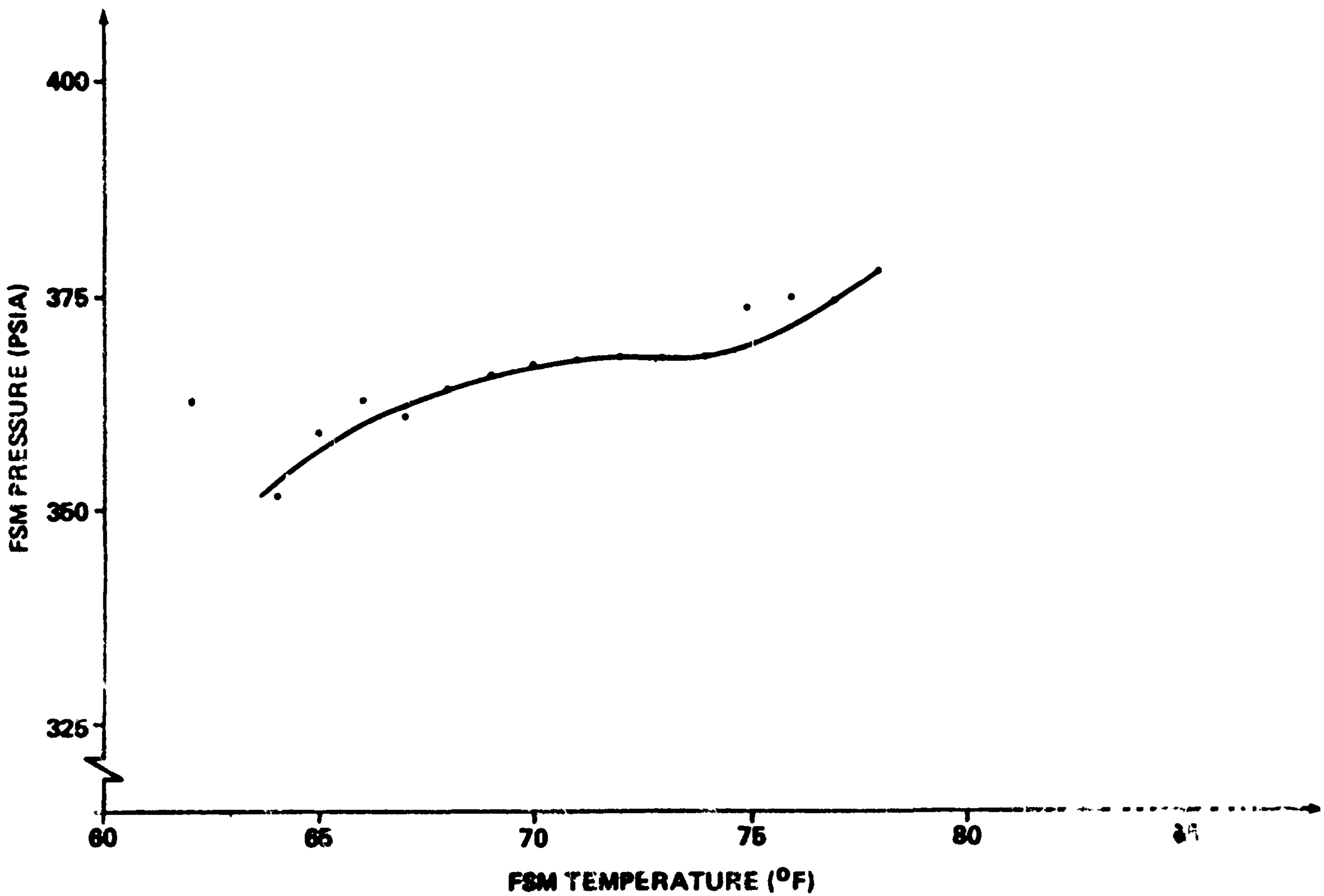


FIGURE 7

APU FUEL LOCKED TESTS

OBJECTIVES

To determine the consequences of opening the APU secondary speed control valve during a valve leak check with pressurized hydrazine locked between the fuel isolation and APU secondary speed control valves; and APU primary speed and secondary speed control valves.

TEST SEQUENCE

Test 1 (P037-277) For this run, the fuel was locked between the APU secondary speed control valve, and the fuel isolation valve. (See figure 8.) The fuel system's pressure was 20 psig.

Test 2 (P037-278) Repeat of test 1.

Test 3 (P037-279) Same as test 1, except that system's pressure was 400 psig.

Test 4 (P037-280) Repeat of test 3.

Test 5 (P037-281) For this run, the fuel was locked between the APU primary speed and secondary speed control valves, with the APU primary speed control valve in the closed position. (See figure 8.) The fuel system's pressure was 20 psig.

Test 6 (P037-282) Repeat of test 5.

Test 7 (P037-283) Same as test 5, except that system's pressure was 400 psig.

Test 8 (P037-284) Repeat of test 7.

Results

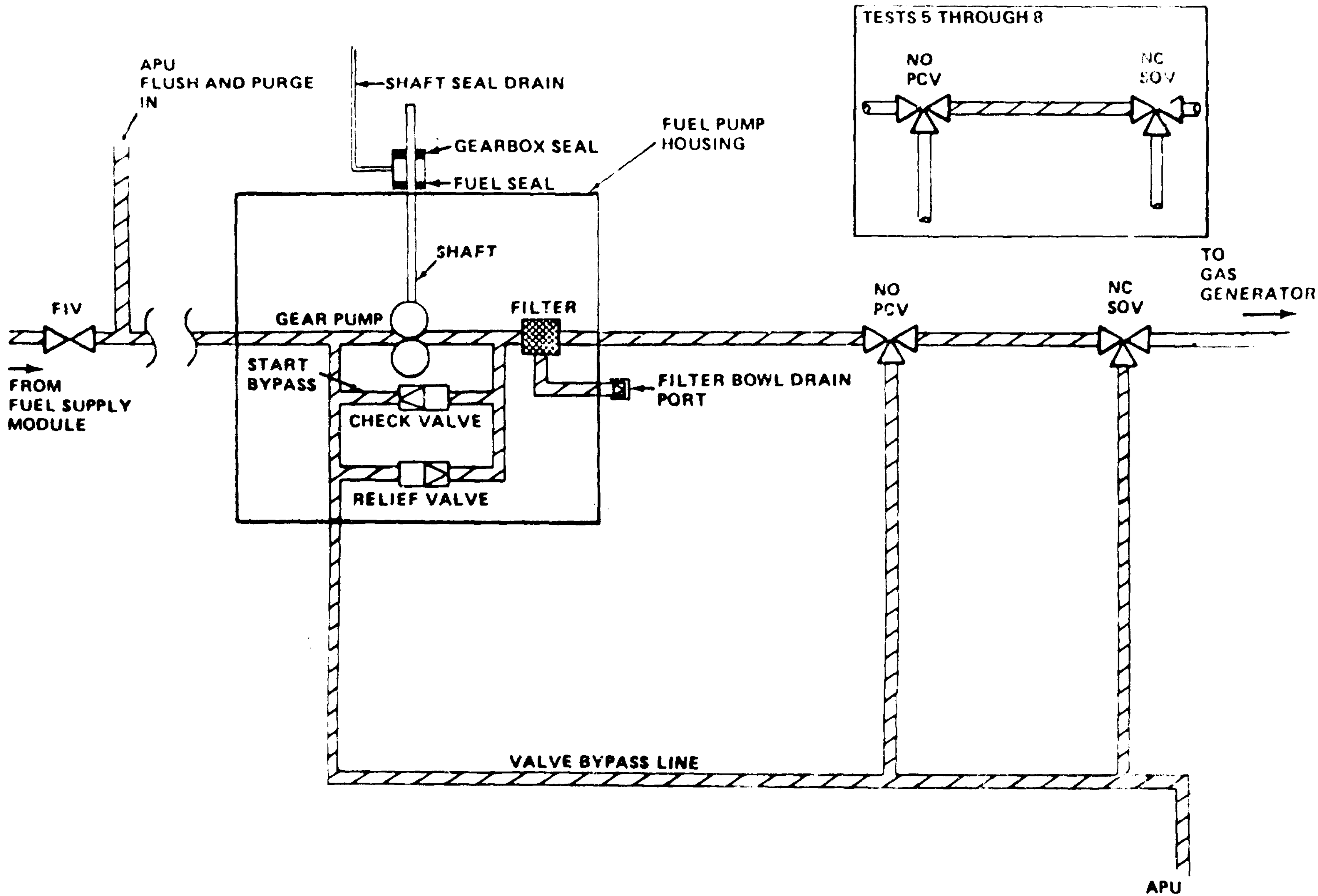
A series of tests was run simulating an inadvertent secondary speed control valve cycling during the APU control valves leak check. During these runs, pressurized hydrazine was locked between the fuel isolation valve, APU primary speed control valve, and APU secondary speed control valve.

During tests 1 and 2, a sound similar to a relief in pressure was heard following the opening of the APU secondary speed control valve. No turbine speed was reflected in the data. It was probably too insignificant to overcome the allowable noise in the reading. There was a slight increase in gas generator bed temperature caused by the hydrazine reaction in the gas generator chamber. (See table 5.) Consequently, the turbine exhaust temperature increased mildly (3 to 4 degrees). This was the result of warm gas leaving the APU through the exhaust line. The increase in gas generator pressure rose when the valve opened. The pressure increased almost instantaneously to 15-20 psig, (the original pressure level in the fuel system), and then decreased to zero psig 2.5 seconds later.

A sharper, penetrating sound was emitted in tests 3 and 4. Although, the data showed no signs of turbine speed. The increase in gas generator temperature was slightly more than in tests 1 and 2. (See figure 10 .) The turbine exhaust temperature also experienced this rise. This means that more hydrazine entered the gas generator chamber. This was expected because of the higher pressure in the fuel system. The fuel capacity downstream of the fuel isolation valve is approximately 11.27 in^3. The chamber pressure increased to 60 psig almost instantaneously and decreased to zero psig 3 seconds later. This higher reading was caused by the 400 psig pressure setting. There was no indication of pressure rise due to hydrazine reaction in the gas generator chamber during this run.

For tests 5 through 8, no reaction was present. The data showed no signs of pressure or temperature increase due to hydrazine decomposition in the gas generator chamber. The amount of fuel used in these tests was approximately .028 in^3.

Each of these tests lasted around 2.5 seconds when the turbine underspeed redline became active. The rock APU and fuel system of the verification testing hardware V-2 was used in these runs. Figures 11 and 12 show the transient data for selected tests.



AUXILIARY POWER UNIT

CONFIGURATION FOR APU FUEL LOCKED TESTS 1 THROUGH 4

FIGURE 8

TABLE 5
APU FUEL LOCKED TESTS
APU TEMPERATURE BEHAVIOR

GAS GENERATOR TEMPERATURE (°F)

	AT START	10 SEC. LATER
TEST 1	222	237
TEST 2	255	267
TEST 3	275	291
TEST 4	288	306
TEST 5	234	234
TEST 6	230	230
TEST 7	230	230
TEST 8	220	220

TURBINE EXHAUST TEMPERATURE (°F)

	START	MAX (AT CUT OFF)
TEST 1	77	80
TEST 2	75	79
TEST 3	77	82
TEST 4	76	83
TEST 5	79	79
TEST 6	77	77
TEST 7	78	78
TEST 8	77	77

NOTE: LUBE OIL TEMPERATURE REMAINED CONSTANT THROUGHOUT EACH TEST (75–80°F)

APU FUEL LOCKED TEST
GAS GENERATOR TEMPERATURE PROFILE

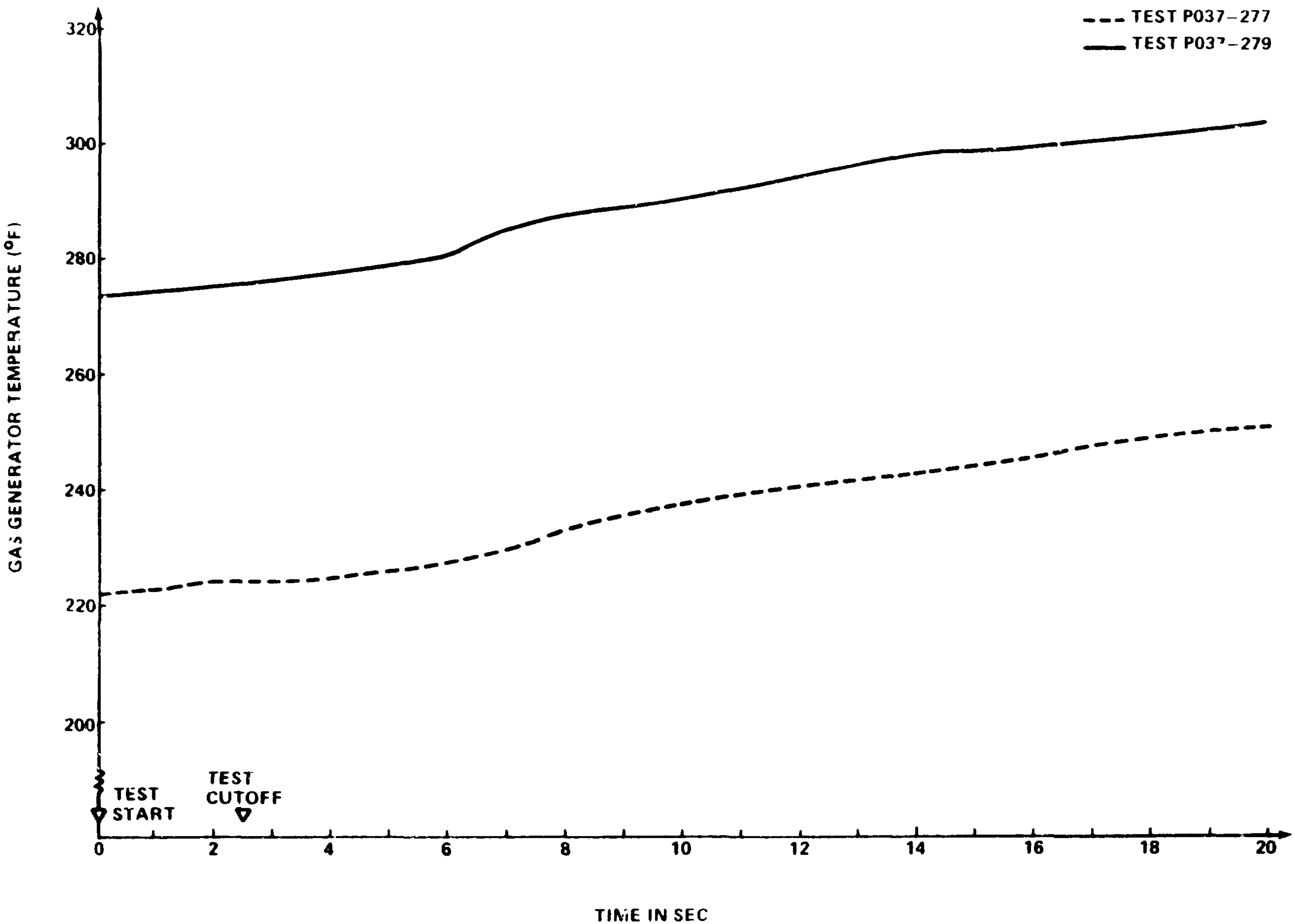


FIGURE 10

APU FUEL LOCKED TESTS
APU PERFORMANCE
TEST P037–277

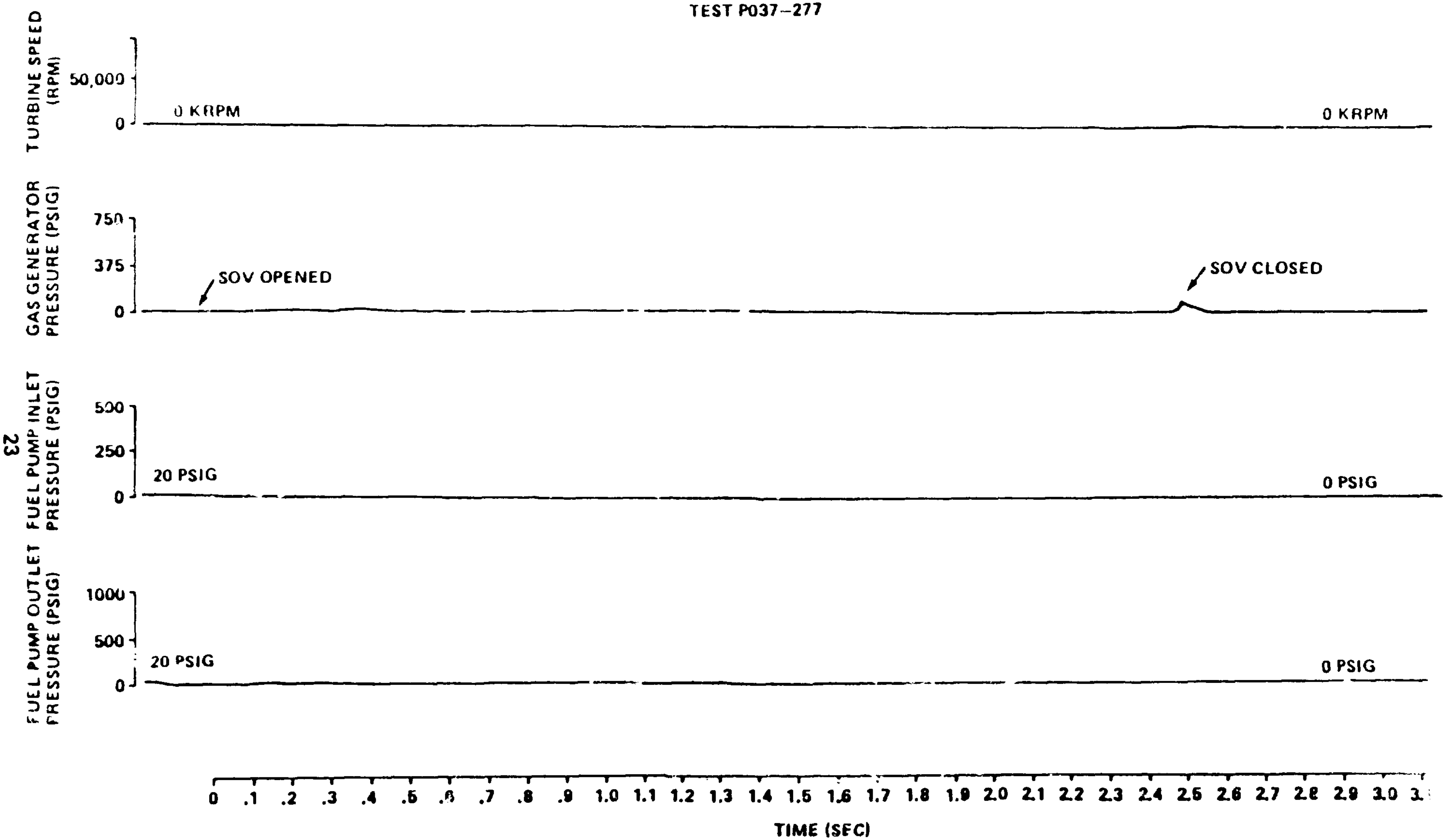


FIGURE 11

APU FUEL LOCKED TESTS
APU PERFORMANCE
TEST P037-279

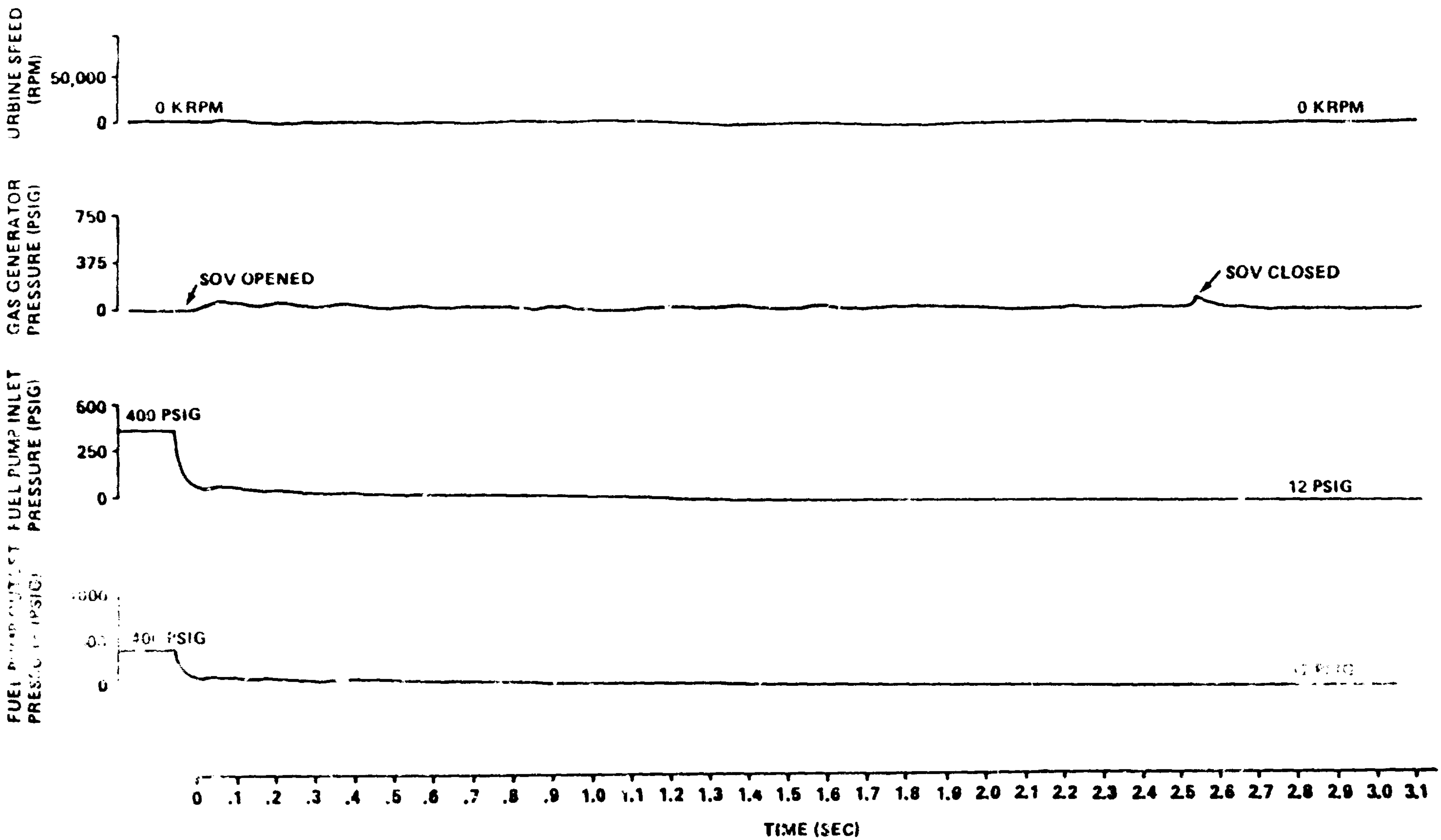


FIGURE 12

LOW RESERVOIR LEVEL TESTS

Objective

To demonstrate the hydraulic system's reaction to possible conditions created by addition of hydraulic accumulators to the TVC subsystem.

Results

The low hydraulic reservoir level test 1 (P037-286) and test 2 (P037-287) were conducted, without any major anomalies, on September 25, 1979. The first run (test P037-285) was aborted because of electronic problems after 7.5 seconds of firing time. Once the problem was corrected, the test was repeated with no difficulties. The reservoir level was set to 50 PCT (rock) and 40 PCT (tilt) for the first firing; and 30 PCT (rock) and 10 PCT (tilt) for the second.

The average hydraulic temperature rise was higher for these tests than in previous runs as a result of less hydraulic fluid in the system. This increase in temperature rise from $14^{o}F$ in normal conditions to $25^{o}F$ in low level conditions was not detrimental to the systems operation. Changes in reservoir level reflected the increase in hydraulic temperature for these tests. (See figures 13 and 14 .) The expected level drop during initial hydraulic supply pressure buildup was similar to that observed in nominal tests and the reservoir piston never came close to bottoming out. The hydraulic supply pressure oscillations remained unchanged throughout this run. (See figures 15 and 16 .) The data showed only a slight increase in pressure spikes amplitude during the frequency response period for the manifold pressure in tilt system. No variations in the number of pressure surges were found. The reservoir pressure spikes remained at the same level of previous hot firings where the reservoir level was set at 70 $\pm$ 5 PCT. (See figures 17 and 18.) Figure 28 presents a detailed area of the N* gimbal program to correlate with the hydraulic pressure transients shown in figures 15 through 19.

V-2 hardware and the N* gimbal program were utilized in these runs. Table 6 shows the temperature and level variations for both tests. Figure 19 shows the return pressure transients at a common time period for these tests. The temperature readings were taken at the reservoir.

TABLE 6
LOW HYDRAULIC RESERVOIR LEVEL TESTS
RESERVOIR PERFORMANCE

	RESERVOIR LEVEL (PCT)					
	ROCK			TILT		
	START	MIN	MAX	START	MIN	MAX
TEST 1 (P037–286)	46	43	48	39	35	39
TEST 2 (P037–287	31	29	33	9	6	10

	HYDRAULIC FLUID TEMPERATURE (°F)	
TEST 1 (P037–286)	71–95 °F	NA
TEST 2 (P037–287)	74–100 °F	NA

NOMINAL RUN TEST P037–291)

RESERVOIR LEVEL (PCT)					
ROCK			TILT		
START	MIN	MAX	START	MIN	MAX
71	68	72	72	69	73

HYDRAULIC FLUID TEMPERATURE (°F)	
54–71 °F	63–83 °F

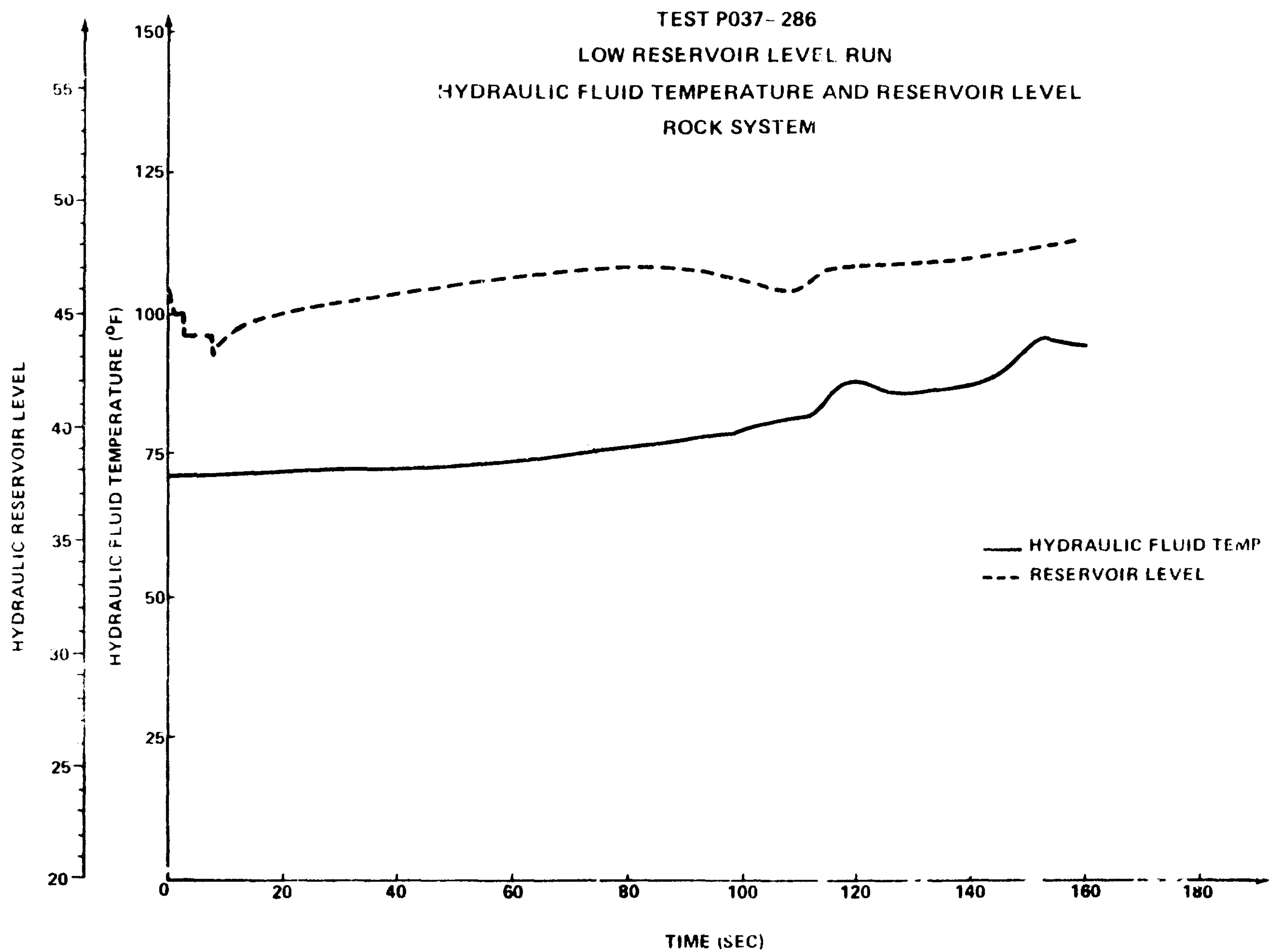

TEST P037 – 286
LOW RESERVOIR LEVEL RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
ROCK SYSTEM
HYDRAULIC RESERVOIR LEVEL
20
25
30
35
40
45
50
55
HYDRAULIC FLUID TEMPERATURE (°F)
25
50
75
100
125
150
0
20
40
60
80
100
120
140
160
180
TIME (SEC)
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL

FIGURE 13

TEST P037–287
LOW RESERVOIR LEVEL RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
ROCK SYSTEM

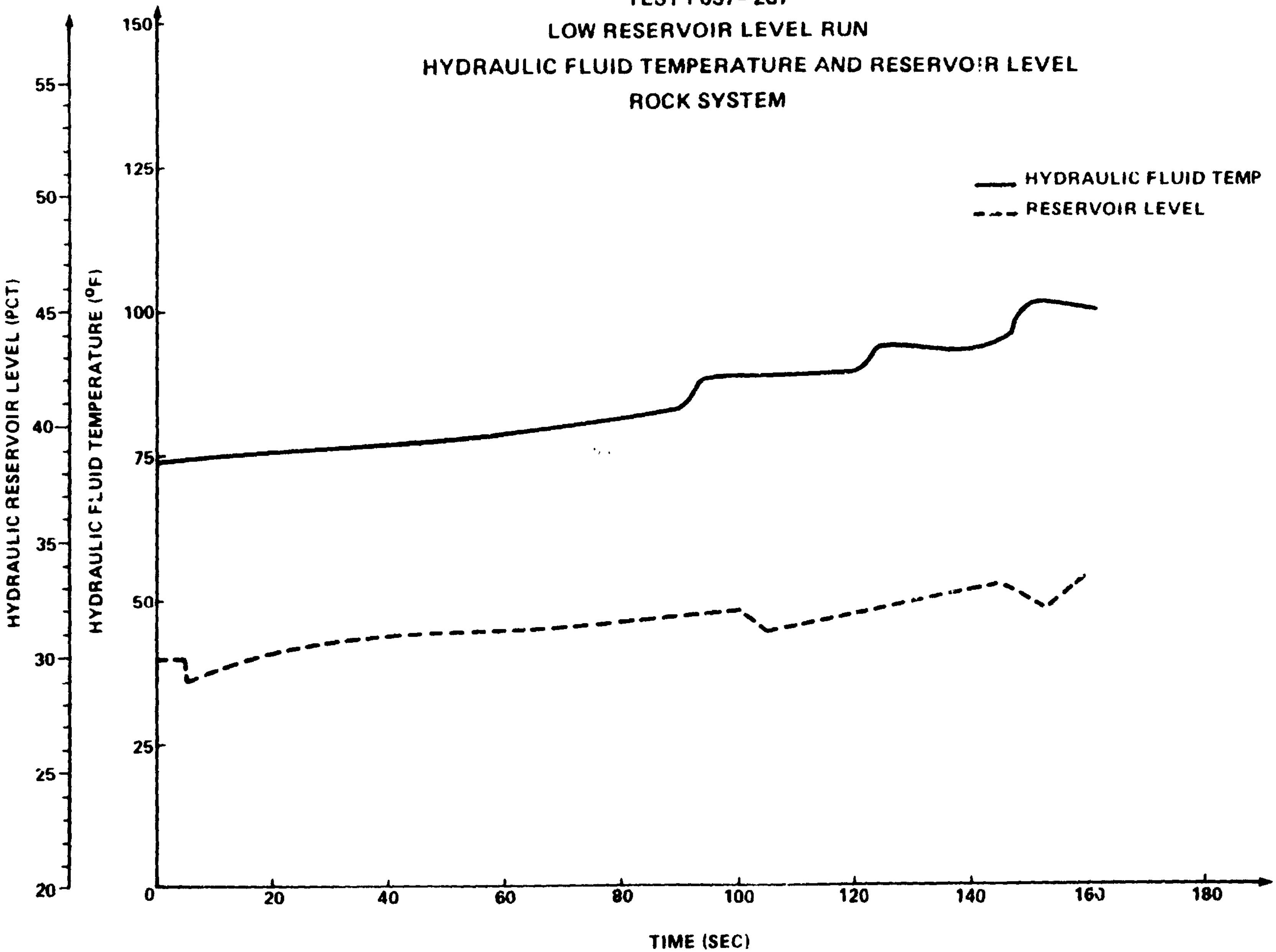


FIGURE 14

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
LOW RESERVOIR LEVEL TESTS

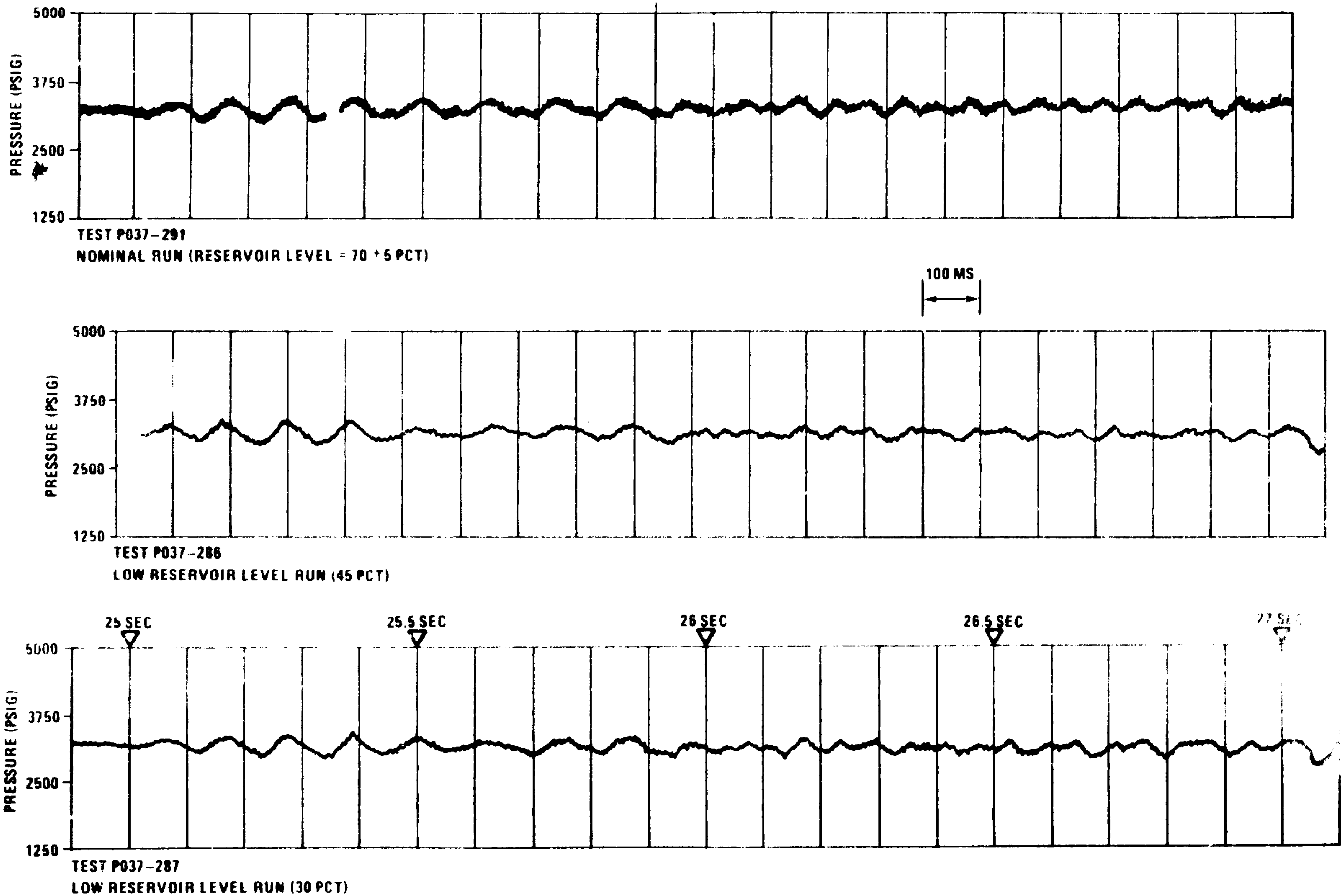
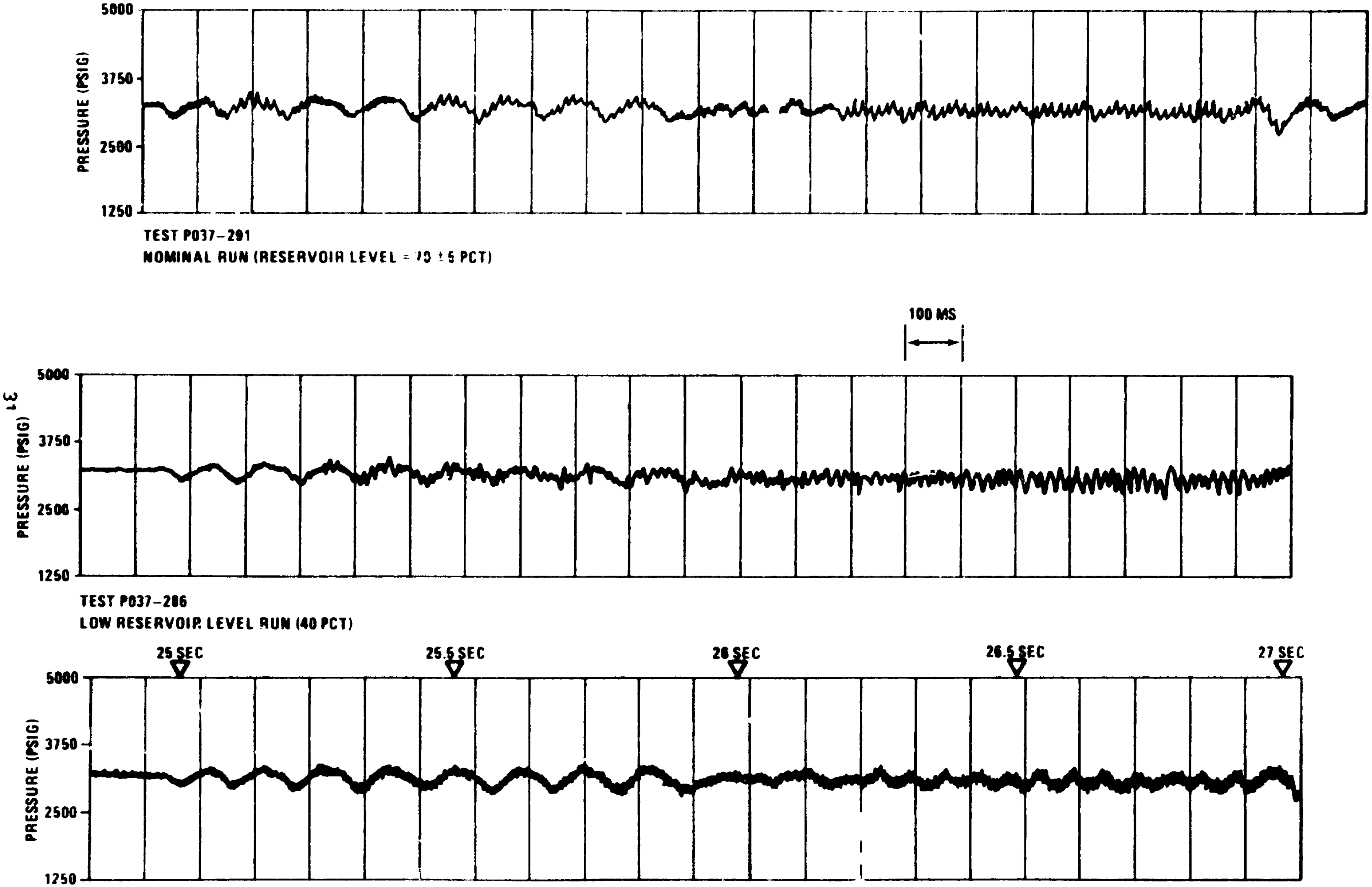


FIGURE 15

TILT HYDRAULIC FLUID SUPPLY PRESSURE

LOW RESERVOIR LEVEL TESTS



TEST P037-287
LOW RESERVOIR LEVEL RUN (10 PCT)

FIGURE 16

RETURN PRESSURE BEHAVIOR
TEST P037–286
LOW RESERVOIR LEVEL RUN
ROCK 45 PCT
TILT 40 PCT

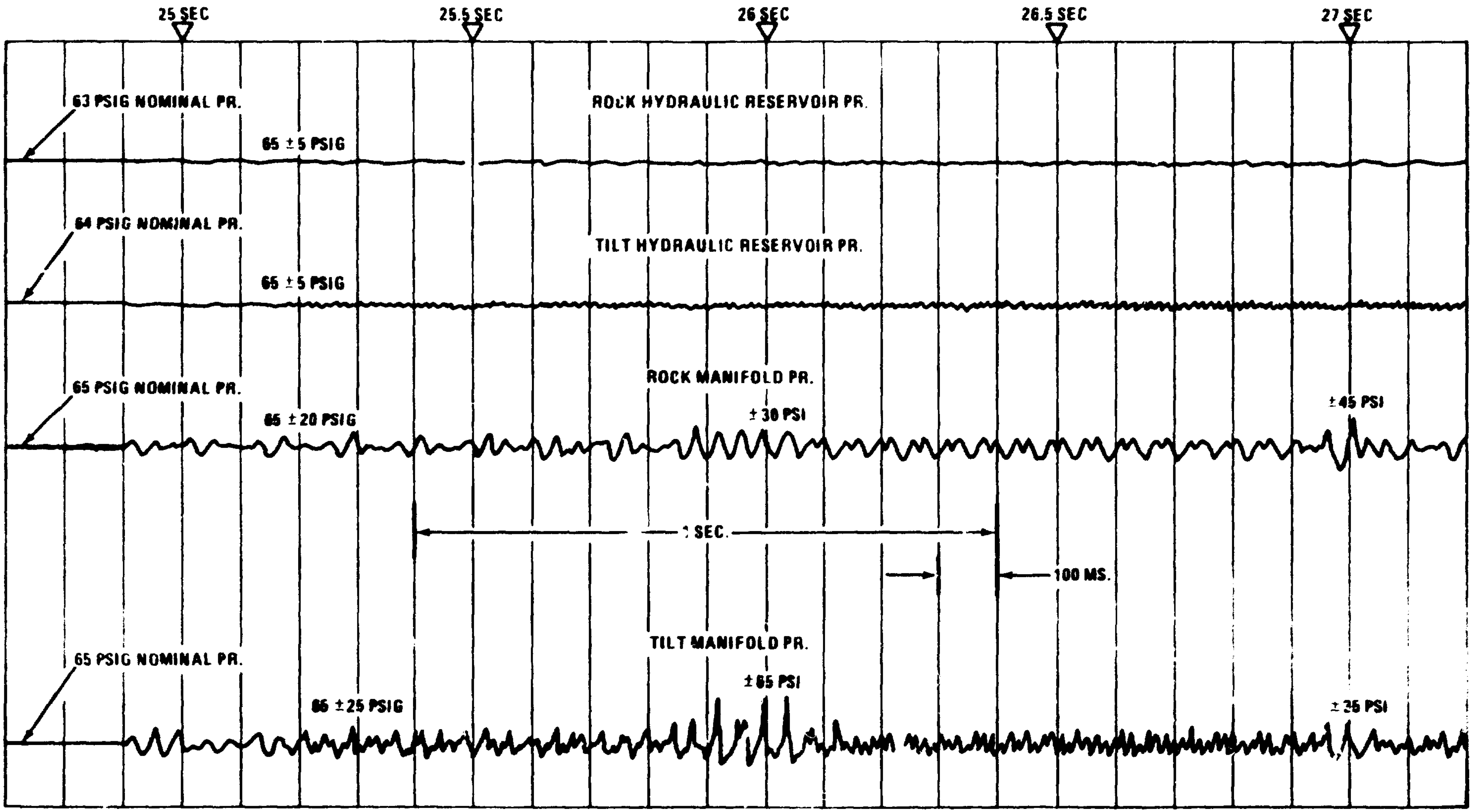


FIGURE 17

RETURN PRESSURE BEHAVIOR
TEST P037–287
LOW RESERVOIR LEVEL RUN
ROCK 30 PCT
TILT 10 PCT

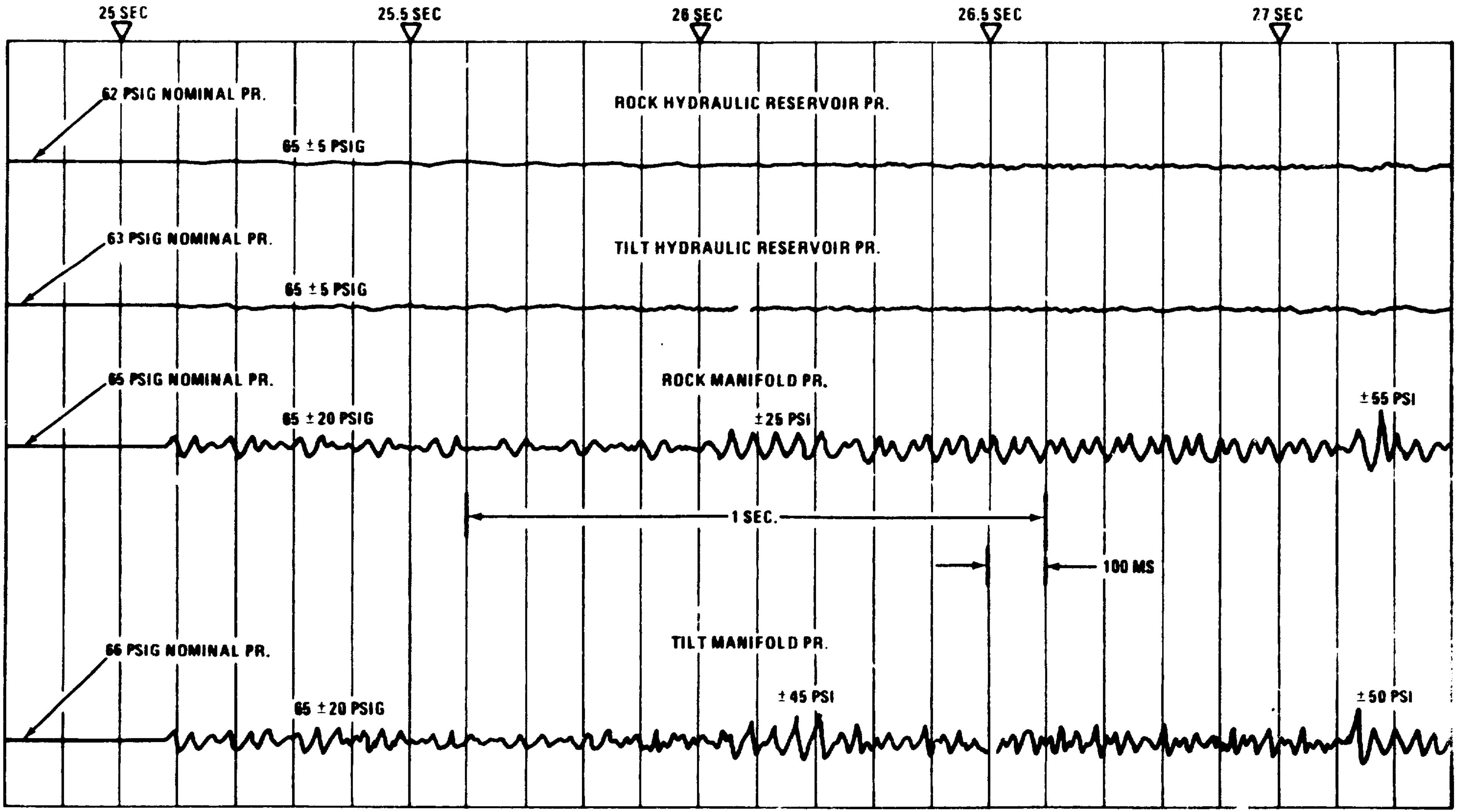


FIGURE 18

TEST PO37-286
LOW RESERVOIR LEVEL TEST 1
HYDRAULIC RESERVOIR AND MANIFOLD PRESSURE TRANSIENTS

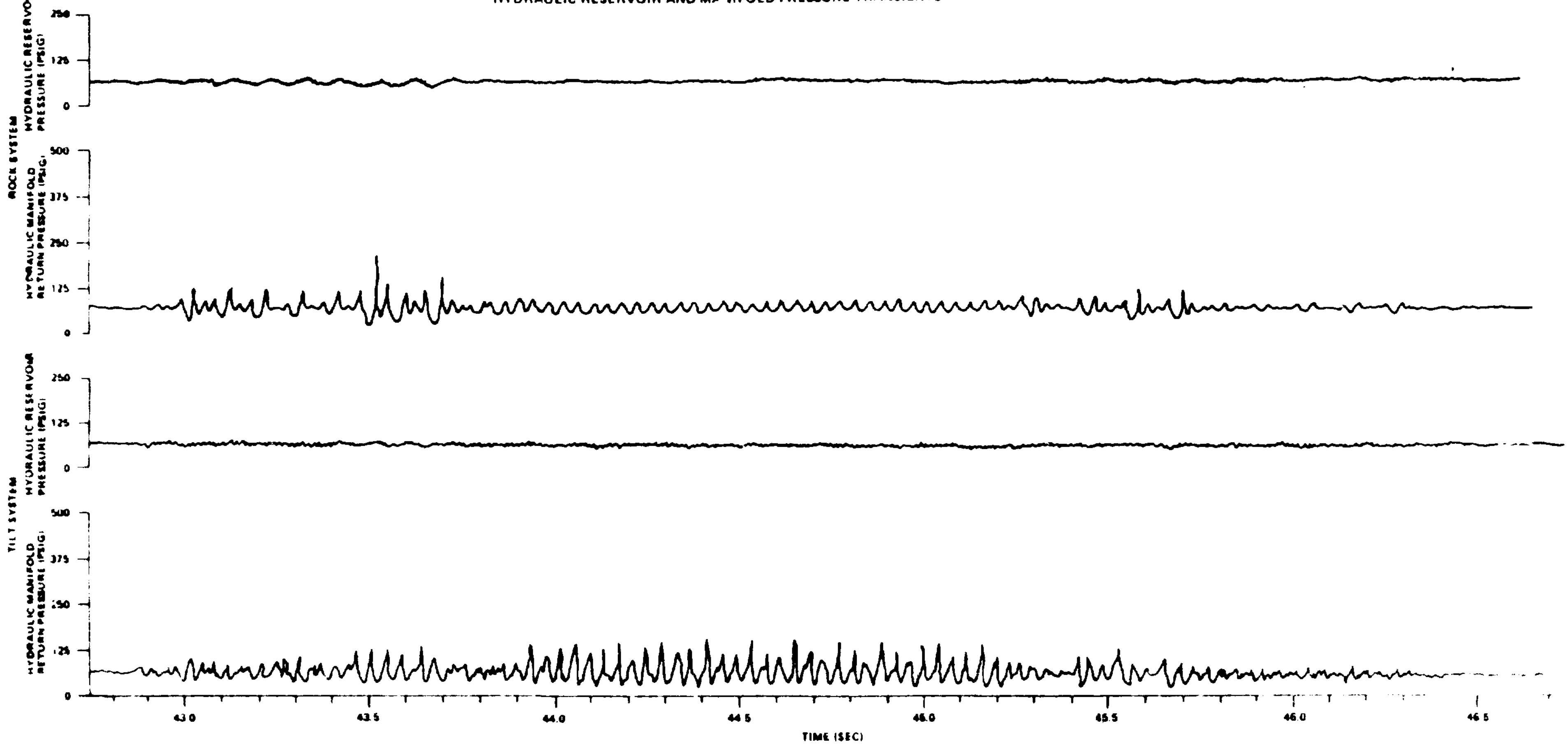


FIGURE 19

HIGH HYDRAULIC RESERVOIR LEVEL TESTS

OBJECTIVE

To demonstrate the hydraulic system reaction to overfill conditions in the TVC subsystem hydraulic reservoir.

RESULTS

The high hydraulic reservoir level test 1 (P037-288) and test 2 (P037-289) were successfully conducted on September 28, 1979. The level for the first test was set at 85 PCT (rock) and 90 PCT (tilt); and at 90 PCT (rock) and 95 PCT (tilt) for the second run. The low pressure relief valve in the hydraulic manifold was left uncapped to prevent any damage in the reservoir in case of an unexpected overfilled condition (more than 100 PCT) during the hot firings.

The data showed no signs of anomalies as a result of the greater amount of fluid in the hydraulic system. The hydraulic fluid temperature increased slightly less than in nominal hot firings. The reservoir level rose less than in nominal tests because of the lesser fluid temperature rise and the low pressure relief valve being uncapped. (See figures 20 and 21.) The hydraulic supply and return pressure oscillations remained unaffected by the higher reservoir level. (See figures 22 and 23.)

These runs used V-2 test hardware and the N* gimbal program. The temperature and level variations for both tests are shown in table 7 Figures 24 through 27 show the pressure transients during common time periods for both tests. Figure 28 presents a detailed area of the N* gimbal program to correlate with the hydraulic pressure transients shown in figures 22 through 27.

TABLE 7
HIGH HYDRAULIC RESERVOIR LEVEL TESTS
RESERVOIR PERFORMANCE

RESERVOIR LEVEL (PCT)

	ROCK			TILT		
	START	MIN	MAX	START	MIN	MAX
TEST 1 (P037–288)	84	82	84	90	86	88
TEST 2 (P037–289)	90	88	90	95	92	93

*LP RELIEF VALVE WAS LEFT OPEN DURING THESE TESTS

HYDRAULIC FLUID TEMPERATURE (°F)

	ROCK	TILT
TEST 1 (P037–288)	68–82 °F	NA
TEST 2 (P037–289)	74–90 °F	NA

NOMINAL RUN (TEST P037–291)

RESERVOIR LEVEL (PCT)

ROCK			TILT		
START	MIN	MAX	START	MIN	MAX
71	68	72	72	69	73

HYDRAULIC FLUID TEMPERATURE (°F)

ROCK	TILT
54–71 °F	63–83 °F

TEST P037–288
HIGH RESERVOIR LEVEL RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
ROCK SYSTEM

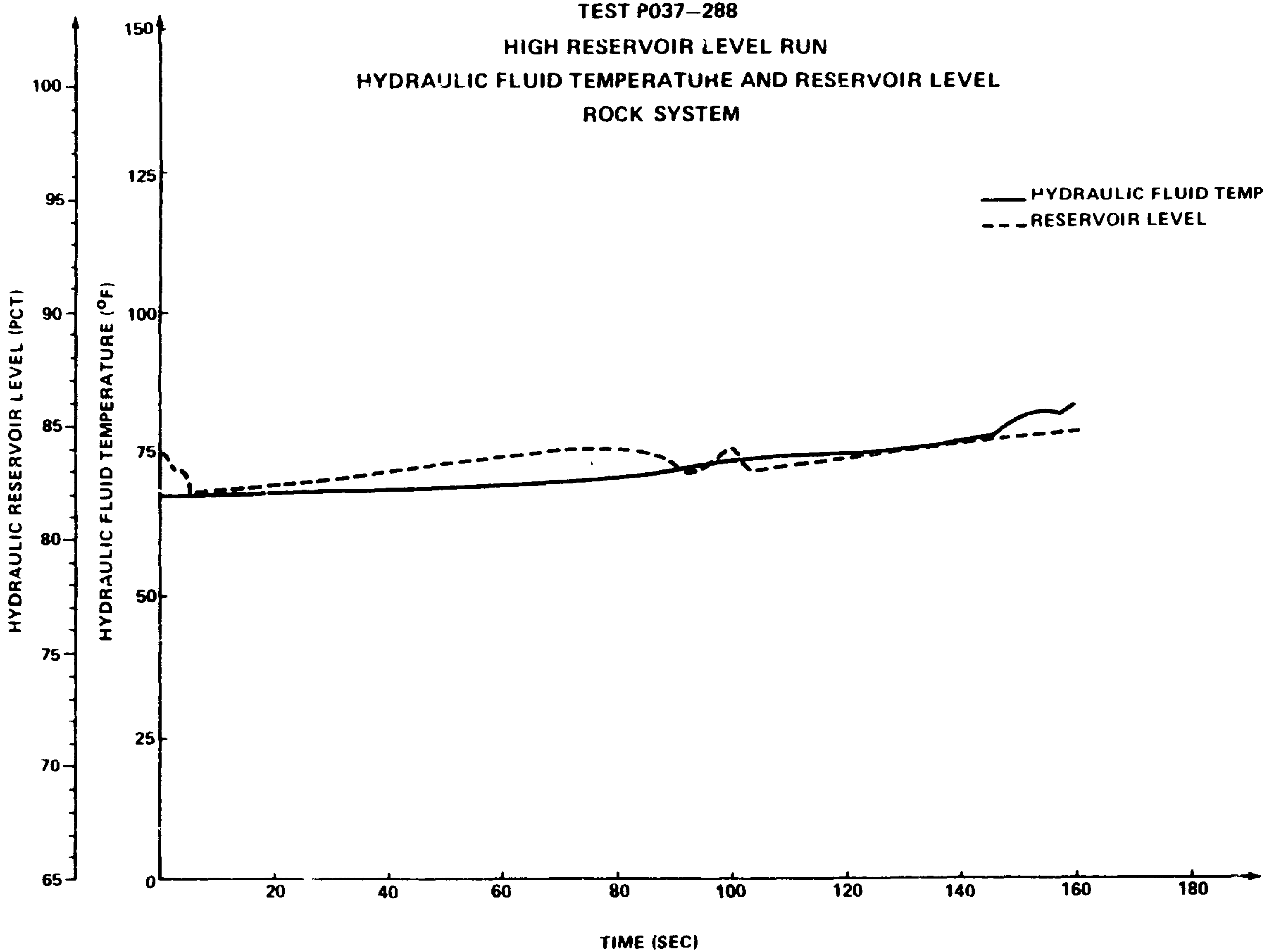


FIGURE 20

TEST P037 – 289

HIGH RESERVOIR LEVEL RUN

HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL

ROCK SYSTEM

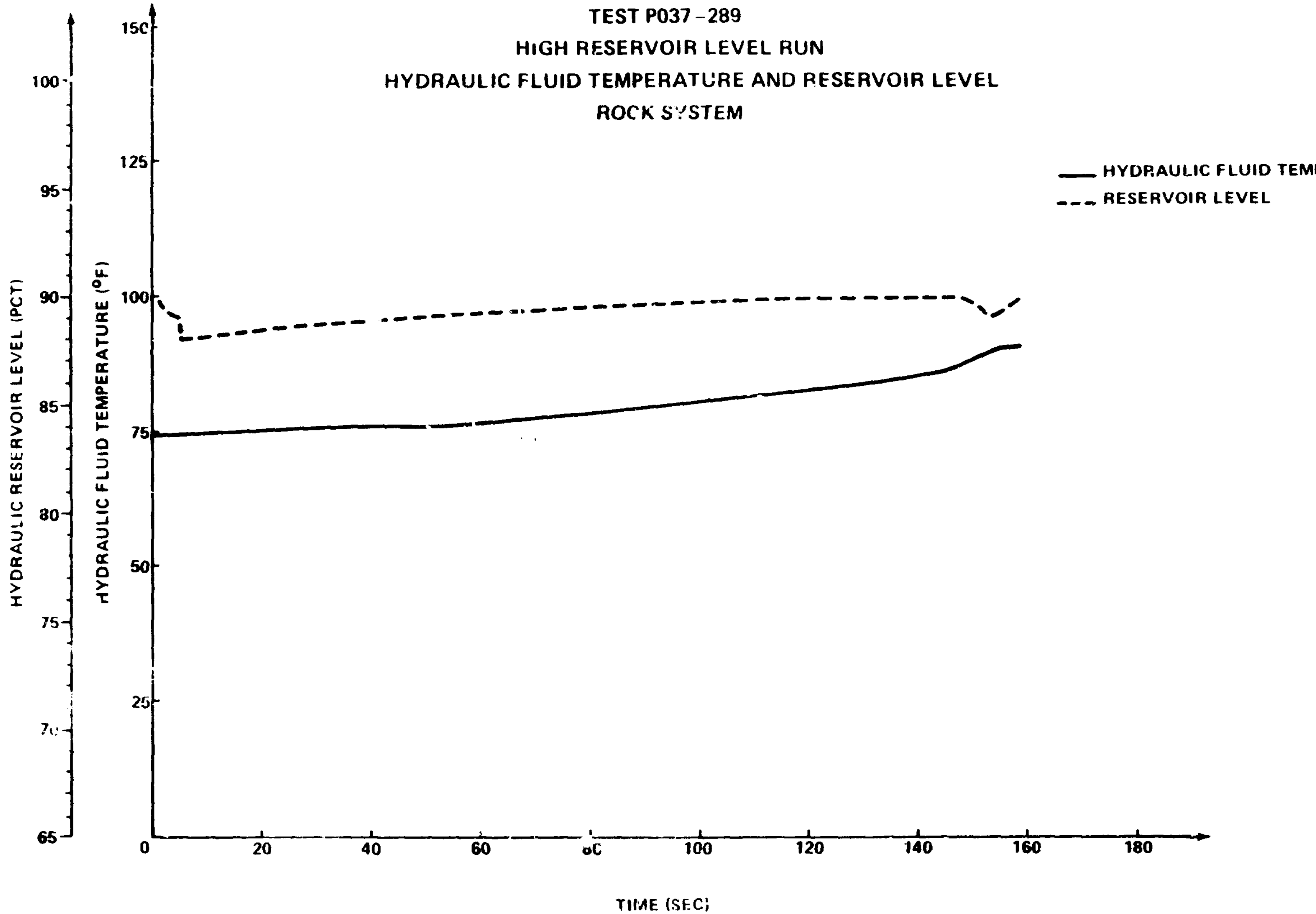


FIGURE 21

POCK HYDRAULIC FLUID SUPPLY PRESSURE
HIGH RESERVOIR LEVEL TESTS

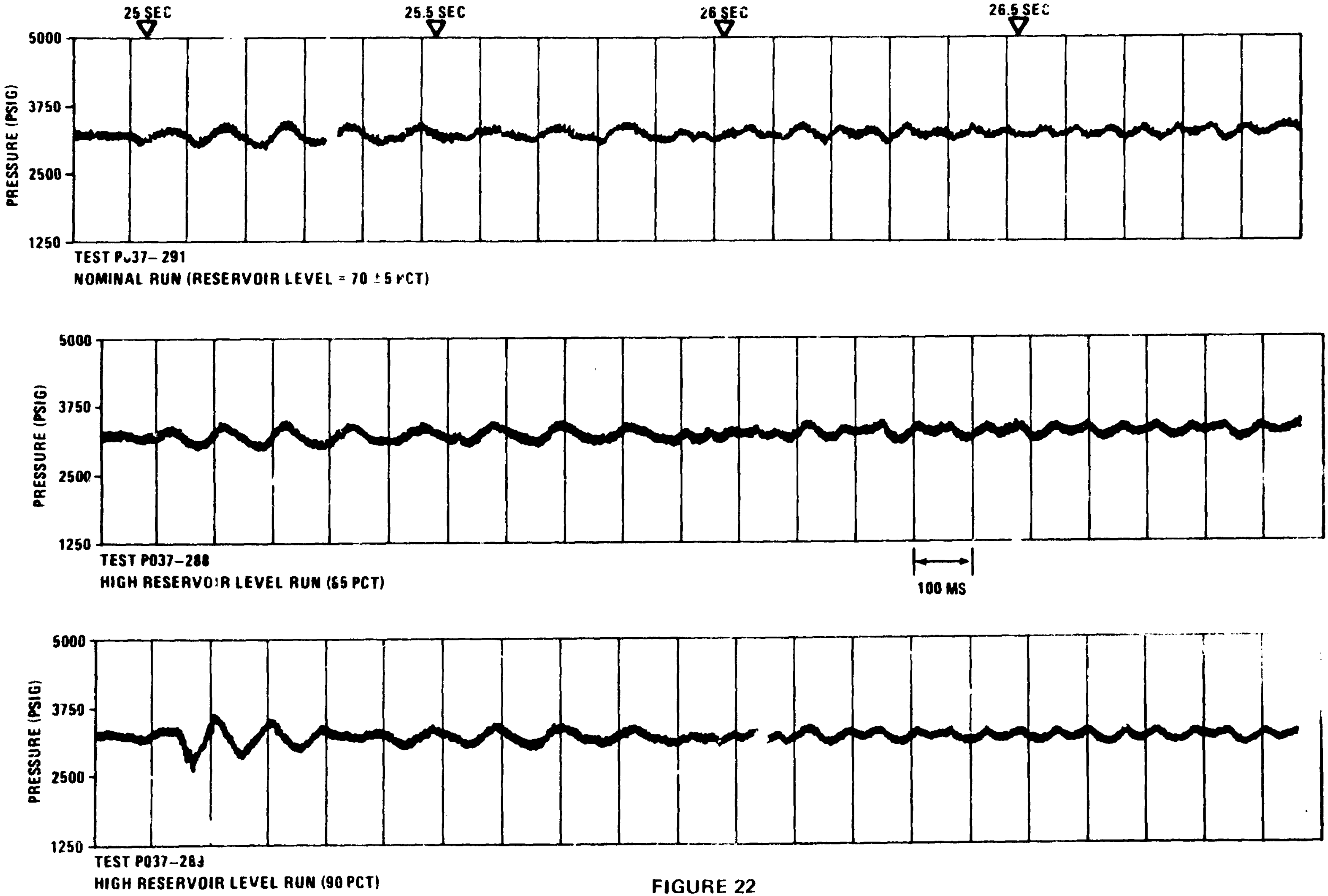


FIGURE 22

TILT HYDRAULIC FLUID SUPPLY PRESSURE
HIGH RESERVOIR LEVEL TESTS

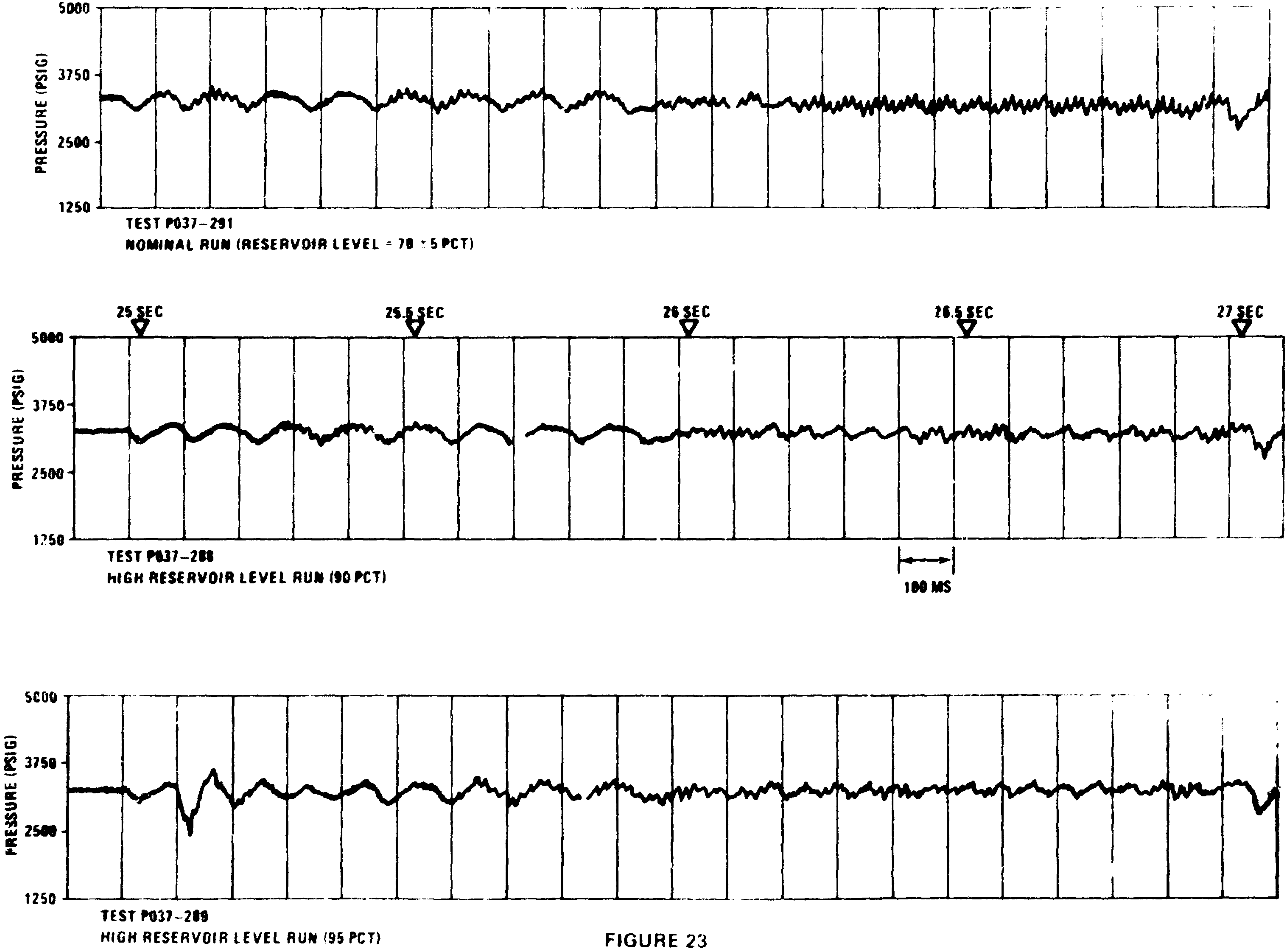


FIGURE 23

RETURN PRESSURE BEHAVIOR
TEST P037–288
HIGH RESERVOIR LEVEL RUN
ROCK 85 PCT
TILT 90 PCT

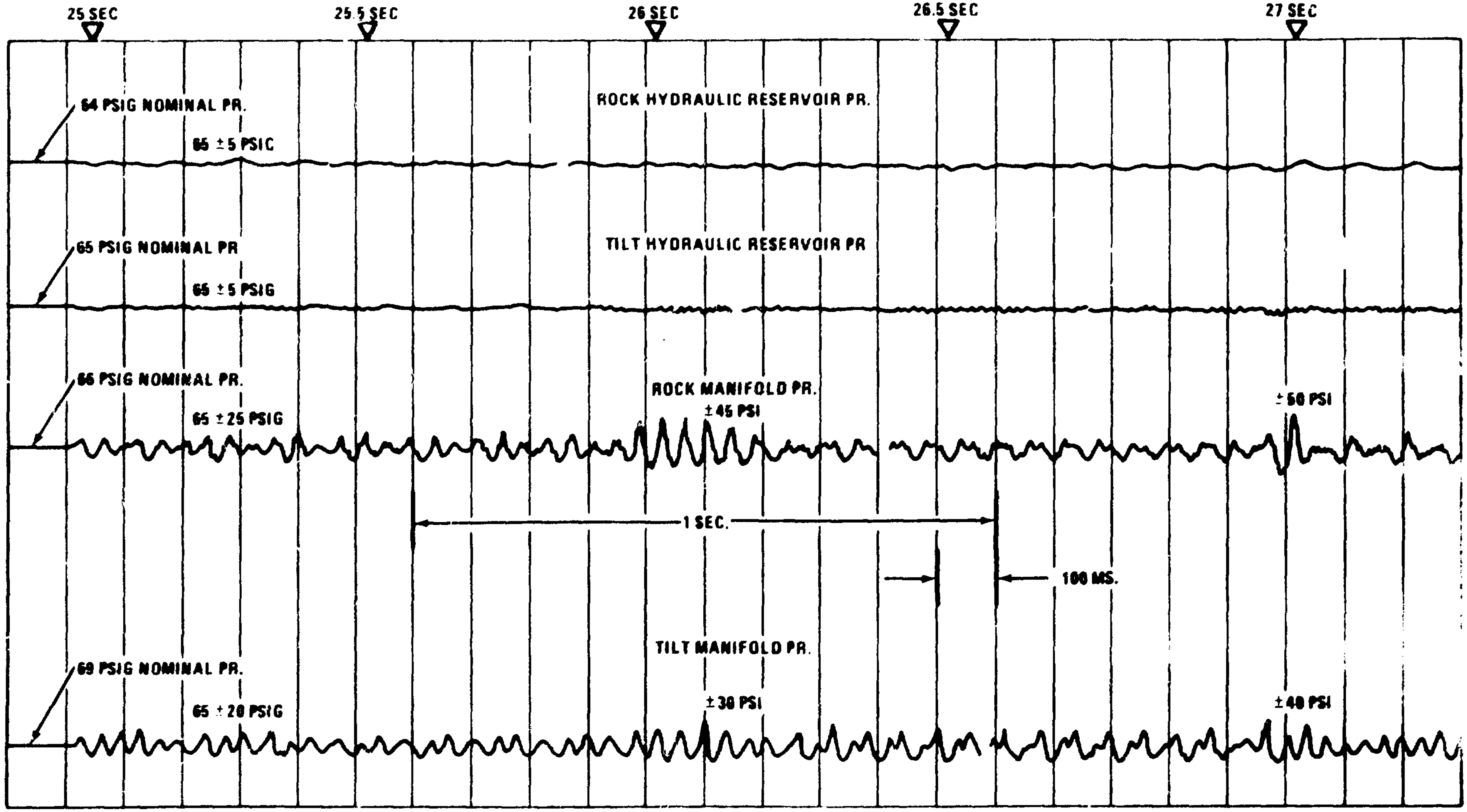


FIGURE 24

RETURN PRESSURE BEHAVIOR
TEST P037–289
HIGH RESERVOIR LEVEL RUN
ROCK 90 PCT
TILT 95 PCT

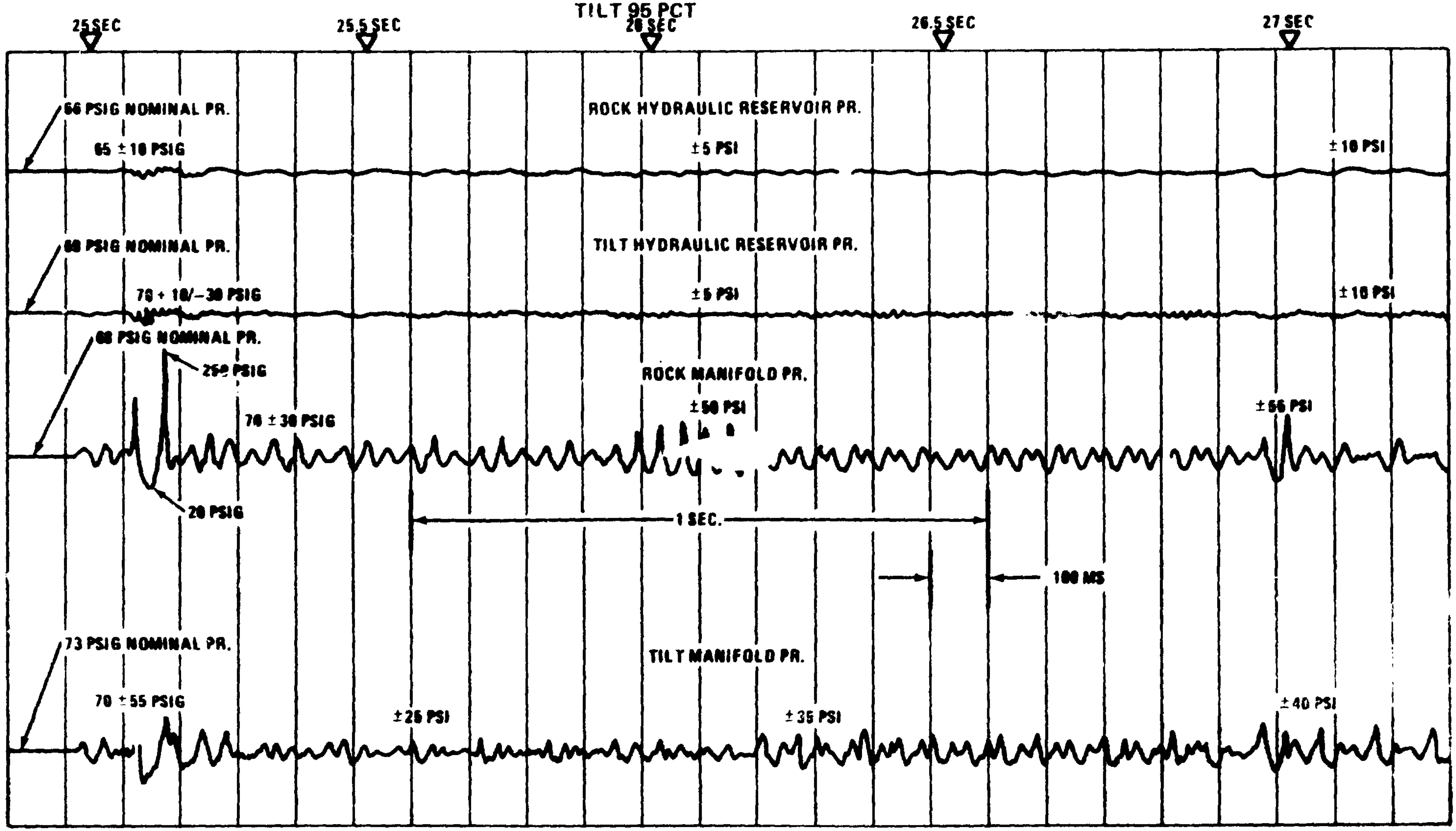


FIGURE 25

TEST P037-288
HIGH RESERVOIR LEVEL TEST 1
HYDRAULIC RESERVOIR AND MANIFOLD PRESSURE TRANSIENTS

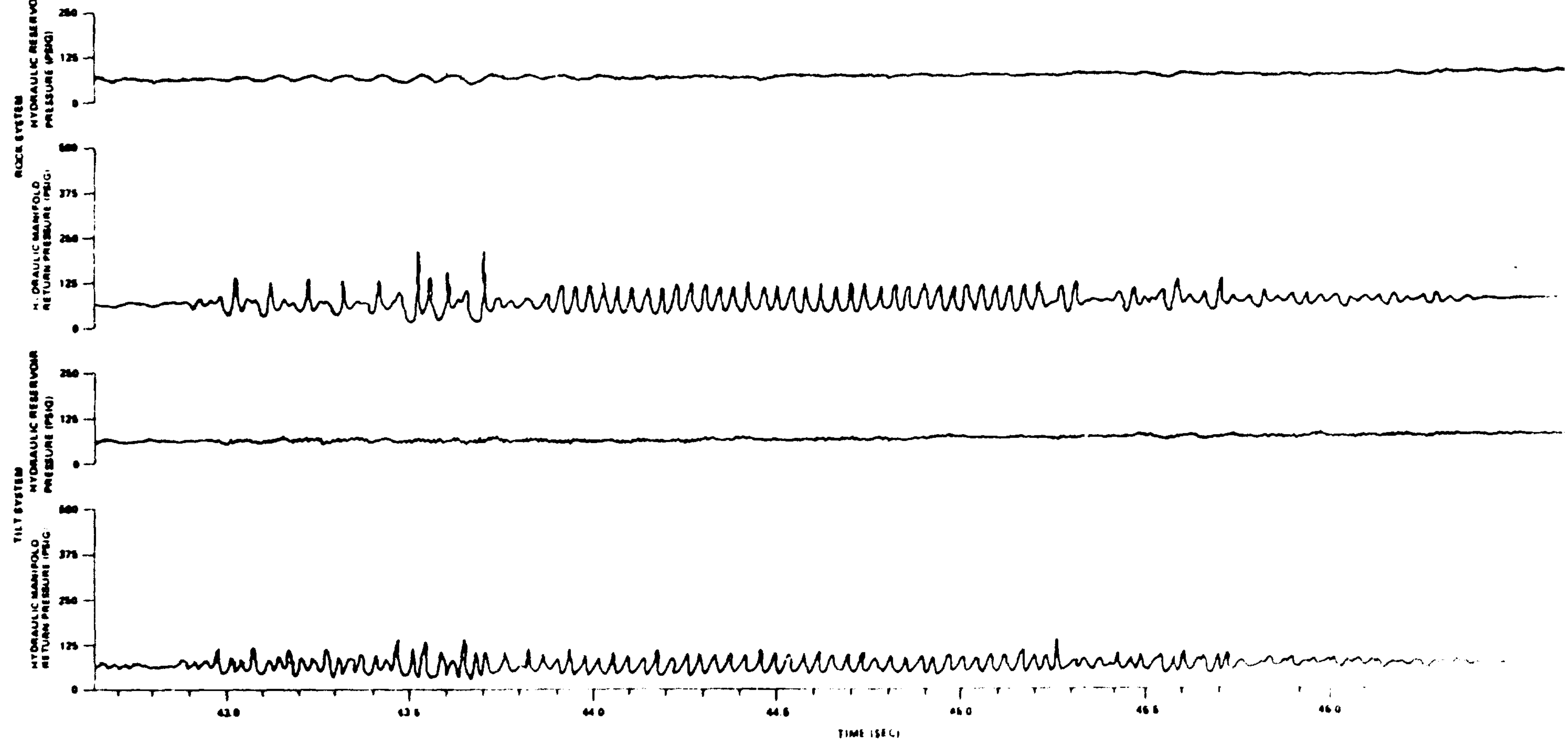


FIGURE 26

TEST P037-280
HIGH RESERVOIR LEVEL TEST 2
HYDRAULIC RESERVOIR AND MANIFOLD PRESSURE TRANSIENTS

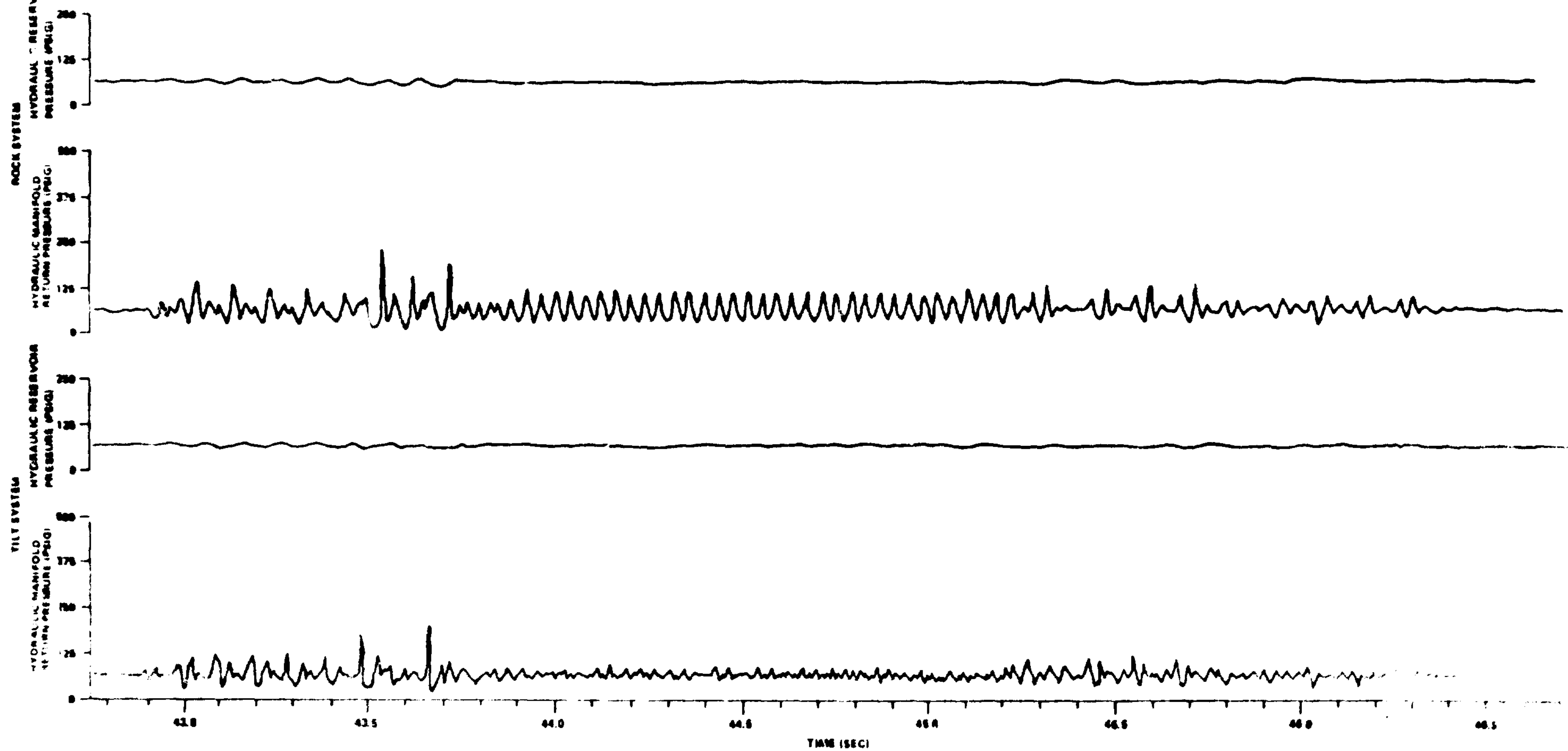
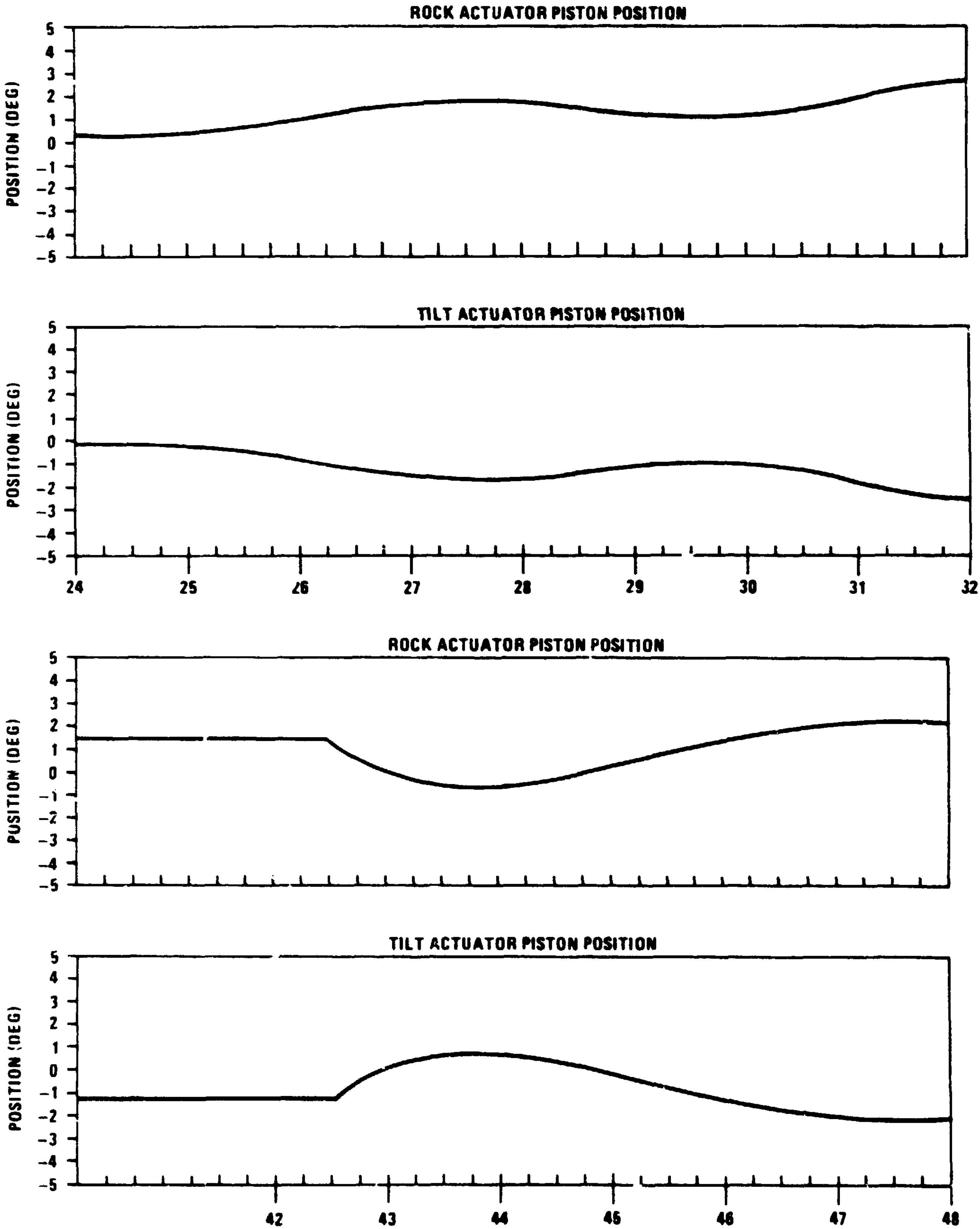


FIGURE 27

ORIGINAL PAGE IS OF POOR QUALITY

DETAILED AREA OF N* GIMBAL PROGRAM



NOTE: FOR TESTS P037–286 THROUGH 289

FIGURE 28

LOW FSM PRESSURE TESTS

Objective

To determine the effect of low FSM pressure on APU and TVC subsystem operations.

Results

Five low FSM pressure tests were run on both systems. (See table 8 .) No aborts or related problems resulted from this condition. The data showed no anomalies or deterioration in performance that could be damaging to the system.

A longer APU start period occurred as expected, as a direct result of the lower FSM pressure. These tests proved that this condition was not detrimental to the system for starting pressures of 150 psig and above. Table 9 and figures 29 through 32 indicate the trend prevalent in this sequence. Figures 33 and 34 present the effect of the low FSM pressure upon the APU starting sequence and the hydraulic system bypass valve closure transient for selected tests.

The turbine speed was not affected at FSM starting pressures of 350 and 300 psig. At 250, 200, and 150 psig FSM pressure, the speed band remained the same, but it shifted down a few hundred rpm (the maximum shift was 500 rpm at 150 psig). Also, during high load periods at 150 psig, the turbine speed dipped another few hundred rpm, but the speed band stayed within the allowable limits. (See figures 35 through 38 .)

There was no significant change in gas generator and fuel pump outlet pressure. The nominal maximum pressure decreased by 25-50 psi between the first and last test. (See table 10.)

PRECEDING PAGE BLANK NOT FILMED

The percent of time the primary control valve [illegible] ing these runs increased with a lower FSM pressure. The [illegible] range from 20.6 percent for 350 psig to 24.5 percent for 150 ps[illegible] start pressure rock system. This was due to the starting period [illegible], and the additional power required to maintain the nominal speed [illegible] during the hot firing.

No change in gas generator temperature increase was experienced. (See table 8.)

TABLE 8

LOW FSM PRESSURE TEST CONDITIONS

TEST NO	ROCK SYSTEM				TILT SYSTEM			
	FSM PRESSURE (PSIG)		GAS GENERATOR TEMPERATURE (°F)		FSM PRESSURE (PSIG)		GAS GENERATOR TEMPERATURE (°F)	
	START	END	START	END	START	END	START	END
P037-291	349	282	226	1130 (1134)	351	280	219	1104
P037-292	296	242	233	1117 (1118)	298	241	218	1105 (1108)
P037-293	248	199	231	1114 (1116)	245	194	232	1117 (1122)
P037-294	202	163	228	1117 (1120)	199	158	221	1123
P037-296	151	121	231	1132 (1137)	153	122	224	1122 (1127)
* P037-286	379	307	227	1130 (1132)	376	301	228	1102 (1108)

NUMBERS IN PARENTHESIS REPRESENT
MAXIMUM GAS GENERATOR TEMPERATURE

*NOMINAL FSM PRESSURE TEST

TABLE 9
LOW FSM PRESSURE TESTS
START TRANSIENT DURATION

		ROCK SYSTEM		TILT SYSTEM	
TEST NO	FSM PRESSURE	START TIME (SEC)	GAS GENERATOR TEMPERATURE (°F)	START TIME (SEC)	GAS GENERATOR TEMPERATURE (°F)
P037-291	350	3.02	226	3.15	219
P037-292	300	3.17	233	3.28	218
P037-293	250	3.93	231	3.75	232
P037-294	200	4.29	228	3.95	221
P037-296	150	5.20	231	4.67	224
*P037-286	375	2.78	227	2.92	228

*NOMINAL FSM PRESSURE TEST

TABLE 10

LOW FSM PRESSURE TESTS

GAS GENERATOR AND FUEL PUMP PRESSURE BEHAVIOR

GAS GENERATOR MAXIMUM PRESSURE (PSIG)

		ROCK SYSTEM			TILT SYSTEM		
TEST NO	FSM PRESSURE	START	20 SEC	150 SEC	START	20 SEC	150 SEC
P037-291	350	1275	1175	1225-1275	1250	1200	1200
P037-296	150	1275	1150	1200-1225	1200	1175	1175

FUEL PUMP OUTLET MAXIMUM PRESSURE (PSIG)

		ROCK SYSTEM			TILT SYSTEM		
TEST NO	FSM PRESSURE	START	20 SEC	150 SEC	START	20 SEC	150 SEC
P037-291	350	1500	1375-1425	1425-1475	1500	1425	1400-1475
P037-296	150	1475	1325-1375	1325-1375	1425	1350-1425	1350-1450

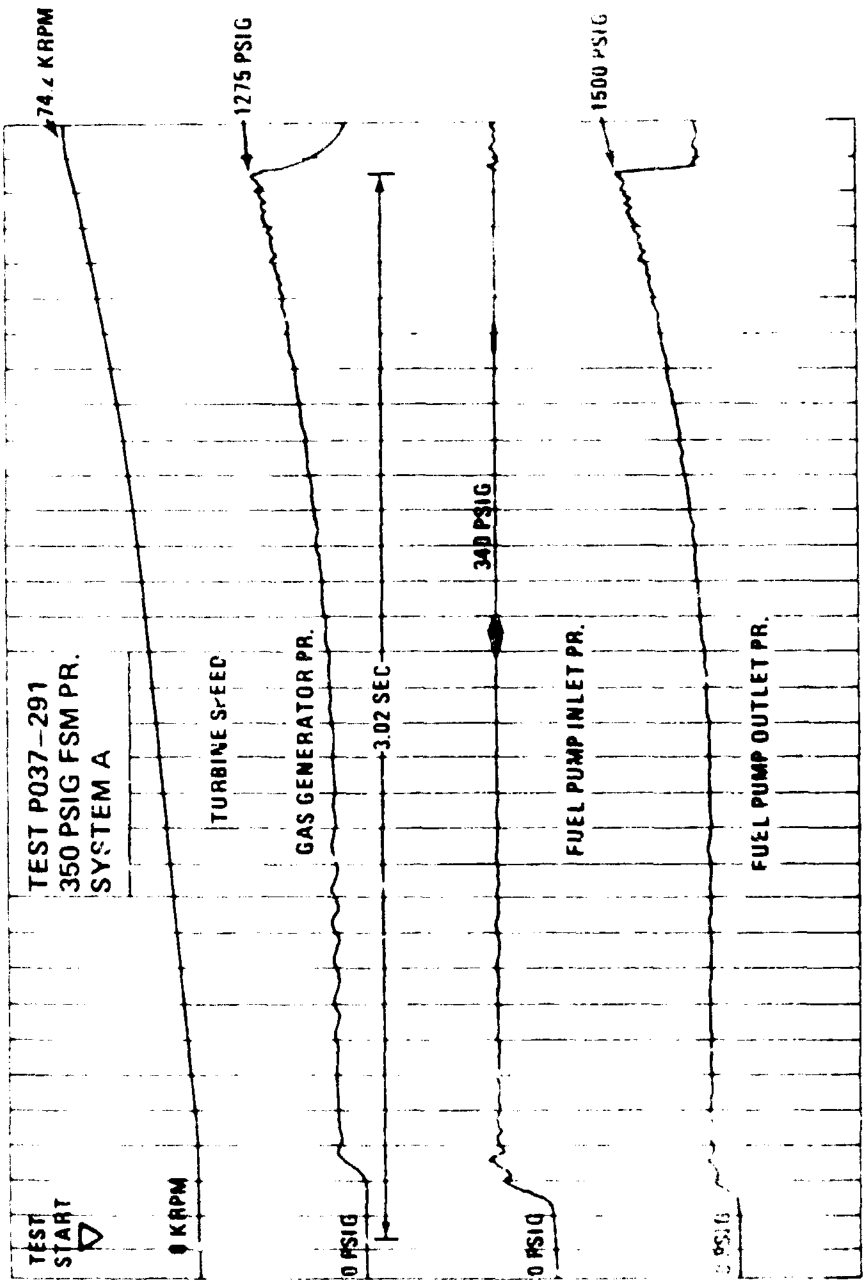

TEST P037–291
350 PSIG FSM PR.
SYSTEM A
TEST START
0 KRPM
74.2 KRPM
TURBINE SPEED
0 PSIG
1275 PSIG
GAS GENERATOR PR.
3.02 SEC
0 PSIG
340 PSIG
FUEL PUMP INLET PR.
0 PSIG
1500 PSIG
FUEL PUMP OUTLET PR.

FIGURE 29

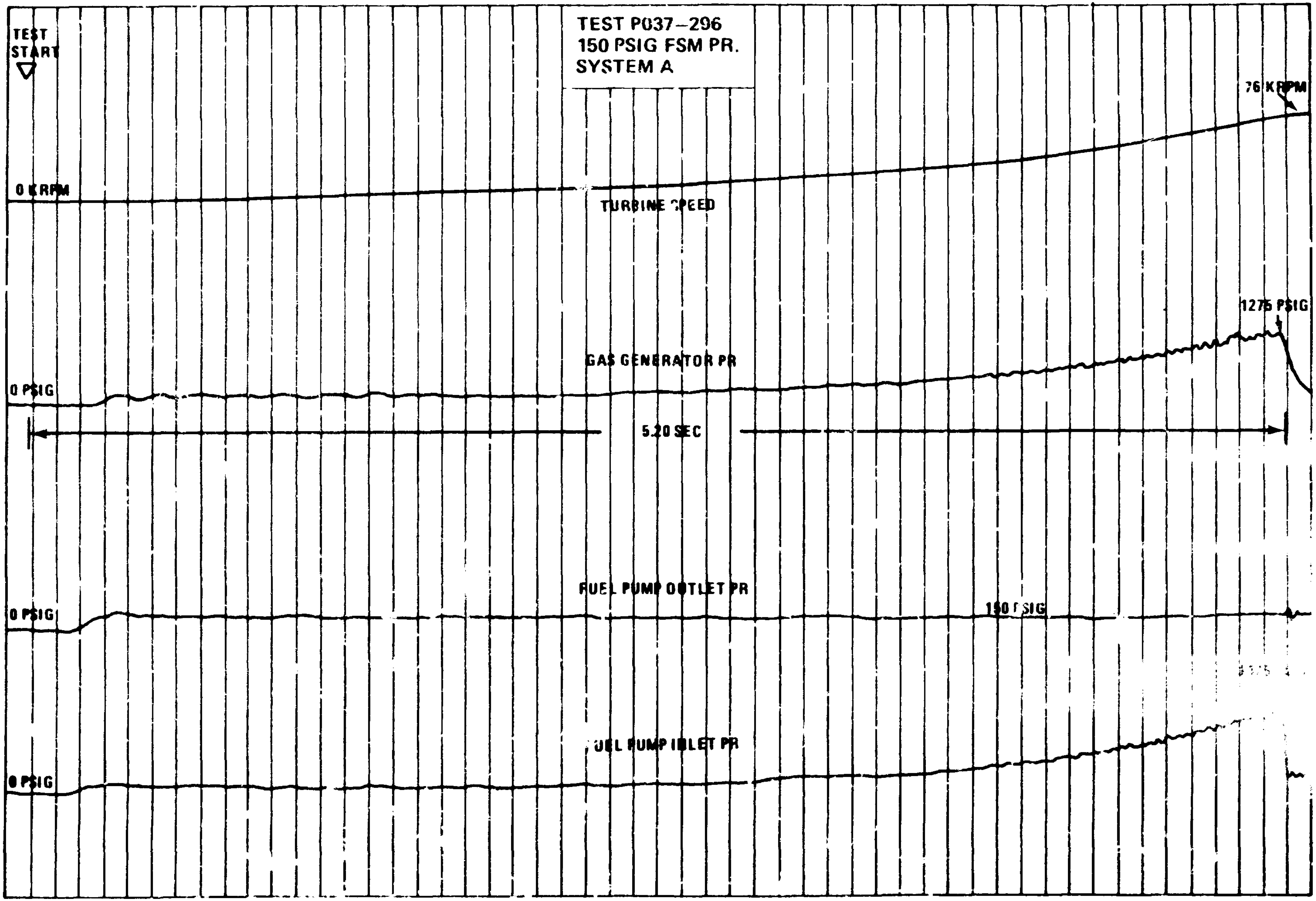

TEST P037–296
150 PSIG FSM PR.
SYSTEM A
TEST START
0 KRPM
76 KRPM
TURBINE SPEED
0 PSIG
1275 PSIG
GAS GENERATOR PR
5.20 SEC
0 PSIG
FUEL PUMP OUTLET PR
150 PSIG
0 PSIG
FUEL PUMP INLET PR

FIGURE 30

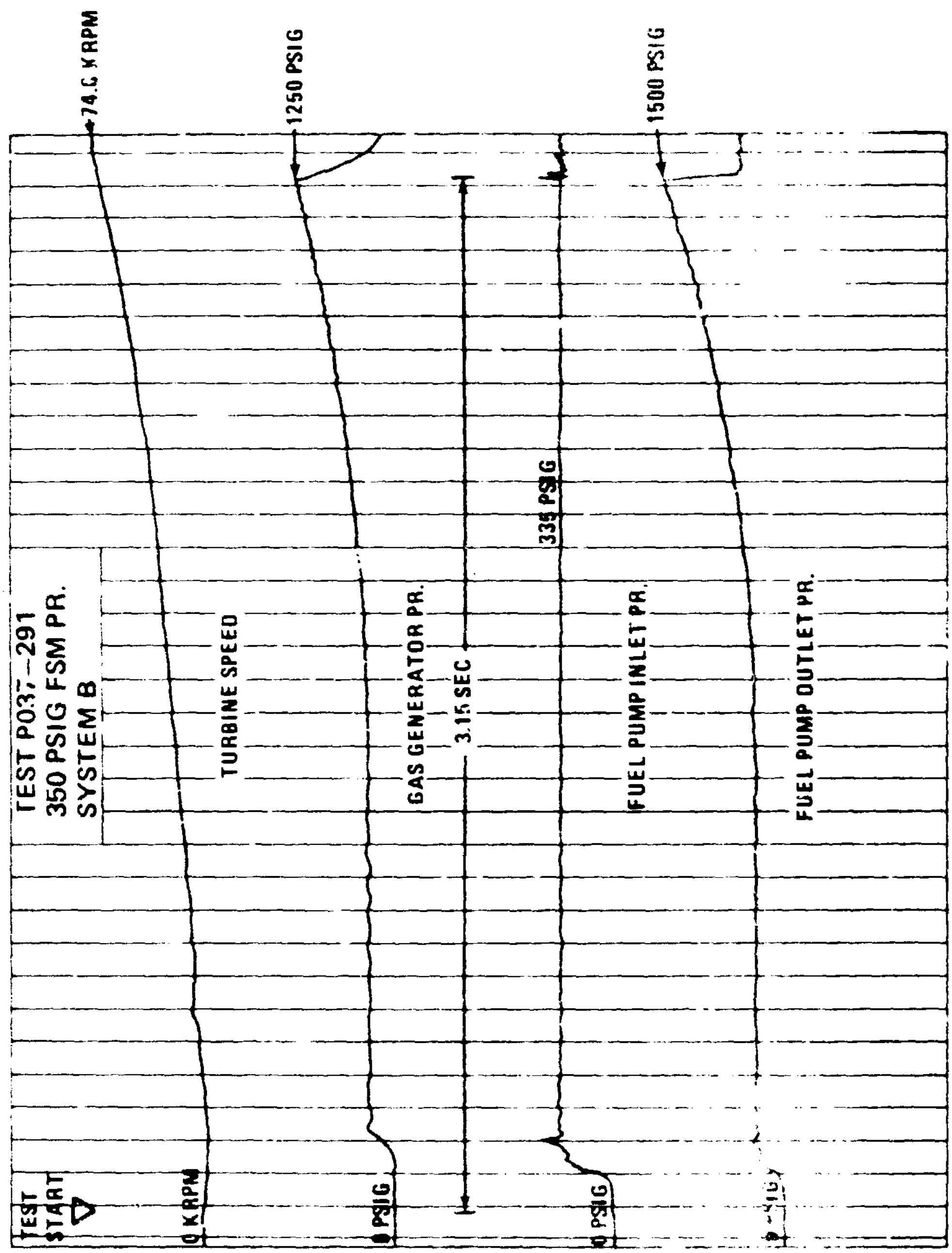

TEST P037-291
350 PSIG FSM PR.
SYSTEM B
TEST START
0 K RPM
1250 PSIG
0 PSIG
3.15 SEC
335 PSIG
0 PSIG
1500 PSIG
TURBINE SPEED
GAS GENERATOR PR.
FUEL PUMP INLET PR.
FUEL PUMP OUTLET PR.

FIGURE 3i

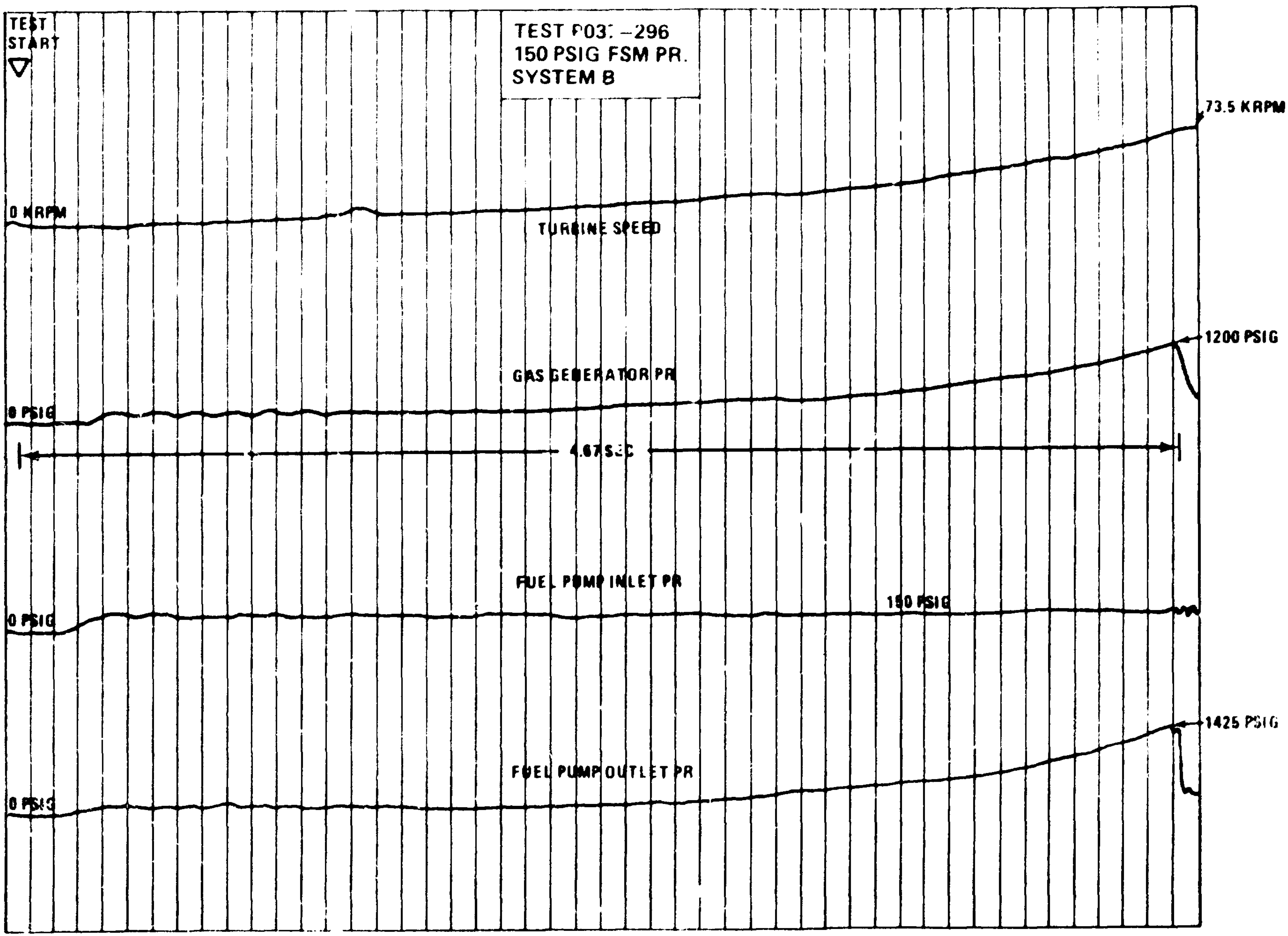

TEST START
TEST P03: -296
150 PSIG FSM PR.
SYSTEM B
73.5 KRPM
0 KRPM
TURBINE SPEED
1200 PSIG
GAS GENERATOR PR
0 PSIG
4.67 SEC
FUEL PUMP INLET PR
150 PSIG
0 PSIG
1425 PSIG
FUEL PUMP OUTLET PR
0 PSIG

FIGURE 32

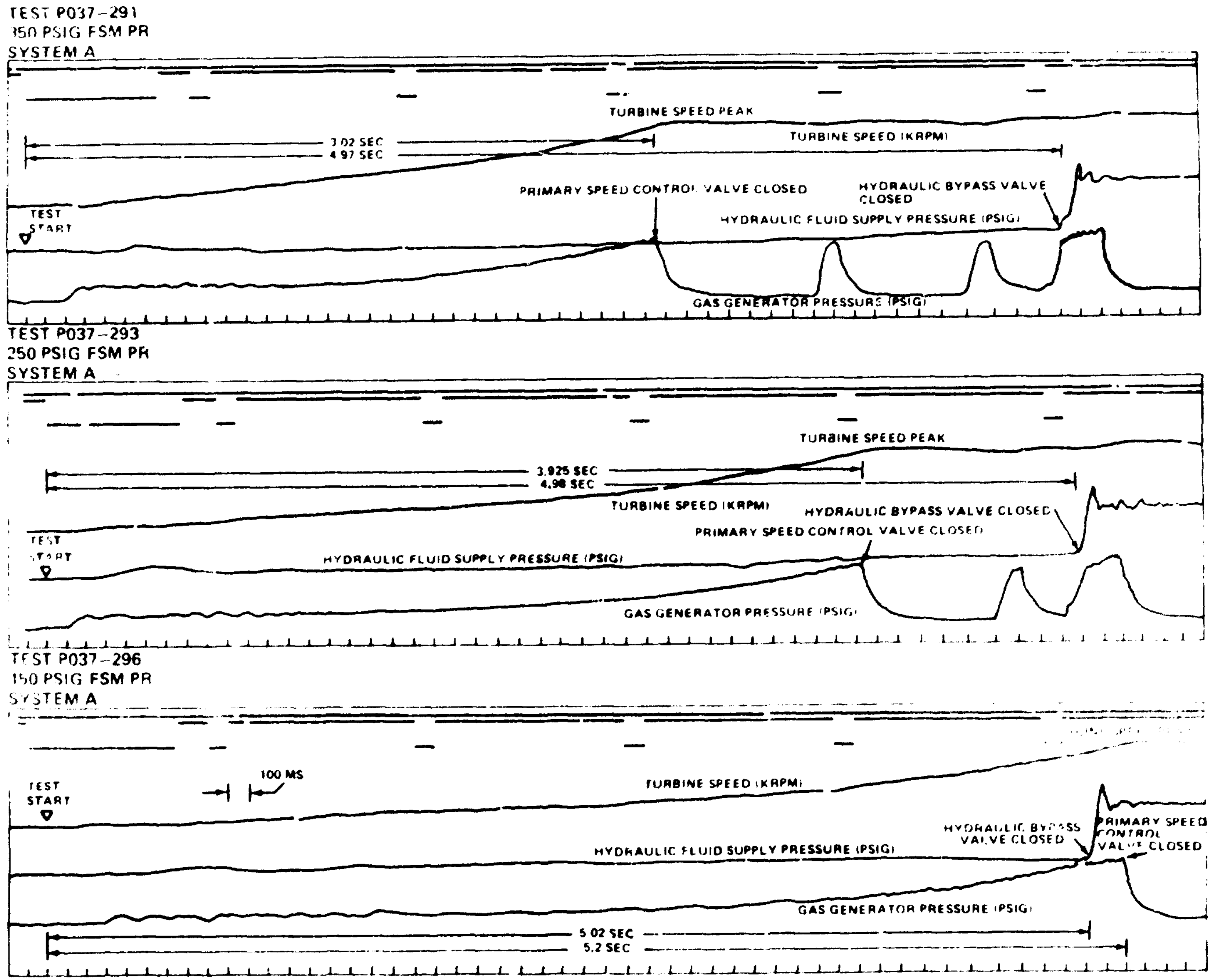

TEST P037-291
350 PSIG FSM PR
SYSTEM A
TURBINE SPEED PEAK
3.02 SEC
4.97 SEC
TURBINE SPEED (KRPM)
TEST START
PRIMARY SPEED CONTROL VALVE CLOSED
HYDRAULIC BYPASS VALVE CLOSED
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
GAS GENERATOR PRESSURE (PSIG)
TEST P037-293
250 PSIG FSM PR
SYSTEM A
TURBINE SPEED PEAK
3.925 SEC
4.98 SEC
TURBINE SPEED (KRPM)
HYDRAULIC BYPASS VALVE CLOSED
PRIMARY SPEED CONTROL VALVE CLOSED
TEST START
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
GAS GENERATOR PRESSURE (PSIG)
TEST P037-296
150 PSIG FSM PR
SYSTEM A
100 MS
TEST START
TURBINE SPEED (KRPM)
HYDRAULIC BYPASS VALVE CLOSED
PRIMARY SPEED CONTROL VALVE CLOSED
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
GAS GENERATOR PRESSURE (PSIG)
5.02 SEC
5.2 SEC

FIGURE 33

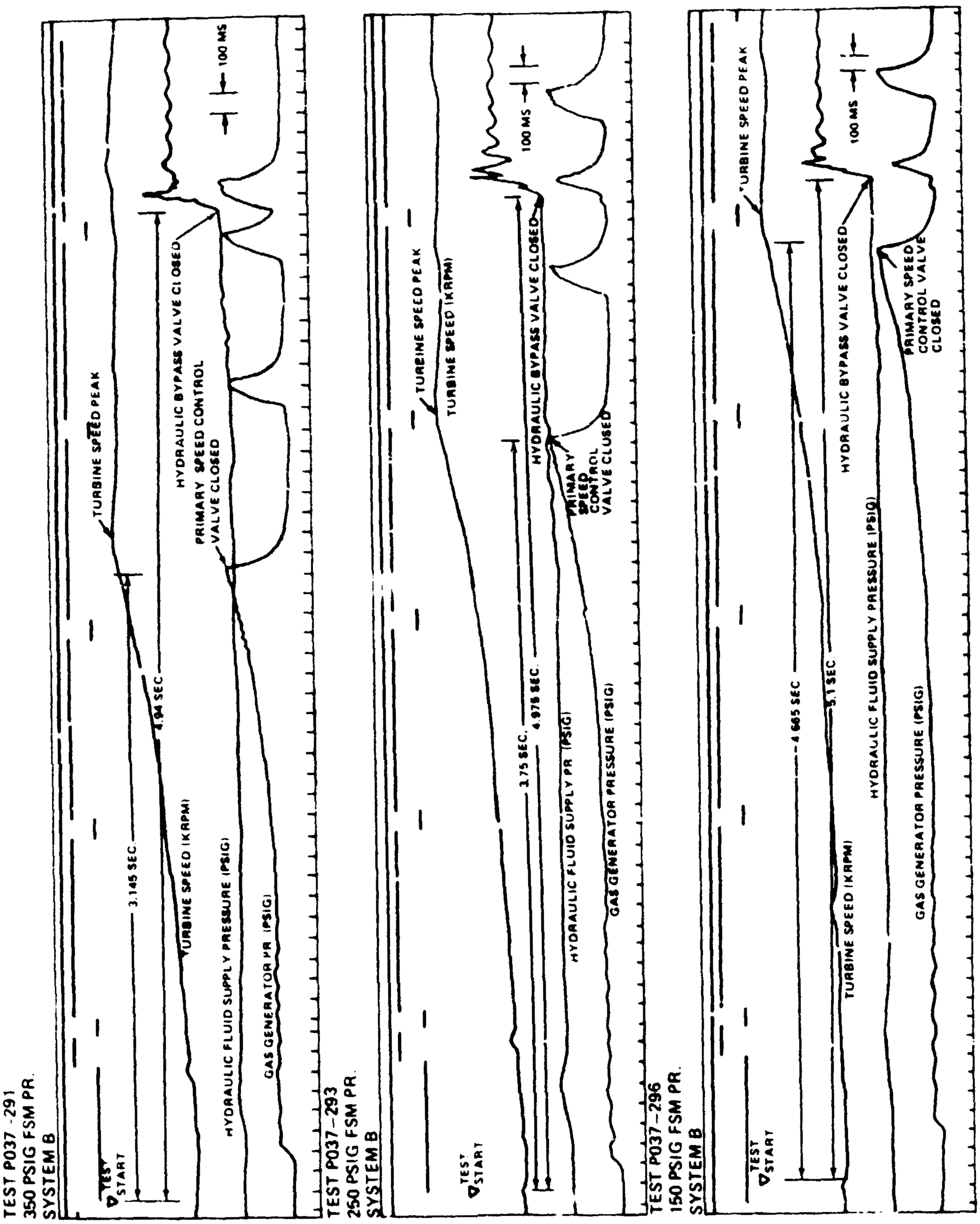

TEST P037-291
350 PSIG FSM PR.
SYSTEM B
TEST START
3.145 SEC
4.94 SEC
TURBINE SPEED (KRPM)
TURBINE SPEED PEAK
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
HYDRAULIC BYPASS VALVE CLOSED
PRIMARY SPEED CONTROL VALVE CLOSED
GAS GENERATOR PR (PSIG)
100 MS
TEST P037-293
250 PSIG FSM PR.
SYSTEM B
TEST START
3.75 SEC.
4.975 SEC.
TURBINE SPEED PEAK
TURBINE SPEED (KRPM)
HYDRAULIC BYPASS VALVE CLOSED
HYDRAULIC FLUID SUPPLY PR (PSIG)
PRIMARY SPEED CONTROL VALVE CLOSED
GAS GENERATOR PRESSURE (PSIG)
100 MS
TEST P037-296
150 PSIG FSM PR.
SYSTEM B
TEST START
4.665 SEC
5.1 SEC
TURBINE SPEED PEAK
TURBINE SPEED (KRPM)
HYDRAULIC BYPASS VALVE CLOSED
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
PRIMARY SPEED CONTROL VALVE CLOSED
GAS GENERATOR PRESSURE (PSIG)
100 MS

FIGURE 34

ROCK APU
TURBINE SPEED START TRANSIENT
LOW FSM FRESSURE TESTS

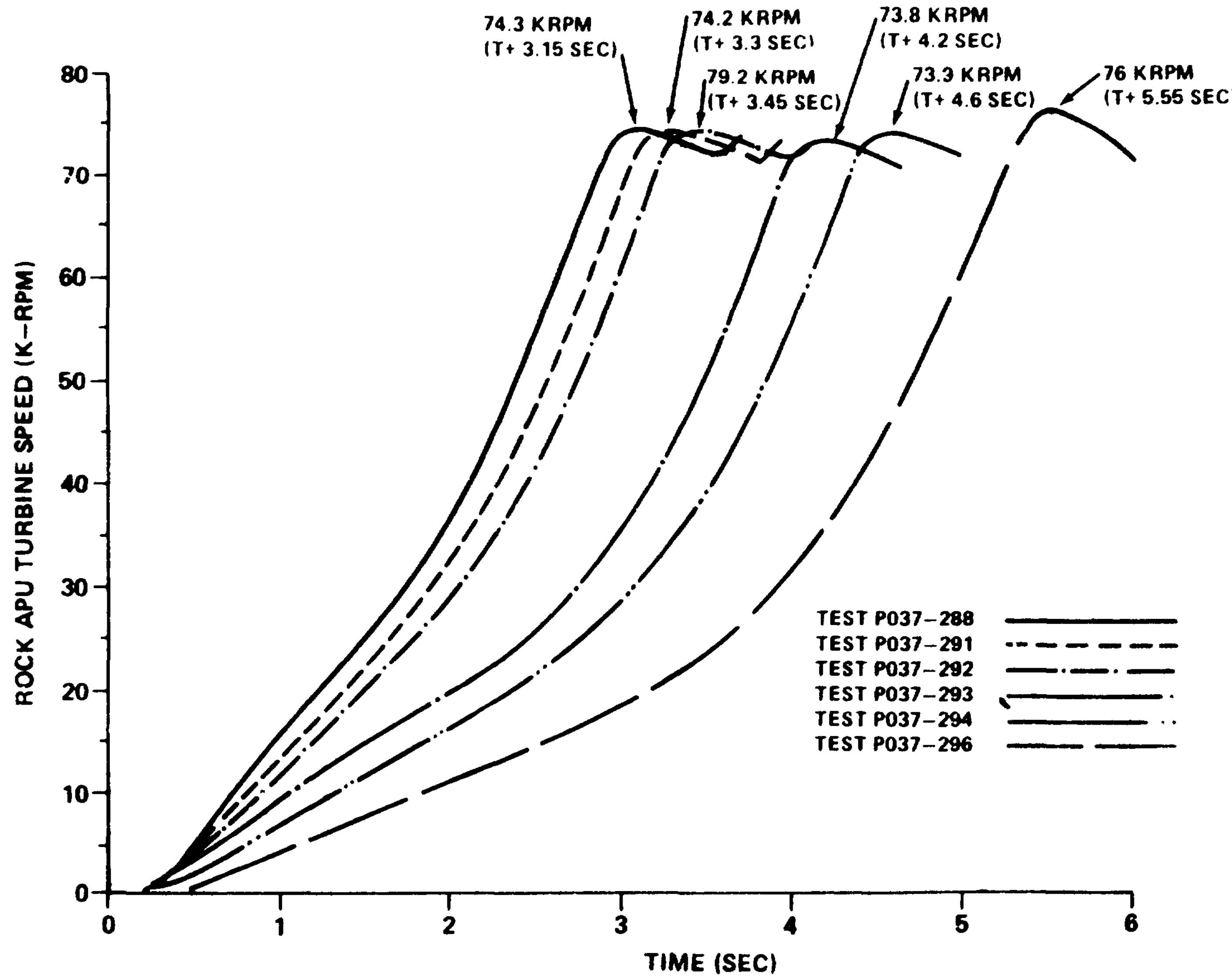


FIGURE 35

TILT APU
TURBINE SPEED START TRANSIENT
LOW FSM PRESSURE TESTS

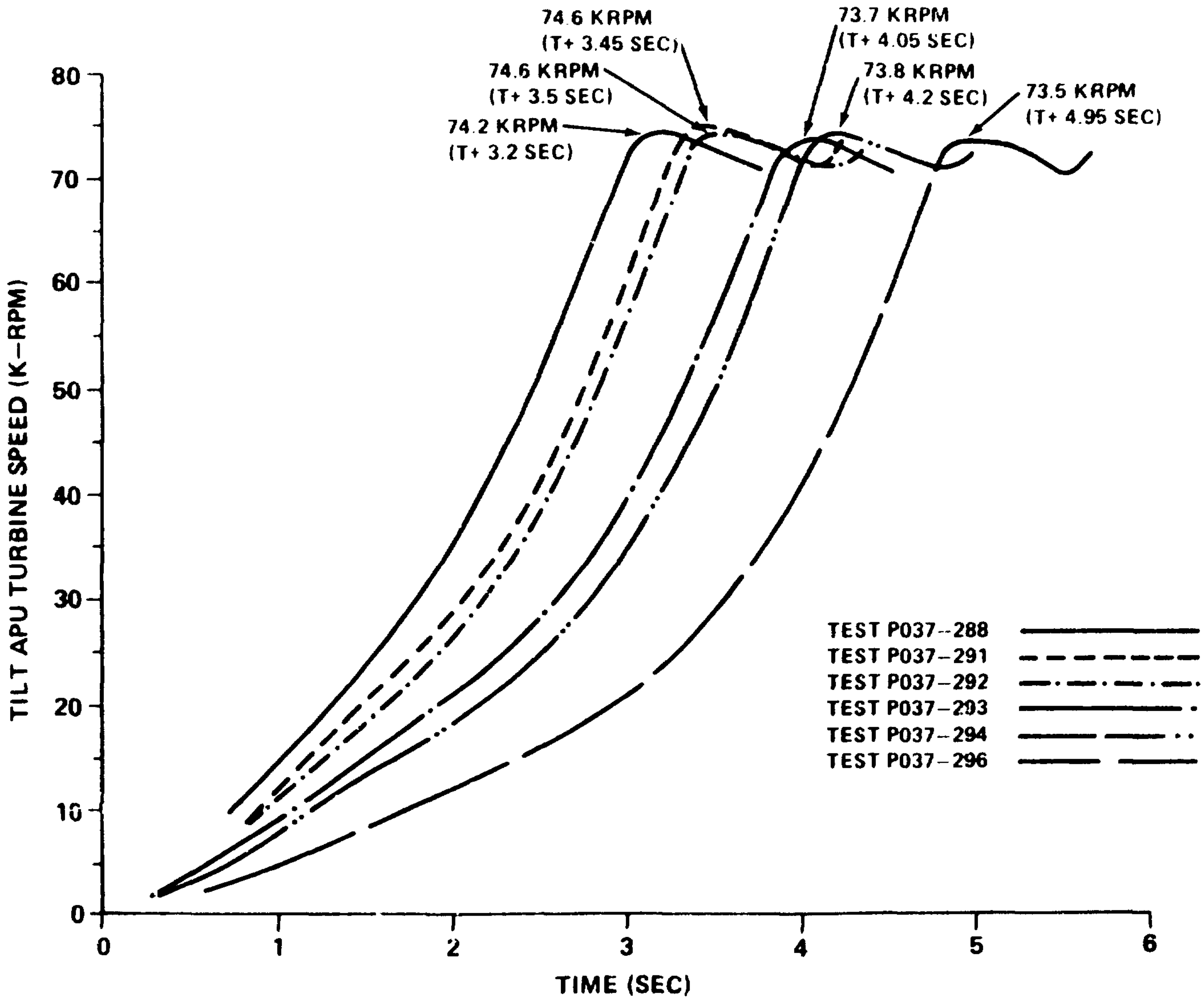


FIGURE 36

ROCK APU
TURBINE SPEED TRANSIENT FOR
TEST P037 - 296

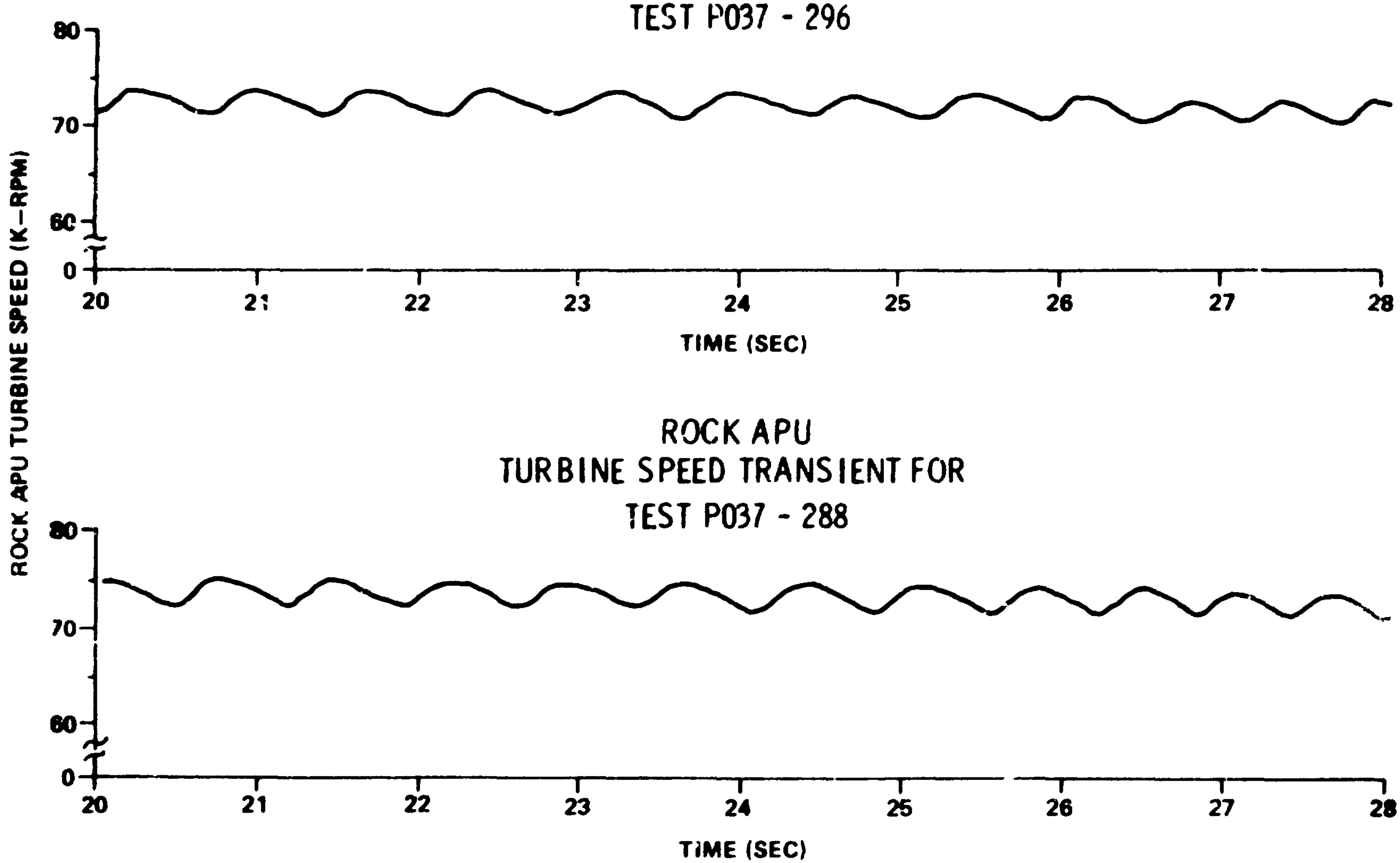


FIGURE 37

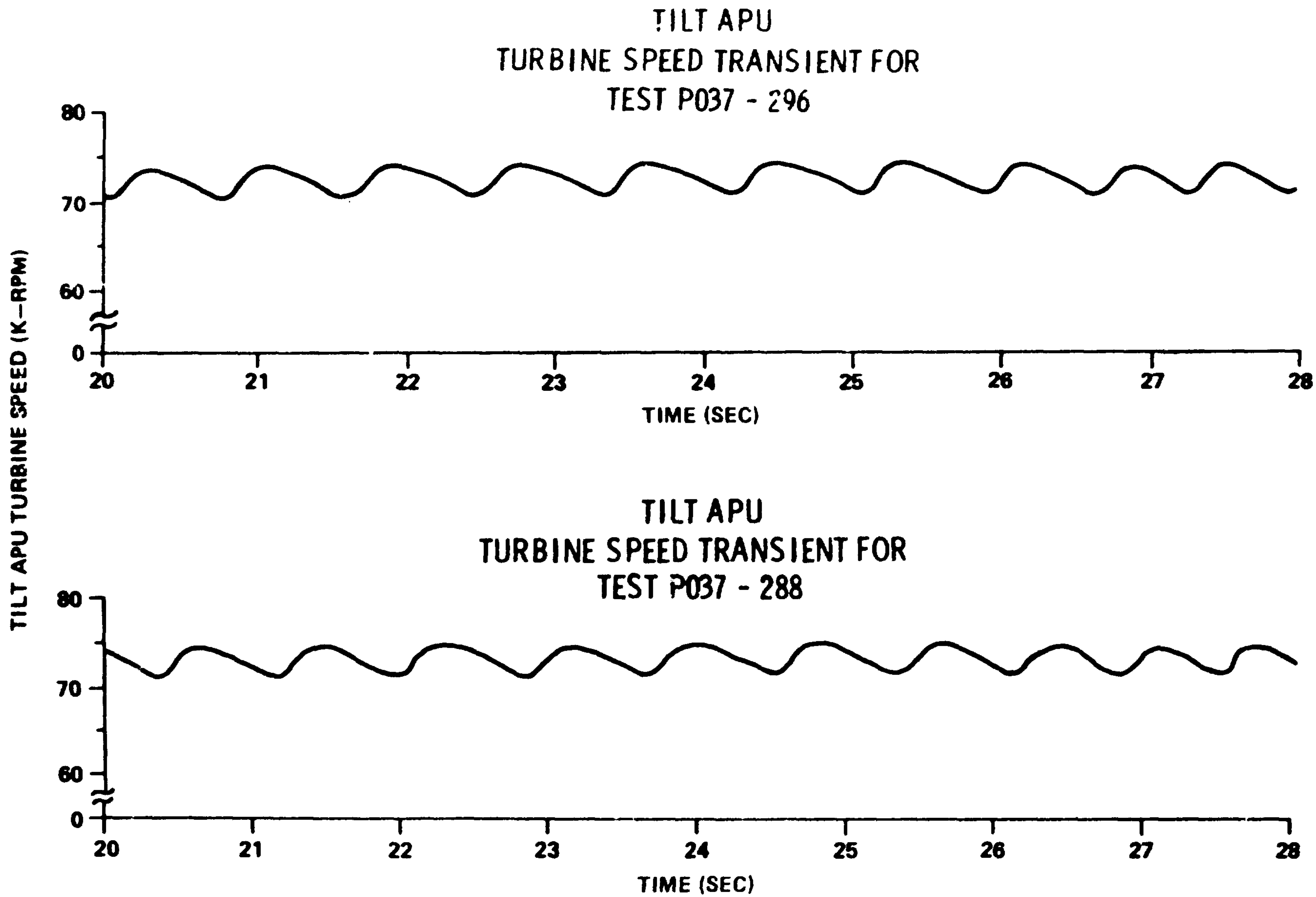

TILT APU
TURBINE SPEED TRANSIENT FOR
TEST P037 - 296
80
70
60
0
20
21
22
23
24
25
26
27
28
TIME (SEC)
TILT APU
TURBINE SPEED TRANSIENT FOR
TEST P037 - 288
TIME (SEC)
TILT APU TURBINE SPEED (K—RPM)

FIGURE 38

GN_2 SPIN PORT LEAK TEST

OBJECTIVE

To determine the magnitude of hazard associated with leakage from the GN_2 spin port during a hot firing.

RESULTS

This test (P037-295) was run for 160 seconds and no anomalies were reported. There was no degradation in system's performance. The turbine speed, gas generator temperature rise, and pressure oscillations remained normal. No change in primary control valve cycling performance and in APU start transient period was observed in the data. Both APUs were used for this case. The GN_2 spin port temperature rise due to heat released by the APU was: 71-88 ^{o}F (95 ^{o}F high) for rock APU, 67-85 ^{o}F for tilt APU. (See figures 39 and 40 .) Table 11 shows the general APU behavior compared to a nominal run.

TABLE 11

TEST P037-295 GN_2 SPIN PORT LEAK TEST DATA

APU PERFORMANCE

APU MEASUREMENTS		TEST P037–295		TEST P037–297 (NOMINAL RUN)
ACTUATOR GIMBAL PROFILE		N*		N*
START TIME	ROCK	2.985 SEC.	ROCK	3.03 SEC.
	TILT	2.98 SEC.	TILT	3.055 SEC.
GAS GENERATOR TEMPERATURE	ROCK	227 – 1119 (1123)°F	ROCK	223 – 1128 (1130) °F
	TILT	220 – 1123 (1126)°F	TILT	217 – 1127 (1131) °F
TURBINE SPEED	ROCK	71.5 – 74.3 KRPM	ROCK	71.2 – 74 KRPM
	TILT	71.2 – 74.6 KRPM	TILT	70.8 – 74.5 KRPM
FSM PRESSURE	ROCK	381 – 309 PSIG	ROCK	375 – 302 PSIG
	TILT	380 – 305 PSIG	TILT	370 – 298 PSIG
TURBINE EXHAUST TEMPERATURE	ROCK	74 – 572 (599)°F	ROCK	67 – 566 (595) °F
	TILT	71 – 548 (592)°F	TILT	65 – 533 (583) °F
TIME PRIMARY SPEED CONTROL	ROCK	32.5	PCT	ROCK 32.5 PCT
VALVE IS OPEN (FIRST 20 SECONDS)	TILT	31.9	PCT	TILT 32.5 PCT

ROCK GN_2 SPIN PORT TEMPERATURE PROFILE
TEST P037 -295
GN_2 SPIN PORT LEAK TEST

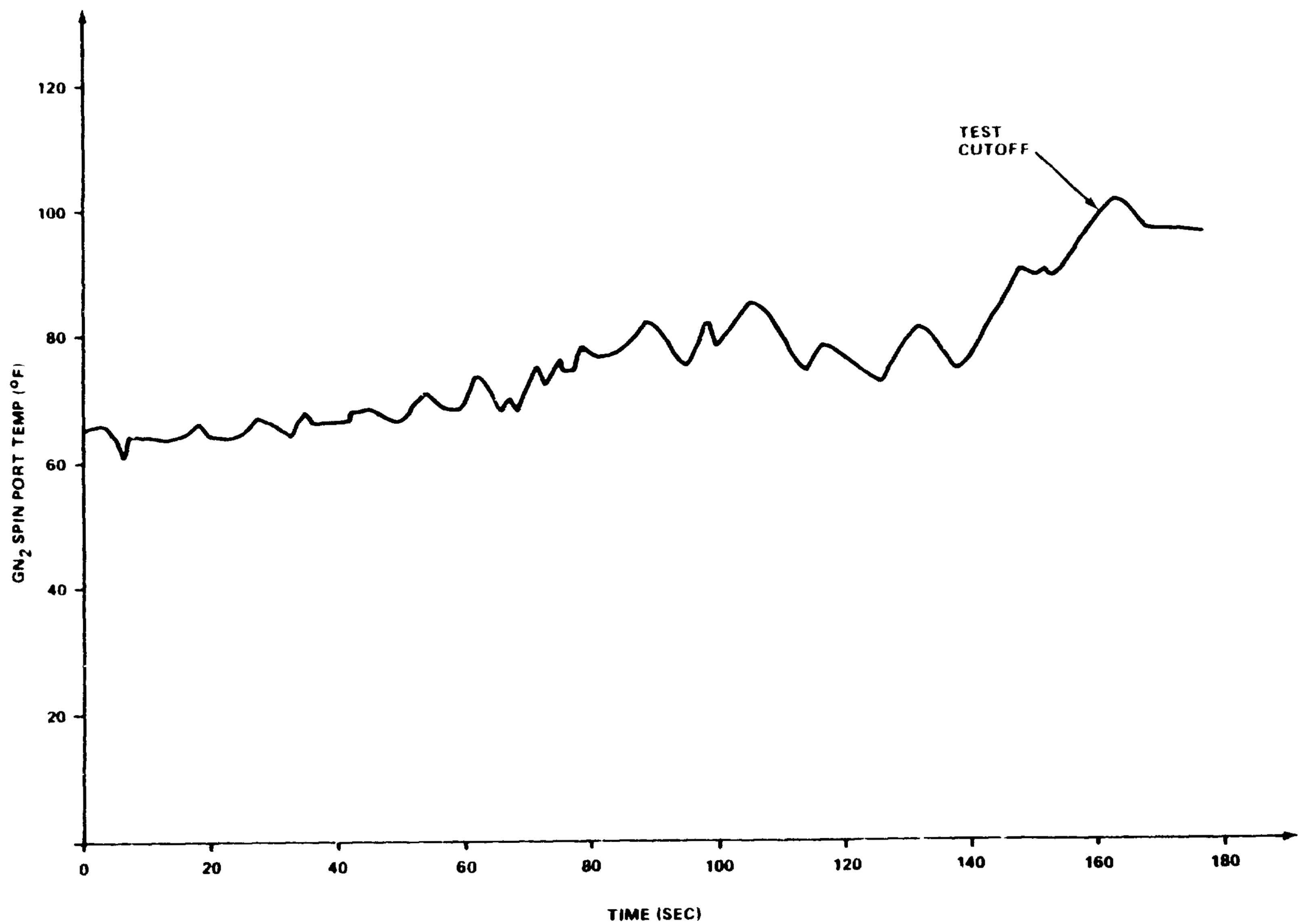


FIGURE 39

TILT GN_2 SPIN PORT TEMPERATURE PROFILE

TEST P037–295

GN_2 SPIN PORT LEAK TEST

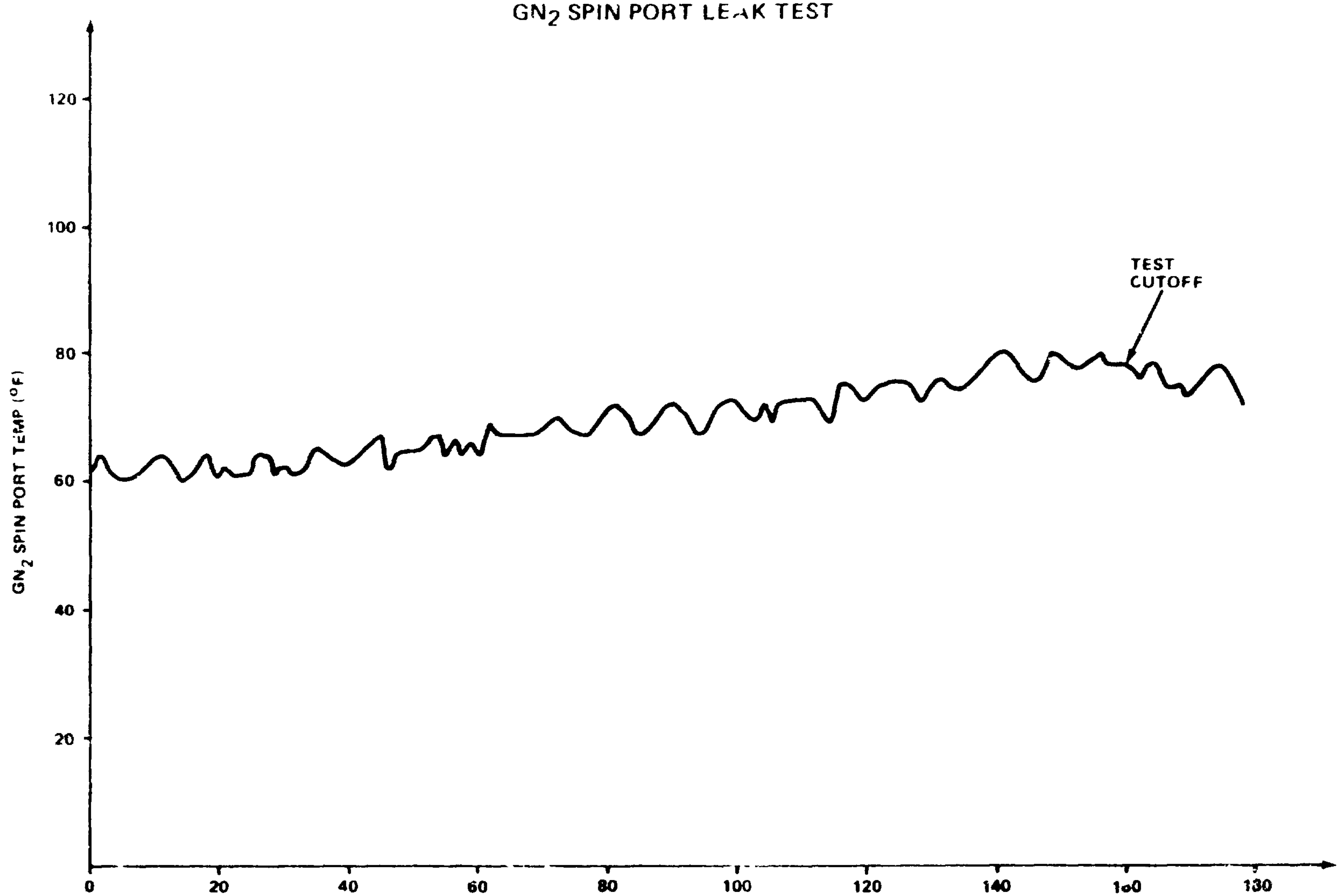


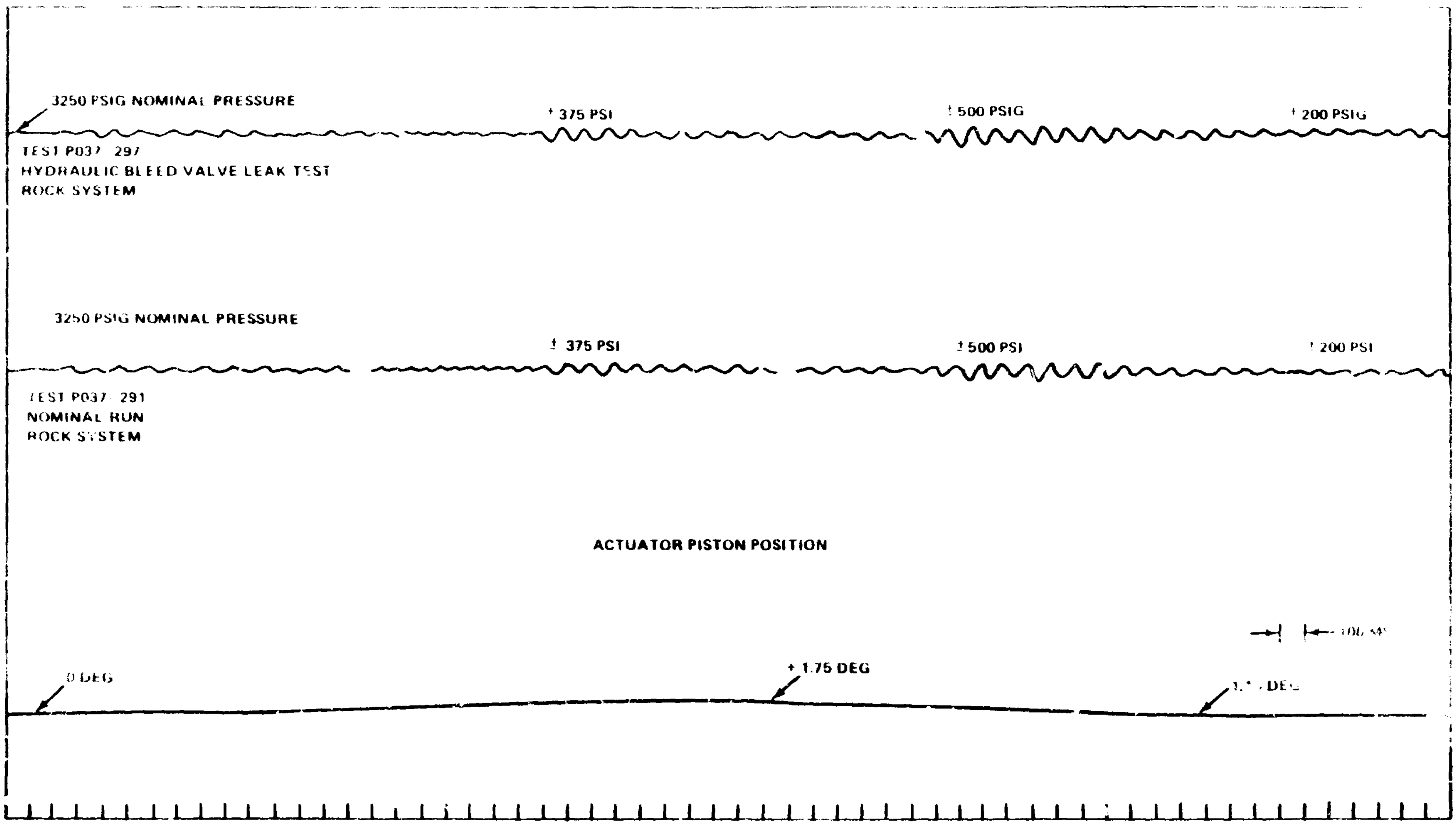
FIGURE 40

TABLE 12

TEST P037-297 HYDRAULIC BLEED VALVE LEAK TEST
HYDRAULIC SYSTEM PERFORMANCE

HYDRAULIC MEASUREMENTS		TEST P037–297				TEST P037–291 (NOMINAL RUN)				
HYDRAULIC FLUID TEMPERATURE	ROCK	59 – 76°F				ROCK	54 – 71°F			
	TILT	66 – 85°F				TILT	63 – 83°F			
RESERVOIR LEVEL		START	MIN	MAX			START	MIN	MAX	
	ROCK	75	72	76	PCT	ROCK	71	68	72	PCT
	TILT	75	72	77	PCT	TILT	72	69	73	PCT
RESERVOIR PRESSURE	ROCK	64 – 67 PSIG				ROCK	62 – 65 PSIG			
	TILT	63 – 67 PSIG				TILT	62 – 65 PSIG			
MANIFOLD PRESSURE	ROCK	66 – 70 PSIG				ROCK	63 – 67 PSIG			
	TILT	57 – 65 PSIG				TILT	62 – 67 PSIG			

TEST P037–297
HYDRAULIC BLEED VALVE LEAK TEST
HYDRAULIC SUPPLY PRESSURE TRANSIENT



F.GURE 4

HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

OBJECTIVE

To determine the consequences of a leaking high pressure relief valve on the hydraulic system performance.

RESULTS

Test P037-298 was conducted on October 26, 1979. Prior to this run, the rock high pressure relief valve in the manifold was set at 2800-2900 psig. During the firing, the rock APU ran for 105.5 sec. At this point, the system was shut down because the FSM pressure dropped below the pressure redline of 240 psig, indicating low fuel level. (See figure 42.) Excess fuel usage was required by this test because the hydraulic pump operated at full capacity throughout the entire run. The maximum flow rate through the relief valve is 70 gpm. This flow, plus the flow required to gimbal the actuators, resulted in a continuous hp output by the APU. The hydraulic temperature rise was much higher than in any previous test (53-267°F), indicating that the pump operated continually at full capacity. (See figure 43.) The hydraulic reservoir level increase reflects the effects of hydraulic temperature rise during the hot firing. The normal temperature rise for the same profile and test duration is 10°F or less. The turbine speed was lower and the band wider (68.76-72.61 k-rpm), when compared to a previous nominal hot firing (71.5-74.3 k-rpm in test P037-295). Figure 44 shows the turbine speed transient during this run for both 100 and 110 percent APU operations. The gas generator bed and turbine exhaust temperatures also experienced a large increase because of the greater hydraulic power requi[illegible] by the TVC system. (See figure 45.) The percent of time the primary speed control valve stayed open increased notably (to 77.7 percent, during the first 20 sec) to maintain the required power to the actuator (figure 46).

Rock actuator gimbaled according to the imposed command except for the checkout profile: 5 deg/sec, 1 deg. Amplitude (see figures 47 and 48). Also, the hydraulic pressure oscillations were normal during all the gimbal program except for the checkout profile (see figures 46 and 49). The hydraulic reservoir pressure was slightly lower (61 psig) than normal, because of the lower hydraulic supply pressure while the manifold return pressure was slightly higher (71 psig) because the high pressure relief valve was releasing pressure into the return pressure side of this component. (See figure 50.) Selected parameters in table 13 compare the overall TVC subsystems performance during this hot firing to a nominal test.

TABLE 13

TEST P037-298

HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

TVC SUBSYSTEM PERFORMANCE

SYSTEM MEASUREMENTS	TEST P037-298	TEST P037-297 (NOMINAL RUN)
ACTUATOR GIMBAL PROGRAM	N*	N*
HYDRAULIC SUPPLY PRESSURE (PSIG)	2950	3250
SECONDARY PRESSURE (PSIG)	3120	3120
HYDRAULIC RESERVOIR TEMPERATURE (^{o}F)	53-267	59-66
HYDRAULIC RESERVOIR LEVEL (PCT)	START 66, MIN 64, MAX 78	START 75, MIN 72, MAX 75
HYDRAULIC RESERVOIR PRESSURE (PSIG)	58-62	64-66
HYDRAULIC MANIFOLD PRESSURE (PSIG)	69-74	66-69
LP RELIEF VALVE PRESSURE (PSIG)	0	93
CASE DRAIN PRESSURE (PSIG)	69-75	68-71
APU TURBINE SPEED (KRPM)	68.8-71.5	71.2-74
APU START TIME (SEC.)	3.01	3.03
GAS GENERATOR TEMPERATURE (^{o}F)	224-1304	225-1060
TURBINE EXHAUST TEMPERATURE (^{o}F)	64-773	67-518
FSM PRESSURE (PSIG)	379-239	370-320
FUEL PUMP INLET PRESSURE (PSIG)	370-232	366-321
MAXIMUM FUEL PUMP OUTLET PRESSURE (PSIG)	1475	1375
MAXIMUM GAS GENERATOR PRESSURE (PSIG)	1300	1175
TIME PRIMARY SPEED CONTROL VALVE IS OPEN-FIRST 20 SECONDS - (PCT)	77.7	32.5
LUBE OIL TEMPERATURE (^{o}F) T6	60-146	65-140
T6 AUX	57-162	64-154

NOTES: ROCK SYSTEM ONLY
105.5 SEC TEST DURATION

FUEL SUPPLY MODULE (FSM) PRESSURE BEHAVIOR

HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

ROCK SYSTEM

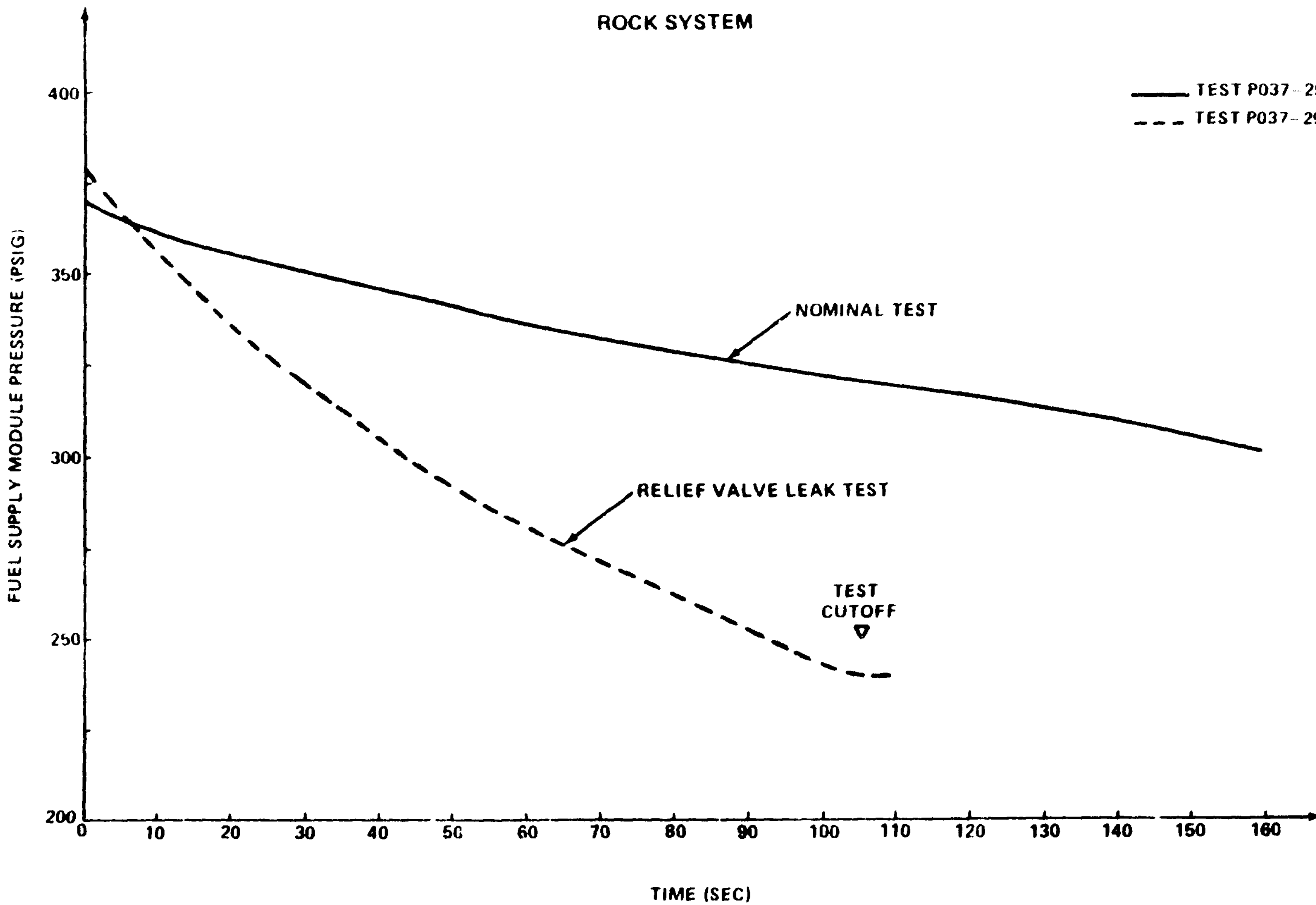


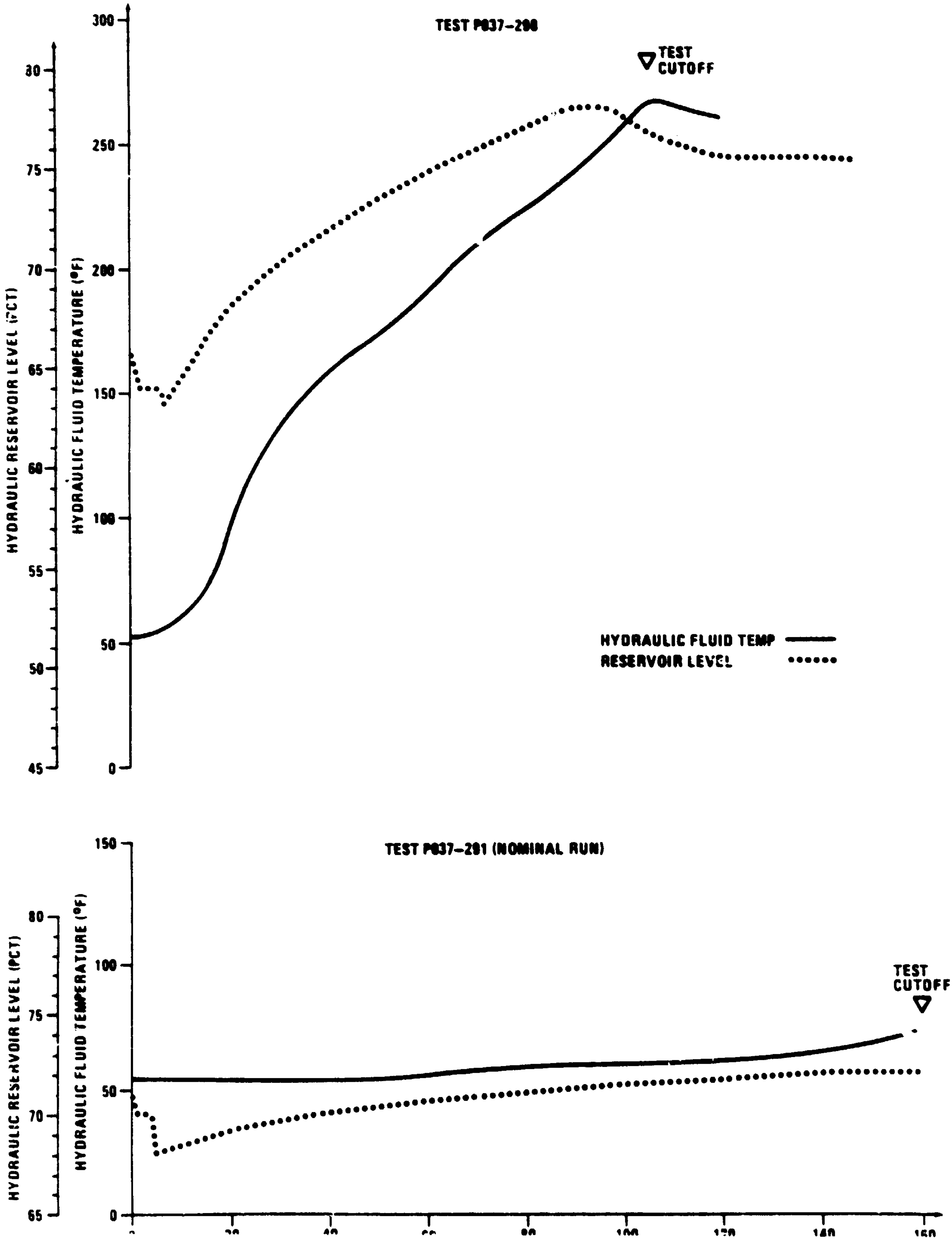
FIGURE 42

FIGURE 43

TEST P037-298

HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL



TEST P037–298

HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

TURBINE SPEED BEHAVIOR

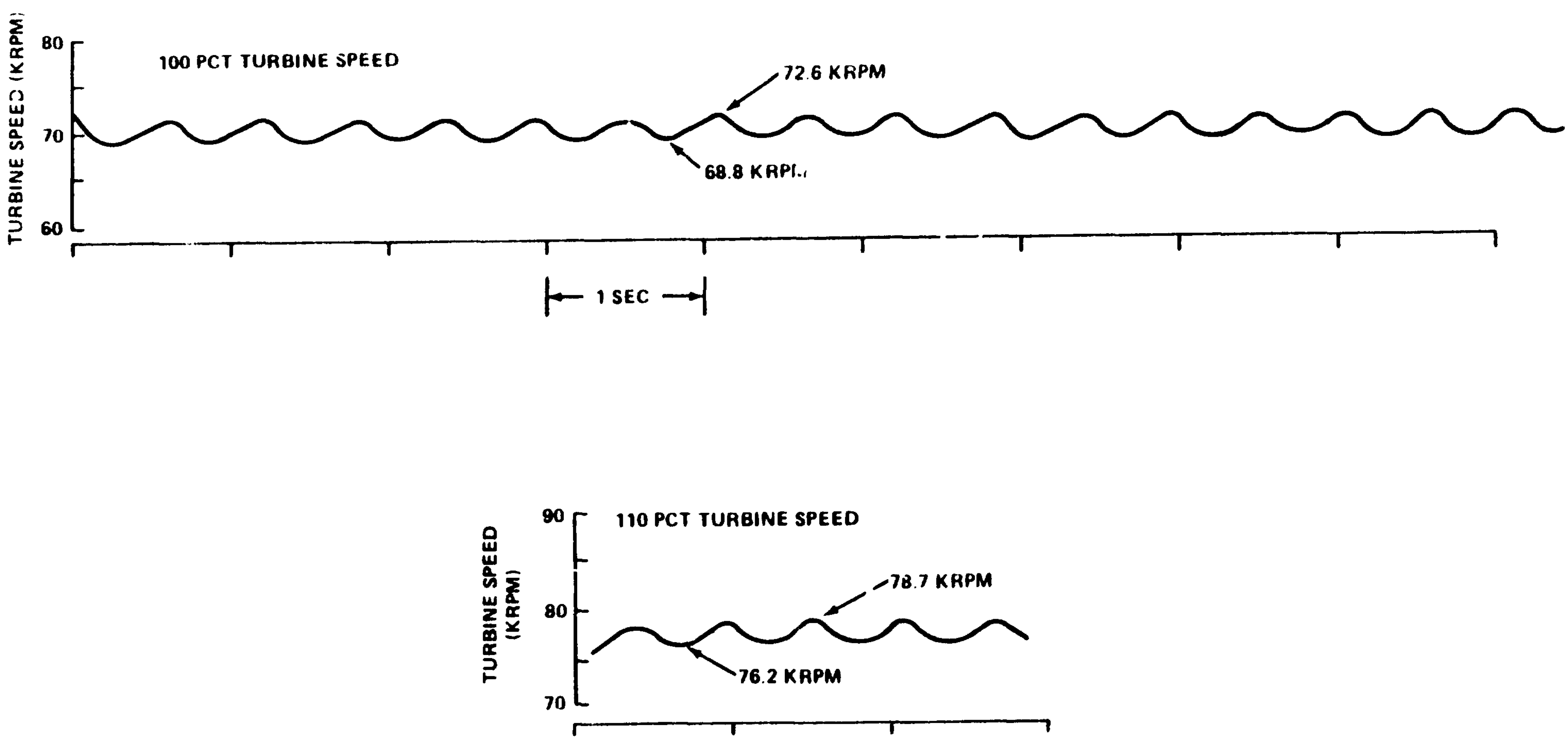


FIGURE 44

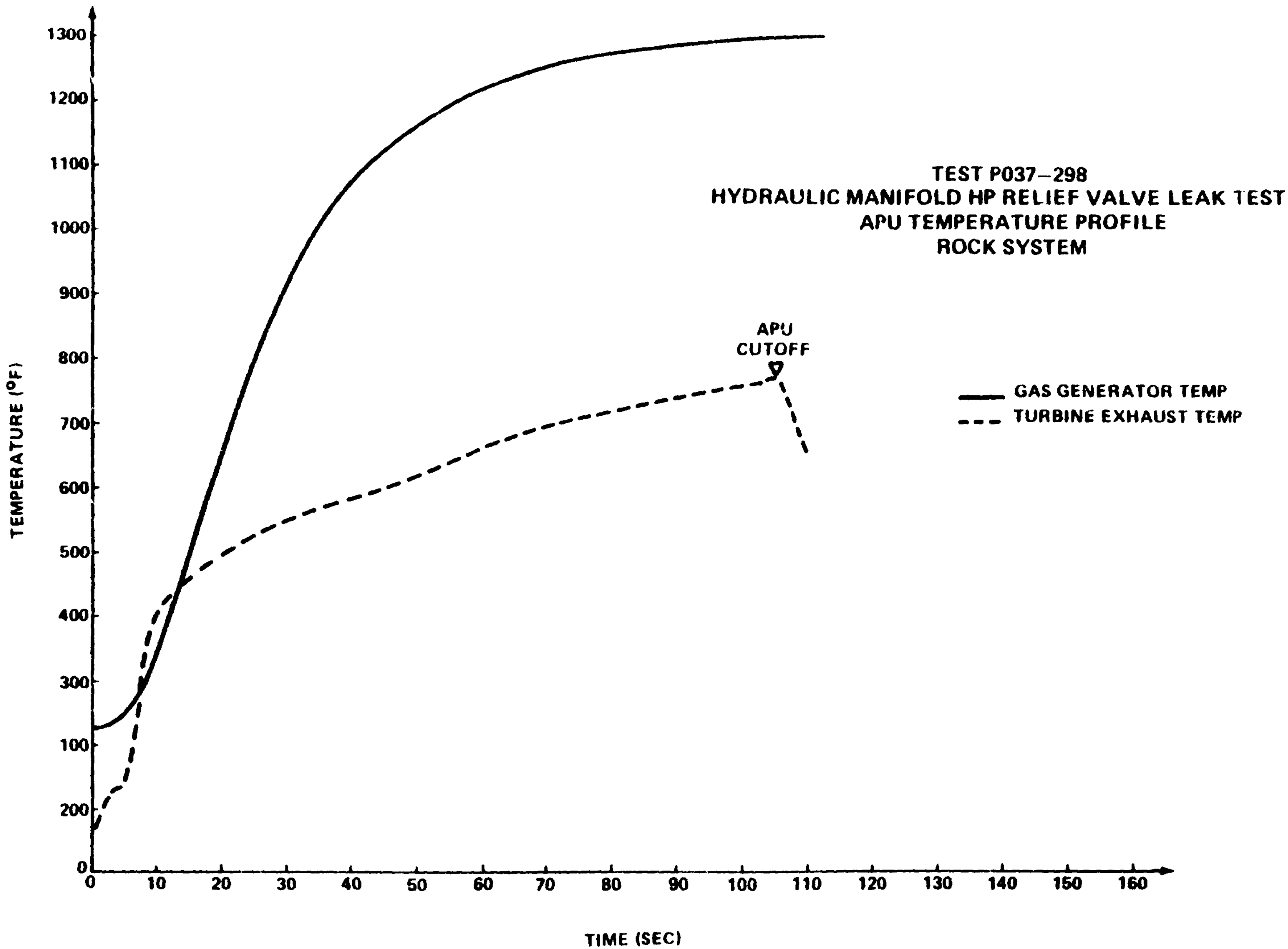

TEST P037–298
HYDRAULIC MANIFOLD HP RELIEF VALVE LEAK TEST
APU TEMPERATURE PROFILE
ROCK SYSTEM
APU
CUTOFF
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TEMPERATURE (°F)
1300
1200
1100
1000
900
800
700
600
500
400
300
100
200
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)

FIGURE 45

TEST P037–298
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST
TVC SUBSYSTEM PERFORMANCE

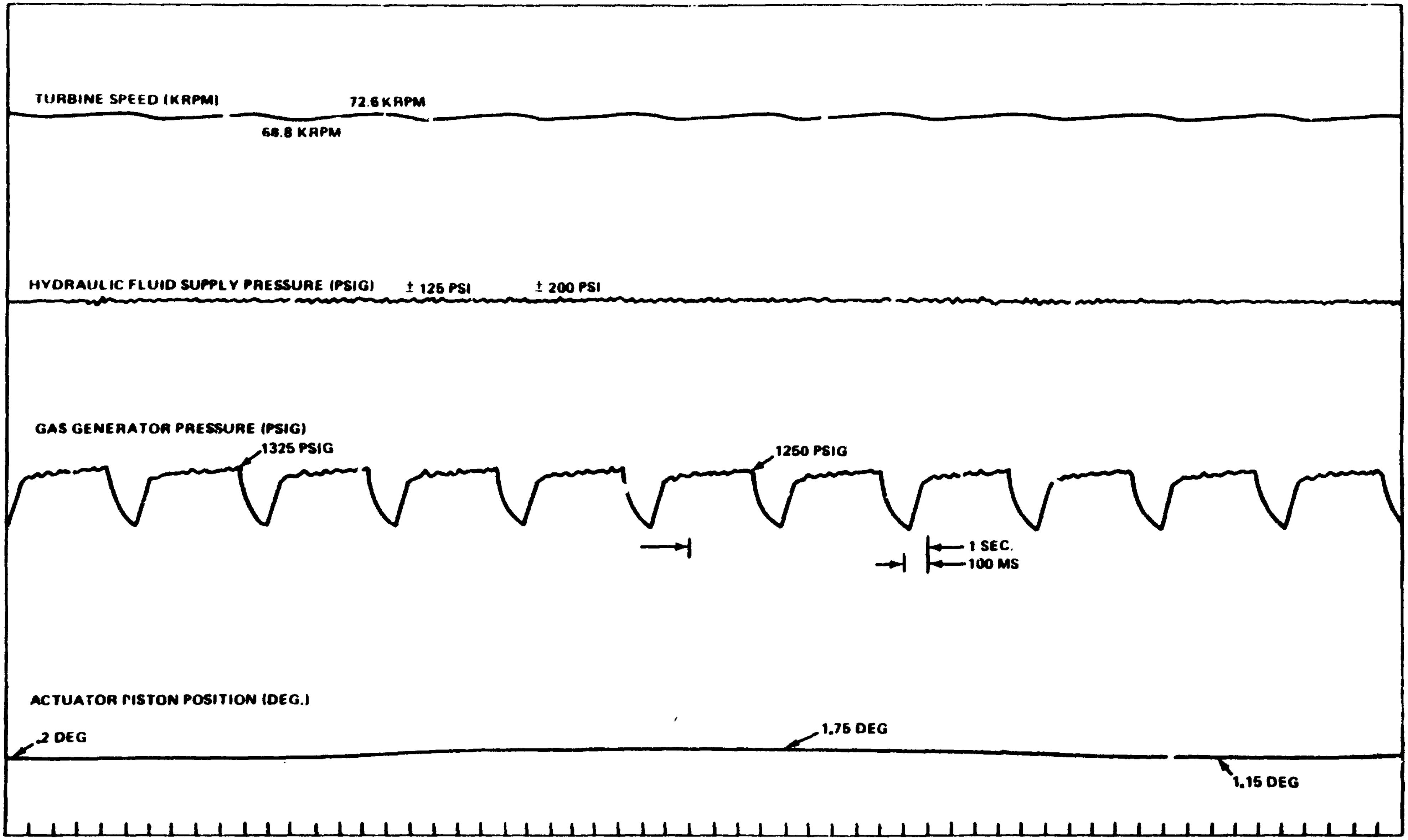


FIGURE 46

ACTUATOR COMMAND AND PISTON POSITION-NOMINAL GIMBAL PROGRAM
TEST P037–298
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST

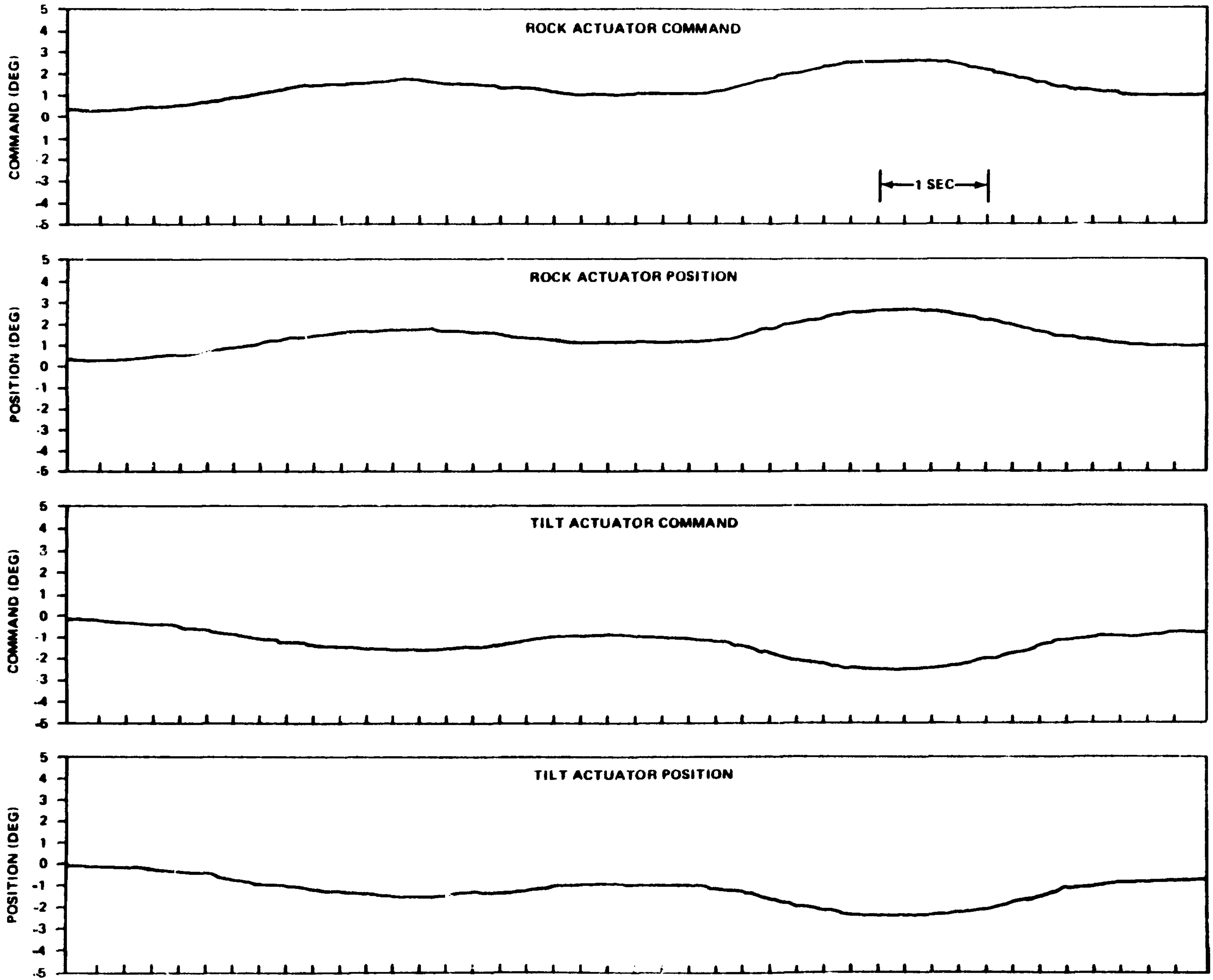


FIGURE 47

ACTUATOR COMMAND AND PISTON POSITION
TEST P037–298
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST
KSC CHECKOUT GIMBAL PROGRAM

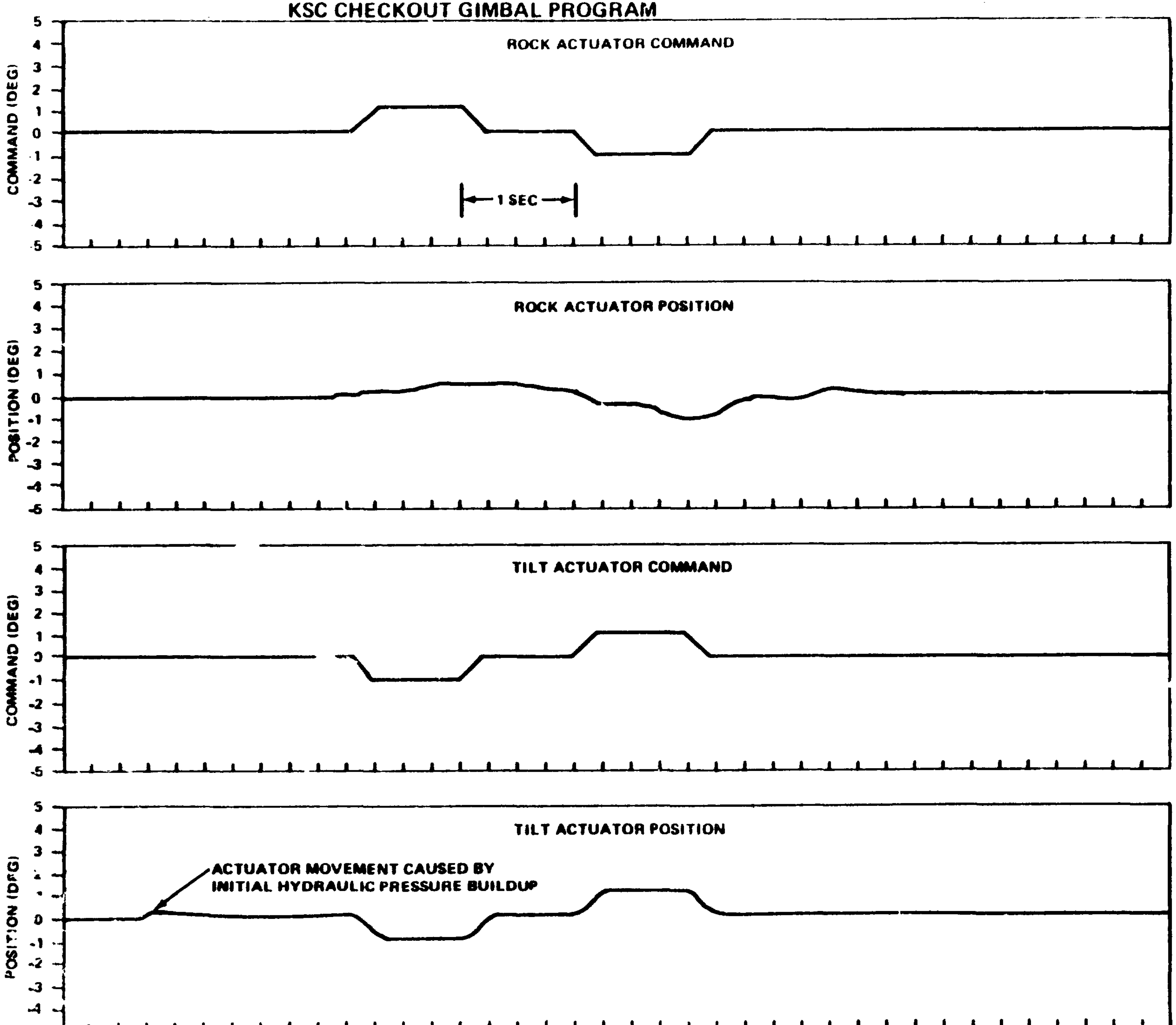


FIGURE 49

TEST P037–298
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST
ROCK HYDRAULIC FLUID SUPPLY PR AND ACTUATOR PISTON POSITION

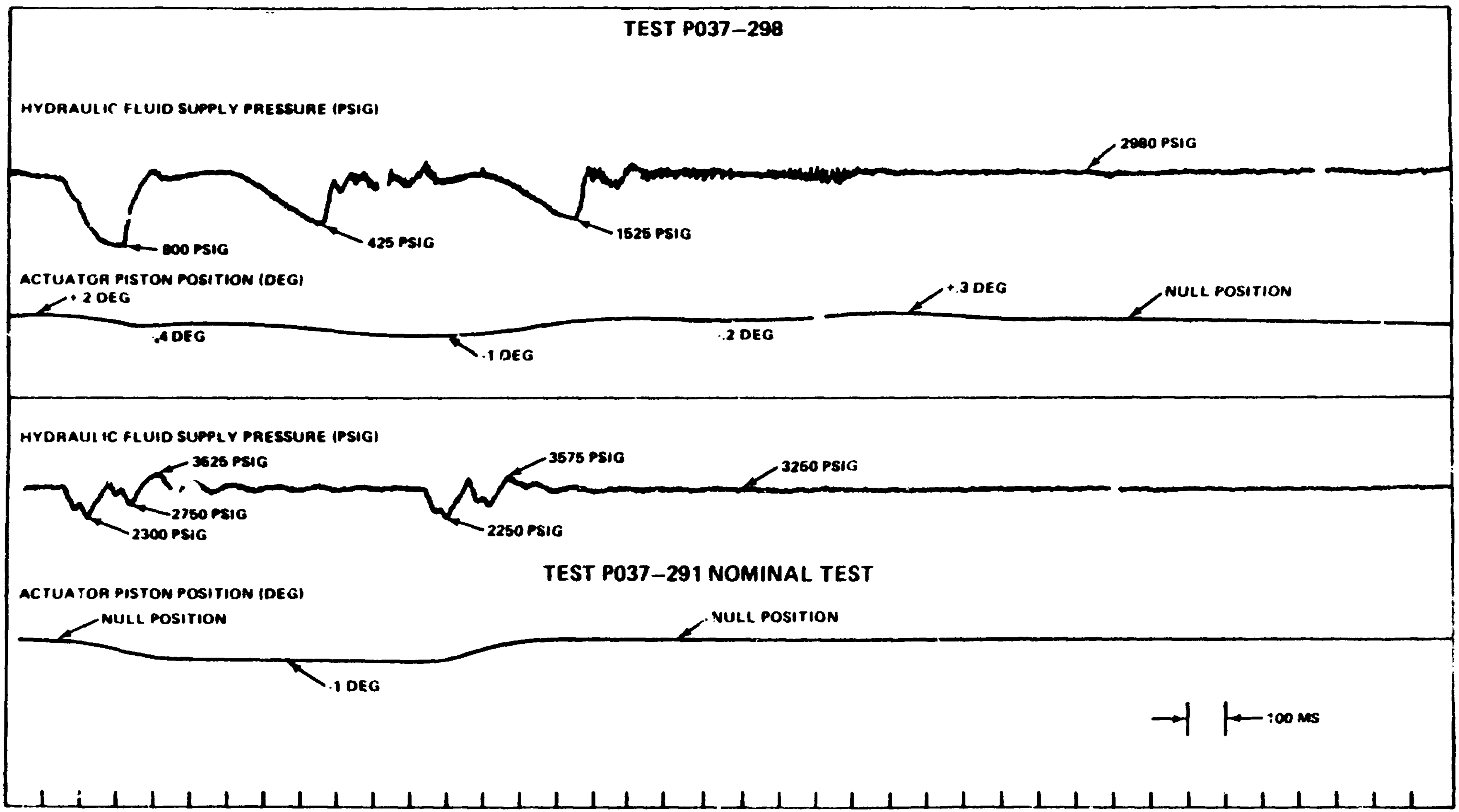


FIGURE 49

TEST P037–298
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAK TEST
HYDRAULIC RETURN PRESSURES

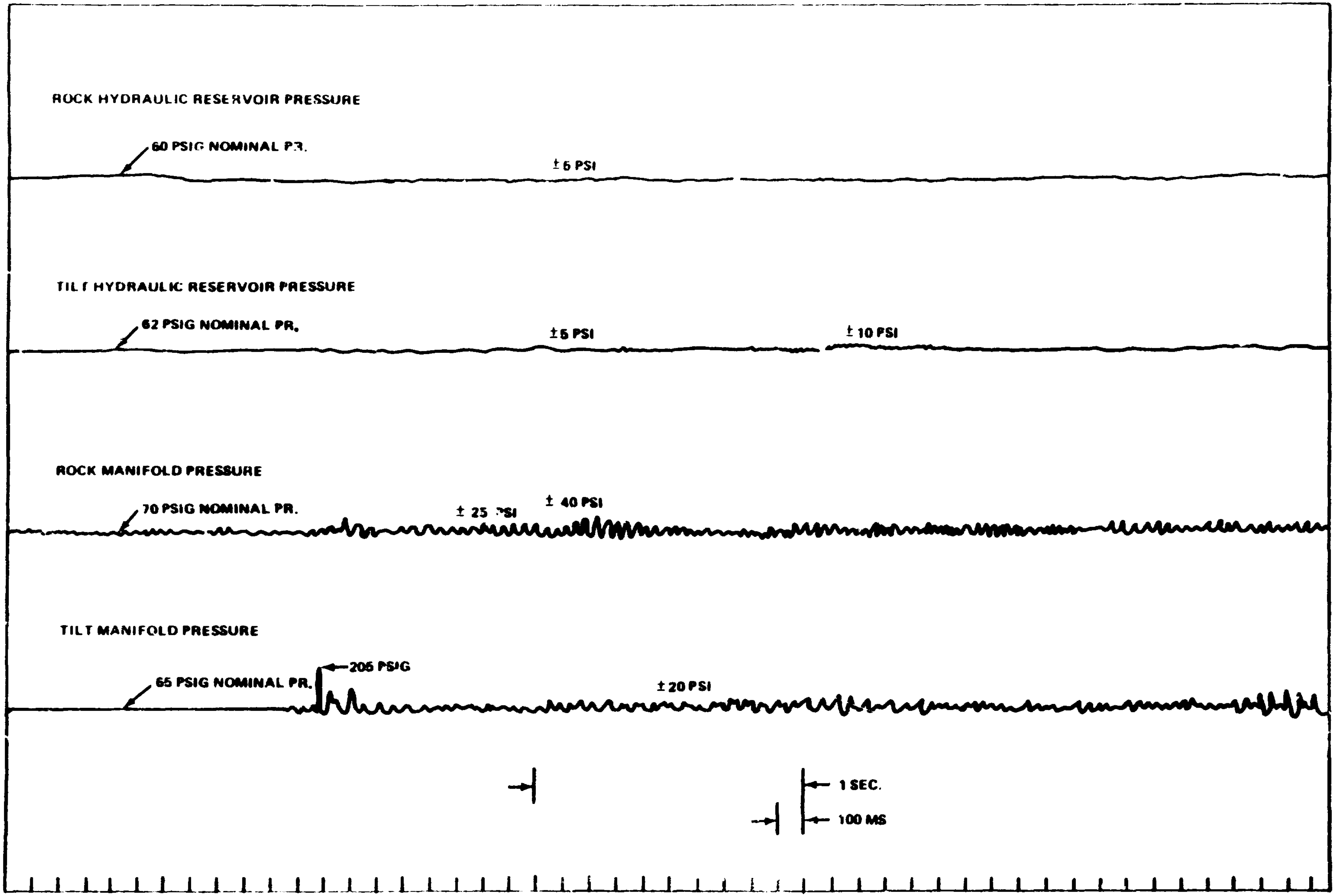


FIGURE 50

NOMINAL TESTS

OBJECTIVE

To verify the condition of the TVC subsystem hardware and software following the ascent thrust vector control (ATVC) system testing.

To establish a data base and utilize this base for comparison purposes on succeeding off-nominal tests.

To prepare and service the hydraulic system following actuator substitution.

RESULTS

A sequence of runs consisting of low pressure GN_2 spin (test P037-314), high pressure GN_2 spin (test P037-317), 20-second checkout hot firing (test P037-318), and full duration hot firing (test P037-319), was conducted successfully between June 8 and June 20, 1980. All objectives were accomplished, and no hardware anomalies were present. Test P037-315 experienced an early cutoff because of a facility electronic problem. Test P037-316 was aborted when the hydraulic reservoir low level redline was violated. Air in the hydraulic system created this problem. These aborts are not uncommon during system's servicing. Testing resumed after the system was bled with no further problems. Figures 51 through 57 show the behavior of several TVC components and their parameters. Tables 14 through 16 present the overall TVC subsystem performance during the high pressure GN_2 spin test and the full duration nominal hot firing.

TABLE 14

TEST RESULTS ON

TEST NO	P037–317
DATE	5–13–80
TYPE	HIGH PRESSURE GN_2 SPIN

		LOCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3230	3160
SECONDARY PR (PSIG)		3160	3185 ±10
HYDRAULIC RESERVOIR TEMP (°F)		83–110°F	92–120°F
HYDRAULIC RESERVOIR LEVEL (PCT)		76–75 (71)–72	74–71 (70)–71
HYDRAULIC RESERVOIR PR (PSIG)		64	65–67
HYDRAULIC MANIFOLD PR (PSIG)		66	59–65
LP RELIEF VALVE (PSIG)		NA	NA
FSM TEMP (°F)		76	75
FSM PR (PSIG)		133	133
TURBINE SPEED (K–RPM)			
	START	51.66	52.56
	MIN–MAX PROGRAM	38.55–48.44	40.68–47.98
LUBE OIL TEMP (°F)			
	T6	88–149	88–158
	T6 AUX	81–144	93–157
TURBINE SPIN PR (PSIG)		800	800
TURBINE SPIN TEMP (°F)		NA (BAD MEAS)	82–41
AMBIENT TEMP (°F)		73	73

ROCK LUBE OIL TEMPERATURE
TEST P037-317
800 PSIG GN_2 SPIN PRESSURE

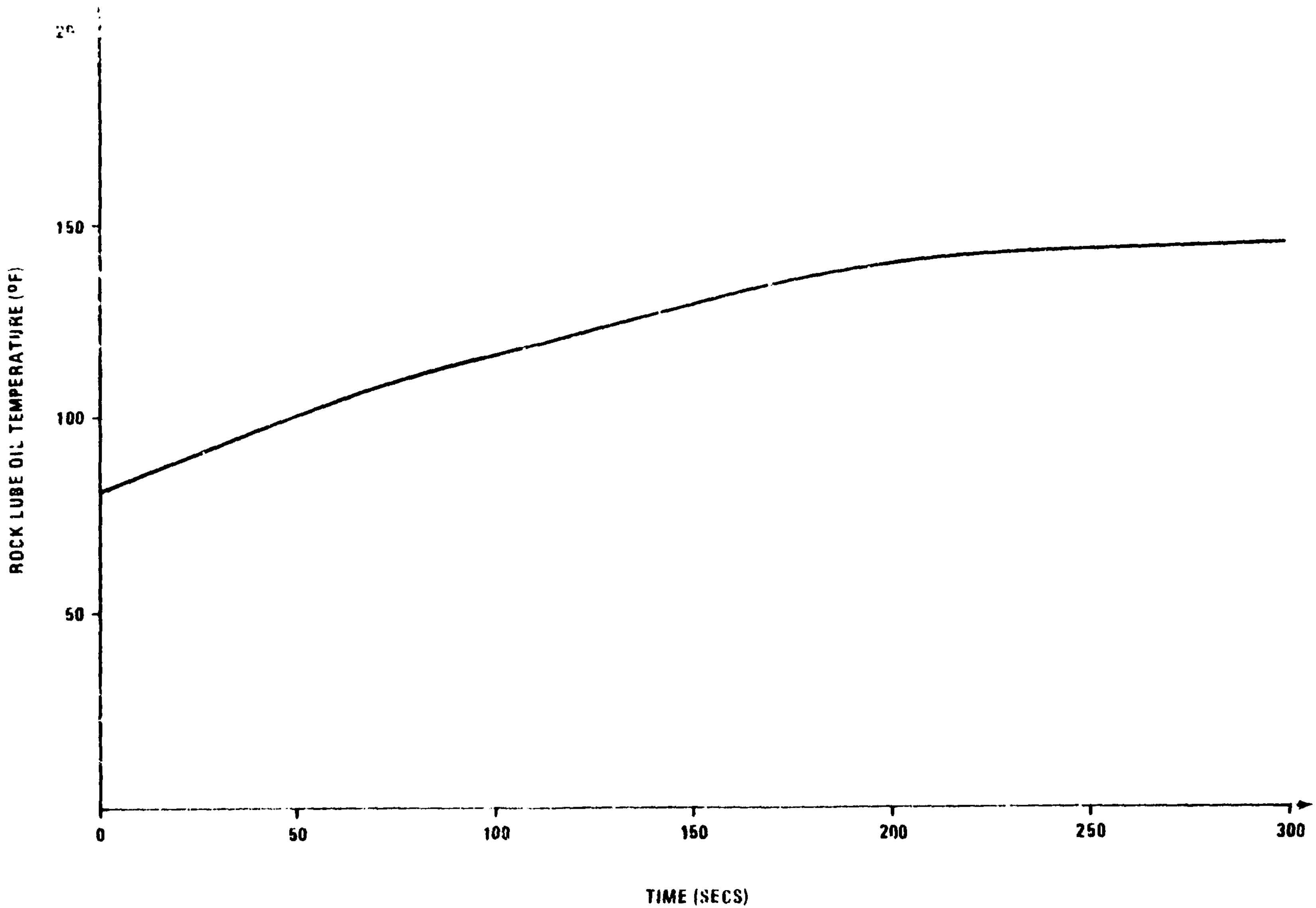


FIGURE 51

TILT LUBE OIL TEMPERATURE

TEST P037-317

800 PSIG GN_2 SPIN PRESSURE

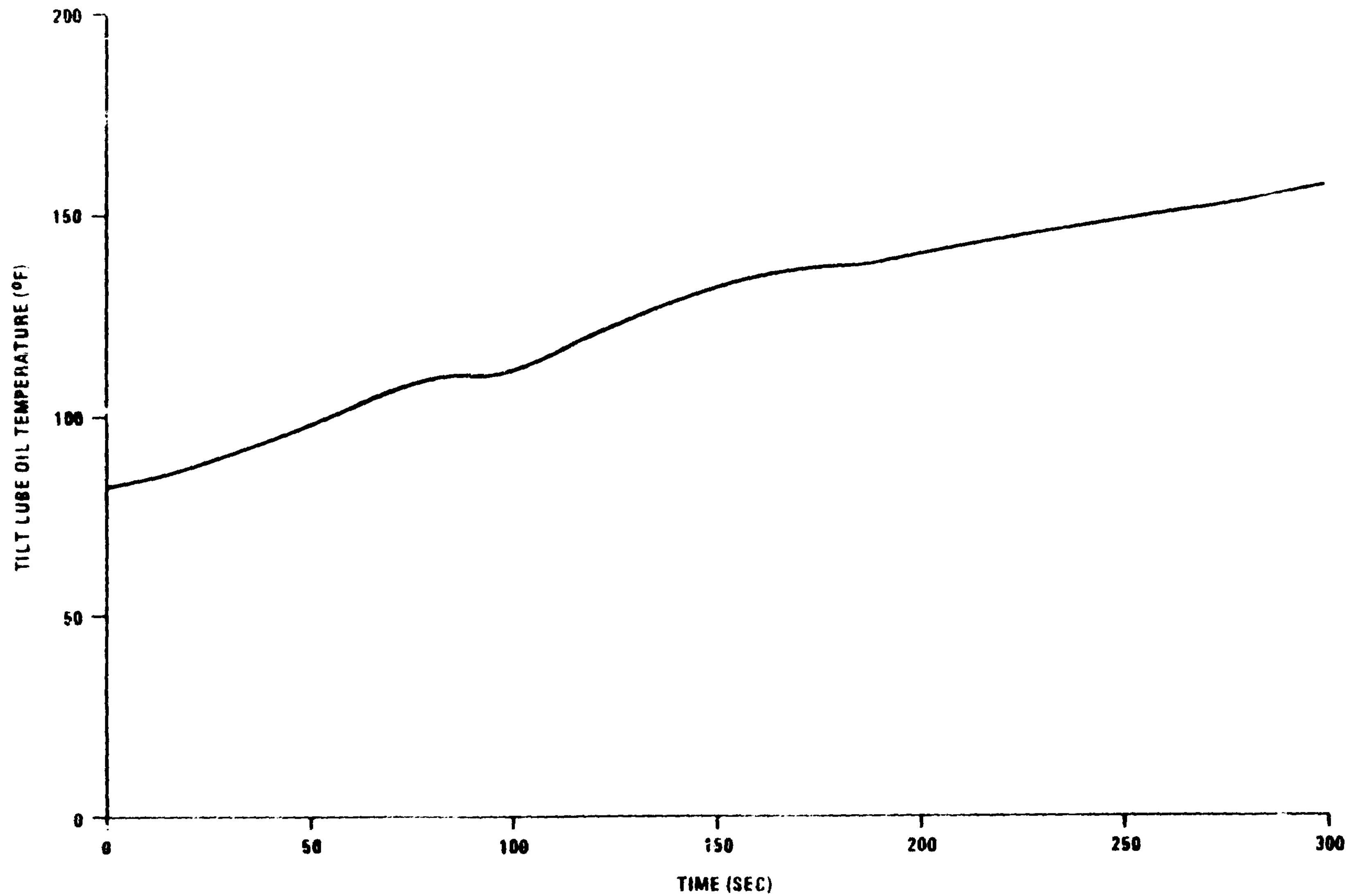


FIGURE 52

TABLE 15

TEST RESULTS ON

TEST NO	P037 - 318
DATE	5/15/80
TYPE	CHECKOUT HOT FIRING

		ROCK	TILT	
HYDRAULIC SUPPLY PR (PSIG)		3240 ± 5	3180 ± 5	
SECONDARY PR (PSIG)		3180 ± 5	3200 ± 5	
ACTUATOR DIFFERENTIAL PR (PSID)		235	NA (BAD MEAS)	
HYDRAULIC RESERVOIR TEMP (°F)		71	80	
HYDRAULIC RESERVOIR LEVEL (PCT)		73	74-70-70	
HYDRAULIC RESERVOIR – PR. (PSIG)		64	60-63	
HYDRAULIC MANIFOLD PR (PSIG) LP		65	62-65	
LP RELIEF VALVE PR (PSIG)		0–42	0	
CASE DRAIN PR (PSIG)		66	NA	
FSM TEMP (°F)		68°F	72°F	
FSM PR (PSIG)		366 – 350	363 – 349	
FUEL PUMP INLET PR (PSIG)		361 – 325	363 – 349	
MAXIMUM FUEL PUMP OUTLET PR (PSIG)		1375	1425	AT 15 SEC
		1475	1525	GIMBAL PROGRAM
MAXIMUM GAS GENERATOR PR (PSIG)		1150	1175	AT 15 SEC
		1225	1250	GIMBAL PROGRAM
GAS GENERATOR TEMP (°F)		206 – 569	205 – 522	
TURBINE EXHAUST TEMP (°F)		85 – 343	90 – 198	
TURBINE SPEED (K- RPM)		68.45 – 74.72	68.36 – 75.9	
LUBE OIL TEMP	T6	78 – 95	77 – 80	
	T6 AUX	77 – 111	77 – 86	
TURBINE SPIN PR (PSIG)		NA	NA	
TURBINE SPIN TEMP (°F)		NA	NA	
AMBIENT TEMP (°F)		75	75	

TABLE 15 (CONT.)

TEST RESULTS ON (CONT.)

TEST NO	P037-318
DATE	5/15/80
TYPE	CHECKOUT HOT FIRING

VALVE CONDITIONS AND OPERATION	ROCK	TILT
HYDRAULIC BYPASS VALVE	OK	OK
FIV	OK	OK
SOV	OK	OK
SWITCHING VALVE	NO SWITCH	NORMAL SWITCH (5 SEC)
SHAFT SEAL LEAKAGE	NA	15-20 CC
PCV CYCLING		
CONDITION	OK	OK
VALVE TIME OPEN	.110 SEC	.125 SEC
PERCENT OPEN		
NO GIMBAL	21.9%	16.2%
5 DEG/SEC.	37.8%	27.4%
OPEN TRANSIENT	60 MS	65 MS
CLOSING TRANSIENT	20 MS	10-15 MS
PRESSURE OSCILLATION	± 50 PSI	± 25 PSI
START TRANSIENT TIME	2.96 SEC.	3.1 SEC
HYDRAULIC PRESSURE OSCILLATIONS		
LOW	2200 PSIG	2300 PSIG
HIGH	3700 PSIG	3575 PSIG
LOW PRESSURE TRANSIENTS	10-12 HZ MODE	10-12 HZ MODE
RESERVOIR	45-70 PSIG	45-75 PSIG
MANIFOLD(PRESSURE AND DURATION)	5 PSIG	25 PSIG
	535 PSIG (5 MS)	215 PSIG (5 MS)

TABLE 16

TEST RESULTS ON

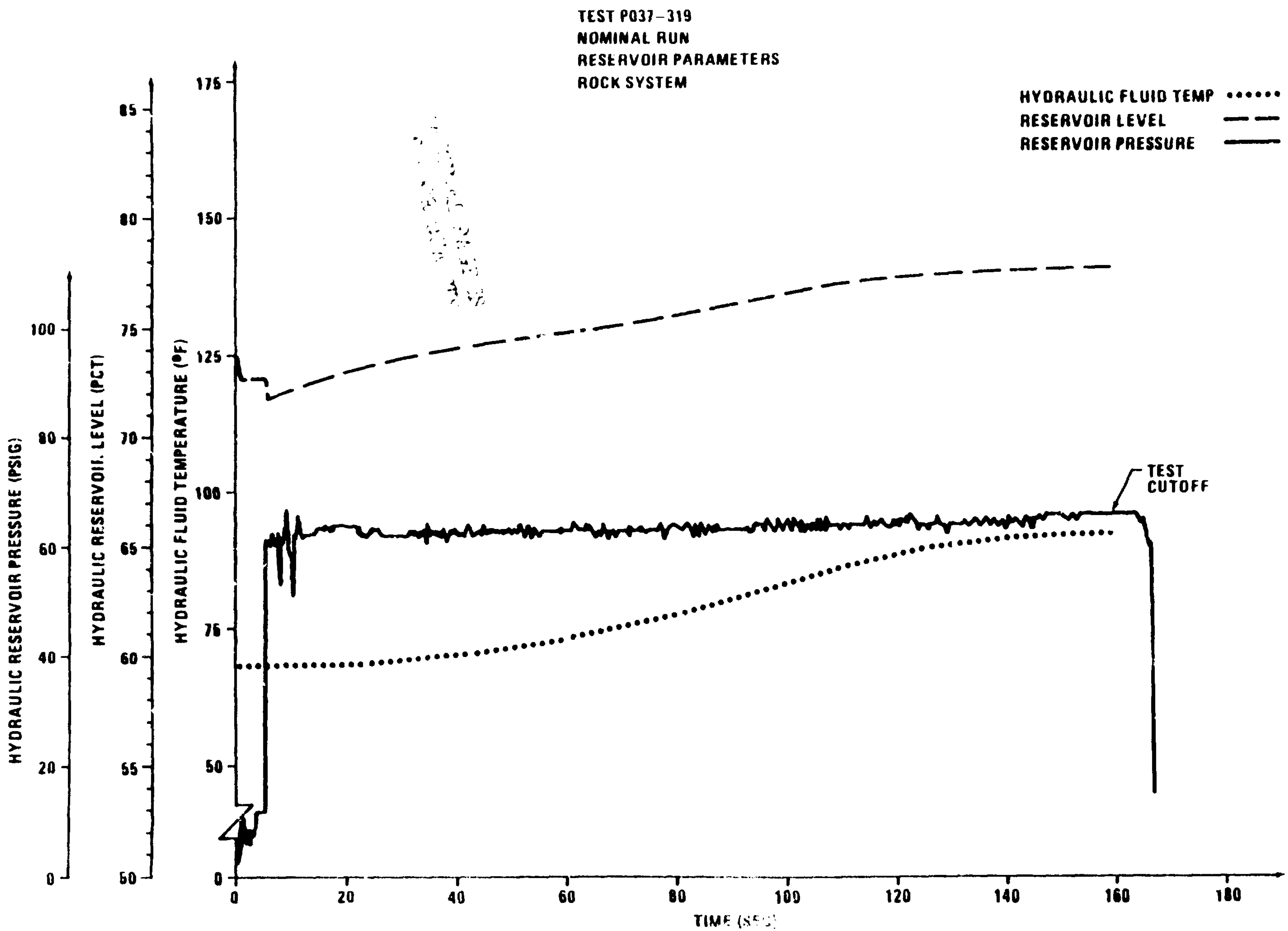
TEST NO	P037 – 319
DATE	5/20/80
TYPE	NOMINAL FULL DURATION HOT FIRING D – GIMBAL PROGRAM

	ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)	3250 ± 10	3180^{+20}_{-5}
SECONDARY PR (PSIG)	3180 +20/ –5	3200 ± 5
ACTUATOR DIFFERENTIAL PR (PSID)	225 +50/ – 30	NA (BAD MEAS)
HYDRAULIC RESERVOIR TEMP (°F)	69-93	77-103
HYDRAULIC RESERVOIR LEVEL (PCT)	74-72-78	74-69-74
HYDRAULIC RESERVOIR PR (PSIG)	62-67	65 ± 2
HYDRAULIC MANIFOLD PR (PSIG) LP	63-69	65 ± 2
LP RELIEF VALVE PR (PSIG)	0 – 124	NA (BAD MEAS)
CASE DRAIN PR (PSIG)	65-68	NA
FSM TEMP (°F)	70	69-70
FSM PR. (PSIG)	377-291	371-292
FUEL PUMP INLET PR (PSIG)	380-295	330-270
MAXIMUM FUEL PUMP OUTLET PR (PSIG)	1250	1375 (AT 15 SEC)
	1425	1475 (AT GIMBAL PROGRAM)
MAXIMUM GAS GENERATOR PR (PSIG)	1100	1175 (AT 15 SEC)
	1225	1275 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP (°F)	209-1128 (1125)	199-1103
TURBINE EXHAUST TEMP (°F)	75-579	75-589
TURBINE SPEED (K – RPM)	70.25-75.46	70.11-75.92
LUBE OIL TEMP T6	75-180	72-176
T6 AUX	73-181	72-181

TEST RESULTS ON (CONT.)

TEST NO P037 319
DATE 5/20/80
TYPE FULL DURATION HOT FIRING
D GIMBAL PROGRAM

VALVE CONDITIONS AND OPERATION	ROCK	TILT
HYDRAULIC BYPASS VALVE	OK	OK
FIV	OK	OK
SOV	OK	OK
SWITCHING VALVE	NORMAL SWITCH	NORMAL SWITCH (5 SEC)
SHAFT SEAL LEAKAGE		15 CC
PCV CYCLING		
CONDITION	OK	OK
VALVE TIME OPEN START	.120 SEC	.140 SEC
END	.120 SEC	.140 SEC
PERCENT OPEN		
NO GIMBAL	17.6%	18.3%
5 DEG/SEC	31.3%	31.6%
GIMBAL PROGRAM	28.2%	28.1%
END	14.8%	16.9%
OPEN TRANSIENT	70 MS	70 MS
CLOSING "	25 MS	15-20 MS
PRESSURE OSCILLATION	± 50 PSI	± 80 PSI
START TRANSIENT TIME	2.94 SEC.	2.995 SEC.
HYDRAULIC PRESSURE OSCILLATIONS		
5 DEG/SEC LOW - HIGH	2000-3800 PSIG	2275-3700 PSIG
GIMBAL PROGRAM	2700-3600 PSIG	2925-3450 PSIG
LOW PRESSURE TRANSIENTS		
RESERVOIR	35-75 PSIG	35-80 PSIG
MANIFOLD (PRESSURE AND DURATION)	[illegible] PSIG (20 MS)	5 PSIG (30 MS)
	650 PSIG (< 5 MS)	490 PSIG (< 5 MS)



TEST P037-319
NOMINAL RUN
RESERVOIR PARAMETERS
ROCK SYSTEM
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL
RESERVOIR PRESSURE
TEST CUTOFF
HYDRAULIC RESERVOIR PRESSURE (PSIG)
HYDRAULIC RESERVOIL LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
0
20
40
60
80
100
50
55
60
65
70
75
80
85
0
50
75
100
125
150
175
0
20
40
60
80
100
120
140
160
180

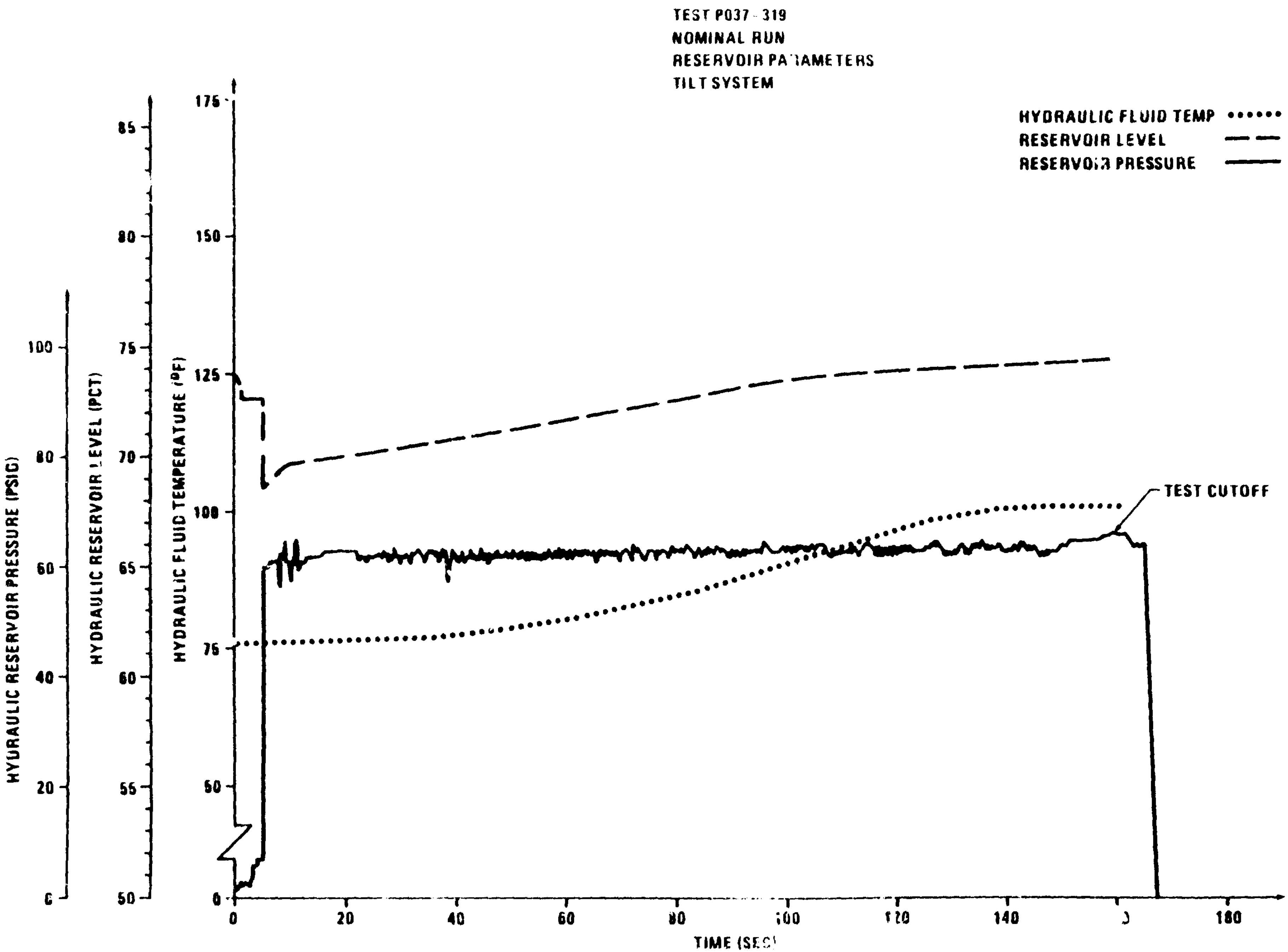

TEST P037 - 319
NOMINAL RUN
RESERVOIR PARAMETERS
TILT SYSTEM
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL
RESERVOIR PRESSURE
TEST CUTOFF
HYDRAULIC RESERVOIR PRESSURE (PSIG)
HYDRAULIC RESERVOIR LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
TIME (SEC)
0
20
40
60
80
100
120
140
180
50
55
60
65
70
75
80
85
175
150
125
100
75

FIGURE 54

TEST P037-319 NOMINAL TEST

RESERVOIR AND MANIFOLD HYDRAULIC PRESSURE TRANSIENT

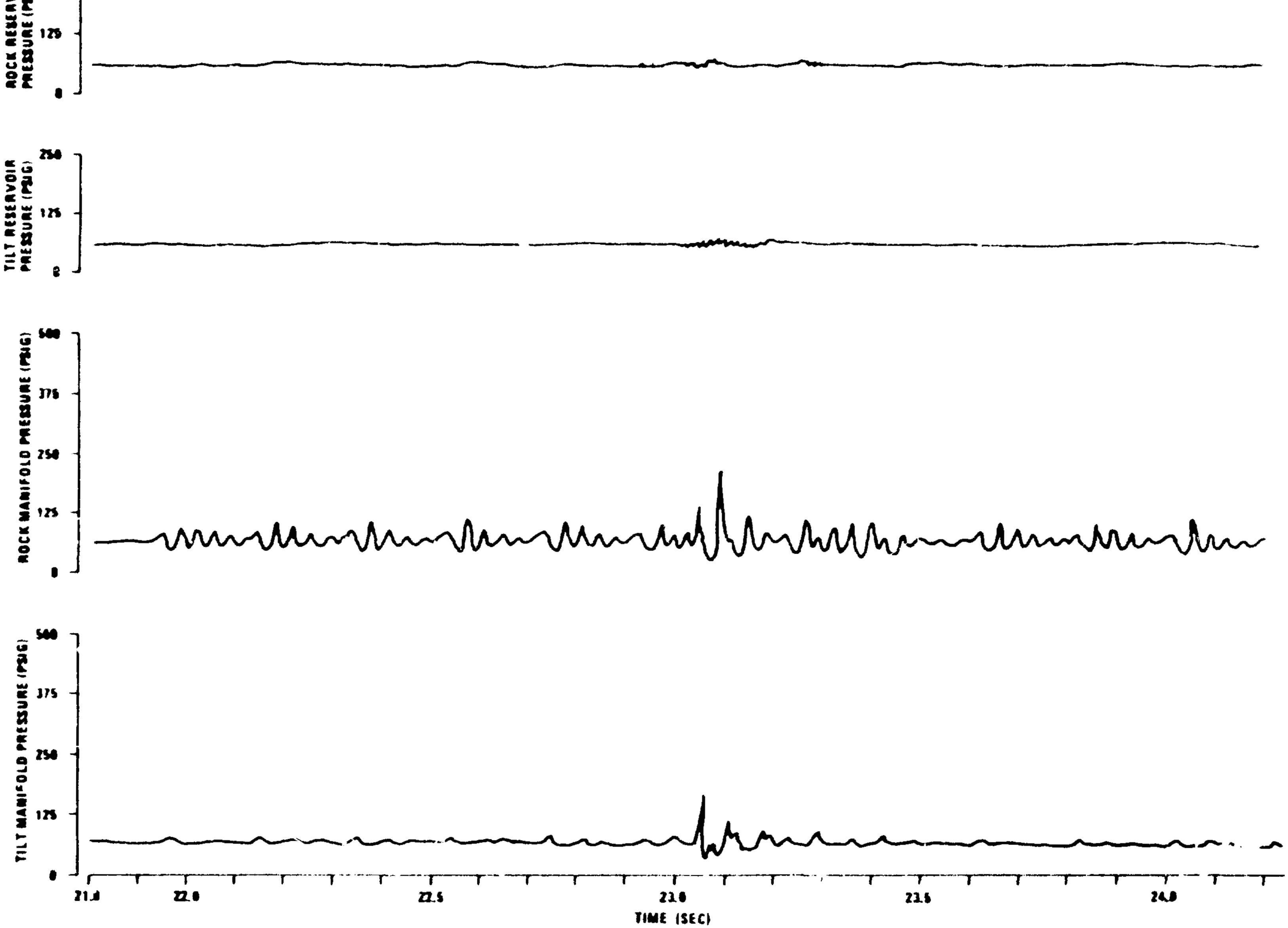
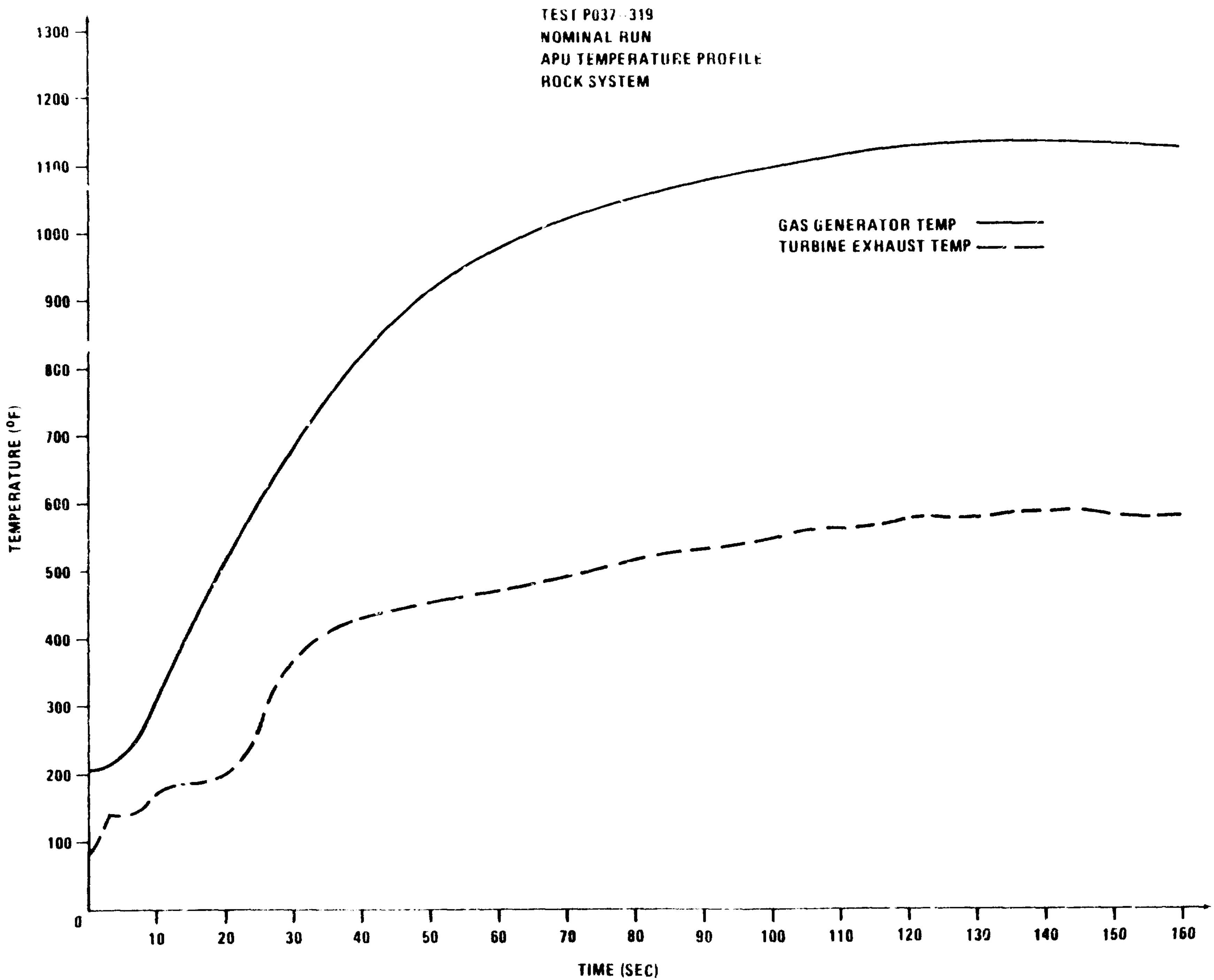
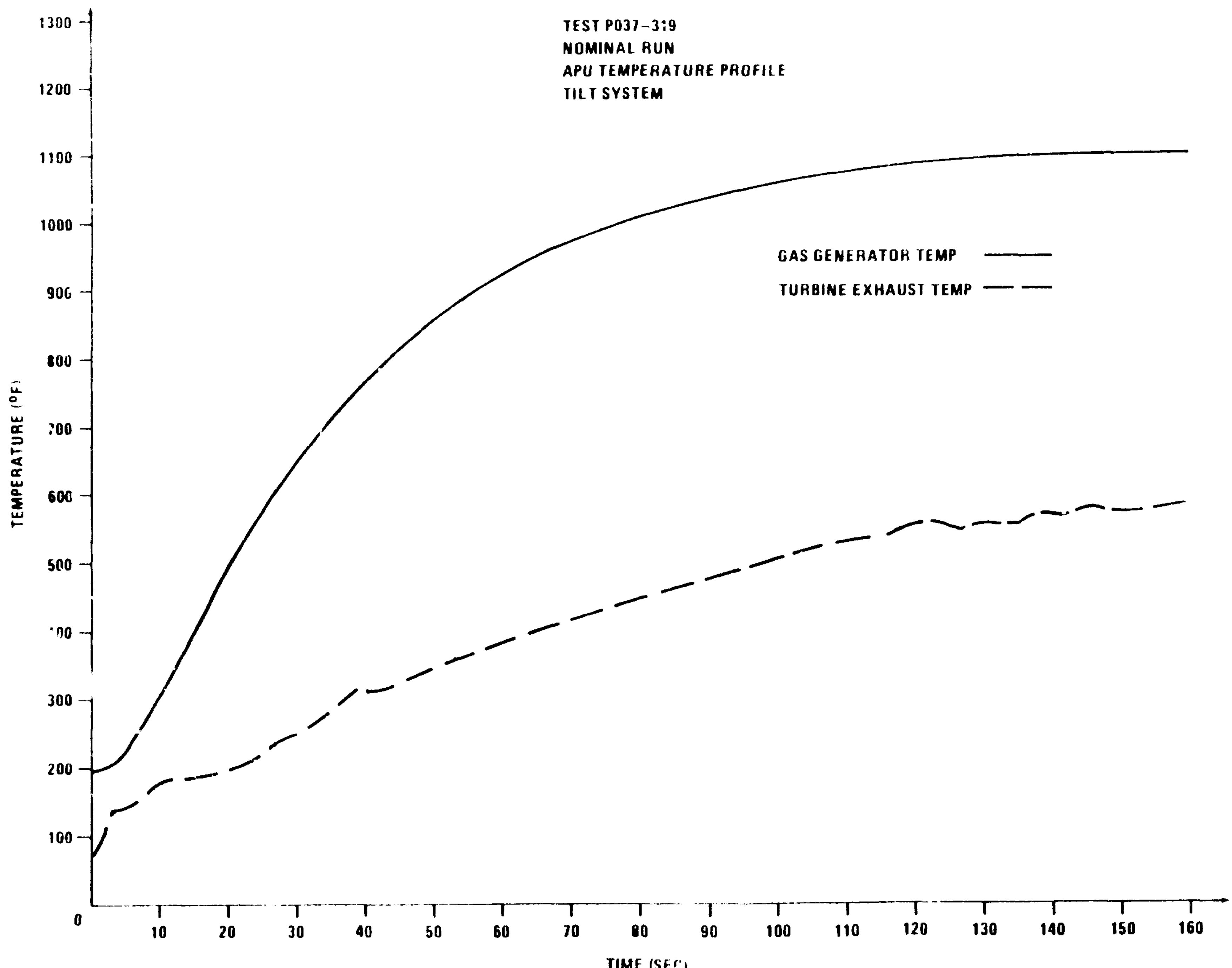


FIGURE 55



TEST P037-319
NOMINAL RUN
APU TEMPERATURE PROFILE
ROCK SYSTEM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TEMPERATURE (°F)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)

FIGURE 56


TEST P037-319
NOMINAL RUN
APU TEMPERATURE PROFILE
TILT SYSTEM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TEMPERATURE (°F)
1300
1200
1100
1000
900
800
700
600
500
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

LOW HYDRAULIC RESERVOIR LEVEL TEST 5

TEST P037-320

OBJECTIVE

To demonstrate the hydraulic system reaction to low fluid level in the reservoir for a nominal flight mission gimbal program ("D" gimbal profile).

RESULTS

The low hydraulic reservoir level test 5 (P037-320) was successfully conducted on May 20, 1980. Prior to start, the hydraulic reservoir level was set to 10 PCT. The data shows an increase in temperature rise as a result of less hydraulic fluid in the system. This rise amounted to 25^{o}F for nominal reservoir level (70 PCT); and 37-38^{o}F for a 10 PCT level. (See figures 58 and 59.) This condition proved to be nondetrimental to the system's performance (as stated for tests P037-286 and P037-287). The hydraulic supply pressure oscillations remained unchanged during the hot firing. (See figure 60.) There was no effect in the hydraulic reservoir and manifold pressure surges in terms of magnitude and number. (See figure 61.) The reservoir level dropped down to 6 PCT because of air in the system. This was expected for the provided starting level. Table 17 shows the overall performance of the hydraulic system for the test.

TABLE 17

TEST P077 – 320

LOW RESERVOIR LEVEL TEST 3

HYDRAULIC SYSTEM PERFORMANCE

HYDRAULIC MEASUREMENTS:

HYDRAULIC FLUID TEMPERATURE	ROCK		77–114 (115) °F		
	TILT		85–115 (122) °F		
		START	MIN	MAX	
RESERVOIR LEVEL	ROCK	10	8	14	PCT
	TILT	10	3	10	PCT
RESERVOIR PRESSURE	ROCK		60–63 PSIG		
	TILT		60–63 PSIG		
MANIFOLD PRESSURE	ROCK		62–66 PSIG		
	TILT		55–61 PSIG		

TEST P037-320
LOW RESERVOIR LEVEL RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
ROCK SYSTEM

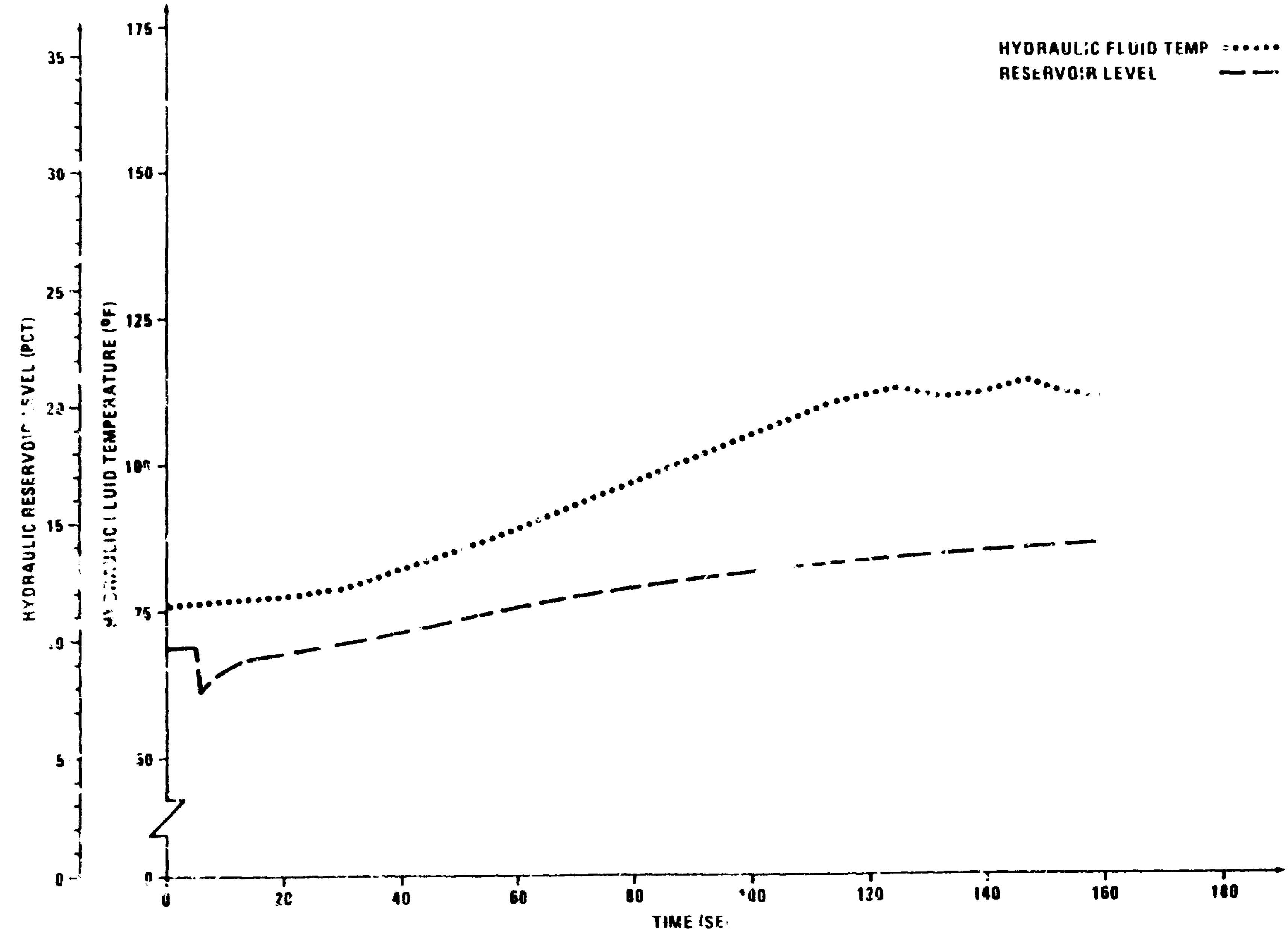


FIGURE 58

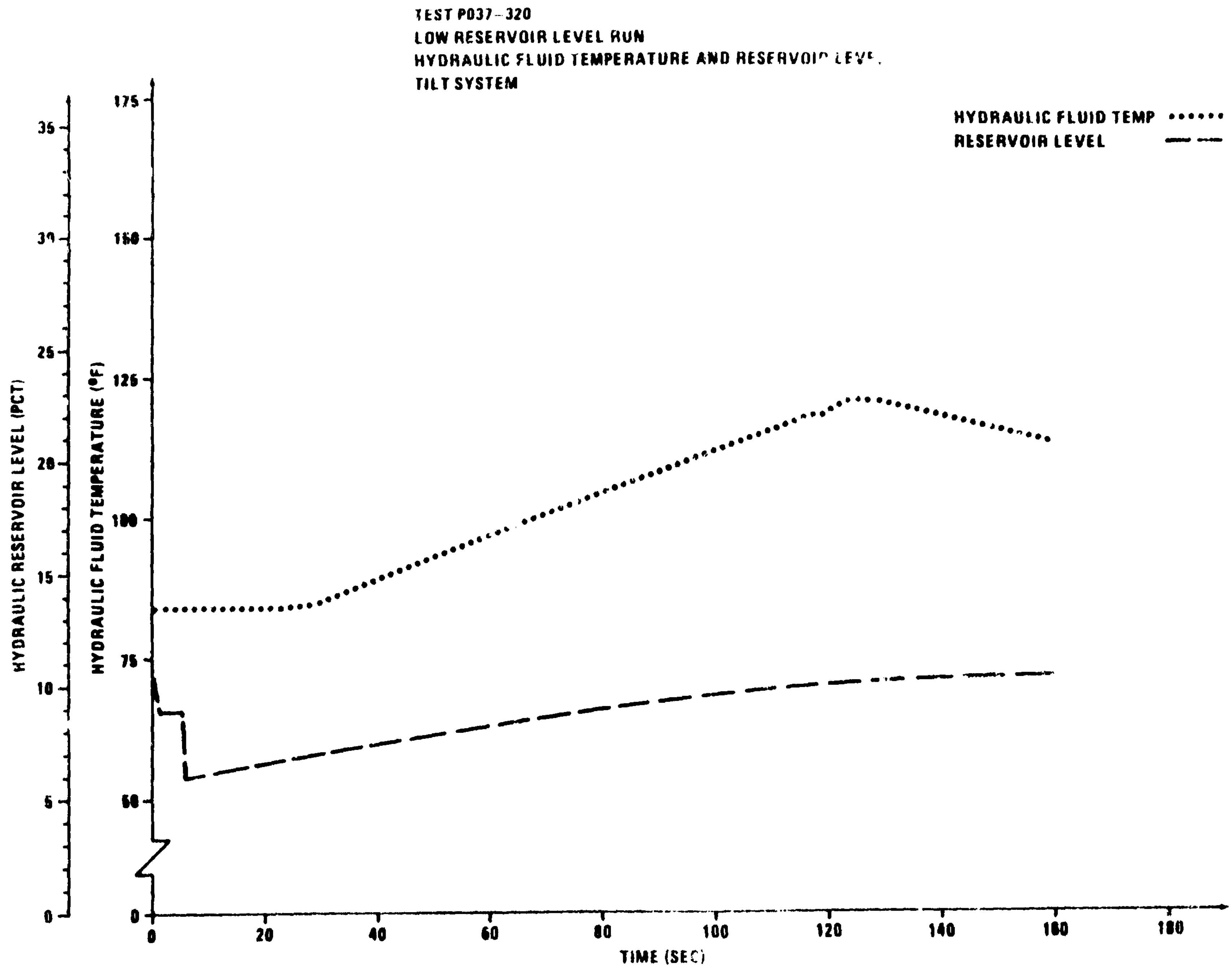

TEST P037-320
LOW RESERVOIR LEVEL RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
TILT SYSTEM
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL
HYDRAULIC RESERVOIR LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
TIME (SEC)
0
20
40
60
80
100
120
140
160
180
50
75
100
125
150
175
5
10
15
20
25
35

FIGURE 59

TEST P037–320
LOW RESERVOIR LEVEL TEST
TVC SUBSYSTEM TRANSIENT
TILT SYSTEM

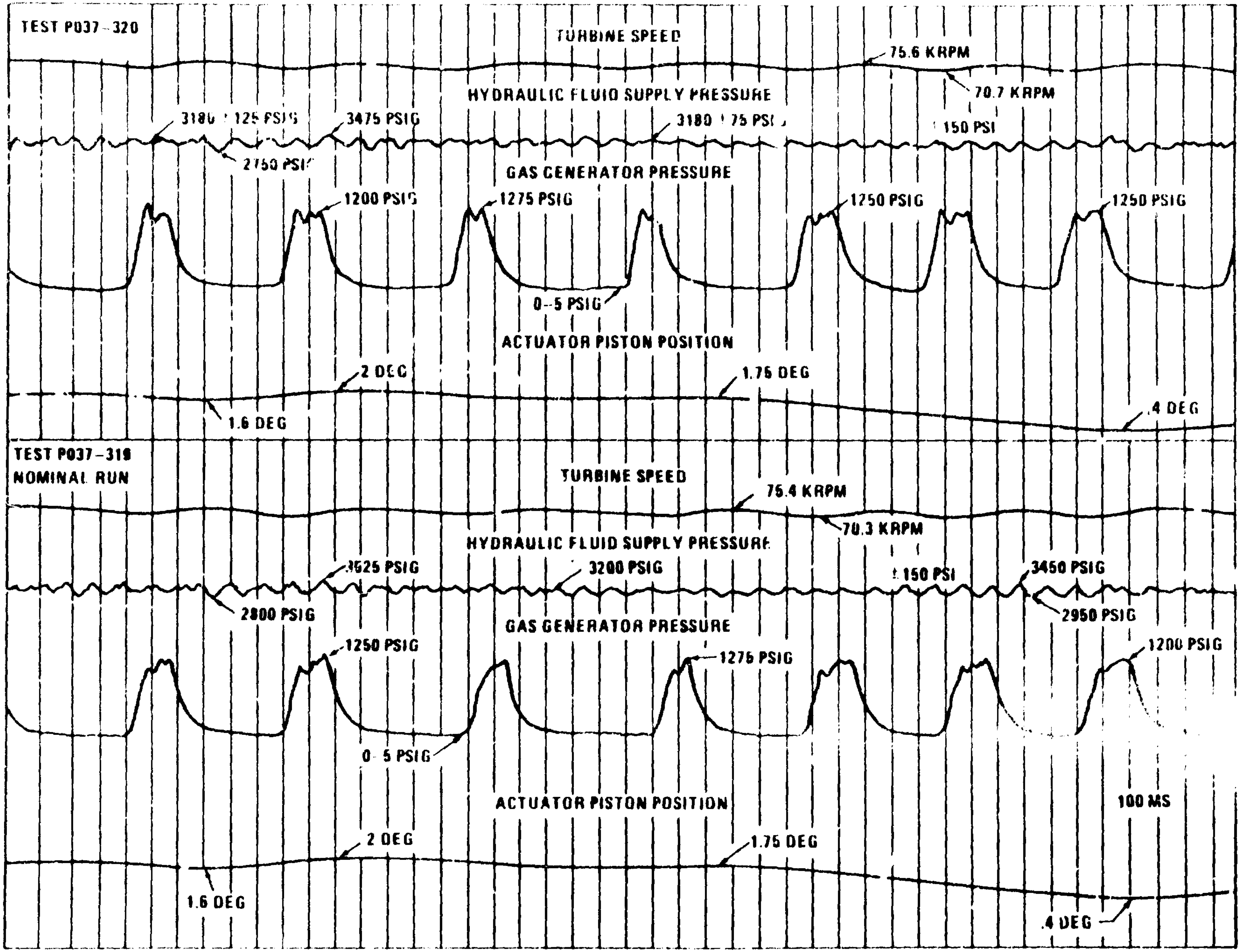


FIGURE 60

TEST P037-320 LOW RESERVOIR LEVEL TEST
RESERVOIR AND MANIFOLD HYDRAULIC PRESSURE TRANSIENT

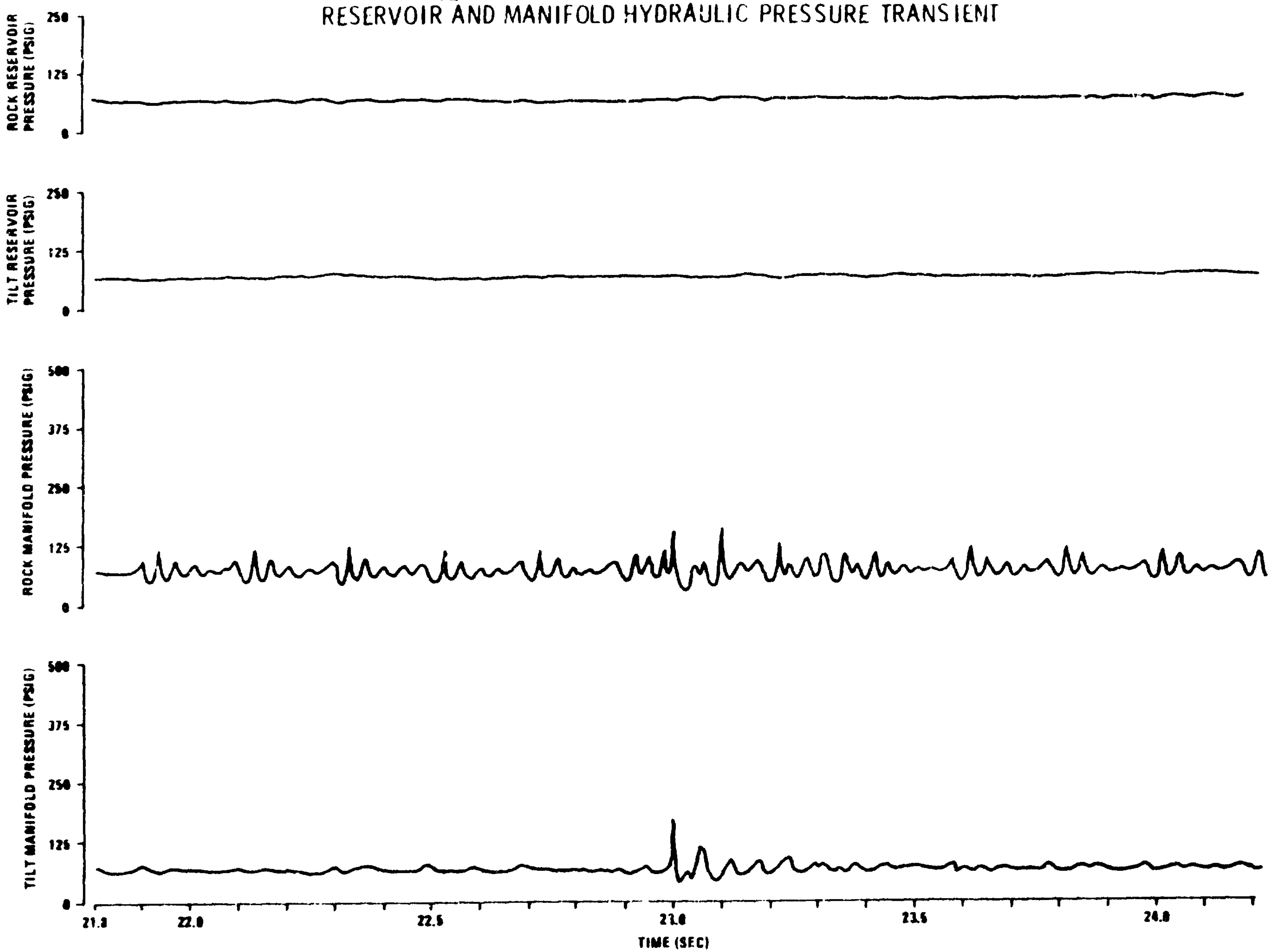


FIGURE 61

DETAILED AREA OF D GIMBAL PROGRAM

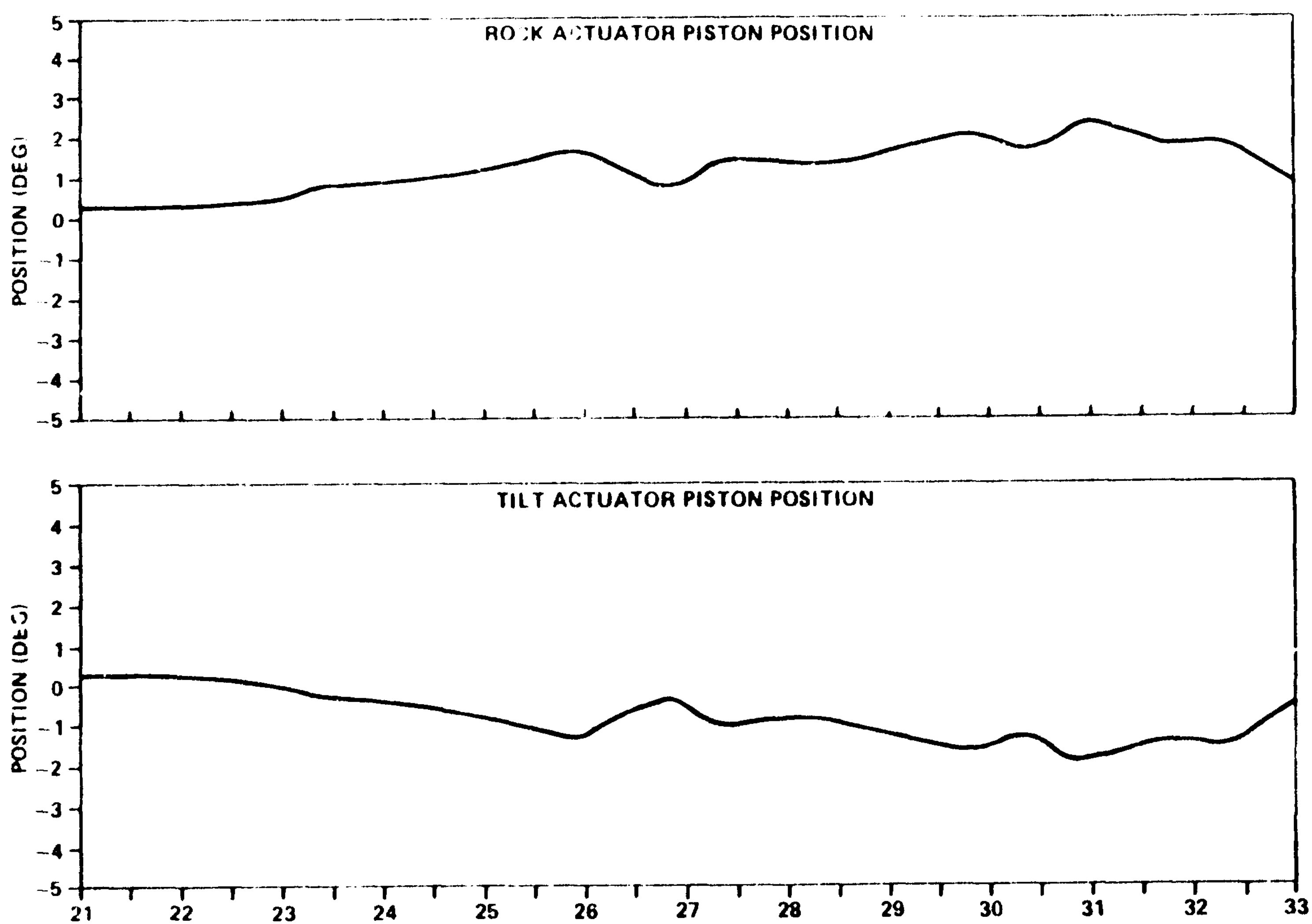


FIGURE 62

GN_2 SPIN TESTS

1000 PSIG GN_2 SPIN PRESSURE

OBJECTIVE

To map performance of TVC subsystem when subjected to a spin pressure of 1000 psig.

RESULTS

Five GN_2 spin tests were successfully conducted on March 22, 1980. Each spin test lasted 300 seconds. In summary, the most significant results obtained during these series are:

a. Higher turbine speed.

b. Improved hydraulic system performance. (Pressure oscillations during gimbal program are more stable.)

c. Higher lube oil temperature rise as a consequence of the higher turbine speed.

The gimbal program used for these runs was the same as for spin tests set of GN_2 spin pressures of 800 psig. Additional data showing the results stated above plus other follows. (Tables 18 through 22 and figures 63 through 65.)

The GN_2 spin pressure normally drops 50-100 psi from the original setting of 1000$\pm$50 psig. This accounts for the difference in pressure reading for each test.

Lube oil temperature readings utilized for this mapping are: T6AUX taken at the lube oil pump outlet, and T6 taken 12 inches downstream.

TABLE 18

TEST RESULTS ON

TEST NO P037-321

DATE 5/22/80

TYPE HIGH PRESSURE GN_2 SPIN TEST (1000 PSIG)

		ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3250 ± 10	3180 +20/−0
SECONDARY PR (PSIG)		3175 +25/−0	3200 +15/−10
HYDRAULIC RESERVOIR TEMP (°F)		66–91	74–101
HYDRAULIC RESERVOIR LEVEL (PCT)		74–73–78	77–71–76
HYDRAULIC RESERVOIR PR (PSIG)		60 ± 5	60 +5/−0
HYDRAULIC MANIFOLD PR (PSIG)		60 ± 5	60 ± 2
LP RELIEF VALVE (PSIG)		0–107	0–51
FSM TEMP (°F)		70	68–67
FSM PR. (PSIG)		129	137
TURBINE SPEED (K-RPM)			
	START	52.56	53.16
	MIN-MAX PROGRAM	42.45–49	42.09–48.86
LUBE OIL TEMP (°F)			
	T6	68–133	66–147
	T6 AUX	63–133	65–149
TURBINE SPIN PR (PSIG)		887	890
TURBINE SPIN TEMP (°F)		74–44	80–29
AMBIENT TEMP (°F)		NA (BAD MEAS)	NA (BAD MEAS)

TABLE 19

TESTS RESULTS ON

TEST NO	P037-322
DATE	5/22/80
TYPE	HIGH PRESSURE GN_2 SPIN TEST (1000 PSIG)

		ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3250 ± 15	3180 ± 20
SECONDARY PR (PSIG)		3200 ± 10	3250 $^{+20}_{-15}$
HYDRAULIC RESERVOIR TEMP (°F)		84–107	93–118
HYDRAULIC RESERVOIR LEVEL (PCT)		74–77	76–73–77
HYDRAULIC RESERVOIR PR (PSIG)		NA	NA
HYDRAULIC MANIFOLD PR (PSIG)		NA	NA
LP RELIEF VALVE (PSIG)		0–124	0–71
FSM TEMP (°F)		70	67
FSM PR (PSIG)		130	134
TURBINE SPEED (K-RPM)			
	START	53.51	53.64
	MIN-MAX PROGRAM	42.71–48.38	43.03–49.84
LUBE OIL TEMP (°F)			
	T6	84–150	84–156 °F
	T6 AUX	75–150	74–161 °F
TURBINE SPIN PR (PSIG)		915	917–919
TURBINE SPIN TEMP (°F)		63–46	74–30
AMBIENT TEMP (°F)		NA	NA

ROCK LUBE OIL TEMPERATURE
TEST P037 - 322
1000 PSIG GN_2 SPIN PRESSURE

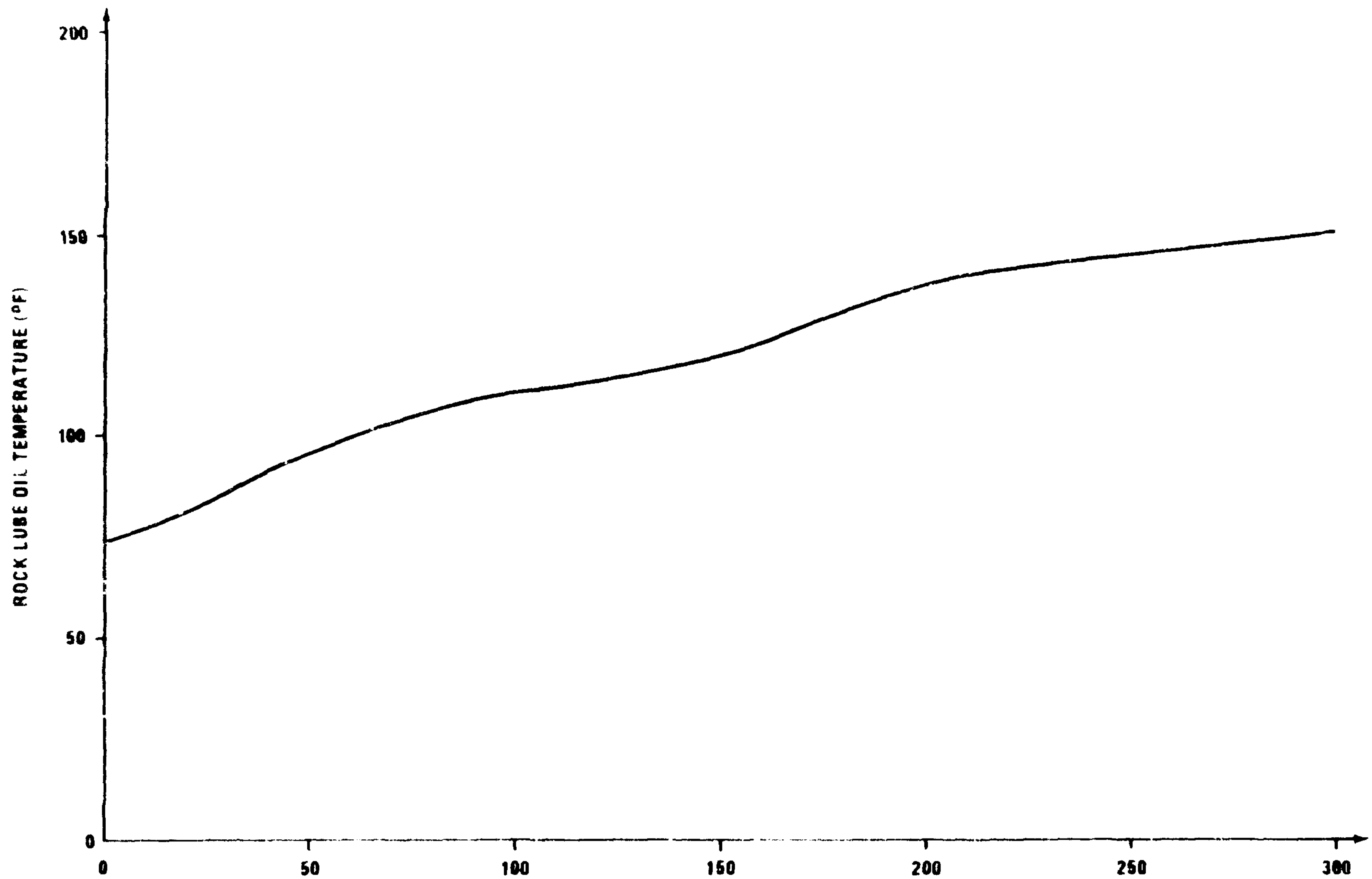


FIGURE 63

TILT LUBE OIL TEMPERATURE

TEST P037 - 322

1000 PSIG GN_2 SPIN PRESSURE

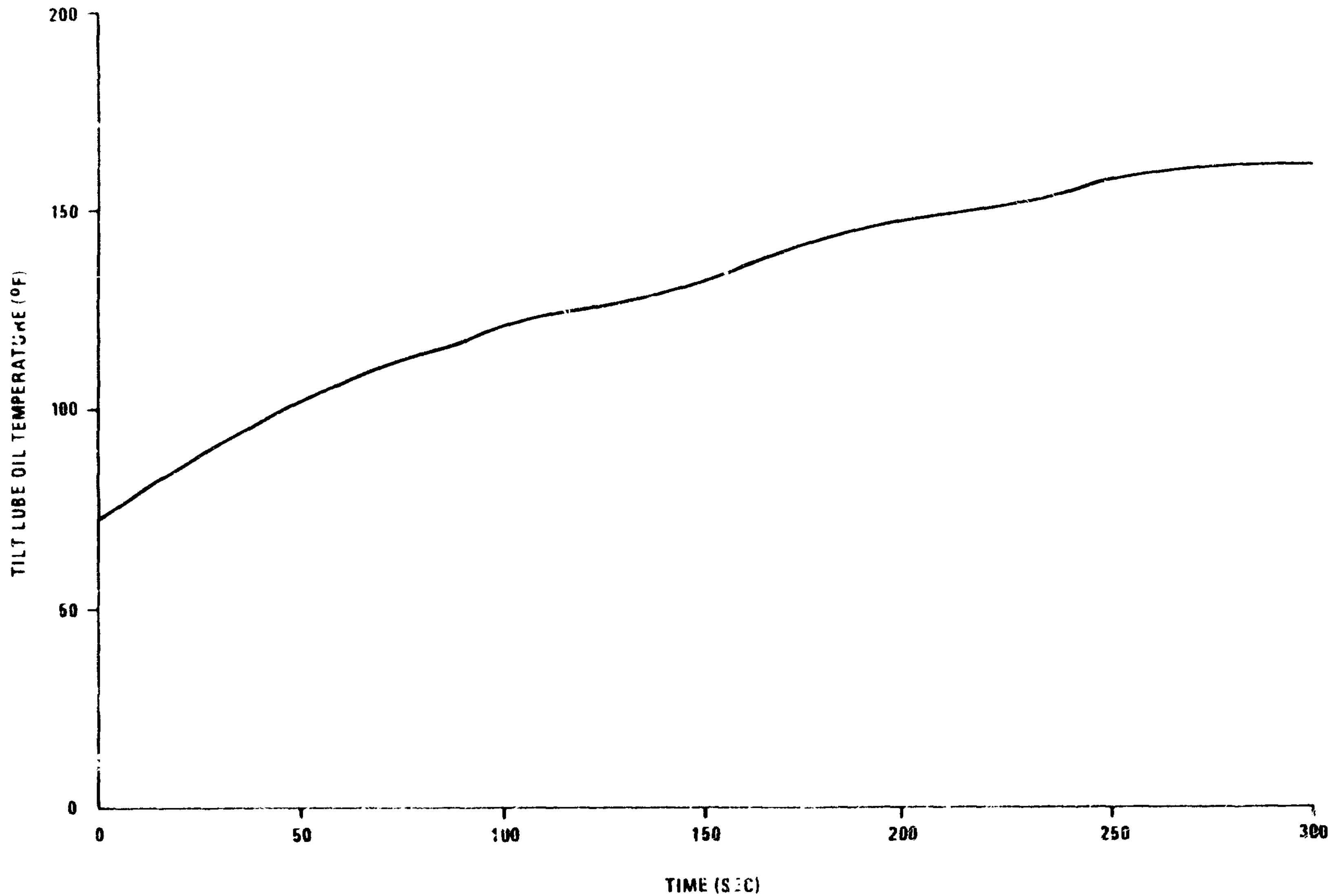


FIGURE 64

TABLE 20

TEST RESULTS ON

TEST NO P037-323
DATE 5/22/80
TYPE HIGH PRESSURE GN_2 SPIN TEST (1000 PSIG)

		ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3250 +20/-10	3180 ± 10
SECONDARY PP (PSIG)		3180 ± 15	3250 +25/-10
HYDRAULIC RESERVOIR TEMP (°F)		97-117	105-127
HYDRAULIC RESERVOIR LEVEL (PCT)		76-75-80	77-74-78
HYDRAULIC RESERVOIR PR (PSIG)		NA	NA
HYDRAULIC MANIFOLD PR (PSIG)		NA	NA
LP RELIEF VALVE (PSIG)		122-170	56-75
FSM TEMP (°F)		68	67-66
FSM PR (PSIG)		127	131
TURBINE SPEED (K-RPM)			
	START	53.44	53.80
	MIN-MAX PROGRAM	42.59-49.27	42.64-49.72
LUBE OIL TEMP (°F)			
	T6	97-157	96-164
	T6 AUX	84-154	86-165
TURBINE SPIN PR (PSIG)		910-913	917-915
TURBINE SPIN TEMP (°F)		66-44	80-28
AMBIENT TEMP (°F)		NA	NA

*STARTED AT 122 PSIG
X STARTED AT 70 PSIG

TABLE 21

TESTS RESULTS ON	
TEST NO	P037–324
DATE	5/22/90
TYPE	HIGH PRESSURE GN_2 SPIN TEST (1000 PSIG)

		ROCK	[illegible]
HYDRAULIC SUPPLY PR (PSIG)		3250 +15/–10	3200 ± 20
SECONDARY PR (PSIG)		3180 +15/–10	3250 +30/–10
HYDRAULIC RESERVOIR TEMP (°F)		107–126	115–135
HYDRAULIC RESERVOIR LEVEL (PCT)		76–76–81	78–75–79
HYDRAULIC RESERVOIR PR (PSIG)		NA	NA
HYDRAULIC MANIFOLD PR (PSIG)		NA	NA
LP RELIEF VALVE (PSIG)		0–126	0–90
FSM TEMP (°F)		69	67–66
FSM PR (PSIG)		137	137
TURBINE SPEED (K–RPM)			
	START	53.51	53.96
	MIN–MAX PROGRAM	42.44–49.20	42.12–49.80
LUBE OIL TEMP (°F)	T6	104–168	103–169
	T6 AUX	88–159	91–173
TURBINE SPIN PR (PSIG)		913–910	916–913
TURBINE SPIN TEMP (°F)		65–46	75–28
AMBIENT TEMP (°F)		NA	NA

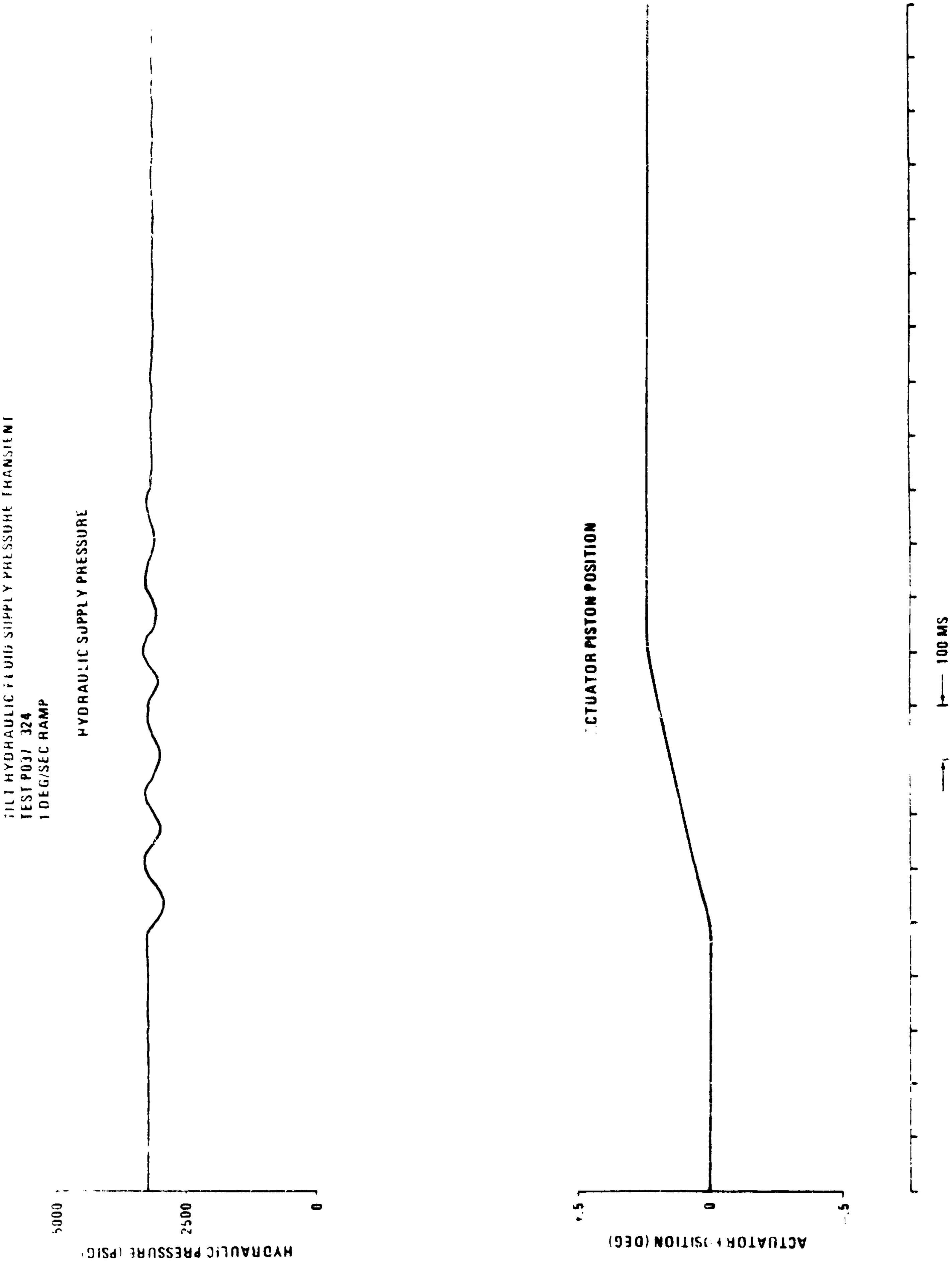

TILT HYDRAULIC FLUID SUPPLY PRESSURE TRANSIENT
TEST P037 324
1 DEG/SEC RAMP
HYDRAULIC SUPPLY PRESSURE
5000
2500
0
HYDRAULIC PRESSURE (PSIG)
ACTUATOR PISTON POSITION
+.5
0
-.5
ACTUATOR POSITION (DEG)
100 MS

FIGURE 65

TABLE 22

TESTS RESULTS ON	
TEST NO	P037–325
DATE	5/22/80
TYPE	HIGH PRESSURE GN_2 SPIN TEST (1000 PSIG)

		ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3250 +15/–10	3200 ±20
SECONDARY PR (PSIG)		3200 ±15	3200 +30/–10
HYDRAULIC RESERVOIR TEMP (°F)		109–129	117–138
HYDRAULIC RESERVOIR LEVEL (PCT)		77–76–81	77–75–79
HYDRAULIC RESERVOIR PR (PSIG)		NA	NA
HYDRAULIC MANIFOLD PR (PSIG)		NA	NA
LP RELIEF VALVE (PSIG)		0–128	0–87
FSM TEMP (°F)		69	67–66
FSM PR (PSIG)		133	134
TURBINE SPEED (K–RPM)			
	START	53.39	54.04
	MIN–MAX PROGRAM	40.89–49.12	42.38–50.10
LUBE OIL TEMP	T6	105–188	104–178
	T6 AUX	85–177	88–180
TURBINE SPIN PR (PSIG)		912–910	915–913
TURBINE SPIN TEMP (°F)		62–46	74–30
AMBIENT TEMP (°F)		NA	NA

GEARBOX POST TEST TEMPERATURE STABILIZATION

OBJECTIVE

To map the thermal conduction from the gearcase to the APU N_2H_4 pump following a high pressure GN_2 spin and a hot firing.

RESULTS

The gearbox post test temperature profile during high pressure GN_2 spin tests and hot firings was obtained to study the effects of heat transfer from the gearbox to the fuel pump on the N_2H_4 temperature and the possibility of N_2H_4 ignition. The data shows that the gearbox skin temperature stabilizes at 155°F (worst case) during hot firings; and consequently the temperature rise in the fuel pump reached 135-137°F with a 10-minute stabilization period (see figures 66 and 67). This temperature rise is not detrimental to the APU, or to the N_2H_4 trapped in the fuel lines after a hot firing. GN_2 spin tests experienced a lesser rise with the fuel pump temperature reaching 115°F (worst case) and stabilized in 2 minutes. This resulted from a lesser temperature gradient (as expected) in the gearcase. Lube oil (gearbox) temperature for hot firings reached 181-188°F and for GN_2 spin tests reached 166°F.

The measurements for this analysis were taken at the gearbox, fuel pump top side, and fuel pump bottom side of rock APU. All readings are skin measurements. GN_2 spins utilized for this analysis were P037-317 and P037-323 with GN_2 spin pressures of 800 psig and 1000 psig respectively. Both spin tests lasted 5 minutes. Hot firings involved were test P037-319 and P037-320.

TEST P037 - 319
GEAR CASE AND FUEL PUMP TEMPERATURE PROFILE

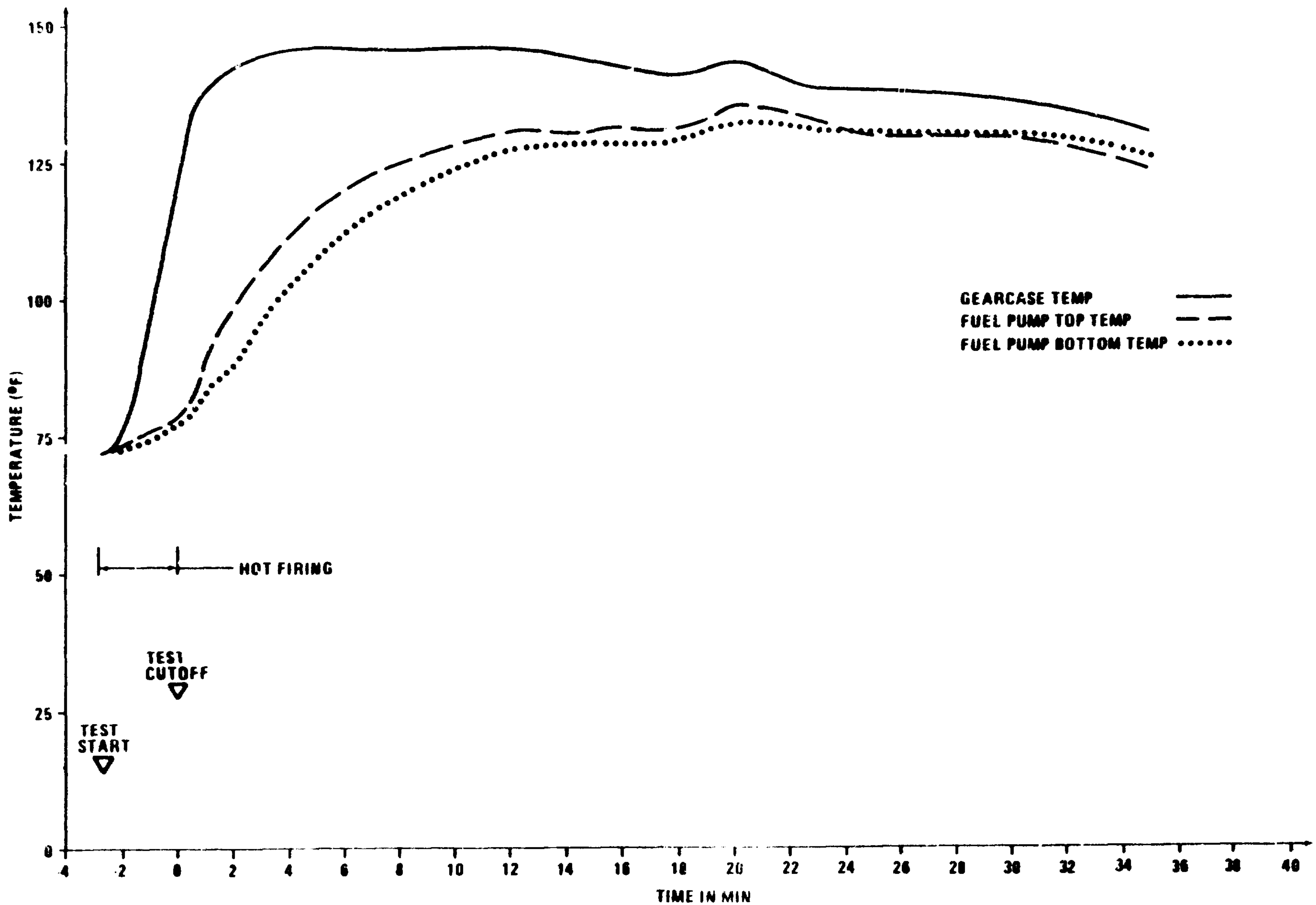


FIGURE [illegible]

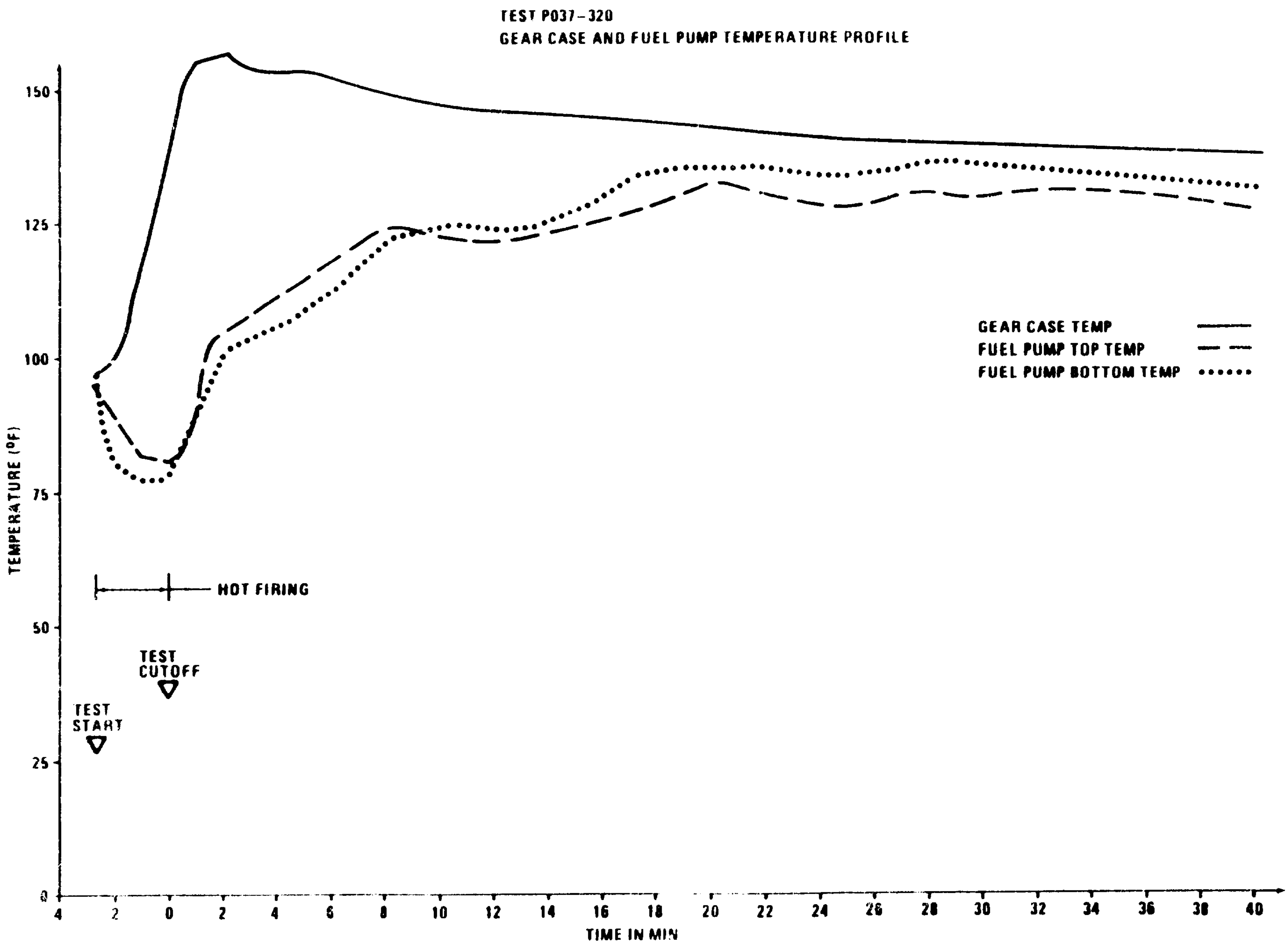

TEST P037-320
GEAR CASE AND FUEL PUMP TEMPERATURE PROFILE
TEMPERATURE (°F)
150
125
100
75
50
25
0
GEAR CASE TEMP
FUEL PUMP TOP TEMP
FUEL PUMP BOTTOM TEMP
HOT FIRING
TEST CUTOFF
TEST START
4
2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TIME IN MIN

FIGURE 67

HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION

OBJECTIVE

To simulate a hydraulic pump compensator failure and observe its effects on the TVC hydraulic system.

RESULTS

Test P037-329 and P037-330 were successfully conducted on June 2 and 4, 1980. Test P037-329 simulated the compensator failure in the backup mode (only one APU operating) while test P037-330 simulated the failure during a nominal mission. The tilt hydraulic pump compensator was set to 3850-3900 psig prior to hot firing. The TVC subsystem performed acceptably under the tests conditions encountered.

The TVC actuators followed the commands imposed similarly to nominal runs (see figures 68 and 74). Additional fuel usage resulted from the greater hydraulic power output required by the new compensator setting (as shown by the fuel supply module pressure decay in figure 69). This condition was reflected by higher APU temperatures (figures 70 and 75), but was not detrimental to the TVC subsystem operations. The APU turbine ran at nominal speed for the backup mode test, but showed an increase in speed band for the 100-percent operation hot firing. This degraded performance resulted from the greater power output by the APU. This behavior was not present in test P037-329 because only tilt actuator was gimbaled. The hydraulic fluid temperature increased more than in nominal hot firings because of the greater heat dissipation resulting from the additional

PRECEDING PAGE BLANK NOT FILMED

hydraulic pump pressure output (figures 71 and 76). Consequently, the reservoir level rose slightly more than in nominal runs. The hydraulic pump maintained the required pressure throughout both hot firings. The hydraulic supply pressure experienced a slight degree of instability caused by the additional hydraulic power output. The instability consisted of more pressure oscillations and greater amplitudes (see figures 72 and 77). This had no harmful effect in TVC hardware performance. The data show no high pressure relief valve actuation due to pressure surges. The hydraulic fluid supply pressure experienced no clips and the APU performance diminished slightly as expected. The manifold return and reservoir pressures showed a slight increase in nominal pressure and pressure spikes as expected. (See figures 78 and 79.) Figures 73 and 80 show a selected transient area for each hot firing compared to a nominal run.

Tables 23 and 24 summarize the overall system's performance for each firing.

Prior to these hot firings, a series of GN_2 spin tests were run to set and verify this compensator setting. A minor problem forced the repetition of these runs when the hydraulic high pressure relief valve became active several times during the spin tests. This lead to a turbine speed drop that eventually violated the low speed redlines. Adjustments made before test P037-328 prevented this situation from reoccurring. An additional GN_2 spin (test P037-331) was conducted without any problems following the last hot firing to set and verify that the hydraulic pump compensator setting returned to the original nominal pressure.

TABLE 23

TEST RESULTS ON

TEST NO.	P037-329
DATE	6/2/80
TYPE	FULL DURATION HOT FIRING TILT SYSTEM ONLY HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION BACKUP MODE

	TILT
HYDRAULIC SUPPLY PR. (PSIG)	3900 ±20
SECONDARY PR. (PSIG)	NA
ACTUATOR DIFFERENTIAL PR. (PSIG)	NA (BAD MEAS.)
HYDRAULIC RESERVOIR TEMP (°F)	98 - 140
HYDRAULIC RESERVOIR LEVEL (PCT)	70 - 67 - 72
HYDRAULIC RESERVOIR PR. (PSIG)	70 - 77
HYDRAULIC MANIFOLD PR. (PSIG)	NA (BAD MEAS.)
LP RELIEF VALVE PR. (PSIG)	112-180
CASE DRAIN PR. (PSIG)	NA
FSM TEMP (°F)	84 - 85
FSM PR. (PSIG)	367 - 268
FUEL PUMP INLET PR. (PSIG)	358 - 263
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)	NA
MAXIMUM GAS GENERATOR PR. (PSIG)	1400 (AT 15 SEC) 1450 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP (°F)	208 - 1151 (1175)
TURBINE EXHAUST TEMP (°F)	88 - 654
TURBINE SPEED (K-RPM)	77.02 - 82.72
LUBE OIL TEMP T6	94 - 208
T6 AUX	92 - 216

TABLE 23 (CONT.)

TEST RESULTS ON (CONT.)

TEST NO. F037-329

DATE 6/2/80

TYPE FULL DURATION HOT FIRING TILT SYSTEM ONLY
HYDRAULIC PUMP COMPENSATOR FAILURE
SIMULATION BACKUP MODE

VALVES CONDITION AND OPERATION	
HYDRAULIC BYPASS VALVE	OK
FIV	OK
SOV	OK (110 PCT OPERATION)
SWITCHING VALVE	OK (110 PCT OPERATION)
PCV CYCLING	
CONDITION	OK
VALVE TIME OPEN START	150 MS
END	140 MS
PERCENT OPEN	
NO GIMBAL	23.9%
5 DEG/SEC	43.3%
GIMBAL PROGRAM	31.9%
END	19.9%
OPEN TRANSIENT	70 MS
CLOSING TRANSIENT	NA
PRESSURE OSCILLATION	±80 PSI
START TRANSIENT TIME	2.97 SEC.
HYDRAULIC PRESSURE OSCILLATIONS	
5 DEG/SEC LOW-HIGH	2800 – 4100 PSIG
GIMBAL PROGRAM	3500 – 4050 PSIG
NOMINAL PRESSURE	3900 PSIG
LOW PRESSURE TRANSIENTS	
RESERVOIR	75 – 85 PSIG (55 PSIG MIN.)
MANIFOLD	NA

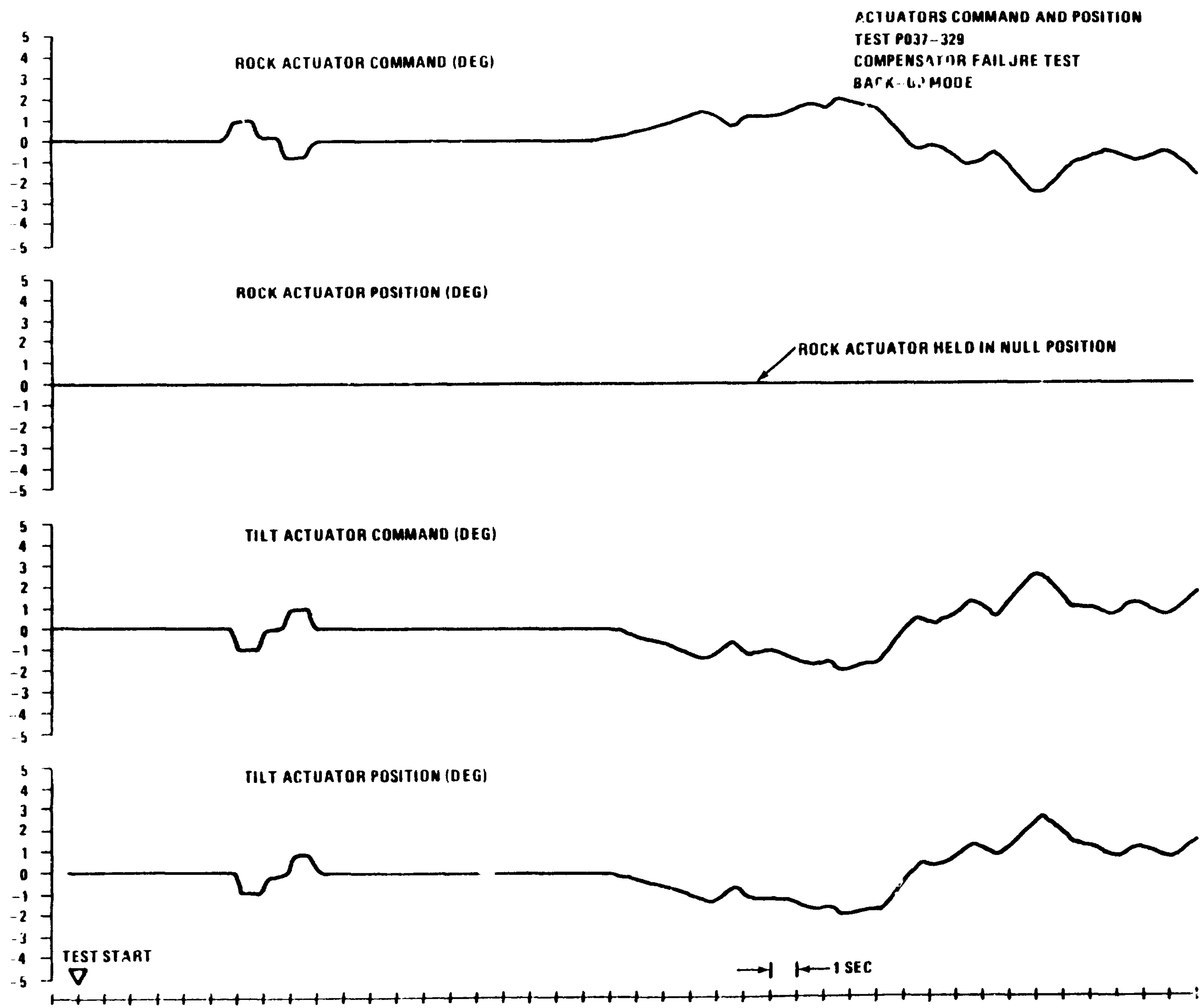
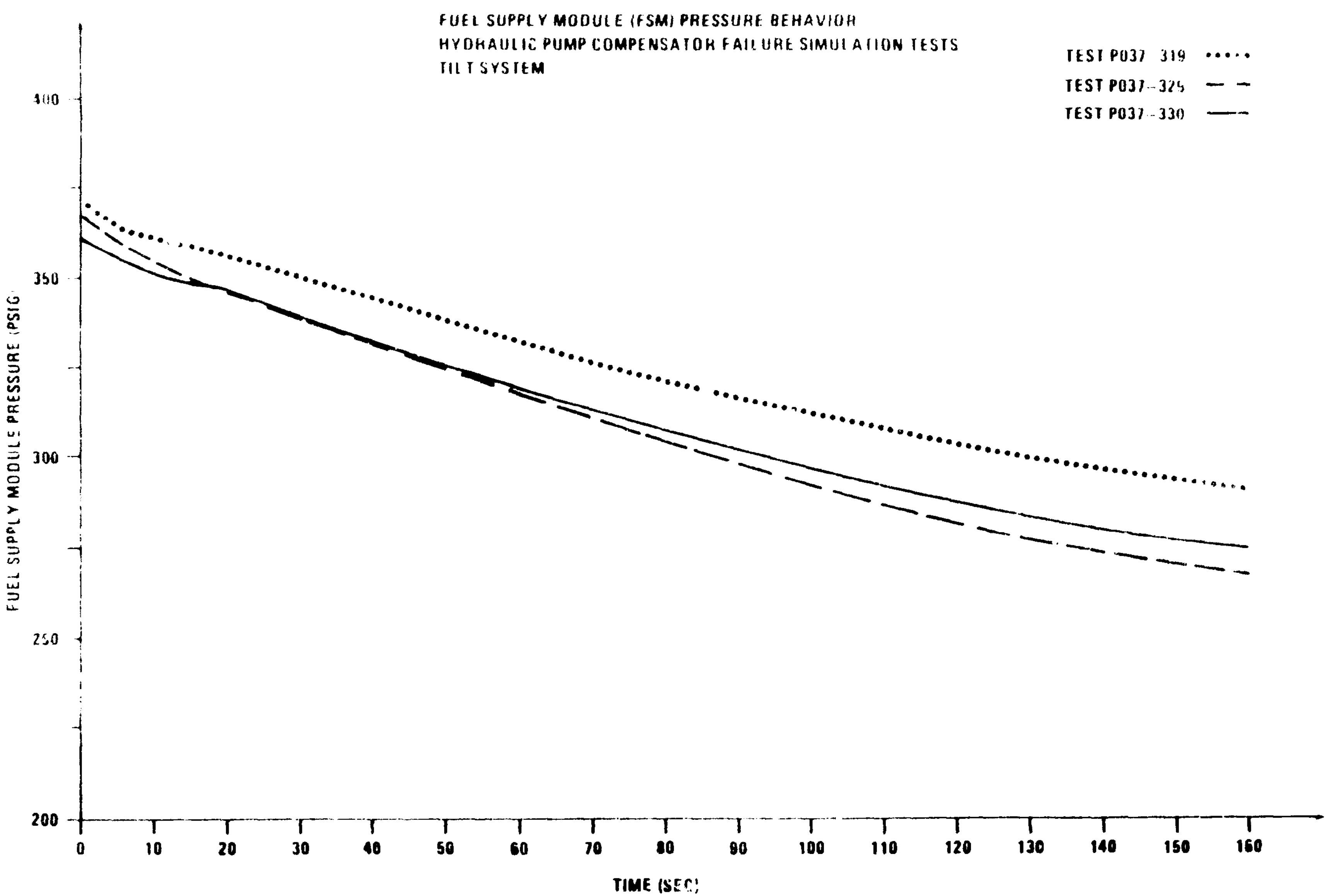

ACTUATORS COMMAND AND POSITION
TEST P037-329
COMPENSATOR FAILURE TEST
BACK-UP MODE
ROCK ACTUATOR COMMAND (DEG)
ROCK ACTUATOR POSITION (DEG)
ROCK ACTUATOR HELD IN NULL POSITION
TILT ACTUATOR COMMAND (DEG)
TILT ACTUATOR POSITION (DEG)
TEST START
1 SEC
5
4
3
2
1
0
-1
-2
-3
-4
-5

FIGURE 68


FUEL SUPPLY MODULE (FSM) PRESSURE BEHAVIOR
HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION TESTS
TILT SYSTEM
TEST P037 319
TEST P037–325
TEST P037–330
FUEL SUPPLY MODULE PRESSURE (PSIG)
400
350
300
250
200
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)
FIGURE 69

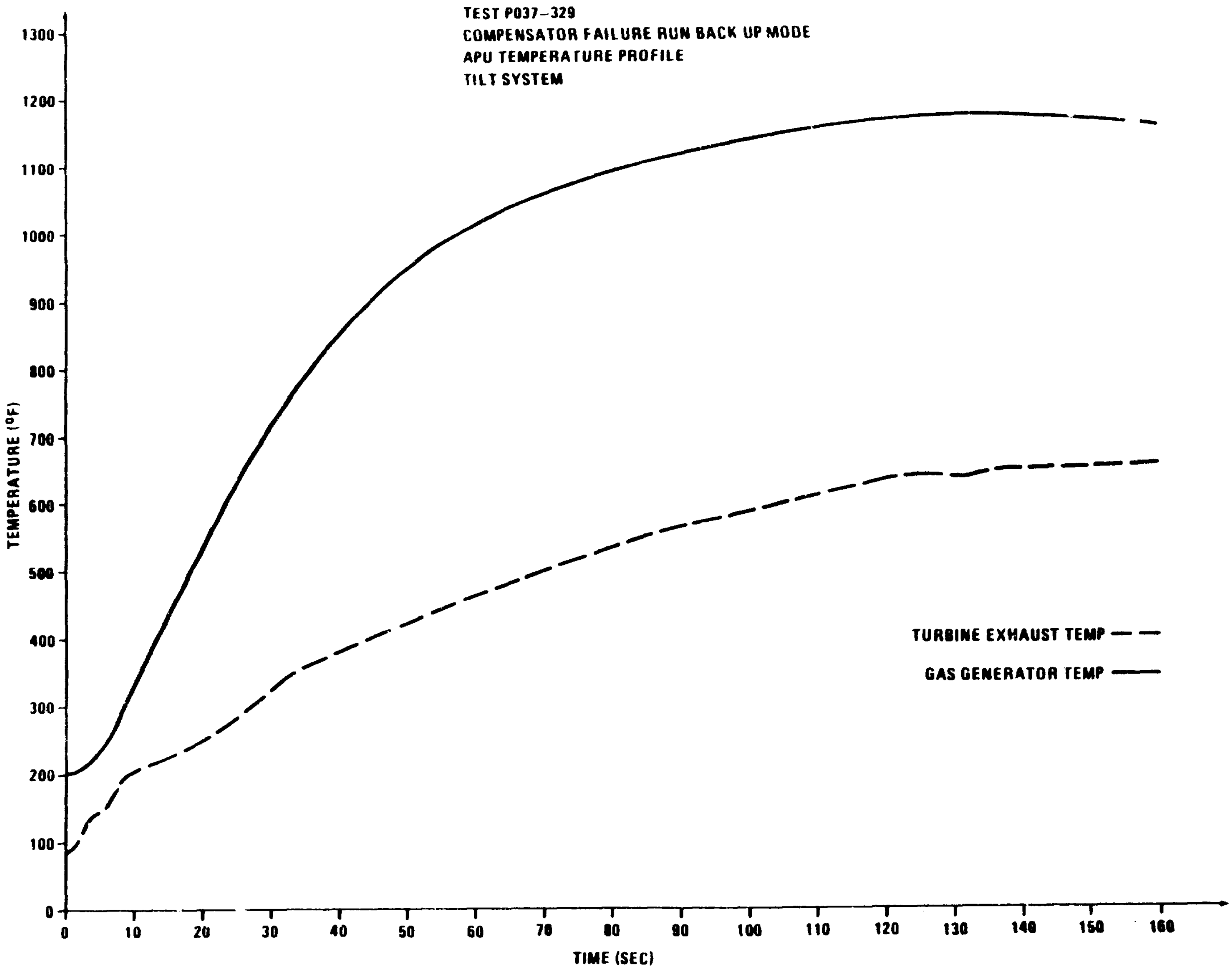

TEST P037–329
COMPENSATOR FAILURE RUN BACK UP MODE
APU TEMPERATURE PROFILE
TILT SYSTEM
TEMPERATURE (°F)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)
TURBINE EXHAUST TEMP
GAS GENERATOR TEMP

FIGURE 70

TEST P037-129
COMPENSATOR FAILURE SIMULATION RUN BACK UP MODE
RESERVOIR PARAMETERS
TILT SYSTEM

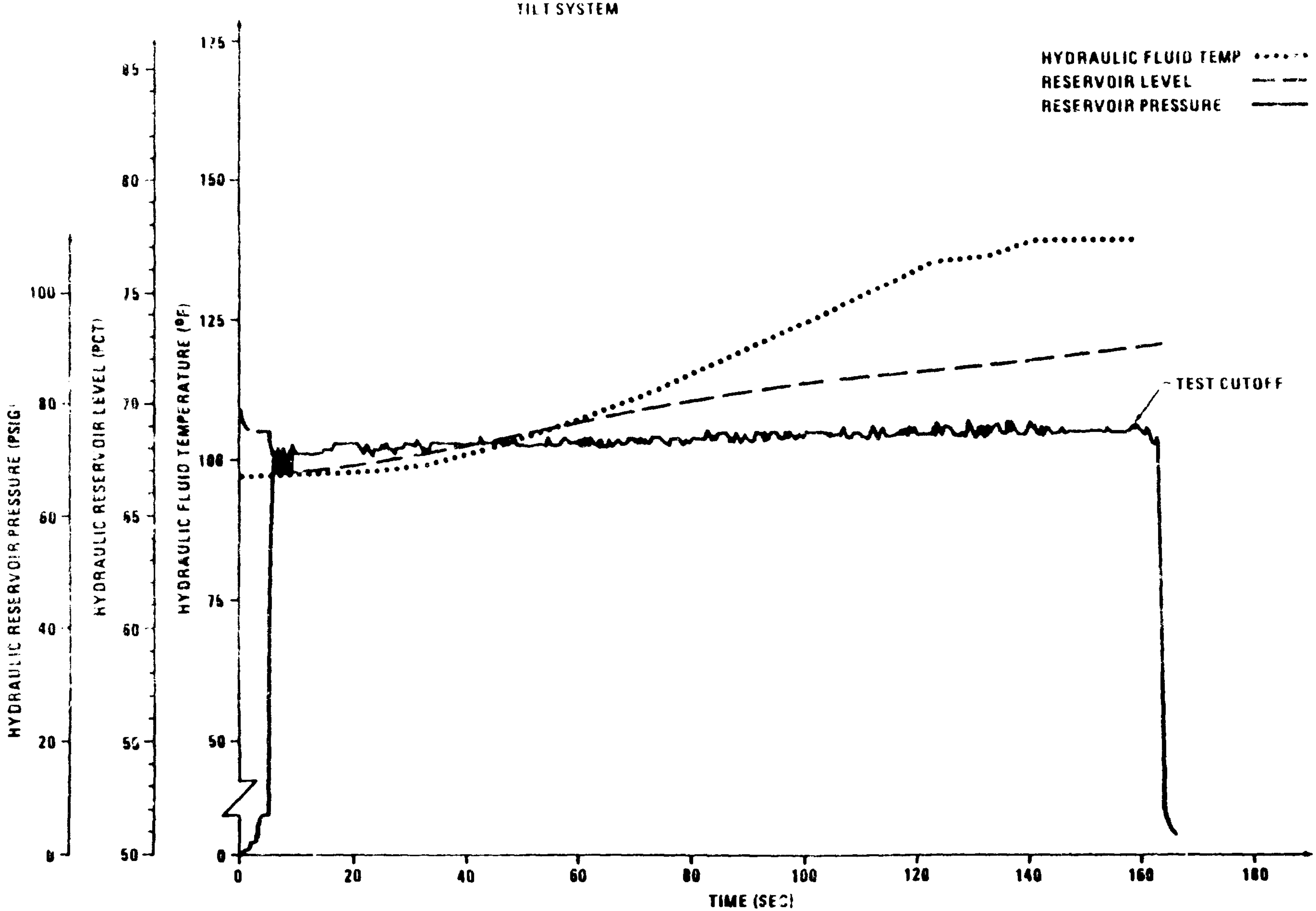


FIGURE 71

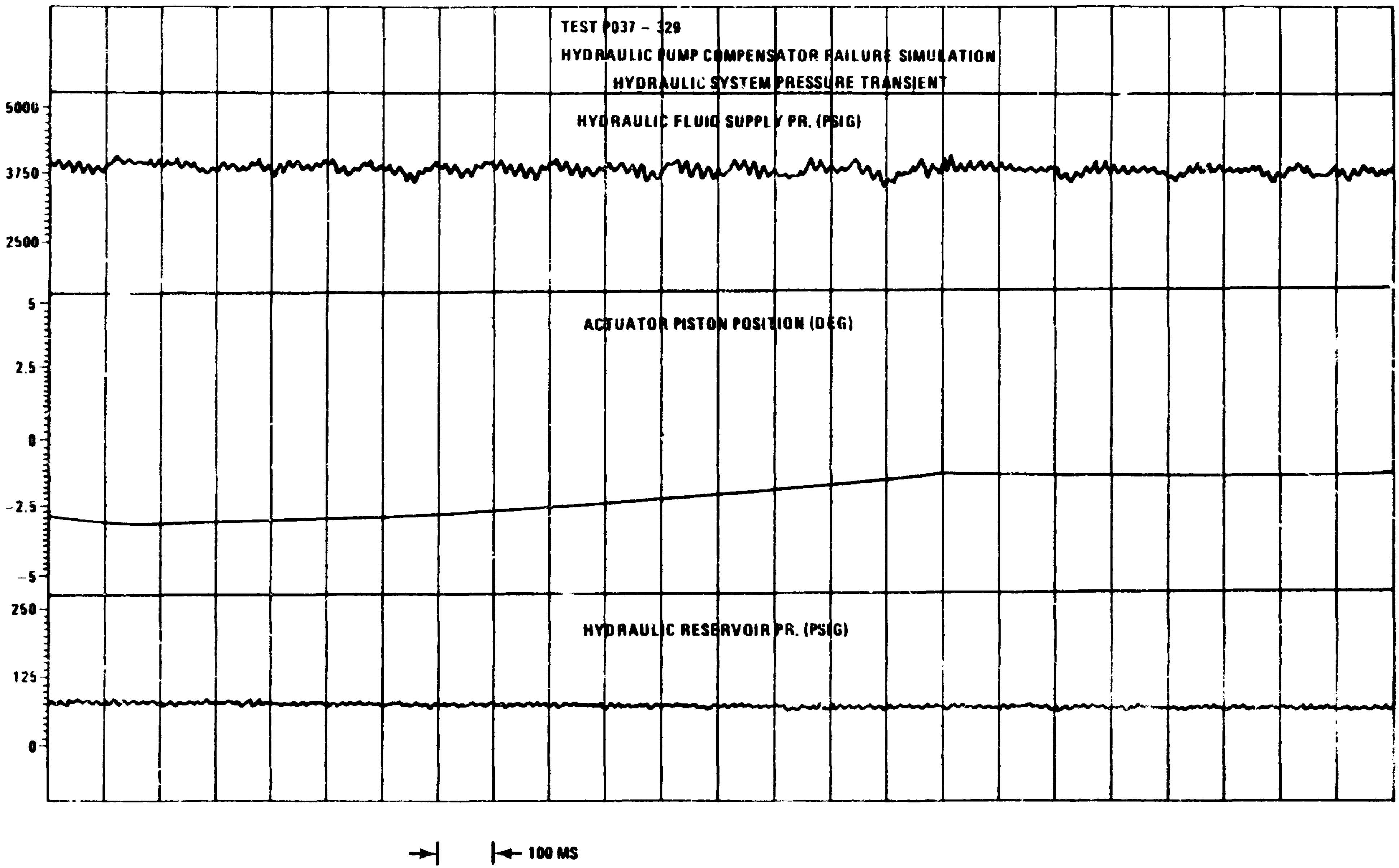

TEST P037 – 329
HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION
HYDRAULIC SYSTEM PRESSURE TRANSIENT
HYDRAULIC FLUID SUPPLY PR. (PSIG)
ACTUATOR PISTON POSITION (DEG)
HYDRAULIC RESERVOIR PR. (PSIG)
5000
3750
2500
5
2.5
0
–2.5
–5
250
125
0
100 MS

FIGURE 72

TEST P037-329
COMPENSATOR FAILURE - BACKUP MODE
TVC SUBSYSTEM TRANSIENT
DLT SYSTEM

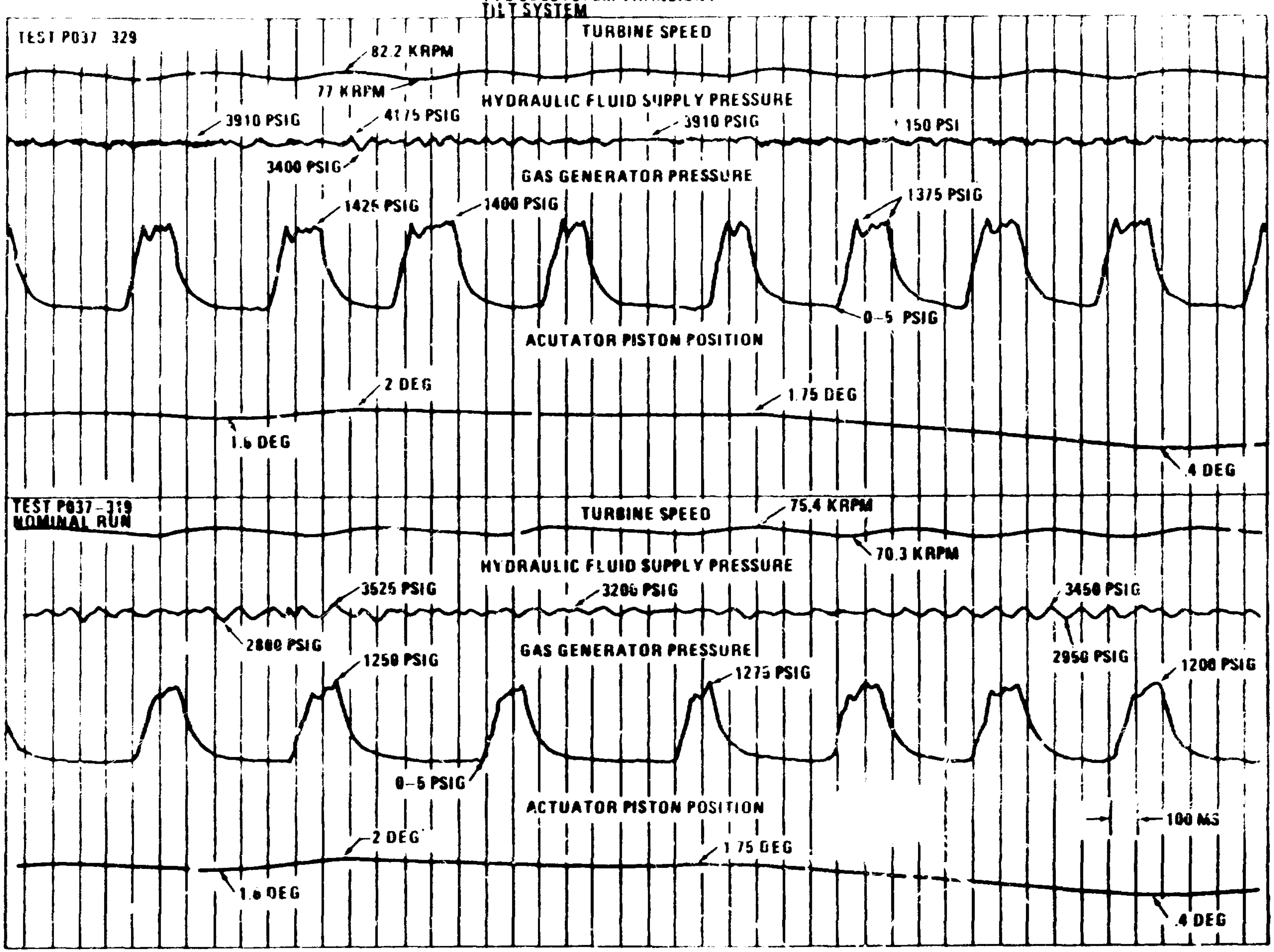


FIGURE 73

TABLE 24
TEST RESULTS ON

TEST NO. P037–330
DATE 6/4/80
TYPE HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION HOT FIRING

	ROCK	TILT
HYDRAULIC SUPPLY PR. (PSIG)	3240 ± 25	3875 + 30/ −20
SECONDARY PR. (PSIG)	3640 ± 35	3200 ± 30
ACTUATOR DIFFERENTIAL PR. (PSID)	240 ± 30	NA
HYDRAULIC RESERVOIR TEMP. (°F)	84 – 110	92 – 133
HYDRAULIC RESERVOIR LEVEL (PCT)	78 – 77 – 84	68 – 66 – 71
HYDRAULIC RESERVOIR PR. (PSIG)	60 – 69	73 – 79
HYDRAULIC MANIFOLD PR. (PSIG)	62 – 71	72 – 77
LP RELIEF VALVE PR. (PSIG)	237	95
CASE DRAIN PR. (PSIG)	62 – 71	NA
FSM TEMP (°F)	82	83 – 84
FSM PR. (PSIG)	373 – 282	383 – 275
FUEL PUMP INLET PR. (PSIG)	363 – 283	355 – 265
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)	NA	NA
MAXIMUM GAS GENERATOR PR. (PSIG)	NA	1200 (AT 15 SEC) 1325 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP (°F)	214 – 1125 (1132)	207 – 1147 (1152)
TURBINE EXHAUST TEMP (°F)	90 – 574 (584)	94 – 621 (628)
TURBINE SPEED (K–RPM)	70.99 – 75.49	69.84 (64.43) – 75.81
LUBE OIL TEMP T6	90 – 189	88 – 184
T6 AUX	85 – 188	87 – 186

TABLE 24 (CONT.)

TEST RESULTS ON (CONT.)

TEST NO	P037-330
DATE	6/4/80
TYPE	HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION HOT FIRING

VALVE CONDITIONS AND OPERATION		RUCK	TIL.
HYDRAULIC BYPASS VALVE		OK	OK
FIV		OK	OK
SOV		OK	OK
SWITCHING VALVE		NORMAL SWITCH	NORMAL SWITCH (5 SEC)
PCV CYCLING			
CONDITION			OK
VALVE TIME OPEN	START		.145 SEC
	END		.140 SEC
PERCENT OPEN			
NO GIMBAL			20.1%
5 DEG/SEC			46.0%
GIMBAL PROGRAM			32.6%
END			15.9%
OPEN TRANSIENT			75 MS
CLOSING "			15-20 MS
PRESSURE OSCILLATION			± 100 PSI
START TRANSIENT TIME			2.99 SEC
HYDRAULIC PRESSURE OSCILLATIONS			
5 DEG/SEC LOW - HIGH			2700-4150 PSIG
GIMBAL PROGRAM			3600-4150 PSIG
LOW PRESSURE TRANSIENTS			
RESERVOIR		36-70 PSIG	60-85 PSIG
MANIFOLD (PRESSURE AND DURATION)		0 PSIG (5-10 MS)	10 PSIG (5 MS)
		610 PSIG (5 MS)	405 PSIG (< 5 MS)

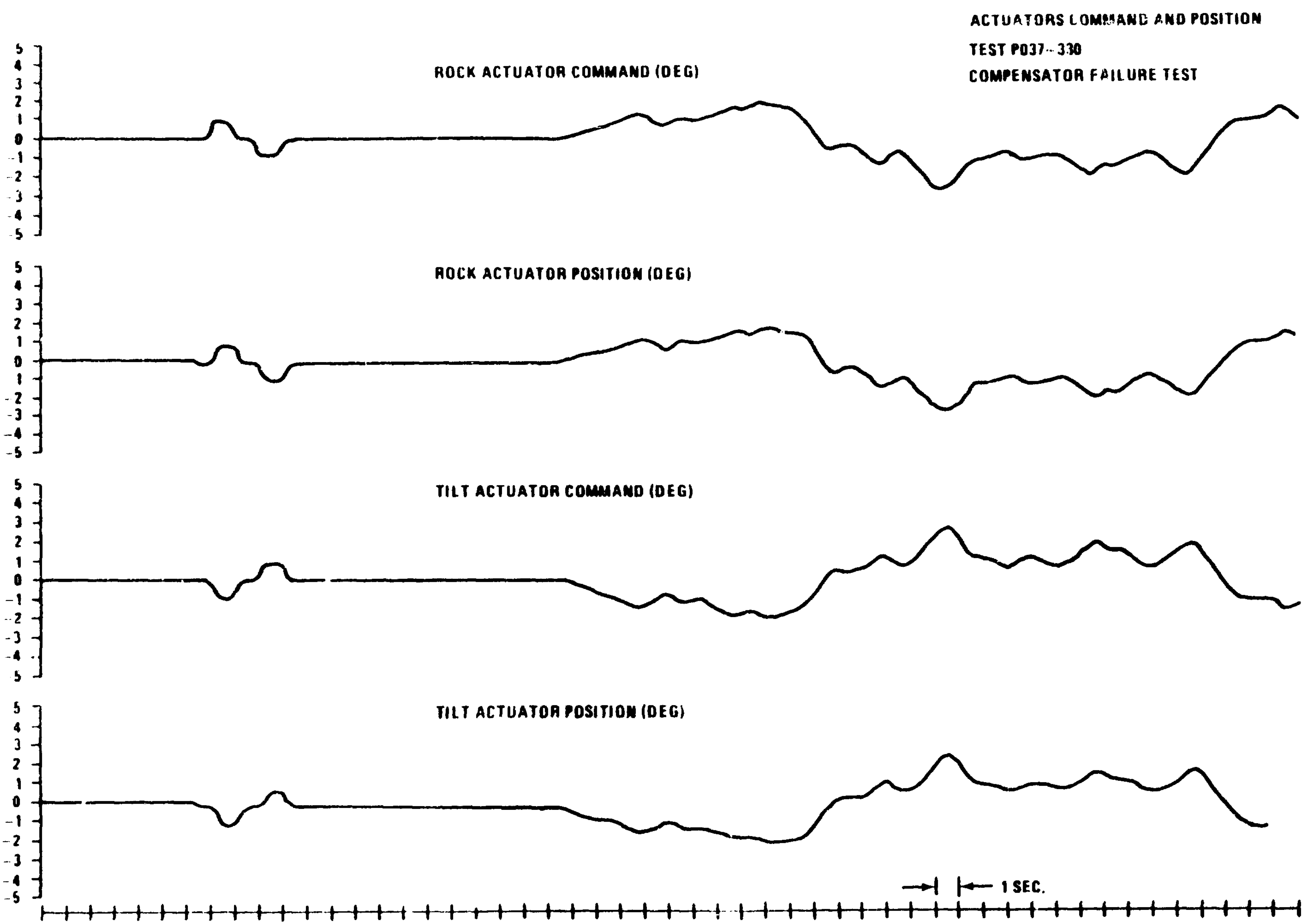

ACTUATORS COMMAND AND POSITION
TEST P037-330
COMPENSATOR FAILURE TEST
ROCK ACTUATOR COMMAND (DEG)
ROCK ACTUATOR POSITION (DEG)
TILT ACTUATOR COMMAND (DEG)
TILT ACTUATOR POSITION (DEG)
1 SEC.
5
4
3
2
1
0
-1
-2
-3
-4
-5

FIGURE 74

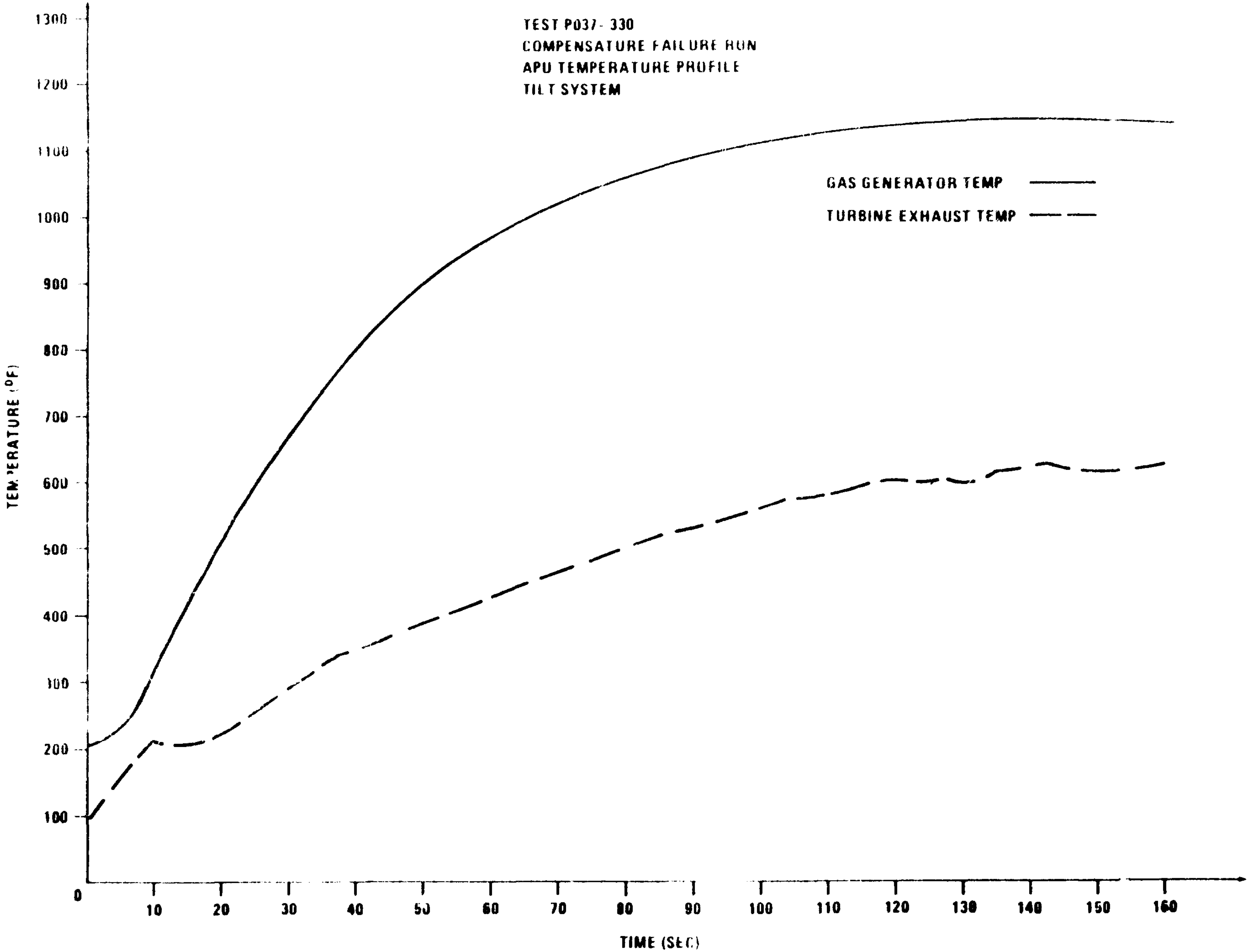

TEST P037- 330
COMPENSATURE FAILURE RUN
APU TEMPERATURE PROFILE
TILT SYSTEM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TEMPERATURE (°F)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)

FIGURE 73

TEST P037–330
COMPENSATOR FAILURE SIMULATION RUN
RESERVOIR PARAMETERS
TILT SYSTEM

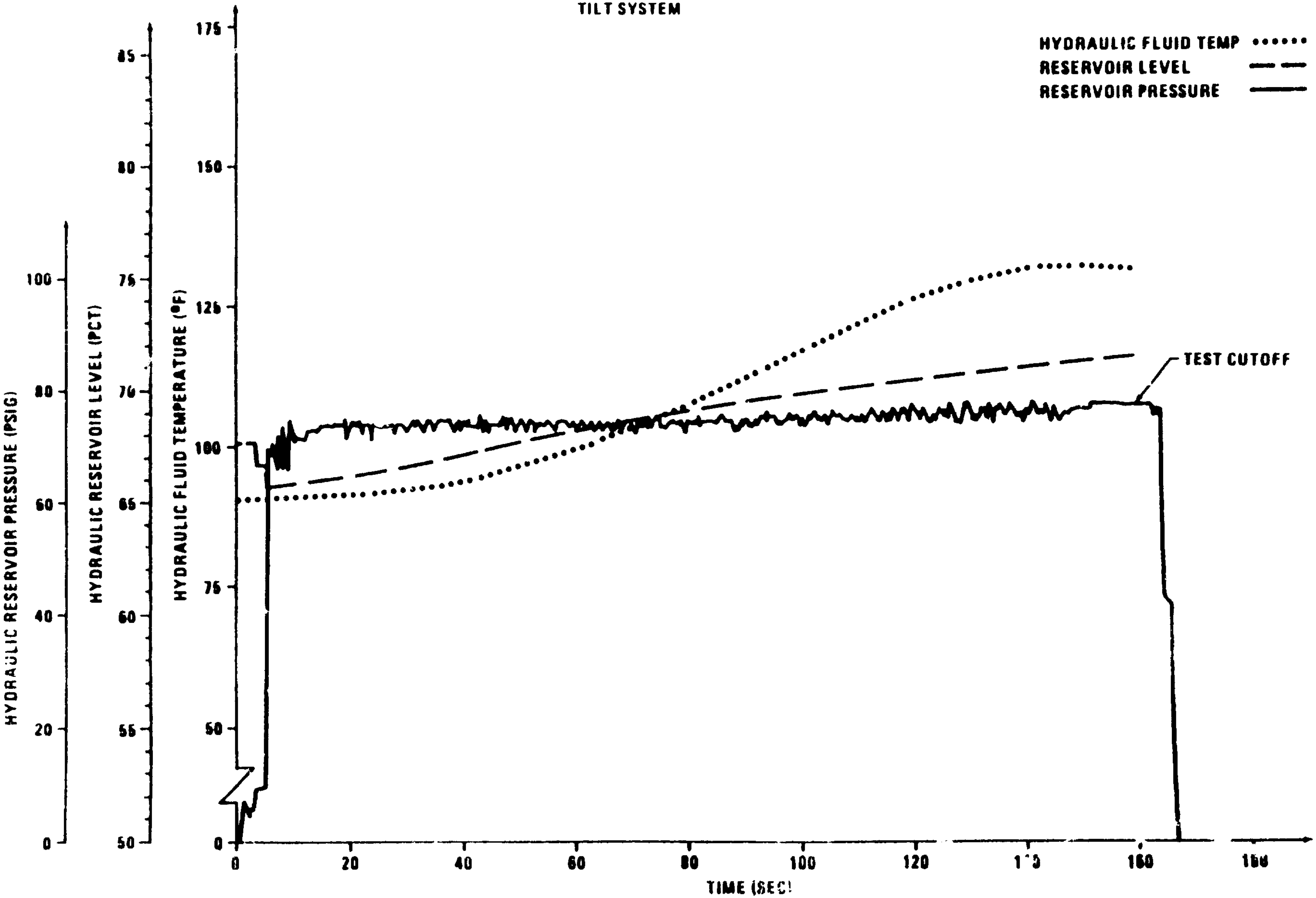
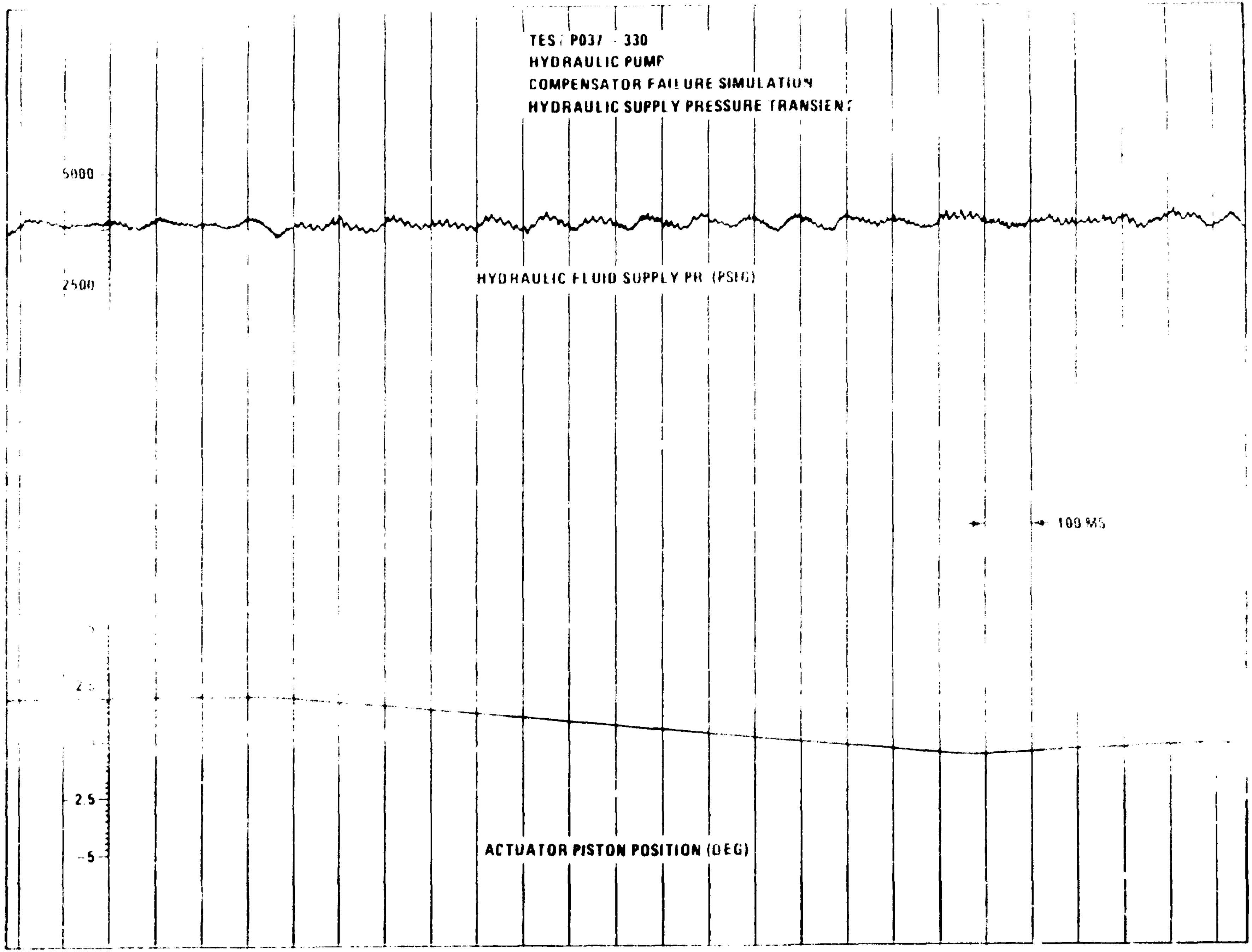


FIGURE 76



TEST P037 - 330
HYDRAULIC PUMP
COMPENSATOR FAILURE SIMULATION
HYDRAULIC SUPPLY PRESSURE TRANSIENT
5000
2500
HYDRAULIC FLUID SUPPLY PR (PSIG)
100 MS
2.5
-5
ACTUATOR PISTON POSITION (DEG)

FIGURE 77

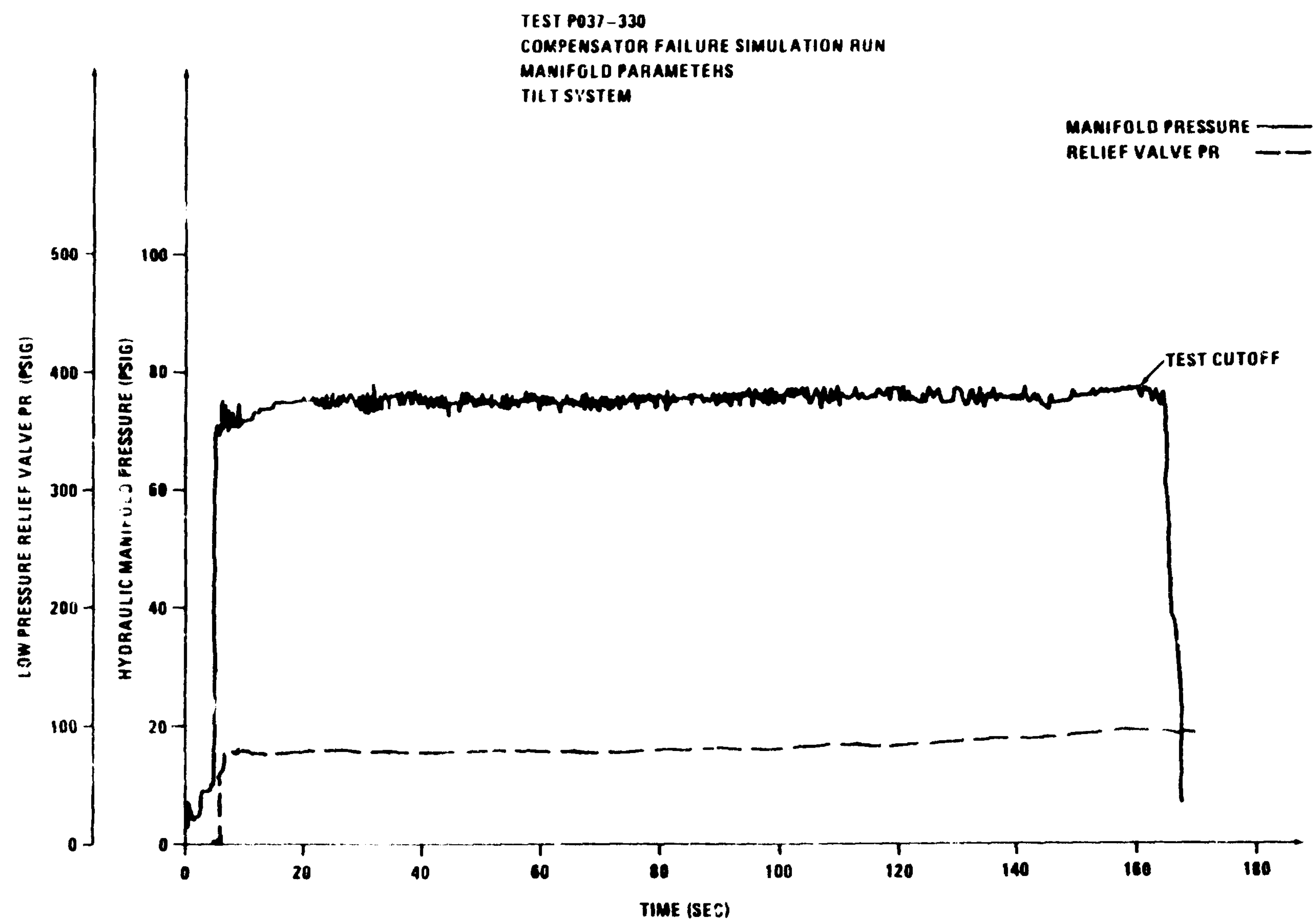

TEST P037-330
COMPENSATOR FAILURE SIMULATION RUN
MANIFOLD PARAMETERS
TILT SYSTEM
MANIFOLD PRESSURE
RELIEF VALVE PR
TEST CUTOFF
LOW PRESSURE RELIEF VALVE PR (PSIG)
0
100
200
300
400
500
HYDRAULIC MANIFOLD PRESSURE (PSIG)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
TIME (SEC)

FIGURE 78

TEST P037-330
COMPENSATOR FAILURE SIMULATION RUN
RETURN PRESSURE TRANSIENTS

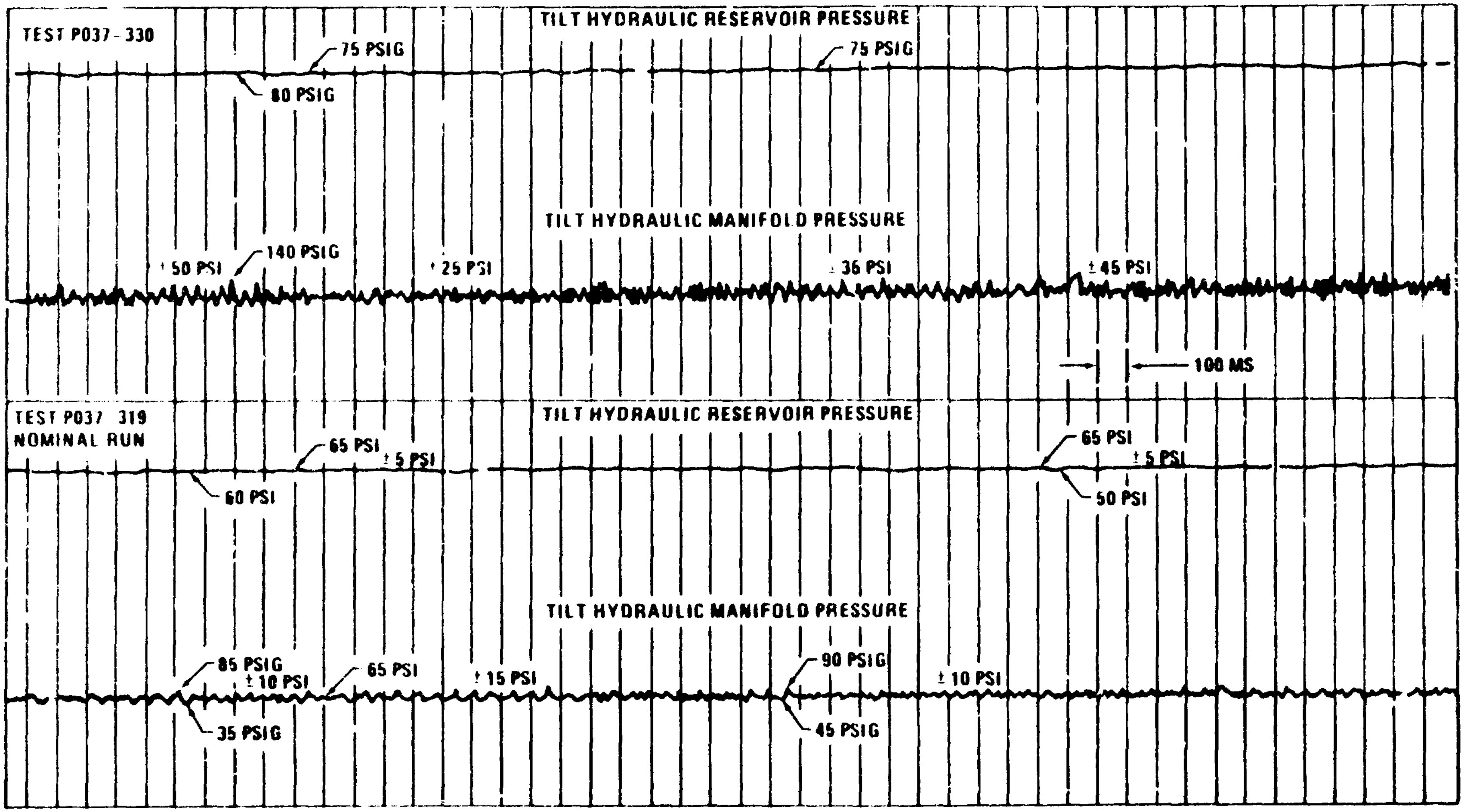


FIGURE 79

TEST P037-330
COMPENSATOR FAILURE-NOMINAL MODE
TVC SUBSYSTEM TRANSIENT
TILT SYSTEM

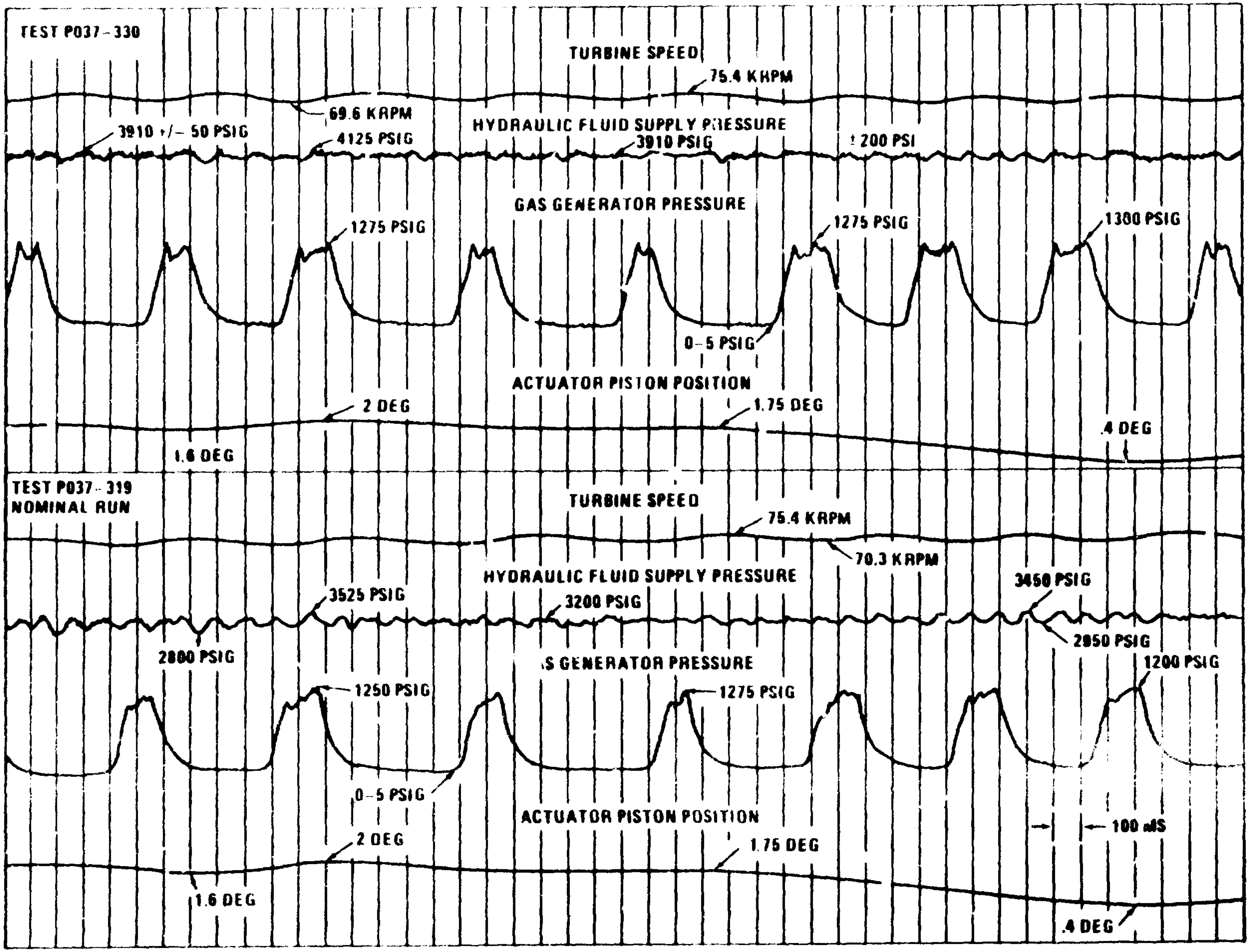


FIGURE 80

KSC COUNTDOWN SIMULATION TESTS

Objective

To verify the KSC launch countdown procedures.

To demonstrate the operational validity of KSC prelaunch redlines.

To create a baseline to support flight data evaluation.

Results

Tests P037-332, P037-334, and P037-335 were successfully conducted from June 9 through 19, 1980. All objectives were met with no difficulties. Tables 25 through 27 show the results obtained from these runs. Maximum and minimum parameter readings were implemented to obtain a baseline for TVC performance based on the redlines implemented. The redlines imposed during the countdown phase were comfortably passed. Test P037-333 was aborted after 142 seconds of runtime because an actuator prefiltration valve was left open during pretest servicing. This condition prevented the actuator from following the imposed command during test. No anomalies or component malfunction resulted from this mistake. All the hot firings lasted 160 seconds.

PRECEDING PAGE BLANK NOT FILMED

TABLE 25

TEST NO. P037 - 332
DATE JUNE 9, 1980
TYPE KSC FLIGHT COUNTDOWN SIMULATION: NOMINAL PARAMETERS
FULL DURATION HOT FIRING

	ROCK	TILT
HYDRAULIC SUPPLY PR. (PSIG)	3240 + 10/-40	3220 + 20/-30
SECONDARY PR. (PSIG)	3210 + 20/-30	3230 + 30/-40
ACTUATOR DIFFERENTIAL PR. (PSID)	230 ± 25	NA
HYDRAULIC RESERVOIR TEMP. (°F)	68 - 93	76 - 101
HYDRAULIC RESERVOIR LEVEL (PCT)	68 - 66 - 72	72 - 69 - 74
HYDRAULIC RESERVOIR PR. (PSIG)	62 - 66	64 - 70
HYDRAULIC MANIFOLD PR. (PSIG)	63 - 67	NA
LP RELIEF VALVE PR. (PSIG)	0-105	0-62
CASE DRAIN PR. (PSIG)	65 ± 3	NA
FSM TEMP (°F)	71	68 - 69
FSM PR. (PSIG)	373 - 292	369 - 290
FUEL PUMP INLET PR. (PSIG)	380 - 297	364 - 282
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)	1350	NA
	1425	
MAXIMUM GAS GENERATOR PR. (PSIG)	1125	1225 (AT 15 SEC.)
	1225	1350 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP (°F)	224 - 1115 (1121)	234 - 1109 (1120)
TURBINE EXHAUST TEMP (°F)	74 - 597	72 - 587
TURBINE SPEED (K - RPM)	70.85 - 75.53	70.22 (67.61) - 76.01
LUBE OIL TEMP T6	74 - 174	71 - 170
T6 AUX	72 - 176	71 - 174

TABLE 26

TEST NO. P037-334
DATE JUNE 19, 1980
TYPE KSC FLIGHT COUNTDOWN SIMULATION MAXIMUM PARAMETERS
FULL DURATION HOT FIRING

	ROCK	TILT
HYDRAULIC SUPPLY PR. (PSIG)	3240 ± 25	3220 + 30/-40
SECONDARY PR. (PSIG)	3215 ± 30	3240 + 30/-40
ACTUATOR DIFFERENTIAL PR. (PSID)	240 + 15/-20	NA
HYDRAULIC RESERVOIR TEMP. (°F)	83-111	91-120
HYDRAULIC RESERVOIR LEVEL (PCT)	81-80-85	80-77-83
HYDRAULIC RESERVOIR PR. (PSIG)	NA	NA
HYDRAULIC MANIFOLD PR. (PSIG)	NA	NA
LP RELIEF VALVE PR. (PSIG)	0-106	0-69
CASE DRAIN PR. (PSIG)	NA	NA
FSM TEMP. (°F)	79	81-82
FSM PR. (PSIG)	388-300	392-307
FUEL PUMP INLET PR. (PSIG)	375-289	376-282
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)	1325 1375	NA
MAXIMUM GAS GENERATOR PR. (PSIG)	1150 1175	1250 (AT 15 SEC.) 1325 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP. (°F)	247 - 1126	263-1138 (1143)
TURBINE EXHAUST TEMP. (°F)	91-609	90-617
TURBINE SPEED (K-RPM)	70.76 (69.64) -75.32	70.28 (69.15) -75.88
LUBE OIL TEMP. T6	90-169	88-185
T6 AUX.	87-165	88-182

TABLE 27

TEST NO. TEST P037 335
DATE JUNE 19, 1980
TYPE KSC FLIGHT COUNTDOWN SIMULATION: MINIMUM PARAMETERS
FULL DURATION HOT FIRING

	ROCK	TILT
HYDRAULIC SUPPLY PR. (PSIG)	3230 + 20/−40	3210 ± 30
SECONDARY PR. (PSIG)	3210 ± 30	3230 ± 25
ACTUATOR DIFFERENTIAL PR. (PSID)	240 ± 20	NA
HYDRAULIC RESERVOIR TEMP. (°F)	91−127	99−133
HYDRAULIC RESERVOIR LEVEL (PCT)	63−62−68	65−62−68
HYDRAULIC RESERVOIR PR. (PSIG)	61−66	60−69
HYDRAULIC MANIFOLD PR. (PSIG)	62−67	NA
LP RELIEF VALVE PR. (PSIG)	0−111	0−49
CASE DRAIN PR. (PSIG)	62−66	NA
FSM TEMP (°F)	82	85
FSM PR. (PSIG)	364−280	369−287
FUEL PUMP INLET PR. (PSIG)	354−261	353−265
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)	NA	NA
MAXIMUM GAS GENERATOR PR. (PSIG)	1175 1200	1275 (AT 15 SEC.) 1375 (AT GIMBAL PROGRAM)
GAS GENERATOR TEMP. (°F)	202−1130	192−1134
TURBINE EXHAUST TEMP. (°F)	93−617	91−610
TURBINE SPEED (K−RPM)	70.73 (67.70) − 75.44	70.20 (68.31) −75.74
LUBE OIL TEMP T6	102−190	99−196
T6 AUX	96−186	97−199

ACTUATOR POST FIRING GIMBALING

OBJECTIVE

To demonstrate actuator gimbaling during the first 5 seconds following a normal test cutoff.

To obtain the hydraulic supply pressure and APU turbine speed transient decay.

RESULTS

At the end of tests P037-332 through P037-335, and prior to cutoff, rock (tilt) actuator was commanded to 1.2 degrees extended (retracted) at 1 deg/sec gimbal rate. The hot firing was terminated immediately thereafter. Two seconds later, an identical signal returned the actuators back to null position.

The data shows that the actuators followed the commands imposed (see figure 81). The hydraulic supply pressure experienced abnormal oscillations, 7 cps and $\pm$600 psi, for that gimbal rate (figure 82). However, the nominal pressure was maintained through the entire gimbaling. The low hydraulic horsepower available in this area generated these pressure cycles. The hydraulic pressure necessary to position the actuator was obtained from the horsepower available during turbine speed decay. The turbine speed dropped faster for these tests than for no gimbal cases because of the increased hydraulic system flow demand. This produced a faster decay in hydraulic supply pressure. For a normal cutoff, the turbine wheel stops turning 9 to 10 seconds later. This time depends on where the turbine speed peaked before cutoff. For these runs, the average slowdown time was around 5 seconds. (See figure 83.)

TEST P037-332
ACTUATOR COMMAND AND POSITION
ACTUATOR POST-HOT FIRING GIMBALING

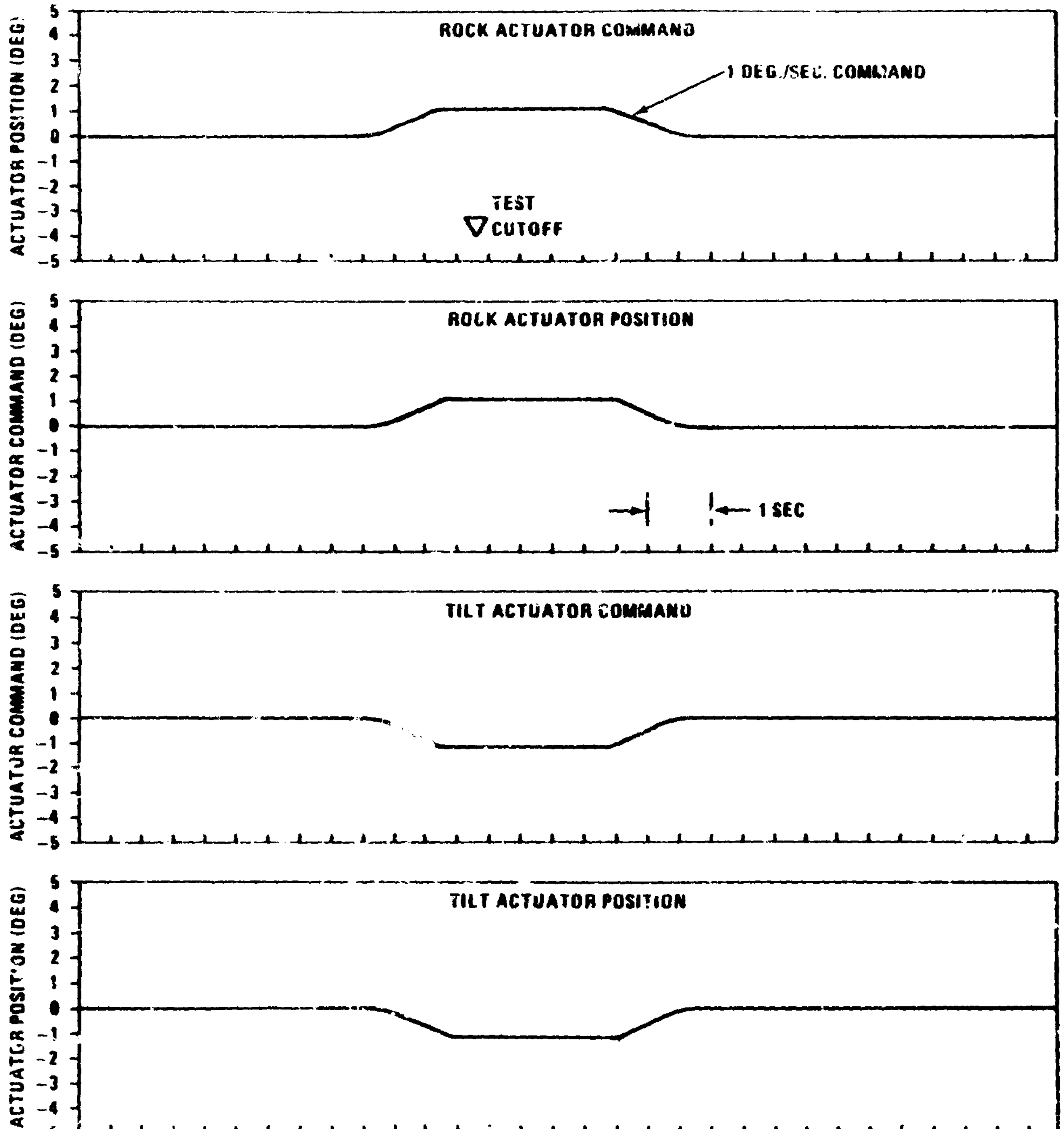


FIGURE 81

TEST P037-332
HYDRAULIC SYSTEM PERFORMANCE
ACTUATOR POST-HOT FIRING GIMBALING
ROCK SYSTEM

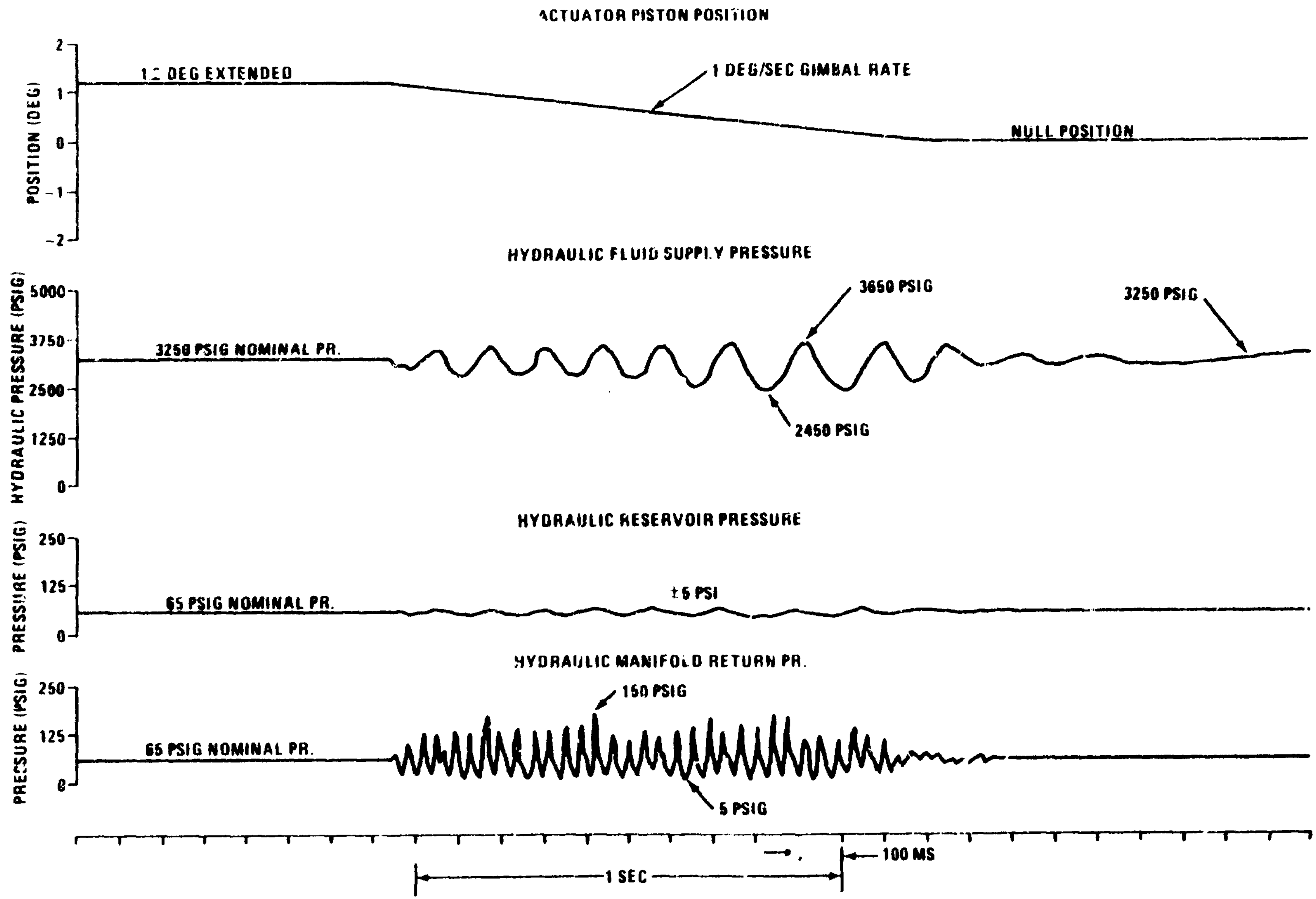
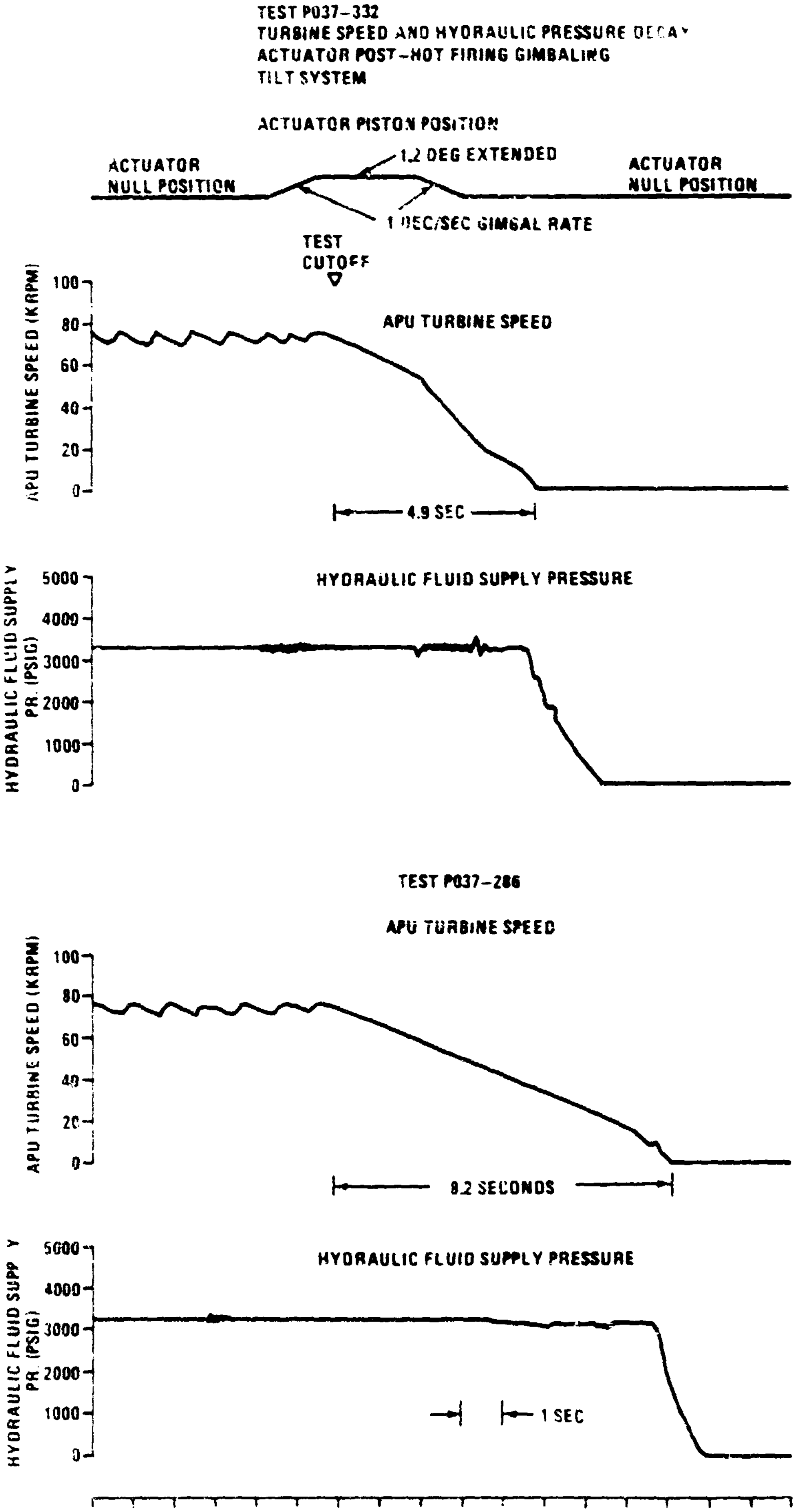


FIGURE 82



TEST P037-332
TURBINE SPEED AND HYDRAULIC PRESSURE DECAY
ACTUATOR POST-HOT FIRING GIMBALING
TILT SYSTEM
ACTUATOR PISTON POSITION
ACTUATOR NULL POSITION
1.2 DEG EXTENDED
ACTUATOR NULL POSITION
1 DEG/SEC GIMBAL RATE
TEST CUTOFF
APU TURBINE SPEED (KRPM)
100
80
60
40
20
0
APU TURBINE SPEED
4.9 SEC
HYDRAULIC FLUID SUPPLY PR. (PSIG)
5000
4000
3000
2000
1000
0
HYDRAULIC FLUID SUPPLY PRESSURE
TEST P037-286
APU TURBINE SPEED
APU TURBINE SPEED (KRPM)
100
80
60
40
20
0
8.2 SECONDS
HYDRAULIC FLUID SUPPLY PR. (PSIG)
5000
4000
3000
2000
1000
0
HYDRAULIC FLUID SUPPLY PRESSURE
1 SEC

FIGURE 83

RECYCLE TEST

TEST P037-336

OBJECTIVE

To demonstrate recycle procedure in case of an abort during launch and to obtain recycle time and data to map recycle operations.

RESULTS

Test P037-336 was successfully conducted on June 23, 1980. It consisted of a 15 second run simulating a flight abort prior to launch, followed by a full duration mission (160 seconds). A recycle time of 40 minutes was obtained. This being the time it took the gas generator temperature to fall within flight specification limits (190-248°F). No other constraints were observed during this abort simulation. The data shows good systems operation during both runs with no anomalies or hazards presented by this sequence. Table 28 shows temperature and pressure parameters of interests for this test.

TABLE 28

TVC SUBSYSTEM PERFORMANCE
RECYCLE TEST
TEST P037 - 336

		ROCK SYSTEM	
		SIMULATED ABORT	FULL DURATION RUN
HYDRAULIC SUPPLY PR (PSIG)		3250	3240 + 20/—40
HYDRAULIC RESERVOIR TEMP (°F)		73	77 – 105
HYDRAULIC RESERVOIR LEVEL (PCT)		74 – 73	74 – 73 – 79
LP RELIEF VALVE PR (PSIG)		0–111	106–147
FSM PR (PSIG)		376 – 363	363 – 278
GAS GENERATOR TEMP. (°F)		224 – 432	240 – 1129
TURBINE EXHAUST TEMP (°F)		83 – 199	83 – 614
LUBE OIL TEMP	T6	NA	NA
	T6AUX	81 – 88	81 – 190

		SYSTEM	
		SIMULATED ABOR	FULL DURATION RUN
HYDRAULIC SUPPLY PR. (PSIG)		3230	3220 ± 30
HYDRAULIC RESERVOIR TEMP (°F)		81	84 – 114
HYDRAULIC RESERVOIR LEVEL (PCT)		74 – 71 – 72	73 – 71 – 77
LP RELIEF VALVE PR. (PSIG)		0–55	49–63
FSM PR (PSIG)		375 – 362	366 – 281
GAS GENERATOR TEMP (°F)		224 – 426	253 – 1135 (1140)
TURBINE EXHAUST TEMP (°F)		80 – 200	81 – 621
LUBE OIL TEMP (°F)	T6	78 – 80	85 – 190
	T6AUX	80 – 82	80 – 200
	RECYCLE TIME	40 MINUTES	

HYDRAULIC BYPASS VALVE FAILURE SIMULATION

OBJECTIVE

To obtain the hydraulic fluid temperature and hydraulic level behavior when the hydraulic bypass valve is left or fails open.

To observe the APU and hydraulic system performance.

RESULTS

Test P037-337 was conducted on June 23, 1980. No problems were encountered during this run. The hydraulic bypass valve was left intentionally open for the 160 sec hot firing. The data shows a low hydraulic fluid temperature rise. This was due to a very low hydraulic hp and low heat rejection to fluid. The reservoir level increased slightly as a result of lower hydraulic temperature rise (see figures 84 and 85). As expected, no level drop was observed during initial pressure buildup. The APU turbine operated nominally because of the low horsepower output required. The actuators were not gimbaled during the test. Table 29 presents the overall TVC subsystem performance for this hot firing.

TABLE 29

TEST RESULTS ON

TEST NO.	P037-337
DATE	6/23/80
TYPE	HYDRAULIC BYPASS VALVE FAILURE SIMULATION

		ROCK	TILT
HYDRAULIC SUPPLY PR. (PSIG)		610-660	630-645
SECONDARY PR. (PSIG)		630-650	610-650
ACTUATOR DIFFERENTIAL PR. (PSID)		0	0
HYDRAULIC RESERVOIR TEMP. (°F)		77-85	95-88
HYDRAULIC RESERVOIR LEVEL (PCT)		74-76	73-72-73
HYDRAULIC RESERVOIR PR. (PSIG)		NA	NA
HYDRAULIC MANIFOLD PR. (PSIG)		NA	NA
LP RELIEF VALVE PR. (PSIG)		63-75	29--31
CASE DRAIN PR. (PSIG)		NA	NA
FSM TEMP (°F)		78	76
FSM PR. (PSIG)		367-315	365-318
FUEL PUMP INLET PR. (PSIG)		368-316	360-307
MAXIMUM FUEL PUMP OUTLET PR. (PSIG)		NA	NA
MAXIMUM GAS GENERATOR PR. (PSIG)		1125-1225	1175-1275
GAS GENERATOR TEMP (°F)		275-1060	282-1049
TURBINE EXHAUST TEMP (°F)		75-497	74-442
TURBINE SPEED (K-RPM)		71.12-75.91	71.16-76.31
LUBE OIL TEMP	T6	NA	66-184
	T6 AUX	81-183	77-185

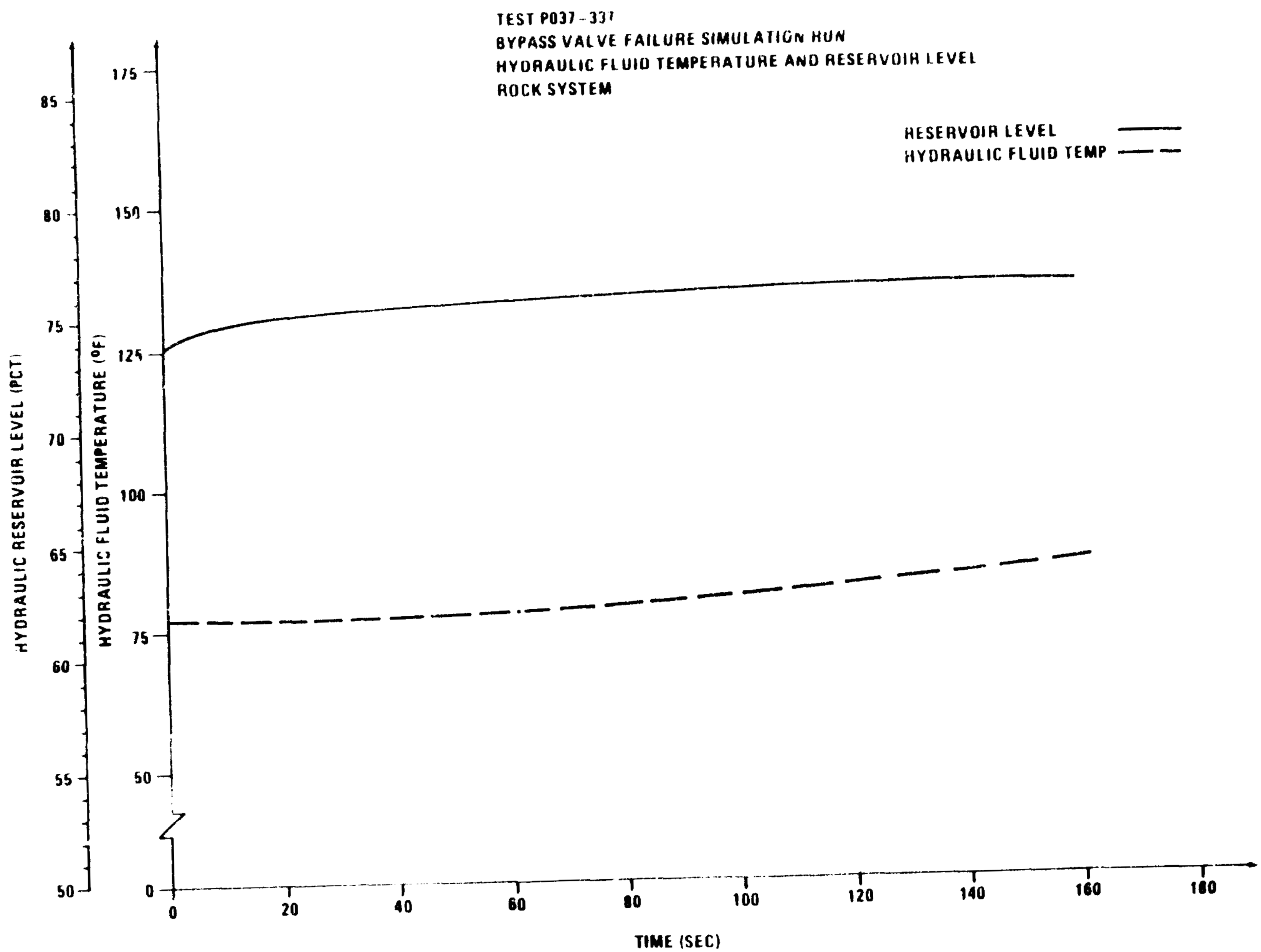
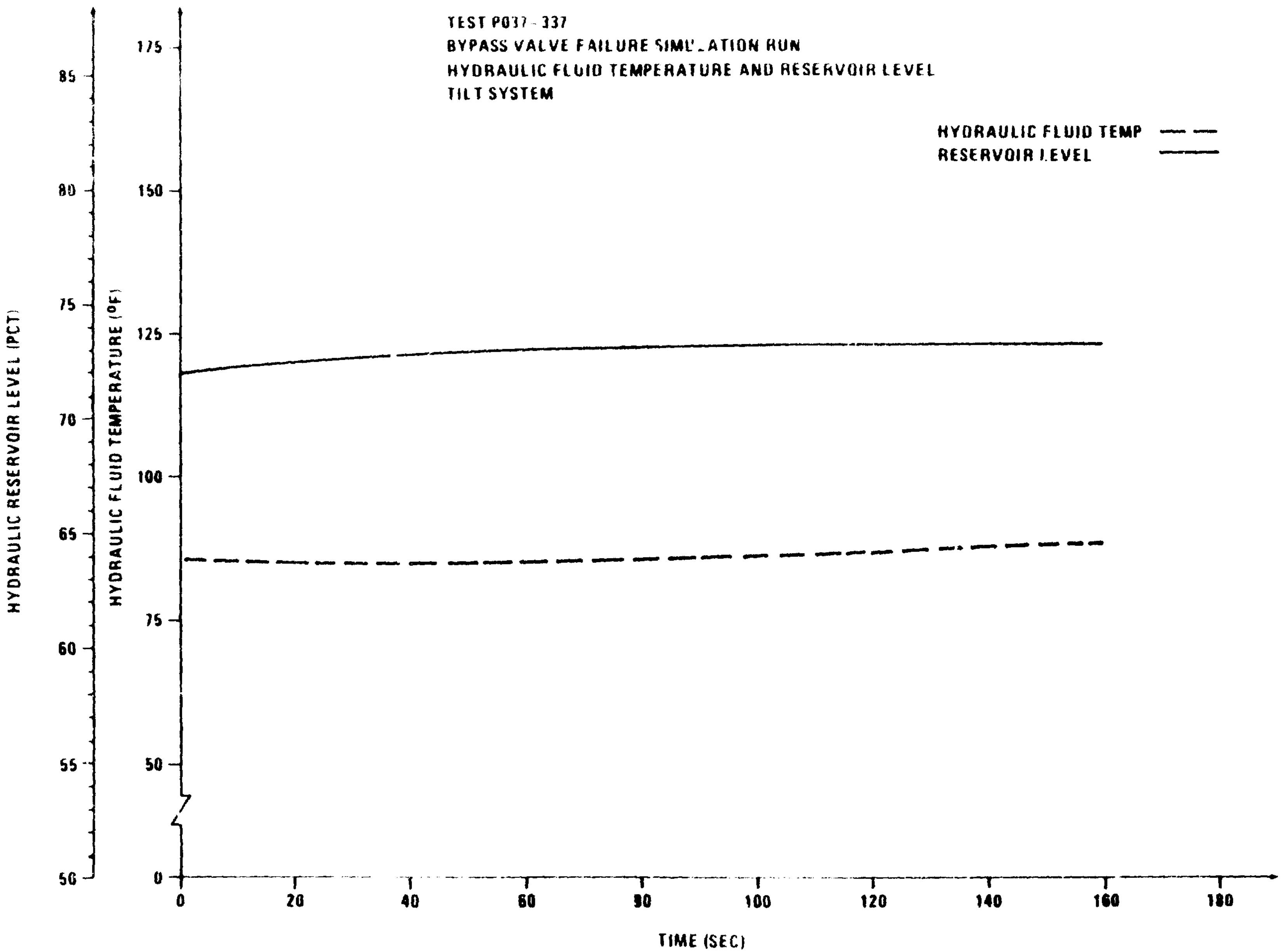

TEST P037-337
BYPASS VALVE FAILURE SIMULATION RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
ROCK SYSTEM
RESERVOIR LEVEL
HYDRAULIC FLUID TEMP
HYDRAULIC RESERVOIR LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
85
80
75
70
65
60
55
50
175
150
125
100
75
50
0
0
20
40
60
80
100
120
140
160
180
TIME (SEC)

FIGURE 84



TEST P037 - 337
BYPASS VALVE FAILURE SIMULATION RUN
HYDRAULIC FLUID TEMPERATURE AND RESERVOIR LEVEL
TILT SYSTEM
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL
HYDRAULIC RESERVOIR LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
85
80
75
70
65
60
55
50
175
150
125
100
75
50
0
0
20
40
60
80
100
120
140
160
180
TIME (SEC)

FIGURE 89

HYDRAULIC PUMP COMPENSATOR FAILURE TEST
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE OPEN

OBJECTIVE

To determine the consequences of a compensator failure simulation and a leaking high pressure relief valve on the hydraulic system performance.

RESULTS

Test P037-342 was conducted on July 15, 1980. The rock hydraulic pump compensator setting was adjusted until the high pressure relief valve in the hydraulic manifold relieved. This setting took place during a GN_2 spin test, prior to this run. This resulted in a nominal hydraulic supply pressure of 3950 psig. This hot firing lasted 152.5 seconds and was aborted when the rock APU turbine speed stalled (see figure 87).

During the hydraulic pressure buildup following the bypass valve closed command, the pressure peaked at 4500 psig and stayed above 4000 psig for 10 ms. Then, it stabilized to 3990 psig in 110 ms (see figure 86). From there on, the nominal pressure dropped steadily to 3860 psig at 150 sec (prior to cutoff). Figure 88 shows the hydraulic supply pressure behavior during the entire run. This pressure drop was caused by an APU turbine speed slowdown throughout the test as it tried to maintain the required horsepower output. An oscillation mode consisting of a 25-30 cps frequency and $\pm$125 psi appeared throughout the run. The hydraulic fluid temperature experienced a lesser increase (93-239°F) than for test P037-298. This indicates a lower hydraulic flow rate. The actuators were held at null during this hot firing. The hydraulic reservoir level rise reflected the increase in hydraulic fluid temperature. The reservoir and manifcld return pressure reached 80 psig and maintained that pressure for most of the test (see figures 89 and 90). This reflected into higher low pressure relief valve pressures.

The APU operated off-nominally, as expected during this test. As the bypass valve closed, the turbine speed dropped to 68 KRPM (in 200 ms) continuing dropping to 40 KRRM 2 seconds later. The nominal speed stabilized at 41 KRPM and diminished steadily to 37 KRPM near the end of the test. The turbine stalled 4 seconds later at a 33 KRPM speed and reached zero rotation 2.5 seconds afterwards (see figure 88). The latter speed decay is normal for low speed conditions. The low speed condition observed resulted from the APU maintaining the required horsepower output. The primary speed control valve remained open from the hydraulic bypass valve closure to APU cutoff. This occurred because the APU controller received a low speed signal and commanded the valve to open. This prolonged valve opening lead to higher gas generator and turbine exhaust temperatures (see figure 91). Lube oil temperature rose less than in a nominal speed test and closely followed a high pressure GN_2 spin tests behavior (see figure 92). The FSM pressure decayed more than in nominal tests because of the extra fuel needed to maintain the horsepower output (figure 93). Table 30 presents the overall TVC subsystem performance for this hot firing.

TABLE 30

TEST RESULTS ON:

TEST P037-342

HYDRAULIC PUMP COMPENSATOR FAILURE TEST
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE OPEN
ROCK SYSTEM

		ROCK	TILT
HYDRAULIC SUPPLY PR (PSIG)		3990-3860	3220-3240
SECONDARY PR (PSIG)		3210-3230	3980-3840
HYDRAULIC RESERVOIR TEMP. (^oF)		96-239	102-112
HYDRAULIC RESERVOIR LEVEL (PCT)		71-70-80	74-72-76
HYDRAULIC RESERVOIR PR. (PSIG)		76-83	57-65
HYDRAULIC MANIFOLD PR. (PSIG)		77-86	58-66
LP RELIEF VALVE PR. (PSIG)		18-448	0
CASE DRAIN PR. (PSIG)		77-85	NA
FSM TEMP (^oF)		30	93-94
FSM PR. (PSIG)		379-247	378-316
FUEL PUMP INLET PR. (PSIG)		380-247	367-309
GAS GENERATOR TEMP (^oF)		236-1251	221-1071
TURBINE EXHAUST TEMP (^oF)		101-878	99-543
TURBINE SPEED (K RPM)		40.9-34.9	71.0-75.2
LUBE OIL TEMP	T6	100-153	102-189
	T6 AUX	99-151	100-192

NOTE: NO GIMBAL PROGRAM

TEST DURATION — 151.8 SEC.

TEST P037 342
COMPENSATOR FAILURE SIMULATION RUN
TVC SUBSYSTEM TRANSIENT - HYDRAULIC BYPASS VALVE CLOSED

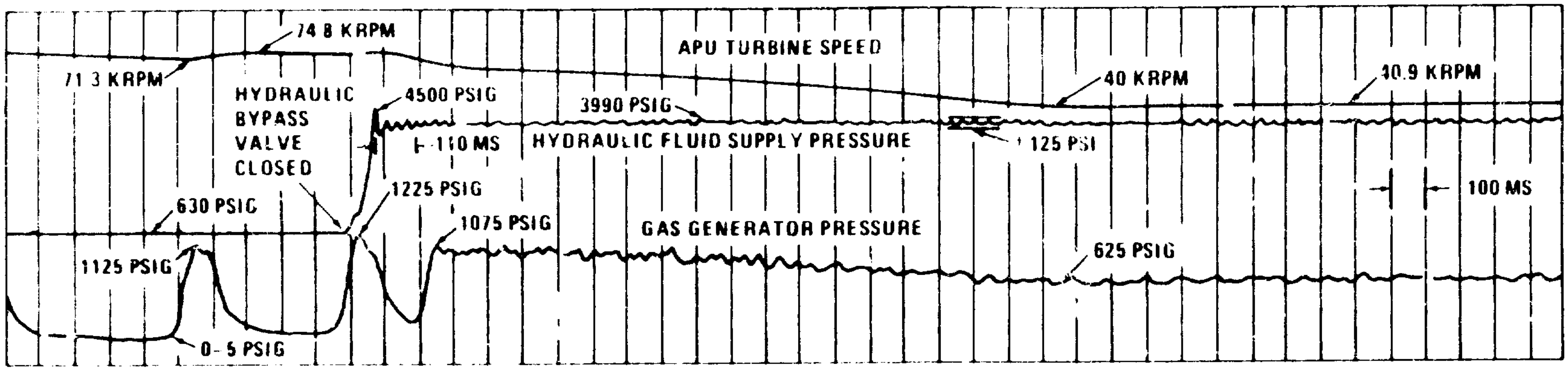


FIGURE 86

TEST P037-342
COMPENSATOR FAILURE SIMULATION RUN
TVC SUBSYSTEM TRANSIENT - APU TURBINE STALLED

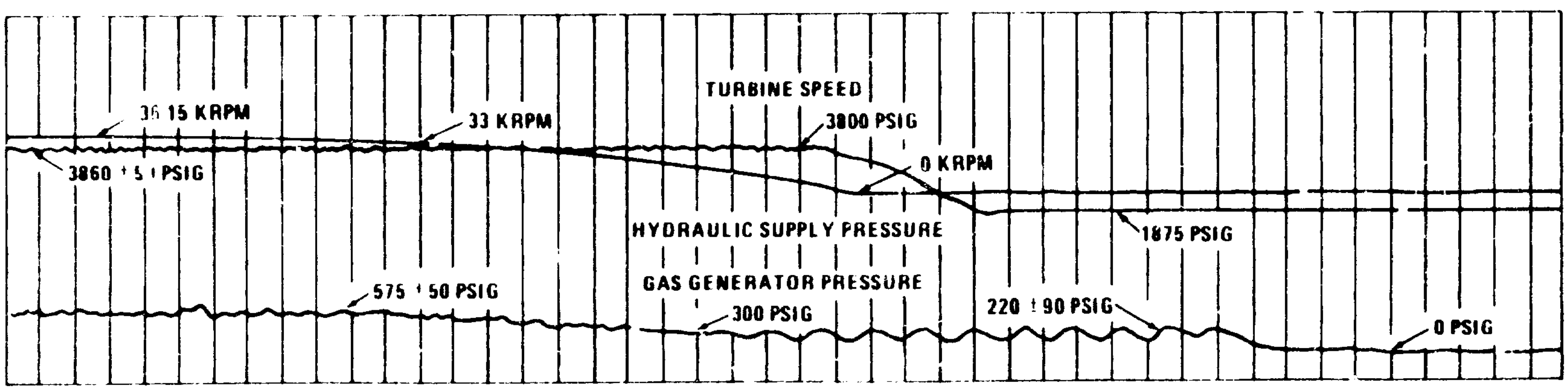
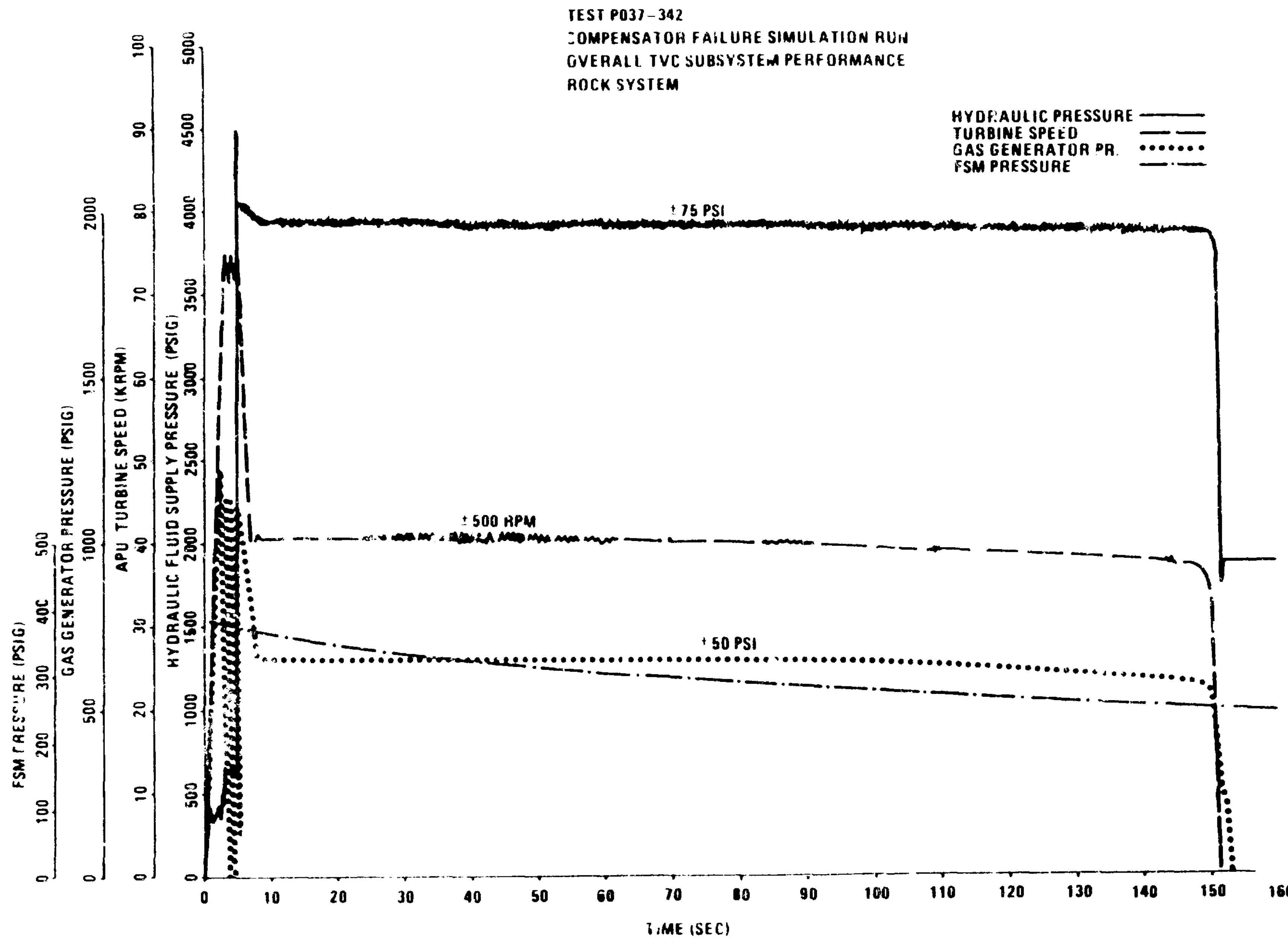


FIGURE 87



TEST P037-342
COMPENSATOR FAILURE SIMULATION RUN
OVERALL TVC SUBSYSTEM PERFORMANCE
ROCK SYSTEM
HYDRAULIC PRESSURE
TURBINE SPEED
GAS GENERATOR PR.
FSM PRESSURE
± 75 PSI
± 500 RPM
± 50 PSI
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
APU TURBINE SPEED (KRPM)
GAS GENERATOR PRESSURE (PSIG)
FSM PRESSURE (PSIG)
TIME (SEC)

FIGURE 86

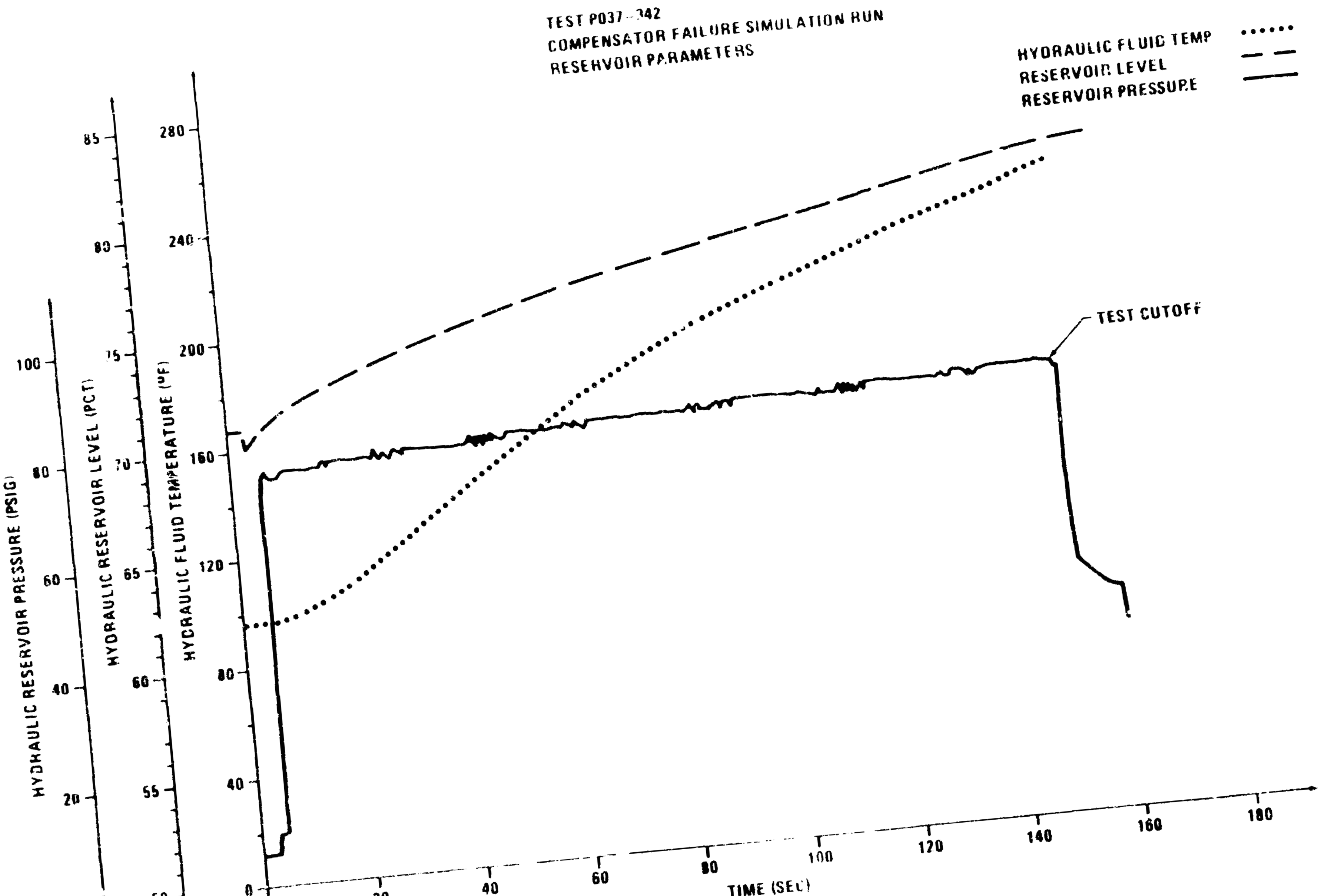

TEST P037--342
COMPENSATOR FAILURE SIMULATION RUN
RESERVOIR PARAMETERS
HYDRAULIC FLUID TEMP
RESERVOIR LEVEL
RESERVOIR PRESSURE
TEST CUTOFF
HYDRAULIC RESERVOIR PRESSURE (PSIG)
HYDRAULIC RESERVOIR LEVEL (PCT)
HYDRAULIC FLUID TEMPERATURE (°F)
TIME (SEC)

FIGURE 89

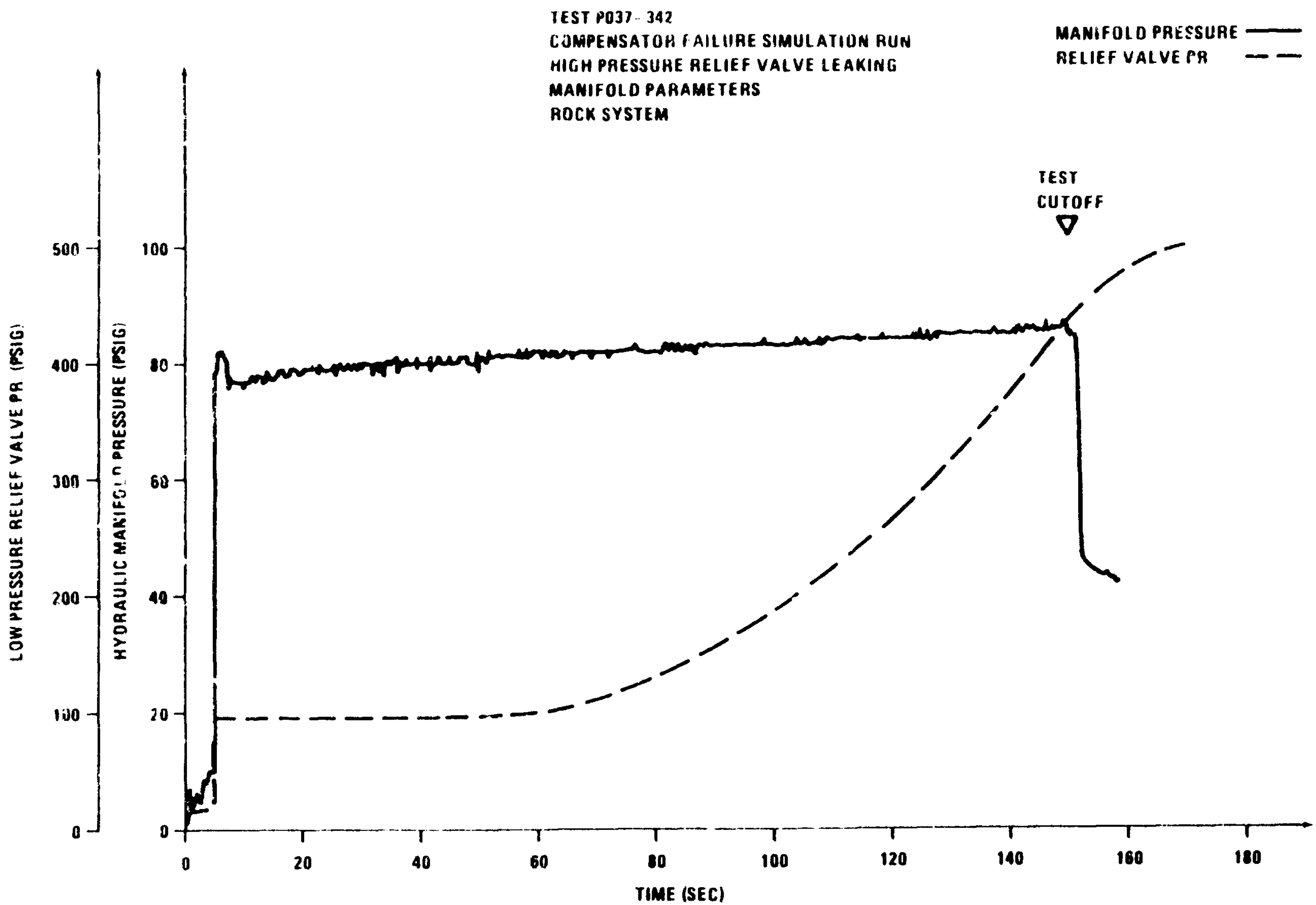

TEST P037-342
COMPENSATOR FAILURE SIMULATION RUN
HIGH PRESSURE RELIEF VALVE LEAKING
MANIFOLD PARAMETERS
ROCK SYSTEM
MANIFOLD PRESSURE
RELIEF VALVE PR
TEST
CUTOFF
LOW PRESSURE RELIEF VALVE PR (PSIG)
HYDRAULIC MANIFOLD PRESSURE (PSIG)
0
100
200
300
400
500
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
TIME (SEC)

FIGURE 90

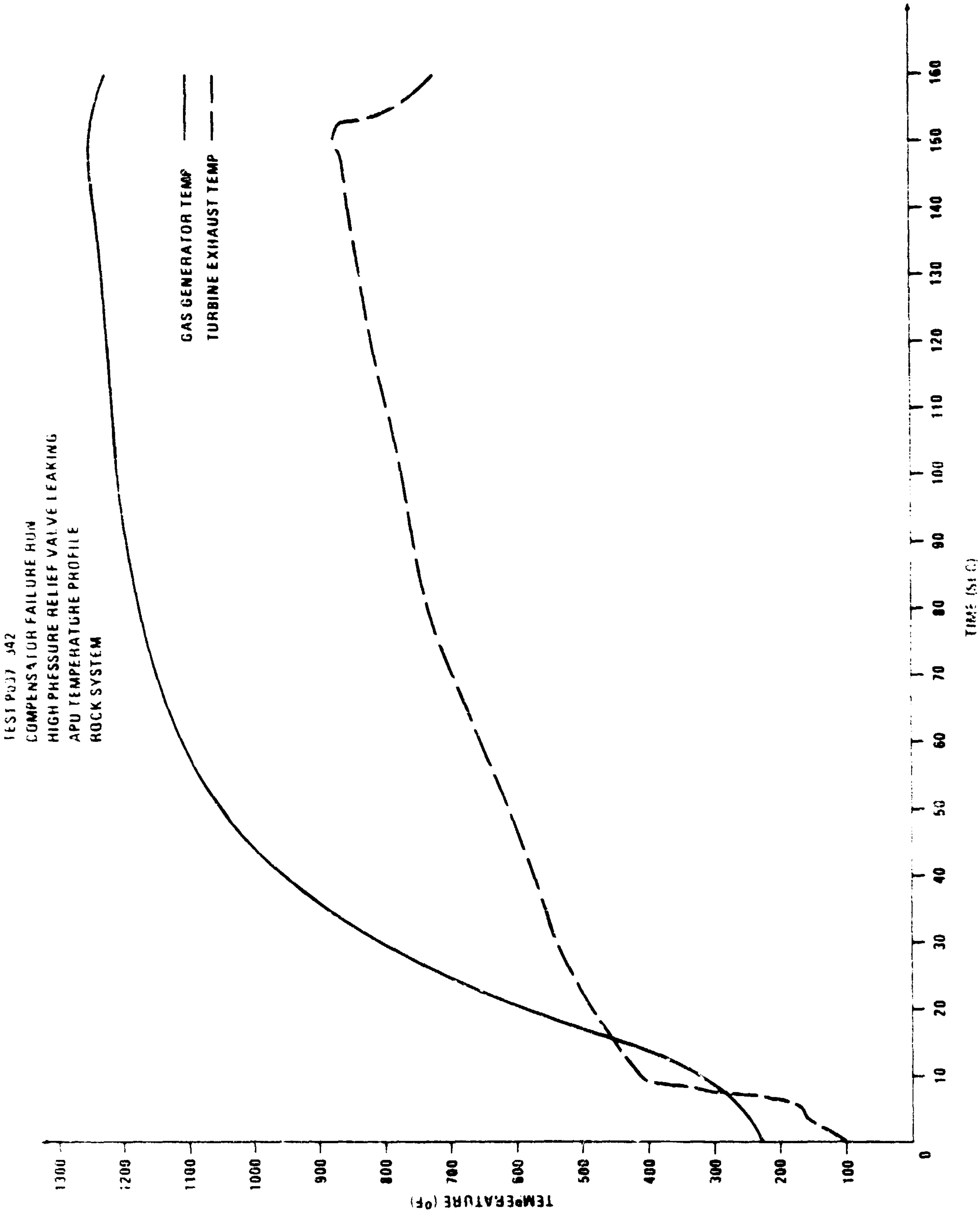

COMPENSATOR FAILURE RUN
HIGH PRESSURE RELIEF VALVE LEAKING
APU TEMPERATURE PROFILE
ROCK SYSTEM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TEMPERATURE (°F)
TIME (SEC)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

FIGURE 91

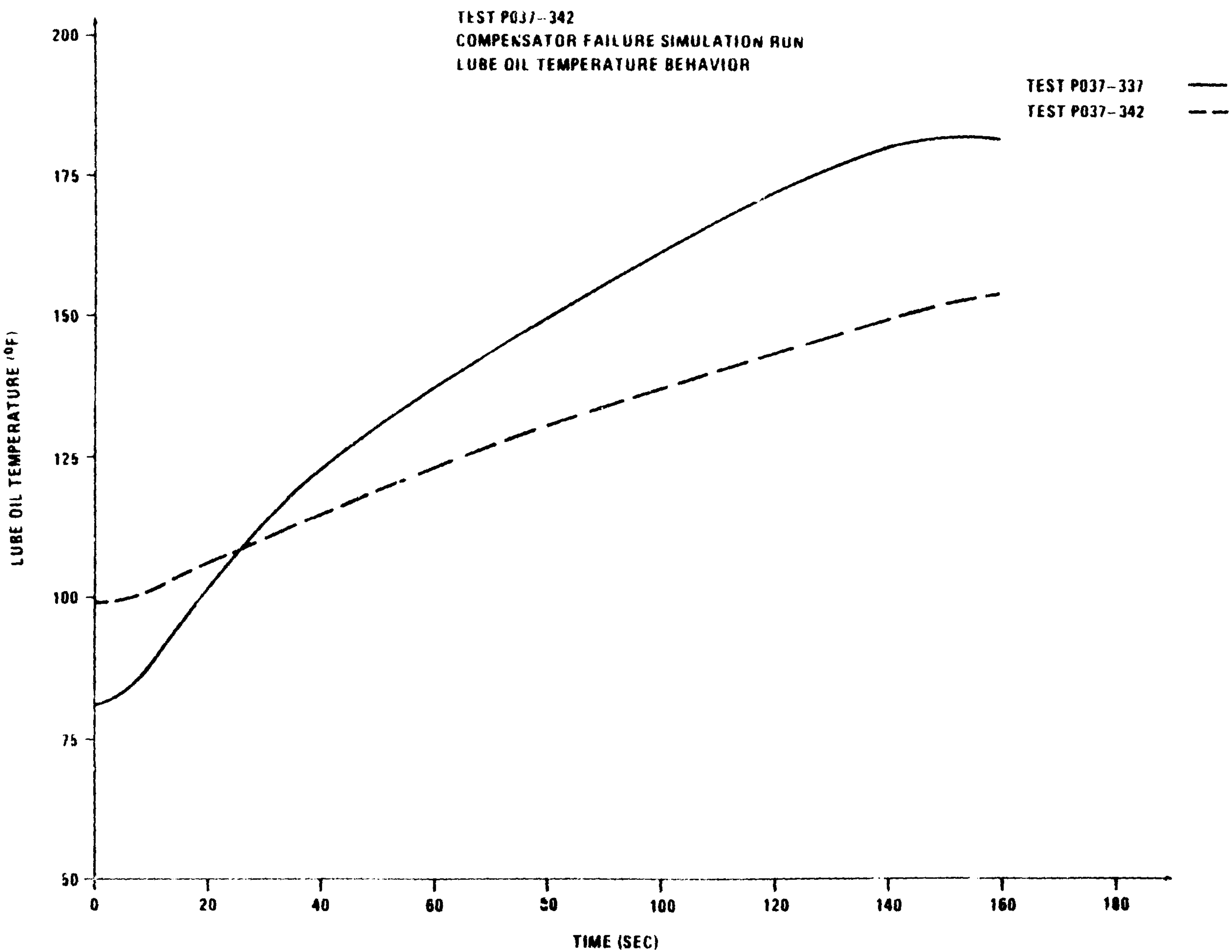

TEST P037-342
COMPENSATOR FAILURE SIMULATION RUN
LUBE OIL TEMPERATURE BEHAVIOR
TEST P037-337
TEST P037-342
LUBE OIL TEMPERATURE (°F)
200
175
150
125
100
75
50
0
20
40
60
80
100
120
140
160
180
TIME (SEC)

FIGURE 92

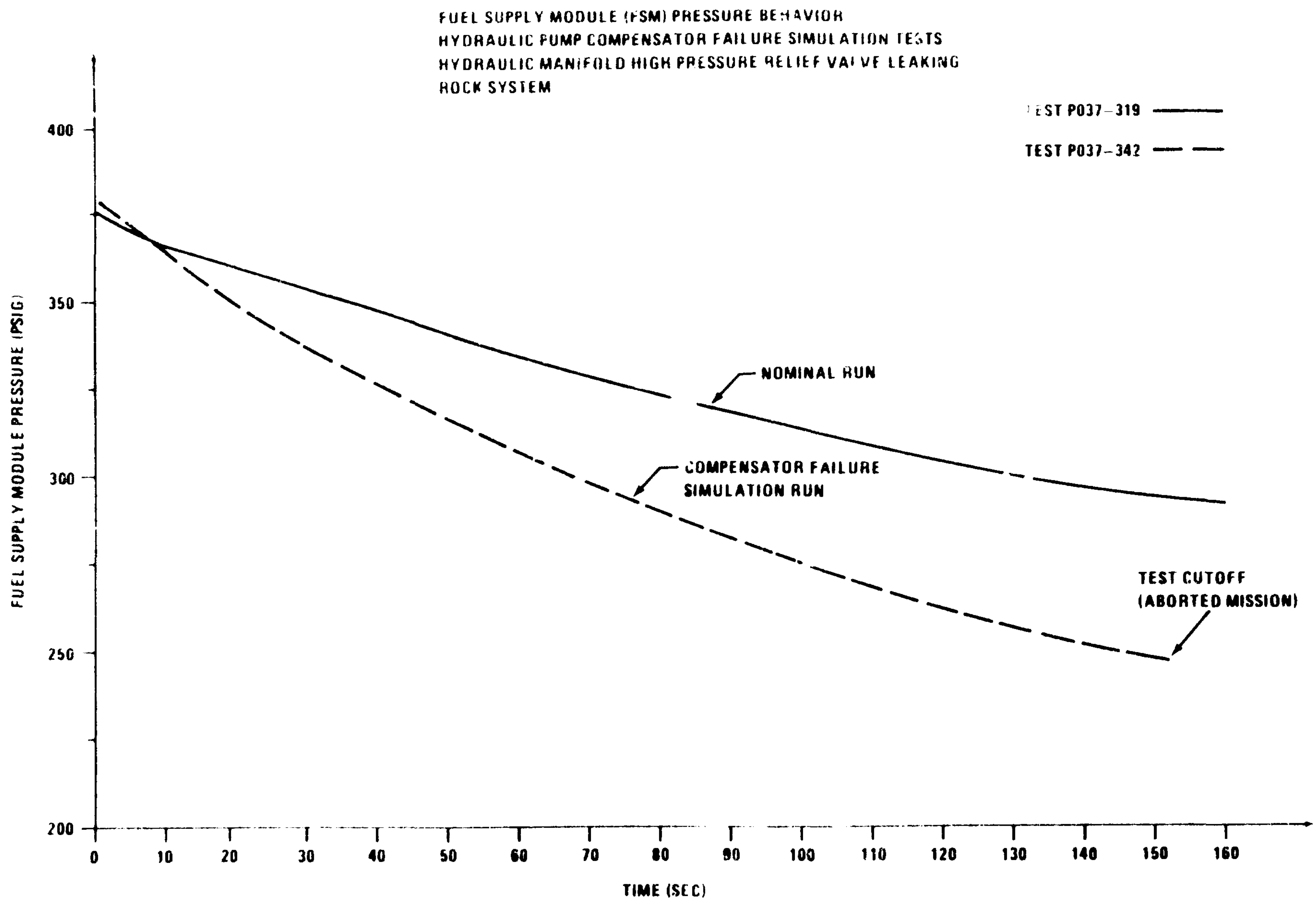

FUEL SUPPLY MODULE (FSM) PRESSURE BEHAVIOR
HYDRAULIC PUMP COMPENSATOR FAILURE SIMULATION TESTS
HYDRAULIC MANIFOLD HIGH PRESSURE RELIEF VALVE LEAKING
ROCK SYSTEM
TEST P037-319
TEST P037-342
NOMINAL RUN
COMPENSATOR FAILURE
SIMULATION RUN
TEST CUTOFF
(ABORTED MISSION)
FUEL SUPPLY MODULE PRESSURE (PSIG)
400
350
300
250
200
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
TIME (SEC)

FIGURE 93

PORTABLE COMMAND SIGNAL CONTROLLER (PCSC) FAILURE SIMULATION

OBJECTIVE

To determine the consequences of a command signal loss to the actuators in the hydraulic system.

RESULTS

The tilt actuator was positioned to 3.5 degrees extended during test P037-344. Then, the signal from the PCSC was interrupted, and the actuator response obtained. The actuator returned to null position in 700 ms following a linear path. This signal loss produced a maximum gimbal rate of 5.75 deg/sec. Consequently, the hydraulic supply pressure dropped to 950 psig in 60 ms and maintained 1250 psig for 550 ms indicating that the gimbal rate exceeded the hydraulic pump flow capabilities. Hydraulic pressure recovery looked normal. Figure 94 shows the actuator commands and positions when the loss of signal occurred. Figure 95 shows the actuator position and hydraulic supply pressure transients during that period.

TEST P037 - 344
PCSC FAILURE SIMULATION TEST
ACTUATOR COMMANDS AND POSITION

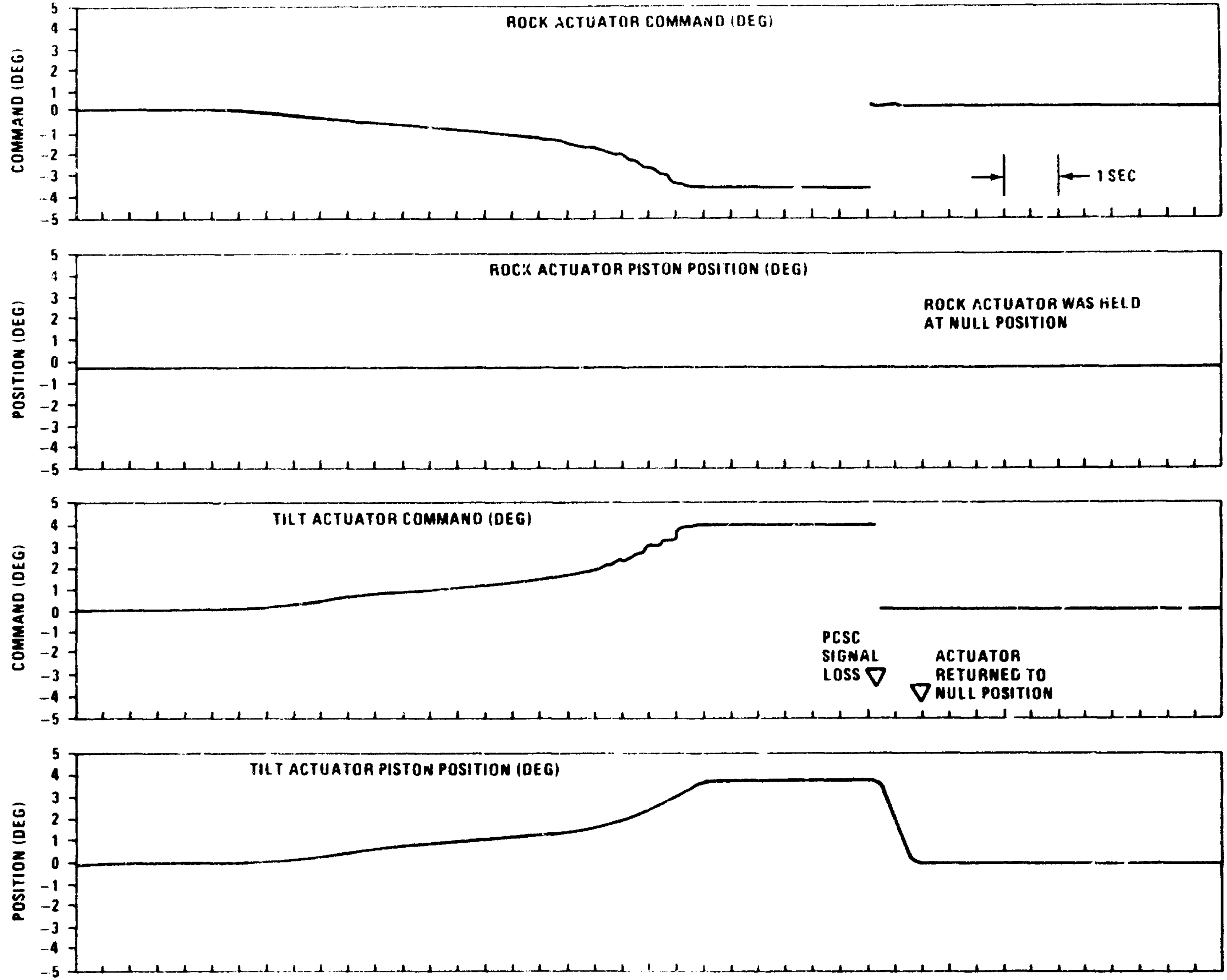


FIGURE 94

TEST P037-344
PCSC FAILURE SIMULATION TEST
HYDRAULIC PRESSURE TRANSIENTS

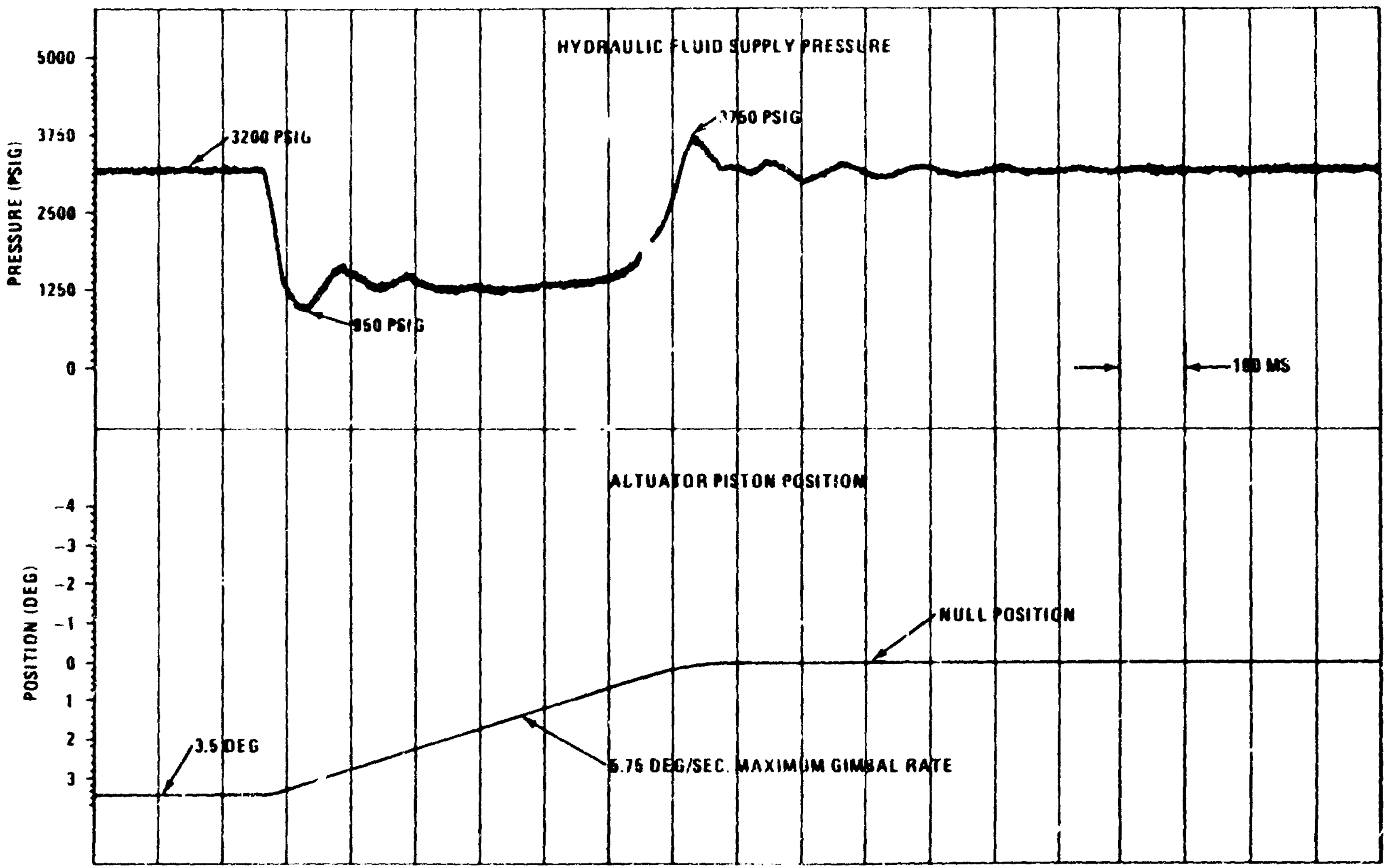


FIGURE 95

ACTUATOR OFF-NULL FLIGHT CUTOFF SIMULATION

OBJECTIVE

To simulate a flight cutoff with the actuators in the off-null position.

RESULTS

During test P037-345, the tilt actuator was positioned to 1 degree extended. The position signal to the actuator was discontinued simulating flight SRB separation from the orbiter. Both the command loss signal and the test cutoff signal were executed simultaneously. Actually, the data indicates 190 ms difference between both signals. The actuator returned to null in 270 ms, following a linear path. The maximum gimbal rate was 5.4 deg/sec. The hydraulic supply pressure dropped to 950 psig in 60 ms and recovered immediately. Figure 96 shows the actuator commands and positions when cutoff, and command loss signals occurred. Figure 97 shows the actuator position and hydraulic supply pressure transients for that period.

TEST P037-345
ACTUATOR FLIGHT CUT OFF SIMULATION
ACTUATOR COMMANDS AND POSITION

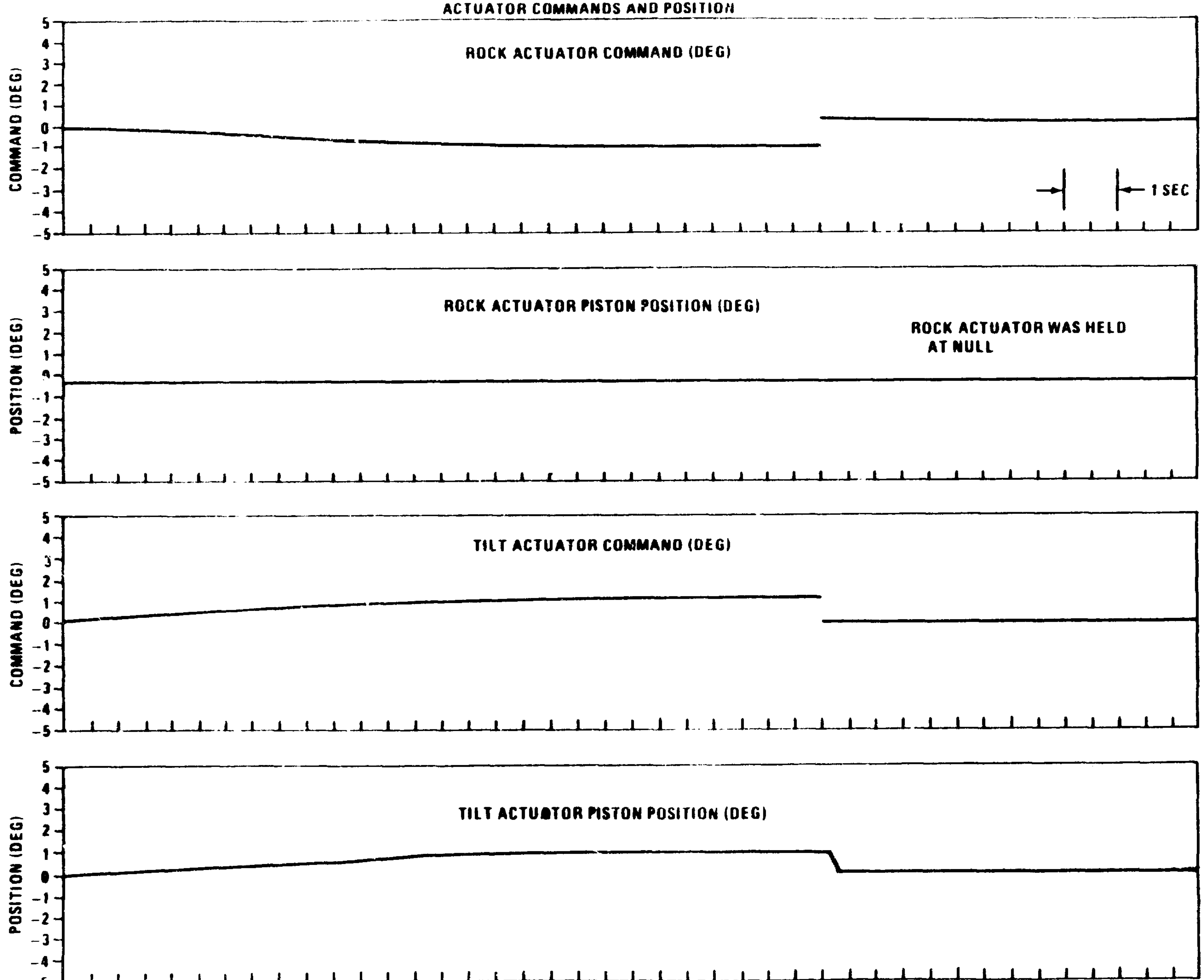


FIGURE 96

TEST P037-345
ACTUATOR FLIGHT CUTOFF SIMULATION
HYDRAULIC PRESSURE TRANSIENT

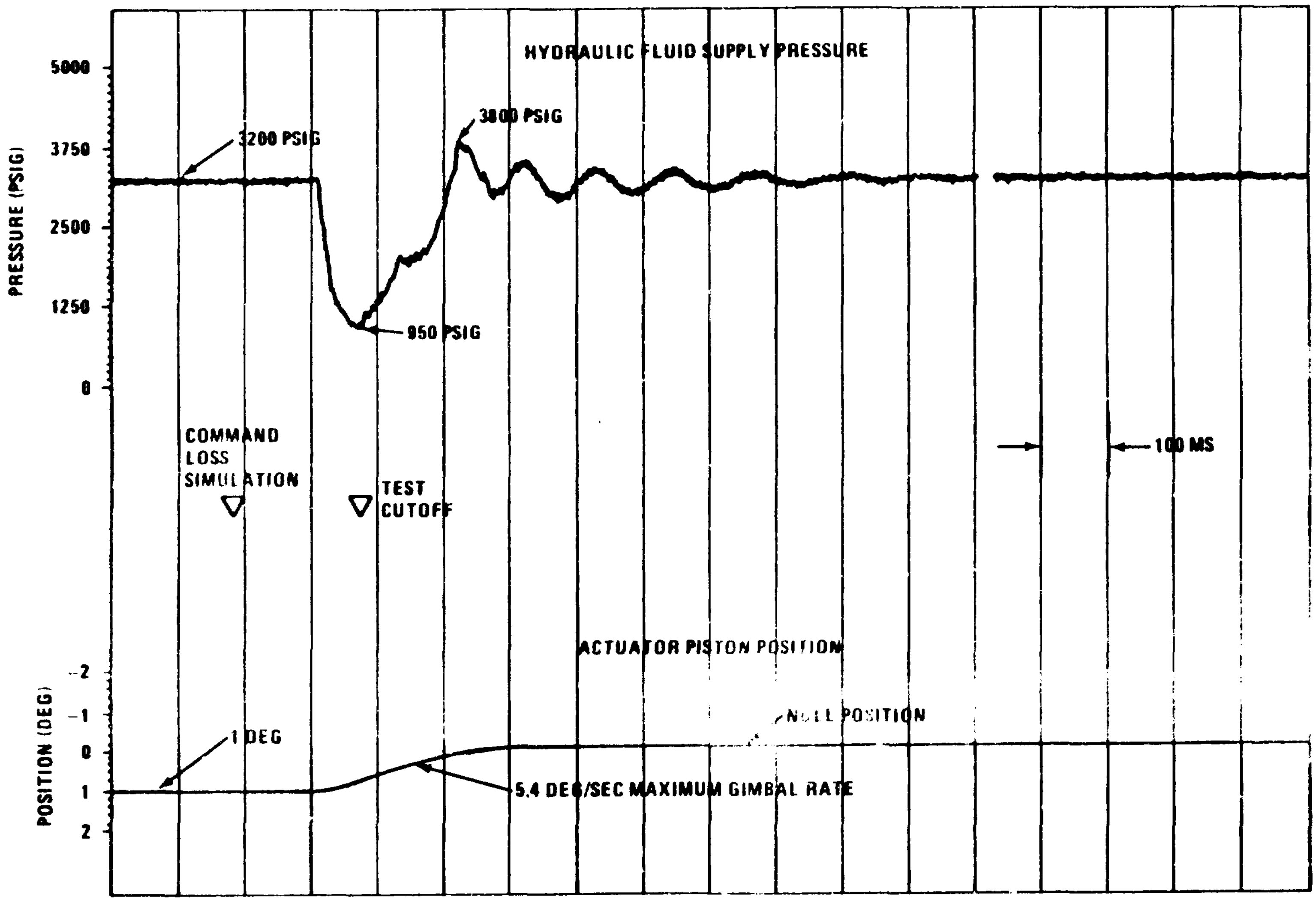


FIGURE 97

ORIGINAL PAGE IS
OF POOR QUALITY

FSM PRESSURE DECAY TEST 2

OBJECTIVE

To obtain the GN_2 pressure variations due to temperature changes inside the fuel system.

To obtain the GN_2 pressure-temperature behavior during the FSM pressurization operations.

RESULTS

Test P037-346 was conducted on July 22, 1980. For this run, the fuel system was pressurized to 400+0/-25 psia and held at that pressure for 12 hours. Prior to this test, flight type insulation was added to the FSM, and the line routing changed to meet STS-1 configuration.

The fuel system pressurization was monitored to obtain the pressure-temperature behavior and validate actual TVC fuel servicing procedures, plus prelaunch redlines. The data consisted of ullage, liquid and ambient temperature readings, and FSM pressure (P5). The results demonstrate that FSM pressure reached stability 15 minutes after the GN_2 pressure and purge valve was closed. Most of the pressure drop occurred during the first 2 minutes. Pressure decay for the stabilization period totaled 20 psi. (403 to 383 psia) Figures 98 and 99, plus tables 31 and 32 show the temperature-pressure decay following the pressurization period.

The temperature-pressure variations were monitored for 12 hours. While the ambient temperature changed from 66 to 84°F, the ullage temperature change totalled 6°F (78 to 84°F), and the total FSM pressure variation was 4.5 psi (378.5 to 383 psia). Table 3? shows the temperature-pressure variation for this monitoring.

This test employed the rock FSM and fuel system and the data base of the FSM pressure decay test 1.

PRECEDING PAGE BLANK NOT FILMED

TABLE 31

2 MINUTE PRESSURIZATION TRANSIENT
FSM PRESSURE DECAY TEST 2

TIME	P5	SKIN TEMP T1	LIQ. TEMP	ULL. TEMP
START	403	82	82	89
10 SEC.	402	82	82	89
20 SEC.	402	82	82	90
30 SEC.	401	82	82	90
40 SEC.	401	82	82	89
50 SEC.	400	82	82	89
60 SEC. (1 MIN)	400	82	82	89
70 SEC.	399	82	82	89
80 SEC.	397	82	82	89
90 SEC.	397	82	82	88
95 SEC.	392	82	82	88
100 SEC.	392	82	82	88
105 SEC.	388	82	83	88
110 SEC.	383	82	82	87
120 SEC (2 MIN)	384	82	83	87

TABLE 32

PRESSURIZATION TRANSIENT
FSM PRESSURE DECAY TEST 2

TIME	PS	SKIN TEMP T1	LIQ. TEMP	ULL. TEMP
START	403	82	82	89
1 MIN.	400	82	82	[illegible]
2 MIN.	384	82	83	87
3 MIN.	385	82	83	86
4 MIN.	385	82	83	86
5 MIN.	385	82	83	85
6 MIN.	384	82	83	[illegible]
7 MIN.	384	82	83	[illegible]
8 MIN.	384	82	83	[illegible]
9 MIN.	384	82	83	[illegible]
10 MIN.	384	82	83	85
11 MIN.	384	82	83	85
12 MIN.	384	82	83	85
13 MIN.	383	82	83	84
13 MIN 20 SEC.	383	82	83	84

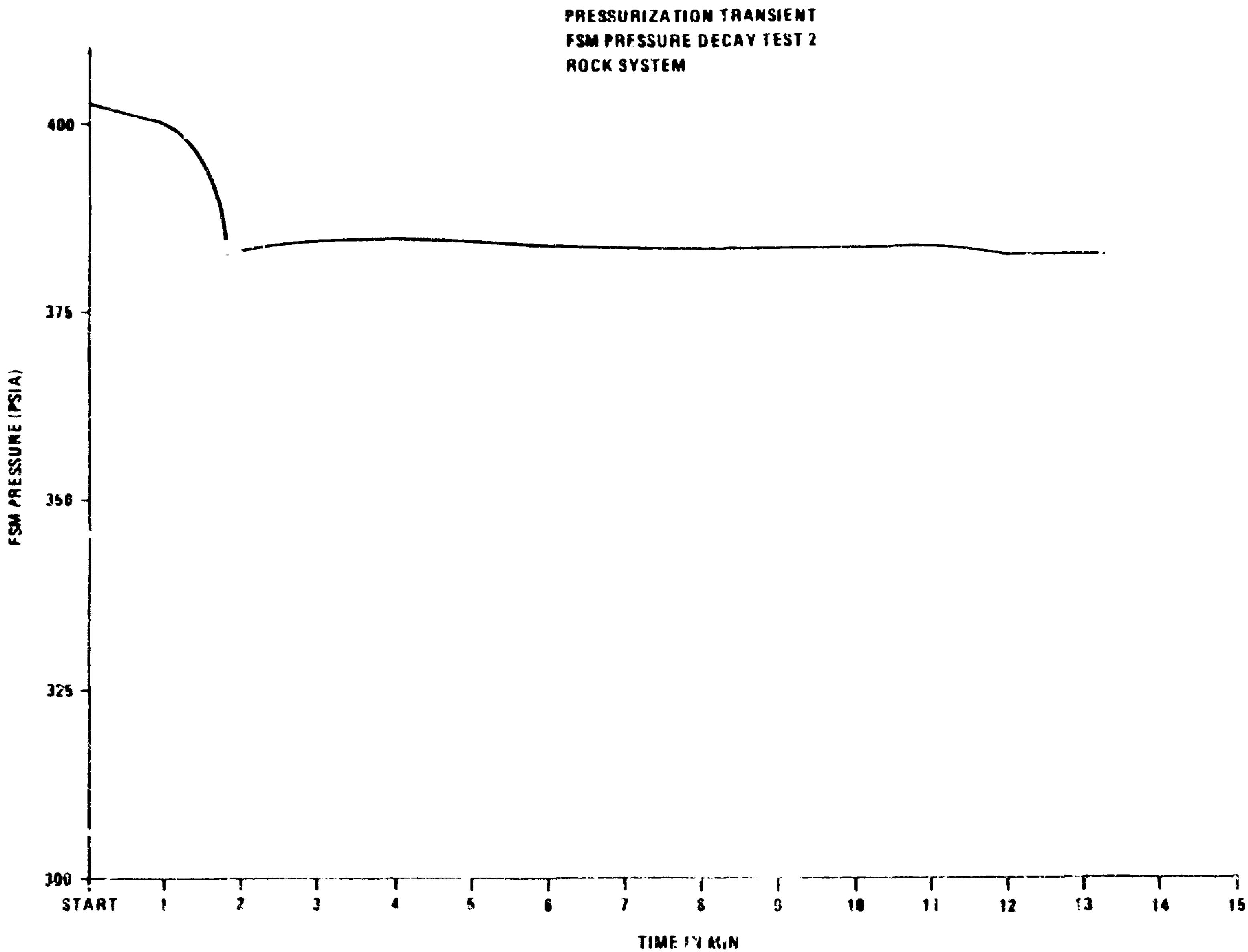

PRESSURIZATION TRANSIENT
FSM PRESSURE DECAY TEST 2
ROCK SYSTEM
400
375
350
325
300
FSM PRESSURE (PSIA)
START
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
TIME IN MIN

FIGURE 98

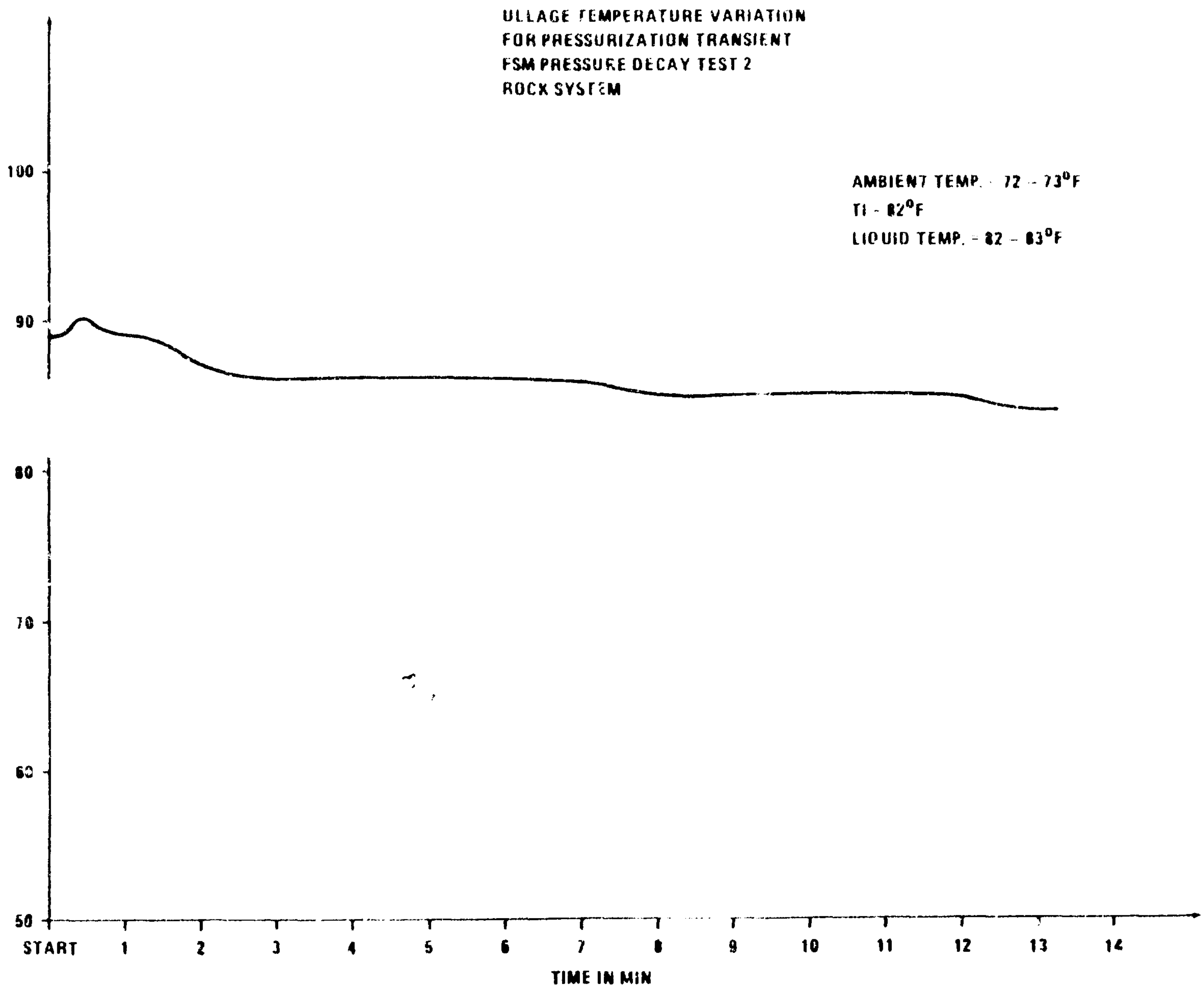

ULLAGE TEMPERATURE VARIATION
FOR PRESSURIZATION TRANSIENT
FSM PRESSURE DECAY TEST 2
ROCK SYSTEM
AMBIENT TEMP. - 72 - 73°F
TI - 82°F
LIQUID TEMP. - 82 - 83°F
100
90
80
70
60
50
START
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME IN MIN

FIGURE 99

TABLE 33

TEMPERATURE – PRESSURE VARIATIONS
FSM PRESSURE DECAY TEST 2

TIME	SKIN TEMP T1	LIQ. TEMP	PS	ULL. TEMP	AMB. TEMP
5:12 AM	82	83	383	84	74
6:05 AM	81	81	380	80	68
6:50 AM	81	80	379	79	68
7:19:30 AM	81	79	379	79	66
7:40 AM	81	79	379	78	67
8:30 AM	80	78	378.5	78	71.5
9:20 AM	80	79	378.5	78	73
10:10 AM	80	79	378.5	79	74
11:00 AM	80	80	379	80	77
11:58 AM	81	[illegible]	380	81	80
12:40 PM	81	81	380	82	81
1:30 PM	81.5	82	381	82.5	84
2:20 PM	82	[illegible]	381	83	81
3:10 PM	82	82	381	83	80
4:00 PM	82	82	381	83	79
4:50 PM	82	82	381	82	75
5:40 PM	82	81	380	81	73

APPROVAL

SOLID ROCKET BOOSTER

THRUST VECTOR CONTROL
V-2 OFF NOMINAL TESTING
REPORT

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

A. A. McCool
Director
Structures and Propulsion Laboratory

A. J. Verble, Jr.
Chief
Mechanical Division

J. H. Potter
Chief
Propulsion Control Branch