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OCCUPANT RESPONSE
AND
VEHICLE ACCELERATION
IN A
30-MPH FRONTAL CRASH TEST

1978 Subaru Brat MPV
NHTSA 781302

E. Enserink
R. Pirtle

Contract DOT-HS-6-01478



March 1978

FINAL REPORT

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PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

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16. Abstract A 1978 Subaru Brat MPV (NHTSA 781302 - VIN A69L005745) was crash tested for compliance with FMVSS 301-75 (Fuel System Integrity) and FMVSS 219 (Windshield Zone Intrusion). As a parallel, non-conflicting effort, the anthropomorphic dummies and the vehicle were instrumented with accelerometers to measure occupant response and vehicle acceleration. The results of this effort are documented herein. The vehicle impacted the fixed collision barrier in a zero degree frontal mode at a speed of 29.56 mph. The occupant response is summarized below: <table border="1"> <thead> <tr> <th></th> <th>DRIVER</th> <th>PASSENGER</th> </tr> </thead> <tbody> <tr> <td>Head Injury Criterion</td> <td>688.0</td> <td>836.6</td> </tr> <tr> <td>Chest Severity Index</td> <td>334.4</td> <td>235.3</td> </tr> </tbody> </table> Peak vehicle accelerations were as follows: Occupant Compartment - Front: 47G at 46 msec Occupant Compartment - Rear : 35.5G at 39 msec					DRIVER	PASSENGER	Head Injury Criterion	688.0	836.6	Chest Severity Index	334.4	235.3
	DRIVER	PASSENGER										
Head Injury Criterion	688.0	836.6										
Chest Severity Index	334.4	235.3										
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol When You Know Multiply by To Find Symbol

LENGTH

in inches 2.5 cm
ft feet 30 cm
yd yards 0.9 m
mi miles 1.6 km

AREA

in² square inches 6.5 square centimeters
ft² square feet 0.09 square meters
yd² square yards 0.8 square meters
mi² square miles 2.6 square kilometers
acres 0.4 hectares

MASS (weight)

oz ounces 28 grams
lb pounds 0.45 kilograms
short tons (2000 lb) 0.9 tonnes

VOLUME

tsp teaspoons 5 milliliters
Tbsp tablespoons 15 milliliters
fl oz fluid ounces 30 milliliters
c cups 0.24 liters
pt pints 0.47 liters
qt quarts 0.95 liters
gal gallons 3.8 liters
ft³ cubic feet 0.03 cubic meters
yd³ cubic yards 0.76 cubic meters

TEMPERATURE (exact)

°F Fahrenheit temperature 5/9 (after subtracting 32) Celsius temperature °C

Approximate Conversions from Metric Measures

Symbol When You Know Multiply by To Find Symbol

LENGTH

mm millimeters 0.04 inches
cm centimeters 0.4 inches
m meters 3.3 feet
m meters 1.1 yards
km kilometers 0.6 miles

AREA

cm² square centimeters 0.16 square inches
m² square meters 1.2 square yards
km² square kilometers 0.4 square miles
ha hectares (10,000 m²) 2.5 acres

MASS (weight)

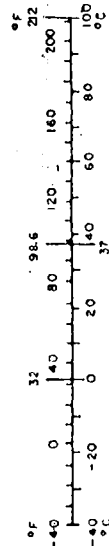
g grams 0.035 ounces
kg kilograms 2.2 pounds
t tonnes (1000 kg) 1.1 short tons

VOLUME

ml milliliters 0.03 fluid ounces
l liters 2.1 pints
l liters 1.06 quarts
l liters 0.26 gallons
m³ cubic meters 35 cubic feet
m³ cubic meters 1.3 cubic yards

TEMPERATURE (exact)

°C Celsius temperature 9/5 (then add 32) Fahrenheit temperature °F



Units of weights and measures are given in approximate values. For exact conversions, see Table A.1, p. 100.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the effort documented herein was to acquire occupant response and vehicle acceleration data in a 1978 Subaru Brat MPV (NHTSA 781302) during a 30-mph fixed-barrier (zero-degree, frontal mode) crash test. The test was performed by Dynamic Science, Inc., a subsidiary of Talley Industries, for the National Highway Traffic Safety Administration under Contract No. DOT-HS-6-01478.

The test was conducted in conjunction with Federal Motor Vehicle Safety Standard (FMVSS) 301-75 (Fuel System Integrity) and FMVSS 219 (Windshield Zone Intrusion) compliance test. The occupant response and vehicle acceleration aspects of the test are covered in this report.

1.2 PROCEDURE

The test was conducted in accordance with the Dynamic Science Test Procedure for FMVSS 301-75 and FMVSS 219 submitted to and approved by the NHTSA FMVSS 301-75/219 Contract Technical Manager.

The scope of the above test procedure was expanded to accommodate the acquisition of occupant response and vehicle acceleration data. This was accomplished without creating any conflict with the FMVSS 301-75/219 Procedure or the NHTSA Laboratory Procedure issued by the Office of Standards Enforcement. Specific procedures issued to obtain the additional data are detailed in Section 4.0.

2.0 TEST SUMMARY

2.1 VEHICLE GENERAL INFORMATION

Manufacturer: Subaru of America

Make/Model: Subaru Brat

Body Style: MPV Year: 1978

VIN: A69L005745 Build Date: November 1977

NHTSA No.: 781302 Color: Tan

Engine: 4 Cylinders, 97 c.i.d.

Transmission: 4 speeds, Manual X Automatic

Major Options: Radio, Power Brakes, Air Conditioning

Seating Capacity: Front 2 Rear 2 Total 4

Capacity Weight (lb): NA

GVWR (lb): Front 1680 Rear 1680 Total 3110

Recommended Cold Tire Pressure (psi): Front 28 Rear 32

Tire Size: 155 SR13

Load Range: -

Tires on Vehicle: 155 SR13

Delivered-Vehicle Values (fluids to capacity)

Weights (lb)

Wheel: RF 663 LF 668 RR 439 LR 464

Axle : F 1331 (59.6 %) R 903 (40.4 %)

Total: 2234

Attitude (in.)

RF 31.0 LF 31.0 RR 31.0 LR 31.0

Target Vehicle Test Weight (lb): 2862

2.2 TEST CONDITIONS

Date: March 15, 1978

Time: 1103

Temperature: 70 °F

Test Speed (mph): 29.56

Vehicle Weights (lb)

Wheel: RF 737 LF 766 RR 668 LR 695

Axle : .F 1503 (52.4%) R 1363 (47.6 %)

Total: 2866

Vehicle Attitude (in.)

RF 30.5 LF 30.3 RR 29.3 LR 29.5

Pre-test Dummy Positions

<u>Measurement</u>	<u>Driver (in.)</u>	<u>Passenger (in.)</u>
Dummy Centerline to Vehicle Centerline	12.5	12.8
Nose to Upper Rim Steering Wheel	16.3	-
Nose to Windshield (Horizontal Distance)	-	21.5
Left Knee to Closest Point on Lower Panel	5.5	4.5
Right Knee to Closest Point on Lower Panel	5.8	4.5
Ankle Distance	10.0	6.5
Knee Distance	9.0	9.0

Additional dummy positioning information is presented in the
PART 572 DUMMY IN-VEHICLE POSITION RECORDING SHEET which follows.

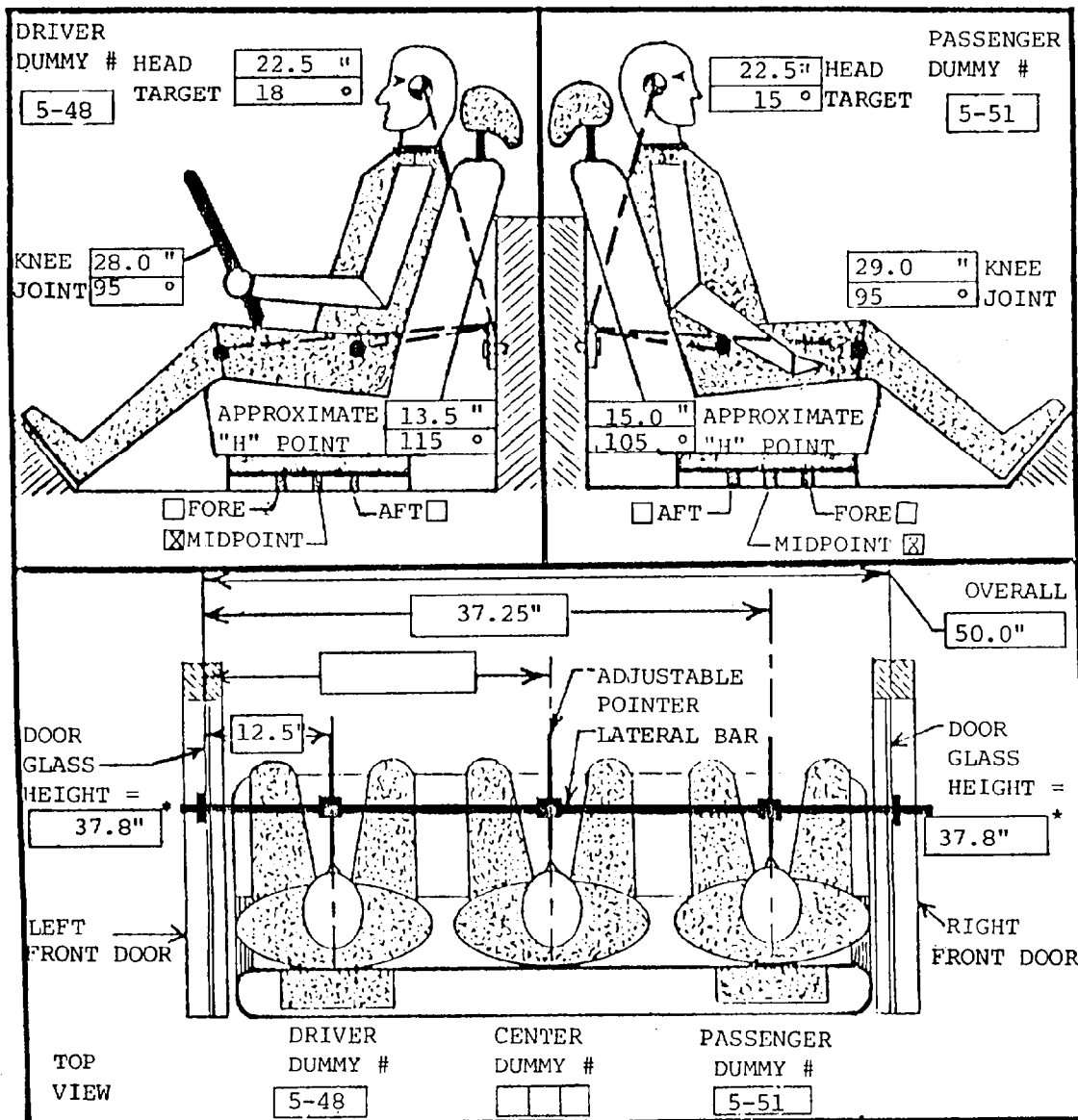
**PART 572 DUMMY IN-VEHICLE POSITION
RECORDING SHEET**

VEH. NHTSA NO.: 7 8 1 3 0 2 MFR./MAKE/MODEL Subaru Brat MPV

SEAT TYPE: ☐ Bench ☒ Bucket ☐ Split Bench
 ADJUSTER TYPE: ☒ Manual ☐ Power
 BUCKET SEAT BACK TYPE: ☐ Fixed ☒ Adjustable Reclining

POSITIONING DATE: 8/16, 1978; TECHNICIANS: 1. R. Pirtle
 AMBIENT TEMP.: 75 °F TIME: 0945 2. C. Bergman

All front seat dummies shall be positioned according to the procedure "OSE RECOMMENDED PROCEDURE FOR POSITIONING PART 572 DUMMIES IN TEST VEHICLE".



*Door glass height is equal on the right and left side of vehicle

2.3 SUMMARY OF TEST RESULTS

The following data sheets summarize:

1. The occupant response data (PART 572 DUMMY DATA SHEET)
2. The vehicle acceleration data (VEHICLE STRUCTURAL DATA SHEET)

More comprehensive data is presented in the appendix in the form of computer-generated plots.

PART 572 DUMMY DATA SHEET

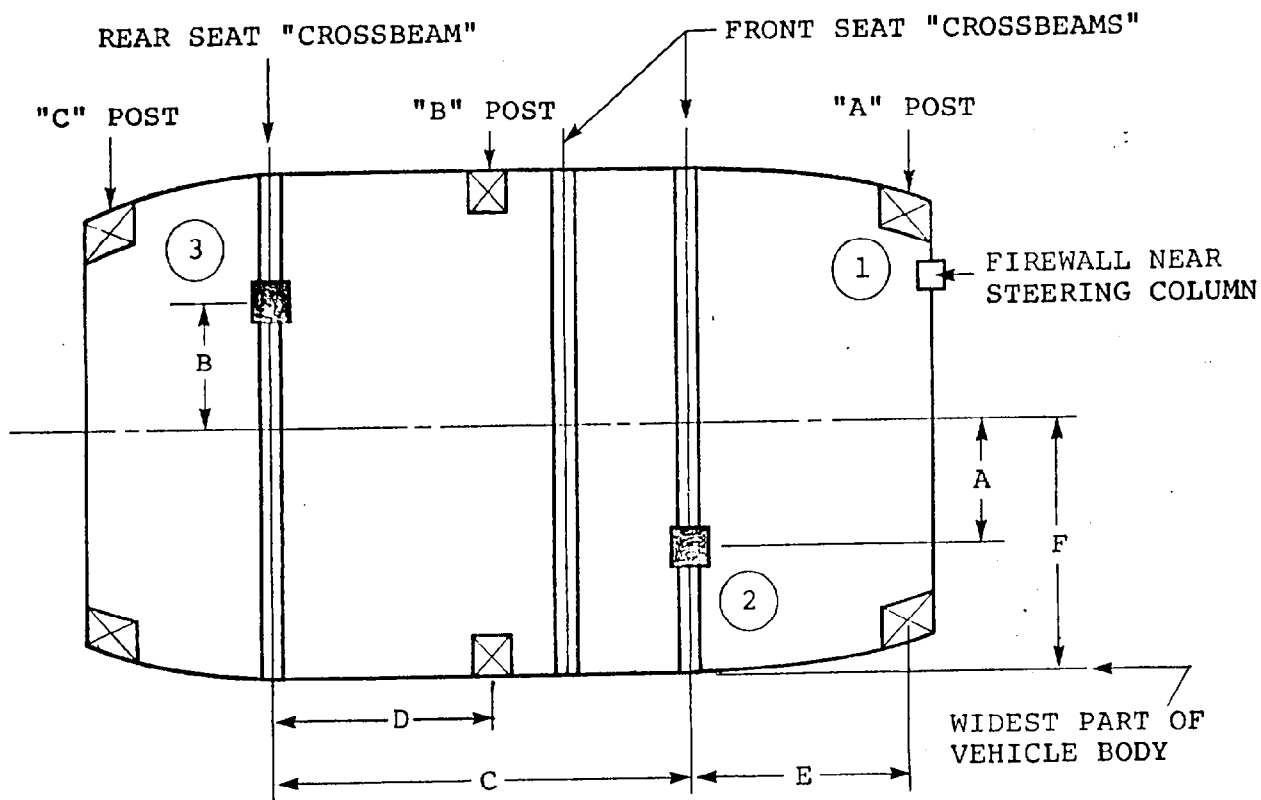
	Driver				Passenger			
	Positive*		Negative*		Positive*		Negative*	
	Direction	Direction	Direction	Direction	Direction	Direction	Direction	Direction
	Peak G	Time (msec)	Peak G	Time (msec)	Peak G	Time (msec)	Peak G	Time (msec)
Head Acceleration								
Longitudinal	8.1	15	115.9	68	16.7	50	158.4	90
Lateral	17.5	104	7.1	76	30.8	90	11.4	160
Vertical	37.9	84	5.6	29	55.9	94	29.3	161
Resultant	118.9	68			162.8	90		
HIC	688.0 (67 - 110 msec)				836.6 (87 - 114 msec)			
Chest Acceleration								
Longitudinal	7.5	191	53.1	77	1.2	166	32.7	72
Lateral	3.0	51	7.4	75	12.4	78	2.7	51
Vertical	12.2	60	10.3	85	14.1	61	4.9	85
Resultant	53.1	77			34.0	72		
SEVERITY INDEX	334.4				235.3			
Belt Loads	(lb)	Time (msec)			(lb)	Time (msec)		
Lap*	1589.2	74			1368.3	71		
Torso	1160.1	79			1198.5	92		
Vehicle Impact Speed (mph): 29.56								
*Positive Direction - Longitudinal: Forward Lateral: Rightward Vertical: Downward Negative Direction - Longitudinal: Rearward Lateral: Leftward Vertical: Upward								

*Peak Lap Belt Load measurement was taken from available data. Lap Belt opened at 75 msec.

VEHICLE STRUCTURAL DATA

VEHICLE Subaru Brat MPV NHTSA NO. 781320
 TEST SPEED 29.56 mph TEST DATE March 15, 1978

00087608



DIMENSIONS							
Location		Measurement (in.)		Location		Measurement (in.)	
A		19.8		D		2.0	
B		16.5		E		-1.8	
C				F			
Steering Column Movement (in.) 1.9 forward, 0.5 down							
Vehicle Overall Crush (in.) 21.0							
Test Weight (lb) 2866							
ACCELERATION PEAKS (CLASS 60 FILTER)							
Location	Positive* Direction		Negative* Direction		Average Longi- tudinal (G)	Dynamic Crush	
	Peak G	Time (msec)	Peak G	Time (msec)		Amount (ft)	Time (msec)
No. 1 Longitudinal							
No. 1 Vertical							
No. 2 Longitudinal	2.9	152	50.5	42	19.5	1.80	69
No. 3 Longitudinal	9.7	21	43.9	36	15.9	2.08	85
No. 3 Vertical	10.2	49	12.5	36			
*Positive Direction - Longitudinal: Forward, Vertical: Downward Negative Direction - Longitudinal: Rearward, Vertical: Upward							

3.0 DISCUSSION OF TEST RESULTS

3.1 VEHICLE GUIDANCE AND IMPACT

A steel follower shoe riding on the monorail guided the vehicle to the fixed collision barrier. The follower shoe is detached from the vehicle just prior to the barrier impact. The vehicle impact speed was 29.56 mph, based on breakwire speed traps which are located within 5 feet of the impact point. The required speed range at impact is 29.4 ± 0.5 mph. The test vehicle longitudinal centerline contacted the barrier within 1 inch of the barrier centerline.

3.2 VEHICLE REBOUND AND CRUSH

The distance from the front of the vehicle to the barrier after impact was 15.1 inches. The average overall static crush of the vehicle was 21.0 inches.

3.3 PHOTOGRAPHS

Figures 3-1 through 3-4 are pre-test and post-test views of the occupant compartment, restraint systems, and dummies.

3.4 POST-TEST DAMAGE OBSERVATIONS

A post-test inspection of the vehicle revealed the following:

- The spare tire dislodged from its fixture, tipping the air cleaner from the carburetor and disconnecting the carburetor air hoses.
- The battery case was broken.
- The vehicle hood latch remained secure.
- The front fenders impacted both front wheels.



Figure 3-1. Pre-test View of Driver Dummy - 1978 Subaru Brat MPV - NHTSA 781302.

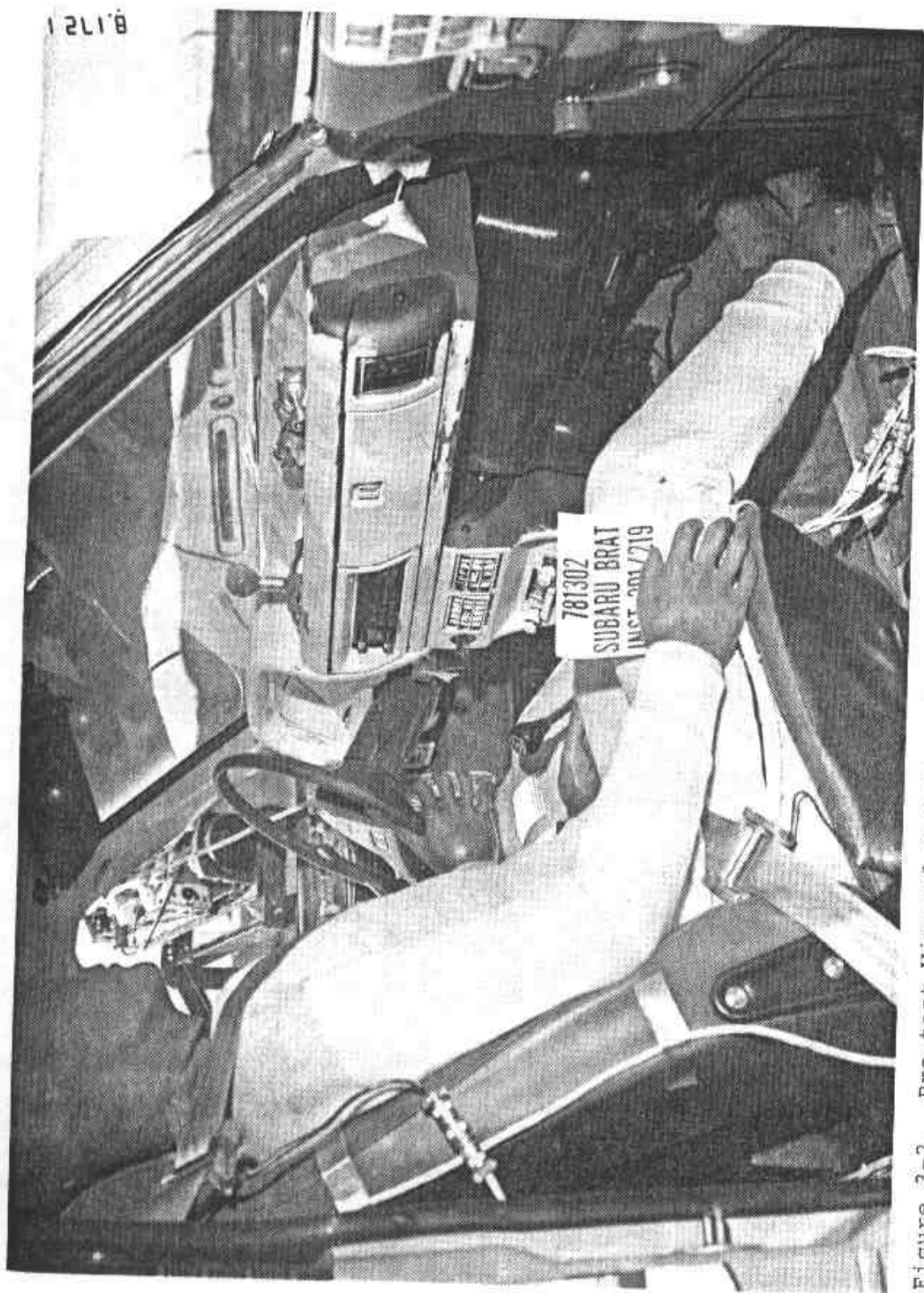


Figure 3-2. Pre-test View of Passenger Dummy - 1978 Subaru Brat MPV - NHTSA 781302.



Figure 3-3. Post-test View of Driver Dummy - 1978 Subaru Brat MPV - NHTSA 781302.



Figure 3-4. Post-test View of Passenger Dummy - 1978 Subaru Brat MPV - NHTSA 781302.

4.0 TEST PROCEDURES

4.1 CRASH TEST

The procedures for conducting the barrier crash test are presented in detail in the FMVSS 301 (Fuel System Integrity) report previously submitted to the NHTSA Office of Standards Enforcement.

4.2 DUMMY POSITIONING

The driver and right front passenger were placed in the center of the seat cushion and pushed into the seat back. The shoulders were pushed back against the seat back and the head centered on the head restraint (the head restraint is integral with the seat back and not adjustable). The thighs were pushed down on the seat cushion and the heels placed on the floor. The upper portion of the arms of the passenger was pushed against the seat back and the hands placed to the side of the thighs. The thumbs and index fingers of the driver dummy were positioned around the steering wheel rim at the 3 and 9 o'clock positions.

The front seat was placed at the mid fore-aft position. The seat back was positioned at its mid angle.

4.3 DATA ACQUISITION AND REDUCTION

The acceleration and belt load signals from the two dummies were converted to FM signals along with the signal from the impact (event) switch and transmitted to an analog tape recorder. The electrical signal was transmitted through an umbilical cable trailing the vehicle to the test control center. A redundant telemetry system was installed in the vehicle in case of umbilical cable failure or inadvertent separation of the cable from the vehicle.

Instruments used in this test are listed in Table 4-1.

The flow of the data during reduction phase is shown in Figure 4-1. Test data stored in a frequency format on analog tape serves as the input to the data reduction effort. These data are played back and the signal from the tape is passed through the appropriate demodulators which convert the data back to its original voltage form. These data are then passed through a presample filter, digitally sampled, and stored on a magnetic tape for subsequent processing on the digital computer by the Dynamic Science computer program "Crash". The procedure used for handling each data channel will first be discussed, followed by a discussion of the operations the computer program performs on each type of data from the crash tests.

Figure 4-2 illustrates the manner in which each data channel is handled from analog playback to digital processing. Following the discrimination process, the raw data in its original analog form is prefiltered through a linear phase low pass filter. The presampled filtered data are then digitized and stored on magnetic tape for subsequent computer processing. Digitizing rate (sampling rate) is dependent upon the presample filter as shown in Table 4-2. Also given in this table are the J211a data classes, the presample filters which Dynamic Science uses, and the data sampling rates for each J211a data class. The presample filters were chosen from those which Dynamic Science has in its playback systems to give a satisfactory data representation for each data class. Sample rates were selected to ensure that no aliasing of the presample filtered data would occur and yet provide sufficient sample rates to give adequate definition of the wave form of the original data.

Following the digitizing process, the data is then processed via the digital computer where it undergoes further filtering by means of a digital filter.

TABLE 4-1. INSTRUMENTATION SUMMARY FOR COLLISION TESTS

Measurand	Type of Transducer	Manufacturer and Model No.	Full-Scale Capacity	Full-Scale Output	Transducer Accuracy	Frequency Response (maximum)
<u>I. Test Vehicle</u>						
Vehicle impact	Contact switch	Tapeswitch	On-Off	0 - 2.5V	-	350 μ sec rise time
Acceleration	Unbonded strain gauge accelerometer	Statham Model No. A69Tc-200-350	200 G	4 MV/V	$\pm 75\%$	2300 Hz
<u>II. Occupant</u>						
Head and chest accelerations (triaxial)	Piezoresistive strain gauge accelerometer	Endevco Model No. 7332C-750	± 750 G (2500 G overload)	.1 MV/G @ 5V DC excitation	$\pm 1\%$ of reading	2000 Hz
<u>III. Facility</u>						
Approach velocity	Pulse generator/digital counter	Dynamic Science	>100 mph	600 Hz @ 100 mph	$\pm .5\%$ @ 30 mph	NA ⁽¹⁾
Impact velocity	Breakwire speed trap	Dynamic Science	>100 mph	10^4 counts	.01%	NA ⁽¹⁾
Barrier impact	Contact switch	Tapeswitch	On-Off	2.5V	-	350 μ sec rise time

(1) NA - Not applicable.

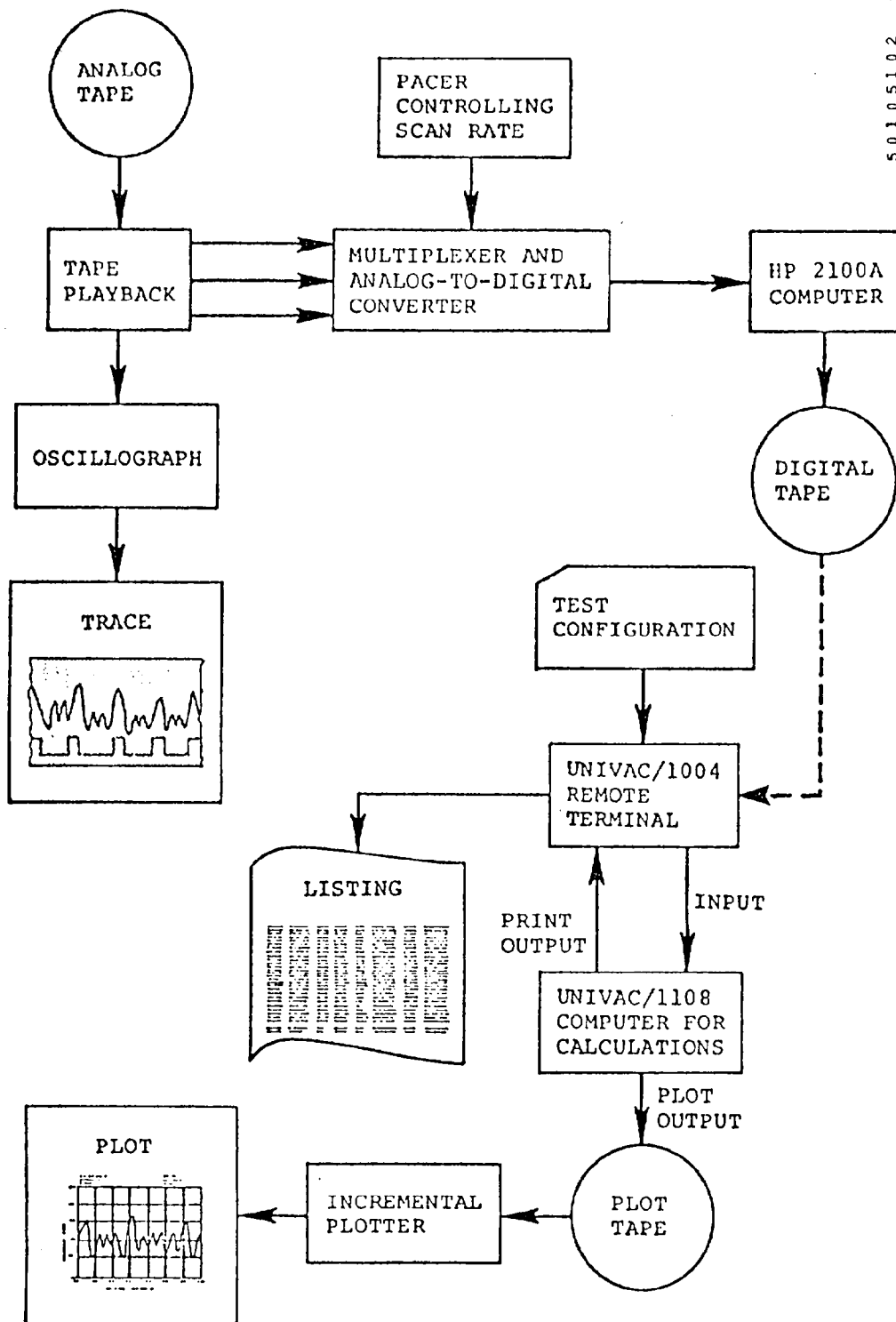


Figure 4-1. Data Reduction Flow Diagram.

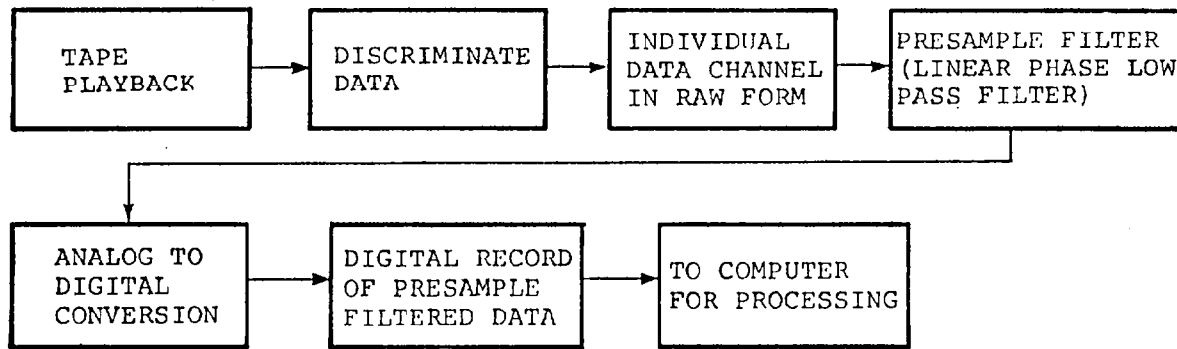


Figure 4-2. Flow of Individual Data Channel.

TABLE 4-2. DIGITAL SAMPLING RATES FOR J211a DATA CLASSES

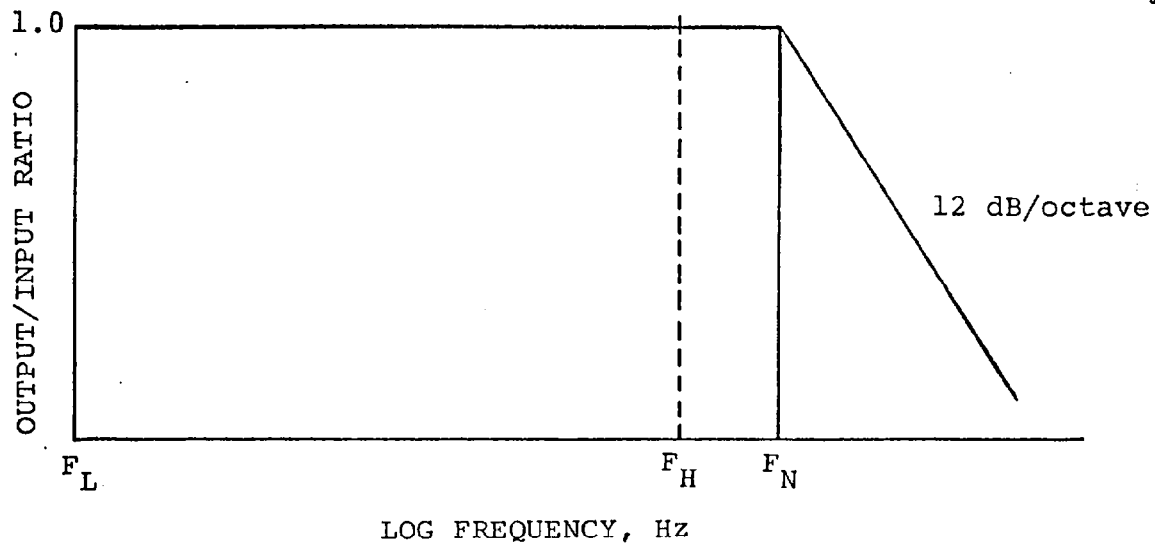
Item	Data Class	Presample Filter (3dB Frequency)	Sampling Rate	Digital Filter Cutoff Frequency
Chest Accelerations	180	250	1000	Not Filtered
Head Accelerations	1000	2000 Hz	8000	1650

The digital filter used a fast Fourier transformation to transfer the data to the frequency domain where the filtering occurs. Filtering is achieved by multiplying the Fourier transformed data by the filter transfer characteristics shown in Figure 4-3. The data from the product are transferred back to the time domain where the analysis is then performed.

The data are then processed in more detail by means of the computer.

The output from the computer is basically in two forms:
 (1) a listing of the basic data and the resulting calculations derived from the data and (2) selected incremental plots of these data.

TRANSFER FUNCTION



DATA CLASSES

<u>DATA CLASS</u>	<u>F_H-Hz</u>	<u>F_H-Hz</u>	<u>ROLL OFF - dB/oct</u>
1000	1000	1650	12
600	600	1000	12
180	180	300	12
60	60	100	12

Figure 4-3. Digital Filter Transfer Function
for SAE J211a Data Classes.

Data from each type of test are discussed below.

4.4 CRASH DATA

4.4.1 Dummy Head Data

The dummy head acceleration data are processed as class 1000 data, combined to form the resultant and integrated to five velocities and displacements. The HIC is computed as well as the Severity Index. The HIC is maximized over the event interval on the basis of every 5th time point (~ 0.001 second) to establish the maximum HIC value and the interval over which it occurred.

Data output is in the form of a computer printout at one (1) millisecond intervals, as well as incremental computer plots (shown in the Appendix plotted at one millisecond intervals).

4.4.2 Dummy Chest Accelerations

The dummy chest accelerations are processed as class 180 data, combined to get resultants, and integrated to get velocities and displacements. The resultant accelerations, velocities, displacements, and severity index are listed on the digital printout at one (1) millisecond intervals. These outputs can also be plotted on an incremental plotter. Also outputted is the time duration above 60G.

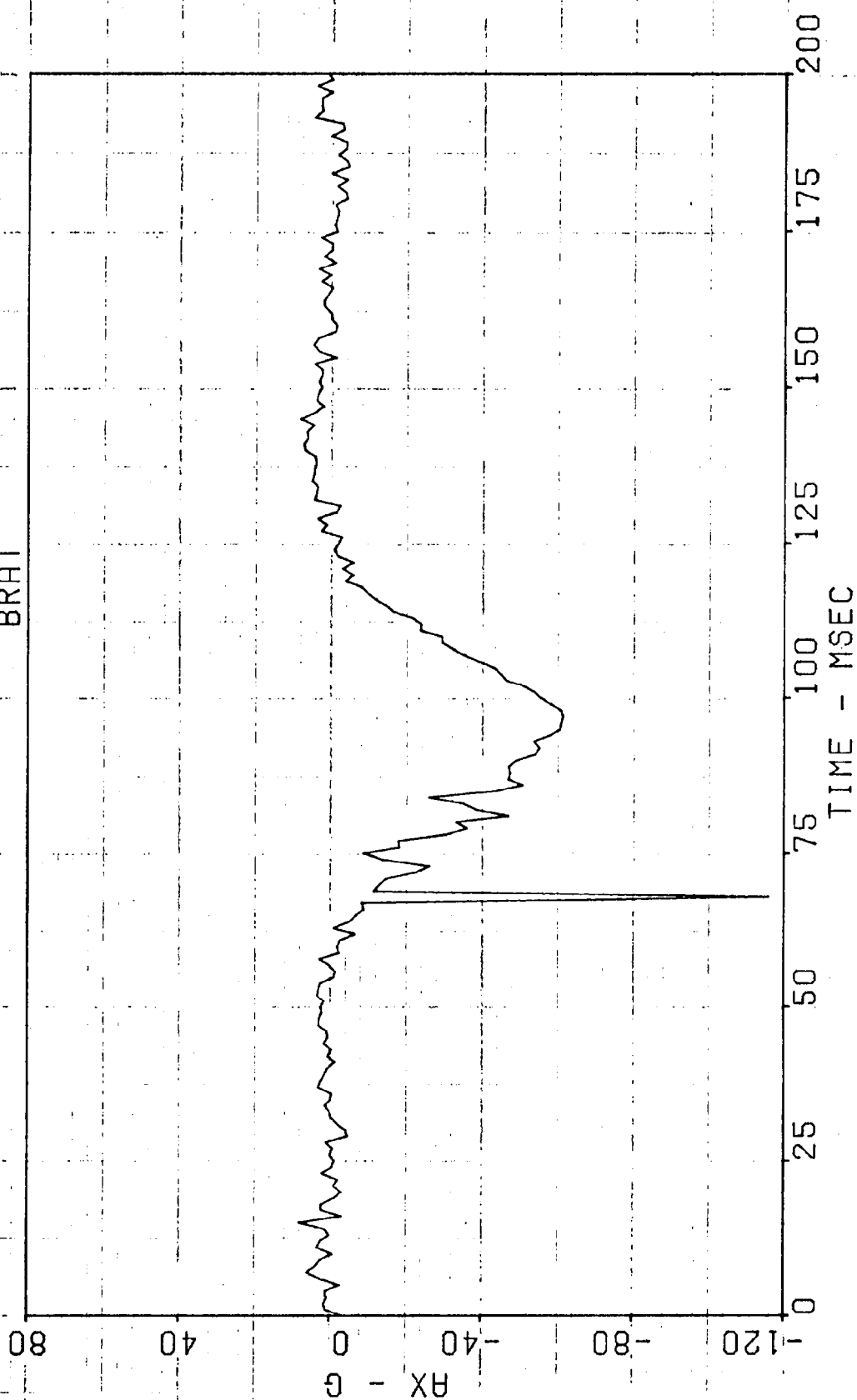
APPENDIX

CALCOMP PLOTS

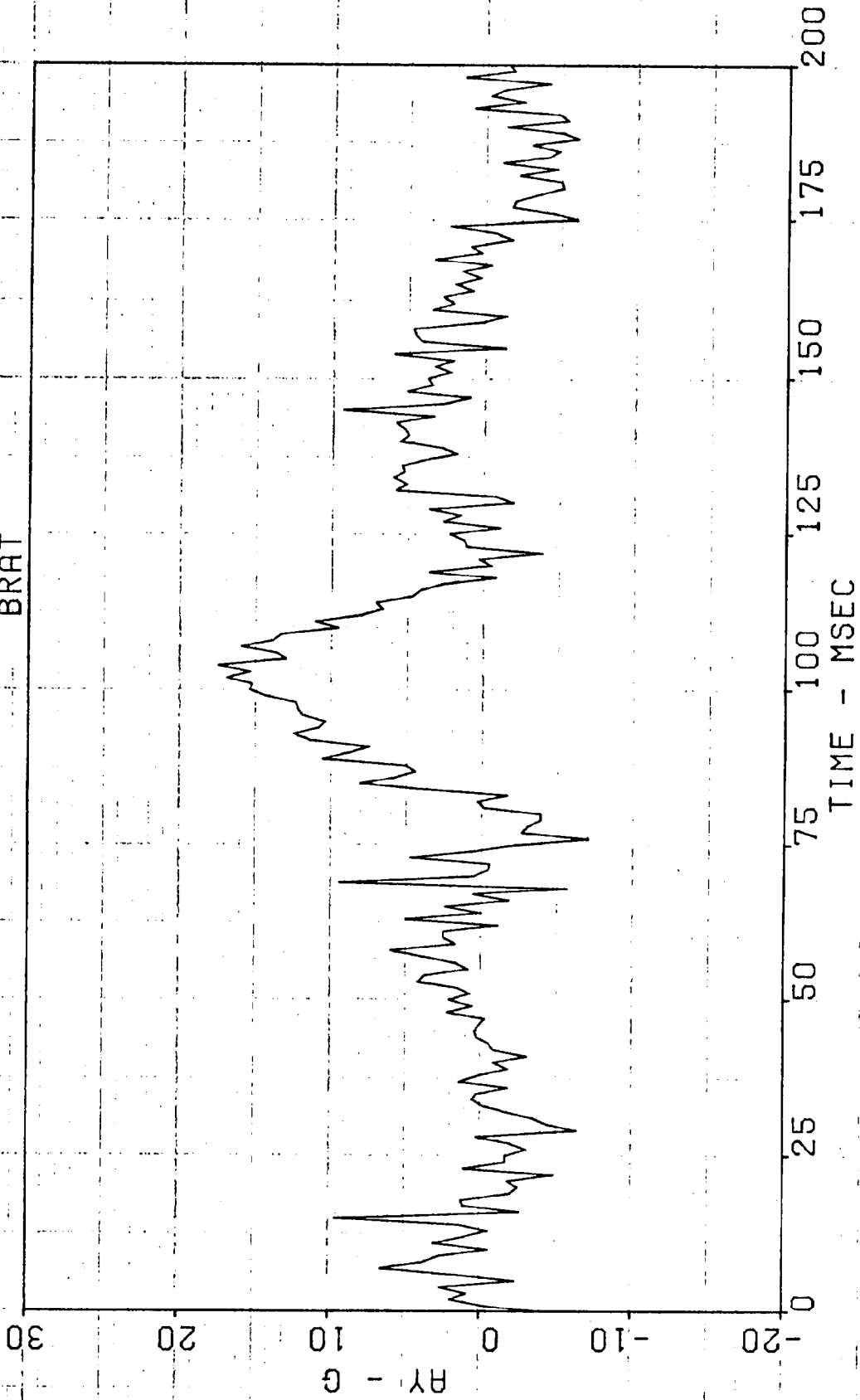
The following location numbers are used in the CalComp plot titles to identify transducer locations:

<u>Location</u>	<u>Number</u>
Driver Head Accelerometer	501
Driver Chest Accelerometer	1101
Driver Lap Belt Load Cell	4110
Driver Torso Belt Load Cell	4111
Passenger Head Accelerometer	503
Passenger Chest Accelerometer	1103
Passenger Lap Belt Load Cell	4130
Passenger Torso Belt Load Cell	4131
Occupant Compartment Front Accelerometer	102
Occupant Compartment Rear Accelerometer	103

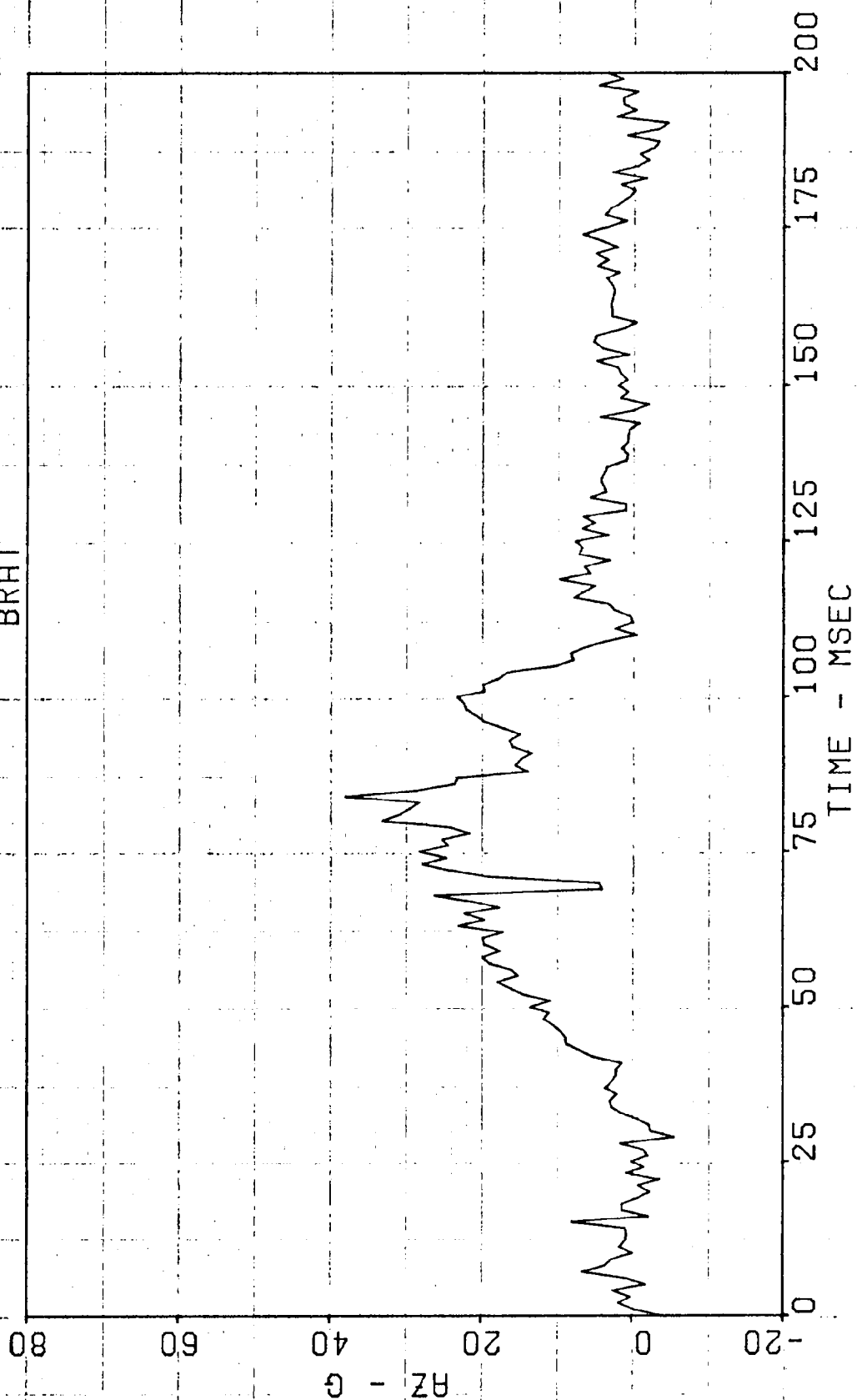
DATE 3-16-78 FILTER 1600 LOCATION 501 TEST NO 032878
SUBARU/BAR
BRAT



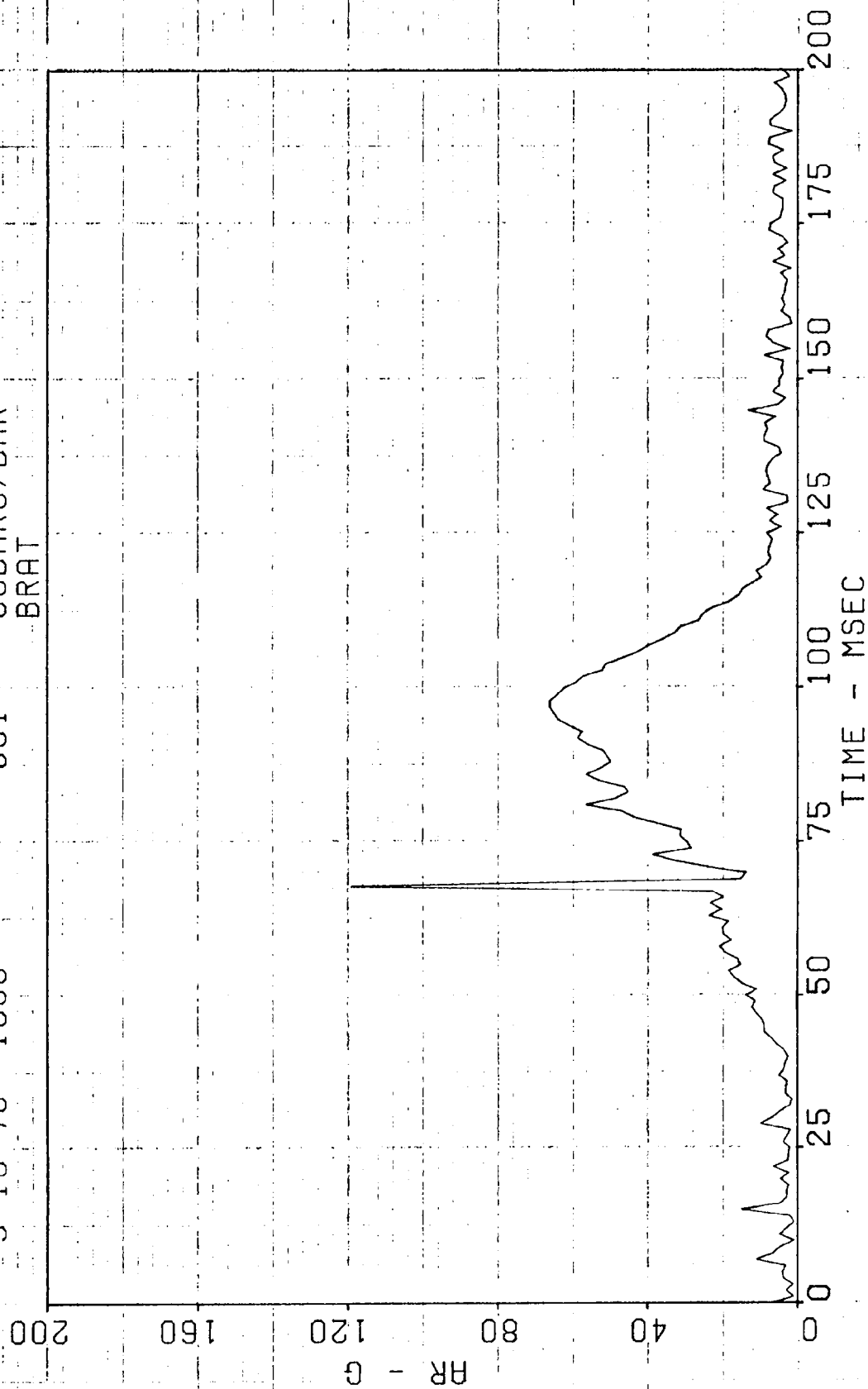
DATE 3-16-78 FILTER 1600 LOCATION 501 TEST NO 032878
SUBARU/BAR
BRAT



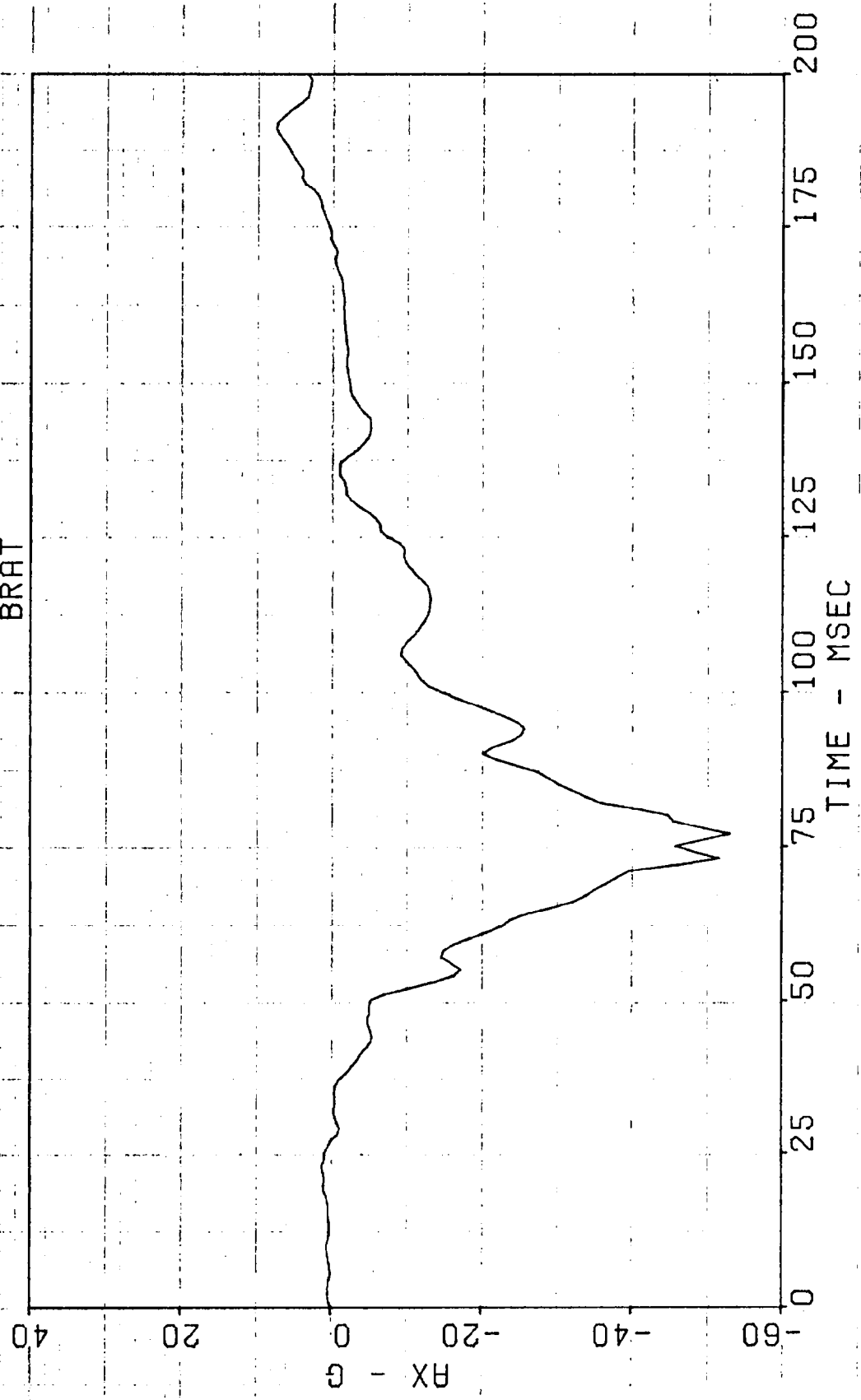
DATE 3-16-78 FILTER 1600 LOCATION 501 TEST NO 032878
SUBARU/BAR
BRAT



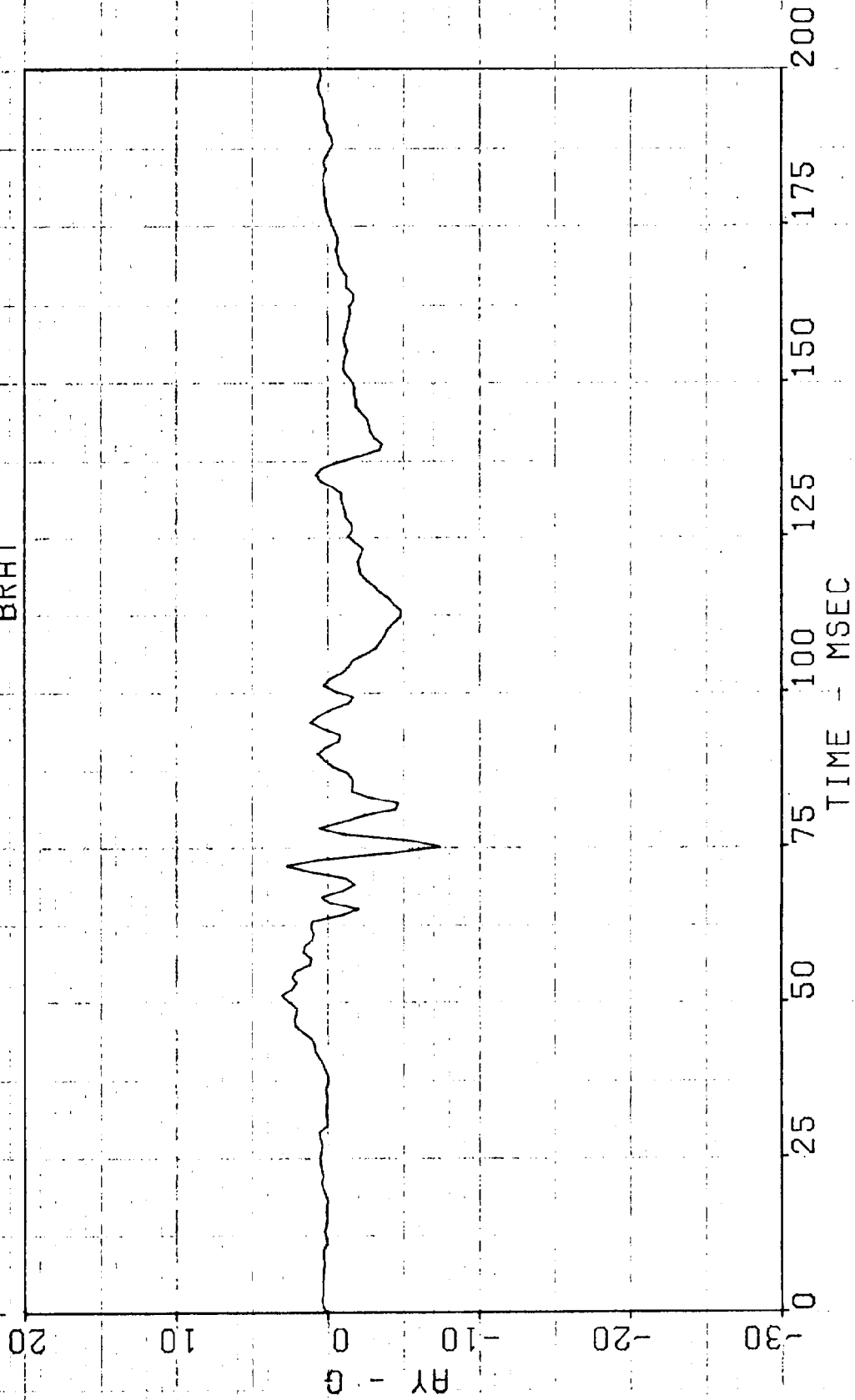
DATE 3-16-78 FILTER 1600 LOCATION 501 TEST NO. 033178
SUBARU/BAR
BRAT



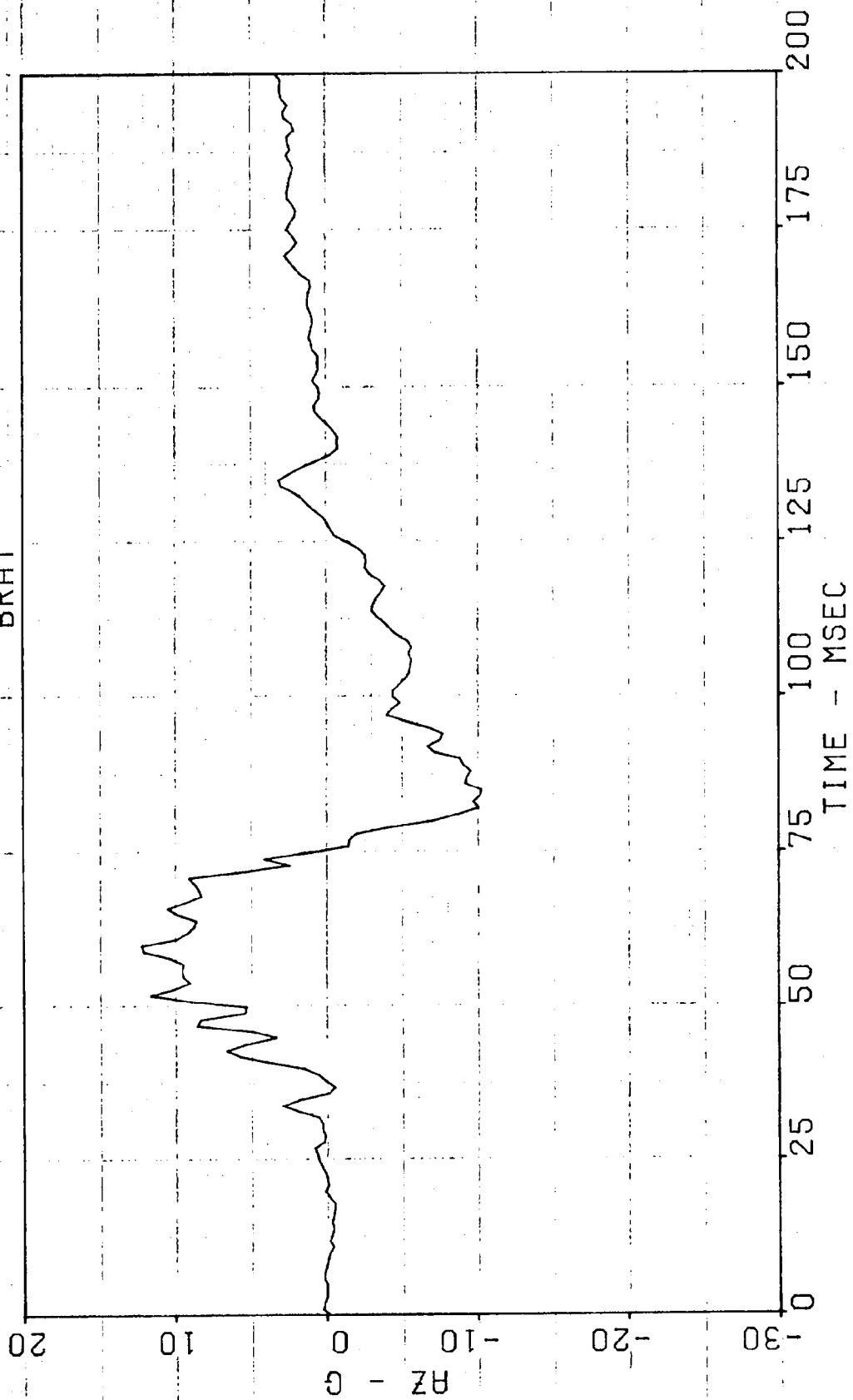
DATE 3-16-78 FILTER 315 LOCATION 1101 TEST NO 032878
SUBARU/BAR
BRAT



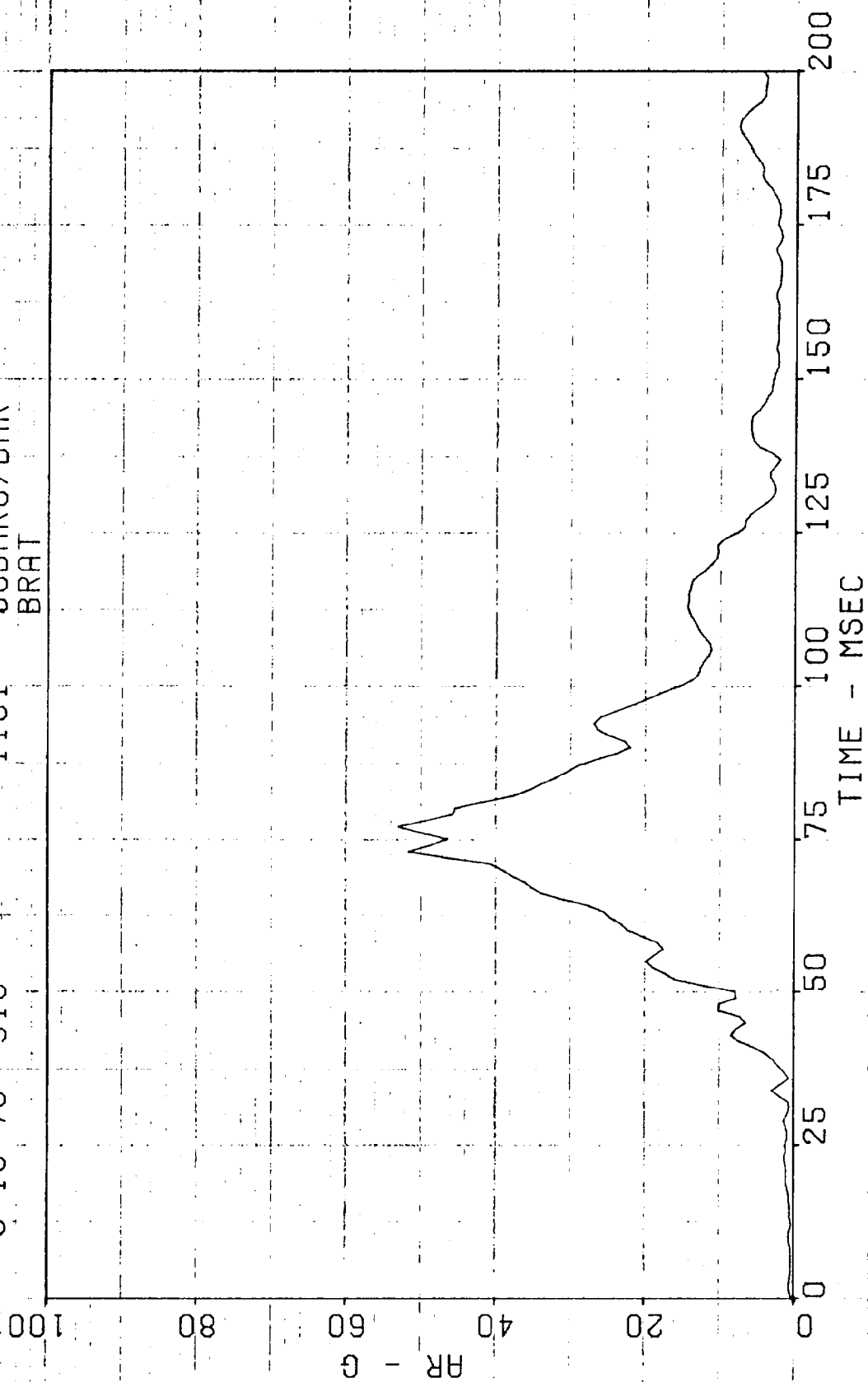
DATE 3-16-78 FILTER 315 LOCATION 1101 TEST NO 032878
SUBARU/BAR
BRAT



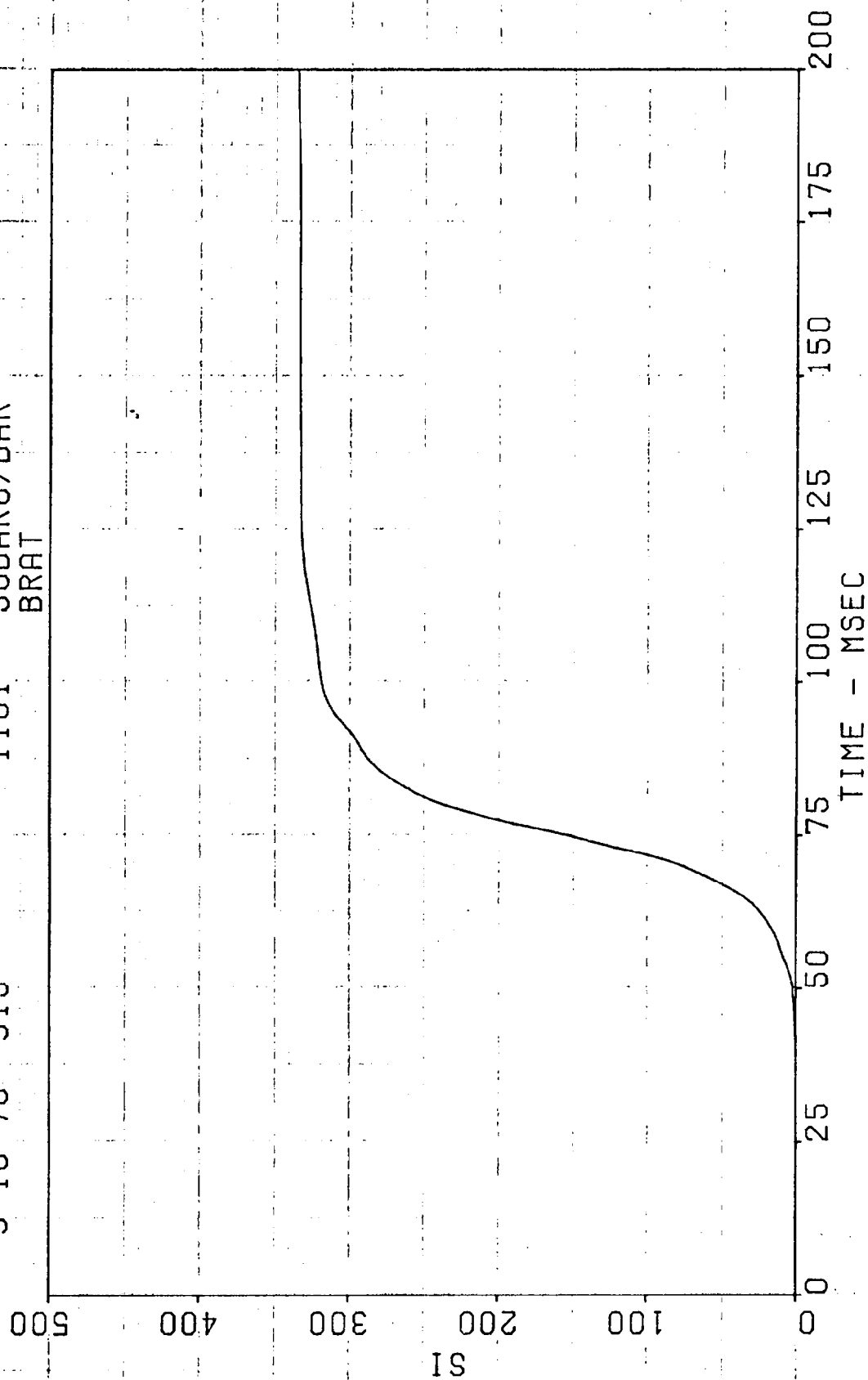
DATE 3-16-78 FILTER 315 LOCATION 1101 TEST NO 032878
SUBARU/BAR
BRAT



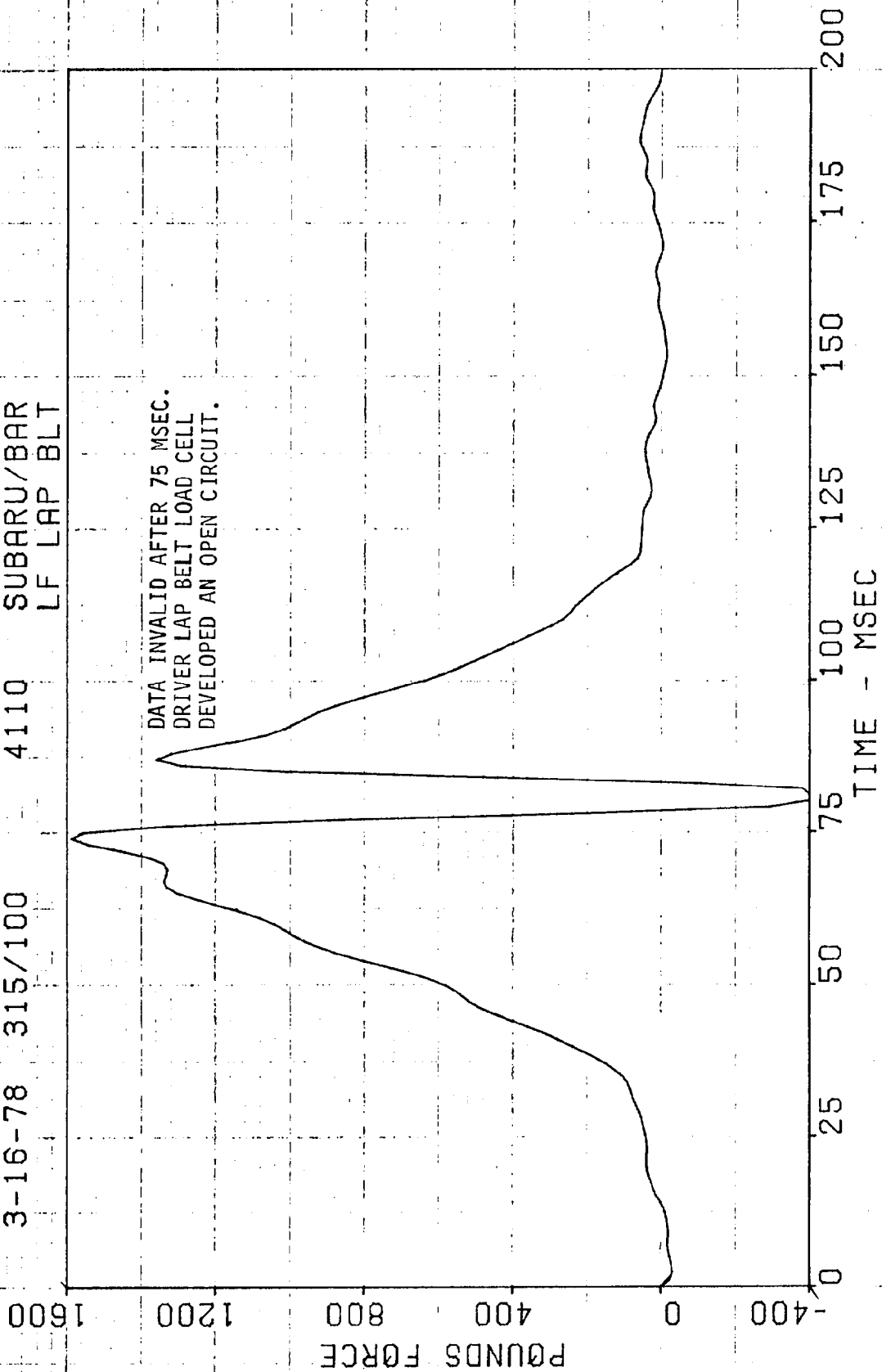
DATE 3-16-78 FILTER 315 LOCATION 1101 TEST NO 040378
SUBARU/BAR
BRAT



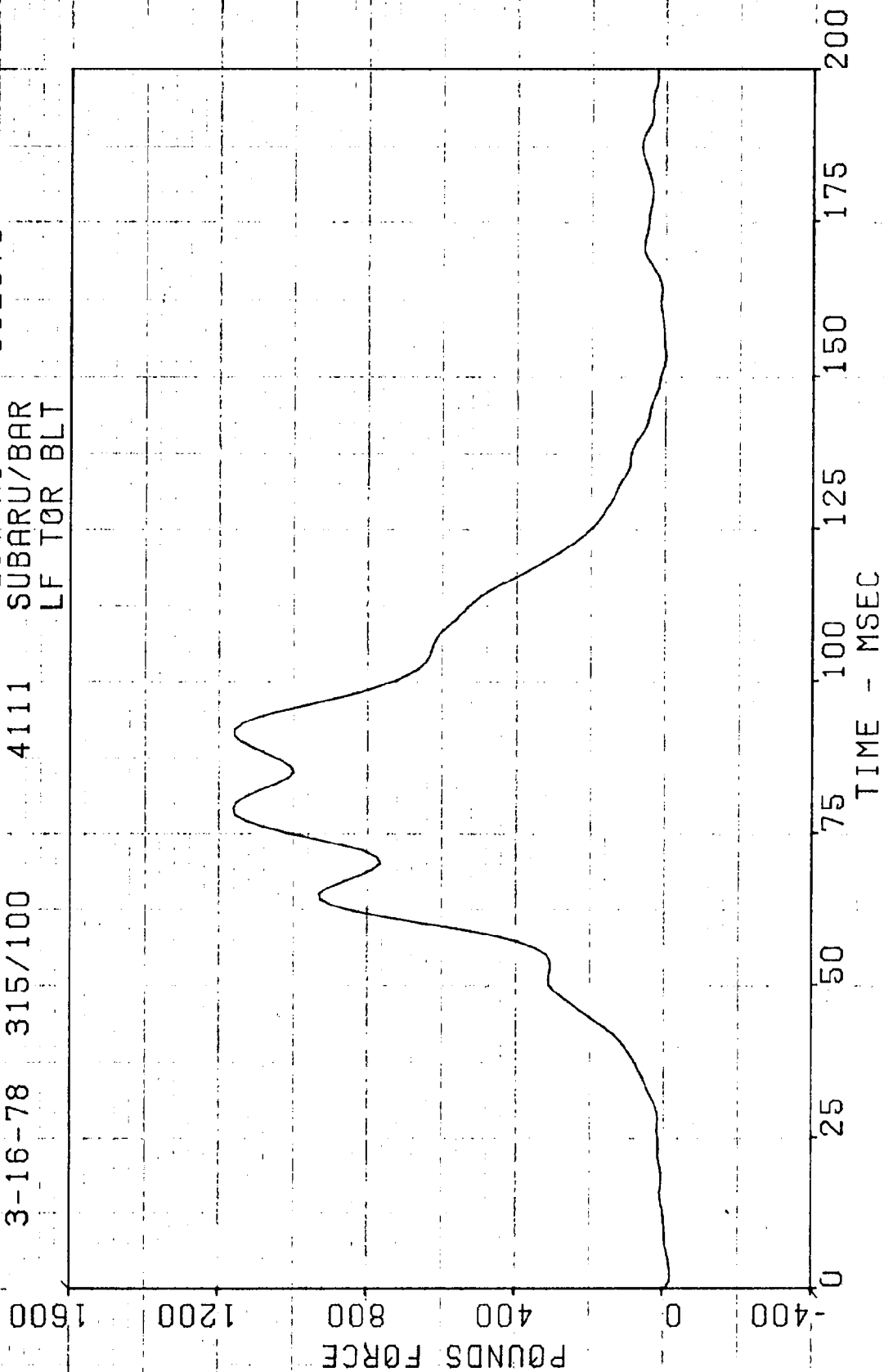
DATE 3-16-78 FILTER 315 LOCATION 1101 TEST NO 032878
SUBARU/BAR
BRAT



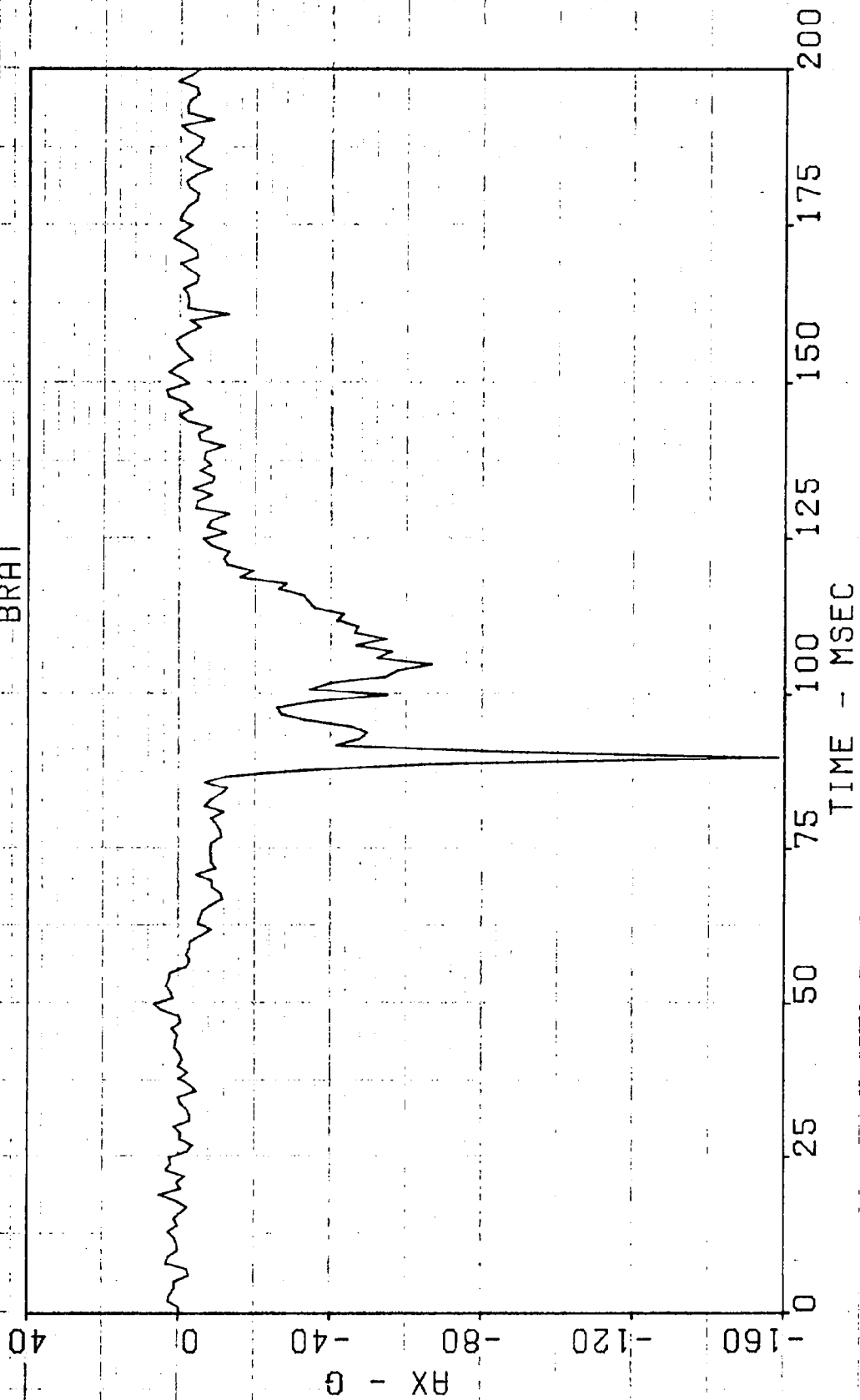
DATE 3-16-78 FILTER 315/100 LOCATION 4110 TEST NO 032878
SUBARU/BAR LF LAP BLT



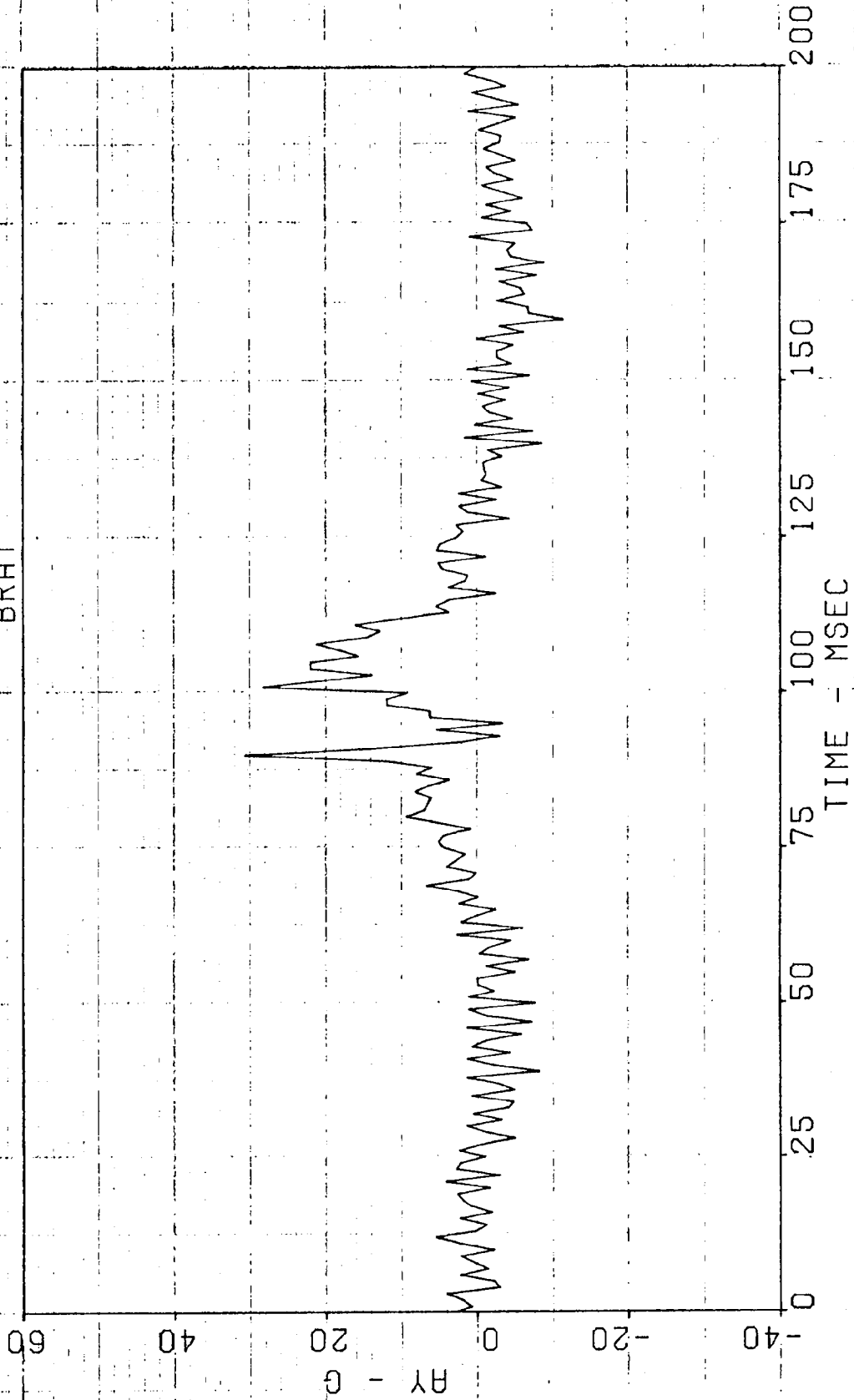
DATE 3-16-78 FILTER 315/100 LOCATION 4111 TEST NO 032878
SUBARU/BAR LF TOR BLT



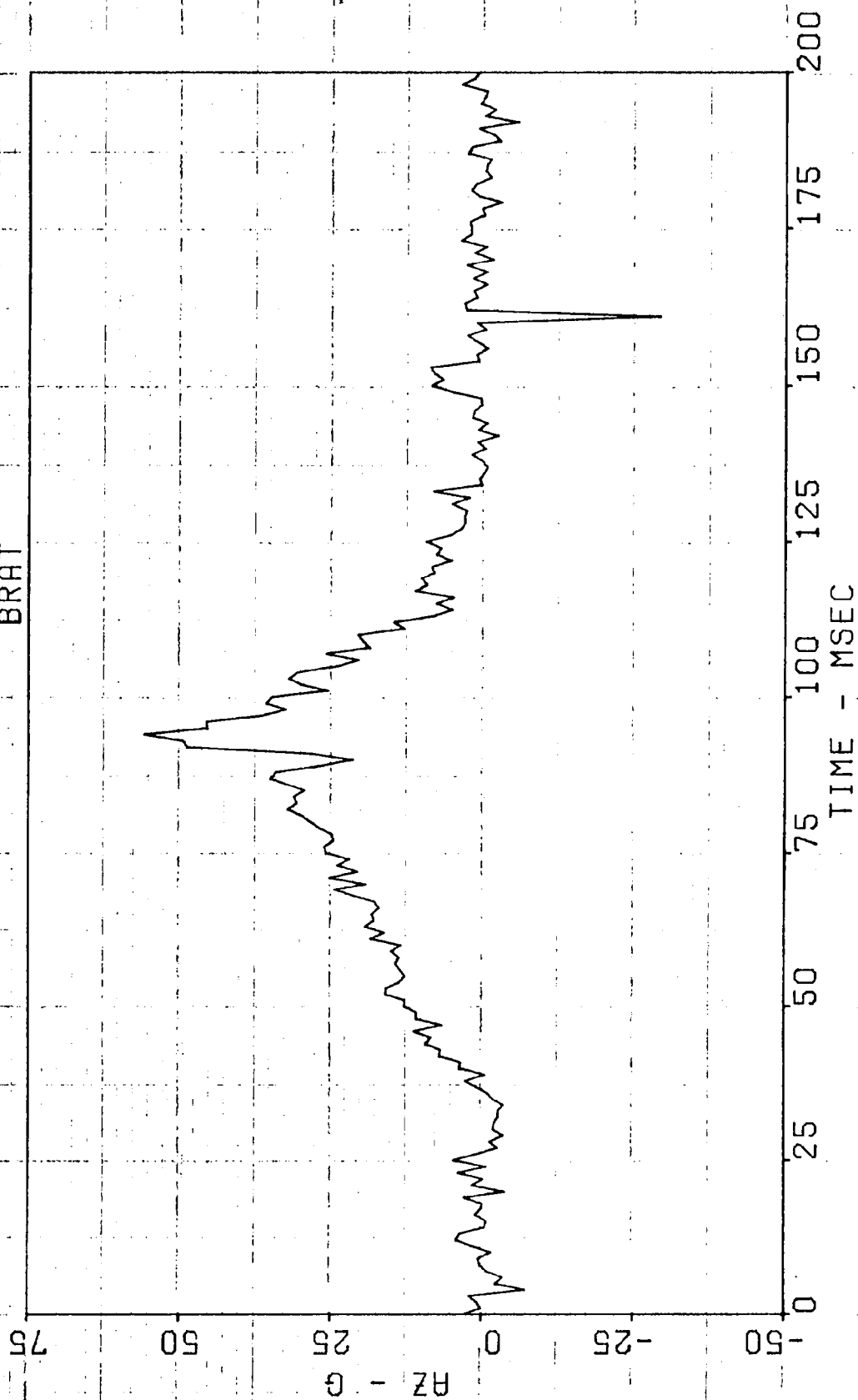
DATE 3-16-78 FILTER 1600 LOCATION 503 TEST NO 032878
SUBARU/BAR
BRAT



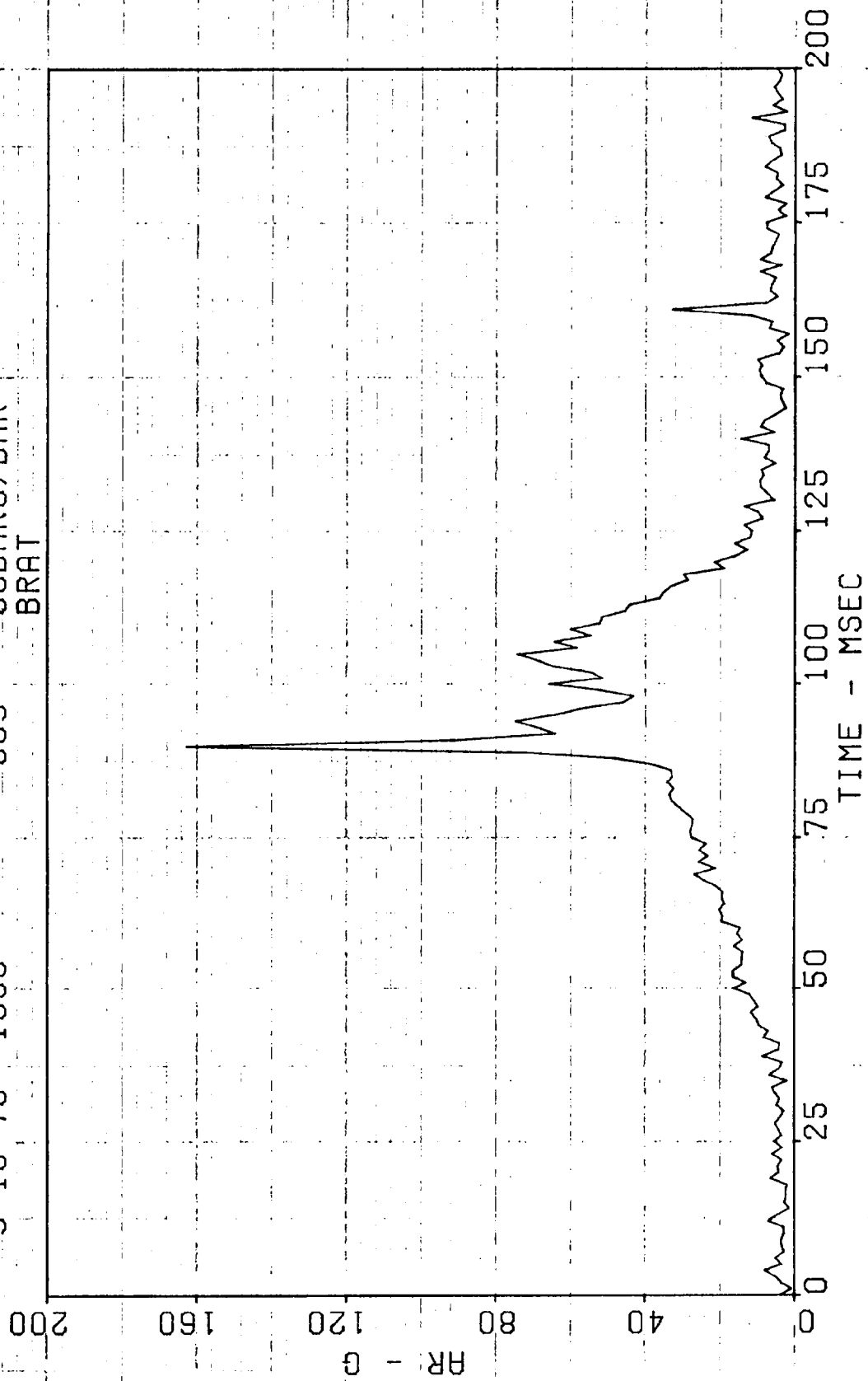
DATE 3-16-78 FILTER 1600 LOCATION 503 TEST NO 033178
SUBARU/BAR
BRAT

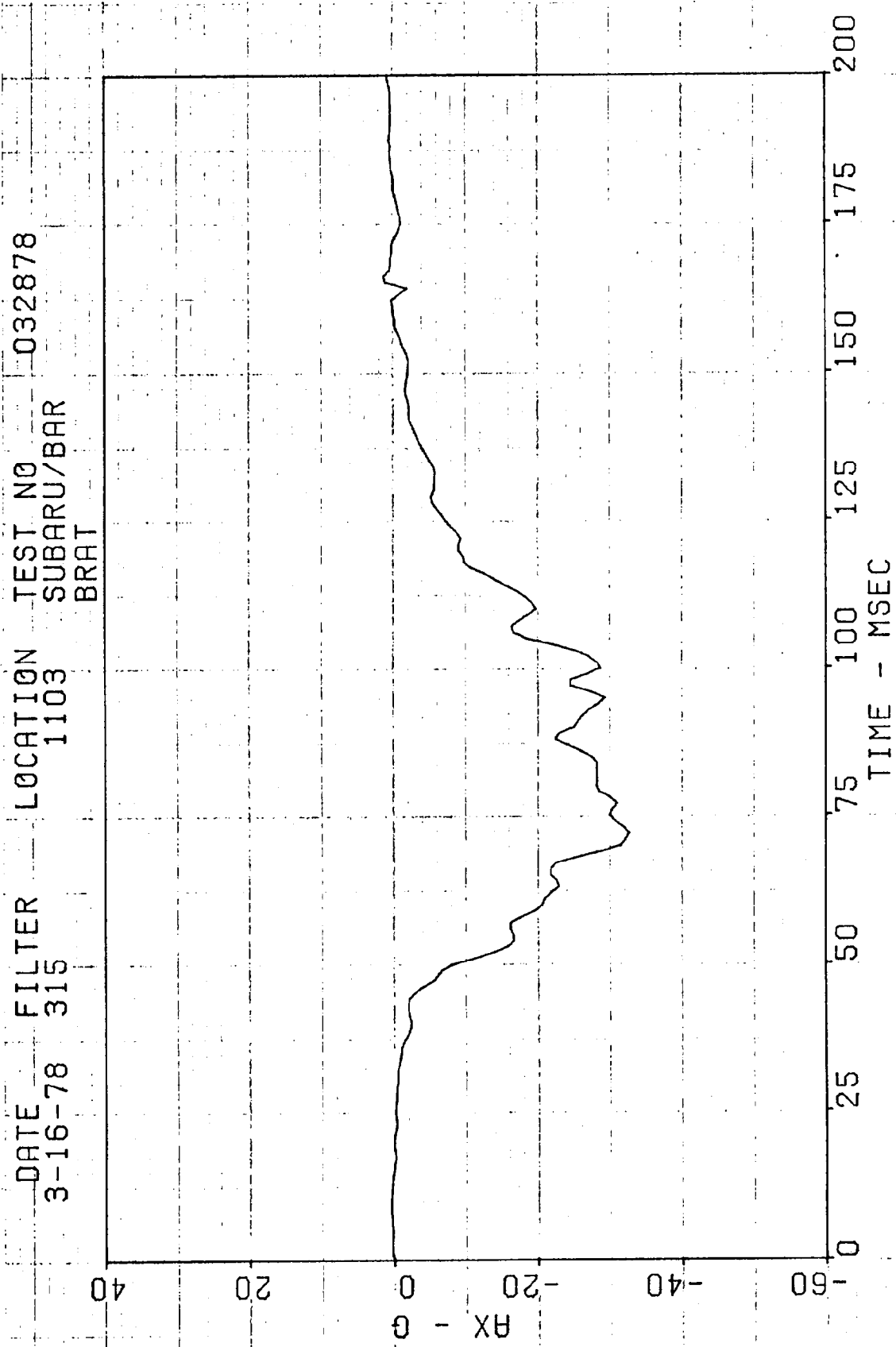


DATE 3-16-78 FILTER 1600 LOCATION 503 TEST NO 032878
SUBARU/BAR BRAT

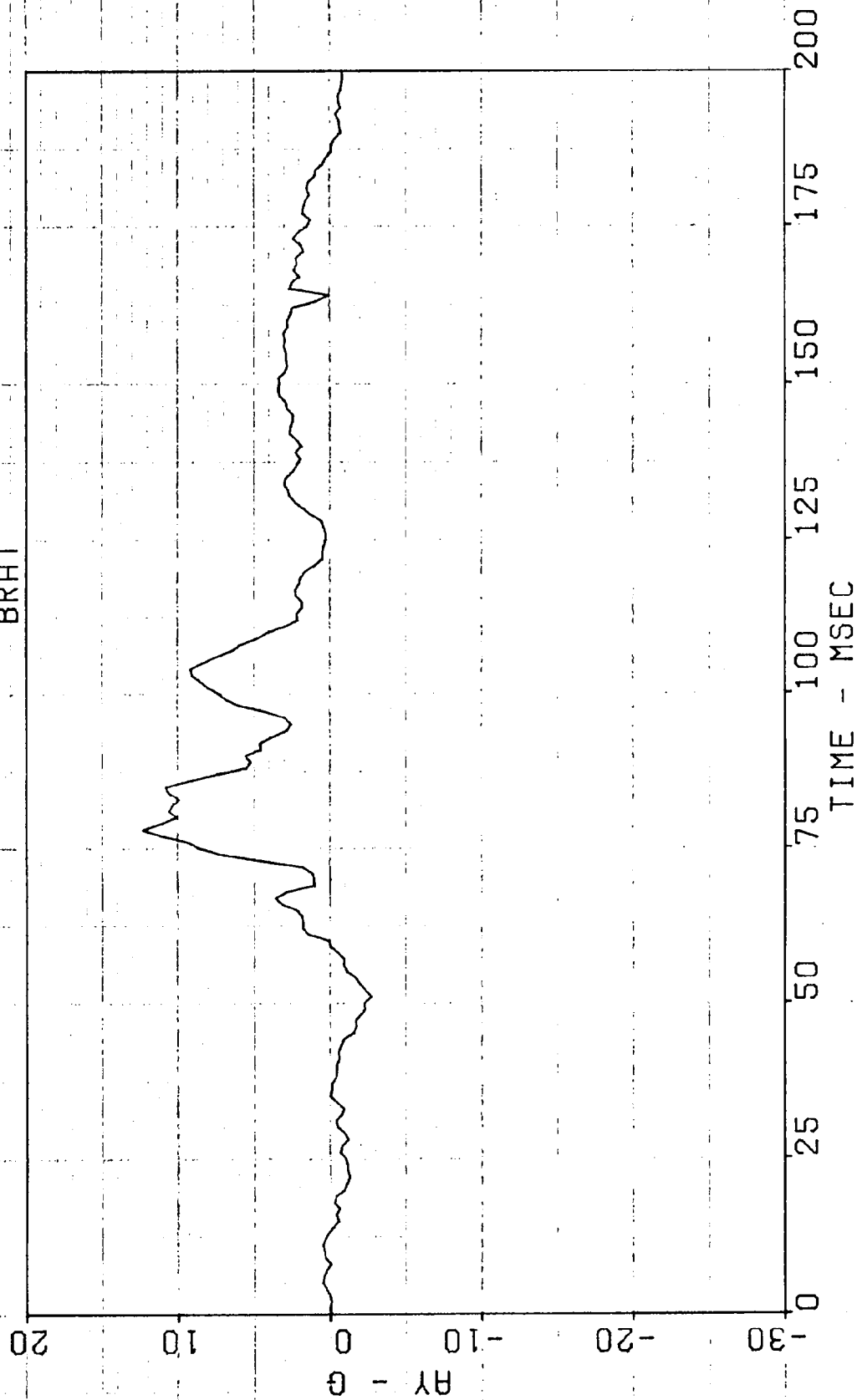


DATE 3-16-78 FILTER 1600 LOCATION 503 TEST NO 032878
SUBARU/BAR BRAT

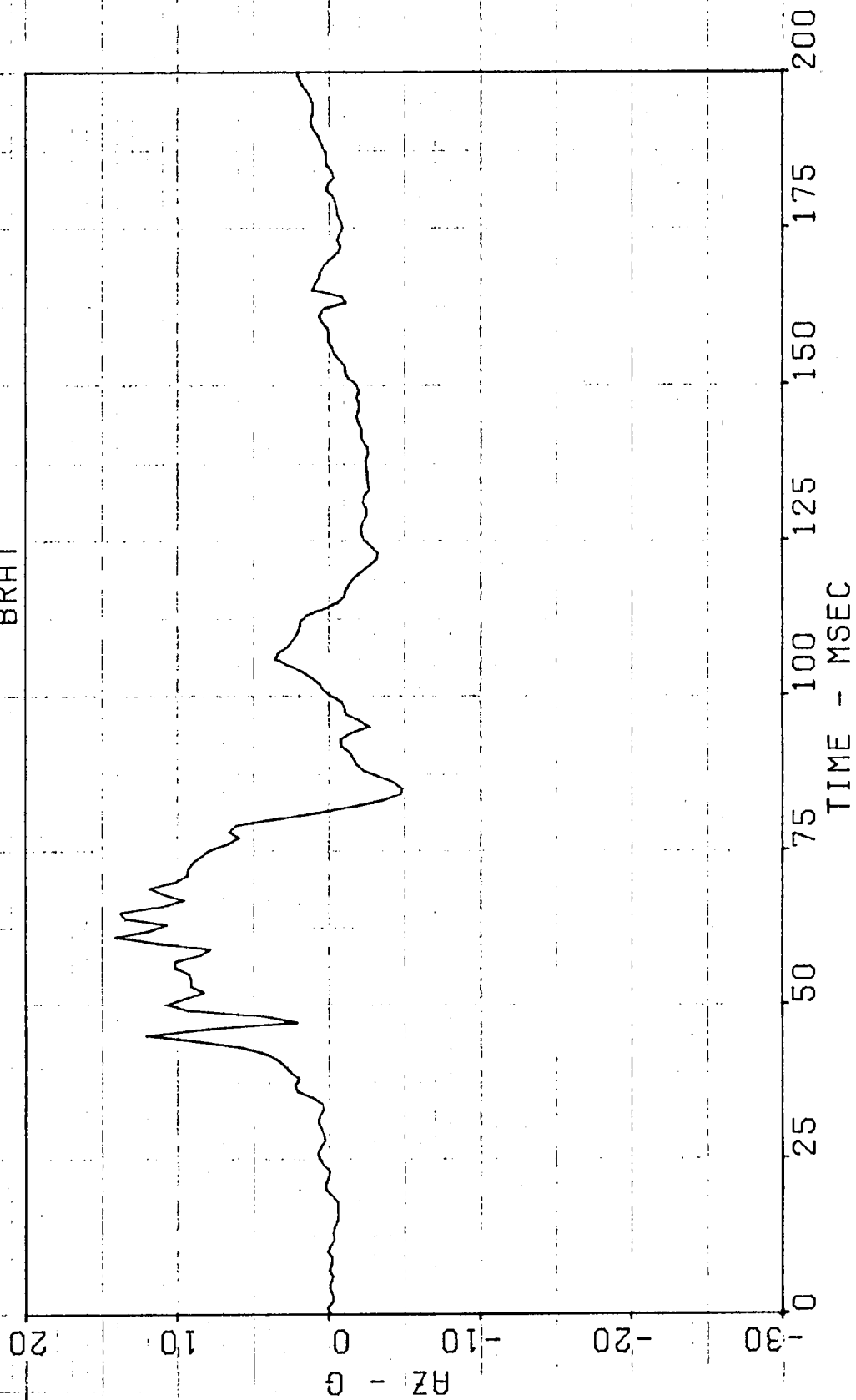




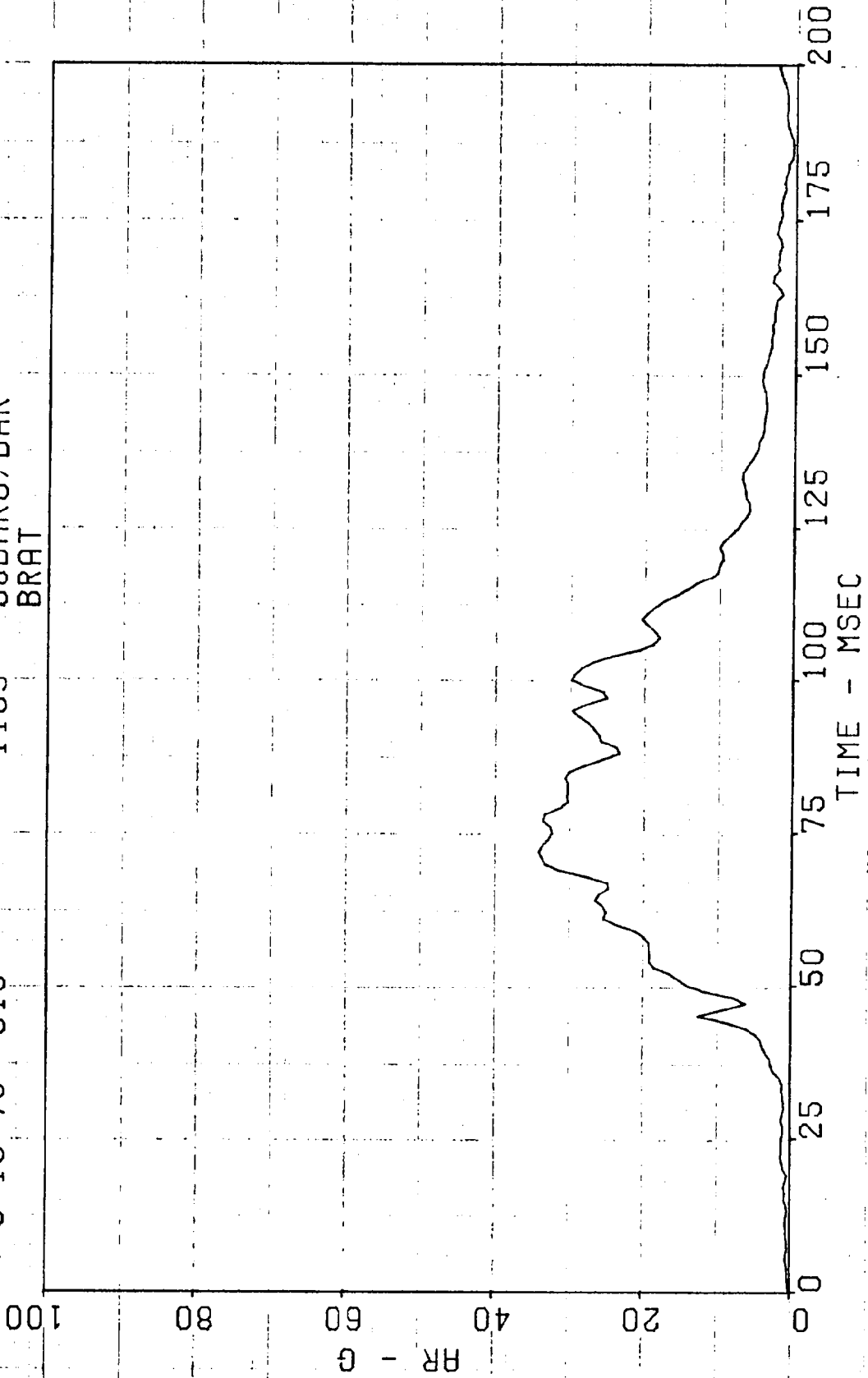
DATE 3-16-78 FILTER 315 LOCATION 1103 TEST NO 032878
SUBARU/BAR
BRAT



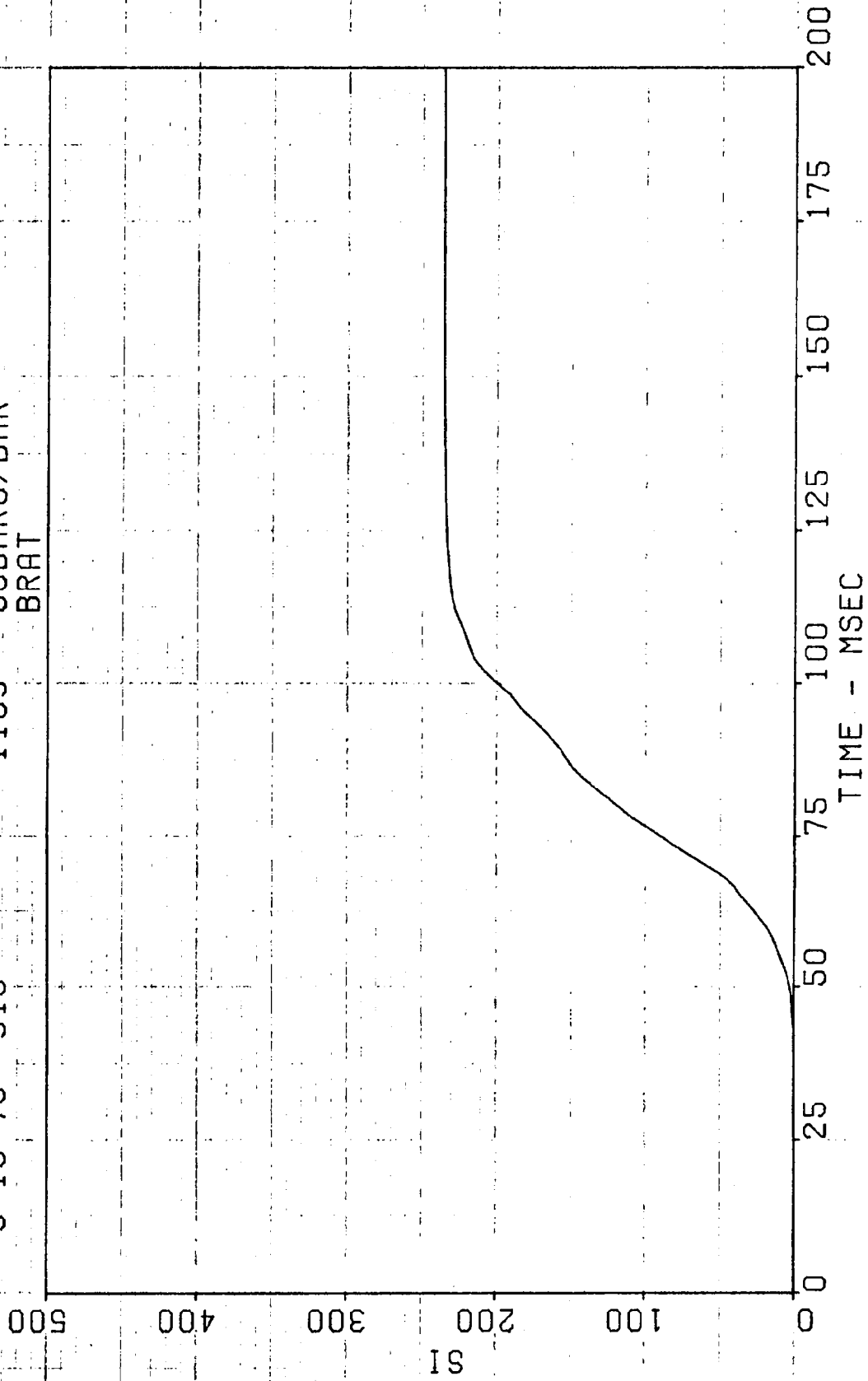
DATE 3-16-78 FILTER 315 LOCATION 1103 TEST NO 032878
SUBARU/BAR
BRAT



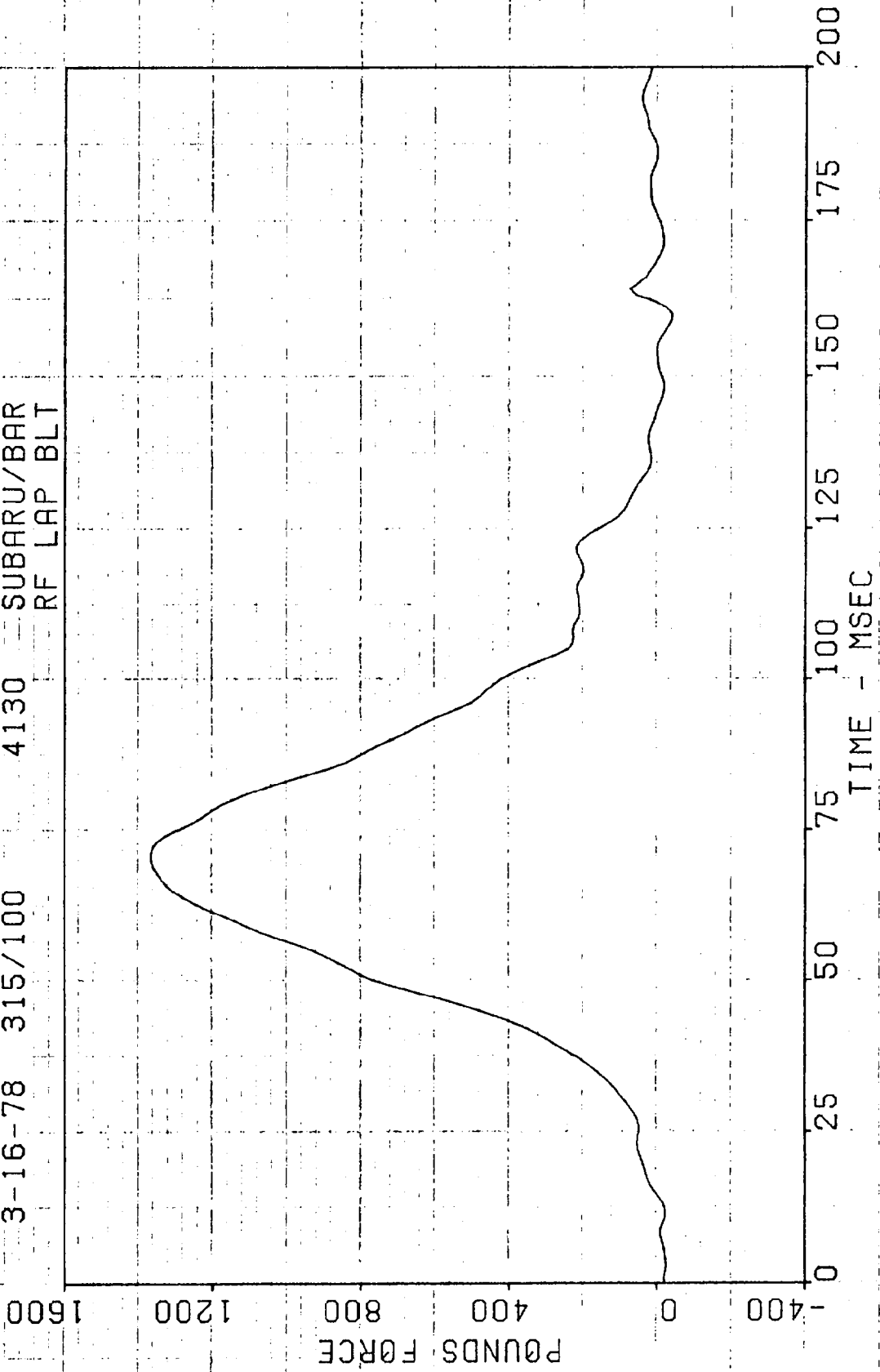
DATE 3-16-78 FILTER 315 LOCATION 1103 TEST NO 032878
SUBARU/BAR
BRAT



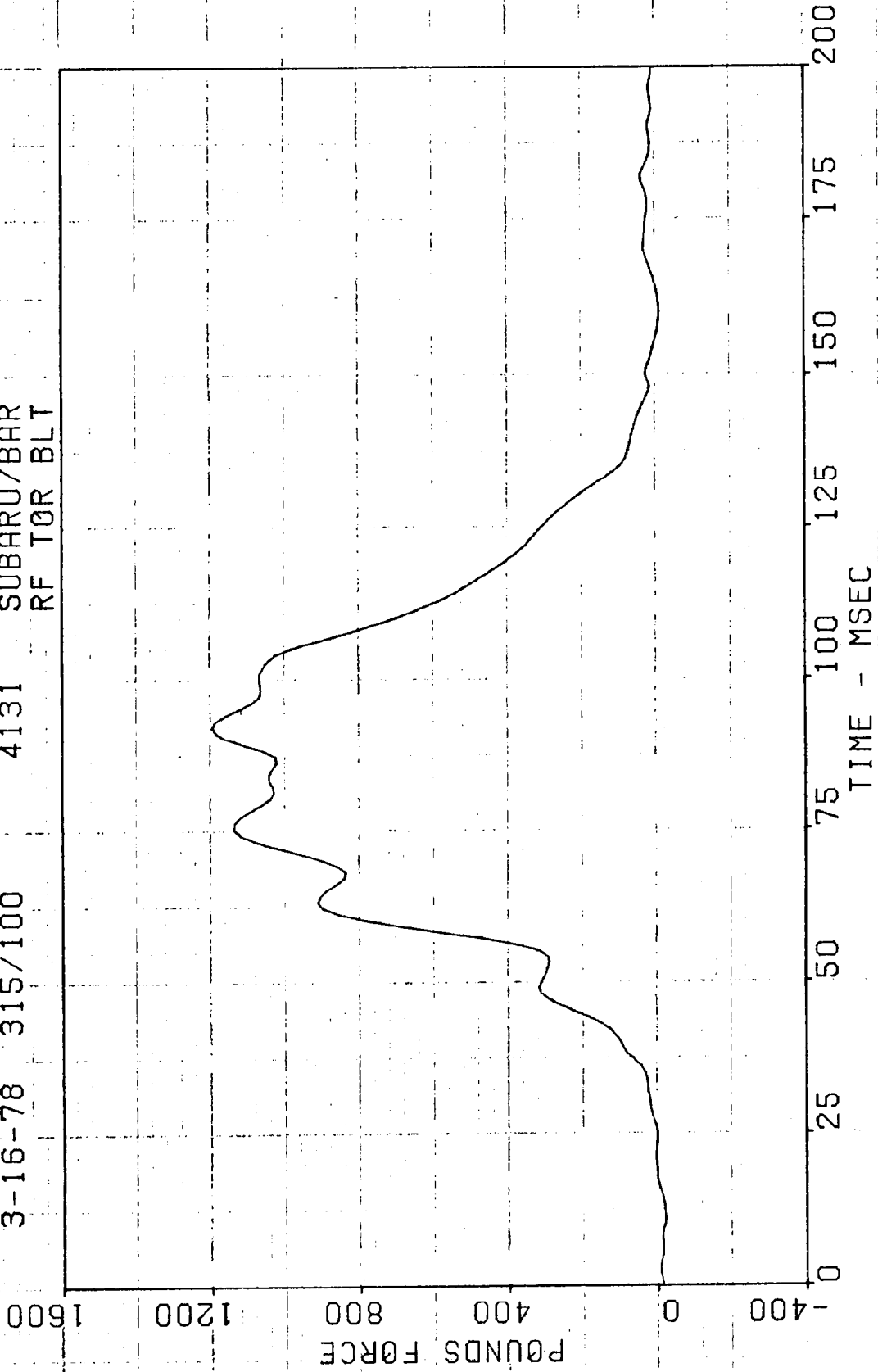
DATE 3-16-78 FILTER 315 LOCATION 1103 TEST NO 032878
SUBARU/BAR
BRAT



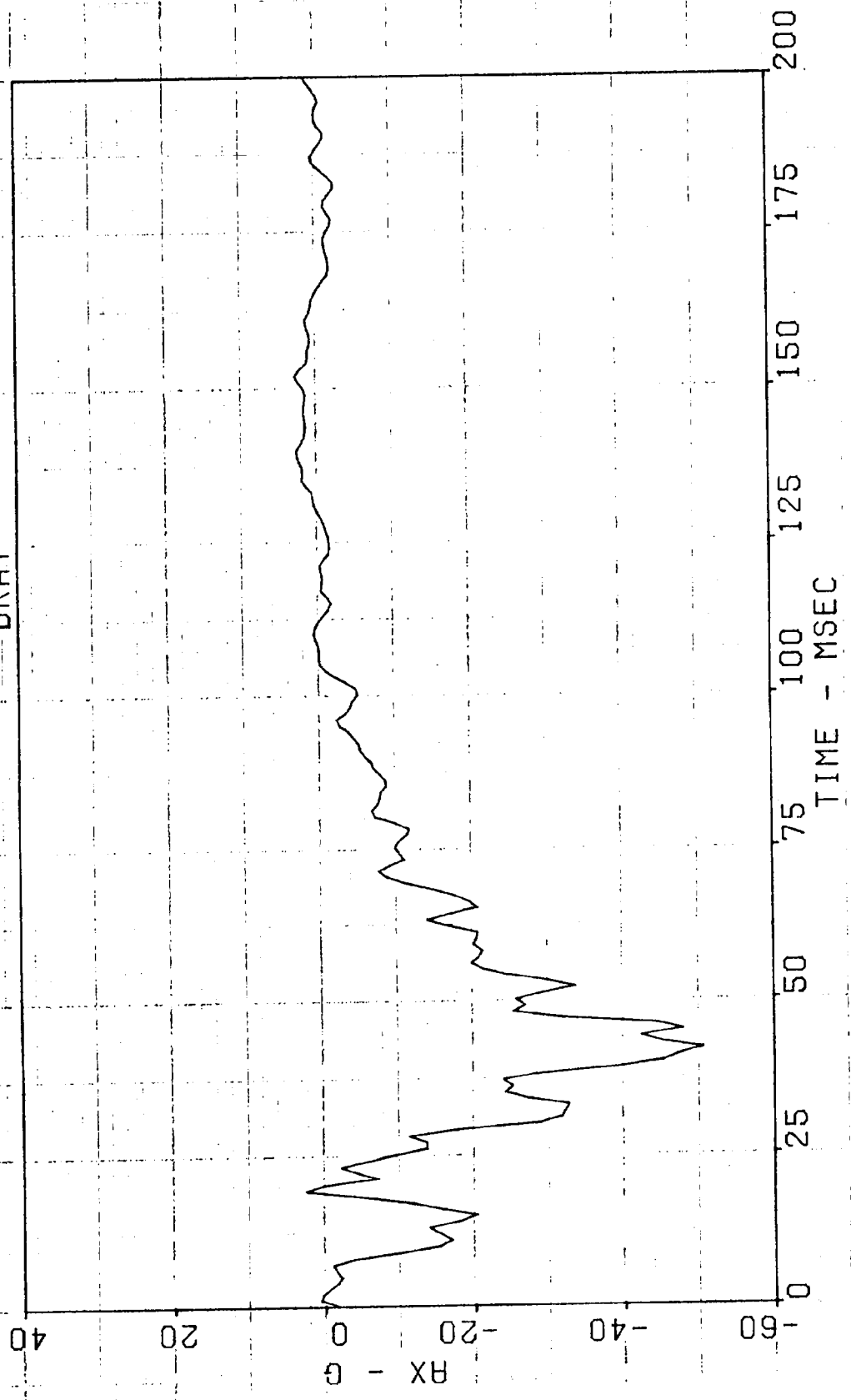
DATE 3-16-78 FILTER 315/100 LOCATION 4130 TEST NO 032878
SUBARU/BAR RF LAP BLT



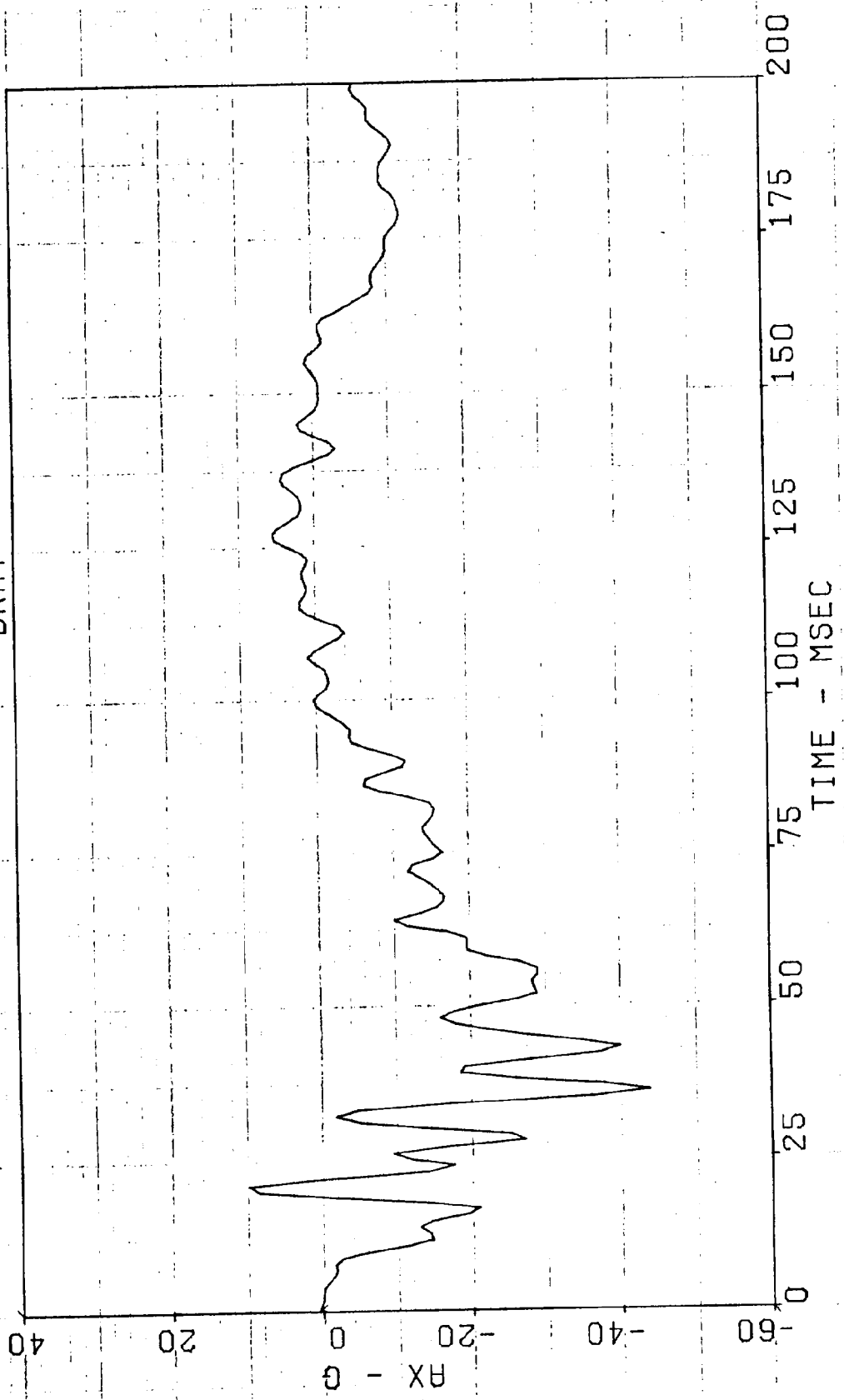
DATE 3-16-78 FILTER 315/100 LOCATION 4131 TEST NO 032878
SUBARU/BAR RF TOR BLT



DATE 3-16-78 FILTER 315/100 LOCATION 102 TEST NO 032878
SUBARU/BAR
BRAT



DATE 3-16-78 FILTER 315/100 LOCATION 103 TEST NO 032878
SUBARU/BAR
BRAT



DATE 3-16-78 FILTER 315/100 LOCATION 103 TEST NO 032878
SUBARU/BAR
BRAT

