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Technical Report

No. 13515

AGT 1500 POWERPACK IMPROVEMENT PROJECT (M1 TMEPS)

CONTRACT NUMBER DAAE07-87-C-R006

MARCH 1991

VOLUME II OF II

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APPENDIX I

APPENDIX I

Report No. LYC 90-18
(03-P-902-90)

TME Interchangeability Demonstration Test

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September 1990

Report No. LYC 90-18

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I	TME Interchangeability Test Plan
II	TEMPS/MIAI Engine Module Interchangeability Testing: Performance Results

I. ABSTRACT

Compatibility of AGT 1500 and TME (AGT 1500A) engine forward and rear modules and control units was successfully demonstrated during interchangeability testing conducted between 11 July and 1 August 1989. The interchangeability test consisted of steady-state and transient evaluation of various module configurations (as specified in government contract DAC-100001) of one AGT 1500 and one AGT 1500A (TME) automotive gas turbine selected to participate. Interchangeability testing of the standard electronic control unit and the TME digital electronic control unit (DECU) was also conducted.

Steady-state engine performance demonstrated improved SFC at part power and idle with operation of the TME DECU. Trim power demonstrated for each configuration tested revealed acceptable requirements for vehicle mobility. Engine mechanical data was also found to be acceptable.

Transient response of each configuration was evaluated and data indicates a slight increase in acceleration and deceleration time with operation of the TME DECU. Surge-free operation of all configurations was demonstrated by engine waveoff procedures.

II. BACKGROUND

The AGT 1500 and AGT 1500A (TME) are both automotive gas turbine engines which are comprised of a two-spool gas generator with a stationary recuperator and free power turbine. The power turbine assembly on both engine models utilizes variable geometry for optimum efficiency at all power levels. The Transverse Mount Engine (TME) design is part of a combined effort by Textron-Lycoming, General Dynamics Land Systems (GDLS), Allison Transmission Division (ATD) of GM and Donaldson Corporation to produce an advanced propulsion system for an improved M-1 Abrams derivative tank. The TME system when fully developed will result in a thirty percent reduction in power-pack volume when compared to the current Abrams main battle tank. Changes in engine design will also result in improved thermodynamic efficiency, increased power output and lower fuel consumption.

TME Featured Hardware

Principal changes in engine design of the Transverse Mount Engine as related to the current production AGT 1500 automotive gas turbine which result in improved operating efficiency and power output are described briefly below.

High Pressure Turbine Rotor

The HP turbine rotor was redesigned for increased efficiency and durability. Turbine cooling was optimized and the blades consist of single crystal design (see Figure 1). Modifications to the high pressure turbine account for approximately one percent in SFC improvement.

High Pressure Turbine Cylinder

The high pressure turbine features a ceramic (TBC) coated cylinder (see Figure 1) for increased efficiency through a reduction in blade tip leakage.

Recuperator

Improvements to the present design include Hastelloy-S material and increased pre-load for greater durability and effectiveness.

Power Turbines

The TME power turbine assembly incorporates fuel economy (FEP) turbines which are resized for improved part power performance. Thermodynamic efficiency is increased by 4.5 percent over the current production power turbines.

Electronic Control Unit

The electronic control unit utilizes digital technology for increased capabilities. The engine operating schedules are also enhanced for improved efficiency and durability. The TME digital electronic control unit (DECU) includes 'Easy-Ride' protection features which consist of improved starting logic, and the T7-Lag logic to reduce thermal gradients during transient operation. The digital control unit will also feature (when fully developed) diagnostic software to assist in troubleshooting engine related problems.

Accessory Gearbox Module

The TME accessory gearbox assembly is redesigned to allow for reduced engine volume. The customer power take-off pad used on the current AGT 1500 engine to drive a hydraulic pump for vehicle turret rotation is relocated to the TME (7) seven speed transmission.

As part of sub-contract DAC-100001, an interchangeability test was required to verify compatibility of engine hardware between AGT 1500 and TME configurations. The following module configurations were selected to complete engine dynamometer testing:

TME front module/AGT 1500 rear module - TME DECU
TME front module/AGT 1500 rear module - Standard ECU
AGT 1500 front module/TME rear module - TME DECU
AGT 1500 front module/TME rear module - Standard ECU
Full AGT 1500 engine - TME DECU
Full AGT 1500A (TME) engine - standard ECU

One AGT 1500 engine (A68, S/N LE87680) and one AGT 1500A (TME) engine (A66, S/N LE87100) were selected to complete interchangeability testing and demonstrate compatibility of engine modules and control units.

Test Objectives

Objectives of the interchange test are as follows:

1. Demonstrate compatibility of AGT 1500 and AGT 1500A engine modules and control units.

2. Compare steady state engine performance (power and SFC requirements) of engine configurations.

3. Review engine transient response - handling and stability checks.

III. TEST EQUIPMENT

Starter

A Delco Remy 1113883 or Leece Neville 17414MA electric starter powered by a 28 VDC Hobart 6T28-400CL motor generator is used to start the engine.

Power Absorption

A Textron Lycoming water brake is used for engine power absorption (LC28800). In addition, this water brake has provisions for monitoring its speed and radial vibration.

Power Extraction

A Bendix model 30858-3-B 400 ampere starter/generator with associated switches and load bank (United Manufacturing Model DCLB) is used for power extraction from the engine customer power takeoff pad on the M1A1 configuration only.

Oil Coolers

Engine oil is cooled by means of an industrial type oil to water heat exchanger, Lycoming TES 77-1.

Oil Level Measurement

A Robertshaw Controls, Model 5000, indicator and probe were used to measure oil level.

Vibrations

Vibration measurement will consist of Trig-Tek vibration meters in conjunction with velocity-displacement pickups.

Temperatures

Temperatures are measured by Chromel Alumel (Type K) thermocouples. Signals are conditioned through appropriate analog to digital converters.

Pressures

Pneumatic and hydraulic pressures are measured through calibrated pressure transducers.

Flows

Turbine flow meters with associated converters, amplifiers and readouts are used to measure oil and fuel flow rates.

Speeds

Magnetic pickups with associated electrical hardware are used to measure the compressor/turbine and output shaft speeds.

Torque

A strain gauged torque element which supports an AGT 1500 water brake is used to measure engine torque.

Air Flow

A calibrated axial bellmouth assembly (ASME standards) with static and total pressure probes is utilized for airflow measurement during performance calibrations.

Engine main bearing flow rates, pressures and temperatures were observed to be within specified limits for all configurations tested. Oil consumption measured during interchange testing was also found to be in specification.

VI. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that all configurations tested (as outlined in contract DAC100001) demonstrated acceptable compatibility of AGT 1500 and TME engine modules.

Engine performance indicates improved SFC at idle and part power operation with use of the TME digital electronic control unit and hardware (see Appendix II).

All module configurations tested demonstrated adequate trim power requirements (as needed for vehicle mobility). When the standard AGT 1500 control unit was utilized in each configuration additional power was available by readjusting the trim NH governor setting established during the baseline AGT 1500 test.

Mechanical data measured during the test did not reveal any significant problems when AGT 1500 and TME hardware are interchanged. All configurations tested operated free of surge as verified by engine waveoff procedures. Transient response (acceleration and deceleration time measurement) does indicate a slight increase when the TME DECU is utilized. The acceleration and deceleration times measured during the interchangeability test were observed to be within the specification limits defined for operation with the Production AGT 1500 Fuel Economy DECU.

It is recommended that if the TME digital electronic control unit (DECU) is used with AGT 1500 forward or rear module components, the trim NH governor should be readjusted to maintain AGT 1500 operating conditions.

It is recommended that this report be accepted as evidence of the successful demonstration of interchangeability between AGT 1500 and TME modules and control units.

FIGURES

FIGURE 1

HP TURBINE ASSEMBLY - TME

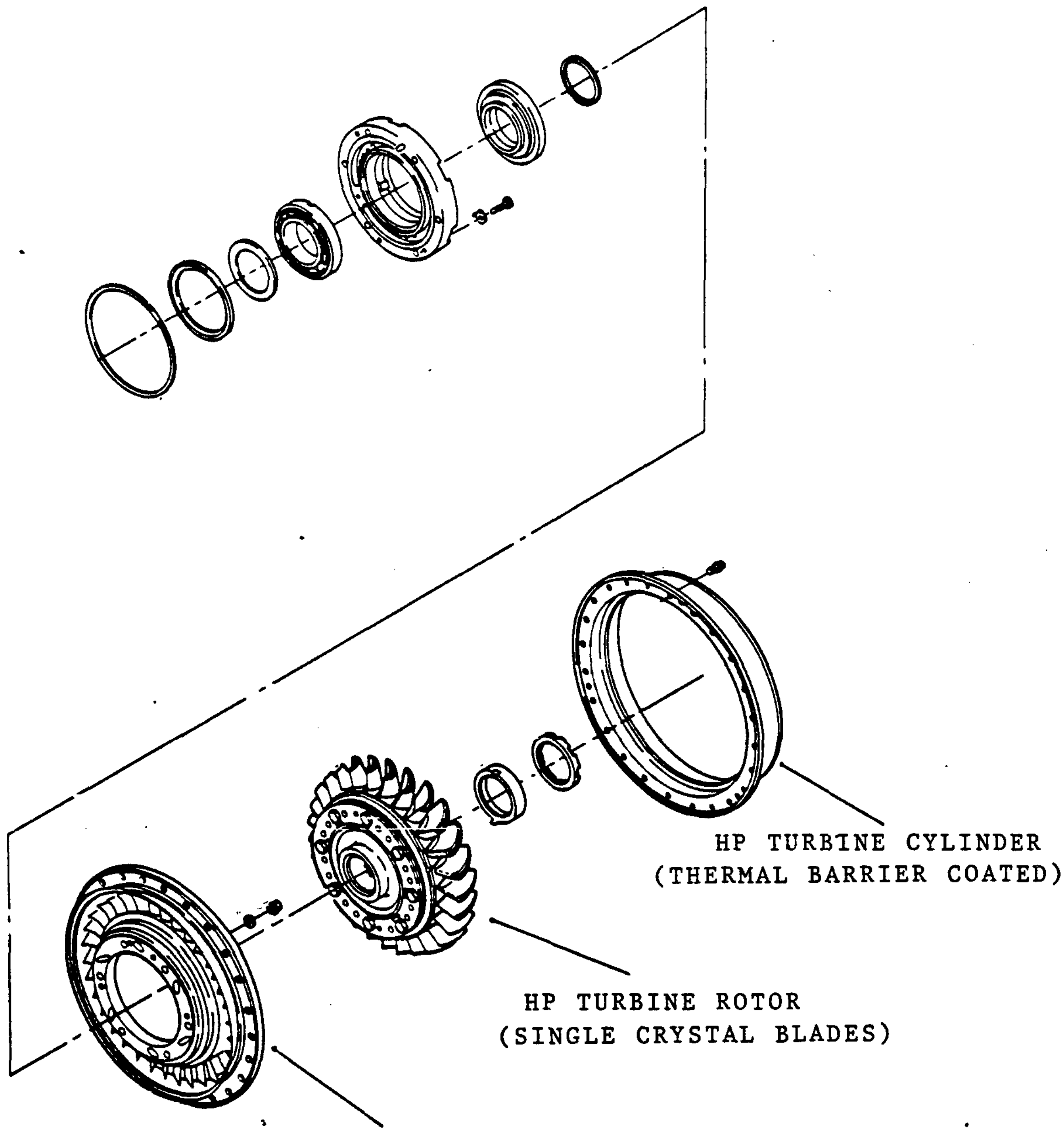
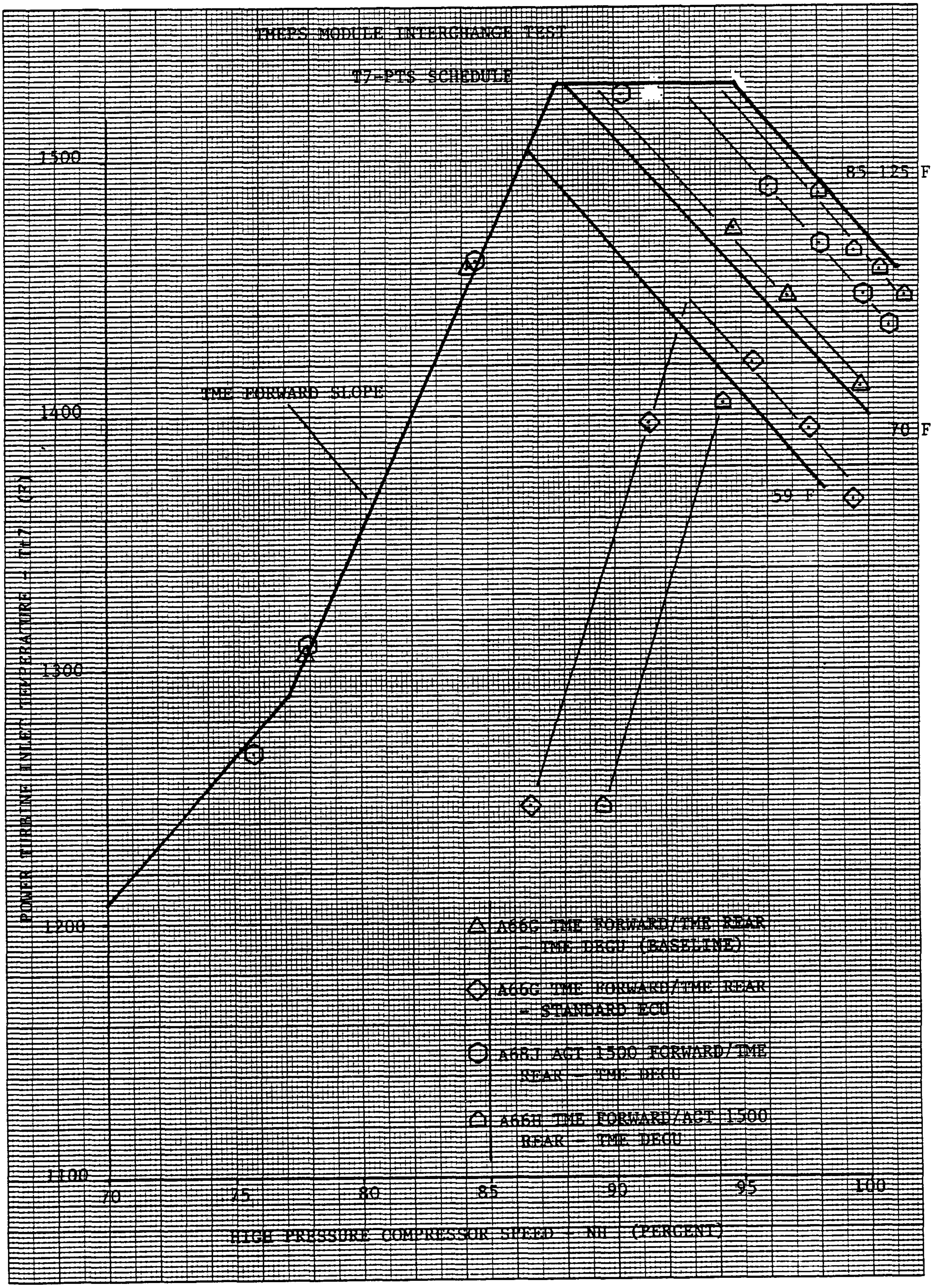
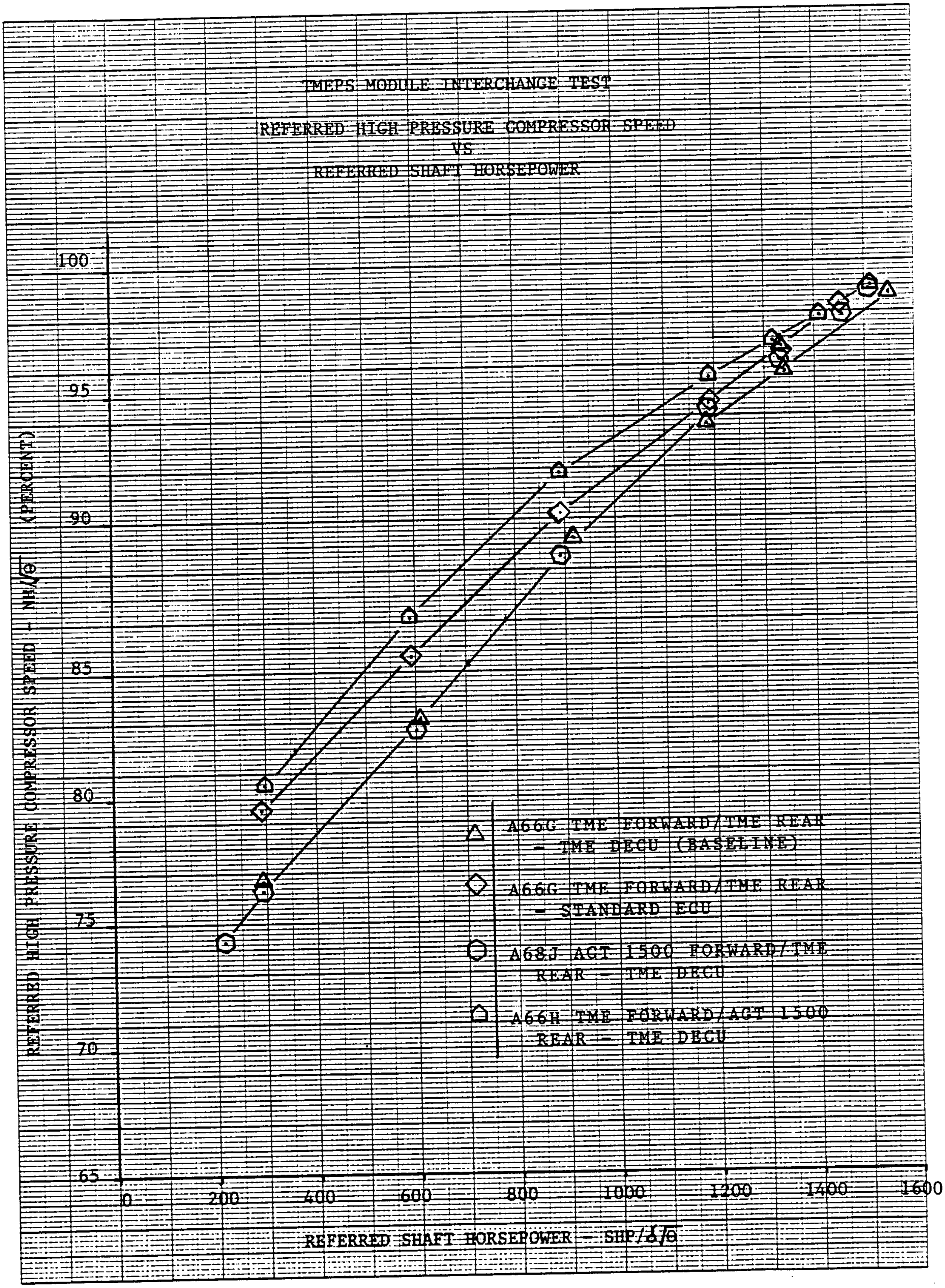


FIGURE 2



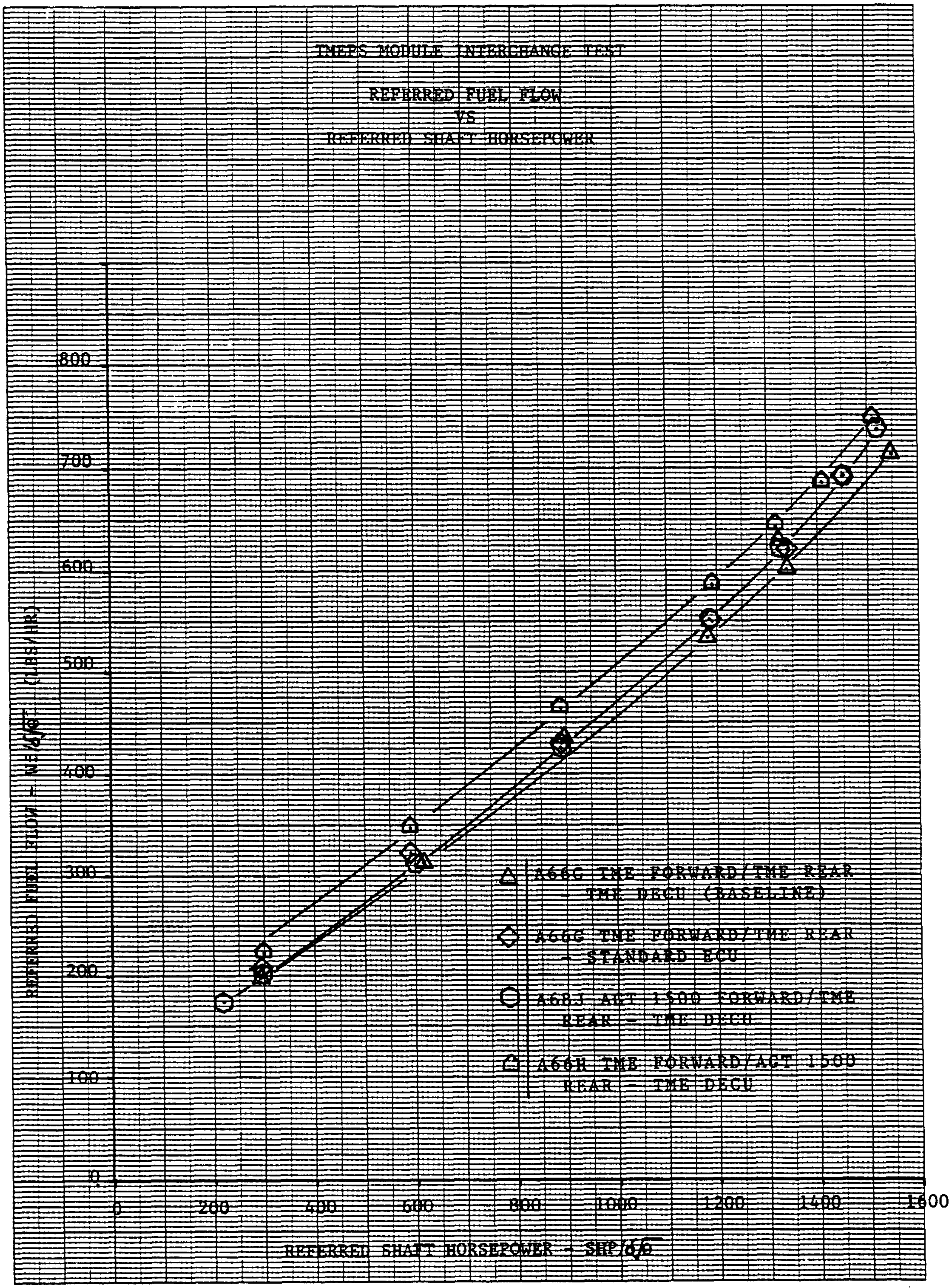
10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1510

FIGURE 3



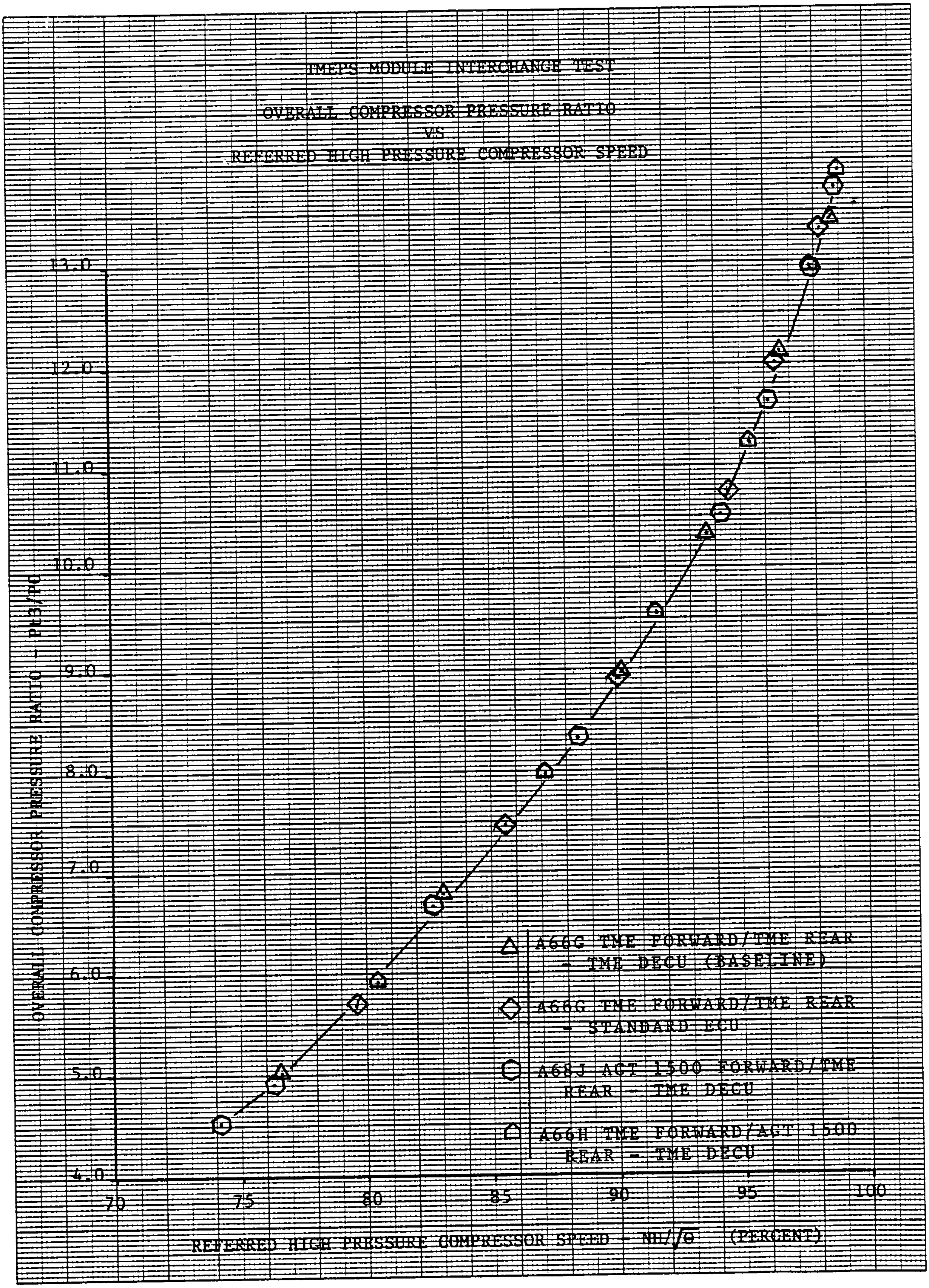
TMEPS MODULE INTERCHANGE TEST
REFERRED HIGH PRESSURE COMPRESSOR SPEED
VS
REFERRED SHAFT HORSEPOWER
REFERRED HIGH PRESSURE COMPRESSOR SPEED - NH/√θ (PERCENT)
100
95
90
85
80
75
70
65
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
A66G TME FORWARD/TME REAR - TME DECU (BASELINE)
A66G TME FORWARD/TME REAR - STANDARD ECU
A68J ACT 1500 FORWARD/TME REAR - TME DECU
A66H TME FORWARD/ACT 1500 REAR - TME DECU

FIGURE 4



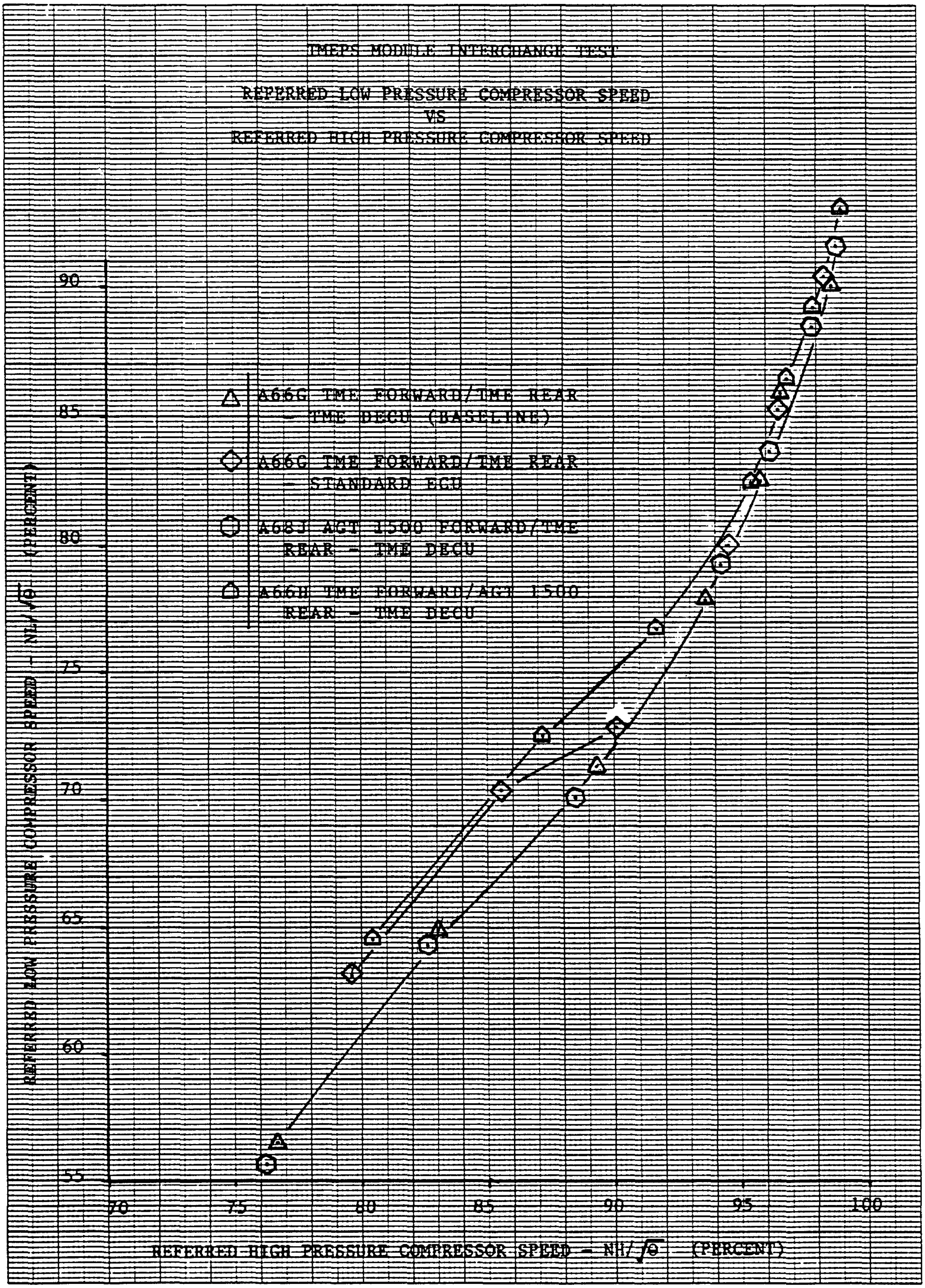
TMEPS MODULE INTERCHANGE TEST
REFERRED FUEL FLOW
VS
REFERRED SHAFT HORSEPOWER
REFERRED FUEL FLOW - WF/δ√θ (LBS/HR)
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
A66G TME FORWARD/TME REAR - TME DECU (BASELINE)
A66G TME FORWARD/TME REAR - STANDARD ECU
A68J AGT 1500 FORWARD/TME REAR - TME DECU
A66H TME FORWARD/AGT 1500 REAR - TME DECU

FIGURE 5



TMEPS MODULE INTERCHANGE TEST
OVERALL COMPRESSOR PRESSURE RATIO
VS
REFERRED HIGH PRESSURE COMPRESSOR SPEED
OVERALL COMPRESSOR PRESSURE RATIO - Pt3/P0
REFERRED HIGH PRESSURE COMPRESSOR SPEED - NH/√θ (PERCENT)
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
70
75
80
85
90
95
100
A66G TME FORWARD/TME REAR - TME DECU (BASELINE)
A66G TME FORWARD/TME REAR - STANDARD ECU
A68J AGT 1500 FORWARD/TME REAR - TME DECU
A66H TME FORWARD/AGT 1500 REAR - TME DECU

FIGURE 6



TMEPS MODULE INTERCHANGE TEST
REFERRED LOW PRESSURE COMPRESSOR SPEED
VS
REFERRED HIGH PRESSURE COMPRESSOR SPEED
A66G TME FORWARD/TME REAR - TME DECU (BASELINE)
A66G TME FORWARD/TME REAR - STANDARD ECU
A68J AGT 1500 FORWARD/TME REAR - TME DECU
A66H TME FORWARD/AGT 1500 REAR - TME DECU
REFERRED LOW PRESSURE COMPRESSOR SPEED - NL/√θ (PERCENT)
55
60
65
70
75
80
85
90
70
75
80
85
90
95
100
REFERRED HIGH PRESSURE COMPRESSOR SPEED - NH/√θ (PERCENT)

FIGURE 7

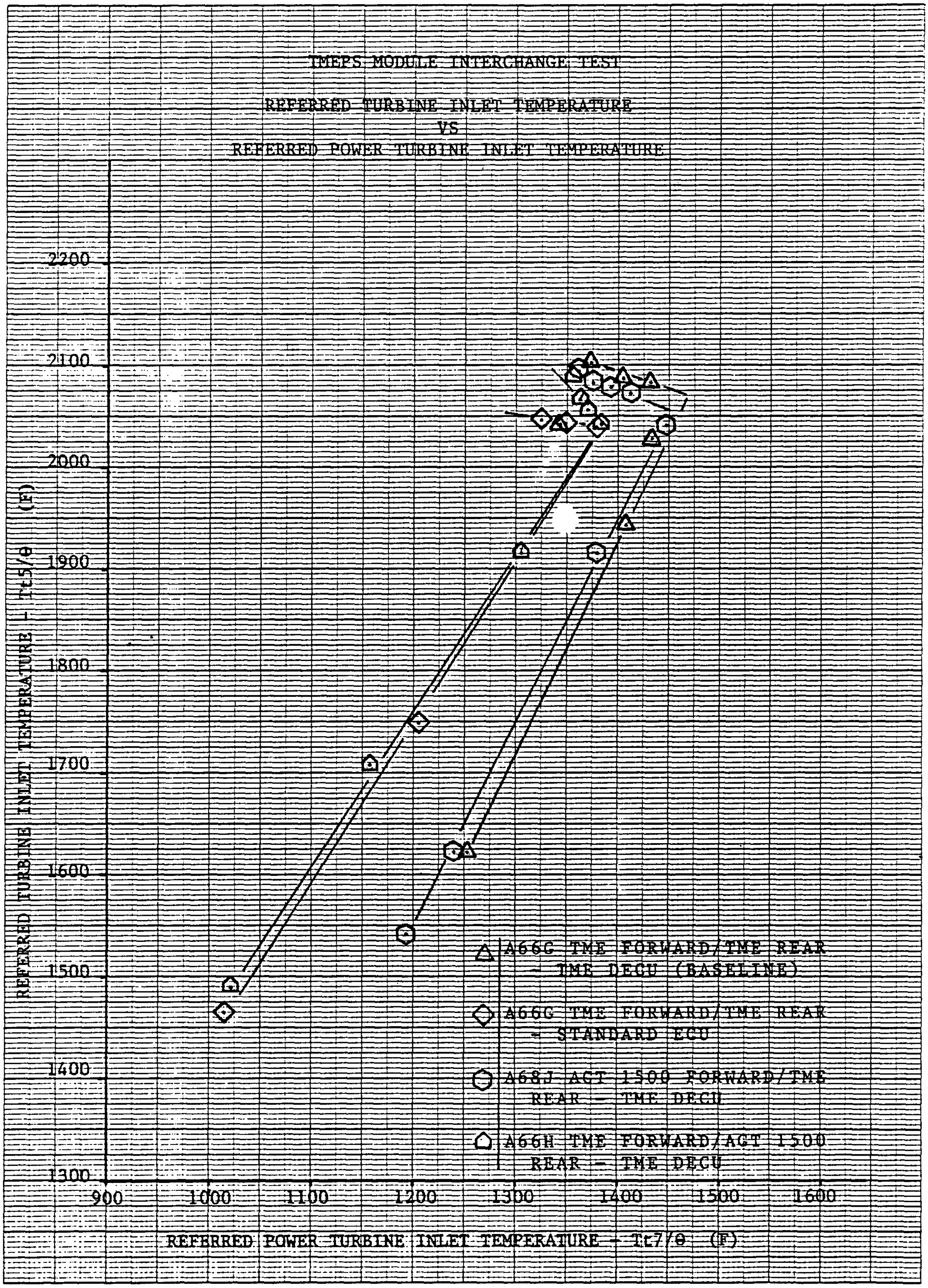
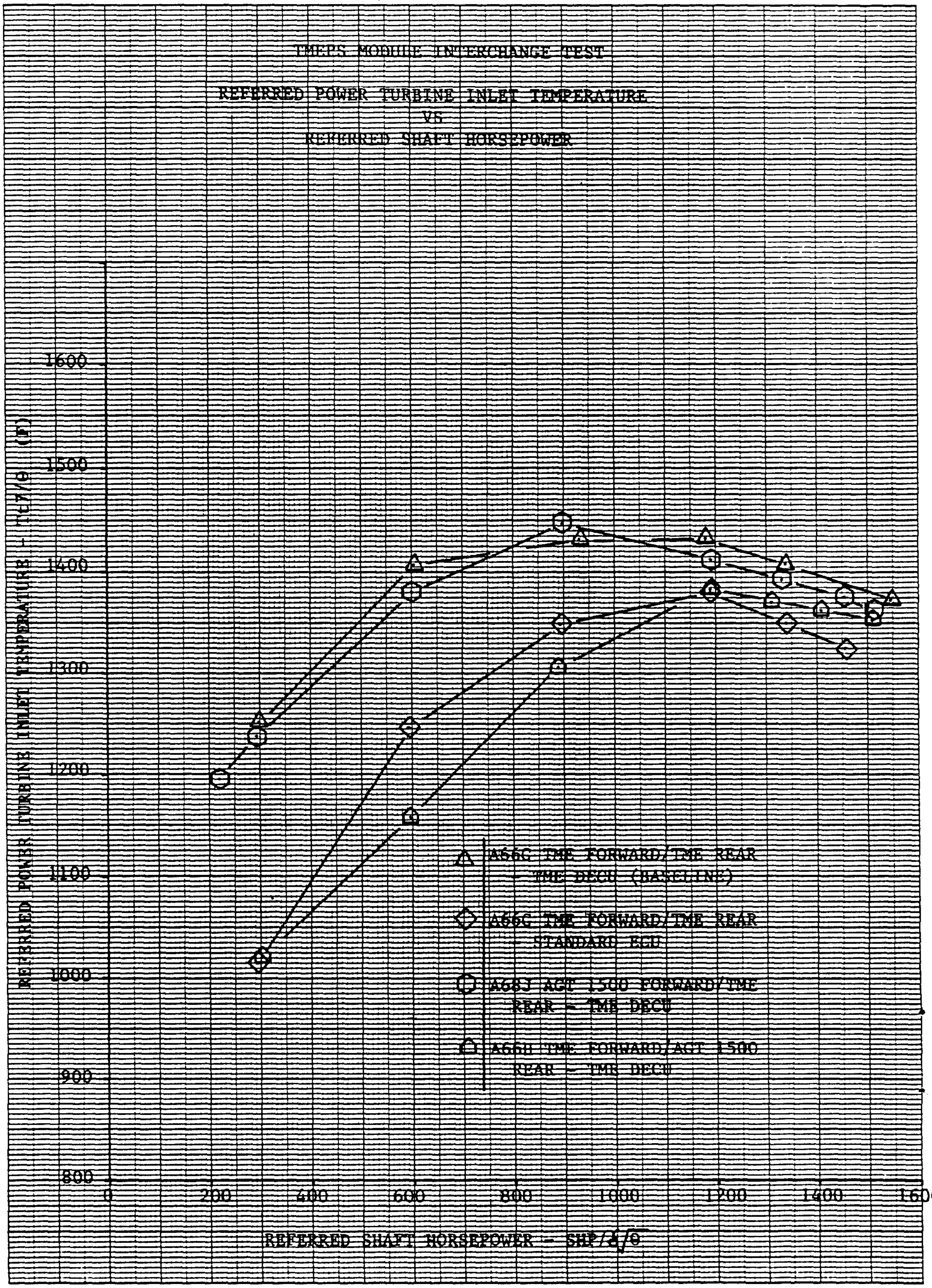
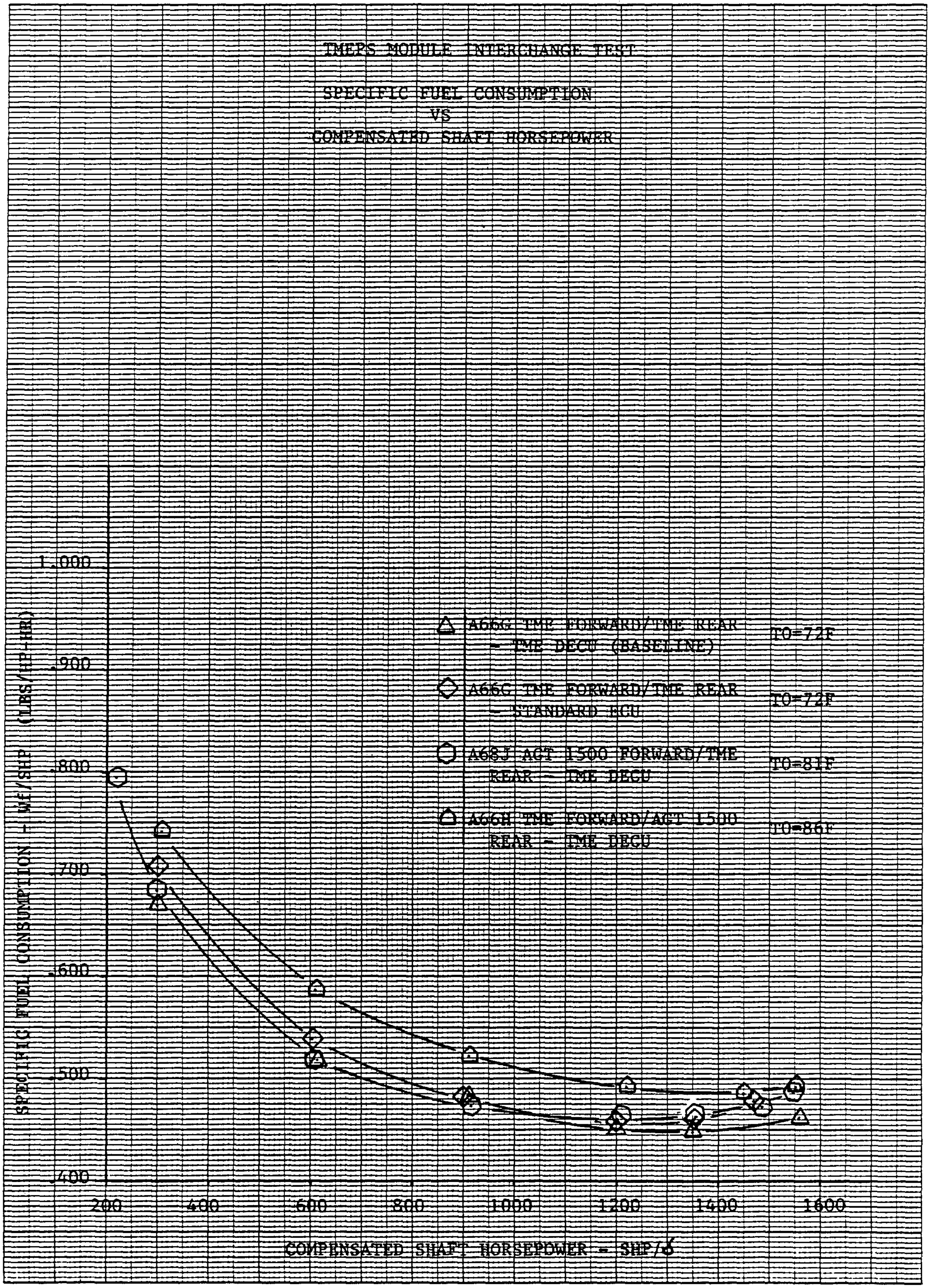

TMEPS MODULE INTERCHANGE TEST
REFERRED TURBINE INLET TEMPERATURE
VS
REFERRED POWER TURBINE INLET TEMPERATURE
REFERRED TURBINE INLET TEMPERATURE - Tt5/θ (F)
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
900
1000
1100
1200
1300
1400
1500
1600
REFERRED POWER TURBINE INLET TEMPERATURE - Tt7/θ (F)
A66G TME FORWARD/TME REAR - TME DECU (BASELINE)
A66G TME FORWARD/TME REAR - STANDARD ECU
A68J AGT 1500 FORWARD/TME REAR - TME DECU
A66H TME FORWARD/AGT 1500 REAR - TME DECU

FIGURE 8



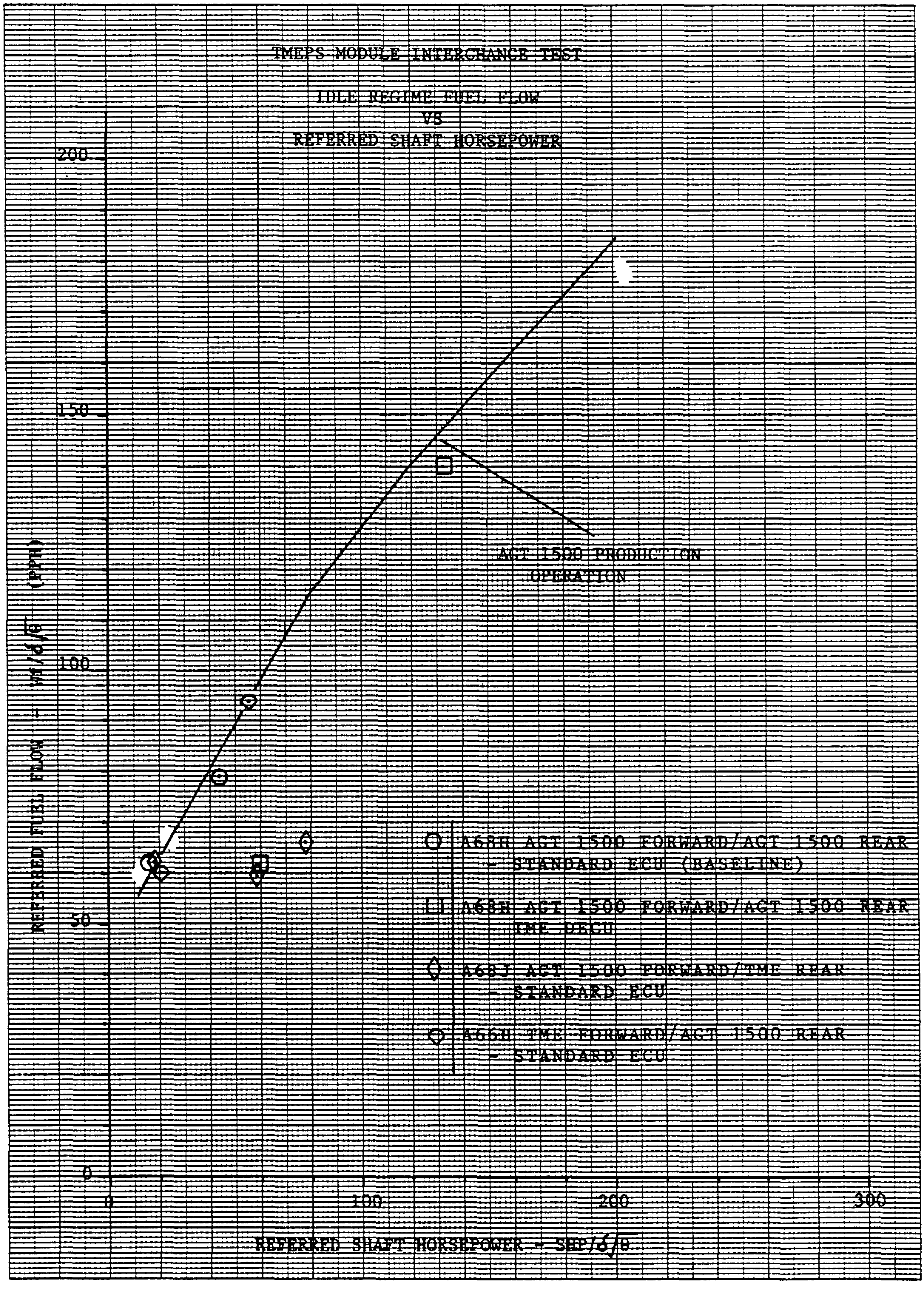
10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN USA
46 1510

FIGURE 10



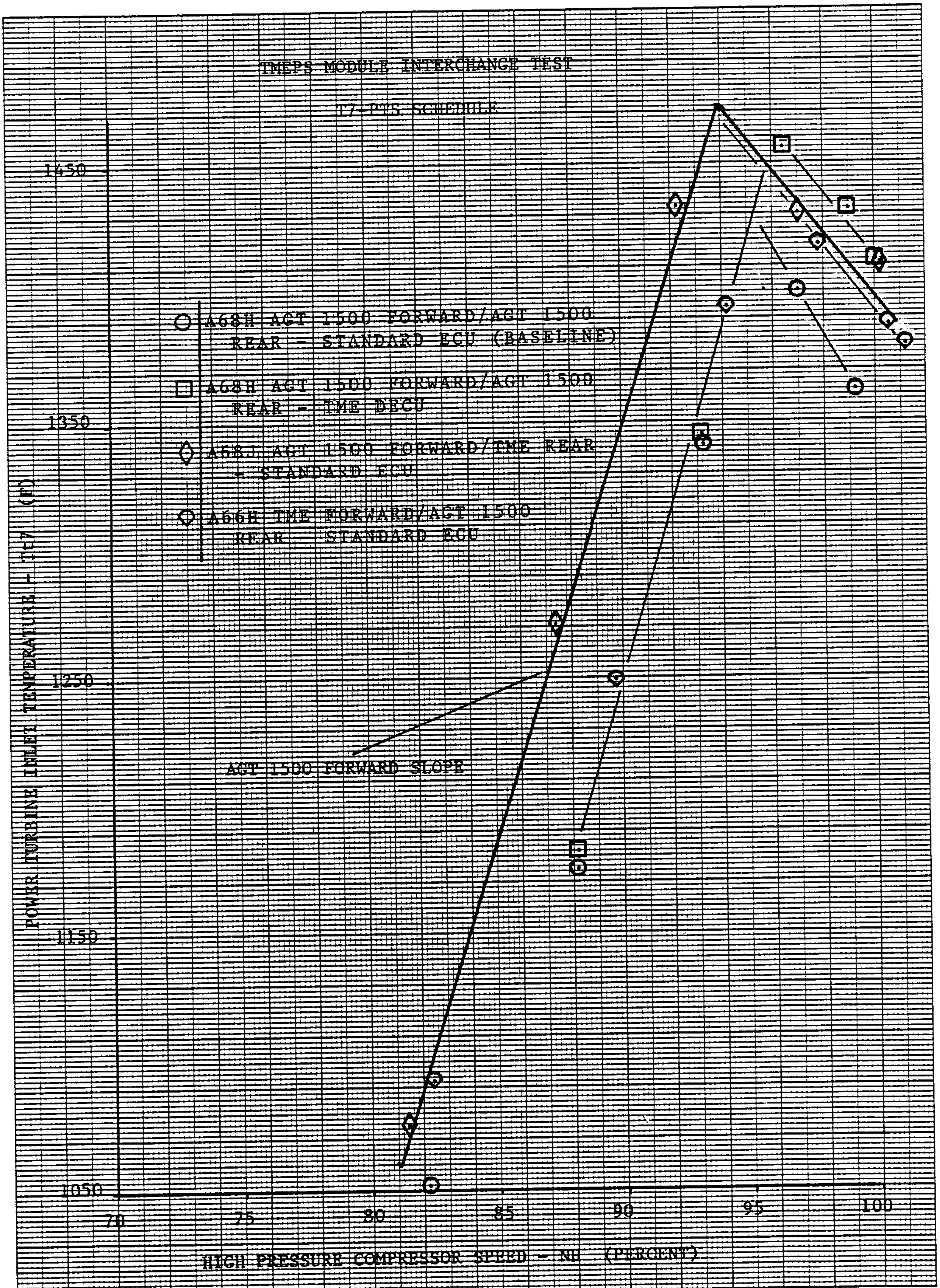
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1510

FIGURE 11



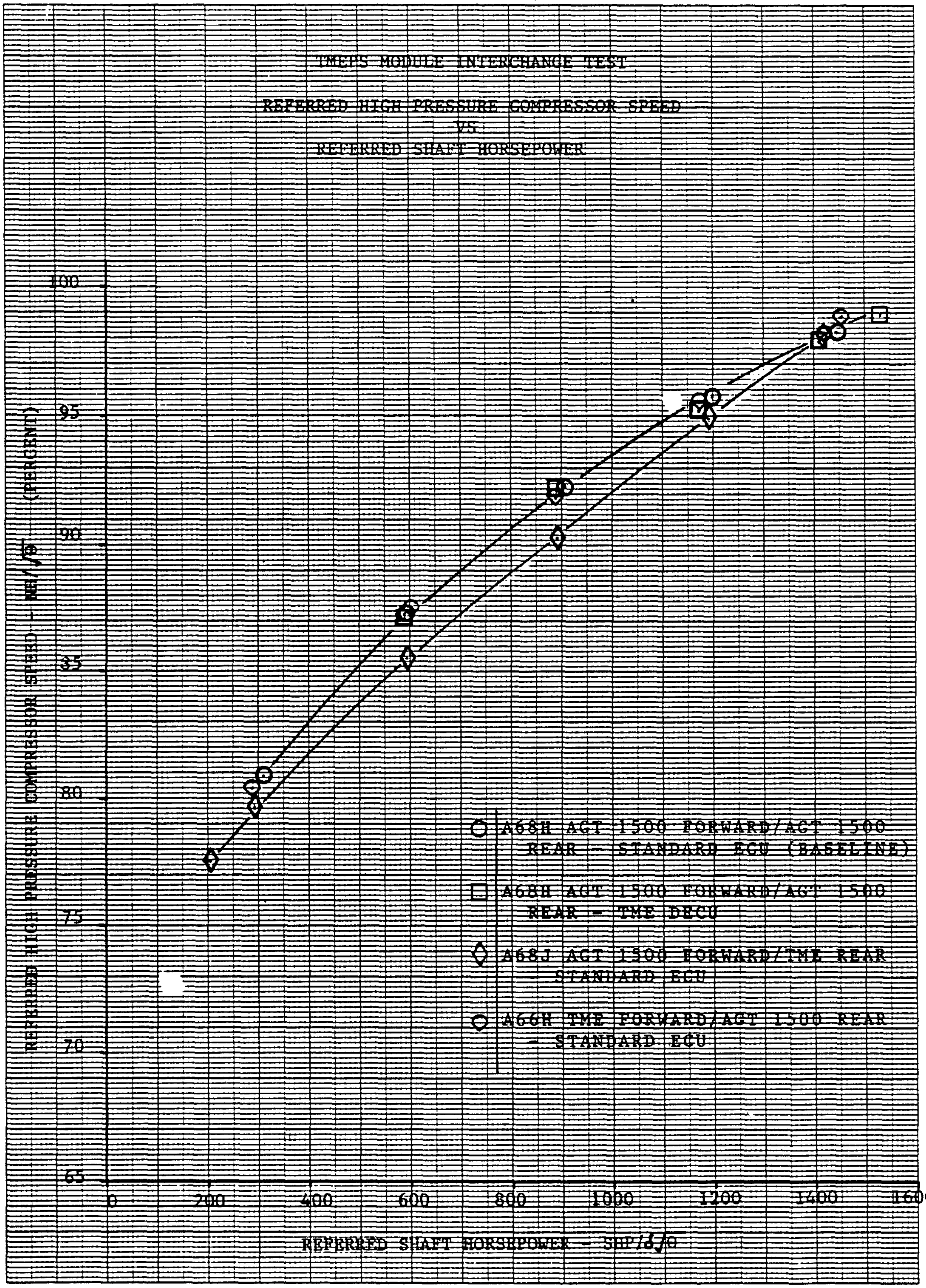
TMEPS MODULE INTERCHANGE TEST
IDLE REGIME FUEL FLOW
VS
REFERRED SHAFT HORSEPOWER
200
150
100
50
0
0
100
200
300
REFERRED FUEL FLOW - Wf/δ√θ (PPH)
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
AGT 1500 PRODUCTION
OPERATION
A68H AGT 1500 FORWARD/AGT 1500 REAR
- STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR
- TME DECU
A68J AGT 1500 FORWARD/TME REAR
- STANDARD ECU
A66H TME FORWARD/AGT 1500 REAR
- STANDARD ECU

FIGURE 12



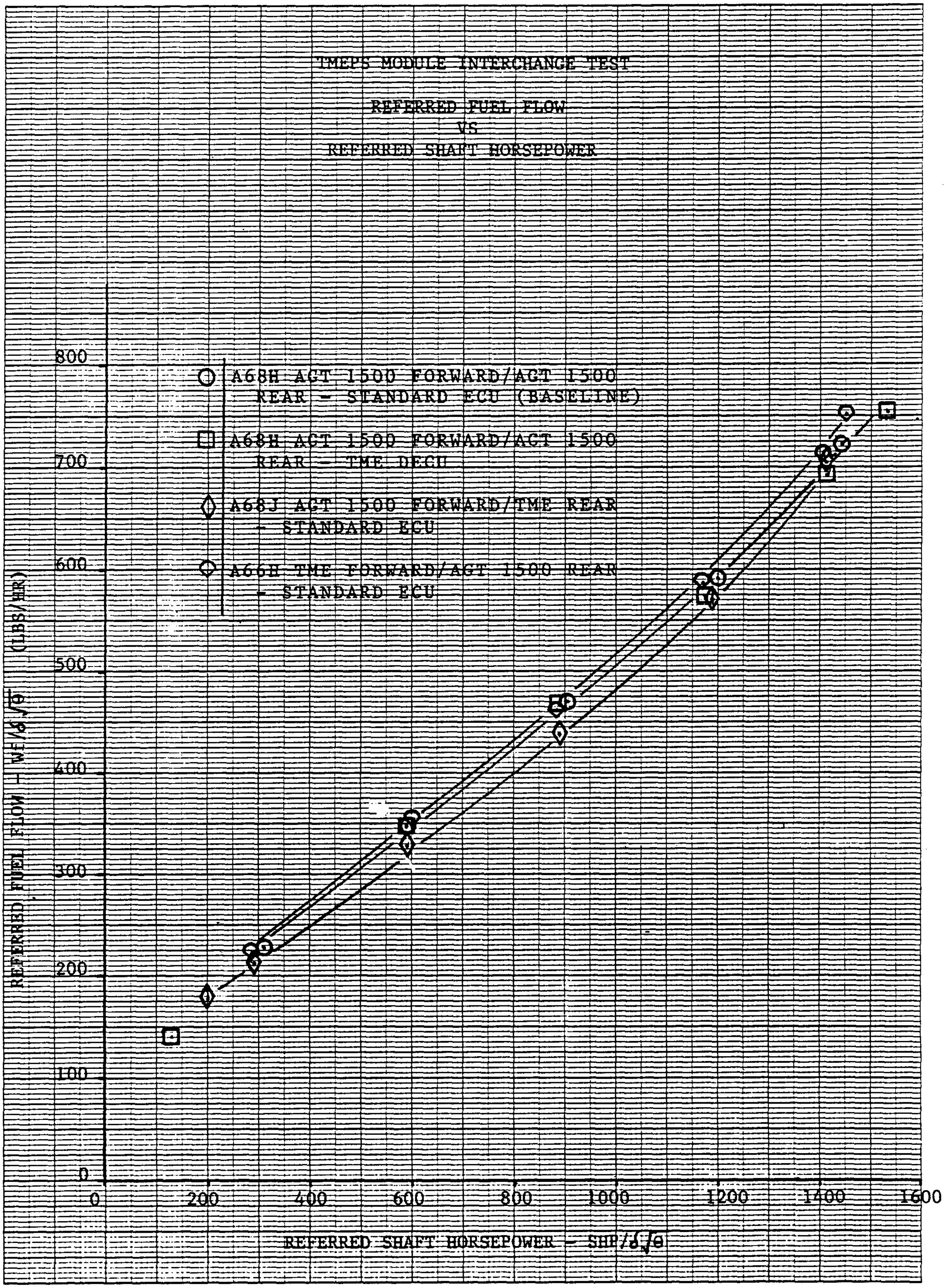
TMEPS MODULE INTERCHANGE TEST
T7-PTS SCHEDULE
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU
AGT 1500 FORWARD SLOPE
POWER TURBINE INLET TEMPERATURE - Tt7 (F)
1050
1150
1250
1350
1450
70
75
80
85
90
95
100
HIGH PRESSURE COMPRESSOR SPEED - NH (PERCENT)

FIGURE 13



TMEPS MODULE INTERCHANGE TEST
REFERRED HIGH PRESSURE COMPRESSOR SPEED
VS
REFERRED SHAFT HORSEPOWER
REFERRED HIGH PRESSURE COMPRESSOR SPEED - NH/√θ (PERCENT)
100
95
90
85
80
75
70
65
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU

FIGURE 14



TMEPS MODULE INTERCHANGE TEST
REFERRED FUEL FLOW
VS
REFERRED SHAFT HORSEPOWER
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU
REFERRED FUEL FLOW - WF/δ√θ (LBS/HR)
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ

FIGURE 15

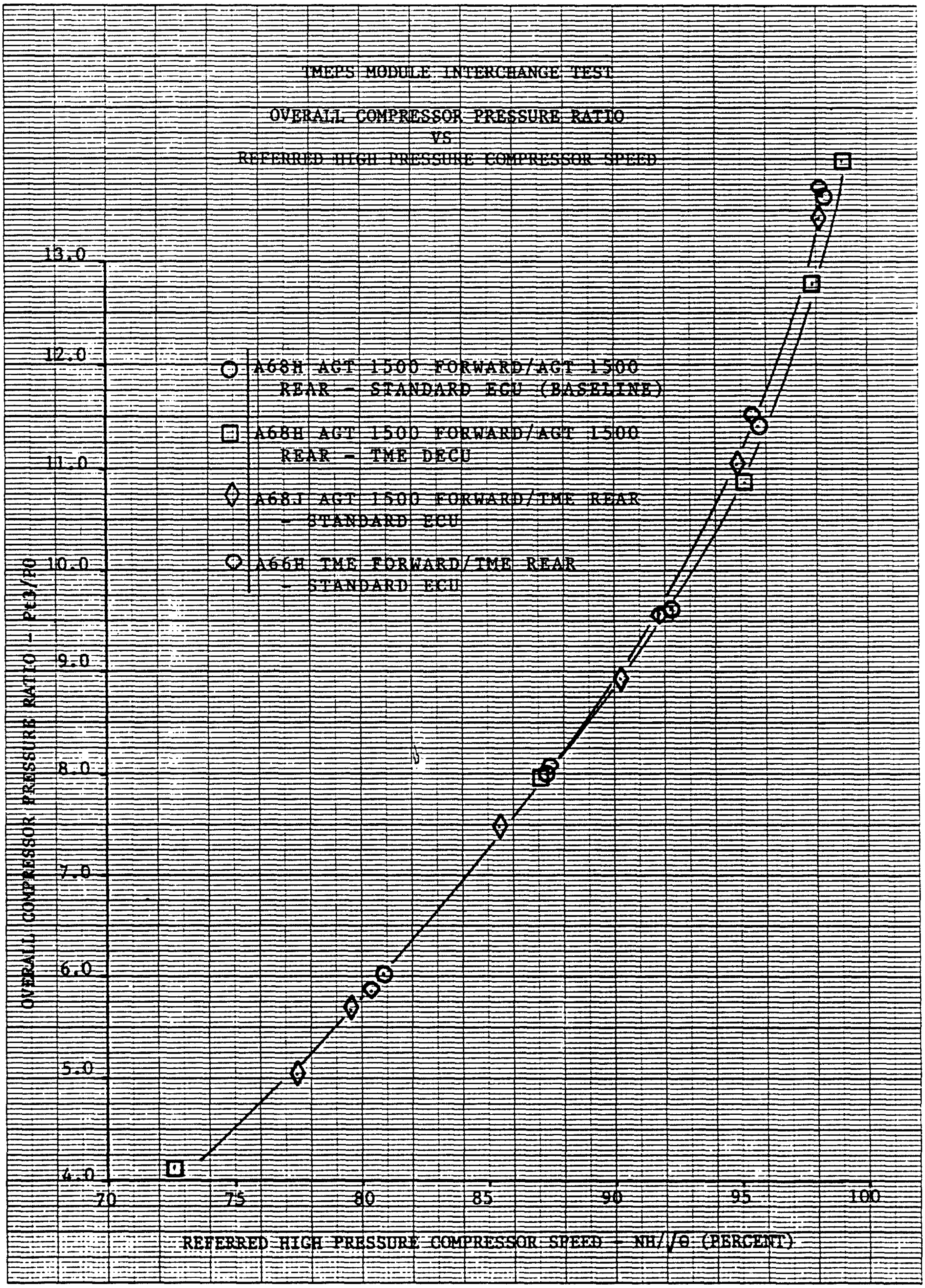
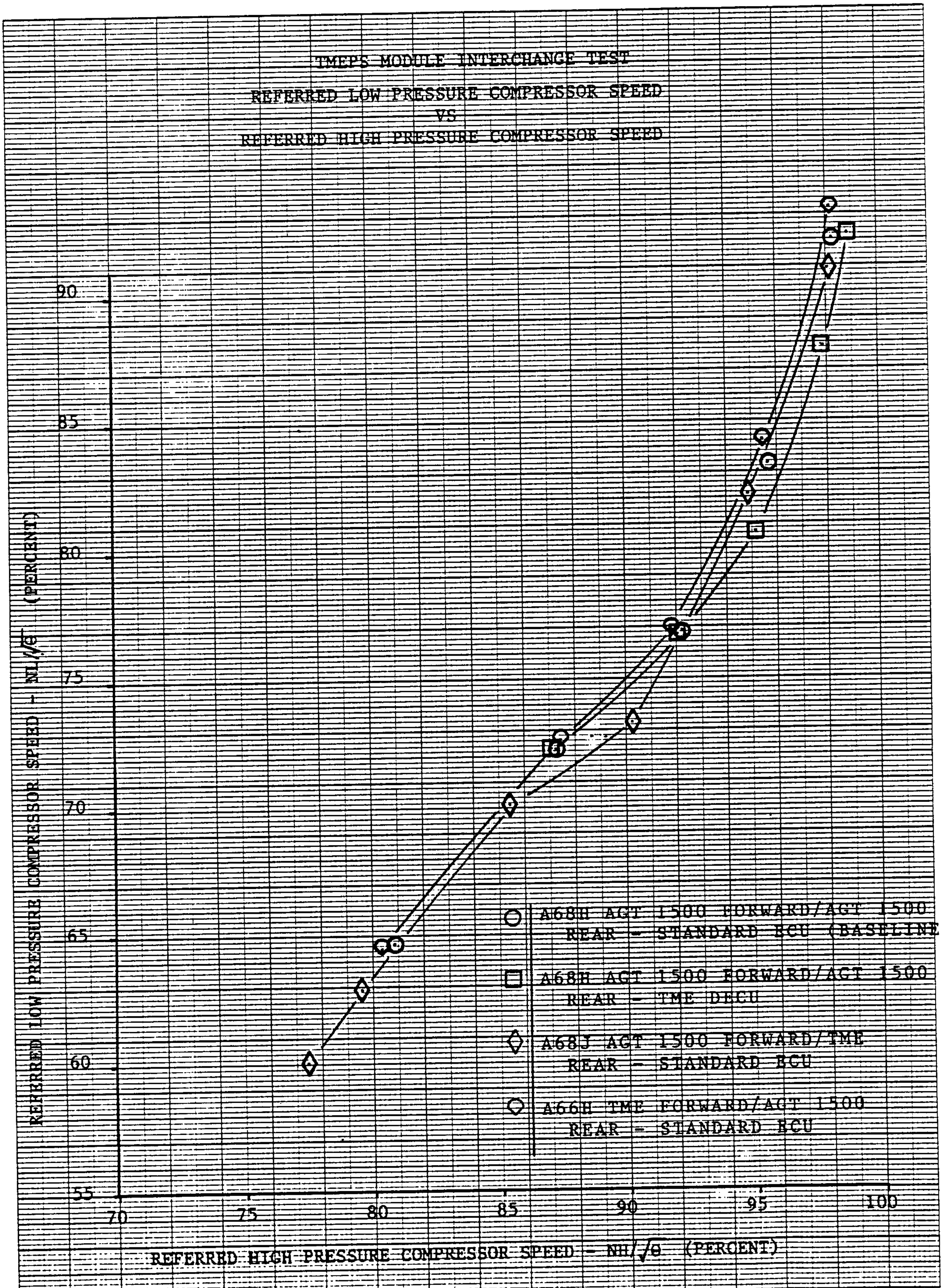

TMEPS MODULE INTERCHANGE TEST
OVERALL COMPRESSOR PRESSURE RATIO
VS
REFERRED HIGH PRESSURE COMPRESSOR SPEED
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/TME REAR - STANDARD ECU
OVERALL COMPRESSOR PRESSURE RATIO - Pt3/P0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
70
75
80
85
90
95
100
REFERRED HIGH PRESSURE COMPRESSOR SPEED - NH/√θ (PERCENT)

FIGURE 16



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1510

FIGURE 17

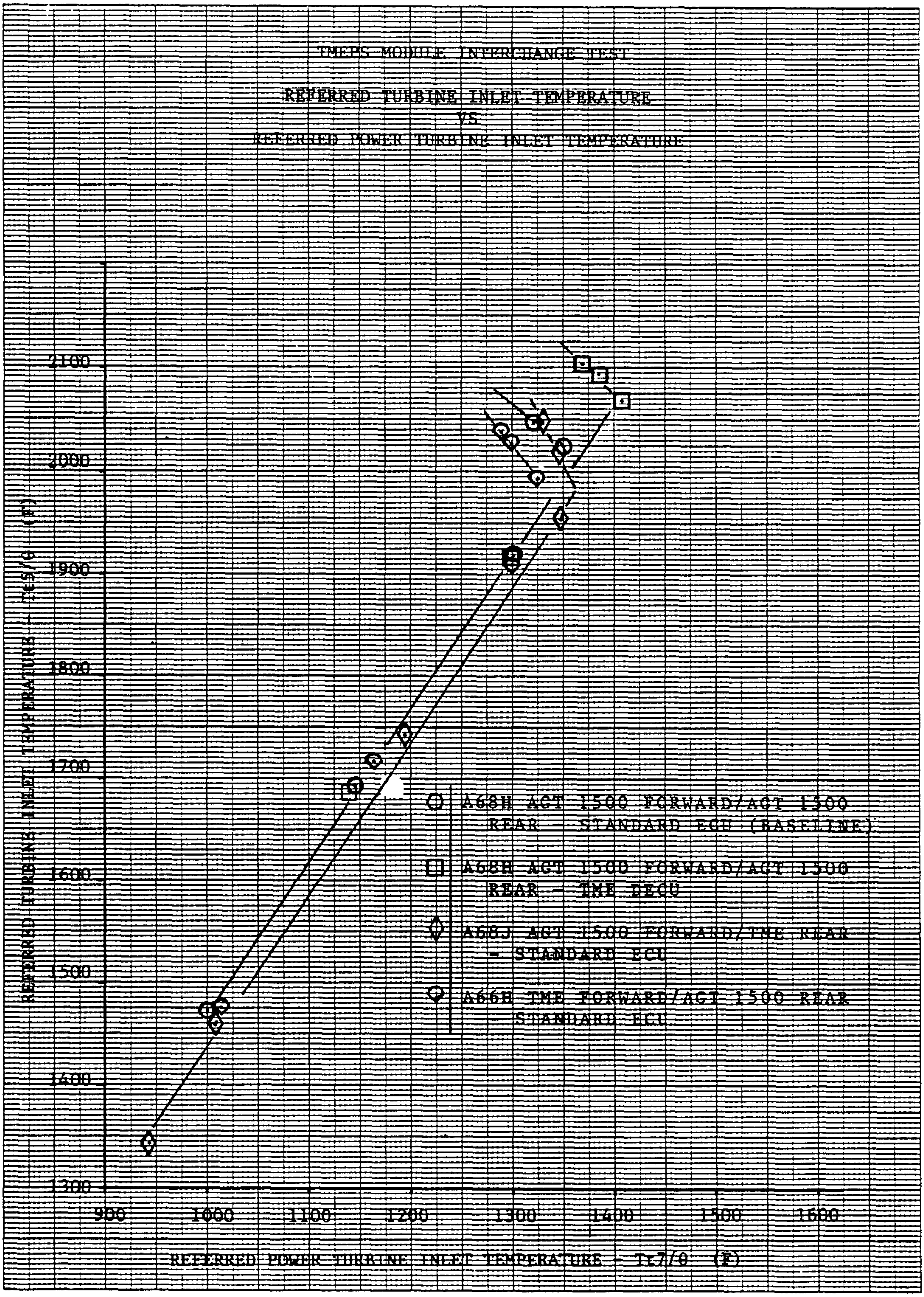

TMEPS MODULE INTERCHANGE TEST
REFERRED TURBINE INLET TEMPERATURE
VS
REFERRED POWER TURBINE INLET TEMPERATURE
REFERRED TURBINE INLET TEMPERATURE - Tt5/θ (F)
2100
2000
1900
1800
1700
1600
1500
1400
1300
900
1000
1100
1200
1300
1400
1500
1600
REFERRED POWER TURBINE INLET TEMPERATURE - Tt7/θ (F)
A68H ACT 1500 FORWARD/ACT 1500 REAR - STANDARD ECU (BASELINE)
A68H ACT 1500 FORWARD/ACT 1500 REAR - TME DECU
A68J ACT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/ACT 1500 REAR - STANDARD ECU

FIGURE 18

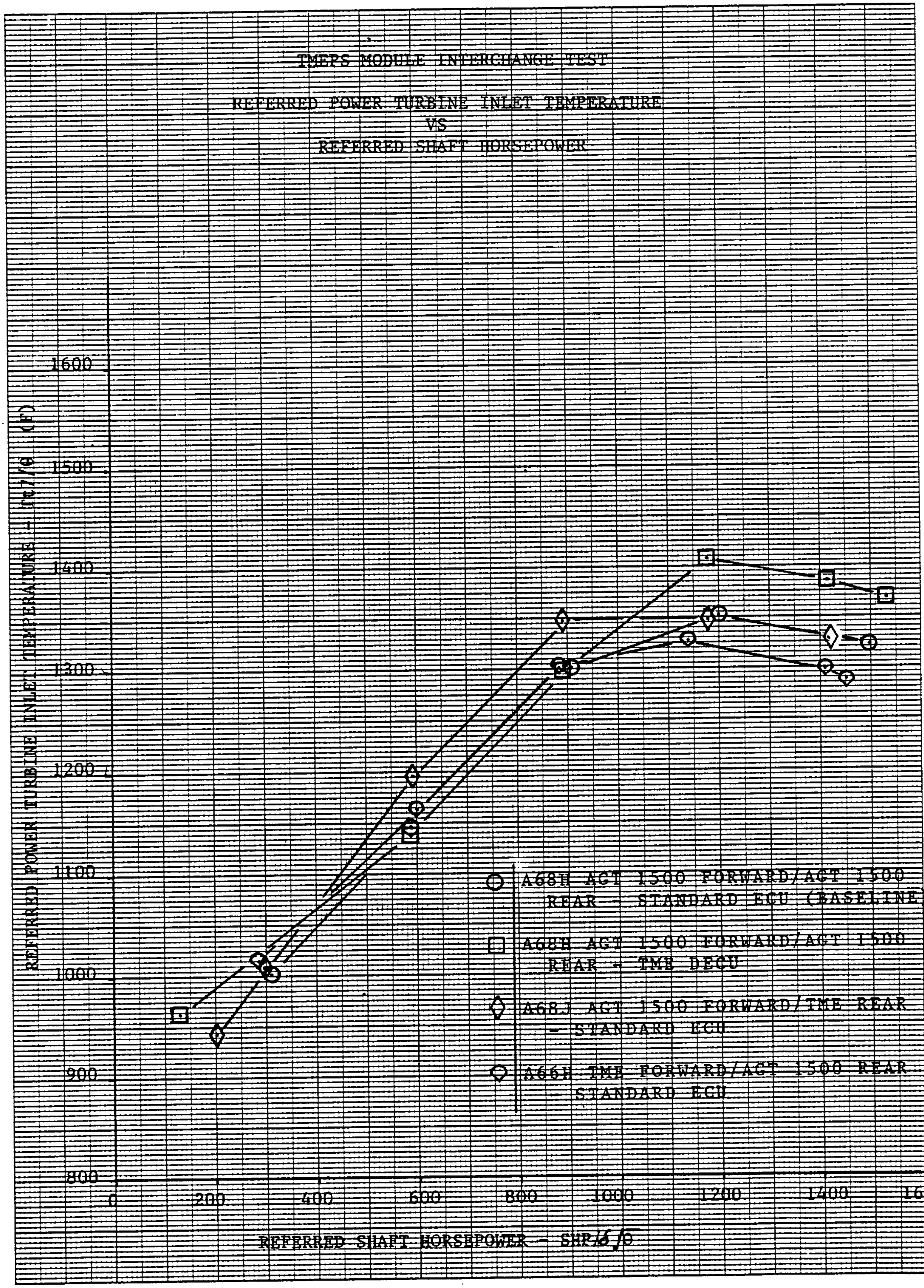

TMEPS MODULE INTERCHANGE TEST
REFERRED POWER TURBINE INLET TEMPERATURE
VS
REFERRED SHAFT HORSEPOWER
REFERRED POWER TURBINE INLET TEMPERATURE - Tt7/θ (F)
1600
1500
1400
1300
1200
1100
1000
900
800
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU

FIGURE 19

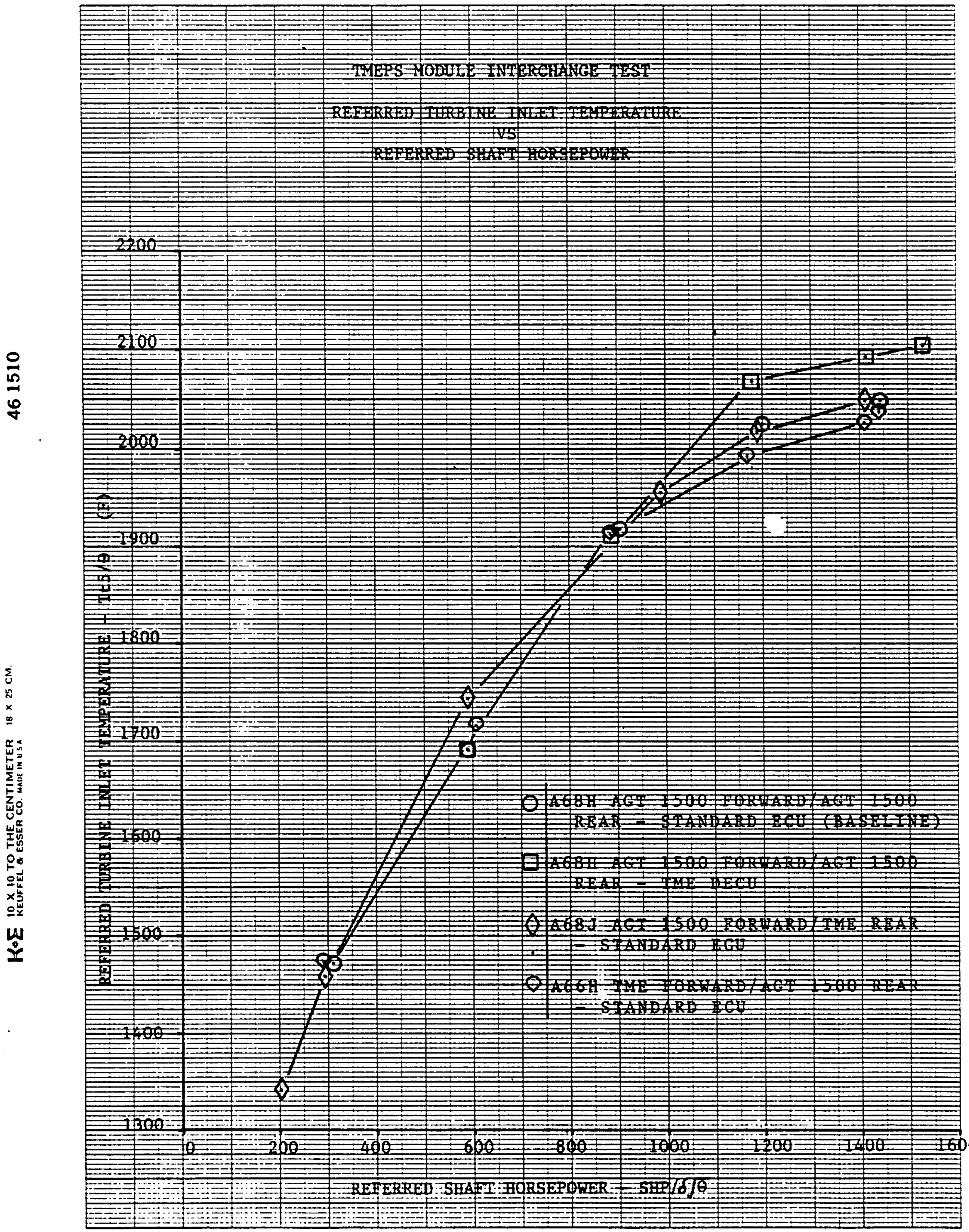

TMEPS MODULE INTERCHANGE TEST
REFERRED TURBINE INLET TEMPERATURE
VS
REFERRED SHAFT HORSEPOWER
REFERRED TURBINE INLET TEMPERATURE - Tt5/θ (F)
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
0
200
400
600
800
1000
1200
1400
1600
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
○ A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE)
□ A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU
◇ A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU
♢ A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU
46 1510
K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 20

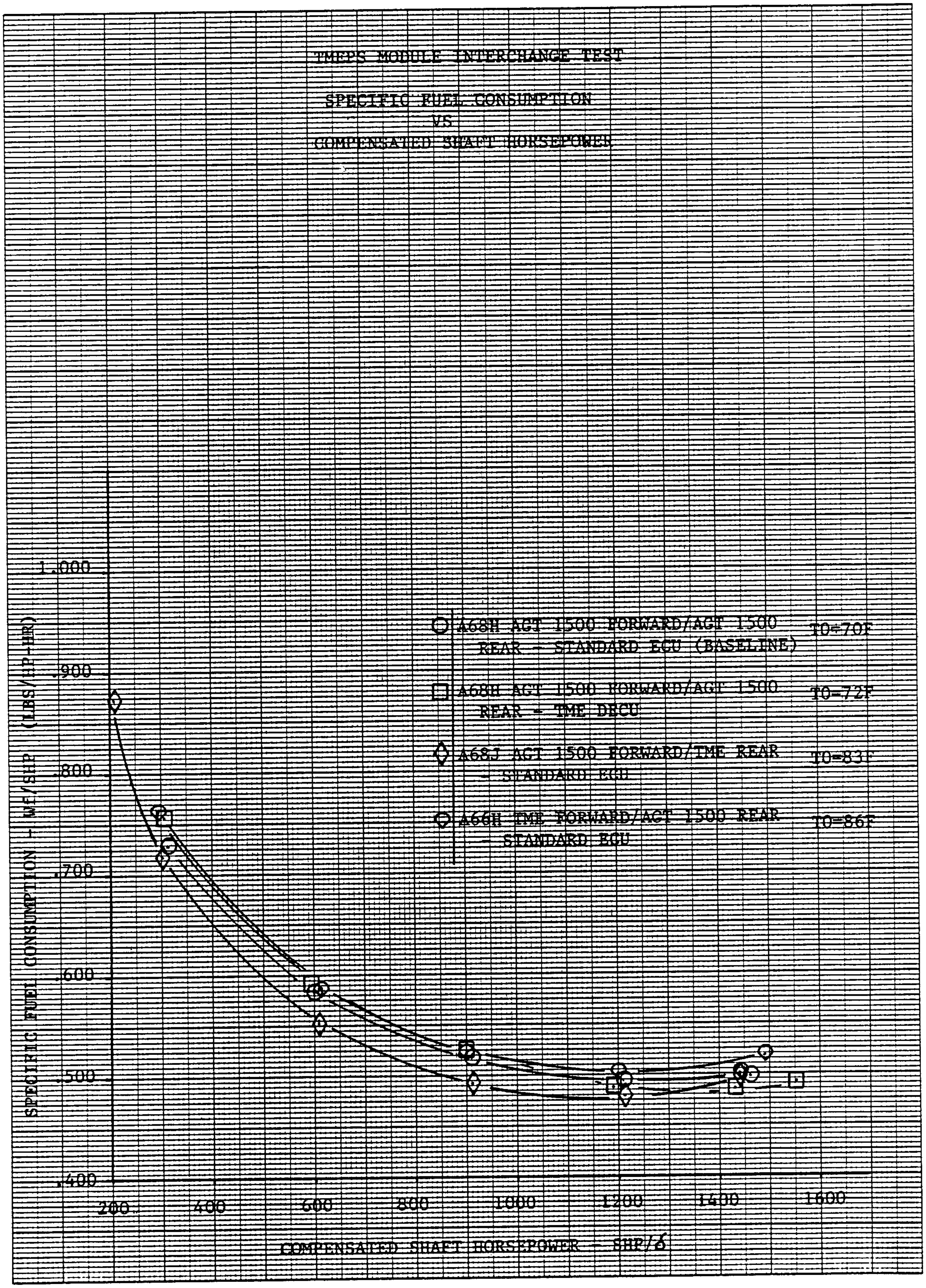
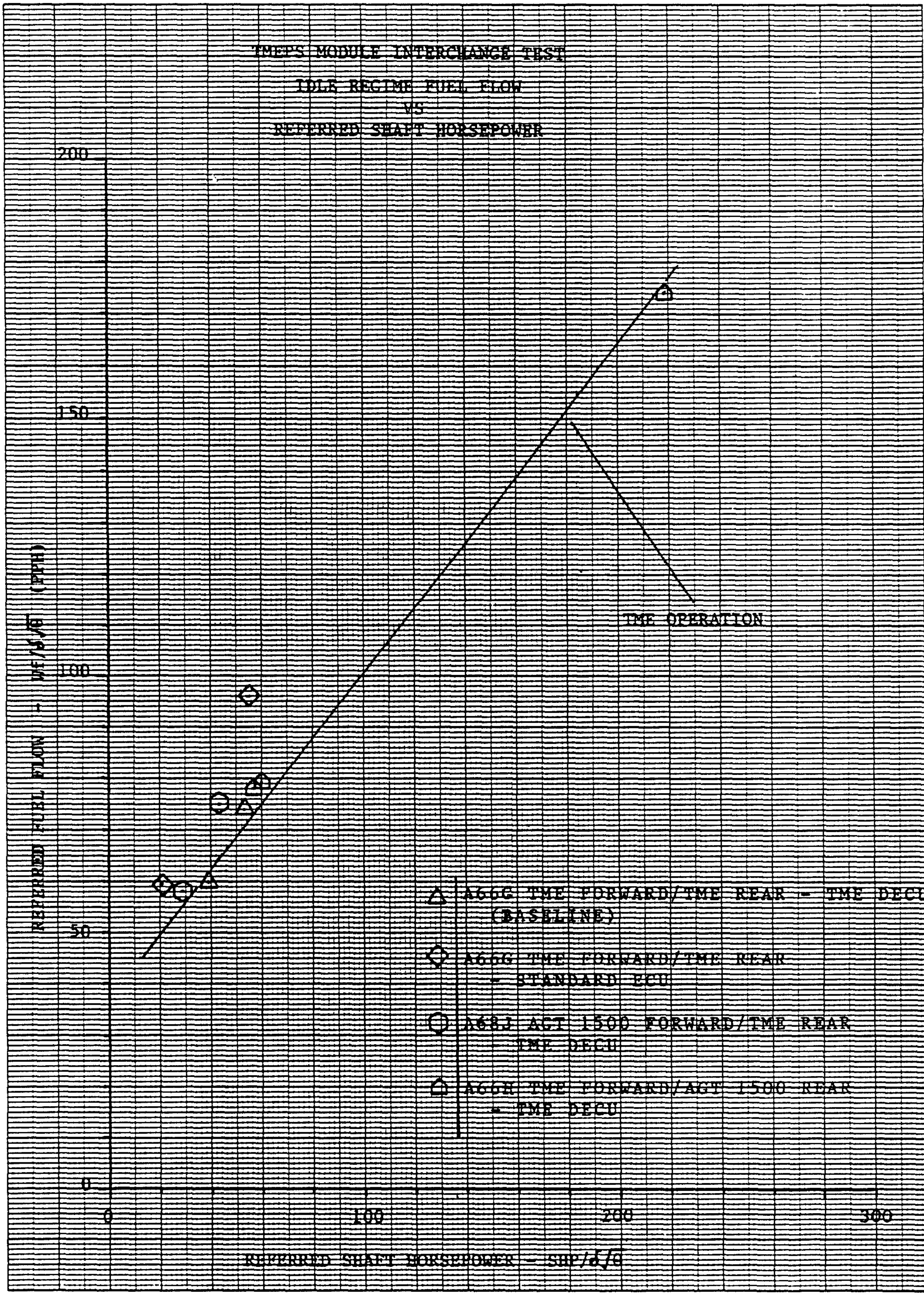

TMEPS MODULE INTERCHANGE TEST
SPECIFIC FUEL CONSUMPTION
VS
COMPENSATED SHAFT HORSEPOWER
A68H AGT 1500 FORWARD/AGT 1500 REAR - STANDARD ECU (BASELINE) T0=70F
A68H AGT 1500 FORWARD/AGT 1500 REAR - TME DECU T0=72F
A68J AGT 1500 FORWARD/TME REAR - STANDARD ECU T0=83F
A66H TME FORWARD/AGT 1500 REAR - STANDARD ECU T0=86F
SPECIFIC FUEL CONSUMPTION - WF/SHP (LBS/HP-HR)
1.000
.900
.800
.700
.600
.500
.400
200
400
600
800
1000
1200
1400
1600
COMPENSATED SHAFT HORSEPOWER - SHP/δ

FIGURE 21



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1510

FIGURE 22

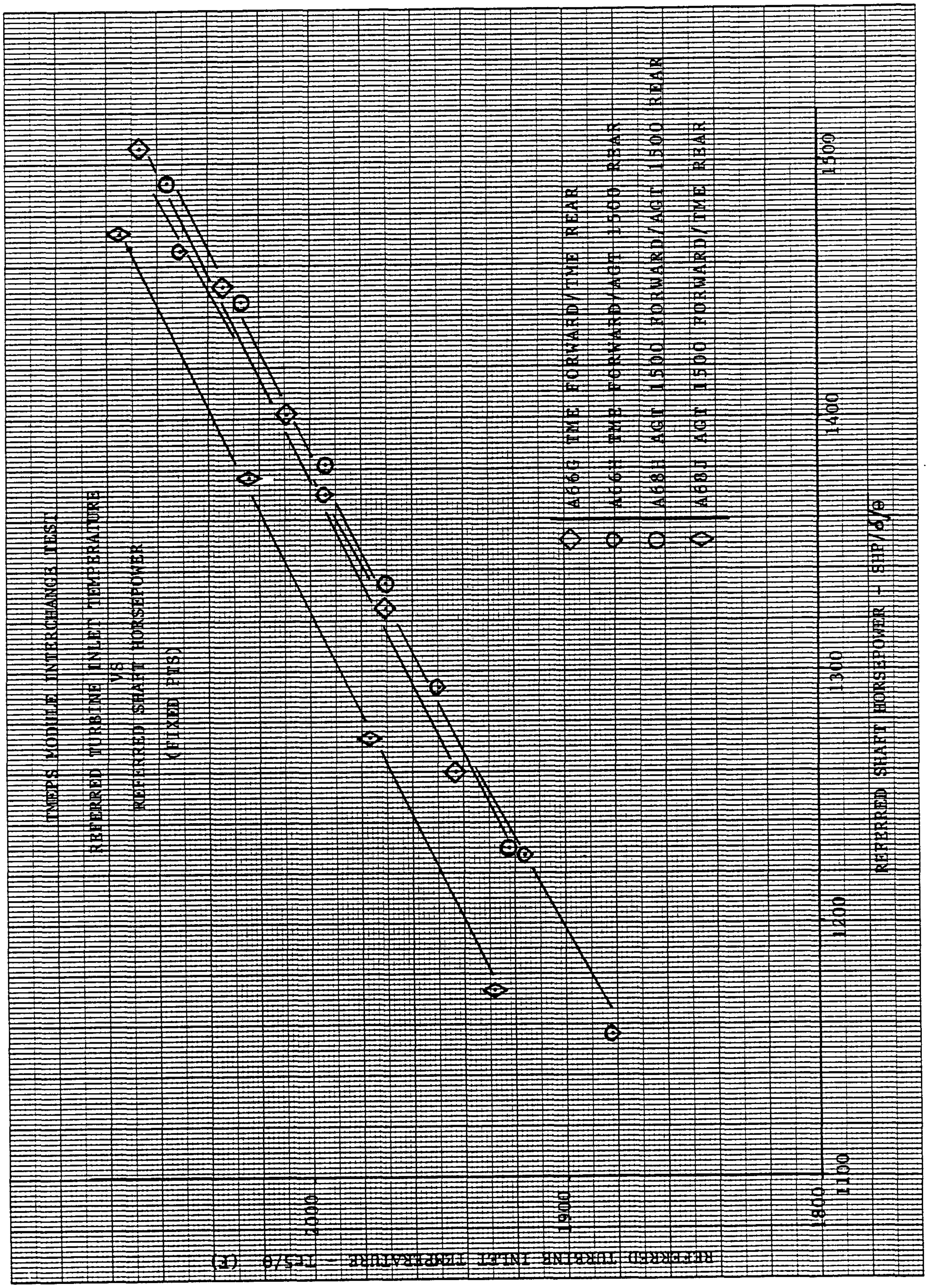
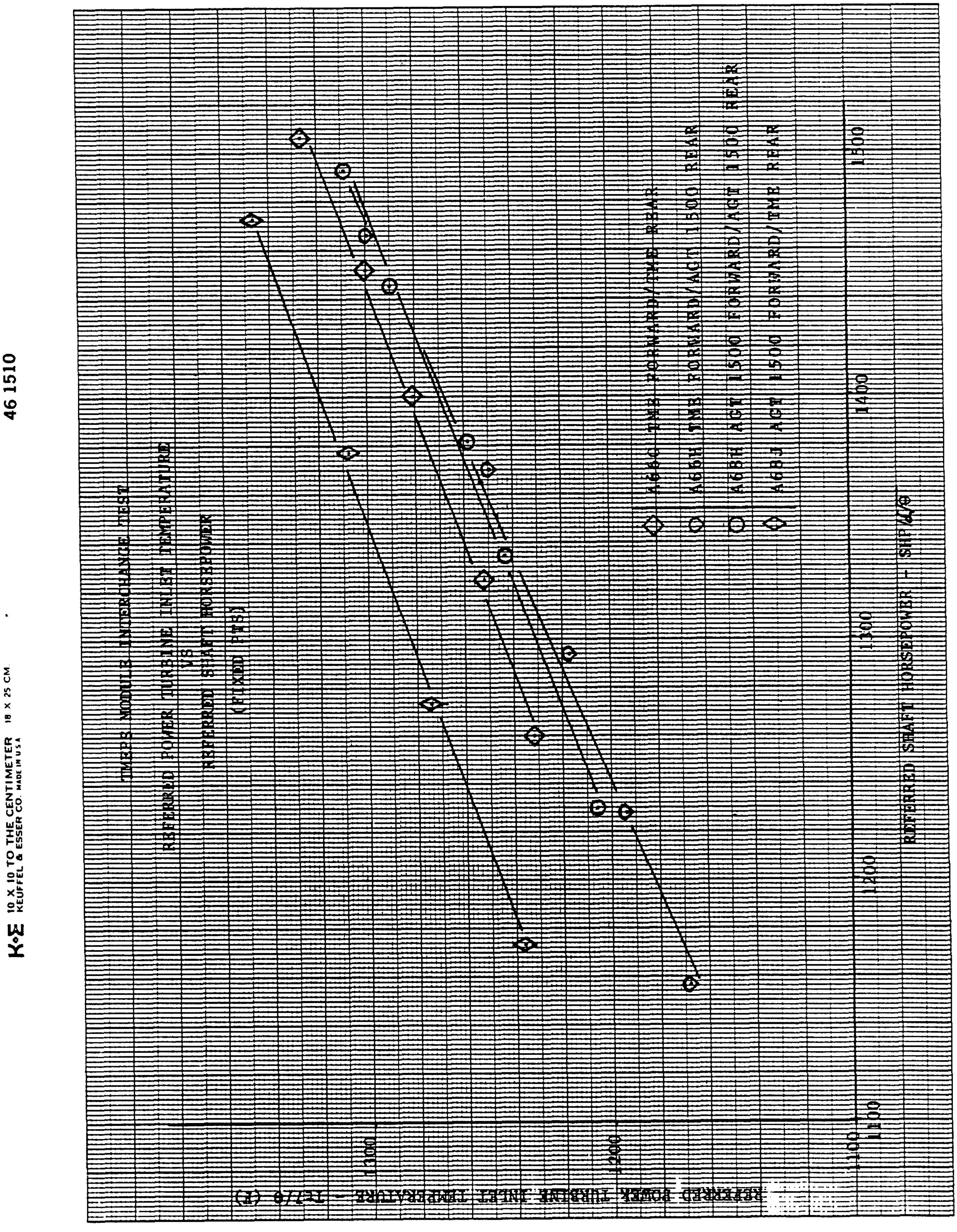

TMEPS MODULE INTERCHANGE TEST
REFERRED TURBINE INLET TEMPERATURE
VS
REFERRED SHAFT HORSEPOWER
(FIXED PTS)
A66G TME FORWARD/TME REAR
A66H TME FORWARD/AGT 1500 REAR
A68H AGT 1500 FORWARD/AGT 1500 REAR
A68J AGT 1500 FORWARD/TME REAR
1800
1900
2000
REFERRED TURBINE INLET TEMPERATURE - Tt5/θ (F)
1100
1200
1300
1400
1500
REFERRED SHAFT HORSEPOWER - SHP/δ√θ

FIGURE 23



10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1510
MODULE INTERCHANGE TEST
REFERRED POWER TURBINE INLET TEMPERATURE
VS
REFERRED SHAFT HORSEPOWER
(FIXED PTS)
A66C TMS FORWARD/TMS REAR
A66H TMS FORWARD/ACT 1500 REAR
A68H ACT 1500 FORWARD/ACT 1500 REAR
A68J ACT 1500 FORWARD/TMS REAR
REFERRED POWER TURBINE INLET TEMPERATURE - T/θ (F)
REFERRED SHAFT HORSEPOWER - SHP/δ√θ
1100
1200
1300
1400
1500

TABLES

TABLE 1

TEMPS MODULE INTERCHANGE TEST

ENGINE A68/A66 SUMMARY OF TEST EVENTS

AGT 1500

Accumulated Engine Run Time (Hrs)	Date	Description of Test Activity
0	7-11-89	Engine A68H (Baseline AGT 1500) installation in cell T-11. Compressors B&B cleaned prior to initial calibration (performance testing).
7.98	7-14-89	Initial mechanical checkout and fixed PTS optimum power setting. Baseline engine performance calibration with analog control unit (accessory load on and off). Handling & stability checks also completed.
10.25	7-17-89	Engine performance calibration with TME digital control unit. Handling and stability checks completed.
10.25	7-17-89	Engine removed from cell T-11.

TABLE 1

TEMPS MODULE INTERCHANGE TEST

ENGINE A68/A66 SUMMARY OF TEST EVENTS

AGT 1500

Accumulated Engine Run Time (Hrs)	Date	Description of Test Activity
0	7-18-89	Engine A66 installation in cell T-11. Mechanical checkout and PTS optimization performed.
11.27	7-18-89	Performance (baseline) calibrations with TME DECU and A68 standard analog control units completed. Handling and stability checks with both control units completed.
11.27	7-26-89	Engine forward module (A66) removed (split) from cell T-11 to accommodate interchange of TME and AGT 1500 modules.

TABLE 1

TEMPS MODULE INTERCHANGE TEST

ENGINE A68/A66 SUMMARY OF TEST EVENTS

AGT 1500

Accumulated Engine Run Time (Hrs)	Date	Description of Test Activity
0	7-26-89	AGT 1500 engine forward module (including accessory gearbox) installed on rear module of engine A66 (TME).
4.78	7-28-89	Performance calibration and handling and stability checks conducted with both control units (TME and AGT 1500).
4.78	8-1-89	Engine A68J (AGT 1500 forward module and TME rear module) removed from cell T-11.

TABLE 1

TEMPS MODULE INTERCHANGE TEST

ENGINE A68/A66 SUMMARY OF TEST EVENTS

AGT 1500

SUMMARY OF EVENTS

Accumulated Engine Run Time (Hrs)	Date	Description of Test Activity
0	8-2-89	Engine A66 (TME) forward module mated with A68 (AGT1500) rear module. Installation in cell T-11 completed.
5.87	8-3-89	Engine performance calibrations including handling and stability checks completed with each control unit.
5.87	8-4-89	Engine A66H removal from cell T-11 completed. Interchangeability testing completed.

TABLE 2

BUILD	MODULE FRONT	MODULE REAR	CONTROL UNIT	SHP (1) (87 DEG. F DAY)	(59 DEG. F DAY) SFC AT POWER 1200 SHP	DEMONSTRATED TRIM POWER AMBIENT	DEMONSTRATED TRIM POWER SHP/δ	DEMONSTRATED TRIM POWER NH	MGT
A68H	AGT1500	AGT1500	STANDARD	1542	.488	70	1464 (2)	99.3	1362
			TME DIGITAL	1600	.483	71	1553	100.2	1410
A66G	TME	TME	TME DIGITAL	1596	.448	70	1566	99.9	1415
			STANDARD	1530	.456	72	1473	99.5	1369
A68J	AGT1500	TME	STANDARD	1476	.471	83	1452	100.3	1413
			TME DIGITAL	1503	.458	79	1548	100.7	1434
A66H	TME	AGT1500	STANDARD	1490	.490	85	1446	100.6	1387
			TME DIGITAL	1576	.478	83	1558	101.3	1451

NOTES

1) MAXIMUM POWER CAPABILITY (87 DEG. F DAY) FOR EACH CONFIGURATION PERTAINS TO EACH ENGINE (TME/AGT1500) MODEL LIMITS (T5, T7, NH)

2) ENGINE A68H TRIM NH SETTING SET FOR 1500 SHP (WITH 20 SHPX). THE 1464 SHP/δ DATA POINT LISTED PERTAINS TO TRIM NH SETTING WITH NO HORSEPOWER EXTRACTION.

TABLE 3

INTERCHANGE TEST DATA ORGANIZATION

Group 1 (Figures 2-11)

Test Sequence	Engine Build	Module Forward	Module Rear	Control Unit	Description
3	A66 G	TME	TME	TME DECU	TME Baseline
4	A66 G	TME	TME	Standard	Effect of Standard Control Unit
6	A68 J	AGT 1500	TME	TME DECU	Effect of AGT 1500 forward module
8	A66 H	TME	AGT 1500	TME DECU	Effect of AGT 1500 rear module

Group 2 (Figures 12-21)

Test Sequence	Engine Build	Module Forward	Module Rear	Control Unit	Description
1	A68 H	AGT 1500	AGT 1500	Standard	AGT 1500 Baseline
2	A68 H	AGT 1500	AGT 1500	TME DECU	Effect of TME DECU
5	A68 J	AGT 1500	TME	Standard	Effect of TME rear module
7	A66 H	TME	AGT 1500	Standard	Effect of TME forward module

NOTE: See Appendix II (page 2) for additional test configuration descriptions.

TABLE 4

ENGINE TRANSIENT PERFORMANCE

Engine Build	Control Unit	Acceleration (sec)	Deceleration (sec)
A68 H (STD)	Standard	2.5	2.0
	TME DECU	3.1	2.6
A66 G (TME)	Standard	2.2	2.0
	TME DECU	4.2	3.1
A68 J	Standard	2.4	2.0
	TME DECU	3.7	4.6
A66 H	Standard	2.5	2.1
	TME DECU	3.6	2.8

NOTE: Acceleration times measured from gear engaged idle to 90 percent of maximum compensated power.

Deceleration times measured from trim power to 30 percent compensated power.

APPENDICES

APPENDIX 1

TME INTERCHANGEABILITY PROGRAM
TEST PLAN
ENGINE A66/A68
LYC 89-44

Prepared by: ________________
F. Macri
AGT 1500 Development
Test Engineer

Approved by: ________________
R. Hudson
AGT 1500 Development
Test Manager

JULY 1989

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7.0	Data	7

TITLE: TMEPS/AGT 1500 Module Interchangeability Test

1.0 **Introduction**:

This test plan describes test requirements associated with the TMEPS/M1A1 interchangeability test as described in Section 5.10 of TME subcontract DAC100001. Testing will be performed at Textron Lycoming in Stratford, Connecticut and will commence in July of 1989. Duration of testing will be approximately two weeks. This test plan is prepared under the Contract DAAE07-87-C-R006.

The interchange program will involve the use of one AGT 1500 engine (A68, S/N LE87680) and one AGT 1500A engine (A66, S/N LE87100) to demonstrate interchangeability of engine modules. Testing will involve the the following configurations (as specified in the TME statement of work):

1) TMEPS Front Engine Module/M1A1 Rear Engine Module with TMEPS ECU.
2) TMEPS Front Engine Module/M1A1 Rear Engine Module with M1A1 ECU.
3) TMEPS Rear Engine Module/M1A1 Front Engine Module with TMEPS ECU.
4) TMEPS Rear Engine Module/M1A1 Front Engine Module with M1A1 ECU.
5) TMEPS Engine with M1A1 ECU.
6) M1A1 Engine with TMEPS ECU.

2.0 **Applicable Documents**:

2.1 A68/A66 Build parts list.

2.2 TME Fuel Economy Test Plan (LYC88028, 03-P-802-88).

2.3 TME Engineering Test Requests.

3.0 **Objectives**:

3.1 Demonstrate interchangeability of M1A1 and TMEPS engine configurations.

4.0 **Test Article Description/Configuration**:

The AGT 1500 and AGT 1500A (TME) are both recuperative, free power turbine shaft, automotive engines which incorporate a two-spool compressor and variable geometry operation. The AGT 1500A engine features more advanced components which include reduced cooling flow single crystal H.P. turbine blades, fuel economy power (FEP) turbines and a digital electronic control unit. The TME

4.0 Test Article Description/Configuration (continued):

Accessory gearbox has also been redesigned in which the customer power takeoff pad is removed and relocated (transmission).

5.0 Test Requirements:

All engine configurations shall be performed in one designated test cell with the same test equipment and instrumentation utilized throughout.

5.1 Test Facilities:

A Textron Lycoming development test cell, capable of steady-state and transient condition monitoring with data acquisition systems.

5.2 Test Conditions:

Testing is to be conducted under prevailing ambient temperature (no greater than 87^{o}F) and sea level pressure.

5.3 Special Test Equipment

5.3.1 Starter

A Delco Remy 1113883 or Leece Neville 17414MA electric starter powered by a 28 VDC Hobart 6T28-400CL motor generator is used to start the engine.

5.3.2 Power Absorption

A Textron Lycoming water brake is used for engine power absorption (LC8800). In addition, this water brake has provisions for monitoring it s speed and radial vibration.

5.3.3 Power Extraction

A Bendix model 30858-3-8 400 ampere starter/generator with associated switches and load bank (United Manufacturing Model DCLB) is used for power extraction from the engine customer power takeoff pad on the M1A1 configuration only.

5.3.4 Oil Coolers

Engine oil is cooled by means of an industrial type oil to water heat exchanger, Lycoming TES 77-1.

5.4 Instrumentation

A list of instrumentation required for the test is provided in Table I. Critical installation procedures as specified in Lycoming T.O.D. B0003-69 will be applied to engine performance parameters during the initial phase of interchangeability testing.

5.4.1 Vibrations

Vibration measurement will consist of Trig-Tek vibration meters in conjunction with velocity-displacement pickups.

5.4.2 Temperatures

Temperatures are measured by Chromel Alumel (Type K) thermocouples. Signals are conditioned through appropriate analog to digital converters.

5.4.3 Pressures

Pneumatic and hydraulic pressures are measured through calibrated pressure transducers.

5.4.4 Flows

Turbine flow meters with associated converters, amplifiers and readouts are used to measure oil and fuel flow rates.

5.4.5 Speeds

Magnetic pickups with associated electrical hardware are used to measure the compressor/turbine and output shaft speeds.

5.4.6 Torque

A strain gauged torque element which supports an AGT 1500 water brake is used to measure engine torque.

5.4.7 Air Flow

A calibrated axial bellmouth assembly (ASME standards) with static and total pressure probes is utilized for airflow measurement during performance calibrations.

5.4.8 Accuracy of Data

For all engine and component calibrations and tests, or demonstrations, reported data shall have a steady-state accuracy within the tolerances shown below. The accuracy

5.4.8 Accuracy of Data (continued)

of transient data and the corresponding instrument calibration methods shall be subject to the approval of the using service and shall be described in the test report. All instruments and equipment shall be calibrated as necessary to ensure that the required degree of accuracy is maintained.

Item of Data	Tolerance
Rotor Speed(s)	± 0.2 percent of the value obtained at maximum rating.
Torque	± 0.5 percent of the value measured for intermediate rating and above.
	± 0.5 percent of the value measured at intermediate rating for all values below intermediate rating.
Air Flow	± 1.0 percent of the value measured for intermediate rating and above.
	± 1.0 percent of the value measured at intermediate rating for all values below intermediate rating.
Temperatures	±1.0°C up to 200°C. ±2.0°C between 200°C and 800°C. ±4.0°C above 800°C.
Engine Weight	±1.0 lbs or ±0.1 percent of the weight being determined, whichever is greater.
Vibration Velocity	±5.0 percent of specified engine limit during 4.5.7 vibration survey, 4.6.2.4.2 vibration scan and resonant search and 4.6.6.5 vibration and stress test.

5.4.8 Accuracy of Data (continued)

Item of Data	Tolerance
Vibration Velocity	± 10.0 percent of specified engine limit for all other tests.
All Other Data	± 2.0 percent of the value obtained at maximum rating.

5.5 Data Acquisition Equipment

5.5.1 Automatic Data Acquisition Equipment

Continuous automatic monitoring is facilitated by a HP 1000 processor based turbine engine measurement and data acquisition system. The computer, in conjunction with individual measurement sensors, will acquire, display and calculate steady-state and transient data. A Gould model 2800 strip chart recorder will record transient data for selected parameters continuously during engine operation.

5.6 Operating Parameters

5.6.1 Fuel and Oil Data

Samples of fuel and oil shall be taken at the discretion of the responsible test engineer. As a minimum, a fuel and oil sample shall be obtained at the start and completion of the test. Both samples shall be analyzed for physical and chemical properties to determine conformance with applicable fuel and oil specifications.

5.6.2 Engine Operating Limits

The engine operating limits are to be used as guidelines for the operator during the test

Maximum Gas Generator Speed - NH: 103.4% (TME)
102.0% (AGT 1500)

Maximum Output Shaft Speed - NPT: 104.0% (TME)
104.0% (AGT 1500)

Maximum H.P. Turbine Inlet Temperature: 2225°F (TME)
2200°F (AGT 1500)

Maximum Measured Temperature (T_T7): 1570°F (TME)
1530°F (AGT 1500)

6.0 Test Procedures:

6.1 Test Matrix

Interchangeability testing will be performed on the following engine configurations:

1) M1A1 (AGT 1500) baseline
   a) M1A1 ECU
   b) TMEPS DECU

2) TMEPS (AGT 1500A) baseline
   a) M1A1 ECU
   b) TMEPS DECU

3) TMEPS Rear Module/M1A1 Forward Module
   a) M1A1 ECU
   b) TMEPS DECU

4) TMEPS Forward Module/M1A1 Rear Module
   a) M1A1 ECU
   b) TMEPS DECU

An engine calibration will be performed to establish the performance characteristics of each configuration. Testing conducted on the AGT 1500 baseline configuration shall be completed with and without customer power extraction. In addition, prior to the beginning of each calibration, the engine may be cleaned with B&B solution and water as specified in an acceptable procedure.

A PTS (power turbine stator) optimization procedure will be completed on each baseline configuration (M1A1/TMEPS) to establish the engine maximum power capability at 87 °F seal level, uninstalled.

Engine transient performance shall be evaluated for each configuration as specified in Table II. Data obtained for each configuration specified above shall be acquired at power levels described in Table II.

6.2 Inspections

Boroscope inspection and limited disassembly may be performed as necessary to document hardware conditions during the test.

7.0 Data:

7.1 Data Collection Methodology

7.1.1 Miscellaneous Data

The date, test title, engine model designation and serial number shall be recorded on each log sheet.

7.1.2 Test Notes

Notes shall be placed on the log sheets of all incidents of the run, such as leaks, vibrations and other irregular functioning of the engine or equipment, and corrective measures taken.

7.1.3 Steady-State Data

During operation at each specified steady state condition and after performance stabilization, the data shall be recorded as specified in Table I. Stabilization time at each steady-state power level in Table II shall be no less than 5 minutes.

7.1.4 Transient Data

For each calibration transient performed, the data shall be recorded as specified in Table I.

7.1.5 During each start requiring start data evaluation, the data shall be recorded as specified in Table I.

7.1.6 Barometer Reading

The barometer reading shall be corrected for temperature and shall be read and recorded at intervals not exceeding three hours, if required for engine performance calibrations.

7.1.7 Corrections

Reading of shaft horsepower, rotor speed, airflow rate, fuel flow rate, specific fuel consumption, gas pressure and gas temperatures will be corrected to standard sea level atmospheric conditions.

TABLE I

		STARTING	STEADY STATE	PRE POST TEST CAL TRANSIENTS
1.	Time of Day	X	X	
2.	Engine Build Run Time		X	
3.	Power Setting		X	
4.	L.P. Compressor Rotor Speed, % RPM	X	X	X
5.	H.P. Compressor Rotor Speed, % RPM	X	X	X
6.	Power Turbine Rotor Speed, % RPM	X	X	X
7.	Variable Inlet Guide Vane Position, Volts		X	X
8.	Power Turbine Stator Position, Volts		X	X
9.	Fuel Flow LBM/HR	X	X	X
10.	Bellmouth Inlet Total Pressure, in H_2O		X	
11.	Bellmouth Inlet Static Pressure, in H_2O (4)		X	
12.	Bellmouth Inlet Delta Pressure, in H_2O (4)		X	
13.	L.P. Compressor Discharge Total Pressure, PSIA		X	X
14.	H.P. Compressor Discharge Total Pressure, PSIA		X	X
15.	L.P. Compressor Discharge Total Temperature, ^oF		X	X
16.	H.P. Compressor Discharge Total Temperature, ^oF		X	X
17.	Recuperator Total Discharge Temperature (4) ^oF		X	X
18.	Measured Gas Temperature, ^oF	X	X	X
19.	Maximum Measured Gas Temperature, ^oF	X	X	X
20.	Gas Generator Rotor Inlet Temperature, ^oF (Calculated)			
21.	Oil Level, QTS.		X	
22.	No. 1 Bearing Scavenge Pressure, PSIG		X	
23.	No. 1 Bearing Scavenge Temperature, ^oF		X	
24.	No. 1 Bearing Oil Flow, LBM/HR		X	
25.	No. 2 Bearing Feed Pressure, PSIG		X	
26.	No. 2 Bearing Oil Flow, LBM/HR		X	
27.	No. 4 Bearing Feed Pressure, PSIG		X	
28.	No. 4 Bearing Scavenge Pressure, PSIG		X	

TABLE I (Cont'd)

		STARTING	STEADY STATE	PRE POST TEST CAL TRANSIENTS
29.	No. 4 Bearing Scavenge Temperature, °F		X	
30.	No. 4 Bearing Oil Flow, LBM/HR		X	
31.	No. 5 & 6 Bearing Scavenge Pressure, PSIG		X	
32.	No. 5 & 6 Bearing Scavenge Temperature, °F		X	
33.	No. 5 & 6 Bearing Oil Flow, LBM/HR		X	
34.	No. 6B Bearing Scavenge Pressure, PSIG		X	
35.	No. 6B Bearing Scavenge Temperature, °F		X	
36.	Reduction Gearbox Oil Flow, LBM/HR		X	
37.	Accessory Gearbox Scavenge Pressure, PSIG		X	
38.	Accessory Gearbox Oil Flow, LBM/HR		X	
39.	Oil Cooler Inlet Temperature, °F		X	
40.	Oil Cooler Exit Temperature, °F		X	
41.	Fuel Inlet Pressure, PSIG		X	
42.	Fuel Inlet Temperature, °F		X	
43.	Water brake Lube Pressure, PSIG		X	
44.	Water brake Inlet Temperature, °F		X	
45.	Water brake Exit Temperature, °F		X	
46.	Water brake Inlet Pressure, PSIG		X	
47.	Displacement - L.P. Compressor Hsg, MIL		X	X
48.	Velocity - L.P. Compressor Hsg, IPS		X	X
49.	Displacement - Intermediate Hsg, MIL		X	X
50.	Velocity - Intermediate Hsg, IPS		X	X
51.	Displacement Air Diffuser, MIL		X	X
52.	Velocity - Air Diffuser, IPS		X	X
53.	Displacement - Water brake, MIL		X	X
54.	Velocity - Water brake, IPS		X	X
55.	Output Shaft Torque, LBF-FT		X	X
56.	Barometer		X	X
57.	Start Number	X		
58.	Time to Ignition Actuation	X		
59.	Time to Light Off, Sec.	X		
60.	Time to Starter Cutout, Sec.	X		
61.	Time to Stabilize Idle % RPM, Sec.	X		
62	Additional Data as Required	X	X	X

NOTE: Transient recording capability may be altered to meet test requirements.

TABLE II

I. TMEPS/M1A1 INTERCHANGE DATA POINTS.

NOTE: The following data points are to be collected as a minimum:

Power Level	NPT % (M1A1)	NPT % (TMEPS)
Maximum SHP	100.00	100.0
1200 SHP	99.0	98.7
900 SHP	94.0	96.3
600 SHP	83.0	87.5
Tactical Idle	43.3	43.3
Low Idle	30.0	30.0

II. HANDLING AND STABILITY CHECK

1. Accelerate to 20 percent compensated power and record a long scan after a 5 minute stabilization. Mark P3 on the Gould recorder and log sheet.
2. Accelerate to 90 percent compensated power and record a long scan after a 5 minute stabilization. Mark P3 on the Gould recorder and log sheet at this power.
3. Set maximum power. Obtain a long scan after a 5 minute stabilization period.
4. Snap decelerate to idle, leaving water brake preset. Time deceleration to P3 (from step 1) noted on Gould. Initiate a transient during this sequence.
5. Stabilize at idle for 10 minutes.
6. Jam throttle to maximum power (throttle stop adjusted). Time to P3 noted on Gould in Step 2. Initiate a transient during this sequence.
7. Waveoff engine in 5 percent NH increments until 75 percent NH is reached. Waveoffs must be surge free. Initiate a transient during this sequence.
8. Decelerate to idle and shutdown after 10 minutes.

APPENDIX II

TMEPS/M1A1 ENGINE MODULE INTERCHANGEABILITY TESTING: PERFORMANCE RESULTS

BACKGROUND

Since 1980 Textron Lycoming, General Dynamics Land Systems (GDLS) and Allison Transmission Division (ATD) have jointly been developing an improved derivative of the M1A1 Abrams Tank propulsion system. This system is termed the Transverse Mounted Engine Propulsion System (TMEPS). The TMEPS incorporates an advanced model AGT1500A engine mated to a new 7-speed ATD transmission tranversely mounted in the GDLS Abrams Tank. The contractural guarantee was to reduce the M1A1 Peacetime Annual Duty Cycle fuel usage (excluding APU usage) by 10 percent. In 1988,an AGT1500A engine demonstrated a Peacetime fuel usage reduction of 15.3 percent and 87°F day power of 1550 SHP.

Unique to the AGT1500A are a new power turbine optimized for part power fuel consumption; single crystal high pressure turbine rotor blades with reduced cooling flow; a new Digital Electronic Fuel Control Unit (DECU) scheduled to provide a significant increase in part power turbine inlet temperature and a Hastelloy-S recuperator with increased pre-load to improve effectiveness.

TMEPS hydraulic power is supplied by power takeoff from the transmission; accordingly the engine accessory gearbox module has been redesigned to eliminate the hydraulic pump power takeoff drive present in the AGT1500 gearbox.

Note, for clarity, herein the TMEPS engine is referred to as TME (rather than AGT1500A); the current production engine is referred to as the AGT1500.

PURPOSE

The subject series of engine tests were designed to verify the functional interchangeability of engine modules between the AGT1500 and TME engine. This appendix documents the successful test demonstrations of this interchangeability feature in terms of overall engine performance.

TABLE I: TEST CONFIGURATIONS

	MODULE			TEST PURPOSE DEMONSTRATION
TEST	FORWARD	REAR	CONTROL	
1	AGT1500	AGT1500	AGT1500 ECU	AGT1500 Production Baseline
2	AGT1500	AGT1500	TME DECU	TME DECU Effect on AGT1500
3	TME	TME	TME DECU	TME Baseline
4	TME	TME	AGT1500 ECU	AGT1500 ECU Effect on TME
5	AGT1500	TME	AGT1500 ECU	TME Rear Module Effect on AGT1500
6	AGT1500	TME	TME	AGT1500 Front Module Effect on TME
7	TME	AGT1500	AGT1500 ECU	TME Front Module Effect on AGT1500
8	TME	AGT1500	TME DECU	AGT1500 Rear Module Effect on TME

CONCLUSIONS

Overall engine functionality of module interchangeability was demonstrated by safe operation of all builds. The following table summarizes the overall performance effect of these tests.

TABLE II: MAX SHP, PART POWER SFC EFFECT

TEST	PURPOSE	MAXIMUM POWER (SHP)	SFC @1200 SHP 59°F DAY
1	AGT1500 Acceptance Test (20 HPX)	1508	0.486
	BASELINE TESTS		
1A	AGT1500 Baseline (0 HPX)	1464	0.488
3	TME Baseline	1566	0.448
	TME MODULES ON AGT1500		
7	TME Forward Module Effect on AGT1500	1446	0.490
5	TME Rear Module Effect on AGT1500	1452	0.471
2	TME DECU Effect on AGT1500	1553	0.483
	AGT1500 MODULES ON TME		
6	AGT1500 Forward Module Effect on TME	1548	0.458
8	AGT1500 Rear Module Effect on TME	1558	0.478
4	AGT1500 ECU Effect on TME	1473	0.456

DISCUSSION

The TME engine has improved components in each module:

TABLE III: TME MODULE FEATURES

MODULE	FEATURES
FORWARD	• Decreased interstage bleed • LPC IGV closed setting changed to 35° to raise low power surge line • Single crystal HPT blades with -1.5 percent cooling air • Improved HPT efficiency (tighter running tip clearance)
REAR	• LPT nozzle with -0.3 percent cooling air • Power turbine redesigned for improved part power efficiency • -0.76 percent cooling air to power turbine reduction gearbox • Recuperator with higher preload, improved effectiveness • Increased travel power turbine linkage • Enhanced intermodule sealing
DECU	• Schedules set to raise high power T5 25° and part power T5 120°

The location of horsepower extraction for vehicle hydraulic power is a factor in evaluating module interchangeability effects. The source of hydraulic power on the TMEPS power pack is the transmission, while the M1A1 system uses power extracted from the AGT1500 high spool through the accessory gearbox module. Maximum throttle AGT1500 production engine power is controlled to 1500 SHP (+20, -0) by setting the fuel control speed bias to the high spool speed (NH) required to assure flat rated power up to 87°. This calibration, made on every production engine, is accomplished with a referee 20 SHP extraction (hpx) that is included in the quoted rated 1500 SHP. In contrast, due to transmission supplied accessory power, a TME engine is "trimmed" to max power (1545 SHP minimum) with no extraction from the engine high spool. To facilitate TME AGT1500 comparison in this test series, the baseline AGT1500 engine (Test 1) max throttle was calibrated to an NH yielding 1508 SHP per the Acceptance Test Spec ETS1500, with 20 hpx. Subsequently, while holding that speed bias NH setting fixed, another max throttle test point was acquired with 0 hpx. This test (1A) represents the baseline AGT1500 calibration for interchangeability comparative purposes. Removal of high spool power extraction is equivalent to an efficiency increase in the high spool (removal of a parasitic loss). This yields a cooler gas producer turbine inlet temperature and corresponding decrease in power at a fixed (previously "trimmed") NH.

All control variables (compressor inlet guide vane schedule; compressor intercompressor bleed schedule and power turbine maximum area) were maintained at base engine values (Tests 1A and 3); no retrimming was done. This test series therefore simulated a module change in a field environment. This is in contrast to a module change at a repair depot where an engine test cell calibration would facilitate optimization of engine variables, including (degradation permitting) retrim of maximum power to a desired value.

Table II illustrates the effects of discretely placing TME modules on the AGT1500 (Tests 7, 5 and 2 relative to 1A) and conversely, AGT1500 modules on the TME (Tests 6, 8 and 4 relative to 3).

<u>TME Modules Incorporated on the AGT1500</u>: TME forward and rear modules had minor effects on AGT1500 maximum power (Tests 7 and 5). Due to a high-side of nominal overall compressor efficiency on the baseline AGT1500 relative to a nominal level on the TME, the benefits inherent in this module (Table III) are negated, resulting in a slight power decrease and SFC increase (Test 7). Advantages offered in part power SFC due to the TME power turbine was illustrated in Test 5. Note, while the TME power turbine was optimized to provide peak efficiency in the part power region an efficiency penalty may be encountered at the open geometry settings run by the AGT1500 (larger than TME), resulting in a power loss at a fixed ECU NH (Test 5 relative to 1A).

The TME DECU (Test 2) significantly increases AGT1500 power due to higher trim NH and high pressure turbine inlet temperature (T5). Test 2 also reflects the SFC advantage of the increased T5 scheduled by the TME DECU, however note the full part power temperature potential offered by the TME DECU cannot be fully achieved with the available AGT1500 power turbine area variability. That is, in the absence of the TME increased travel linkage, the AGT1500 power turbine cannot close enough to attain the front slope MGT-NH schedule (and therefore T5) the DECU requests. Refer to Figure 2, comparison of steady state TME DECU and AGT1500 ECU MGT NH schedules.

AGT1500 Modules Incorporated on the TME: AGT1500 modules, as expected, had an effect on baseline TME power, however, the configurations were safely functional. The max power loss due to module change was less than 1-1/4 percent (Tests 6 and 8). The significant increase in SFC upon inserting the AGT1500 rear module reflects the inherent design modifications in the TME power turbine to improve peak and part power efficiency and the higher effectiveness recuperator. The power loss experienced upon incorporation of the AGT1500 ECU (Test 4) is due to the 25° cooler T5 this control schedules and the max throttle speed bias (NH) setting which is 0.6 percent NH lower. Note: approximately 50 SHP could be recovered if the AGT1500 ECU NH were retrimmed to the baseline TME level.

Idle Performance: At a common 35 SHP the TME baseline (Test 3) demonstrated a 29 percent lower fuel flow than the AGT1500 (Test 1). Interchangeability tests demonstrated that the dominant factor is the gas producer inlet temperature (T5) difference due to the MGT-NH control difference.

Several physical differences between AGT1500 and TME interact to produce the idle region fuel consumption comparison displayed on Figure 9.

	GOVERNING MODULE	FIGURE
• MGT-NH Schedule	DECU/ECU	2
• Low Compressor IGV Schedule; effect on surge line	FORWARD	10
• Power Turbine Variable Geometry Travel Capability	REAR	--
• Interstage Bleed	DECU/ECU	11

These factors combine to yield the following matrix of low power configurations and accordingly impact idle fuel flow and cycle matching on the Low Compressor map (Figure 10) and MGT-NH Schedule (Figure 2).

TEST	MODULE FRWD	REAR	CONTL	MAX CLOSED IGV(°)	INTER-STAGE BLEED	POWER TURBINE SCHEDULED ACTION	GENERAL MGT-NH LEVEL ATTAINED
1	A	A	A	30	Full	Full Open	AGT
2	A	A	T	30	Reduced	Scheduled to MGT-NH	Reduced TME MGT
3	T	T	T	35	Reduced	Scheduled to MGT-NH	TME
4	T	T	A	35	Full	Full Open	AGT
5	A	T	A	30	Full	Full Open	AGT
6	A	T	T	30	Reduced	Scheduled to MGT-NH	TME
7	T	A	A	35	Full	Full Open	AGT
8	T	A	T	35	Reduced	Scheduled to MGT-NH	Reduced TME MGT

A: AGT1500 T: TME

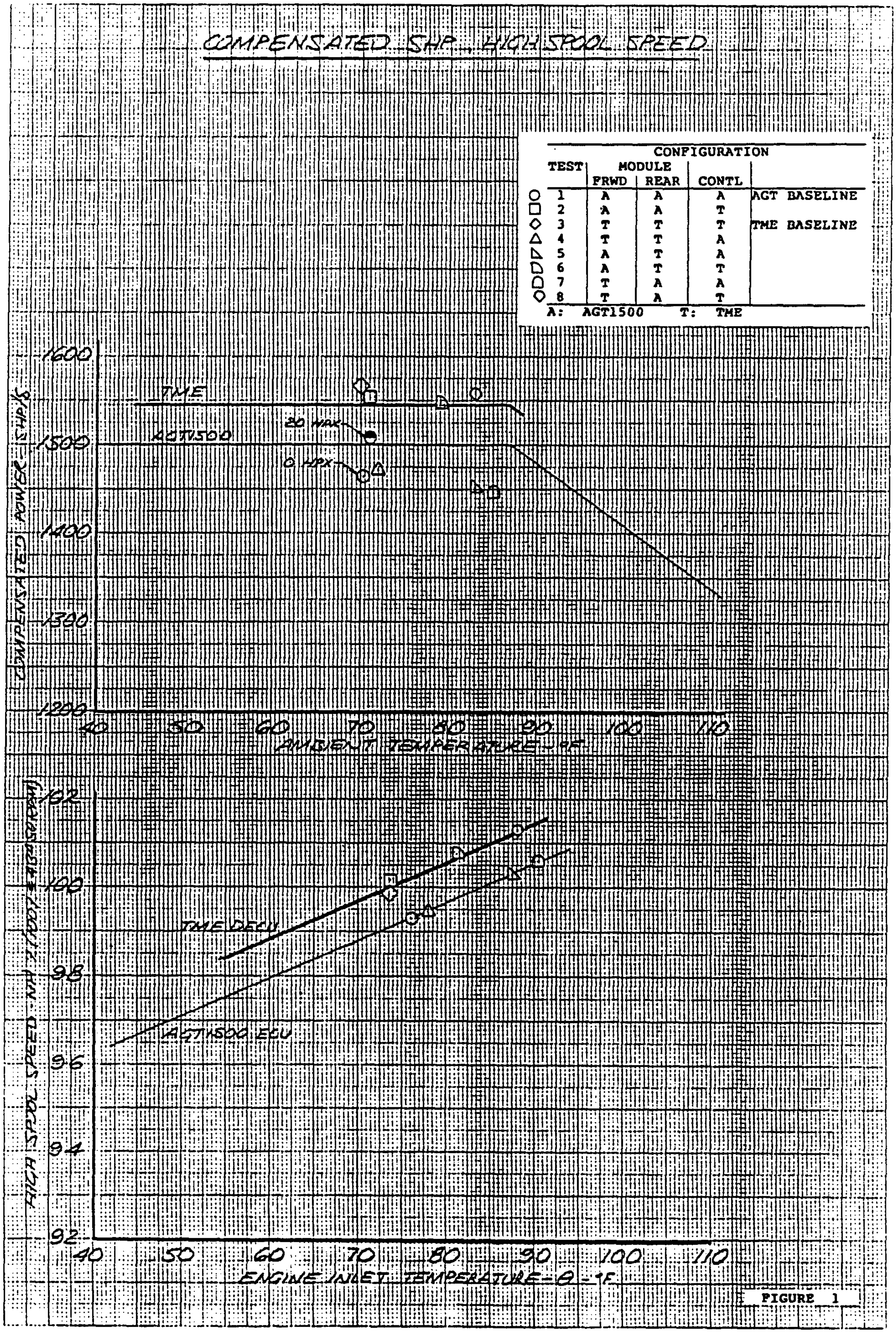
On a percentage change, the AGT ECU increased (penalized) TME fuel flow more than the TME DECU improved AGT fuel flow. This is due to the absence of the power turbine increased travel capability in the AGT engine which prevents it from attaining the TME schedule (Figure 2) and capitalizing fully on the increased T5 potential. This is illustrated on Figure 2 by Tests 2 and 8. Note interchange of the forward modules has the least effect on idle fuel flow.

Figure 10 displays low compressor loading in the idle region. Note the improved surge line offered by the more closed IGV setting. Two distinct load lines were attained. The higher was attained by configurations with reduced bleed (Tests 2, 3, 6, 8). The lower load line is composed of configurations with full interstage bleed (Tests 1, 4, 5, 7). All configurations operated surge free.

CONCLUSIONS

1. The contractual requirement to verify interchangeability of engine modules between the M1A1 and TMEPS configurations was achieved.

2. All configurations operated stably and surge free during all transient movements.



		CONFIGURATION			
	TEST	MODULE FRWD	MODULE REAR	CONTL	
○	1	A	A	A	AGT BASELINE
□	2	A	A	T	
◇	3	T	T	T	TME BASELINE
△	4	T	T	A	
◺	5	A	T	A	
D	6	A	T	T	
▢	7	T	A	A	
◇	8	T	A	T	

A: AGT1500 T: TME

FIGURE 1

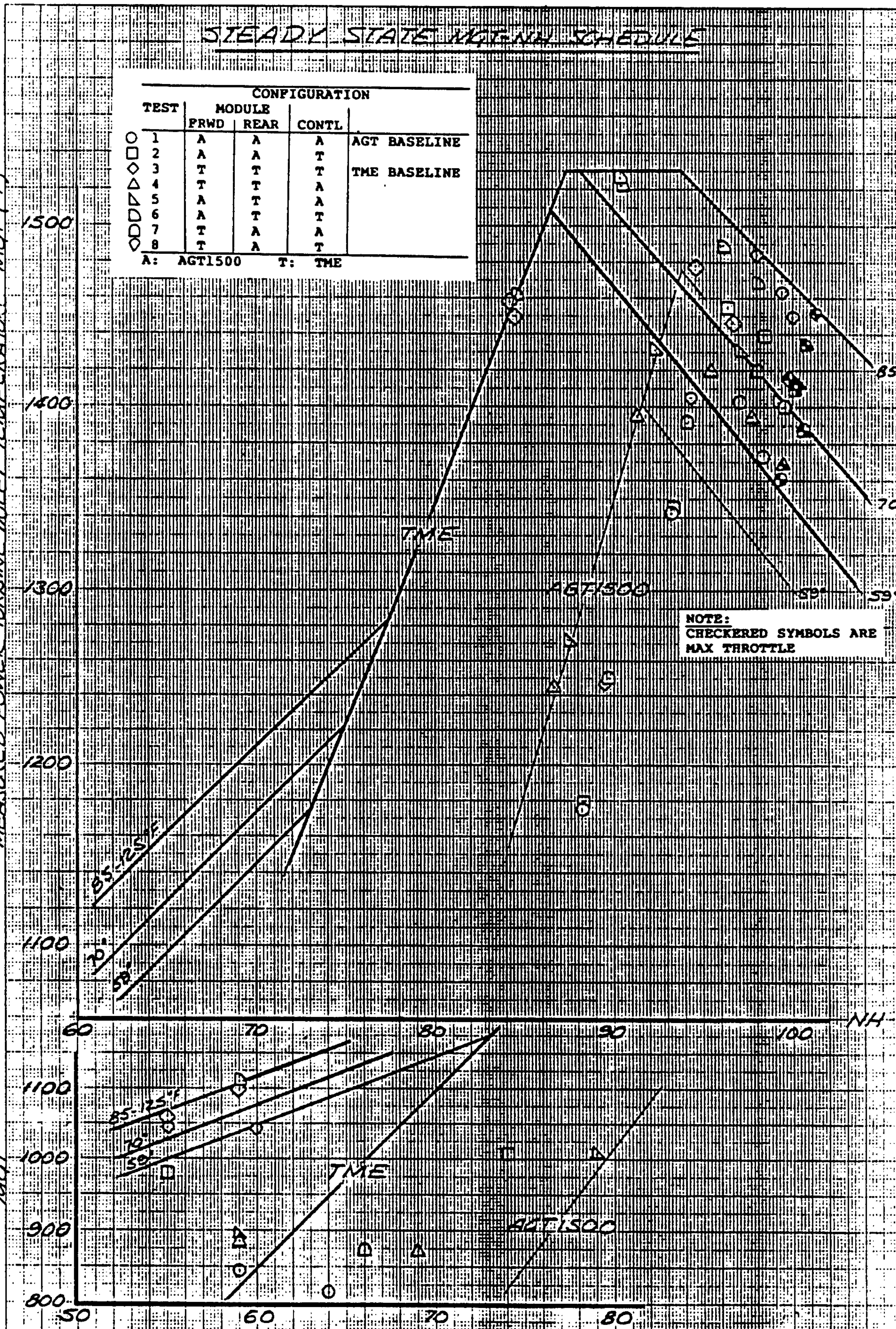

STEADY STATE MGT-NH SCHEDULE
CONFIGURATION
TEST | MODULE FRWD | REAR | CONTL
1 | A | A | A | AGT BASELINE
2 | A | A | T
3 | T | T | T | TME BASELINE
4 | T | T | A
5 | A | T | A
6 | A | T | T
7 | T | A | A
8 | T | A | T
A: AGT1500 T: TME
NOTE: CHECKERED SYMBOLS ARE MAX THROTTLE
MEASURED POWER TURBINE INLET TEMPERATURE - MGT (°F)
MGT
TME
AGT1500
85-125°F
70°
59°
NH
HIGH SPOOL SPEED - NH % (100% = 43450 RPM)

FIGURE 2

AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497

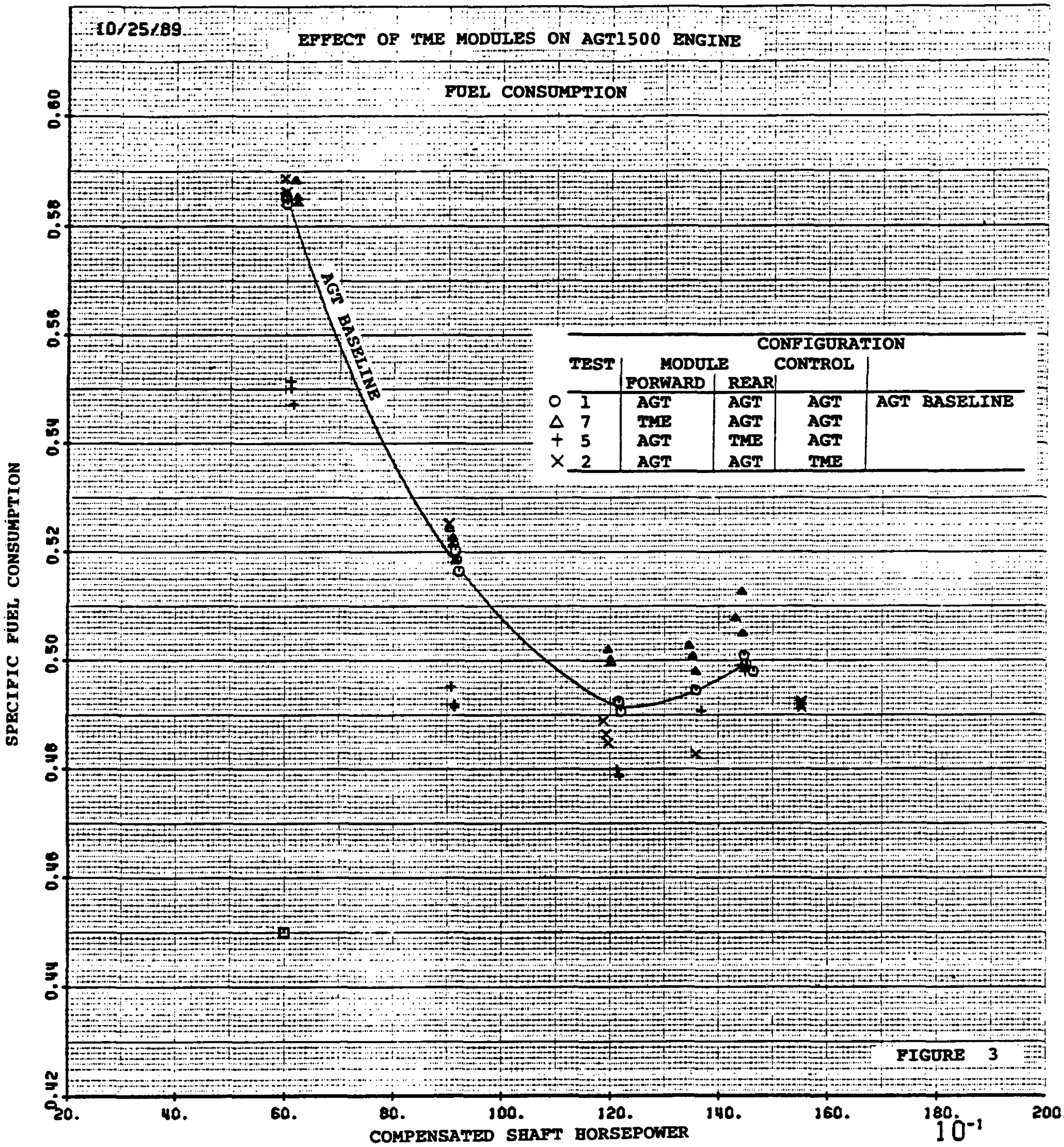


FIGURE 3

AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497

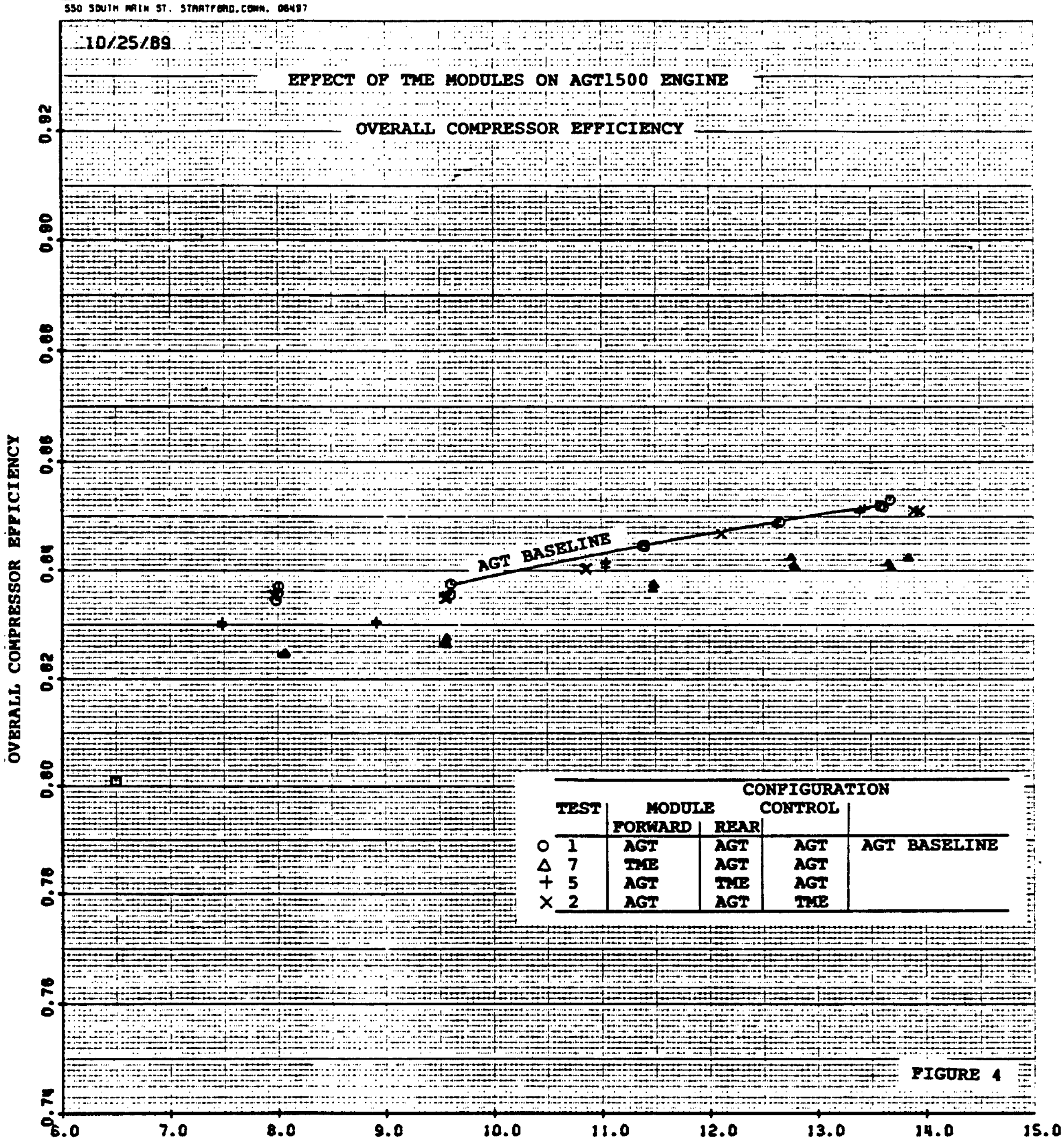
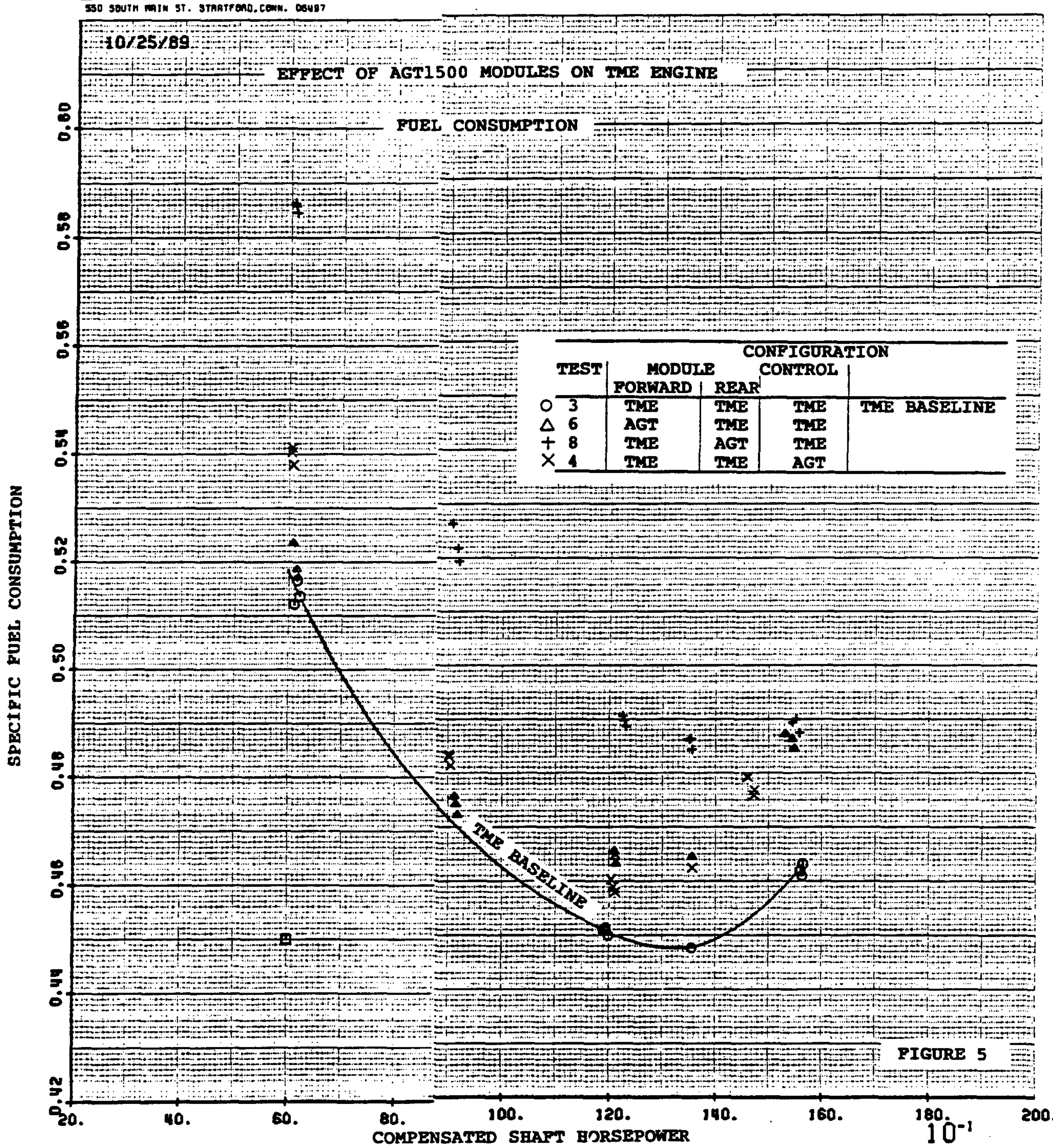


FIGURE 4

AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497



TEST	MODULE FORWARD	MODULE REAR	CONFIGURATION CONTROL	
○ 3	TME	TME	TME	TME BASELINE
△ 6	AGT	TME	TME	
+ 8	TME	AGT	TME	
× 4	TME	TME	AGT	

FIGURE 5

AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497

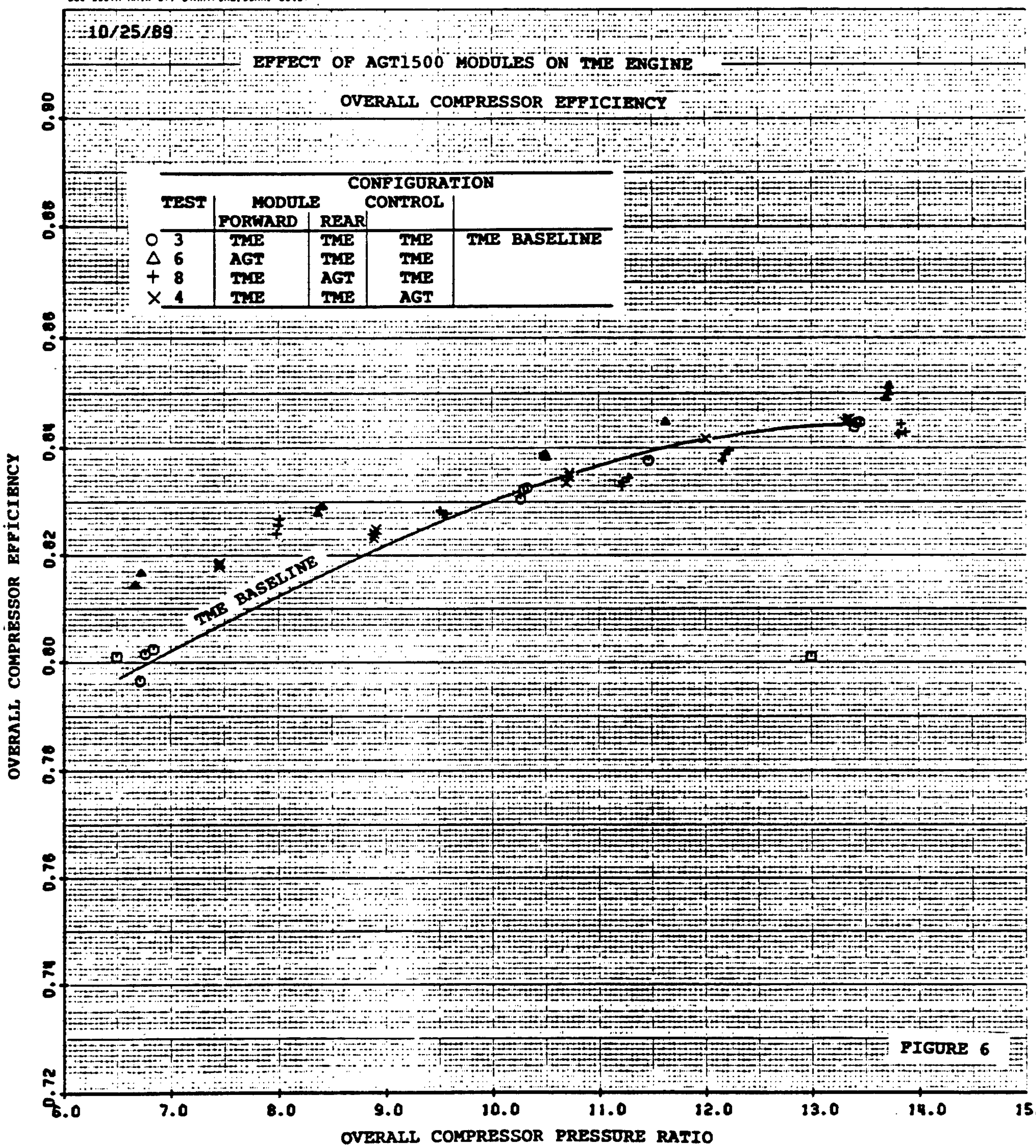


FIGURE 6

AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497

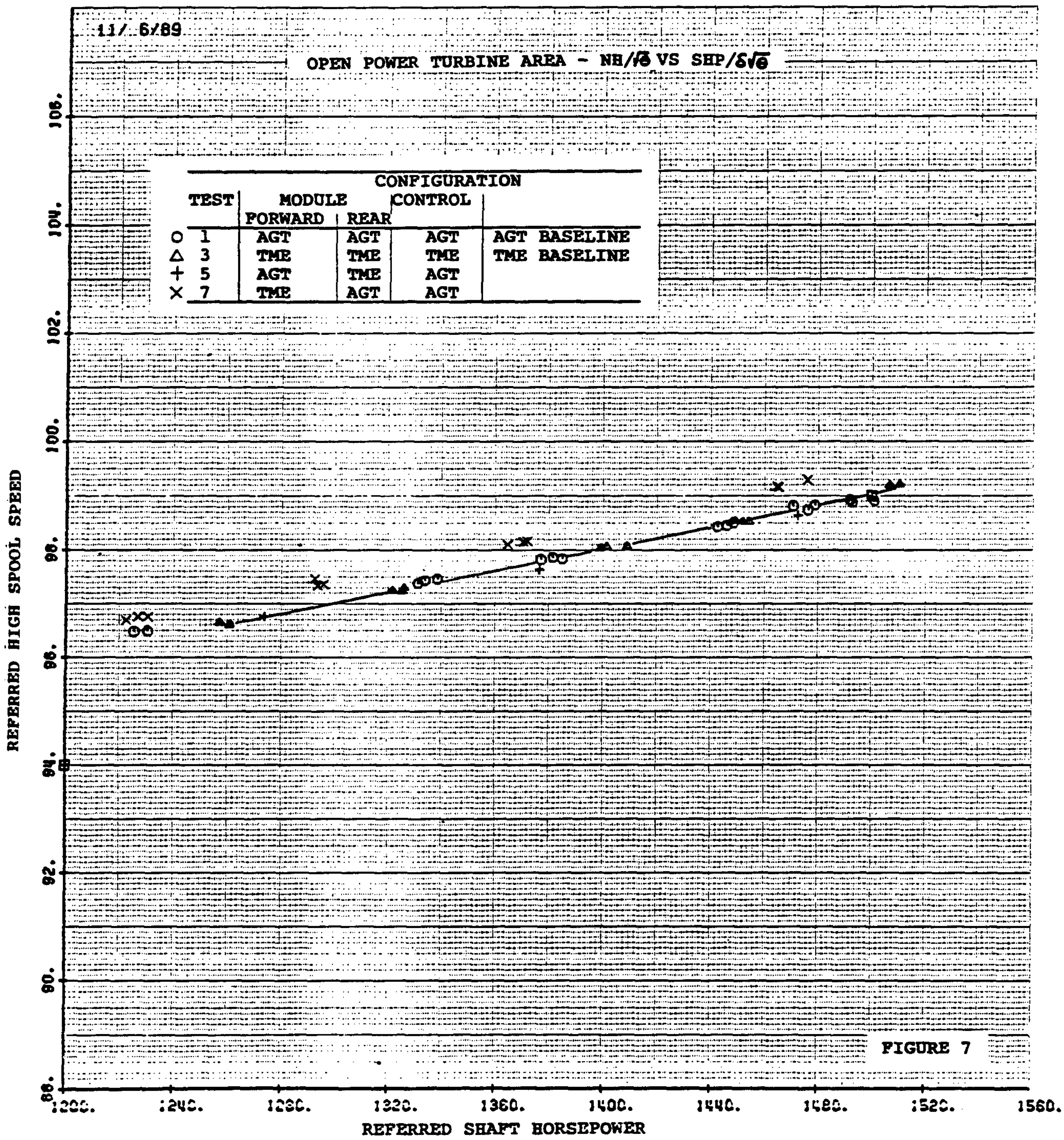
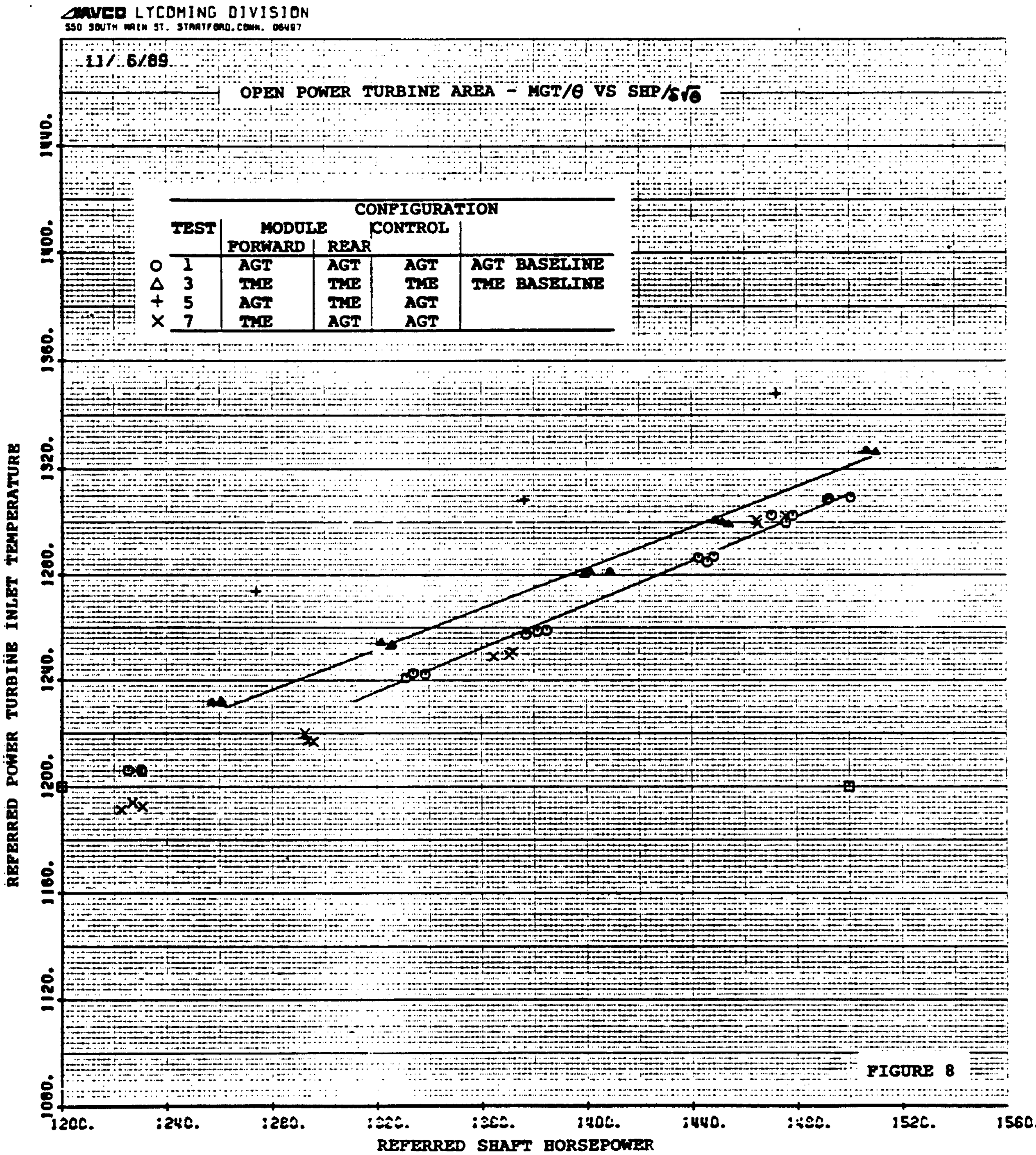


FIGURE 7


AVCO LYCOMING DIVISION
550 SOUTH MAIN ST. STRATFORD, CONN. 06497
11/ 6/89
OPEN POWER TURBINE AREA - MGT/θ VS SHP/δ√θ
CONFIGURATION
TEST
MODULE
FORWARD
REAR
CONTROL
○ 1 AGT AGT AGT AGT BASELINE
△ 3 TME TME TME TME BASELINE
+ 5 AGT TME AGT
× 7 TME AGT AGT
REFERRED POWER TURBINE INLET TEMPERATURE
1080.
1120.
1160.
1200.
1240.
1280.
1320.
1360.
1400.
1440.
REFERRED SHAFT HORSEPOWER
1200.
1240.
1280.
1520.
1560.
FIGURE 8

IDLE PERFORMANCE

TEST	CONFIGURATION MODULE FRWD	REAR	CONTL	
○ 1	A	A	A	AGT BASELINE
□ 2	A	A	T	
◇ 3	T	T	T	TME BASELINE
△ 4	T	T	A	
5	A	T	A	
6	A	T	T	
7	T	A	A	
8	T	A	T	-

A: AGT1500 T: TME

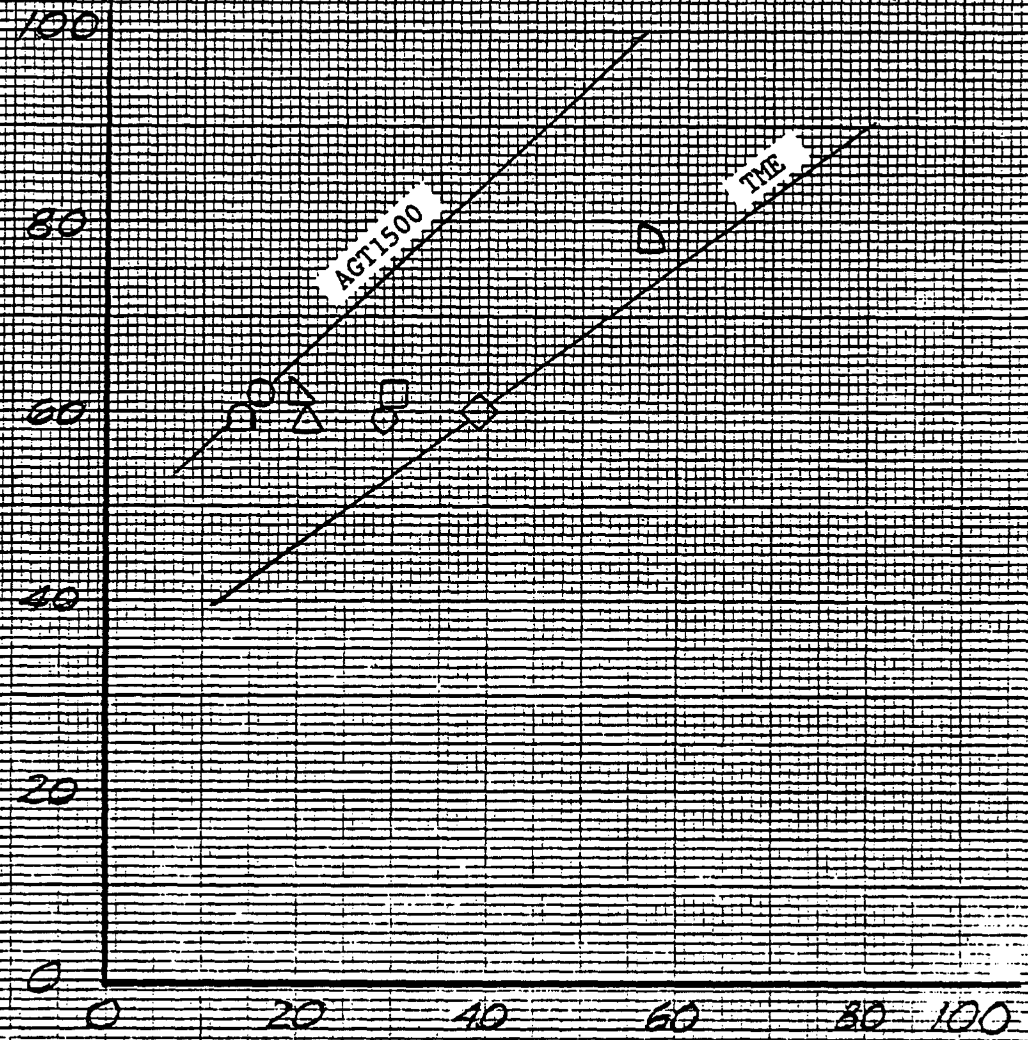
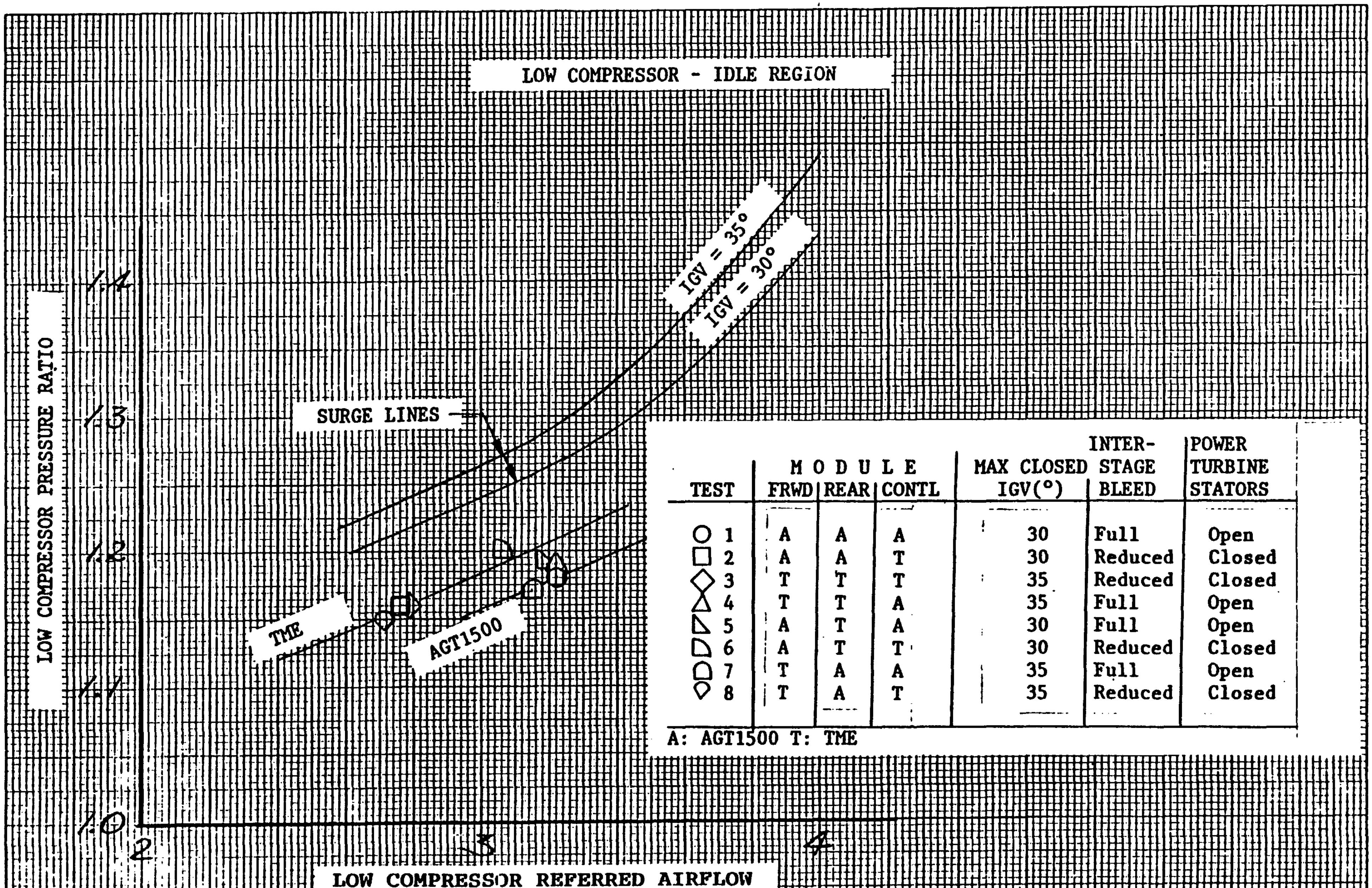


FIGURE 9



TEST	MODULE FRWD	MODULE REAR	MODULE CONTL	MAX CLOSED IGV(°)	INTER-STAGE BLEED	POWER TURBINE STATORS
1	A	A	A	30	Full	Open
2	A	A	T	30	Reduced	Closed
3	T	T	T	35	Reduced	Closed
4	T	T	A	35	Full	Open
5	A	T	A	30	Full	Open
6	A	T	T	30	Reduced	Closed
7	T	A	A	35	Full	Open
8	T	A	T	35	Reduced	Closed

A: AGT1500 T: TME

FIGURE 10

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

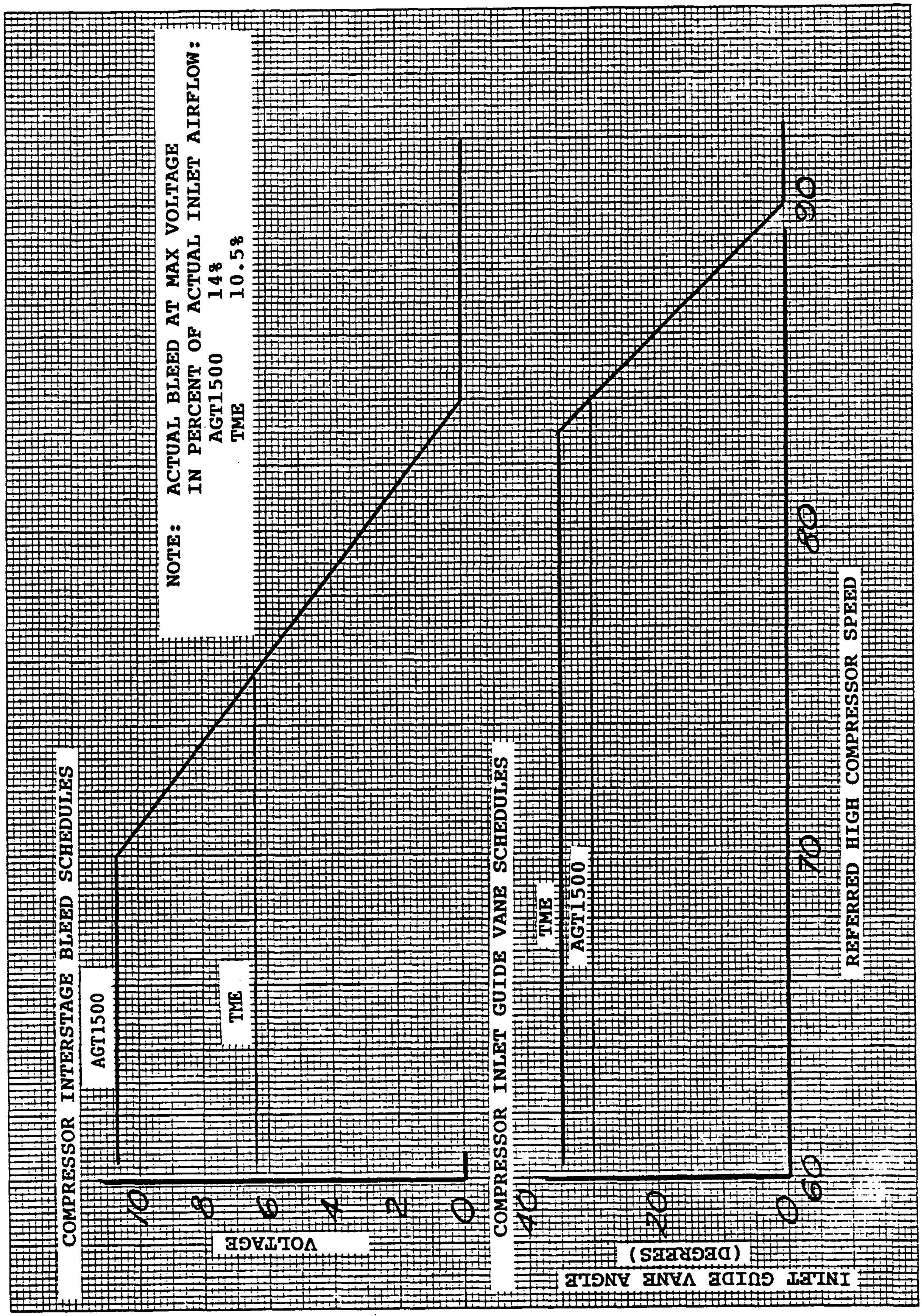


FIGURE 11

APPENDIX II

APPENDIX II

Report No. LYC 88-39
AGT 1500A
TACOM TME FUEL ECONOMY DEMONSTRATION TEST
ENGINE T202N
October 20, 1988

Prepared by _______________
F. Macri
AGT1500 Test Engineer

Approved by _______________
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Concurred by _______________
R. Horan
TME Development Manager

June 1989

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BACKGROUND	2
METHOD OF TEST	3
TEST EQUIPMENT	5
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RECOMMENDATIONS	10

APPENDIX - AGT 1500A TME Fuel Economy Test Plan

LIST OF FIGURES

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4	TME Inlet/Exhaust Losses
5	TME Installed Performance
6	TME Installed Performance
7	TME Peacetime Mission Points - SFC
8	Overall Compressor Pressure Ratio vs. Referred High Pressure Compressor Speed
9	Referred Low Pressure Compressor Speed vs. Referred High Pressure Compressor Speed
10	Referred High Pressure Compressor Speed vs. Referred Shaft Horsepower
11	TME TT7-PTS Schedule
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1	TMEPS Peacetime Mission/Battlefield Day Power Points
2	TME Fuel Economy Demonstration Peacetime Fuel Consumption
3	TME Fuel Economy Demonstration Battlefield Day Fuel Consumption

SUMMARY

Engine S/N T202, Build N, successfully completed a demonstration of TME performance on 20 October 1988 in accordance with Test Plan LYC 88-28 during which all objectives were accomplished. This report documents results obtained during testing at Textron Lycoming, Stratford, Connecticut. Engine operation was conducted at an ambient temperature of 87 ± 5 Degrees F and prevailing barometric pressure.

Weighted fuel savings relative to the current M1A1 production fabrication specification (E2180C) based on the peacetime annual usage duty cycle (excluding normal idle points) achieved during the demonstration were calculated at 15.3 percent. Fuel savings estimated for battlefield day operation were 12.2 percent on an annual basis.

Optimum line engine specific fuel consumption (SFC) was evaluated at 600, 900, 1200 and trim SHP power levels.

Maximum power achieved during the test was 1560 SHP (1550 SHPC) which exceeded the contracted power commitment of 1545 SHP. Testing was conducted over a range of steady-state operating conditions from idle to maximum power. Engine transient maneuvers were also successfully demonstrated. Total run time during the demonstration was 9.97 hours.

All requirements specified in the TME contract DAC100001 were successfully demonstrated with representatives from the Army (TACOM), General Dynamics Land Systems (GDLS) and Allison Transmission Division (ATD) present.

BACKGROUND

During 1986, Textron Lycoming began development of an improved version of the M1A1 Abrams Tank Propulsion System . This advanced design powerpack termed TMEPS (Transverse Mounted Engine Propulsion System) is part of a joint effort with GDLS (General Dynamics Lands Systems), Allison Transmission Division (ATD) and Donaldson (SCAF) in which the goal is to reduce propulsion compartment volume in the current M1 design by 30 percent (See Figures 1 & 2) to allow for additional munitions. In addition, engine operating costs would be lower mainly through a reduction in fuel consumption.

Like the AGT 1500, the TME system is a recuperative free power turbine shaft engine which incorporates a two-spool compressor and variable power turbine stators. The Transverse Mount Engine also incorporates a digital electronic fuel control unit (DECU) with additional engine schedule changes and more advanced components including a Hastelloy S material recuperator, advanced design power turbines (FEP) and reduced cooling flow single crystal H.P. turbine blades. The engine accessory gearbox has also been redesigned in which the customer power takeoff pad is removed (The hydraulic pump is driven off the vehicle mounted accessory gearbox in the TMEPS).

A significant contractual requirement of the program is the ability of the engine to achieve no less than ten percent weighted fuel savings relative to M1A1 Peacetime Mission cycle (non-normal idle points) and an increased power commitment of 1545 SHP. This is basically achieved through improved design hardware and operation of the engine on a more efficient fuel control schedule.

Featured hardware in the TME build is as follows:

- HPT Nozzle 3-110-250-X70, S/N BD8076, EFA = 5.342, GFA = 5.72
- HPT Cylinder 3-110-400-18, S/N 1151
- HPT Wheel Rebladed 3-110-010-88, S/N M807037
- LP Nozzle 3-110-140-33, S/N 202H EFA = 14.34
- New LP Turbine Wheel 3-110-120-11, S/N 88E17
- RGB TBC Double Wall Deflector 3-022-010-04
- RGB Reduce Cooling Flow Turbe 3-162-030R01, S/N 85B031
- RGB Assembly 3-020-400-X10, S/N 0044
- LE9022 Hp & LP Compressors New Bearings and Seals
- Int Housing Assembly 3-105-010 (HSGN 3-105-002R34) Special Sta. 2.1 Instrumentation, S/N 4899
- TME Diffuser Liner 3-130-070-16
- TME Collector 3-130-090-41
- Rope Seal Band Assembly 3-150-350X01
- New Curl Assembly 3-130-020-15
- PT HSGN 3-142-020-01, S/N 82B029
- AGB Module 3-000-050-06, S/N 85B035

METHOD OF TEST

Engine T202, Build N, completed both steady-state and transient operation per procedures set forth in Lycoming Test Plan LYC 88-28 (See Appendix 1) which was reviewed and approved by GDLS. Testing was completed on 20 October 1988 at the Lycoming Division of Textron in Stratford, Connecticut, with personnel from TACOM, ATD and GDLS present. The engine test cell utilized for the demonstration was T-11. The test was conducted at an ambient temperature of 87 ± 5 Degrees F and corrections to standard day barometer were made.

Engine operation was performed with fuel conforming to VV-F-800, Grade DF-2 diesel fuel, and lubricating oil conforming to MIL-L-23699.

The test procedure conducted during the demonstration was completed in the following order:

- Peacetime Mission Cycle Calibration
- TME Tt7 - PTS Tracking Calibration
- Engine Transient Evaluation
- Optimum Area - Fixed PTS Calibration

Each procedure will be discussed below.

Peacetime Mission Cycle Calibration

Power levels associated with the simulated Peacetime Mission cycle were set in accordance with GDLS input and account for all projected system power demands (losses). Actual points required are summarized in Table 1. Additional power levels were set above and below the specified points to allow for preliminary analysis of data in the test cell. Stabilization time at each point was ten minutes. Following the initial start, a fuel sample was collected for lower heating value analysis to allow for corrections to be made from the assumed 18500 BTU/LBM value.

TME Tt7 - PTS Tracking Calibration

Engine steady-state operation was conducted during the demonstration in which powers ranging from idle to trim power were obtained. Power levels were set in descending order from trim power to idle in 100 SHP increments. Total stabilization time at each point was five minutes.

Engine Transient Evaluation

Engine transient maneuvers were completed as specified in attachment three of LYC 88-28 (power and speeds updated for TME operation).

Optimum Area - Fixed PTS Calibration

A five-point open area calibration was conducted at a fixed setting of the PTS (power turbine stator) position as required in the test procedure. Stabilization time at each point was five minutes.

TEST EQUIPMENT

Power Absorption

A Textron Lycoming (LC 28800) waterbrake was used to absorb engine output shaft horsepower. The brake is supported from the engine on four calibrated strain-gauged beams that sense engine output shaft torque. Conversion of the strain-gauge signal to torque (Ft-Lbf) was accomplished by a transducer with signal conditioning to the data acquisition system.

No power extraction was facilitated during testing since TME design does not include an engine customer power takeoff pad.

Engine Starting System

Starting of the engine was accomplished by a Delco Remy, Model 1113883, electronic stepper motor (See Figure 3 for TME starter pad configuration). Power for starting was provided by a 28 VDC Hobart, Model No. 6T28-400CL, motor generator.

Oil Coolers

Engine oil (Mobil 254) was cooled by means of an industrial type oil to water heat exchanger, Lycoming TES 77-1.

Engine Inlet Air Temperature

Engine inlet air temperature was maintained at 87 $\pm$ 5 Degrees F from a tempered air system comprised of 600 SHP motor with a plenum assembly, hydraulic valves, and a variable speed blower with steam heating coils. All operation is monitored by a computer.

Computerized Data Acquisition Equipment

Engine test data was recorded by a Hewlett Packard HP1000 data acquisition system comprised of a digital processor (via disk drive), printer and CRT displays. The system is capable of processing steady-state and transient data collection.

Inlet Airflow Measurement

Engine inlet airflow was measured with a calibrated axial bellmouth assembly TE 26816-01 per ASME standards. Static and total pressures in the bellmouth were measured using pressure transducers in conjunction with a suitable analog to digital digital converter. The inner bellmouth housed the NL rotor speed pickup.

Vibration

Engine vibrations were measured with CEC/IMO velocity transducers in conjunction with Trig-Tek vibration meters, Model No. 203J.

Fuel and Oil Measurement

Cox turbine flowmeters (ANC) with associated signal converters, amplifiers and readouts were used for measuring oil and fuel flow rates.

Rotor Speeds

Magnetic pulse generators in conjunction with signal conditioning and readout equipment were used to measure and display main rotor speeds.

Pressures

Calibrated bourdan tube gauges and transducers measured pneumatic and hydraulic pressures.

Temperatures

Temperatures were measured by I.C. and C.A. thermocouples. Signals were conditioned by analog to digital converts and displayed by means of a printer and CRT.

Transient Recorders

Gould Brush, Model 2800, recorders were used during the demonstration in conjunction with pressure transducers, flowmeters, thermocouples, potentiometers and magnetic speed pickups to provide continuous monitoring of the engine. A high speed analog to digital converter manufactured by Neff Instruments was also utilized in recording transient data.

Oil Level Measurement

A Robertshaw controls, Model 5000, and indicator probe were used to measure engine oil level.

TEST RESULTS

Total engine run time accumulated during the demonstration was 9.97 hours (total run time accumulated on T202N to date is 43.12 hours). Engine oil consumption calculated during testing was .02 gal/hr. Results obtained from each section of the test procedure are summarized below.

Peacetime Duty Cycle - Weighted Fuel Savings

Weighted annual fuel consumption summarized for each engine power condition of the Peacetime Mission points (Table 1) is shown in Table 2. Corrections for an installed configuration at 500 feet altitude (See Figures 4 & 5) and actual measured fuel lower heating value was accounted for.

Uninstalled optimum engine specific fuel consumption measured at each Peacetime Mission point is shown in Figure 7.

Based on test results, engine T202N demonstrated 15.3 percent fuel savings relative to the M1 production specification Peacetime Mission cycle (normal idle points excluded). Engine weighted fuel savings estimated for the M1A1 Combat Mission cycle (battlefield day) were calculated at 12.2 percent on an annual basis (See Table 3). The largest fuel savings occurred at the tactical idle power setting in which an estimate of 217 gallons of fuel would be saved (M1A1 spec - 740 gallons, TME demonstration - 523 gallons) which represents a 29 percent reduction in annual fuel consumption during peacetime operation. This is a significant achievement because a large percentage of tank operation occurs in the low power region.

TME - Performance Calibration

Engine performance calibrations (tracking and open area) conducted during the demonstration were completed in compliance with the TME ETP 1500A Test Specification. Data obtained is plotted in Figures 7 through 15.

Engine specific fuel consumption (See Figure 12) measured during the tracking calibration at each of the specified points noted in attachment three of LYC 88-28 is summarized below:

Power (SHP)	NPT (%)	SFC (LBM/HP-HR)
1500	100.0	.459
1200	98.7	.451
900	96.3	.462
600	87.5	.507
Tac Idle	44.0	1.309
Idle	37.0	1.493

The TME maximum power commitment of 1545 SHP (87 Degrees F) was exceeded during testing. Engine T202N demonstrated 1550 SHPC with a 27 Degree F H.P. turbine inlet temperature margin (Tt5 limit = 2230 Degrees F). Engine trim shaft horsepower characteristics are shown below:

TO	85 Degrees F
Power	1550 SHP
NH	103 Percent (100% = 43450 RPM)
Tt5	2203 Degrees F (2230 limit)
Tt7	1432 Degrees F
PTS	-5.35 VDC

Engine Transient Performance

Results from engine transients conducted during the demonstration are shown below (See Figures 16-18):

Condition	T202	Requirement
Decel (20% SHPC)	4.8 seconds	5.0 seconds
Accel (90% SHPC)	3.8 seconds	4.0 seconds

Engine waveoffs to 75 percent NH - surge free.

Additional features incorporated into the DECU for TME operation during engine transient operation include schedule modifications to reduce temperature gradients.

CONCLUSIONS

In compliance with TME Contract No. DAC100001, engine T202N successfully demonstrated all objectives described in Lycoming Test Plan LYC 88-28.

Weighted fuel savings estimated for both peacetime and battlefield day operation were 15.3 and 12.2 percent, respectively, when compared to the current M1A1 fabrication specification. In addition, significant part-power optimum SFC reduction was demonstrated.

Maximum shaft horsepower demonstrated during the test was 1550 SHPC (87°F day commitment - 1545 SHPC) with a 27°F Tt5 margin.

Transient performance evaluated during starting and accelerations indicate that recuperator durability will be increased with the additional logic incorporated into the TME DECU. This is accomplished by limiting recuperator core temperature gradients during transient operation.

RECOMMENDATIONS

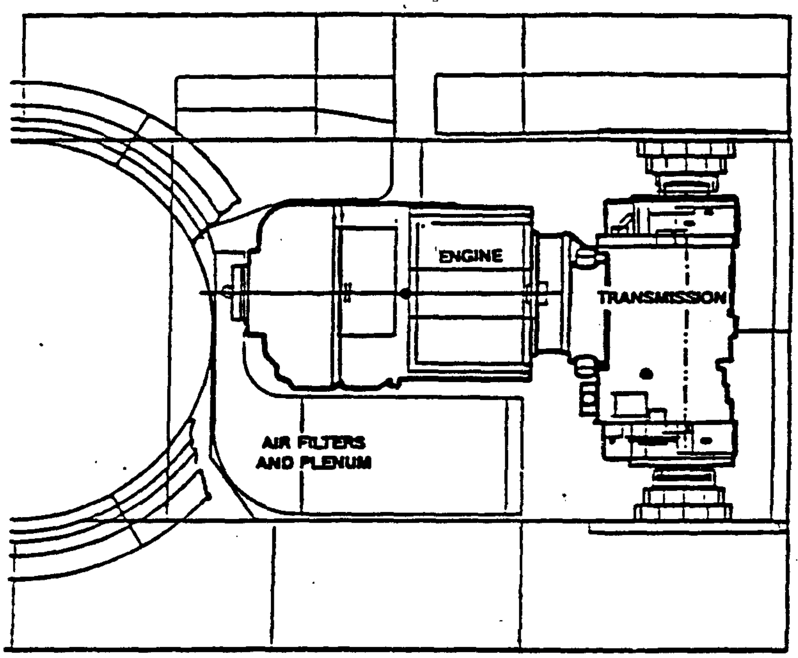
It is recommended that this report be accepted as evidence of the capability of AGT 1500A engine T202N to demonstrate transverse mounted engine operating principles as required in TME Contract No. DAC100001.

It is further recommended that engine T202N complete a Final Acceptance Test as specified in ETP 1500A prior to shipment from Textron Lycoming for further development with the ATD seven-speed transmission and ATR vehicle.

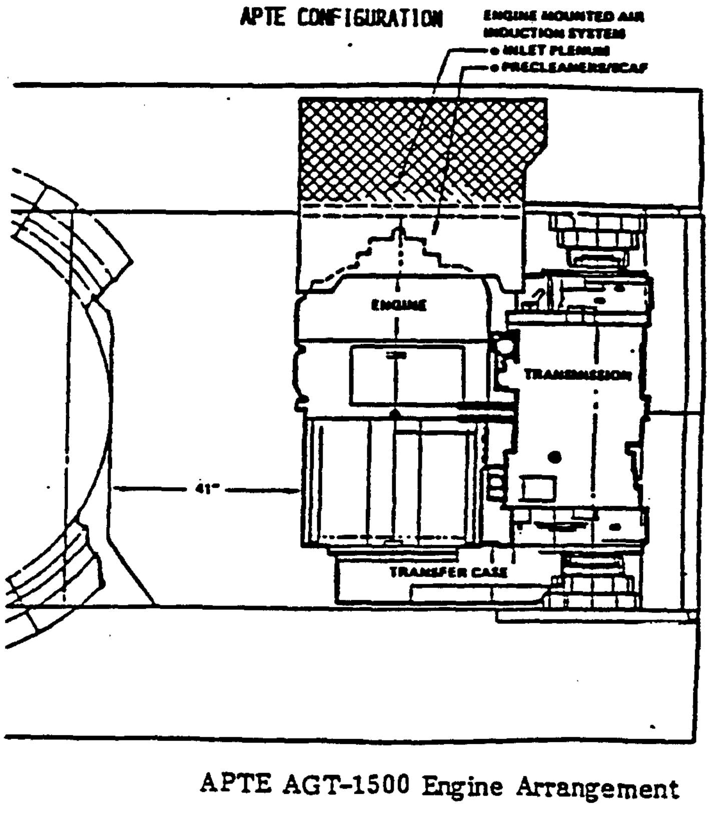
FIGURES

FIGURE 1

AGT 1500/TME Power Pack Arrangement



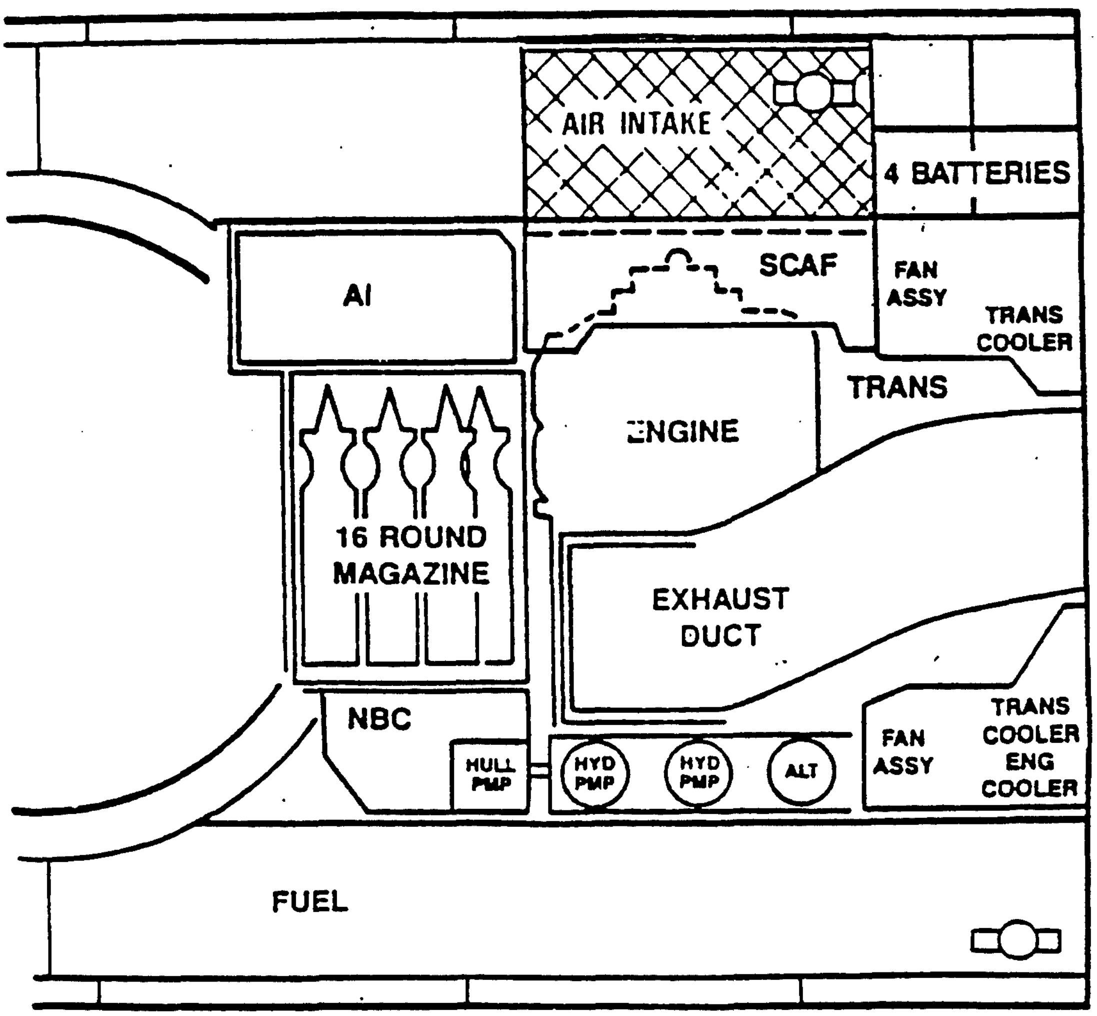
Present AGT-1500 Engine Arrangement



APTE AGT-1500 Engine Arrangement

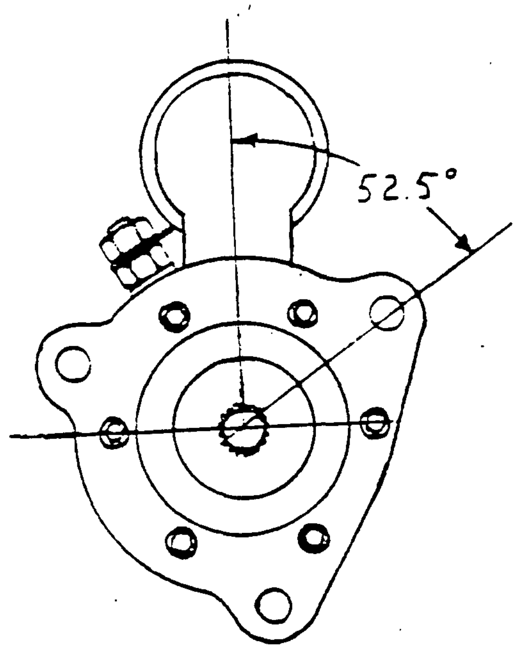
TME Propulsion Compartment

FIGURE 2

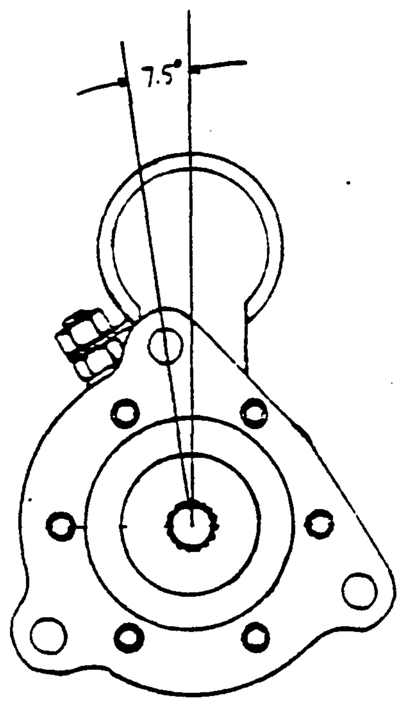


Lycoming TEXTRON

TME/AGT 1500 STARTER PAD CONFIGURATION



AGT 1500



TME

K+E 10 X 10 TO THE CENTIMETER KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1513

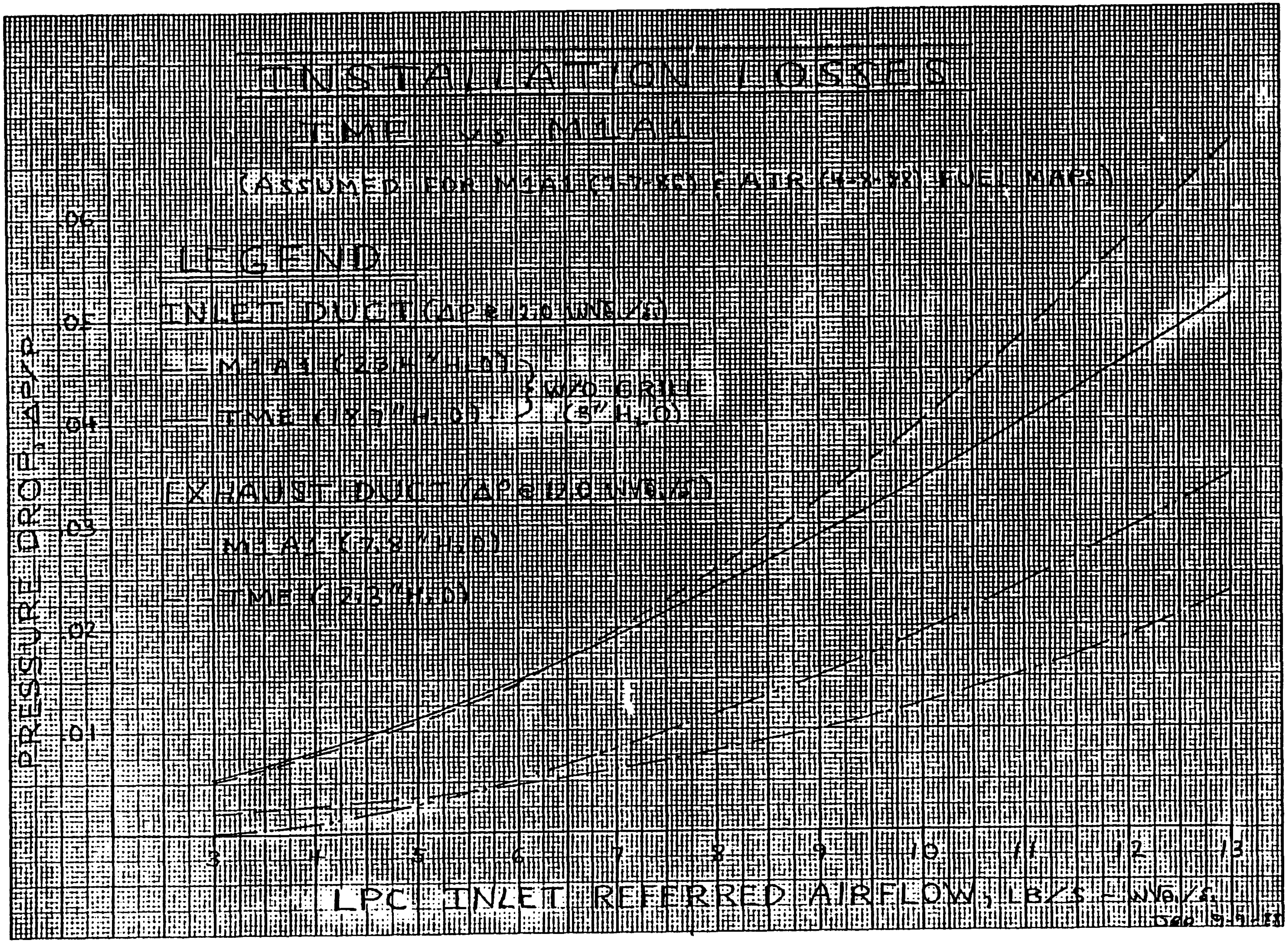
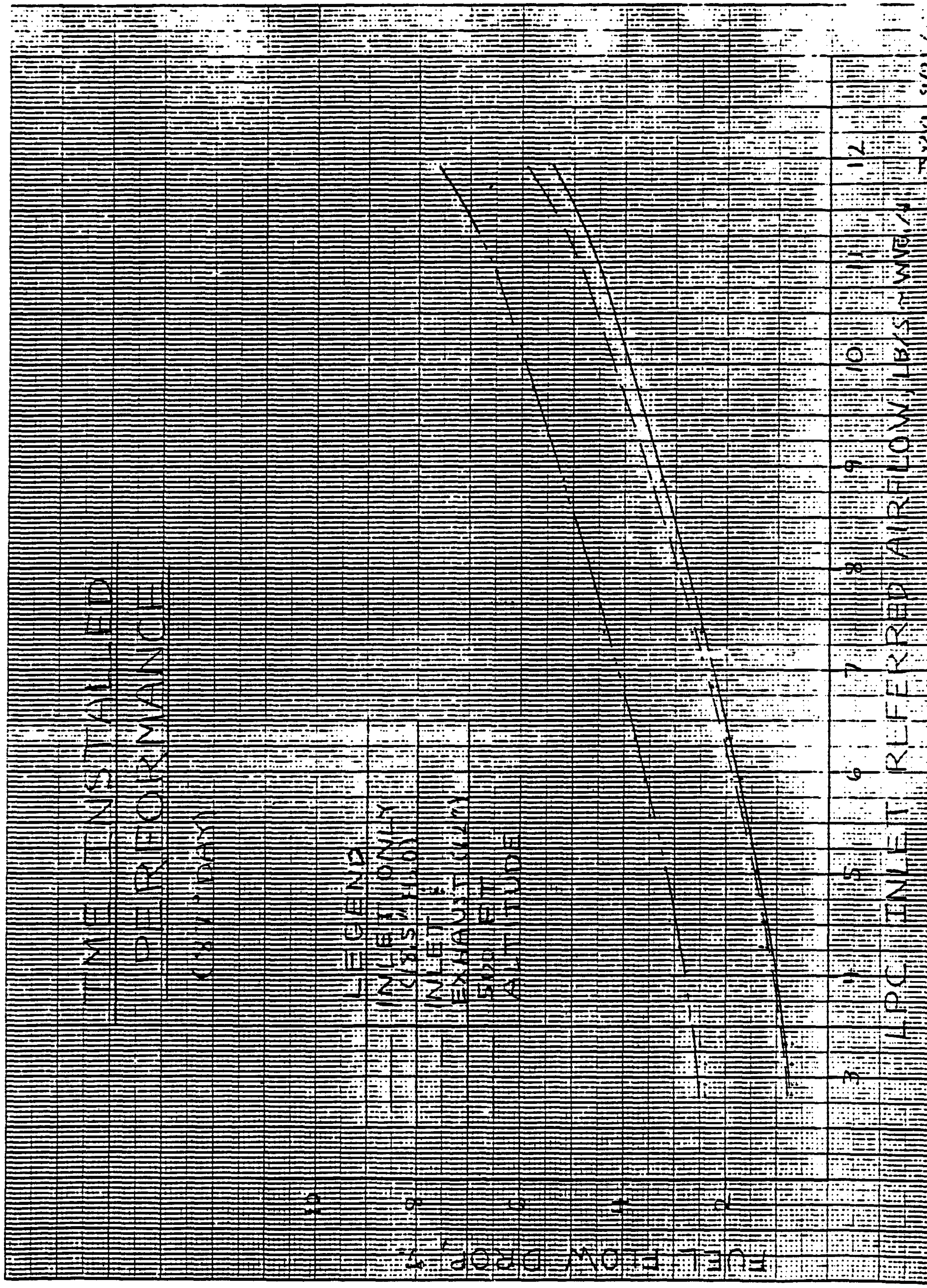


FIGURE 4

FIGURE 5



PERFORMANCE
LEGEND
INLET ONLY
INLET EXHAUST
ALTITUDE
LPC INLET REFERRED AIRFLOW, LB/S
FUEL FLOW DROP, %
3
4
5
6
7
8
9
10
11
12
2
4
6
8
10

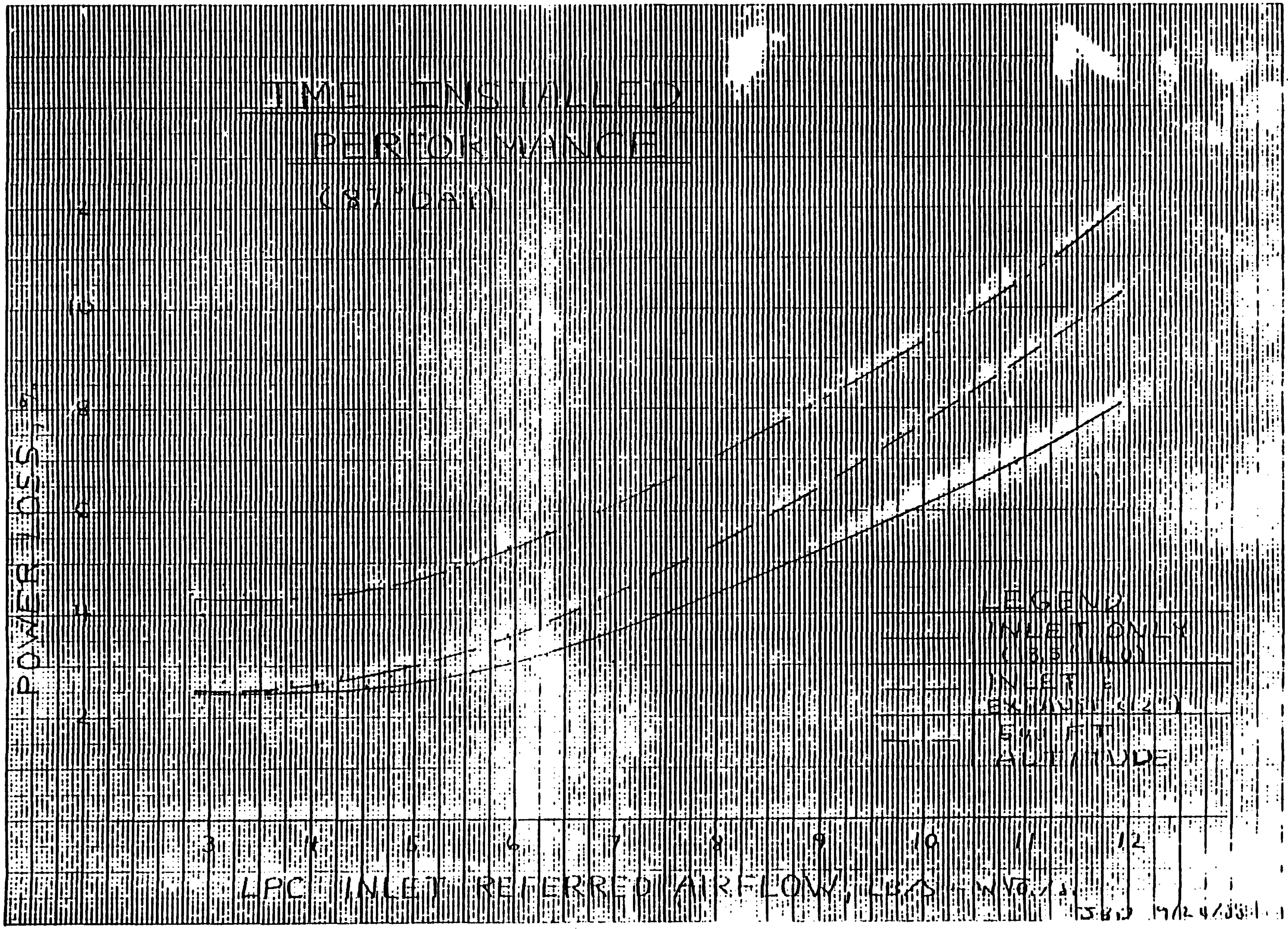

INSTALLED
PERFORMANCE
POWER LOSS, %
LPC INLET REFERRED AIRFLOW
3
4
5
6
7
8
9
10
11
12
LEGEND
INLET ONLY
INLET &
ALTITUDE

FIGURE 6

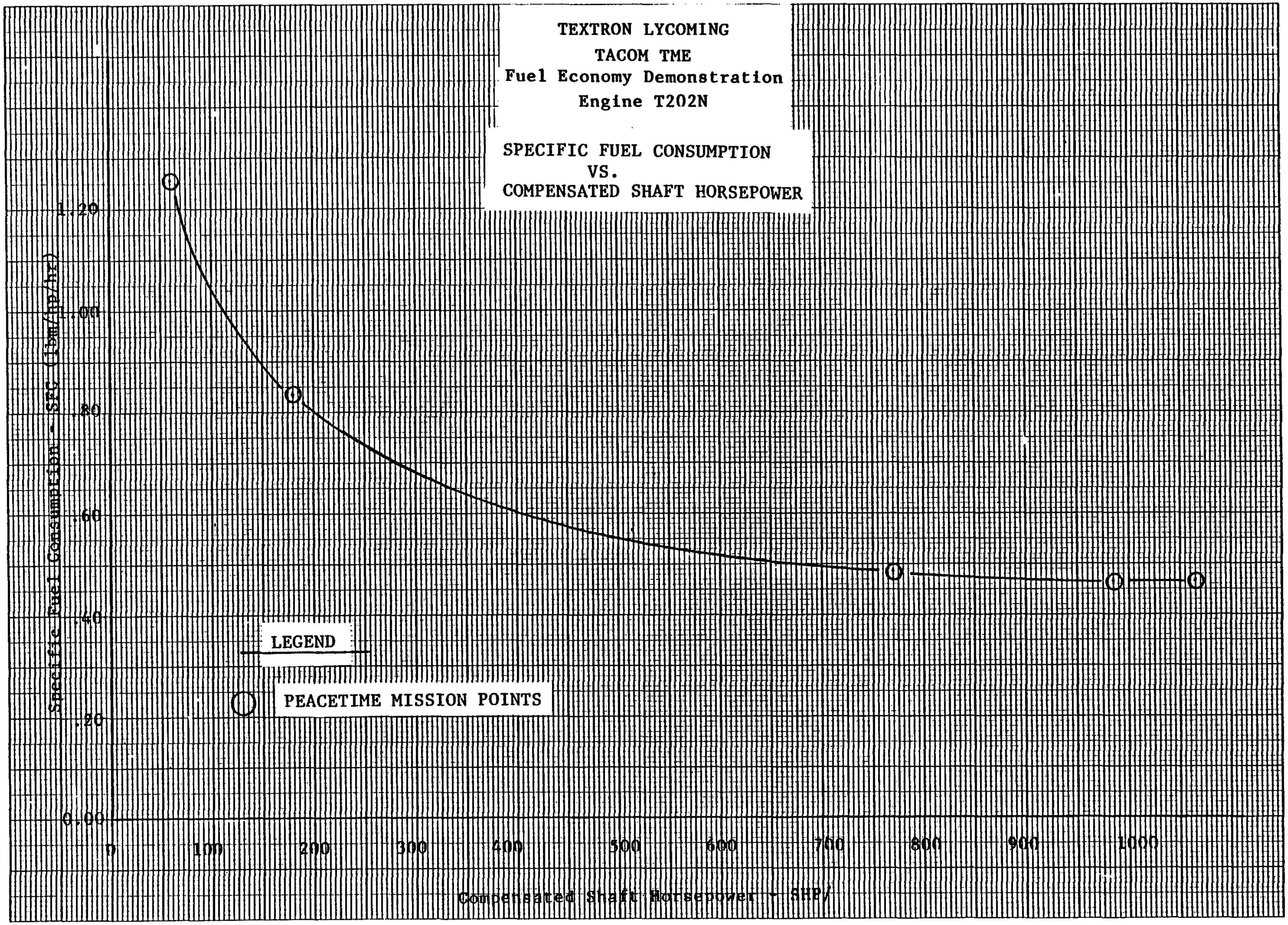
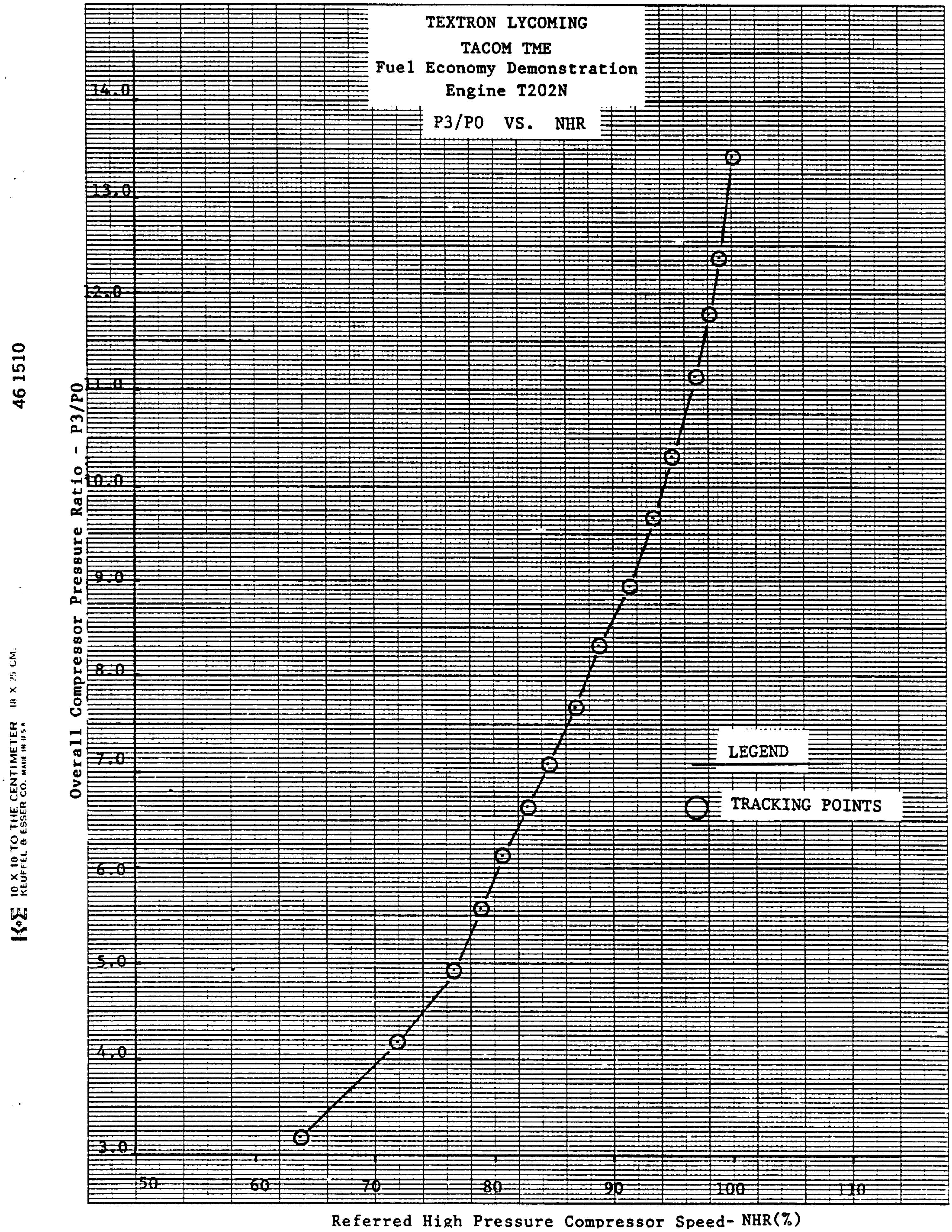

TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
SPECIFIC FUEL CONSUMPTION
VS.
COMPENSATED SHAFT HORSEPOWER
1.20
1.00
.80
.60
.40
.20
0.00
0
100
200
300
400
500
600
700
800
900
1000
Specific Fuel Consumption - SFC (lbm/hp/hr)
Compensated Shaft Horsepower - SHP/
LEGEND
PEACETIME MISSION POINTS

FIGURE 7


TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
P3/PO VS. NHR
LEGEND
TRACKING POINTS
Overall Compressor Pressure Ratio - P3/PO
Referred High Pressure Compressor Speed- NHR(%)
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
50
60
70
80
90
100
110
46 1510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

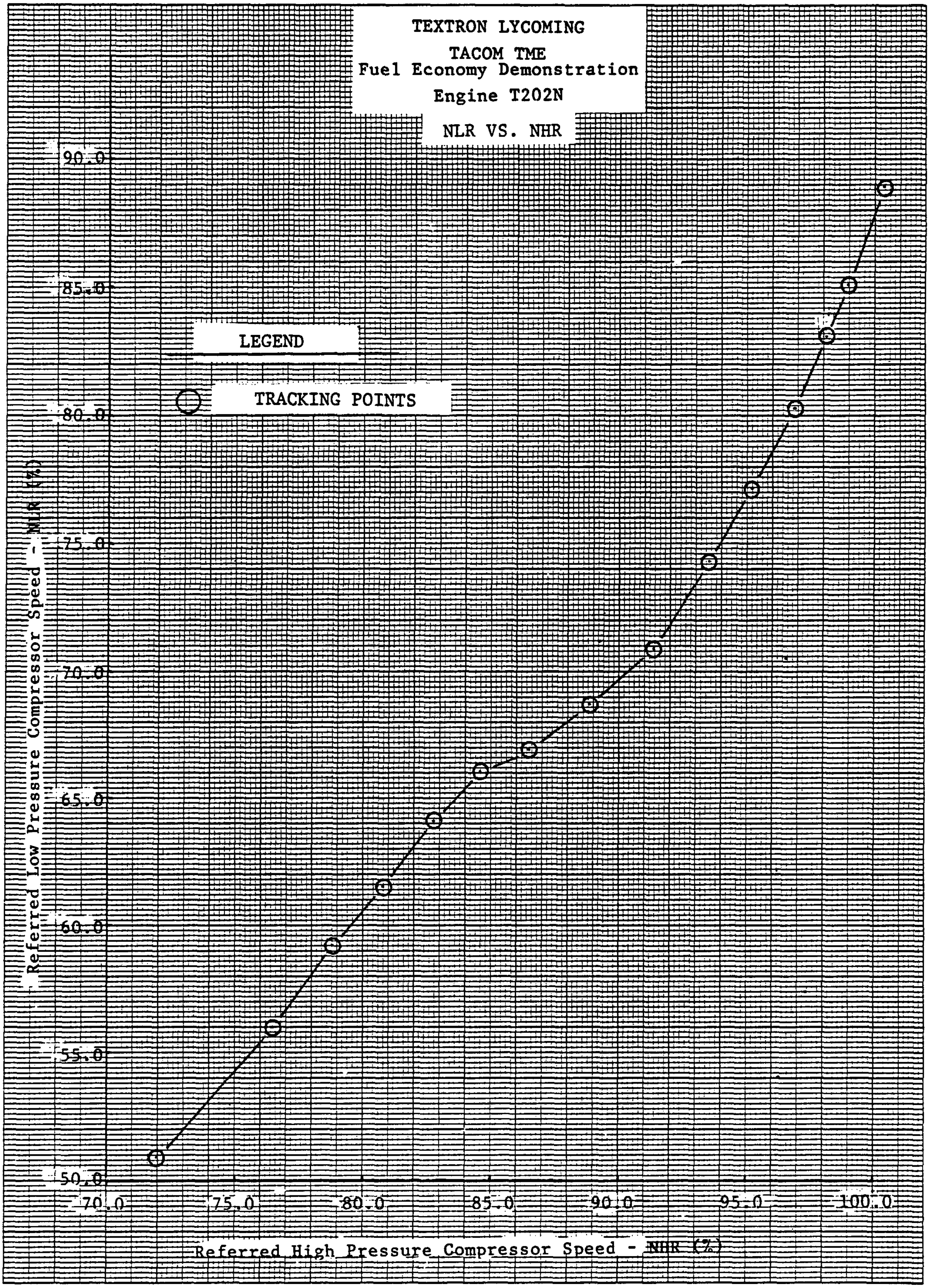
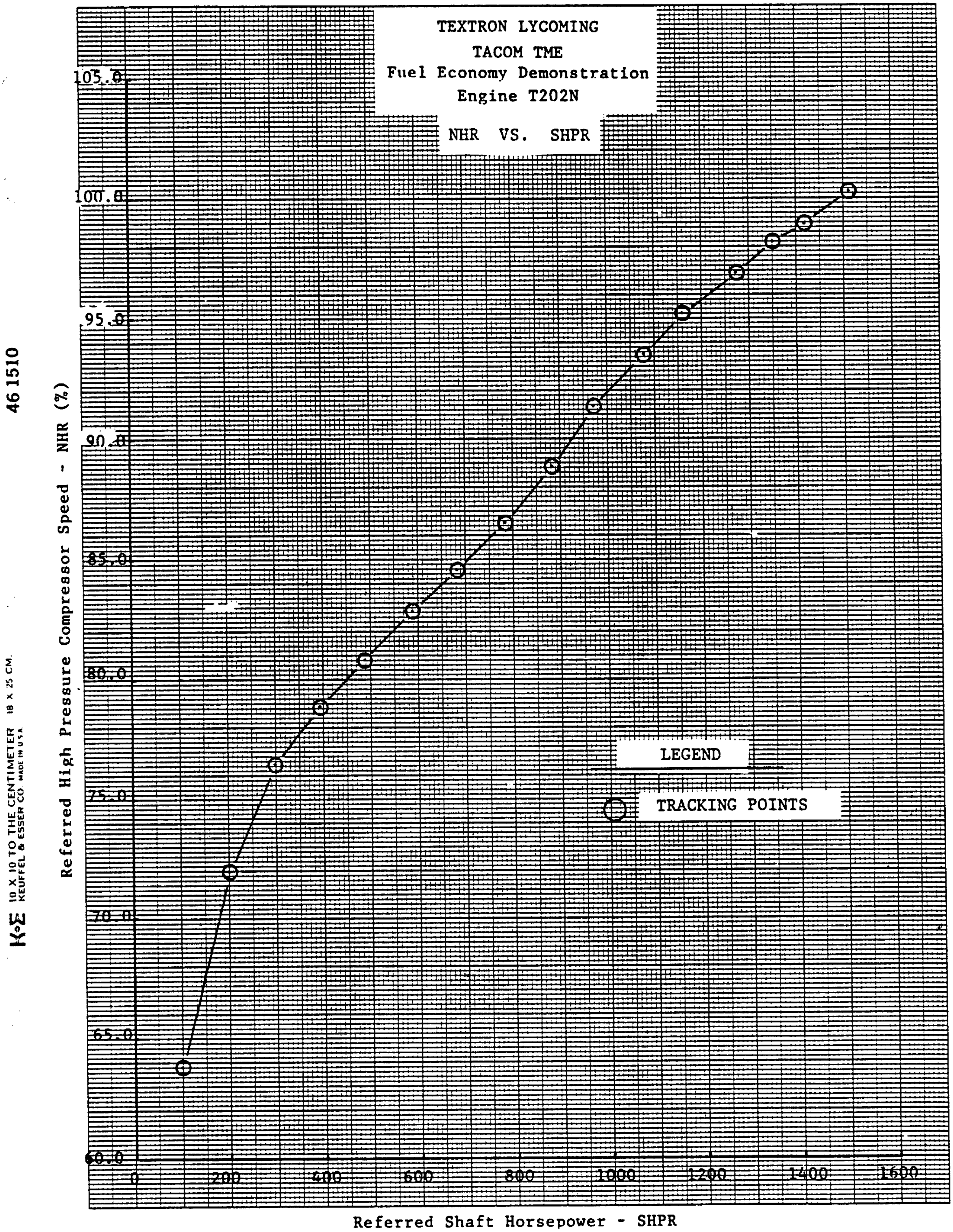
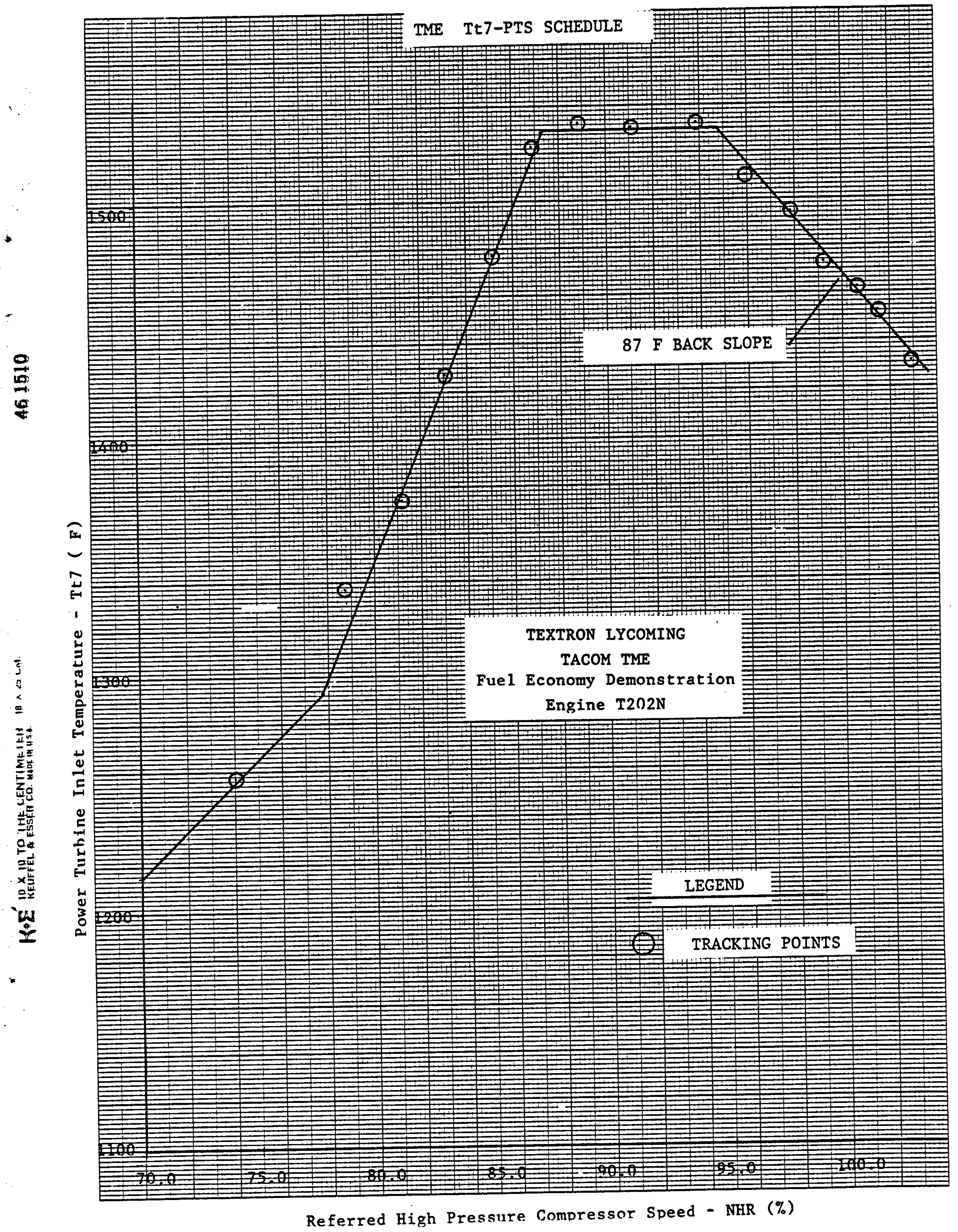

TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
NLR VS. NHR
LEGEND
TRACKING POINTS
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
Referred Low Pressure Compressor Speed - NLR (%)
Referred High Pressure Compressor Speed - NHR (%)

FIGURE 10



TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
NHR VS. SHPR
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
0
200
400
600
800
1000
1200
1400
1600
LEGEND
TRACKING POINTS
Referred High Pressure Compressor Speed - NHR (%)
Referred Shaft Horsepower - SHPR
46 1510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.


TME Tt7-PTS SCHEDULE
1500
1400
1300
1200
1100
87 F BACK SLOPE
TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
LEGEND
TRACKING POINTS
70.0
75.0
80.0
85.0
90.0
95.0
100.0
Power Turbine Inlet Temperature - Tt7 (F)
Referred High Pressure Compressor Speed - NHR (%)
46 1510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

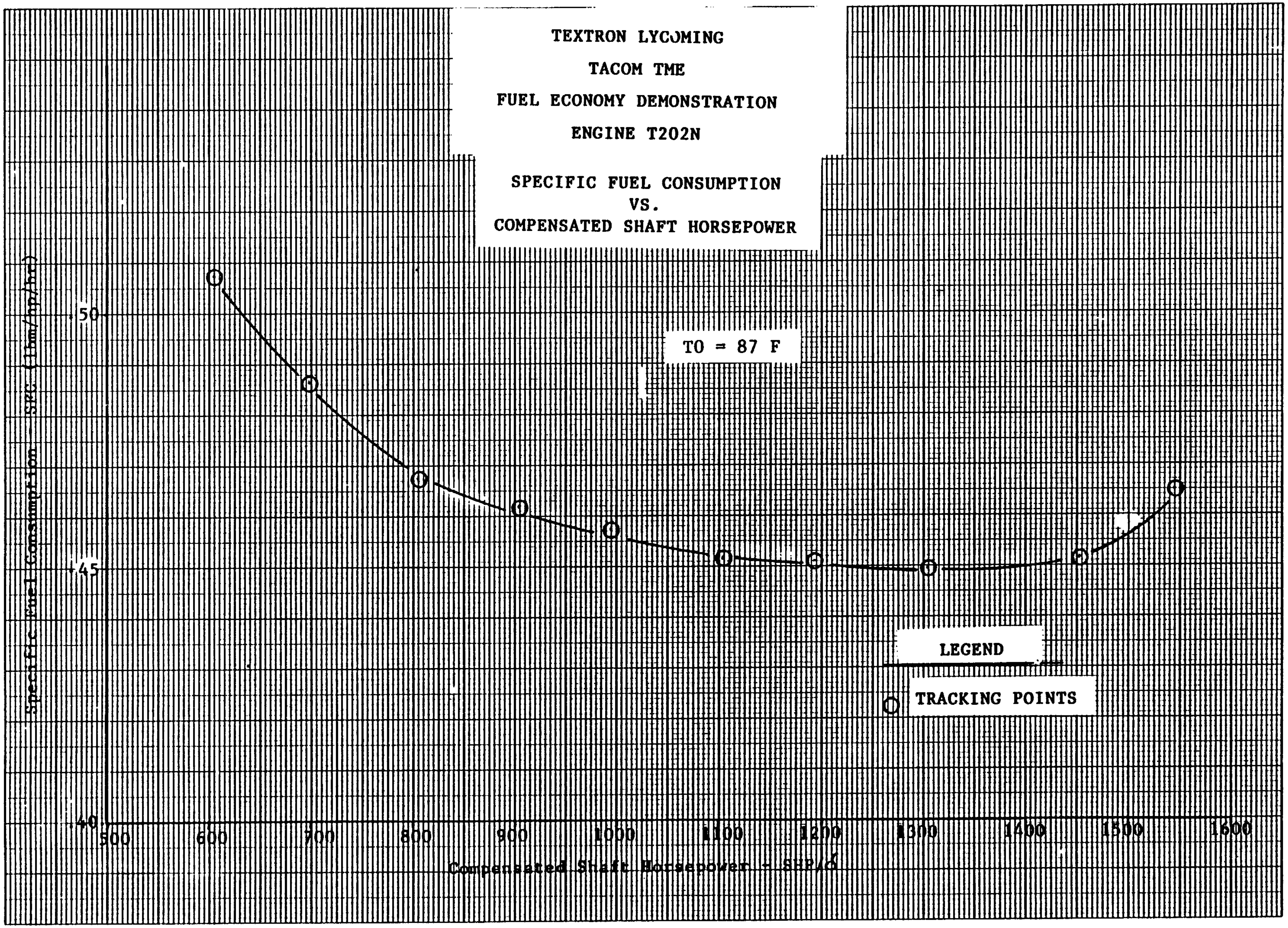
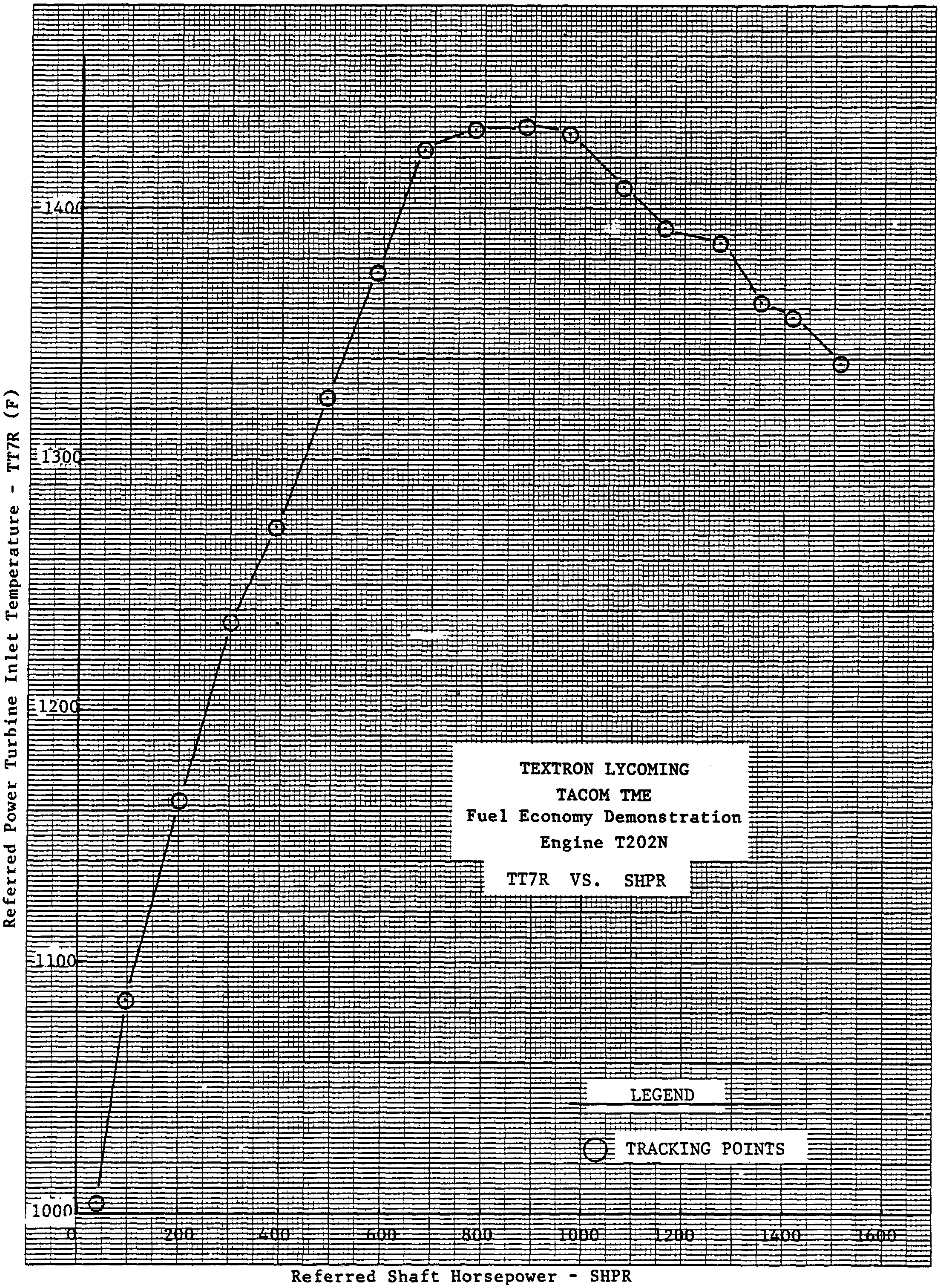

TEXTRON LYCOMING
TACOM TME
FUEL ECONOMY DEMONSTRATION
ENGINE T202N
SPECIFIC FUEL CONSUMPTION
VS.
COMPENSATED SHAFT HORSEPOWER
T0 = 87 F
LEGEND
TRACKING POINTS
.50
.45
.40
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
Compensated Shaft Horsepower - SHP/δ
Specific Fuel Consumption - SFC (lbm/hp/hr)

FIGURE 12



TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
TT7R VS. SHPR
LEGEND
TRACKING POINTS
Referred Power Turbine Inlet Temperature - TT7R (F)
Referred Shaft Horsepower - SHPR
1000
1100
1200
1300
1400
0
200
400
600
800
1000
1200
1400
1600

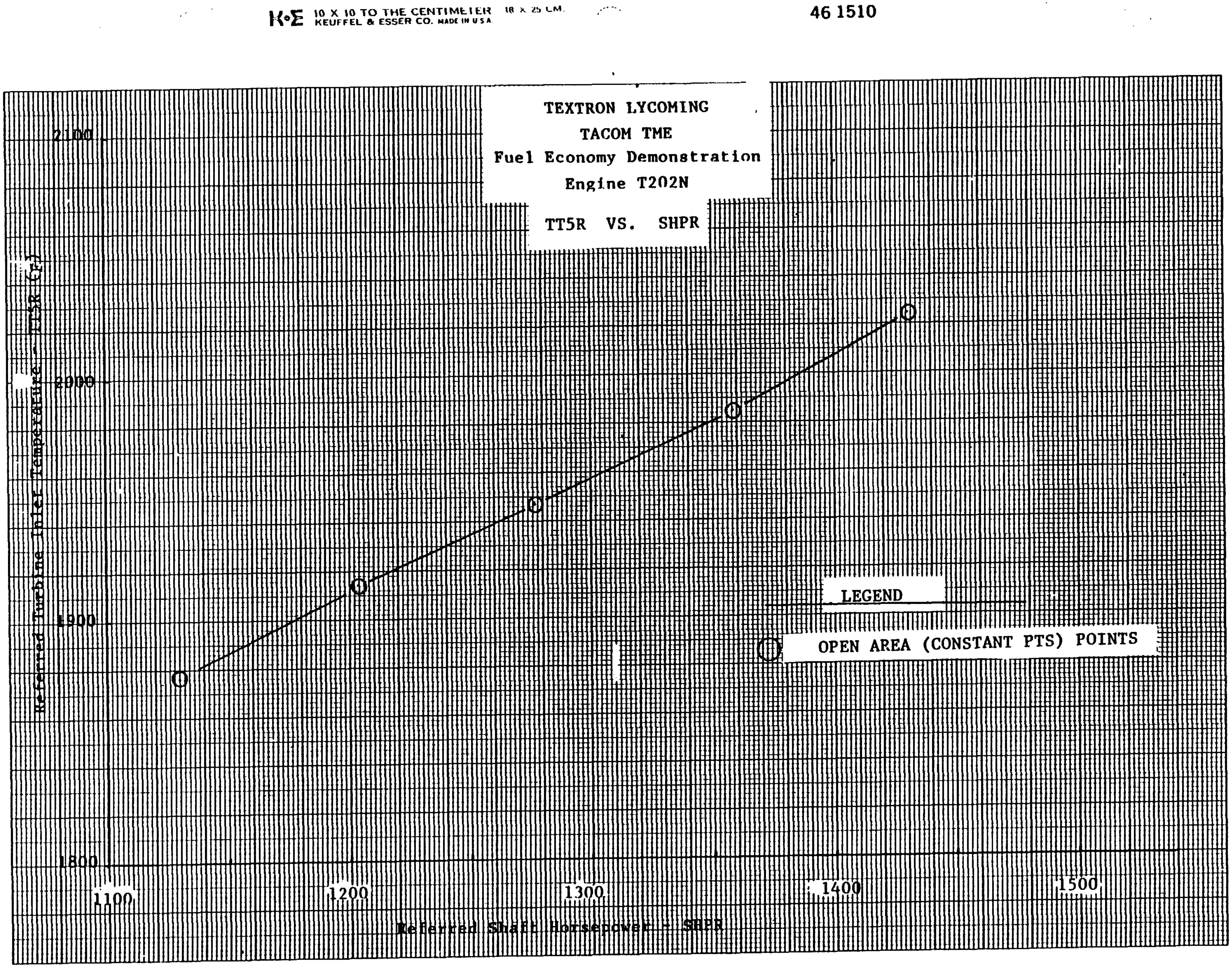
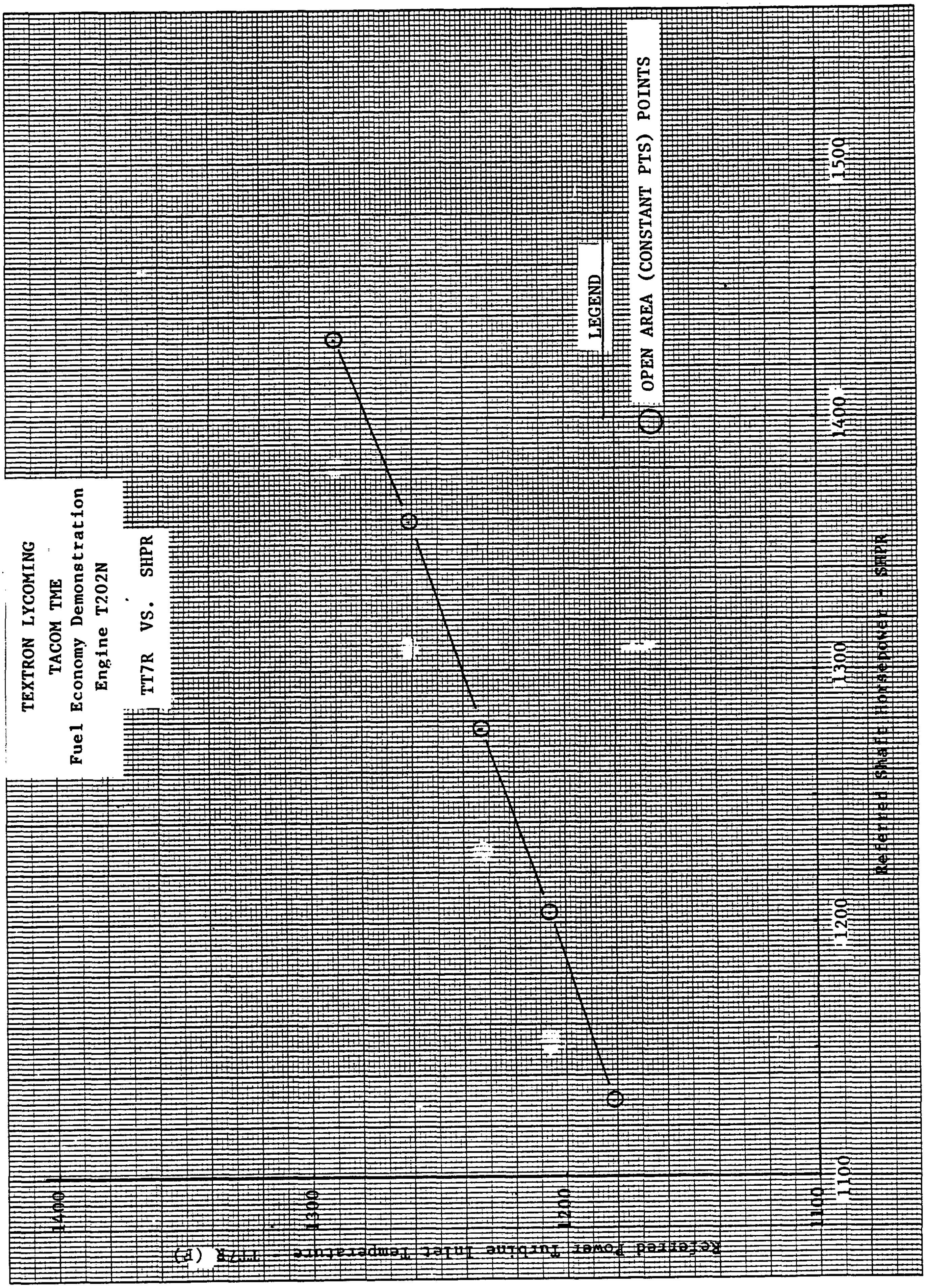

K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1510
TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
TT5R VS. SHPR
LEGEND
OPEN AREA (CONSTANT PTS) POINTS
2100
2000
1900
1800
1100
1200
1300
1400
1500
Referred Turbine Inlet Temperature - TT5R (F)
Referred Shaft Horsepower - SHPR

FIGURE 14

FIGURE 15


TEXTRON LYCOMING
TACOM TME
Fuel Economy Demonstration
Engine T202N
TT7R VS. SHPR
LEGEND
OPEN AREA (CONSTANT PTS) POINTS
1100
1200
1300
1400
1500
Referred Shaft Horsepower - SHPR
1100
1200
1300
1400
Referred Power Turbine Inlet Temperature - TT7R (F)

ENGINE T202N

FIGURE 16

TACOM FUEL ECONOMY DEMO
JAM ACCELERATION TO MAXIMUM POWER

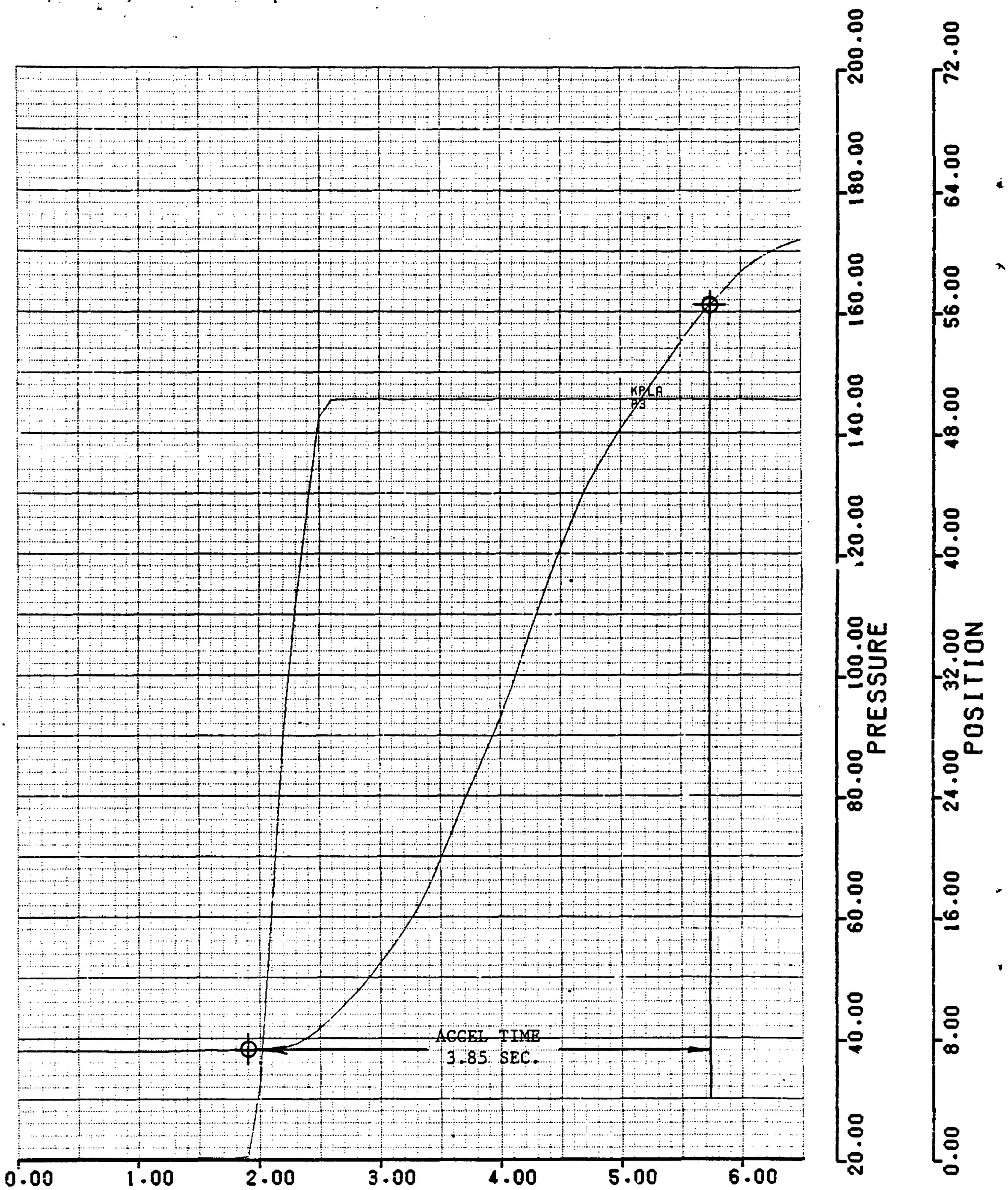
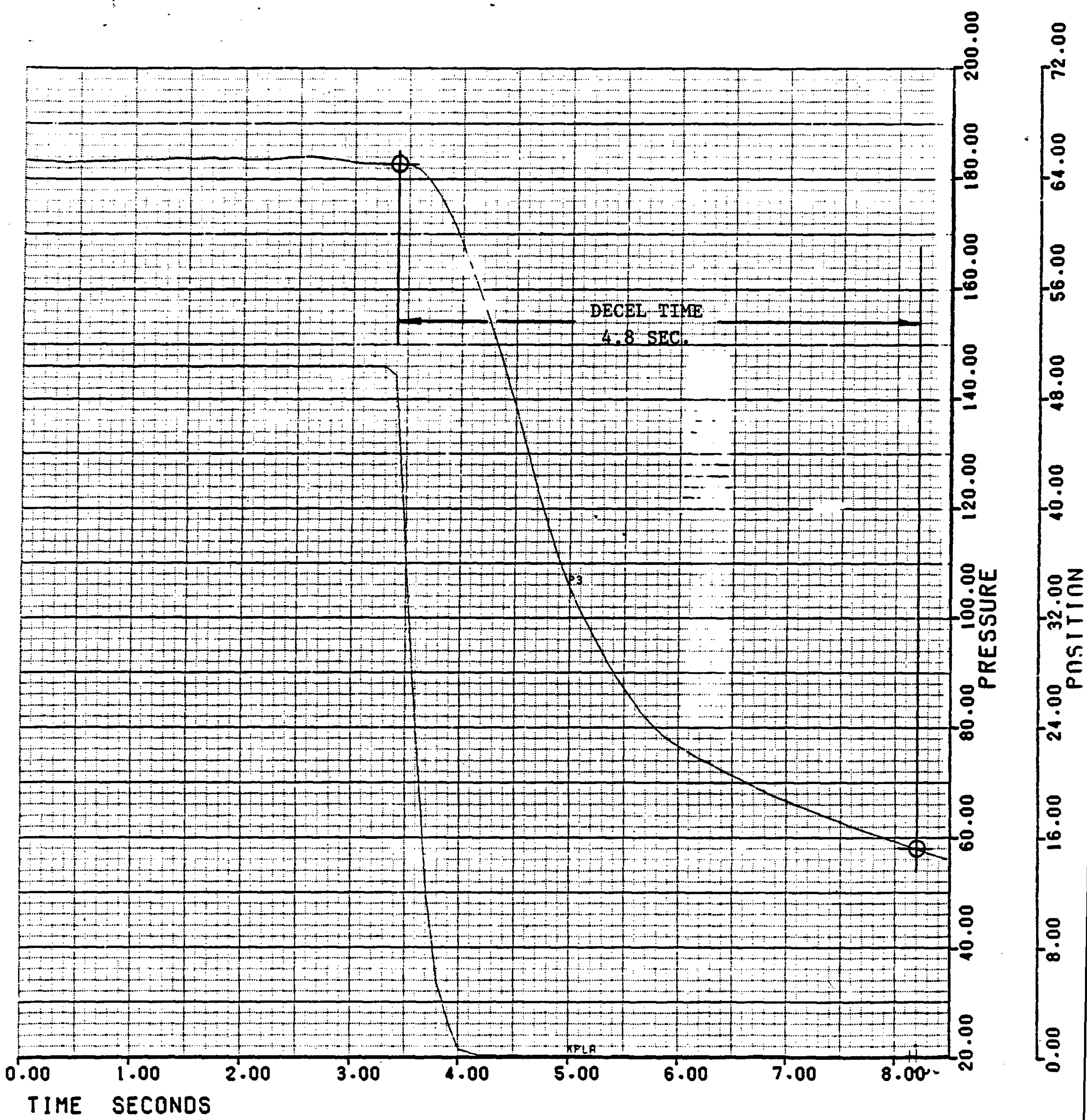


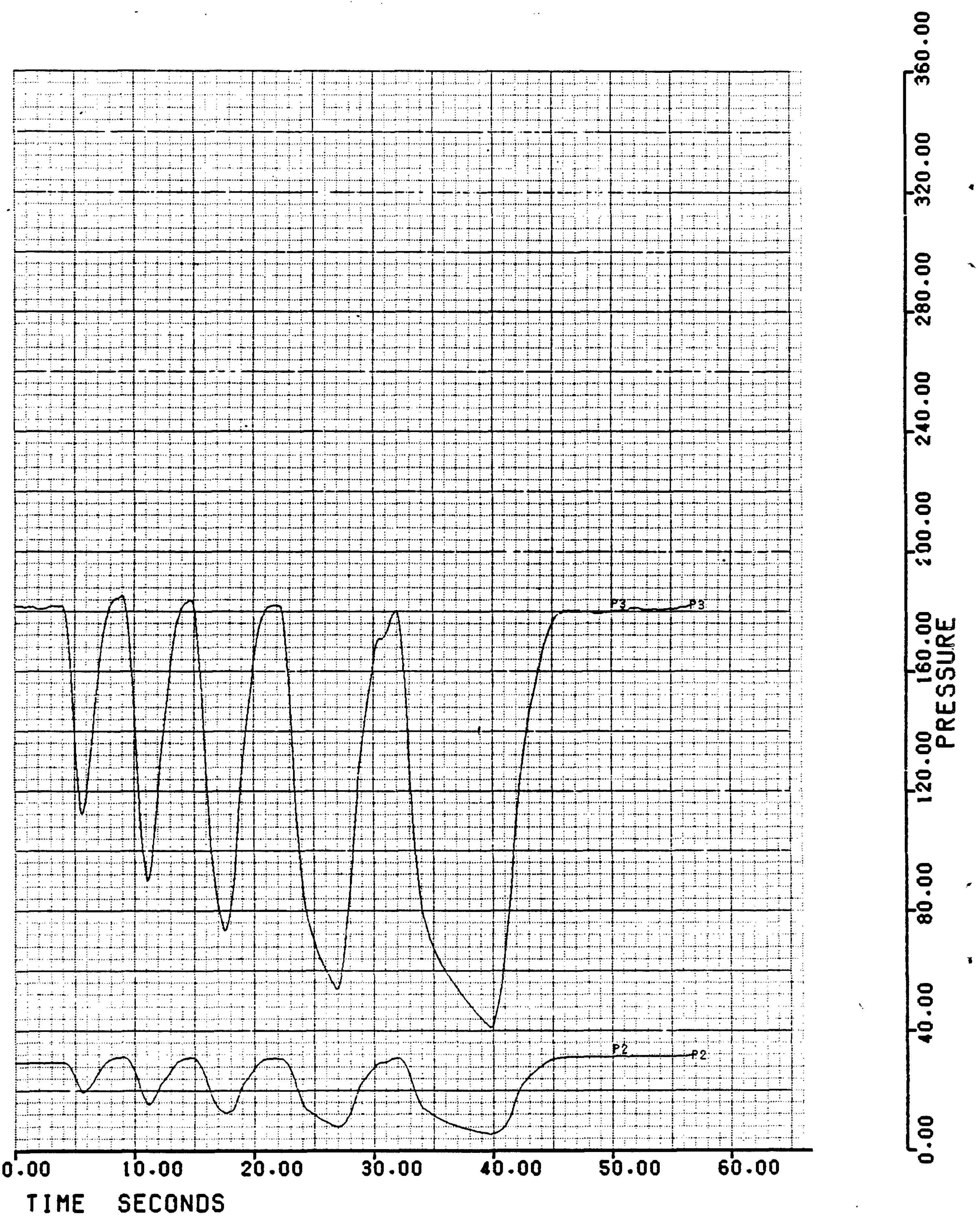
FIGURE 17

TACOM FUEL ECONOMY DEMO
SNAP DECELERATION TO IDLE



TACOM FUEL ECONOMY DEMO
ENGINE WAVEOFFS

FIGURE 18



TABLES

TABLE 1

TMEPS

PEACETIME MISSION/BATTLEFIELD DAY POWER POINTS

OPERATING CONDITION	VEHICLE SPEED (MPH)	ENGINE SPEED (RPM)	ENGINE OUTPUT (HP)
Tactical Idle	-	1300	58.10
Secondary Road	5.0	1174	174.00
Secondary Road	24.9	2389	728.20
Secondary Road	34.8	2379	991.00
Cross Country	16.8	2605	925.00

NOTE: Normal idle points are omitted because they are supplied by the TMEPS APU.

TABLE 2

TME FUEL ECONOMY DEMONSTRATION

PEACETIME FUEL CONSUMPTION, ANNUAL (NBC OFF)

OPERATING CONDITION	TIME (HRS)	ENGINE SPEED (NPT)	ENGINE OUTPUT (HP)	FUEL CONSUMPTION (GALLONS) M1A1 FAB SPEC BASELINE	T202N DEMO
Tactical Idle	50.0	1300	58	740	523
Secondary Road (5 MPH)	12.0	1174	174	271	248
Secondary Road (25 MPH)	14.9	2389	728	840	749
Secondary Road (35 MPH)	9.0	2379	991	672	594
Cross Country	11.3	2605	925	925	690
			TOTAL:	3311	2804
			% REDUCTION:		-15.3%

NOTE: Normal idle points are omitted because they are supplied by the TMEPS APU.

TABLE 3

TACOM TME FUEL ECONOMY DEMONSTRATION

BATTLEFIELD DAY FUEL CONSUMPTION, ANNUAL (NBC OFF)

OPERATING CONDITION	TIME (HRS)	ENGINE SPEED (NPT-RPM)	ENGINE OUTPUT (HP)	FUEL CONSUMPTION (GALLONS) M1A1 FAB SPEC BASELINE	T202N DEMO
Tactical Idle	.917	1300	58.1	13.6	9.6
Secondary Road (25 MPH)	3.4	2389	728.2	191.7	170.9
Cross Country	3.333	2605	925.0	232.3	203.6
			TOTAL:	437.6	384.1
			% REDUCTION:		-12.2%

NOTE: Normal idle points are omitted because they are supplied by the TMEPS APU.

APPENDIX

APPENDIX I

AGT 1500A

TME

FUEL ECONOMY TEST PLAN

LYC 88-28
03-P-902-88

Prepared by ________________
R. Rusu
Sr. Dev. Test Engineer

Concurred by D B Collings for C Stubner
C. Stubner
AGT 1500 Performance Manager

Approved by R Hudson
R. Hudson
AGT 1500 Dev. Test Manager

Approved by ________________ for R. Horan
R. Horan
Manager, TME Engineering

SEPTEMBER 1988

TME
FUEL ECONOMY TEST PLAN

AGT 1500A Model Engine, Turbine, Automotive
(Uninstalled-ASME Bellmouth Air Induction System and Cell Exhaust Duct)

1.0 SCOPE

This Test Plan shall be the governing document for the execution of the Fuel Economy Test of the Transverse Mounted Engine (TME) demonstrator to be performed on the model AGT 1500A automotive turbine engine. The TME Fuel Economy Test will be conducted in accordance with the specific provisions presented in this test plan while assuring the compliance with TME ETP 1500A.

1.1 Objective

The test objective is to demonstrate the ability of the Transverse Mounted Engine (TME) demonstrator to comply with the fuel economy requirements of TME contract No. DAC100001.

1.2 Applicability

This plan shall apply for the Fuel Economy Demonstration Test of TME, AGT 1500A, S/N T202 (LE89752).

2.0 GENERAL COMPOSITION AND ORDER OF THE TEST

The TME demonstrator Fuel Economy Test shall be accomplished in uninstalled configuration using the standard AGT 1500 ASME bellmouth air induction system and cell exhaust duct at 87±5°F ambient temperature and prevalent barometric pressure.

The TME installation losses will be analytically applied to the uninstalled test cell engine performance level per curves used to generate the TME fuel map (See Attachment 1).

The TME Fuel Economy Test shall prove a minimum 10% weighted fuel savings as compared to the current M1A1 Production Fabrication Specification E2180C based on ATR (63 ton) peacetime annual usage duty cycle (See Attachment 2), installed with NBC off, corrected and adjusted to 87±5°F/500 feet altitude ambient conditions.

During the TME Fuel Economy Demonstration Test the engine performance level shall also be compared to the performance goals stated in Appendix A of TME S.O.W. (See Attachement 3).

The TME fuel economy test results will be presented in an in-house test report. The report will include as a minimum: Summary, Background, Method of Test, Test Results, Conclusions and Recommendations.

3.0 GENERAL PROVISIONS

3.1 Data Accuracy

All instruments and apparatus shall be calibrated before the TME Final Acceptance Test to ensure that reported data shall have a static accuracy within 2% of the values obtained at the maximum rating of the engine, except for fuel flow, which shall be accurate within 1.0% and RPM and torque which shall be accurate within .5% of the values obtained at maximum rating of the engine.

3.2 Data Correction

For purpose of on line data analysis, readings of shaft horsepower, RPM, air flow rate, fuel flow rate, specific fuel consumption, gas pressures, and gas temperatures, will be referred to sea level, standard day, as defined in U.S. Standard Atmosphere, 1962 (ASTIA Document 401813).

3.3 Engine Tests

3.3.1 Test Conditions

The TME Fuel Economy Demonstration Test shall be conducted at 87±5°F ambient temperature and prevailing barometric pressure.

3.3.2 Test Apparatus

3.3.2.1 Test Equipment

The following equipment will be used to facilitate conducting test.

3.3.2.1.1 Power Absorption

A waterbrake will be used to absorb the engine output shaft powers. The brake is supported from the engine by an adapter having four beams which are strain-gaged for torque sensing. The TME accessory gearbox does not have provisions for customer power extraction.

3.3.2.1.2 Starting System

A standard electric starter energized by batteries or a motor generator will provide engine starting power.

3.3.2.2 Data Acquisition Equipment

The following apparatus shall be used to measure and record the required data. Where such equipment is available, an automatic data acquisition system may supplement or supplant the indicating devices noted below.

3.3.2.2.1 Output Shaft Torque

The support beams of the waterbrake mounting adapter are equipped with calibrated strain gages which sense the output torque. Conversion of the strain gage signal to torque indication will be accomplished by a suitable signal convertor.

3.3.2.2.2 Rotor Speeds

Magnetic pulse generators with suitable signal conditioning and readout equipment will measure and display engine main rotor speeds.

3.3.2.2.3 Airflow

A calibrated inlet nozzle, with ASME recommended geometry will utilize throat static pressure and entry total pressures to measure airflow during performance calibrations.

3.3.2.2.4 Pressures

Calibrated Bourdon tube gages and/or transducers will measure hydraulic and aerodynamics pressures.

3.3.2.2.5 Temperatures

Temperatures will be measured by I.C. and/or C.A. thermocouples. Indication will be by means of Self-balancing Precision Brown Potentiometers or by digital indicators in conjunction with appropriate signal condition equipment.

3.3.2.2.6 Fuel Flow and Oil Flow

Calibrated turbine elements with associated signal converters, amplifiers, and readouts will be used for fuel and oil flow measurements.

3.3.2.2.7 Engine Control Equipment

The engine power lever and waterbrake load will be manually controlled by the test operator from the control room. The engine normal operation will be monitored by hardware alarms in case any critical parameter exceeds the pre-established limits.

3.3.2.2.8 Transient Recorders

Transient recording apparatus will be used during the TME Fuel Economy Test to provide continuous monitoring of the engine. The following variables vs. time will be continuously recorded during the test: low pressure spool speed (NL), high pressure spool speed (NH), power turbine speed (NPT), high pressure spool outlet pressure (PT3), fuel flow (WF), measured power turbine inlet temperature (TT7), and throttle position (PLA).

3.3.2.2.9 Vibration Measurement

The vibration measuring equipment will consist of Trig-Tek vibration meters Model No. 203J in conjunction with velocity-displacement pick-ups Model No. 4-128MA or equivalent. The meter will have incorporated in its system appropriate high pass filters. Displacement values (peak to Peak amplitude in mils) will be recorded by a minimum of two vibration pick-ups mounted on the engine.

3.3.3 Operating Conditions

3.3.3.1 Oil Pressure

The operating oil pressure is measured at the engine oil pump manifold (POMA). Operating condition shall be as described in E2147B with the exception of low idle pressure which must be readjusted according to the corresponding lower NH speed at TME low idle.

3.3.3.2 Oil Servicing

The oil system will be drained and filled with new, MIL-L-23699 oil, Mobil 254 (containing anticoking additives), at the start of the test.

The oil filters shall be inspected and the filtration elements replaced and the oil changed if required. All oil additions and oil changes shall be noted and the chart of oil consumption prepared. Oil samples, chemical and spectro shall be taken prior to the beginning of the TME Fuel Economy Test and also after the end of the test. All samples will be subjected to laboratory analysis.

3.3.3.3 Accessory Drives

The fuel control, the oil pump, and the electric starter will be the engine accessories installed and run during the TME Final Acceptance Test. The newly designed TME Accessory Gearbox does not have provisions for the electrical generator or the hydraulic pump, therefore, no accessory load will be extracted from the TME.

3.3.3.4 Barometer Readings

The barometric pressure shall be read, corrected for the actual ambient temperature, and recorded at intervals not exceeding three hours.

3.3.3.5 Measured Gas Temperatures

Gas temperatures shall be determined by a thermocouple harness located at the inlet of the power turbine.

3.3.3.6 Fuel

The TME Fuel Economy Demonstration Test will be run on DF-2 diesel fuel conforming to Federal Specification VV-F-800. Fuel samples will be taken prior and after the Final Acceptance Test. All samples will be subjected to laboratory analyses.

3.3.3.7 TME Fuel Economy Test Repeat

In case an engine component problem should occur during the TME Fuel Economy Test which requires engine disassembly, the test will be interrupted for appropriate corrective actions. The Fuel Economy Test will be reinitiated from the beginning and completed.

3.3.4 Method of Test

3.3.4.1 Procedure

The TME Fuel Economy Test shall be conducted in accordance with the specific provisions stipulated in this test plan assuming the compliance with TME ETP 1500A. Sufficient data shall be obtained to establish the 500 ft, 87±5°F day, installed performance requirements required by the TME S.O.W. As a minimum, the data described in Paragraph 3.3.4.2 shall be acquired at the power levels described in Table I. The power levels shall be maintained for a sufficient period (not less than 3 minutes duration) to allow the engine stable functioning (stabilized engine parameters). The compressors may be cleaned with B & B 3100 solution and water.

The TME transient acceptability shall be evaluated versus the TME S.O.W., Appendix A, Paragraph D (See Attachment 3).

The TME Fuel Economy Test will be conducted in the uninstalled configuration with an ASME bellmouth mounted at the engine inlet. The fuel to be used is DF-2 which conforms to Federal Specification VV-F-800.

Throughout the test, power levels will be established using the power lever which establishes the amount of fuel delivered by the fuel control to the engine and the corresponding power turbine load to be applied through the power absorption system (waterbrake) setting the required power turbine speed.

The TME Fuel Economy Test should confirm that the PTS is properly optimized and based on maximum allowable high pressure turbine inlet temperature, establish the engine maximum power capability at 87±5°F, sea level, uninstalled.

3.3.4.2 Data

During the TME Fuel Economy Test the following data shall be recorded on each long reading (full scan):

- Time of Day
- L.P. Spool Speed, % RPM
- H.P. Spool Speed, % RPM
- Power Turbine Speed, % RPM
- Variable Inlet Guide Vane Position, Volts
- Shaft Horsepower, SHP (calculated based on measured output shaft torque)
- Torquemeter Reading, LBFt (measured output shaft torque)
- Fuel Consumption Rate (LB/HR)
- Engine Inlet Air Temperature, °F
- Bellmouth Static Air Pressure, inches H_2O
- Bellmouth Total Air Pressure, inches H_2O
- Barometric Pressure, PSIA

- LP Compressor Total Discharge Temperature, °F
- LP Compressor Total Discharge Pressure, PSIA
- HP Compressor Total Discharge Temperature, °F
- HP Compressor Total Discharge Pressure, PSIA
- Recuperator Total Discharge Temperature, °F
- Oil Inlet Temperature, °F
- Scavenge Oil Discharge Temperature, °F
- Fuel Pressure at Fuel System Inlet, °F
- Measured Gas Temperature, TT7, °F
- Fuel Temperature, °F
- Throttle Position, Volts
- Vibration Displacements, MILS

3.4 Criteria

3.4.1 Performance

It is required that TME AGT 1500A, S/N T202 (LE89752) will demonstrate as a minimum 10% mission fuel savings when compared to M1A1 annual usage duty cycle at 87±5°F and 500 feet altitude installed conditions (See Attachment 2).

It is required that the engine pass the ETP 1500A requirements during the TME Fuel Economy Test.

3.4.2 Mechanical Integrity

In the event an engine component fails, affecting the engine performance and/or the engine mechanical integrity, the test will be interrupted for immediate corrective action and then the TME Fuel Economy Test must be reinitiated again.

3.5 Test Monitoring

3.5.1

The test controller (General Dynamics Land Systems Division) shall be involved in the decision to stop, fix, and rerun the TME Fuel Economy Test due to the incidents described in 3.4.2.

3.5.2

The test controller shall be informed of any action taken to correct hardware deficiencies.

3.5.3

All incidents shall be reported to the test controller as they occur during the testing. Reporting will be accomplished by telephone with a written report to follow. A close-out report will be provided when the problem is resolved.

TABLE I

TME FUEL ECONOMY DEMONSTRATION TEST

The following tabulation presents the TME test conditions to be set, where the engine performance should be collected and evaluated.
NOTE: Tempered air of 87±5°F shall be provided.

I. The Peacetime Power Points

Operating Condition	NPT	SHP
Cross Country	86.83	989
35 MPH	79.30	1063
25 MPH	79.63	771
5 MPH	39.13	181
Tac Idle	43.30	60.9

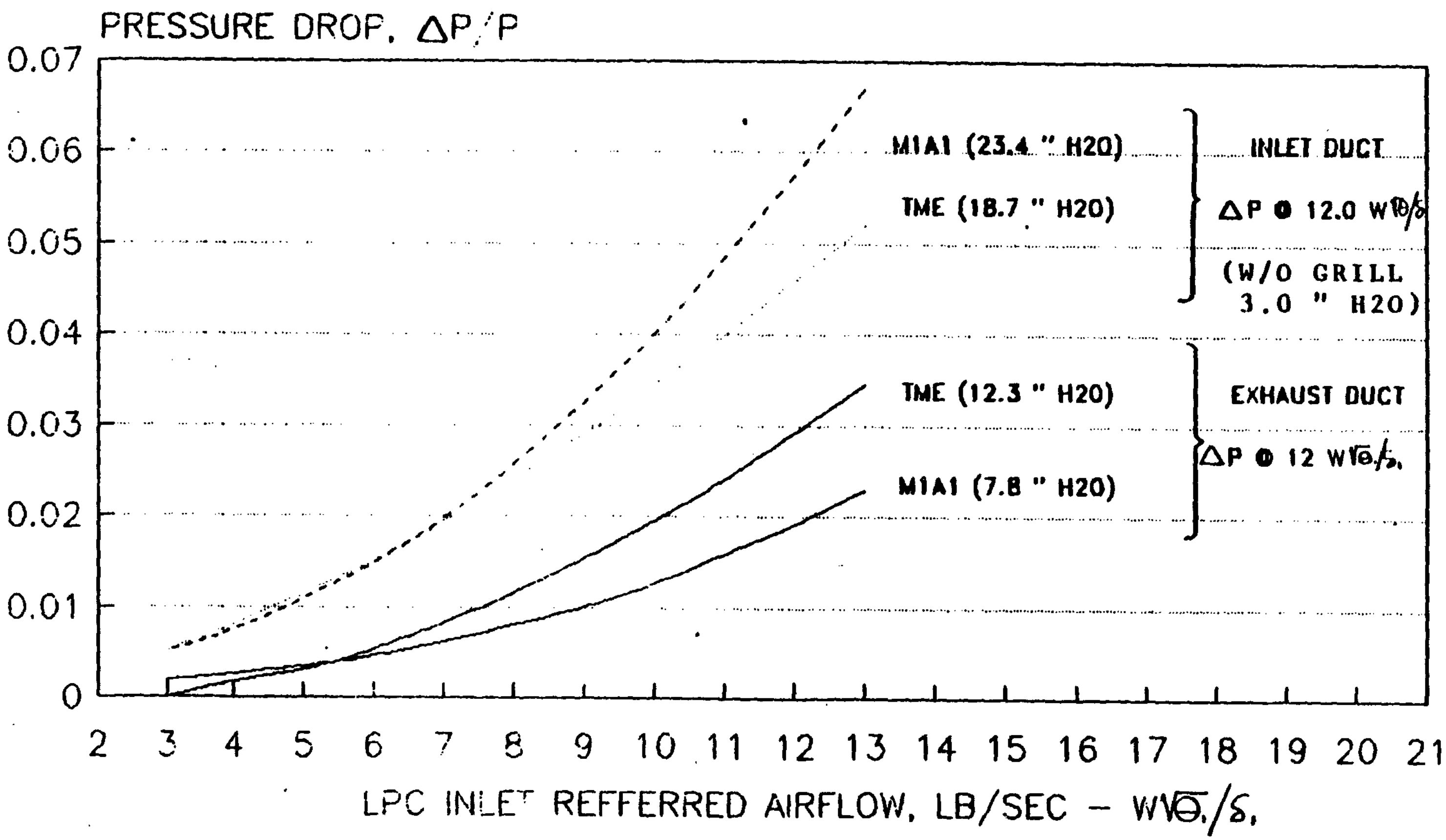
II. The optimum PTS O/A Calibration

Acquire 5 data scans at that open area PTS which provides 1505 $SHP/\delta\sqrt{\theta}$ (1545 referred to 87°F) at minimum $T5/\theta$.

III. The TME TT7 - PTS Tracking Calibration
(At 87°±5°F ambient temperature)

Acquire data scans at normal idle, tac idle, and subsequently at 100 SHP increments to max of 1545 SHP/δ at optimum NPT speeds.
Normal idle = 40 SHP, NPT = 900 RPM, Tac Idle = 55 SHP, NPT = 1300 RPM.

INSTALLATION LOSSES
TME VS M1A1



TME FUEL ECONOMY TEST PLAN LYC-88-28

ATTACHMENT 1

PEACETIME ANNUAL FUEL USAGE
NBC OFF

OPERATING CONDITION	TIME (HOURS)	VEHICLE SPEED (MPH)	M1A1 (4-SPEED) ENGINE SPEED (RPM)	M1A1 (4-SPEED) ENGINE OUTPUT SHP	M1A1 (4-SPEED) TOTAL FUEL USED (GALLONS)	TMEPS (7-SPEED) ENGINE SPEED (RPM)	TMEPS (7-SPEED) ENGINE OUTPUT SHP	TMEPS (7-SPEED) TOTAL FUEL USED (GALLONS)
TAC IDLE	50.0	-----	1300	55	740.0	1300	58.1	499.0
SECONDARY ROAD	12.0	5.0	1095	172	271.1	1174	174.0	253.2
SECONDARY ROAD	14.9	24.9	1855	675	840.3	2389	728.2	745.0
SECONDARY ROAD	9.0	34.8	2593	1018	671.9	2379	991.0	593.1
CROSS COUNTRY	11.3	16.8	1853	859	787.6	2605	925.0	684.8
TOTAL					3310.9			2775.1

GVW = 63 TONS
87 F, 500 FT., INSTALLED
5KW ELECTRICAL POWER USAGE
FUEL DENSITY = 7.05 LBM/GALLON
FUEL LHV = 18,500 BTU/LBM

ATTACHMENT 2
TME
FUEL ECONOMY TEST PLAN
LYC 88-28

Attachment 3

TME
FUEL ECONOMY TEST PLAN
LYC 88-28

Engine Performance Goals

Unless otherwise specified the performance goals stated in the following subparagraphs not include installation losses. The inlet is configured with as ASME bellmouth. Fuel is DF-2 which meets Military Specification VV-F-800 (reference lower heating value 18,500 BTU/pound).

In general the type of engine performance characteristics which follow are typical of those quoted M1/M1A1 engine configuration.

A. The engine shall develop the minimum corrected brake horsepower (BHP) at the applicable shaft speed specified below when operated at an ambient temperature of 87°F with barometric pressure corrected to 29.92 in. Hg.

Nominal Speed (RPM)	BHP
1800 ± 50	1295
2000 ± 50	1371
2600 ± 50	1500
3000 ± 50	1500

B. The engine specific fuel consumption shall meet or be less than the values provided below. Note: Ambient temperature 87°F at 29.92 in Hg. Actual SFC calibration data shall be provided at the points listed below.

Gross Brake HP	RPM	SFC (LBM/HP-HR)
600	2748 ± 60	.50
900	3000 ± 60	.45
1200	3000 ± 60	.44
1500	3000 ± 60	.45
Idle (neutral) (40 Hp)	900 ± 25	1.48
Tc Idle (55 Hp)	1300 ± 25	1.28

C. Maximum and minimum governed speed.

- o Drive and reverse range

  1300 SHP 3075 + 75 RPM -5 RPM
  1200 SHP 3075 ± 75 RPM -5 RPM

- o Low Idle

  100 SHP 900 ± 50 RPM
  0 SHP 930 ± 50 RPM

Reference Appendix A of TME S.O.W.

ATTACHMENT 3

TME
Fuel Economy Test PLan
LYC-88-28

Engine Performance Goals (con't)

D. Transient Response. Verification of conformance to transient response requirement shall be accomplished as follows:

a. Set the power condition from 300, (+25, -0), power turbine speed (Np) at 63 ± 2%. Stabilize for 3 minutes. Note high pressure compressor discharge pressure (PT3) at 300 shp.

b. Accelerate to 90 percent of compensated gross horsepower obtained from Figure 4 with 20 ± 5 hp extracted at the power takeoff pad. Note PT3 at this horsepower.

c. Set compensated gross horsepower per Figure 4, (+25, -0), with 20 ± 5 hp extracted at the power takeoff pad. Power turbine speed shall be 100 ± 2%. Run for 3 minutes.

d. Snap decelerate to minimum power lever angle, leaving output shaft power absorption device preset. Time deceleration to PT3 determined in "a". Deceleration time shall not exceed 5.0 seconds. Stabilize at idle for 3 minutes.

e. Jam throttle to maximum power. Time acceleration to PT3 determined in "b". Response time not to exceed 4 seconds. Stabilize for 3 minutes.

f. Wave off engine in 5% high pressure compressor speed (Nh) increments until 75 percent Nh is reached. Waveoffs shall be surge-free.

Reference Appendix A of TME S.O.W.

APPENDIX III

APPENDIX III

donaldson

PO. NO. E225693

FINAL REPORT FOR THE DEVELOPMENT OF A ROTATING ELEMENT SELF-CLEANING AIR FILTER (RESCAF)

JULY 1989

PREPARED FOR:

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LIMITATIONS

It should be understood that Donaldson Company's reservations regarding these RESCAF systems is based upon the fact that an adequate level of component maturity testing has not been accomplished on these units and long term field tests will quite likely result in component failures. Additional component maturity testing is planned for FSED RESCAF systems. Problems occurred on two occasions with the RESCAF drive motors and a fix to one of the problems remains to be implemented (a larger straight keyway machined on the drive motor output shafts.) Problems also occurred with the RESCAF to engine mounting strut pins during shock testing which are not yet addressed at the time of this publication.

In addition, there are critical components, not developed by Donaldson Company, Inc. under this contract, that also must perform properly or performance will be substandard, these include:

Air Cleaner Scavange Blower & Ductwork

Inadequate scavange of the RESCAF, which can result from component problems (e.g., scavange blower) or improper sizing of ductwork, will severely reduce the RESCAF system dust capacity because a common duct is used for both cleaning mechanism and precleaner scavange.

RESCAF Air Compressor and Pressure Regulation Equipment

If compressed air is supplied to the RESCAF at inadequate (low) pressure, a reduction in cleaning performance will occur which reduces system dust capacity. If compressed air is supplied to the RESCAF systems at too high a pressure, the filter medium may rupture and the engine will be endangered. A "safe" performance pressure band exists which must be maintained.

CONCLUSIONS

Under this contract a Rotating Element Self-Cleaning Air Filter (RESCAF) was designed, fabricated, and successfully laboratory tested. The RESCAF system met performance objectives by demonstrating in laboratory tests resistance to shock, vibration, and dust life under zero visibility conditions in excess of 200 hours.

Pressure drop characteristics of the RESCAF system met system requirements and are shown on figure 1.

An overall system dust collection efficiency of 99.999 was demonstrated during the life test of the RESCAF. Efficiency of the filter element at all times exceeded 99.9%. These efficiency levels exceed all Government and Textron Lycoming requirements.

The RESCAF system was subjected to shock and vibration testing and survived in operating condition . Dust testing after shock and vibration tests indicated that a satisfactory level of performance was maintained. Results of these tests are discussed in sections 5.4 and 5.5.

RECOMMENDATIONS

The RESCAF system demonstrated satisfactory performance during laboratory tests, and may be installed on an engine for limited field evaluation. Additional recommendations for next generation systems are discussed in Section 6.4. Limitations discussed at the beginning of this report apply.

DISCUSSION

HARDWARE

The RESCAF system operation, mechanical description, and laboratory test summary is presented in this section. The RESCAF assembly is shown on figure 2 and with major removable components disassembled on figure 3.

SUMMARY

This report covers the development of a Rotating Element Self-Cleaning Air Filter (RESCAF) for a transverse mounted Textron Lycoming AGT 1500 gas turbine engine (TME). The results of laboratory testing is included. Shock, vibration, and simultaneous vibration and dust testing were successfully completed. Additional maturity testing will be required on FSED RESCAF systems, however, the RESCAF systems shipped under this contract are ready for installation in a main battle tank for limited field test evaluation.

The RESCAF systems supplied under this contract to Textron Lycoming are subject to the limitations discussed in the next section.

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1.0 INTRODUCTION

This final technical report, prepared by Donaldson Company, covers work performed under contract with Textron Lycoming, Stratford, Connecticut, for development of a Rotating Element Self-Cleaning Air Filter (RESCAF). Work conducted on several purchase orders is covered in this report.

2.0 OBJECTIVES

The overall objective of the program, summarized in this report, was to design and laboratory test a prototype RESCAF system for the Textron Lycoming transverse mounted AGT 1500 engine (TME). The laboratory test results are used as an indicator of the readiness of the hardware for installation on an engine for vehicle tests. The design objective was to build a RESCAF system which would fit the available space envelope. This envelope changed and became more defined as work progressed. The performance objective was to exceed the performance level demonstrated by the M1 Abrams tank SCAF and standard two-stage air cleaner. To meet this objective the RESCAF had to exceed the following environmental resistance characteristics.

a. Operating Temperature - Exposure to ambient air temperatures ranging from -65°F to +200°F for 8 hours minimum.

b. Humidity - Ambient relative humidity to a maximum of 100 percent, with air temperatures to a maximum of 95°F for 48 hours minimum.

c. Chemicals - Exposure to the vapors of, and contact with, the following materials for durations up to 48 hours:

- Fuel - Per VV-F-800, Mil-T-5624, MIL-G-3056, and MIL-F-16884
- Hydraulic fluid - Per MIL-H-46170

- Cleaning agents - Per P-C-437

- Lubrication oils - Per MIL-L-2104, MIL-L-23699, and MIL-L-7808

d. Basic Shock - Three 40 ± 4.0 accelerations due to gravity (g), 18 ± 0.02 milliseconds (ms) half sine wave shocks applied in each direction along the three mutually perpendicular axes, for a total of 18 shocks.

e. Gun Firing Shock - Three 55 + 5.5 g, 2.5 ± 0.02 ms half sine wave shocks applied in each direction along the three mutually perpendicular axes, for a total of 18 shocks.

f. Operational Shock - Three 55 ± 5.5 g, 0.5 ± 0.1 ms half sine wave shocks applied in each direction along the three mutually perpendicular axes, for a total of 18 shocks.

g. Nondestructive Ballistic Shock - Shock impulses as specified in table 1 at the assembly mounting interface. Three shock impulses in each direction of the specified axis (six shocks per axis) shall be imposed.

h. Vibration - Sinusoidal vibrations in each of the three mutually perpendicular axes at the frequencies and accelerations specified in the following table. Vibration frequencies shall be applied at a logarithmic sweep rate of 20 minutes per sweep cycle from 5 Hz to 500 Hz to 5 Hz. Total vibration time, shall be 120 minutes in each axis. Unless otherwise specified, the conditions of specification MIL-STD-810D, Method 514.1 shall prevail (see table 2).

Table 1. Nondestructive Ballistic Shock Conditions

Axis	Level (g)	Duration (ms)
Latitudinal	200 ± 20	0.5 ± 0.1
Vertical	200 ± 20	0.5 ± 0.1
Longitudianl	550 ± 55	0.5 ± 0.1

Table 2. Vibration Levels

Axis	Frequency (Hz)	Level (g)
Vertical	5 to 25	1
	25 to 57	0.030 inch DA
	57 to 500	5
Laterial and	5 to 25	1
Longitudinal	25 to 44	0.020 inch DA
	44 to 500	3

i. Flame Resistance - Filter media

1. Filter media materials must be self-extinguishing after burning .50 inch or less during upward flame propagation, with no spark, sputter, or drip of flaming particles.

2. Downward flame propagation rates of filter media shall not exceed 0.3 inch per second with no spark, sputter, drop or transfer of solid mass during burning.

3. Filtering materials shall offer no evolution of flashing vapors below 100°F or evidence charring, self-sustained combustion, or pyrolysis at less than 150°F.

j. Storage Temperature - Ambient storage temperatures within the range of -70°F to +300°F for extended durations.

K. Fungus - Inoculation of external and internal surfaces and components of the assembly with spore suspension as defined by the Specimen Inoculation paragraph of MIL-F-13927 followed by exposure to ambient air temperatures between 80°F and 84°F at relative humidity between 96 to 100 percent for a 28-day duration.

3.0 CONCLUSIONS

Under this contract a Rotating Element Self-Cleaning Air Filter (RESCAF) was designed, fabricated, and successfully laboratory tested. The RESCAF system met performance objectives by demonstrating in laboratory tests resistance to shock, vibration, and dust life under zero visibility conditions in excess of 200 hours.

Pressure drop characteristics of the RESCAF system met system requirements and are shown on figure 1.

An overall system dust collection efficiency of 99.999 was demonstrated during the life test of the RESCAF. Efficiency of the filter element at all times exceeded 99.9%. These efficiency levels exceed all Government and Textron Lycoming requirements.

The RESCAF system was subjected to shock and vibration testing and survived in operating conditions. Dust testing after shock and vibration tests indicated that a satisfactory level of performance was maintained. Results of these tests are discussed in sections 5.4 and 5.5.

4.0 RECOMMENDATIONS

The RESCAF system demonstrated satisfactory performance during laboratory tests, and may be installed on an engine for limited field evaluation. Additional recommendations for next generation systems are discussed in Section 6.4. Limitations discussed at the beginning of this report apply.

5.0 DISCUSSION

5.1 HARDWARE

The RESCAF system operation, mechanical description, and laboratory test summary is presented in this section. The RESCAF assembly is shown on figure 2 and with major removable components disassembled on figure 3.

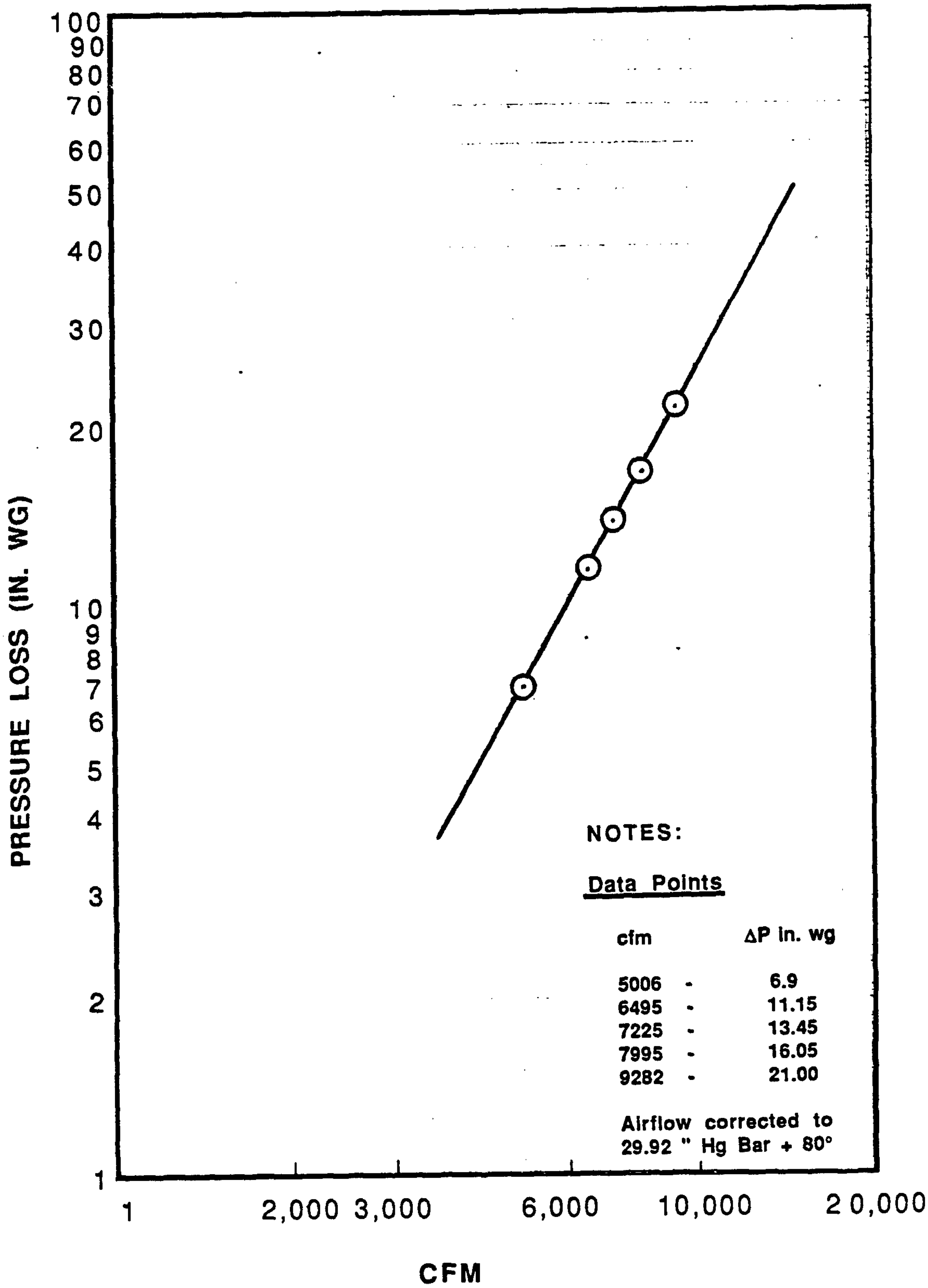

Figure 1. RESCAF Pressure Drop Characteristics

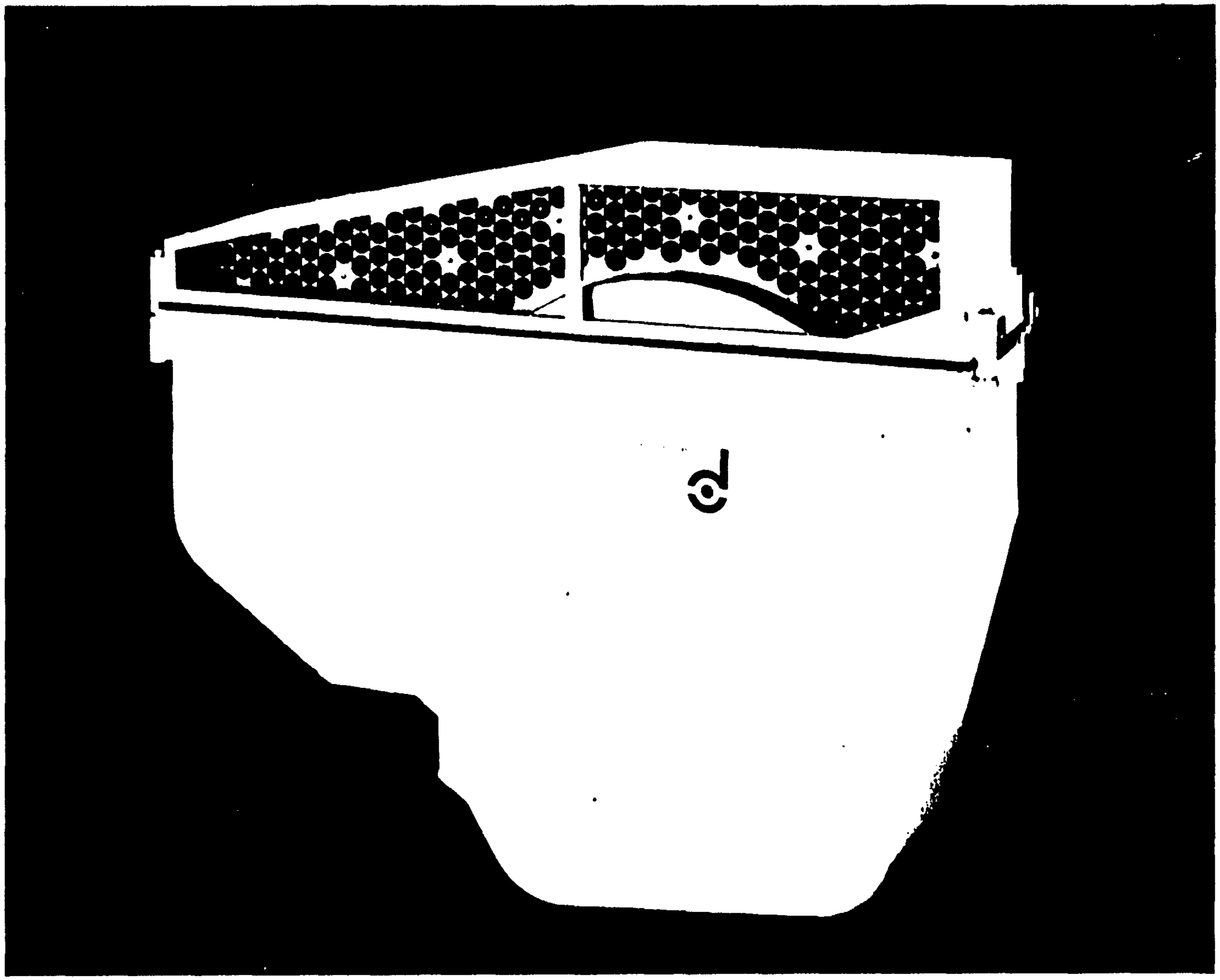

Figure 2. RESCAF Assembly

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5.1.1 Description of Operation

The RESCAF system, designed for use on a main battle tank, uses a two-stage process to provide a clean air supply to the engine. The first stage of the system is a precleaner which uses an inertial separation mechanism to reduce the quantity of dust reaching the second stage. The second stage contains four cylindrical segment barrier filters to collect the remaining dust and are automatic cleaning mechanism for filter element rejuvenation. Figure 4 is a schematic of this nozzle receiver type of self-cleaning air filter. The following paragraphs describe the RESCAF operational sequence.

a. Dust-laden air enters the system after passing through the ballistic grills located on the left sponson. A stainless steel inlet screen, mounted on the inlet of the ballistic grill intercepts leaves, stones, and large debris.

b. The dust-laden air then enters the precleaner where it is drawn through STRATA® tubes. Here the heavier dust particles are separated from the airstream by inertial forces. The separated dust is conveyed by a scavenge airstream and discharged overboard. This first stage of the system has an efficiency of 92 to 94 percent on AC Coarse test dust.

c. The air and remaining dust next enters the four cylindrical segment barrier filters. These filters collect a high percentage of the remaining dust through the traditional filtration mechanisms. After leaving the filters (99.9 percent efficient on AC Coarse test dust), the clean air passes directly into the engine inlet.

d. As dust continues to collect on the barrier filters, airflow to the engine becomes restricted. When airflow restriction reaches a preset level, a pressure sensor activates the automatic cleaning process. The filter elements are rotated by a small servo motor past a cleaning nozzle which back flushes thru the filter elements compressed air from a small auxillary compressor.

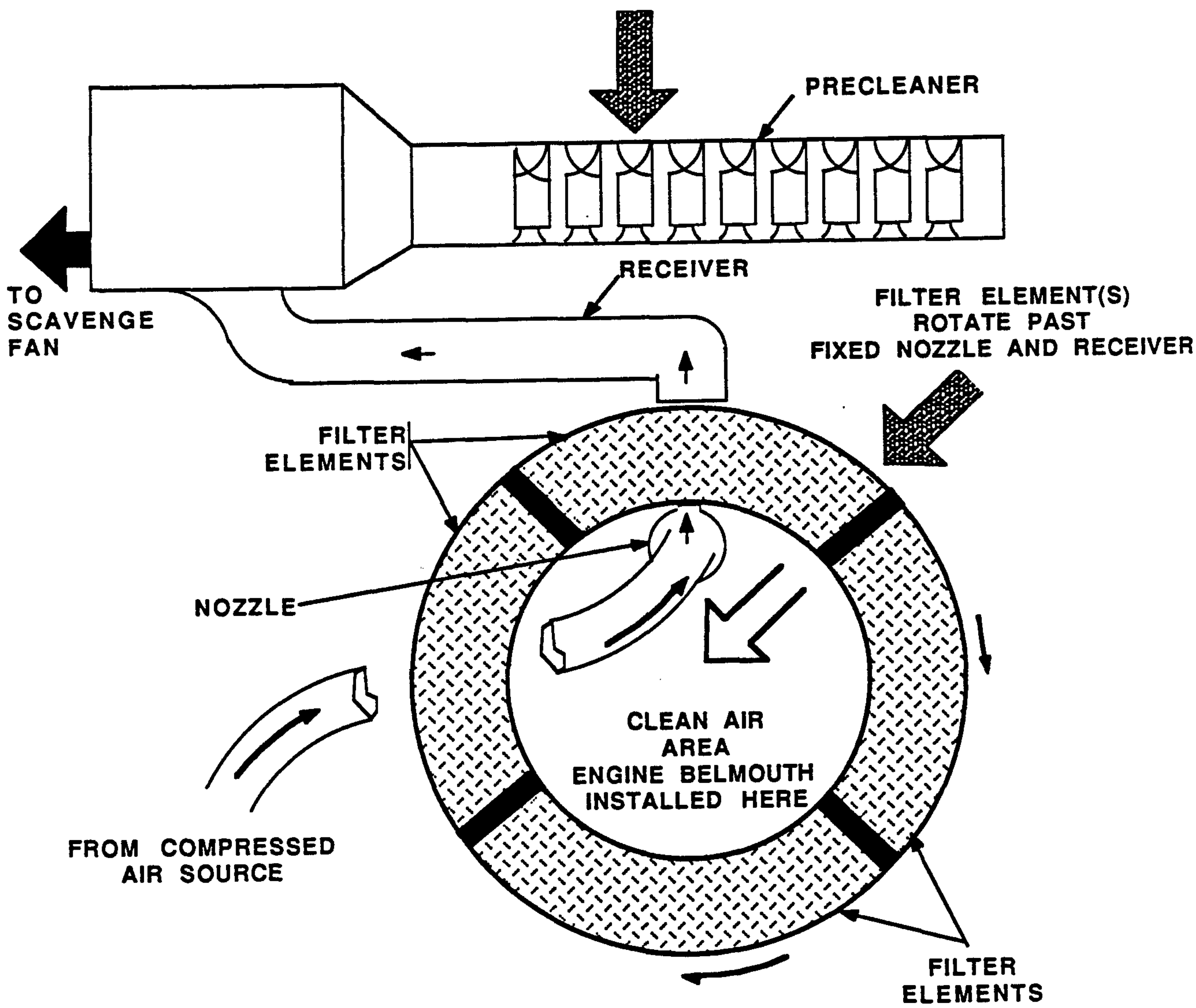

Figure 4. RESCAF Assembly Schematic

The dislodged dust is vacuumed by the receiver and conveyed into the precleaner scavenge system. The self-cleaning process stops after one complete cleaning cycle, lasting about 30 seconds. This process is reactivated only when airflow restriction again reaches the preset level or if manual override actuation is desired. Airflow to the engine remains uninterrupted during the automatic cleaning process.

5.1.2 Description of Hardware

The physical size and shape of the RESCAF was influenced by the mechanical layout of the propulsion system components, the availability of access for service, and the application of appropriate RESCAF components. The resulting configuration, shown on figure 5, provides top access for filter service. The paragraphs on the following pages describe the major assemblies that make up the 9800P0200 RESCAF.

5.1.2.1 Precleaner Assembly

The RESCAF precleaner assembly was designed to provide the following functions:

a. Effectively remove a high percentage of dust entering the engine air cleaner inlet, thus reducing the quantity of dust which must be collected on the second stage barrier filters. A separation efficiency of 93 percent on AC Coarse test dust was the performance objective.

b. Support internal ductwork for conveying dust cleaned from the second stage filter elements.

The precleaner functional requirements combined with environmental requirements provided the basis on which component selection, materials and finishes were made.

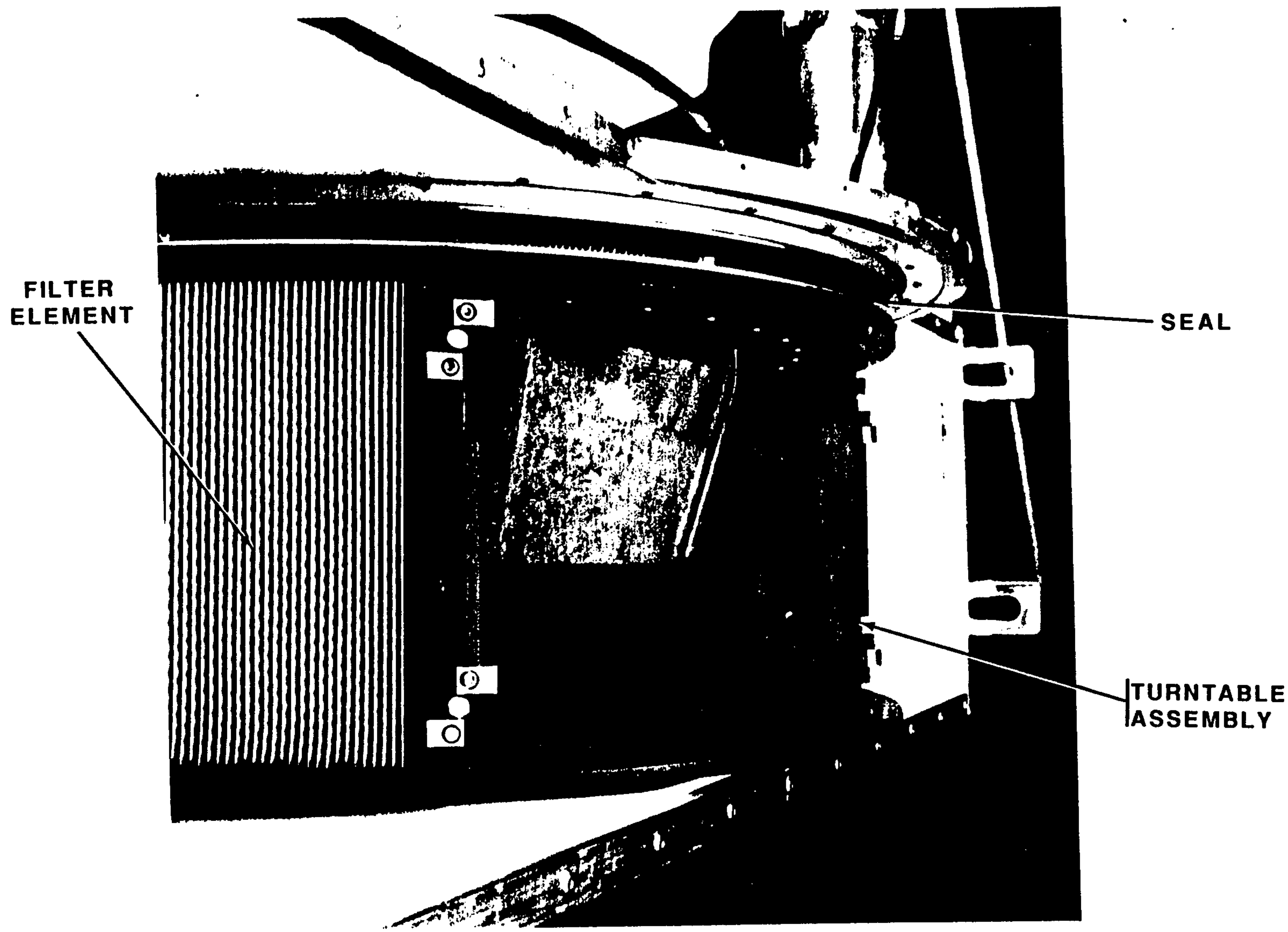

Figure 5. Final RESCAF Configuration Showing Top Access For Filter Removal

The RESCAF precleaner contains inertial separator tubes pressed into aluminum alloy baffles. The inertial separator tubes are constructed as a tube assembly and are sealed into a welded frame constructed of aluminum alloy fabricated parts. The framework houses a gasket assembly providing the seal between the RESCAF body assembly and the precleaner. A Marman type connection is provided for attachment of scavenge ducting. Four captive bolt fasteners are provided to secure the precleaner to the body assembly.

5.1.2.2 RESCAF Body Assembly

The RESCAF body assembly is a 5052 alloy aluminum weldment, and a 356 alloy transition casting to which is attached the RESCAF filter rotating drum and cleaning nozzles. This assembly is shown on figure 6. The four filter elements are secured to the rotating drum with four retention bolts per filter.

The cleaning mechanism consists of two fixed cleaning nozzles located on the inner circumference of the drum and two fixed receivers flanking the nozzles on the outer circumference of the drum. The filters pass between the nozzles and receivers when the drum rotates.

The drum is bolted to a bearing which in turn is bolted to the body assembly outlet casting. A gear is cut on the bearing which is engaged with a fractional hp 28 Vdc gearhead motor. This motor provides the power to rotate the drum when a signal is received from the RESCAF control. Four redundant circumferential seals are provided between the drum and casting. All body assembly components are constructed of corosion resistant materials, stainless steel, or treated aluminum.

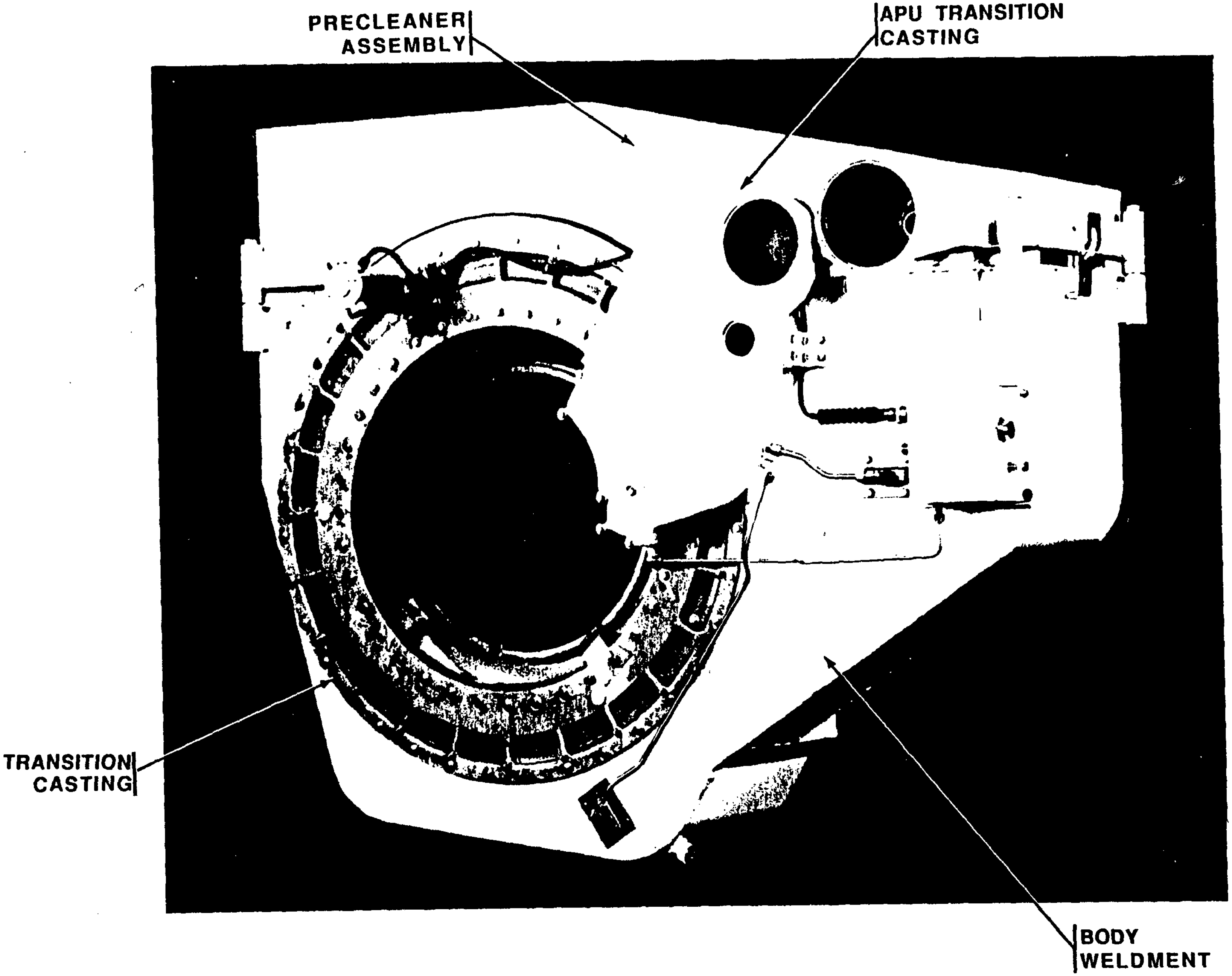

Figure 6. RESCAF Body Assembly

5.2 RESCAF System Specifications & Weight

Max Rated Airflow	9221 cfm (11.3#/sec) (corr to 29.92 "Hg bar. and 80 F
Scavange Airflow	692 cfm @ 17.5" wg. (.847#/sec) corr to 29.92
Compressed Air Requirement	175 SCFM @ 8 psig
Electrical Power Requirement	2.5 amps @ 28 Vdc
Efficiency (AC Coarse test dust)	99.9% Filter 99.99% System
Maximum Compressed Air Temperature	230^{o}F at Cleaner Supply Port

RESCAF Weights:

Drive motor	7.5#
Filter element (4 required)	13.5# ea (54# total)
Body assembly (less turntable and outlet casting)	73.5#
Precleaner	56.5 #
APU casting	15.25#
Turntable and outlet casting	173 #
Misc gaskets, bolts, nuts	6.75#

Total Weight	386.75#

Coordinates of RESCAF CG	STA	30.25
("as shipped" configuration with	WL	44.75
filters installed)	BL	31.30

5.3 Dust Test Summary

Two aborted attempts to complete a 100 hour dust test were made (December 1988 and January 1989). Dust leakage through the filter medium were the cause. A decision was made to use the proven filter medium developed for the M1A1 SCAF system after the two aborted attempts. Filters were constructed and this third (successful) test was started 16 February 1989.

The test plan is summarized for dust testing on figure 7. A summary of the pressure loss vs time (i.e., life characteristics) is presented on figure 8. A summary of efficiency data gathered during this test is presented on table 3. The test setup is shown on figure 9.

5.4 Vibration Tests

Vibration testing is summarized in Appendix A. During vibration testing a turntable motor gearbox failed. The cause of this failure was traced to an interference between the pre-cleaner and turntable which occurred during vibration. The pre-cleaner inlet frame was reinforced to prevent further interference. The interference caused the load on the motor to increase beyond acceptable limits.

5.5 Shock Tests

Shock testing is summarized in Appendix B. During shock testing, the woodruff key connecting the drive gear to the turntable motor sheared. This key will be changed to a straight key (for increased contact area) on FSED units. A copy of the motor manufacturer failure report is attached to this report.

Figure 7. Dust Test Plan

Item to be Tested: TME Self Cleaning Air Filter System (pn 9800P200) (Testing with actual compressor, compressor ductwork, and pressure regulation equipment to be determined.)

Test Objective: The objective of this test is to demonstrate that the SCAF system designed for the Transverse Mounted AGT 1500 gas turbine (TME) meets or exceeds the design dust capacity and efficiency levels currently considered necessary for effective and efficient operation of the AGT 1500 propulsion system in an M1 main battle tank. Since specific performance goals are not stated in the current contract, the following performance guidelines are considered by Donaldson Company to be minimum acceptable levels:

Overall System Efficiency (accumulative) . . . . 99.99% when challenged with SAE coarse test dust

Filter element efficiency (accumulative . . . . 99.90% on precleaned dust.

Dust capacity - the total pressure loss characteristic from the inlet of the RESCAF pre cleaner to the outlet of the RESCAF filter elements should not rise more than twenty (20) inches of water gage (w.g.) when challenged with SAE coarse test dust at a concentration of .025 gm/ft^3 zero visibility for 20 hours, when tested at 80% of max engine airflow (air cleaner outlet air flow).

The test airflow rate for the TME SCAF was determined to be 7223 cfm (corrected to 29.95" Hg bar and 80°F) by Mr. Richard Horan, Textron Lycoming and agreed to by Mr. Harry Camplin, Donaldson Company, Inc. This airflow rate is based upon the engine max rated airflow being 10.7# sec. installed X .8 (based upon government requirement) plus a 239 cfm allowance for the NBC system.

Test Procedure:

The self-cleaning air cleaner system will be set up and prepared for dust testing with test equipment, fixtures, and ducting defined on the attached test setup sketch (figure 9).

The following test parameters will be set.

Qp (primary airflow) . . . . 7223 cfm (corrected to 29.95" Hg. Bar. and 80°F) 8.85#/sec.

Qs (scavenge airflow . . . . 655 cfm (corrected to 29.92" Hg. Bar. and 80°F) 80#/sec.

Figure 7. Dust Test Plan (Cont)

Scavenge airflow is 7.5% of primary airflow at 100% rated power. Distribution of this airflow internal to the SCAF is 5% for the precleaner and 2.5% for the receivers.

Pn (pressure inside cleaning nozzles) . . . . . **8.0 psig.**

Dust Concentration . . . . .05 gm/cubic foot (2 x zero visibility)

Dust Type . . . . SAE coarse test dust

During the test a periodic record will be kept (and corrections made to test procedures as required to assure set levels stay constant) of the following:

Ambient temperature (°F)

Barometric pressure (" Hg)

Relative humidity (%)

Upstream Mercury (UpsHg) changes affecting flow correction on all flow meters not automatically controlled.

Qn nozzle flow rate (cfm)

T comp outlet (nozzle compressed air temperature, °F)

A continuous record will be kept of all changes in filter element pressure drop. (Via a strip chart recorder or appropriate data recording device)

The test duration will be 100 hours.

The RESCAF system will be subjected to vibration for the duration of the test per the following:

Vibrator Setting: .00875 inc. DA with 10-100-10 Hz sweeps continuously with total sweep time of 10 minutes.

Absolute filters will be changed and overall system and filter element efficiency will be measured at the following intervals:

5 hours after the start of testing.
10 hours after the start of testing.
50 hours after the start of testing.
100 hours after the start of testing.

Schedule: This test is scheduled to be conducted November 5 - 15, 1988

Table 3. Life/Efficiency Summary Sheet

Date: To
Tester: JAE
Originator: HRC
Test Item: RESCAF
Page 1 of 1

Project # 9260P
Task #
Customer: Textron
Dust Type: SAE Coarse
Inlet Airflow,cfm: 7878
Initial Filter dP: 6.90

Cum Time Hours	Segment Time Hours	Filter delta P in H2O	Abs * Gain Wa, gms	Abs * Cum gms	Dust Fed Wd, lbs	Dust Cum lbs	Feed Rate x 0 vis	Cum Feed Rate x 0 vis	Preclner Effy (e) Ep, %	Filter Effy Ef, %	Filter Effy-Cum %	System Effy Es, %	System Effy-Cum %
7	7	13.0	1.14	1.14	332.00	332.00	1.82	1.82	93.5	99.988	99.988	99.9992	99.9992
15.5	8.5	15.8	1.26	2.40	453.50	785.50	2.05	1.95	93.5	99.991	99.990	99.9994	99.9993
29	13.5	17.8	2.15	4.55	629.50	1415.00	1.79	1.87	93.5	99.988	99.989	99.9992	99.9993
48.5	19.5	19.8	4.06	8.61	950.50	2365.50	1.87	1.87	93.5	99.986	99.988	99.9991	99.9992
65	16.5	20.5	3.64	12.25	846.50	3212.00	1.97	1.90	93.5	99.985	99.987	99.9991	99.9992
80.6	15.6	22.2	2.84	15.09	804.50	4016.50	1.98	1.91	93.5	99.988	99.987	99.9992	99.9992
100	19.4	23.5	3.94	19.03	987.00	5003.50	1.95	1.92	93.5	99.986	99.987	99.9991	99.9992

* Absolute weight gains are measures of dust which passed through the filter and in a vehicle installation would be ingested by the engine.

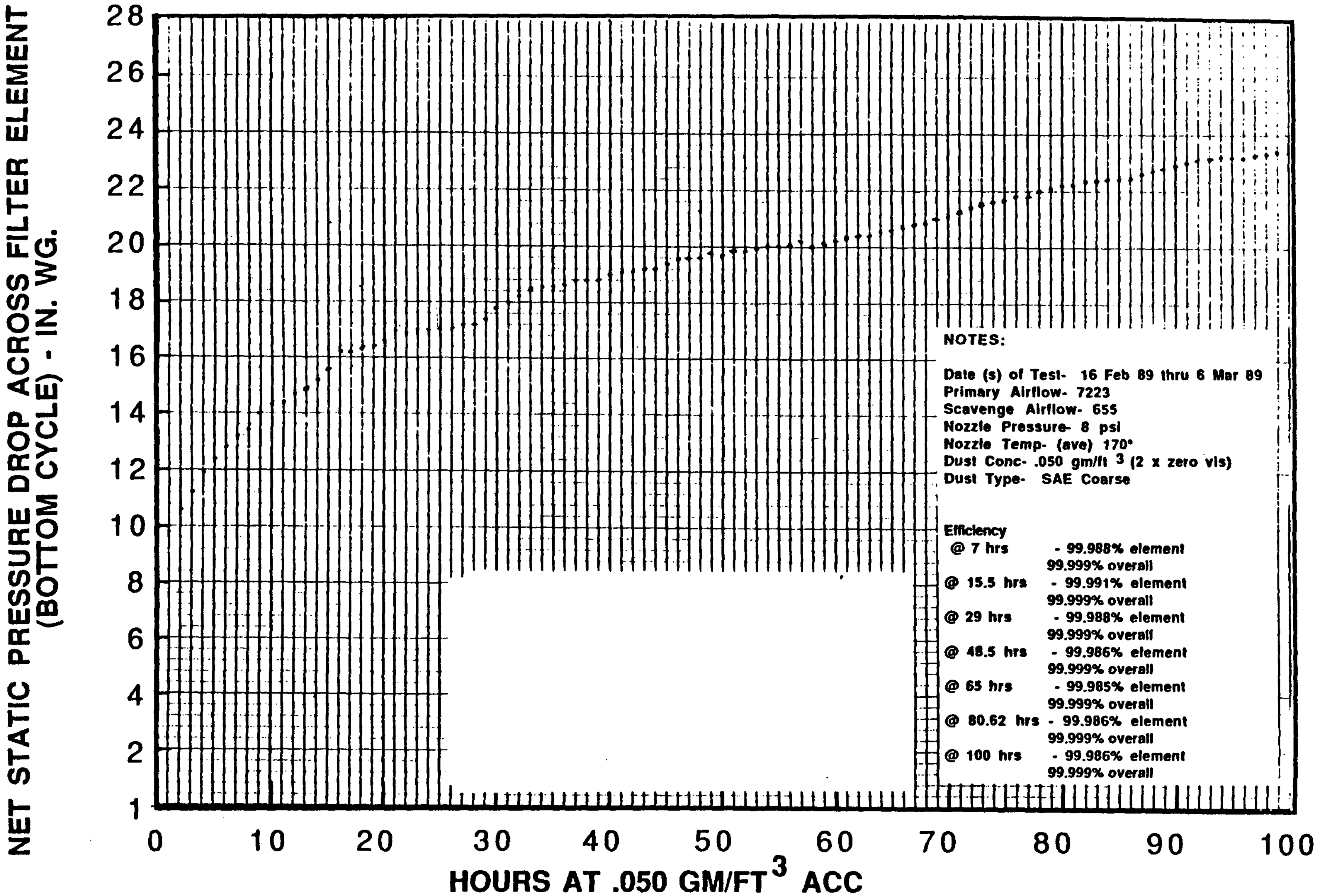

Figure 8. TME RESCAF Life Characteristics
(9800P200 Air Cleaner Assembly)

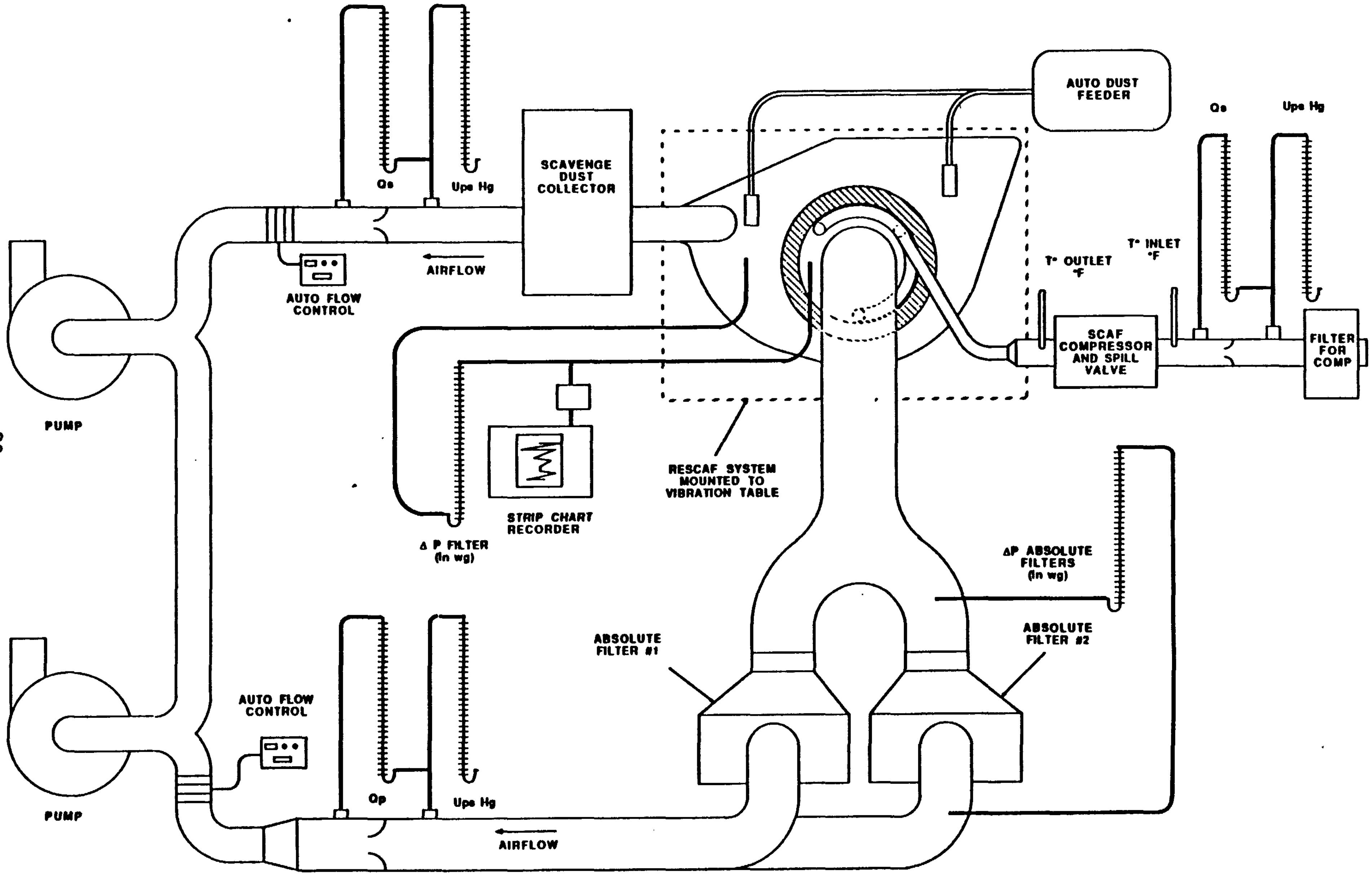

Figure 9. TME SCAF Test Setup

6.0 RESCAF Development Issues

6.1 Design Changes

During development of the RESCAF System, changes were made to RESCAF hardware to correct unanticipated problems that occurred. A complete list of these changes is as follows:

Change	Reason for Change
Spacers added to increase gap between precleaner and body assembly by 3/4 inch.	As a result of development test #5, it was shown that the pressure drop could be significantly reduced by adding a 3/4 inch spacer between the precleaner and body assembly (See figure 11).
Filter medium change to "Yuma" M1A1 SCAF medium.	Problems occurred with original thin substrate filter medium, and Donaldson Co. Inc. recommended a change to a "proven" medium. The first test of the RESCAF with the "Yuma" M1A1 SCAF medium also failed, due to a different (QA) problem. The second test with the "Yuma" medium was successful and data from this test is included in this report (See figure 8). The change to the thicker Yuma medium resulted in raising the pressure loss of the system. The result is quantified on figure 11.
Reinforcement of precleaner inlet frame.	During vibration testing, the precleaner distorted and came into contact with the filter turntable. This change was made to stiffen and prevent precleaner distortion.
Cutout added to precleaner to provide relief for APU duct.	This change was added to correct a design interference which occurred due to a misinterpretation of blueprints by the APU casting vendor.
Lock nuts welded in place (instead of Loctite) on element retainer bolt captive devices.	Loctite did not hold when removing filters, which resulted in bolts not staying captive.

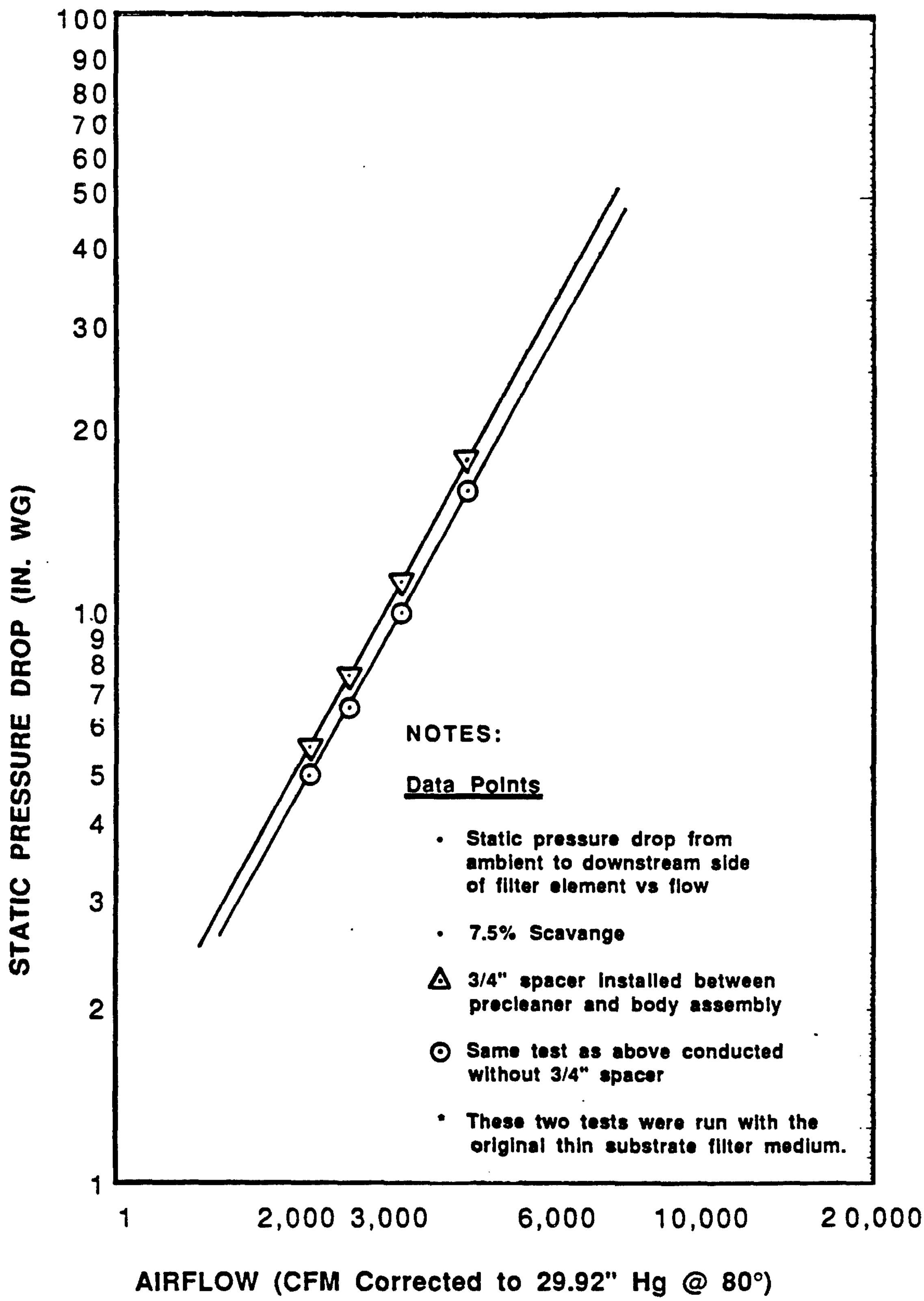

Figure 10. Pressure Drop of RESCAF System with Thin Substrate Medium, With and Without 3/4" Spacer

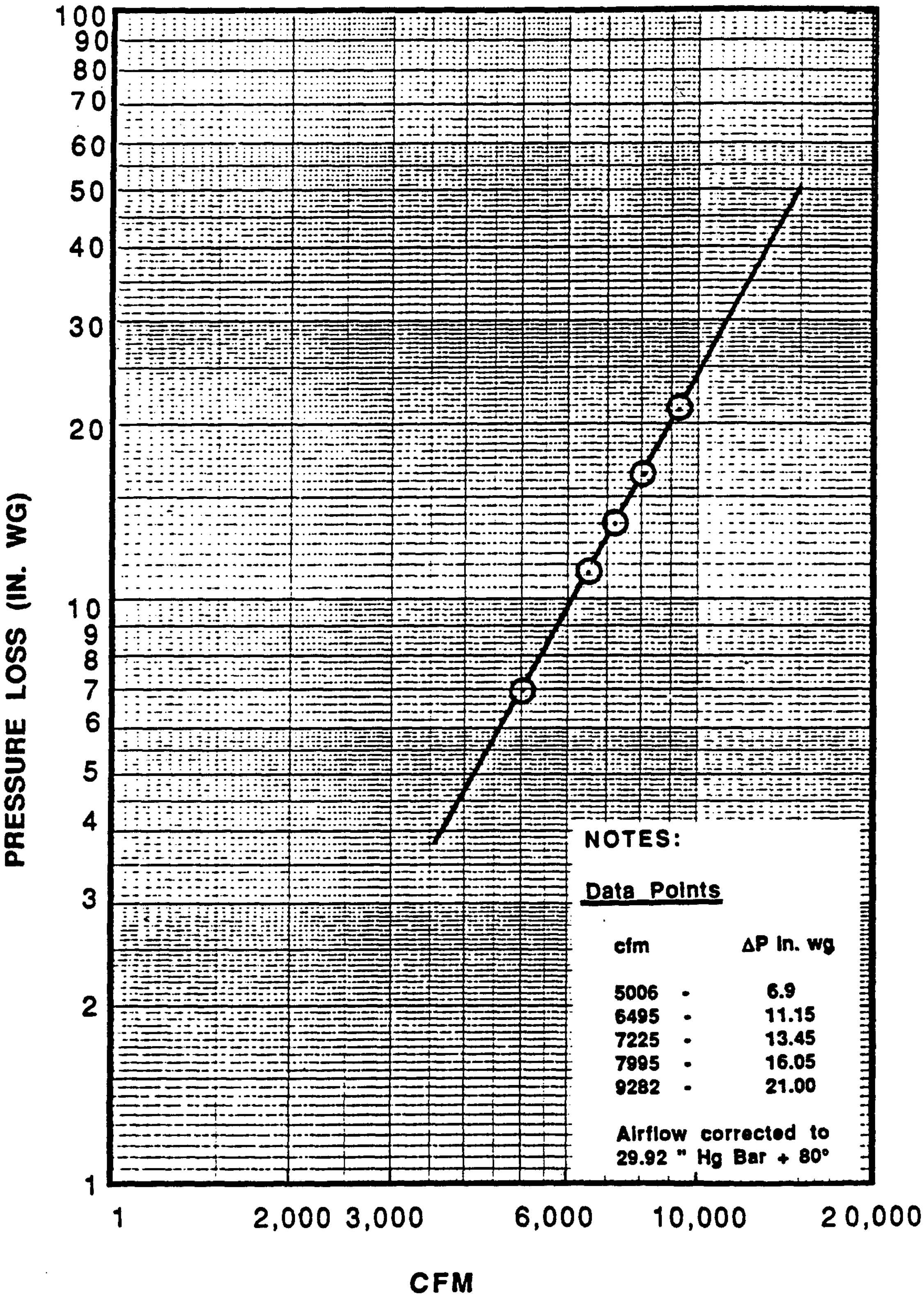

Figure 11. Pressure Drop of RESCAF System with Yuma Filter Medium and 3/4" Spacer

Secondary seal level changed on transition casting.	Secondary seal interfered with primary seal (design error).
Motor gear material changed to hardened steel.	Excessive wear noted after first dust test on soft gear.

6.2 Tests Run on RESCAF

The following tests were completed on RESCAF for developmental reasons, or at the request of Textron Lycoming, per contract agreement. Data from tests contracted by Lycoming is provided in this report.

NOTES: Data from tests conducted for developmental reasons is proprietary and is not part of this report.

	TEST	DATE	OBJECTIVE
1)	Static-pressure loss characterization of RESCAF, inlet to filter element and inlet to clean side of filter element.	6/28/88	Define system, pre-cleaner, and filter element pressure loss.
2)	Static-pressure loss characterization - clean air side of casting - control box, upstream element - receiver, upper - receiver, lower (7 1/2% scavange rate) (filter elements in and out)	6/28/88	Define filter element loss characteristics and calibrate receiver circuits (developmental).
3)	Static-pressure loss characterization (same data as test 2 except scav. rate at 10%).	6/28/88	Define SCAV. depression characteristics of RESCAF (developmental).
4)	Static-pressure loss characterization of RESCAF with precleaner removed.	6/28/88	Define precleaner distortion/duct losses (developmental).
5)	Static-pressure loss with precleaner raised 3/4".	6/30/88	Determine if pre-cleaner distortion level can be corrected if space added at element interface (developmental).
6)	Static-pressure loss characterization with precleaner raised 1 1/4".	7/5/88	Determine effect of increasing gap by 3/4" (developmental).

7)	Static-pressure loss characterization with precleaner raised 1/2".	7/5/88	Determine effect of decreasing gap by 1/2" (developmental).
8)	Static-pressure loss characterization with tapered gap 3/4" - 0.	7/11/88	Determine effect of running with tapered gap (developmental).
9)	Nozzle pressure vs. flow characteristics - hot nozzle (from M1A1 SCAF compressor) - nozzle 1 and nozzle measured - temperature gradient mounted	10/18/88	Determine nozzle pressure vs. flow characteristics at varying Temperatures. (developmental).
10)	Static-pressure loss characterization - new elements constructed with "proper" spacers - precleaner on and off	11/10/88	Determine effect of "proper" pleat spacing on system P with original pre-cleaner spacing (developmental).
11)	Static-pressure loss characterization - same as test 10 except pre-cleaner raised 3/4"	11/14/88	Determine total effect of "proper" pleat spacing and 3/4" spacer (developmental).
12)	RESCAF rig test (8" x 8' filter) - test run for 20 hours at 10 x 0 vis.	11/22/88	Verify test parameters for full scale dust test on rig test (developmental).
13)	RESCAF rig/precleaner efficiency	11/18/88	Calibrate rig pre-cleaner to simulate full scale RESCAF.
14)	Full scale RESCAF dust test	12/16/88	Demonstrate life and efficiency characteristics of full scale RESCAF. (Test ran 51 hours and was shut down due to thin substrate medium failure.)
15)	Nozzle flow distribution test	12/19/88	Determine level of nozzle jet distortion on RESCAF.

16)	Full scale RESCAF dust test	1/16/89	Demonstrate life and efficiency characteristics of full scale RESCAF. (Test ran 18.87 hours and was shut down due to medium failure, traced to QA failure of supplier.)
17)	RESCAF nozzle and spill valve loss characterization	3/7/89	Characterize nozzle flow and pressure from spill valve to nozzle with Lycoming supplied spill valve manifold.
18)	Full scale RESCAF pressure drop test	2/16/89	Determine pressure loss characteristics of RESCAF with "Yuma" M1A1 medium.
19)	Full scale RESCAF dust test	2/17/89	Demonstrate life and efficiency characteristics of full scale RESCAF (test successful).
20)	RESCAF vibration test	3/27/89	Demonstrate vibration resistance.
21)	RESCAF shock test	5/12/89	Demonstrate shock resistance.
22)	RESCAF post shock and vibration efficiency test	6/15/89	Demonstrate RESCAF efficiency after shock and vibration tests.
23)	GDLS APU duct test	6/16/89	Determine GDLS manifold pressure loss characteristics.

6.3 RESCAF Teardowns

The RESCAF system was disassembled three times during the laboratory test program. The purpose of these teardowns was to perform a complete post test inspection of the RESCAF system and determine if failures had occurred. The following paragraphs describe these teardowns and what was found.

Teardown 1

The first teardown occurred immediately after the first dust test failure in December, 1988. The following conditions were noted and corrective action taken:

- Excessive wear was noted on the drive motor spur gear. This problem was corrected by changing requirements to specify a hardened drive motor spur gear and replacing the gear.

- Interference was noted between the primary and secondary turntable seals. This interference with the seal bolt heads resulted from a tolerance stack up. The gap was increased between these seals (drawing change), and the seals were reinstalled. No further problems were found on subsequent tests.

- The lock nuts on the filter element retainer assembly came loose when removing the filters. These nuts were welded in place after assembly for subsequent tests. This fix worked well and the change was incorporated in the design.

Teardown 2

The second teardown occurred immediately after the third successful dust test, in February, 1989. The RESCAF was found to be in good condition throughout, with only normal wear noted.

Teardown 3

The third teardown occurred after completion of the dust test which followed shock testing. The RESCAF was found again to be in good condition. The turntable seal manufacturer inspected the critical seals and figure 12 is an excerpt from the manufacturers letter report.

6.4 Recommendations for Next Generation Systems

For next generation systems Donaldson Company, Inc. recommends use of thin substrate filter medium (after successfully passing development tests) because of the lower system pressure loss and longer life benefits it would provide. An onboard diagnostics system is also recommended because it would reduce trouble-shooting time in the event of a problem.

Donaldson Co. Inc. recommends that an alternate air compressor for RESCAF be developed. This recommendation is made because the compressor chosen is considerably larger and capable of performance in excess of that required for this application. Donaldson Co. originally recommended (for the 4 speed RESCAF) a compressor with pressure capability of 22.5 psig and flow capabilities of 280 SCFM. Development work during the summer of 1988 indicated adequate performance could be achieved with a compressor capable of only 12 psig and 175 SCFM. Recommended pressure in the cleaning nozzles dropped from 15 psig to 8 psig during this period. This drop in pressure is necessary to prevent filter medium failure which may occur at higher pressures. In addition, a lower operating pressure should result in reduced compressor size and cost.

Donaldson Co. Inc. also recommends that an alternative RESCAF drive motor be developed. This is recommended because some problems with the motor occurred during RESCAF development.

Donaldson Co. Inc. would recommend the development of a composite body assembly to reduce system weight; however, since additional changes to the body are planned, and tooling costs are high, this change should only be implemented when the design frozen.

Donaldson Co. also recommends that the larger 1 1/2 inch diameter separator tubes continue to be used in the pre-cleaner for this RESCAF and with subsequent versions. This recommendation is made because of recent experience with plugging of smaller 3/4 inch diameter tubes with stones and vegetation at Yuma Proving Ground. The larger air passages of the 1-1/2 inch diameter tubes make them less prone to this plugging problem and, it is well established in the current M-1, MBT that the larger diameter tubes are more efficient at removing moisture from the intake airstream.

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Below are excerpts from seal manufacturers report on the condition of the seals after shock, vibration, and dust testing was completed.

1) Teflon member showed little wear. Approximately 0.002/0.003 (inches) teflon lost from sealing bead which equals less than 2 percent of total seal life. Teflon members machined shape and formed angle remained constant after deflection from installation and testing. Although spliced spring joints did not show excessive wear there was evidence of inconsistent wear at joints.

2) Seal mating (hardened running surface) showed no sign of overheating, or wear although there had been more polishing from teflon member than expected; I believe this was a result of grind marks across running surface. This can be corrected by Blanchard grinding the hardened running surface so all grind marks lay in circumferential direction.

Finding on secondary seal

1) Seal element and mating surface looked excellent. Very little wear was noted on element. The seal interface looked as if only toe contact is being made at this time, and with continued running the contact pattern will increase with element wear.

2) The inside mating surface which the element runs against looked as if the seal had moved. Note there were two contact patterns made by the element. Each of which appeared approximately 0.040 (inches) in width and 0.125 apart. There were only a few number of hours on the first interface. Although both interface patterns appeared the same the initial running is at an accelerated rate until break-in has seated.

In conclusion, the overall performance appeared to be excellent.

Figure 12 (cont.)
Report on condition of the critical seals after teardown No. 3. These seals were used for all testing.

APPENDIX A

VIBRATION TESTING

Honeywell | # ENGINEERING REPORT

DATE 03-27-89	REPORT NUMBER OEXM 30299D
DEVELOPMENT NUMBER G2068-AA-0001-2760	PAGE 1 OF 3
ISSUED BY D&E Environmental Lab	CONTRACT NUMBER D7800-920

COPYLIST: ☐ AVIONICS ☒ DEFENSE SYSTEMS

R Leach MN50-4100
G Hedstrom MN11-1352
S Nisbet Textron Lycoming (2)
H Camplin Donaldson Corp. (2)
D Swanson* MN50-4100
Uniterm File* MN50-4100
D&E Files MN50-4100

KEYWORDS:
Donaldson Co.
SCAF
Vibration

ATTACHMENTS:
Tables 1 - 3
Figure 1
Appendices A, B, and C

UNIT TESTED:

One Donaldson Corporation M1 tank air filter (SCAF), P/N 9800P0200, was vibration tested per Mil-Std-810D, Method 514.2, Procedure VIII, Table 514.2-VI -- Sinusoidal transportation vibration for tracked vehicles. See Table 3.

SCOPE:

This report covers the procedures used for vibration testing, the response location descriptions from which data was acquired during the vibration tests, and magnitude and phase plots of the resultant data.

SUMMARY:

One Donaldson air filter was vibration tested per customer specifications from Mil-Std-810D. Testing was performed on an Unholtz-Dickie TA-4000 electrodynamic vibration machine. The air filter was instrumented at thirteen locations as specified by Donaldson Corp. and Textron Lycoming customers. (See Figure 1 and Table 1.) Vibration was induced in three axes and data was acquired at select locations for each axis.

PROBLEMS:

During both lateral axis and axial axis vibration, bolts were sheared on the air filter's supporting struts and torque arms. Since these had no direct bearing on the test they were replaced and testing was resumed. The second 1/3 of the lateral axis vibration and the final 1/3 of the axial axis vibration, however, were run at only 70% of the full level as directed by Scott Nisbet of Textron Lycoming. After completion of lateral axis vibration, it was noted that a bolt, which held the gear box to the AGT 1500 tank engine (used as a fixture for the SCAF), had broken and a decision was made to run without the gear box for the vertical and axial axes.

DATA BOOK NUMBER 0-3280	PAGE 150-153	TEST STARTED 13-Mar-89	TEST COMPLETED 15-Mar-89
REQUESTED BY Harry Camplin	DATE 08-Feb-89	WRITTEN BY Alan Kenny	
DEPARTMENT Donaldson Corporation		APPROVED BY Robert Leach	RH Leach 3/28/89

HE-44A REV 12/78

PROCEDURE

The Donaldson Corp. Air Filter (SCAF) was mounted to an AGT 1500 M1 tank engine and coupled to a base plate for vibration testing. The filter was instrumented at thirteen different locations as shown in figure 1. Testing was performed per Mil-Std 810D, Method 514.2 Procedure VIII, Transportation vibration for Tracked Vehicles. The sinusoidal test profile was:

5-5.5	Hz.	1.0"	D.A.
5.5-30	Hz.	1.5	G pk.
30-50	Hz.	0.033"	D.A.
50-500	Hz.	4.2	G pk.

This profile was used for all three axes of vibration.

During vibration all thirteen response locations and the control response were recorded to analog tape and were also recorded real time on a Gen Rad 2515 analyzer. Control of the test was performed on a Gen Rad 2511 Vibration Control System.

The test sequence was randomly selected as:

1: Lateral Axis
2: Vertical Axis
3: Axial Axis

During vibration in the Lateral Axis, after 1/3 of the test had completed, a bolt sheared on a strut/torque arm supporting the air filter. The bolt did not have a direct effect on the focus of the test so it was replaced and the test was resumed at 70% of the full test level, as decided by the Textron Lycoming customer representative. After 2/3 of the test had completed the bolt sheared again and a decision was made to change from a three strut configuration to a four strut configuration. The remainder of the lateral axis and both the vertical and axial axis vibration runs were performed using this four strut configuration. Following the lateral axis vibration, it was noted that the gear box attachment to the AGT 1500 engine was loose. The gear box was removed and, since extensive rework would have been required to secure the gear box, the customer decided to run in the vertical and axial axes without the gear box attached. Vertical axis vibration was performed without problems. Axial axis vibration also saw the bolt shearing problem on the torque arms. After completing 1/3 of the vibration and again after completing 2/3 of the test run, a bolt sheared on one of the supporting struts. Again the bolt was replaced each time and the test resumed until it was completed. No other failures occured.

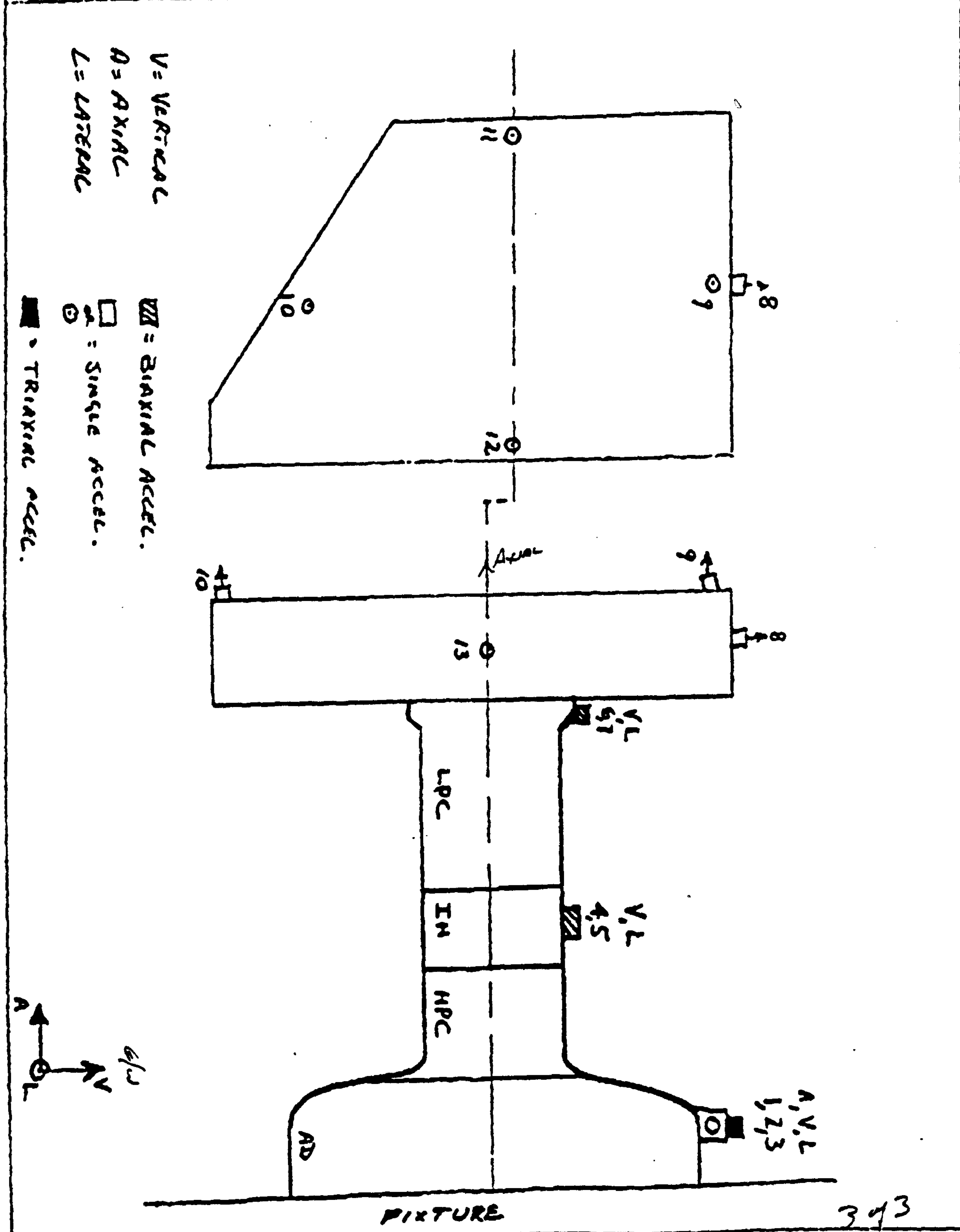
During each axis, vibration response signals of interest to the customer were acquired and are included here in Appendices A-C (see also figure 1 and tables 1 and 2 for locations). The response locations of concern were:

- -Lateral axis: Locations 3,5,7,11,12,13
- -Vertical axis: Locations 2,4,6,8,9,10,11,12
- -Axial axis: Locations 1,6,7,9,10,11,12

For each response location a magnitude, a transfer function magnitude, and a transfer function phase plot were generated. The relative axis of orientation of each response location is included in the calibration sheet (table 1).

The test was completed on Wednesday, March 15, 1989, to the customer's approval.

PREPARED	NAME S. NIEBET	DATE 3-6-89	TEXTRON Lycoming	SHEET NO. 1
CHECKED			TITLE TME SCAF SHAKER TEST	MODEL SCAF
DRAWING			ACCELEROMETER LAYOUT	WORK ORDER NO.



3 of 3

CF1019

FIGURE 1

PHOTO 1 - VERTICAL AXIS SETUP

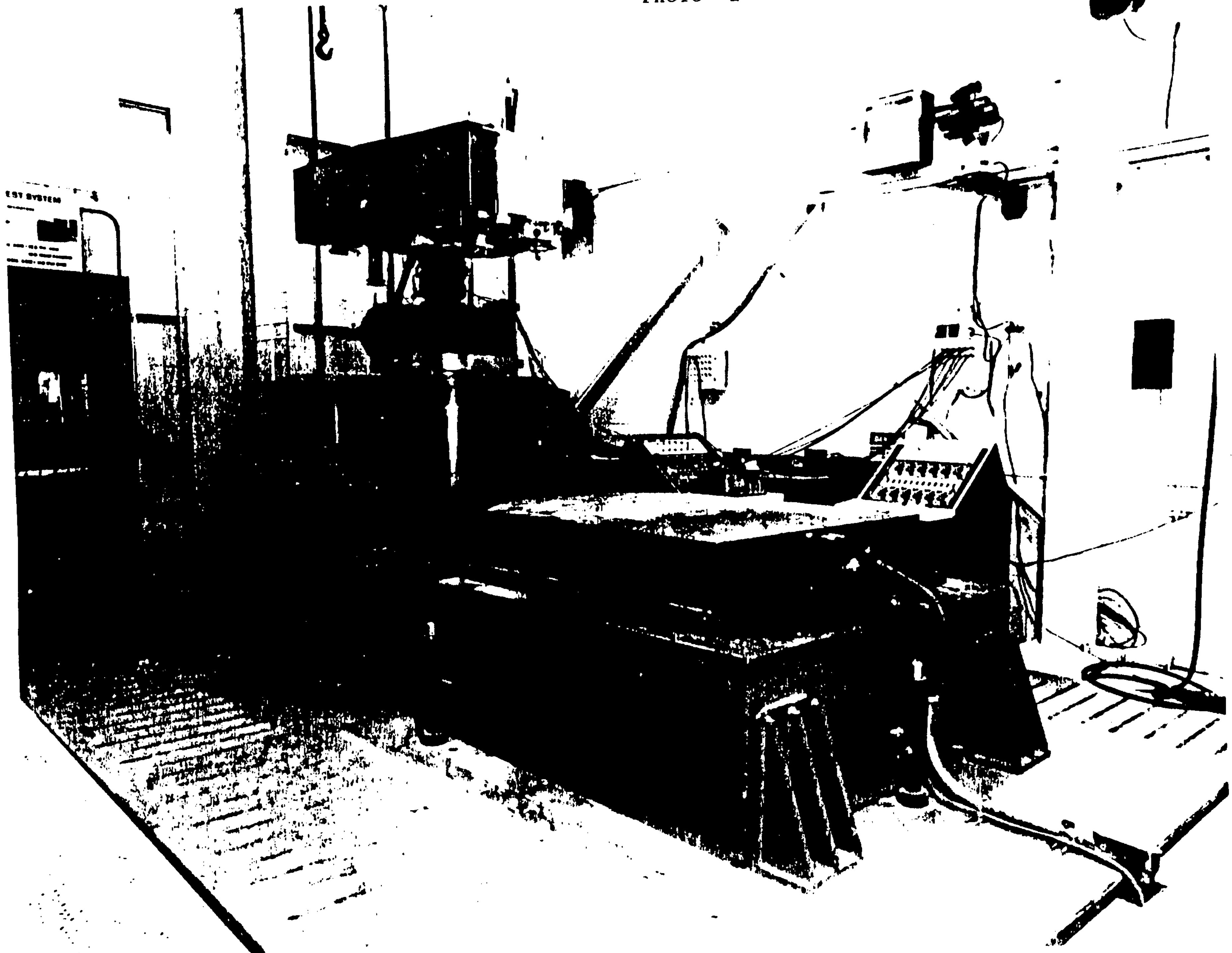


PHOTO 2 - VERTICAL AXIS SETUP

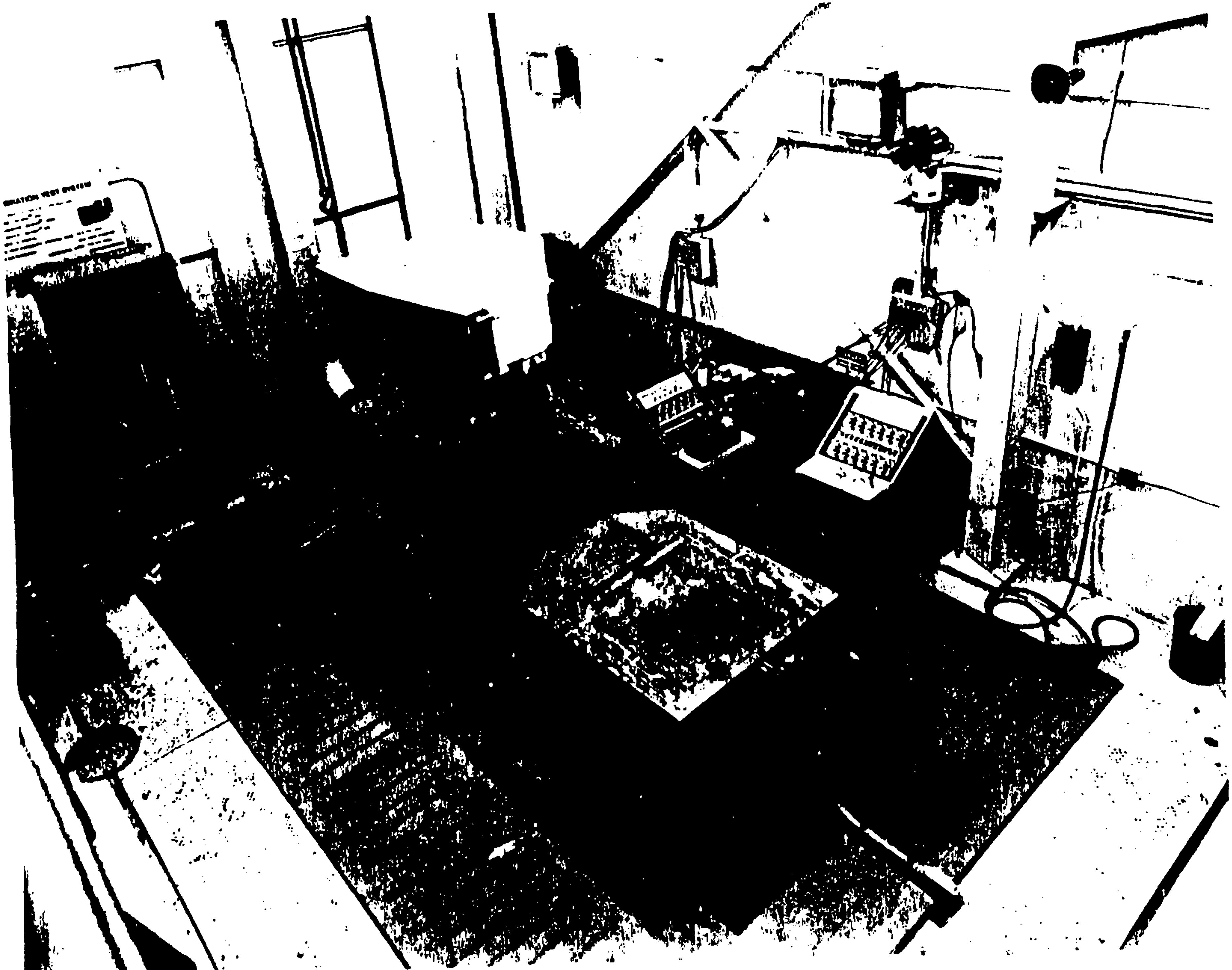
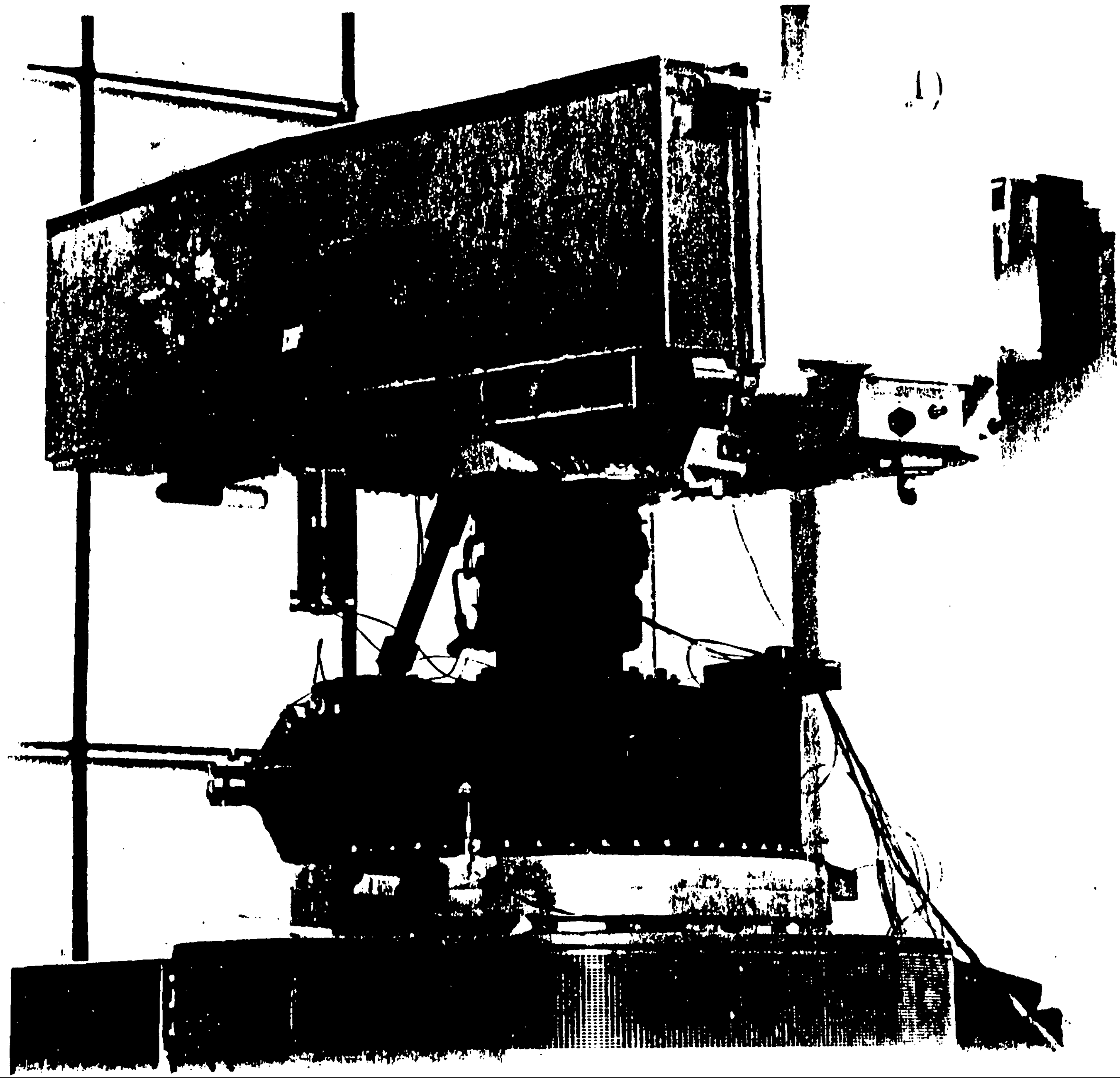


PHOTO 3 - VERTICAL AXIS SETUP



DATA ROOM LOG

TITLE Donaldson SCAF (M1)

TABLE 1

OEXM 30,299D

TALLY NO. G 2068-AA-0001 2760

RESP. AXIS / Loc. #	ACCEL.	LINE / Patch Line #	SENS.	D22 (UD) CHG. AMP.	F.S.	TAPE CHAN.	COMMENTS
VERT / 6	BK69	1 / 2	3.215	1	10 mV/g	2	Cal Bias - 12.9V 2.0mA
LAT / 7	BK39	2 / 3	2.885	2	10 mV/g	3	394 Bias = 9.06 V 2.0 mA
VERT / 8	BK54	3 / 4	3.20	3	10 mV/g	4	
AXIAL / 9	BK63	4 / 5	3.19	4	10 mV/g	5	All response accelerometers
AXIAL / 10	BK65	5 / 6	3.23	5	10 mV/g	6	except KF49 are Endevco
AXIAL / 11	BF83	6 / 7	3.09	6	10 mV/g	7	Model 2229C's. KF49 is
AXIAL / 12	BF82	7 / 8	3.04	7	10 mV/g	8	an Endevco 2222C.
AXIAL / 1	TA63	8 / 9	3.26	8	10 mV/g	9	Control Accel is a Dytran
VERT / 2	BK70	9 / 10	3.30	9	10 mV/g	10	Model 3010A8
LAT / 3	BB66	10 / 11	2.84	10	10 mV/g	11	
/	BB56	11 /	2.78	11	10 mV/g		-Not used- Space restriction replaced by KF49
LAT / 5	BD56	12 / 2A	3.26	12	10 mV/g	14	
LAT / 13	BA37	13 / 1A	3.085	13	10 mV/g	13	
VERT / 4	KF49	14 / 12	1.43	15	10 mV/g	12	All axes are defined
Dytran 3010A CONTROL	394	15 / 1		Dytran 4121 Current Source	9.95 mV/g	1	relative
COLA	(Freq. Synch)	/			1 Volt	15	RESPONSE AXES: (1) VERT - VERTICAL (2) AXIAL - AXI...

DATA ACQUISITION RESPONSE LOCATIONS

REQUESTED BY TEXTRON LYCOMING

LATERAL AXIS EXCITATION:

Response locations: 3,5,7,11,12,13
- Magnitude plots
- Transfer functions relative to Input (Magnitude and Phase plots)
- Transfer Function of:
  location 11 vs. location 12
  (Magnitude and Phase plots)

VERTICAL AXIS EXCITATION:

Response locations: 2,4,6,8,9,10
- Magnitude plots
- Transfer functions relative to Input (Magnitude and Phase plots)
- Transfer Function of:
  location 9 vs. location 10
  (Magnitude and Phase plots)
- Magnitude plots of:
  locations 11 and 12

AXIAL AXIS EXCITATION:

Response locations: 1,6,7,9,10,11,12
- Magnitude plots
- Transfer functions relative to Input (Magnitude and Phase plots)
- Transfer Function of:
  location 9 vs. location 10
  location 11 vs. location 12
  (Magnitude and Phase plots)

TABLE 2

THE SCAF VIBRATION TEST PROCEDURE

Ref.: MIL-STD-810C, Method 514.2
Equipment category f (equipment installed in ground vehicles)
Procedure VIII - proceed according to section 4.5.1.3

Applicable table: 514.2-VI
Applicable figure: 514.2-6

4.5.1.3 Cycling. The test item shall be vibrated along each axis in accordance with the applicable test levels, frequency range, and times from the applicable tables and figures. The frequency of applied vibration shall be swept over the specified range logarithmically in accordance with figure 514.2-10. The specified sweep time is that of an ascending plus a descending sweep and is twice the ascending sweep time shown on figure 514.2.10 for the specified range.

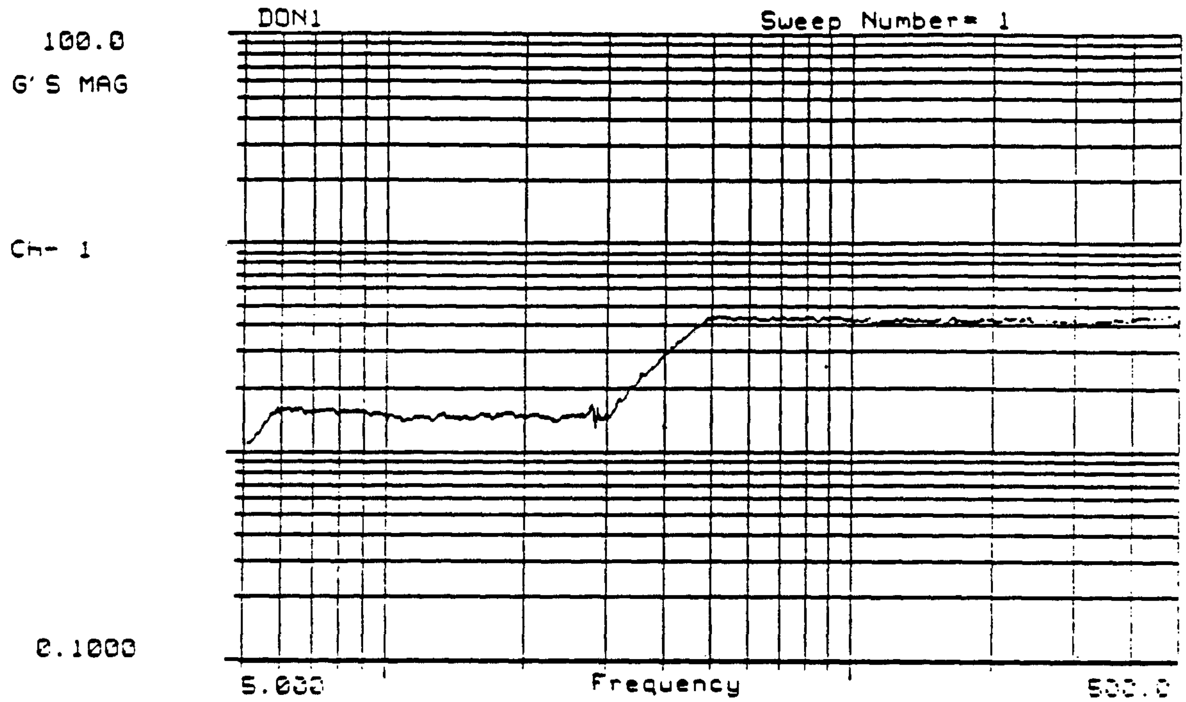
From table 514.2-VI for tracked vehicles:
  Sinusoidal cycling time, 30 minutes/1000 miles, not to exceed 3 hours per axis.
  Maximum cycling time, 3 hours per axis
  Sweep time, 15 min for 5-500-5 Hz
  Curve W

Vibration input, from figure 514.2-6, Curve W:
  1.0 inch double amplitude from 5 - 5.5 Hz
  1.5g constant acceleration from 5.5 - 30 Hz
  0.033 inch double amplitude from 30 - 50 Hz
  4.2g constant acceleration from 50 - 500 Hz

TABLE 3

APPENDIX A1
LATERAL AXIS INPUT

13-MARCH-1989
3-strut Configuration



DON1

3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

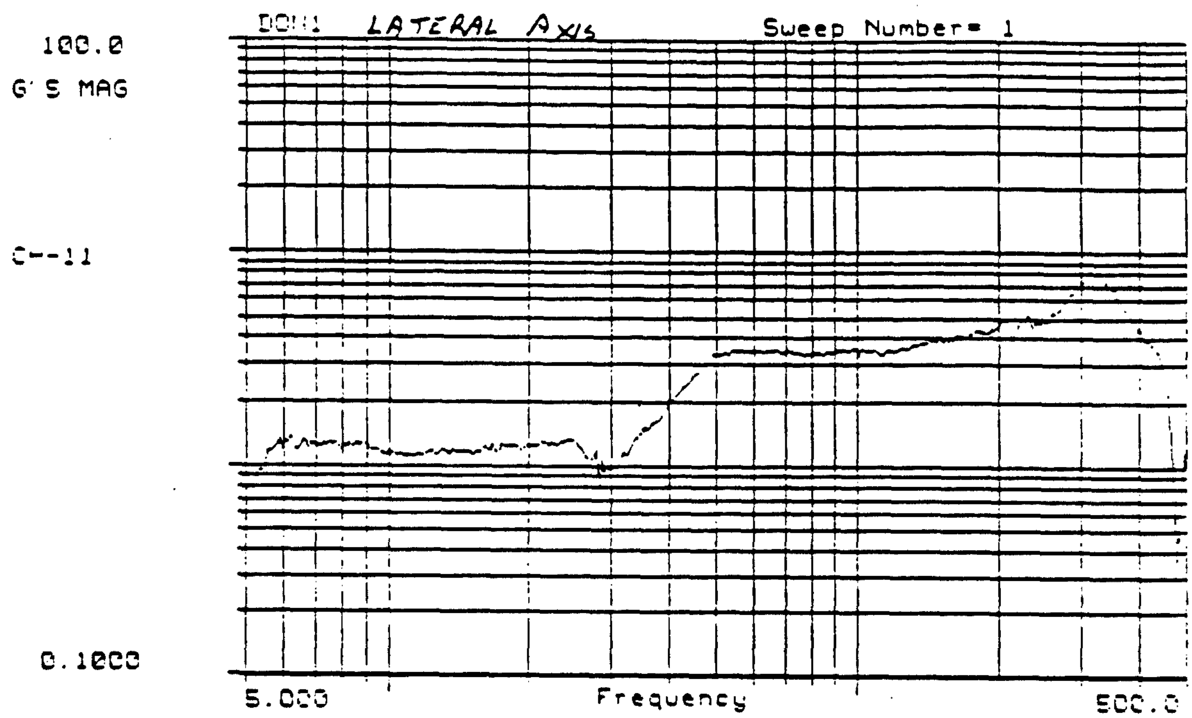
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	lateral	Unfiltered	
	.	Tape Chn.	1
Resp. Loc	CONTROL	Footage	
Resp. Accel	394	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1

3/13/89 CH-11: LINE #10 Loc #3
DONALDSON SCAF TESTING

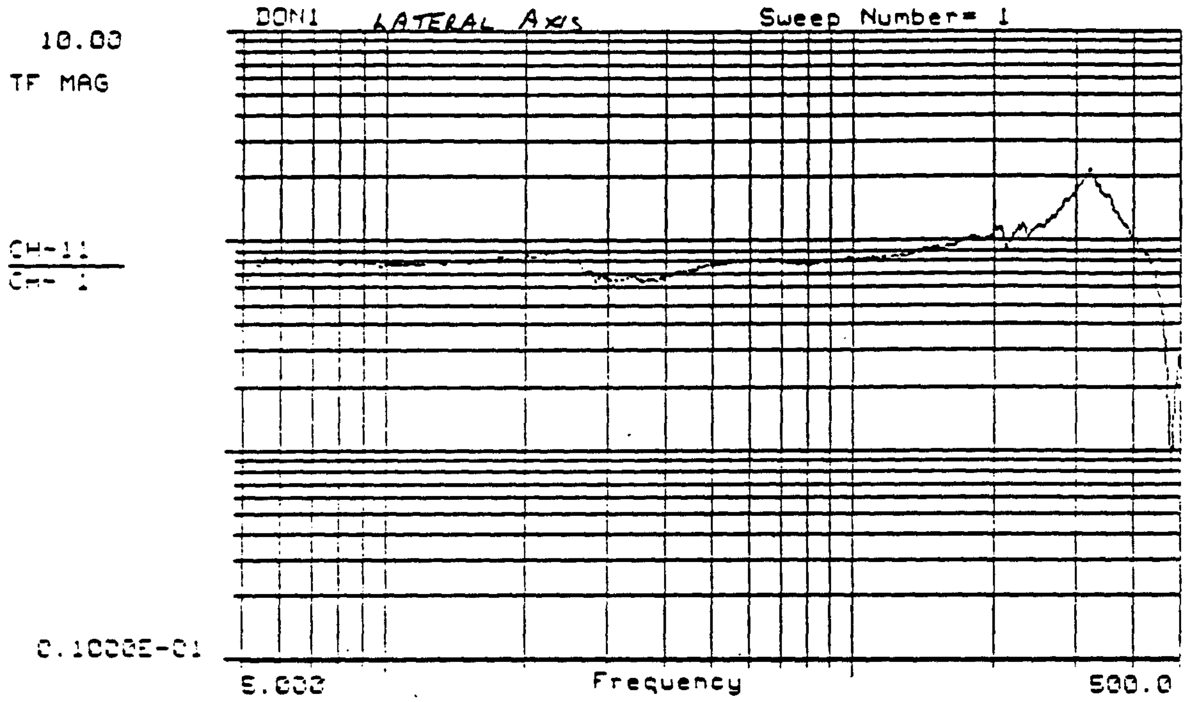
' E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	11
Resp. Loc	#3	Footage	
Resp. Accel	BB66	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1
CH-11: LINE #10 Loc #3
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

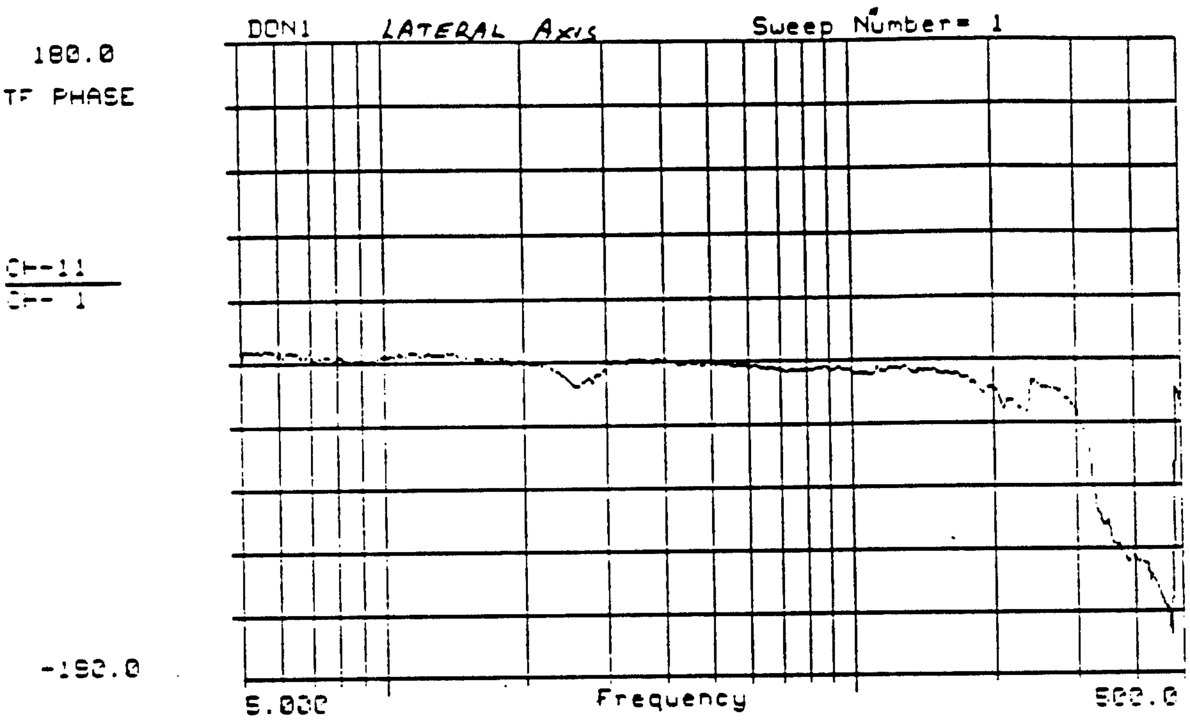
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	11
Resp. Loc	#3	Footage	
Resp. Accel	BB66	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DON1
CH-11: LINE #10 Loc #3
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

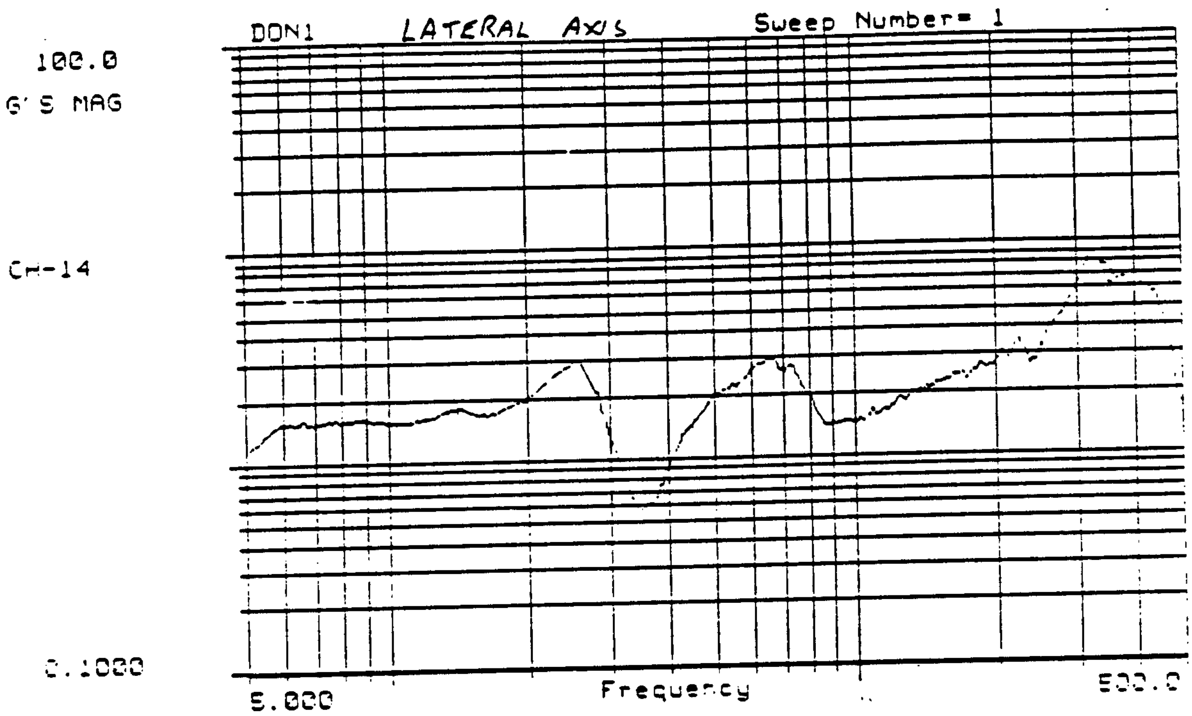
E

Honeywell Hopkins Sine Vibration

OEXM #	**30,299D**	**Test Date**	**13-MAR-89**
Input Axis	**Lateral**	**Filtered**	**YES**
Resp. Axis	**Lateral**	**Unfiltered**	
		Tape Chn.	**11**
Resp. Loc	**#3**	**Footage**	
Resp. Accel	**BB66**	**Filename**	**Don1.swp**
Test Temp	**ROOM**	**Operator**	**A. KENNY**

Donaldson Air Filter (SCAF)

Transfer Function Phase



DON1

3/13/89 CH-14: LINE #13 LOC #5
DONALDSON SCAF TESTING

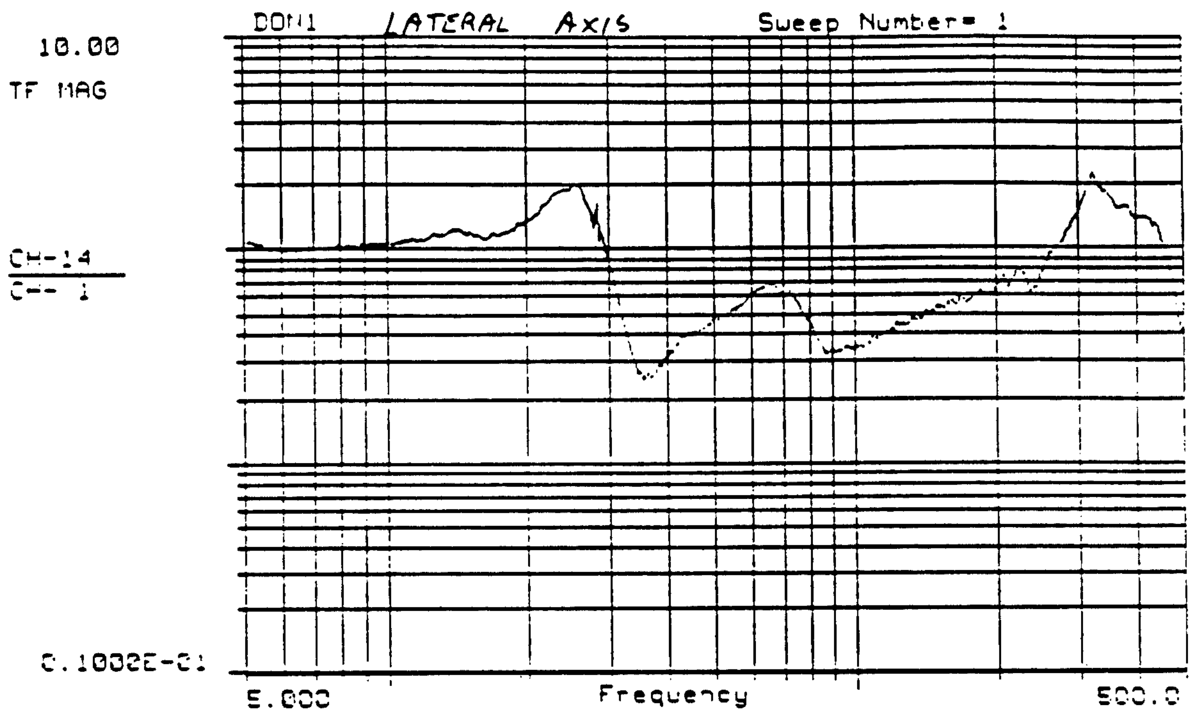
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1
CH-14: LINE #13 LOC # 5
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

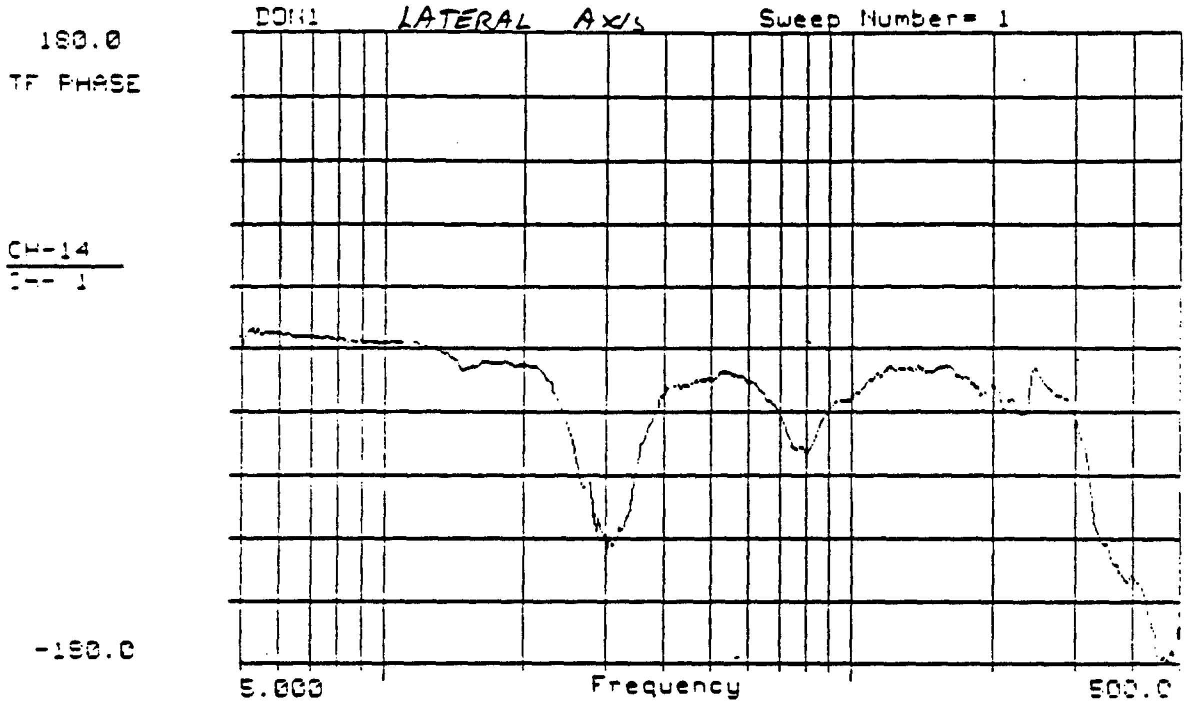
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DON1
CH-14: LINE #13 LOC # 5
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

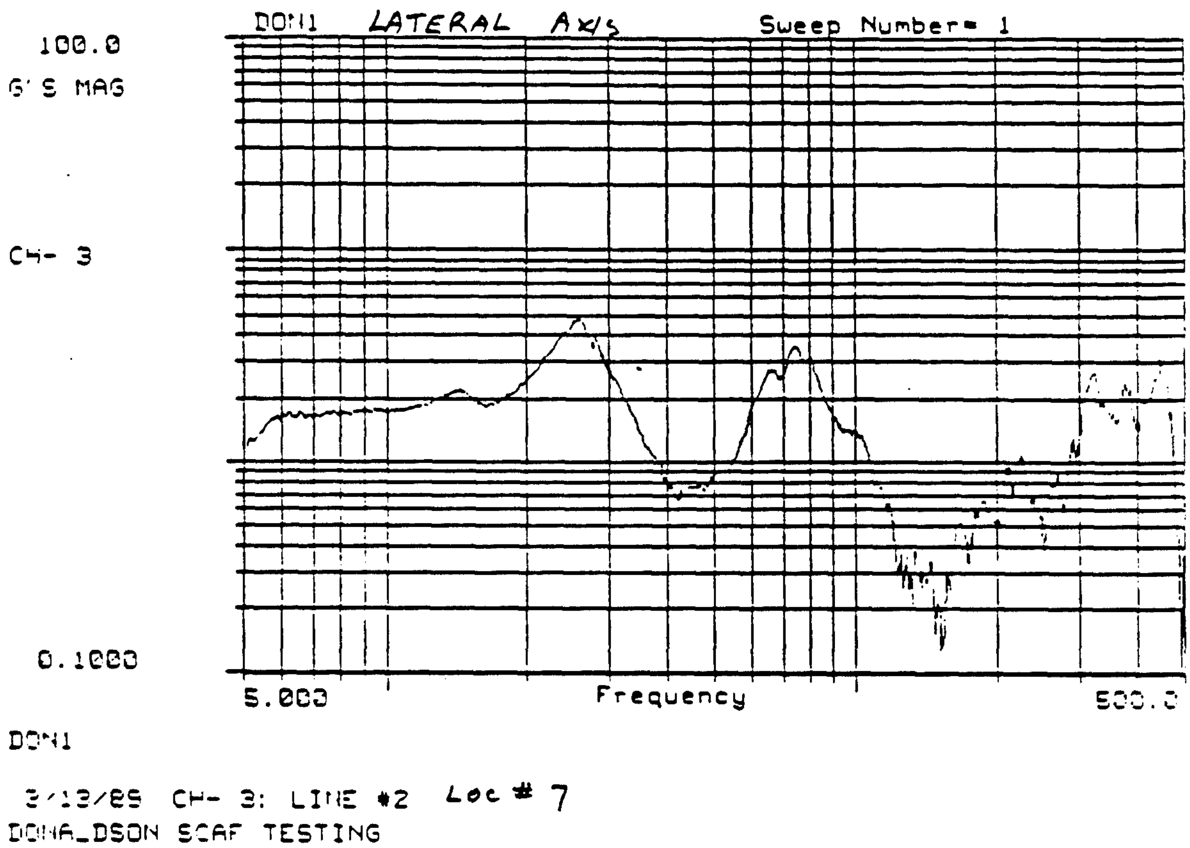
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



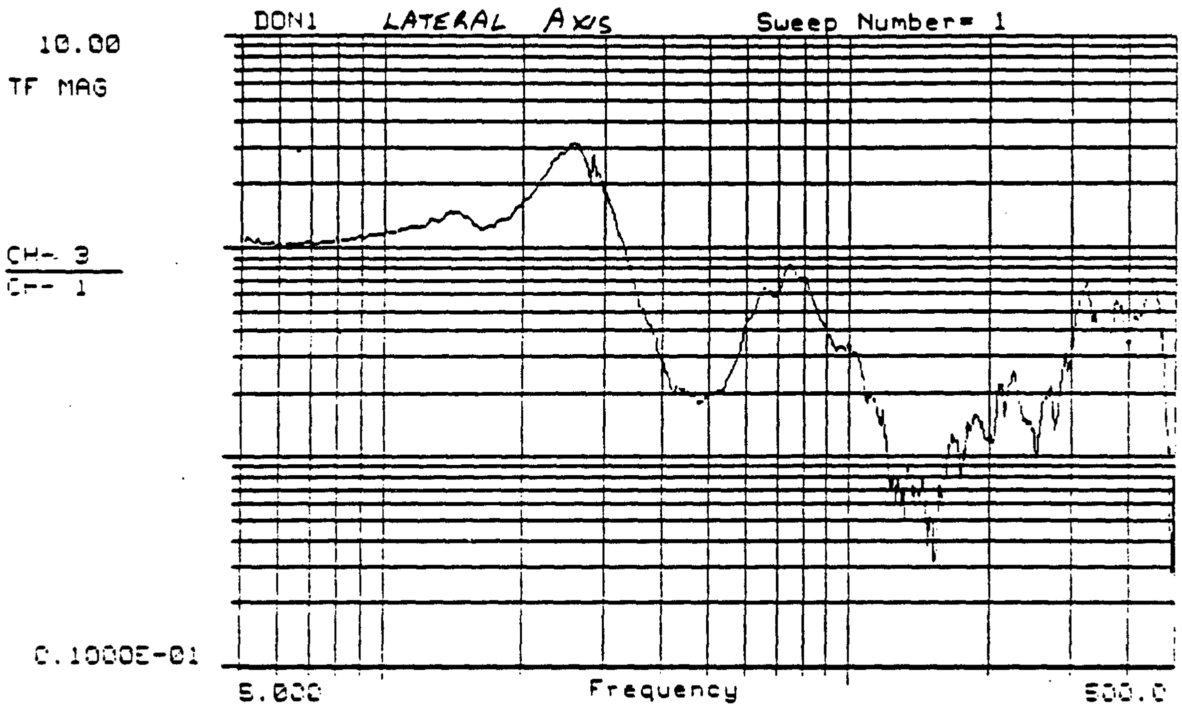
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1
CH- 3: LINE #2 Loc #7
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

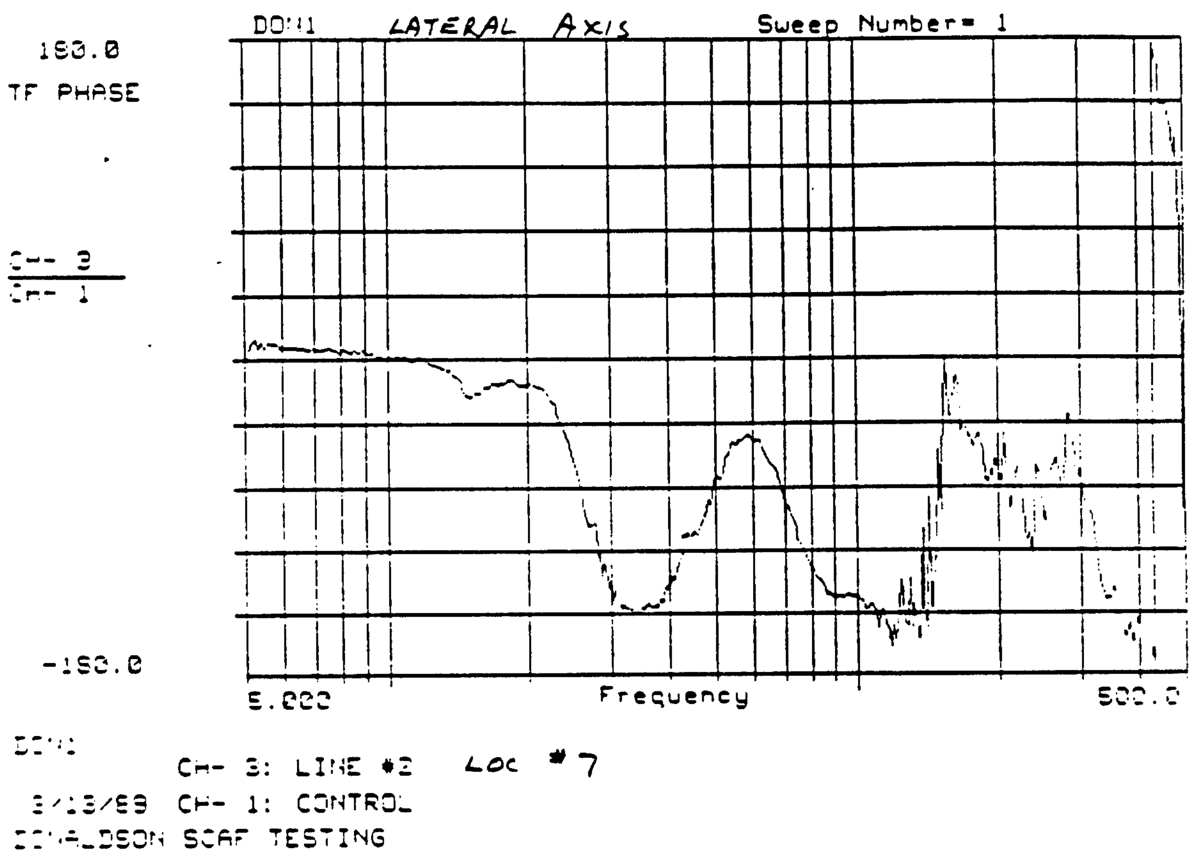
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



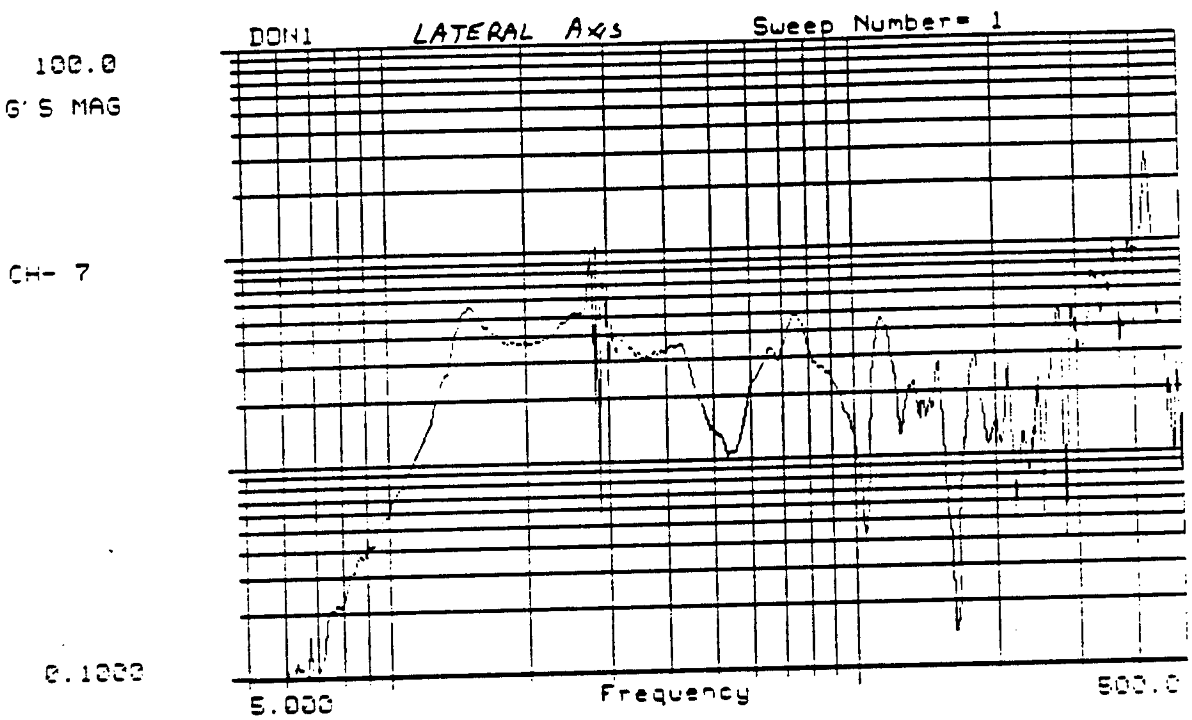
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DON1

3/13/89 CH- 7: LINE #6 Loc #11
DONALDSON SCAF TESTING

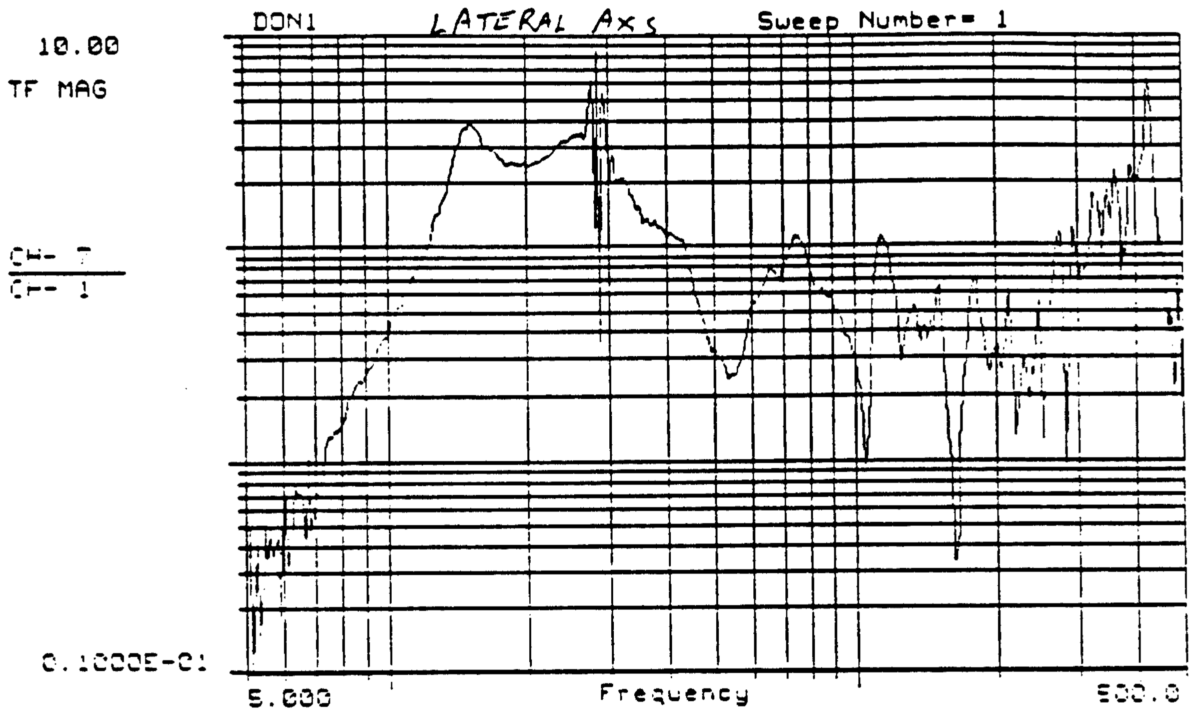
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1
CH- 7: LINE #6 Loc #11
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

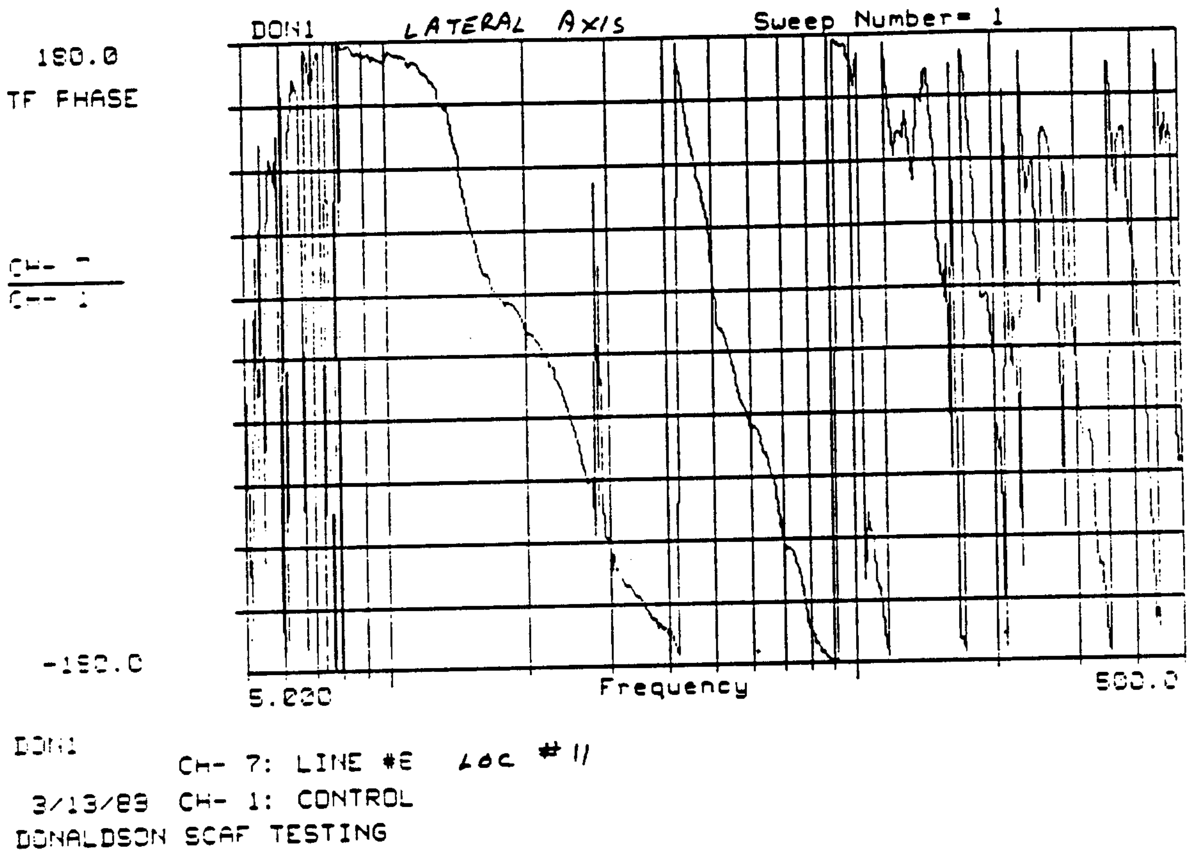
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



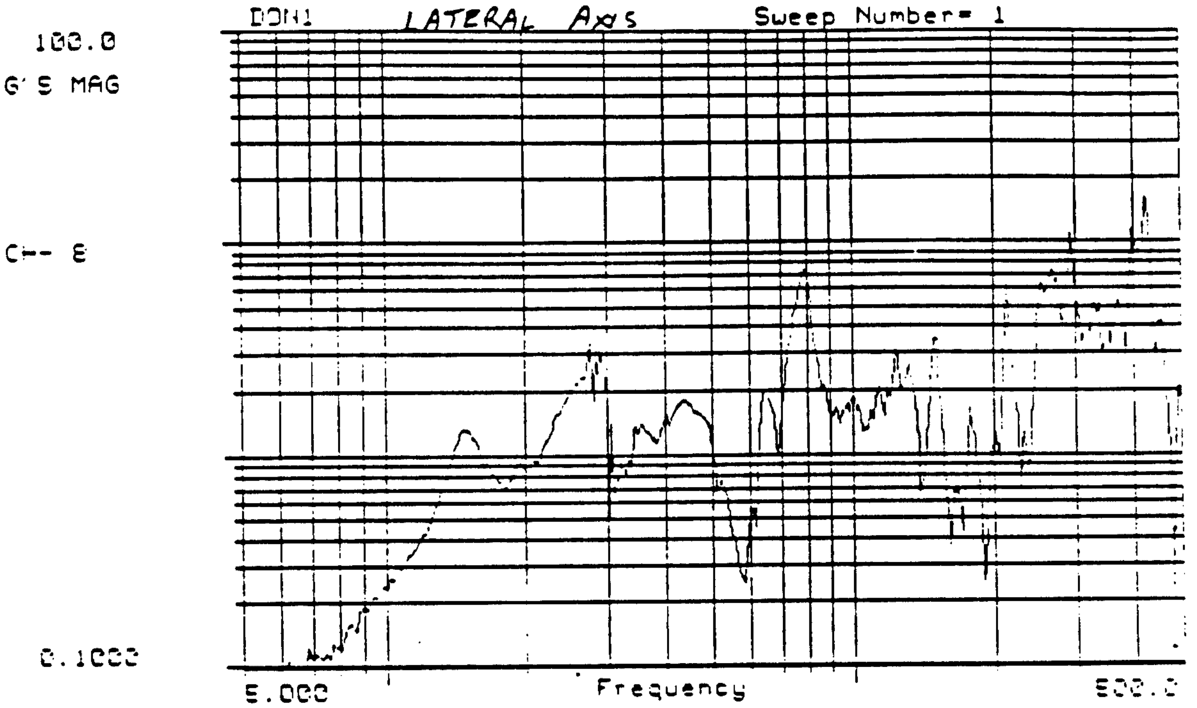
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DON1

3/13/89 CH- 8: LINE #7 Loc #12
DONALDSON SCAF TESTING

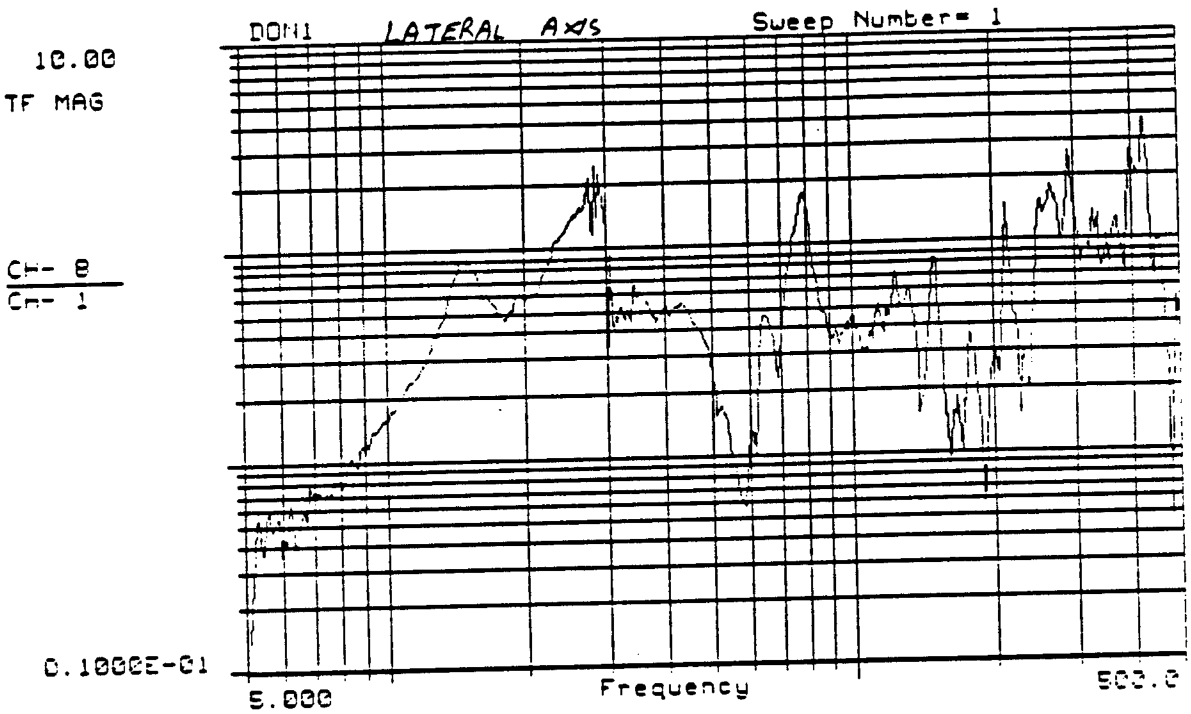
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DON1
CH- 8: LINE #7 Loc #12
3/13/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

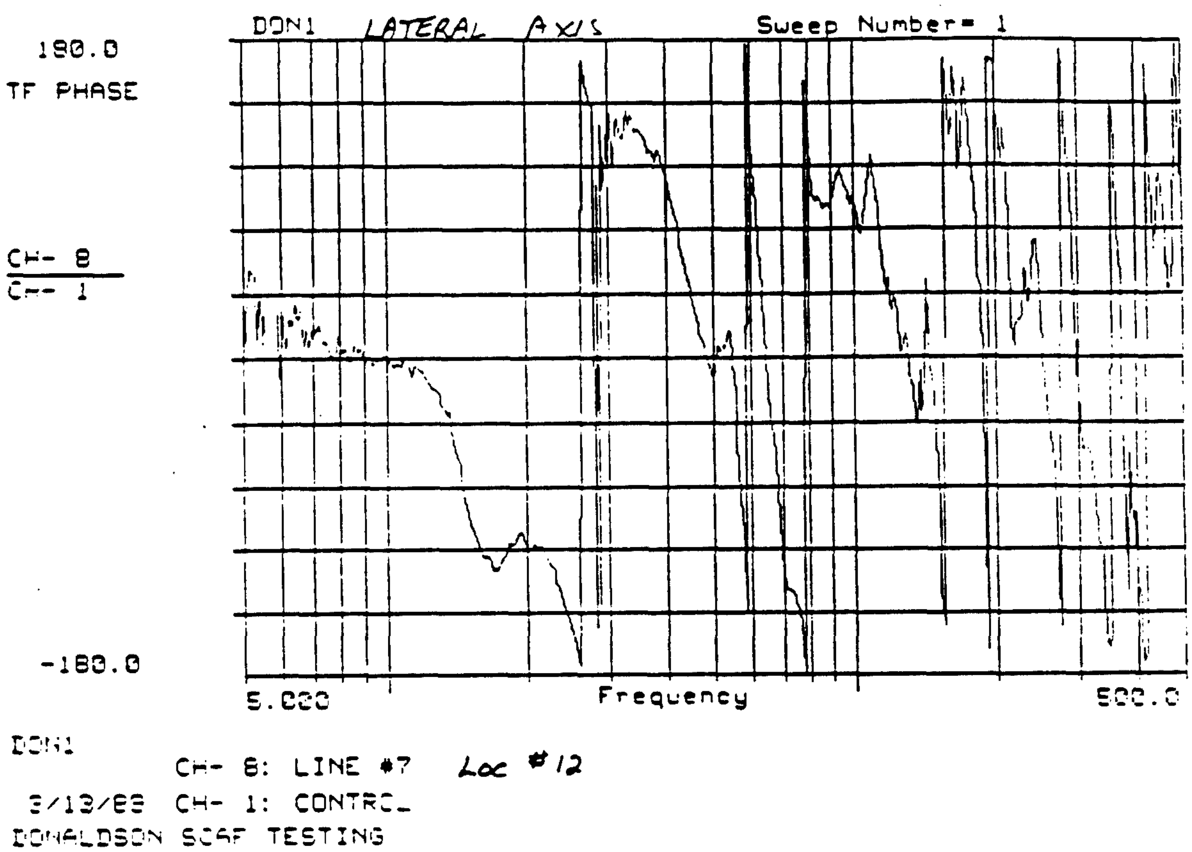
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



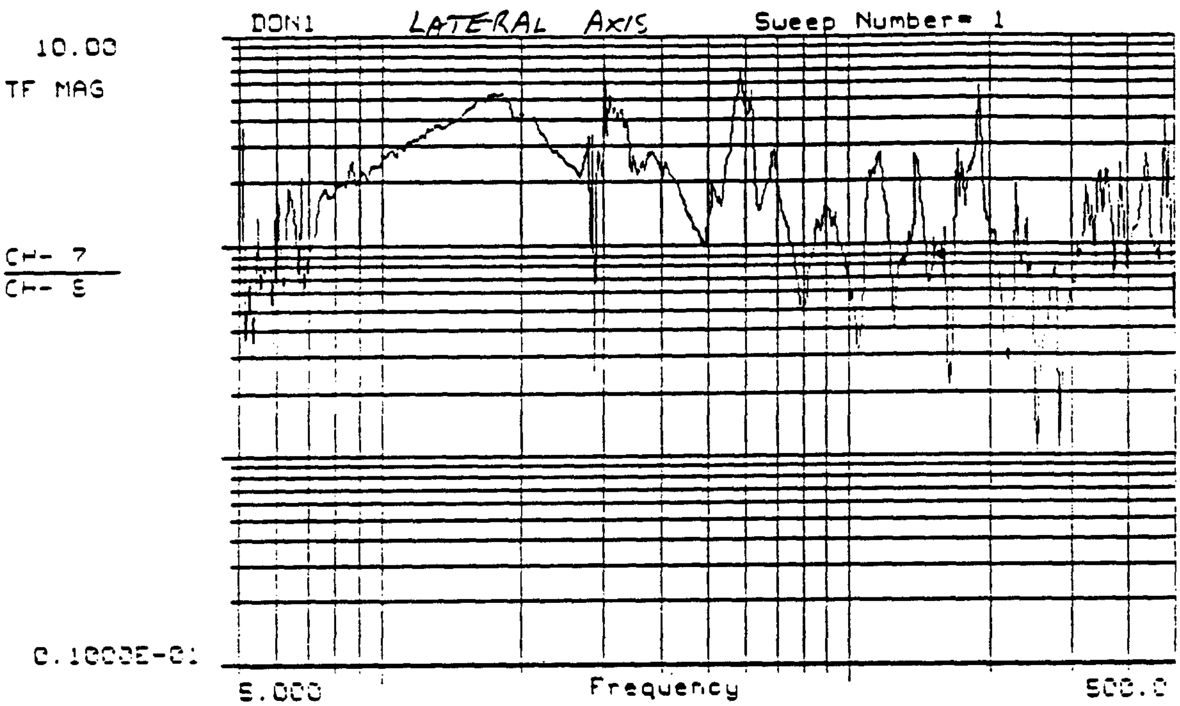
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DON1
CH- 7: LINE #8 Loc # 11
3/13/89 C-- 8: LINE #7 Loc # 12
DONALDSON SCAF TESTING

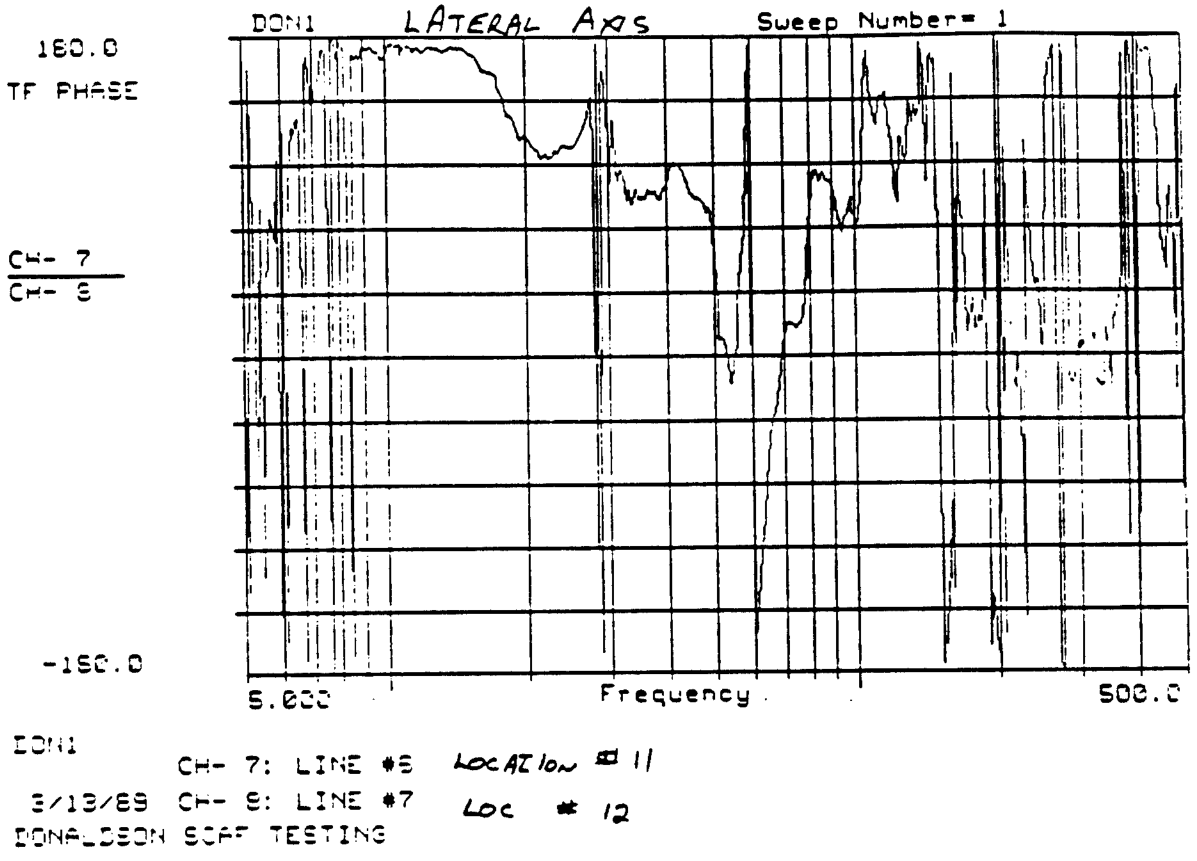
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 VS. #12	Footage	
Resp. Accel	BF83/BF82	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donalds ... Filter (SCAF)

Transfer Function Magnitude



E

Honeywell Hopkins Sine Vibration

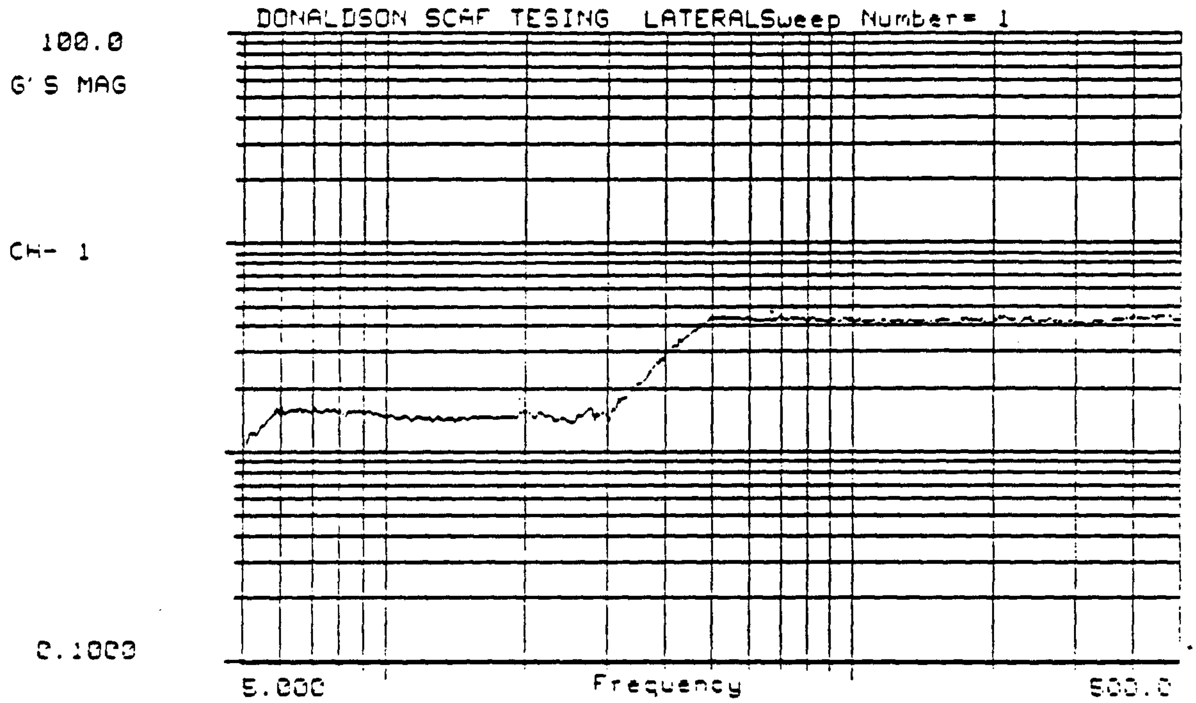
OEXM #	30,299D	Test Date	13-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 VS. #12	Footage	
Resp. Accel	BF83/BF82	Filename	Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase

APPENDIX A2
LATERAL AXIS INPUT

14-MARCH-1989
4-strut Configuration



DL1:DON1

3/14/89 CH- 1: CONTROL

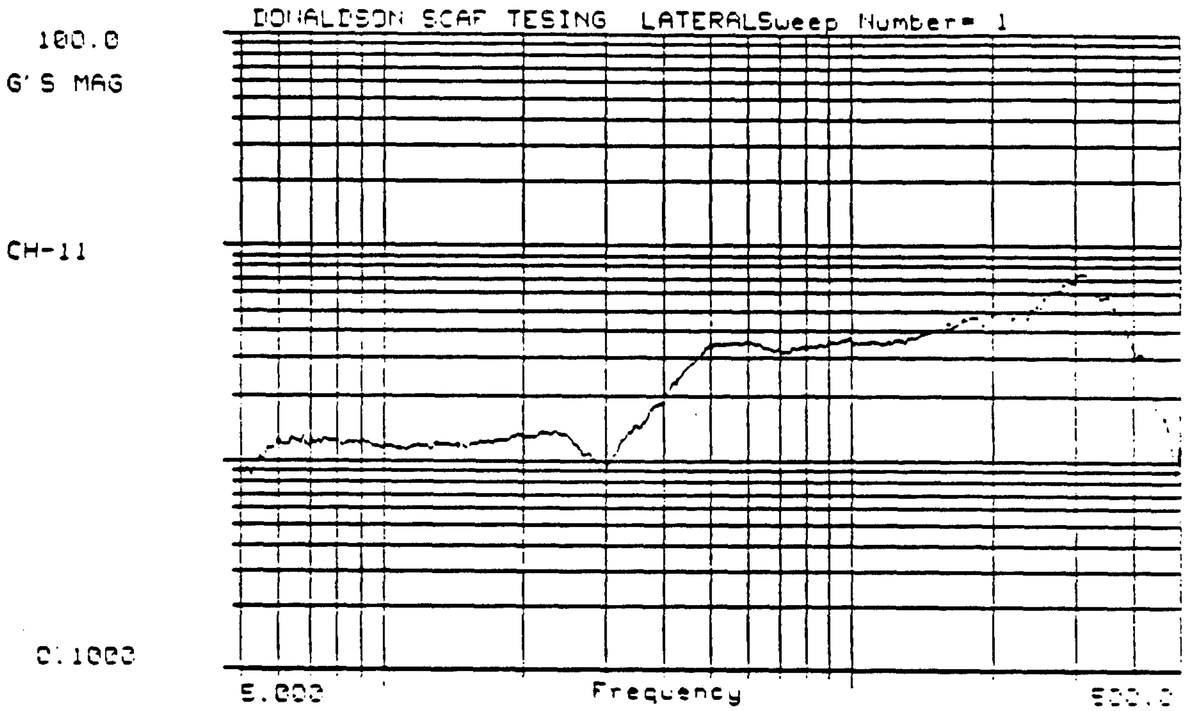
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	1
Resp. Loc	CONTROL	Footage	
Resp. Accel	394	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON1

3/14/89 CH-11: LINE #10 LOC#3
DONALDSON SCAF TESTING

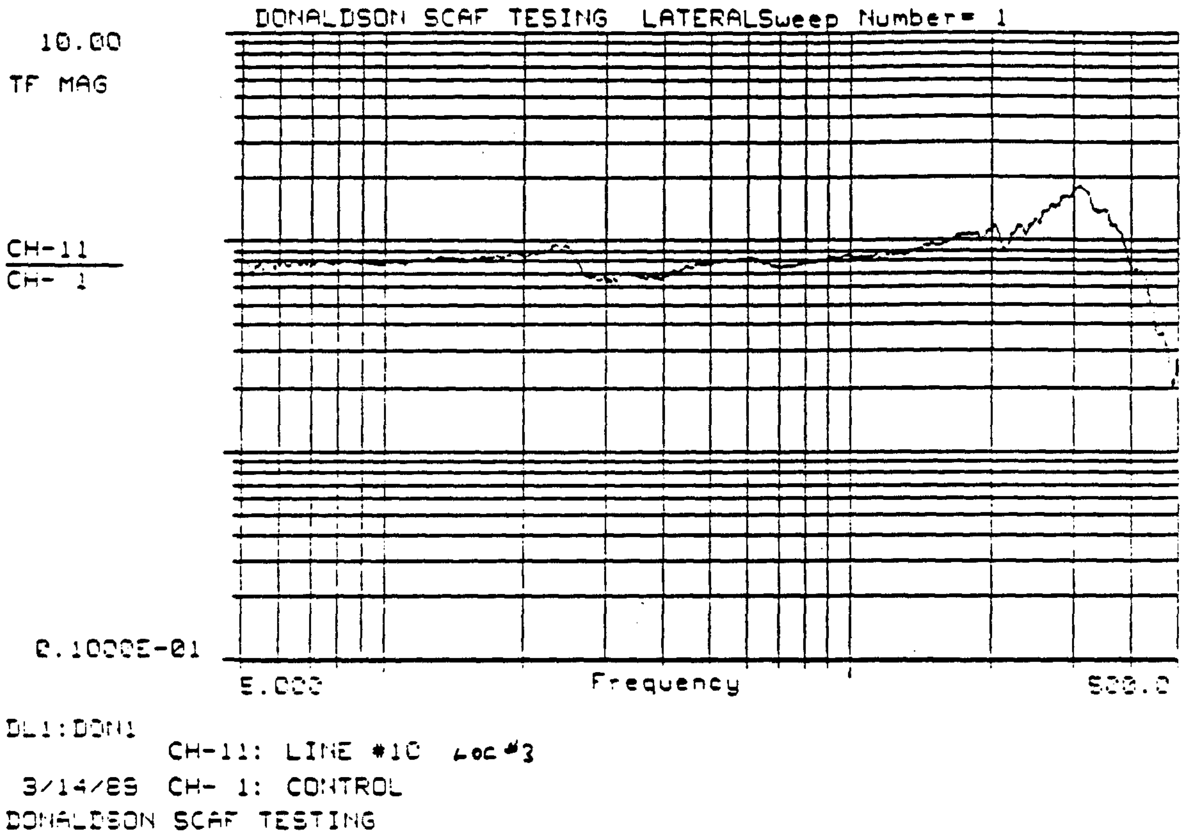
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	11
Resp. Loc	#3	Footage	
Resp. Accel	BB66	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



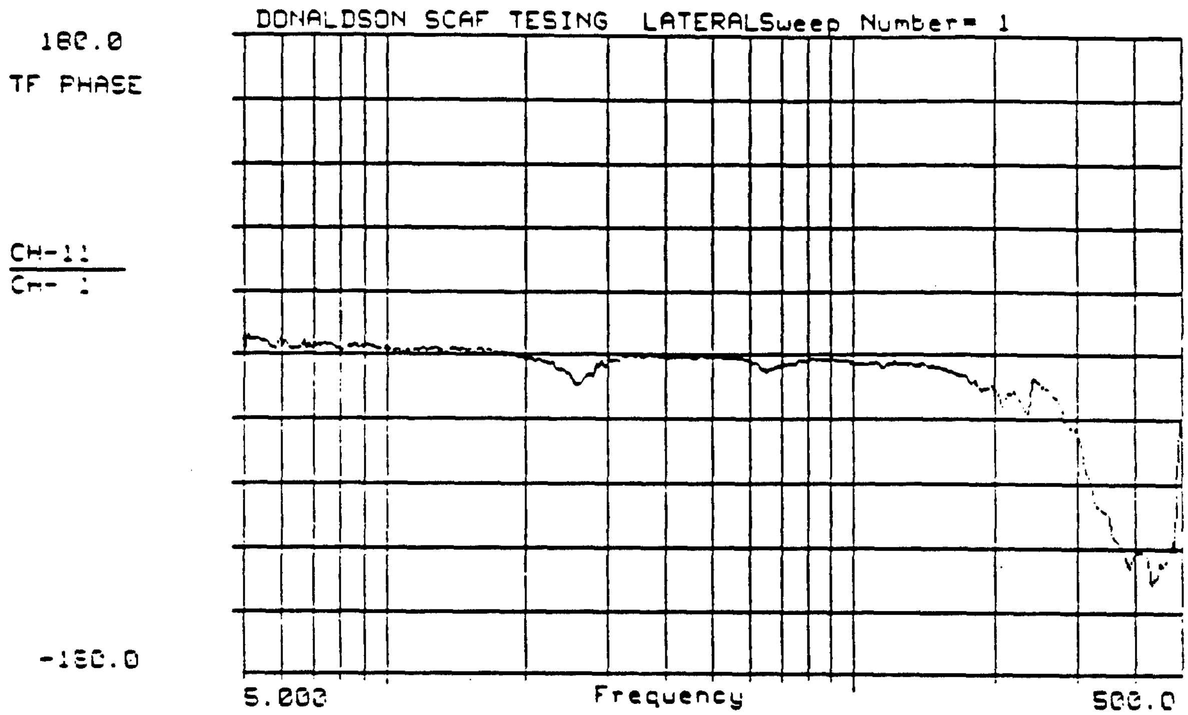
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	11
Resp. Loc	#3	Footage	
Resp. Accel	BB66	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON1
CH-11: LINE #10 Loc #3
3/14/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

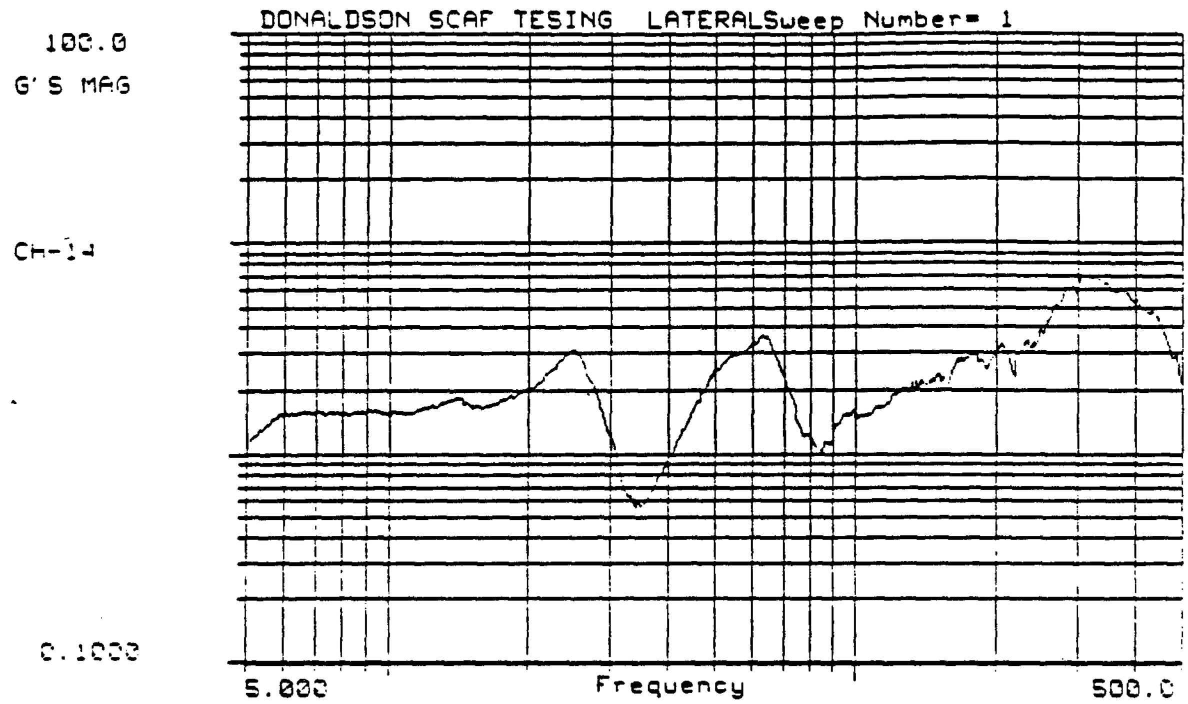
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	11
Resp. Loc	#3	Footage	
Resp. Accel	BB66	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON1

3/14/89 CH-14: LINE #13 *Loc #5*
DONALDSON SCAF TESTING

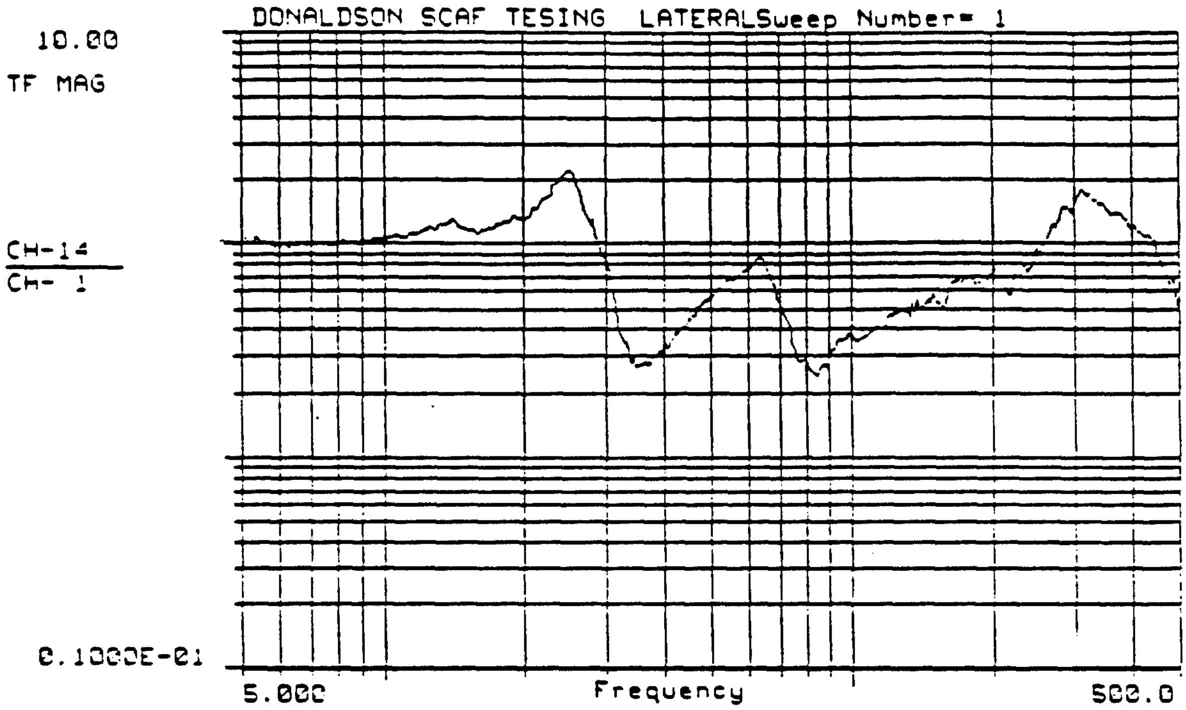
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON1
CH-14: LINE #13 Loc #5
3/14/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

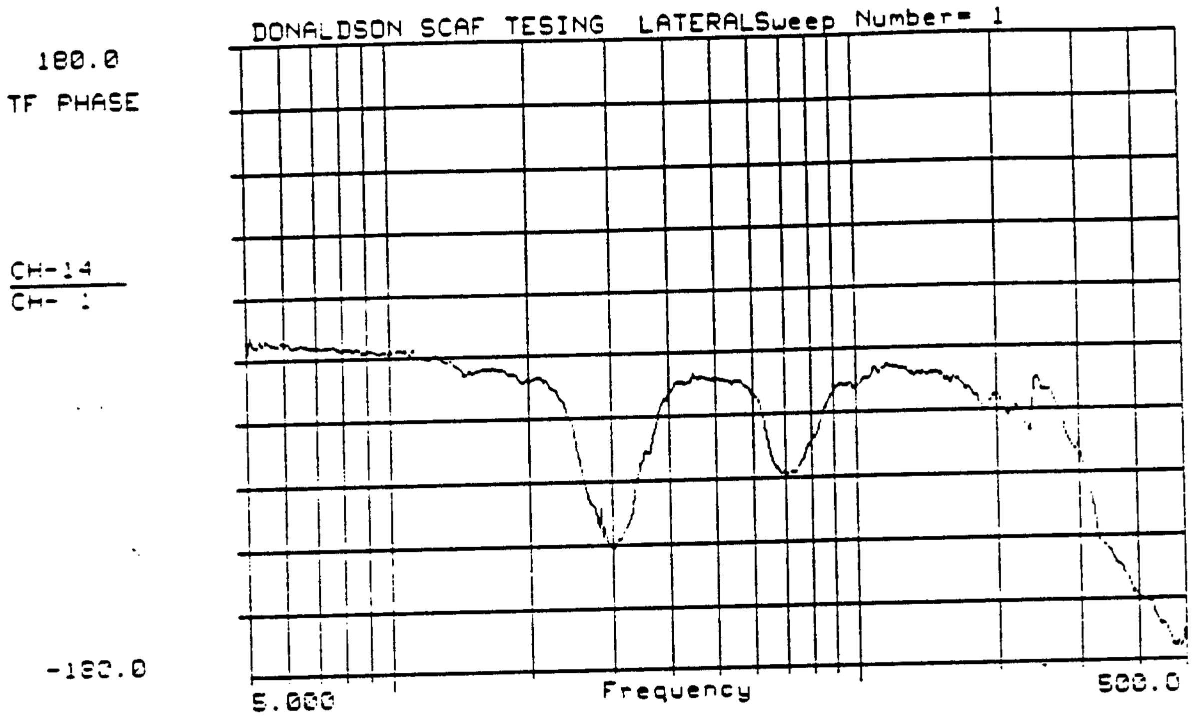
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON1 CH-14: LINE #13 Loc #5

3/14/89 CH- 1: CONTROL

DONALDSON SCAF TESTING

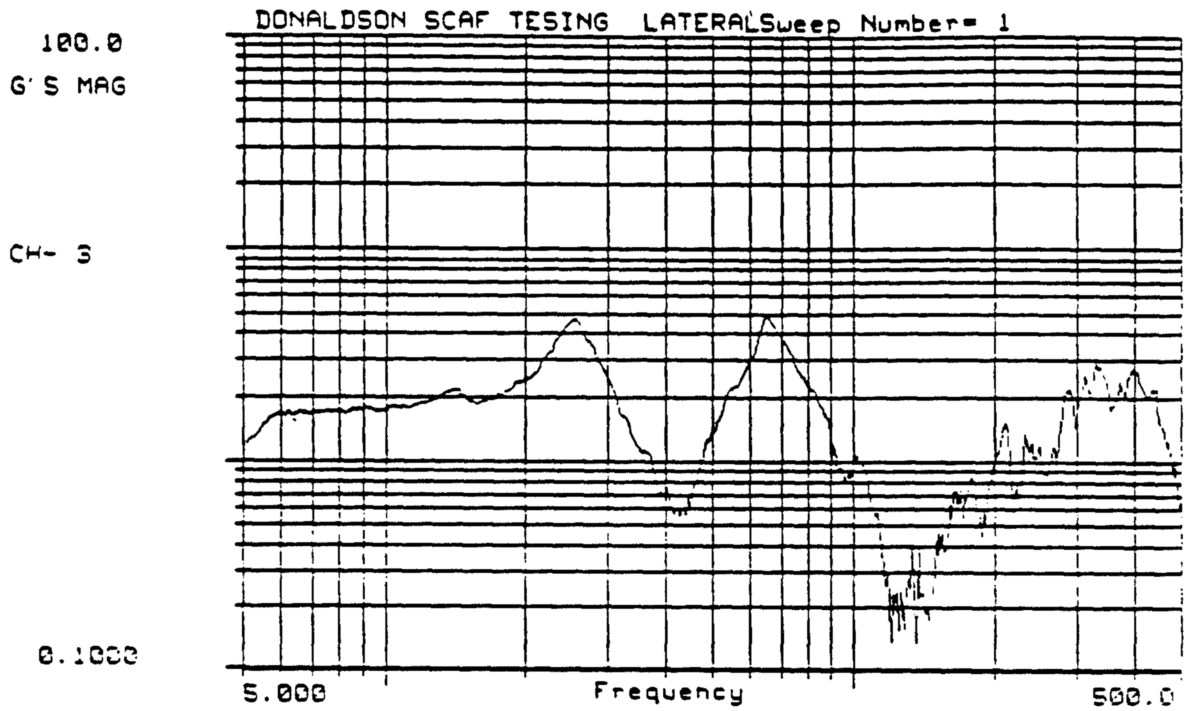
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	14
Resp. Loc	#5	Footage	
Resp. Accel	BD56	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON1

3/14/89 CH- 3: LINE #2 Loc #7
DONALDSON SCAF TESTING

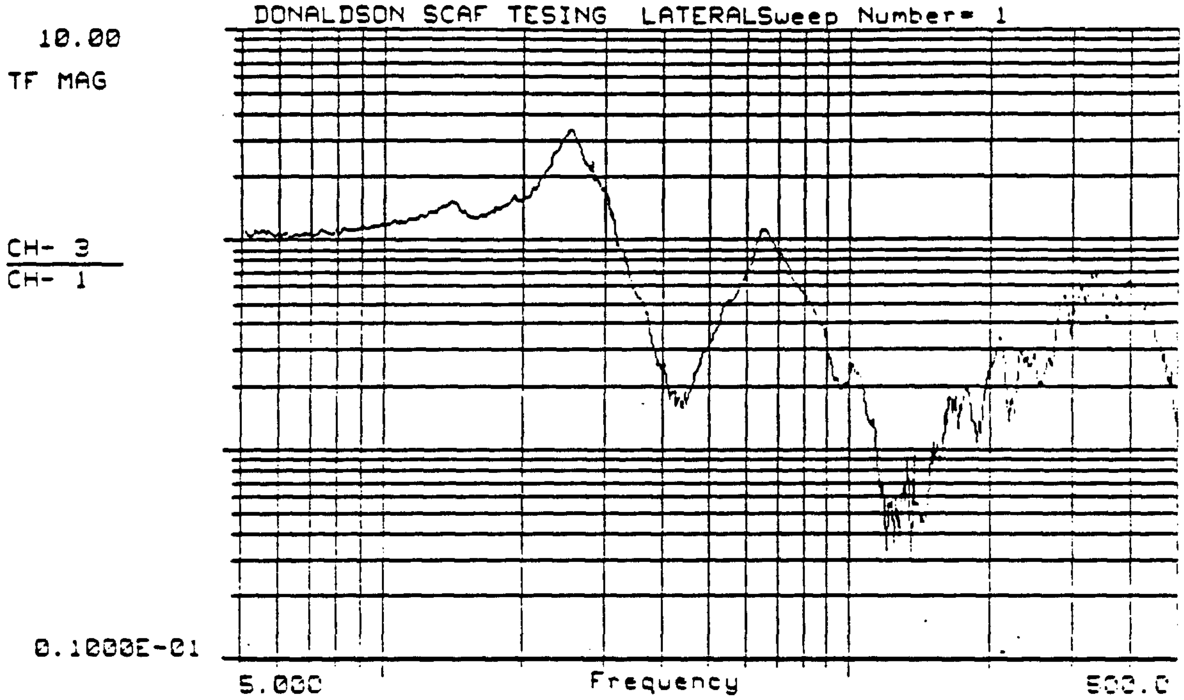
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON1

CH- 3: LINE #2 Loc #7

3/14/89 CH- 1: CONTROL

DONALDSON SCAF TESTING

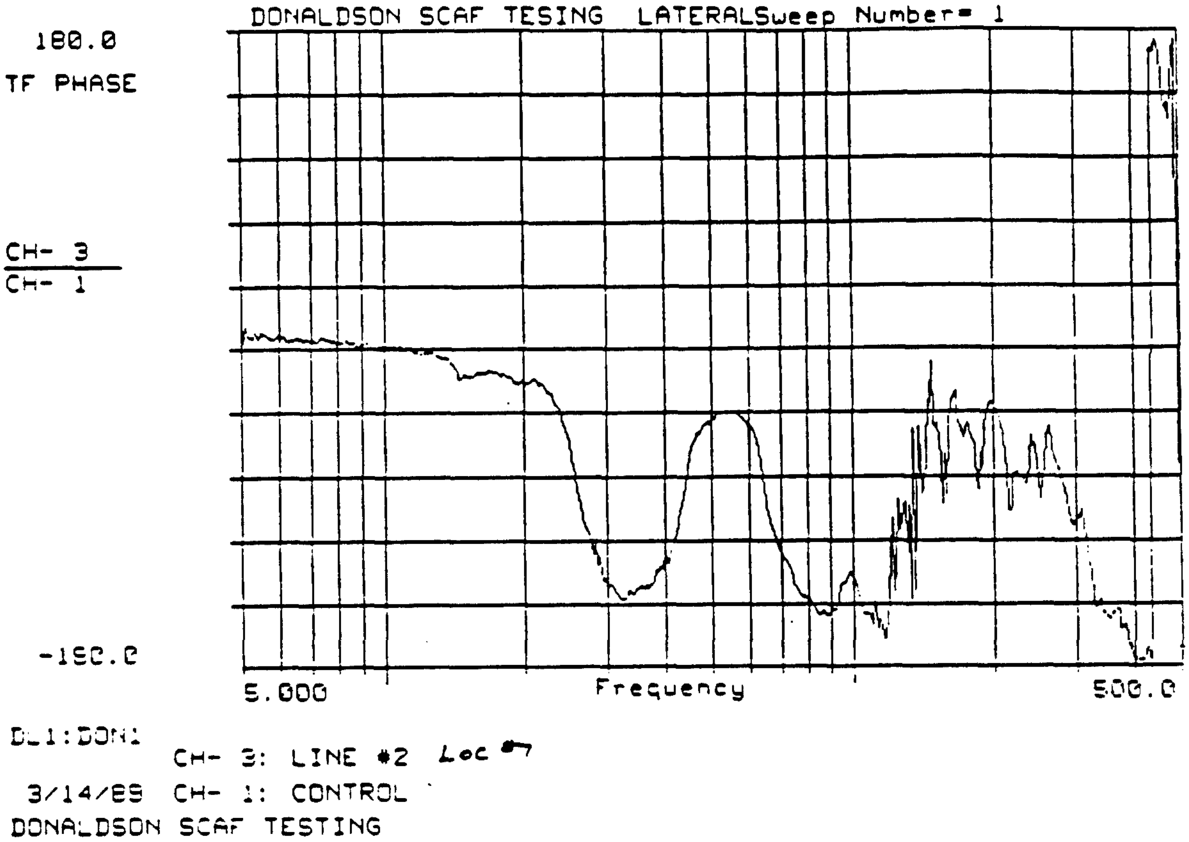
E·

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



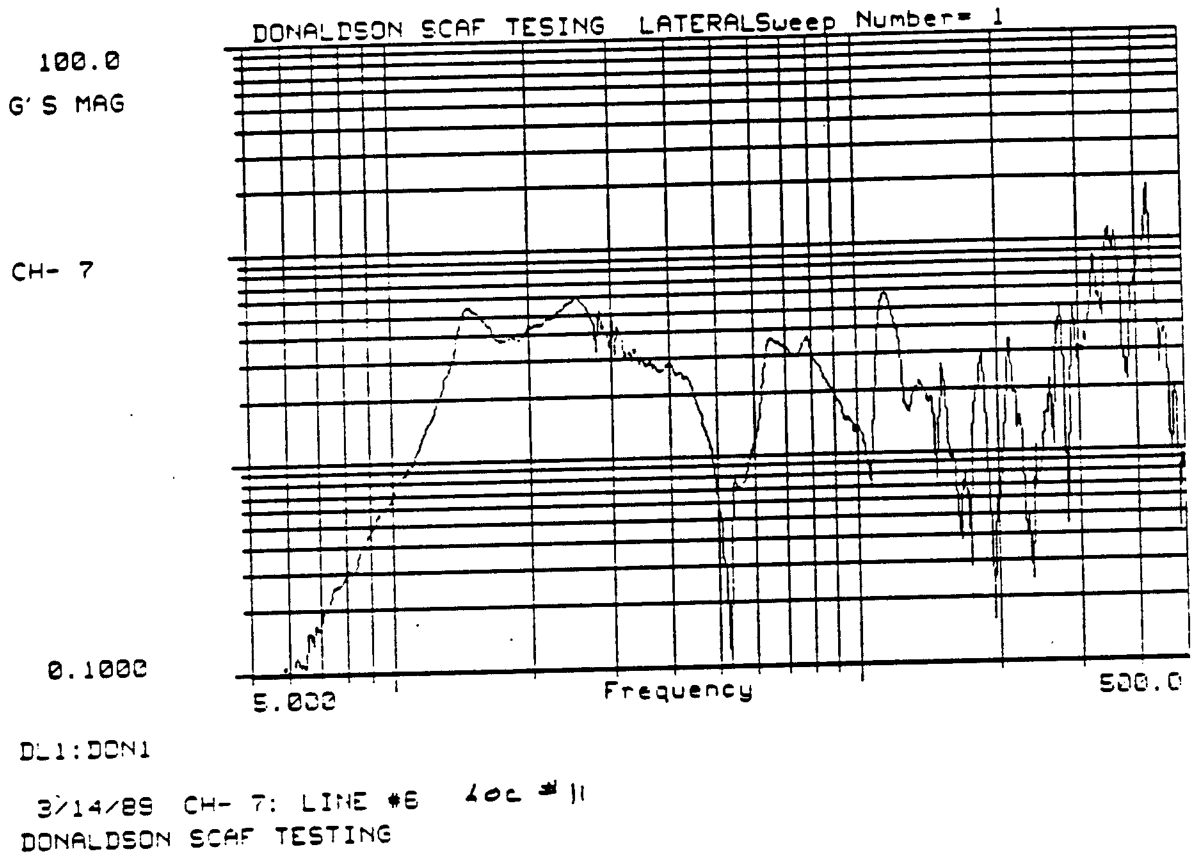
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



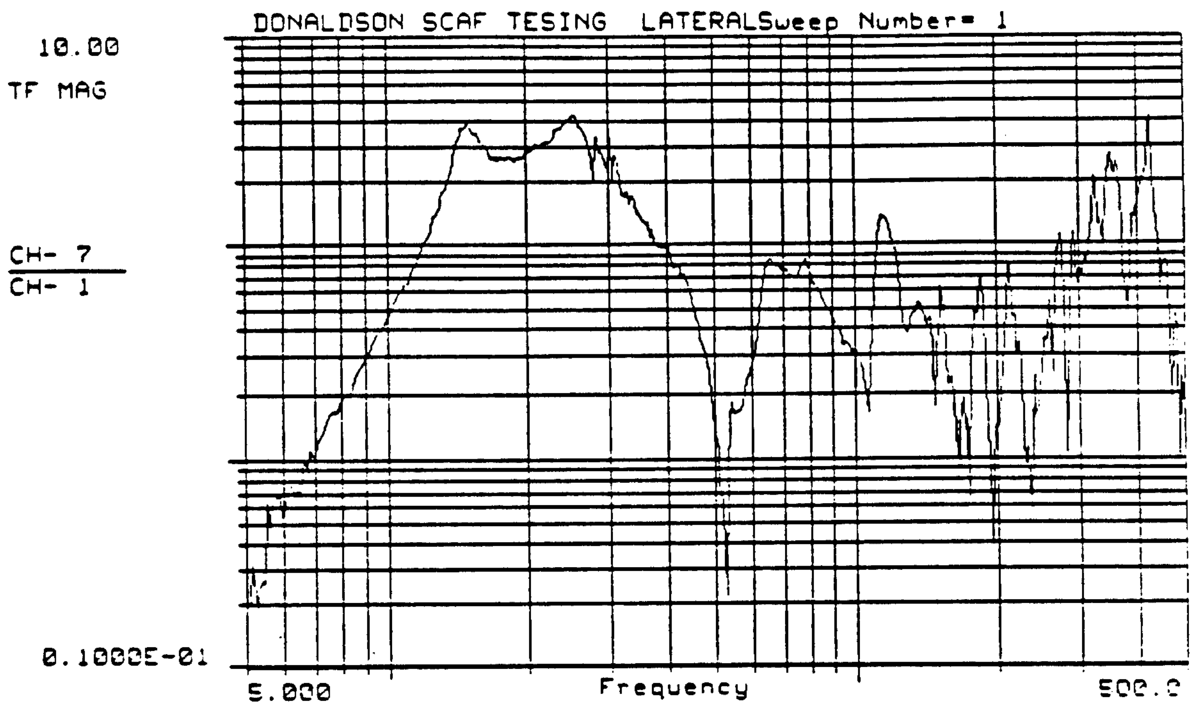
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON1
CH- 7: LINE #5 Loc #11
3/14/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

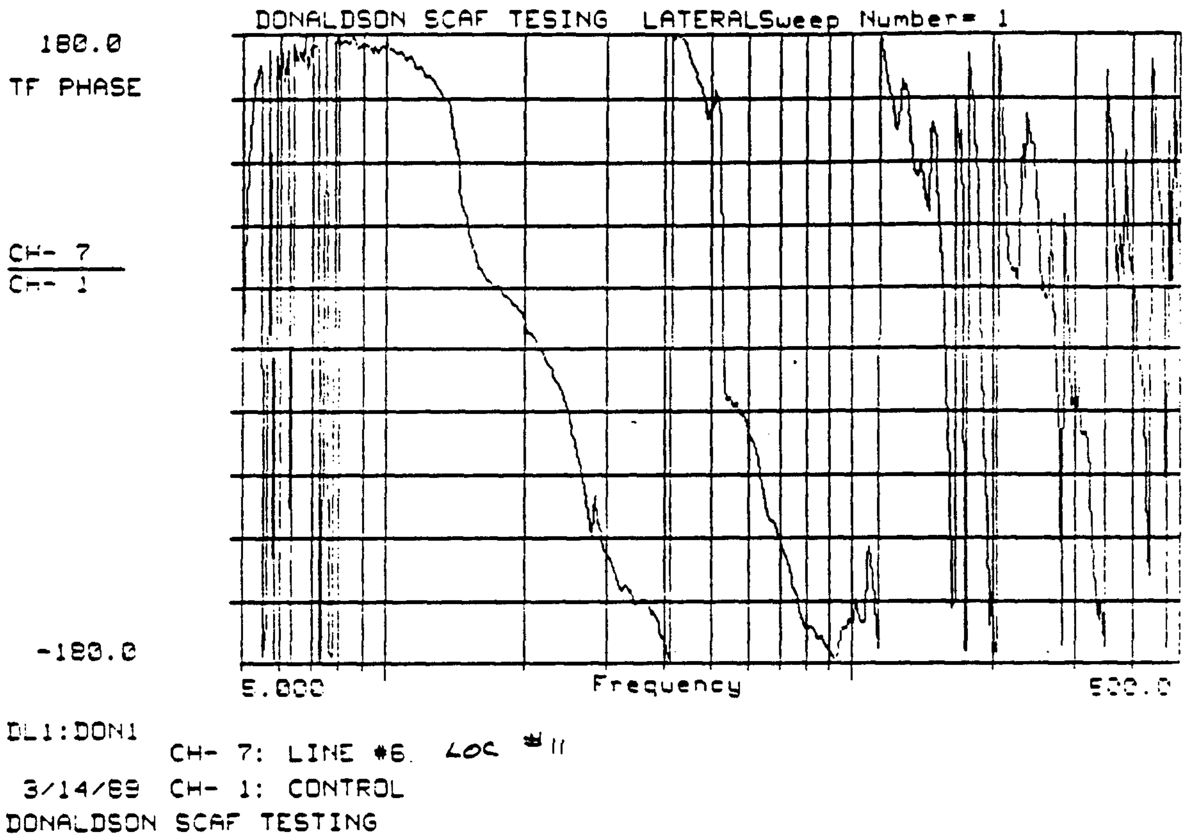
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



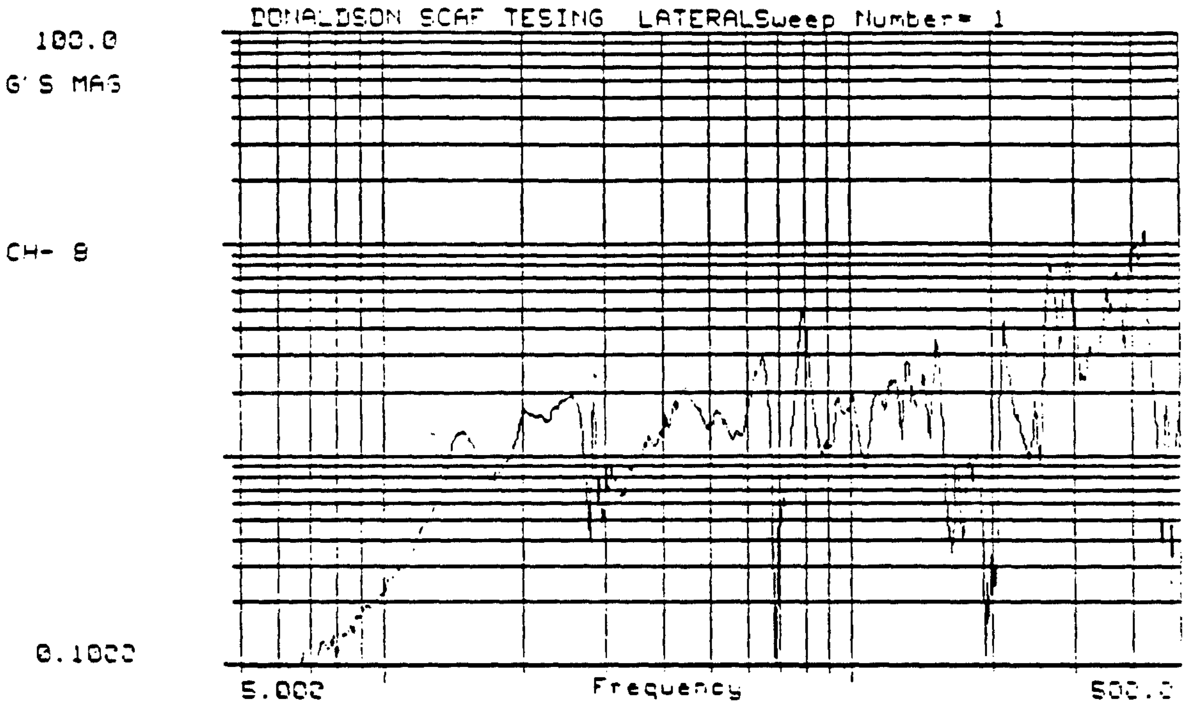
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON1

3/14/89 CH- 8: LINE #7 Loc #12
DONALDSON SCAF TESTING

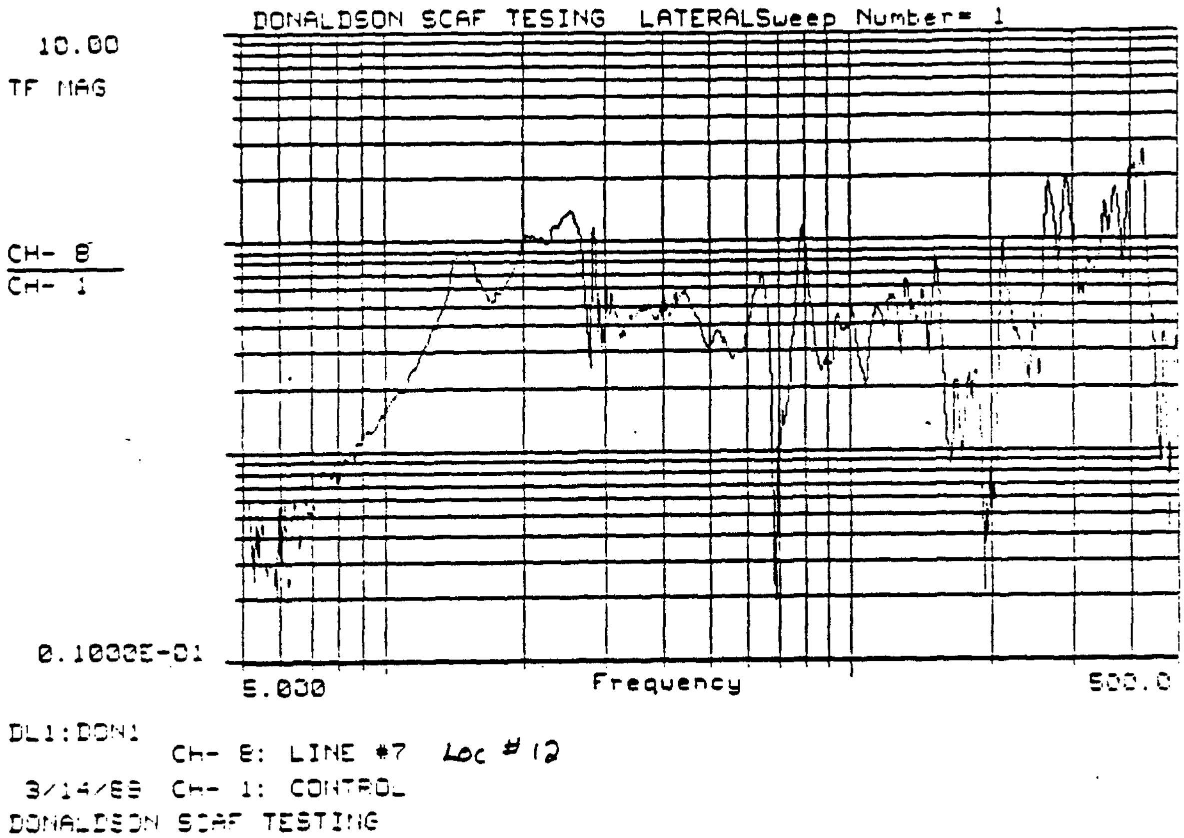
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



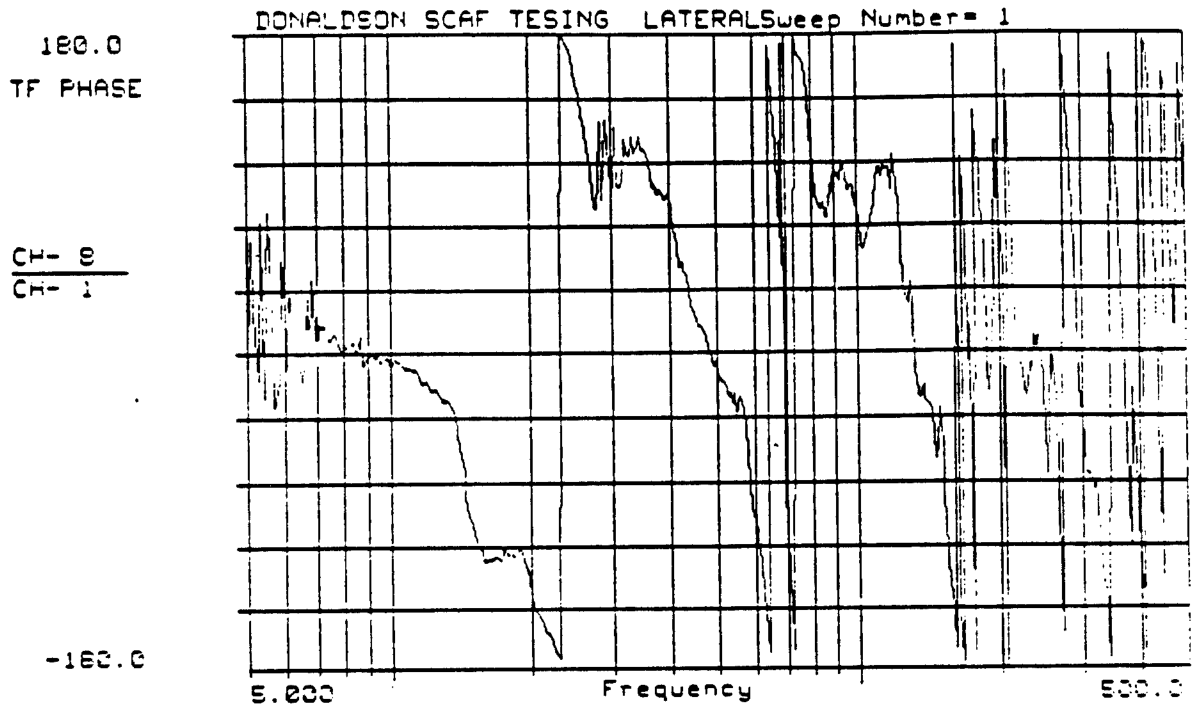
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON1
CH- 8: LINE #7 *Loc # 12*
3/14/88 CH- 1: CONTROL
DONALDSON SCAF TESTING

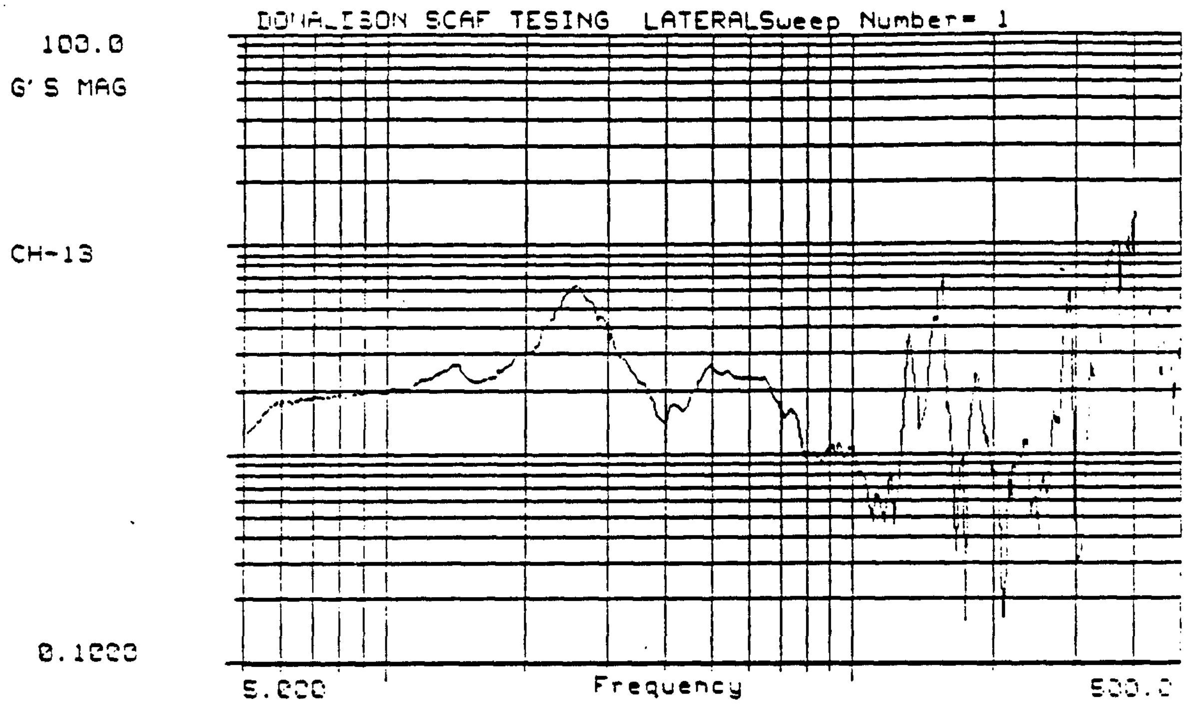
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON1

3/14/89 CH-13: LINE #12 Loc #13
DONALDSON SCAF TESTING

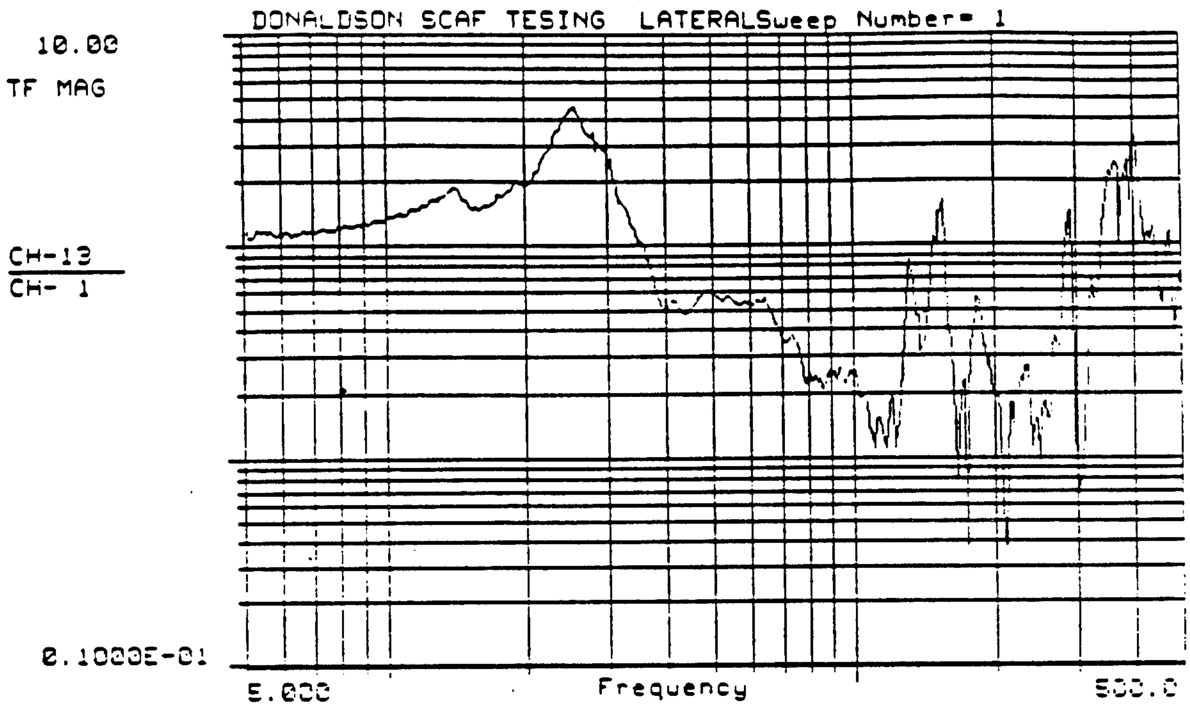
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	13
Resp. Loc	#13	Footage	
Resp. Accel	BA37	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON1
CH-13: LINE #12 LOC #13
3/14/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

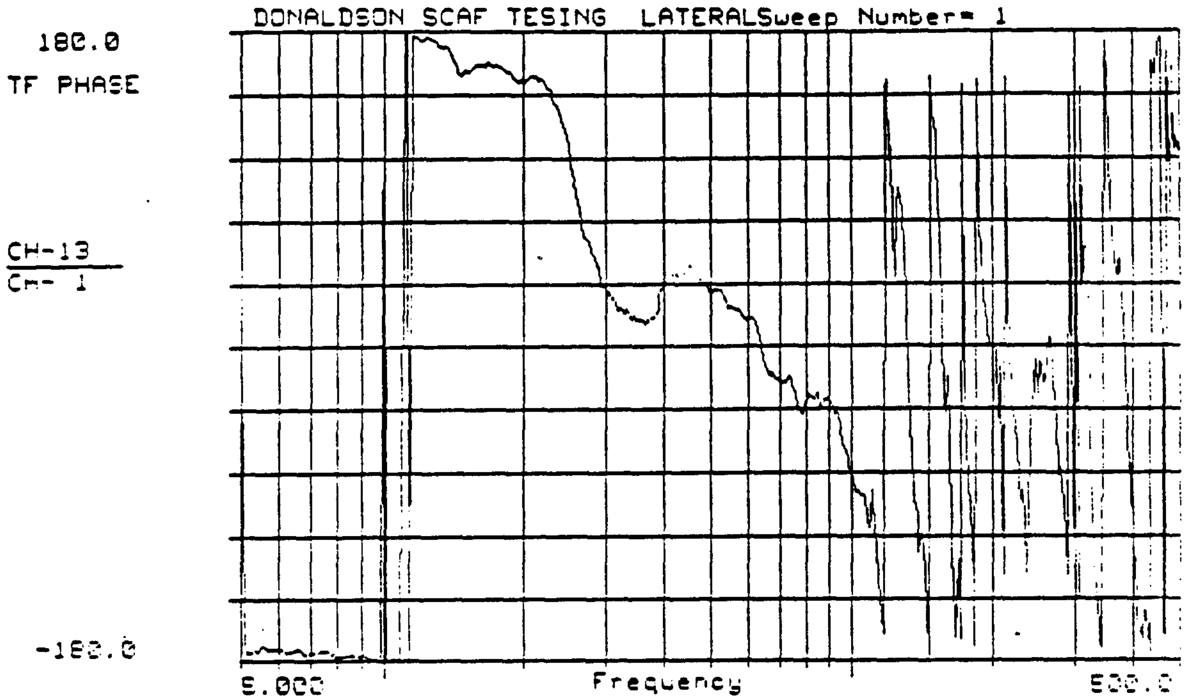
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	13
Resp. Loc	#13	Footage	
Resp. Accel	BA37	Filename	DL1:Don1.swp
Test Temp	[illegible]M	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON1
CH-13: LINE #12 Loc #13
3/14/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

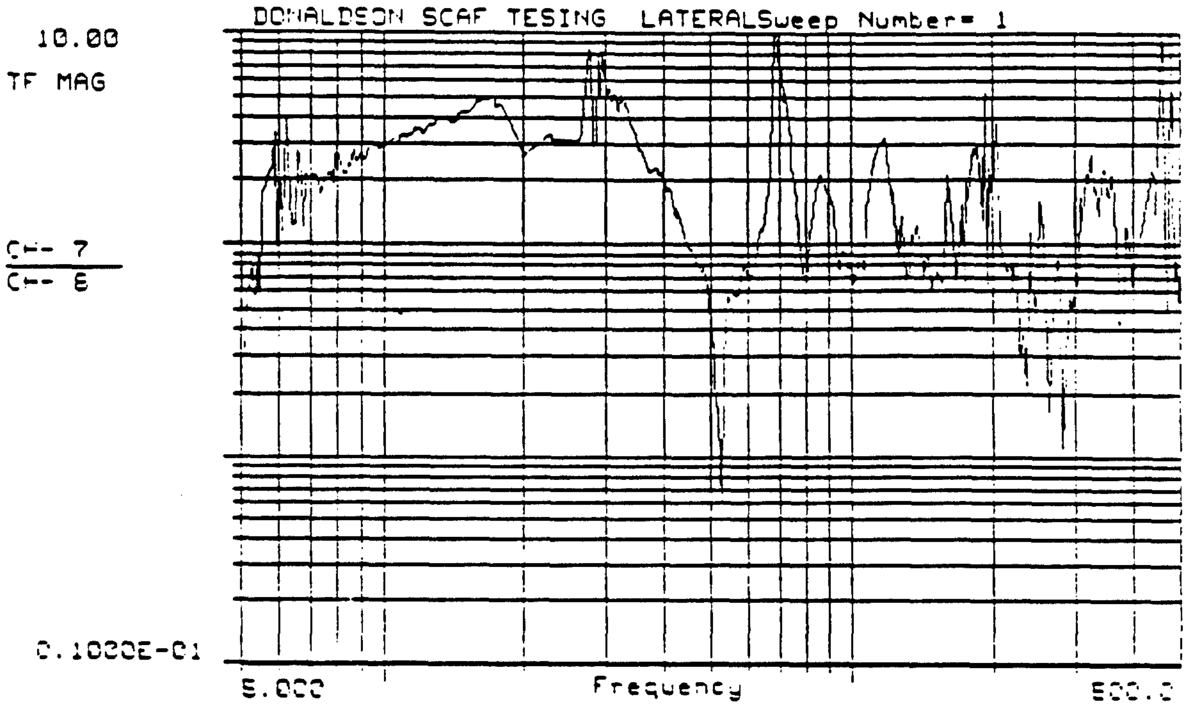
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	13
Resp. Loc	#13	Footage	
Resp. Accel	BA37	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON1
CH- 7: LINE #8 Loc #11
3/14/89 CH- 8: LINE #7 Loc #12
DONALDSON SCAF TESTING

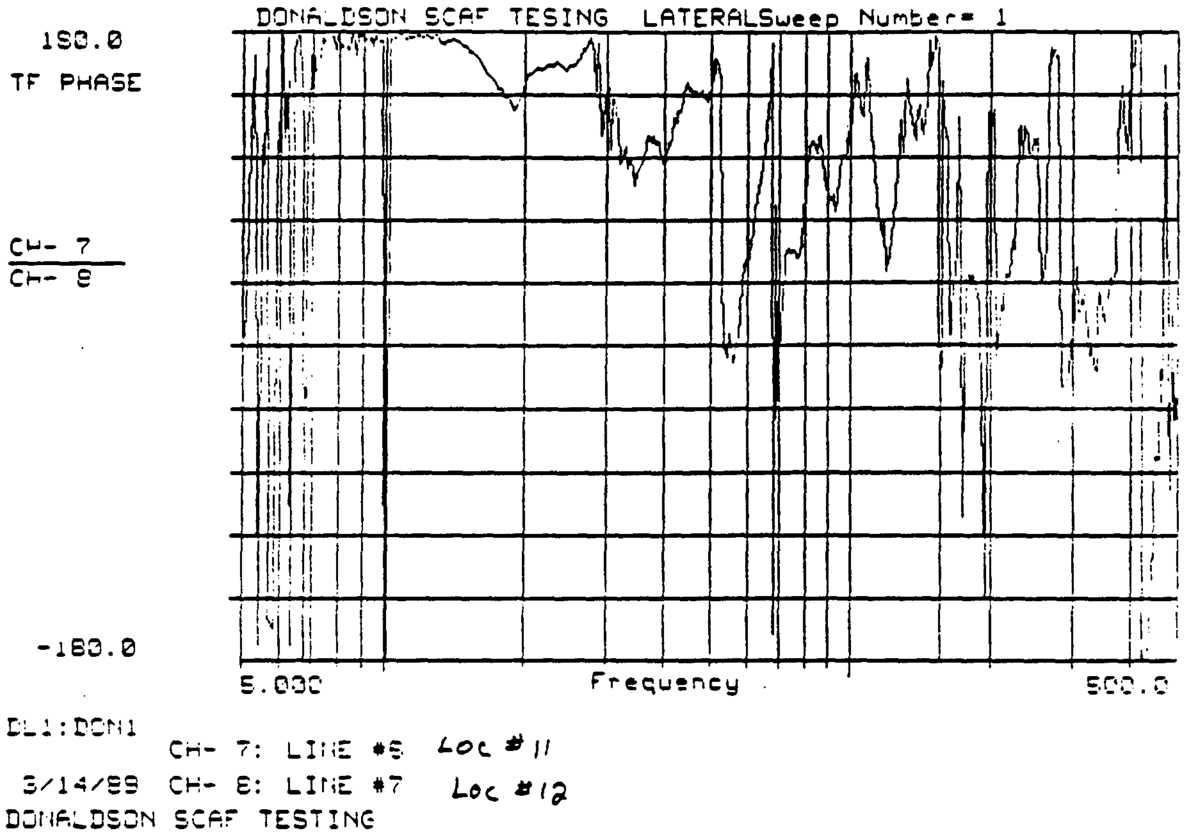
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 vs. #12	Footage	
Resp. Accel	BF83/BF82	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



E

Honeywell Hopkins Sine Vibration

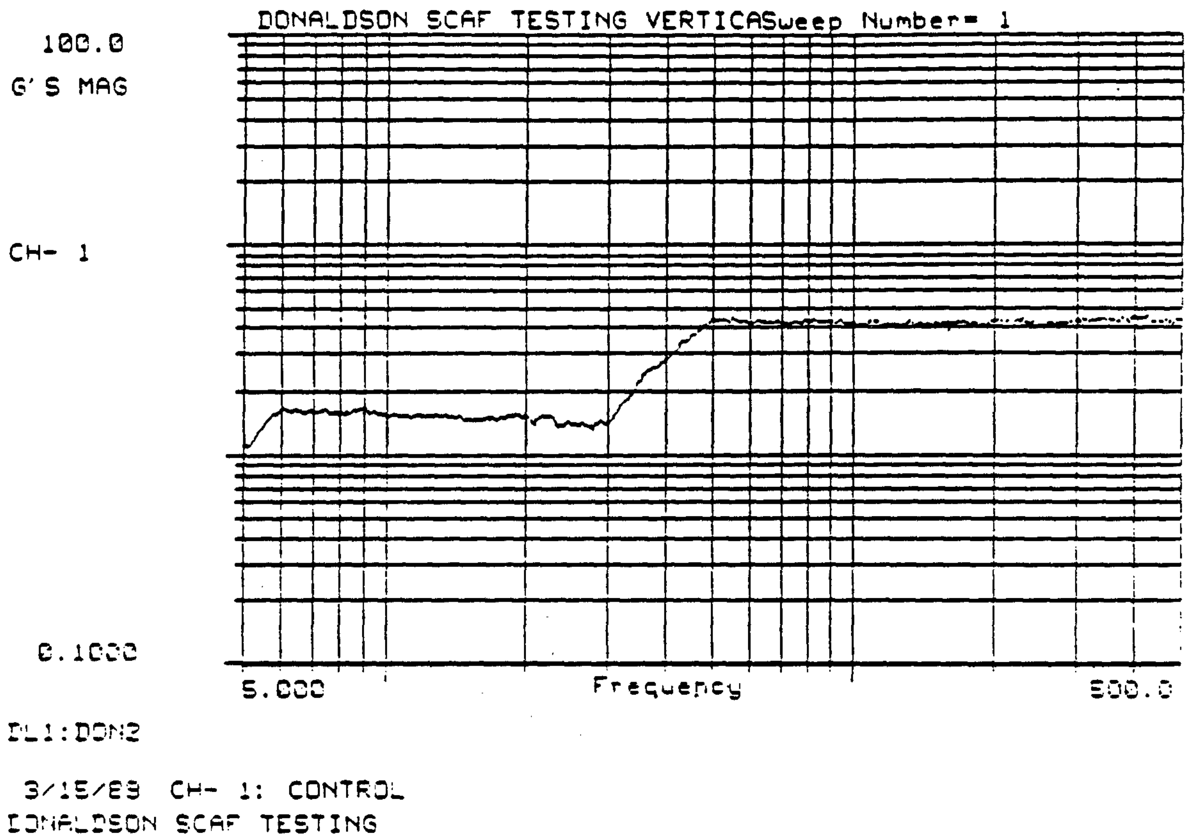
OEXM #	30,299D	Test Date	14-MAR-89
Input Axis	Lateral	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 vs. #12	Footage	
Resp. Accel	BF83/BF82	Filename	DL1:Don1.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase

APPENDIX B
VERTICAL AXIS INPUT

15-MARCH-1989
Gear Box Removed
4-strut Configuration



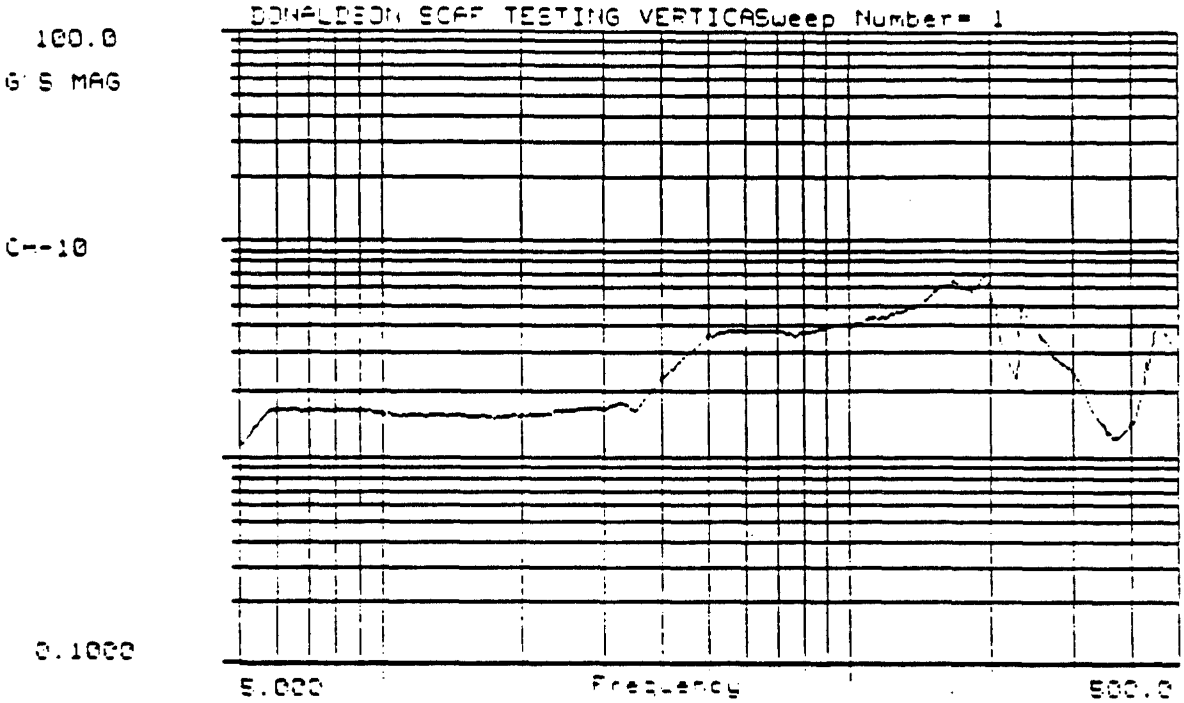
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	vertical	Unfiltered	
		Tape Chn.	1
Resp. Loc	CONTROL	Footage	
Resp. Accel	394	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2

3/15/89 CH-10: LOC. #2
DONALDSON SCAF TESTING

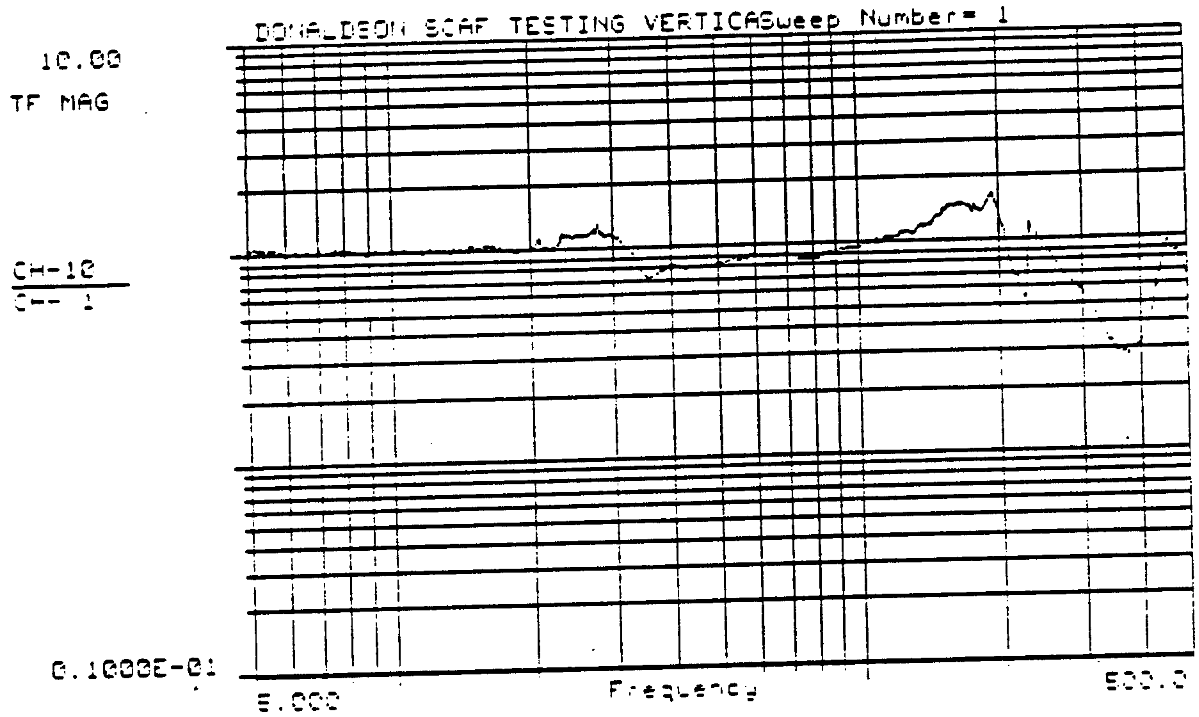
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	10
Resp. Loc	#2	Footage	
Resp. Accel	BK70	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2
CH-10: LOC. #2
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

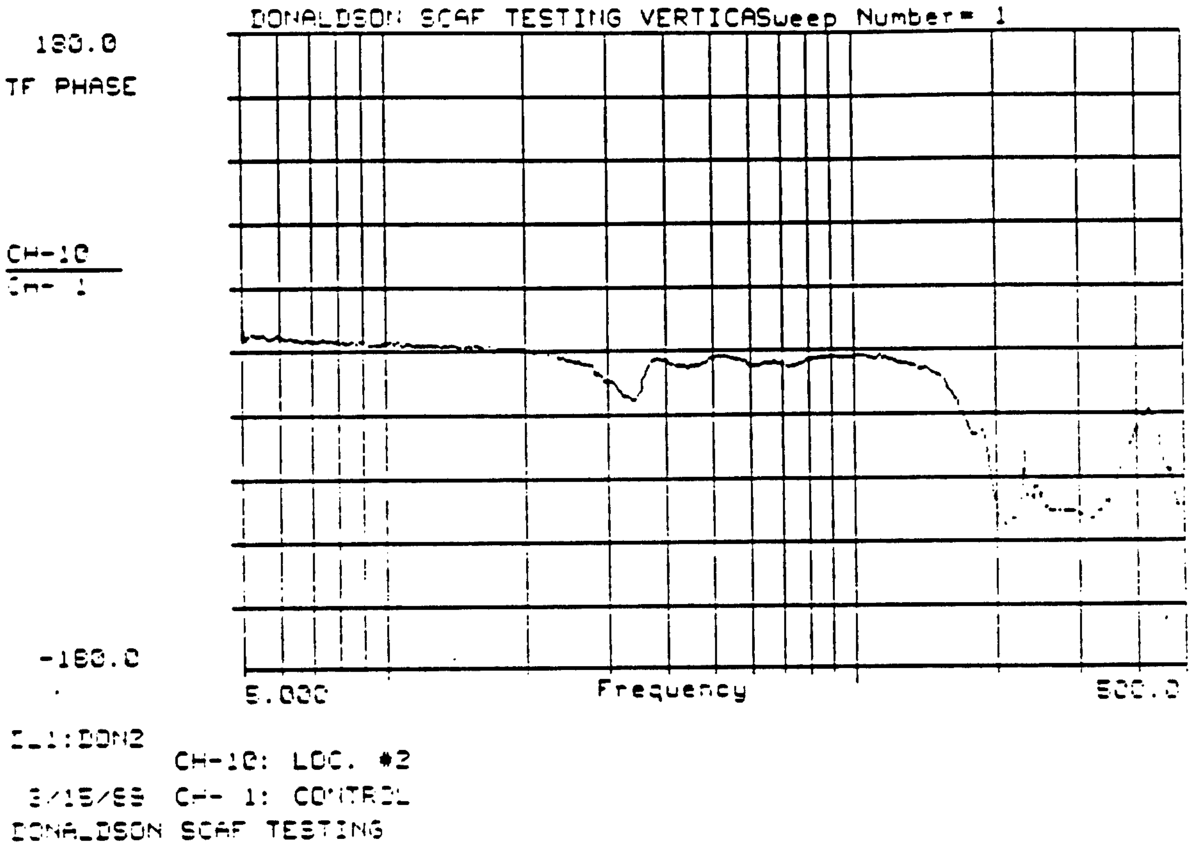
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	10
Resp. Loc	#2	Footage	
Resp. Accel	BK70	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



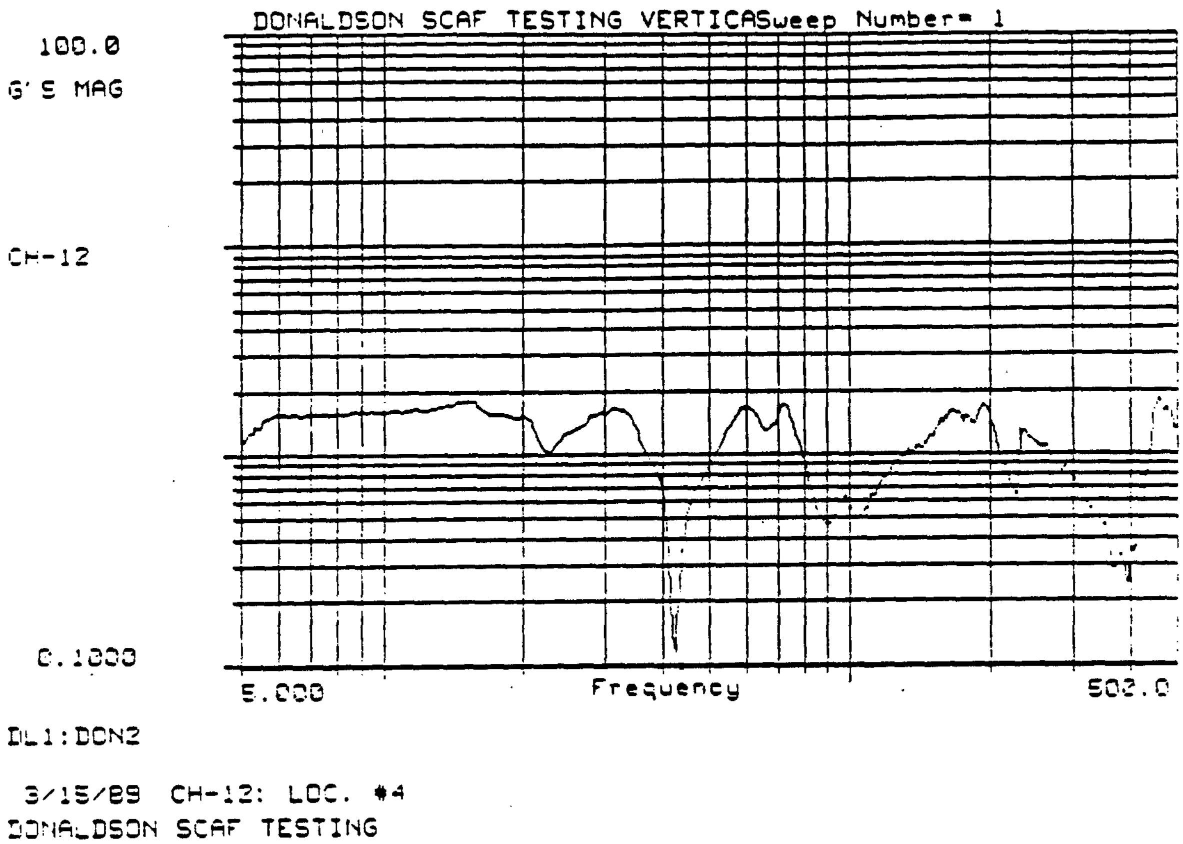
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	10
Resp. Loc	#2	Footage	
Resp. Accel	BK70	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



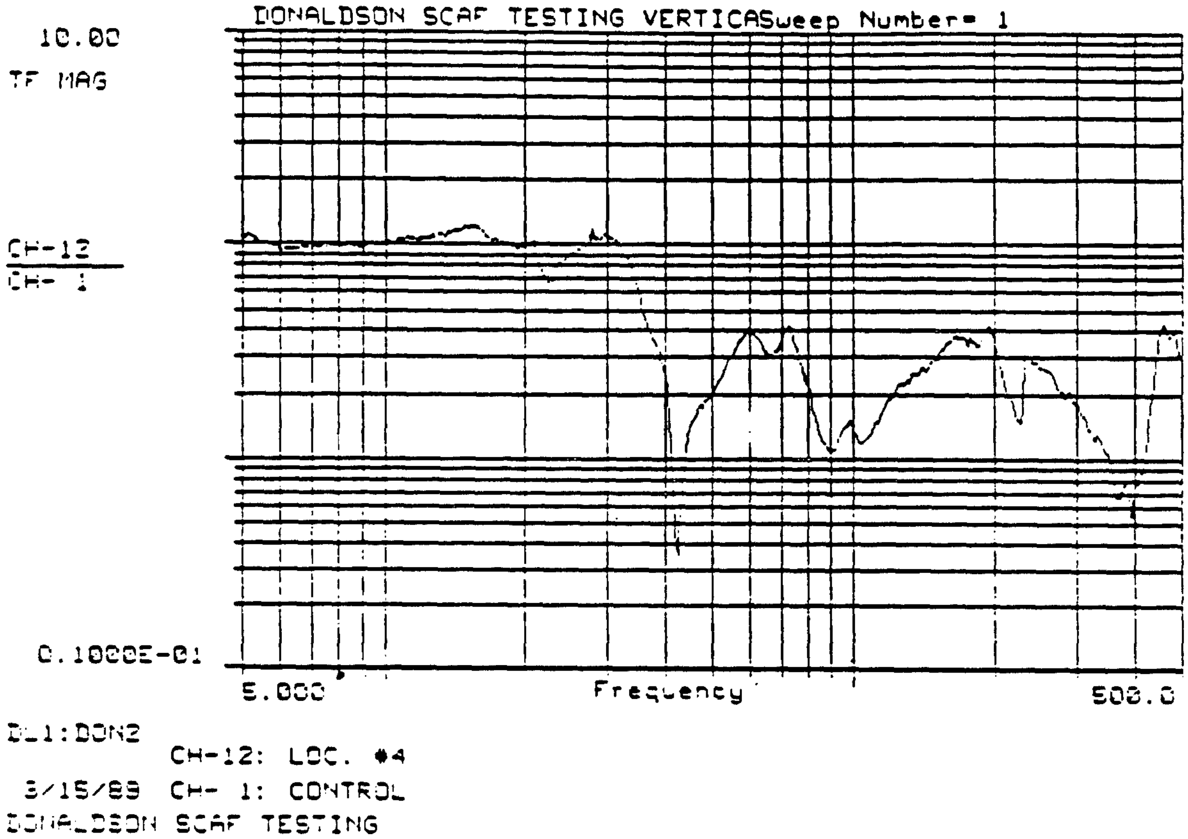
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	12
Resp. Loc	#4	Footage	
Resp. Accel	KF49	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



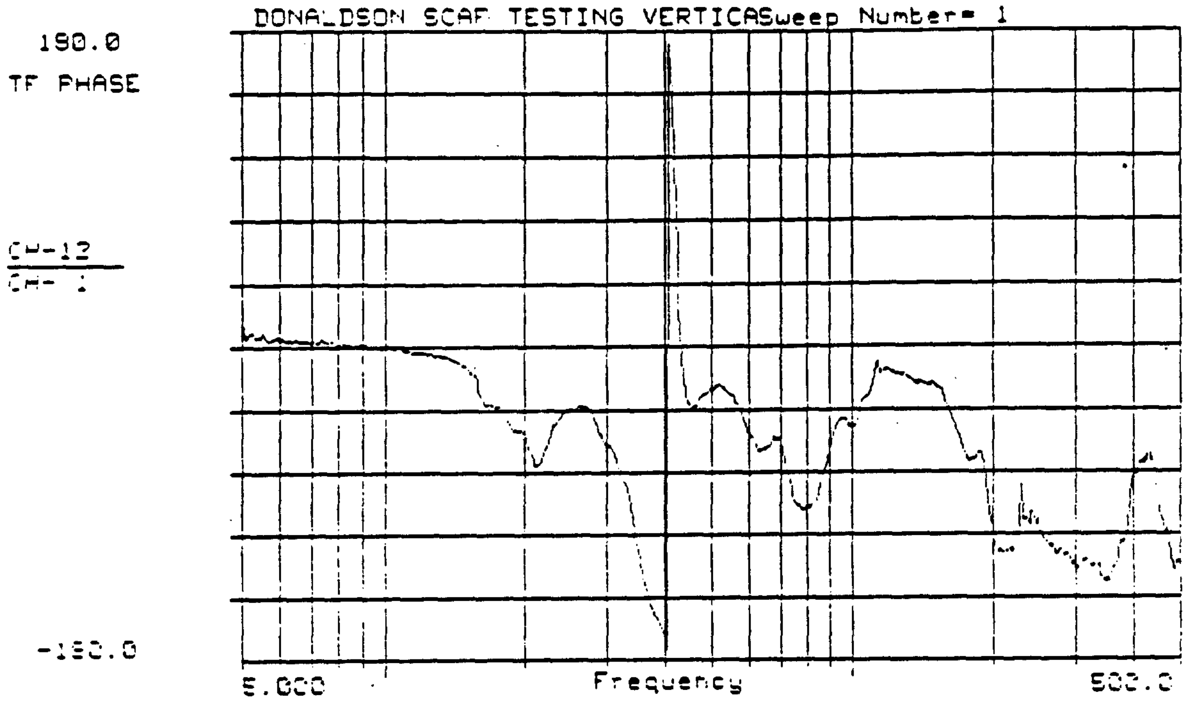
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	12
Resp. Loc	#4	Footage	
Resp. Accel	KF49	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON2
CH-12: LOC. #4
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

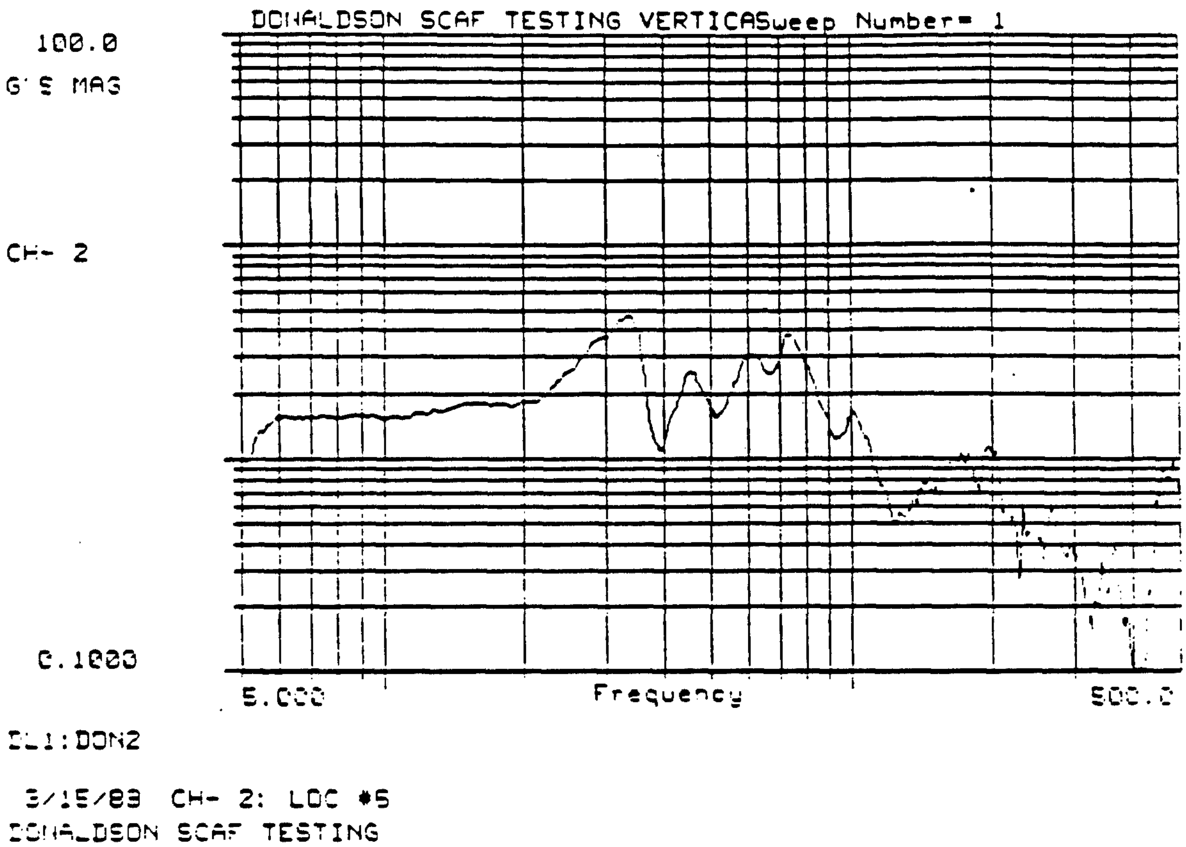
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	12
Resp. Loc	#4	Footage	
Resp. Accel	KF49	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



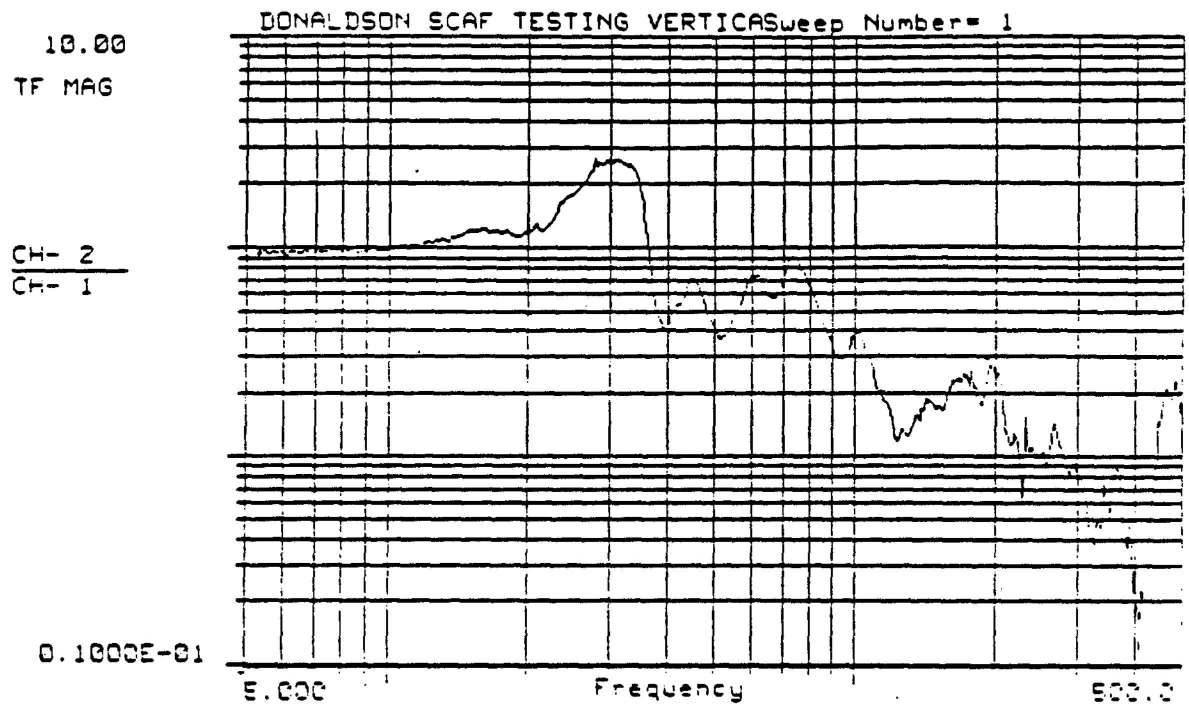
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6	Footage	
Resp. Accel	BK69	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2
CH- 2: LOC #6
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

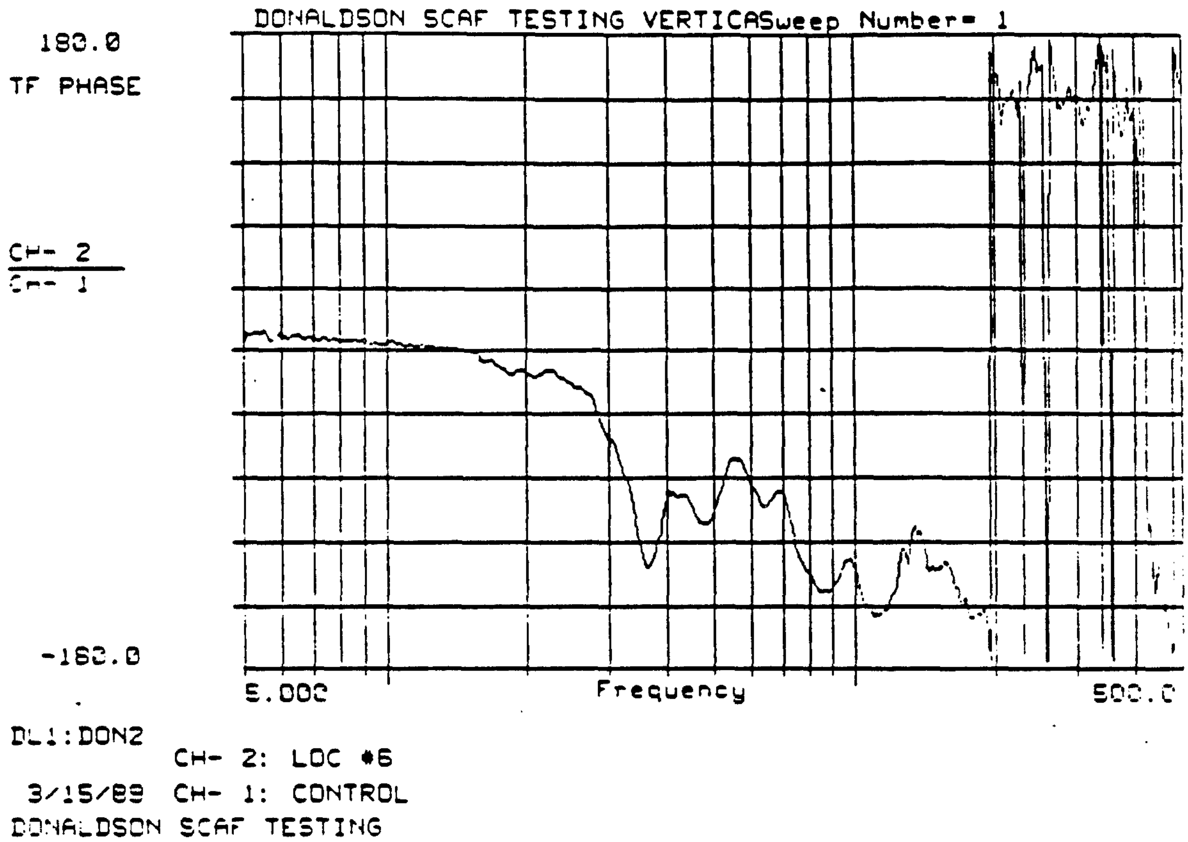
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6.	Footage	
Resp. Accel	BK69	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



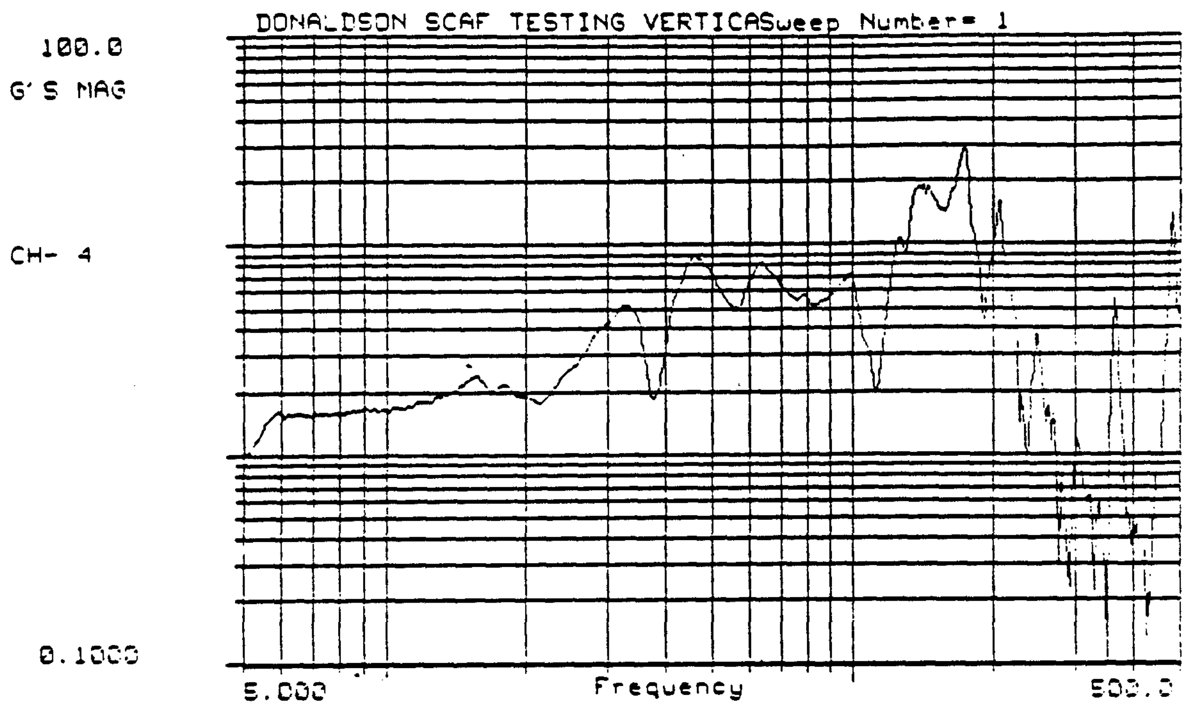
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6	Footage	
Resp. Accel	BK69	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON2

3/15/89 CH- 4: LOC. #8
DONALDSON SCAF TESTING

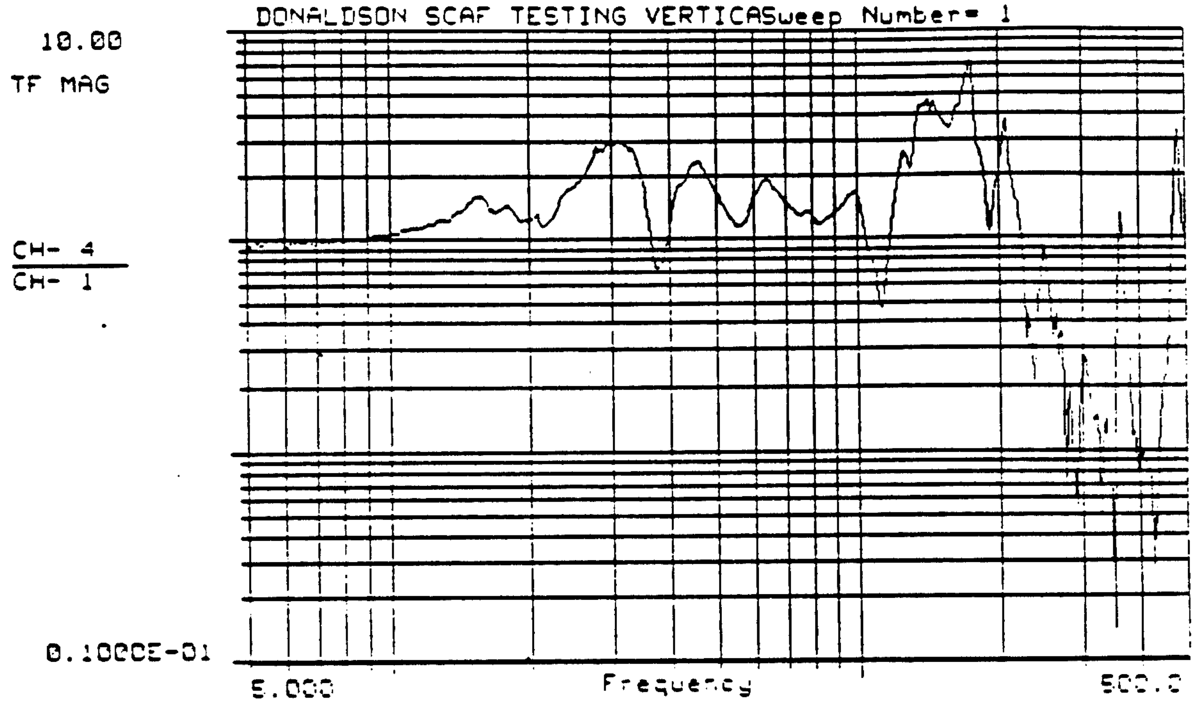
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	4
Resp. Loc	#8	Footage	
Resp. Accel	BK54	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2
CH- 4: LOC. #8
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

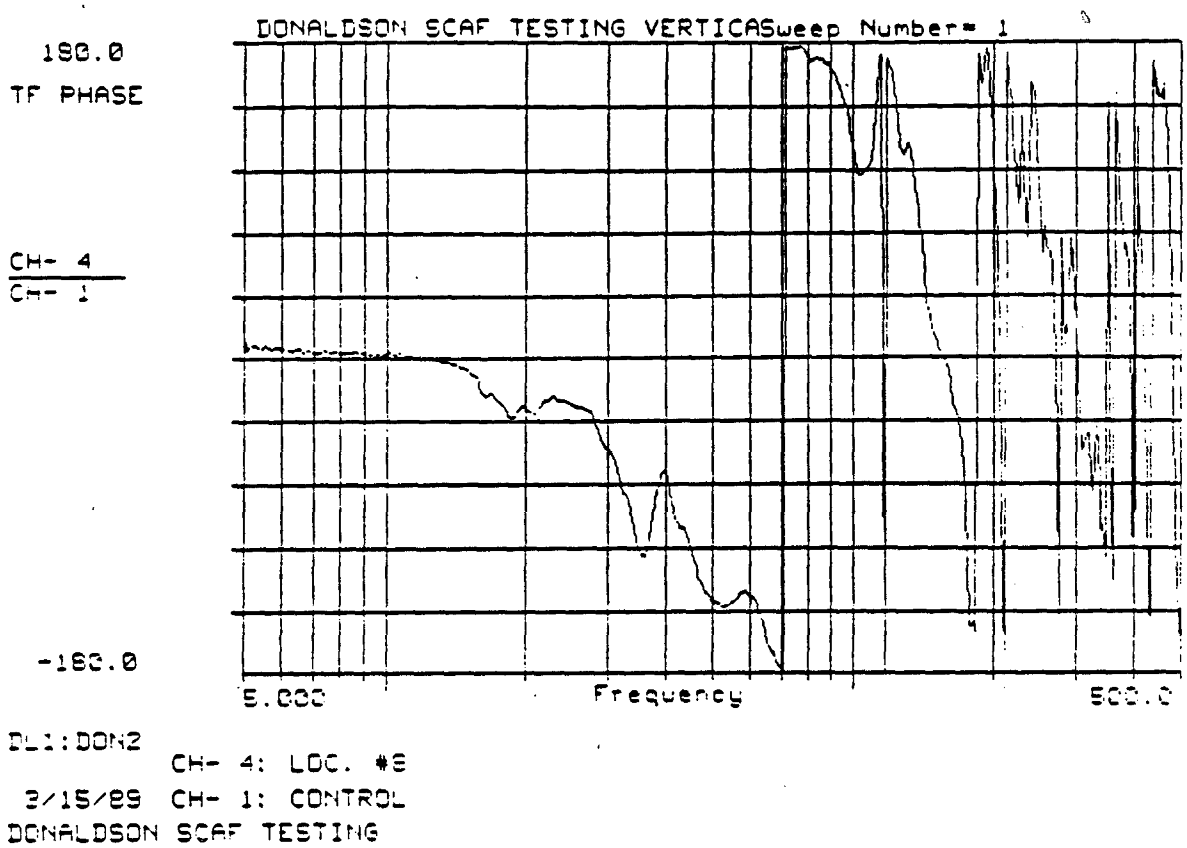
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	4
Resp. Loc	#8	Footage	
Resp. Accel	BR[illegible]	Filename	DL1:Don2.swp
Tes[illegible]	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



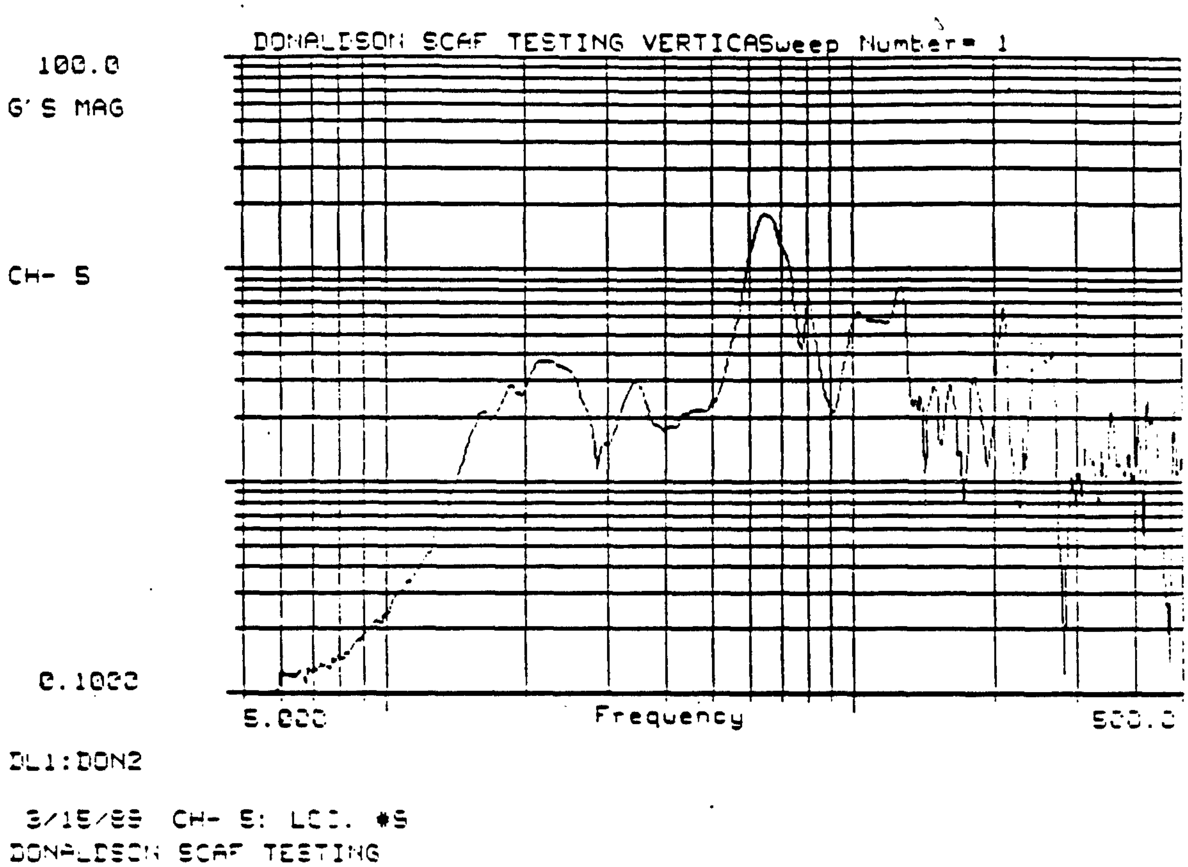
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	4
Resp. Loc	#8	Footage	
Resp. Accel	BK54	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



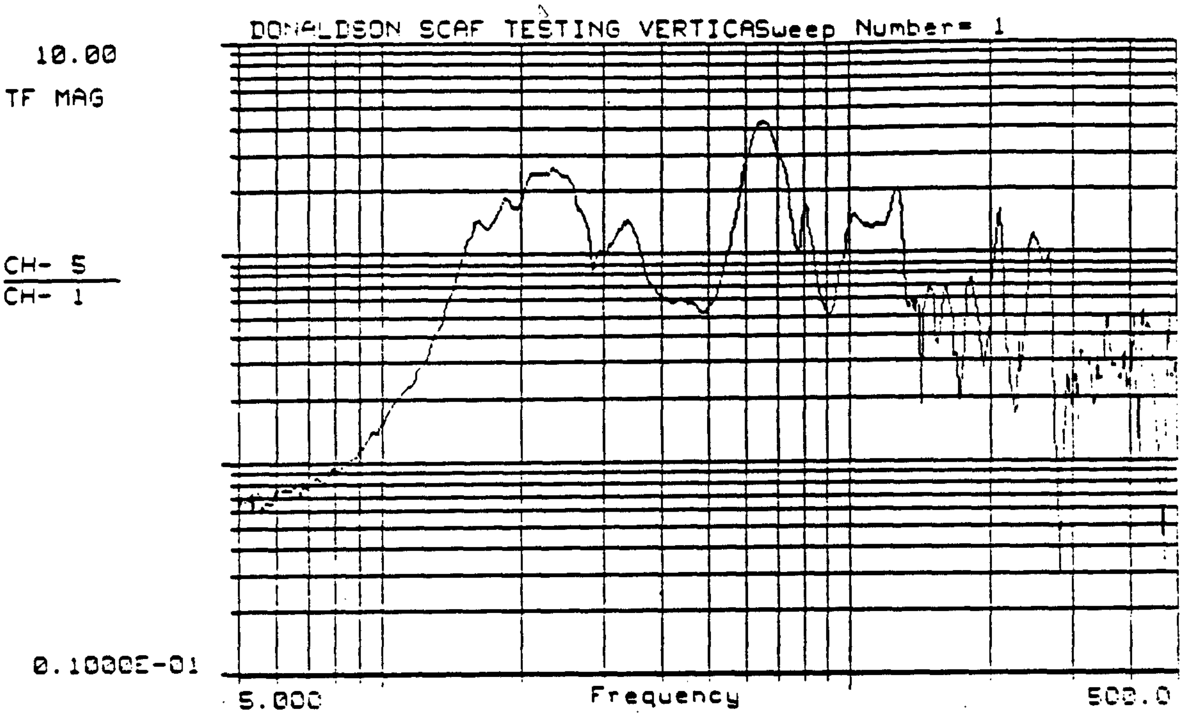
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2
CH- 5: LOC. #9
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

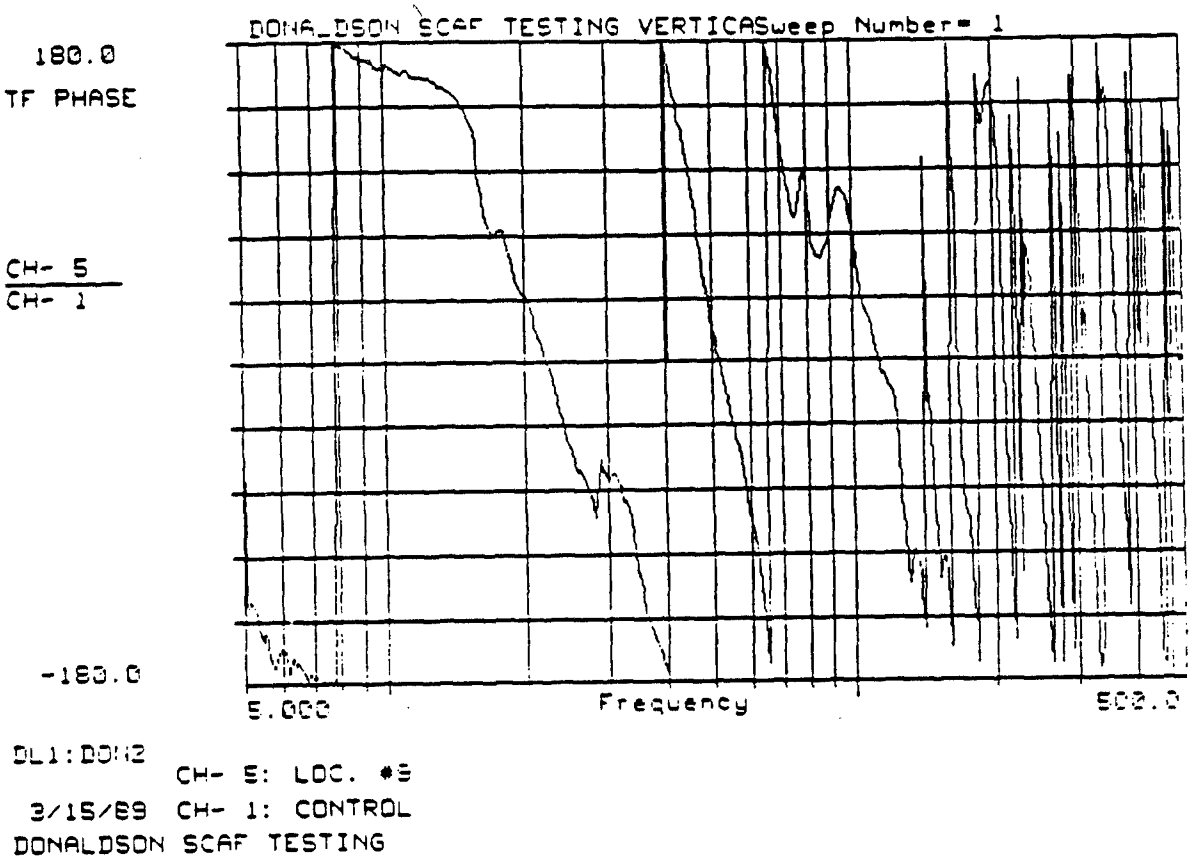
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



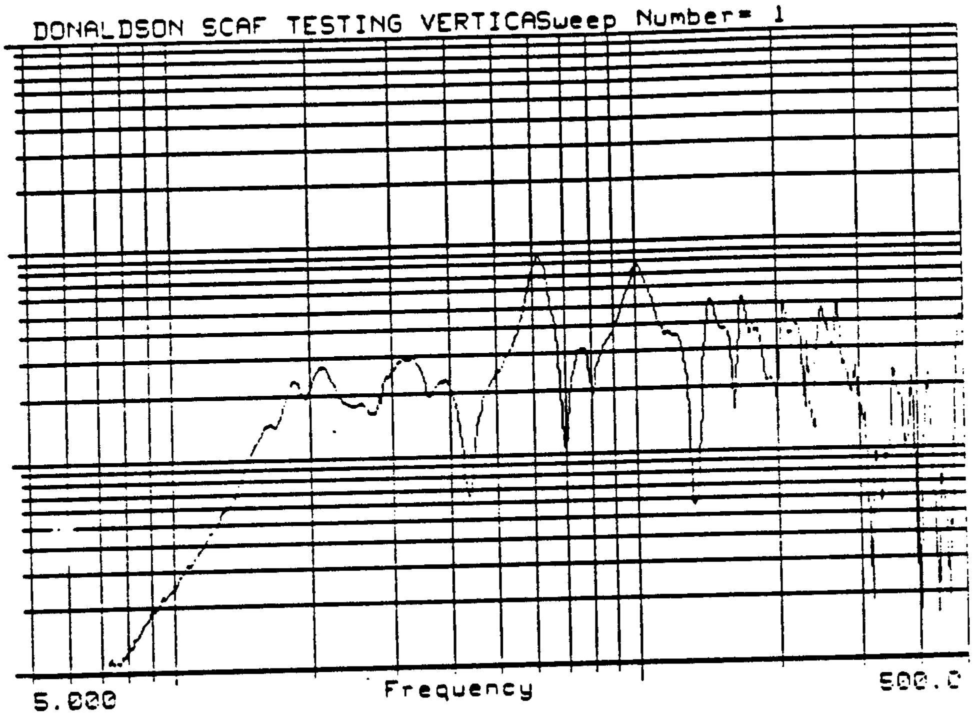
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON2

3/15/89 CH- 6: LOC. #10
DONALDSON SCAF TESTING

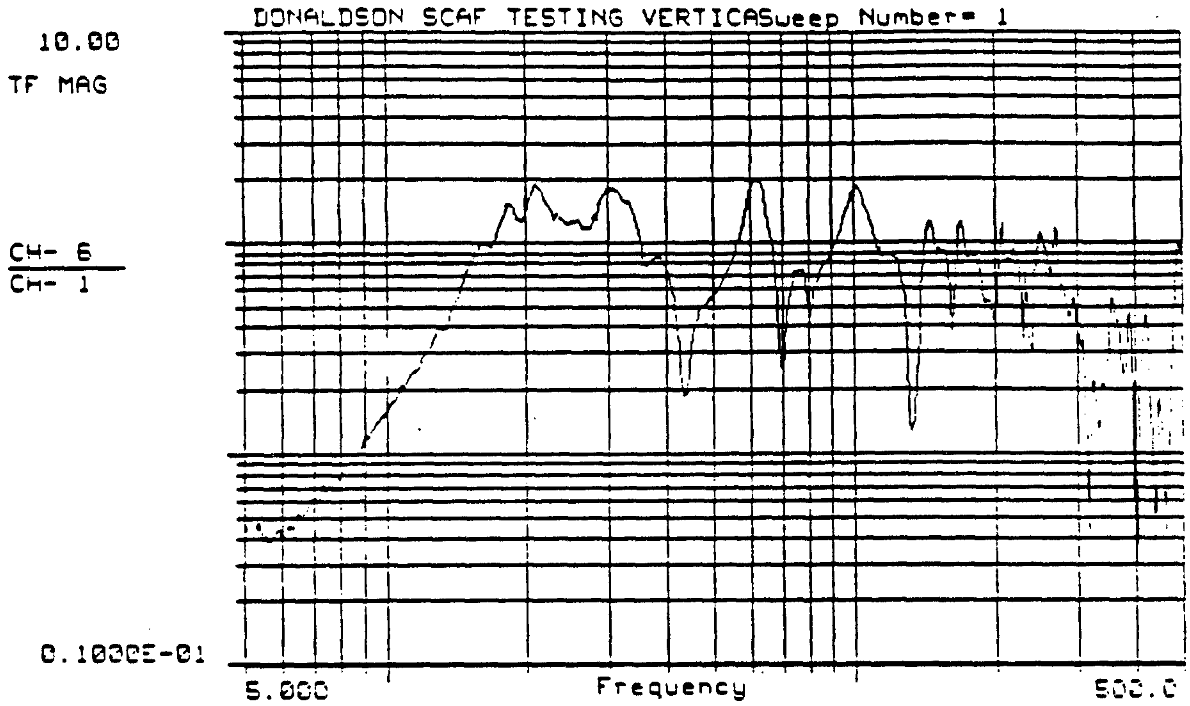
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
		Footage	
Resp. Loc	#10	Filename	DL1:Don2.swp
Resp. Accel	BK65	Operator	A. KENNY
Test Temp	ROOM		

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2
CH- 6: LOC. #10
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

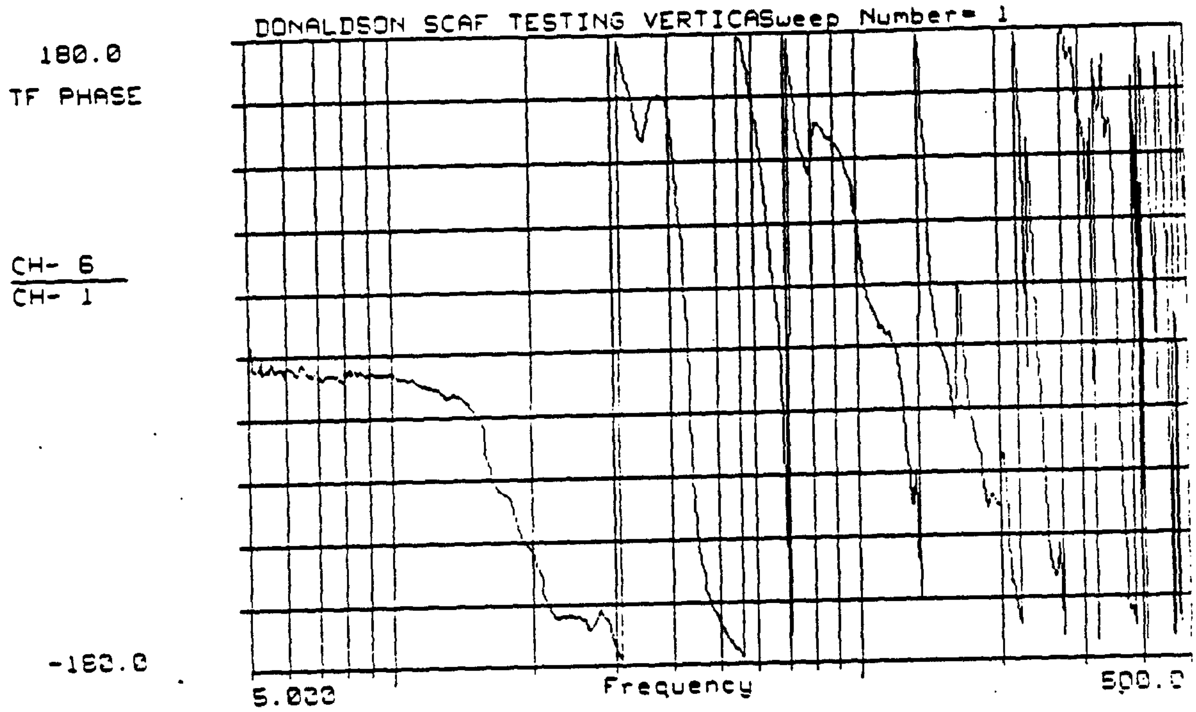
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
Resp. Loc	#10	Footage	
Resp. Accel	BK65	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON2
CH- 6: LOC. #10
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

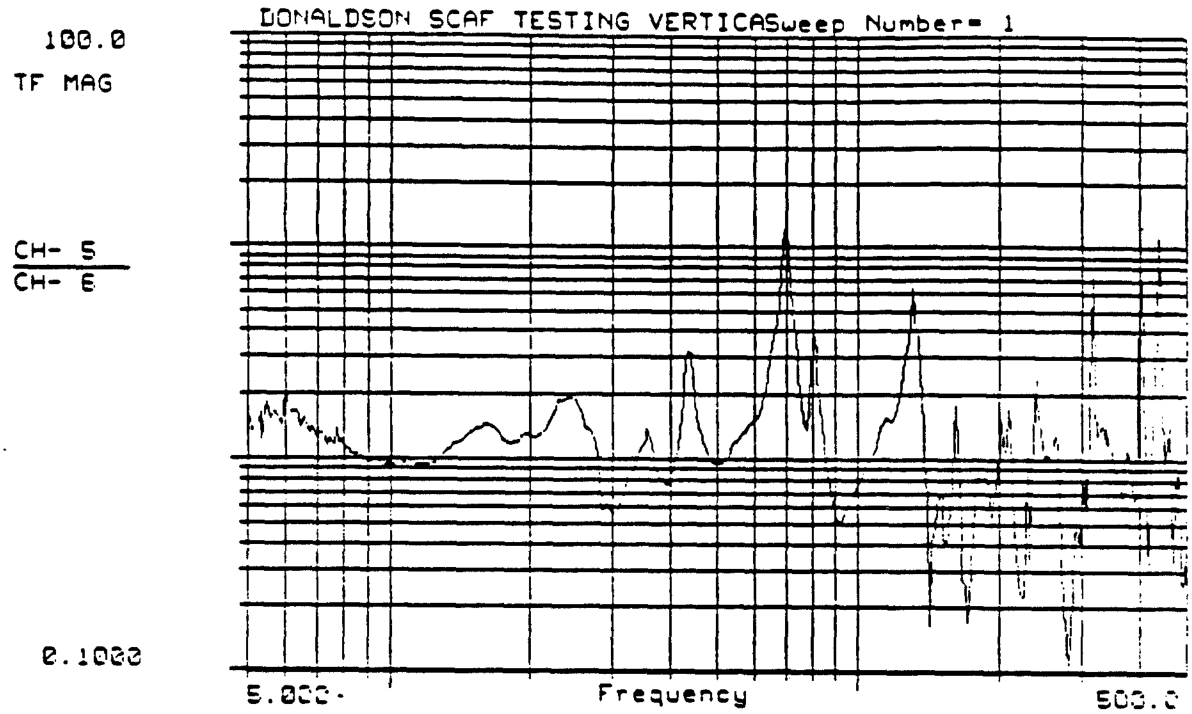
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
Resp. Loc	#10	Footage	
Resp. Accel	BK65	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON2
CH- 5: LOC. #9
3/15/89 CH- 6: LOC. #10
DONALDSON SCAF TESTING

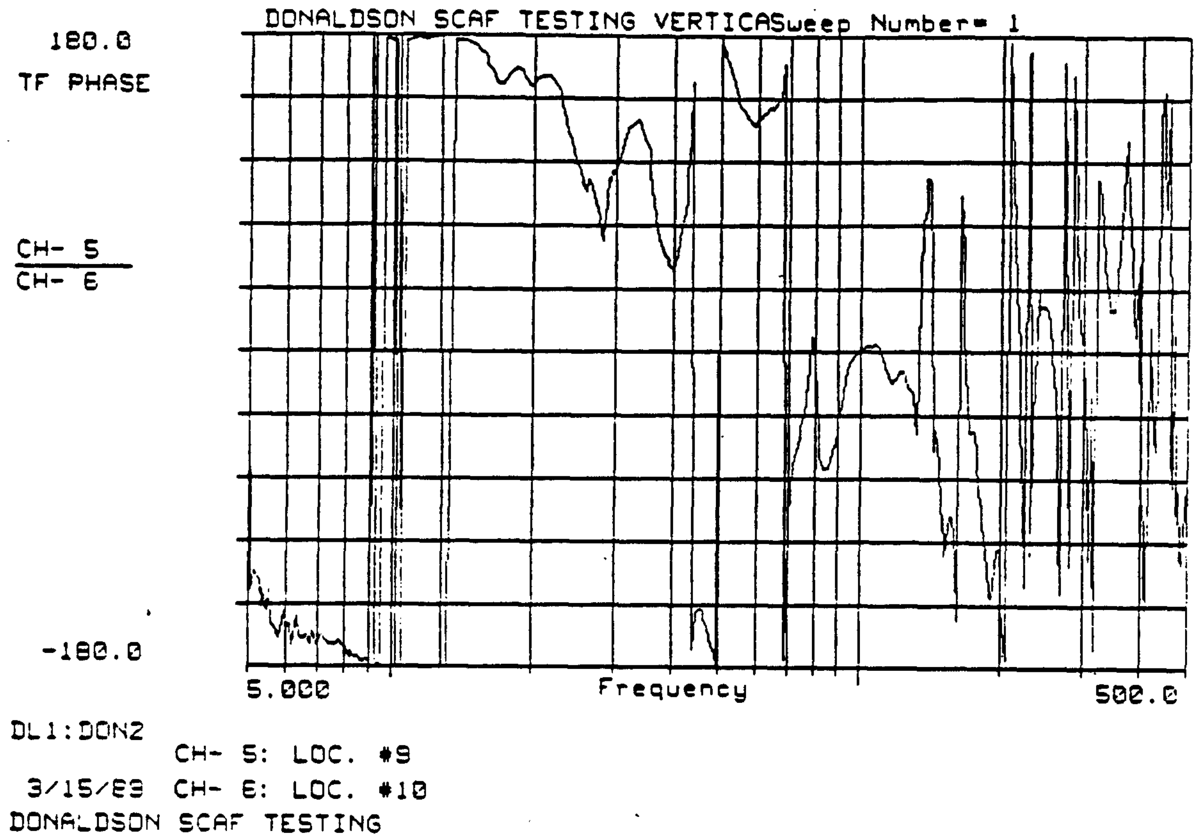
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	5/6
Resp. Loc	#9 VS. #10	Footage	
Resp. Accel	BK63/BK65	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



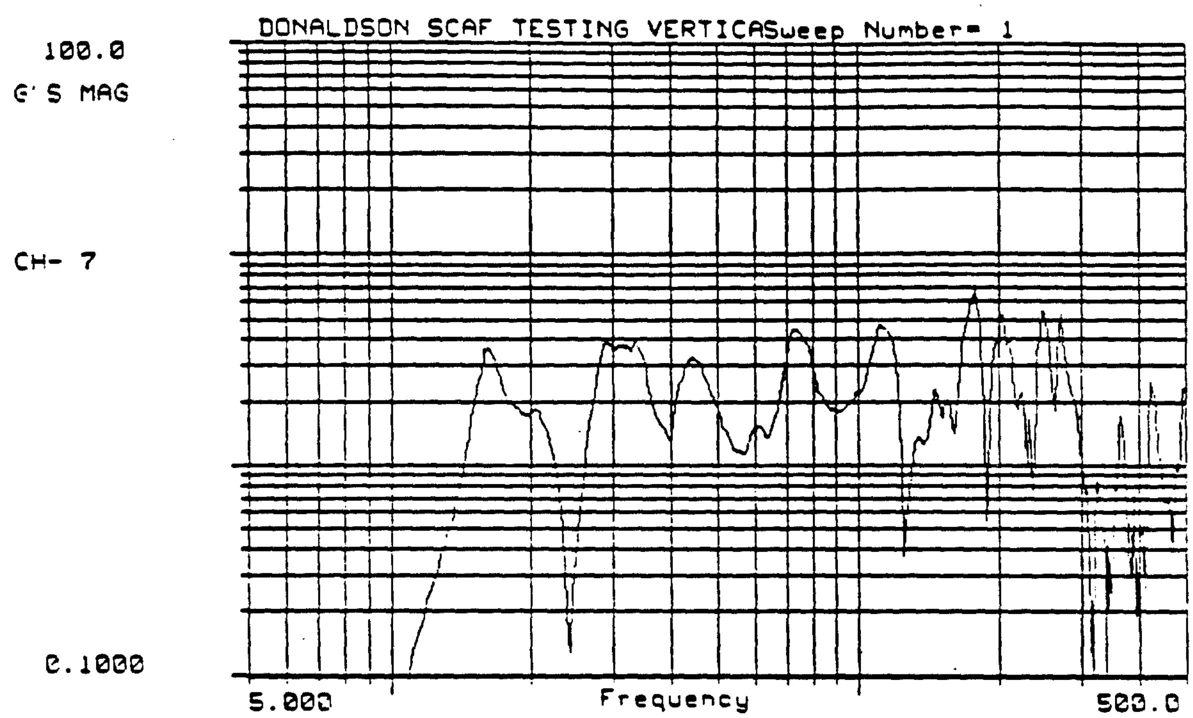
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	5/6
Resp. Loc	#9 VS. #10	Footage	
Resp. Accel	BK63/BK65	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON2

3/15/89 CH- 7: LOC. #11
DONALDSON SCAF TESTING

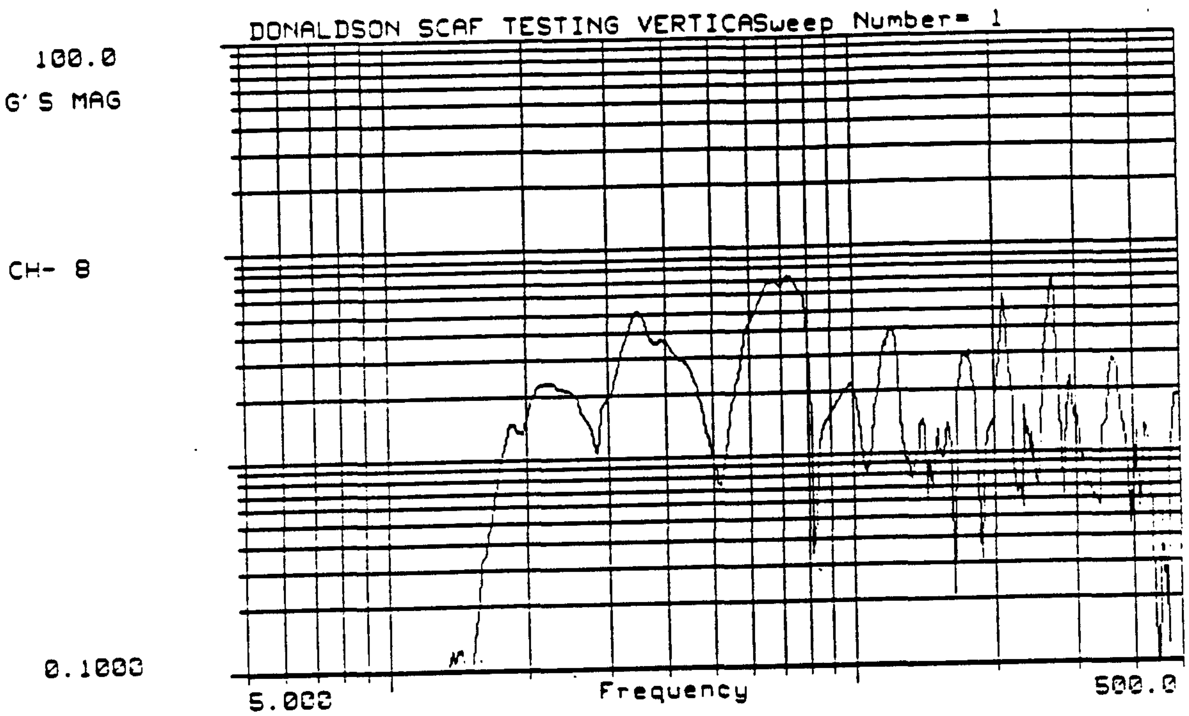
E

Honeywell Hopkins Sine Vibration

OEXM #	**30,299D**	**Test Date**	**15-MAR-89**
Input Axis	**Vertical**	**Filtered**	**YES**
Resp. Axis	**Axial**	**Unfiltered**	
		Tape Chn.	**7**
Resp. Loc	**#11**	**Footage**	
Resp. Accel	**BF83**	**Filename**	**DL1:Don2.swp**
Test Temp	**ROOM**	**Operator**	**A. KENNY**

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON2

3/15/89 CH- 8: LOC. #12
DONALDSON SCAF TESTING

E

Honeywell Hopkins Sine Vibration

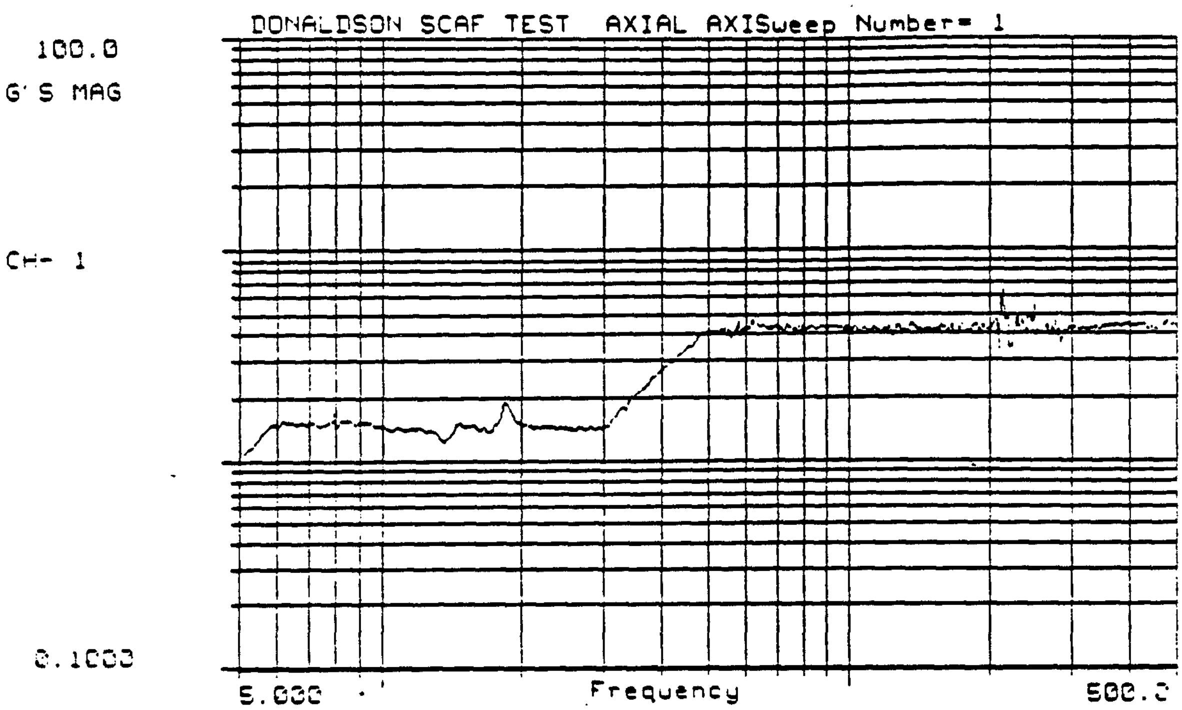
OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Vertical	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don2.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot

APPENDIX C
AXIAL AXIS INPUT

15-MARCH-1989
Gear Box Removed
4-strut Configuration



DL1:DON3

3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

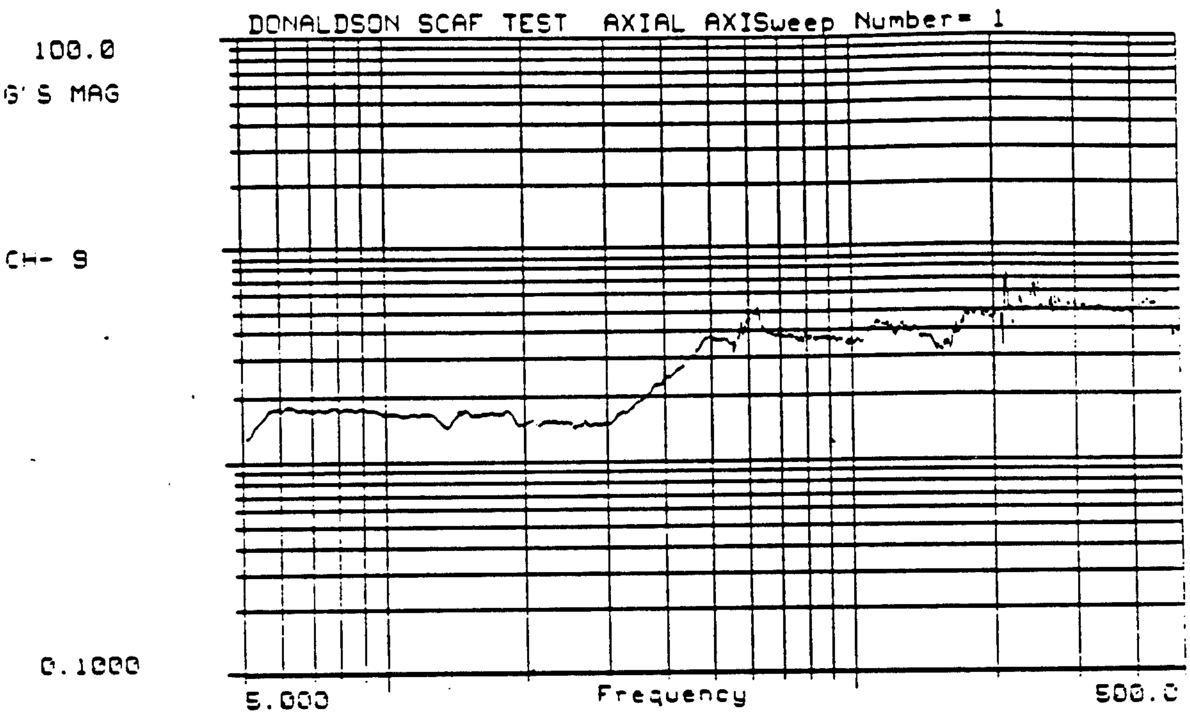
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	axial	Unfiltered	
		Tape Chn.	1
Resp. Loc	CONTROL	Footage	
Resp. Accel	394	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3

3/15/89 CH- 9: LOC. #1
DONALDSON SCAF TESTING

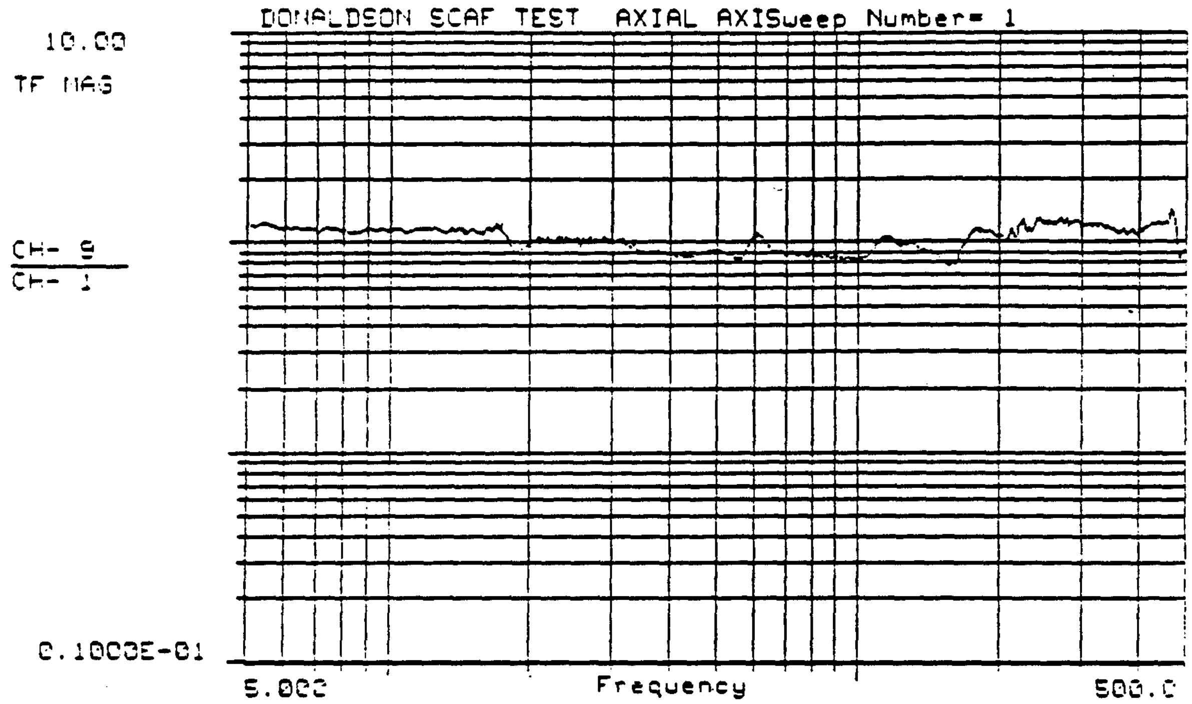
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	9
Resp. Loc	#1	Footage	
Resp. Accel	TA63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3
CH- 9: LOC. #1
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

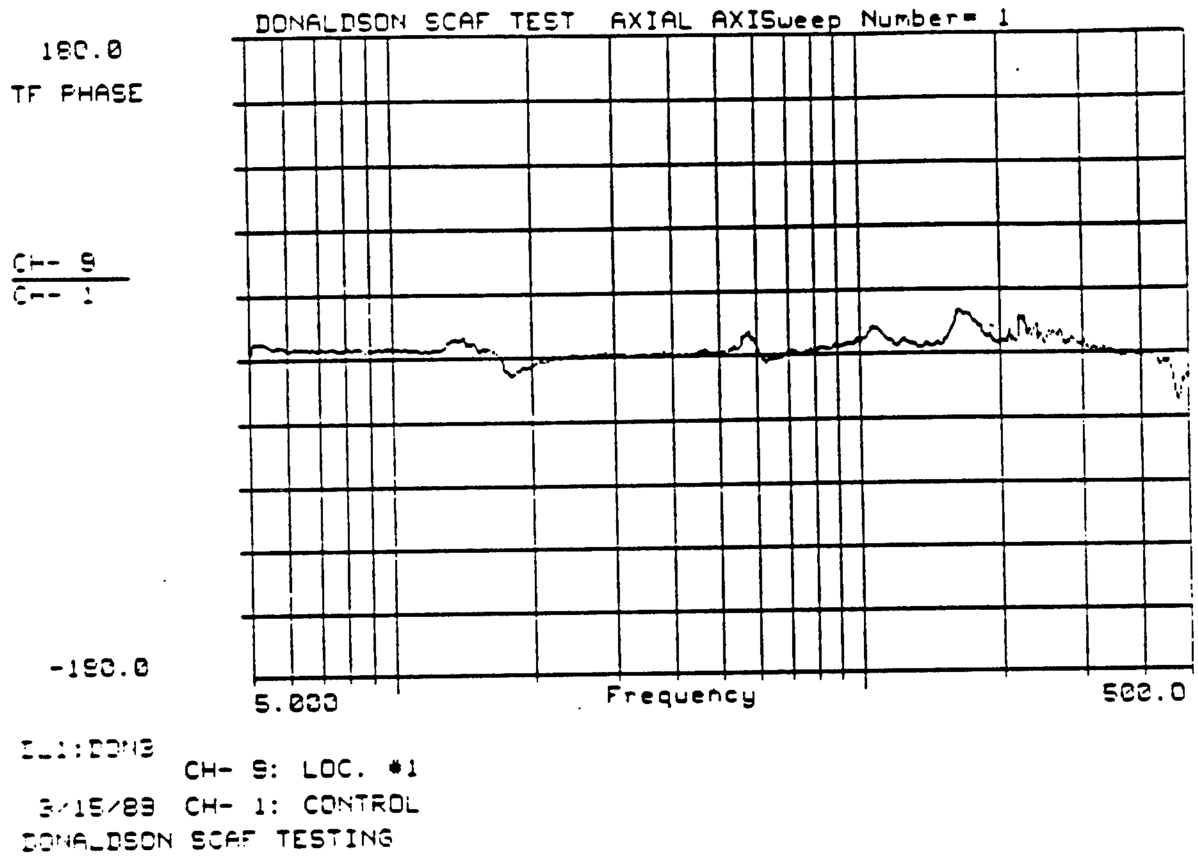
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	9
Resp. Loc	#1	Footage	
Resp. Accel	TA63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



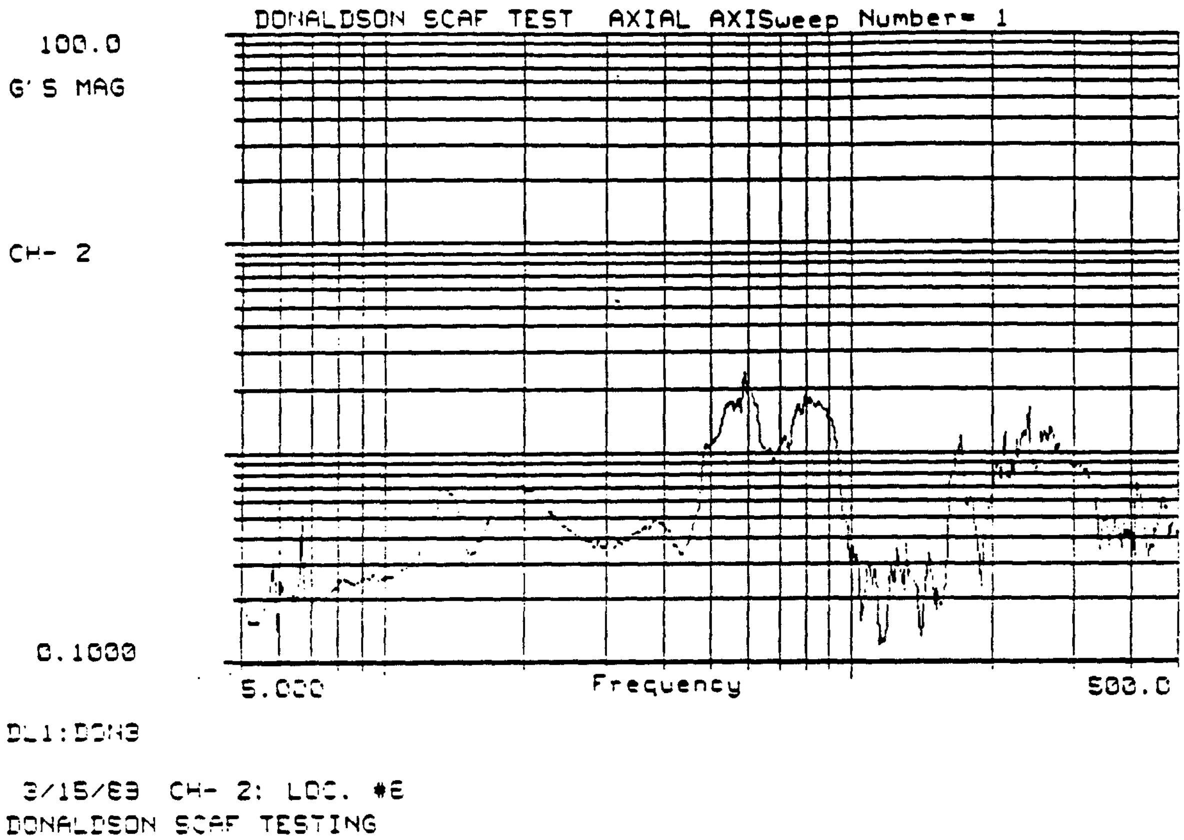
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	9
Resp. Loc	#1	Footage	
Resp. Accel	TA63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



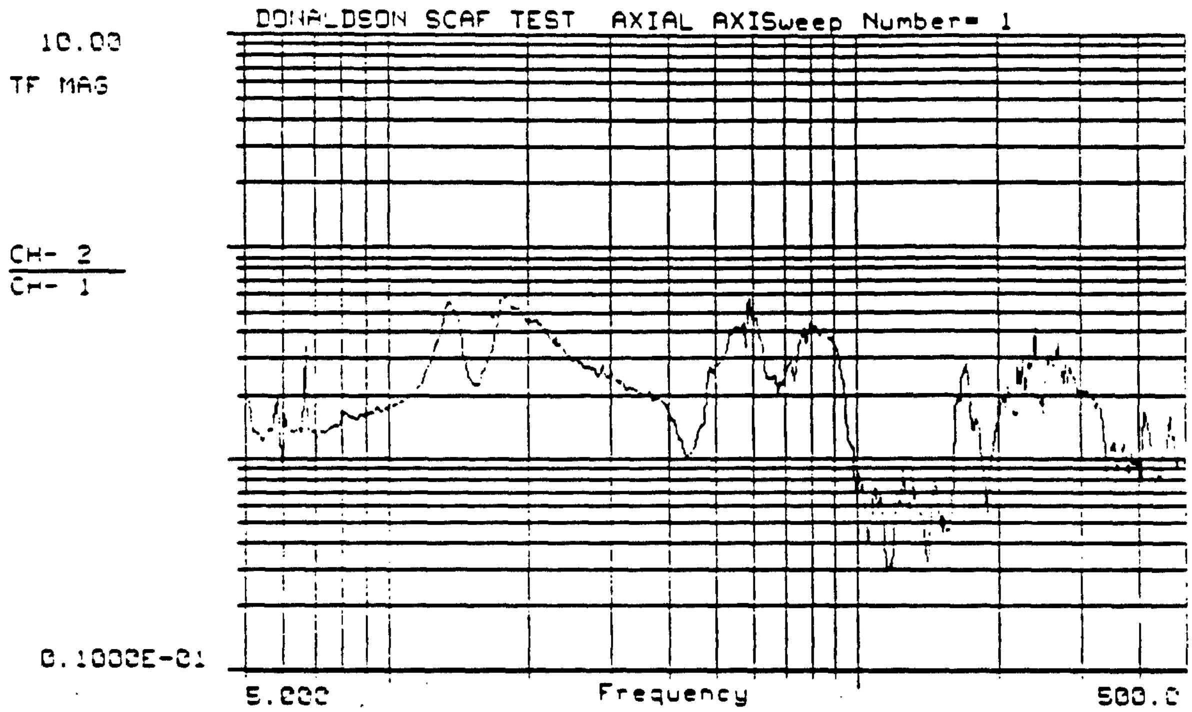
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6	Footage	
Resp. Accel	BK69	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3
CH- 2: LOC. #6
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

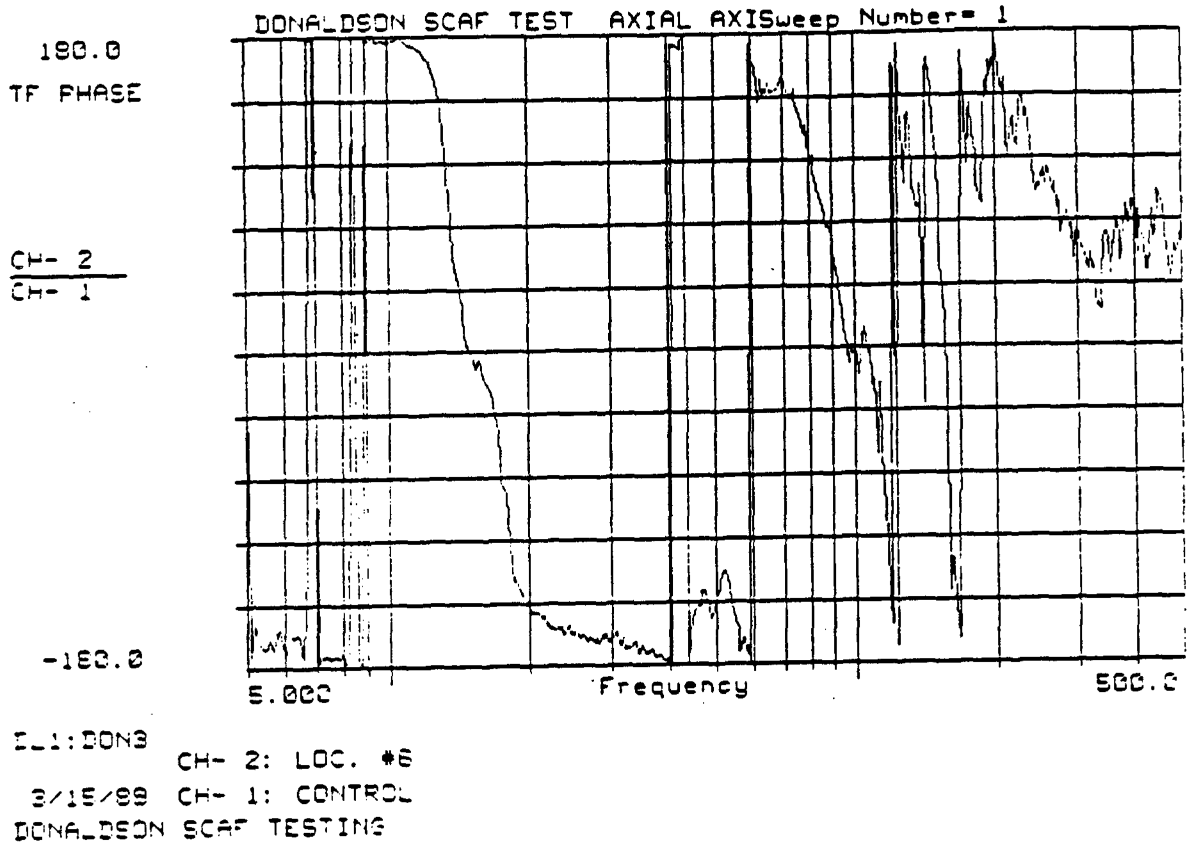
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6	Footage	
Resp. Accel	BK69	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



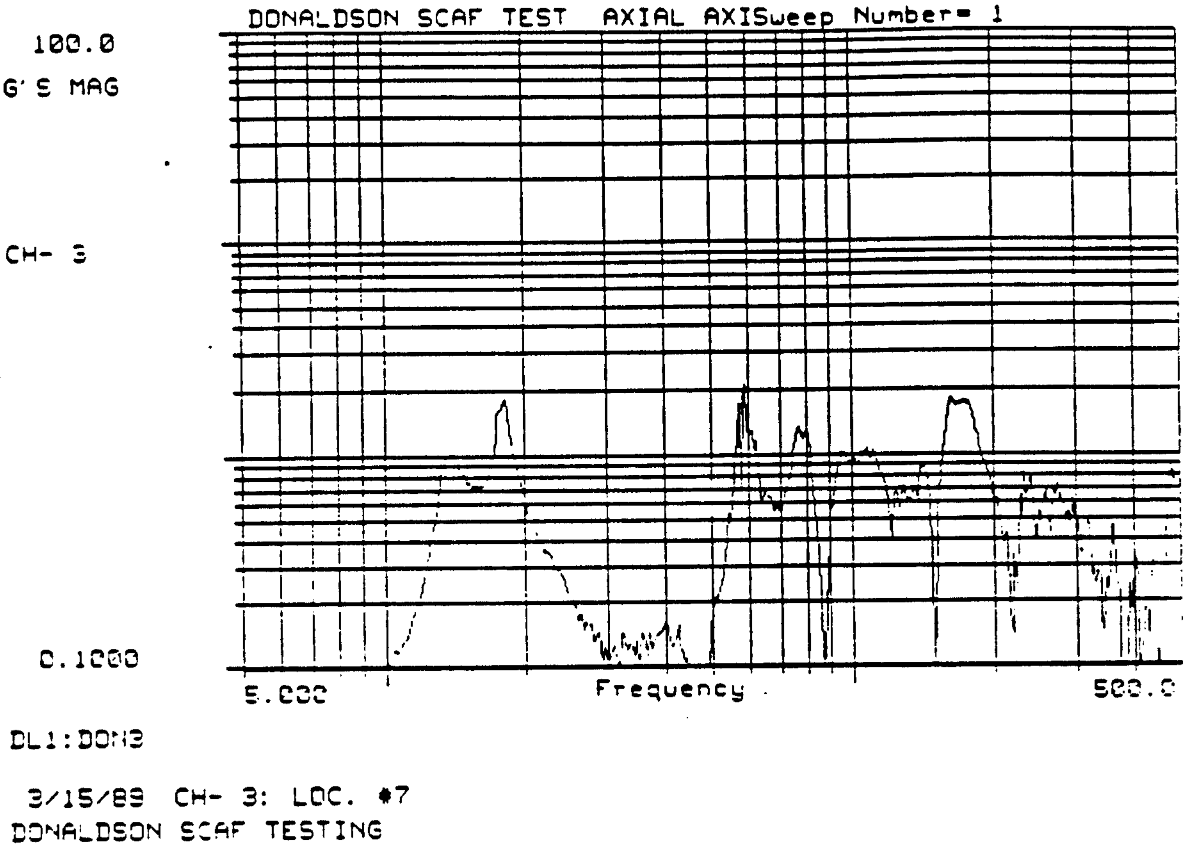
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Vertical	Unfiltered	
		Tape Chn.	2
Resp. Loc	#6	Footage	
Resp. Accel	BK69	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



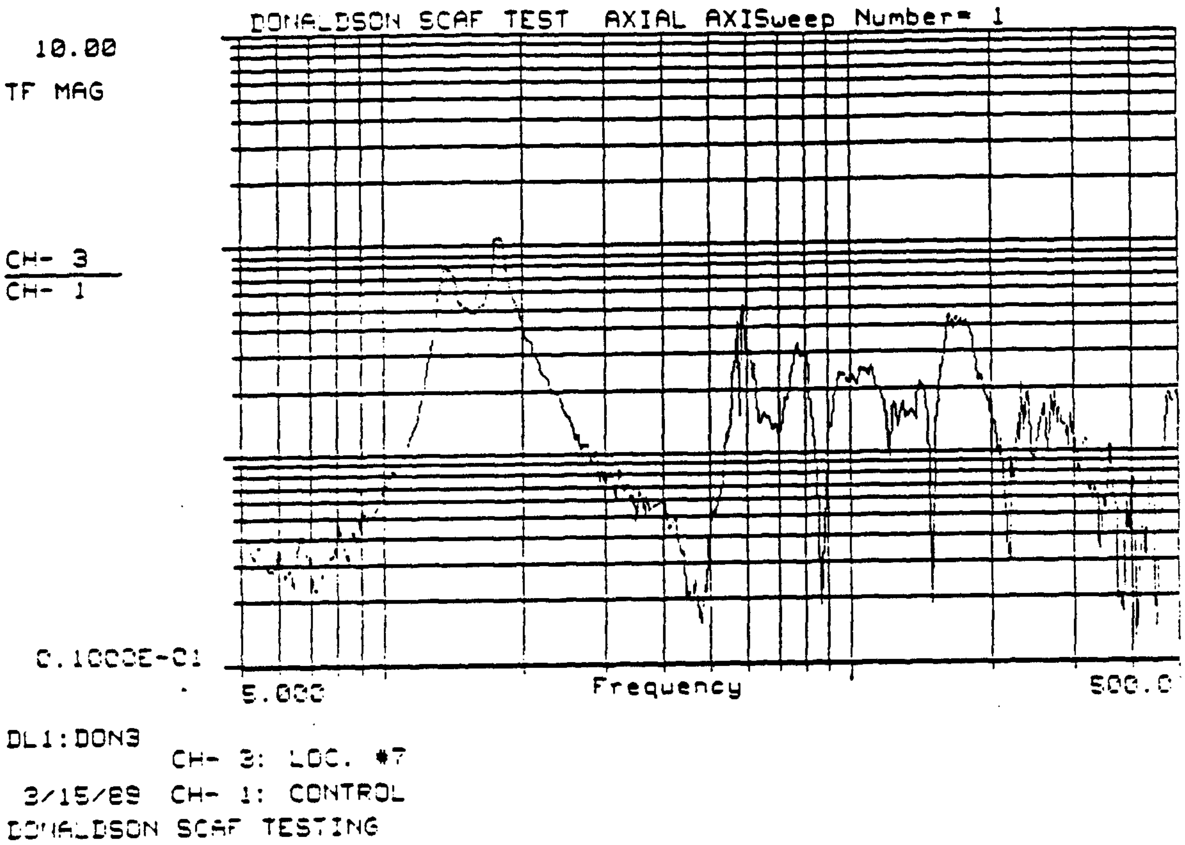
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



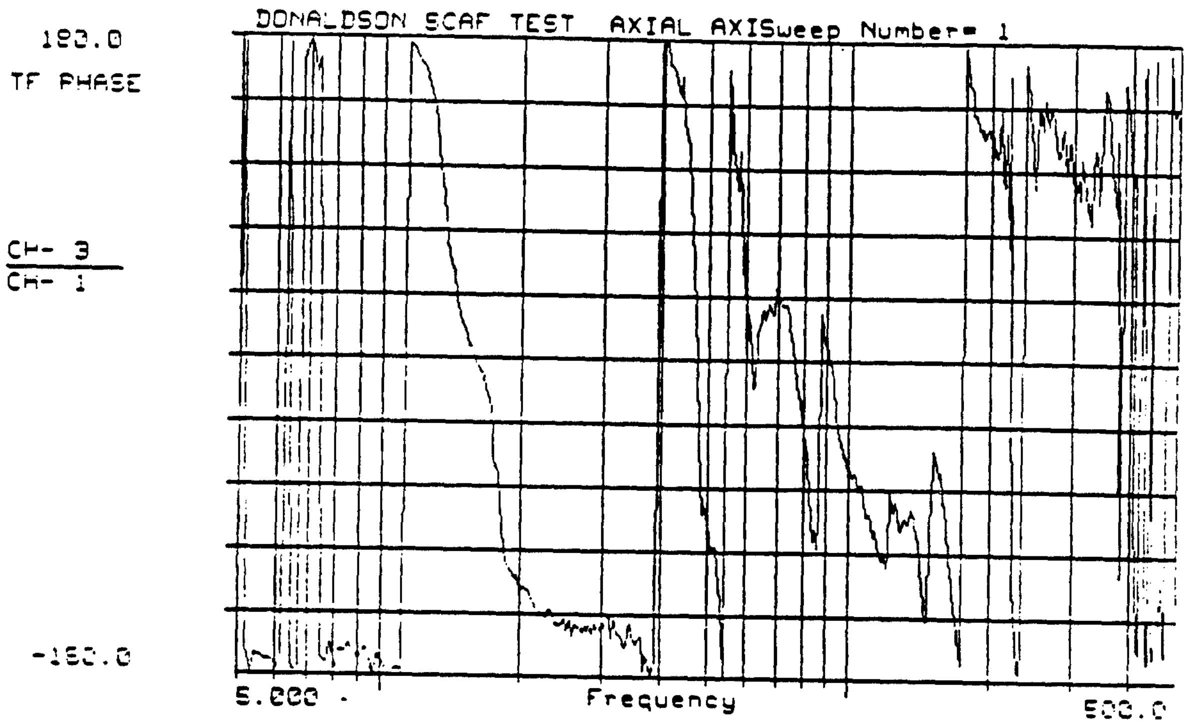
E

Honeywell Hopkins Sine Vibration

OEXM #	3D,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON3
CH- 3: LOC. #7
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

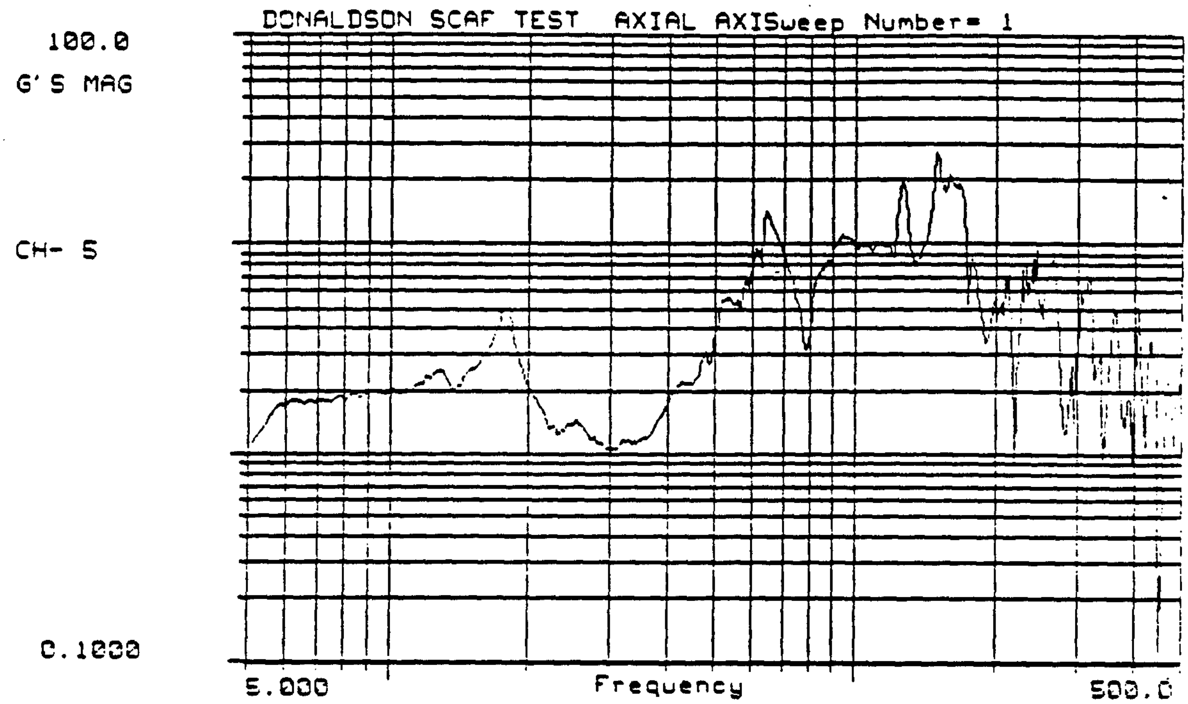
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Lateral	Unfiltered	
		Tape Chn.	3
Resp. Loc	#7	Footage	
Resp. Accel	BK39	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3

3/15/89 CH- 5: LOC. #9
DONALDSON SCAF TESTING

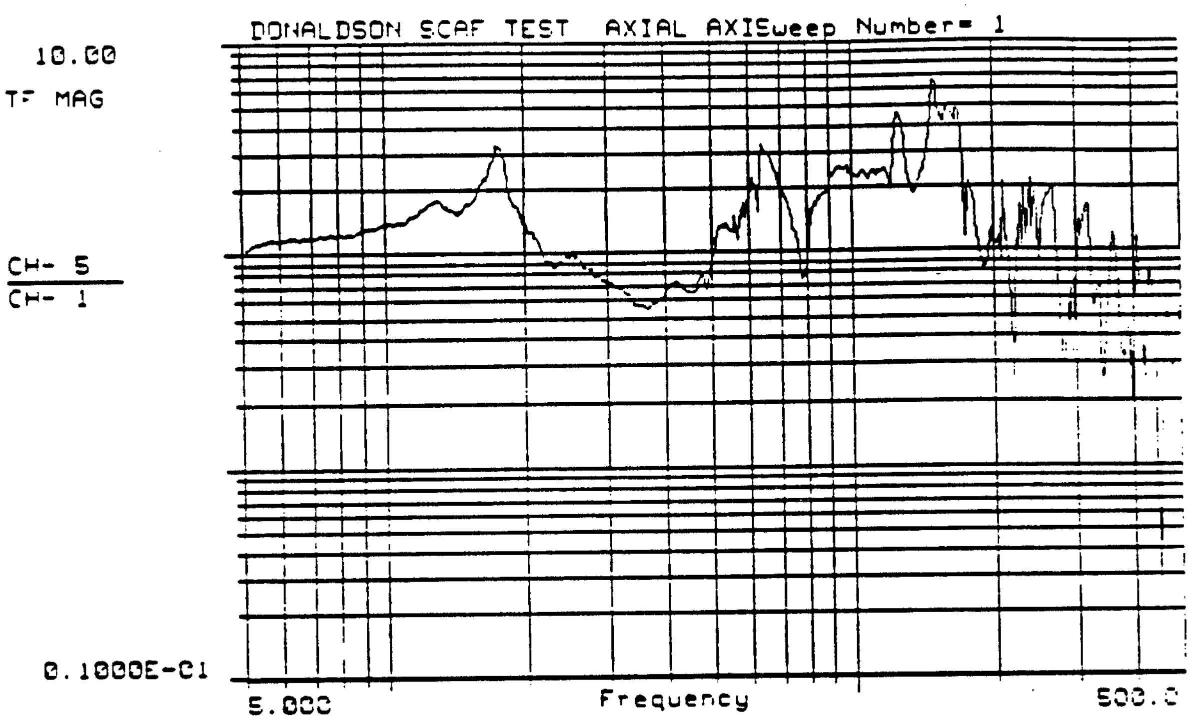
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3
CH- 5: LOC. #9
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

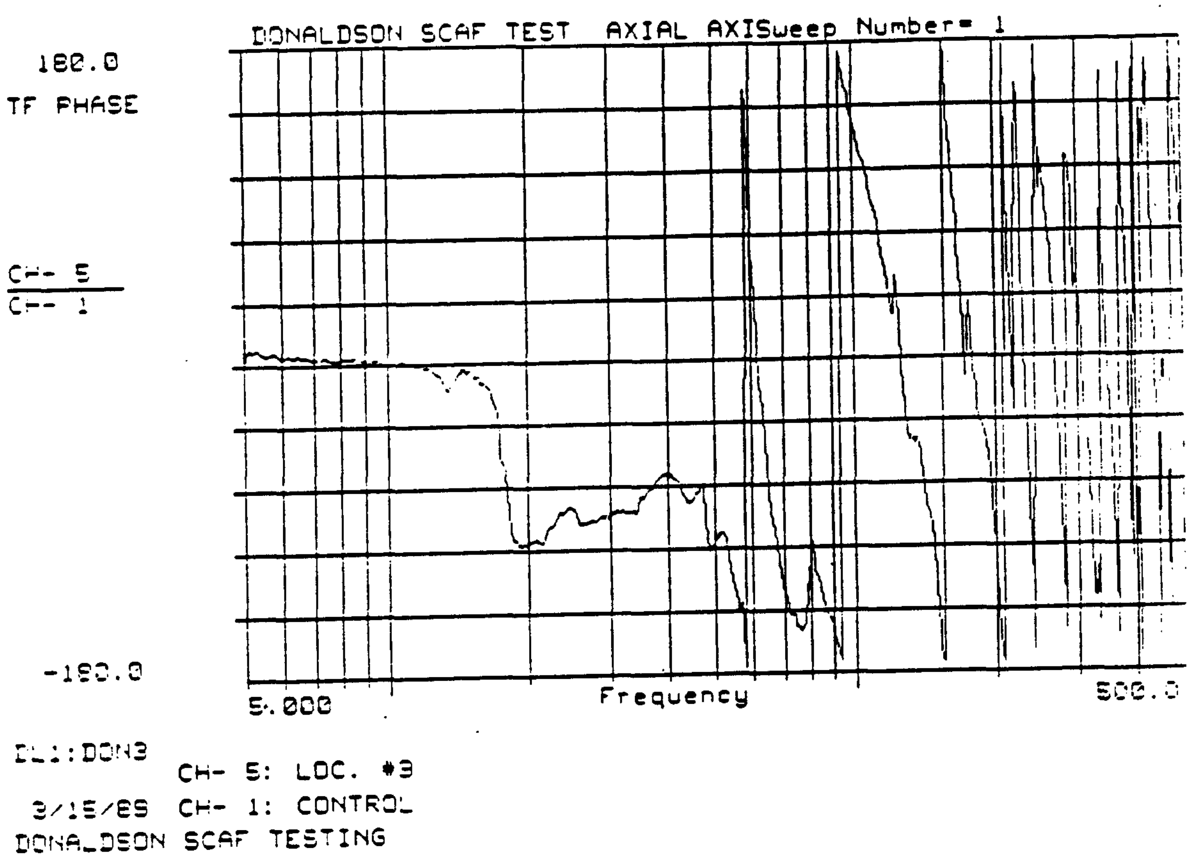
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



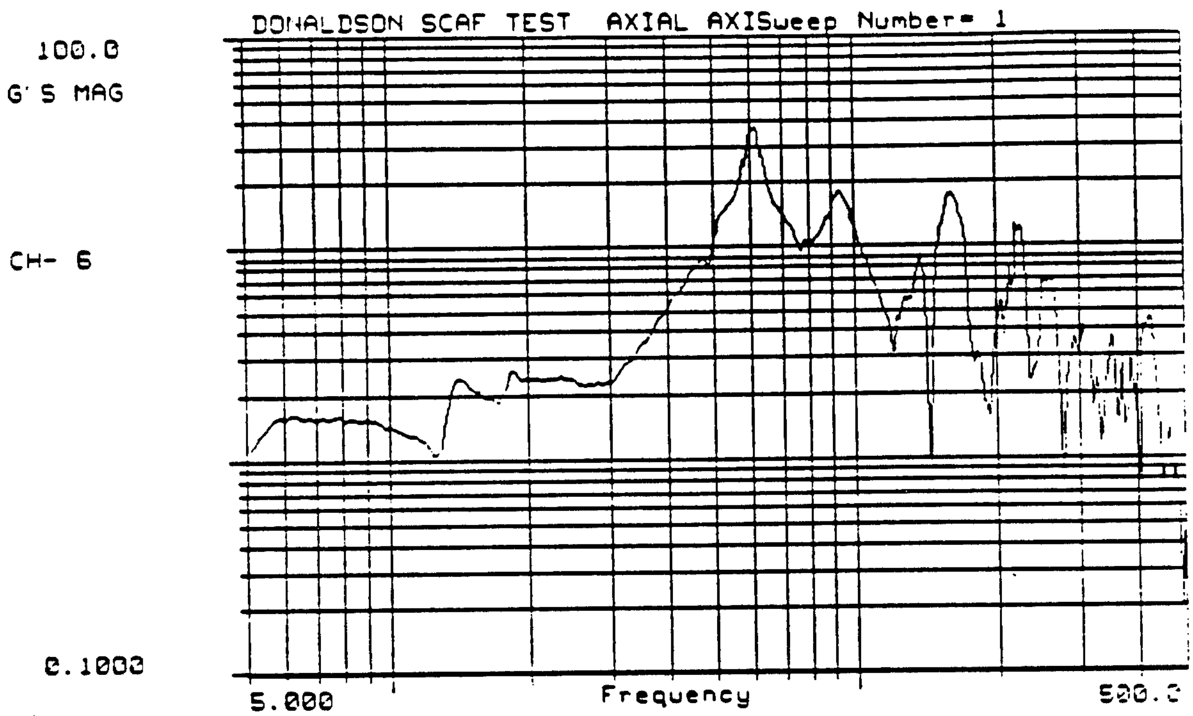
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	5
Resp. Loc	#9	Footage	
Resp. Accel	BK63	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3

3/15/89 CH- 6: LOC. #10
DONALDSON SCAF TESTING

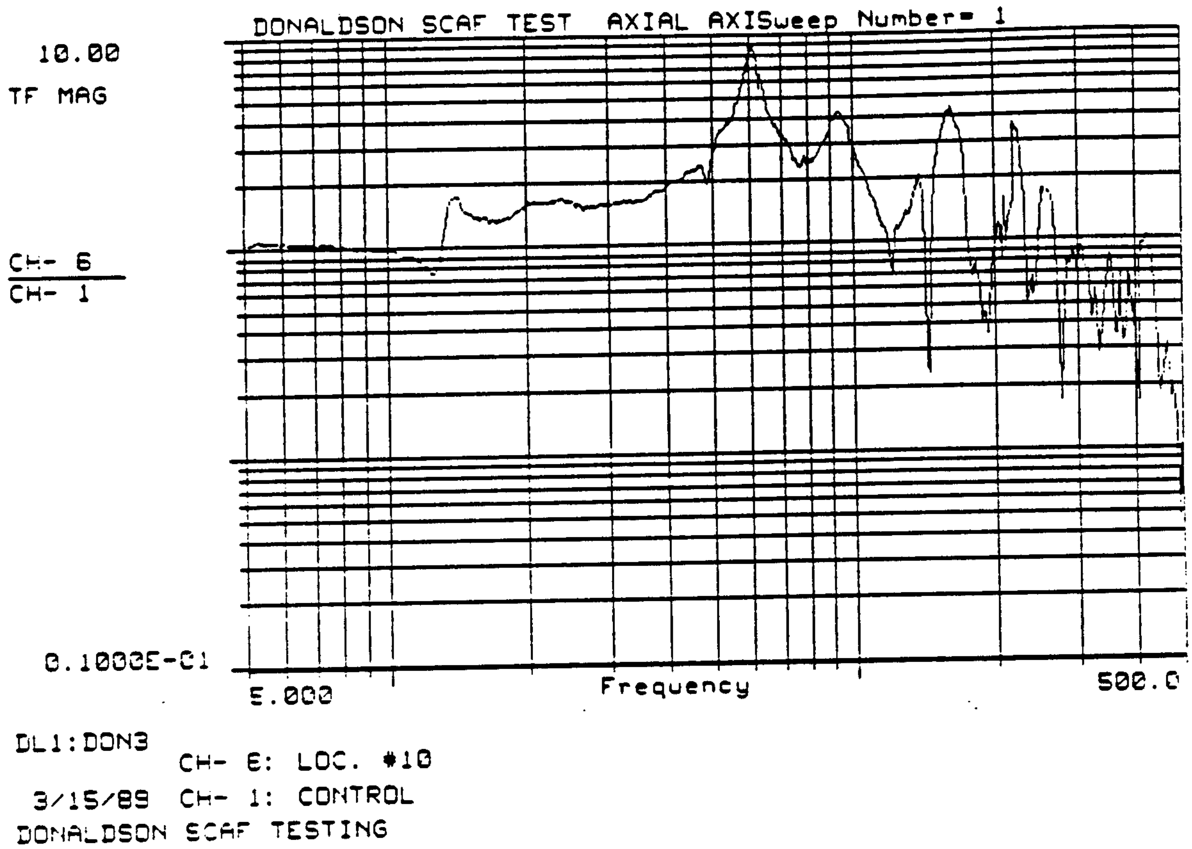
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
Resp. Loc	#10	Footage	
Resp. Accel	BK65	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



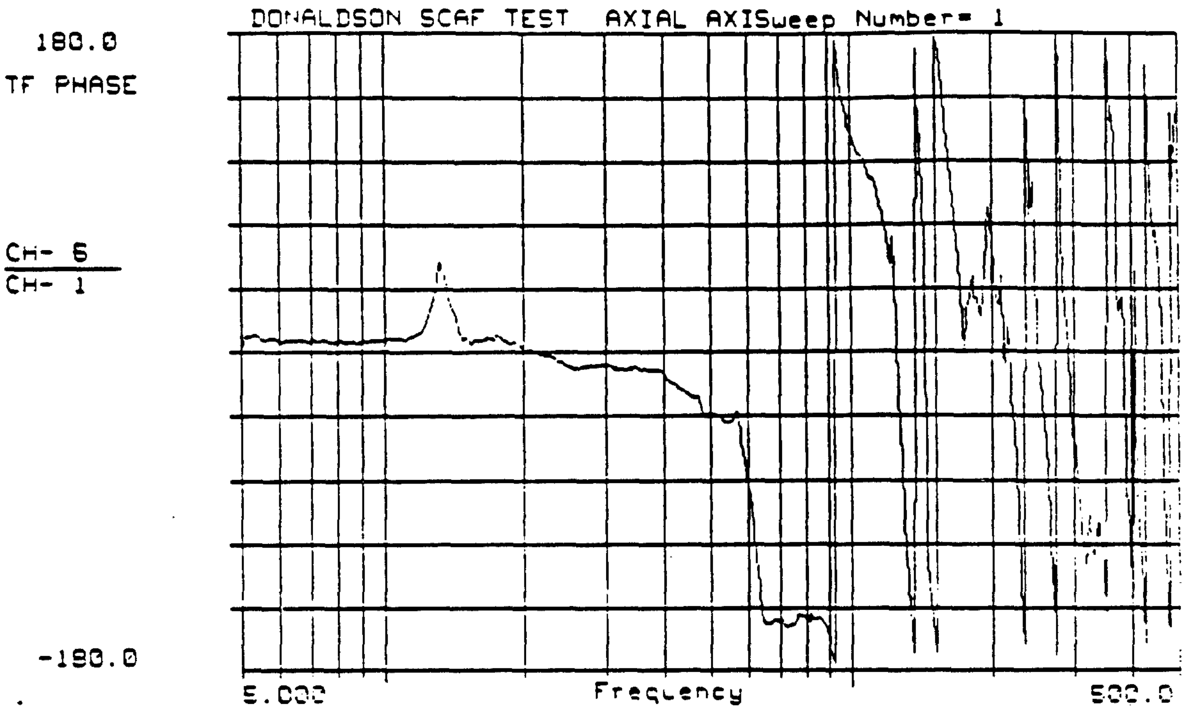
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
Resp. Loc	#10	Footage	
Resp. Accel	BK65	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON3
CH- 6: LOC. #10
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

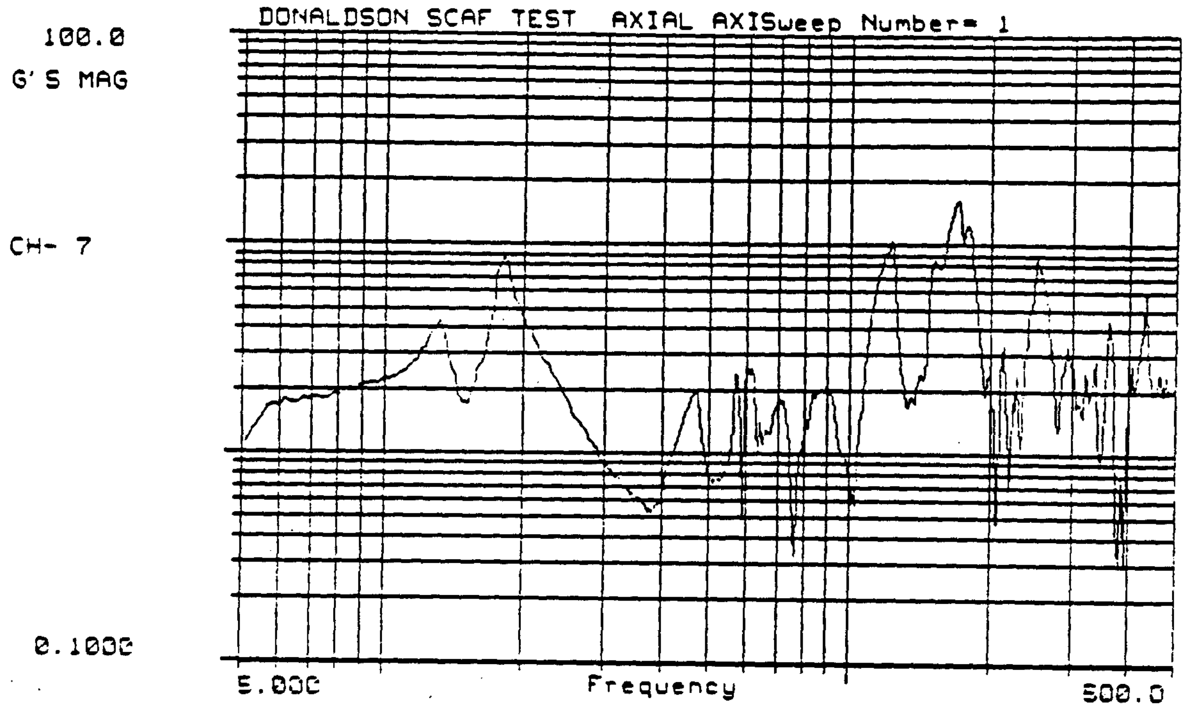
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	6
Resp. Loc	#10	Footage	
Resp. Accel	BK65	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3

3/15/89 CH- 7: LOC. #11
DONALDSON SCAF TESTING

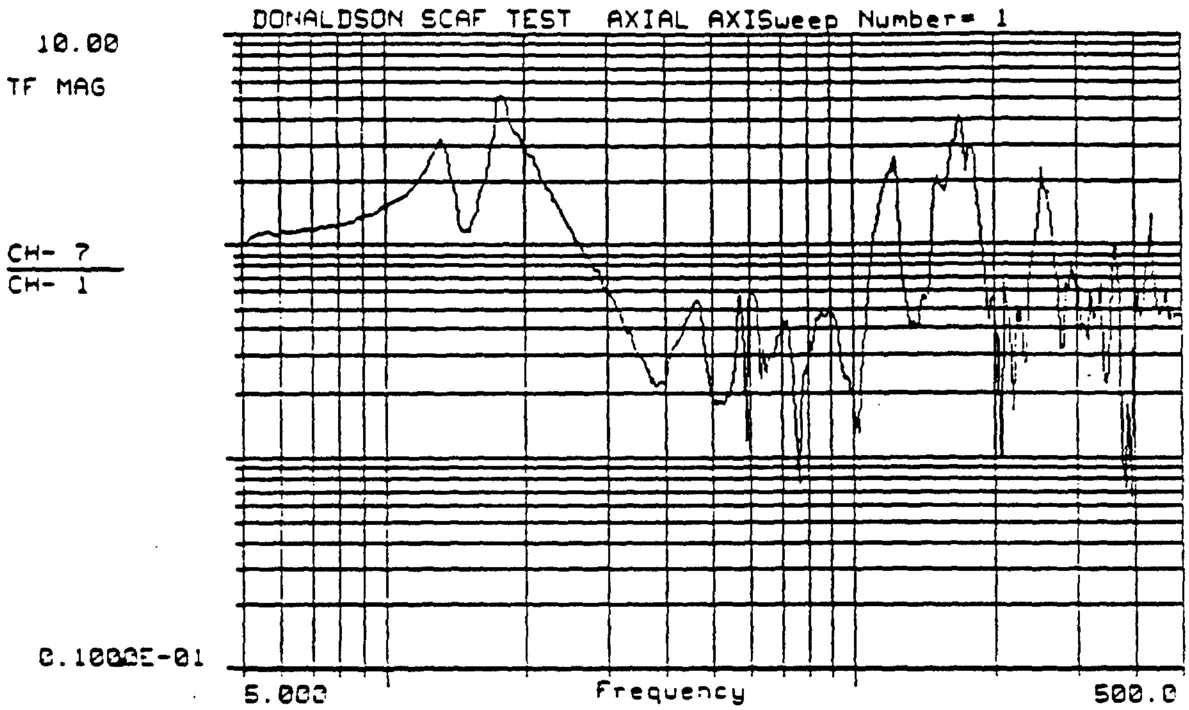
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3
CH- 7: LOC. #11
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

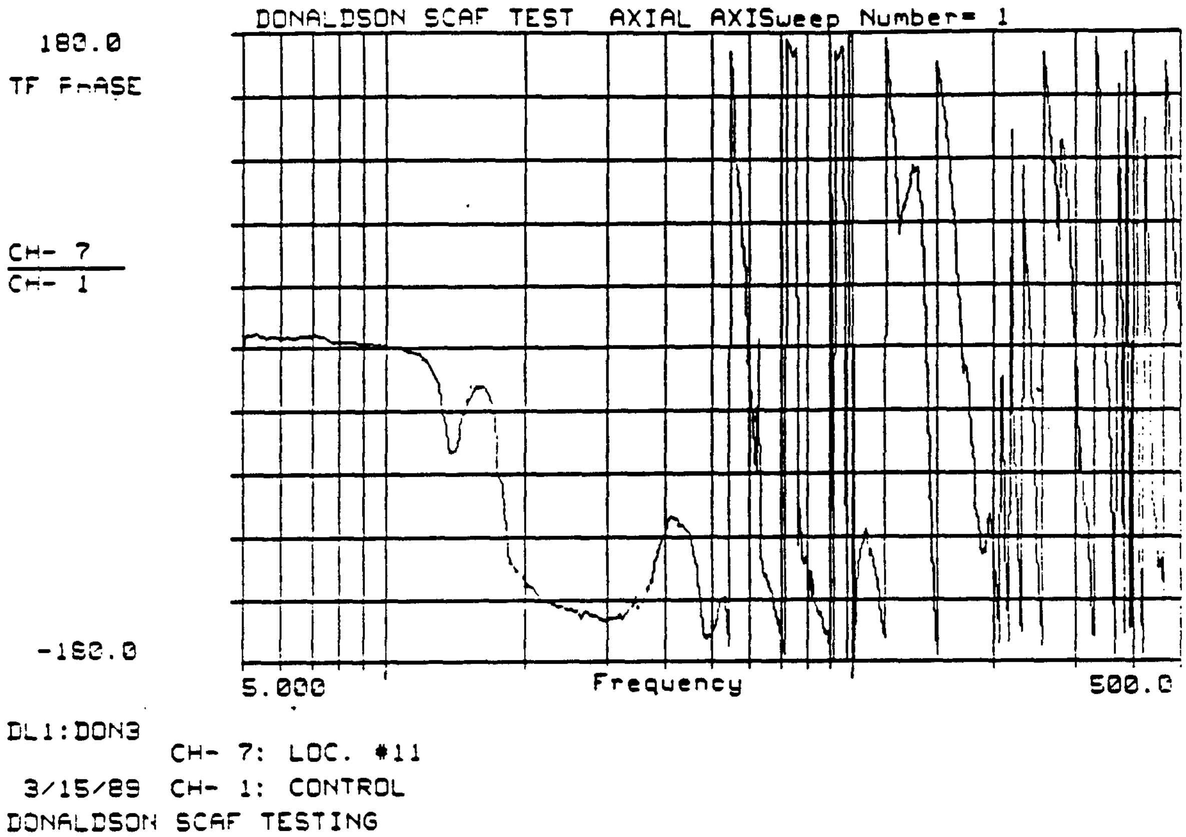
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



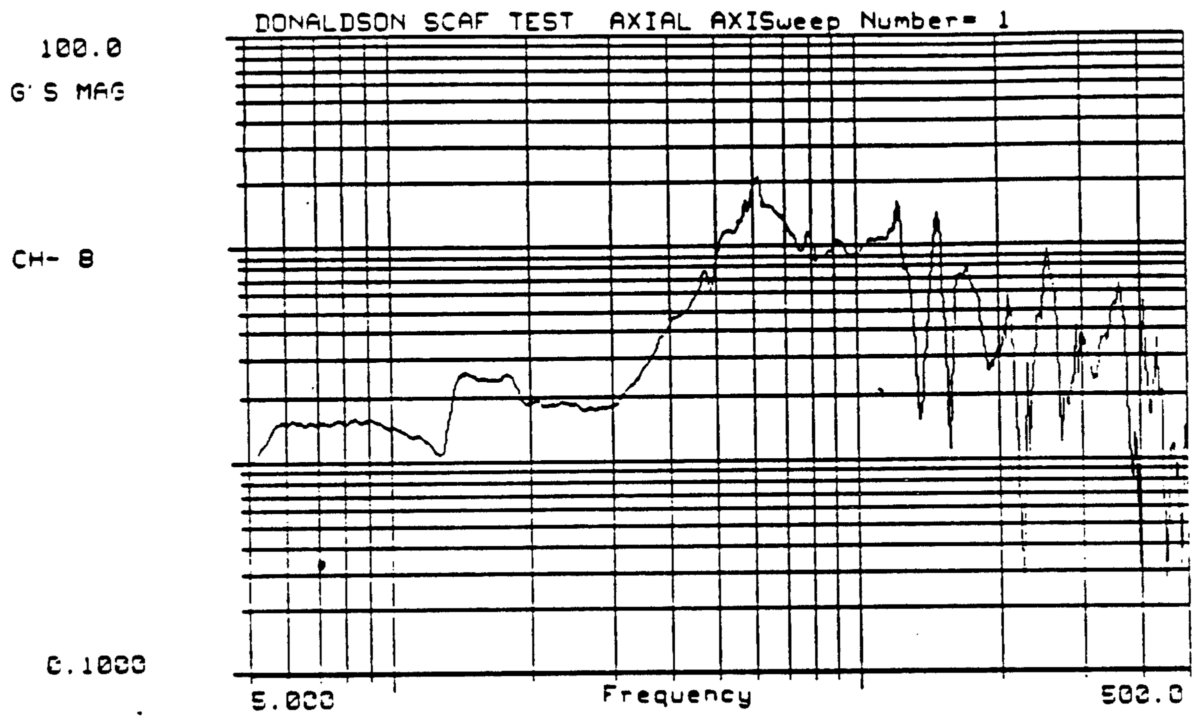
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	7
Resp. Loc	#11	Footage	
Resp. Accel	BF83	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3

3/15/89 CH- 8: LOC. #12
DONALDSON SCAF TESTING

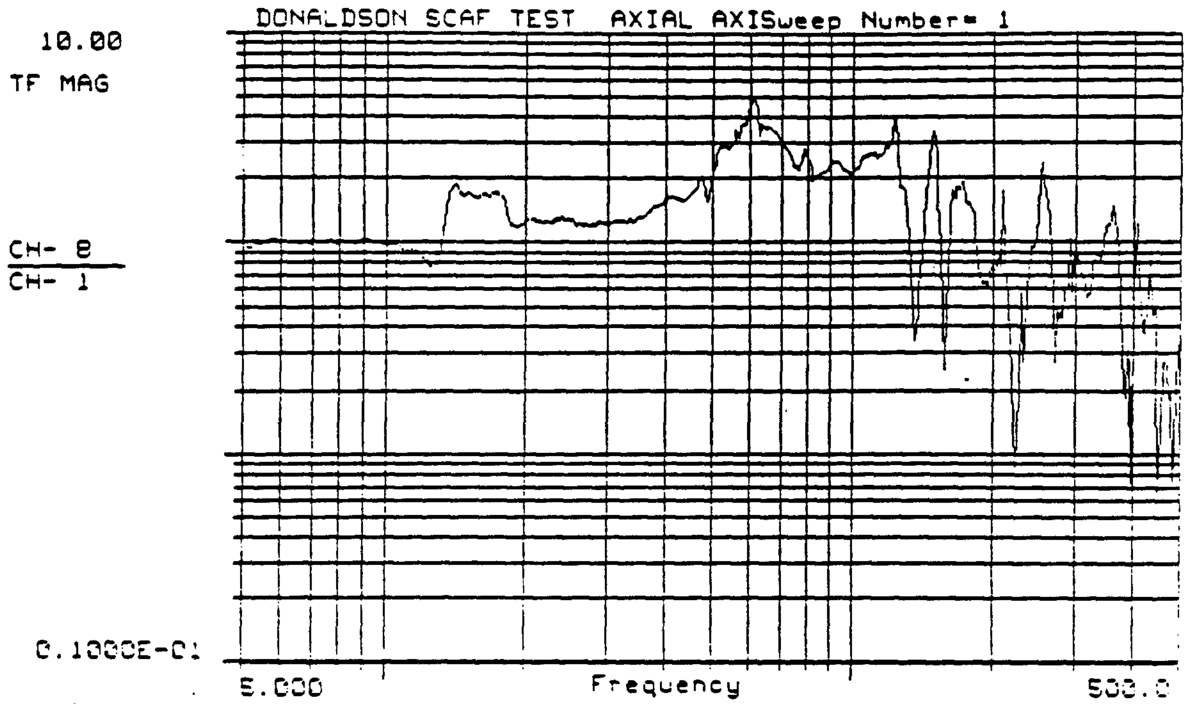
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Magnitude Plot



DL1:DON3
CH- 8: LOC. #12
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

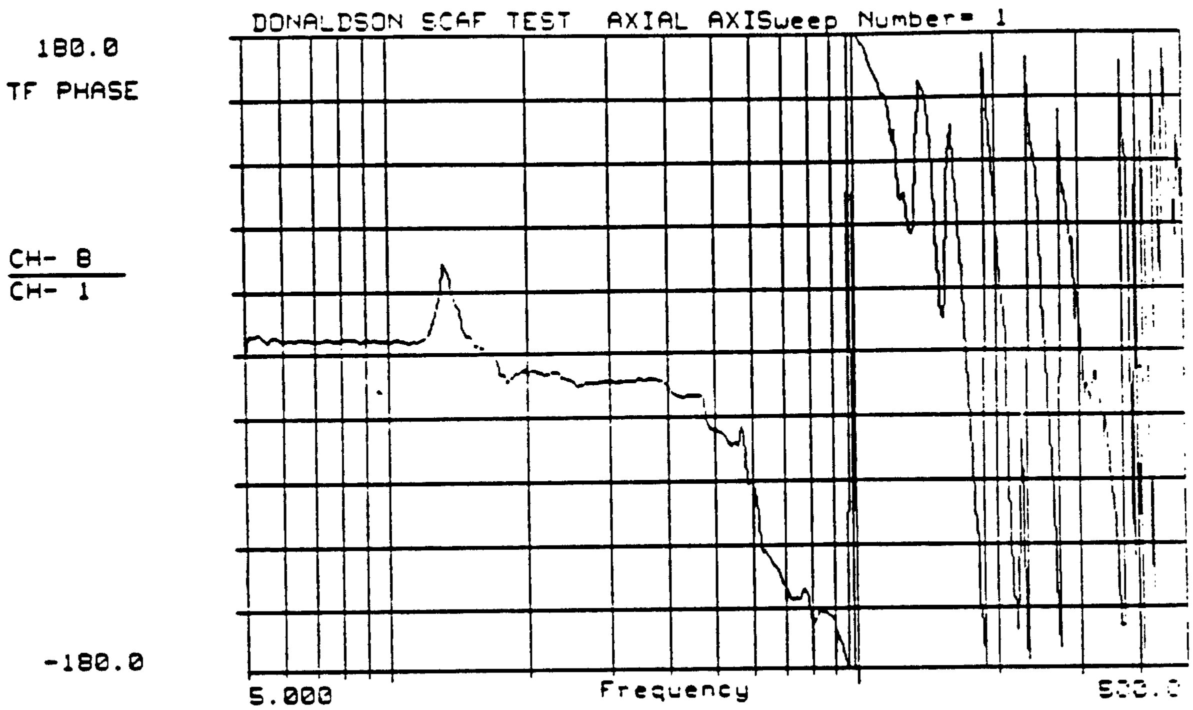
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON3
CH- 8: LOC. #12
3/15/89 CH- 1: CONTROL
DONALDSON SCAF TESTING

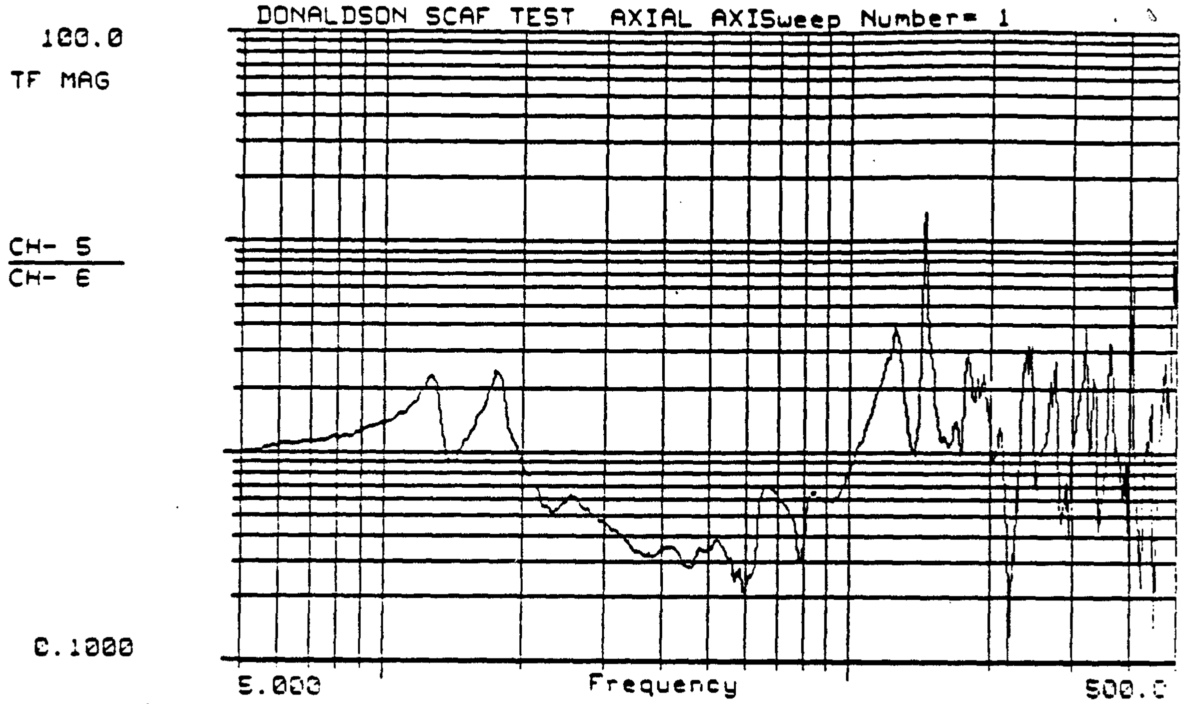
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial	Unfiltered	
		Tape Chn.	8
Resp. Loc	#12	Footage	
Resp. Accel	BF82	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3
CH- 5: LOC. #9
3/15/89 CH- 6: LOC. #10
DONALDSON SCAF TESTING

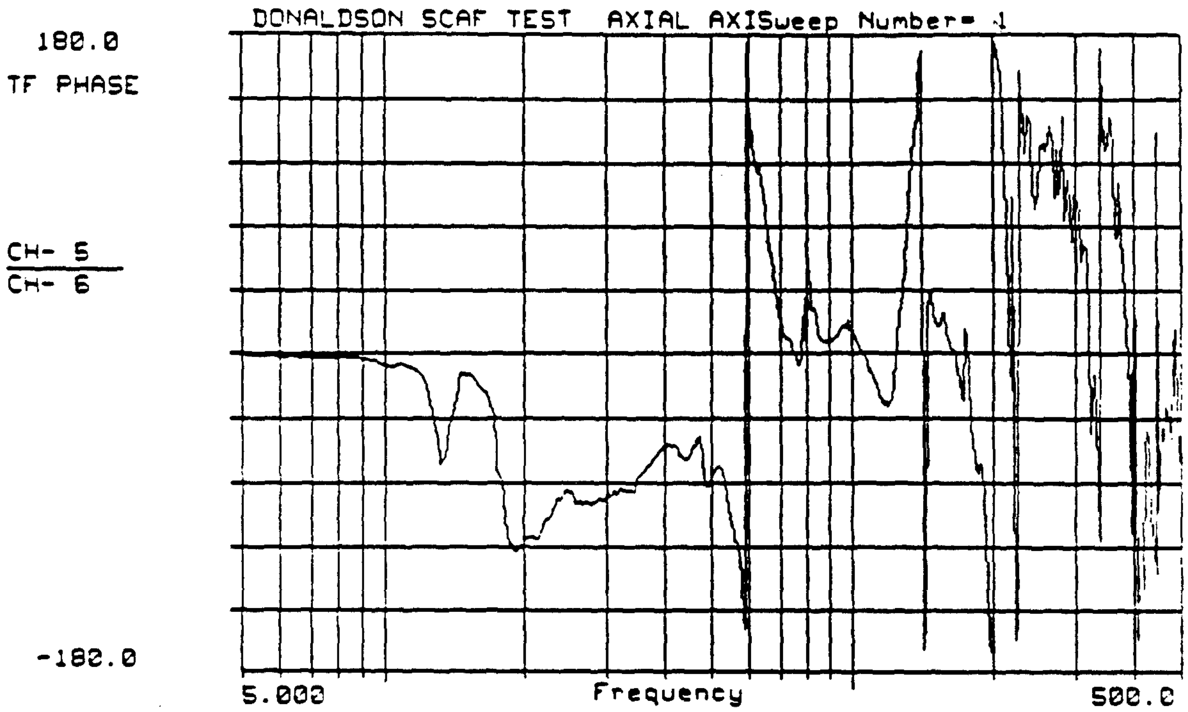
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	5/6
Resp. Loc	#9 VS. #10	Footage	
Resp. Accel	BK63/BK65	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



DL1:DON3
CH- 5: LOC. #9
3/15/89 CH- 6: LOC. #10
DONALDSON SCAF TESTING

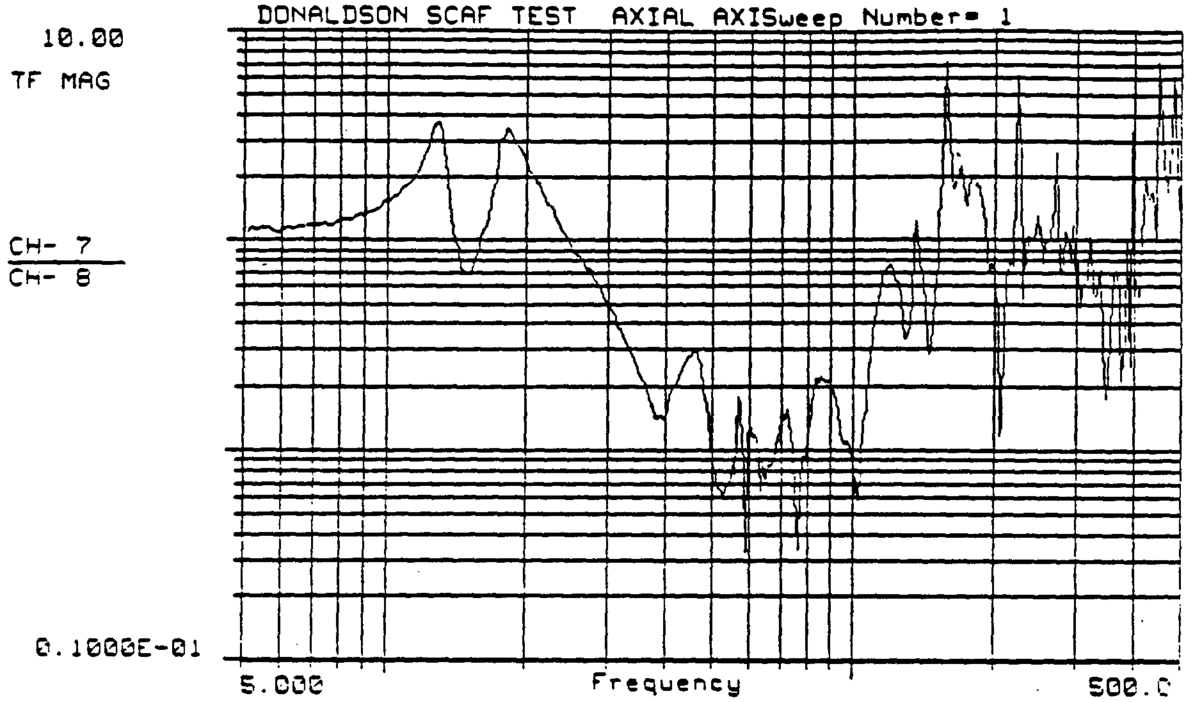
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	5/6
Resp. Loc	#9 VS. #10	Footage	
Resp. Accel	BK63/BK65	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase



DL1:DON3
CH- 7: LOC. #11
3/15/89 CH- 8: LOC. #12
DONALDSON SCAF TESTING

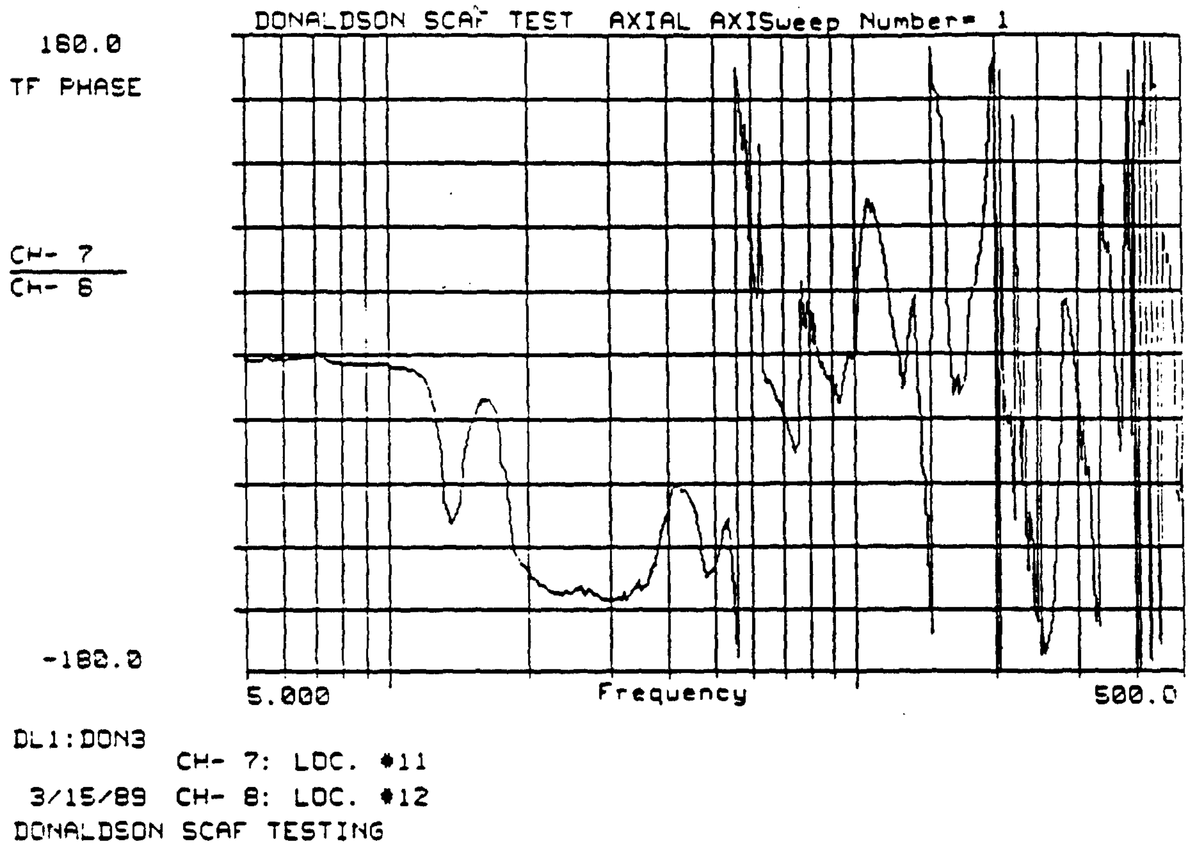
E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 VS. #12	Footage	
Resp. Accel	BF83/BF82	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Magnitude



E

Honeywell Hopkins Sine Vibration

OEXM #	30,299D	Test Date	15-MAR-89
Input Axis	Axial	Filtered	YES
Resp. Axis	Axial/Axial	Unfiltered	
		Tape Chn.	7/8
Resp. Loc	#11 VS. #12	Footage	
Resp. Accel	BF83/BF82	Filename	DL1:Don3.swp
Test Temp	ROOM	Operator	A. KENNY

Donaldson Air Filter (SCAF)

Transfer Function Phase

APPENDIX B

SHOCK TESTING

DAYTON T. BROWN INC

ENGINEERING AND TEST DIVISION
CHURCH STREET, BOHEMIA, LONG ISLAND, NEW YORK 11716 (516) 589-6300

TEST REPORT NO: DTB04R89-0595

DAYTON T. BROWN, INC. JOB NO: 406744-00-000

CUSTOMER: DONALDSON COMPANY, INC.
P.O. BOX 1299
MINNEAPOLIS, MINNESOTA 55440-1299

SUBJECT: SHOCK TEST PROGRAM PERFORMED ON ONE SCAF, PART NUMBER 119385, SERIAL NUMBER 82E018

ATTENTION: MR. HARRY CAMPLIN, MS NO. 222

THIS REPORT CONTAINS: FIVE PAGES AND TWO ENCLOSURES

PREPARED BY	G. HYLAND G. Hyland
TEST ENGINEER	G. HYLAND G. Hyland
TEST OPERATIONS MANAGER	V. VIRGILIO VV
DATE	12 MAY 1989

THE DATA CONTAINED IN THIS REPORT WAS OBTAINED BY TESTING IN COMPLIANCE WITH THE APPLICABLE TEST SPECIFICATION AS NOTED

DAYTON T. BROWN
Founded 1950

TABLE OF CONTENTS

Subject	Paragraph	Page Number
Abstract	1.0	2
References	2.0	3
Administrative Information	3.0	4
Test Program Outline	4.0	5

Enclosures

(1) Shock Test and Results	91 Pages
(2) Photographs	7 Photos

DAYTON T. BROWN

Founded 1950

1.0 ABSTRACT

This test report details the results of the shock test program conducted on one SCAF, part number 119385, serial number 82E018 under reference (a) to the requirements of reference (c).

Results of the test are detailed in the following text.

The test item was nonoperating during testing.

Test data pertinent to this program will remain on file at Dayton T. Brown, Inc. for 90 days.

DAYTON T. BROWN

Founded 1950

2.0 REFERENCES

(a) Customer Purchase Order Number: D78000943

(b) Dayton T. Brown, Inc. Job Number: 406744-00-000

(c) Test Specification: Dayton T. Brown, Inc. Quote ISL-89-0535

3.0 ADMINISTRATIVE INFORMATION

Customer: Donaldson Company, Inc.
P.O. Box 1299
Minneapolis, Minnesota 55440-1299

Test Item Description: SCAF

Quantity Received: One

Part Number: 119385

Serial Number: 82E018

Date Received: 17 April 1989

Date Shipped: 24 April 1989

Customer Representative Present During Portions of Test:

Name	Affiliation
Mr. Harry Camplin	Donaldson Company, Inc.
Mr. Scott Nisbett	Textron Lycoming
Mr. Anthony Ligato	Textron Lycoming

DAYTON T. BROWN
Founded 1950

4.0 TEST PROGRAM OUTLINE

Test	Test Item Description	Results
Shock	SCAF, Part Number 119385, Serial Number 82E018	Refer to Enclosure 1

Enclosure 1

Shock Test and Results

TEST REQUIREMENT

The shock test shall be conducted in accordance with reference (c).

TEST RESULTS

A pretest visual inspection of the test item revealed no anomalies.

All testing was performed in accordance with the referenced specification.

Refer to the shock test summary for tabulated results.

The test item did not complete all phases of testing.

A post test visual inspection of the test item revealed a crack in the turbine base and some small cracks on the SCAF.

TEST RESULTS - (Continued)

SHOCK TEST SUMMARY

Test Item: SCAF

Part Number: 119385

Serial Number: 82E018

Record Number	Axis	Test Condition	Required g	Required ms	Actual g	Actual ms	Graph Page No. (Enc. 1)	Remarks
4/18/89								
1	- Vert.	Basic Shock	40	18.0	19.5	15.5	5	Low Level Cal.
2	- Vert.	Basic Shock	40	18.0	15.0	17.0	5	Low Level Cal.
3	- Vert.	Basic Shock	40	18.0	28.0	16.0	6	Low Level Cal.
4	- Vert.	Basic Shock	40	18.0	22.0	18.0	6	Low Level Cal.
5	- Vert.	Basic Shock	40	18.0	24.0	18.0	6	See Note 1, Low Level Ca
6	- Vert.	Basic Shock	40	18.0	34.0	18.5	7	Low
7	- Vert.	Basic Shock	40	18.0	36.0	17.6	8	Good
8	- Vert.	Basic Shock	40	18.0	39.0	17.5	9 - 11	Good
9	- Vert.	Basic Shock	40	18.0	39.4	16.8	12	Good
10	- Vert.	Gunfire Shock	55	2.5	85.0	2.4	13	High g
11	- Vert.	Gunfire Shock	55	2.5	40.0	2.7	14	Low g
12	- Vert.	Gunfire Shock	55	2.5	59.5	2.5	15	Good
13	- Vert.	Gunfire Shock	55	2.5	55.5	2.5	16 - 20	Good
14	- Vert.	Operational Shock	55	<2.0	52.5	2.1	21	Good
15	- Vert.	Operational Shock	55	<2.0	50.5	2.1	22	Good
16	- Vert.	Operational Shock	55	<2.0	61.0	2.0	23 - 27	High g
17	- Vert.	Ballistic Shock	200	<2.0	100.0	1.5	28	Low Level Cal.
18	- Vert.	Ballistic Shock	200	<2.0	183.0	1.0	29	Good
19	- Vert.	Ballistic Shock	200	<2.0	190.0	1.1	30	Good
20	- Vert.	Ballistic Shock	200	<2.0	193.0	1.1	31 - 35	Good

TEST RESULTS - (Continued)

SHOCK TEST SUMMARY
(Continued)

Test Item: SCAF

Part Number: 119385

Serial Number: 82E018

Record Number	Axis	Test Condition	Required g	Required ms	Actual g	Actual ms	Graph Page No. (Enc. 1)	Remarks
4/19/89								
21	+ Vert.	Basic Shock	40	18.0	40.0	17.7	36	Good
22	+ Vert.	Basic Shock	40	18.0	36.4	18.0	36 - 40	Good
23	+ Vert.	Basic Shock	40	18.0	36.2	17.0	41	Good
24	+ Vert.	Gunfire Shock	55	2.5	66.0	3.6	42	Good
25	+ Vert.	Gunfire Shock	55	2.5	45.2	4.0	42	Low g
26	+ Vert.	Gunfire Shock	55	2.5	41.4	4.4	42	Low g
27	+ Vert.	Gunfire Shock	55	2.5	56.0	3.9	43 - 47	Good
28	+ Vert.	Gunfire Shock	55	2.5	66.0	3.8	43	Good
29	+ Vert.	Operational Shock	55	<2.0	58.5	2.0	48 - 52	Good
30	+ Vert.	Operational Shock	55	<2.0	70.0	2.0	48	Good
31	+ Vert.	Operational Shock	55	<2.0	57.5	1.7	53, 54	Good
32	+ Vert.	Ballistic Shock	200	<2.0	176.0	1.3	55	Low g
33	+ Vert.	Ballistic Shock	200	<2.0	236.0	1.2	56	Good
34	+ Vert.	Ballistic Shock	200	<2.0	250.0	1.3	57 - 61	Good
35	+ Vert.	Ballistic Shock	200	<2.0	220.0	1.3	62	Good
36	+ Long.	Basic Shock	40	18.0	43.0	16.5	63	Good
37	+ Long.	Basic Shock	40	18.0	39.0	16.0	63 - 67	Good

TEST RESULTS - (Continued)

SHOCK TEST SUMMARY
(Continued)

Test Item: SCAF

Part Number: 119385

Serial Number: 82E018

Record Number	Axis	Test Condition	Required g	Required ms	Actual g	Actual ms	Graph Page No. (Enc. 1)	Remarks
4/19/89								
38	+ Long.	Basic Shock	40	18.0	39.0	19.0	68	Good, See Note 2
39	+ Long.	Gunfire Shock	55	2.5	81.0	2.1	69	Good
40	+ Long.	Gunfire Shock	55	2.5	51.0	2.4	70 - 74	Good
41	+ Long.	Gunfire Shock	55	2.5	50.0	1.8	75	Good
42	+ Long.	Operational Shock	55	<2.0	57.5	1.8	76	Good
43	+ Long.	Operational Shock	55	<2.0	59.0	1.8	77 - 81	Good
44	+ Long.	Operational Shock	55	<2.0	52.5	1.8	82	Good
45	+ Long.	Ballistic Shock	550	<2.0	250.0	1.5	83	Low g
46	+ Long.	Ballistic Shock	550	<2.0	330.0	1.5	84	Low g
47	+ Long.	Ballistic Shock	550	<2.0	420.0	1.7	85	Low g, See Note 3
48	+ Long.	Ballistic Shock	550	<2.0	510.0	1.3	86 - 90	Good, See Note 4

Notes:
1. The strut at the four o'clock position broke during this shock. It appeared that there was not enough thread engagement. It was removed and testing continued.
2. The strut pin at the ten o'clock position bent during this shock. It was replaced and testing continued.
3. After three low level shocks, the base of the turbine was cracked. The crack was welded and testing continued.
4. The base of the turbine cracked again. There were some small cracks in various places on the SCAF (refer to t[illegible] photographs in enclosure 2). Testing was stopped.

Plotted by: [signature]

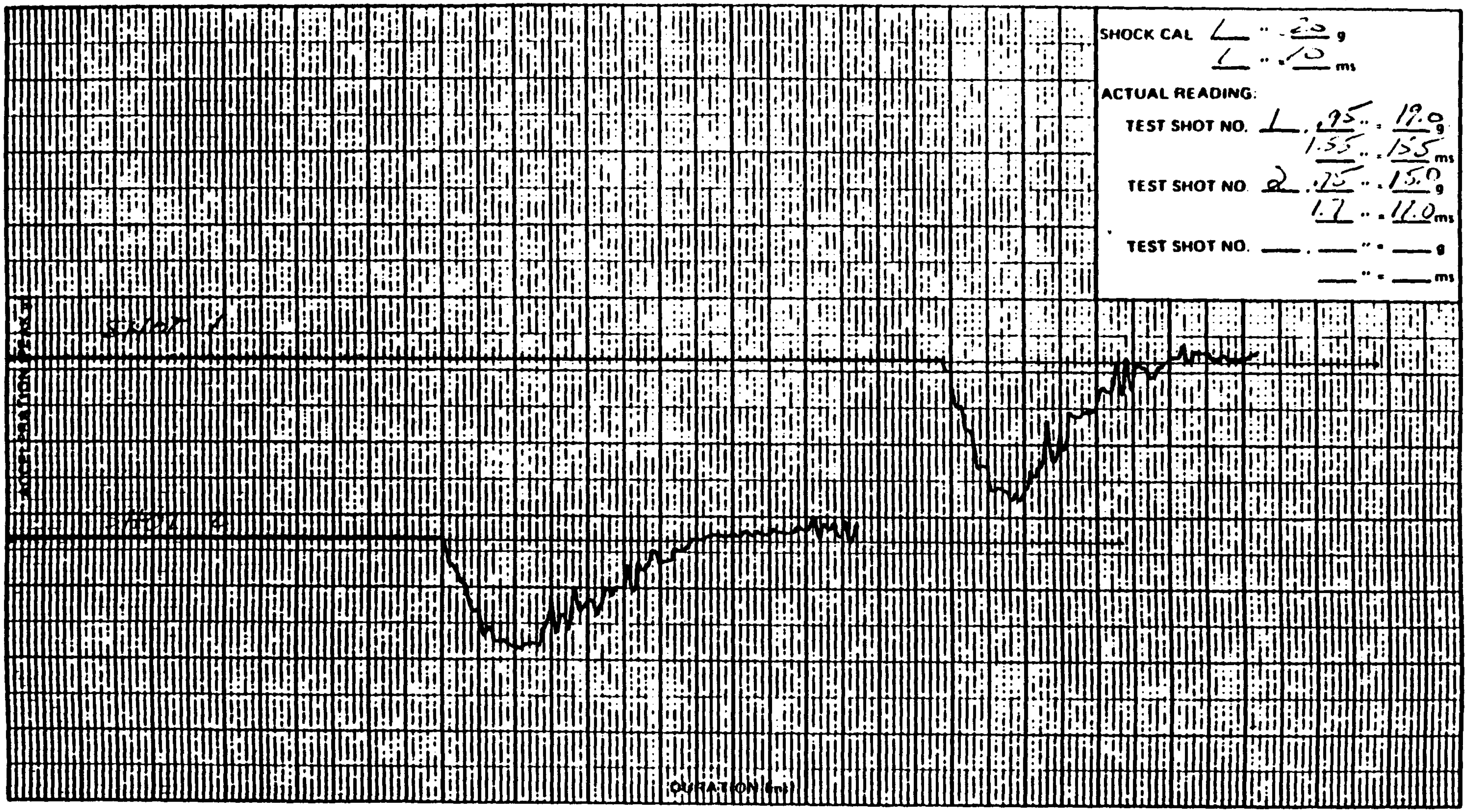
Checked by: G. Hylard

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 8210-8

Unit Operational [ ] Non operational [X]



Pickup Serial Number: NB41

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 $\frac{\text{mv peak}}{\text{g peak}}$

Direction: NEG BASIC

[X] Live [ ] Tape

Job Number: 406744-00-030

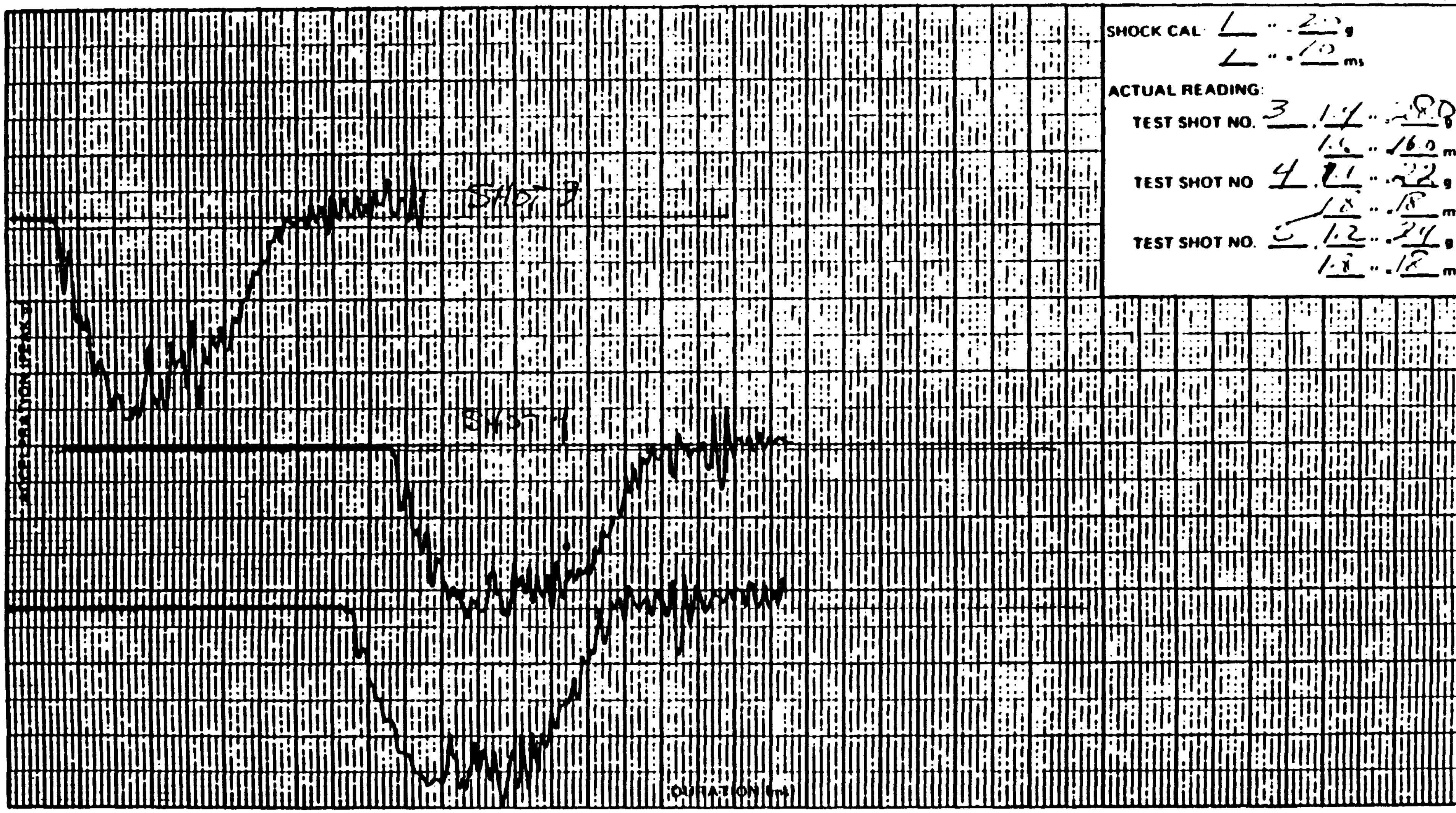
Date: 18 Apr. 89

Time: 1400

Lab Form D24-2

Plotted by: [signature]
Checked by: S. Hyland

Test Item: SCAF
Serial Number(s): 82 E 017
Unit Operational ☐ Non operational ☒



SHOCK CAL: L " 20 g
L " 10 ms

ACTUAL READING:

TEST SHOT NO. 3 . 1.4 " 28 g
1.6 " 16.0 ms

TEST SHOT NO 4 . 1.1 " 22 g
1.8 " 18 ms

TEST SHOT NO. 5 . 1.2 " 24 g
1.8 " 18 ms

Pickup Serial Number: NB4
Pickup Location: CONTROL
Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: NEG BASIC
☒ Live ☐ Tape

Job Number: 406744-00-030
Date: 18 Apr. 89
Time: 1440

Plotted by: Wm. Cl...

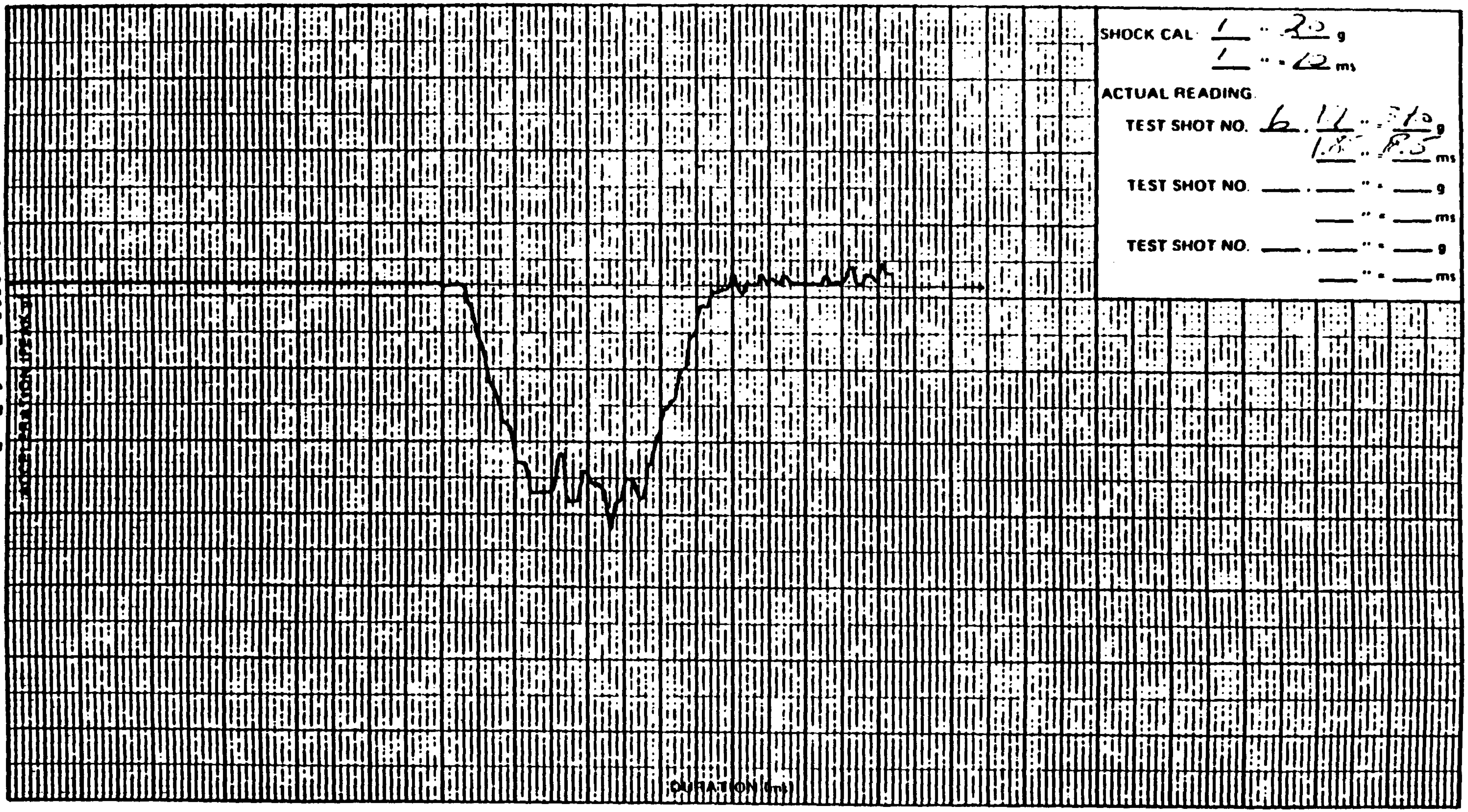
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 822E018

Unit Operational ☐ Non-operational ☒



89-0595 Enc 1 Pg 7

Lab Form D24-2

Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: NEG BASE

☒ Live ☐ Tape

Job Number: 406744-00-070

Date: 18 Apr. 89

Time: 1500

Plotted by: [signature]

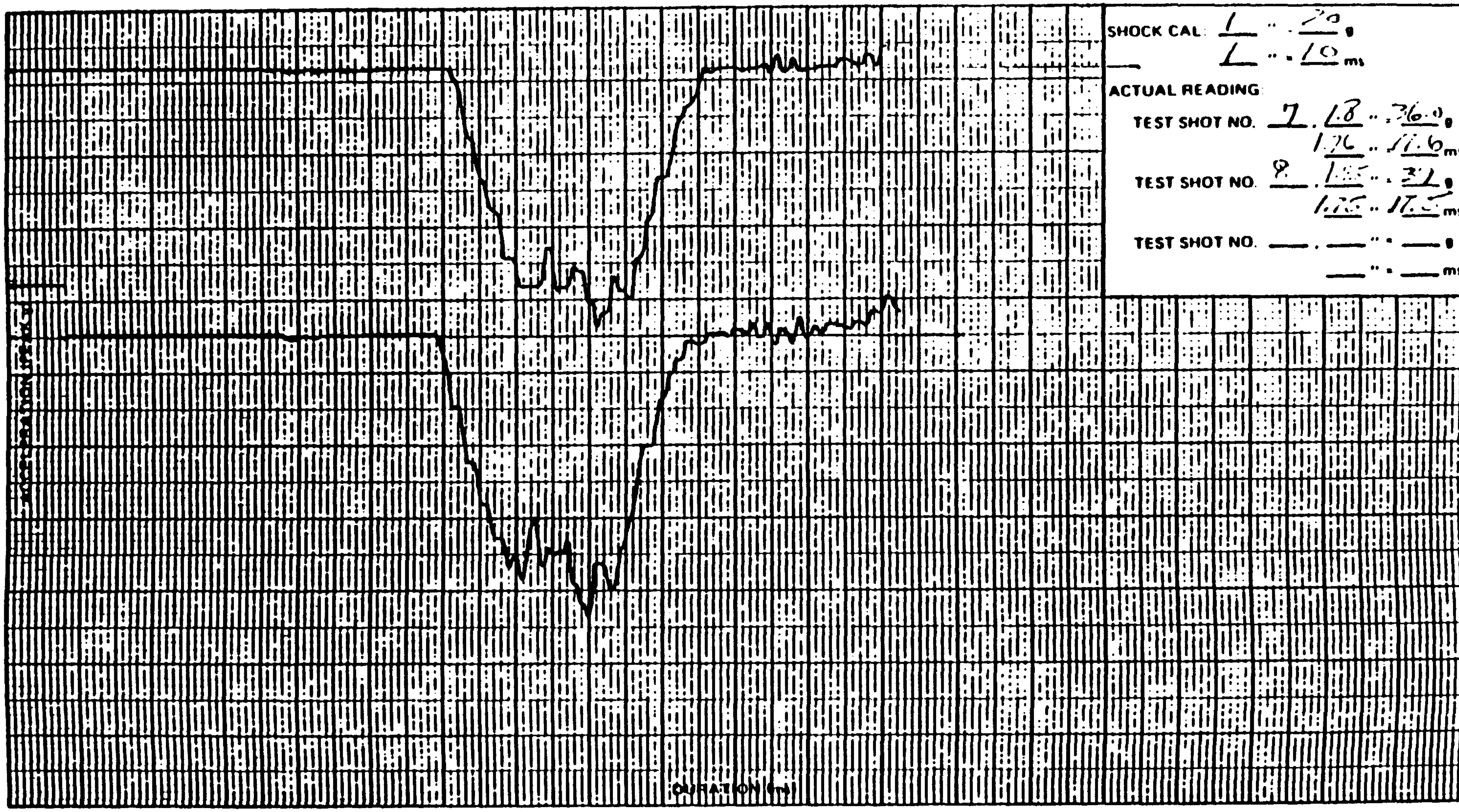
Checked by: G. Hyland

DAYTON

Test Item: SCAB

Serial Number(s): 82E 017

Unit Operational ☐ Non operational ☒



Pickup Serial Number: NBH

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: NEG - BASIC

☒ Live ☐ Tape

Job Number: 406744-00-070

Date: 18 APR. 89

Time: 1540

89-0595 Enc 1 Pg 8

Lab Form D24 2

LOCAL

DAYTON T. BROWN

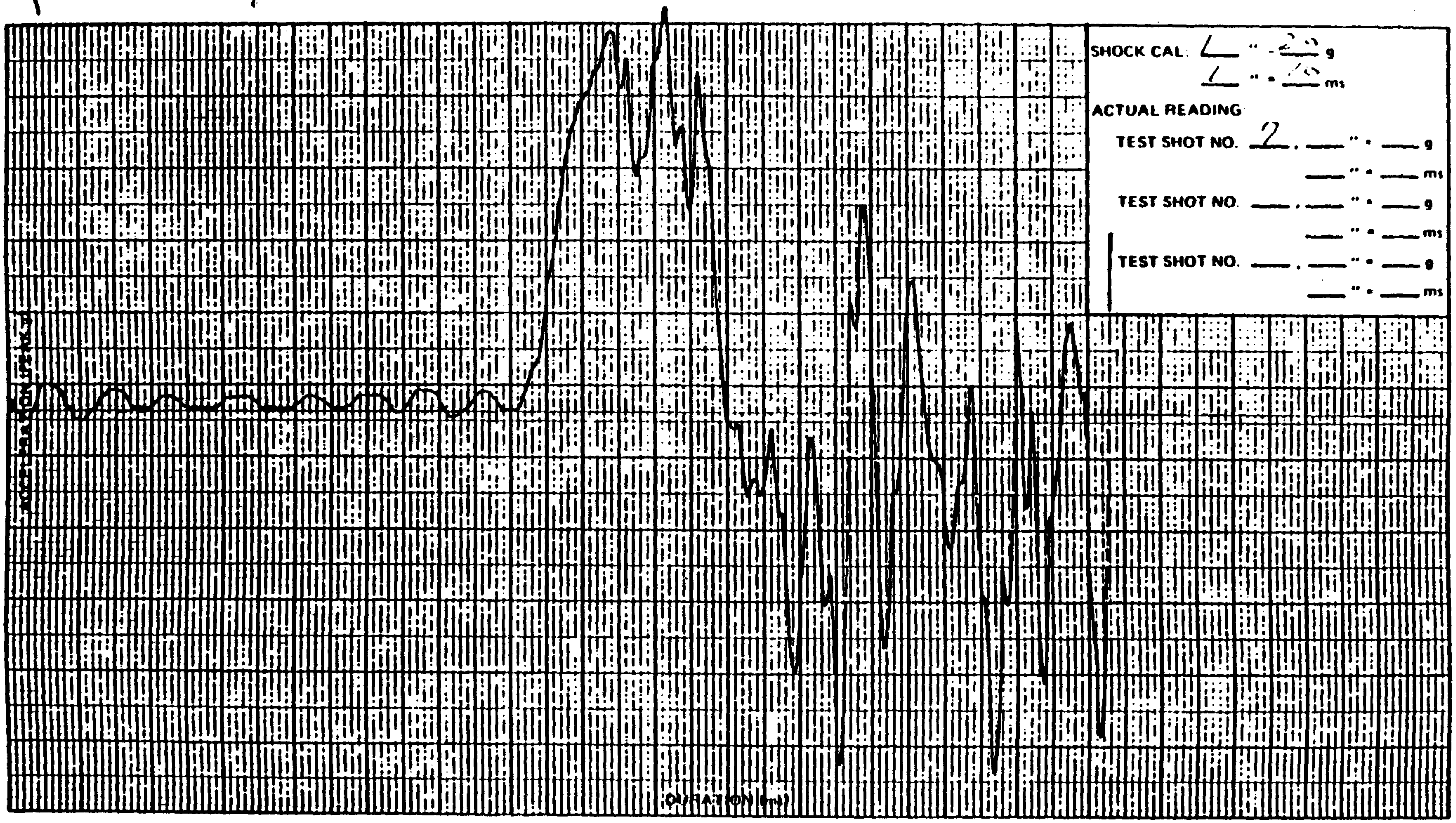
Plotted by: [signature]

Checked by: G. Hyland

Test Item: SCAF

Serial Number(s): [illegible]

Unit: Operational ☐ Non operational ☒



SHOCK CAL: ___ " = ___ g
___ " = ___ ms

ACTUAL READING

TEST SHOT NO. 2 . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: ~~[illegible]~~ 244

Pickup Location: ~~[illegible]~~ TP1

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: NEG [illegible]

☒ Live ☐ Tape

Job Number: F06744-00-070

Date: 18 Apr. 89

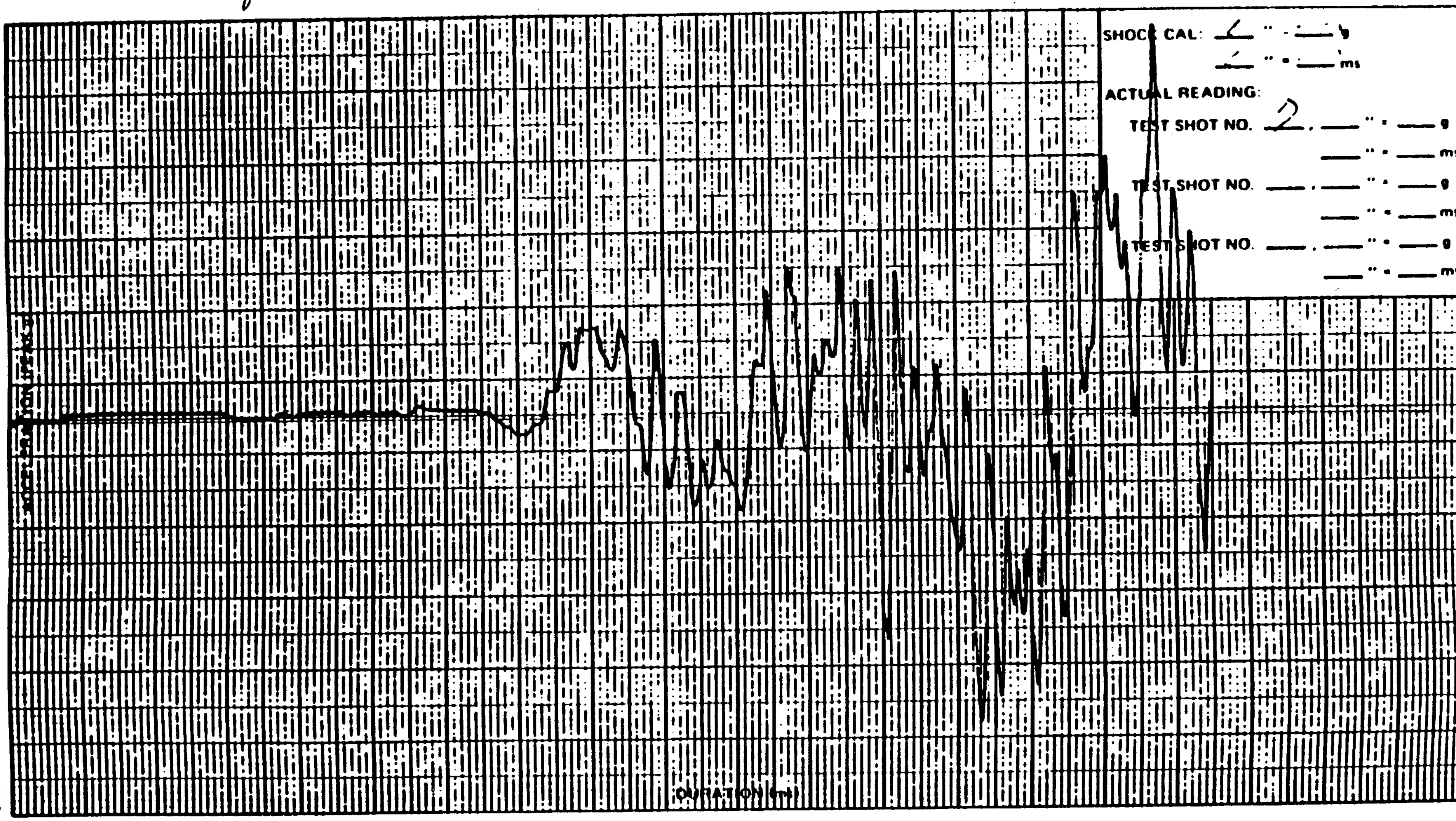
Time: 1510

Lab Form D24-2

Plotted by: [signature]
Checked by: [signature]

DAYTON BROWN

Test Item: SCAF
Serial Number(s):
Unit: Operational [ ] Non operational [X]



Lab Form D24 2

89-0595 Enc 1 Pg 10

Pickup Serial Number: ~~NB44~~ 887
Pickup Location: ~~CONTROL~~ 1P4
Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 $\frac{\text{mv peak}}{\text{g peak}}$
Direction: VERT NEG SAFE
[X] Live [X] Tape

Job Number: 406744-00-030
Date: 17 APR. 89
Time: 15:0

Shock : 8 ...

Plotted by: [signature]

Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 22... 78

Unit: Operational [ ] Non-operational [X]

SHOCK CAL. 1 " = 20 g

1 " = 20 ms

ACTUAL READING:

TEST SHOT NO. 2 , ____ " = ____ g

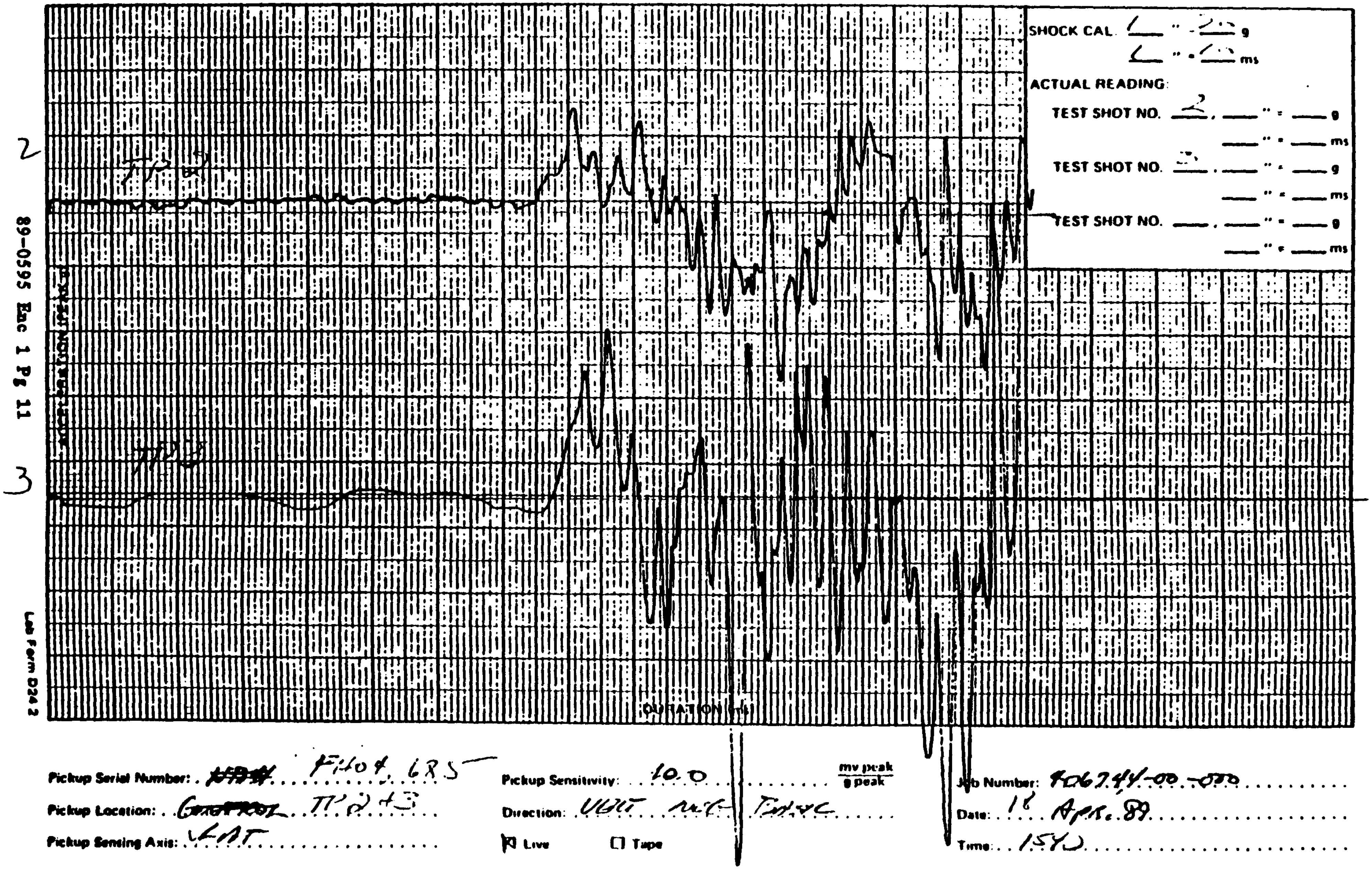
____ " = ____ ms

TEST SHOT NO. 3 , ____ " = ____ g

____ " = ____ ms

TEST SHOT NO. ____ , ____ " = ____ g

____ " = ____ ms



89-0595 Enc 1 Pg 11

Lab Form D24 2

Pickup Serial Number: ~~[illegible]~~ F404, 6RS

Pickup Location: ~~CONTROL~~ TP 2+3

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 $\frac{\text{mv peak}}{\text{g peak}}$

Direction: VERT. ... Thru C

[X] Live [ ] Tape

Job Number: 906744-00-030

Date: 18 Apr. 89

Time: 1540

Plotted by: [illegible signature]

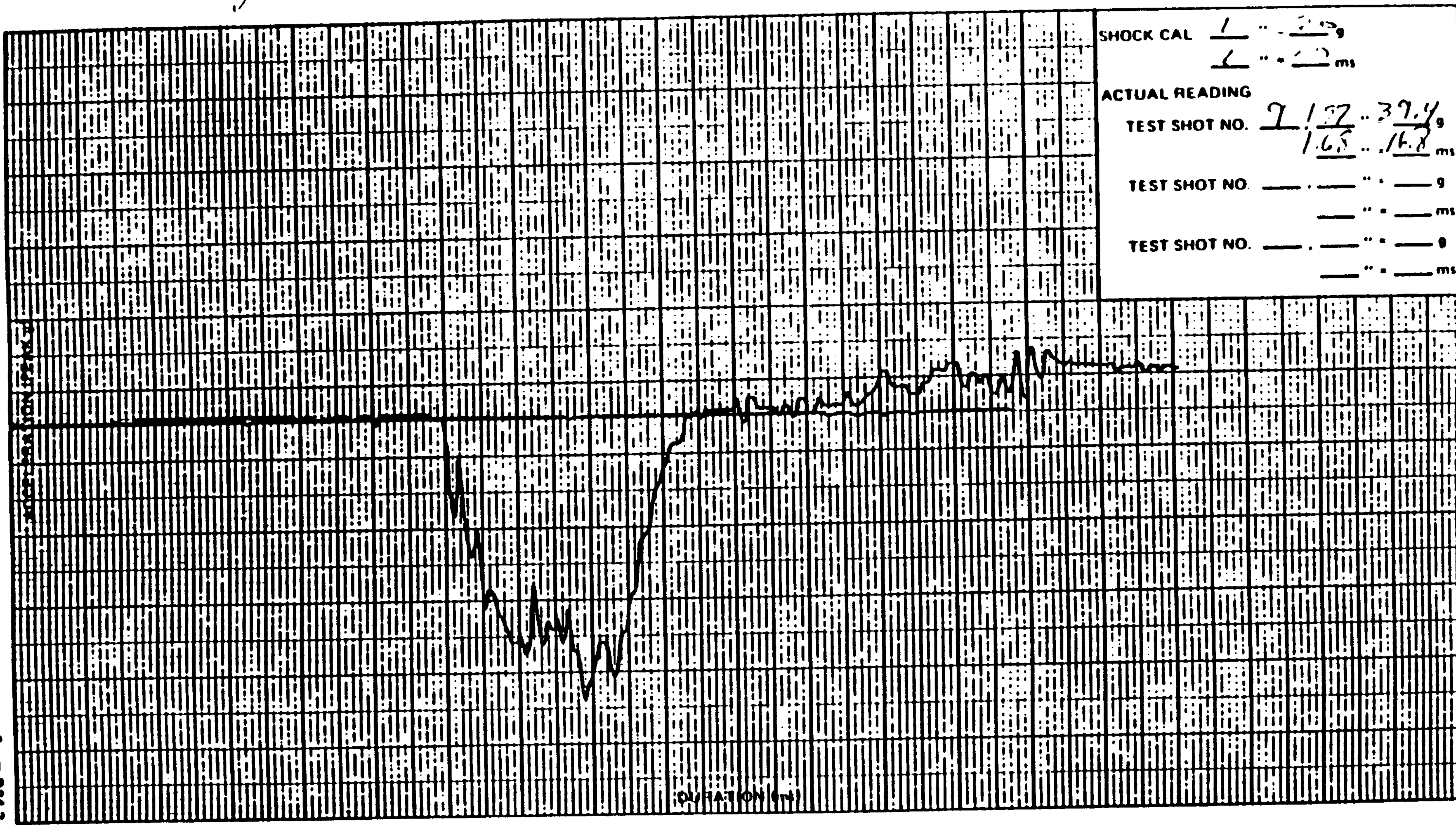
Checked by: [illegible signature]

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E (Y)

Unit Operational [ ] Non operational [X]



Pickup Serial Number: NB41

Pickup Location: CONTROL

Pickup Sensing Axis: [illegible]

Pickup Sensitivity 10.0 $\frac{mv\ peak}{g\ peak}$

Direction: A [illegible] BASIC

[X] Live [ ] Tape

Job Number: 406744-00-070

Date: 18 APR. 89

Time: [illegible]

Lab Form D24-2

Plotted by: [signature]

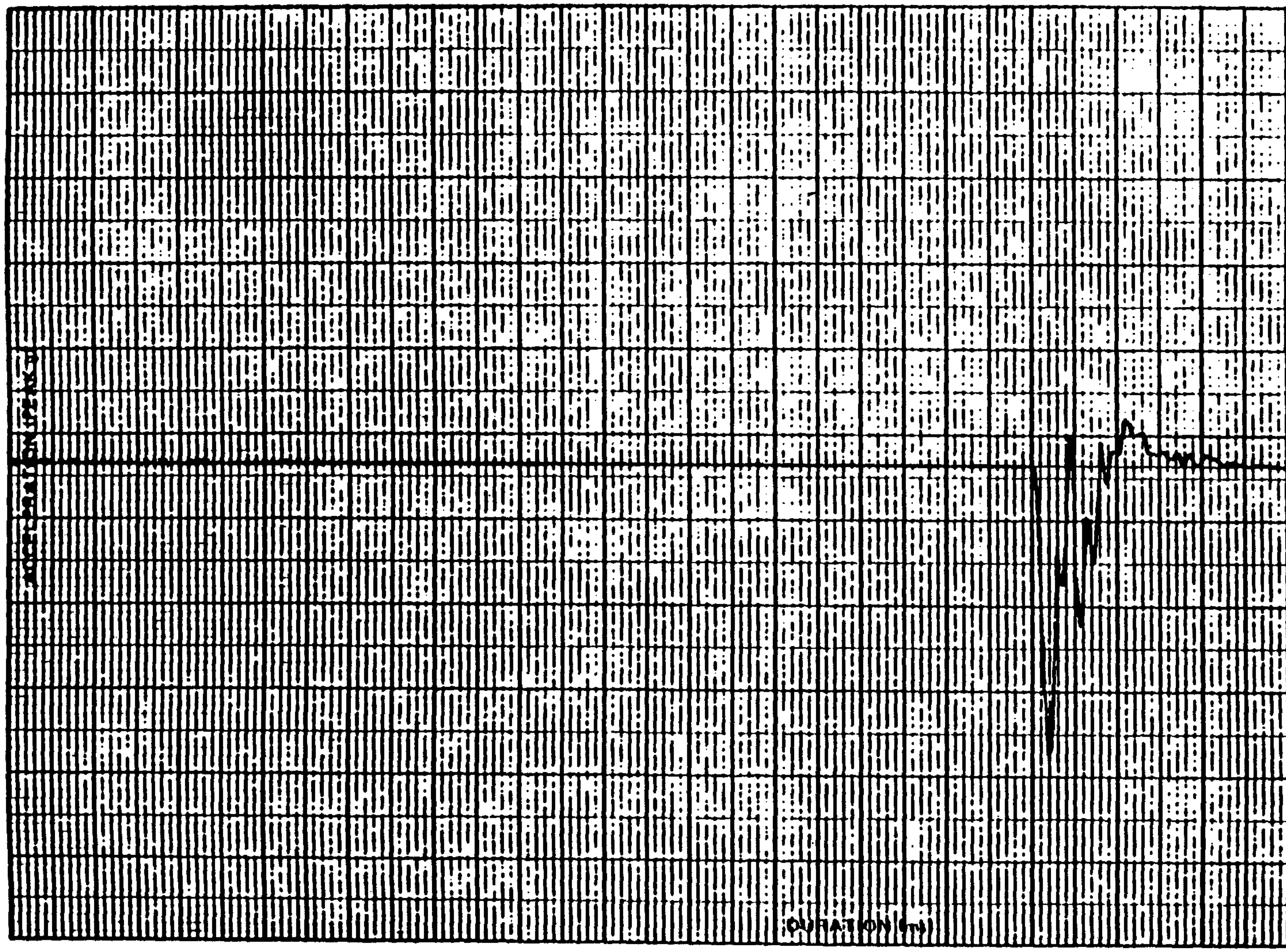
Checked by: G. Hylard

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non-operational ☒



SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 10 1.7" = 85 g
0.24" = 2.4 ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms

Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: - Vert

☒ Live ☐ Tape

Job Number: 406744-00-070

Date: 18 Apr. 89

Time: 1715

Lab Form D24-2

Plotted by: *[signature]*

Checked by: *G. Hyland*

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒

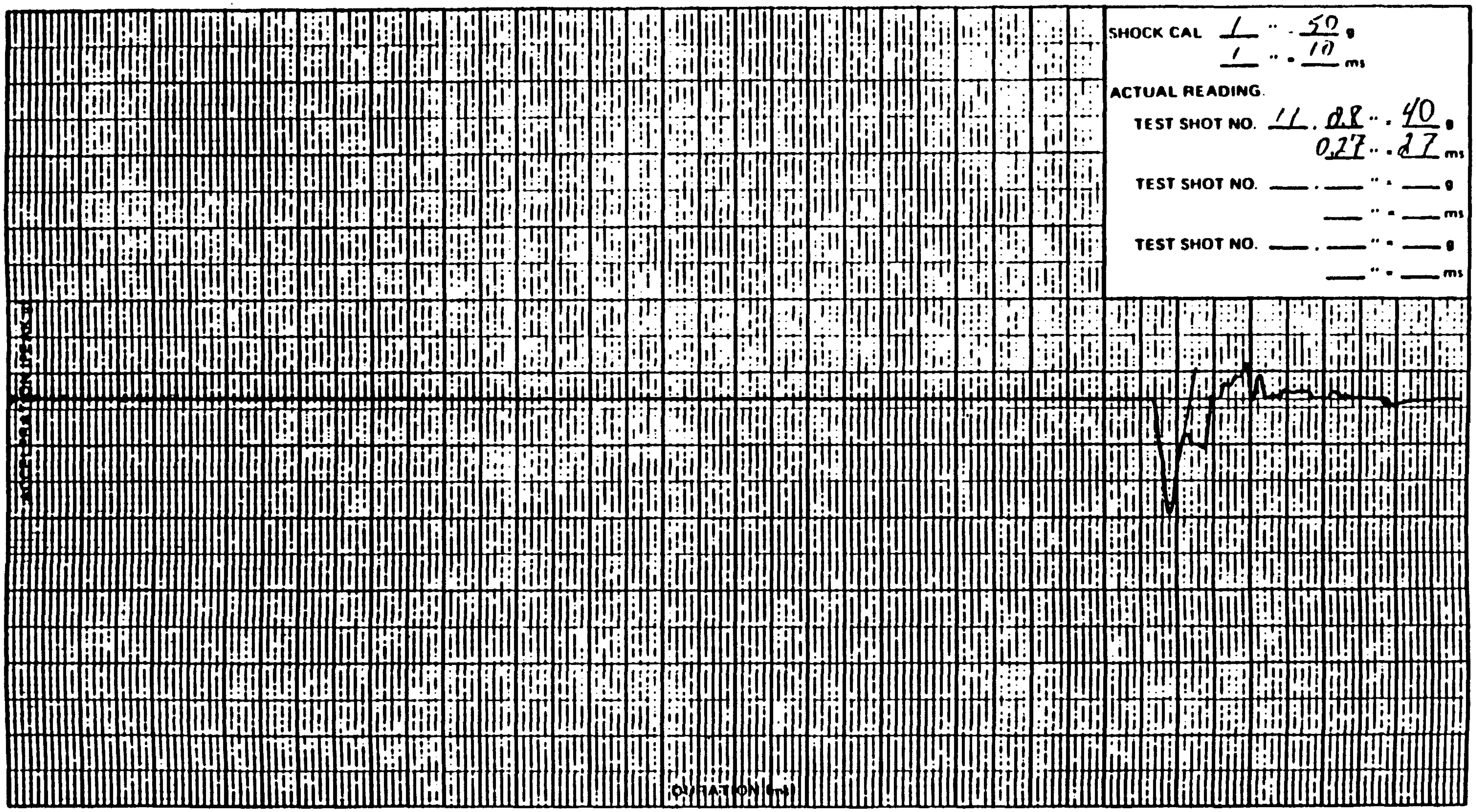
SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING.

TEST SHOT NO. 11 .28 " = 40 g
0.27 " = 27 ms

TEST SHOT NO. ____ . ____ " = ____ g
____ " = ____ ms

TEST SHOT NO. ____ . ____ " = ____ g
____ " = ____ ms



Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 $\frac{\text{mv peak}}{\text{g peak}}$

Direction: -Vert

☒ Live ☐ Tape

Job Number: 406744-00-030

Date: Apr. 89

Time: 1720

Plotted by: [signature]

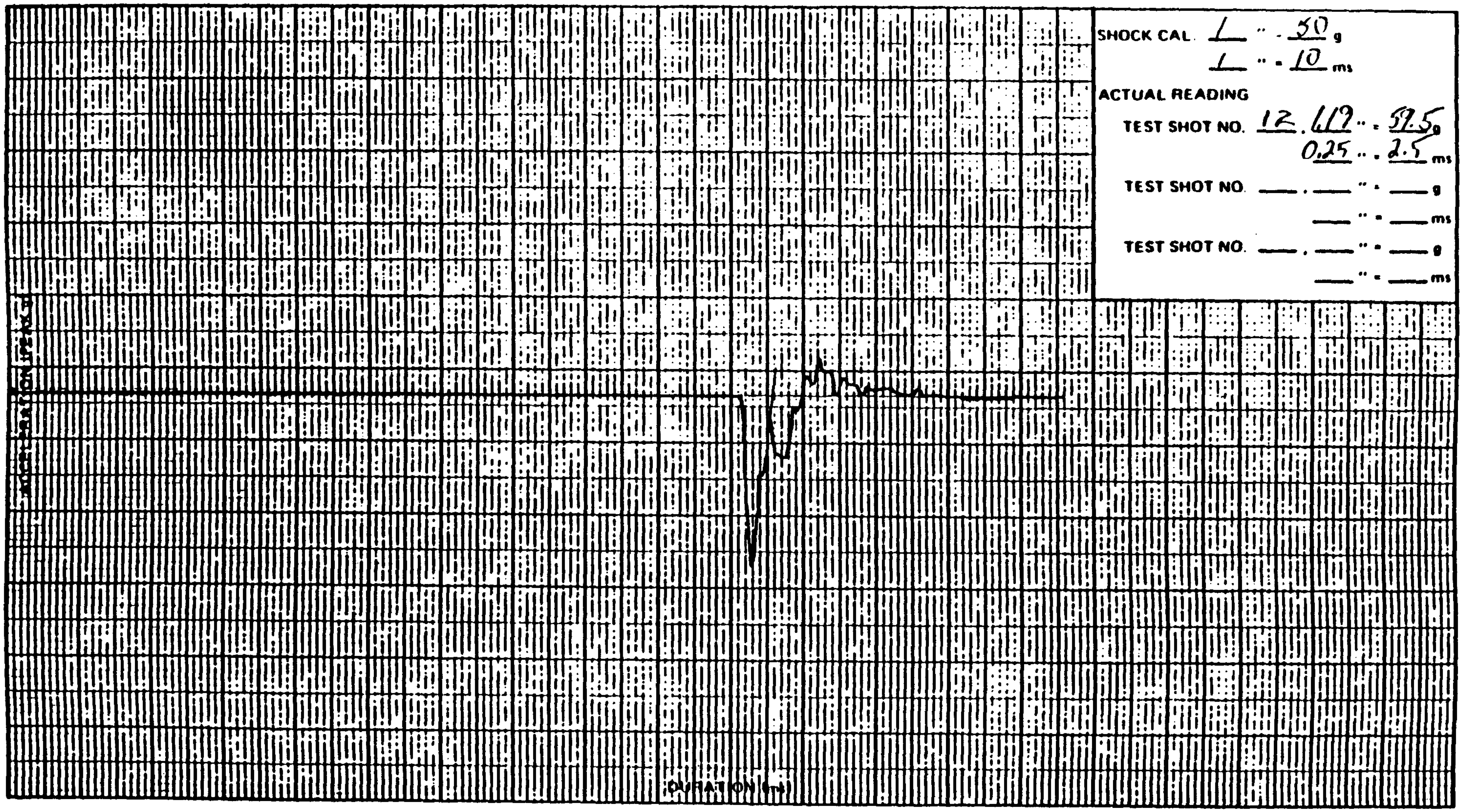
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL. 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 12. 119 " = 59.5 g
0.25 " = 2.5 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[X] Live [ ] Tape

Job Number: 406744-00-030

Date: 18 Apr. 89

Time: 1725

Lab Form D24-2

DAYTON BROWN

Plotted by: [signature]

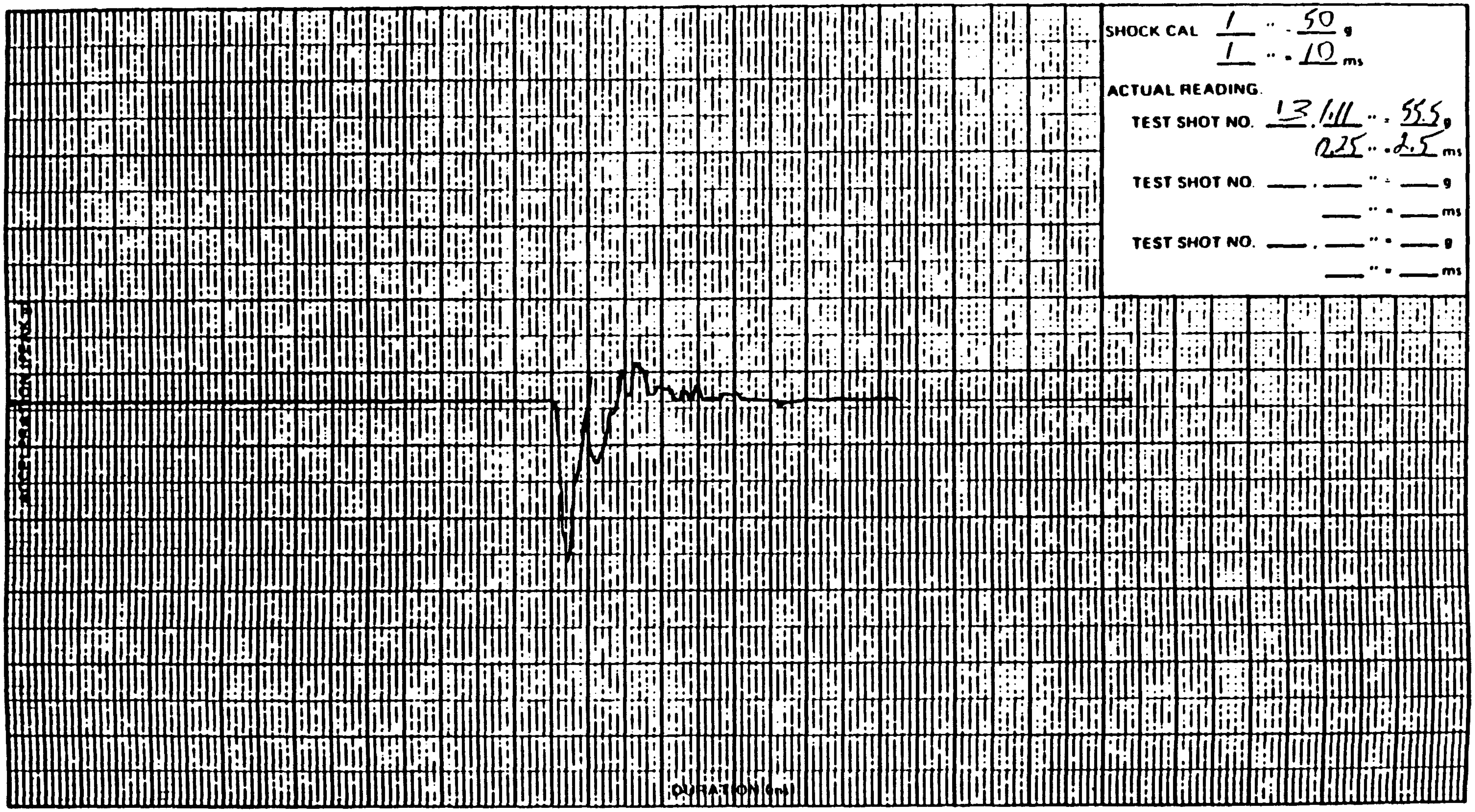
Checked by: G. Hynard

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒

SHOCK CAL	1 " = 50 g		
	1 " = 10 ms		
ACTUAL READING			
TEST SHOT NO. 1	3.1 " = 55.5 g		
	0.25 " = 2.5 ms		
TEST SHOT NO.	" = g		
	" = ms		
TEST SHOT NO.	" = g		
	" = ms		



Pickup Serial Number: NB4

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

☒ Live ☐ Tape

Job Number: 406744-00-020

Date: 18 Apr. 89

Time: 1730

89-0595 Enc 1 Pg 16

Lab Form D24 2

Plotted by: [illegible signature]

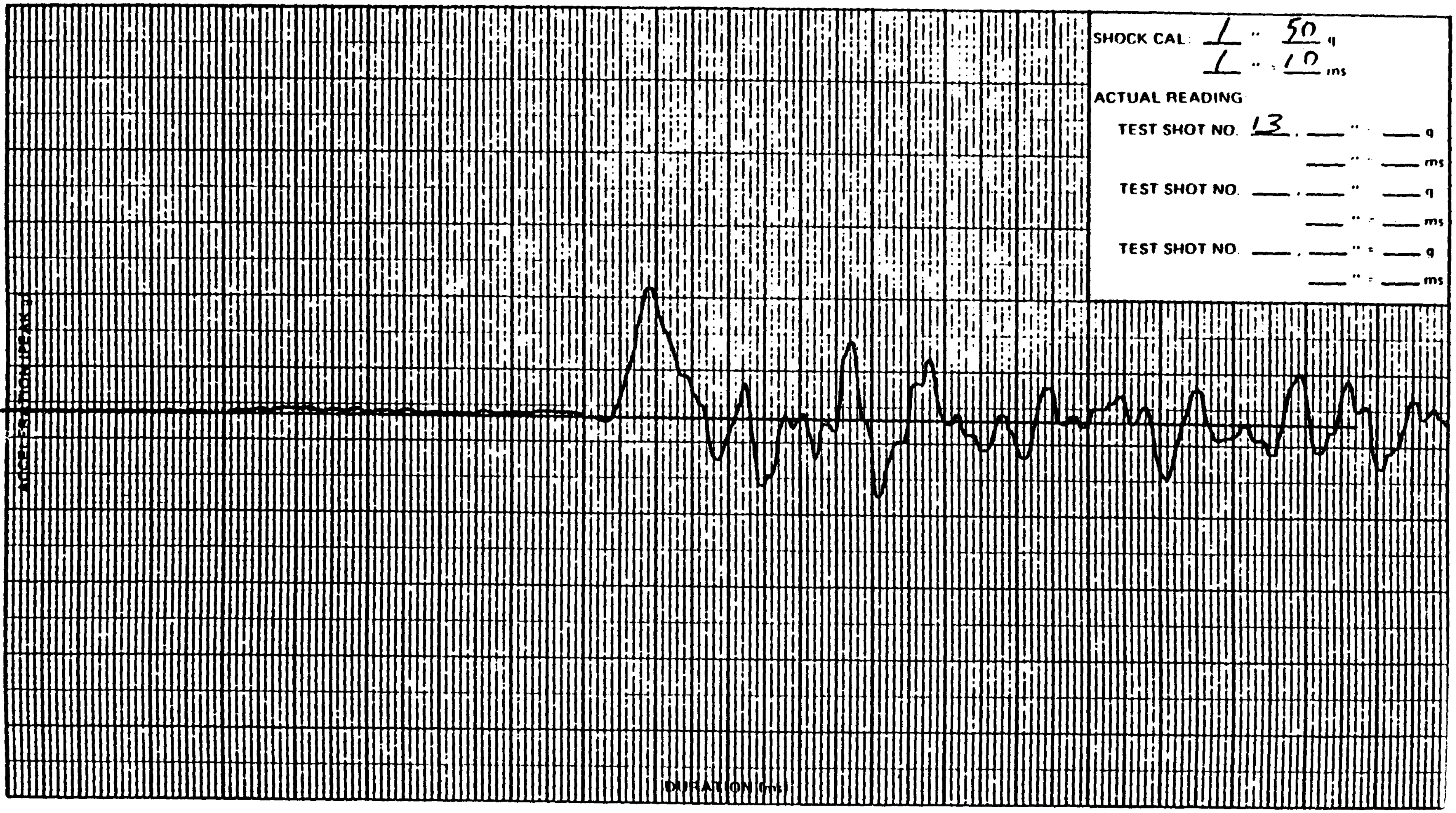
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82L018

Unit Operational [ ] Non-operational [ ]



SHOCK CAL: 1 " = 50 g

1 " = 10 ms

ACTUAL READING:

TEST SHOT NO. 13 , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

Lab Form D24-2

Pickup Serial Number: 244

Pickup Location: TP#1

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: - Vert

[ ] Live [X] Tape

Job Number: 406744

Date: 18 Apr '81

Time: 1730

Plotted by: [signature]

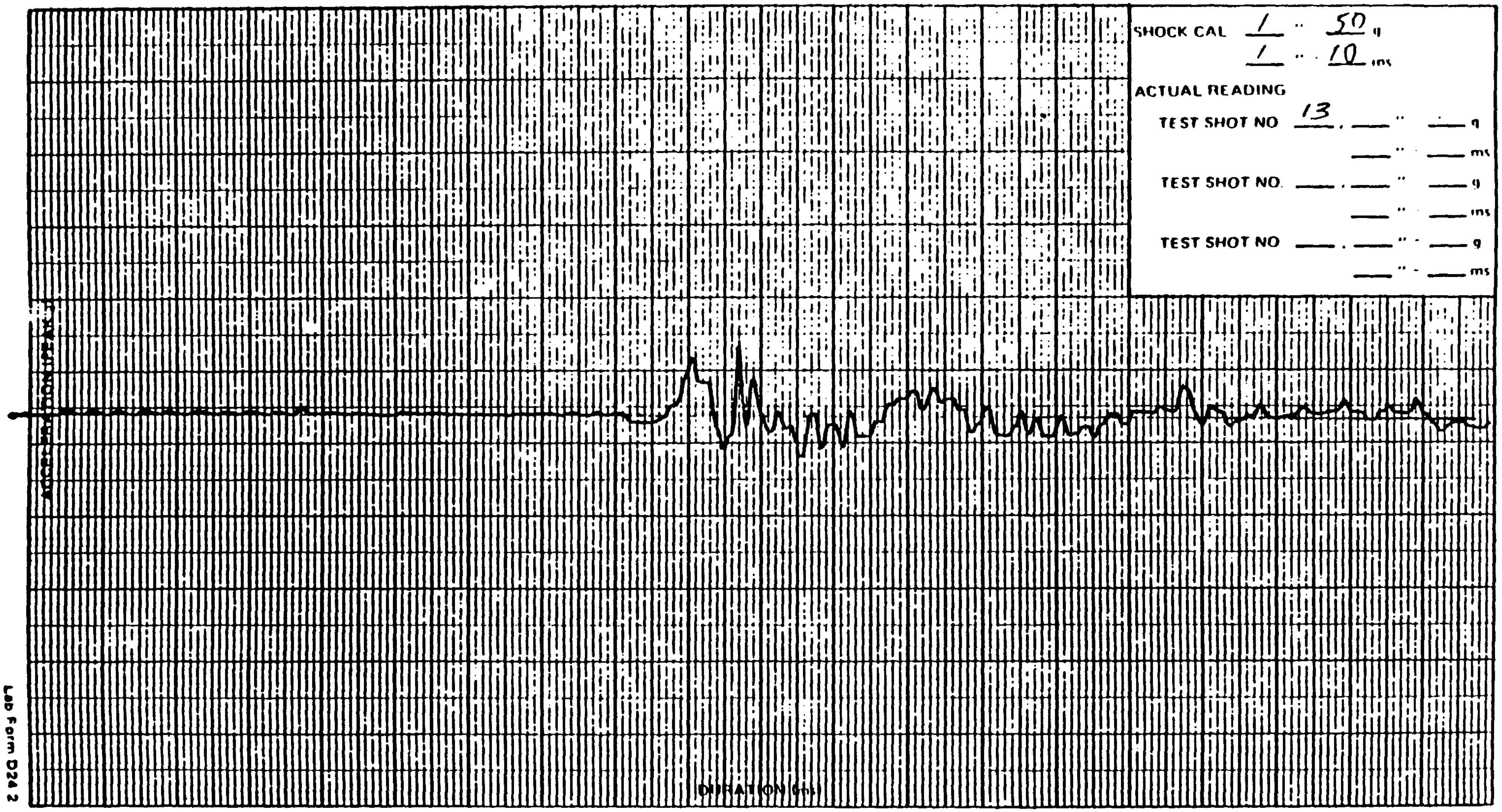
Checked by: G. Hylford

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [✓]



Lab Form D24 2

Pickup Serial Number: FH04

Pickup Location: TP#2

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [✓] Tape

Job Number: 406744

Date: 18 April 80

Time: 1730

Plotted by: G. Heniken

Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [ ]

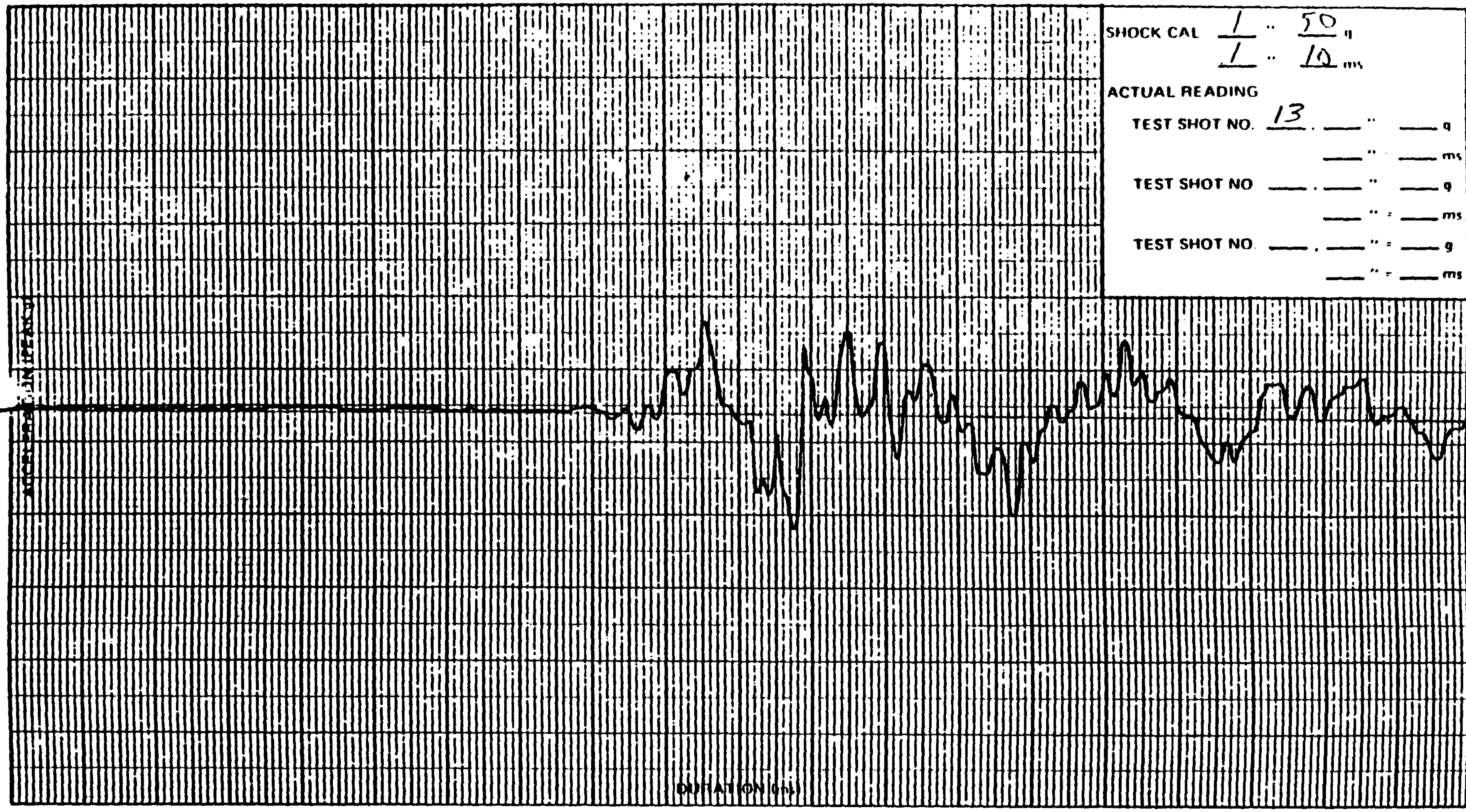
SHOCK CAL 1 " 50 g
1 " 10 ms

ACTUAL READING

TEST SHOT NO. 13 ___ " ___ g
___ " ___ ms

TEST SHOT NO ___ . ___ " ___ g
___ " ___ ms

TEST SHOT NO. ___ . ___ " ___ g
___ " ___ ms



Lab Form D24-2

89-0595 Enc 1 Pg 19

Pickup Serial Number: 1051685

Pickup Location: T.P.#3

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [X] Tape

Job Number: 406744

Date: 18 Apr.'89

Time: 1730

Plotted by: G. Knight

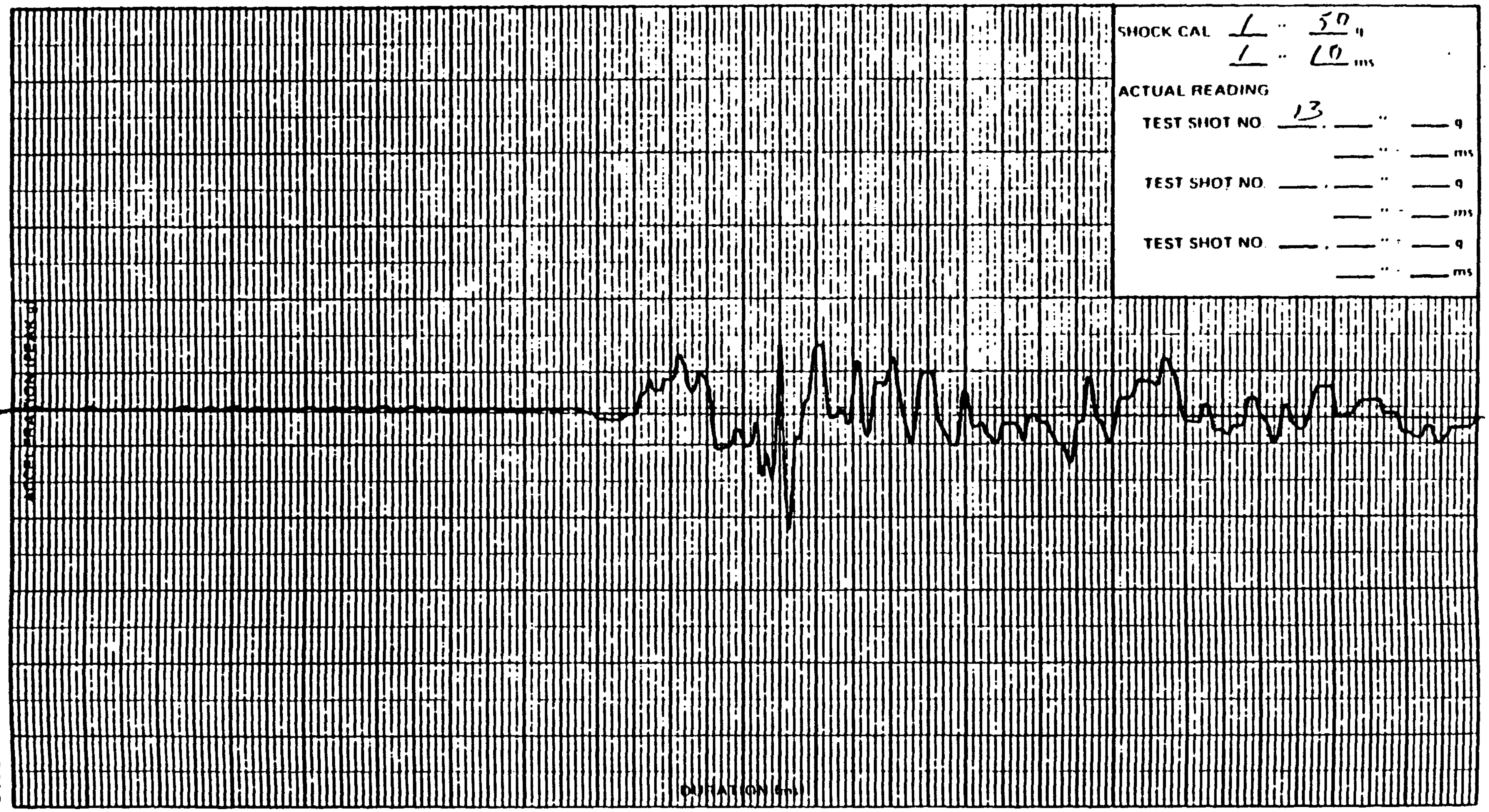
Checked by: G. Hylond

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [x]



SHOCK CAL 1 " 50 g
1 " 10 ms

ACTUAL READING

TEST SHOT NO. 13 . ____ " ____ g
____ " ____ ms

TEST SHOT NO. ____ . ____ " ____ g
____ " ____ ms

TEST SHOT NO. ____ . ____ " ____ g
____ " ____ ms

Pickup Serial Number: 1121887

Pickup Location: T.P.#4

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [x] Tape

Job Number: 406744

Date: 18 April 87

Time: 1730

Lab Form D24 2

Plotted by: [illegible]

Checked by: G. Hyland [illegible]

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]

SHOCK CAL 1 = 50 g

1 = 10 ms

ACTUAL READING

TEST SHOT NO. 14: 1.05 = 52.5 g

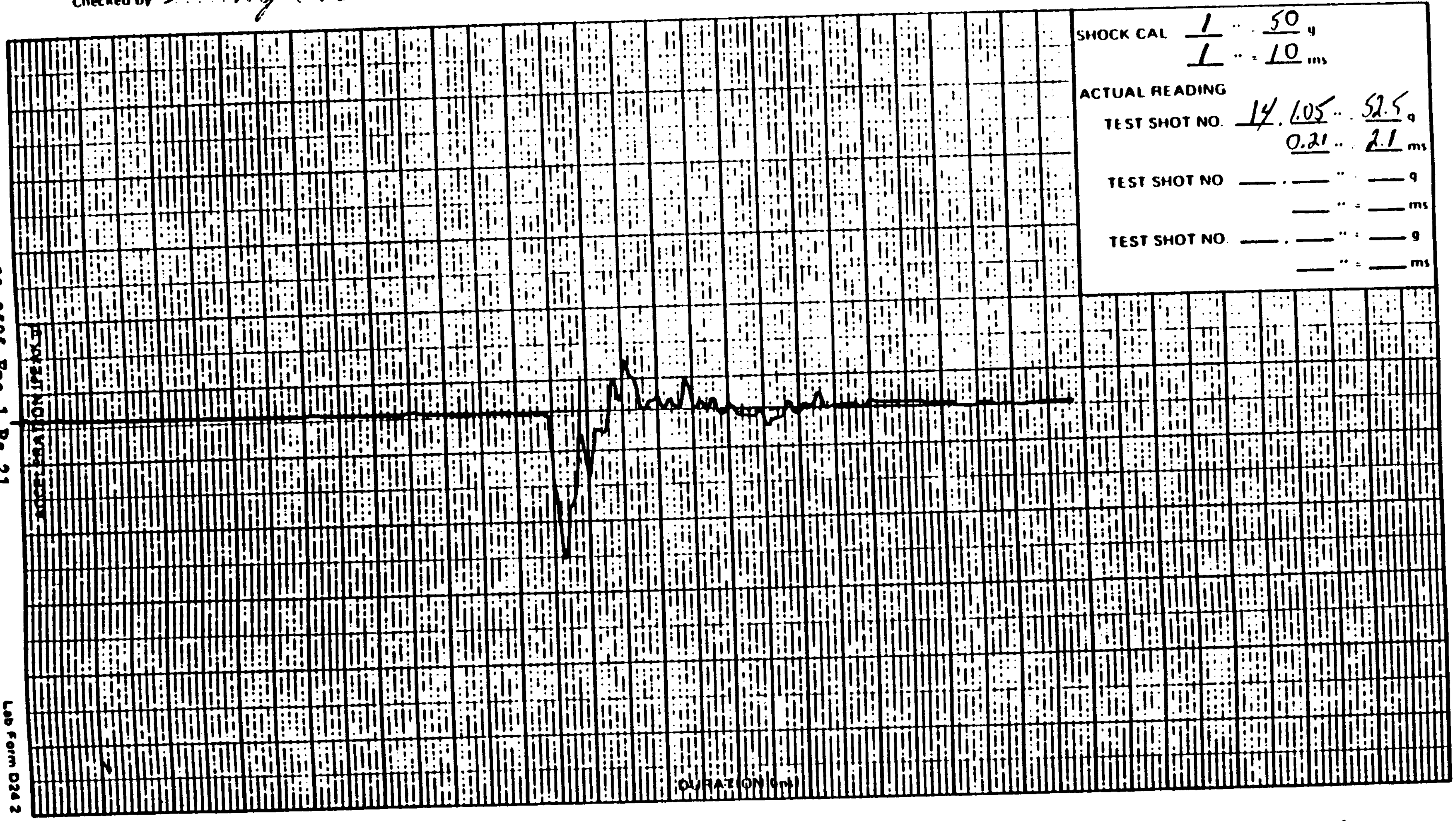
0.21 = 2.1 ms

TEST SHOT NO ___ : ___ = ___ g

___ = ___ ms

TEST SHOT NO ___ : ___ = ___ g

___ = ___ ms



Lab Form D24 2

Pickup Serial Number: NB41

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[X] Live [ ] Tape

Job Number: 406744

Date: 18 April 89

Time: 1840

Plotted by G. [illegible]

Checked by G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]

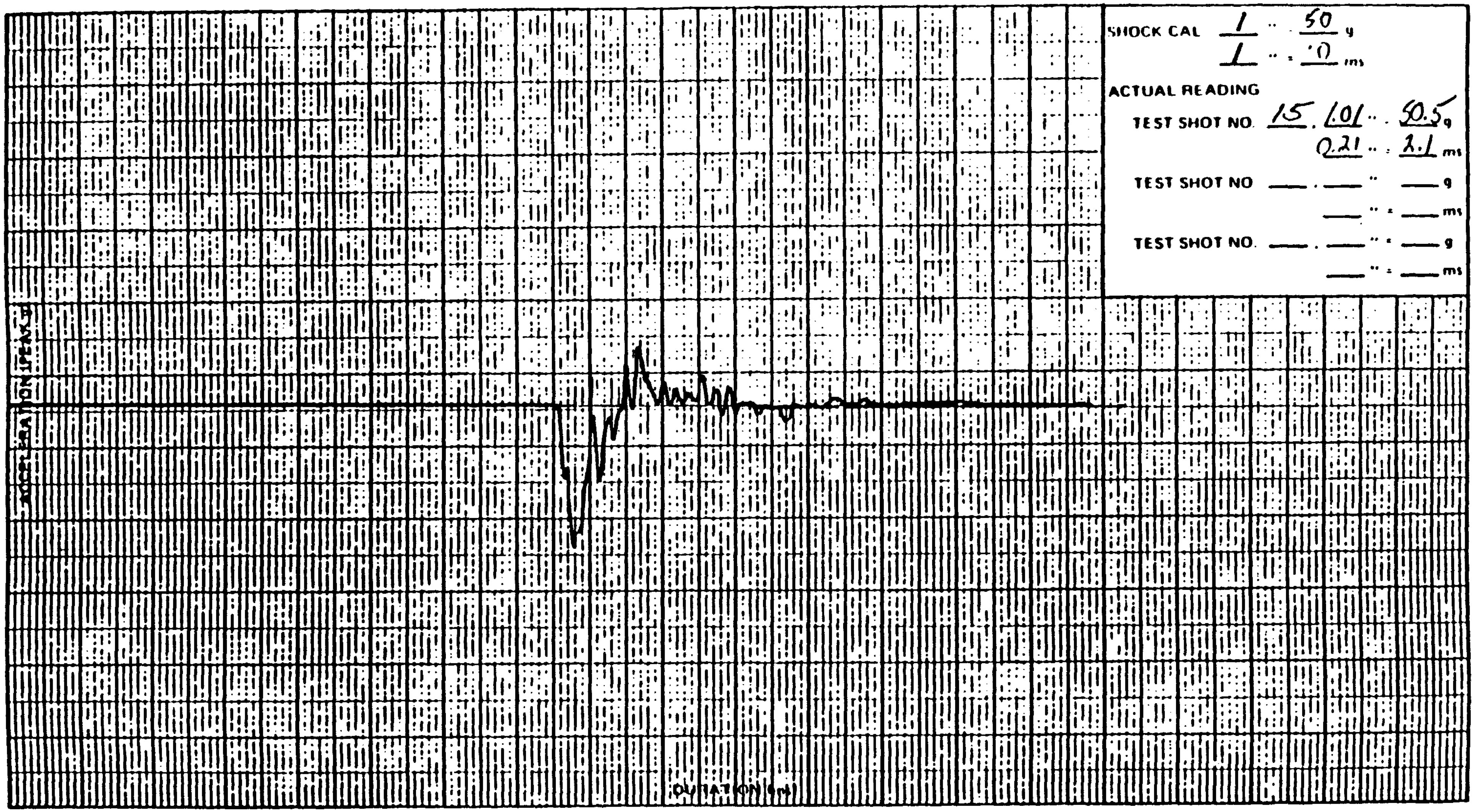
SHOCK CAL 1 " 50 g
1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 15 . 1.01 " 50.5 g
0.21 " : 2.1 ms

TEST SHOT NO. ___ . ___ " ___ g
___ " : ___ ms

TEST SHOT NO. ___ . ___ " ___ g
___ " : ___ ms



Pickup Serial Number: NB41

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [ ] Tape

Job Number: 406744

Date: 18 April 89

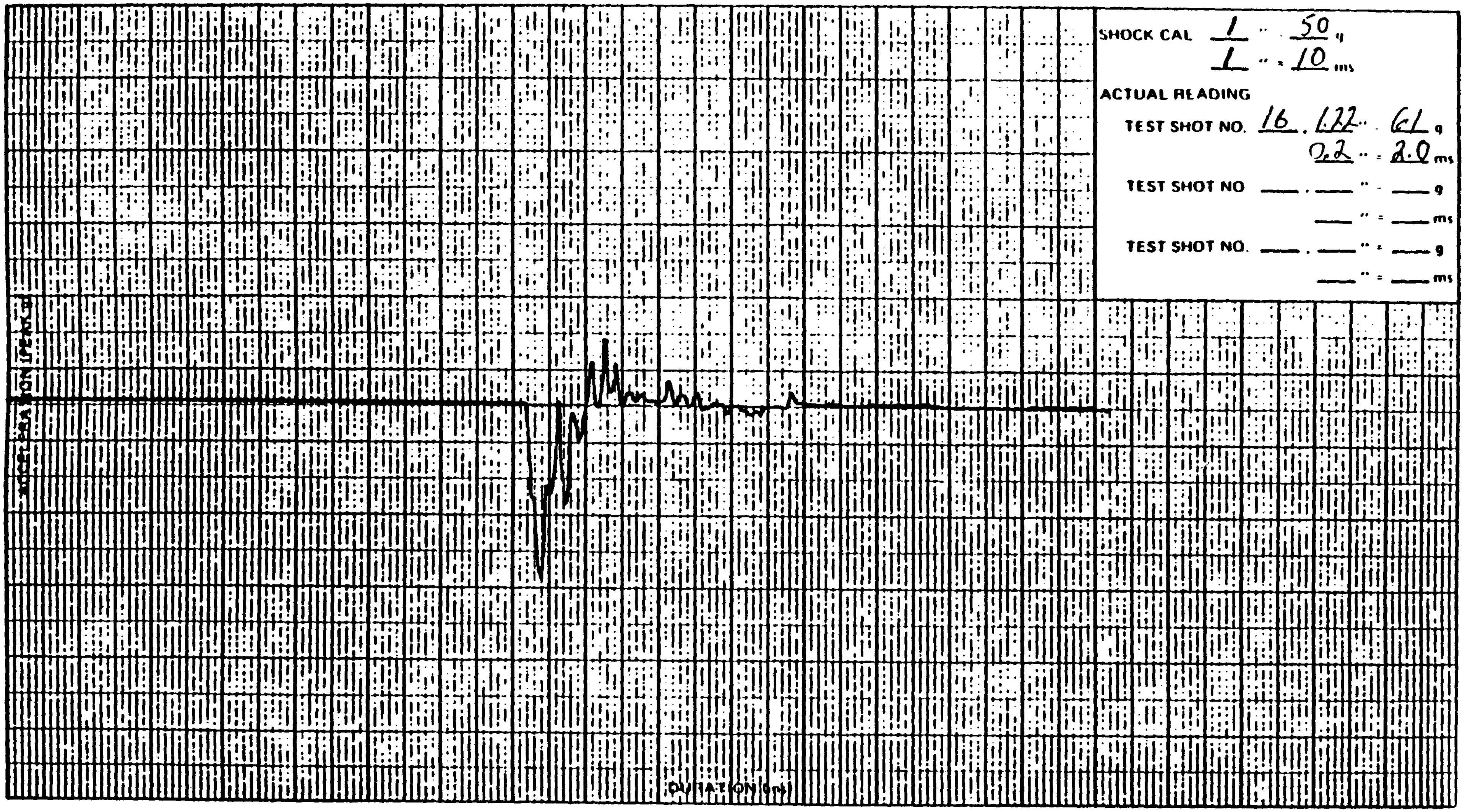
Time: 1845

Lab Form D24 2

Plotted by: [signature]
Checked by: G. Hubbard

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational [ ] Non operational [X]



SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING
TEST SHOT NO. 16 . 1.22 " = 61 g
0.2 " = 2.0 ms
TEST SHOT NO ____ . ____ " = ____ g
____ " = ____ ms
TEST SHOT NO. ____ . ____ " = ____ g
____ " = ____ ms

Pickup Serial Number: NB41
Pickup Location: Control
Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: -Vert
[X] Live [ ] Tape

Job Number: 406744
Date: 18 April 89
Time: 1850

Lab Form D24 2

Plotted by G. Lycaien [illegible]

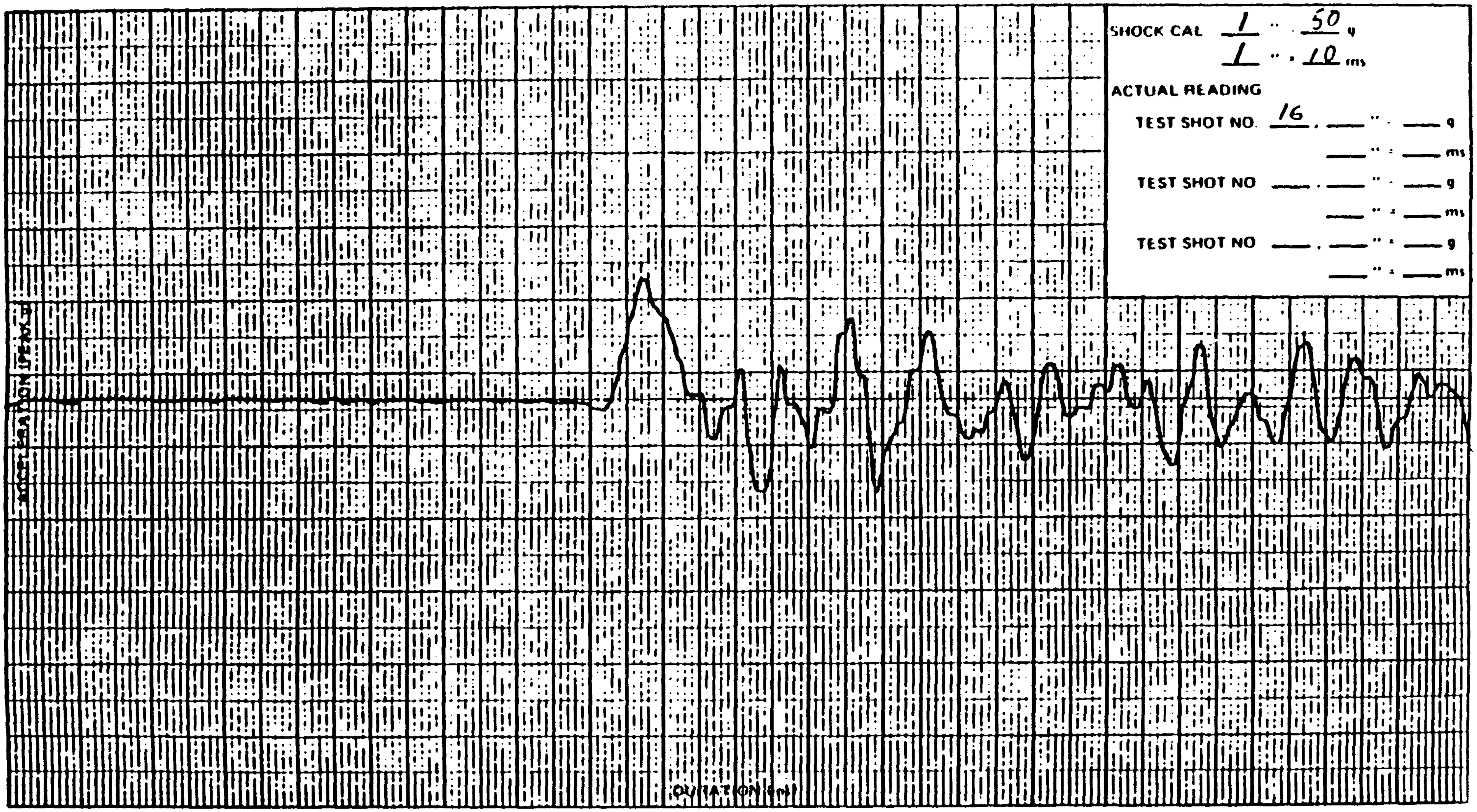
Checked by G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]



SHOCK CAL 1 " 50 g

1 " 10 ms

ACTUAL READING

TEST SHOT NO. 16 . ___ " ___ g

___ " ___ ms

TEST SHOT NO ___ . ___ " ___ g

___ " ___ ms

TEST SHOT NO ___ . ___ " ___ g

___ " ___ ms

Pickup Serial Number: 244

Pickup Location: TP#1

Pickup Sensing Axis: Vert

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [M] Tape

Job Number: 406744

Date: 18 April 89

Time: 1850

Lab Form D24 2

Plotted by: J. [illegible]

Checked by: G. Hylard

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]

SHOCK CAL 1" = 50 g

1" = 10 ms

ACTUAL READING

TEST SHOT NO. 16 ___" = ___ g

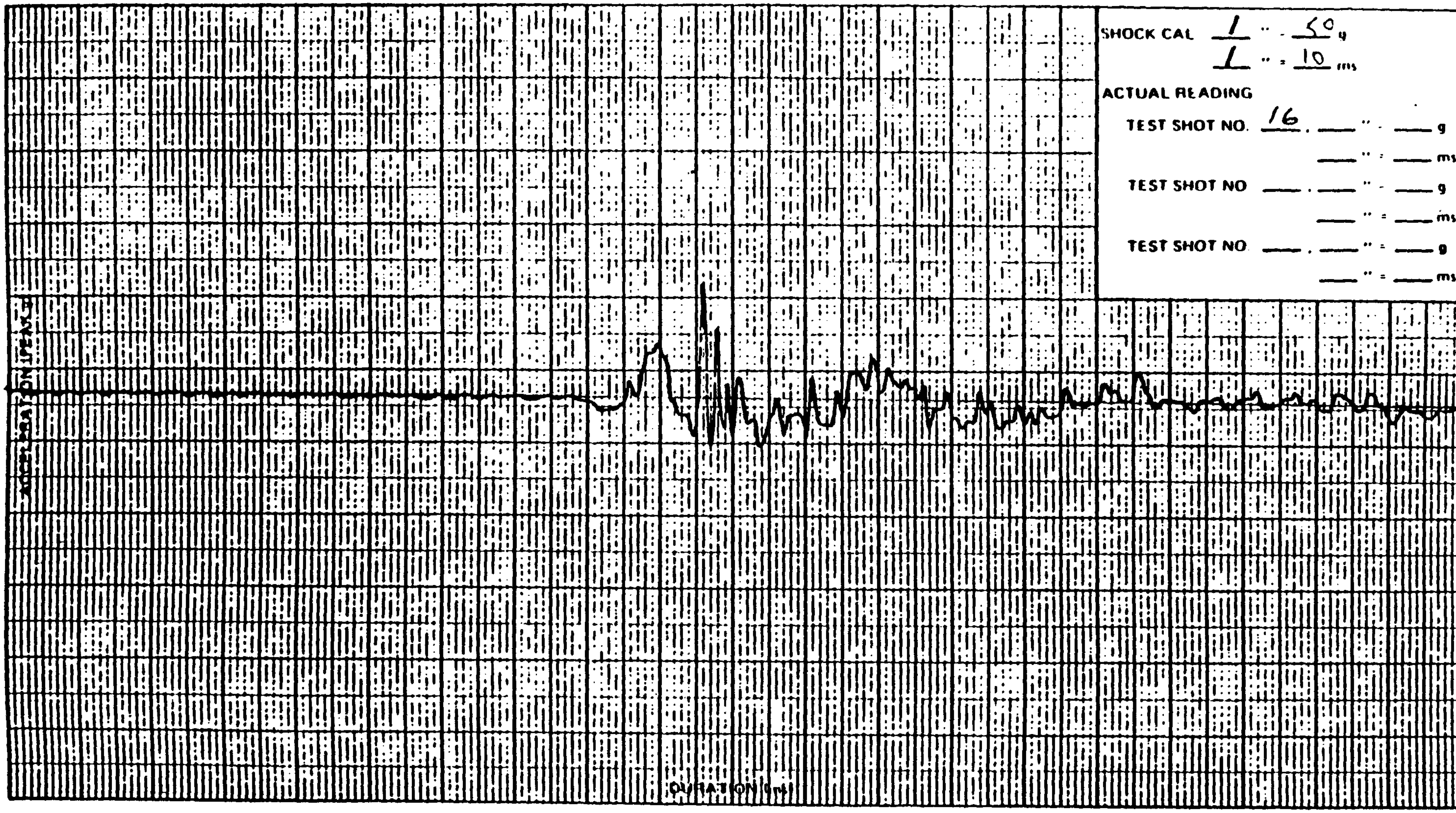
___" = ___ ms

TEST SHOT NO ___ ___" = ___ g

___" = ___ ms

TEST SHOT NO ___ ___" = ___ g

___" = ___ ms



Pickup Serial Number: FH04

Pickup Location: TP#2

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [X] Tape

Job Number: 406744

Date: April 89

Time: 1250

Lab Form D24 2

DAYTON T. BROWN

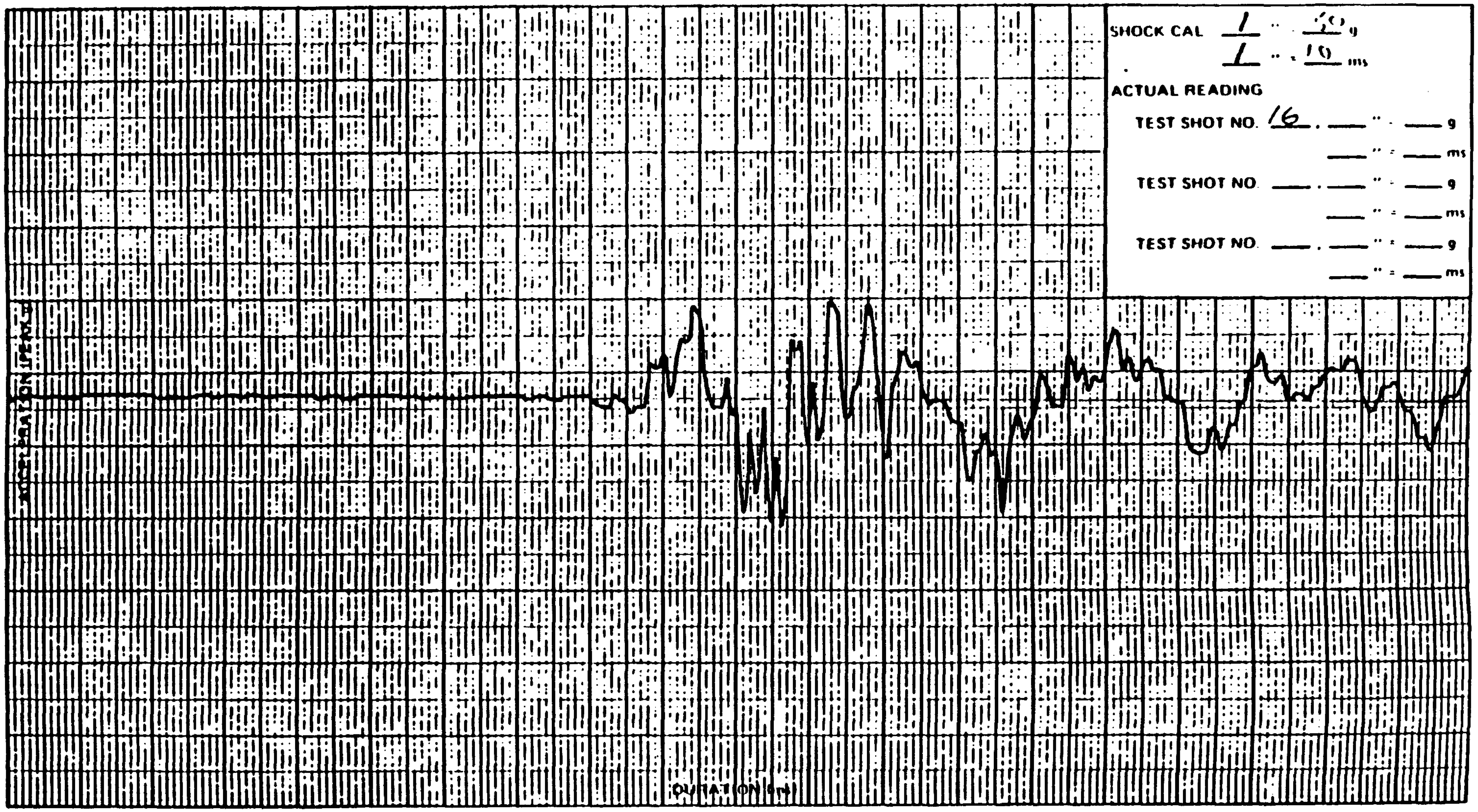
Plotted by: [signature]

Checked by: G. Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]



SHOCK CAL 1 " = 50 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 16 ____ " = ____ g

____ " = ____ ms

TEST SHOT NO. ____ ____ " = ____ g

____ " = ____ ms

TEST SHOT NO. ____ ____ " = ____ g

____ " = ____ ms

Pickup Serial Number: 105168 5

Pickup Location: TP# 3

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: -Vert

[ ] Live [✓] Tape

Job Number: 406744

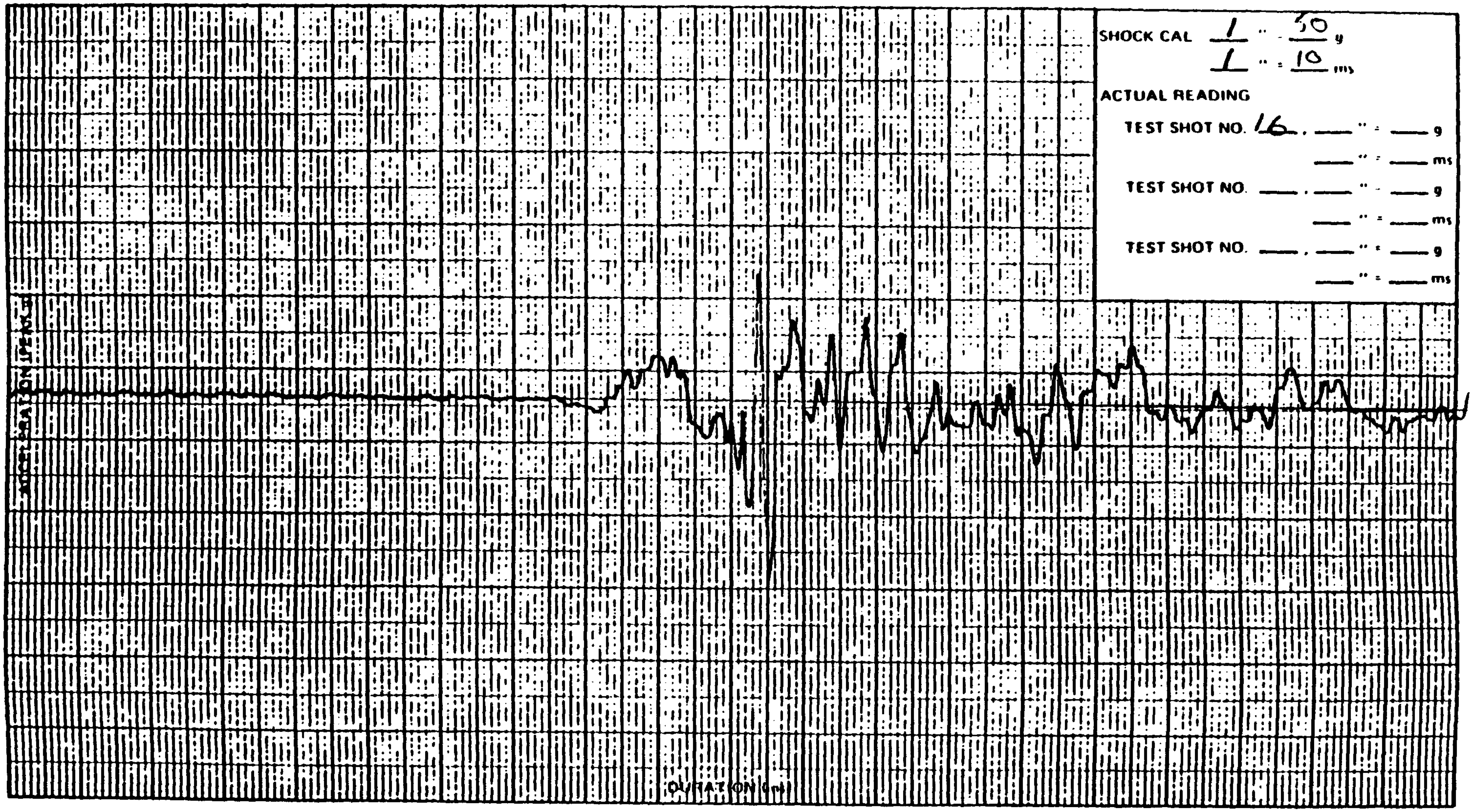
Date: 18 April 89

Time: 1850

Lab Form D24 2

Plotted by: [signature]
Checked by: G. Hylard

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational [ ] Non operational [X]



SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING
TEST SHOT NO. 16 . ___" = ___ g
___" = ___ ms
TEST SHOT NO. ___ . ___" = ___ g
___" = ___ ms
TEST SHOT NO. ___ . ___" = ___ g
___" = ___ ms

Pickup Serial Number: 1121887
Pickup Location: TP#4
Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: -VER+
[ ] Live [X] Tape

Job Number: 406744
Date: 18 April 89
Time: 1850

89-0595 Enc 1 Pg 27

Lab Form D24 2

Plotted by [illegible]

Checked by [illegible]

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational M

SHOCK CAL 1 : 100 g

1 " : ___ ms

ACTUAL READING

TEST SHOT NO. 17 . 1.0 " : 100 g

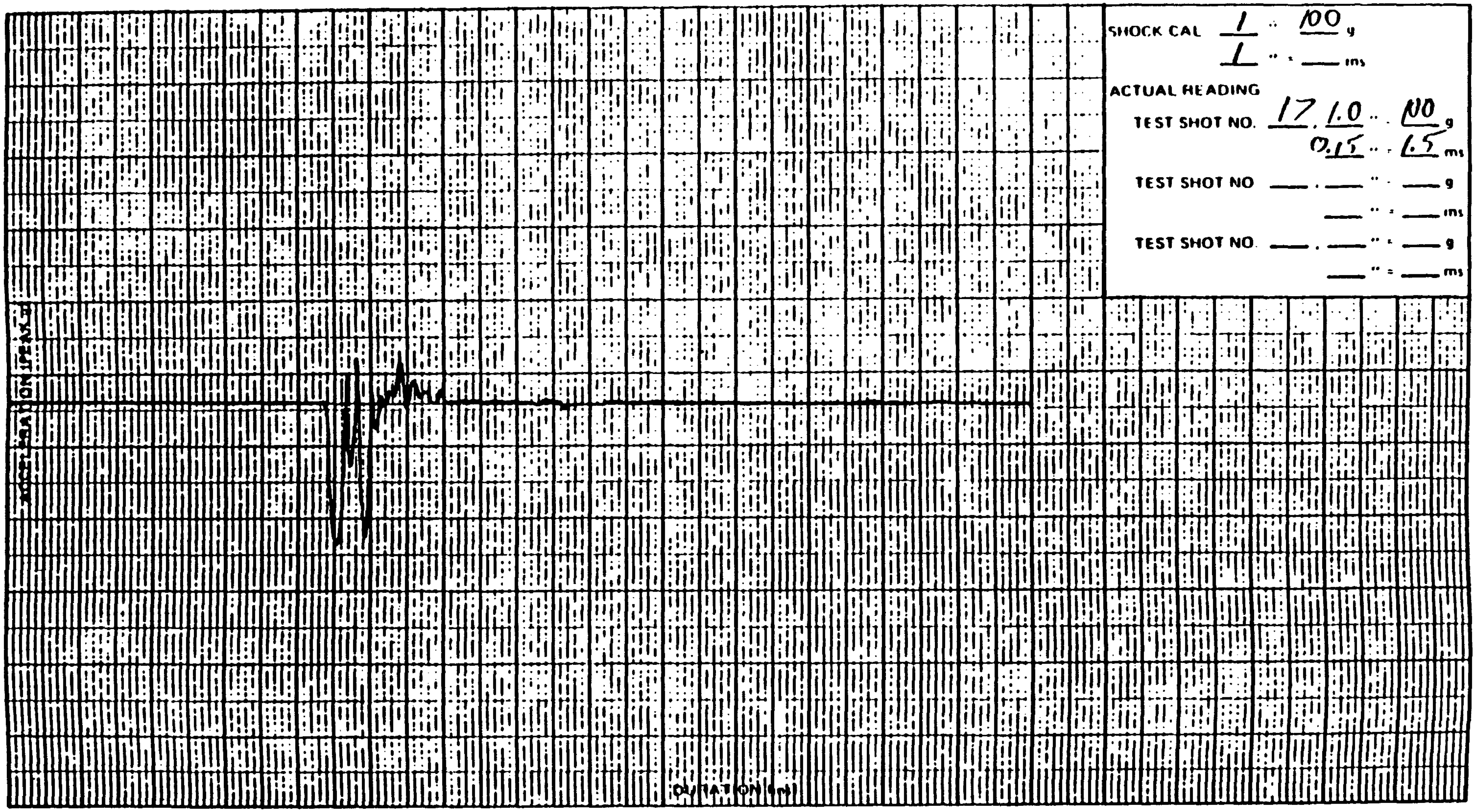
0.15 " : 6.5 ms

TEST SHOT NO ___ . ___ " : ___ g

___ " : ___ ms

TEST SHOT NO. ___ . ___ " : ___ g

___ " : ___ ms



Pickup Serial Number: NB41

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: -Vert

✓ Live [ ] Tape

Job Number: 406744

Date: 18 April 87

Time: 1940

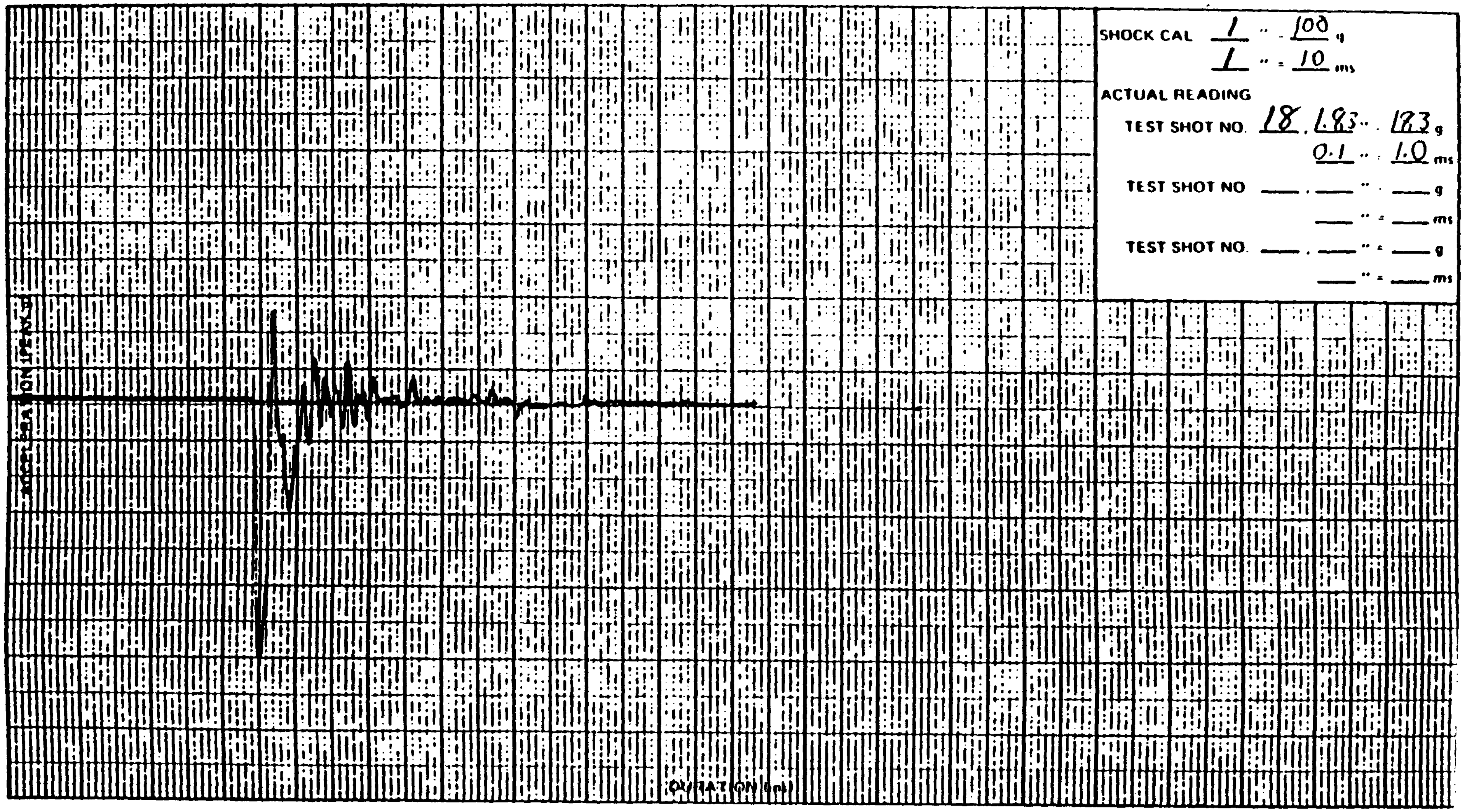
89-0595 Enc 1 Pg 28

Lab Form D24 2

Plotted by: [illegible signature]
Checked by: H. Hyland

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational [ ] Non operational [X]



SHOCK CAL 1 " = 100 g
1 " = 10 ms

ACTUAL READING
TEST SHOT NO. 18 1.83 " = 183 g
0.1 " = 1.0 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: NB 41
Pickup Location: Control
Pickup Sensing Axis: Vert

Pickup Sensitivity: 5.0 mv peak / g peak
Direction: -Vert
[X] Live [ ] Tape

Job Number: 406744
Date: 18 April 89
Time: 1955

Lab Form D24 2

DAYTON T. BROWN

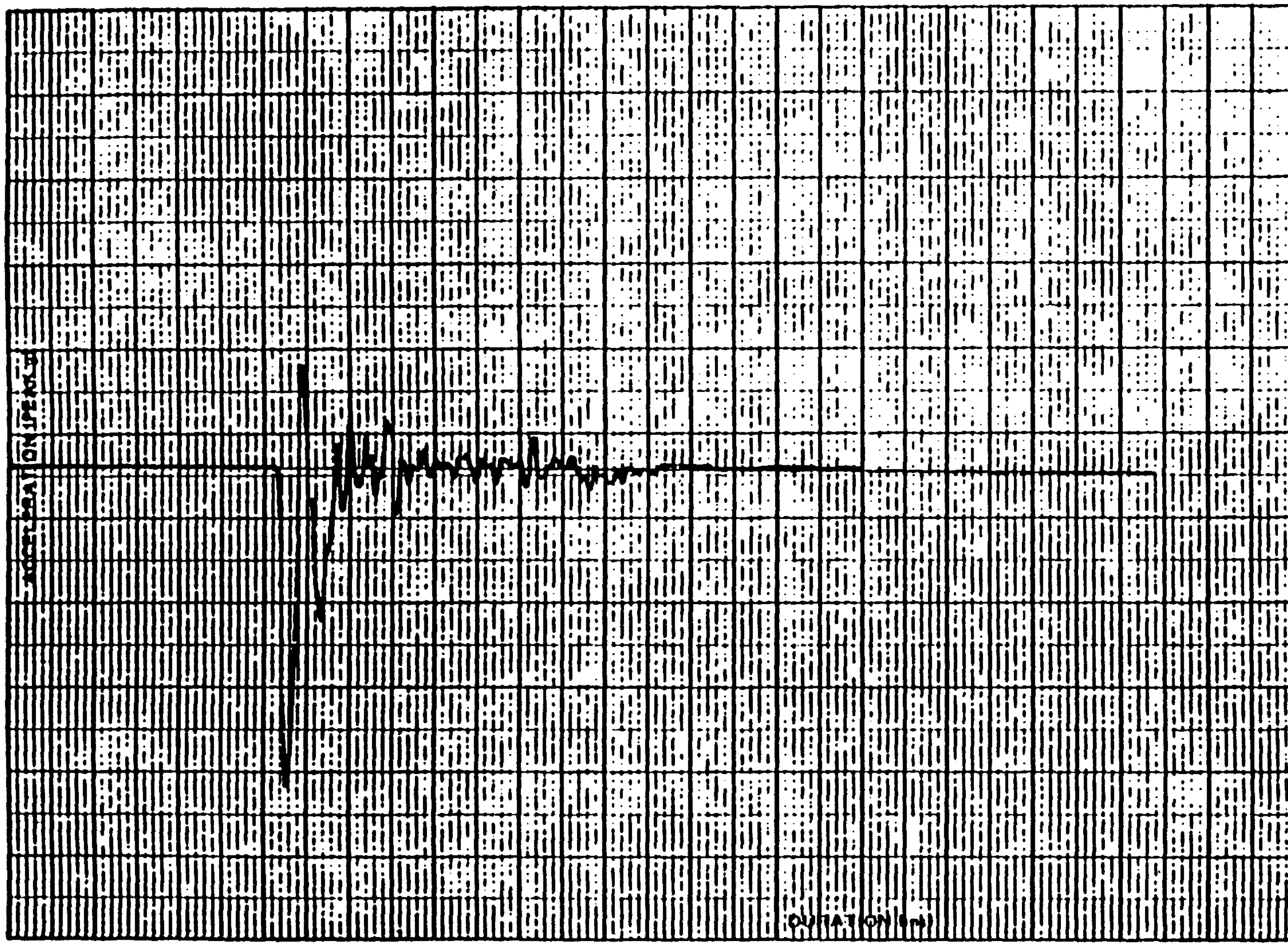
Plotted by: S. [illegible]

Checked by: S. Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational M



SHOCK CAL 1 " ___ g

1 " = ___ ms

ACTUAL READING

TEST SHOT NO. 19 . 190 " 190 g

0.11 " 1.1 ms

TEST SHOT NO. ___ . ___ " ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " ___ g

___ " = ___ ms

Pickup Serial Number: NB41

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: -Vert

[ ] Live [ ] Tape

Job Number: 406744

Date: 18 April 89

Time: 2050

Lab Form D24 2

Plotted by: [signature]

Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational M

SHOCK CAL 1" = 100 g

1" = 10 ms

ACTUAL READING

TEST SHOT NO. 20 1.93" = 193 g

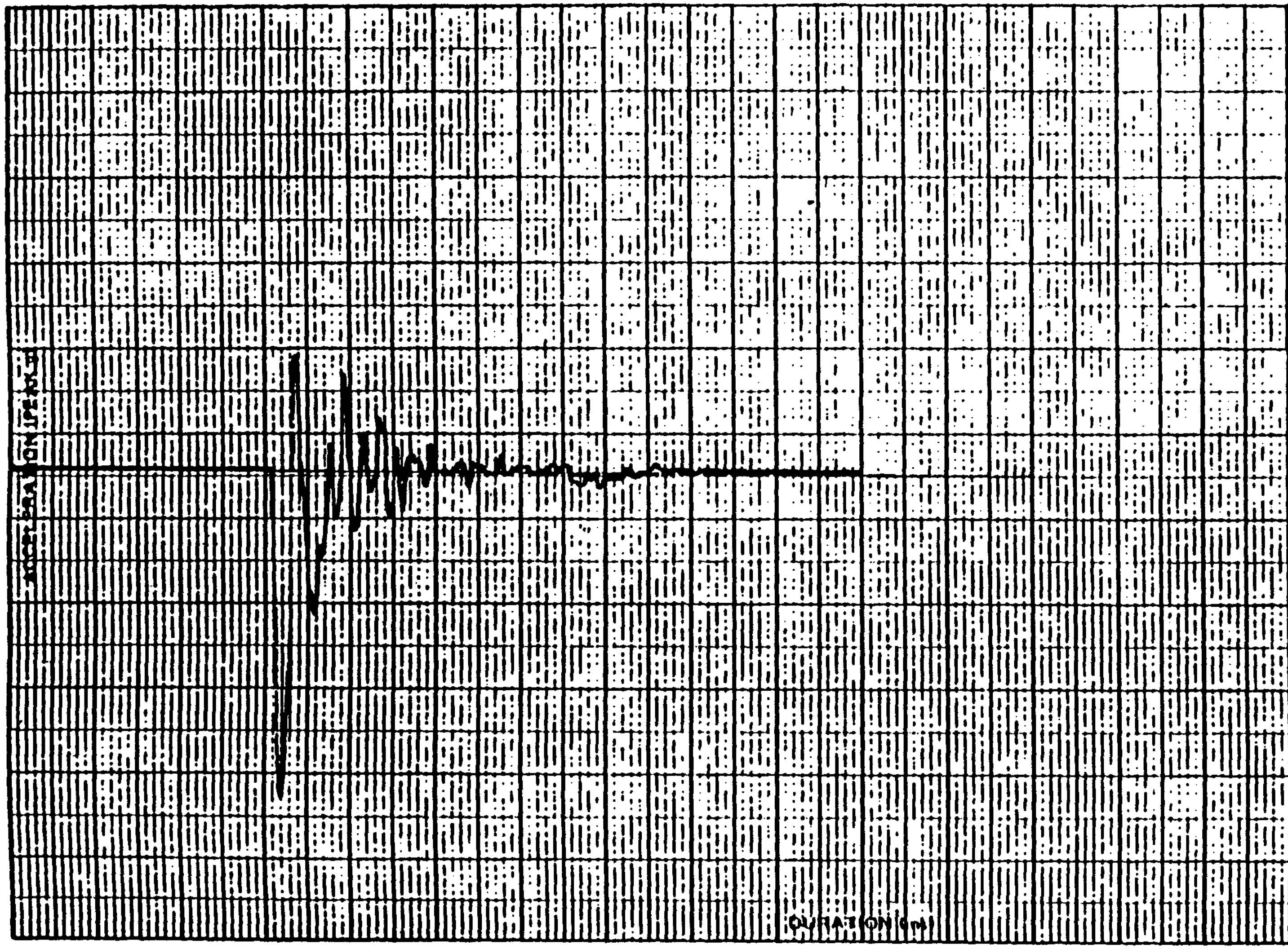
0.11" = 1.1 ms

TEST SHOT NO. ___ . ___" = ___ g

___" = ___ ms

TEST SHOT NO. ___ . ___" = ___ g

___" = ___ ms



89-0595 Enc 1 Pg 31

Lab Form D24 2

Pickup Serial Number: NB41

Pickup Location: Control

Pickup Sensing Axis: Vert

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: - Vert

N Live [ ] Tape

Job Number: 406744

Date: 18 April 89

Time: 2105

Plotted by: L. ...

Checked by: G. Hylard

DAYTON T. BROWN.

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational M

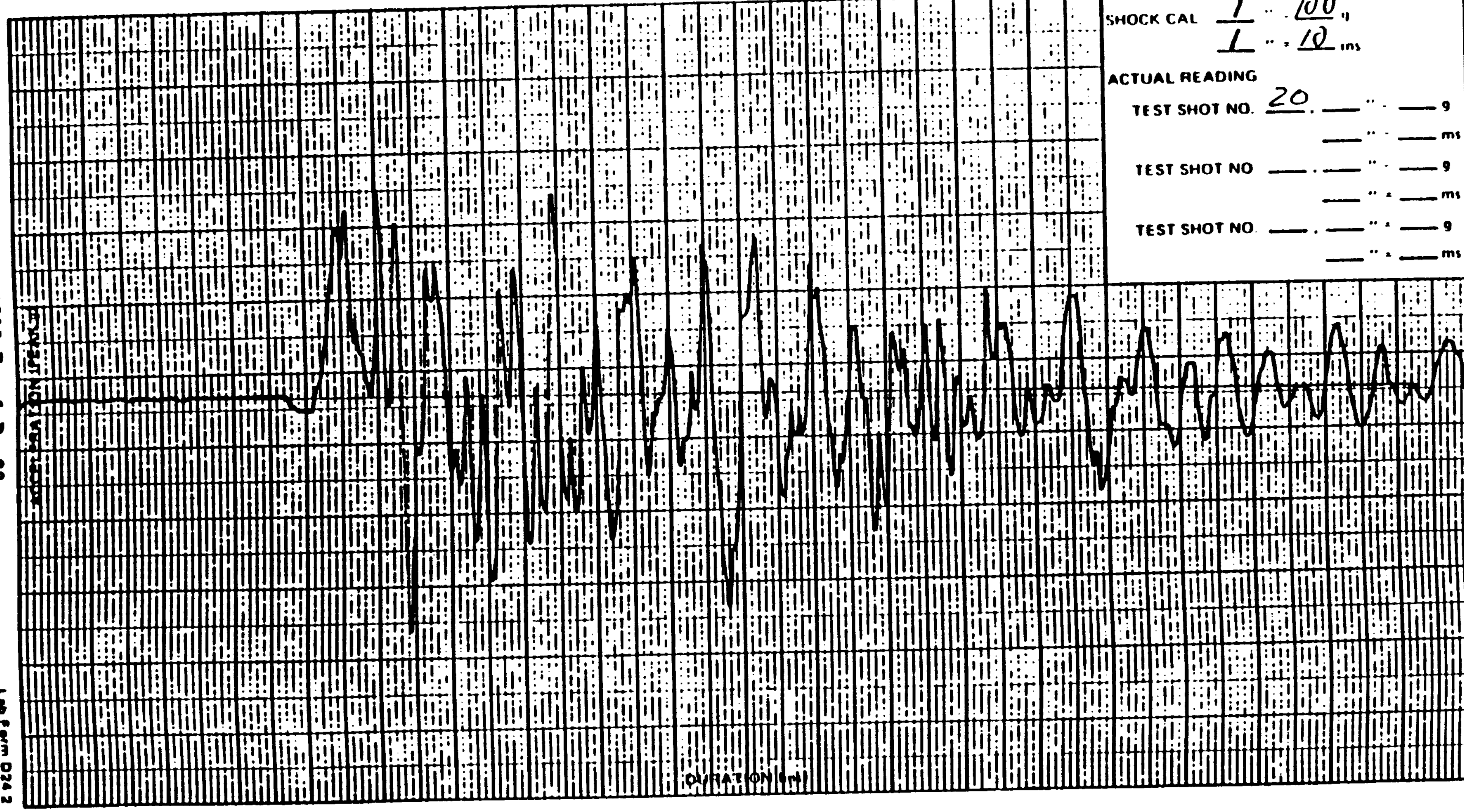
SHOCK CAL 1 " : 100 g
1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 20 . ___ " : ___ g
___ " : ___ ms

TEST SHOT NO ___ . ___ " : ___ g
___ " : ___ ms

TEST SHOT NO. ___ . ___ " : ___ g
___ " : ___ ms



Pickup Serial Number: 241

Pickup Location: T.P.#1

Pickup Sensing Axis: Vert

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: -Vert

[ ] Live [✓] Tape

Job Number: 406744

Date: 18 April 89

Time: 2105

Lab Form D24 2

Plotted by: [illegible signature]

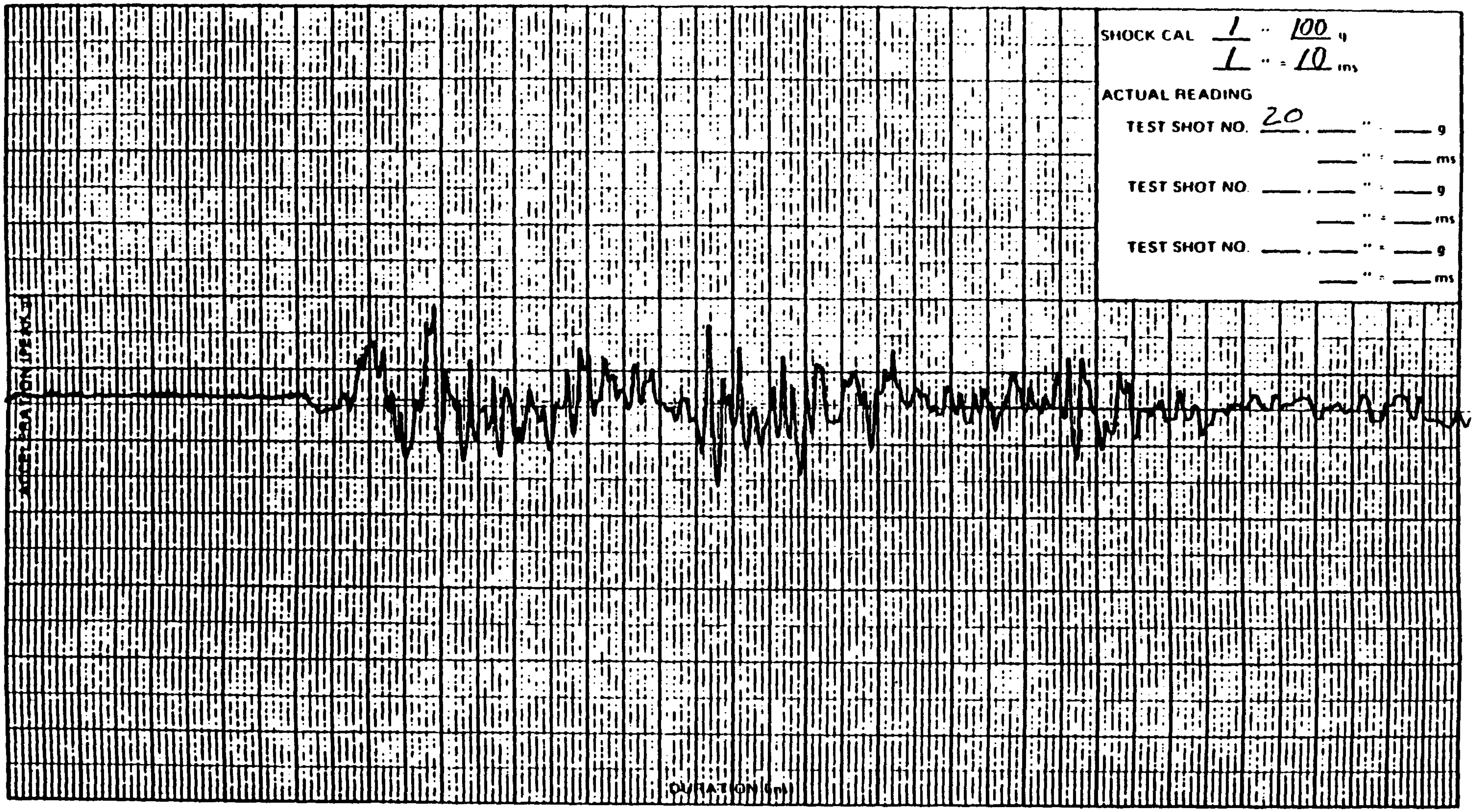
Checked by: [illegible] Hylarnel

DAYTON T BROWN.

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]



SHOCK CAL 1" = 100 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 20 ____ " = ____ g
____ " = ____ ms

TEST SHOT NO. ____ ____ " = ____ g
____ " = ____ ms

TEST SHOT NO. ____ ____ " = ____ g
____ " = ____ ms

Pickup Serial Number: 1051686

Pickup Location: T.C."2

Pickup Sensing Axis: Lat

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: -Vert

[ ] Live [h] Tape

Job Number: 406744

Date: 14 April 89

Time: 2105

Lab Form D24 2

Plotted by J. [illegible]

Checked by G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]

SHOCK CAL 1 " 100 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 20 . ___ " ___ g

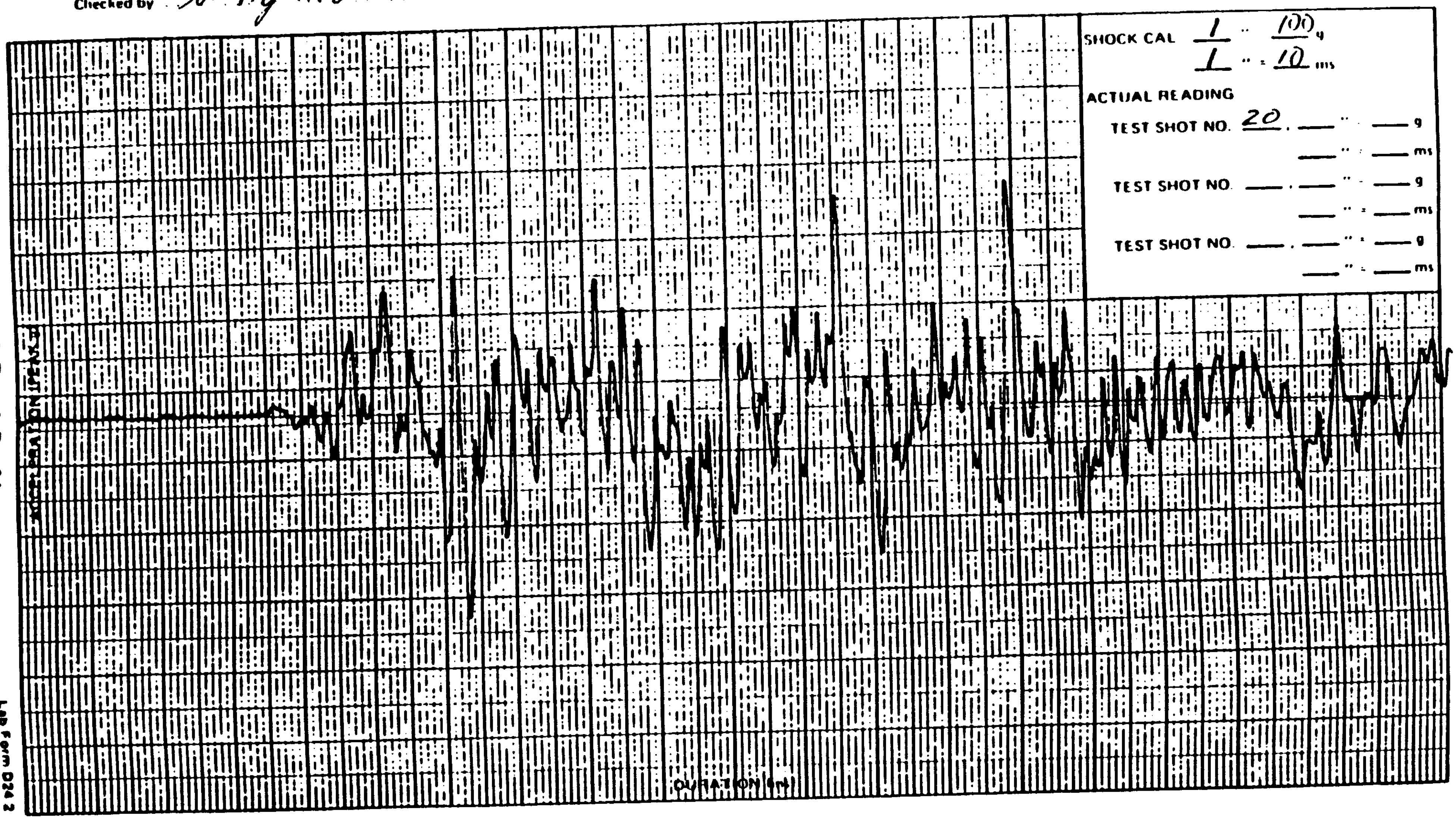
___ " = ___ ms

TEST SHOT NO. ___ . ___ " ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " ___ g

___ " = ___ ms



Pickup Serial Number: 1051685

Pickup Location: TP#3

Pickup Sensing Axis: Lat

Pickup Sensitivity: 5.0 mv peak / g peak

Direction: -Vert

[ ] Live [\] Tape

Job Number: 406744

Date: 18 April 89

Time: 2105

Lab Form D24 2

Plotted by [illegible]

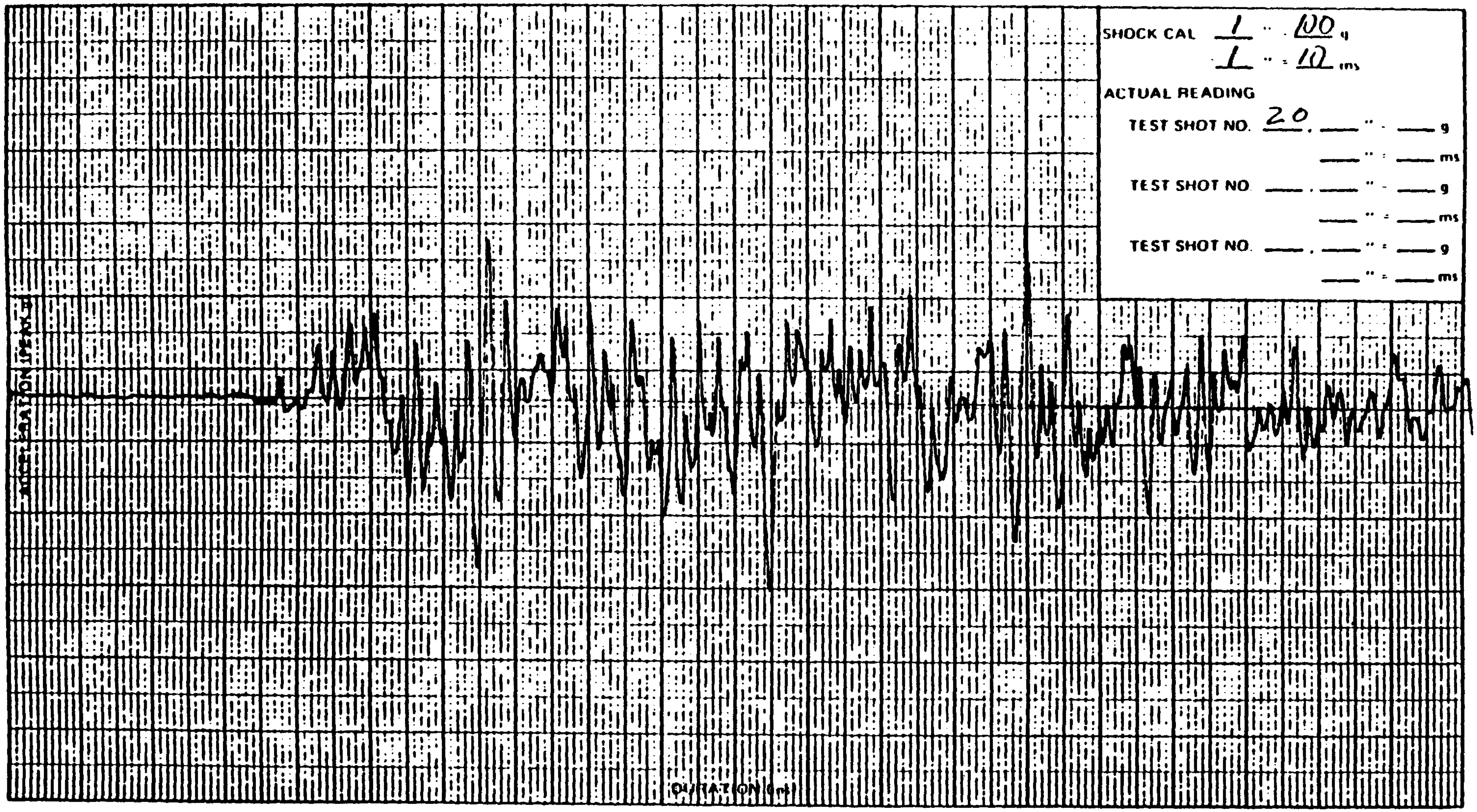
Checked by S Hyland

DAYTON T BROWN

Test Item ..... SCAF

Serial Number(s) 82E018

Unit Operational [ ] Non operational M



SHOCK CAL 1 " = 100 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 20 , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

Pickup Serial Number: ..... 1121887 .....

Pickup Location: ..... TP#4

Pickup Sensing Axis: ..... Lat

Pickup Sensitivity ..... 5.0 ..... mv peak / g peak

Direction: ..... -Vert

[ ] Live [\] Tape

Job Number: ..... 406744 .....

Date: ..... 18 April 89 .....

Time ..... 2105 .....

89-0595 Enc 1 Pg 35

Lab Form D24 2

Plotted by: [signature]

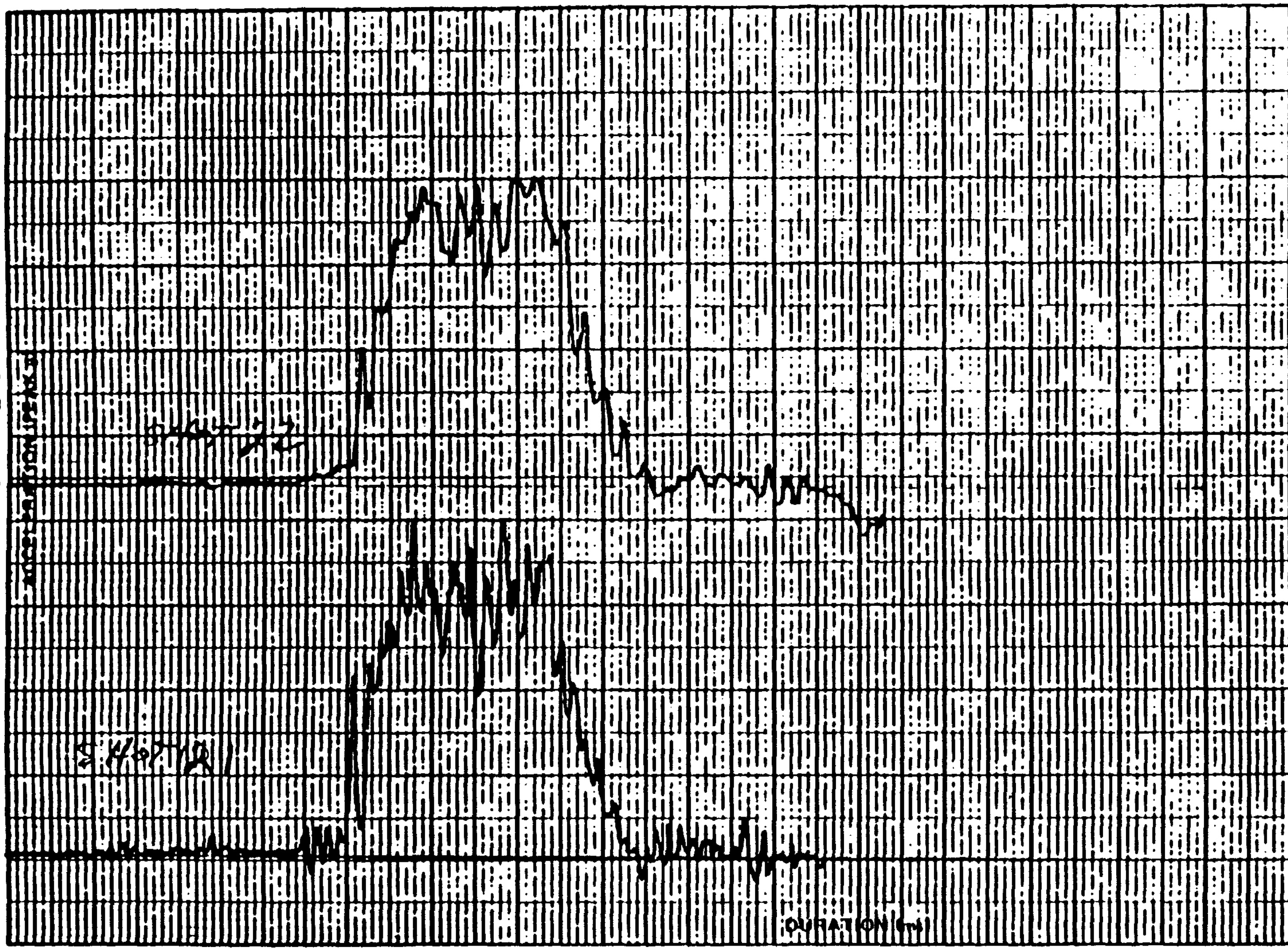
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL 1 " = 20 g
1 " = 10 ms

ACTUAL READING:

TEST SHOT NO. 21 2.0 " = 40 g
1.11 " = 16.2 ms

TEST SHOT NO. 22 1.82 " = 36.4 g
1.8 " = 18.8 ms

TEST SHOT NO. ___ ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: NB41

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: POS PULSE

[X] Live [ ] Tape

Job Number: 406744-00-070

Date: 17 Apr. 89

Time: 0857

Lab Form D24 2

Plotted by: [illegible signature]

Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒

SHOCK CAL. 1" = 20 g

1" = 10 ms

ACTUAL READING:

TEST SHOT NO. 22 ___" = ___ g

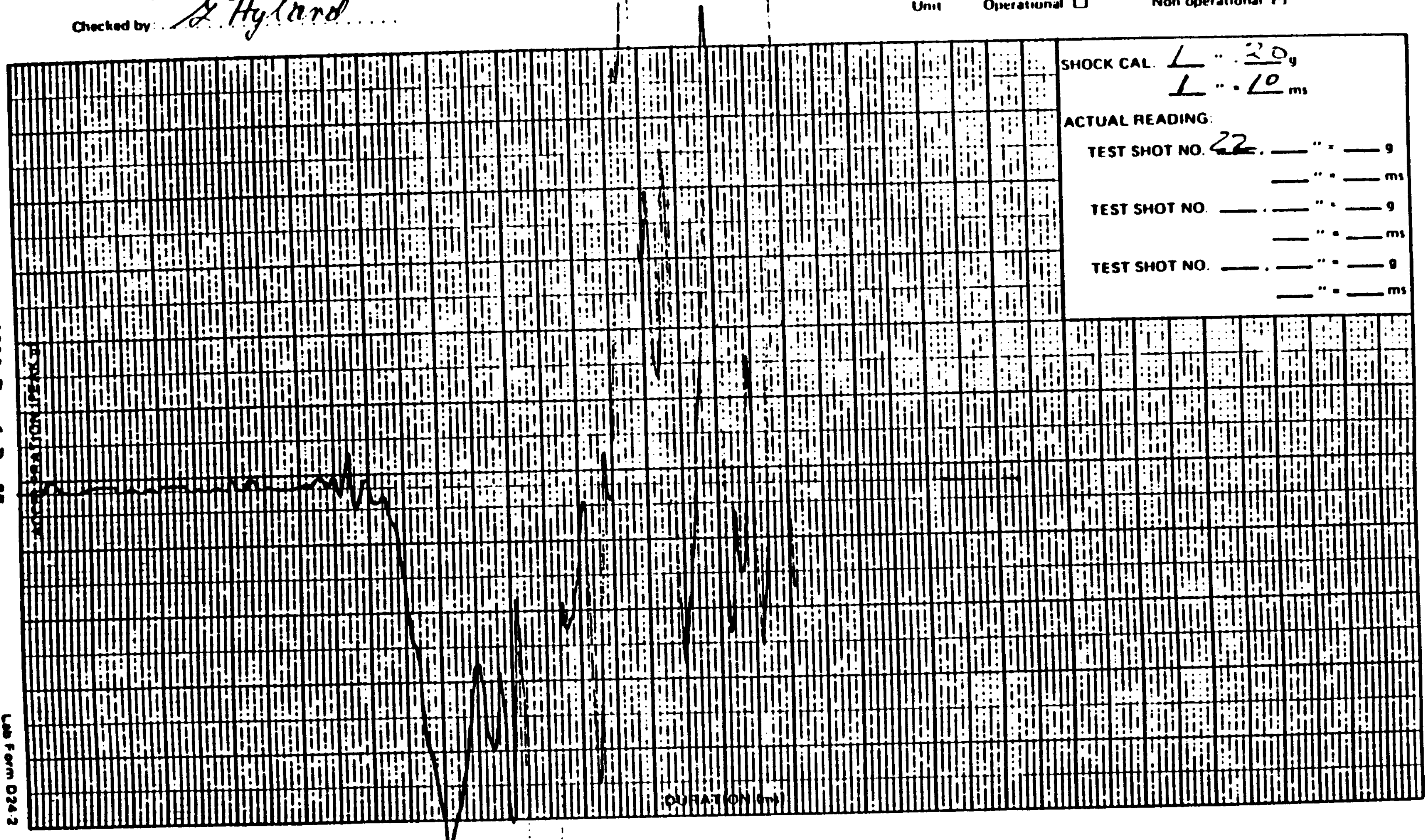
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g

___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g

___" = ___ ms



Pickup Serial Number: ~~[illegible]~~ 244

Pickup Location: ~~[illegible]~~ TP1

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 $\frac{\text{mv peak}}{\text{g peak}}$

Direction: VERT. POS. BASIC

☒ Live ☐ Tape

Job Number: 406744-00-070

Date: 11 APR. 89

Time: 0830

Lab Form D24-2

DAYTON BROWN

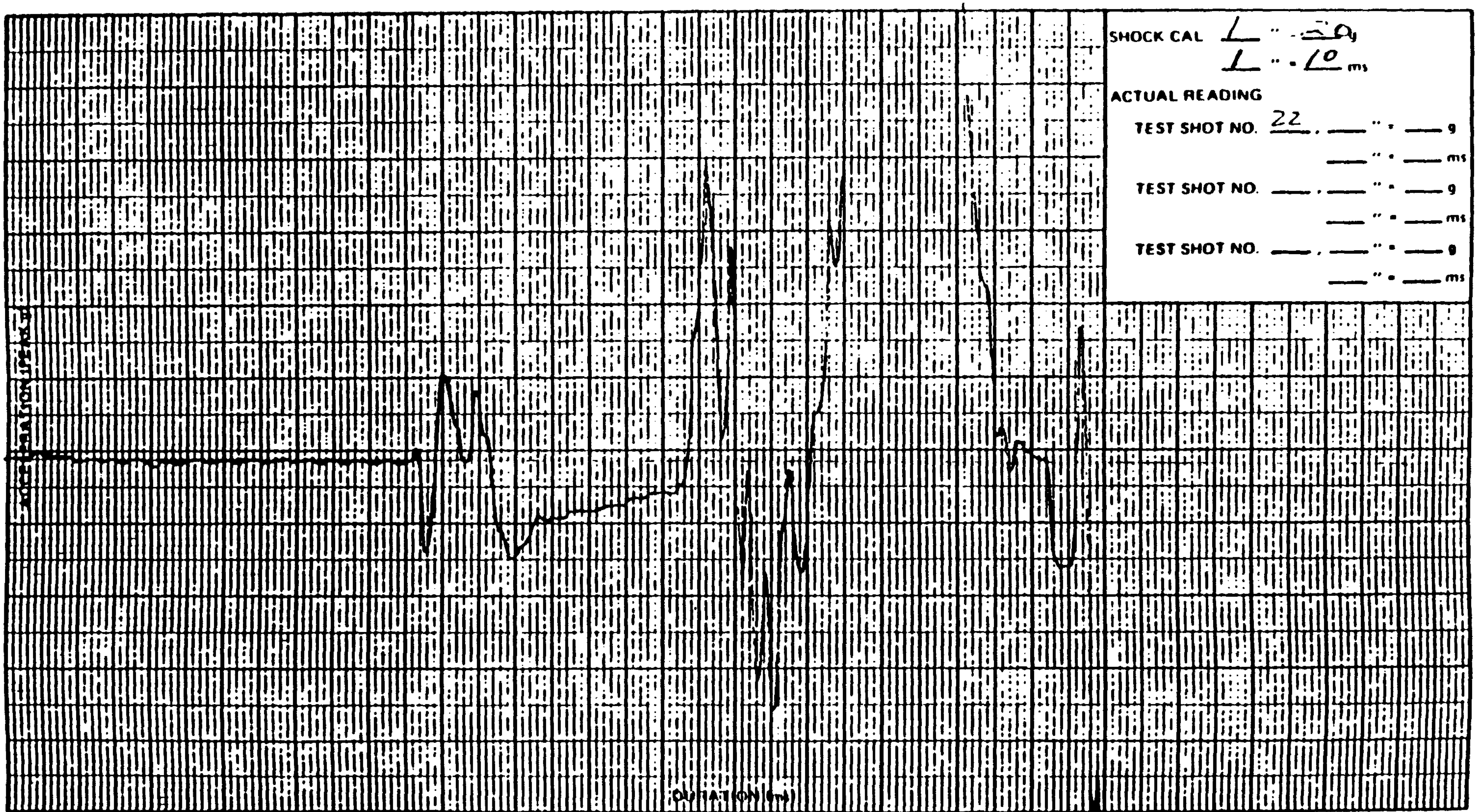
Plotted by: [signature]

Checked by: G Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL L " = 50 g
L " = 10 ms

ACTUAL READING

TEST SHOT NO. 22 , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: ~~[illegible]~~ FH04

Pickup Location: ~~Control~~ TP2

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT. POS. [illegible]

[X] Live [ ] Tape

Job Number: 406244-00-070

Date: 17 Apr. 89

Time: 0:27

Lab Form D24 2

Plotted by: [illegible signature]

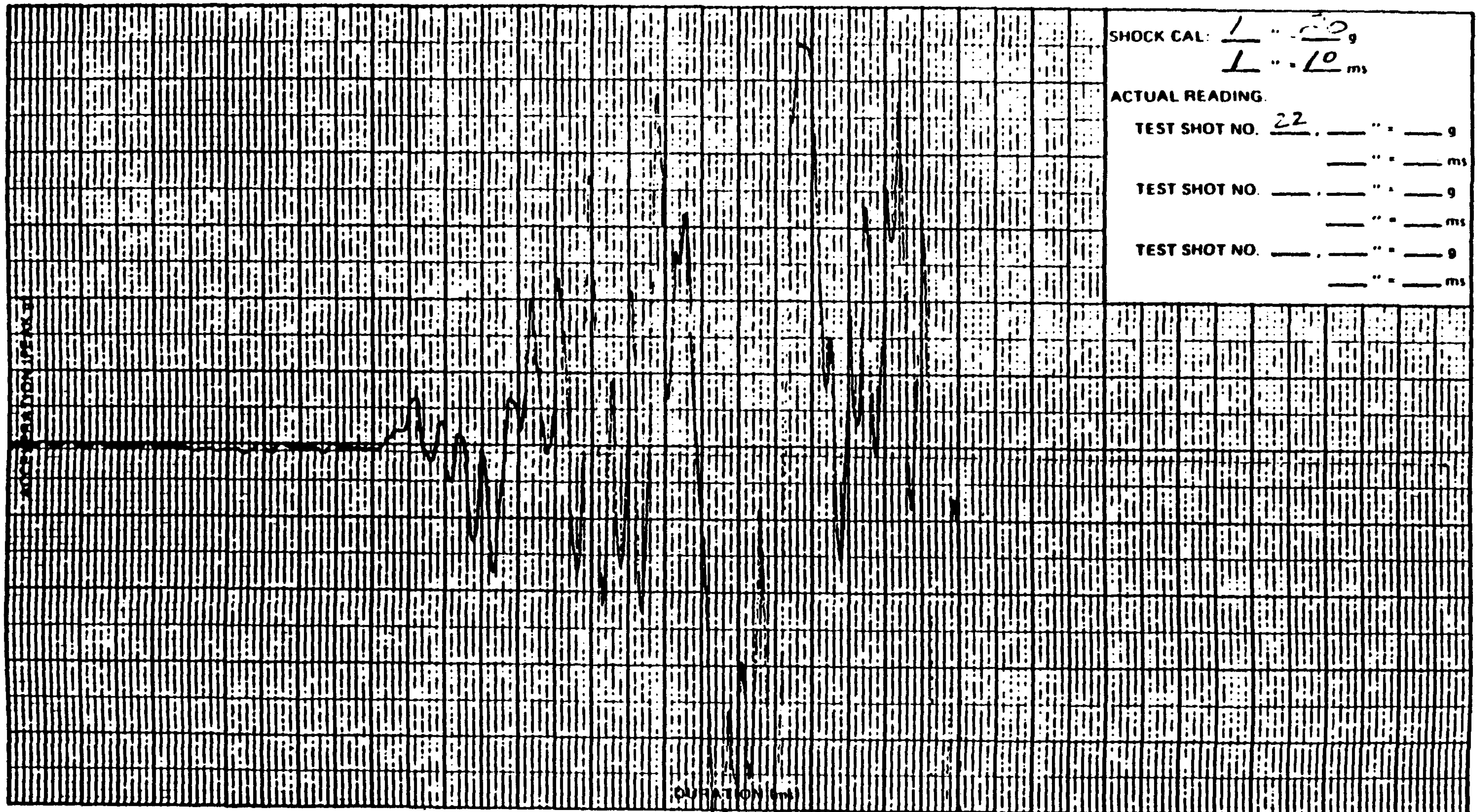
Checked by: G. Hylnid

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]



SHOCK CAL: 1 " = 20 g
1 " = 10 ms

ACTUAL READING:

TEST SHOT NO. 22 , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: ~~[illegible]~~ 685

Pickup Location: ~~[illegible]~~ TP3

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT [illegible]

[X] Live [ ] Tape

Job Number: 40674Y-00-030

Date: 17 Apr. 89

Time: 0830

Lab Form D24 2

DAYTON BROWN

Plotted by: [signature]

Checked by: G. Hyland

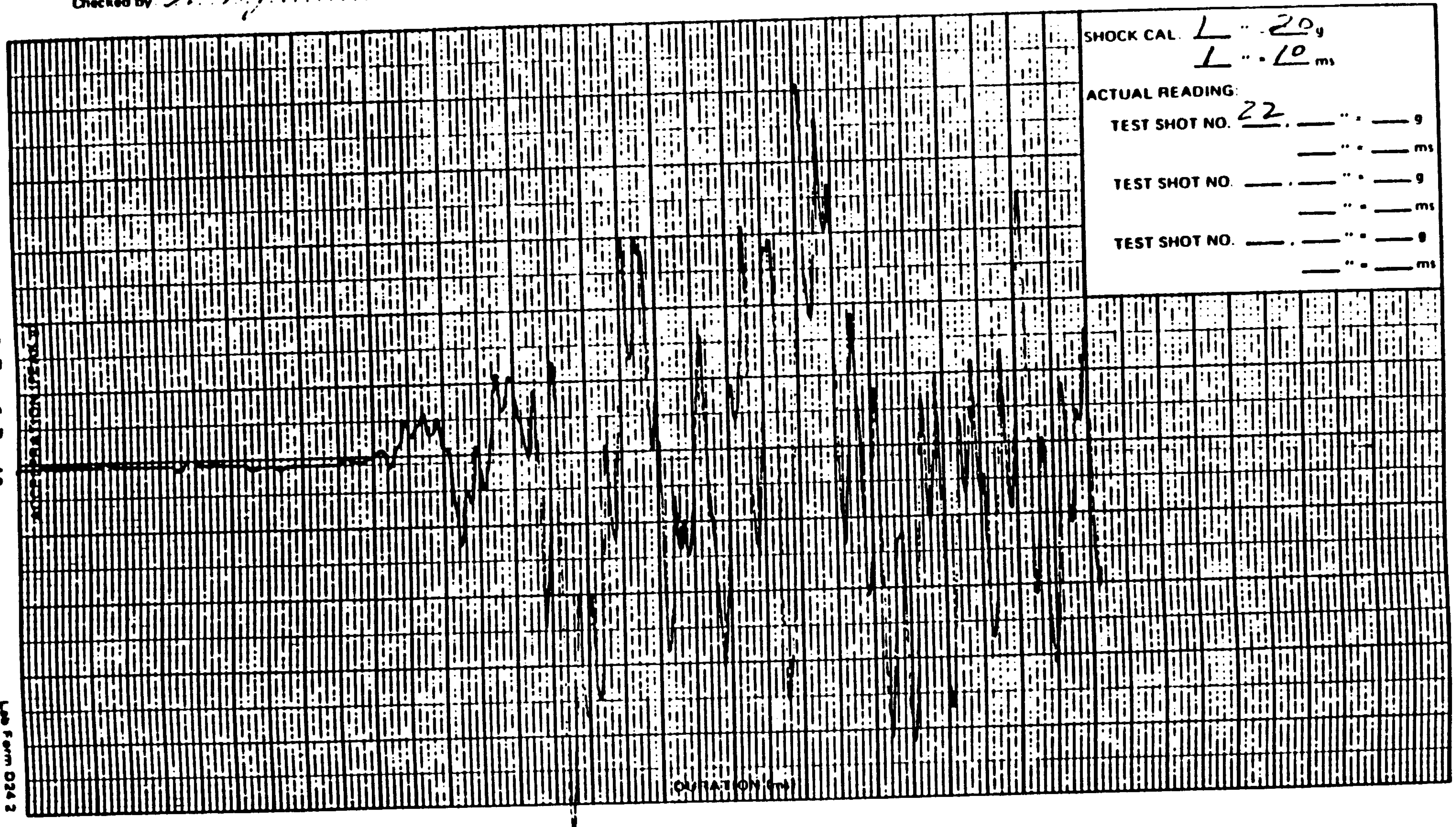
Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]

SHOCK CAL. L " 20 g
L " 10 ms

ACTUAL READING:
TEST SHOT NO. 22 . ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms



Pickup Serial Number: ~~[illegible]~~ 887

Pickup Location: ~~[illegible]~~ TP4

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT [illegible]

[X] Live [ ] Tape

Job Number: 406744-00-030

Date: 17 Apr. 89

Time: [illegible]

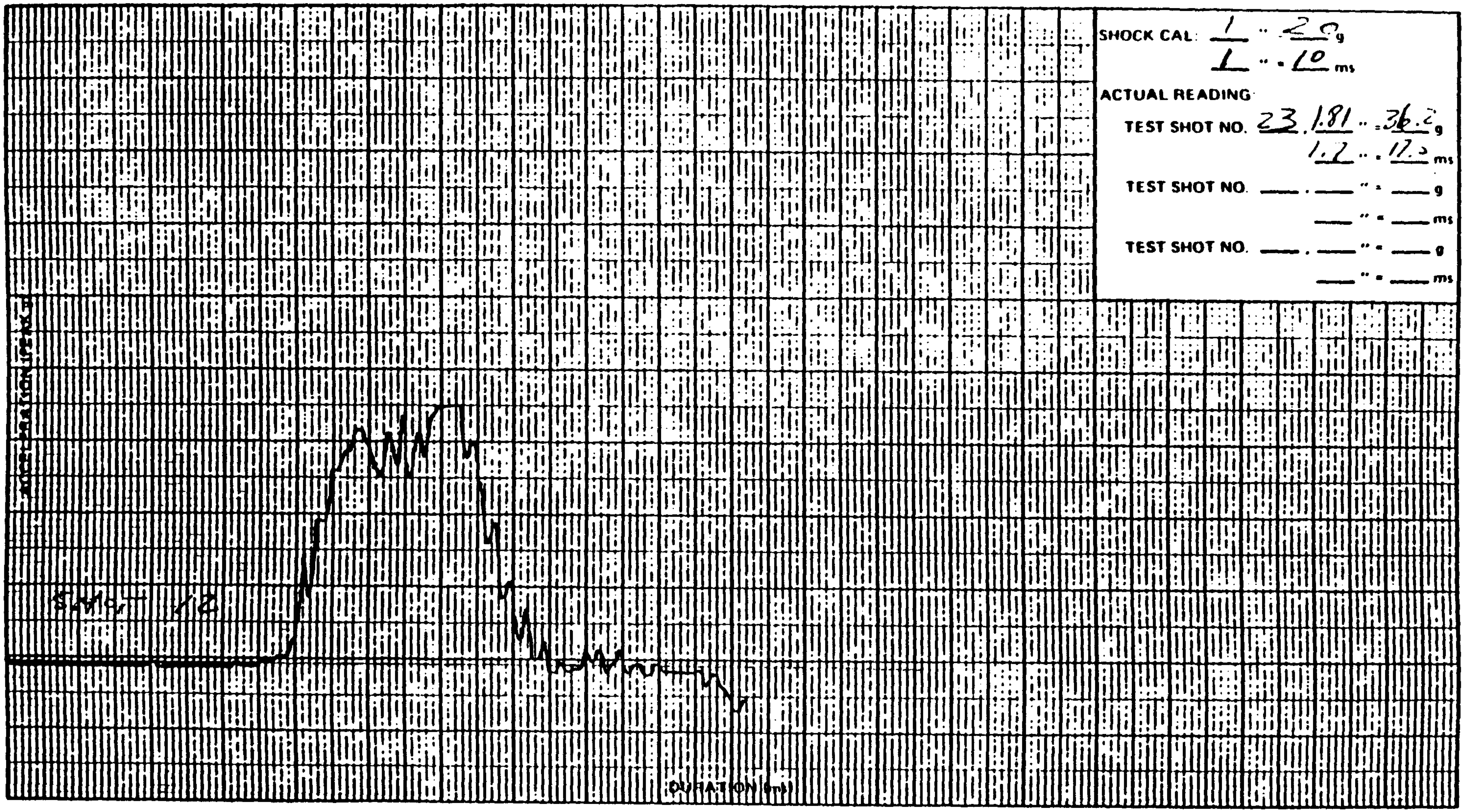
Lab Form D24 2

89-0595 Enc 1 Pg 40

Plotted by: *[signature]*
Checked by: *G. Hyland*

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit Operational [ ] Non-operational [X]



SHOCK CAL: 1 " = 20 g
1 " = 10 ms

ACTUAL READING:
TEST SHOT NO. 23 1.81 " = 36.2 g
1.2 " = 17.3 ms
TEST SHOT NO. ___ ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: NB41
Pickup Location: CONTROL
Pickup Sensing Axis: VERT.

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: PO: BASIC
[X] Live [ ] Tape

Job Number: 406744-00-070
Date: 17 Apr. 89
Time: 0841

Plotted by: [signature]

Checked by: G. Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational ☐ Non operational ☒

SHOCK CAL: 1 " = 20 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 24 .33 " = 66 g

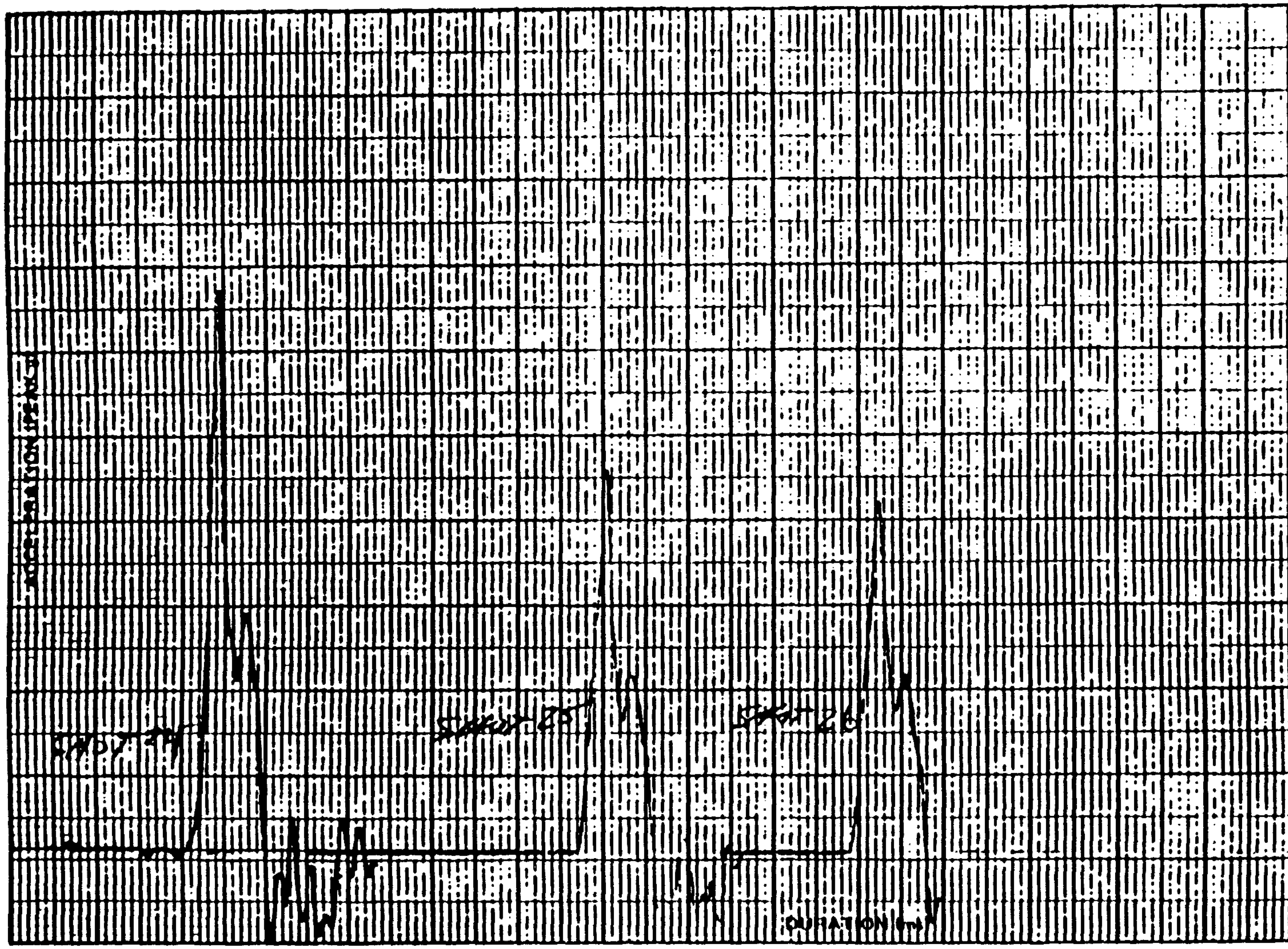
.36 " = 3.6 ms

TEST SHOT NO. 25 .326 " = [illegible] g

" " = 4.0 ms

TEST SHOT NO. 26 .231 " = 41.4 g

.44 " = 4.4 ms



Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: VERT.

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Pos

☒ Live ☐ Tape

Job Number: 406744-00-000

Date: 17 Apr. 89

Time: 0925

Lab Form D24 2

Plotted by: [illegible signature]

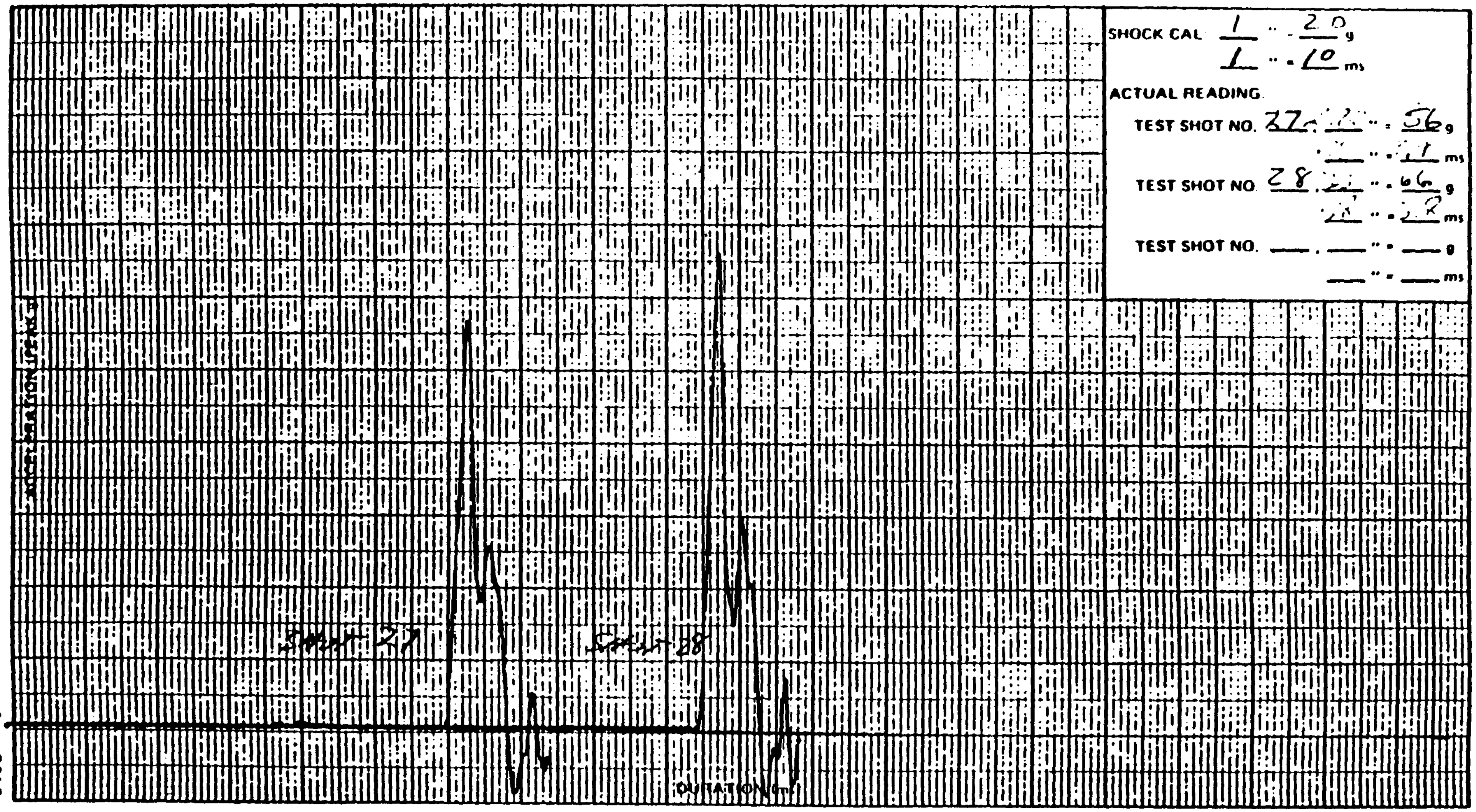
Checked by: G. Hylrod

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒



SHOCK CAL 1 " = 20 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 27 . [illegible] " = 56 g

[illegible] " = [illegible] ms

TEST SHOT NO. 28 . [illegible] " = 66 g

[illegible] " = [illegible] ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms

Pickup Serial Number: NB4

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Pos

☒ Live ☐ Tape

Job Number: 40674Y-00-070

Date: 19 Apr. 89

Time: [illegible]

Lab Form D24-2

Plotted by: [signature]

Checked by: G. Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒

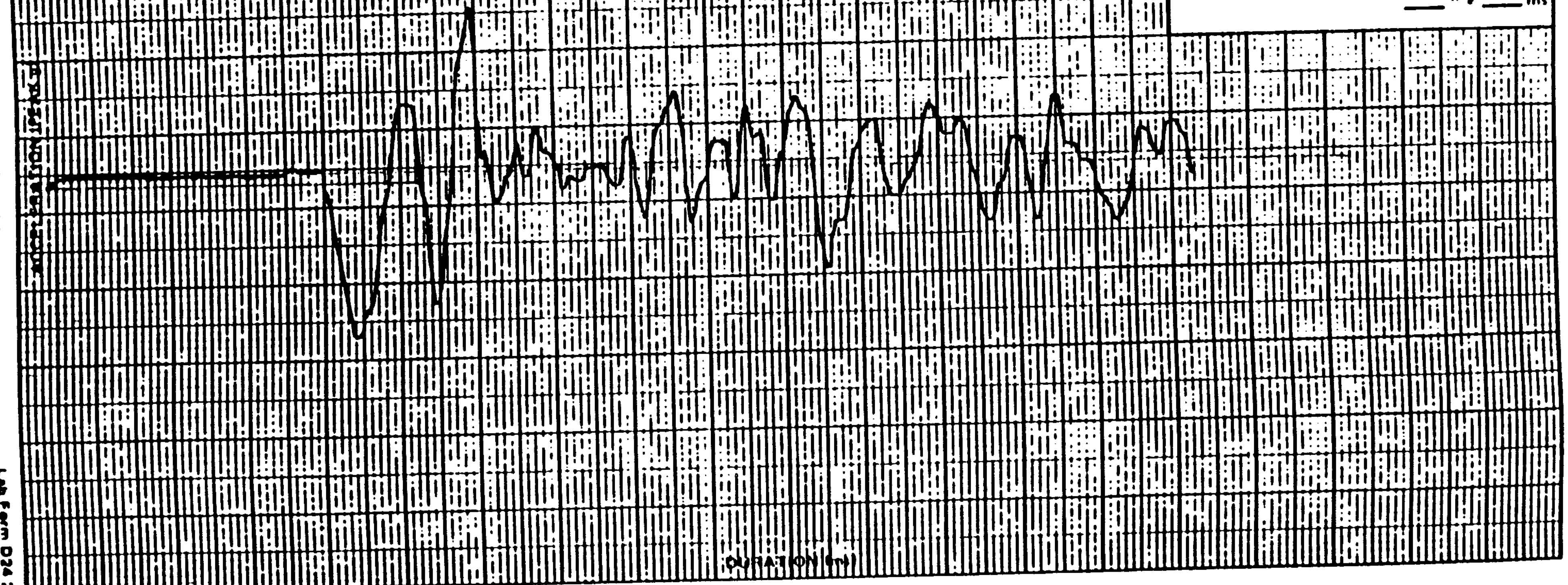
SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 22 . ____" = ____ g
____" = ____ ms

TEST SHOT NO. ____ . ____" = ____ g
____" = ____ ms

TEST SHOT NO. ____ . ____" = ____ g
____" = ____ ms



Pickup Serial Number: ~~[illegible]~~ 244

Pickup Location: ~~[illegible]~~ 71

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT 1/03 [illegible]

☒ Live ☐ Tape

Job Number: 406744-00-070

Date: 17 Apr. 89

Time: 0954

Lab Form D24 2

Plotted by: [signature]

Checked by: A. Huard

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]

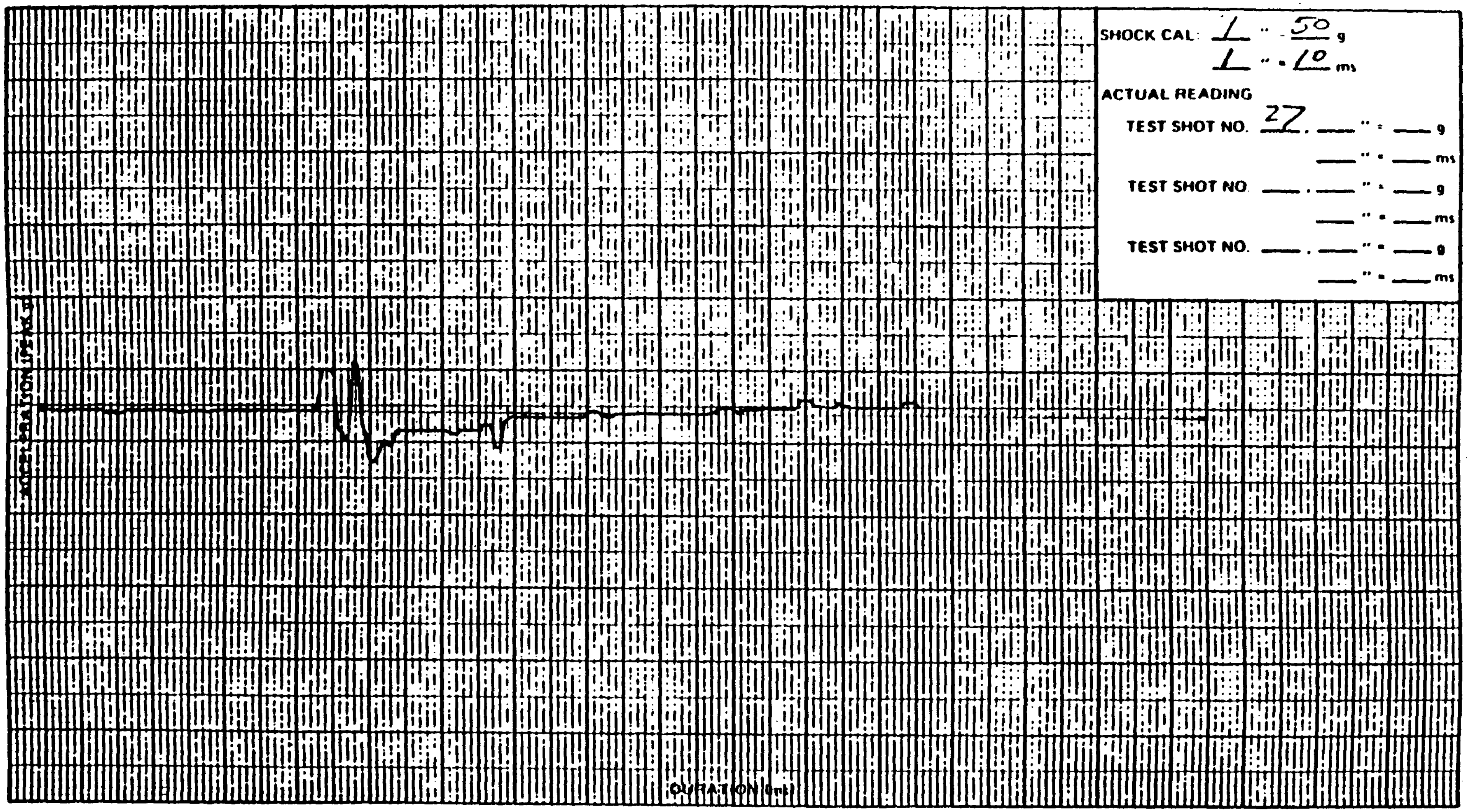
SHOCK CAL: 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 27 ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms



Pickup Serial Number: ~~[illegible]~~ PH04

Pickup Sensitivity: 10.0 mv peak / g peak

Job Number: 406744-00-030

Pickup Location: ~~[illegible]~~ TP2

Direction: VERT [illegible]

Date: 17 Apr. 89

Pickup Sensing Axis: LAT

[X] Live [X] Tape

Time: 0854

Lab Form D24 2

Plotted by: [signature]

Checked by: G Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]

SHOCK CAL 1" = 50 g

1" = 10 ms

ACTUAL READING:

TEST SHOT NO. 27 . ___ " = ___ g

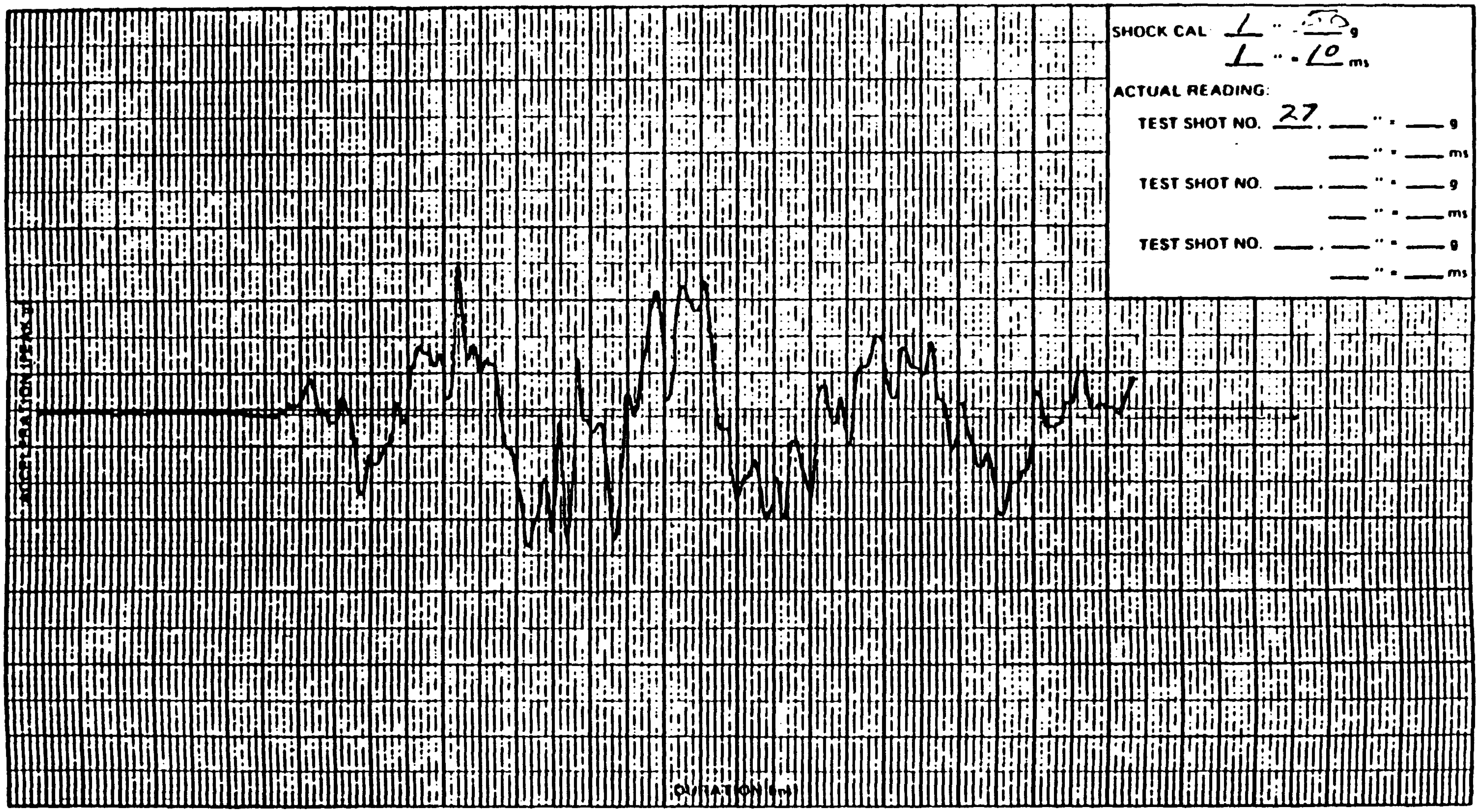
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms



Pickup Serial Number: ~~[illegible]~~ 685

Pickup Location: ~~[illegible]~~ T23

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT RE [illegible]

[X] Live [ ] Tape

Job Number: 406744-00-070

Date: 17 Apr. 89

Time: 0954

89-0595 Enc 1 Pg 46

Lab Form D24 2

DAYTON T. BROWN

Plotted by: [illegible]

Checked by: G. Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational ☐ Non operational ☒

SHOCK CAL. 1 " = 50 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 27. ___ " = ___ g

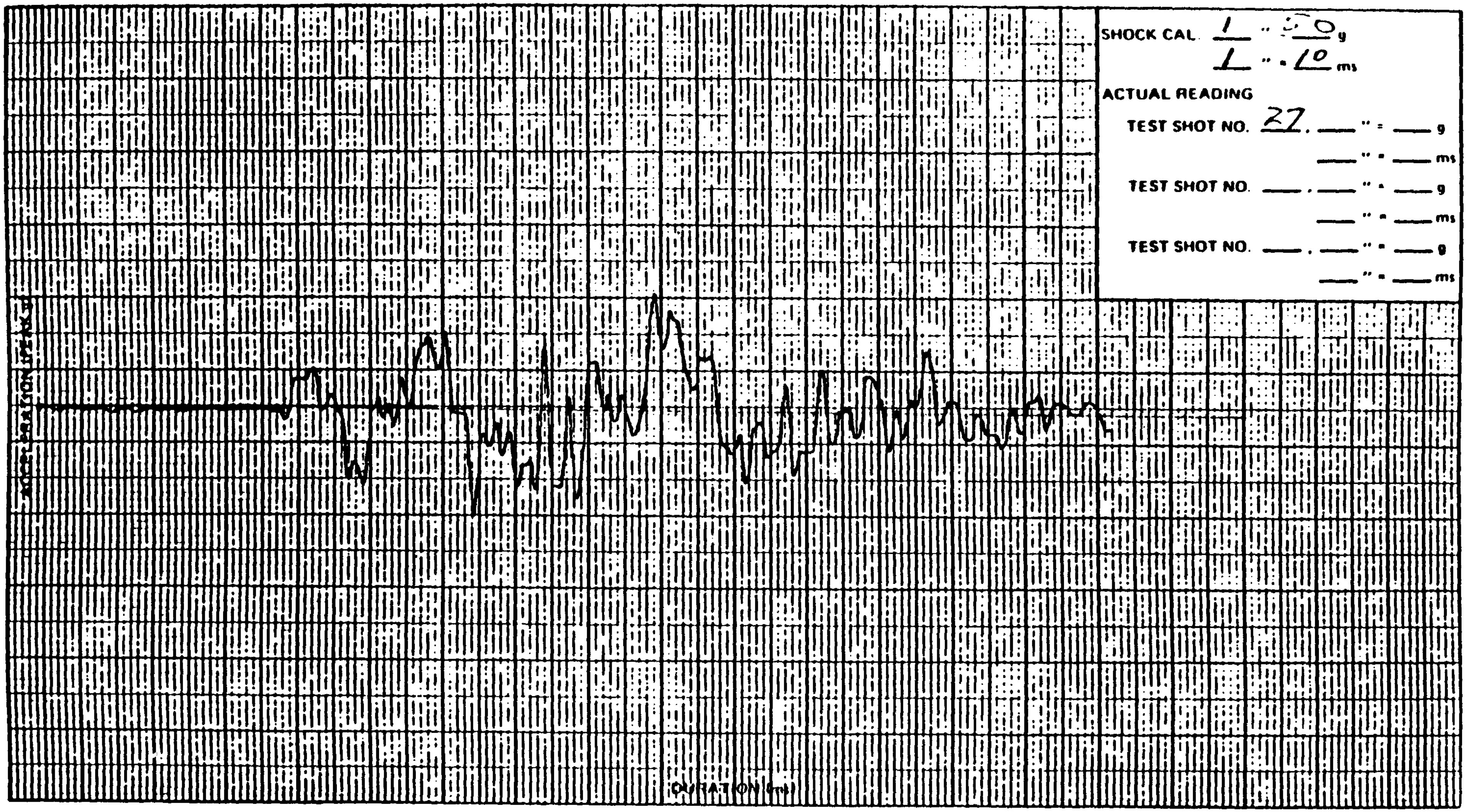
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms



Pickup Serial Number: ~~[illegible]~~ 887

Pickup Location: ~~[illegible]~~ 7/4

Pickup Sensing Axis: LAT.

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT [illegible] G[illegible]RE

☒ Live ☐ Tape

Job Number: 906744-00-030

Date: 17 Apr. 89

Time: 0954

Lab Form D24 2

Test Item: SC4F

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]

DAYTON BROWN

Plotted by: Wm Cleghorn

Checked by: G Hyland

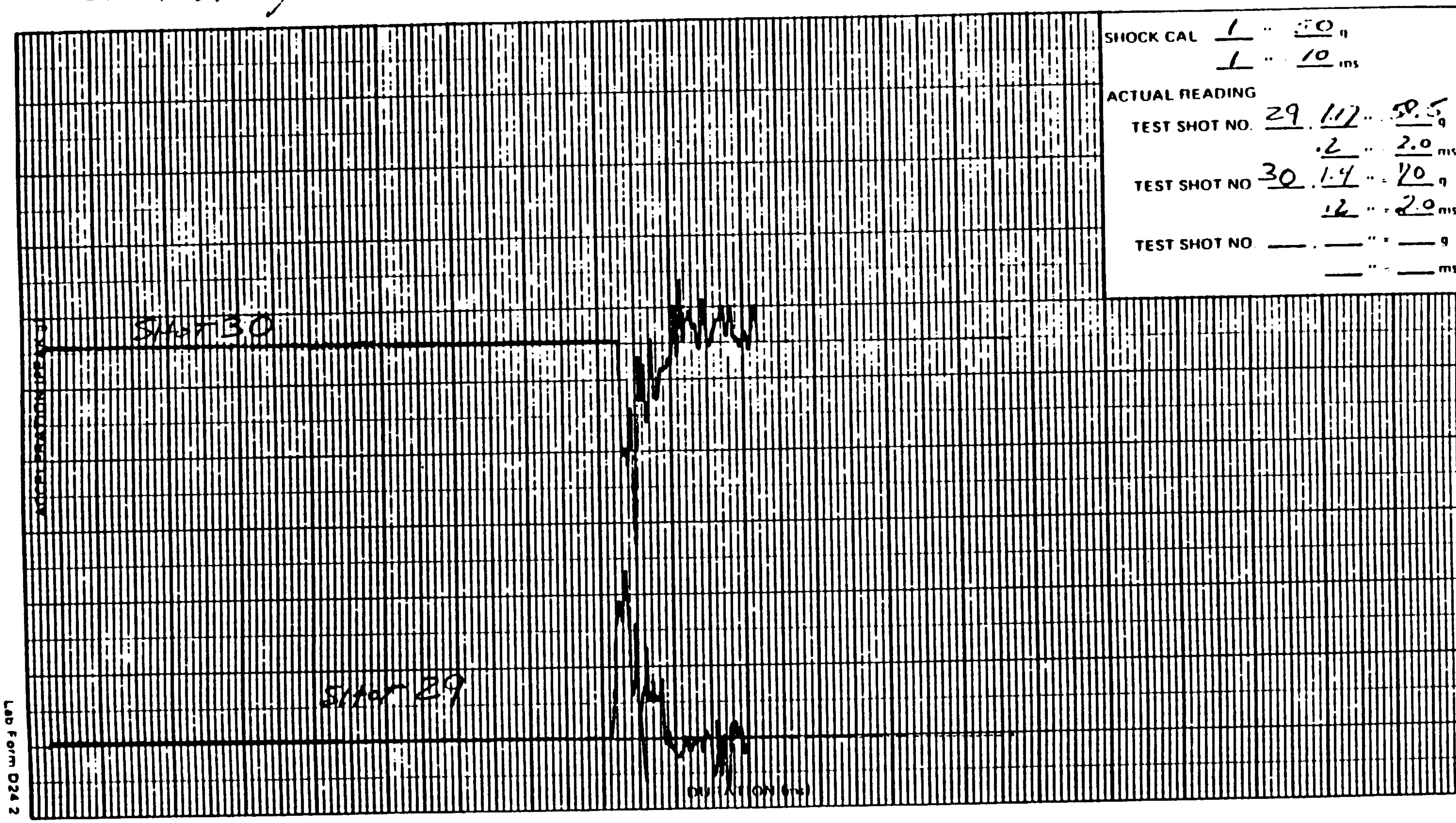
SHOCK CAL 1 " 50 g
1 " 10 ms

ACTUAL READING

TEST SHOT NO. 29 . 1.12 " 50.5 g
.2 " 2.0 ms

TEST SHOT NO 30 . 1.4 " 70 g
.2 " 2.0 ms

TEST SHOT NO ___ . ___ " ___ g
___ " ___ ms



Lab Form D24 2

Pickup Serial Number: NB91

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS OPERATIONAL SHOCK

[X] Live [ ] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1115

Plotted by: Wm Cla...

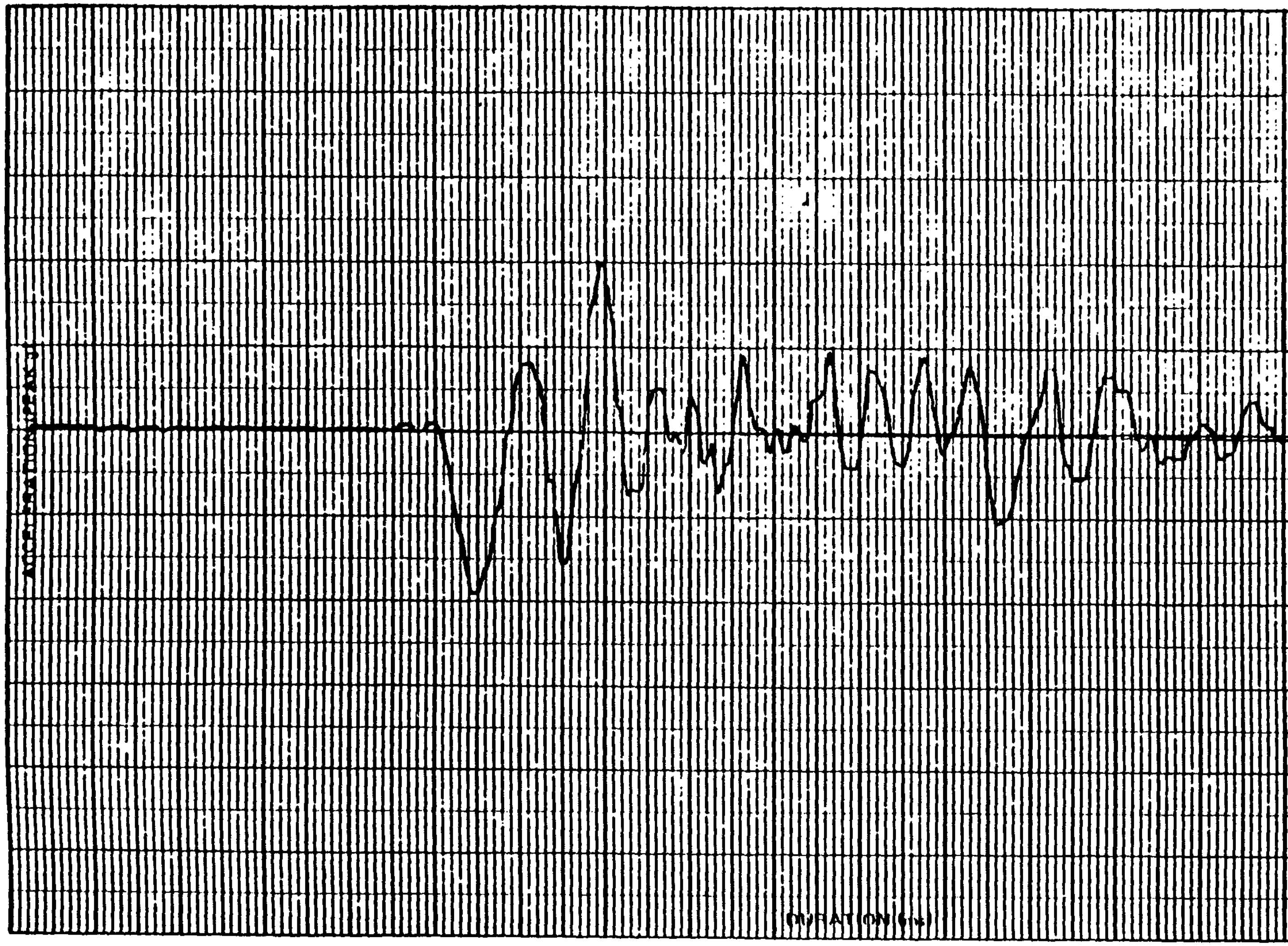
Checked by: G Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL 1 " : 50 g

1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 29 . ___ " : ___ g

___ " : ___ ms

TEST SHOT NO. ___ . ___ " : ___ g

___ " : ___ ms

TEST SHOT NO. ___ . ___ " : ___ g

___ " : ___ ms

Pickup Serial Number: 244

Pickup Location: TP1

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS OPERATIONAL SHOCK

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 17 APR 89

Time: 1115

Lab Form D24 2

DAYTON BROWN

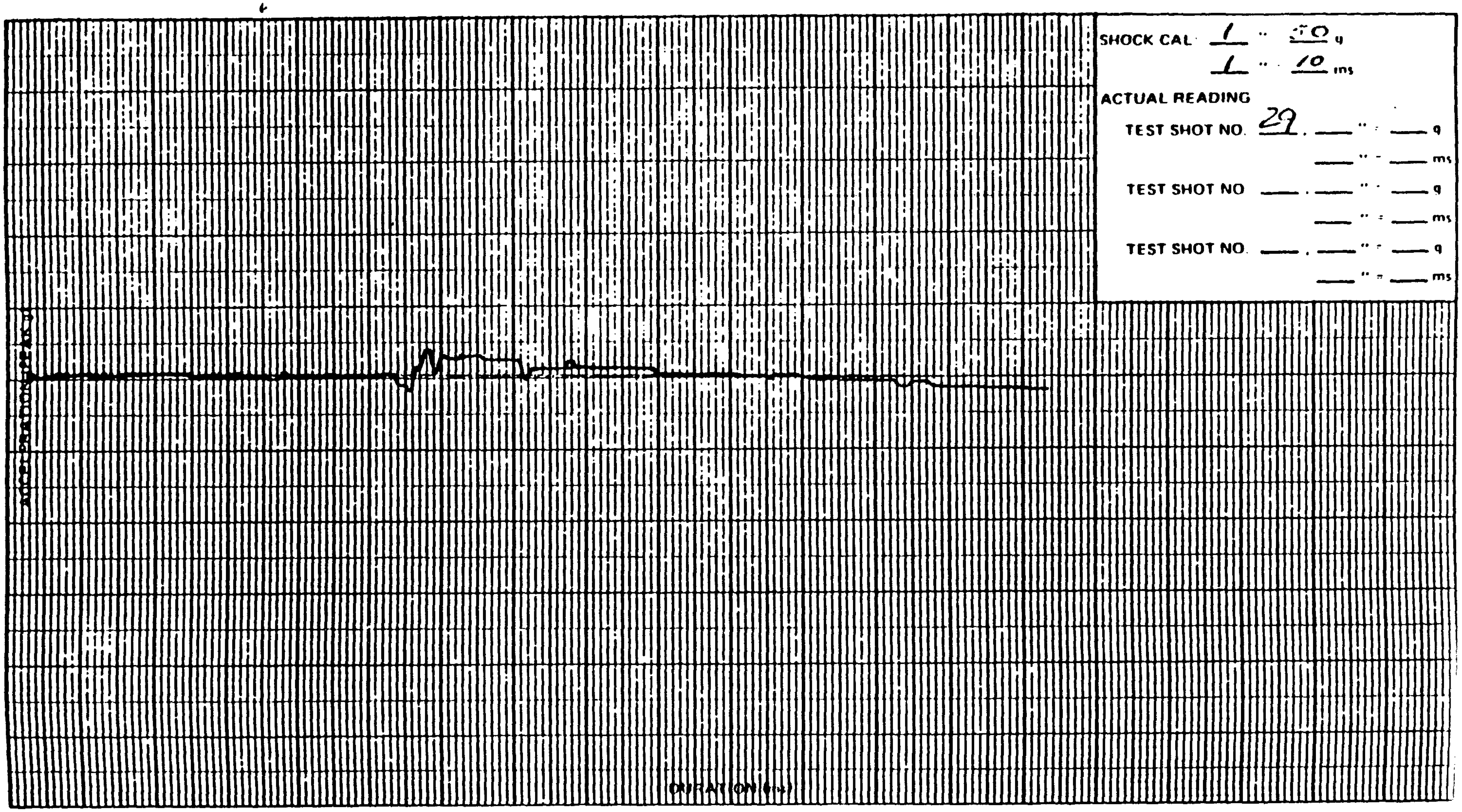
Plotted by: Wm Chin...

Checked by: ... Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]



SHOCK CAL: 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 29. ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: FH021

Pickup Location: TP2

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS OPERATIONAL SHOCK

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1115

Lab Form D24 2

DAYTON T. BROWN

Plotted by: Wm Clendenin

Checked by: G Hyland

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non-operational [X]

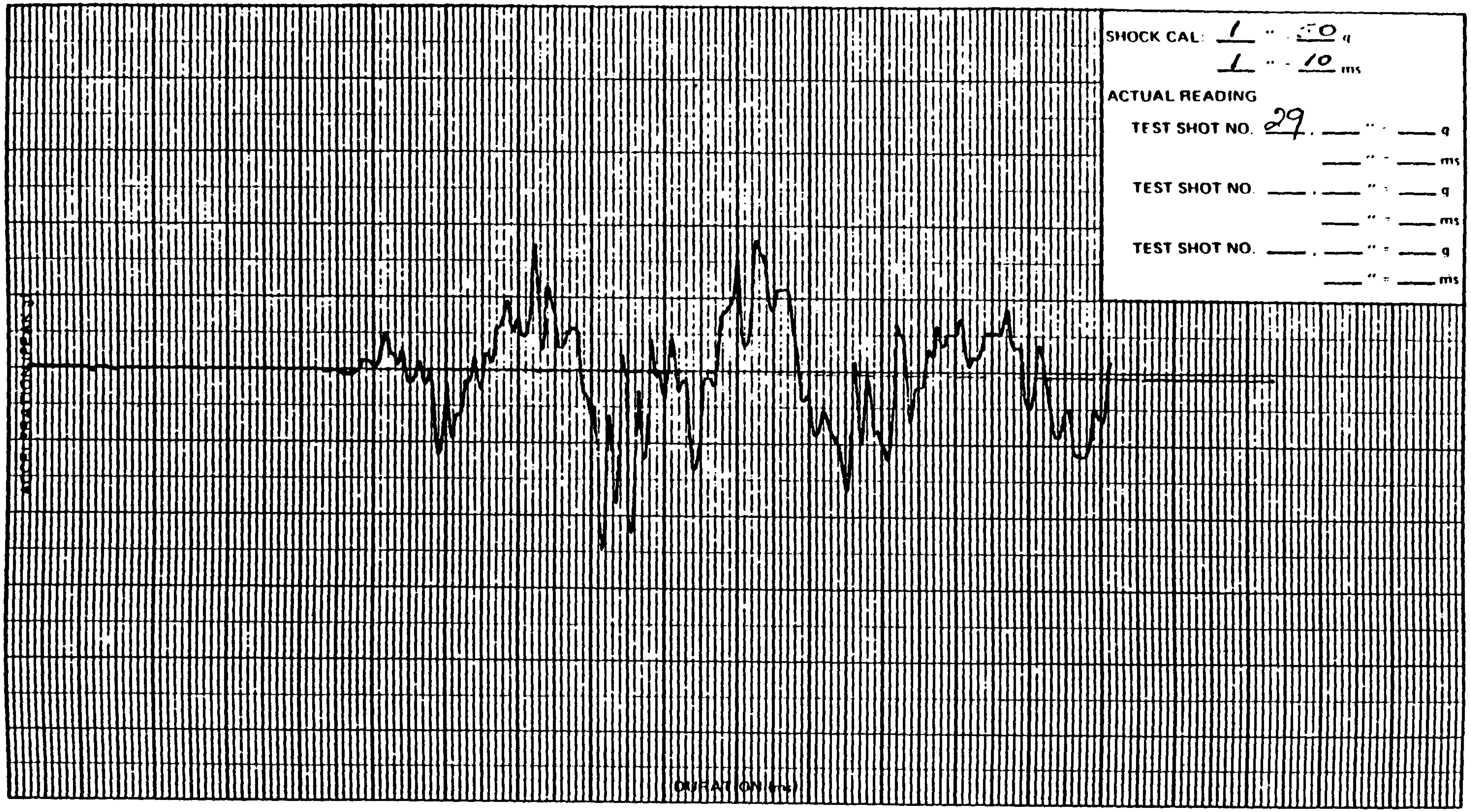
SHOCK CAL: 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 29 ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ ___" = ___ g
___" = ___ ms



Pickup Serial Number: 685

Pickup Location: TP3

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak/g peak

Direction: VERT POS OPERATIONAL SHOCK

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1115

Lab Form D24 2

Plotted by Wm Cle...

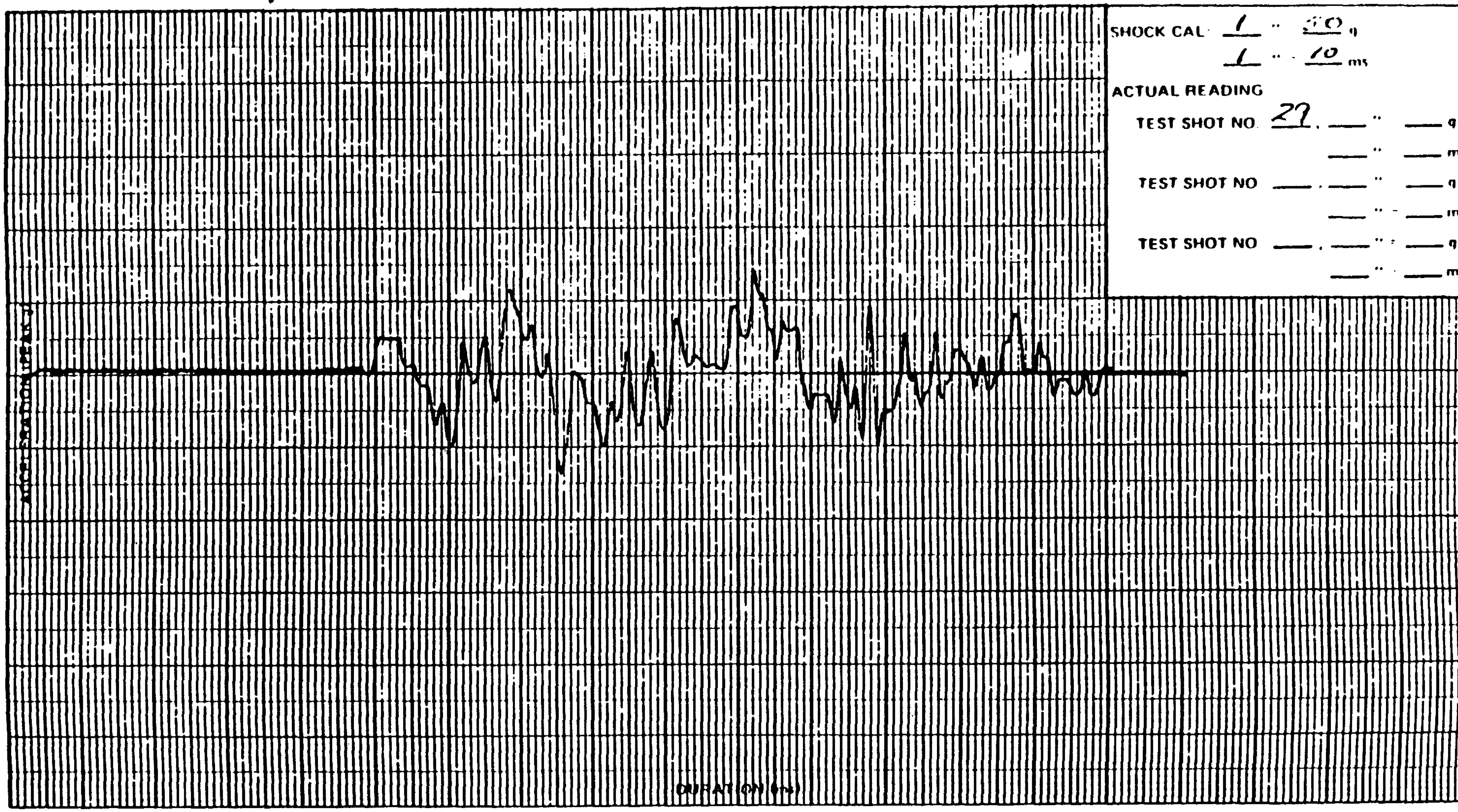
Checked by G. Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]



SHOCK CAL: 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO 27, ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___, ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___, ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: 537

Pickup Location: TP4

Pickup Sensing Axis: LIFT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS OPERATIONAL SHOCK

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 17 APR 89

Time: 1115

Lab Form D24 2

Plotted by: Wm. Cl...

Checked by: S. Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non-operational [X]

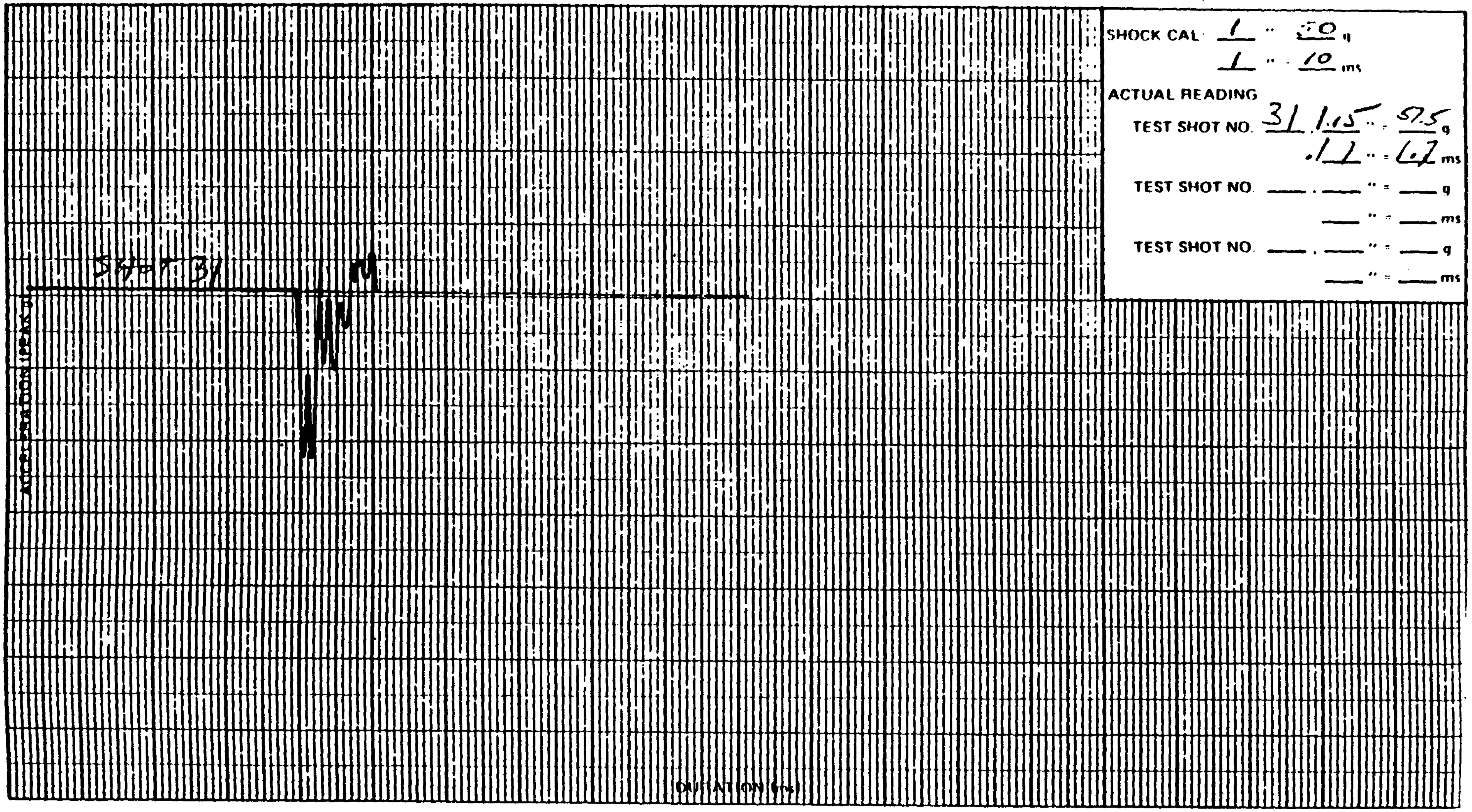
SHOCK CAL: 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 31 1.15" = 57.5 g
.11" = 6.2 ms

TEST SHOT NO. ___ . ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ . ___" = ___ g
___" = ___ ms



Pickup Serial Number: NB41

Pickup Location: Console

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS OPERATIONAL SHOCK

[X] Live [ ] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1203

Plotted by: Wm Ch[illegible]

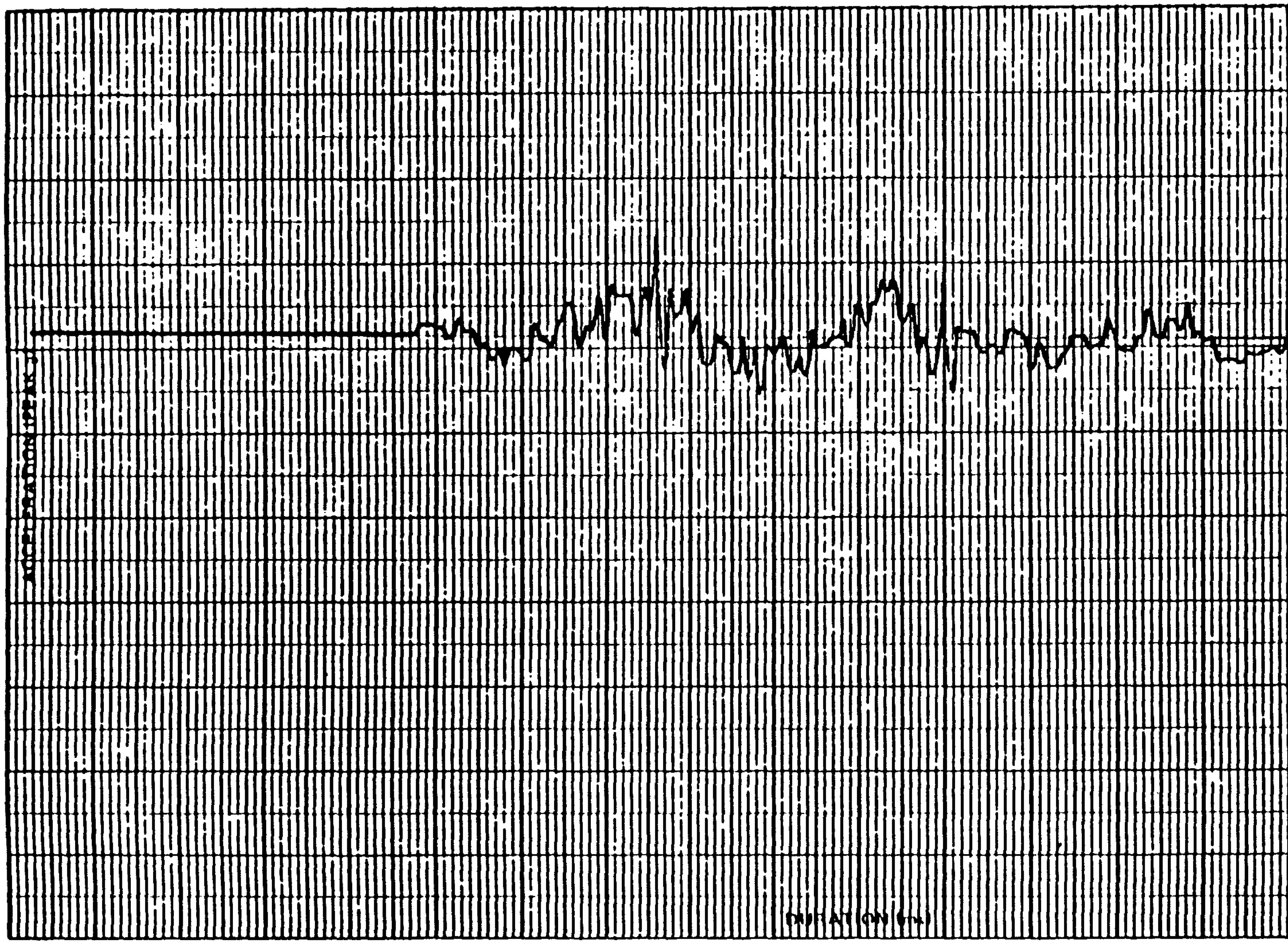
Checked by: G. Hylard

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit   Operational [ ]   Non-operational [x]



SHOCK CAL 1 " 50 g
1 " 10 ms

ACTUAL READING

TEST SHOT NO. 31. ___ " ___ g
___ " ___ ms

TEST SHOT NO. ___ . ___ " ___ g
___ " ___ ms

TEST SHOT NO. ___ . ___ " ___ g
___ " ___ ms

Pickup Serial Number: FH04

Pickup Location: TP2

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VLKT POS OPERATIONAL SHOCK

[ ] Live   [x] Tape

Job Number: 406744-00-000

Date: 17 APR 89

Time: 1202

Lab Form D24 2

Plotted by: Wm Chr[illegible] (signature)
Checked by: G. Hylard (signature)

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational ☐ Non-operational ☒

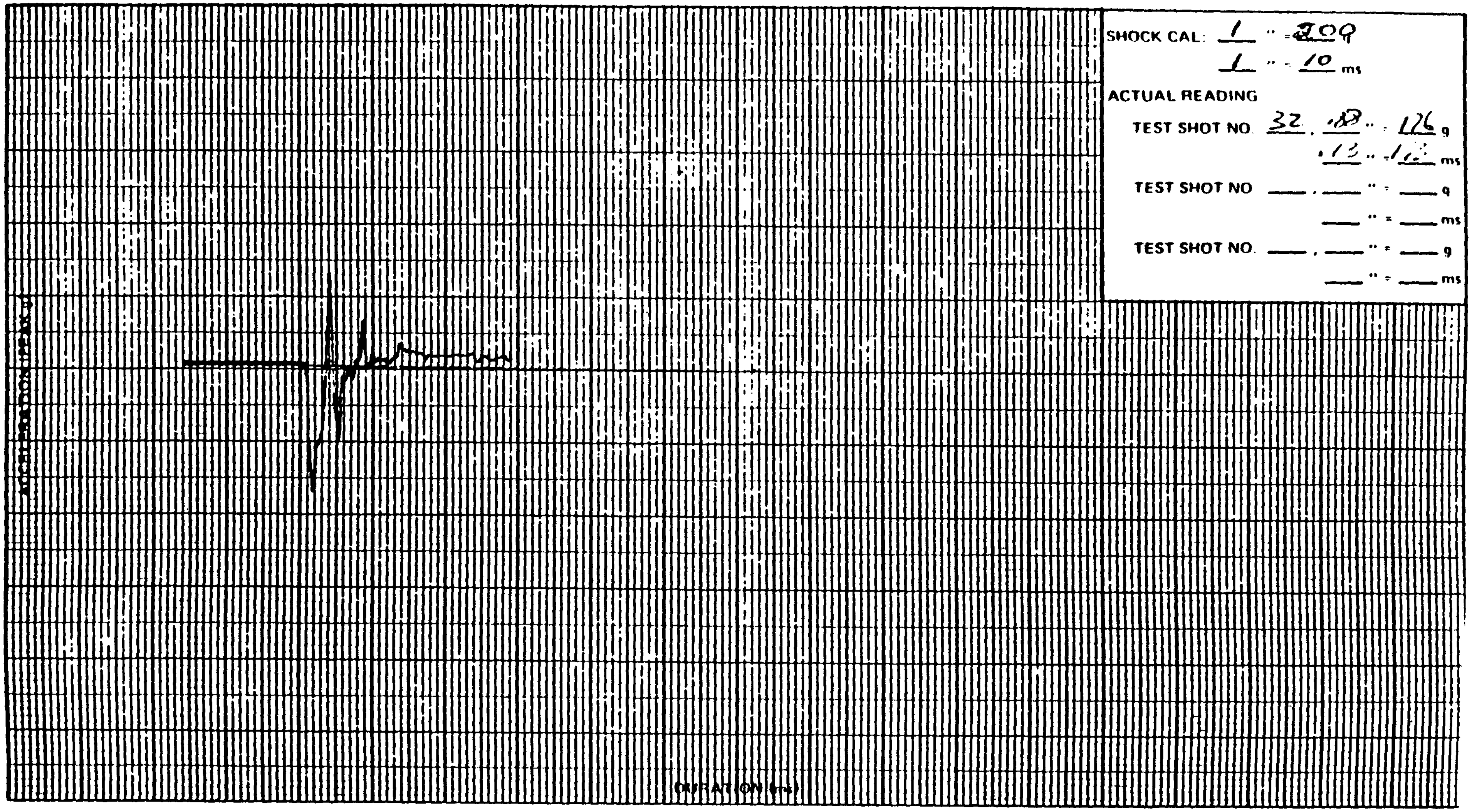
SHOCK CAL: 1" = 200 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 32, .88" = 176 g
.13" = 1.3 ms

TEST SHOT NO. ___, ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___, ___" = ___ g
___" = ___ ms



Pickup Serial Number: 632
Pickup Location: [illegible]
Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: VERT POS NON RECOIL[illegible] BREECH[illegible]
☒ Live ☐ Tape

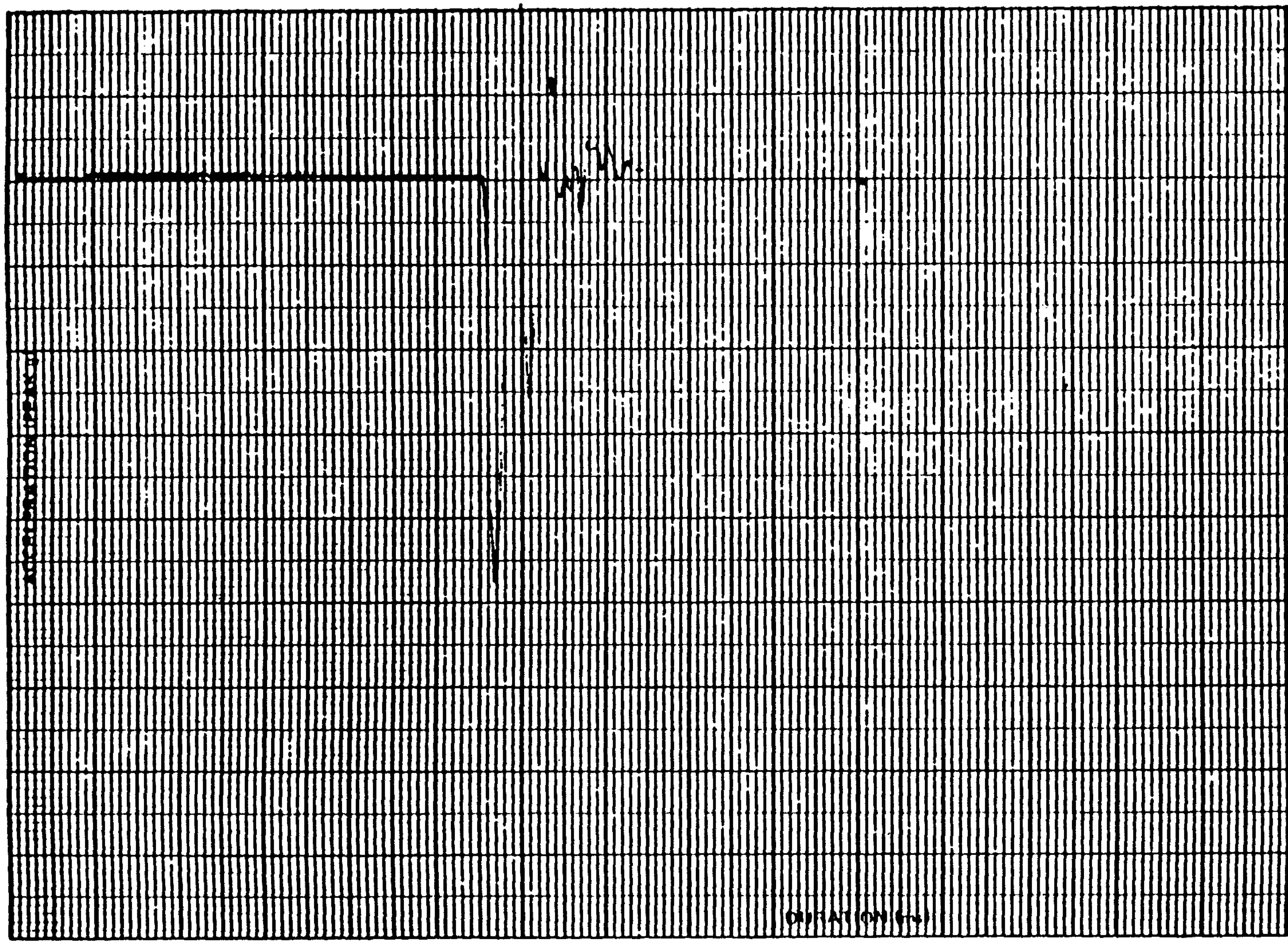
Job Number: 406744-00-000
Date: 19 APR 89
Time: 1315

Lab Form D24 2

Plotted by: Wm Cle[illegible]
Checked by: G. Hyl[illegible]

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational ☐ Non operational ☒



SHOCK CAL: 1 = 100 g
1 = 10 ms

ACTUAL READING
TEST SHOT NO 33 2.36 = 236 g
1.2 = 1.2 ms
TEST SHOT NO ___ ___ = ___ g
___ = ___ ms
TEST SHOT NO ___ ___ = ___ g
___ = ___ ms

Pickup Serial Number: 682
Pickup Location: Cont'l
Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: VERT POS NON DESTRUCTIVE [illegible]
☒ Live ☐ Tape

Job Number: 406744-00-000
Date: 19 APR 89
Time: 1322

Lab Form D24 2

Plotted by: Wm Chidsey (signature)

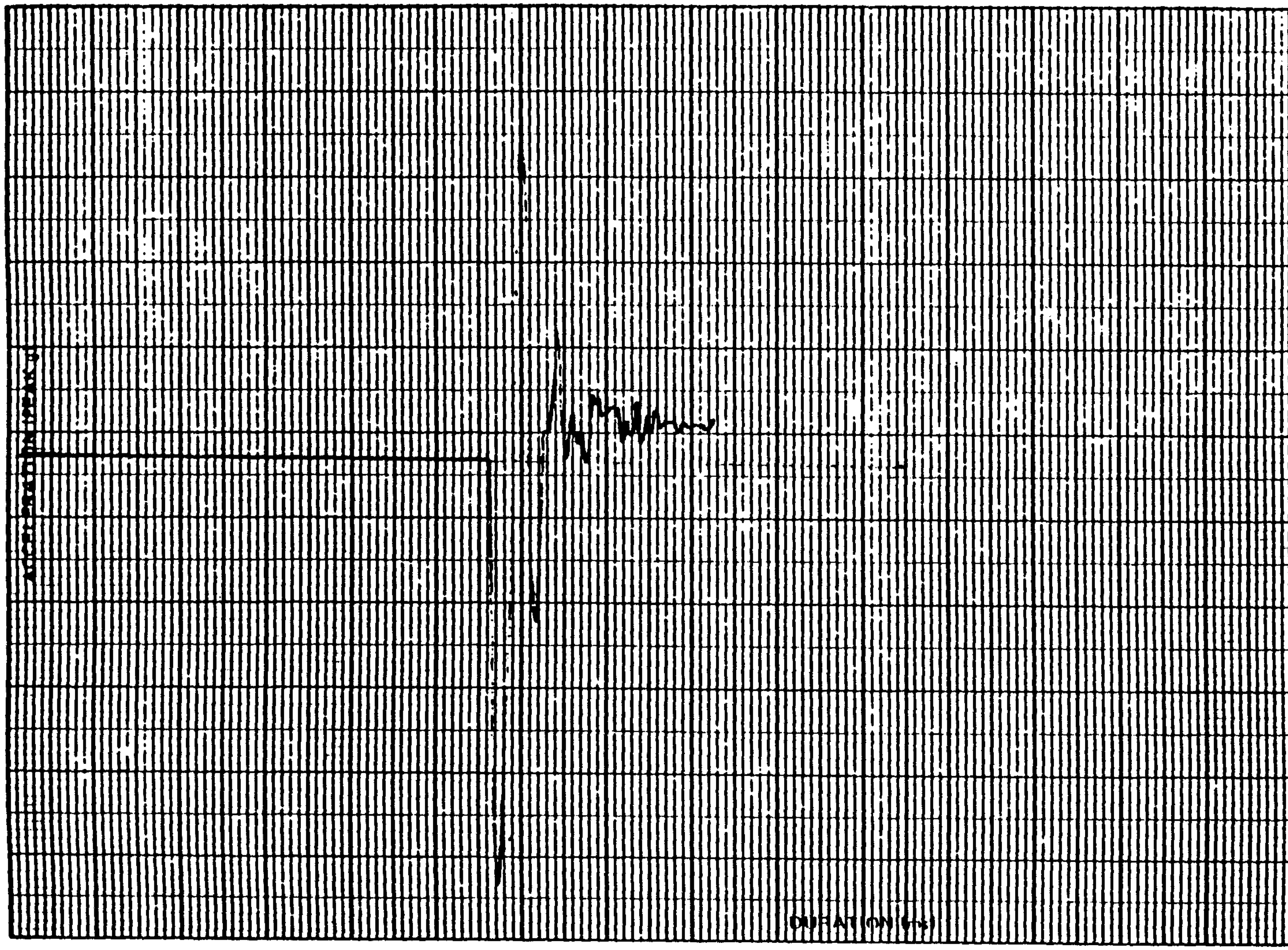
Checked by: G. Hylmar (signature)

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational ☐ Non-operational ☒



SHOCK CAL: 1 " = 100 g

1 " = 10 ms

ACTUAL READING:

TEST SHOT NO. 34 .25 " = 25 g

.13 " = 1.3 ms

TEST SHOT NO. ____ . ____ " = ____ g

____ " = ____ ms

TEST SHOT NO. ____ . ____ " = ____ g

____ " = ____ ms

Lab Form D24 2

Pickup Serial Number: 682

Pickup Location: CONTROL

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS NON [illegible] BALLISTIC

☒ Live ☐ Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1350

Plotted by: Wm Cle...

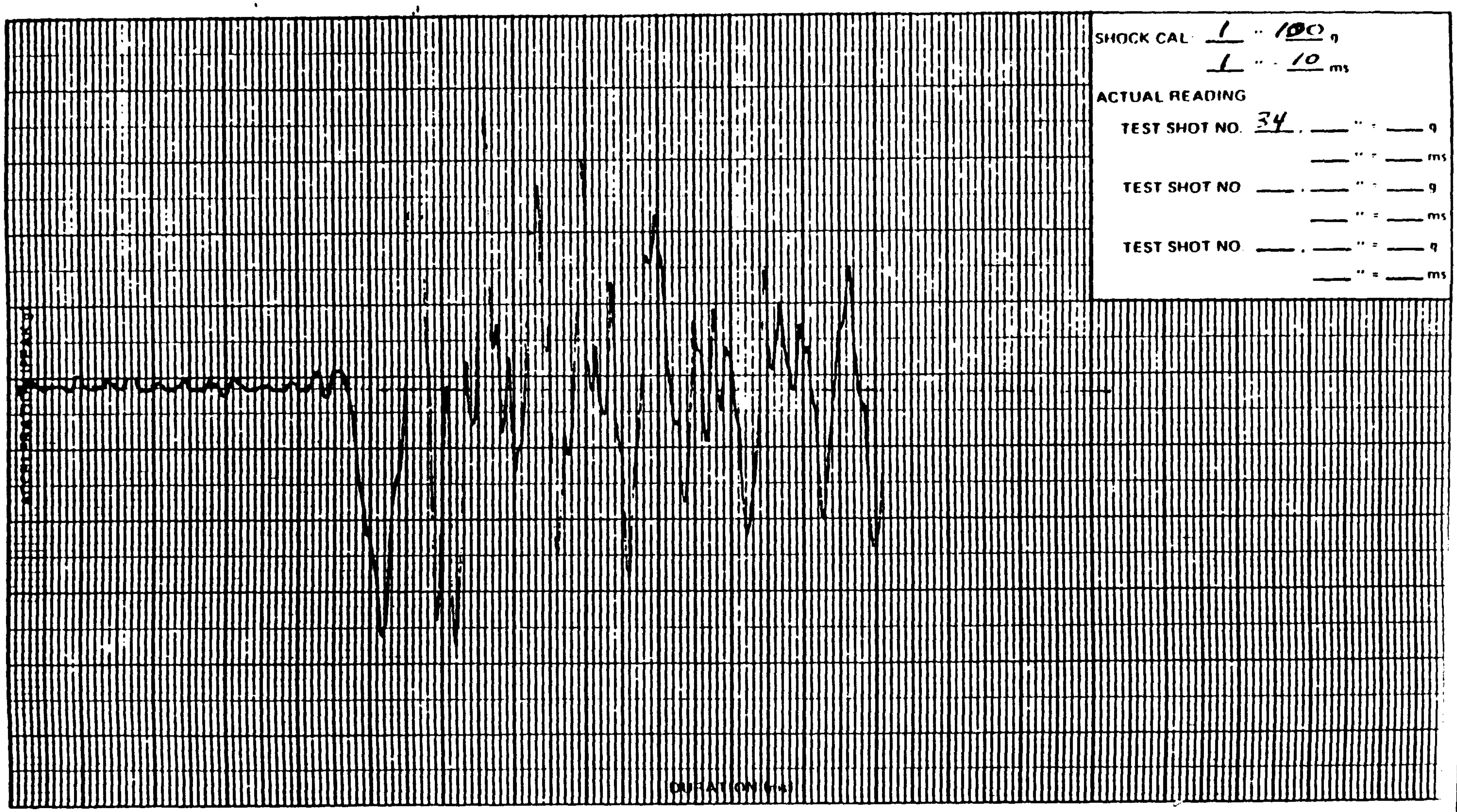
Checked by: [illegible]

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non-operational [X]



SHOCK CAL: 1 " : 100 g
1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 34 ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___ ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___ ___ " = ___ g
___ " = ___ ms

Lab Form D24-2

Pickup Serial Number: 244

Pickup Location: TP1

Pickup Sensing Axis: VERT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT PO[illegible] NON [illegible] [illegible]

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: [illegible]

Plotted by: Wm Chidaing

Checked by: A. Hylnnd

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s) 82E018

Unit Operational [ ] Non operational [X]

SHOCK CAL 1 " = 100 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 34 . ____ " = ____ g

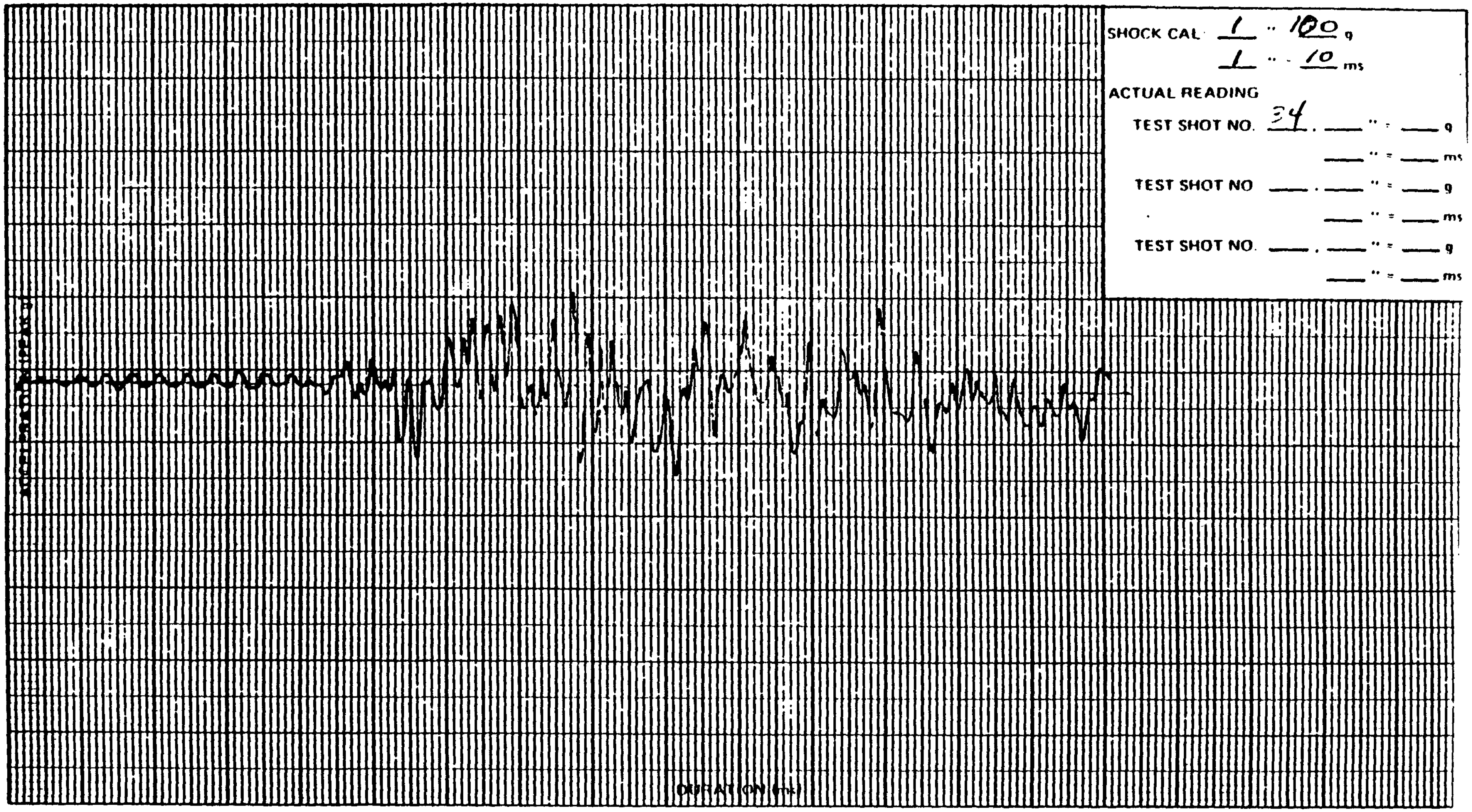
____ " = ____ ms

TEST SHOT NO ____ . ____ " = ____ g

____ " = ____ ms

TEST SHOT NO. ____ . ____ " = ____ g

____ " = ____ ms



Pickup Serial Number: TH04

Pickup Location: T/2

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS NON DESTRUCTIVE BALLISTIC

[ ] Live [X] Tape

Job Number: 406744-00-000

Date 19 APR 89

Time: 1320

Lab Form D24-2

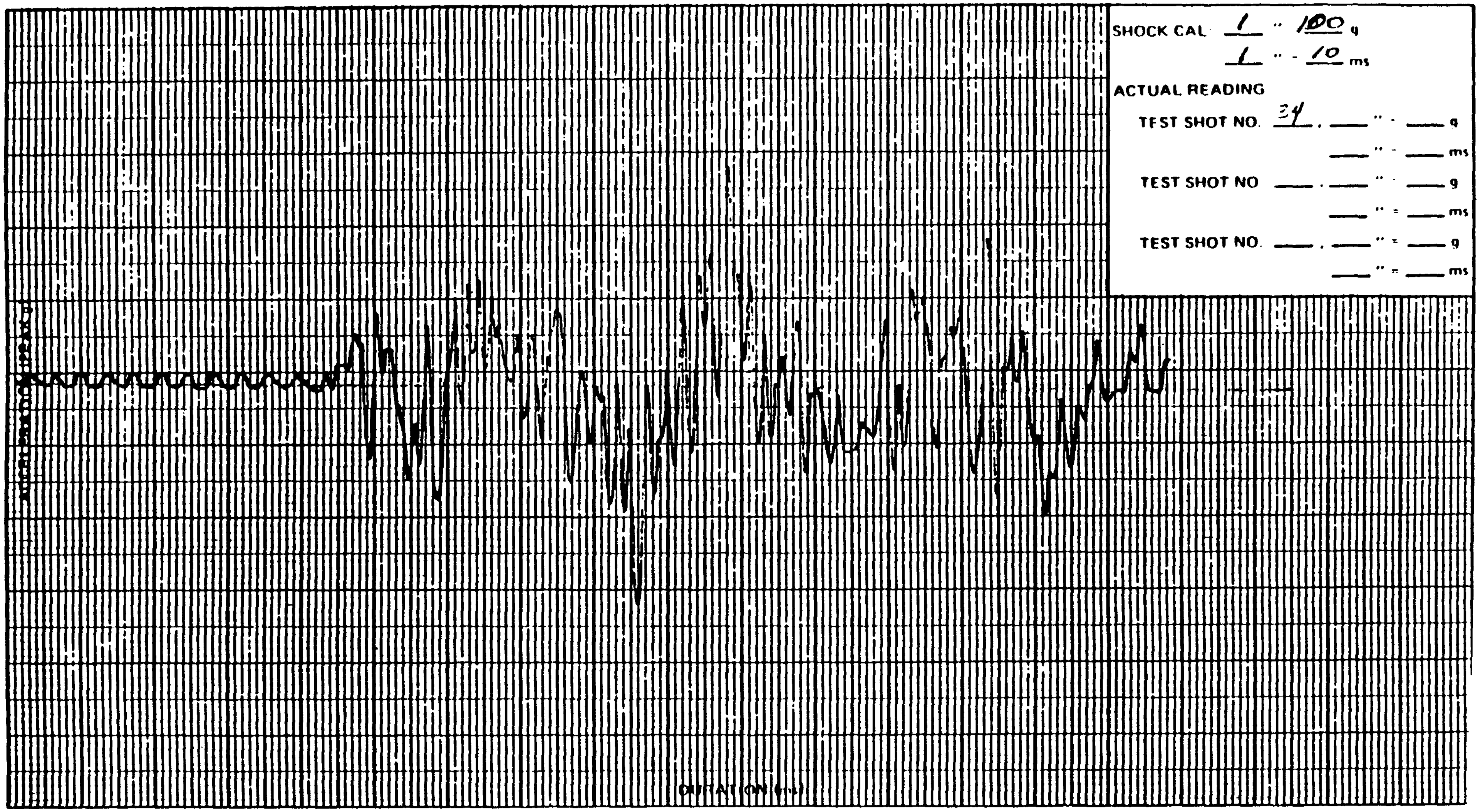
Plotted by: Wm Clay Ami
Checked by: G. Hylord

DAYTON BROWN

Test Item: SCAF
Serial Number(s): 82 E 018
Unit Operational ☐ Non-operational ☒

SHOCK CAL 1" = 100 g
1" = 10 ms

ACTUAL READING
TEST SHOT NO. 34 . ___ " = ___ g
___ " = ___ ms
TEST SHOT NO ___ . ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms



Lab Form D24 2

Pickup Serial Number: 685
Pickup Location: TP3
Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: VERT POS NON DESTRUCTIVE
☐ Live ☒ Tape

Job Number: 406744-00-000
Date: 19 APR 89
Time: 1

DAYTON T. BROWN

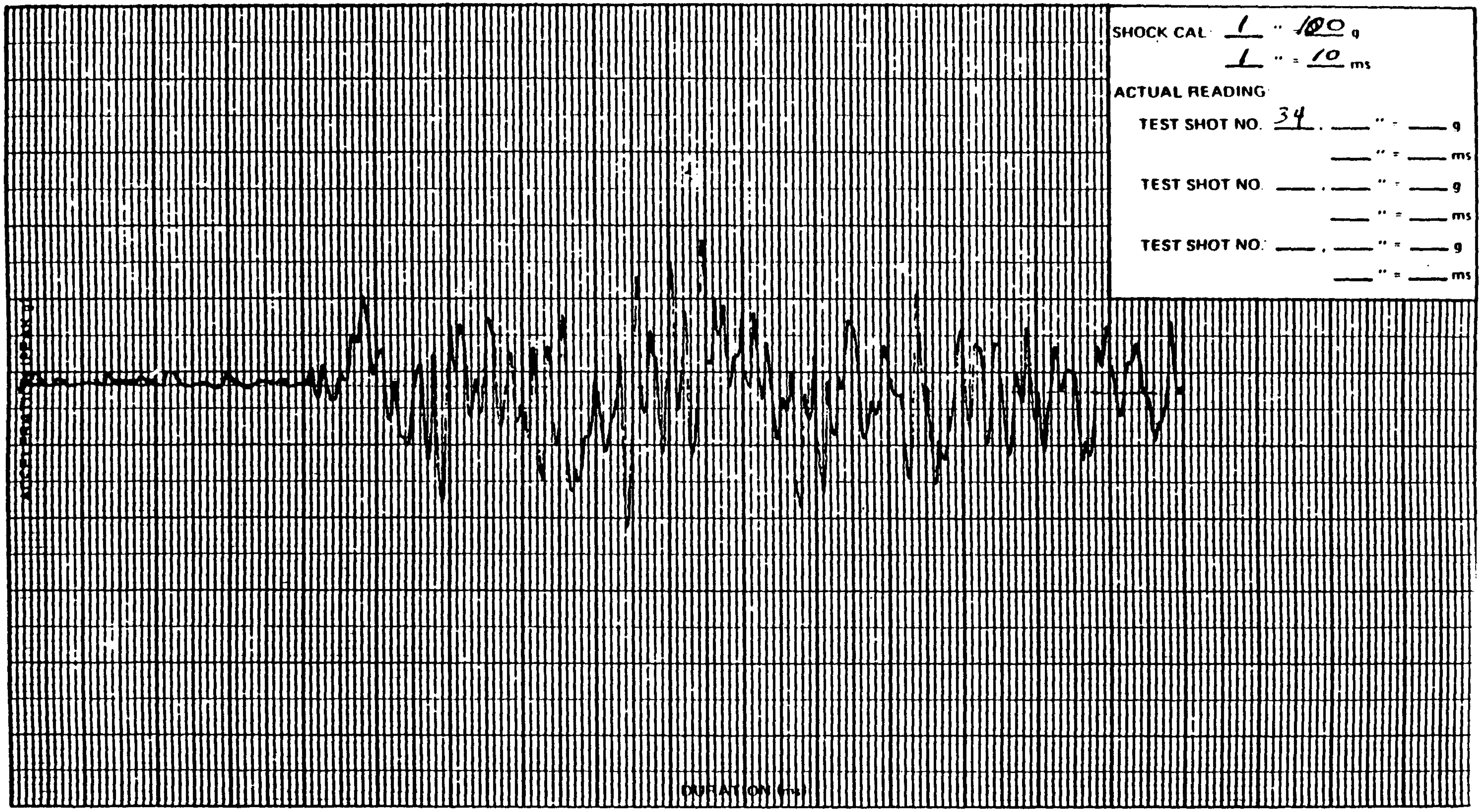
Plotted by: Wm Chaney

Checked by: G Hyland

Test Item: SCAF

Serial Number(s) 82E018

Unit: Operational ☐ Non-operational ☒



SHOCK CAL 1 " = 100 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 34 , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g

___ " = ___ ms

Lab Form D24-2

Pickup Serial Number: 987

Pickup Location: TP4

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT POS NON DESTRUCTIVE [illegible]

☐ Live ☒ Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: [illegible]

Plotted by: Wm Chadwin

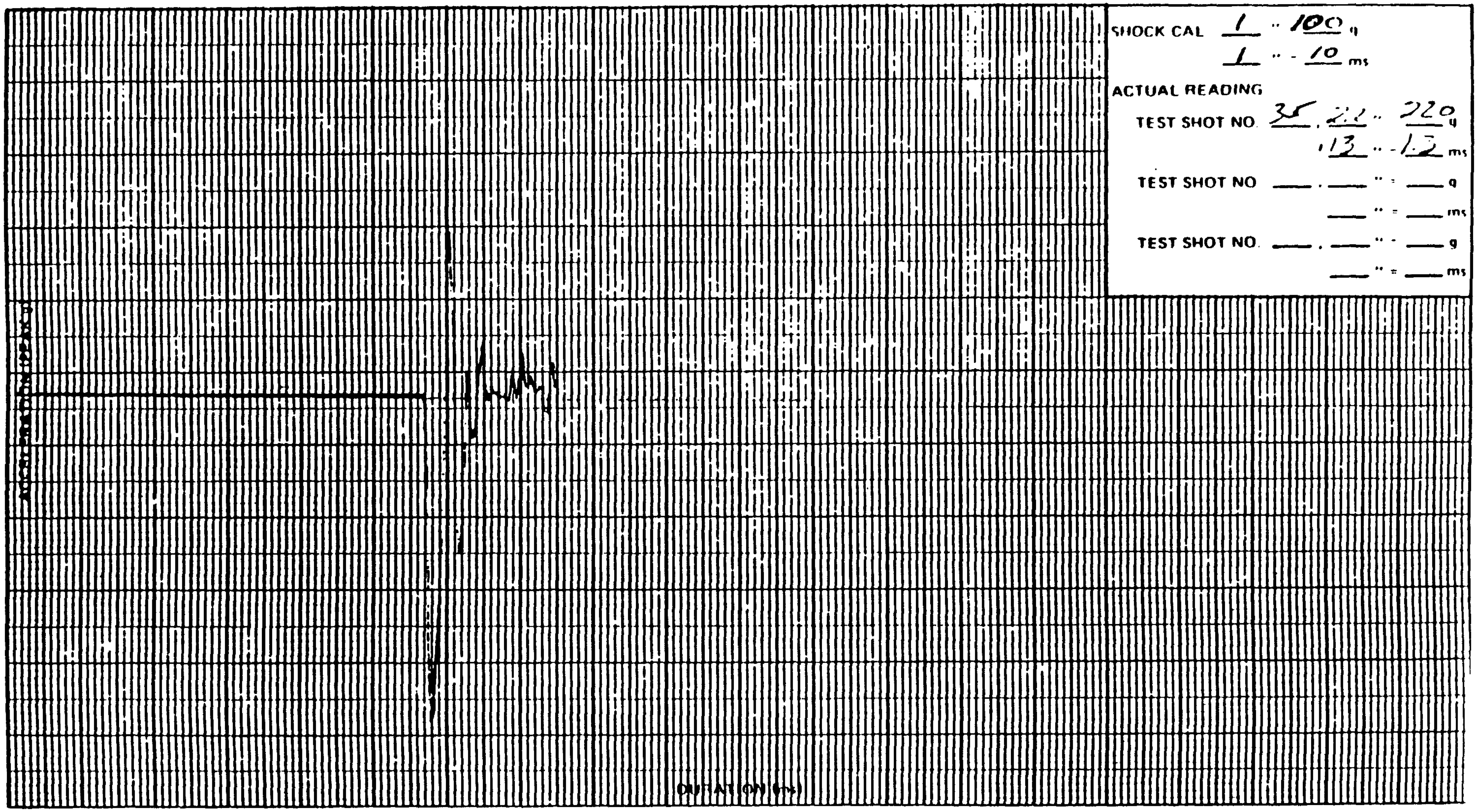
Checked by: L. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 62E018

Unit Operational [ ] Non-operational [X]



SHOCK CAL 1 " = 100 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 35 .22 " = 220 g
.13 " = 1.3 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: L32

Pickup Location: [illegible]

Pickup Sensing Axis: [illegible]

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: VERT. POS. NON DESTRUCTIVE BALLISTIC

[X] Live [ ] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1350

Lab Form D24-2

DAYTON BROWN

Plotted by: Wm Chr[illegible]

Checked by: G. Hyland

Test Item: SCAF

Serial Number(s) 82E018

Unit Operational ☐ Non operational ☒

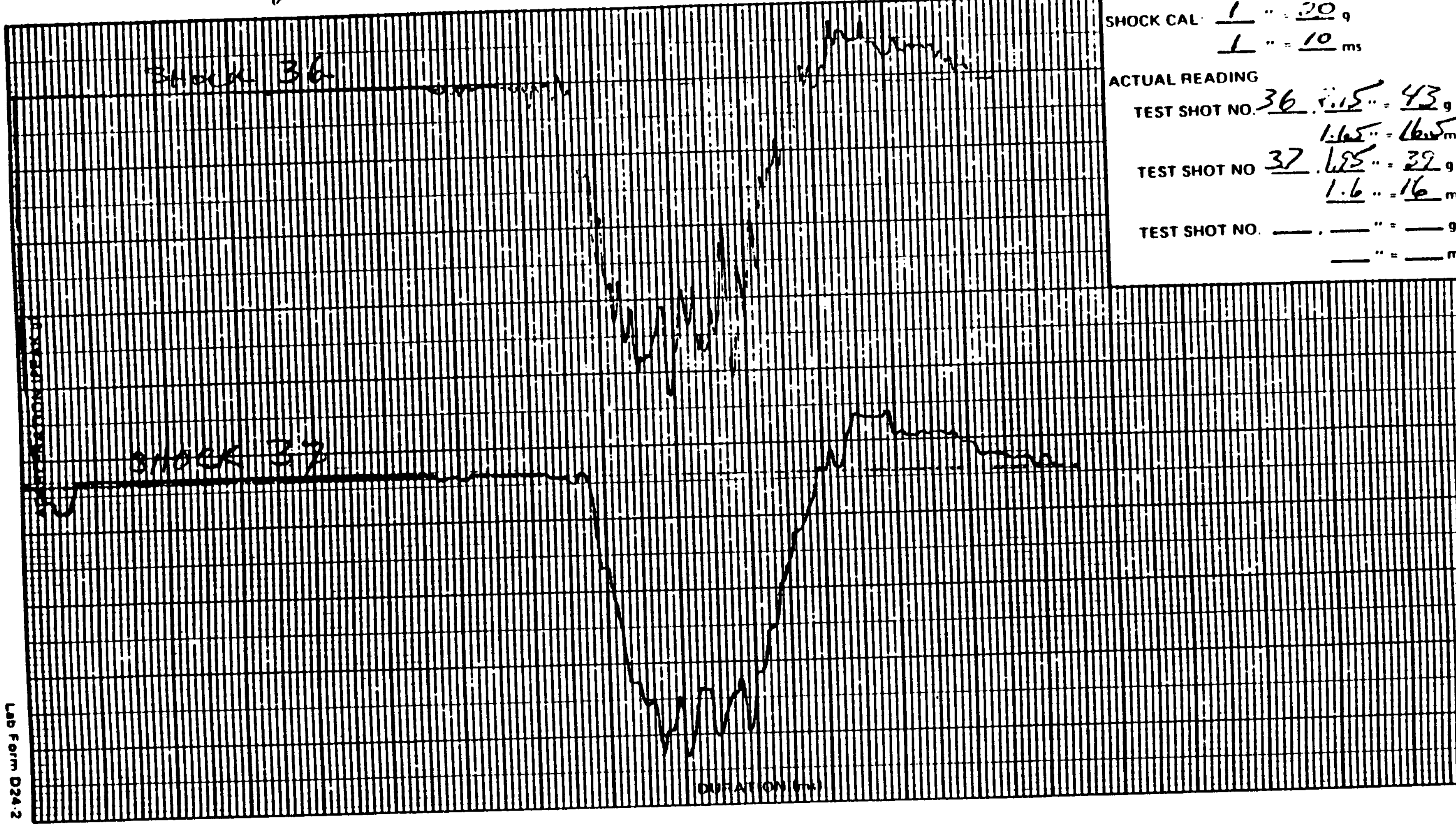
SHOCK CAL 1" = 20 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 36 1.15" = 43 g
1.65" = 16.5 ms

TEST SHOT NO 37 1.85" = 32 g
1.6" = 16 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms



Pickup Serial Number: 682

Pickup Location: CONTROL

Pickup Sensing Axis: LONG

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: LONG POS [illegible] SHOCK

☒ Live ☐ Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 15:5

Lab Form D24-2

DAYTON BROWN

Plotted by: Wm Chr[illegible]

Checked by: G. Hy[illegible]

Test Item: SCAF

Serial Number(s): 82 E 018

Unit Operational [ ] Non-operational [X]

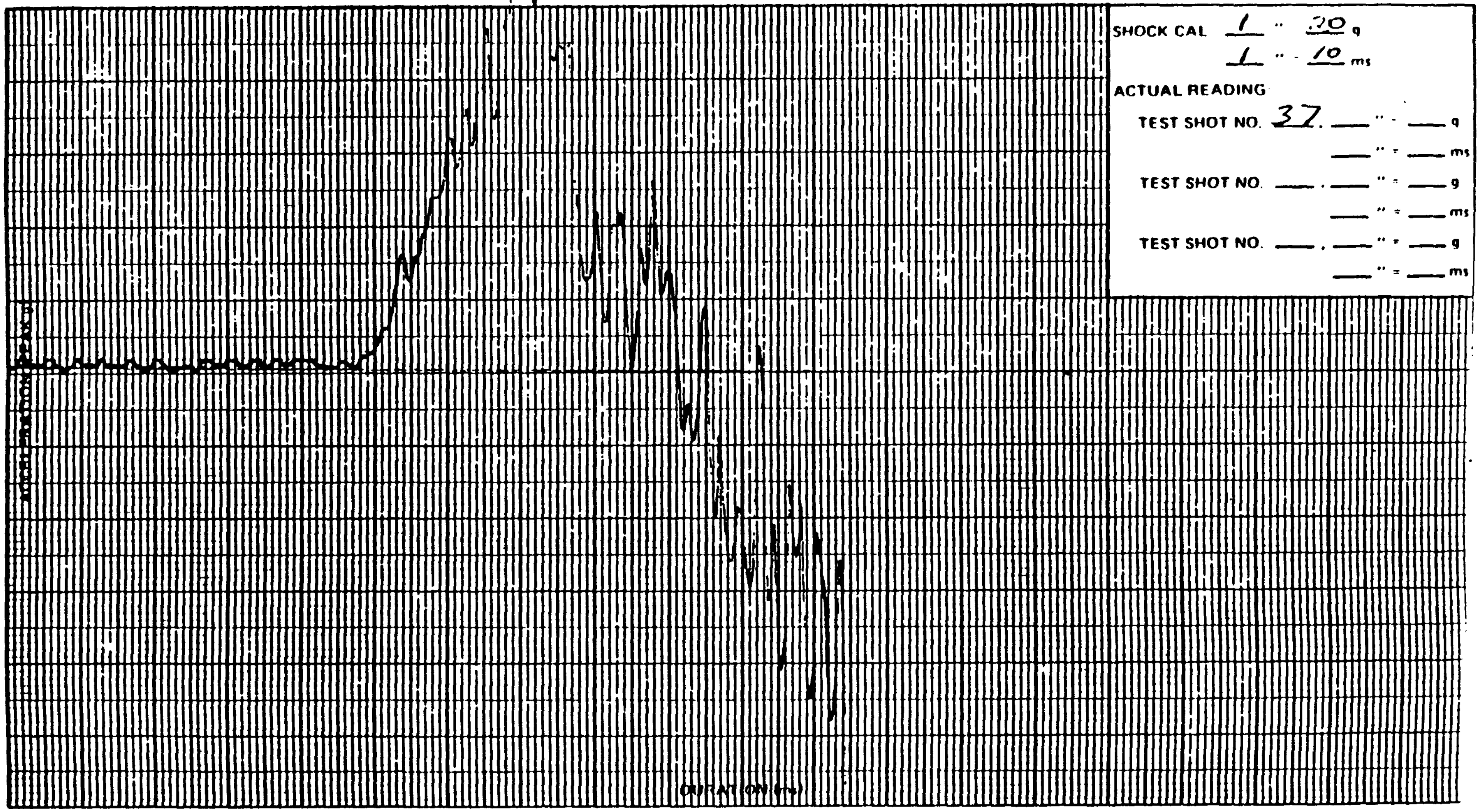
SHOCK CAL 1 " = 20 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 37 ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ ___ " = ___ g
___ " = ___ ms



Lab Form D24-2

Pickup Serial Number: 244

Pickup Location: T/1

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Long Pos [illegible] | [illegible]

[ ] Live [X] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1545

Plotted by: Wm Chri...

Checked by: H. Hyland

DAYTON BROWN

Test Item: SCAF

Serial Number(s) 82E018

Unit: Operational [ ] Non-operational [x]

SHOCK CAL: 1 " = 20 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 37 ___ " = ___ g

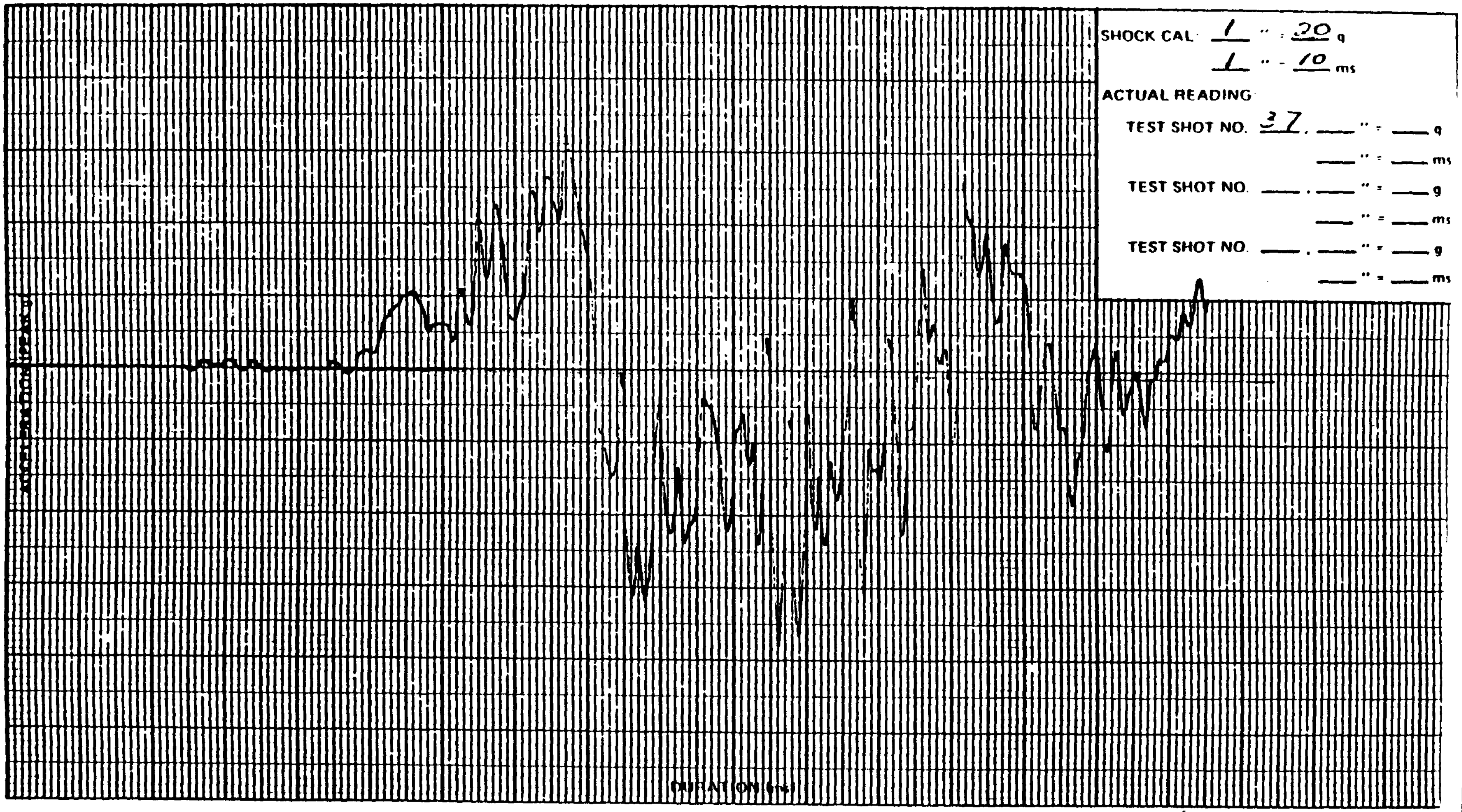
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms



Lab Form D24-2

Pickup Serial Number: 656

Pickup Location: T??

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: LONG POS ... SHOCK

[ ] Live [x] Tape

Job Number: 406744-00-000

Date: 19 APR 89

Time: 1545

Plotted by: Wm Chadwin

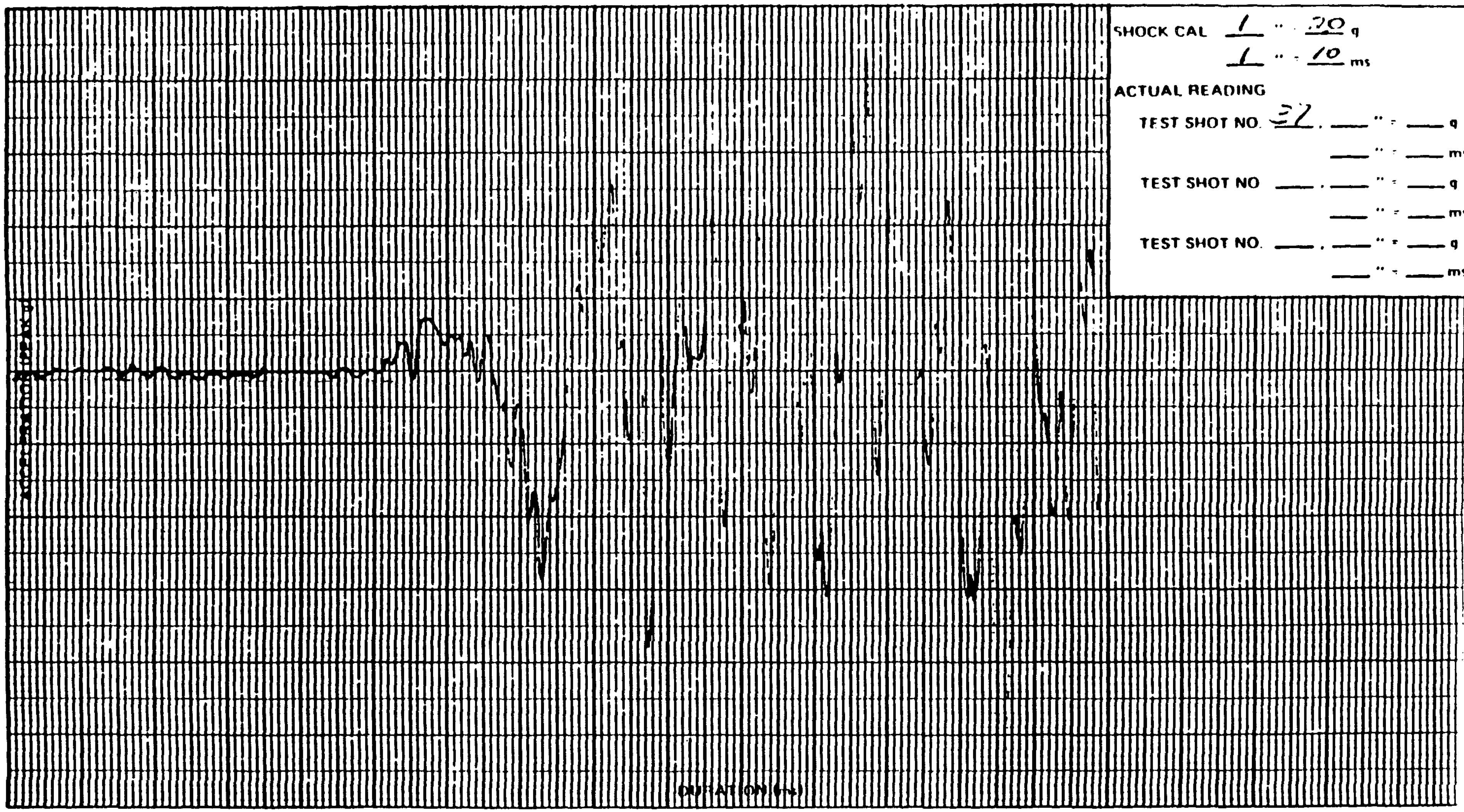
Checked by: G Hylund

DAYTON BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational ☐ Non operational ☒



SHOCK CAL 1" = 20 g

1" = 10 ms

ACTUAL READING

TEST SHOT NO. 37 ___ " = ___ g

___ " = ___ ms

TEST SHOT NO ___ . ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms

Lab Form D24.2

Pickup Serial Number: 685

Pickup Location: TP3

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Long Pos [illegible]

☐ Live ☒ Tape

Job Number: 406744-00-000

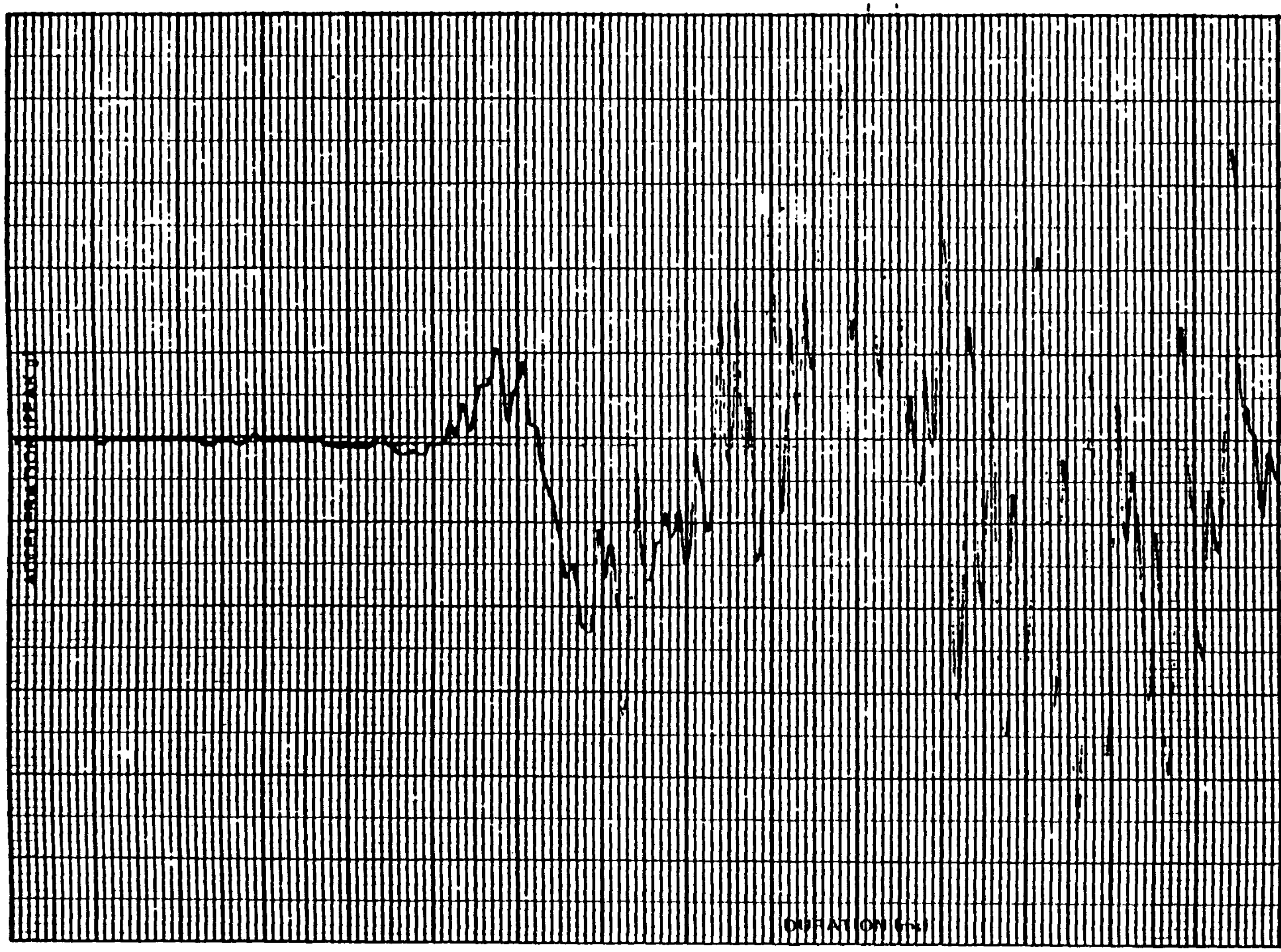
Date: 19 APR 89

Time: [illegible]

Plotted by: [illegible]
Checked by: G Hyland

DAYTON BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational ☐ Non-operational ☒



SHOCK CAL: 1 " = 20 g
1 " = 10 ms

ACTUAL READING
TEST SHOT NO. 37, ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___, ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___, ___ " = ___ g
___ " = ___ ms

Lab Form D24-2

Pickup Serial Number: 887
Pickup Location: TP4
Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: LONG POS [illegible] SHOCK
☐ Live ☒ Tape

Job Number: 406744-00-000
Date: 19 APR 89
Time: 1545

Plotted by: Wm Chadwin

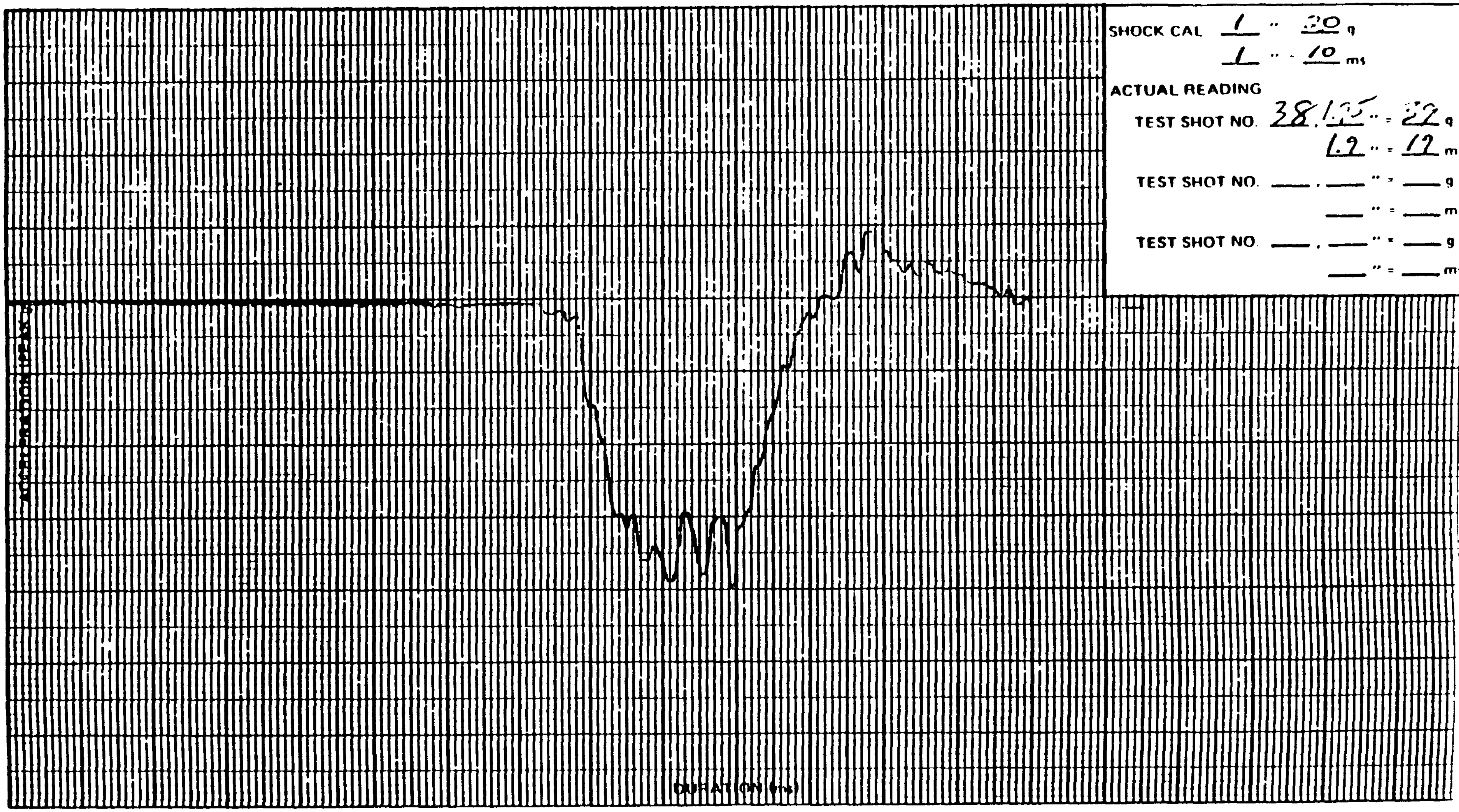
Checked by: G Hyland

DAYTON T BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational ☐ Non operational ☒



SHOCK CAL 1" = 20 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 38 1.1" = 22 g
1.2" = 12 ms

TEST SHOT NO. ____ , ____" = ____ g
____" = ____ ms

TEST SHOT NO. ____ , ____" = ____ g
____" = ____ ms

Pickup Serial Number: 682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Long Pos Within Shock

☒ Live ☐ Tape

Job Number: 406744-00-000

Date: 17 APR 89

Time: 1548

Lab Form D24 2

Plotted by: [signature]

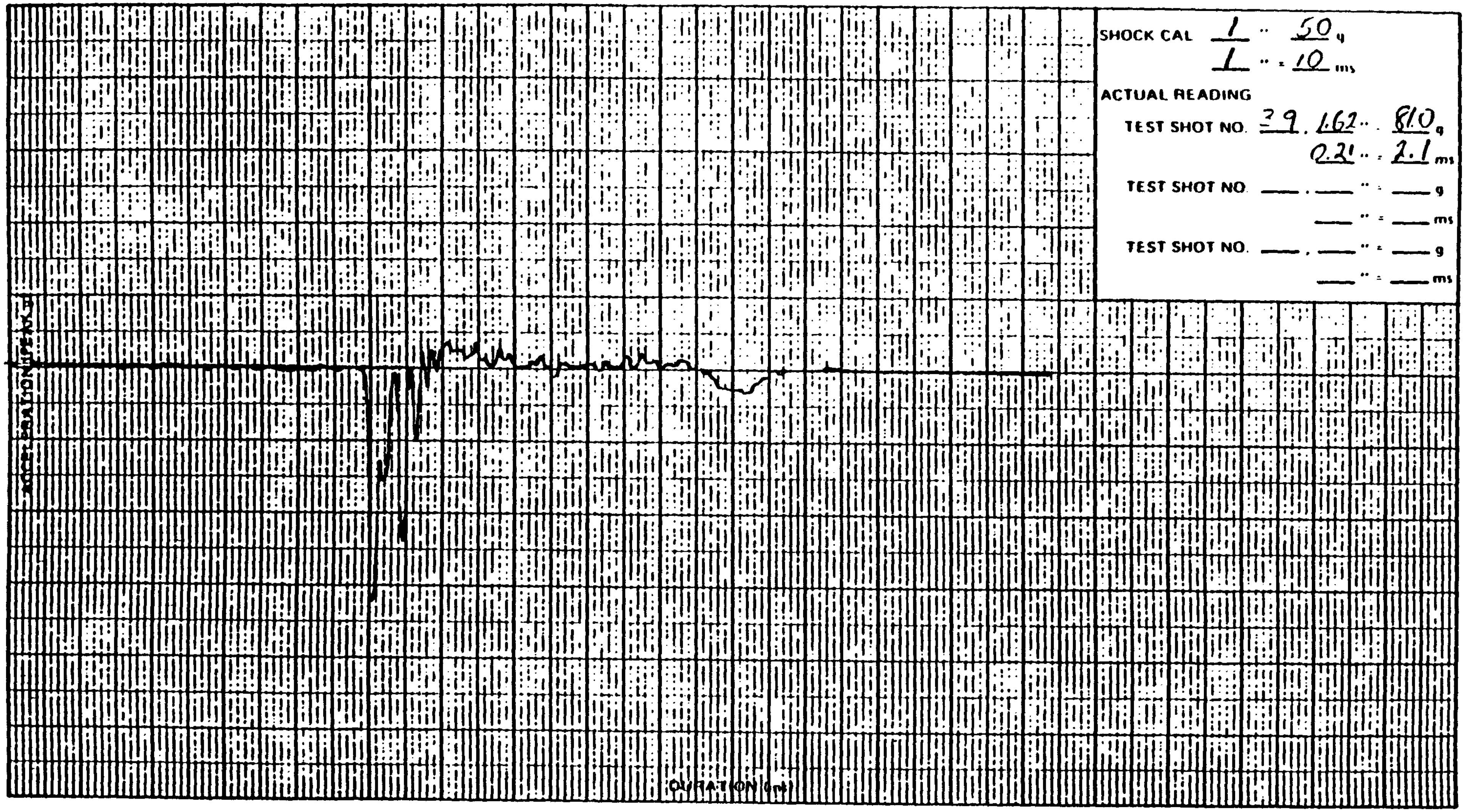
Checked by: G Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 39 1.62 " = 810 g
0.21 " = 2.1 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 17 April 89

Time: 1645

Lab Form D24 2

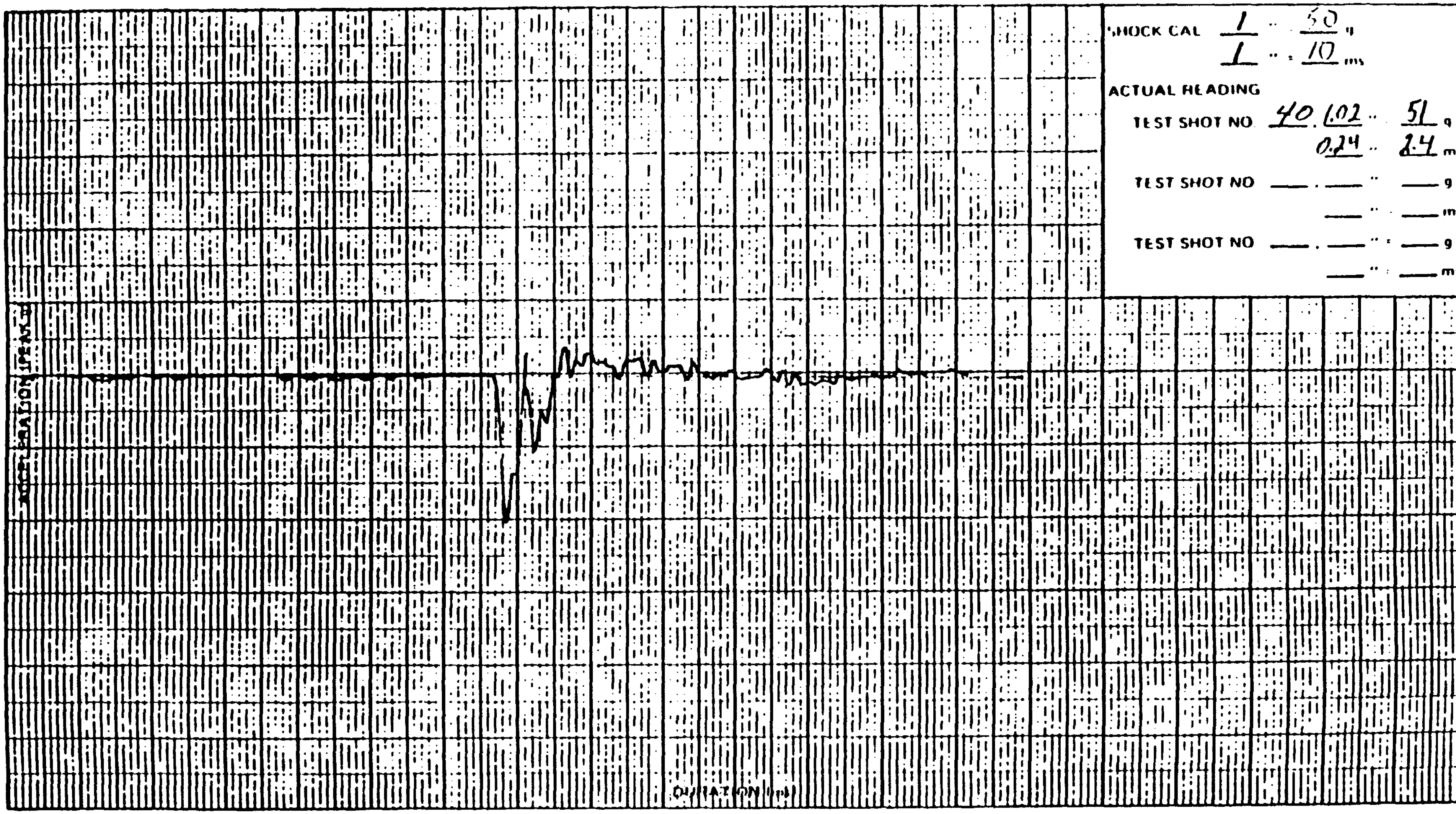
DAYTON T. BROWN

Plotted by [signature]
Checked by [signature]

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational [ ] Non operational M

SHOCK CAL 1 " 50 g
1 " 10 ms

ACTUAL READING
TEST SHOT NO 40.102 " 51 g
0.24 " 2.4 ms
TEST SHOT NO ___.___ " ___ g
___ " ___ ms
TEST SHOT NO ___.___ " ___ g
___ " ___ ms



Pickup Serial Number: 1051682
Pickup Location: Control
Pickup Sensing Axis: Long

Pickup Sensitivity 10.0 mv peak/g peak
Direction + Long
[ ] Live [ ] Tape

Job Number 406744
Date 17 April 89
Time 1655

Lab Form D24 2

Plotted by: G. Ayiccin

Checked by: G Hylard

DAYTON T. BROWN.

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]

SHOCK CAL 1 " 50 g

1 " 10 ms

ACTUAL READING

TEST SHOT NO. 40 . ___ " ___ g

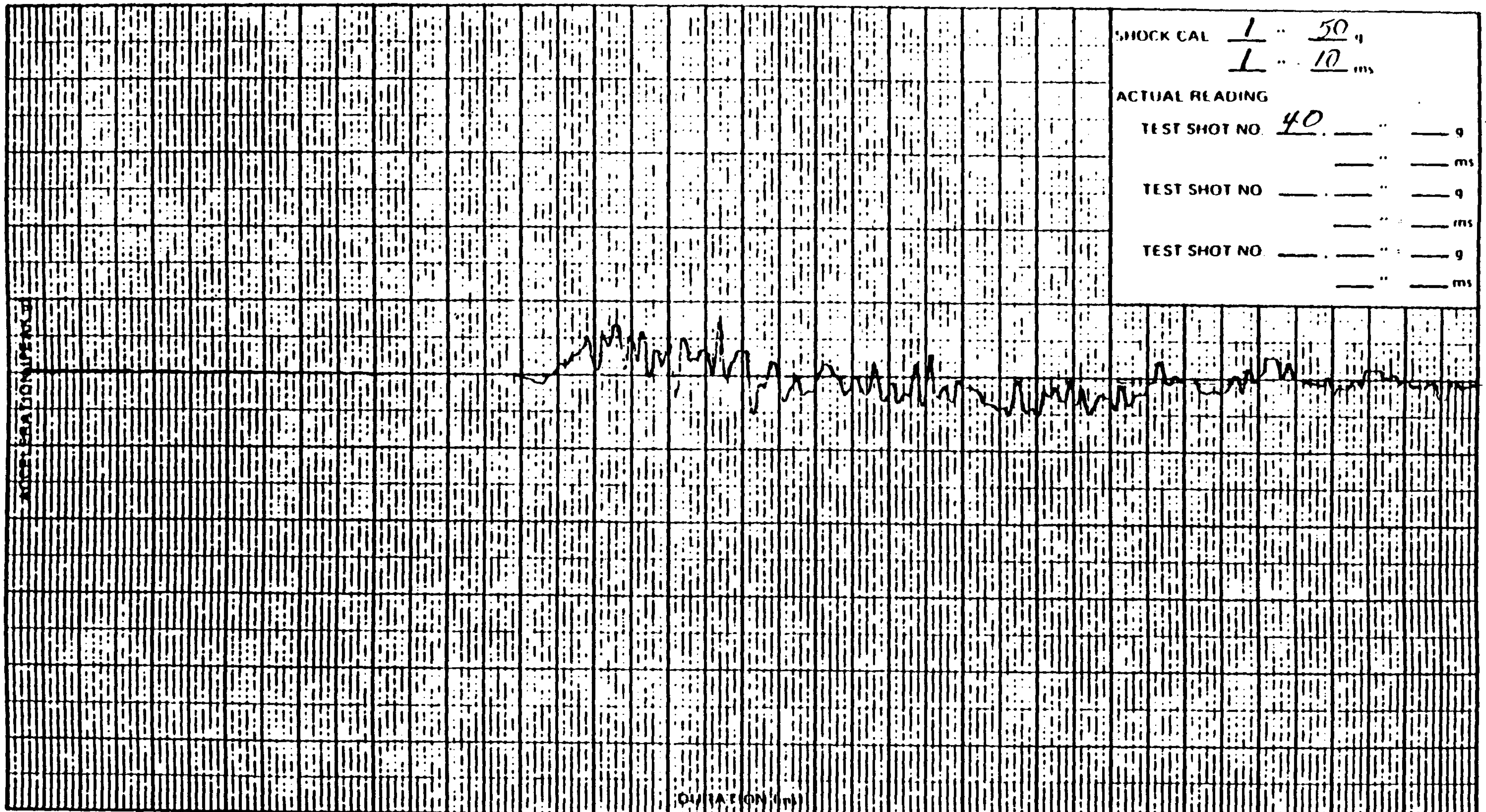
___ " ___ ms

TEST SHOT NO. ___ . ___ " ___ g

___ " ___ ms

TEST SHOT NO. ___ . ___ " ___ g

___ " ___ ms



Pickup Serial Number: 244

Pickup Location: TP#1

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 19 April 89

Time: 1655

89-0595 Enc 1 Pg 71

Lab Form D24 2

Plotted by [signature]

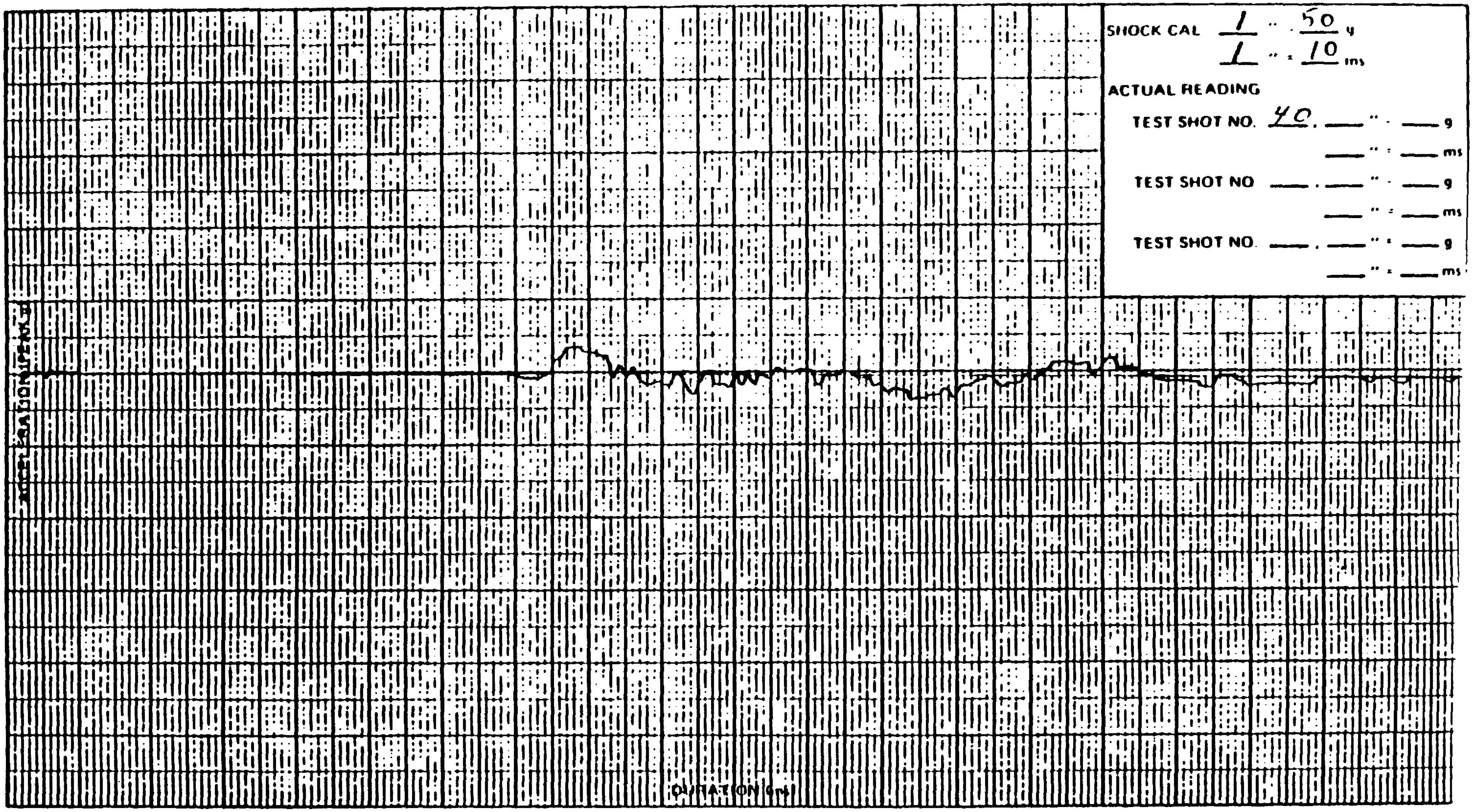
Checked by G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]



SHOCK CAL 1 " : 50 g
1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 40 ___ " : ___ g
___ " : ___ ms

TEST SHOT NO ___ ___ " : ___ g
___ " : ___ ms

TEST SHOT NO ___ ___ " : ___ g
___ " : ___ ms

Pickup Serial Number: 1051686

Pickup Location: TP#2

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: +Long

[ ] Live [M] Tape

Job Number: 406744

Date: 19 April 89

Time: 1655

Lab Form D24 2

Plotted by ~~G. [illegible]~~

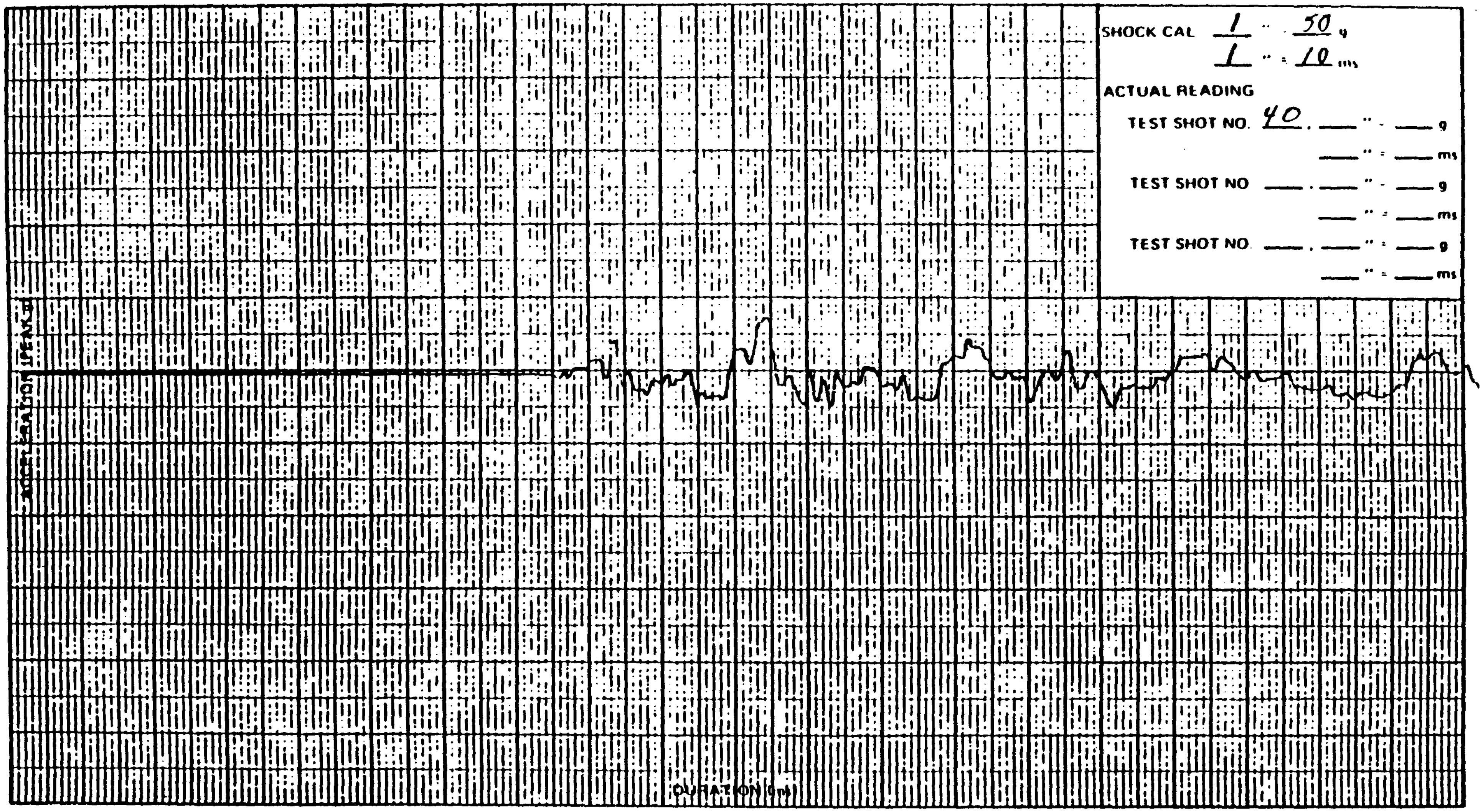
Checked by G. Hyland

DAYTON T. BROWN

Test Item SCAF

Serial Number(s) 82E018

Unit Operational [ ] Non operational [X]



SHOCK CAL 1" = 50 g

1" = 10 ms

ACTUAL READING

TEST SHOT NO. 40 ___" = ___ g

___" = ___ ms

TEST SHOT NO ___ ___" = ___ g

___" = ___ ms

TEST SHOT NO ___ ___" = ___ g

___" = ___ ms

Pickup Serial Number: 1051685

Pickup Location: TP#3

Pickup Sensing Axis: LAT

Pickup Sensitivity 10.0 mv peak / g peak

Direction: +Long

[ ] Live [X] Tape

Job Number: 406744

Date: 17 April 89

Time 1655

89-0595 Enc 1 Pg 73

Lab Form D24 2

Plotted by [signature]

Checked by G Hylund

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]

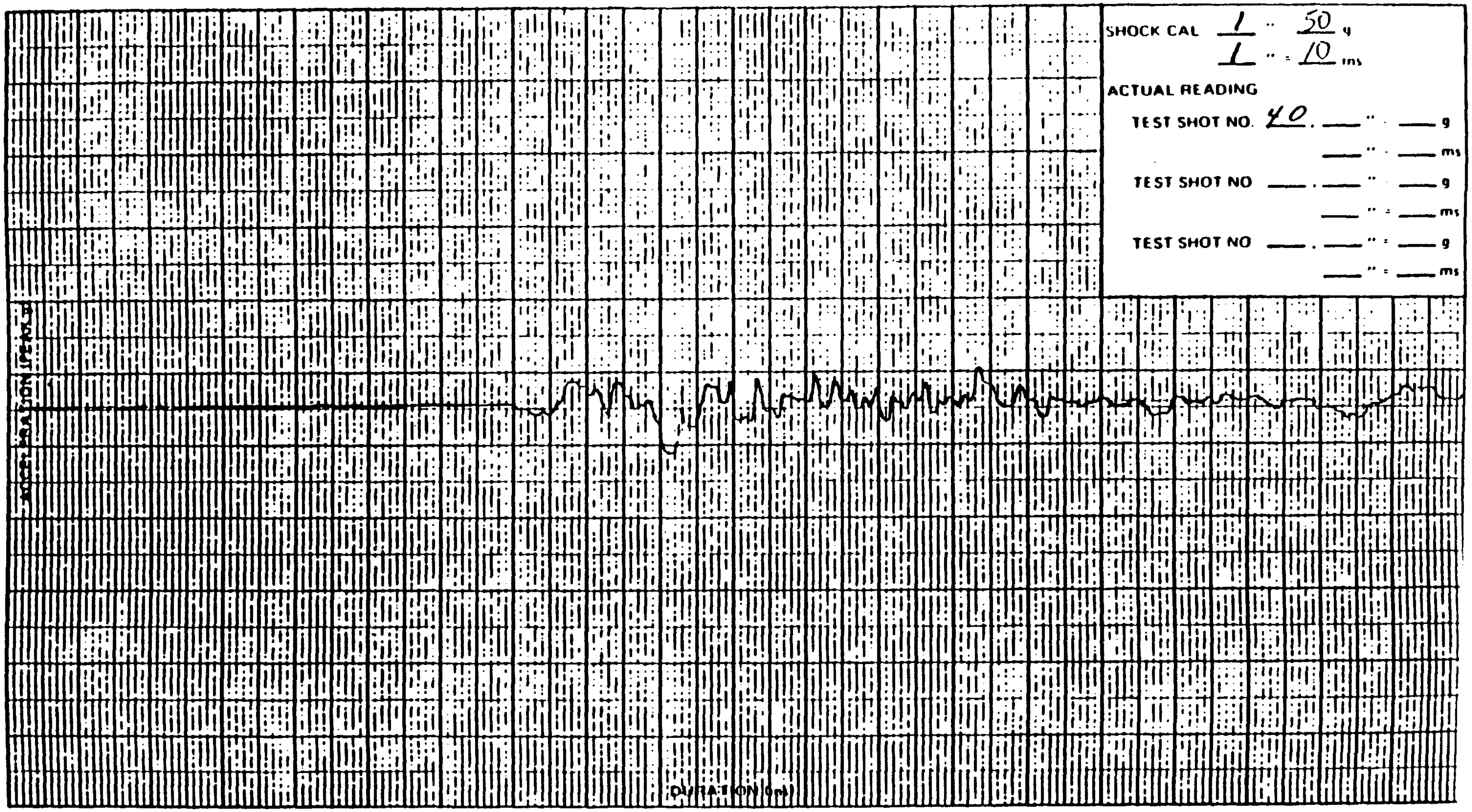
SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 40 ___" = ___ g
___" = ___ ms

TEST SHOT NO ___ ___" = ___ g
___" = ___ ms

TEST SHOT NO ___ ___" = ___ g
___" = ___ ms



Pickup Serial Number: 1121887

Pickup Location: TP#4

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: + Long

[ ] Live [✓] Tape

Job Number: 406744

Date: 17 April 89

Time: 1655

Lab Form D24 2

Plotted by: [illegible signature]

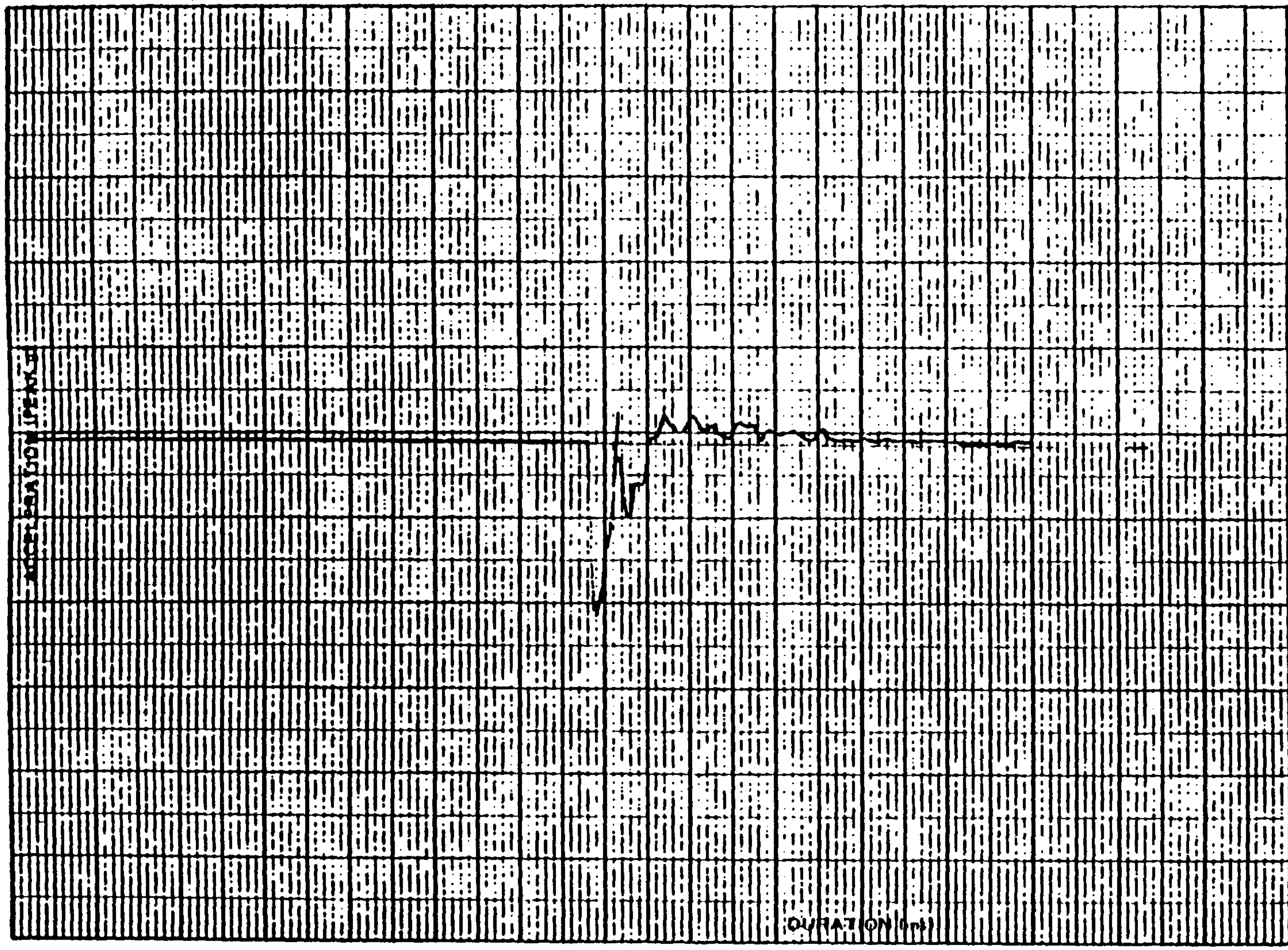
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit Operational [ ] Non operational M



SHOCK CAL 1" = 50 g

1" = 10 ms

ACTUAL READING

TEST SHOT NO. 41 1.01" = 50.5 g

0.18" = 1.8 ms

TEST SHOT NO. ___ . ___" = ___ g

___" = ___ ms

TEST SHOT NO. ___ . ___" = ___ g

___" = ___ ms

Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 16.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 19 April 89

Time: 1703

89-0595 Enc 1 Pg 75

Lab Form D24 2

Plotted by [signature]

Checked by G. Hyland

DAYTON T. BROWN

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [X]

SHOCK CAL 1 " : 50 g

1 " : 10 ms

ACTUAL READING

TEST SHOT NO. 42 1.15 " : 57.5 g

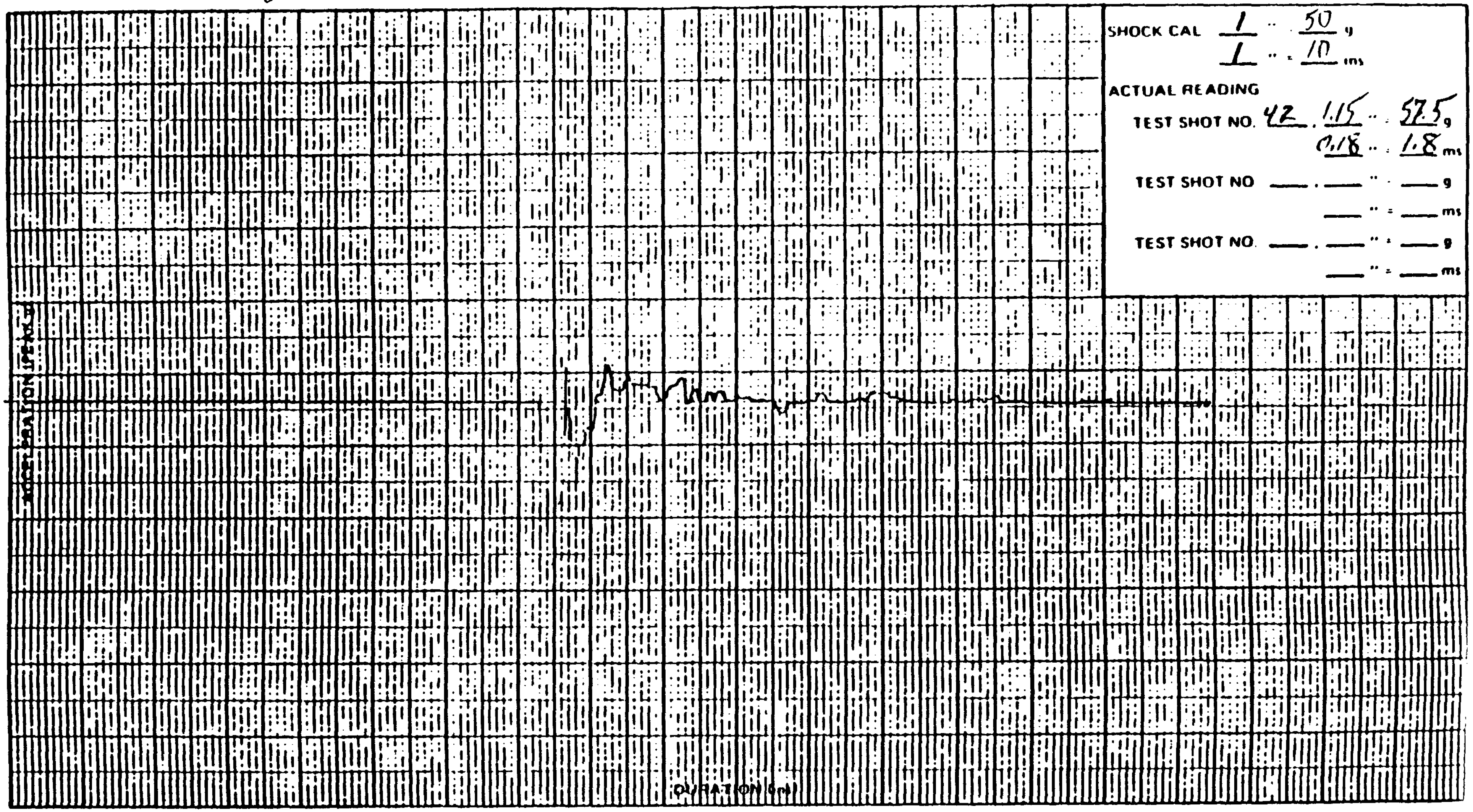
0.18 " : 1.8 ms

TEST SHOT NO. ____ ____ " : ____ g

____ " : ____ ms

TEST SHOT NO. ____ ____ " : ____ g

____ " : ____ ms



Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 17 April 89

Time: 1725

Lab Form D24 2

Plotted by: [illegible signature]

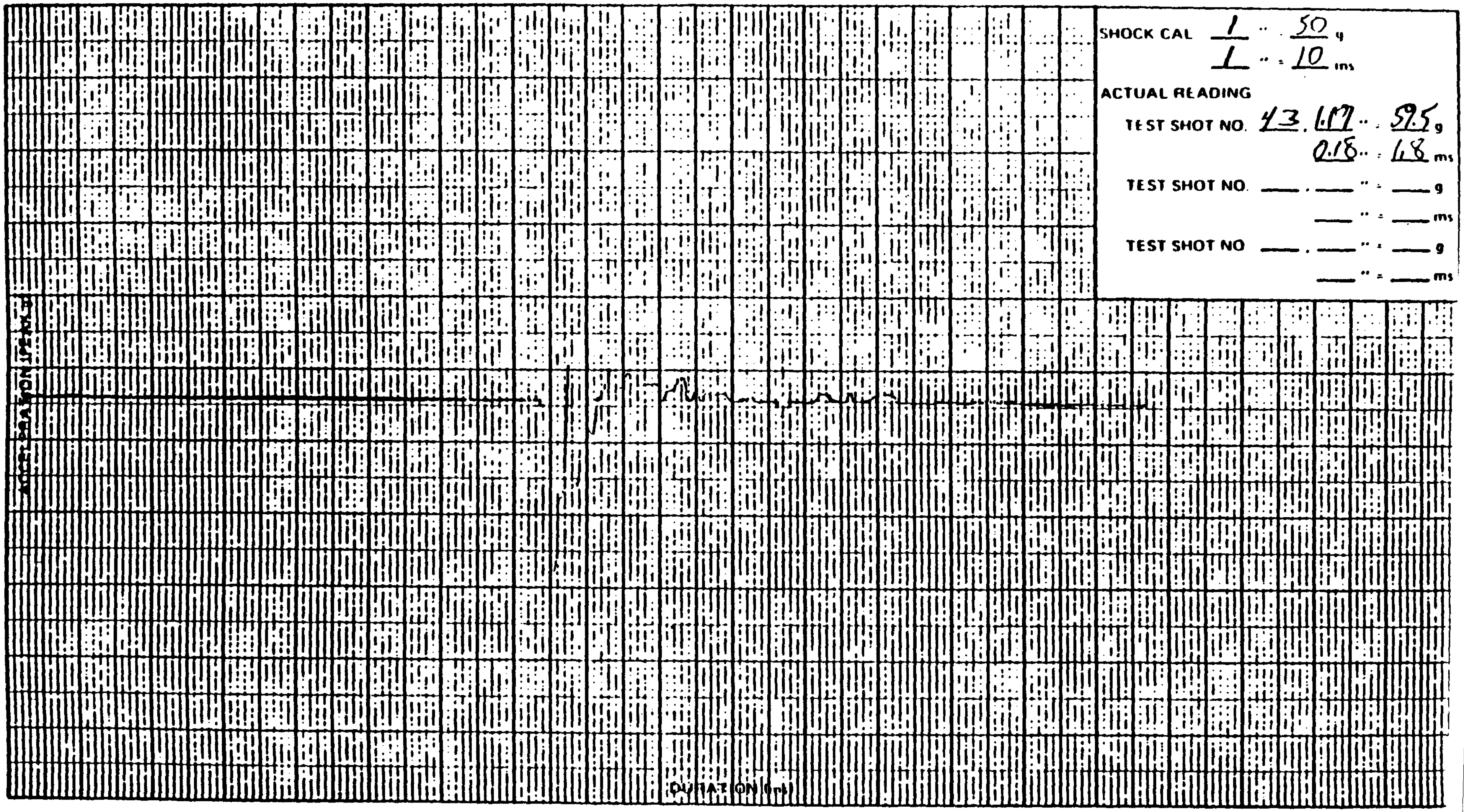
Checked by: G. Hyland

DAYTON T. BROWN.

Test Item: SCAF

Serial Number(s): 82E018

Unit: Operational [ ] Non operational [M]



SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 43 1.19 " = 59.5 g
0.18 " = 1.8 ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___ . ___ " = ___ g
___ " = ___ ms

Pickup Serial Number: 10.51682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 17 April 89

Time: 1730

Lab Form D24 2

Plotted by: G. [signature]
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAF
Serial Number(s): 82E018
Unit: Operational [ ] Non operational M

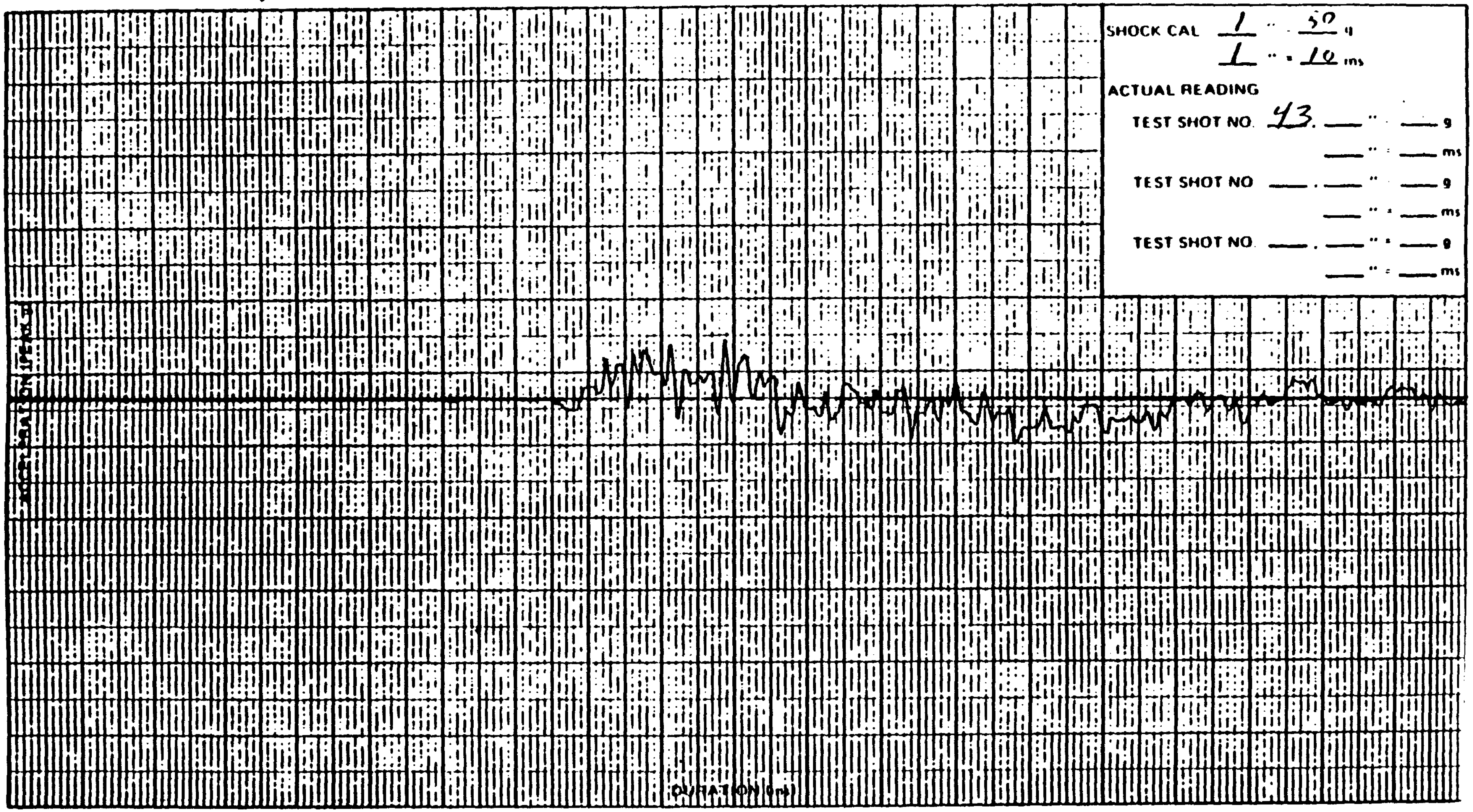
SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 43 ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___ ___ " = ___ g
___ " = ___ ms

TEST SHOT NO ___ ___ " = ___ g
___ " = ___ ms



Pickup Serial Number: 244
Pickup Location: TP#1
Pickup Sensing Axis: Long

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: + Long
[ ] Live [X] Tape

Job Number: 406744
Date: 17 April 89
Time: 1730

Lab Form D24 2

Plotted by [illegible signature]

Checked by G. Hyl[illegible]

DAYTON T. BROWN

Test Item: SCAF [illegible]

Serial Number(s): [illegible]

Unit Operational [ ] Non operational [/]

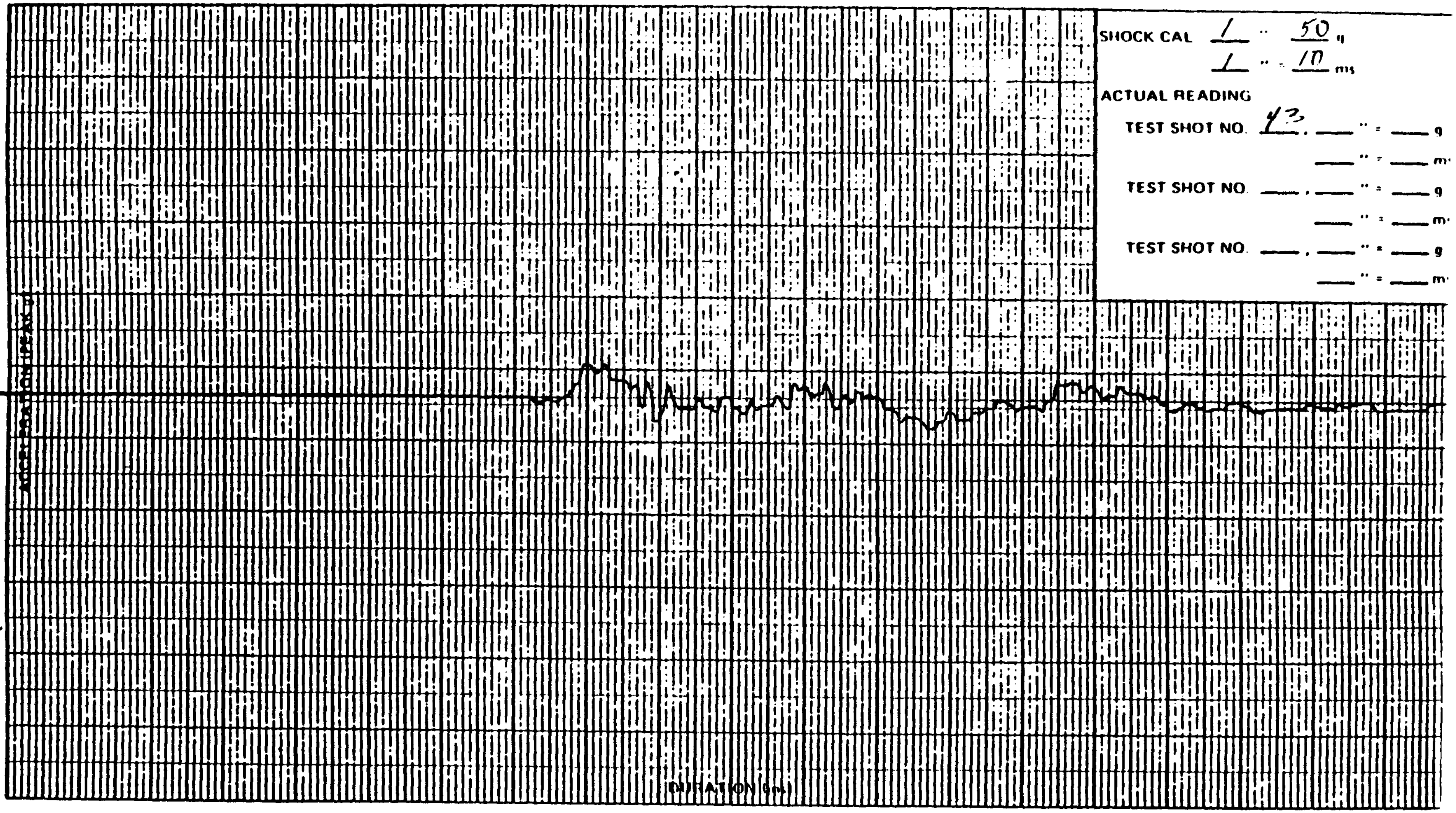
SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 43 , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms



Pickup Serial Number: 105168G

Pickup Location: TP#2

Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak

Direction: Long

[ ] Live [x] Tape

Job Number: 406744

Date: 17 Apr 87

Time: 1730

Lab Form D24-2

Plotted by: [illegible]

Checked by: G. Hyland

DAYTON BROWN

Test Item: [illegible]

Serial Number(s): [illegible]

Unit: Operational [ ] Non operational [/]

SHOCK CAL 1 " = 50 g

1 " = 10 ms

ACTUAL READING

TEST SHOT NO 43. ___ " = ___ g

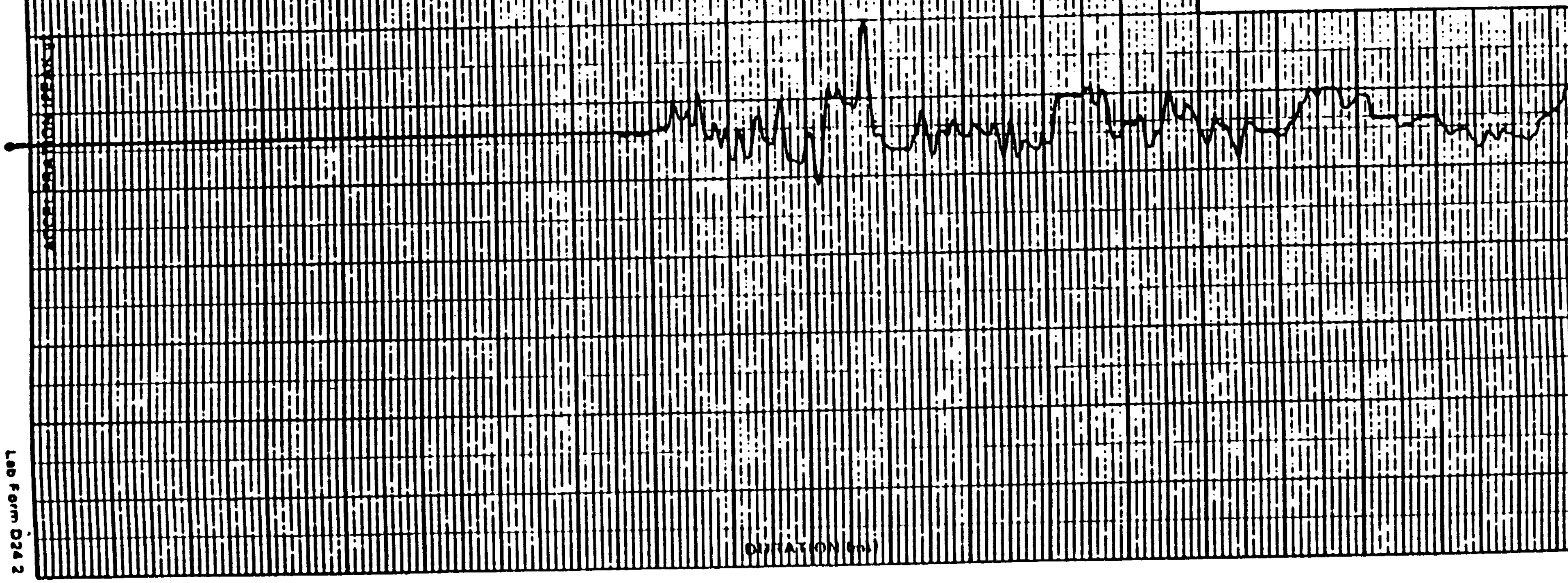
___ " = ___ ms

TEST SHOT NO ___. ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___. ___ " = ___ g

___ " = ___ ms



Lab Form D24 2

Pickup Serial Number: 1051685

Pickup Location: T.P.# 3

Pickup Sensing Axis: LAT

Pickup Sensitivity: 10.0 mv peak/g peak

Direction: +Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 19 April 9?

Time: 1730

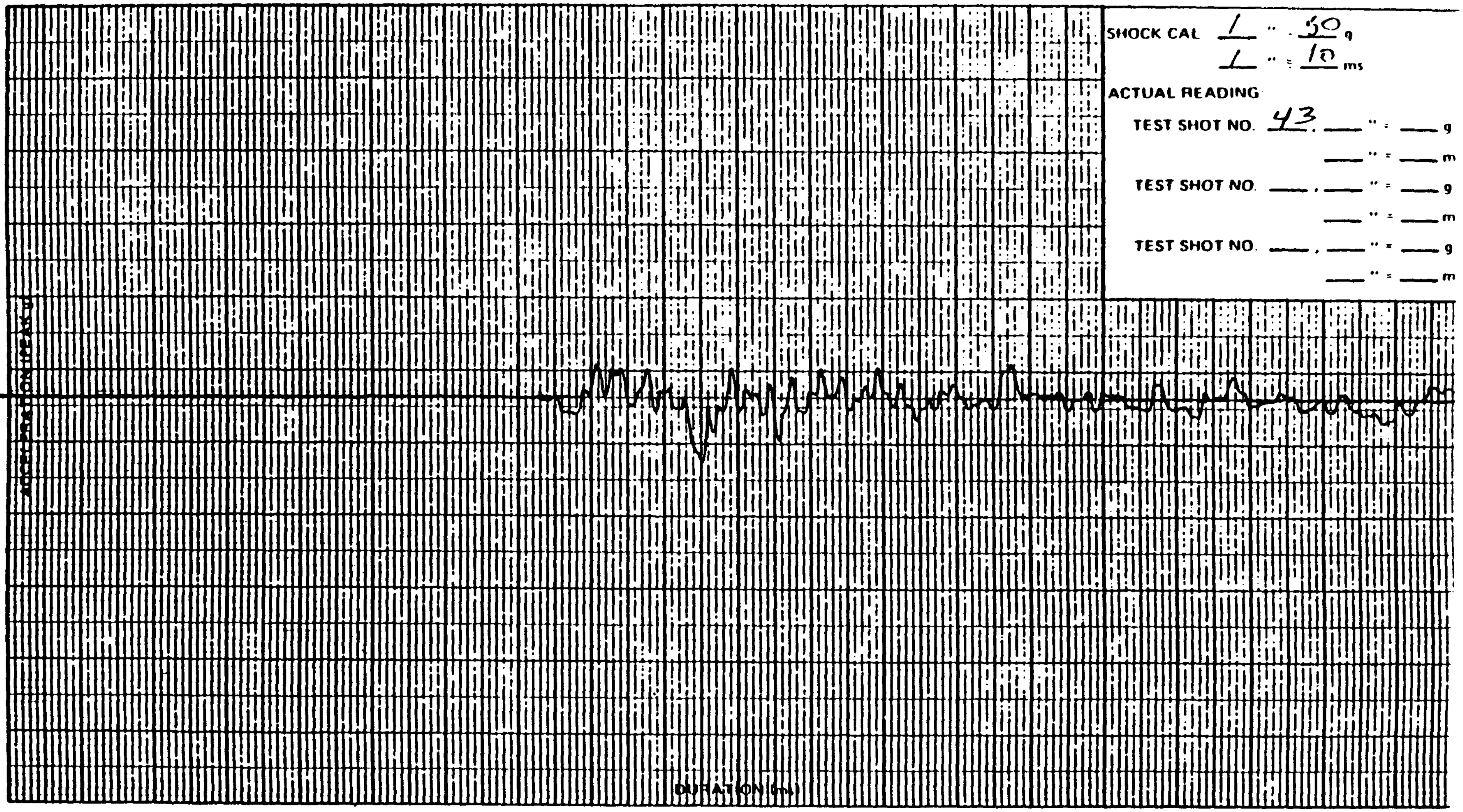
Plotted by: [illegible]
Checked by: G. Hyland

DAYTON T. BROWN

Test Item: SCAT
Serial Number(s): 31EO13
Unit Operational [ ] Non operational [/]

SHOCK CAL 1" = 50 g
1" = 10 ms

ACTUAL READING
TEST SHOT NO. 43 ____ " = ____ g
____ " = ____ m
TEST SHOT NO. ____ , ____ " = ____ g
____ " = ____ m
TEST SHOT NO. ____ , ____ " = ____ g
____ " = ____ m



Lab Form D24-2

Pickup Serial Number: 1121887
Pickup Location: TP#4
Pickup Sensing Axis: Lat

Pickup Sensitivity: 10.0 mv peak / g peak
Direction: Long
[ ] Live [ ] Tape

Job Number: 406744
Date: 19 April 87
Time: 1730

Plotted by [illegible signature]

Checked by G. Hylard

DAYTON T. BROWN

Test Item ..... SCAF

Serial Number(s) 82E018

Unit   Operational [ ]   Non operational [X]

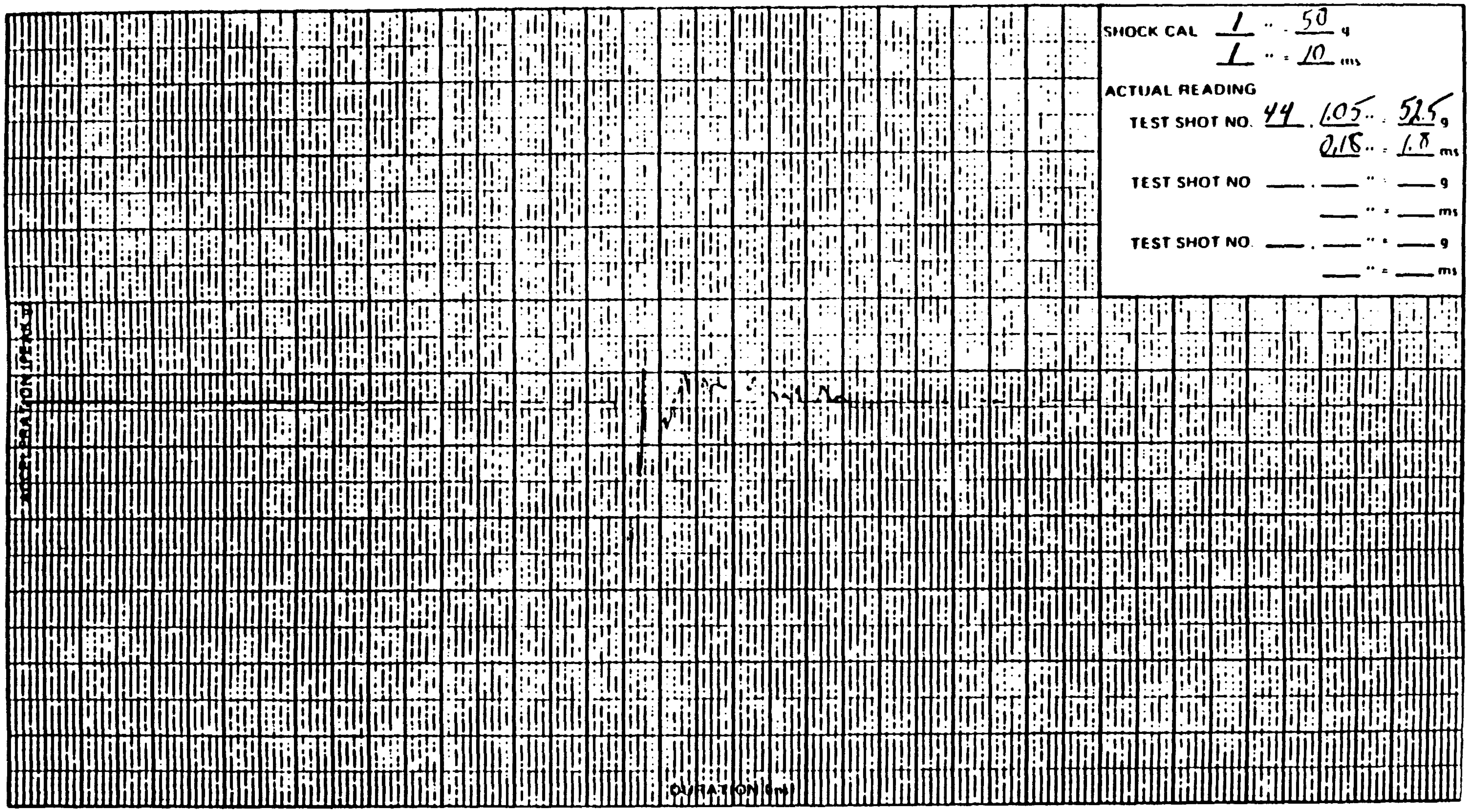
SHOCK CAL 1 " = 50 g
1 " = 10 ms

ACTUAL READING

TEST SHOT NO. 44 . 1.05 " = 52.5 g
0.18 " = 1.8 ms

TEST SHOT NO ___ . ___ " = ___ g
___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms



Pickup Serial Number: 1051GR2

Pickup Location: ..... Control

Pickup Sensing Axis: ..... Long

Pickup Sensitivity ..... 10.0 mv peak / g peak

Direction ..... + Long

[X] Live   [ ] Tape

Job Number: 406744

Date: ..... 19 April 89

Time 1735

89-0595 Enc 1 Pg 82

Lab Form D24 2

Plotted by: [illegible signature]

Checked by: G. Hyland

DAYTON BROWN

Test Item: ....

Serial Number(s) ....

Unit: Operational [ ] Non operational [✓]

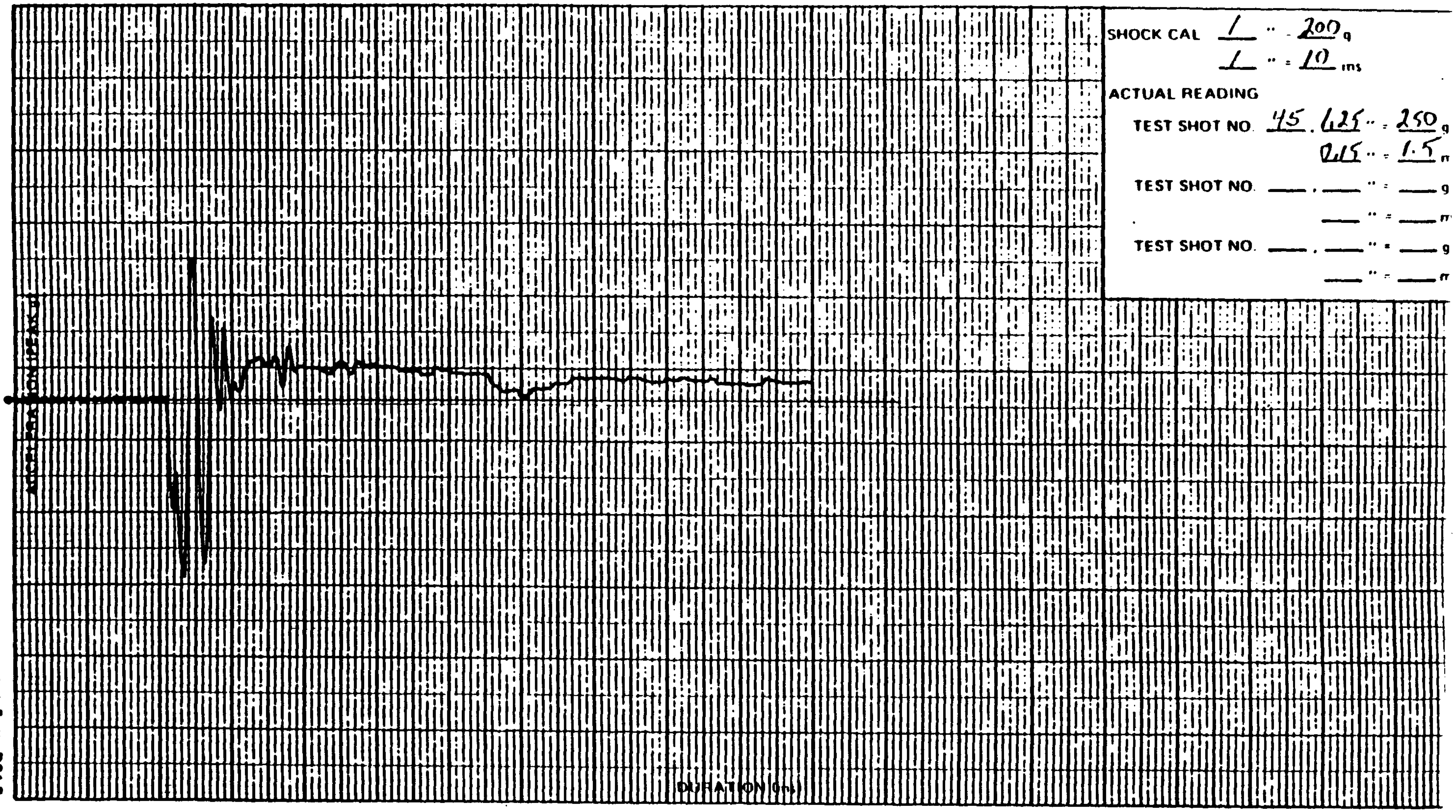
SHOCK CAL 1" = 200 g
1" = 10 ms

ACTUAL READING

TEST SHOT NO. 45 1.25" = 250 g
0.15" = 1.5 ms

TEST SHOT NO. ___ , ___" = ___ g
___" = ___ ms

TEST SHOT NO. ___ , ___" = ___ g
___" = ___ ms



Lab Form D24-2

89-0595 Enc 1 Pg 83

Pickup Serial Number: 1051G82

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity 1.0 mv peak / g peak

Direction: + Long

[✓] Live [ ] Tape

Job Number: 406744

Date: 17 April 87

Time: 1825

Plotted by: [illegible signature]

Checked by: G. Hyland

DAYTON BROWN

Test Item: [illegible]

Serial Number(s): [illegible]

Unit: Operational [ ] Non operational [✓]

SHOCK CAL 1 = 200 g

1 = 10 ms

ACTUAL READING

TEST SHOT NO. 46 1.65 = 330 g

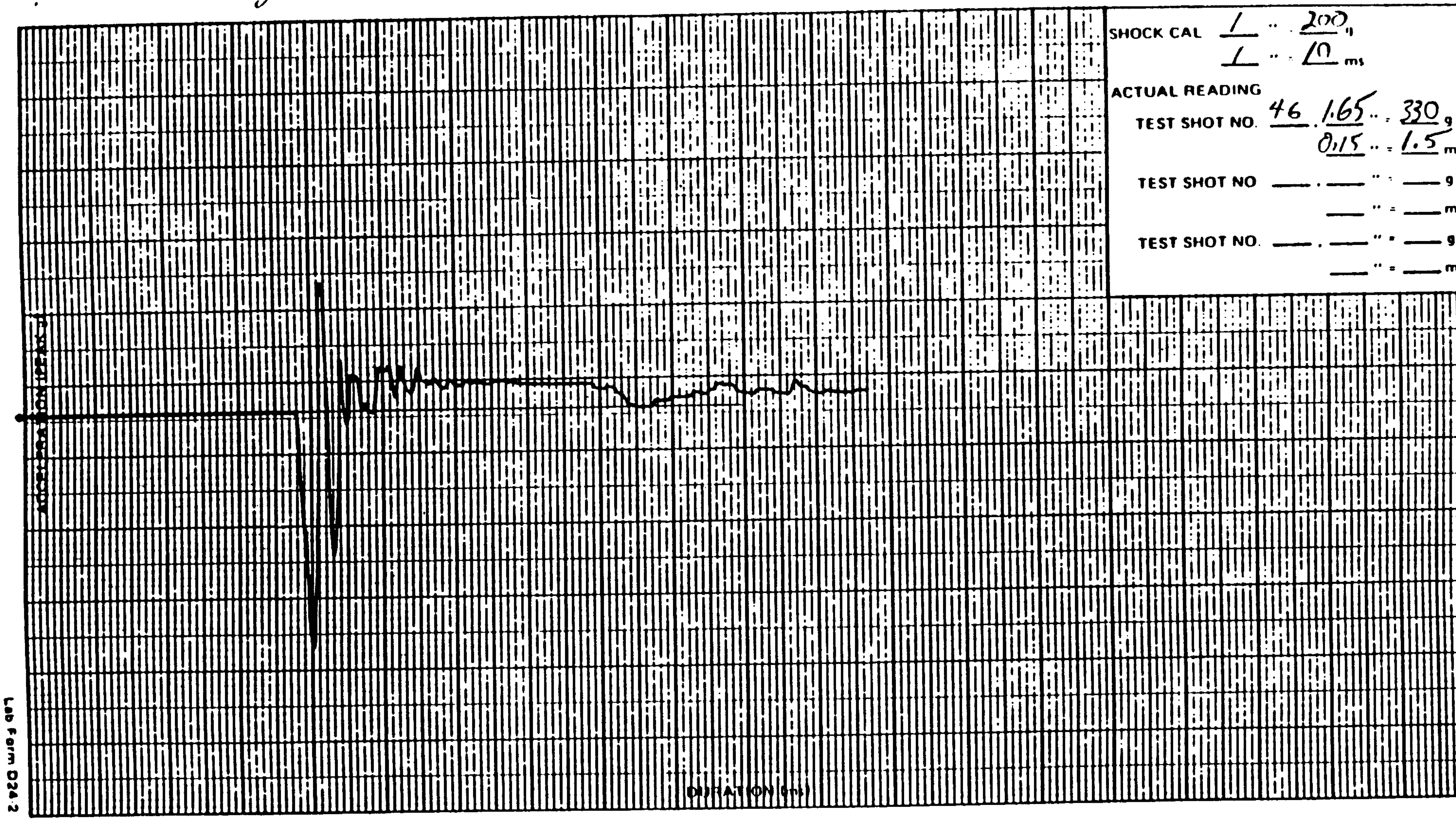
0.15 = 1.5 ms

TEST SHOT NO. ___ . ___ = ___ g

___ = ___ ms

TEST SHOT NO. ___ . ___ = ___ g

___ = ___ ms



Lab Form D24-2

Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity: 1.0 mv peak / g peak

Direction: + Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 17 April 87

Time: 1835

Plotted by ...

Checked by G. Hyland

DAYTON T. BROWN

Test Item ...

Serial Number(s) ...

Unit Operational [ ] Non operational [/]

SHOCK CAL 1 " 200 g

1 " 10 ms

ACTUAL READING

TEST SHOT NO 42 2.10 " 420 g

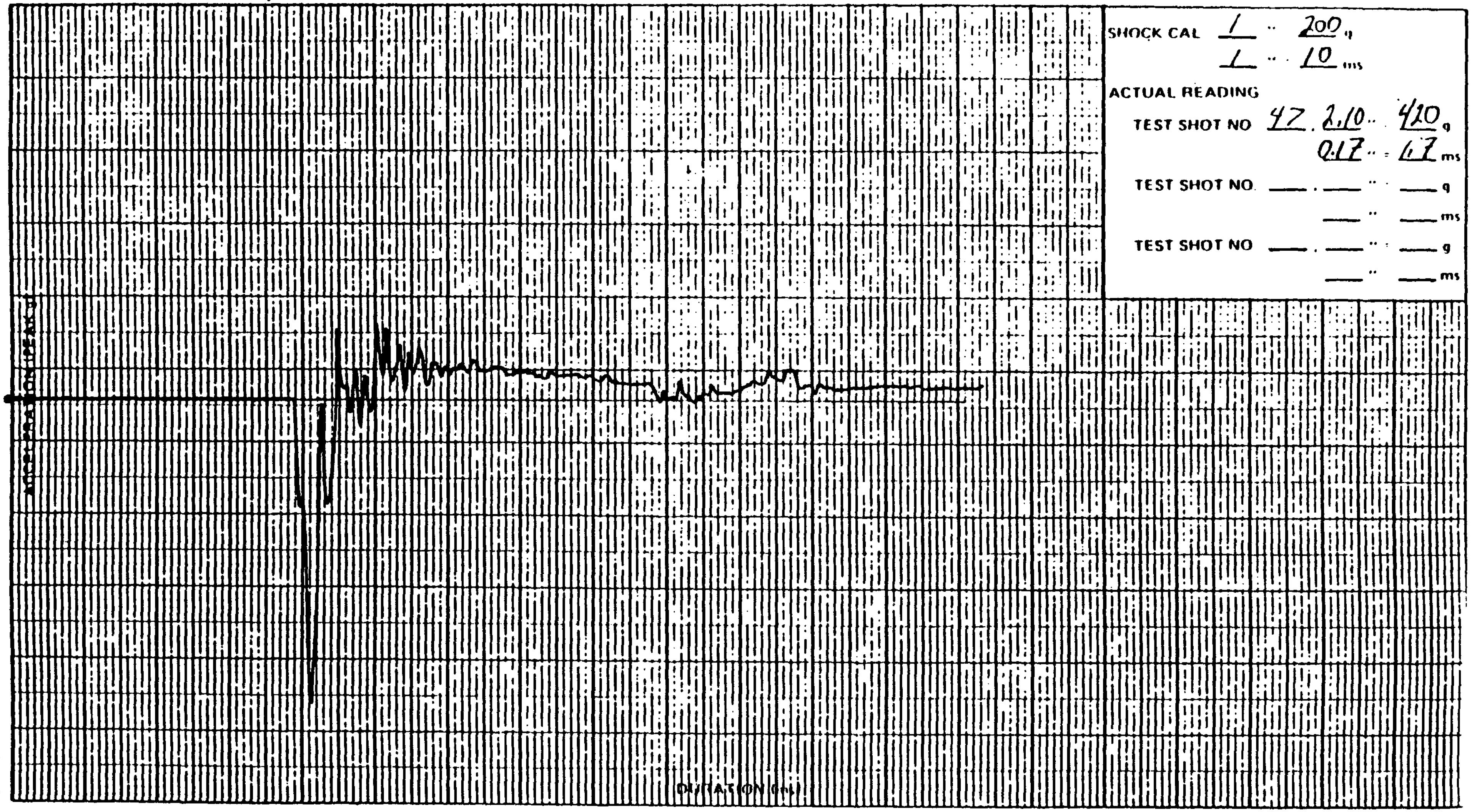
0.17 " 1.7 ms

TEST SHOT NO ___ ___ " ___ g

___ " ___ ms

TEST SHOT NO ___ ___ " ___ g

___ " ___ ms



Lab Form D24 2

Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity 1.0 mv peak / g peak

Direction + Long

[ ] Live [ ] Tape

Job Number: 406744

Date 19 April 87

Time 1850

DAYTON BROWN

Plotted by ......

Checked by G Hyland ......

Test Item ......

Serial Number(s) ......

Unit Operational [ ] Non operational [/]

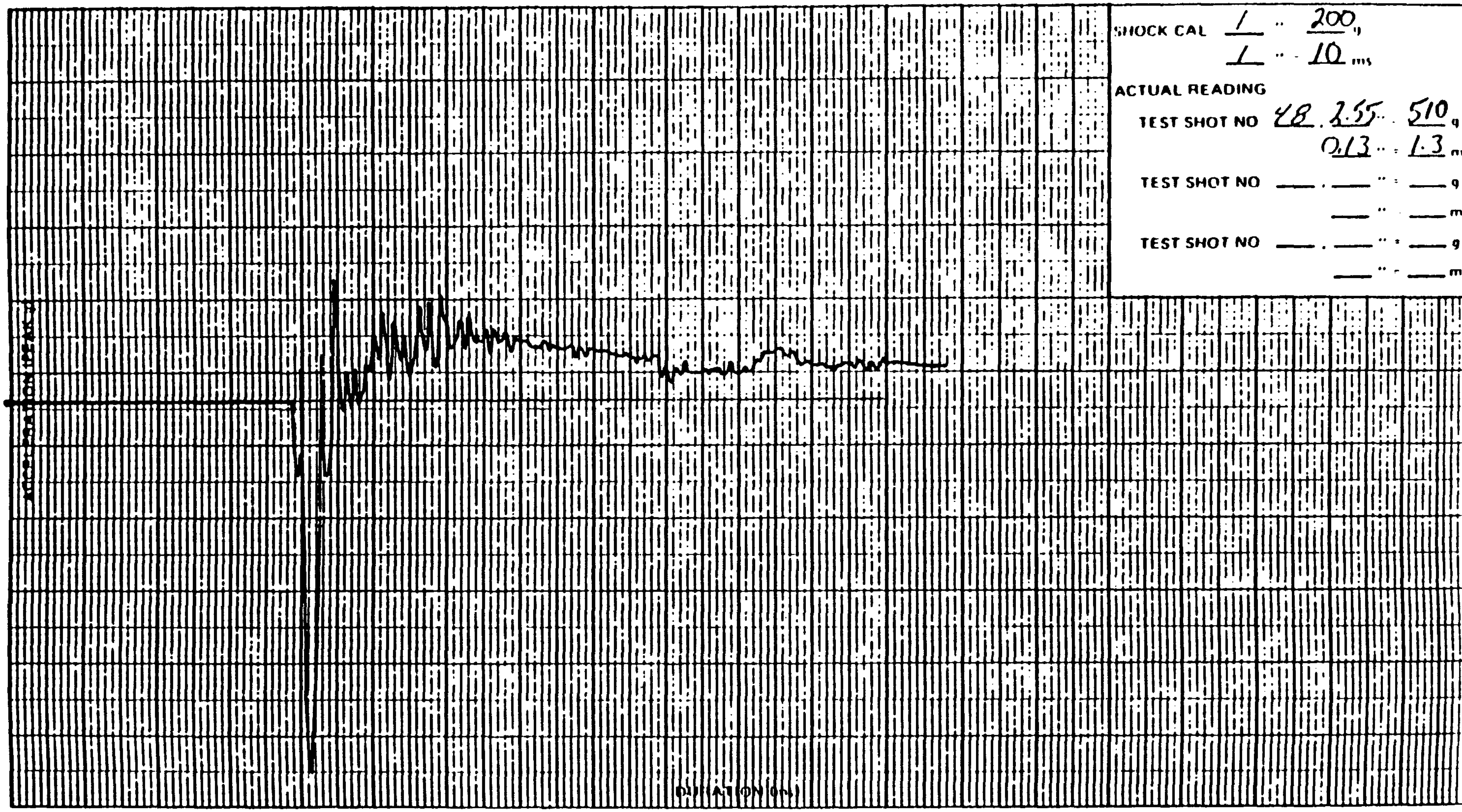
SHOCK CAL 1 " 200 g
1 " 10 ms

ACTUAL READING

TEST SHOT NO 48 . 255 " 510 g
0.13 " 1.3 ms

TEST SHOT NO ___ . ___ " ___ g
___ " ___ ms

TEST SHOT NO ___ . ___ " ___ g
___ " ___ ms



Lab Form D24-2

Pickup Serial Number: 1051682

Pickup Location: Control

Pickup Sensing Axis: Long

Pickup Sensitivity 1.0 mv peak / g peak

Direction + Long

[/] Live [ ] Tape

Job Number 406744

Date 17 April 87

Time 2210

Plotted by: [illegible signature]

Checked by: G. Hylard

DAYTON T. BROWN

Test Item: [illegible]

Serial Number(s): [illegible]

Unit Operational [ ] Non operational [/]

SHOCK CAL. 1 " = 200 g

1 " = 10 ms

ACTUAL READING:

TEST SHOT NO. 48 . ___ " = ___ g

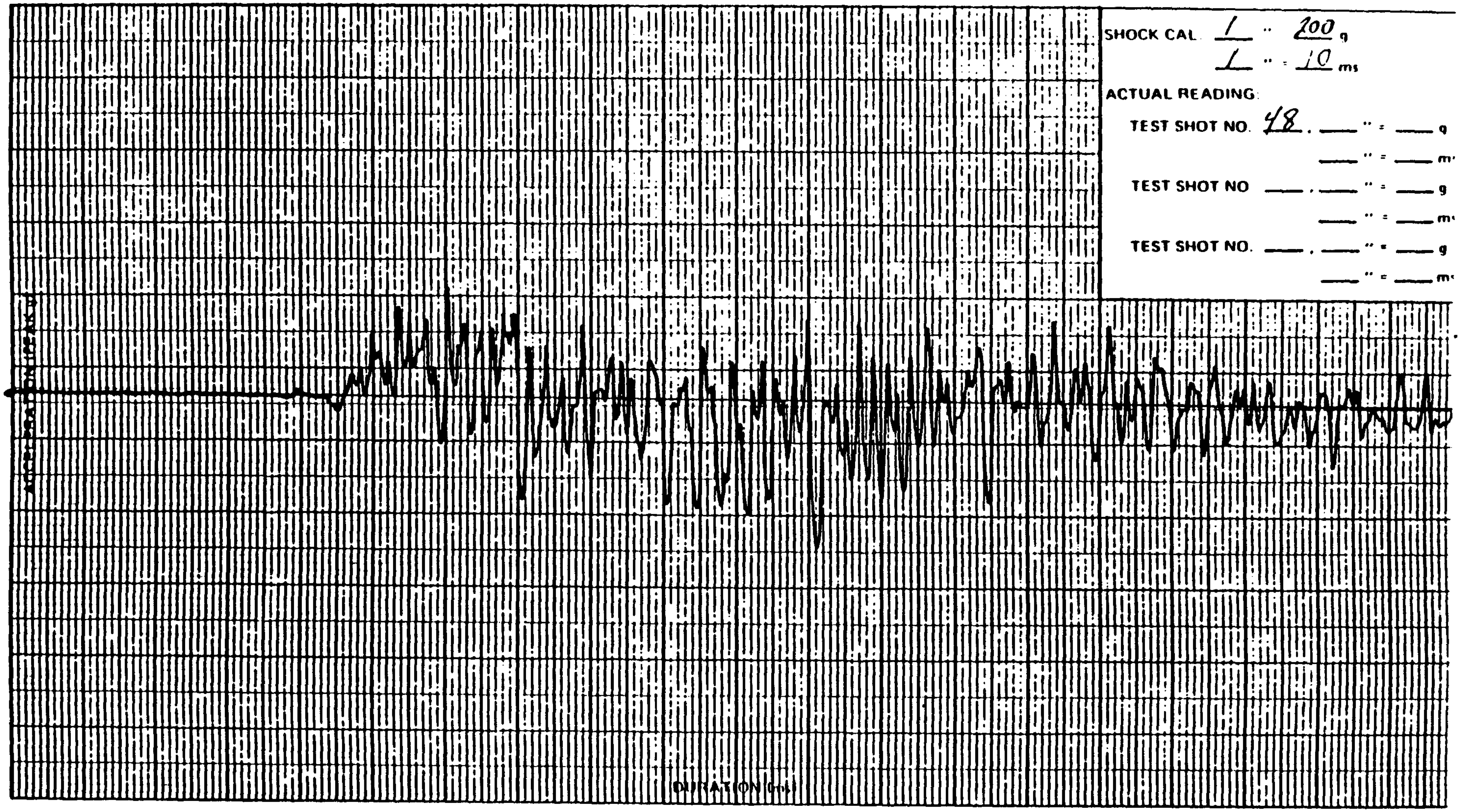
___ " = ___ ms

TEST SHOT NO ___ . ___ " = ___ g

___ " = ___ ms

TEST SHOT NO. ___ . ___ " = ___ g

___ " = ___ ms



Pickup Serial Number: 244

Pickup Location: TP#1

Pickup Sensing Axis: Long

Pickup Sensitivity: 1.0 mv peak / g peak

Direction: +Long

[ ] Live [ ] Tape

Job Number: 406744

Date: 19 April 87

Time: 2210

Lab Form D24-2

Plotted by: [illegible signature]

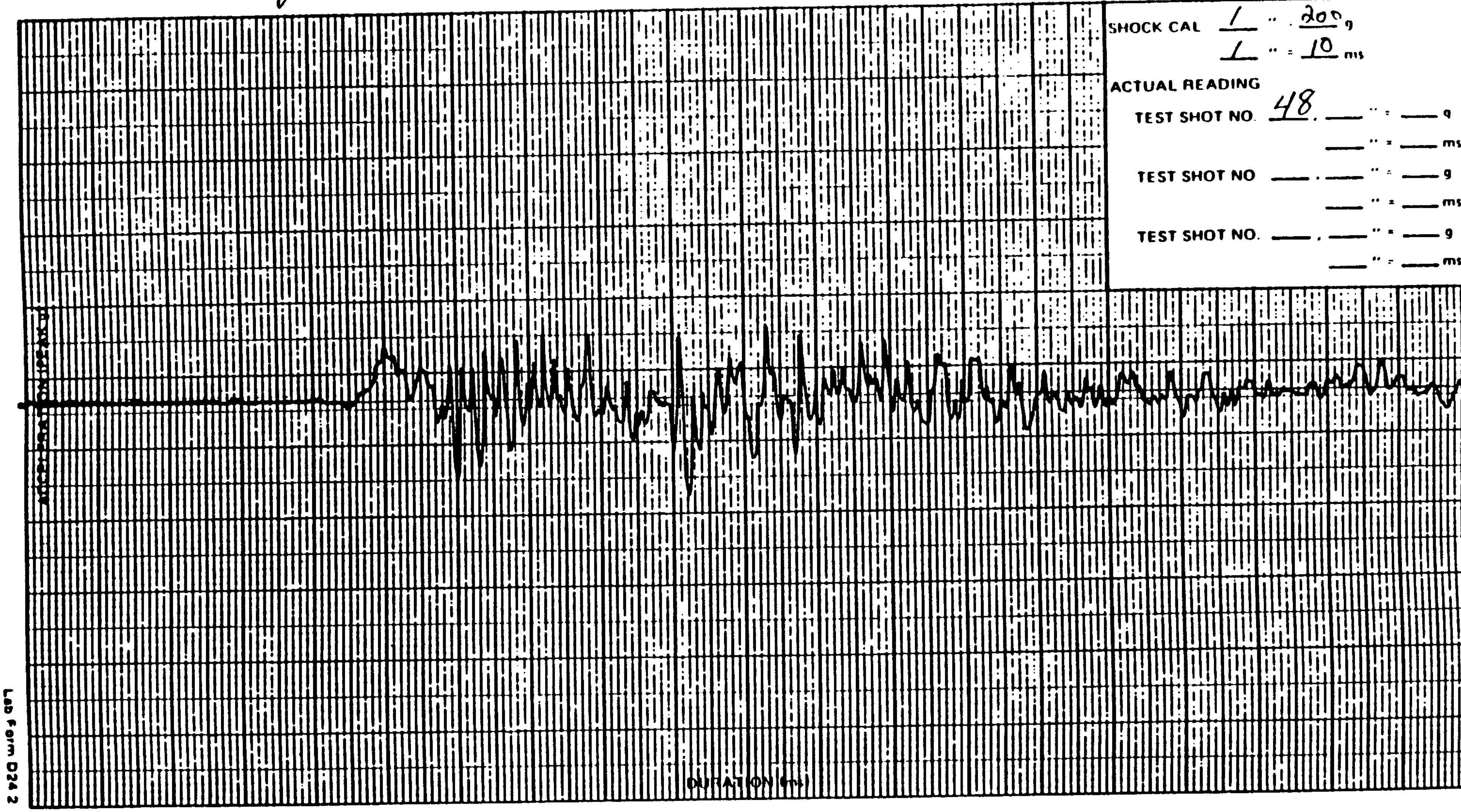
Checked by: G Hyland

Test Item: [illegible]

Serial Number(s): [illegible]

Unit: Operational [ ] Non-operational [/]

SHOCK CAL	1 " = 200 g
	1 " = 10 ms
ACTUAL READING	
TEST SHOT NO. 48	___ " = ___ g
	___ " = ___ ms
TEST SHOT NO ___	___ " = ___ g
	___ " = ___ ms
TEST SHOT NO. ___	___ " = ___ g
	___ " = ___ ms



Lab Form D24 2

Pickup Serial Number: 1051686

Pickup Location: TP#2

Pickup Sensing Axis: LAT

Pickup Sensitivity: 1.0 mv peak / g peak

Direction: + LONG

[ ] Live [ ] Tape

Job Number: 406744

Date: 17 April 87

Time: 2210

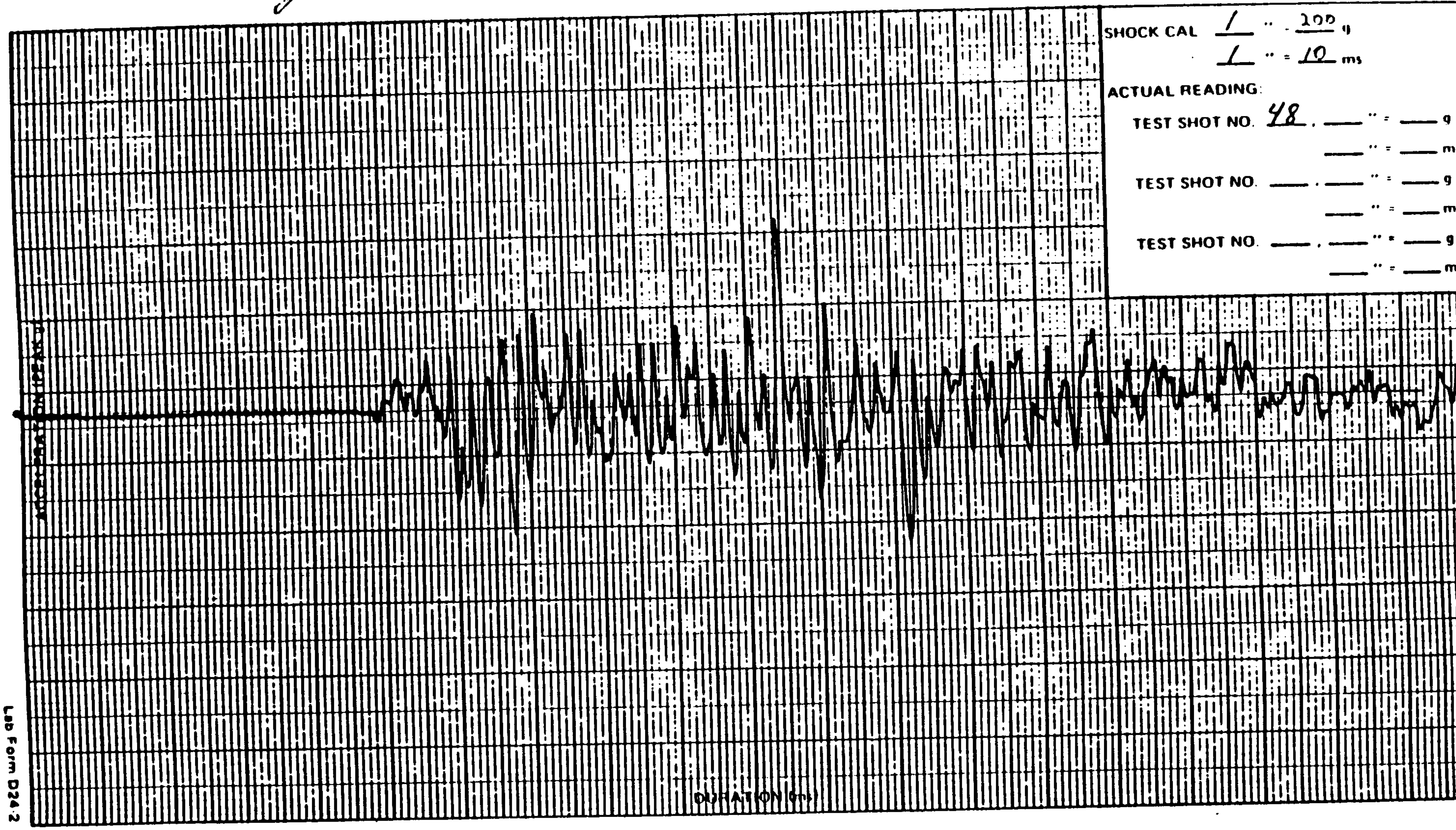
Plotted by: [signature]
Checked by: [signature]

DAYTON BROWN

Test Item: SCAF
Serial Number(s): 321015
Unit Operational [ ] Non operational [✓]

SHOCK CAL 1 " = 200 g
1 " = 10 ms

ACTUAL READING:
TEST SHOT NO. 48 , ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ , ___ " = ___ g
___ " = ___ ms



Lab Form D24-2

Pickup Serial Number: 1051685
Pickup Location: TP#3
Pickup Sensing Axis: LAT

Pickup Sensitivity: 1.0 mv peak / g peak
Direction: + LONG
☐ Live ☑ Tape

Job Number: 406744
Date: 19 April 87
Time: 2210

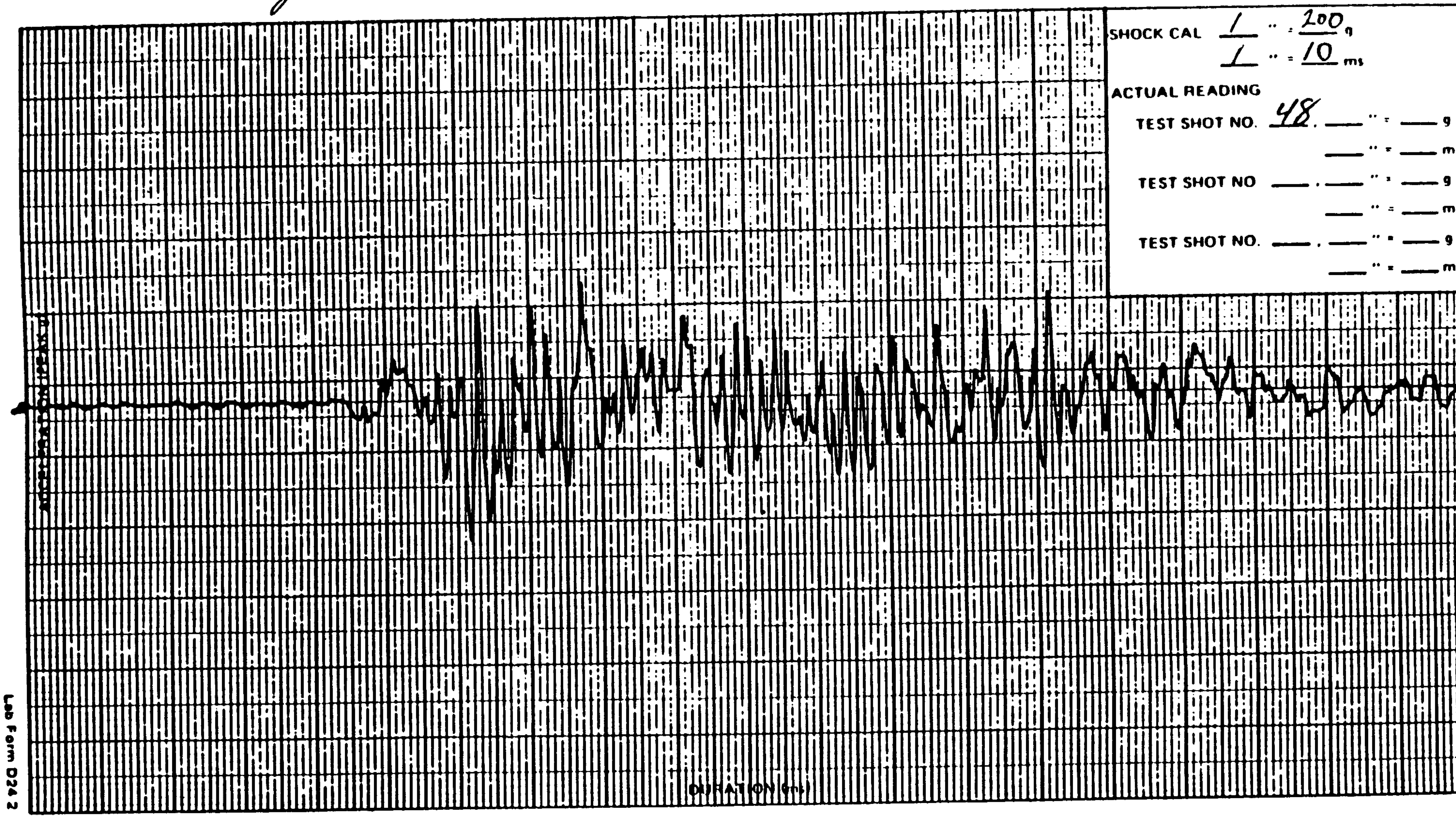
Plotted by: [illegible]
Checked by: G Hyland

DAYTON BROWN

Test Item: [illegible]
Serial Number(s): [illegible]
Unit Operational [ ] Non operational [✓]

SHOCK CAL 1 " = 200 g
1 " = 10 ms

ACTUAL READING
TEST SHOT NO. 48 ___ " = ___ g
___ " = ___ ms
TEST SHOT NO ___ . ___ " = ___ g
___ " = ___ ms
TEST SHOT NO. ___ . ___ " = ___ g
___ " = ___ ms

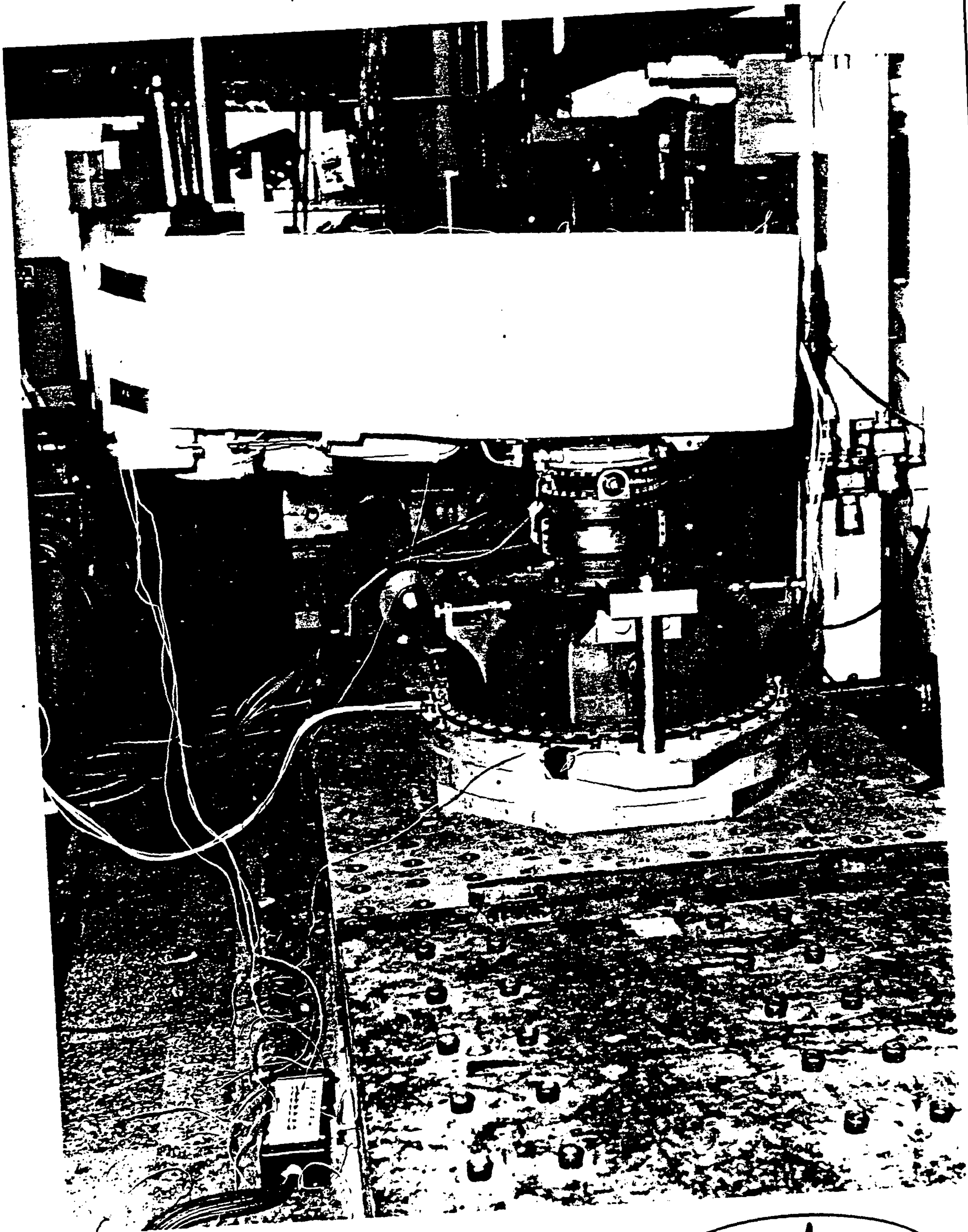


Lab Form D24 2

Pickup Serial Number: 1121887
Pickup Location: TP#4
Pickup Sensing Axis: Lat

Pickup Sensitivity: 1.0 mv peak / g peak
Direction: + long
[ ] Live [✓] Tape

Job Number: 406744
Date: 19 April 87
Time: 2210



TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.
ITEM: SCAF

P/N: 119385
S/N: 82E018

SHOCK, VERTICAL AXIS

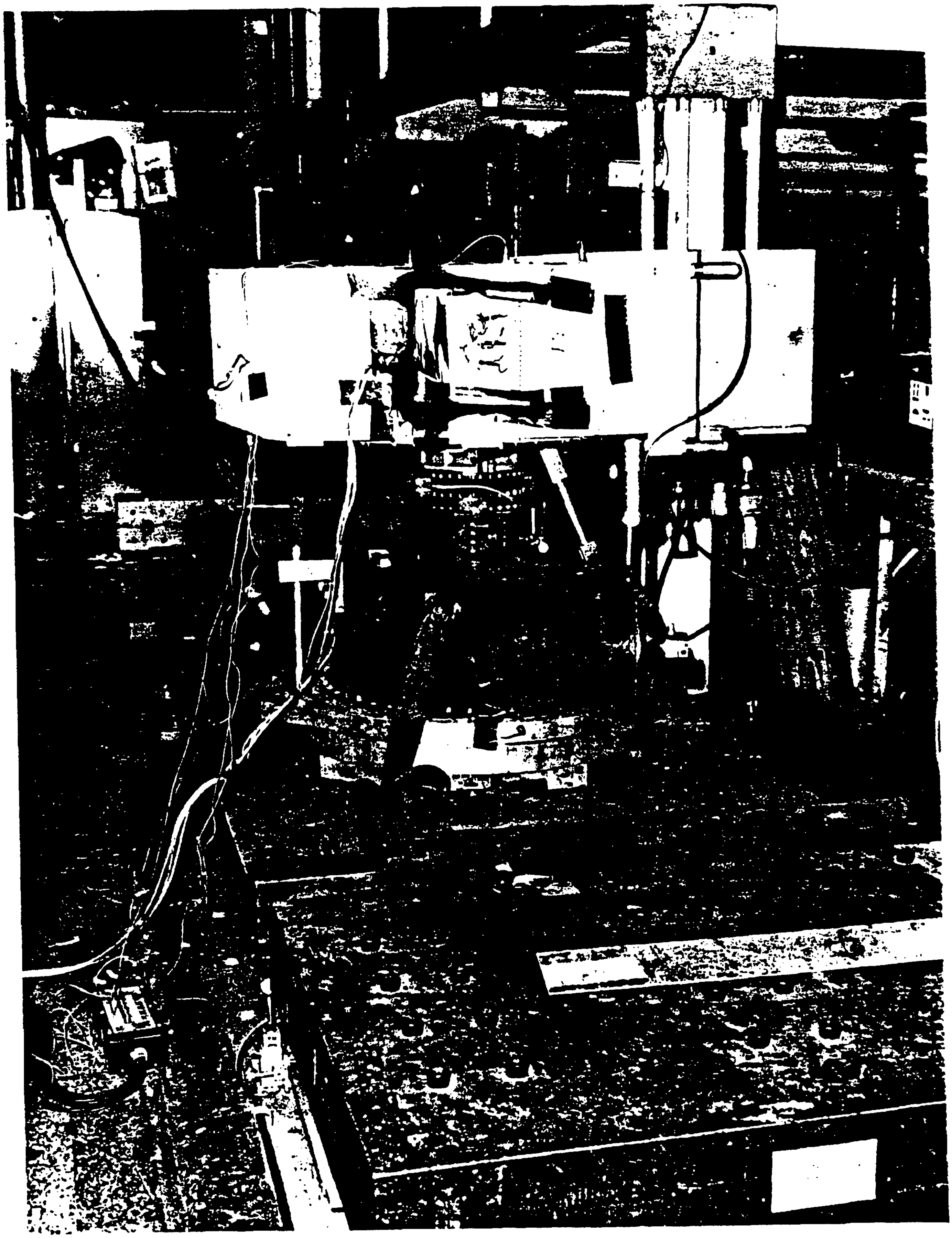
JOB NO: 406744-00-000
DTB04R89-0595

FILE NO: 89-0786
ENCLOSURE: 2

DATE: 18 APRIL 1989
PHOTO: 1

DAYTON T. BROWN INC.

Founded 1950



TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.   P/N: 119385
ITEM: SCAF   S/N: 82E018

SHOCK, LONGITUDINAL AXIS

JOB NO: 406744-00-000   FILE NO: 89-0798   DATE: 19 APRIL 1989
DTB04R89-0595   ENCLOSURE: 2   PHOTO: 2

DAYTON T. BROWN

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TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC. P/N: 119385
ITEM: SCAF S/N: 82E018

CRACKED FLANGE ON TURBINE

JOB NO: 406744-00-000 FILE NO: 89-0801 DATE: 20 APRIL 1989
DTB04R89-0595 ENCLOSURE: 2 PHOTO: 3

DAYTON T. BROWN INC.

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TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.
ITEM: SCAF

P/N: 119385
S/N: 82E018

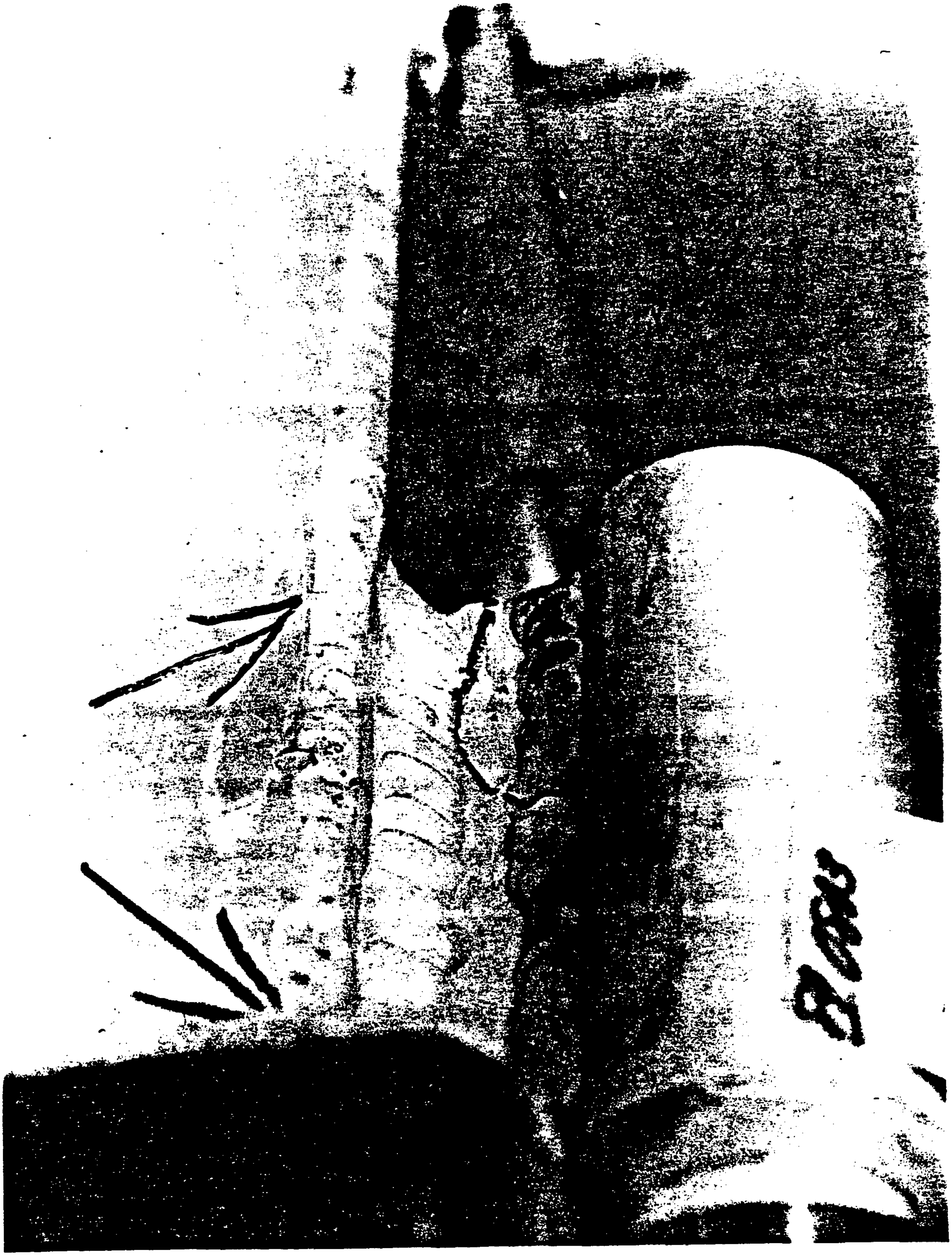
CRACK ON SCAF

JOB NO: 406744-00-000
DTB04R89-0595

FILE NO: 89-0802
ENCLOSURE: 2

DATE: 20 APRIL 1989
PHOTO: 4

DAYTON T. BROWN INC.
©
Founded 1950



TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.
ITEM: SCAF

CRACK ON SCAF

JOB NO: 406744-00-000
DTB04R89-0595

FILE NO: 89-0803
ENCLOSURE: 2

P/N: 119385
S/N: 82E018

DATE: 20 APRIL 1989
PHOTO: 5

DAYTON T. BROWN INC.

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TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.
ITEM: SCAF

P/N: 119385
S/N: 82E018

CRACK ON SCAF

JOB NO: 406744-00-000
DTB04R89-0595

FILE NO: 89-0804
ENCLOSURE: 2

DATE: 20 APRIL 1989
PHOTO: 6

DAYTON T. BROWN INC. ®

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TESTED FOR & MFR'D. BY: DONALDSON COMPANY, INC.
ITEM: SCAF

P/N: 119385
S/N: 82E018

JOB NO: 406744-00-000
DTB04R89-0595

FILE NO: 89-0805
ENCLOSURE: 2

DATE: 20 APRIL 1989
PHOTO: 7

DAYTON T. BROWN INC.

Founded 1950

Appendix C

Comparison Data for M1A1 SCAF, RESCAF, and Conventional 2 Stage Air Cleaner

1.0 Life Characteristics Comparisons

The data in this appendix is provided so that a comparison of dust life characteristics can be made between the conventional 2 stage air cleaner and the RESCAF, and the M1A1 SCAF system. The data provided is basic data from which the user can construct his own curves. The data provided is listed below.

1.1 Vehicle Installation Pressure Loss Data

This set of curves gives the conventional 2 stage air cleaner and early phase II and phase III SCAF system data. The SCAF systems tested at Yuma Proving Ground in 1988-1989 were phase IV systems which had pressure loss characteristics 2"-4" lower than the phase III systems at 10,000 cfm due to elimination of head exchangers and enlarged filter element outlet areas. This data is with clean filters.

1.2 M1A1 SCAF Performance Curves

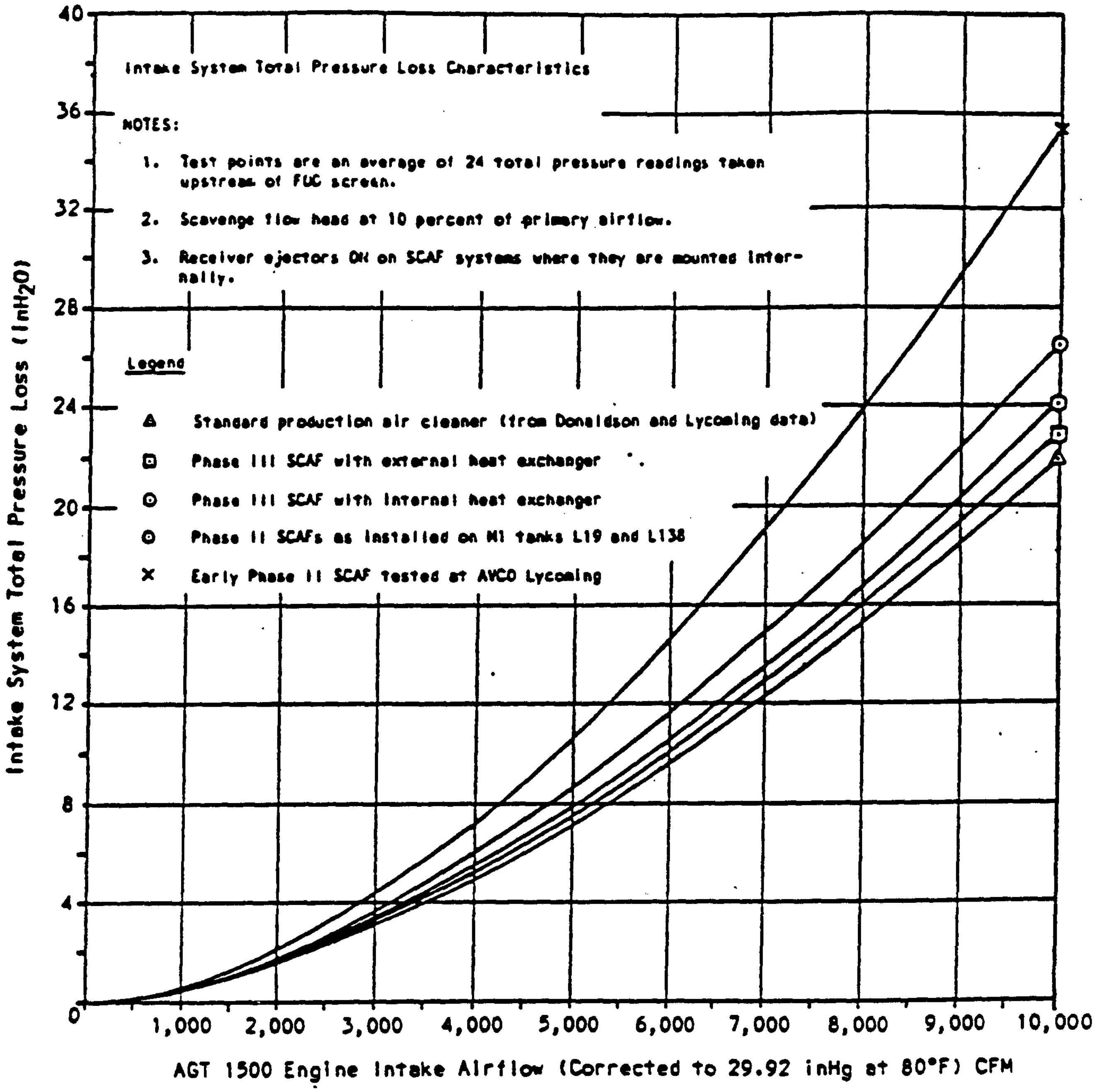
This data shows the life characteristics of the SCAF systems as they were fielded at Yuma after corrections were made to eliminate the cause of engine failures. This data shows dust loading rates.

1.3 Conventional 2 Stage Life Characteristics

This data shows the life characteristics of the conventional system currently installed on the M1A1 SCAF.

1.4 Comparison of SCAF and the Conventional Air Cleaner at Yuma Proving Ground.

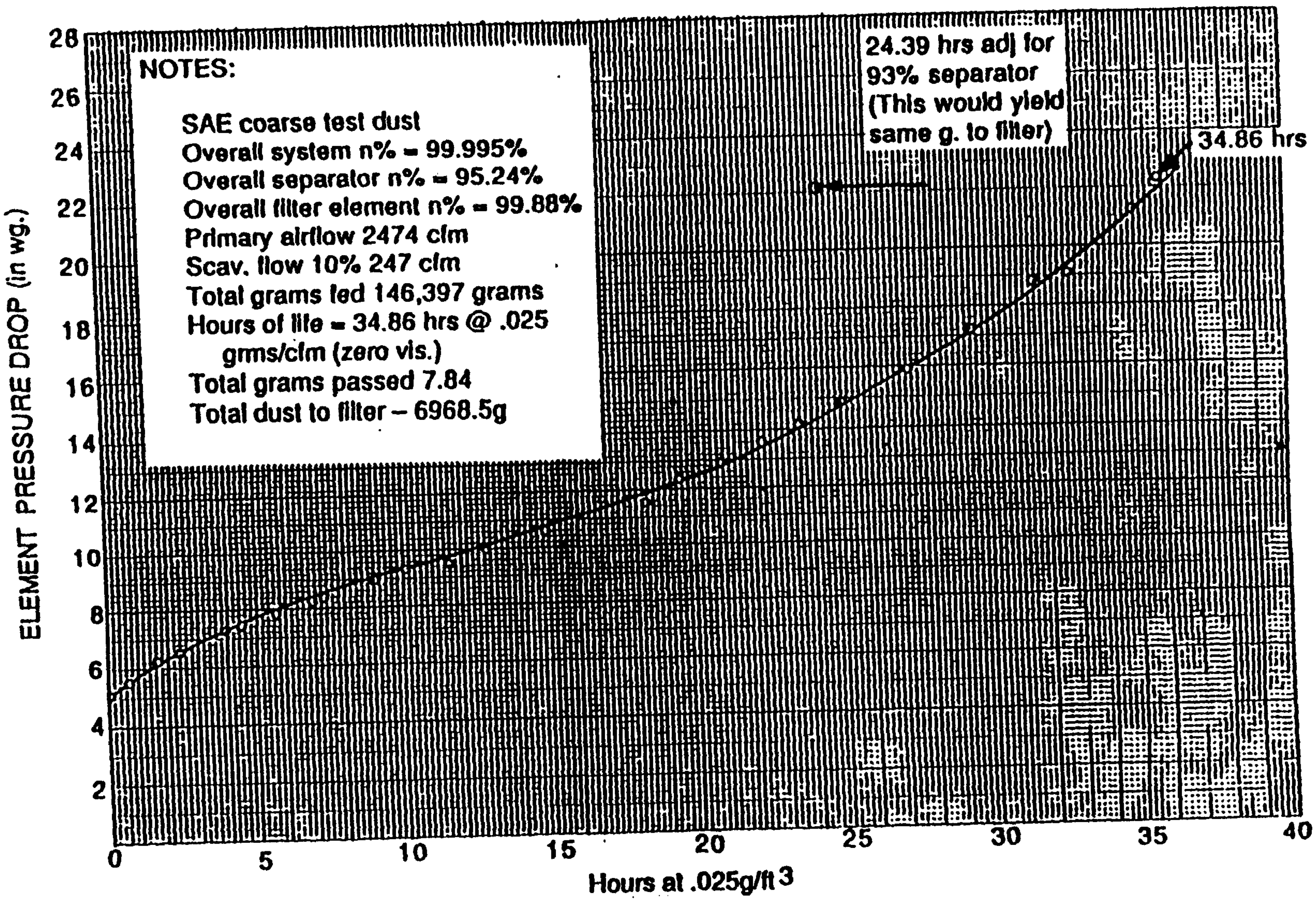
This data shows a comparison based on recent field experience at Yuma Proving Ground. It includes two tables with comparative data.


Intake System Total Pressure Loss Characteristics
NOTES:
1. Test points are an average of 24 total pressure readings taken upstream of FUC screen.
2. Scavenge flow head at 10 percent of primary airflow.
3. Receiver ejectors ON on SCAF systems where they are mounted internally.
Legend
Standard production air cleaner (from Donaldson and Lycoming data)
Phase III SCAF with external heat exchanger
Phase III SCAF with internal heat exchanger
Phase II SCAFs as installed on M1 tanks L19 and L138
Early Phase II SCAF tested at AVCO Lycoming
Intake System Total Pressure Loss (inH2O)
0
4
8
12
16
20
24
28
32
36
40
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
AGT 1500 Engine Intake Airflow (Corrected to 29.92 inHg at 80°F) CFM

Phase III SCAF Vehicle Installation Loss Data

The AGT 1500 gas turbine engine used in the M1 Tank requires protection from damage caused by the ingestion of dust. An air cleaning system is therefore a requirement. The presence of air cleaning system components in the intake airstream causes a pressure loss which results in reduced power output of the engine. The greatest power loss occurs when the highest airflow is required, ie at maximum engine power. The curve shows the pressure loss characteristics of the standard air cleaner, the Phase II SCAF system, and the Phase III SCAF systems, with their variations.

When power loss is calculated, an additional loss of approximately 4.5 in. wg. must be added for the vehicle ballistic grills and the F.O.D. screen. These losses may differ between vehicles, but would be the same for either the SCAF or the standard air cleaner.



Performance Characteristics

M1/M1A1 Air Cleaner System

Simulated with 1 Filter

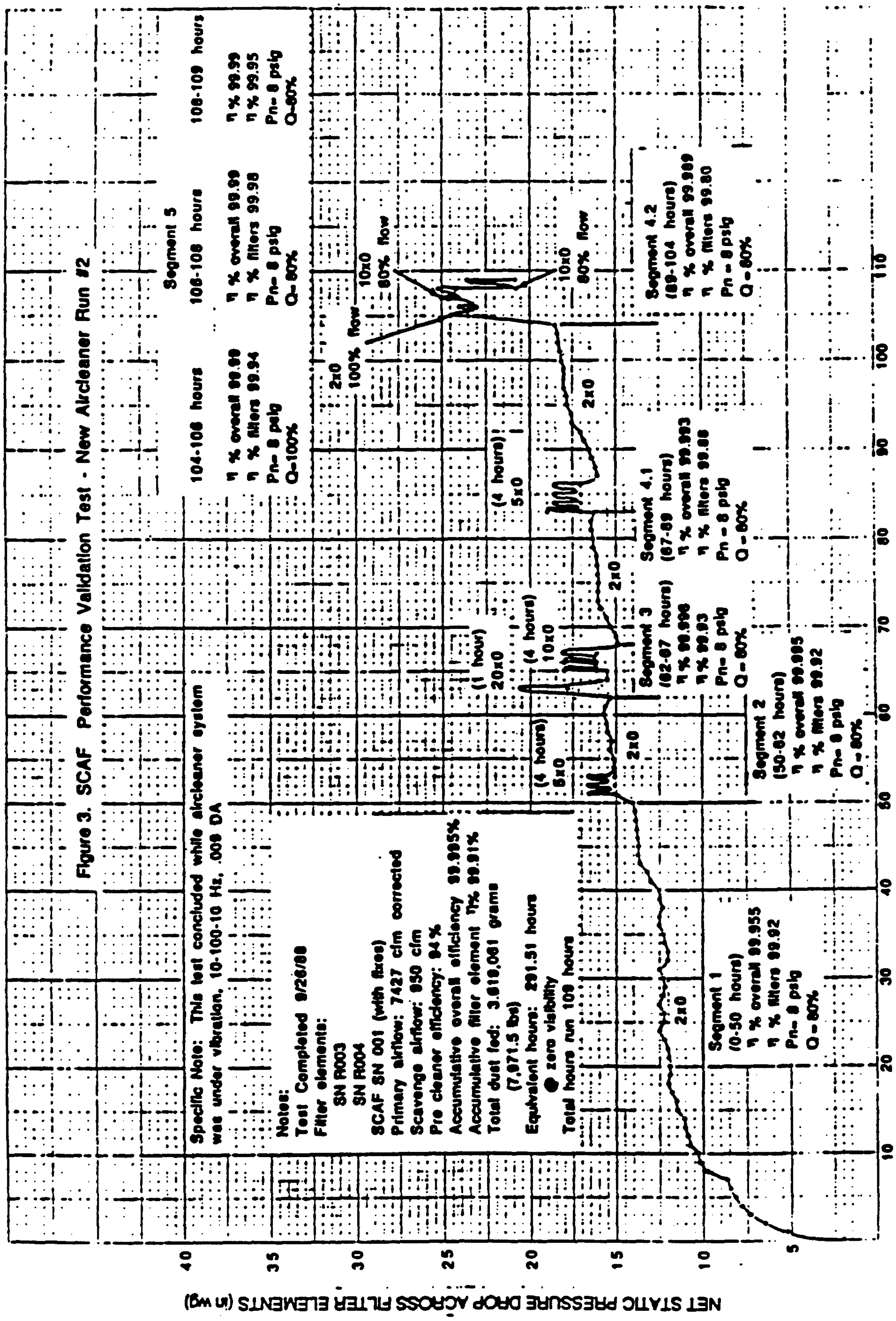


Figure 3. SCAF Performance Validation Test New Air Cleaner Run #2

Table 1. Demonstrated Filter Element Service Life in Kilometers Traveled During Durablility Testing

M1A1 TANK	FILTER ELEMENT SET #	KILOMETERS TRAVERSED AT CHANGE	NOTES
L6403 (S1)	ELEMENT SET #1	2957 Km	NORMAL LIFE
L6403 (S1)	ELEMENT SET #2	2637 Km	FILTERS STILL IN SERVICE AT END OF TEST (RESTRICTION 39" - 40" Wg)
L6404 (S2)	ELEMENT SET #1	812 Km	FILTERS PULLED FOR EFFICIENCY CHECK PER M1 PMO REQUEST
L6404 (S2)	ELEMENT SET #2 ELEMENT SET #3 ELEMENT SET #4	1116 Km 423 Km 113 Km	SPILL VALVE PROBLEMS CAUSED SHORT FILTER LIFE ON SETS 2,3, AND 4. (PROBLEM CORRECTED)
L6404 (S2)	ELEMENT SET #5	3474 Km	NORMAL LIFE

NORMAL LIFE OF SCAF FILTERS during durability miles average 3022Km, based on an average of element Sets 1 and 2 from S1 and Set 5 from S2.

Standard V-Pac equipped tank during durability mileage based upon the observed performance of M1A1 tank L9107 exhibited a NORMAL LIFE OF STANDARD FILTERS of 438 Km. This is based upon data accumulated during consecutive cleanings from 11/1/88 until 1/17/89.

CONCLUSION:

The SCAF equipped tanks wernt 6.9 times further between filter service intervals than the standard V-Pac equipped tank during the durability test phase. This conclusion is based upon a comparison of NORMAL LIFE.

Table 2. Demonstrated Filter Element Service Life in Kilometers Traveled and Time in Service During Dust Bowl Tests

M11 TANK	TIME ON TEST	MILES TRAVERSED	AVERAGE SPEED	RESTRICTION AT END
L6403 (S1)	5 HRS. 25 MIN.	124.3	22.94 MPH	42
L9107(STD)	1 HR. 40 MIN.	30.3	18.18 MPH	57
L6404 (S-2)	(S2 FAILED TO ACCUMULATE SIGNIFICANT MILEAGE DUE TO FAILED COMPRESSOR AND PLUGGED RECEIVER CIRCUIT)			

SCAF wen 4.12 times further and 3.25 times longer than the standard V-Pac equipped tank. This was short of goal performance for SCAF and Donaldson Company engineering believes SCAF system life would have been much longer if the receiver system hadn't plugged due to the extraordinarily high dust concentrations on the dust coarse. The receiver circuit problems can be simply corrected if a minor revision were allowed.

Motor Technology inc

(222)

FAX: 513-294-8336

2796 CULVER AVENUE DAYTON, OHIO 45429 513-294-1041

TO: PAGE 1 OF ____ DATE 10/17/89

FAX NO.: 612/887-3155 FROM: R. BUCHWALDER

COMPANY: DONALDSON

ATTN: HARRY CAMPLIN

REF: FAILURE ANALYSIS & CORRECTIVE ACTION

REF: MTI P/N 276A141

DONALDSON P/N T.B.D.

SEE ATTACHED FA & CA

RECEIVED
OCT 18 1989
DEFENSE PRODUCTS

R. Buchwalder