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

VOLKSWAGEN OF AMERICA, INC.
1978 VOLKSWAGEN RABBIT FOUR-DOOR
CUSTOM HATCHBACK
NHTSA 780526

But E. Enserink
R. Pirtle

Contract DOT-HS-6-01478



August 1978

FINAL REPORT

Copies of this report are available from Technical Reference
Division, National Highway Traffic Safety Administration,
Room 5108, Nassif Building, 400 7th Street, S.W.
Washington, D.C. 20590

PREPARED FOR

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

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7. Author(s) _____, Project Engineer		8. Performing Orgn Rpt No. 3005-78-115										
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16. Abstract A 1978 Volkswagen Rabbit Four-Door Custom Hatchback (NHTSA 780526 - VIN 1783134991) was crash tested for compliance with FMVSS 301 (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 29.58 mph. The occupant response is summarized below: <table border="1"> <thead> <tr> <th></th> <th><u>DRIVER</u></th> <th><u>PASSENGER</u></th> </tr> </thead> <tbody> <tr> <td>Head Injury Criterion</td> <td>1551.9</td> <td>660.6</td> </tr> <tr> <td>Chest Severity Index</td> <td>448.20</td> <td>233.21</td> </tr> </tbody> </table> Peak vehicle accelerations were as follows: Occupant Compartment - Front: 39.1 @ 55 msec Occupant Compartment - Rear: 13.3 @ 31 msec					<u>DRIVER</u>	<u>PASSENGER</u>	Head Injury Criterion	1551.9	660.6	Chest Severity Index	448.20	233.21
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures			
Symbol	When You Know	Multiply by	To Find
LENGTH			
in	inches	2.5	centimeters
ft	feet	30	centimeters
yd	yards	0.9	meters
mi	miles	1.6	kilometers
AREA			
in ²	square inches	6.5	square centimeters
ft ²	square feet	0.09	square meters
yd ²	square yards	0.8	square meters
mi ²	square miles	2.6	square kilometers
acres	acres	0.4	hectares
MASS (weight)			
oz	ounces	28	grams
lb	pounds	0.45	kilograms
	short tons	0.9	metric ton
	(2000 lb)		
VOLUME			
tsp	teaspoons	5	milliliters
Tbsp	tablespoons	15	milliliters
in ³	cubic inches	16	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
ft ³	cubic feet	0.03	cubic meters
yd ³	cubic yards	0.76	cubic meters
TEMPERATURE (exact)			
°F	degrees Fahrenheit	5 (after subtracting 32)	degrees Celsius

Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find
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			
cm ²	square centimeters	0.16	square inches
m ²	square meters	1.2	square yards
km ²	square kilometers	0.4	square miles
ha	hectares	2.5	acres
	(10 000 m ²)		
MASS (weight)			
g	grams	0.035	ounces
kg	kilograms	2.2	pounds
t	metric ton	1.1	short tons
	(1000 kg)		
VOLUME			
mL	milliliters	0.03	fluid ounces
mL	milliliters	0.06	cubic inches
L	liters	2.1	pints
L	liters	1.06	quarts
L	liters	0.26	gallons
m ³	cubic meters	35	cubic feet
m ³	cubic meters	1.3	cubic yards
TEMPERATURE (exact)			
°C	degrees Celsius	9 (then add 32)	degrees Fahrenheit

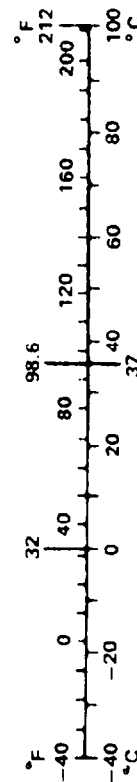


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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the effort documented herein was to acquire occupant response and vehicle acceleration data in a 1978 Volkswagen Rabbit Four-Door Custom Hatchback (NHTSA 780526) 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 (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 and FMVSS 219 submitted to and approved by the NHTSA FMVSS 301/219 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 301/219 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: Volkswagen of America, Inc.

Make/Model: Volkswagen Rabbit

Body Style: Four-Door Hatchback Year: 1978

VIN: 1783134991 Build Date: 10/77

NHTSA No.: 780526 Color: Blue

Engine: 4 Cylinders, 1457 cc

Transmission: 4 speeds, Manual X Automatic

Major Options: Tinted Glass, Rear Window Defrost

Seating Capacity: Front 2 Rear 2 Total 4

Capacity Weight (lb): 807

GVWR (lb): Front 1609 Rear 1278 Total 2822

Recommended Cold Tire Pressure (psi): Front 27 Rear 31

Tire Size: 155 SR13

Load Range: B

Tires on Vehicle: 155 SR13

Delivered-Vehicle Values (fluids to capacity)

Weights (lb)

Wheel: RF 584 LF 571 RR 360 LR 369

Axle : F 1155 (61.3 %) R 729 (38.7 %)

Total: 1884

Attitude (in.)

RF 31.0 LF 31.0 RR 31.0 LR 31.0

Target Vehicle Test Weight (lb): 2419

2.2 TEST CONDITIONS

Date: June 26, 1978

Time: 1056

Temperature: 95 °F

Test Speed (mph): 29.58

Vehicle Weights (lb)

Wheel: RF 706 LF 709 RR 480 LR 532

Axle : F1415 (58.3 %) R1012 (41.7%)

Total: 2427

Vehicle Attitude (in.)

RF 30.0 LF 29.8 RR 28.3 LR 28.9

Pre-test Dummy Positions

<u>Measurement</u>	<u>Driver (in.)</u>	<u>Passenger (in.)</u>
Dummy Centerline to Vehicle Centerline	15.1	14.1
Nose to Upper Rim Steering Wheel	17.8	-
Nose to Windshield (Horizontal Distance)	-	24.4
Left Knee to Closest Point on Lower Panel	7.8	7.6
Right Knee to Closest Point on Lower Panel	8.2	7.4
Ankle Distance	9.8	9.0
Knee Distance	9.0	9.8

Additional dummy positioning information is presented in the
PART 512 DUMMY IN-VEHICLE POSITION RECORDING SHEET which follows.

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

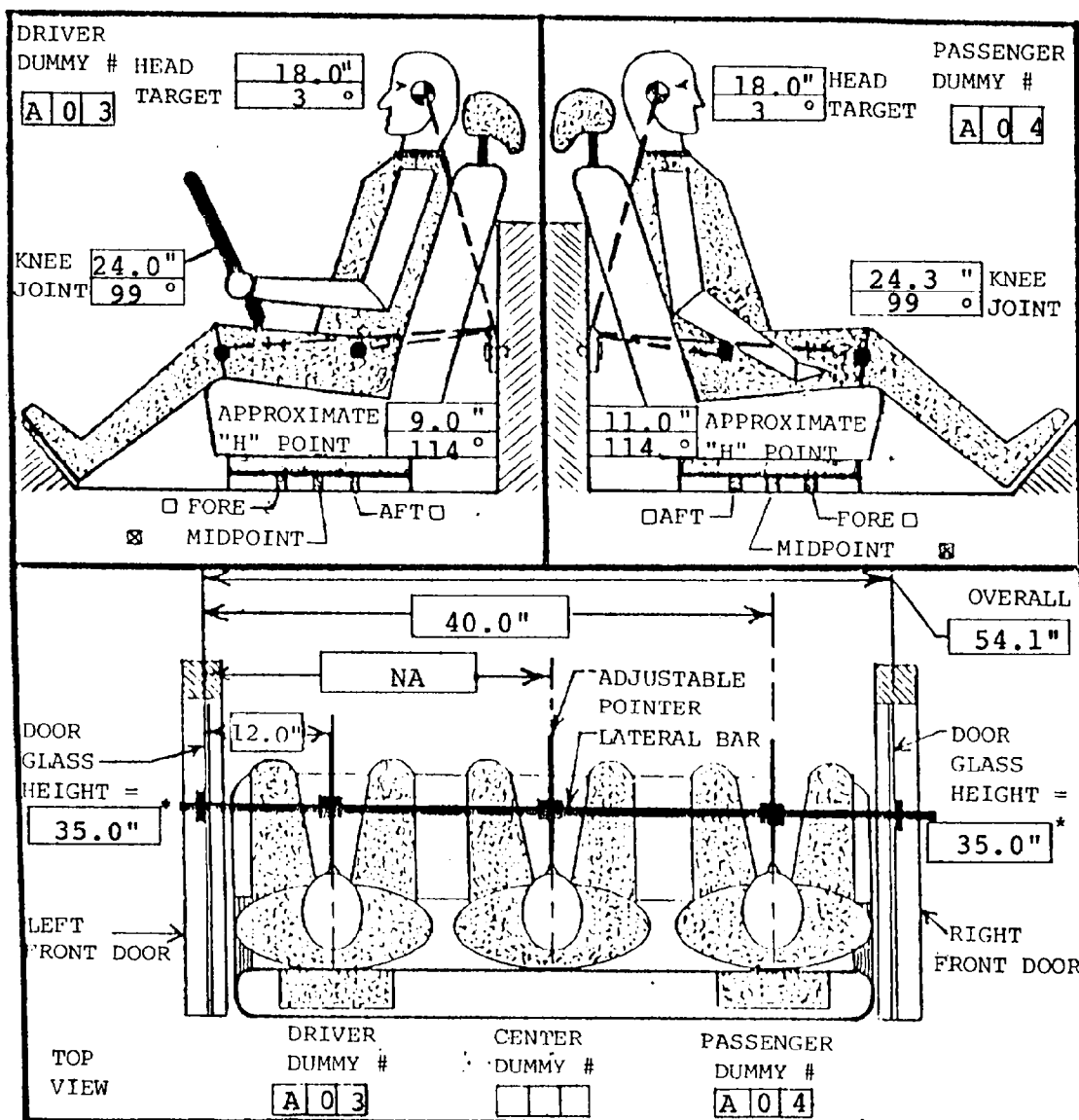
VEH. NHTSA NO.: 7 8 0 5 2 6 MFR./MAKE/MODEL Volkswagen Rabbit

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

POSITIONING DATE: June 26, 1978; TECHNICIANS: 1. R. Pirtle

AMBIENT TEMP.: 96 °F TIME: 1030 2. _____

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.

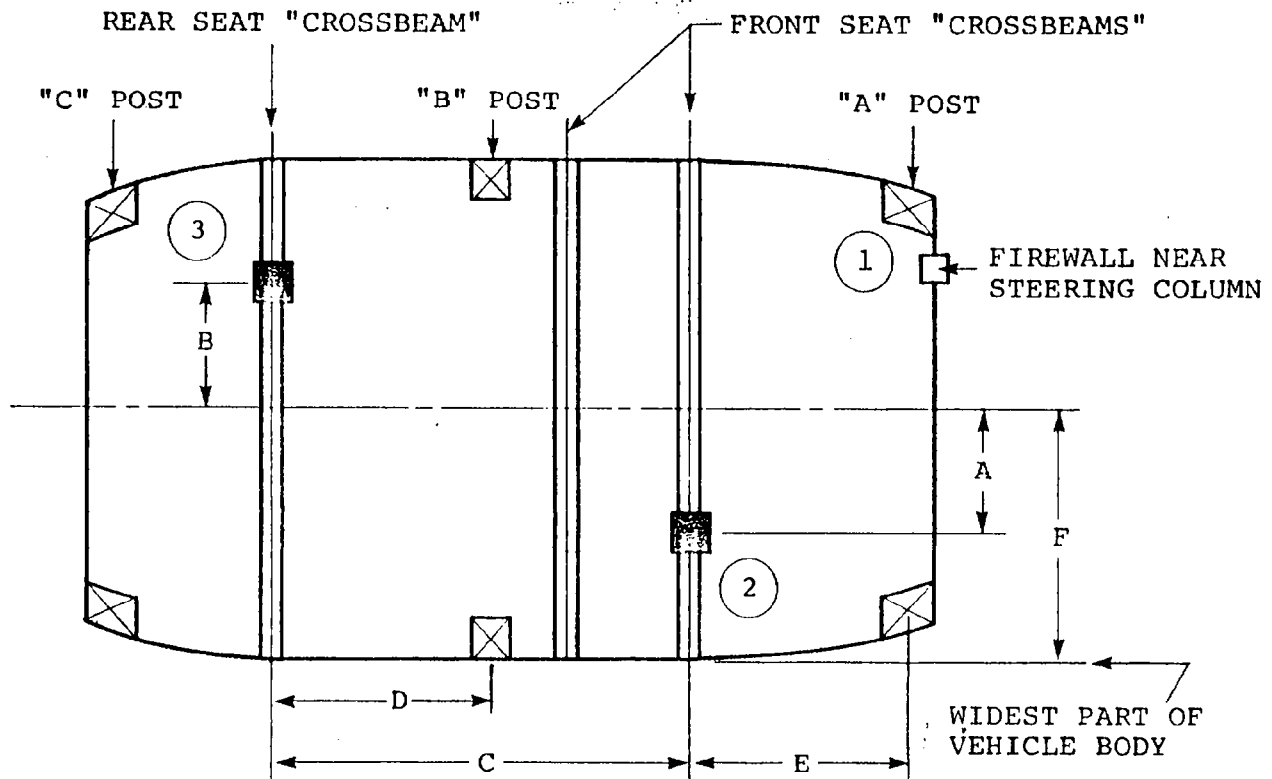
PART 572 DUMMY DATA SHEET

	Driver				Passenger							
	Positive* Direction		Negative* Direction		Positive* Direction		Negative* Direction					
	Peak G	Time (msec)	Peak G	Time (msec)	Peak G	Time (msec)	Peak G	Time (msec)				
Head Acceleration												
Longitudinal	10.72	20	216.67	86	5.60	33	30.84	132				
Lateral	15.84	136	33.64	87	17.30	129	5.84	66				
Vertical	113.4	89	24.87	86	67.46	105	6.90	16				
Resultant	219.4	86			68.63	105						
HIC	1551.9 (84-94 msec)				660.6 (70-148 msec)							
Chest Acceleration												
Longitudinal	5.11	147	55.86	97	1.47	162	40.46	78				
Lateral	32.46	21	15.24	97	14.64	99	2.96	67				
Vertical	28.37	21	22.62	92	17.42	66	14.13	98				
Resultant	58.61	95			41.78	78						
SEVERITY INDEX	448.20				233.21							
Belt Loads	(lb)	Time (msec)			(lb)	Time (msec)						
Lap	1669	72			1390	69						
Torso	699	80			1677	86						
Vehicle Impact Speed (mph): 29.58												
*Positive Direction - Longitudinal: Forward Lateral: Rightward Vertical: Downward Negative Direction - Longitudinal: Rearward Lateral: Leftward Vertical: Upward												

VEHICLE STRUCTURAL DATA

VEHICLE Volkswagen Rabbit NHTSA NO. 780526
 TEST SPEED 29.58 TEST DATE June 26, 1978

00087608



DIMENSIONS								
Location		Measurement (in.)		Location		Measurement (in.)		
A		11.0		D		27.5		
B		17.0		E		14.0		
C				F				
Steering Column Movement (in.) <u>1.0 forward, .4 left, 2.2 upward</u>								
Vehicle Overall Crush (in.) <u>21.5 Static (see page 3.1)</u>								
Test Weight (lb) <u>2427</u>								
ACCELERATION PEAKS (CLASS 60 FILTER)								
Location		Positive* Direction		Negative* Direction		Average Longitudinal (G)	Dynamic Crush	
		Peak G	Time (msec)	Peak G	Time (msec)		Amount (ft)	Time (msec)
No. 1 Longitudinal								
No. 1 Vertical								
No. 2 Longitudinal		1.61	66	39.11	55		2.10	85
No. 3 Longitudinal		1.21	126	13.84	31		.00	
No. 3 Vertical		5.74	32	8.19	65			
*Positive Direction - Longitudinal: Forward, Vertical: Downward <u>Negative Direction</u> - 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 29.58 mph, based on the 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 26.8 inches. The average overall static crush of the vehicle was 21.5 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:

- Steering wheel and dash rotated upward.
- Body damage to "B" pillar.
- Right wheel rotated to right, independent of left.
- Both front wheels locked up.
- Both front doors bowed out at forward edge.

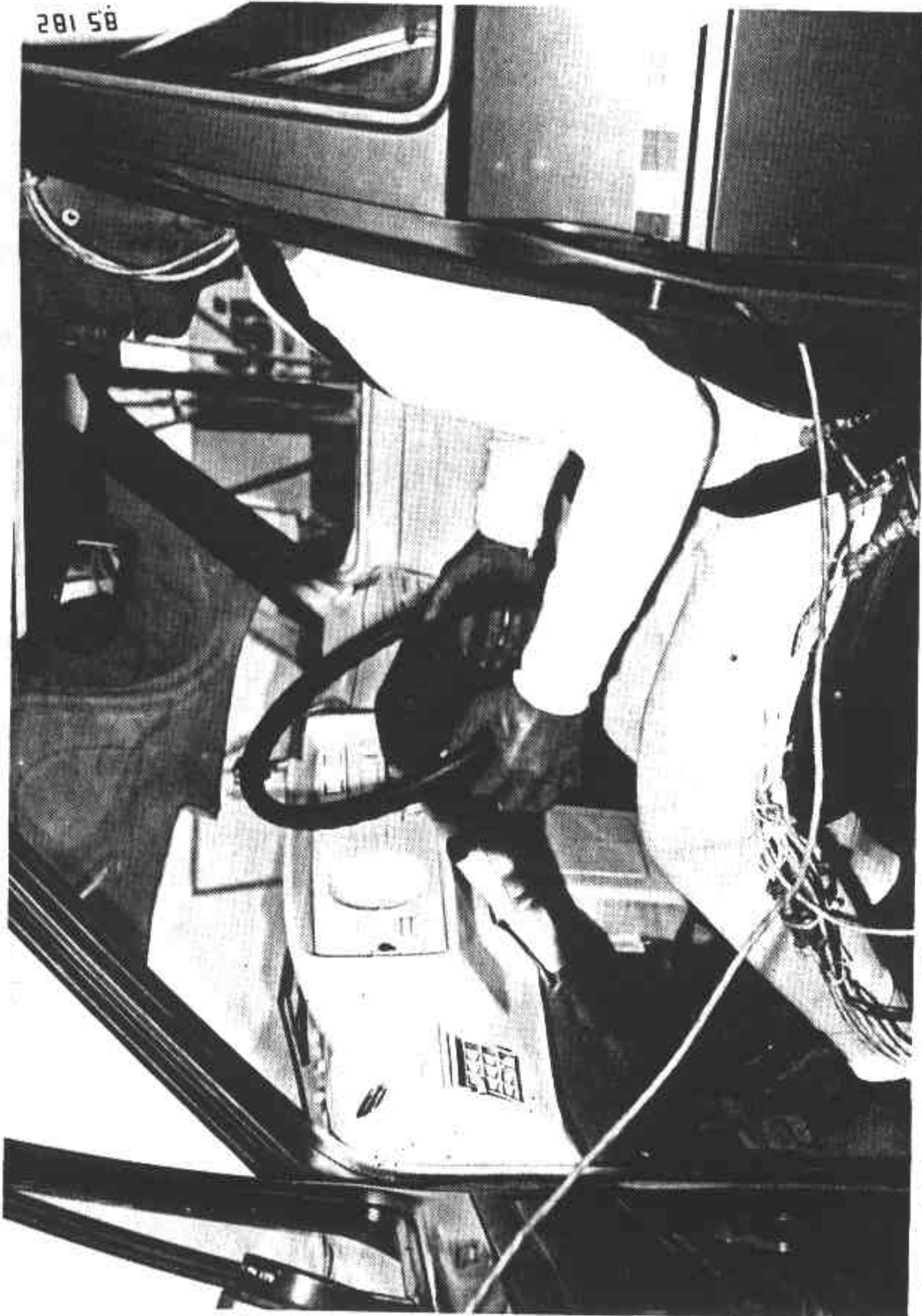


Figure 3-1. Pre-test View of Driver Dummy - 1978 Volkswagen Rabbit Four-Door Custom Hatchback - NHTSA 780526.

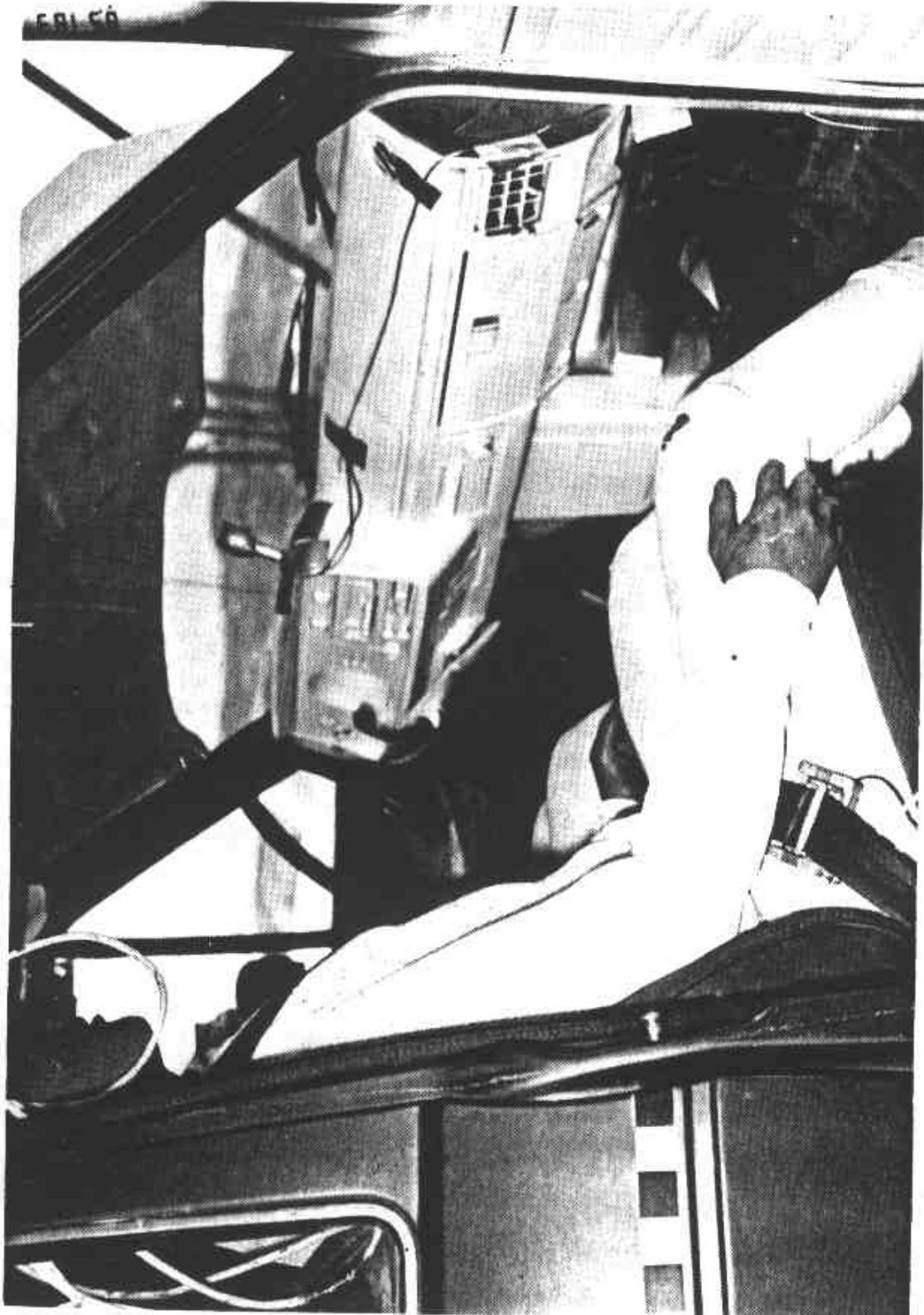


Figure 3-2. Pre-test View of Passenger Dummy - 1978 Volkswagen Rabbit Four-Door Custom Hatchback - NHTSA 780526.

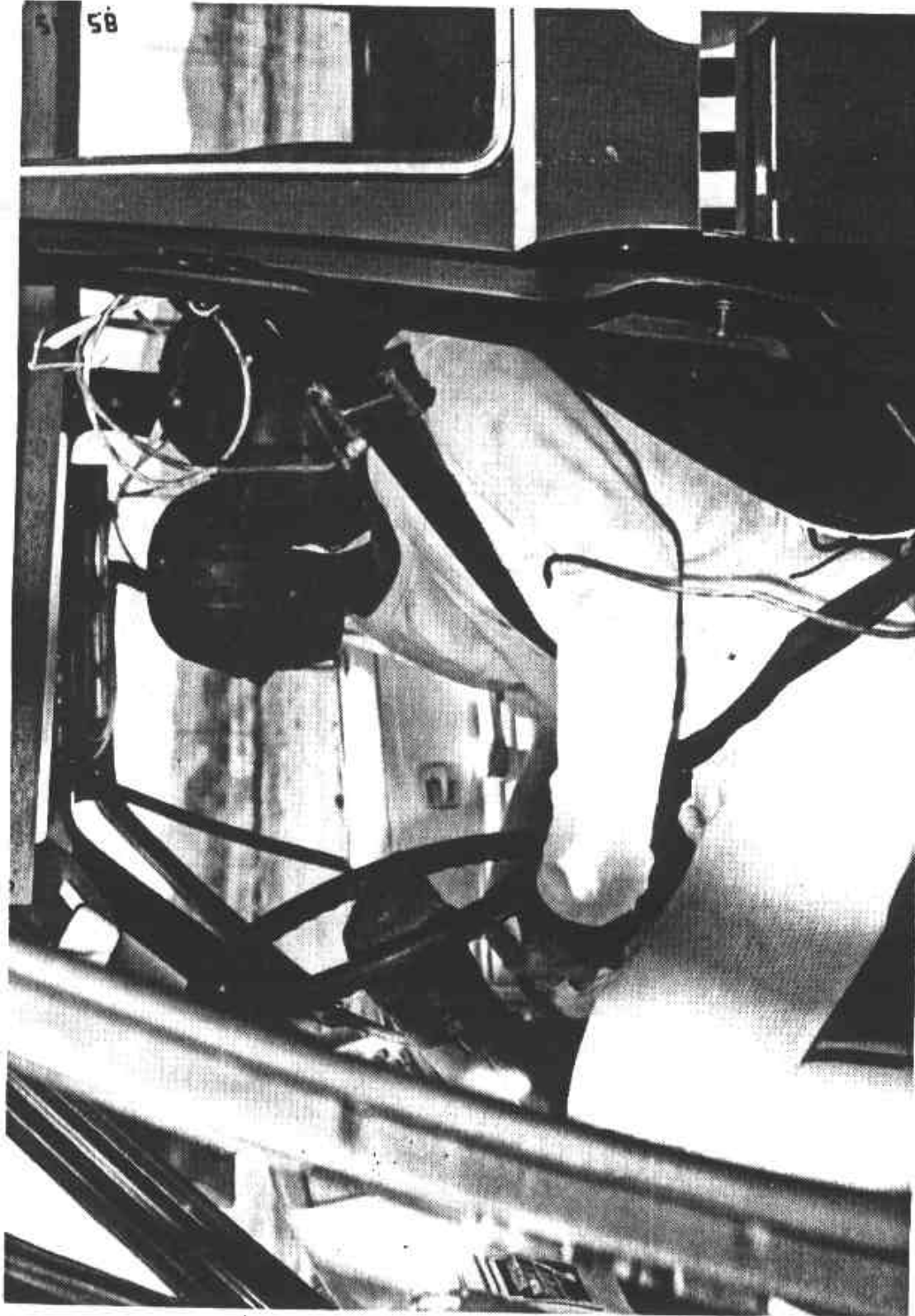


Figure 3-3. Post-test View of Driver Dummy - 1978 Volkswagen Rabbit Four-Door Custom Hatchback - NHTSA 780526.



Figure 3-4. Post-test View of Passenger Dummy - 1978 Volkswagen Rabbit Four-Door Custom Hatchback - NHTSA 780526.

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	$\pm 7.5\%$	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.

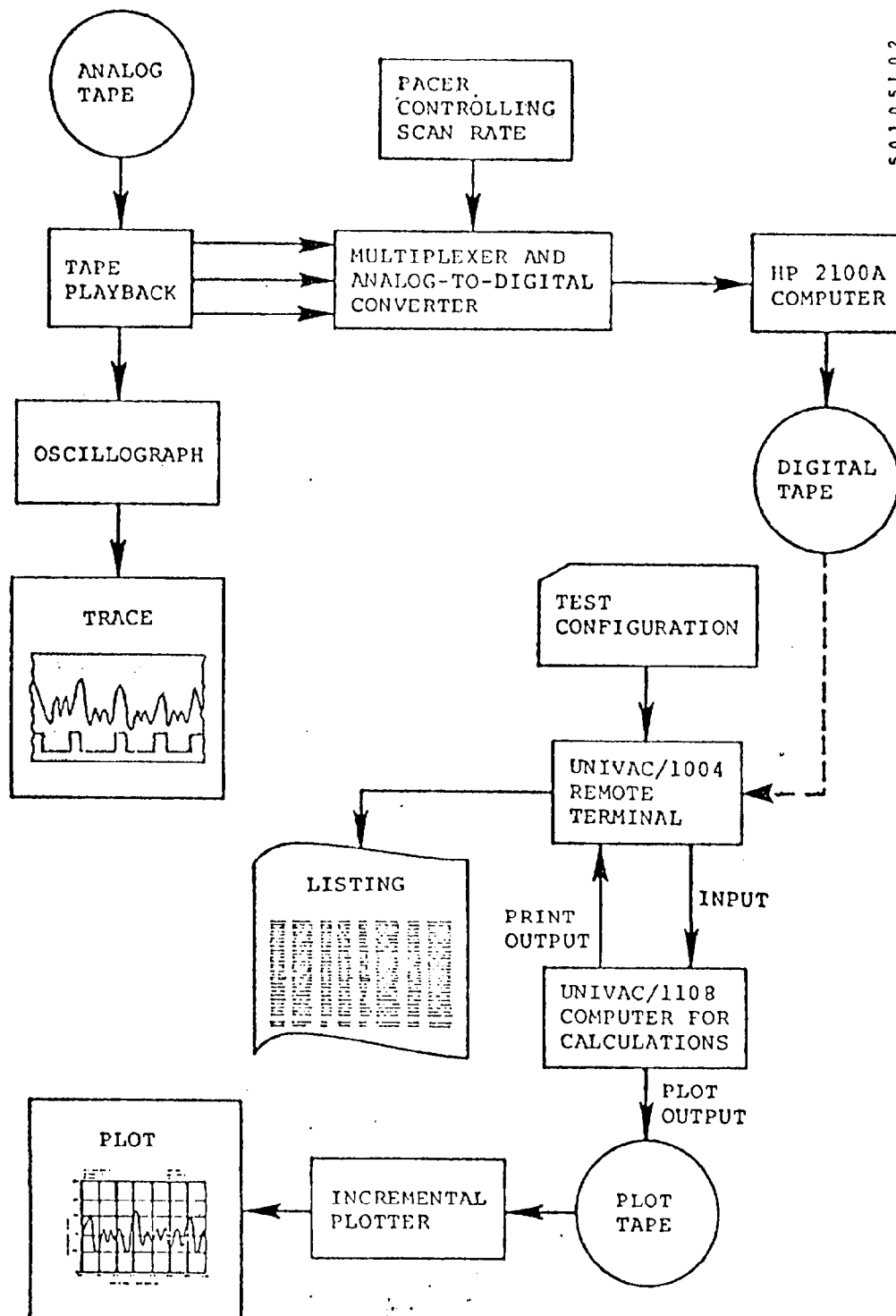


Figure 4-1. Data Reduction Flow Diagram.

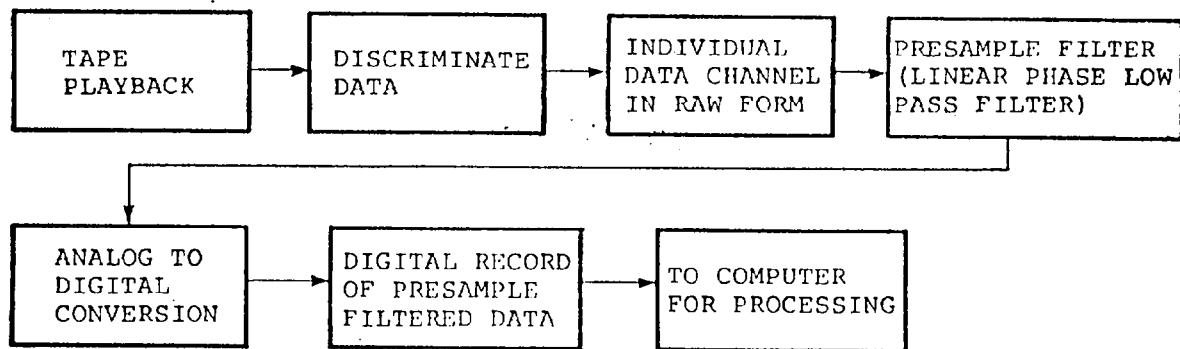


Figure 4-2. Flow of Individual Data Channel.

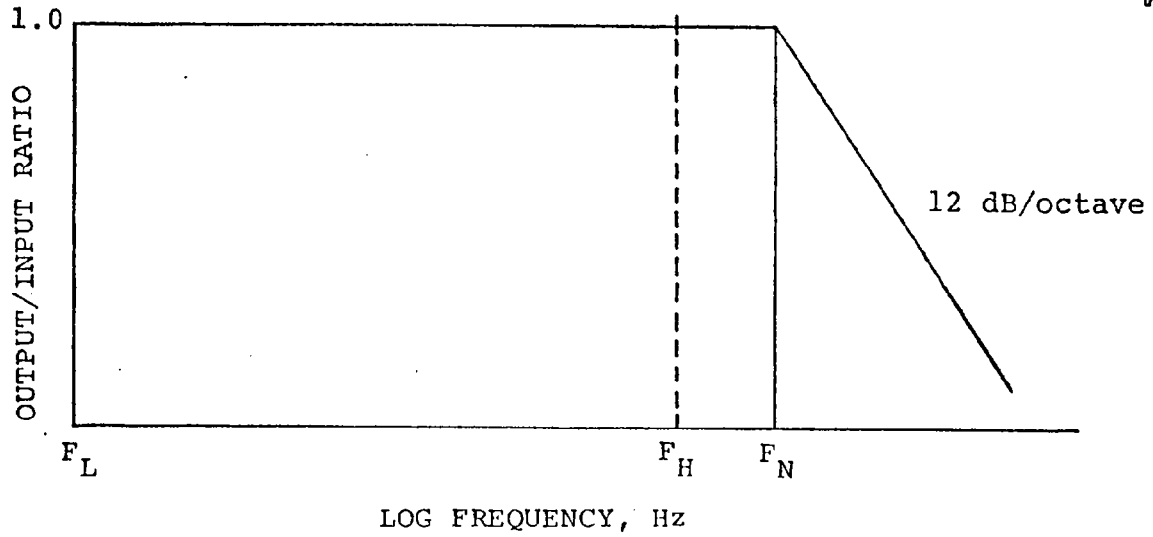
Item	Data Class	Presample Filter (3dB Frequency)	Sampling Rate	Digital Filter Cutoff Frequency
Chest Accelerations	180	250	1000	Not Filtered
Head Accelerations	1000	2000 Hz	8000	1650

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.

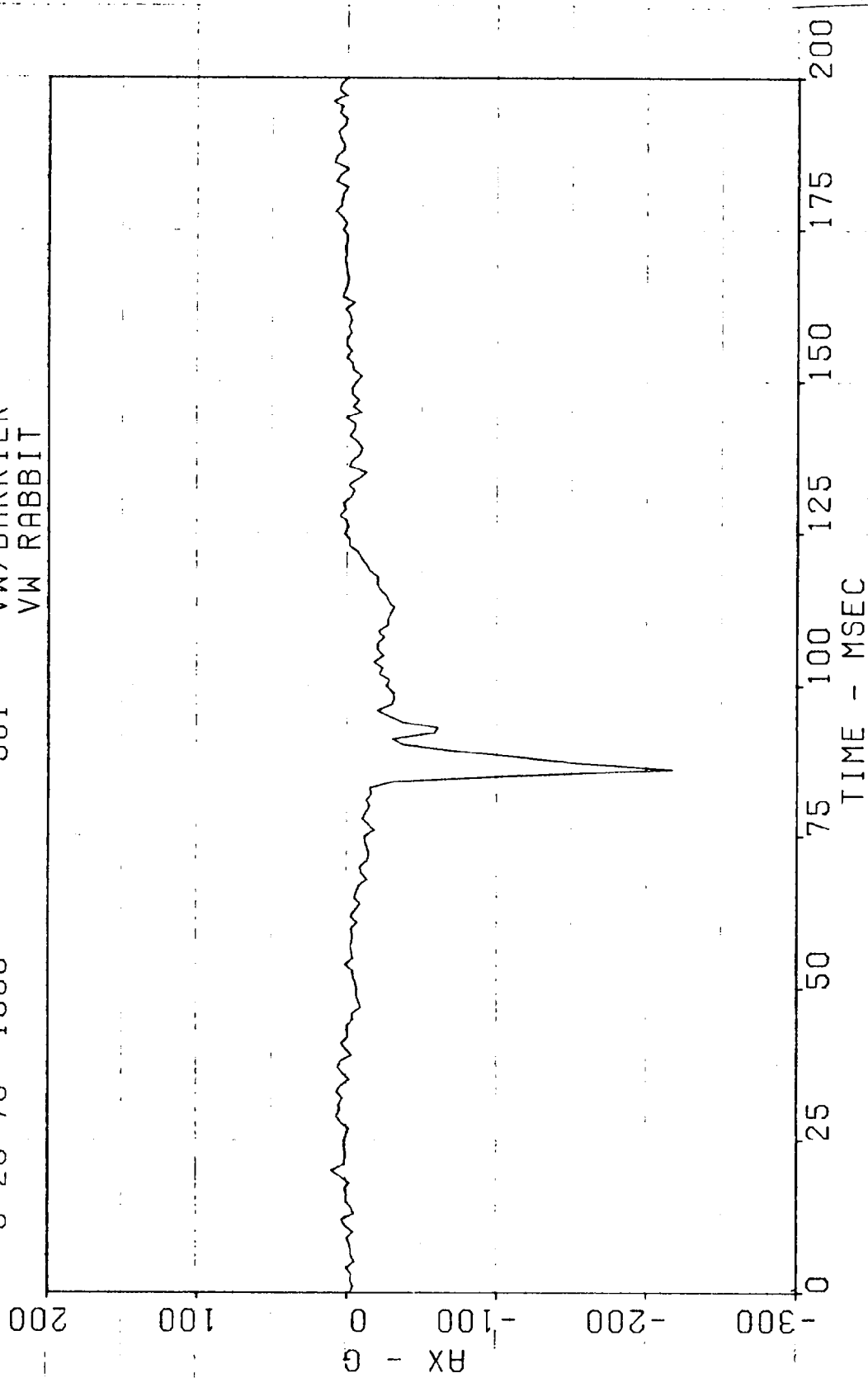
APPENDIX

CALCOMP PLOTS

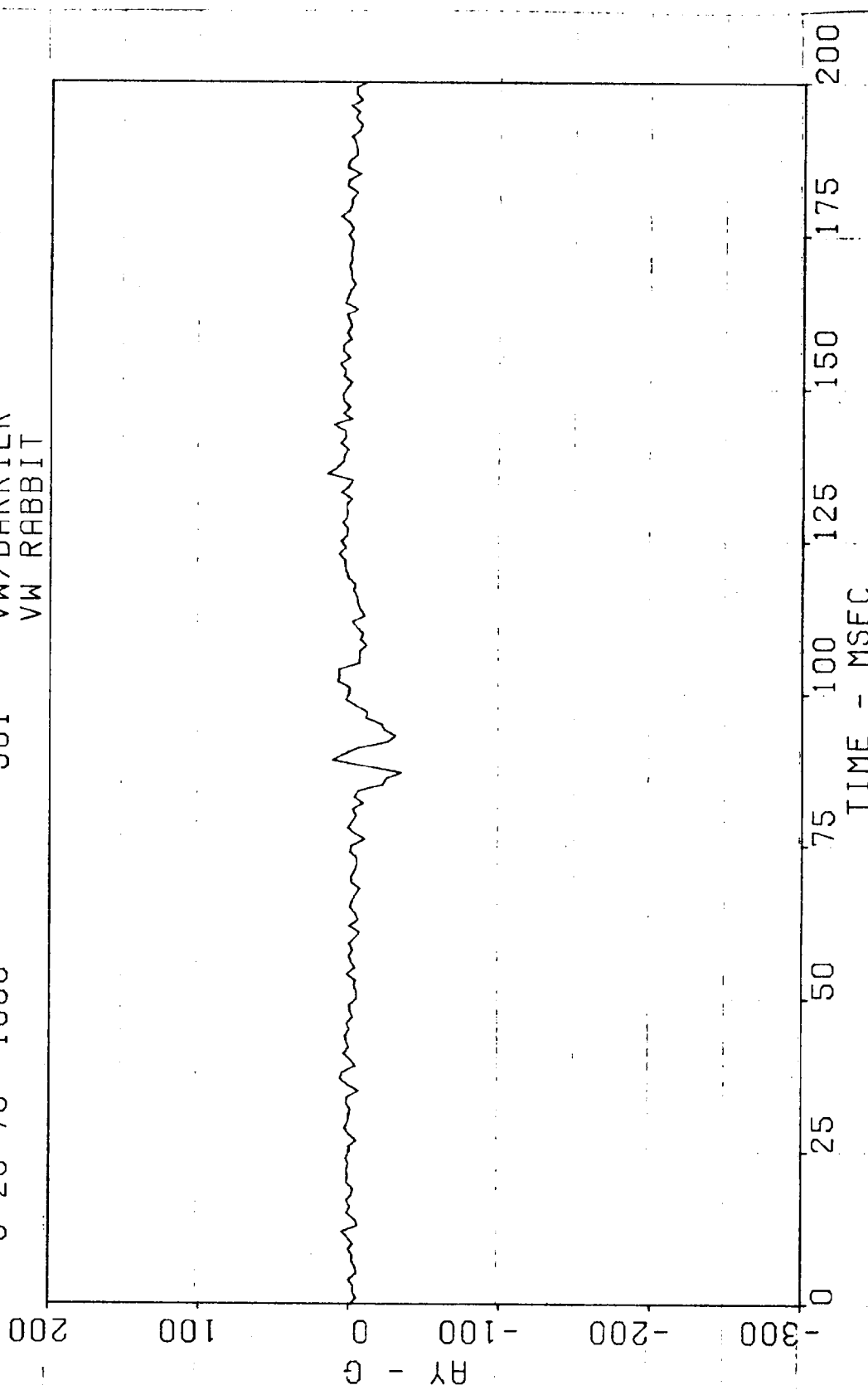
The following location numbers are used in the CalComp plot titles to identify transducer locations.

<u>Location</u>	<u>Number</u>
Driver Head Accelerometer	501
Driver Chest Accelerometer	1101
Driver Lap Belt Load Cell	4001L
Driver Torso Belt Load Cell	4001T
Passenger Head Accelerometer	503
Passenger Chest Accelerometer	1103
Passenger Lap Belt Load Cell	4003L
Passenger Torso Belt Load Cell	4003T
Occupant Compartment Front Accelerometer	102
Occupant Compartment Rear Accelerometer	104

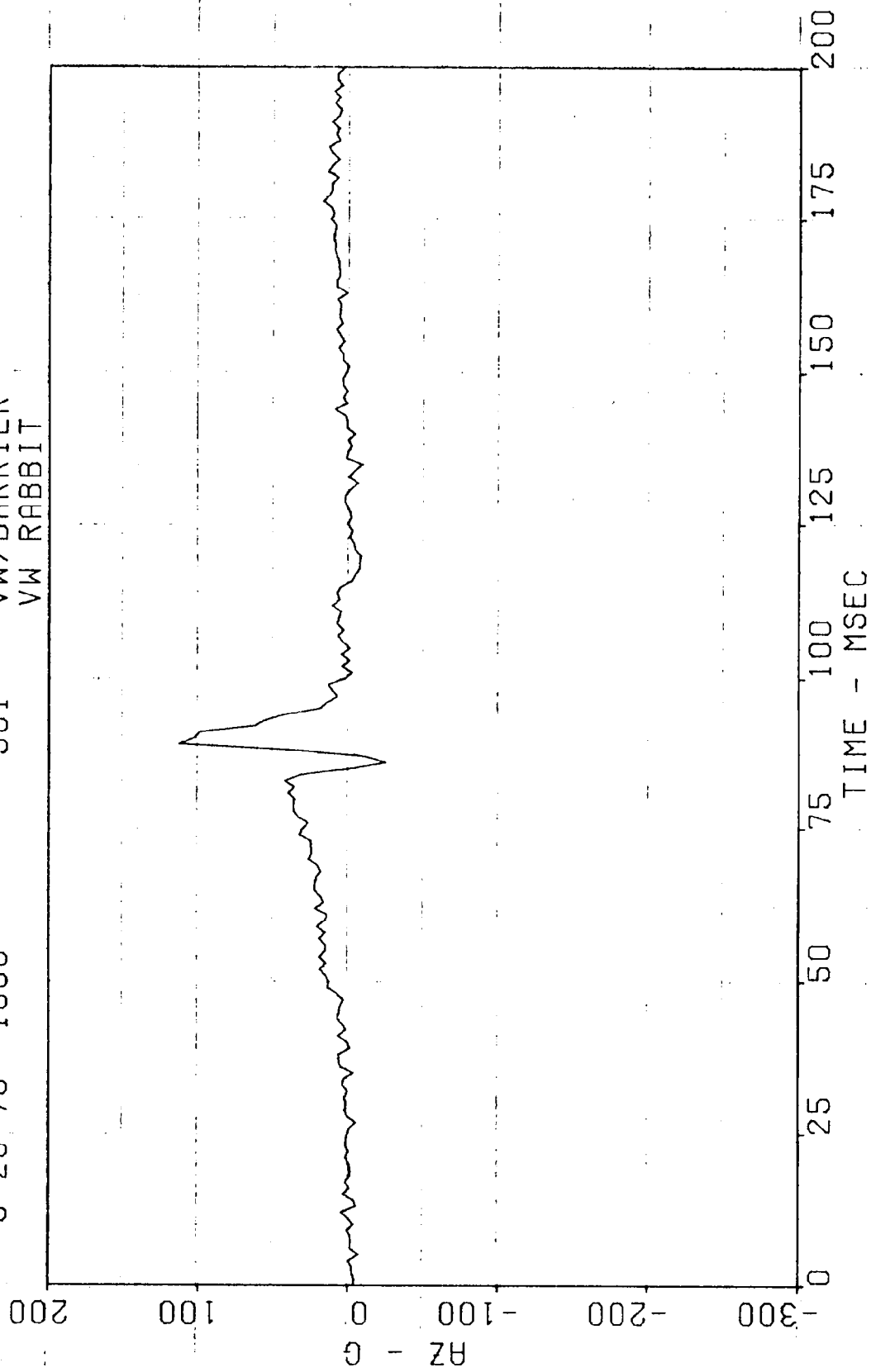
DATE 6-26-78 FILTER 1600 LOCATION 501 TEST NO 072678
VW/BARRIER
VW RABBIT



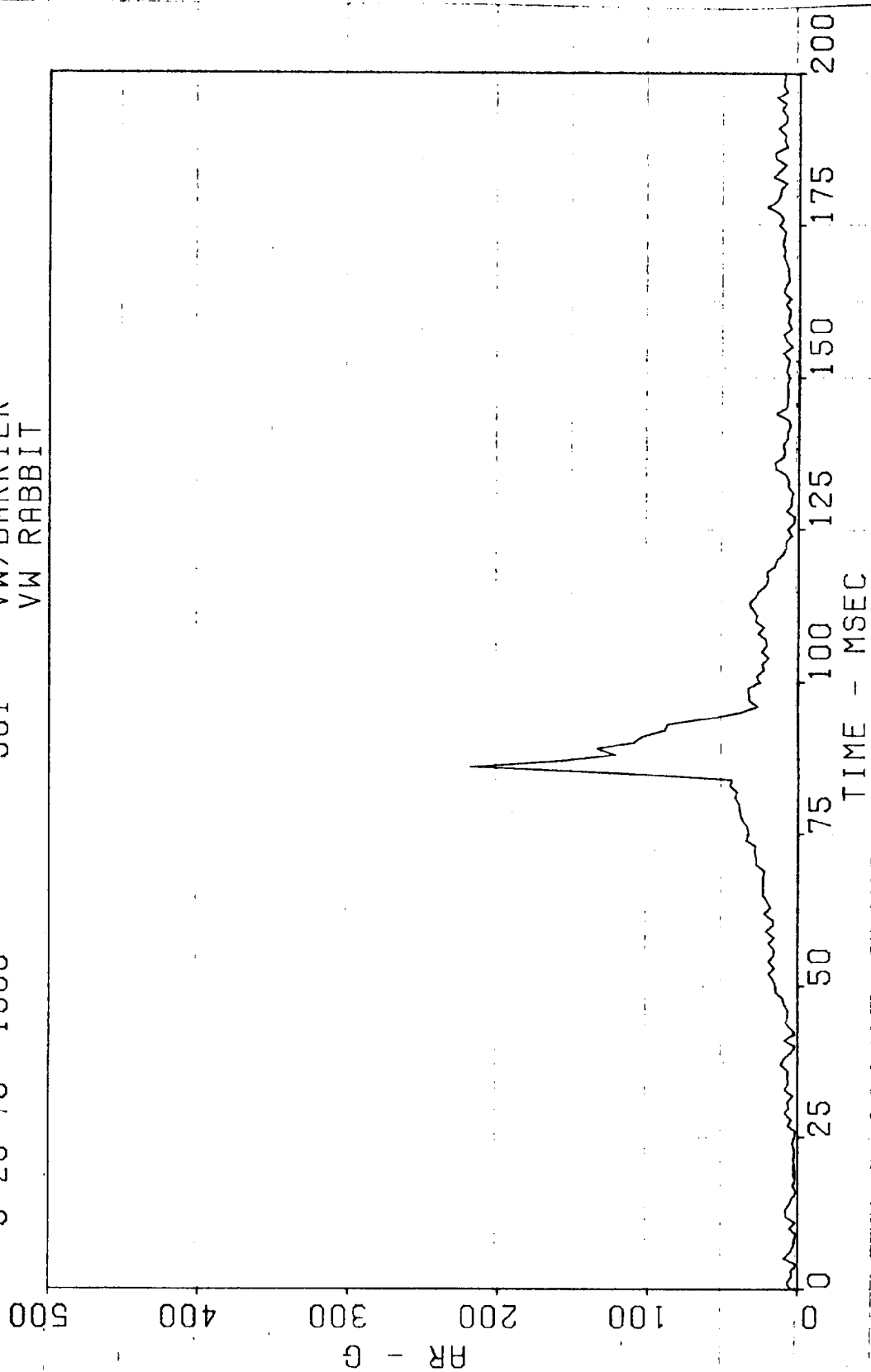
DATE 6-26-78 FILTER 1600 LOCATION 501 TEST NO 072678
VW/BARRIER
VW RABBIT



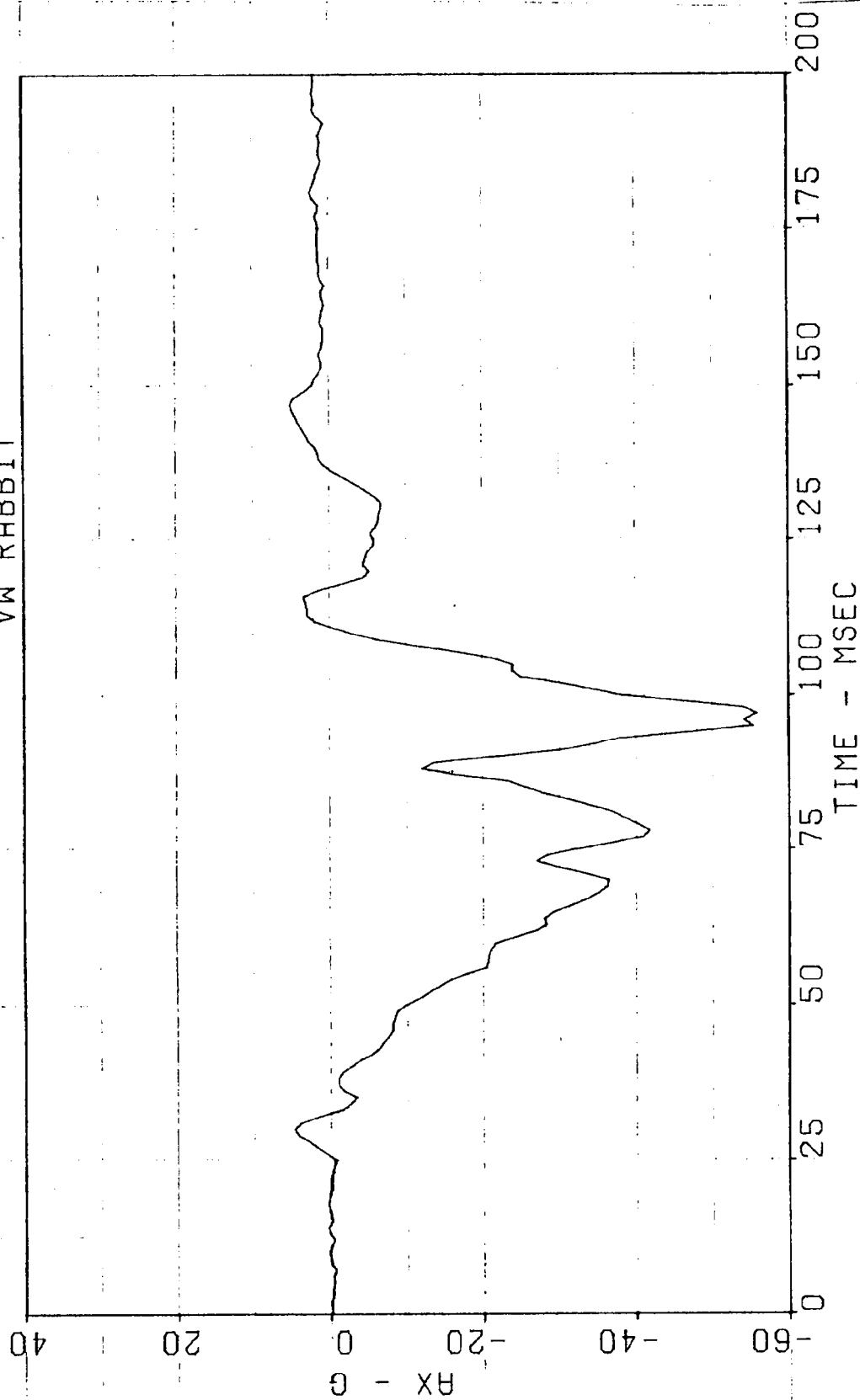
DATE 6-26-78 FILTER 1600 LOCATION 501 TEST NO 072678
VW/BARRIER
VW RABBIT



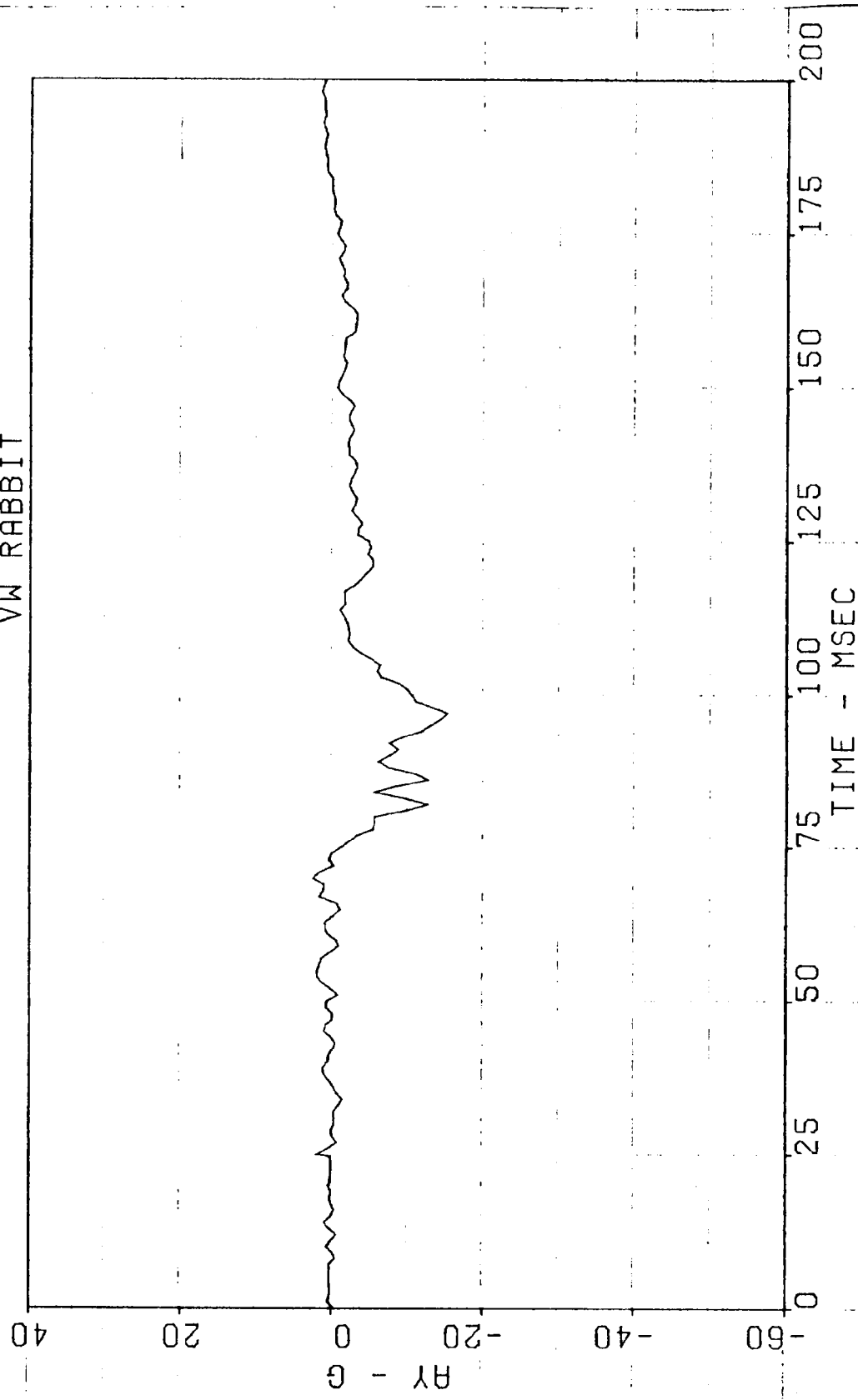
DATE 6-26-78 FILTER 1600 LOCATION 501 TEST NO 072678
VW/BARRIER
VW RABBIT



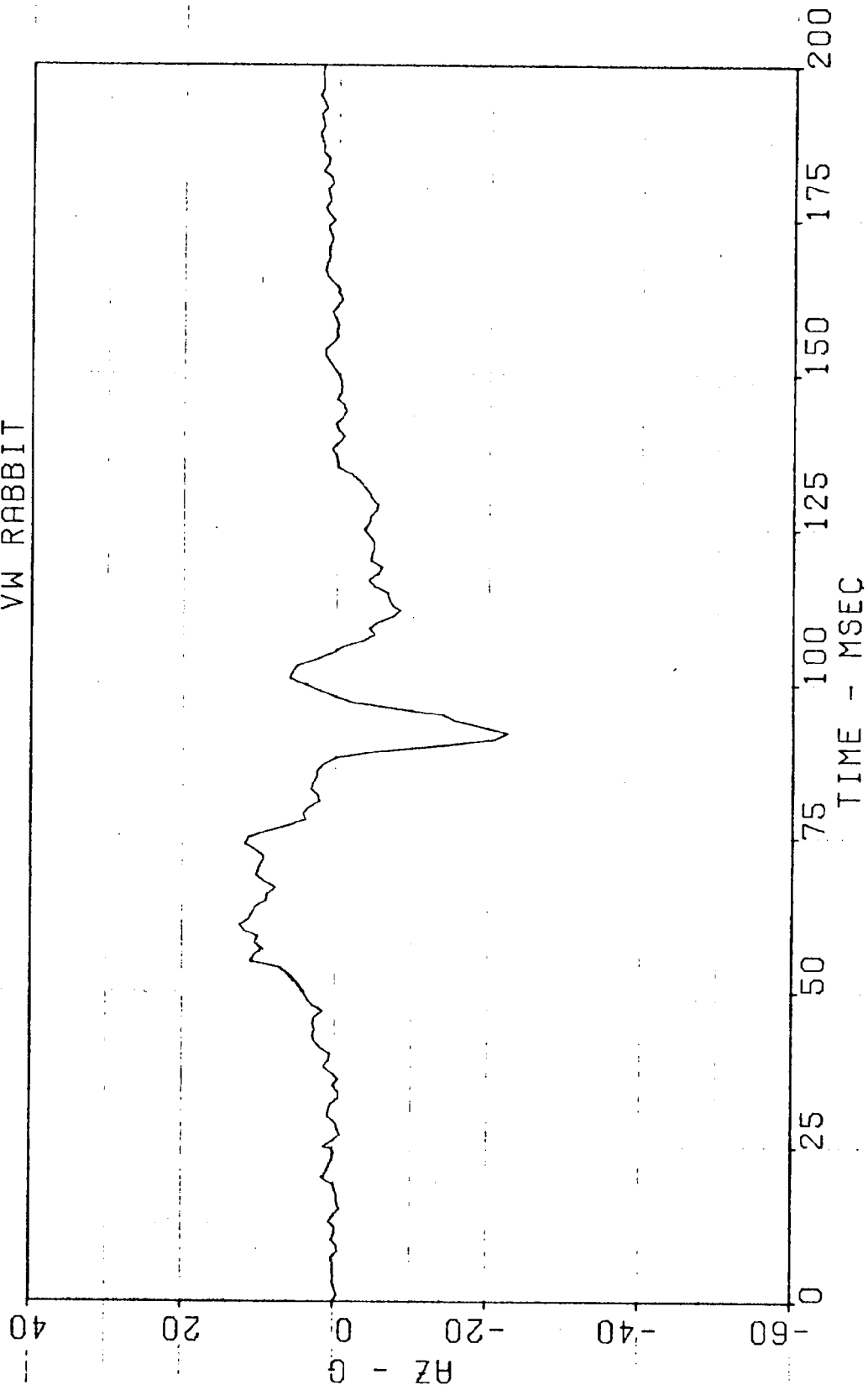
DATE 6-26-78 FILTER 315 LOCATION 1101 TEST NO 072678
VW/BARRIER
VW RABBIT



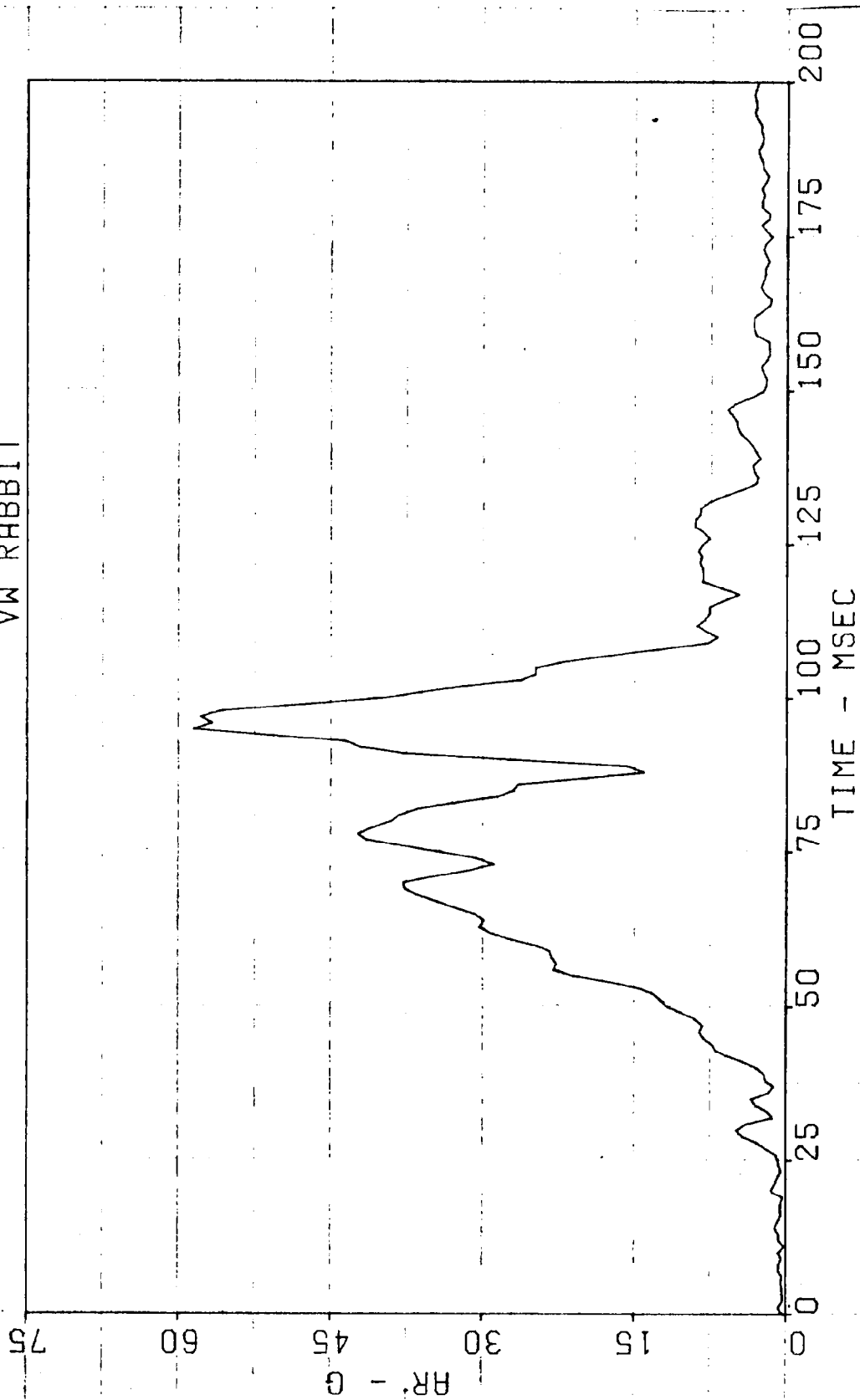
DATE 6-26-78 FILTER 315 LOCATION 1101 TEST NO 072678
VW/BARRIER
VW RABBIT



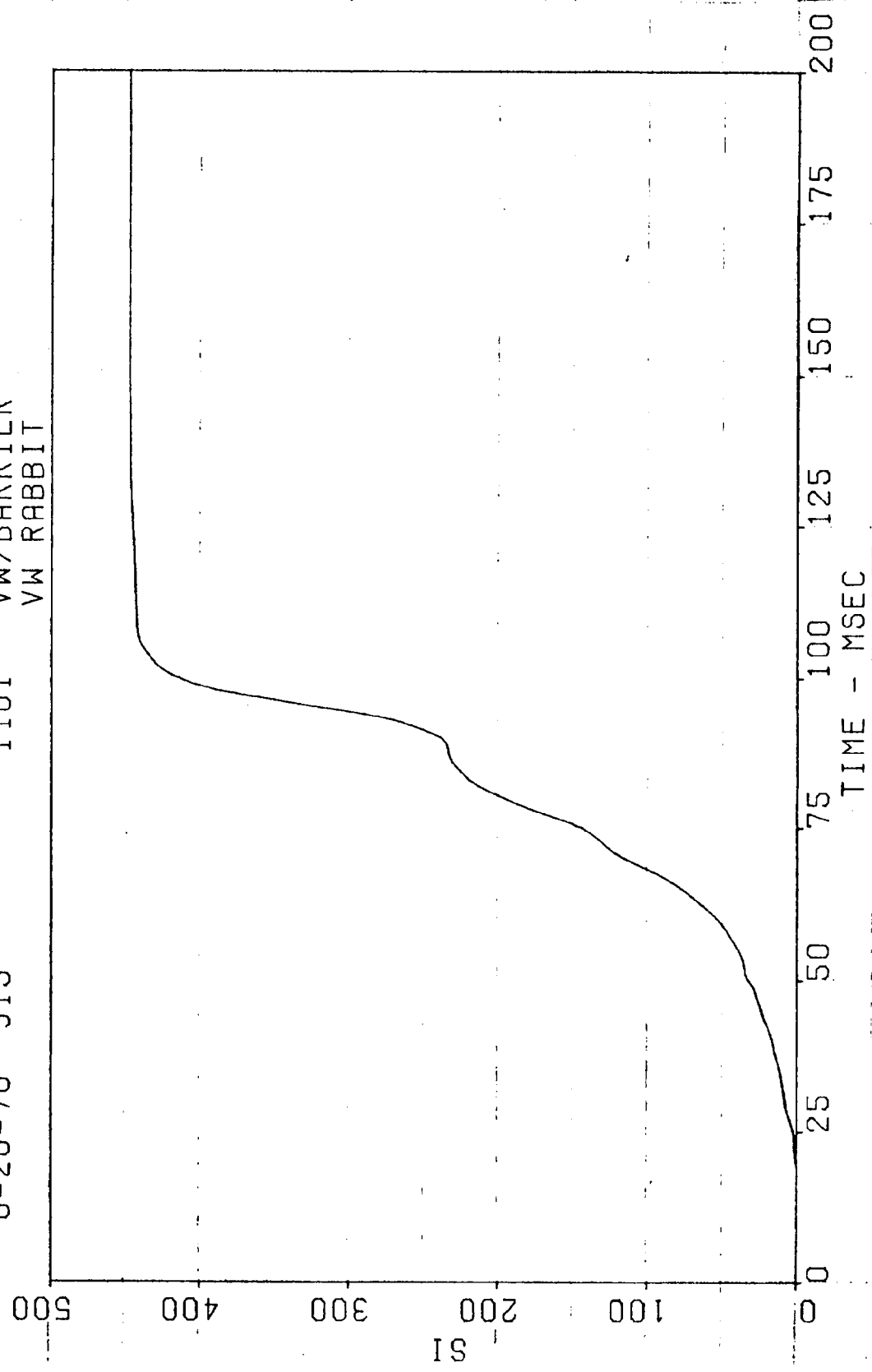
DATE 6-26-78 FILTER 315 TEST NO 072678
LOCATION 1101 VW/BARRIER
VW RABBIT



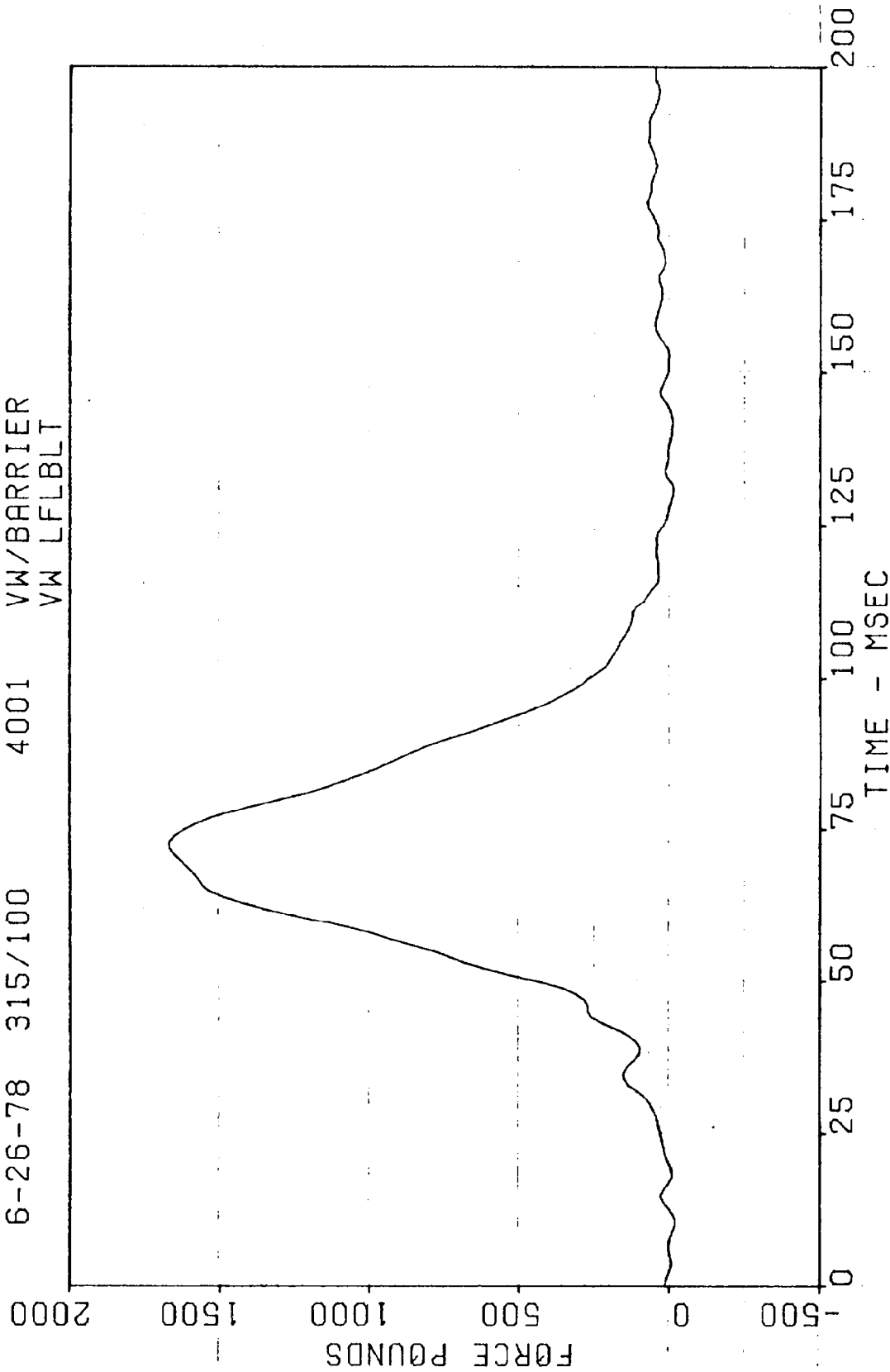
DATE 6-26-78 FILTER 315 LOCATION 1101 TEST NO 073178
VW/BARRIER
VW RABBIT



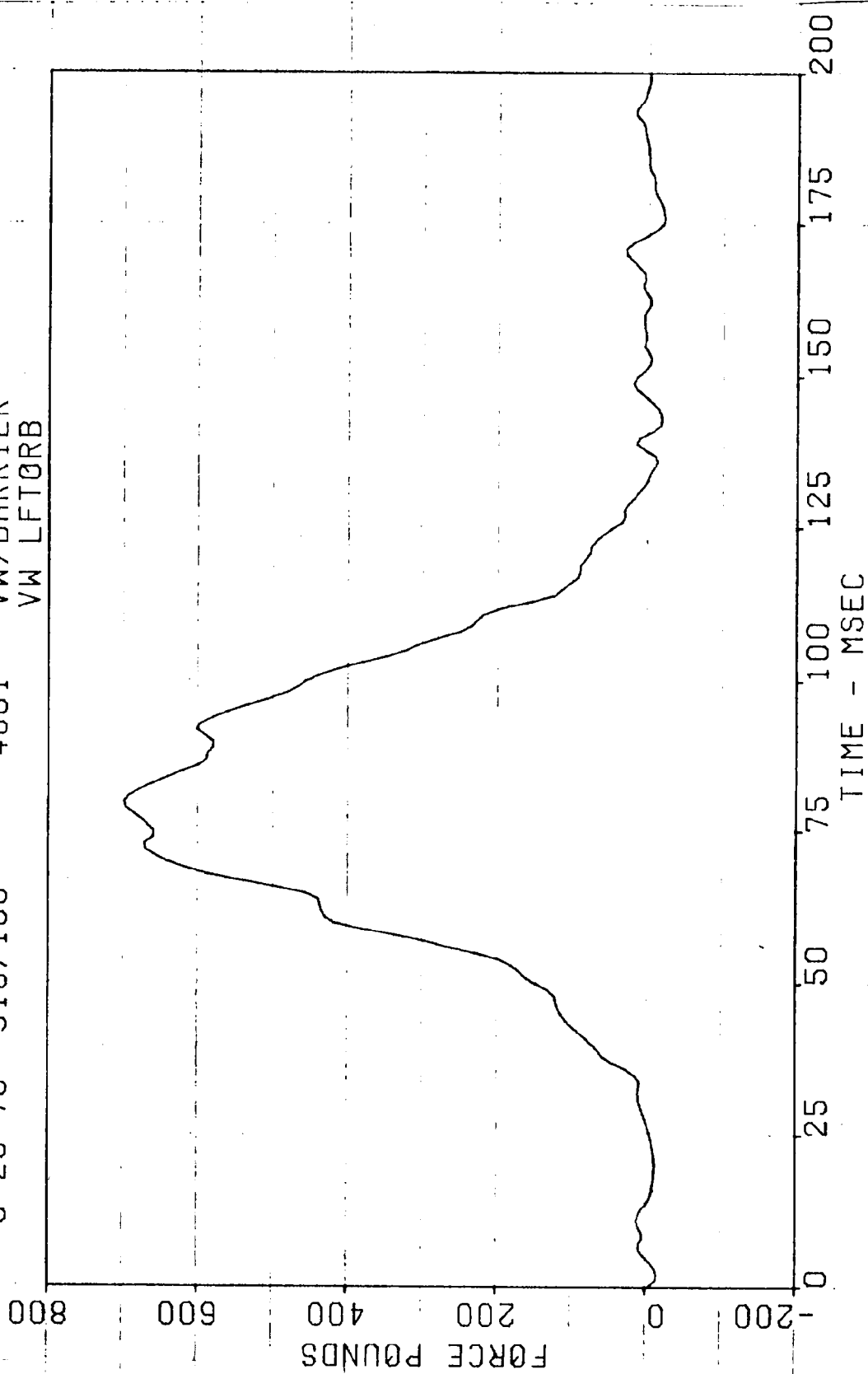
DATE 6-26-78 FILTER 315 LOCATION 1101 TEST NO 072678
VW/BARRIER
VW RABBIT



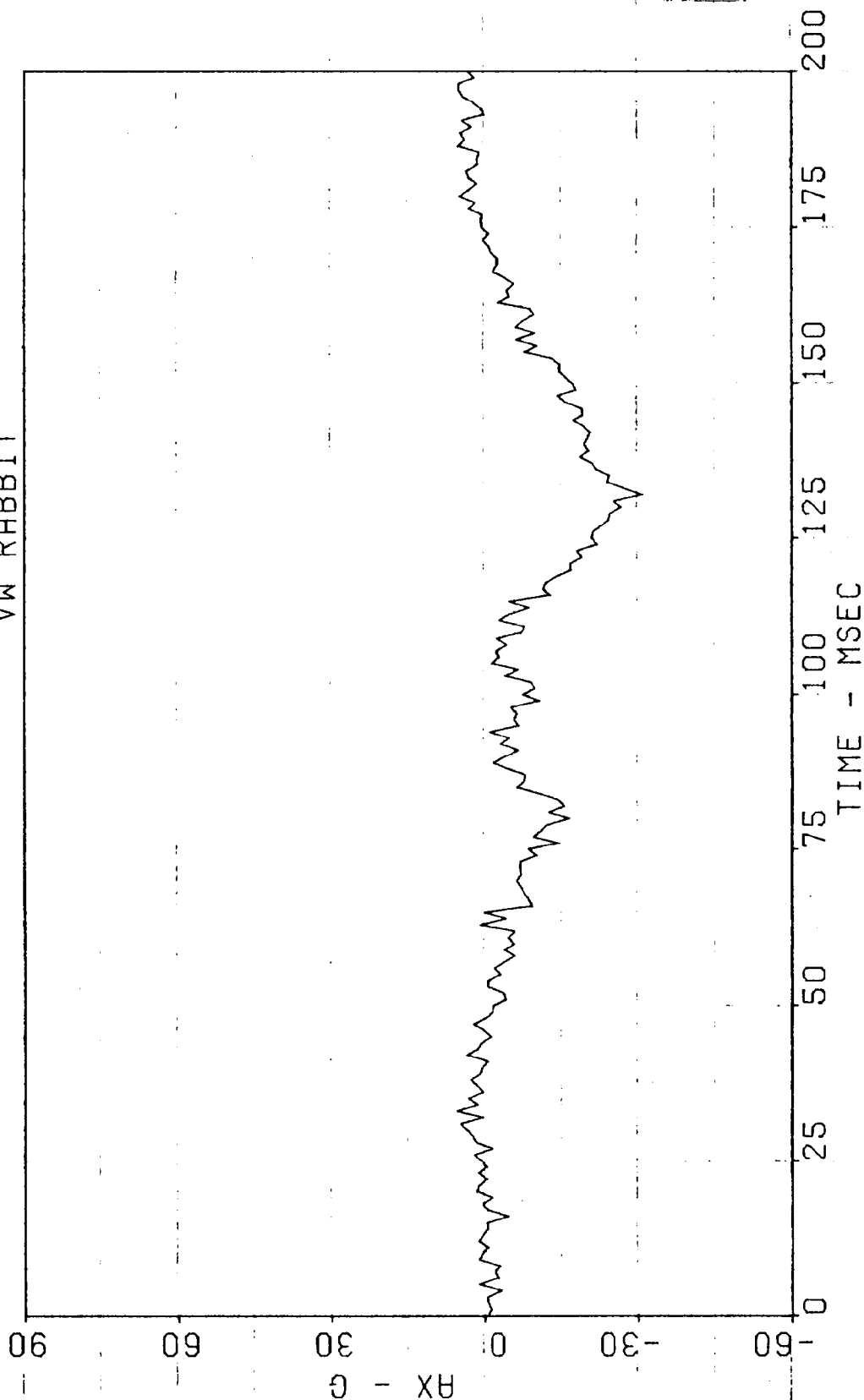
DATE 6-26-78 FILTER 315/100 LOCATION 4001 TEST NO 073178
VW/BARRIER
VW LFLBLT



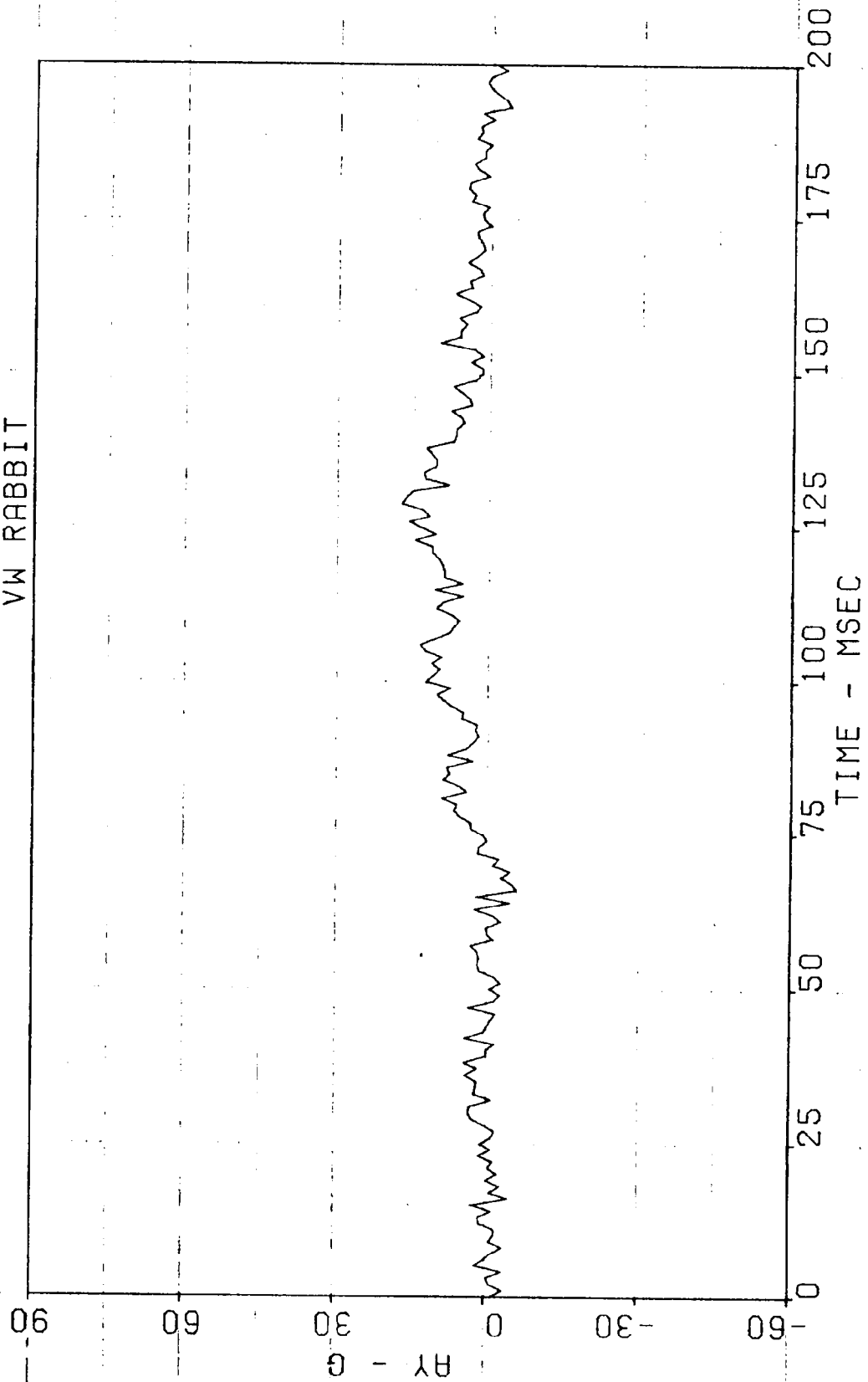
DATE 6-26-78 FILTER 315/100 LOCATION 4001 TEST NO 073178
VW/BARRIER
VW LFT0RB



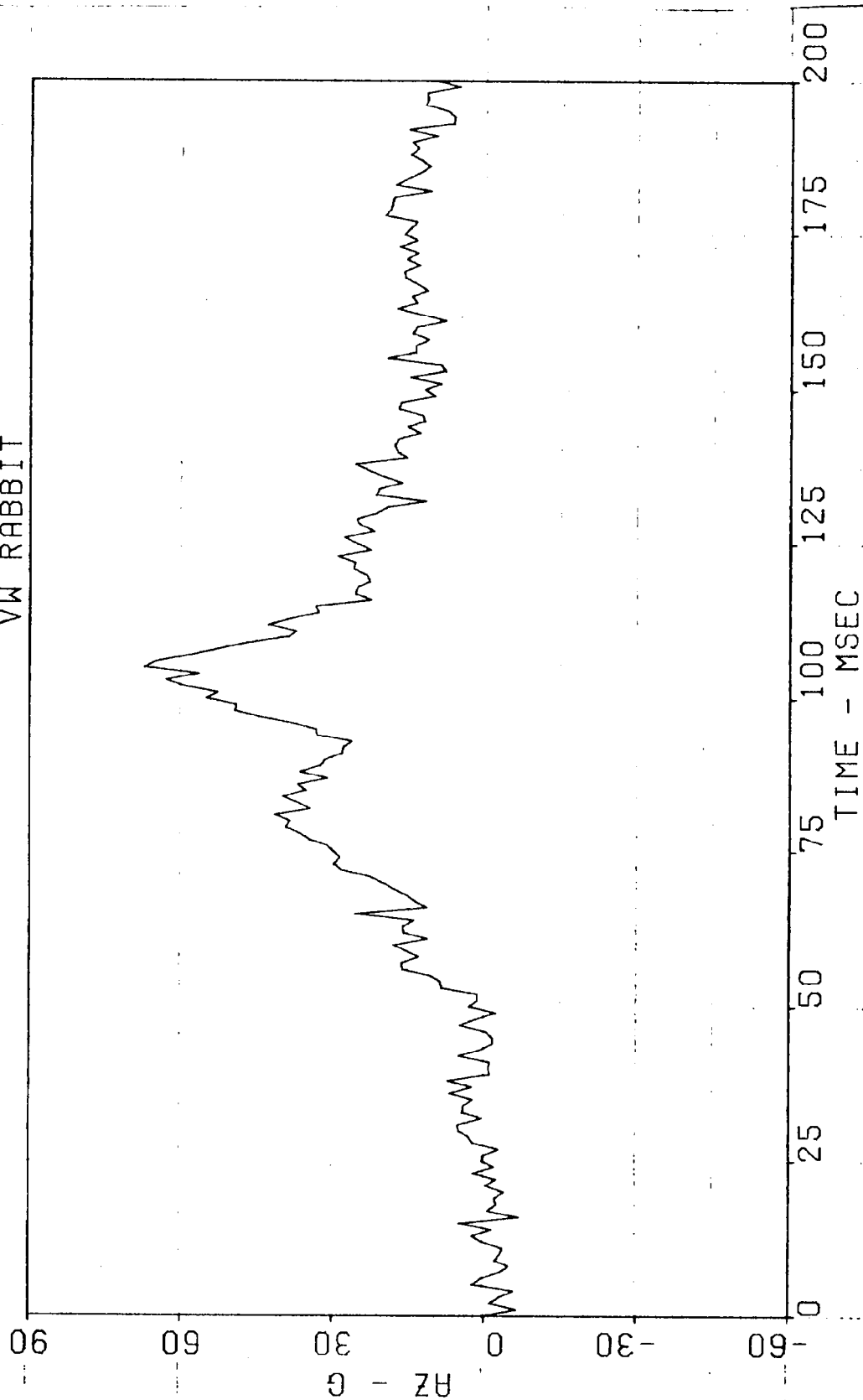
DATE 6-26-78 FILTER 1600 LOCATION 503 TEST NO 072678
VW/BARRIER
VW RABBIT



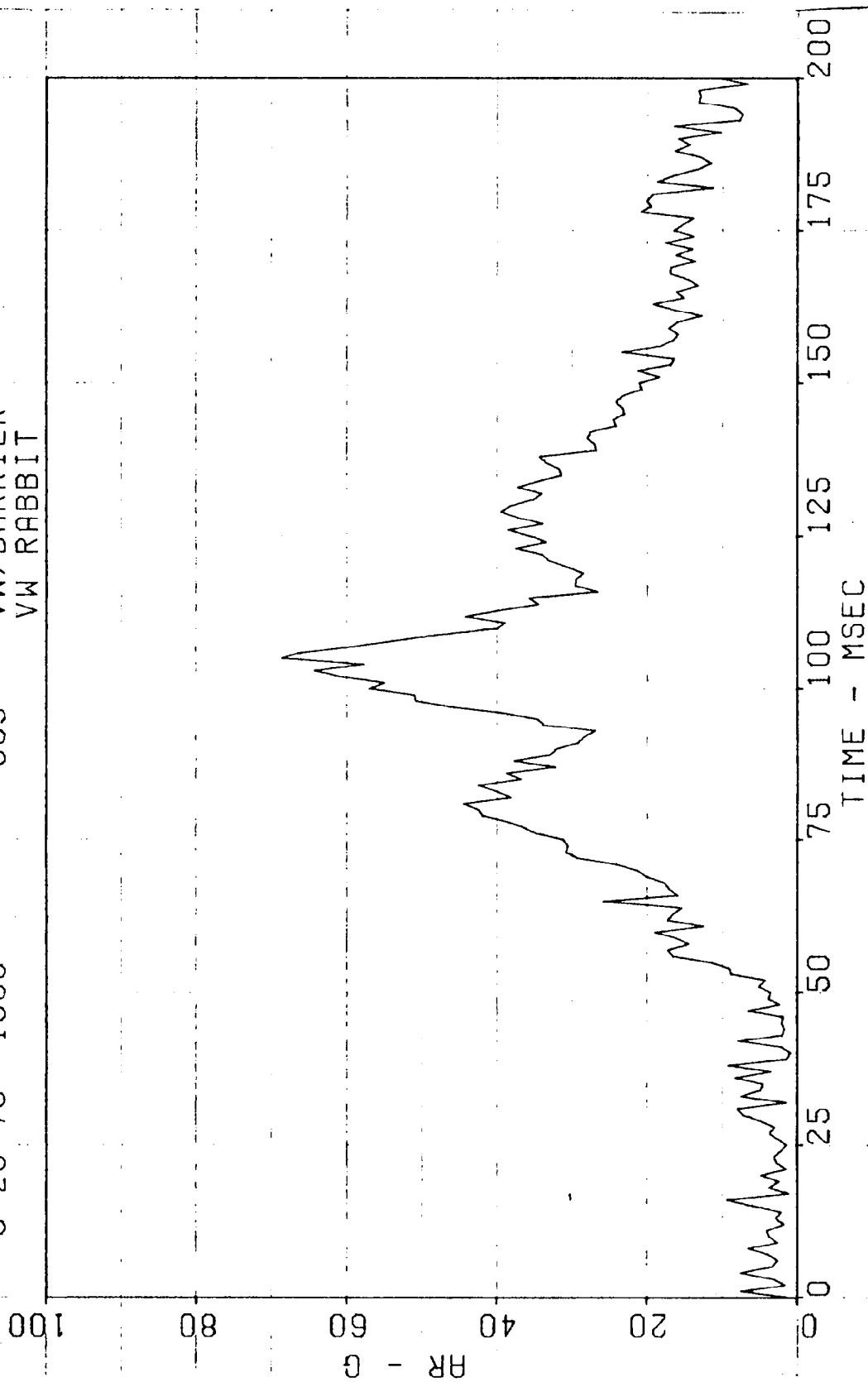
DATE 6-26-78 FILTER 1600 LOCATION 503 TEST NO 072678
VW/BARRIER
VW RABBIT



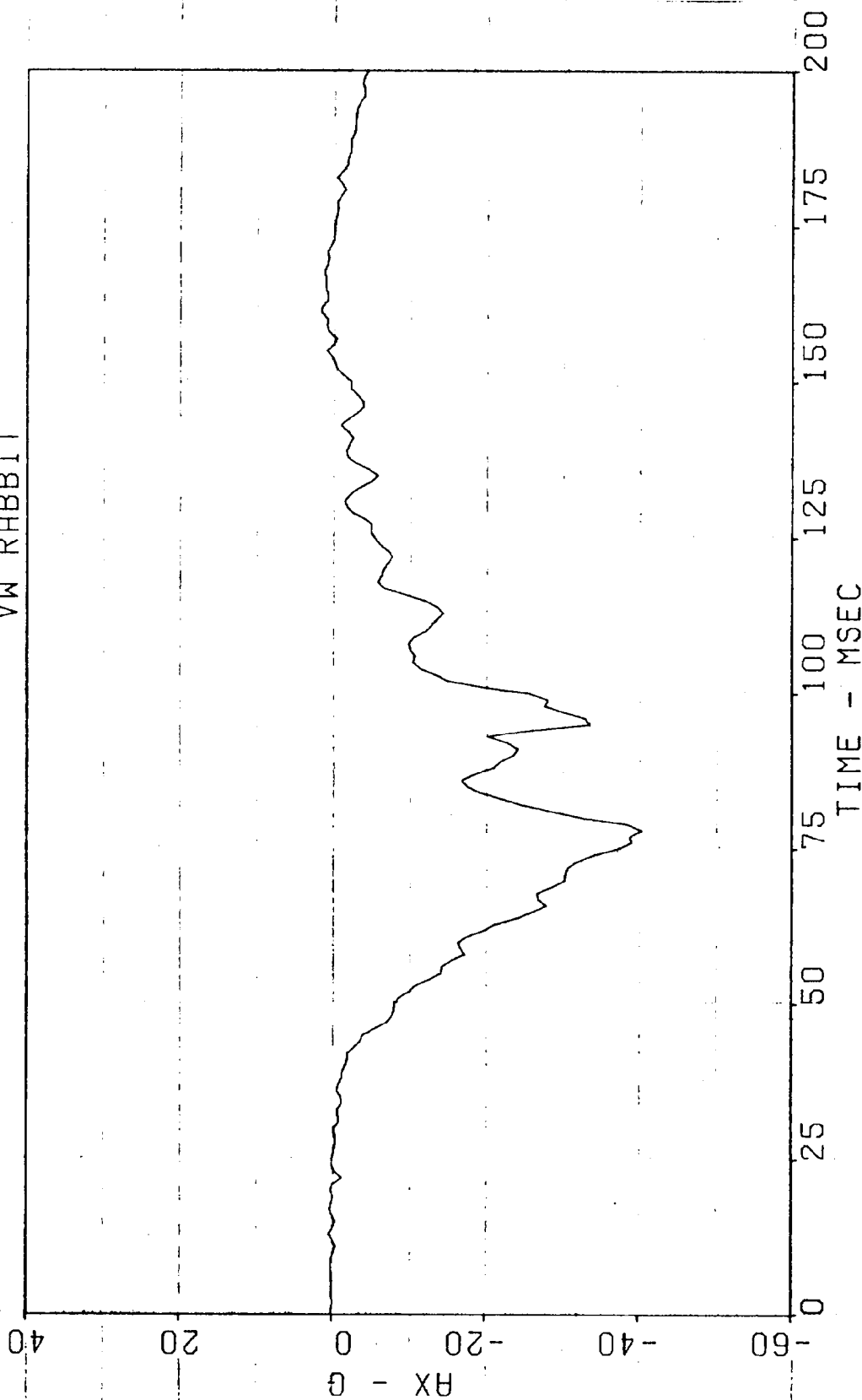
DATE 6-26-78 FILTER 1600 LOCATION 503 TEST NO 072678
VW/BARRIER
VW RABBIT



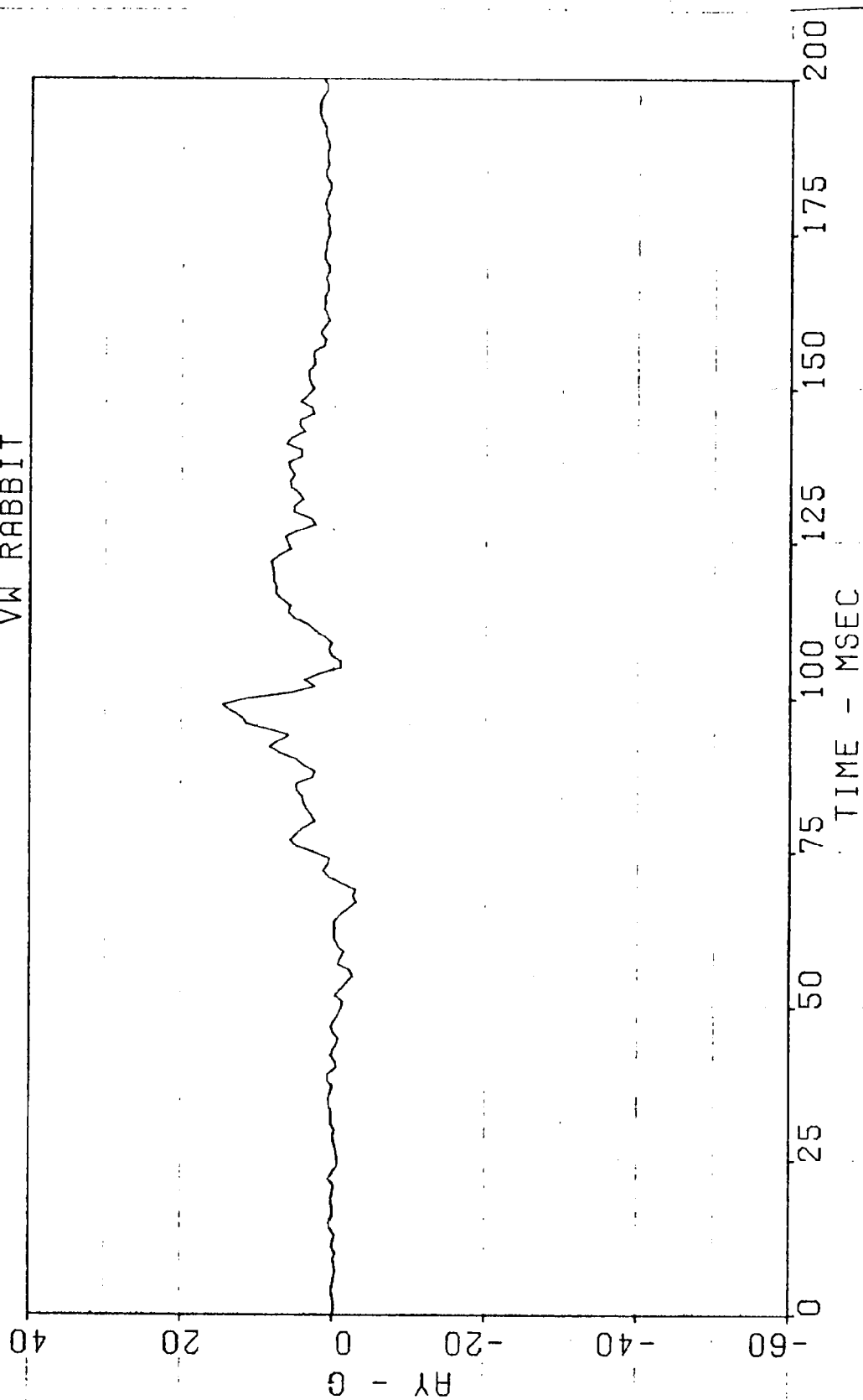
DATE 6-26-78 FILTER 1600 LOCATION 503 TEST NO 072678
VW/BARRIER
VW RABBIT



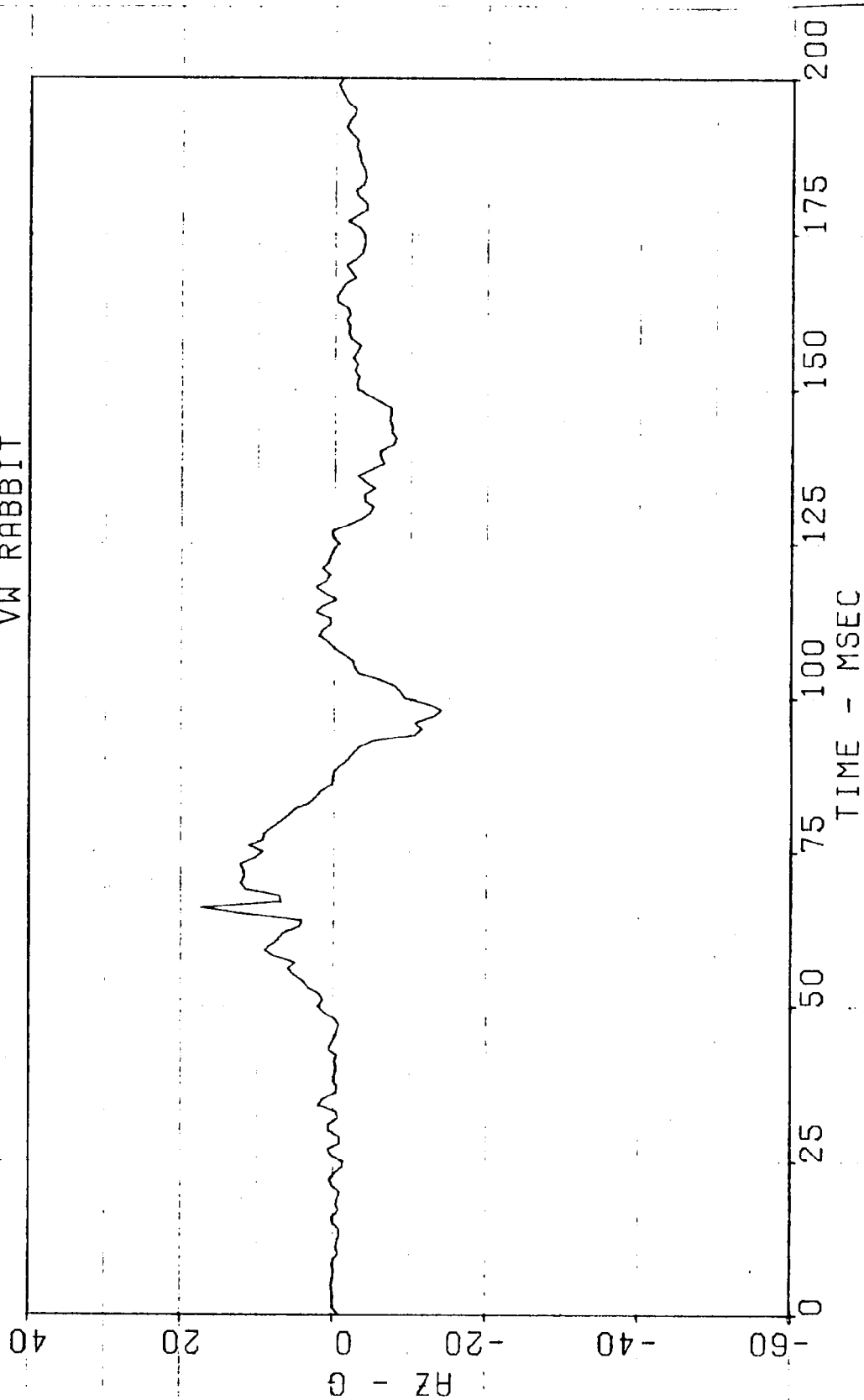
DATE 6-26-78 FILTER 315 LOCATION 1103 TEST NO 072678
VW/BARRIER
VW RABBIT



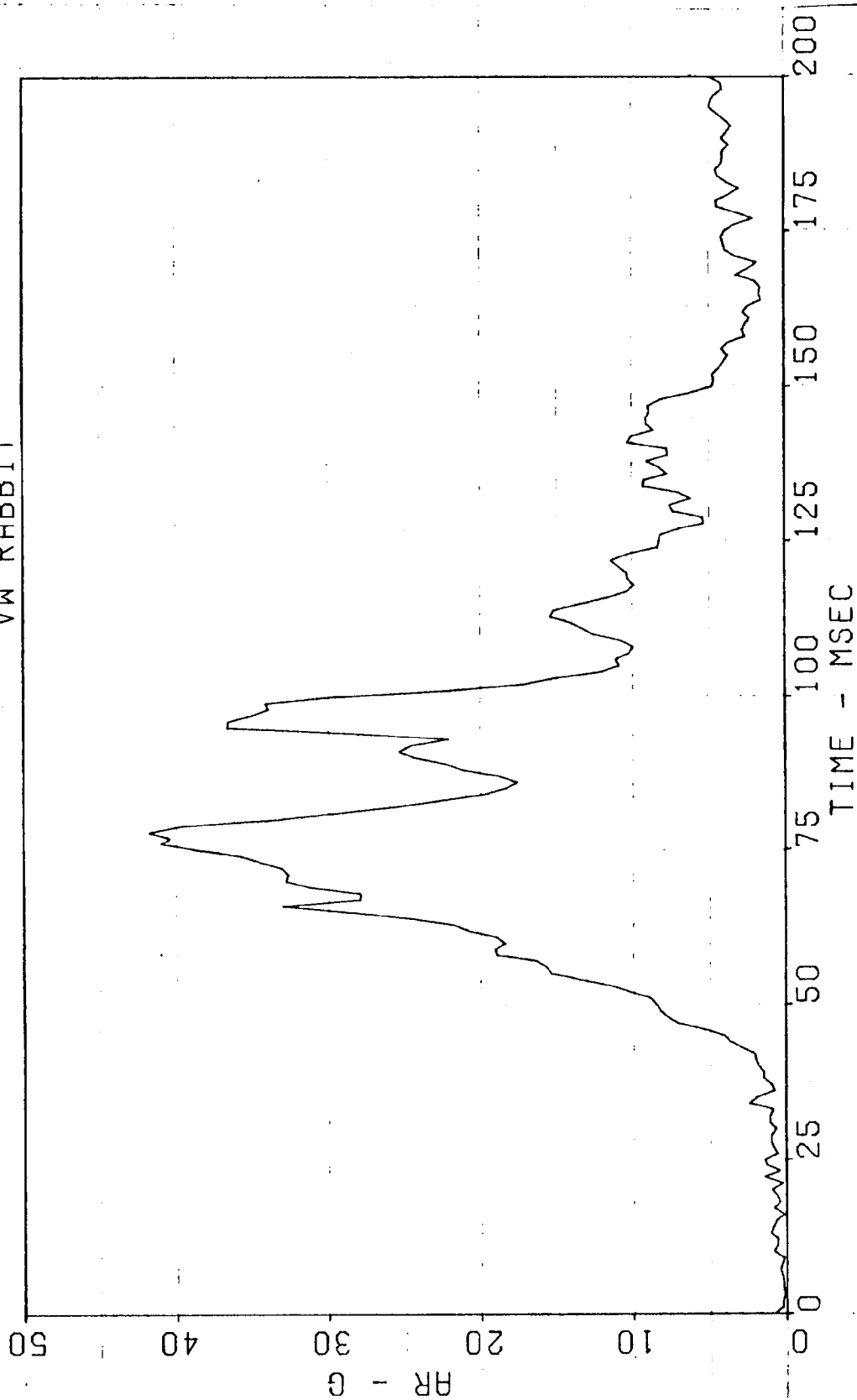
DATE 6-26-78 FILTER 315 TEST NO 072678
LOCATION 1103 VW/BARRIER
VW RABBIT



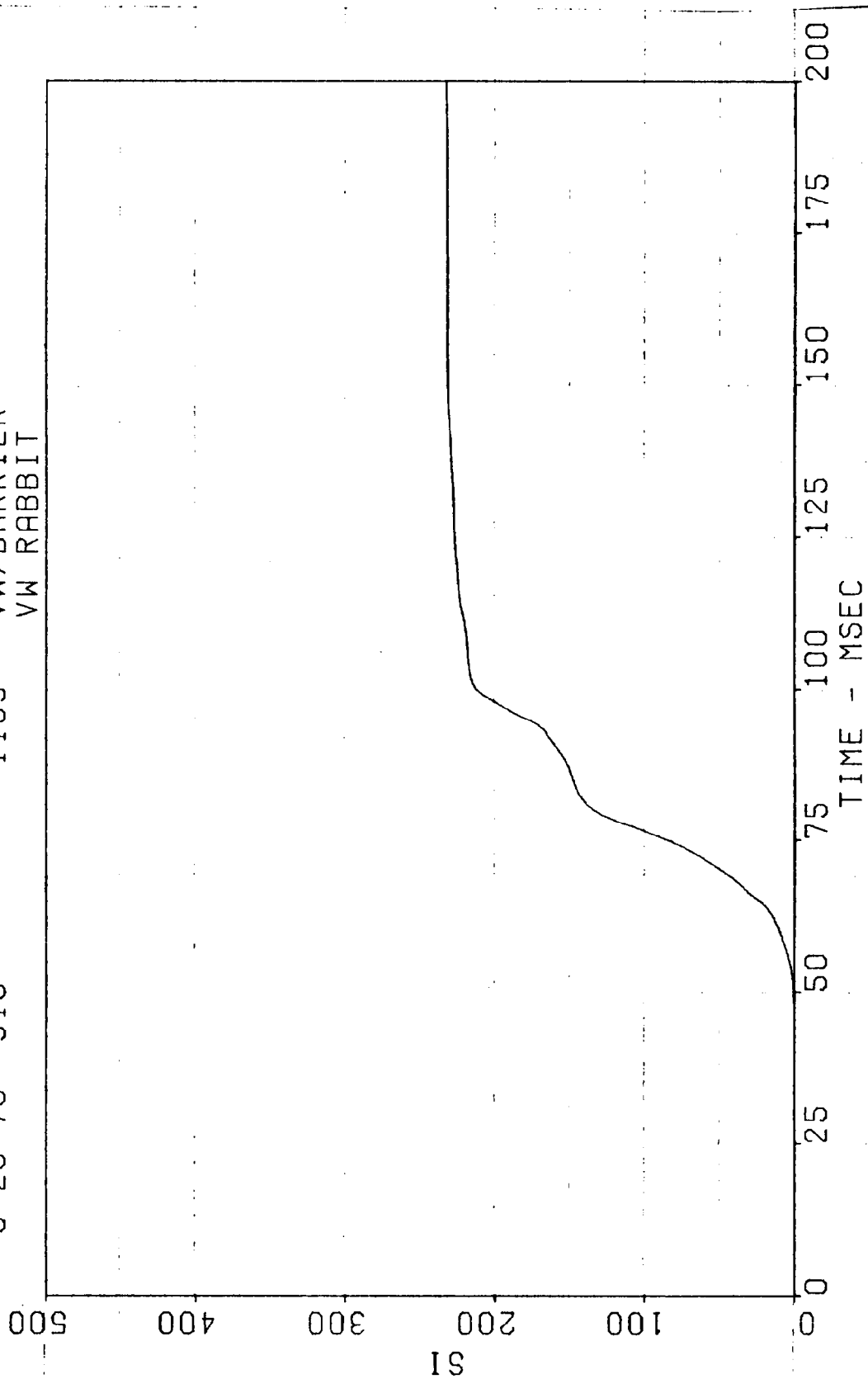
DATE 6-26-78 FILTER 315 LOCATION 1103 TEST NO 072678
VW/BARRIER
VW RABBIT



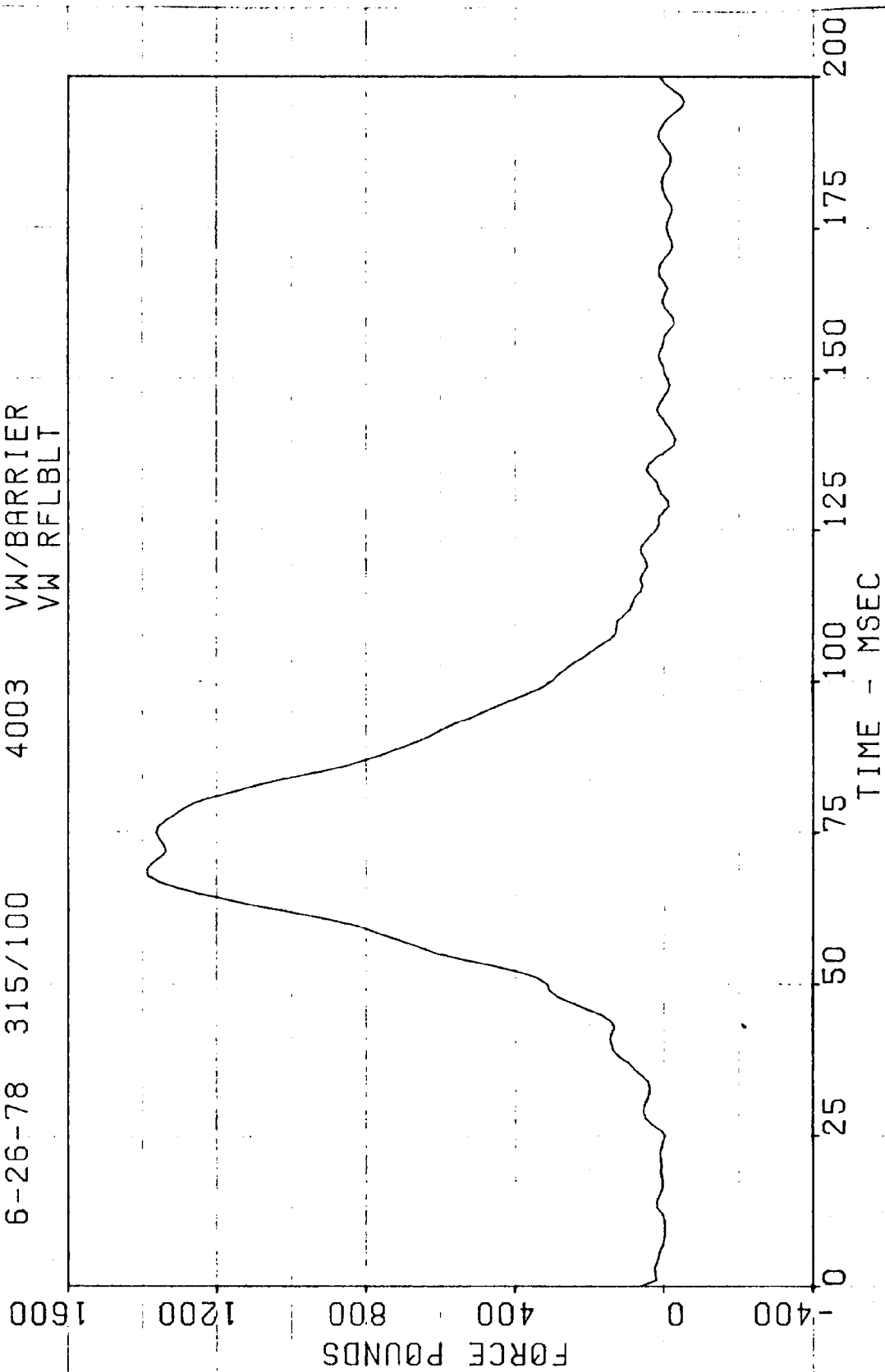
DATE 6-26-78 FILTER 315 LOCATION 1103 TEST NO 072678
VW/BARRIER
VW RABBIT



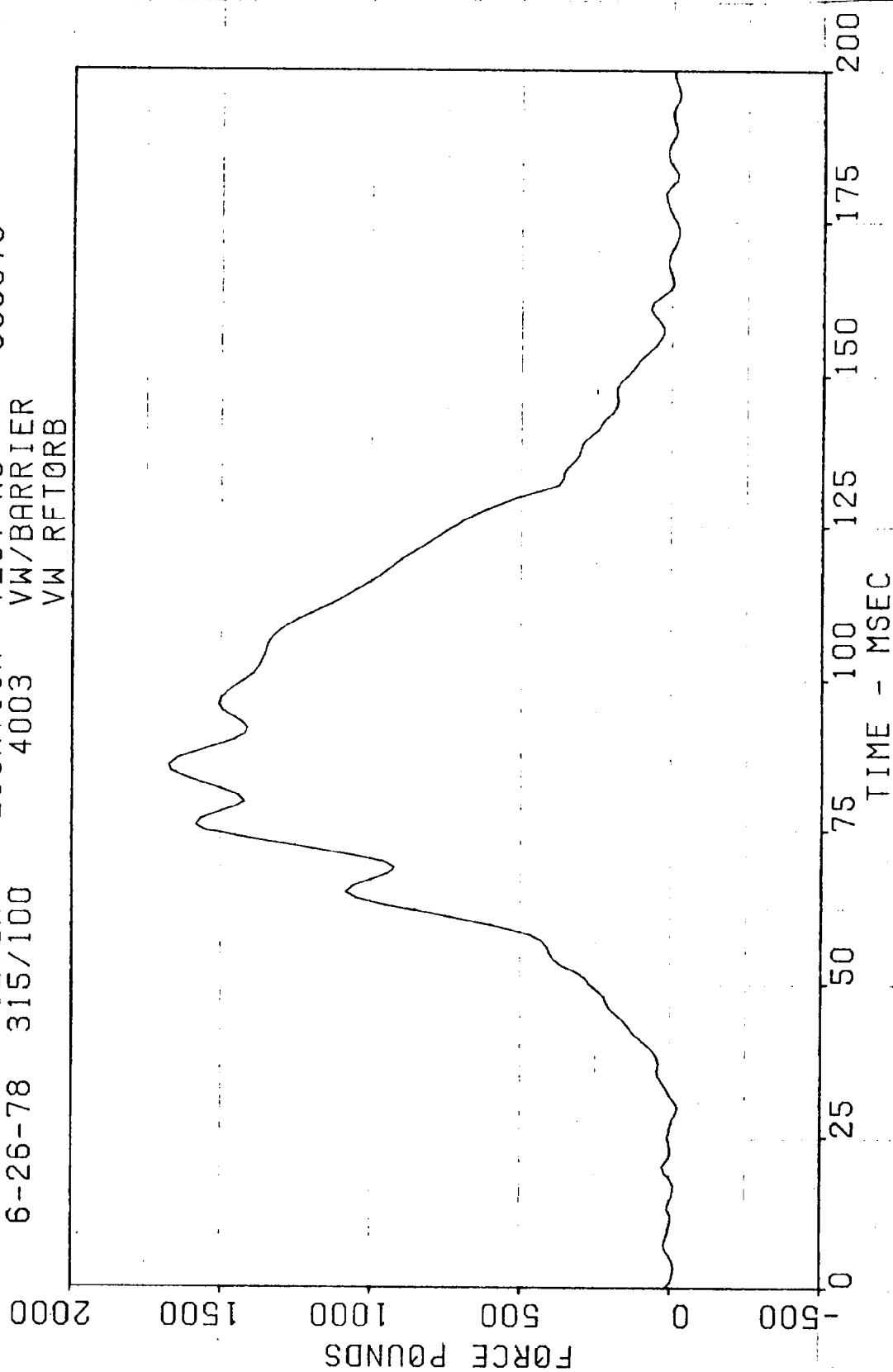
DATE 6-26-78 FILTER 315 LOCATION 1103 TEST NO 072678
VW/BARRIER
VW RABBIT



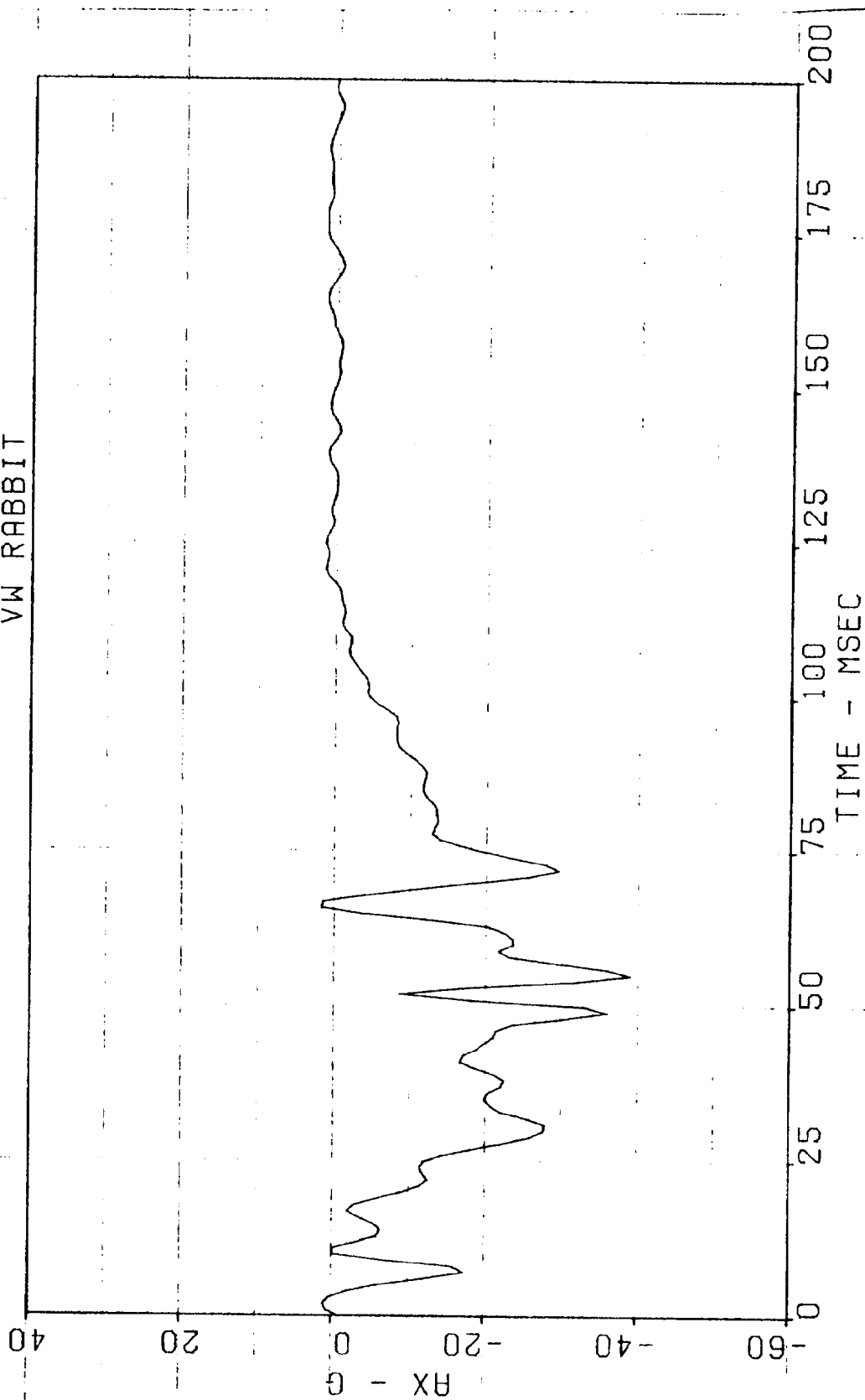
DATE 6-26-78 FILTER 315/100 LOCATION 4003 TEST NO 080878
VW/BARRIER
VW RFLBLT



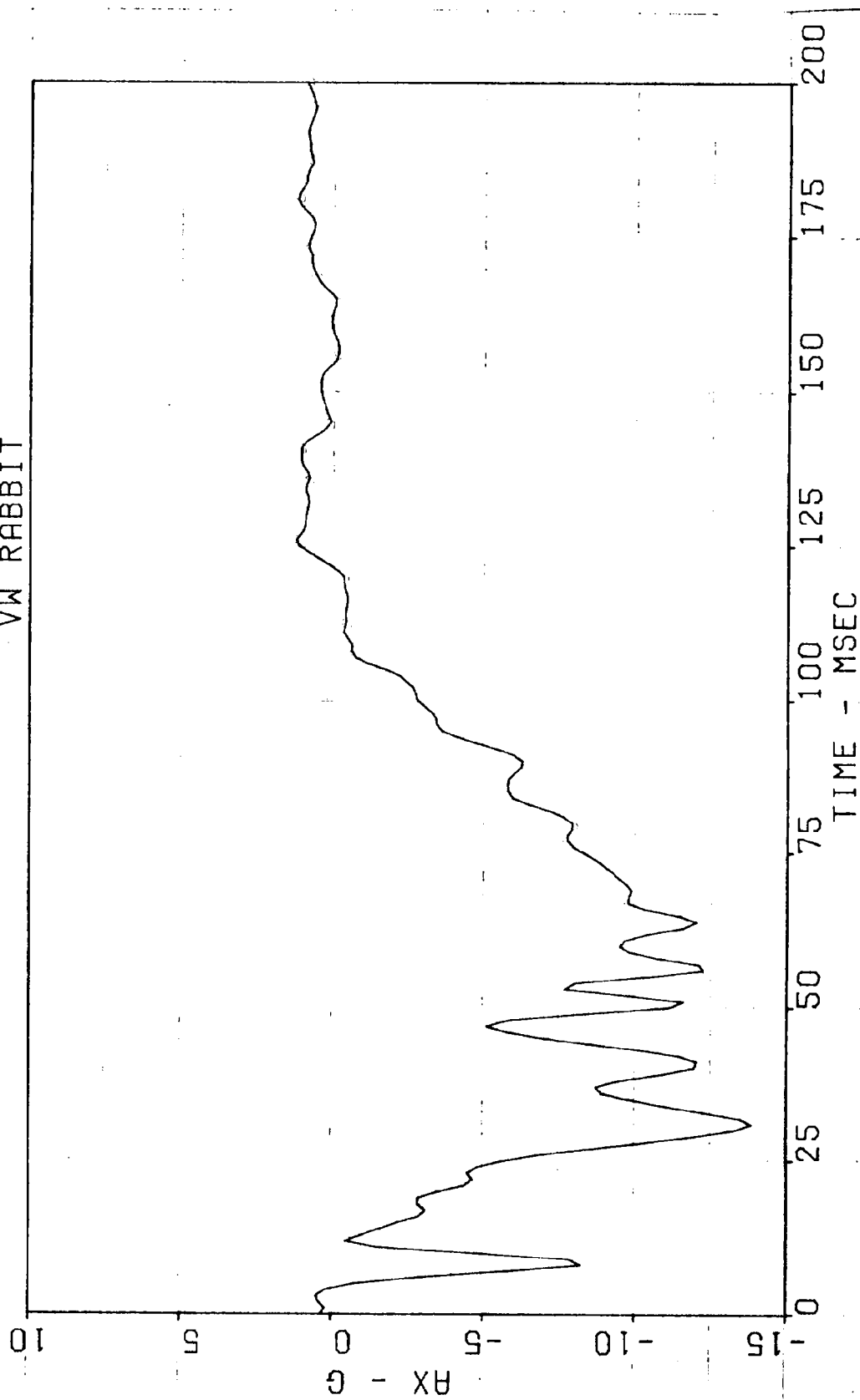
DATE 6-26-78 FILTER 315/100 LOCATION 4003 TEST NO 080878
VW/BARRIER
VW RFT0RB



DATE 6-26-78 FILTER 315/100 LOCATION 102 TEST NO 072678
VW/BARRIER
VW RABBIT



DATE 6-26-78 FILTER 315/100 LOCATION 104 TEST NO 073178
VW/BARRIER
VW RABBIT



DATE 6-26-78 FILTER 315/100 LOCATION 104 TEST NO 073178
VW/BARRIER
VW RABBIT

