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**NORWAY/UNITED STATES DESIGN PROTECTIVE
AIRCRAFT SHELTER (PAS) QUANTITY-DISTANCE
PROGRAM 1/3-SCALE TEST SERIES**

**Volume II of V
Appendix A: PAS-1**

**Edward H. Bultmann, Jr.
Bruce A. Schneider**

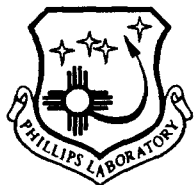
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Albuquerque, NM 87131-1376**

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August 1993

Final Report

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**PHILLIPS LABORATORY
Advanced Weapons and Survivability Directorate
AIR FORCE MATERIEL COMMAND
KIRTLAND AIR FORCE BASE, NM 87117-5776**

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This final report was prepared by the New Mexico Engineering Research Institute, Albuquerque, New Mexico, under Contract F29601-87-C-0001, Job Orders 41181599 and NORWAYYA, with the Phillips Laboratory, Kirtland Air Force Base, New Mexico. The Laboratory Project Officer-in-Charge was Aaron Perea (WSSD).

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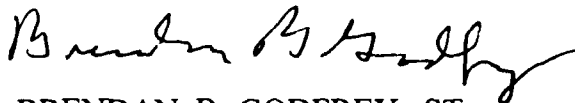
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FOR THE COMMANDER



AARON PEREA
Project Officer



BRENDAN B. GODFREY, ST
Director, Advanced Weapons
and Survivability Directorate

REPORT DOCUMENTATION PAGE			Form Approved OMB No 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE August 1993		3. REPORT TYPE AND DATES COVERED Final; Jul 91 - Mar 93
4. TITLE AND SUBTITLE NORWAY/UNITED STATES PROTECTIVE AIRCRAFT SHELTER (PAS) QUANTITY-DISTANCE PROGRAM 1/3-SCALE TEST SERIES Volume II of V: Appendix A: PAS-I			5. FUNDING NUMBERS C: F29601-87-C-0001 PE: 0603790D PR: 4118 TA: 15 WU: 99	
6. AUTHOR(S) Edward H. Bultmann, Jr. and Bruce A. Schneider				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) New Mexico Engineering Research Institute The University of New Mexico Albuquerque, NM 87131-1376			8. PERFORMING ORGANIZATION REPORT NUMBER NMERL SS 2.33(8)	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Phillips Laboratory 3550 Aberdeen Ave SE Kirtland AFB, NM 87117-5776			10. SPONSORING / MONITORING AGENCY REPORT NUMBER PL-TR--93-1009 Vol. II	
11. SUPPLEMENTARY NOTES This work was funded by the Norwegian Defence Construction Service and the United States Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The objective of the Combined Norwegian/U.S. Aircraft Shelter Quantity-Distance Program was to establish an experimental database that could be used to develop explosives safety criteria for a Norwegian-designed aircraft shelter. These shelters have been constructed at various bases in Europe and are used by U.S. and Norwegian air forces. The current criteria for explosives storage in aircraft shelters are based largely on U.S. aircraft shelter designs, which differ significantly in structural details from the Norwegian version. The program included four tests of 1/3-scale models of the Norwegian shelter. Charges varying from 3.7 to 100 kg of C-4 explosive were detonated inside the model shelters. Airblast pressures were measured in the interior and exterior areas surrounding the models. High-speed photography and accelerometers were used to determine structural debris trajectories and velocities. The final distribution of structural debris in the areas surrounding the models was also recorded. Volume I of this report presents a detailed discussion of the results of each test with selected experimental data. Volumes II through V provide a complete set of the experimental data gathered in each of the test events. These data will be provided to those U.S., Norwegian, and NATO agencies responsible for establishing explosives storage safety criteria for the Norwegian aircraft shelter.				
14. SUBJECT TERMS Aircraft Shelters, Quantity-Distance Criteria, Explosives Storage Airblast, Debris Distribution, Accidental Explosions, MK 84 GP Bomb, Explosives Safety			15. NUMBER OF PAGES 186	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	

PREFACE

This report was prepared by the New Mexico Engineering Research Institute (NMERI), The University of New Mexico, under Subtask 2.33 of Contract F29601-87-C-0001, with the Phillips Laboratory, Kirtland Air Force Base, New Mexico. The Norwegian/US Aircraft Shelter Quantity-Distance Program under which this test program was conducted was cosponsored by the United States and the Kingdom of Norway. The 1/3-scale aircraft shelter models were designed, constructed, instrumented, and tested by NMERI.

The Phillips Laboratory Program Manager and Subtask Officer for this subtask was Capt Mike Ulshafer of PL/WSB. The Phillips Laboratory Technical Coordinator was Aaron Perea. Arfin Jenssen was the Norwegian Technical Advisor/Coordinator. Dr. Edward H. Bultmann, Jr., of NMERI was the Principal Investigator for the subtask. Bruce Schneider of NMERI was the Alternate Principal Investigator for this subtask. Jon A. Kirst was the Instrumentation Engineer, Curtis Burnett was the Lead Construction (Field) Technician for this subtask. Jesse Martinez was the Lead Instrumentation Technician.

A-1

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1.0 PAS-1 ELECTRONIC INSTRUMENTATION, DATA PLOTS

The PAS-1 measurements are listed in Table A-1. The locations of the various on-structure measurements are shown in Figures A-1 through A-8. The PAS-1 data plots are presented (following Figure A-8) in sequential order by measurement number. The measurement number is centered below the plot; that is, PAS-1 *** 0101 *** refers to measurement number (MN) 0101. A measurement may have several plots of different vertical scales or time domains; for example, MN 0101 has both 50 and 100 ms plots.

Table A-1. List of measurements, PAS-1.

MEASUREMENT LIST														DATE	13 FEB 92	PAGE 1 OF 6 PAGES
TEST EQUIP		PAS-1				IE			KIRST			CHANGES				
MEAS NO.	LOCATION			SENS AXIS	PRED MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES					
	GEN	X#	Y#				Z#	MODEL			RANGE	ITEM	DATE			
0101-1	SF	12807	0	367	Z	413.7 kPa	60	KULITE	PRESSURE	689.5 kPa	(3982-2-184) E18-42					
0102-1	SF	12807	3700	367	Z	689.5 kPa	50	KULITE	PRESSURE	1379 kPa	(2200-2-366) O15-82					
0201-1	BW	13010	100	2500	X	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-175) E18-35					
0202-1	BW	13010	1700	1475	X	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-181) E18-40					
0203-1	BW	13010	3700	930	X	482.6 kPa	35	KULITE	PRESSURE	1379 kPa	(3826-4-11) F4-12					
0301-1	SF	3976	0	367	Z	413.7 kPa	60	KULITE	PRESSURE	689.5 kPa	(3982-2-177) E18-37					
0302-1	SF	3976	1850	367	Z	310.3 kPa	60	KULITE	PRESSURE	689.5 kPa	(3982-2-170) E18-31					
0303-1	SF	3976	3700	367	Z	310.3 kPa	60	KULITE	PRESSURE	689.5 kPa	(3982-2-174) E18-34					
0304-1	SC	3976	0	2717	Z	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-172) E18-32					
0305-1	SC	3976	1749	2424	R1	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-176) E18-36					
0306-1	SC	3976	3346	1548	R2	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-168) E18-29					
0307-1	SC	3976	3763	1029	R3	344.7 kPa	50	KULITE	PRESSURE	689.5 kPa	(3982-2-169) E18-30					
NOTES: m = Distance in millimeters																
SF = Shelter Floor																
SC = Shelter Ceiling																
BU = Backwall																

MEASUREMENT LIST															DATE	25 FEB 92	PAGE 2 OF 6 PAGES
TEST CONT		PAS-1				IE			KIRST				CHANGES				
MEAS NO.	GEN	LOCATION		SENS AXIS	PREC MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	ITEM	AUTH	DATE				
		X#	Y#				Z#	MODEL						RANGE			
0401-1	FD	498	100	2500	X	344.7 kPa	%	KULITE	XT-190	689.5 kPa	(Nylon Mount)	PRESSURE	(1861-5-92) O7-73				
0402-1	FD	498	100	1475	X	344.7 kPa	%	KULITE	XT-190	689.5 kPa	(Nylon Mount)	PRESSURE	O15-94		J.K.	2/25	
0403-1	FD	498	100	450	X	551.6 kPa	%	KULITE	XT-190	1379 kPa	(Nylon Mount)	PRESSURE	(2200-2-361) O15-80				
0404-1	FD	498	1700	1475	X	344.7 kPa	%	KULITE	XT-190	689.5 kPa	(Nylon Mount)	PRESSURE	O15-95				
0405-1	FW	498	3700	930	X	482.6 kPa	%	KULITE	XT-190	1379 kPa		PRESSURE	(2200-2-324) I13-88				
0501-1	SF	645	3700	367	Z	689.5 kPa	%	KULITE	XT-190	1379 kPa		PRESSURE	(2200-2-371) O15-87				
0502-1	SC	645	0	2717	Z	482.6 kPa	%	KULITE	XT-190	689.5 kPa		PRESSURE	(3982-2-173) E18-33				
0503-1	SC	645	1749	2424	R1	482.6 kPa	%	KULITE	XT-190	689.5 kPa		PRESSURE	(3982-2-185) E18-43				
0504-1	SC	645	3346	1548	R2	482.6 kPa	%	KULITE	XT-190	689.5 kPa		PRESSURE	(3982-2-180) E18-39				
0601-1	SF	6818	1850	367	Z	1103 kPa	%	KULITE	XT-190	2068 kPa		PRESSURE	(1743-5-145) X6-86				
0602-1	SF	6818	3700	367	Z	551.6 kPa	%	KULITE	XT-190	1379 kPa		PRESSURE	(2200-2-367) O15-83				
0603-1	SF	6818	-3700	367	Z	551.6 kPa	%	KULITE	XT-190	1379 kPa		PRESSURE	(2200-2-368) O15-84				

NOTES:

= Distance in millimeters

FD = Front Door

FN = Front Hall

SC = Structure Ceiling

SF = Structure Floor

Table A-1. Continued.

MEASUREMENT LIST																DATE	13 FEB 92	PAGE 3 OF 8 PAGES
PAS - 1																KIRST		
TEST EVENT	MEAS NO.	LOCATION				SENS AXIS	PREC MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES					
		GEN	X#	Y#	Z#				MODEL	RANGE			ITEM	AUTH	DATE			
0604-1	SC	6818		0	2717	Z	3447 kPa	50 %	KULITE	6895 kPa	PRESSURE	(1906-3-339) F8-38						
0605-1	SC	6818		1749	2424	R1	1103 kPa	53.3 %	KULITE	2069 kPa	PRESSURE	(1743-5-43) X6-71						
0606-1	SC	6818		3346	1548	R2	1103 kPa	53.3 %	KULITE	2069 kPa	PRESSURE	(1743-5-143) X6-84						
0607-1	SC	6818		3763	1029	R3	684.5 kPa	50 %	KULITE	1379 kPa	PRESSURE	(2200-2-365) O15-81						
0701-1	FF	-3000		0	350	Z	34.47 kPa	100 %	KULITE	34.5 kPa	PRESSURE	(1495-6-94) K7-1						
0702-1	FF	-5000		0	350	Z	3.447 kPa	25 %	ENDEVCO	13.8 kPa	PRESSURE	PP49						
0703-1	FF	-7000		0	350	Z	3.447 kPa	25 %	ENDEVCO	13.8 kPa	PRESSURE	RF77						
0704-1	FF	-9000		0	350	Z	3.447 kPa	25 %	ENDEVCO	13.8 kPa	PRESSURE	TM38						
0705-1	FF	-3433		8000	350	Z	34.47 kPa	100 %	KULITE	34.5 kPa	PRESSURE	(1495-7-75) K7-7						
0706-1	FF	-6233		10800	350	Z	3.447 kPa	25 %	ENDEVCO	13.8 kPa	PRESSURE	RF91						
0707-1	FF	6818		8000	350	Z	34.47 kPa	100 %	KULITE	34.5 kPa	PRESSURE	(1491-2-20) U6-17						
0708-1	FF	6818		12000	350	Z	3.447 kPa	25 %	ENDEVCO	13.8 kPa	PRESSURE	C61M						
NOTES:																# = Distance in millimeters		
																SC = Shelter Ceiling		
																FF = Free Field		

Table A-1. Continued.

MEASUREMENT LIST														
PAS-1										KIRST				
TEST EVENT	MEAS NO.	LOCATION			SENS AXIS	PROD MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES		
		GEN	X#	Y#				Z#	MODEL			RANGE	ITEM	AUTH
	0709-1	FF	17041	8000	350	Z	34.474 kPa	100	KULITE	PRESSURE	(1491-2-26) U6-20			
	0710-1	FF	19841	10800	350	Z	3.4474 kPa	25	ENDEVCO	PRESSURE	C84M			
	0711-1	FF	19000	0	350	Z	34.474 kPa	100	ENDEVCO	PRESSURE	(1495-7-76) K7-6			
	0712-1	FF	21000	0	350	Z	3.4474 kPa	25	ENDEVCO	PRESSURE	C93M			
	0713-1	FF	23000	0	350	Z	3.4474 kPa	25	ENDEVCO	PRESSURE	RF93			
	0714-1	FF	6818	-8000	350	Z	34.474 kPa	100	KULITE	PRESSURE	(1491-2-4) U6-16			
	0715-1	FF	6818	-12000	350	Z	3.4474 kPa	25	ENDEVCO	PRESSURE	RF60			
	1301-1	SR	3976	0	2987	Z	1000 g	100	ENDEVCO	ACCELEROMETER	KY63			
	1302-1	SR	3976	0	2987	Y	100 g	100	ENDEVCO	ACCELEROMETER	LP74			
	1303-1	SR	3976	1837	2680	R1	1000 g	100	ENDEVCO	ACCELEROMETER	HN02			
	1304-1	SR	3976	1837	2680	T1	100 g	100	ENDEVCO	ACCELEROMETER	LP64			
	1305-1	SR	3976	3514	1759	R2	1000 g	100	ENDEVCO	ACCELEROMETER	MW04			
NOTES: # = Distance in millimeters g = Gravitational acceleration														
FF = Free field														
SR = Structure Roof														

Table A-1. Continued.

MEASUREMENT LIST																	DATE	17 FEB 92	PAGE 5 OF 6 PAGES	
TEST EVENT		PAS-1				IC		KIRST										CHANGES		
MEAS NO.	LOCATION			SENS AXIS	PREC MAX	CONF LEVEL	TRANSDUCER		RANGE	TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES								
	SEN	X#	Y#				Z#	MODEL				ITEM	AUTH	DATE						
1306-1	SR	3976	3514	1759	T2	100 g	100 %	ENDEVCO	2262A	100 g	ACCELEROMETER	PK28								
1601-1	SR	6818	0	2987	Z	2000 g	100 %	ENDEVCO	2264A	2000 g	ACCELEROMETER	CC53A								
1602-1	SR	6818	0	2987	Y	200 g	100 %	ENDEVCO	2262A	200 g	ACCELEROMETER	AP40								
1603-1	SR	6818	1837	2680	R1	2000 g	100 %	ENDEVCO	2264A	2000 g	ACCELEROMETER	CB24A								
1604-1	SR	6818	1837	2680	T1	200 g	100 %	ENDEVCO	2262A	200 g	ACCELEROMETER	CG72								
1605-1	SR	6818	3514	1759	R2	2000 g	100 %	ENDEVCO	2264A	2000 g	ACCELEROMETER	BW95A								
1606-1	SR	6818	3514	1759	T2	200 g	100 %	ENDEVCO	2262C	200 g	ACCELEROMETER	WB07								
1607-1	SR	6818	0	2987	Z	30000 g	60 %	ENDEVCO	2264A	50000 g	ACCELEROMETER	CL17E								
1609-1	SR	6818	1837	2680	R1	30000 g	60 %	ENDEVCO	2264A	50000 g	ACCELEROMETER	CT12E								
1611-1	SR	6818	3514	1759	R2	30000 g	60 %	ENDEVCO	2264A	50000 g	ACCELEROMETER	CJ75E								
3401-1	FD	415	0	1475	Y	2000 msn	75 %	AILTECH	SG159-11-10-6S	+/- 20000 msn	STRAIN GAGE	N/A								
3402-1	FD	415	0	1475	Z	2000 msn	75 %	AILTECH	SG159-11-10-6S	+/- 20000 msn	STRAIN GAGE	N/A								
NOTES: ■ = Distance in millimeters																				
SR = Shelter Roof																				
F0 = Front Door																				
msn = microstrain																				

msn = microstrain

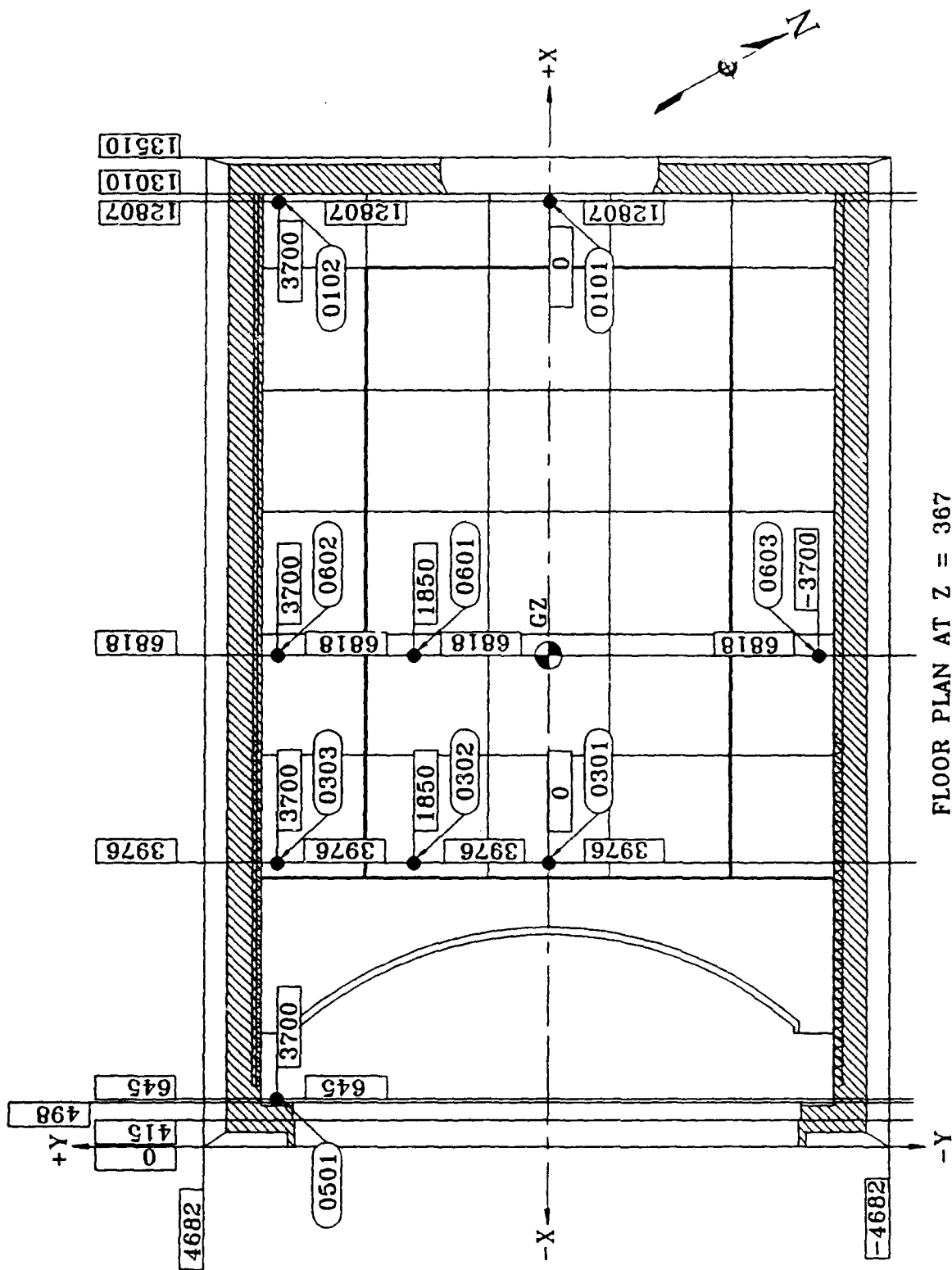
= Distance in millimeters

SR = Shelter Roof

FD = Front Door

Table A-1. Concluded.

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FLOOR PLAN AT Z = 367

Figure A-1. Instrumentation in floor of structure, PAS-1.

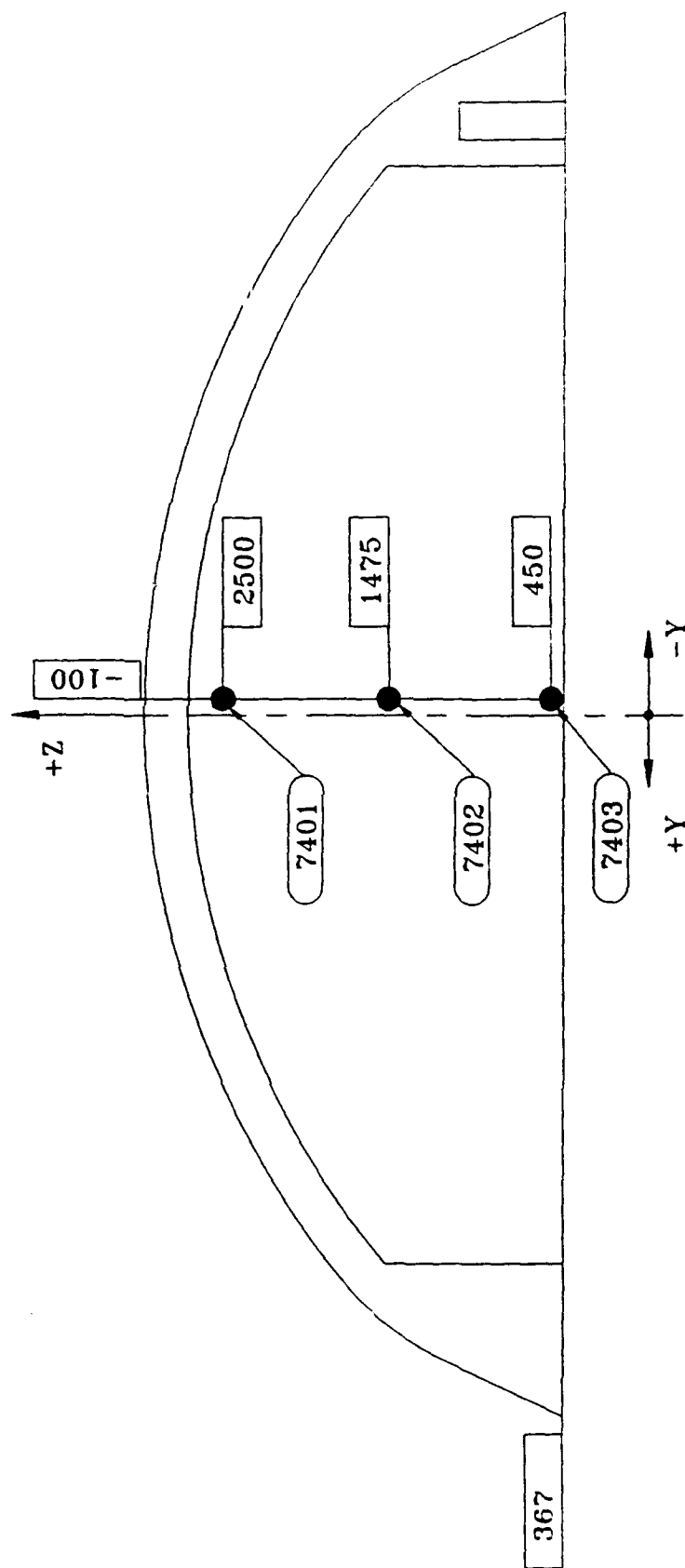


Figure A-2. Instrumentation on outside of front door at $X = 415$, PAS-1.

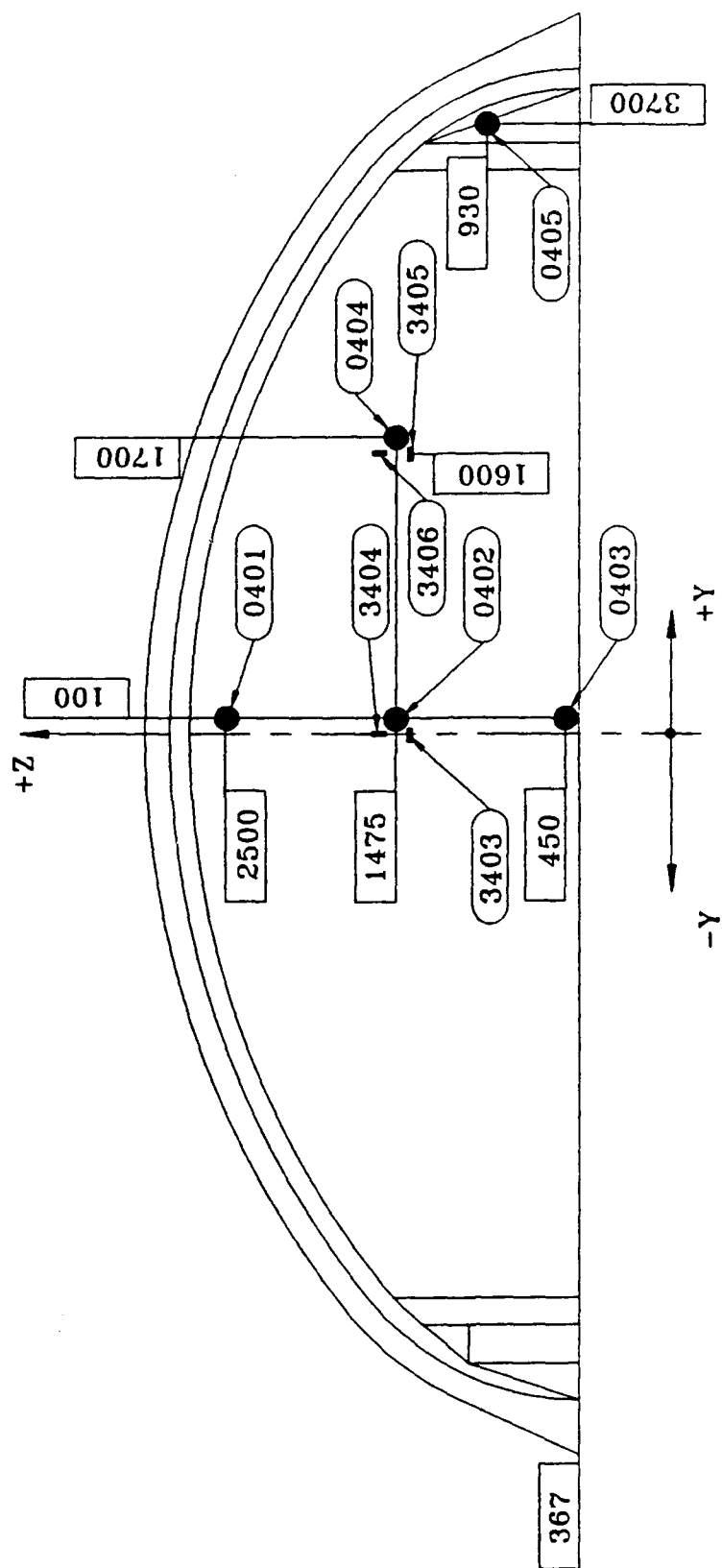


Figure A-3. Instrumentation on inside surface of front door at X = 498, PAS-1.

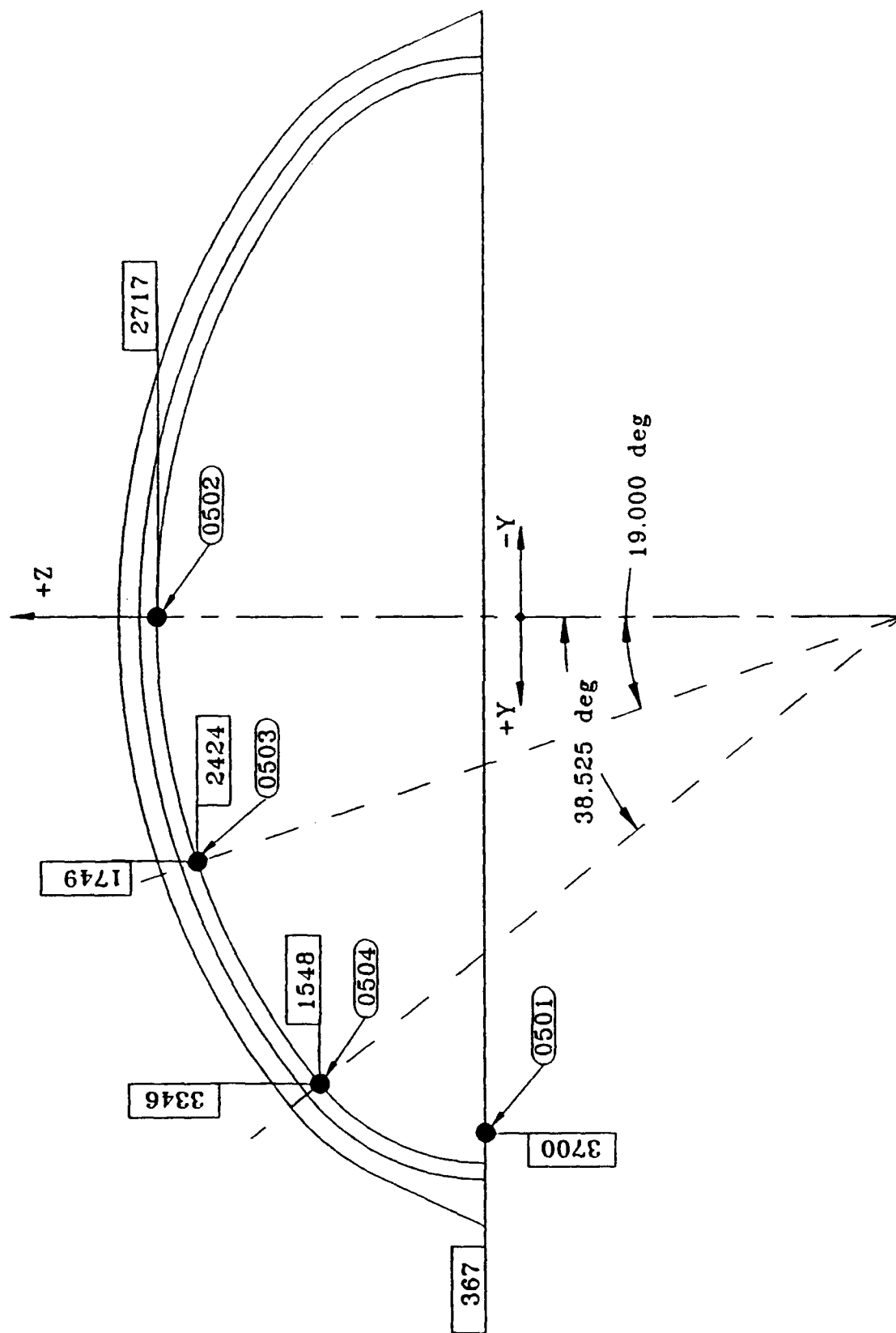


Figure A-4. Instrumentation on arch at $X = 645$, PAS-1.

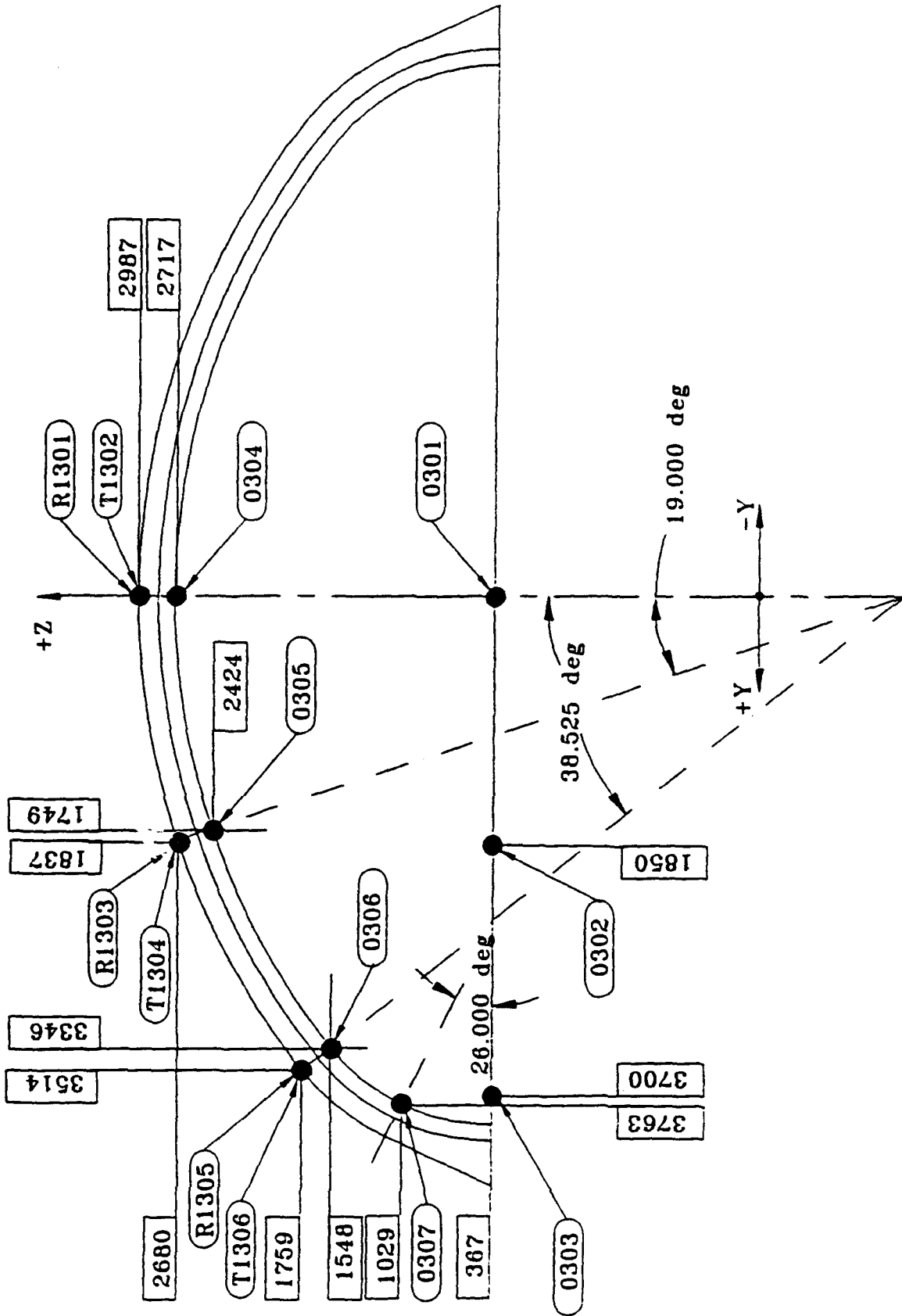


Figure A-5. Instrumentation on arch at X = 3976, PAS-1.

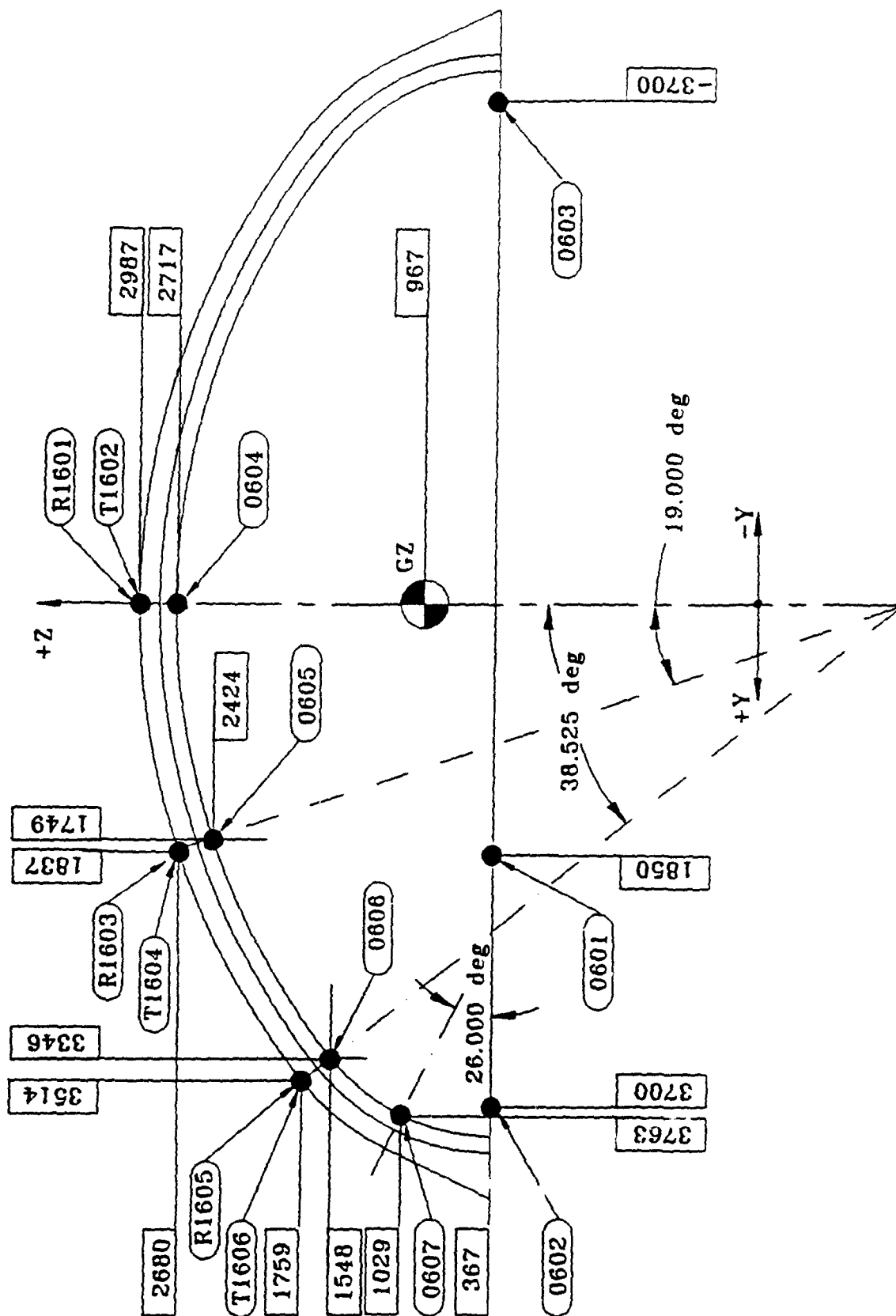


Figure A-6. Instrumentation on arch at X = 6818, PAS-1.

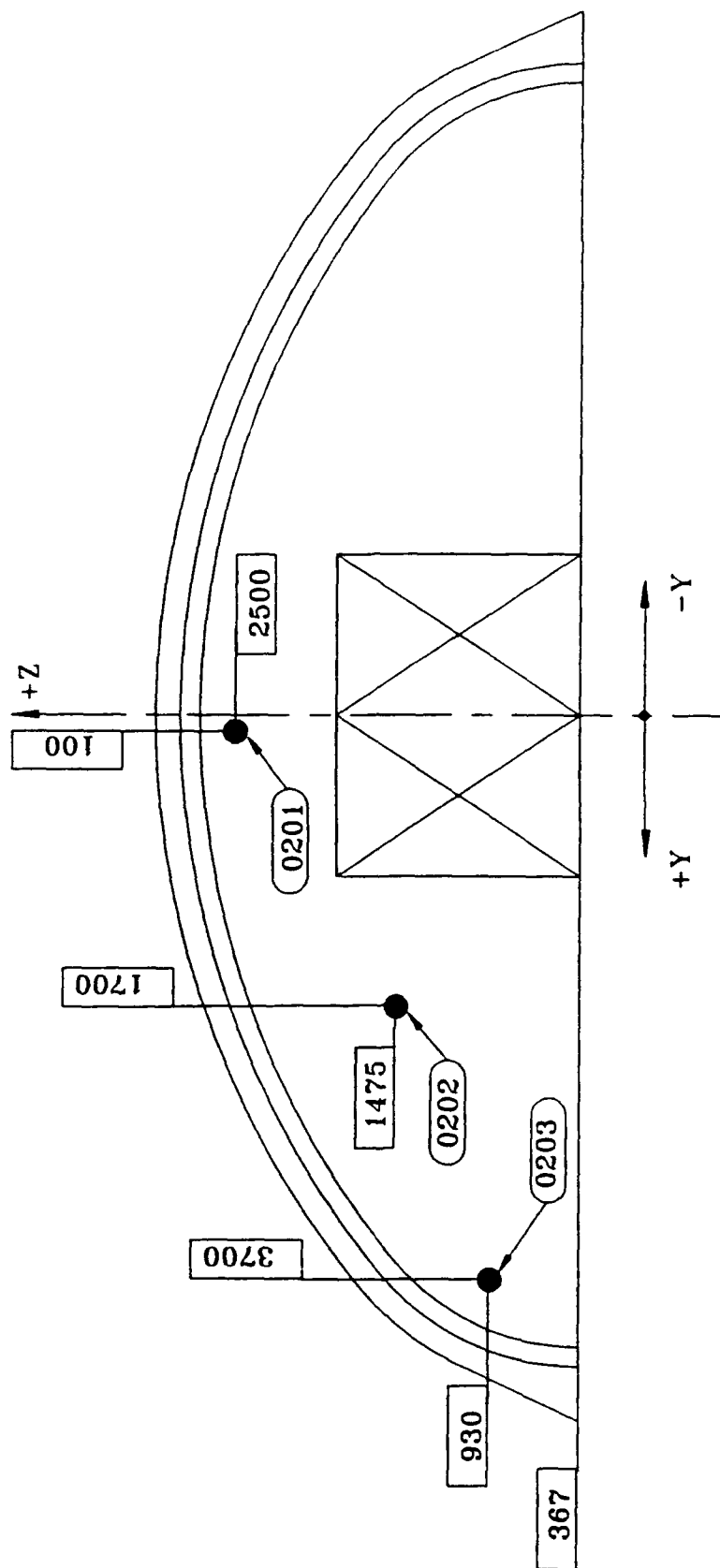


Figure A-7. Instrumentation on inner surface of backwall at X = 13010, PAS-1.

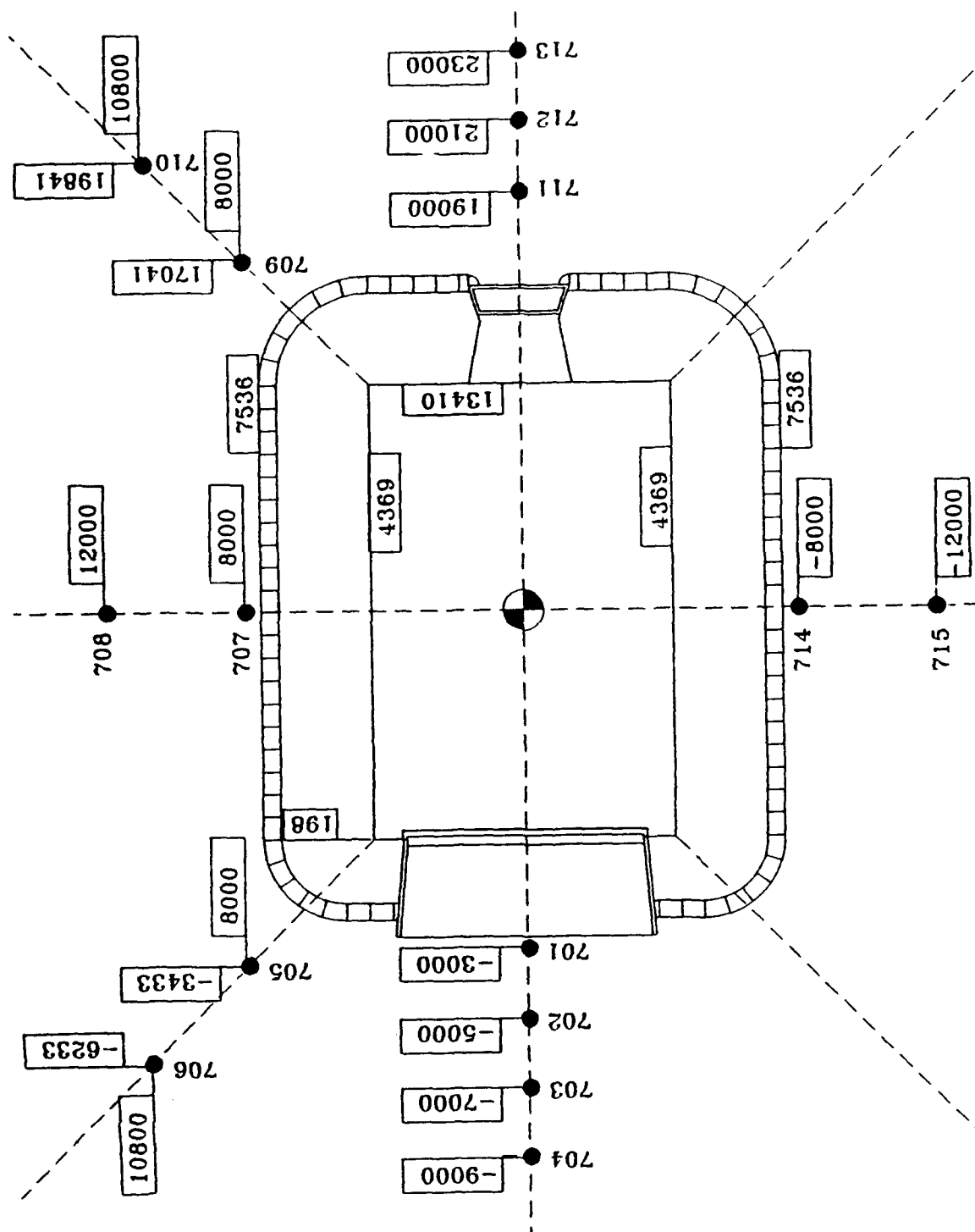
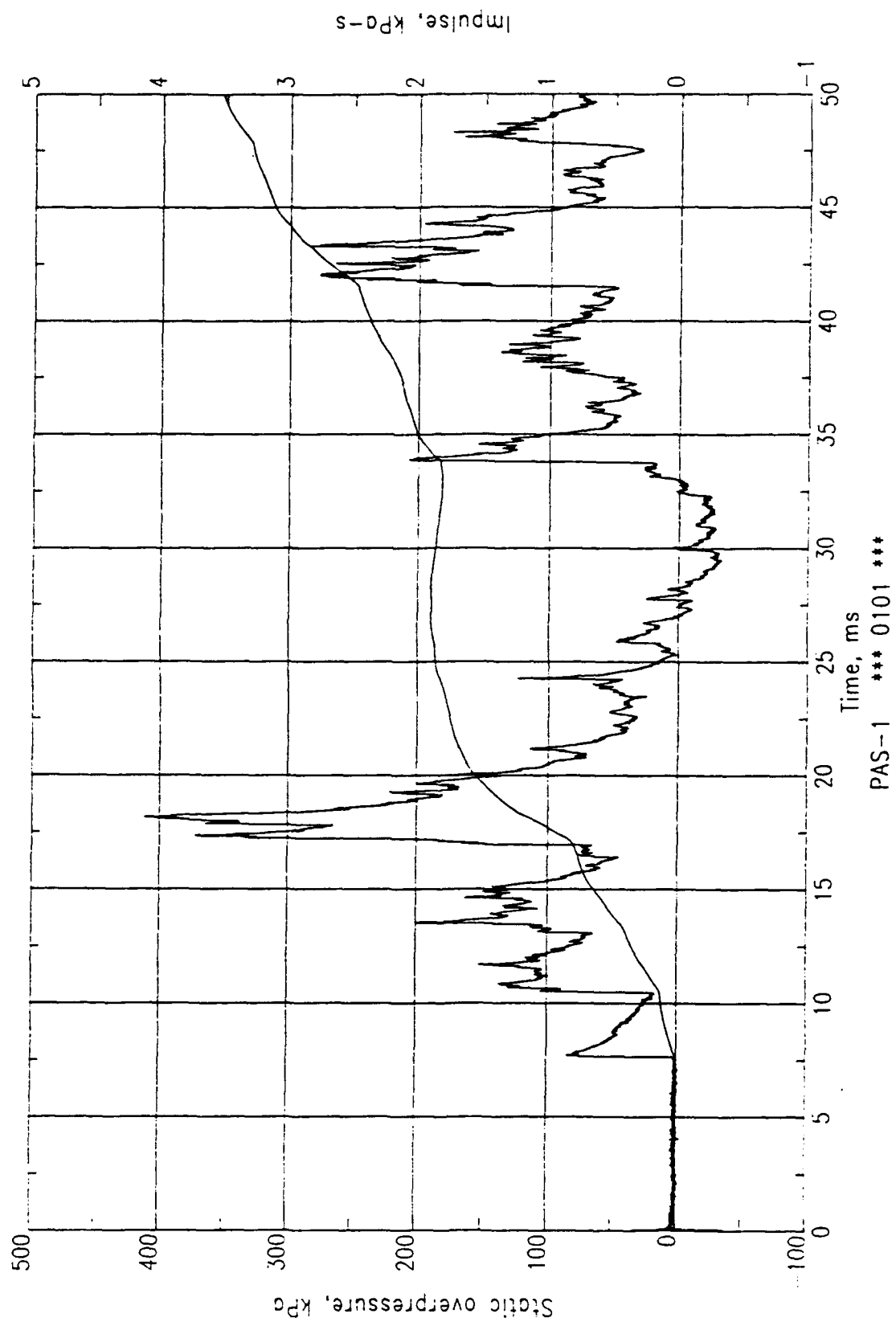
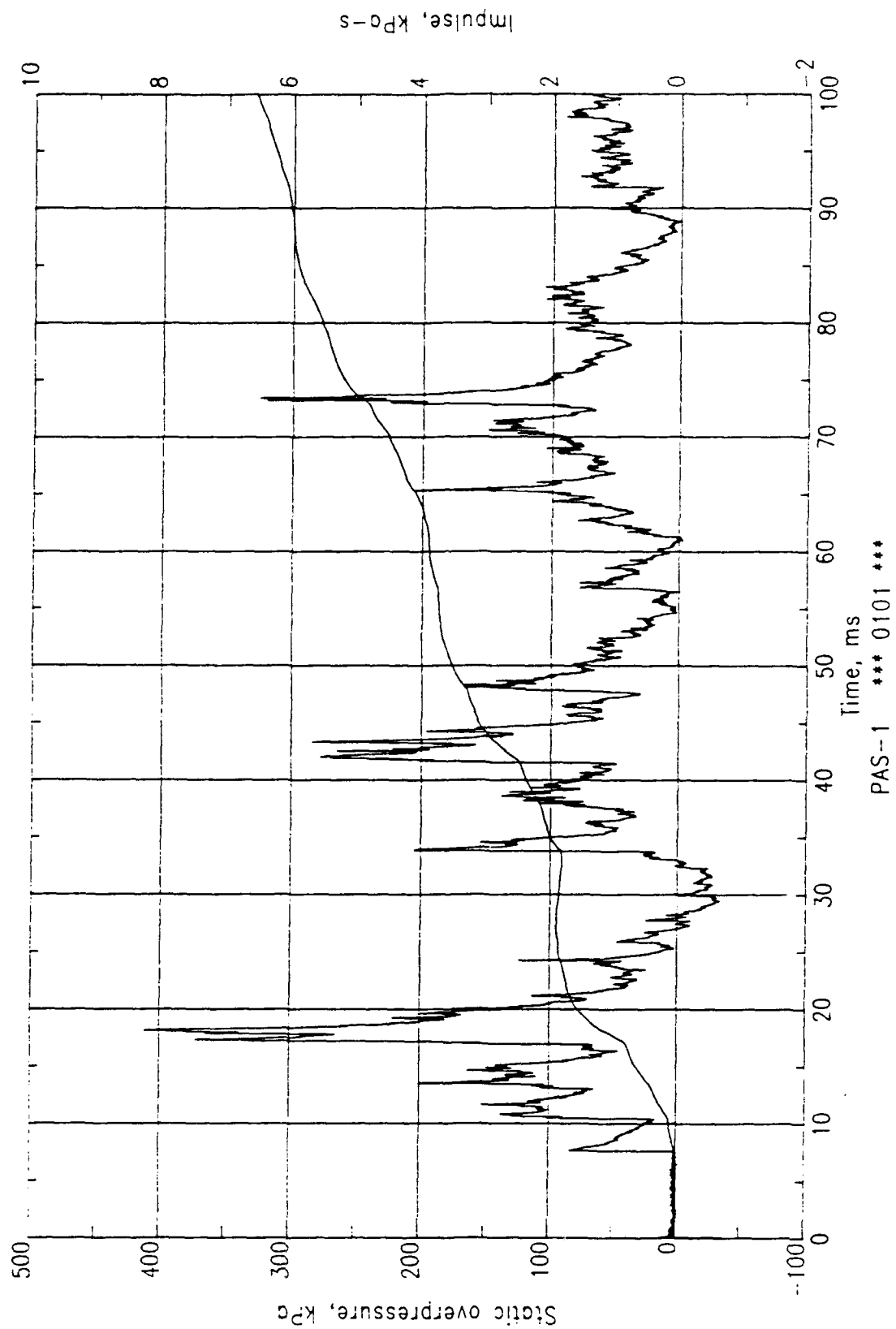
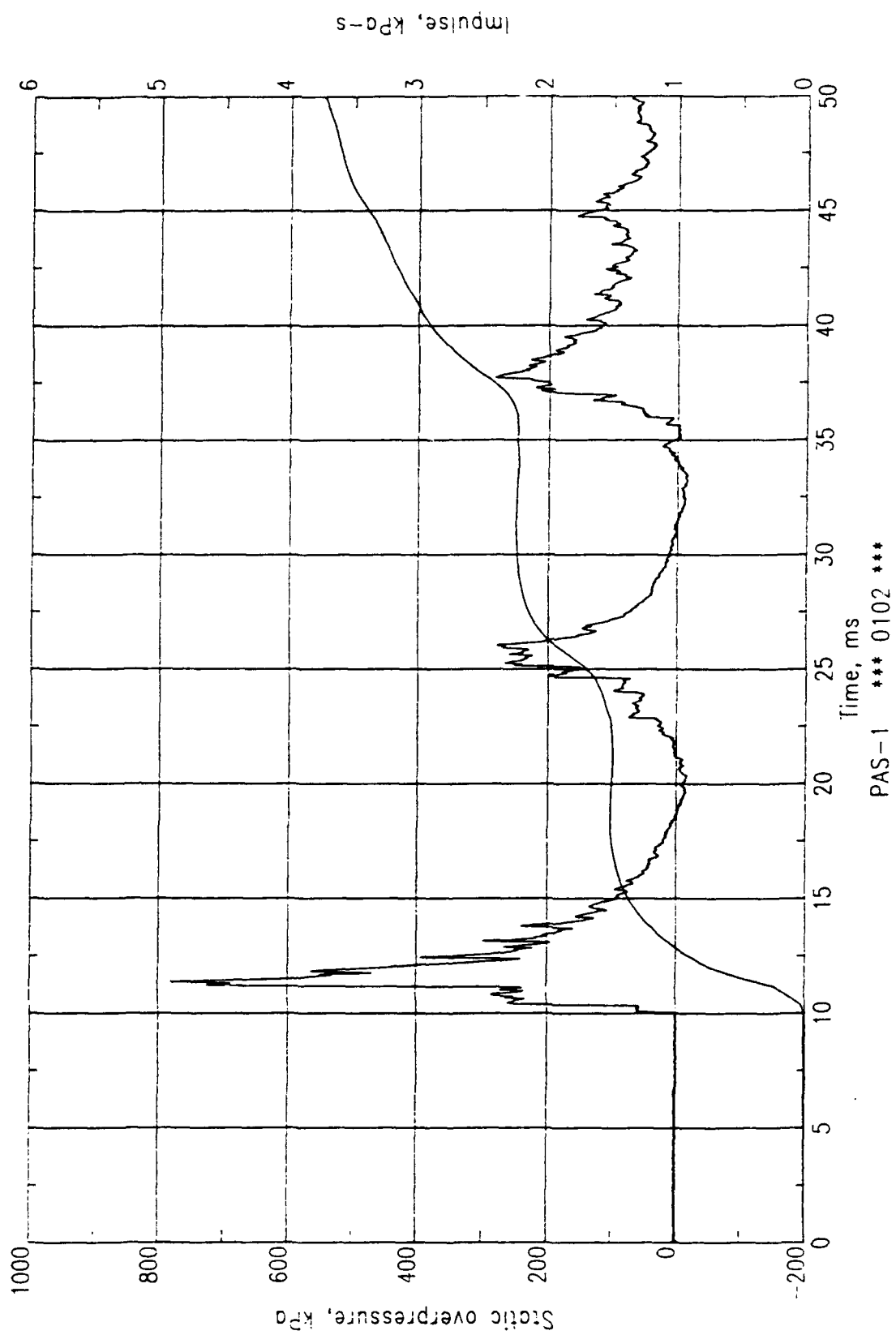
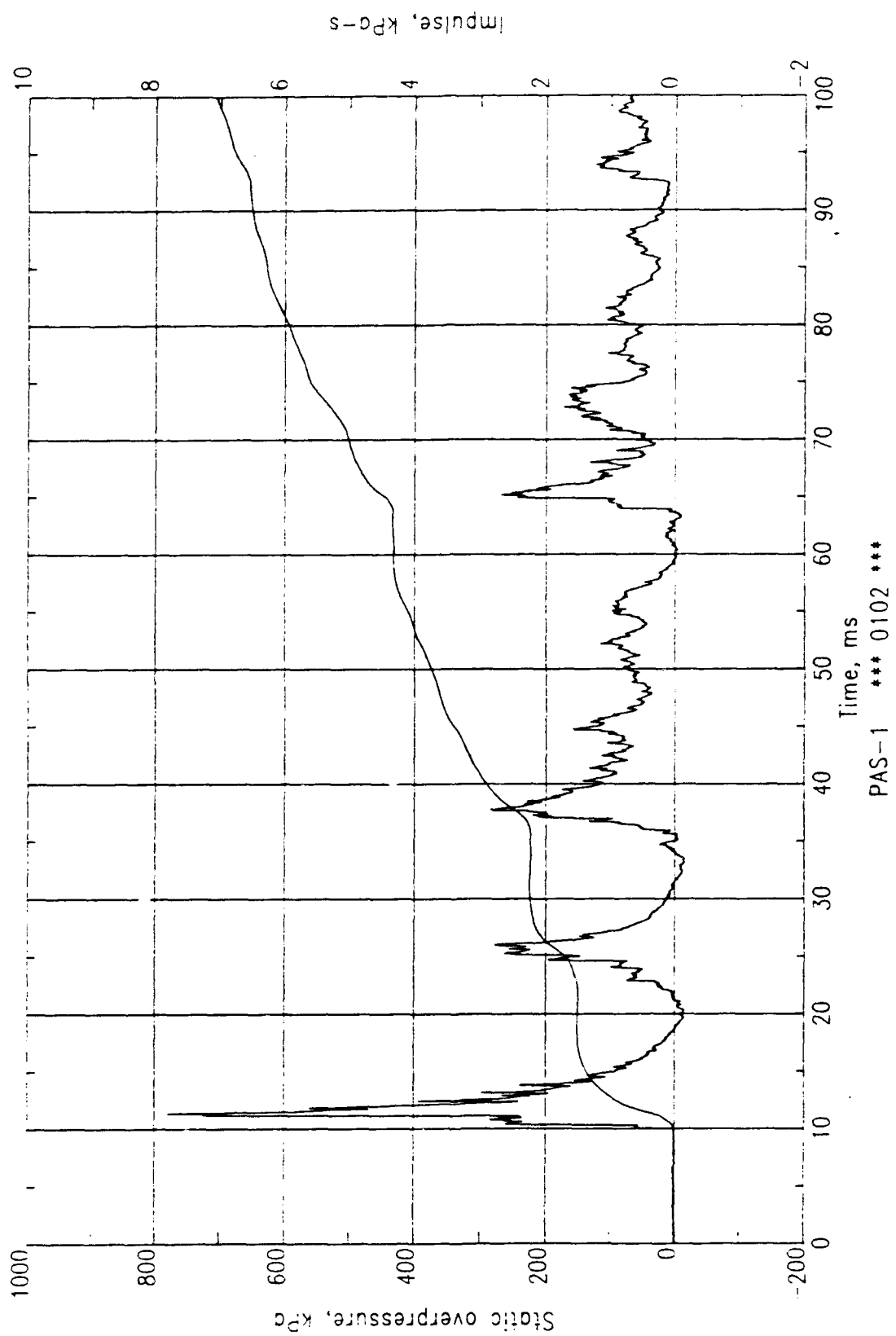


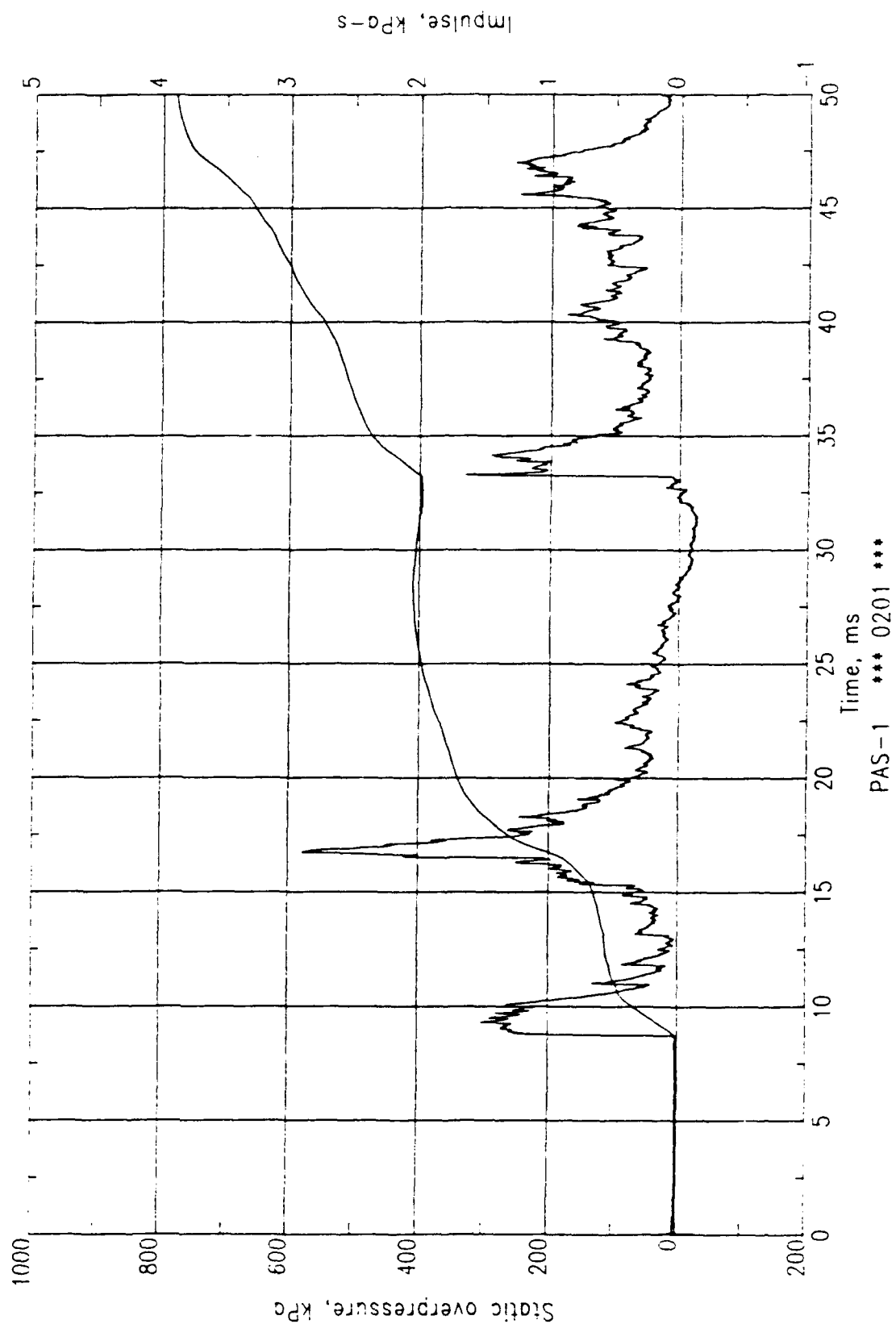
Figure A-8. Free-field airblast gage locations, PAS-1.

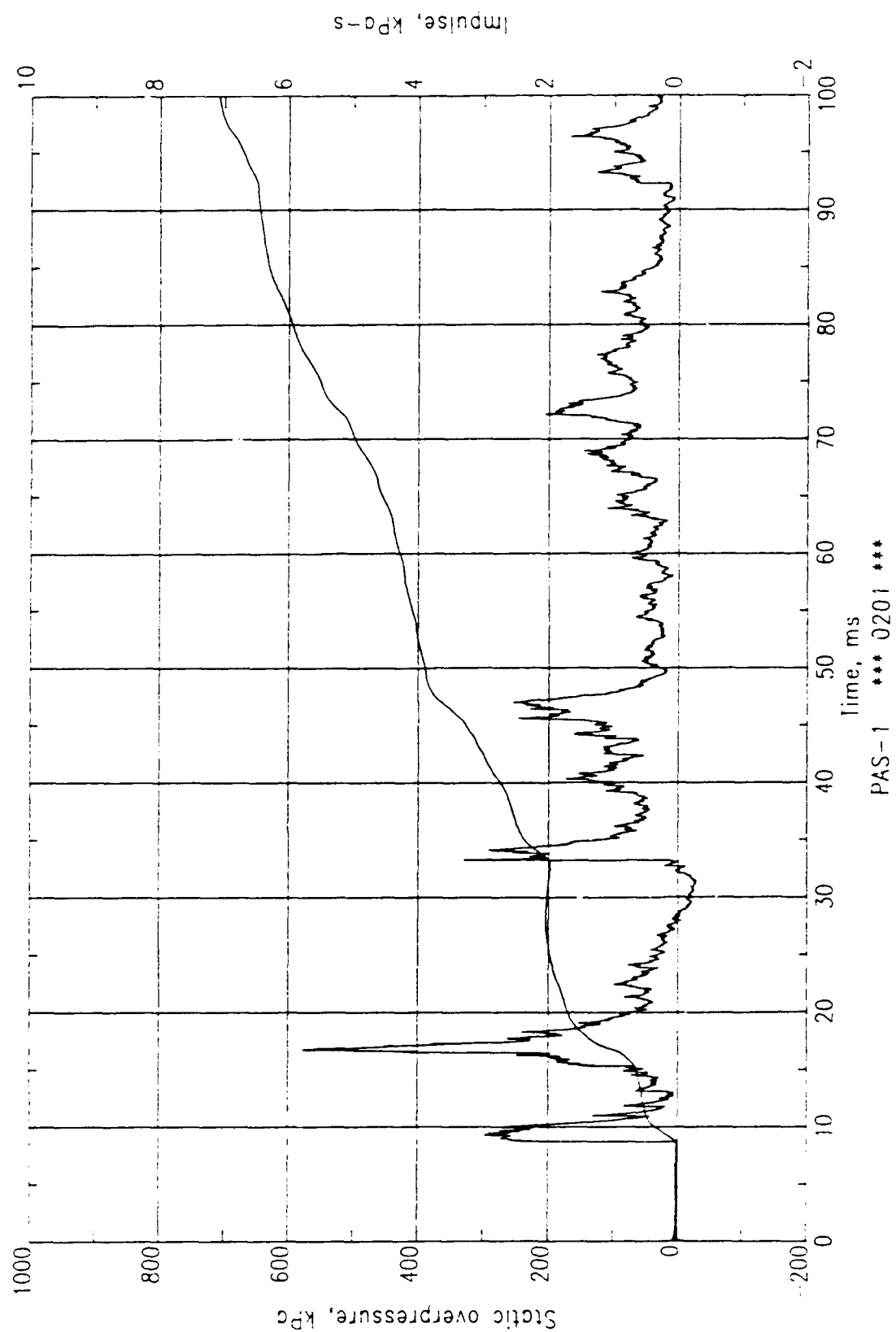


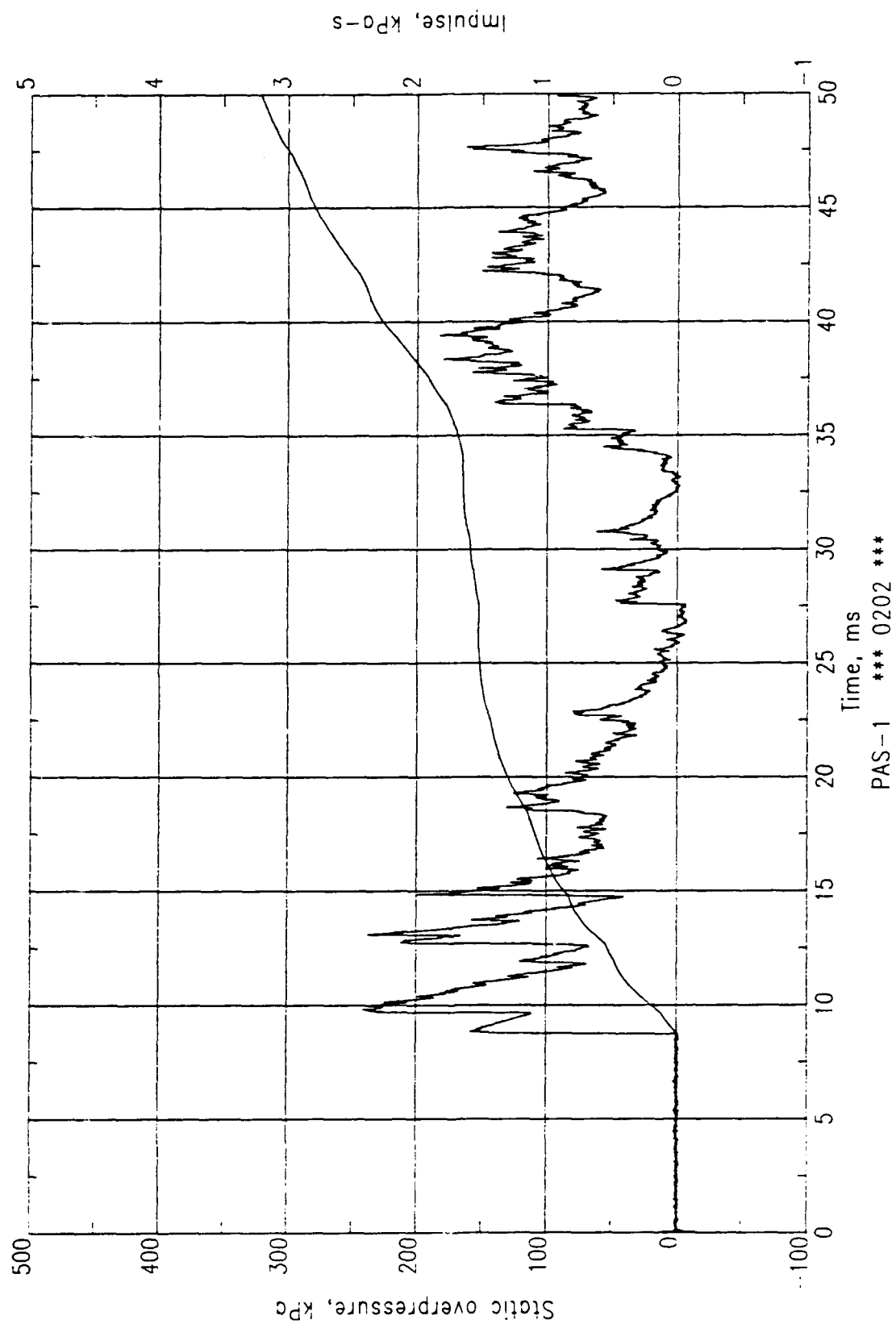


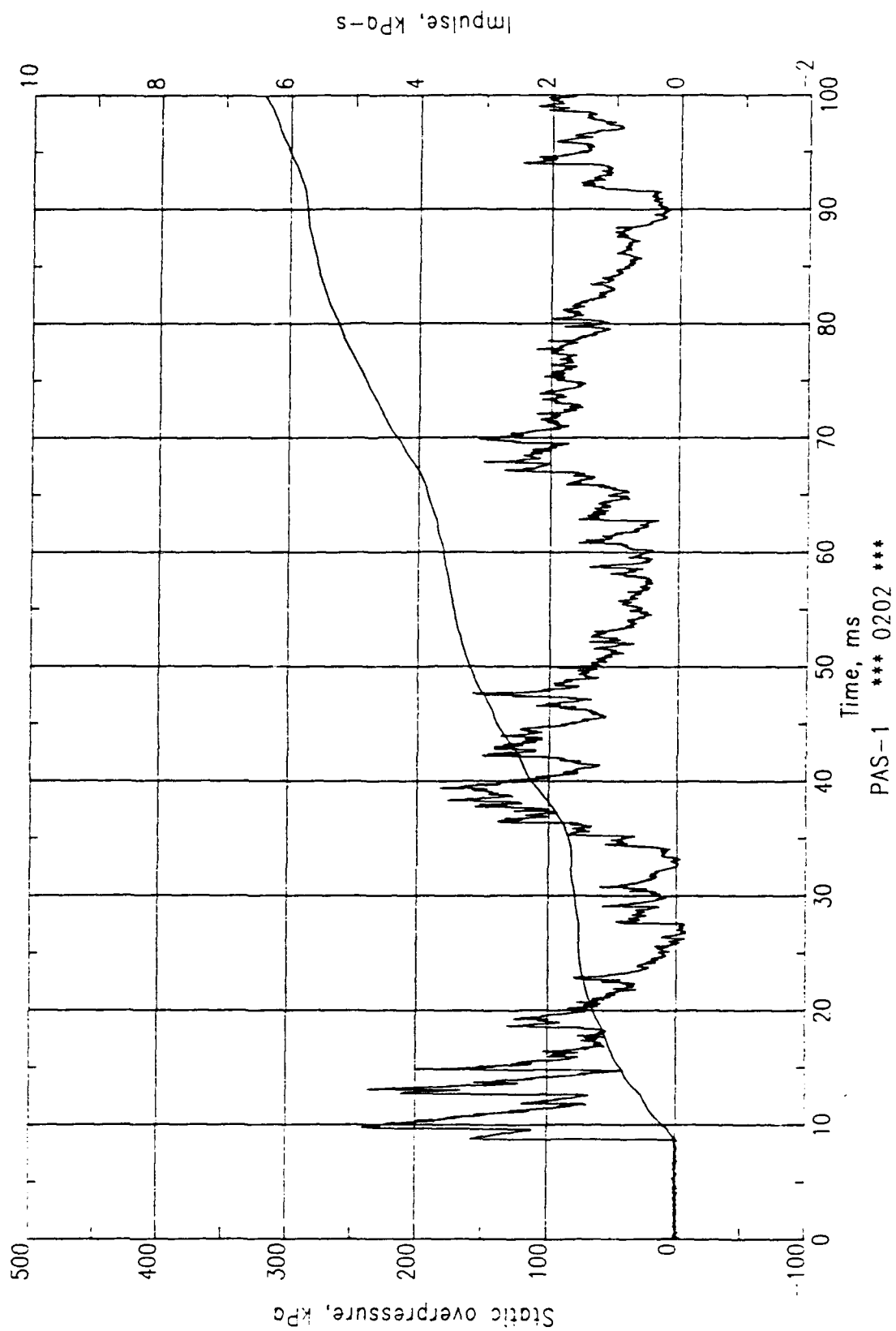


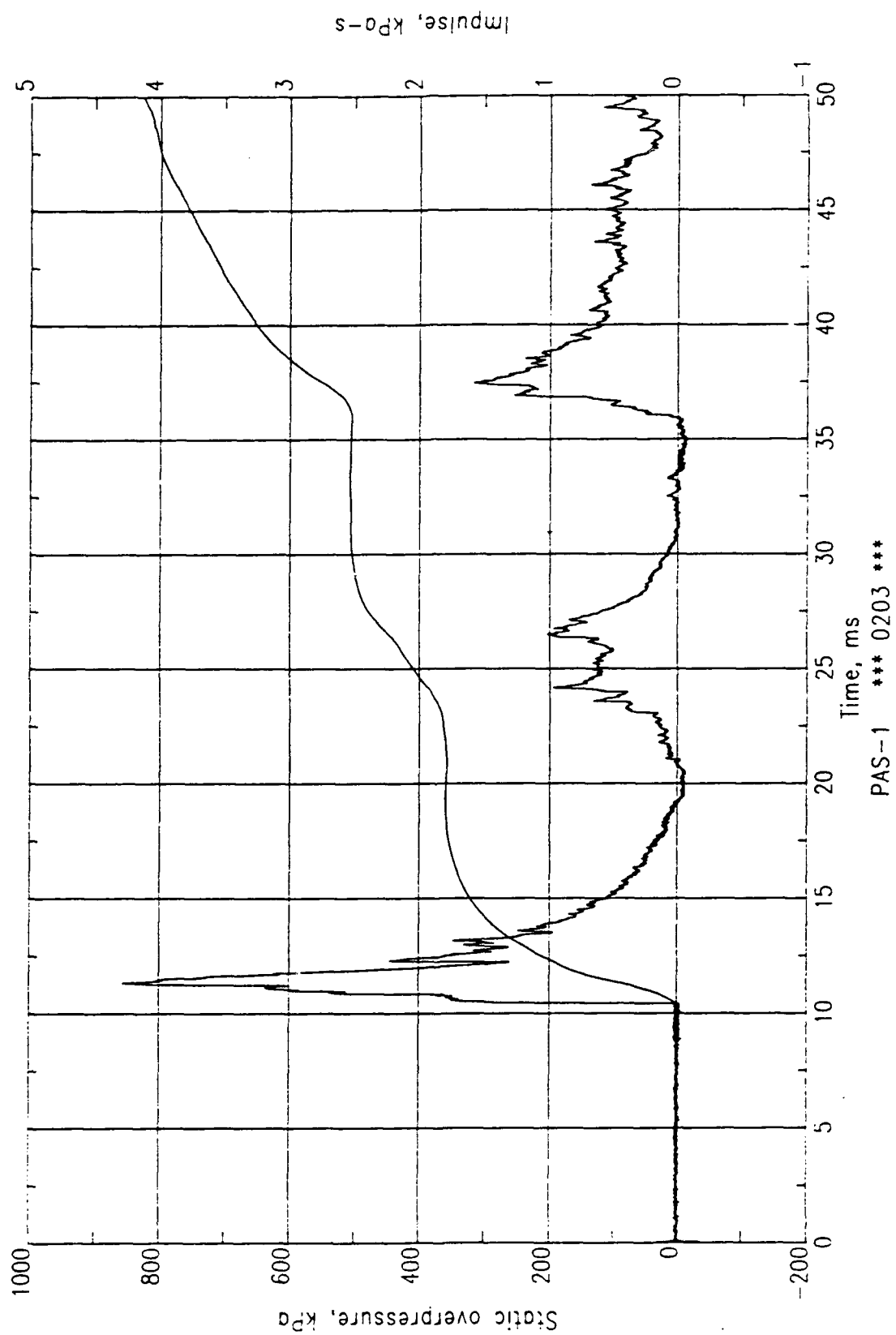


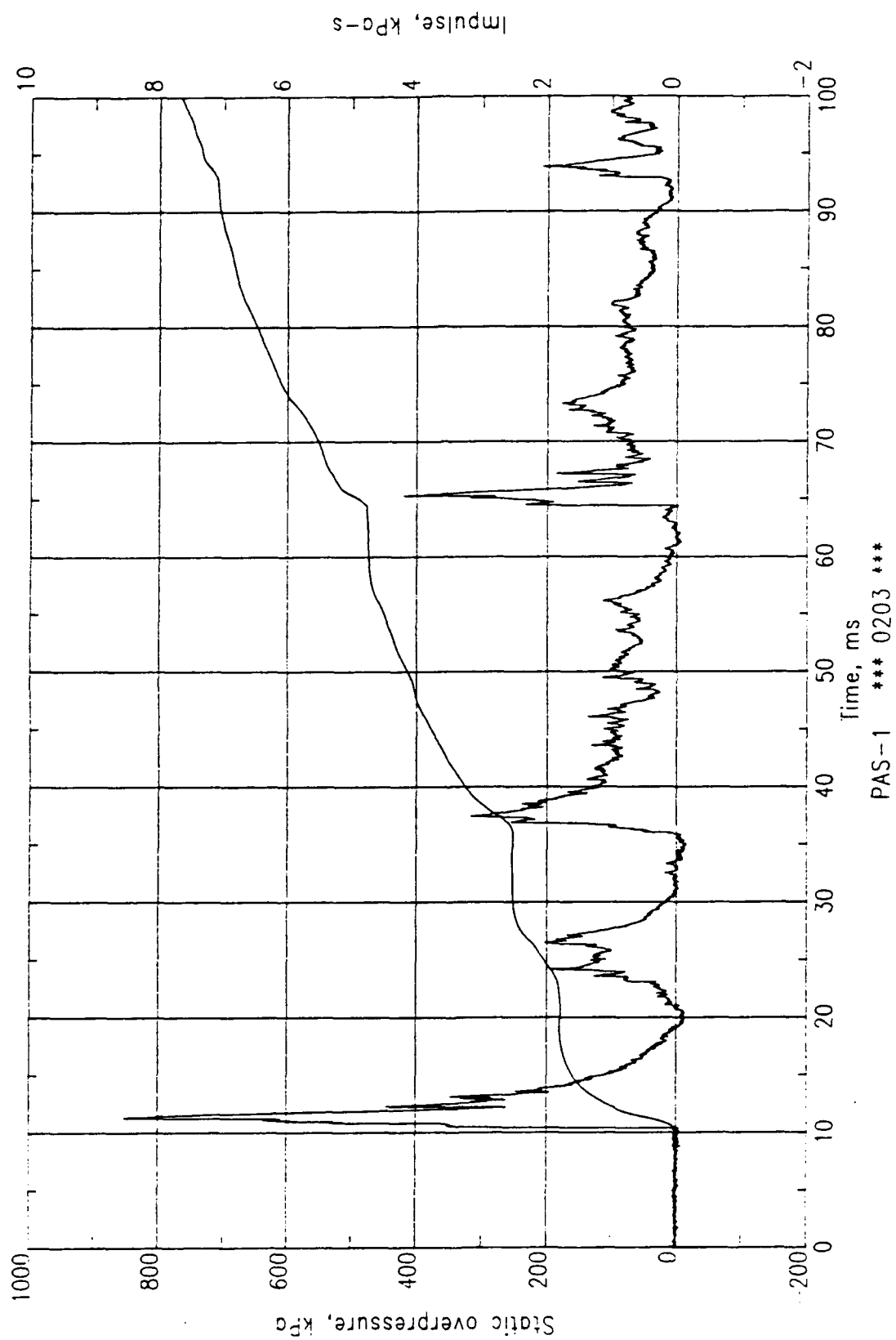


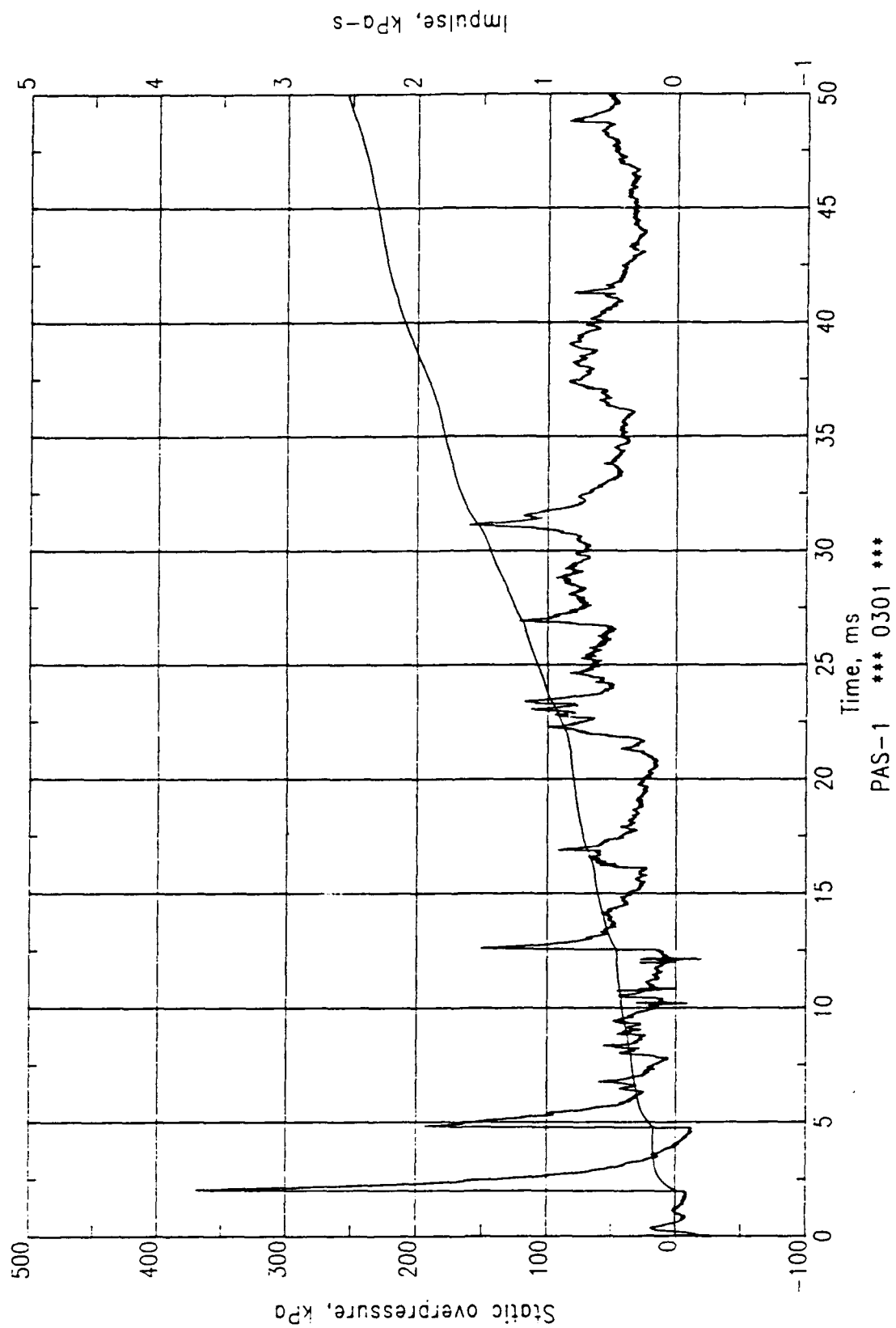


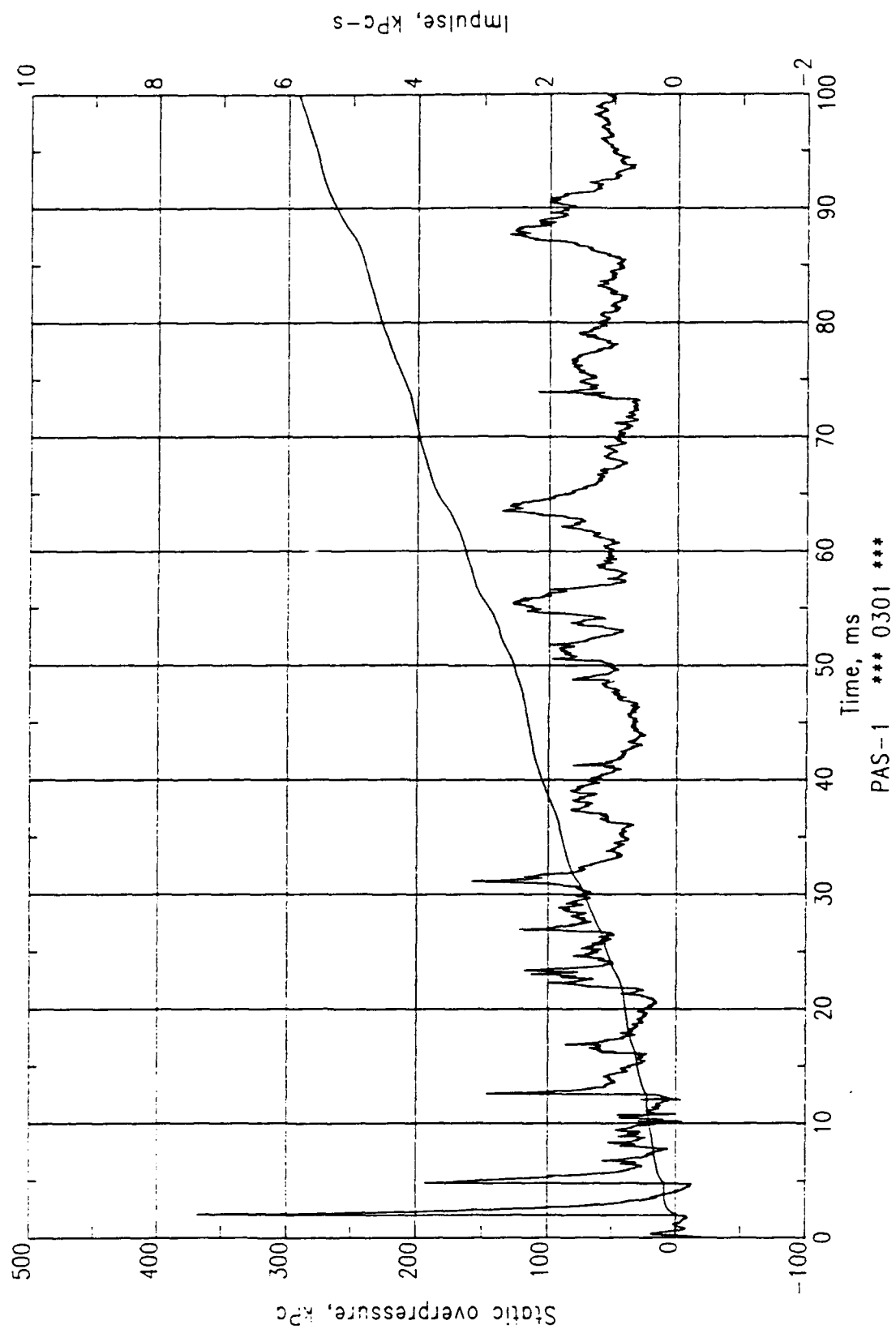


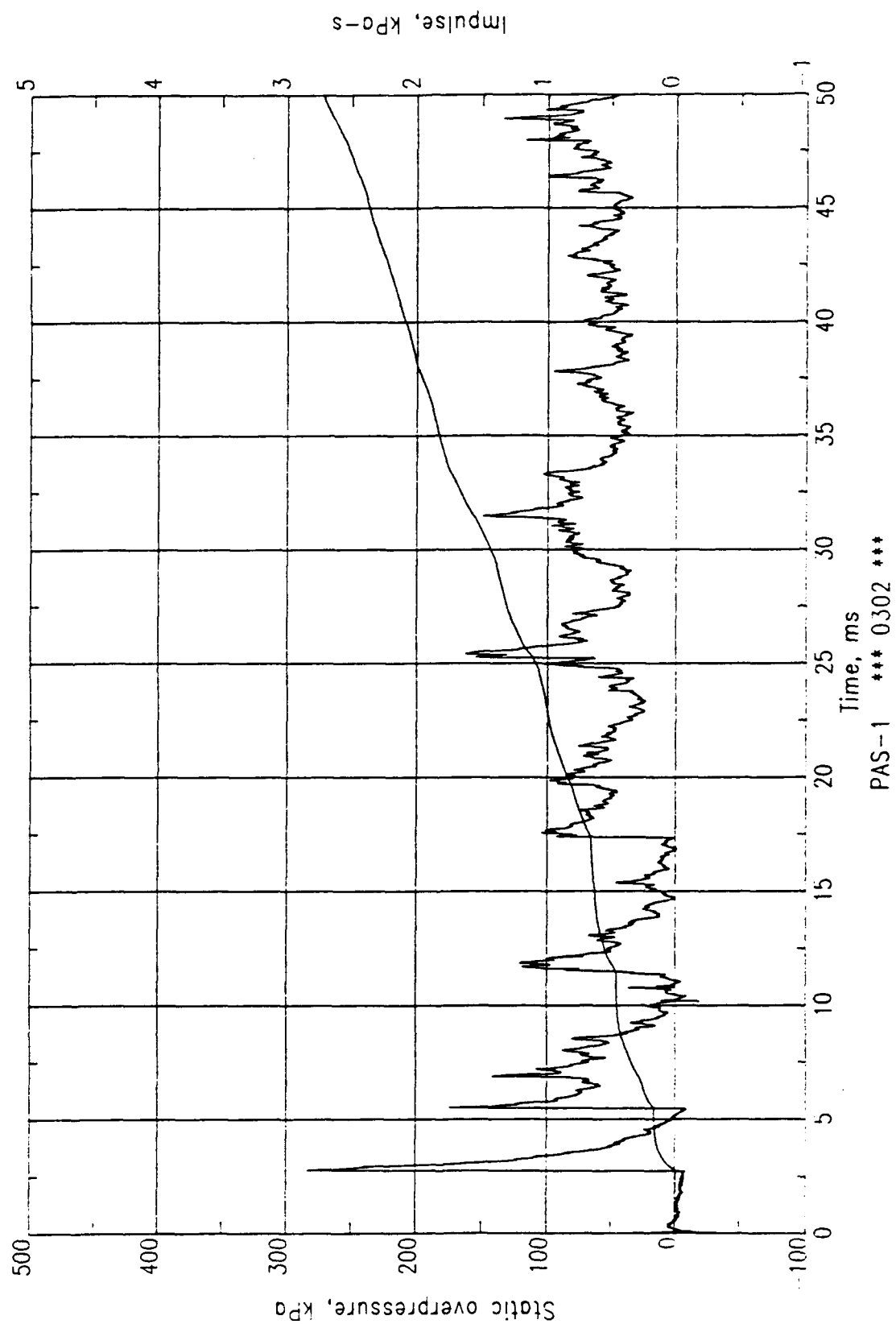


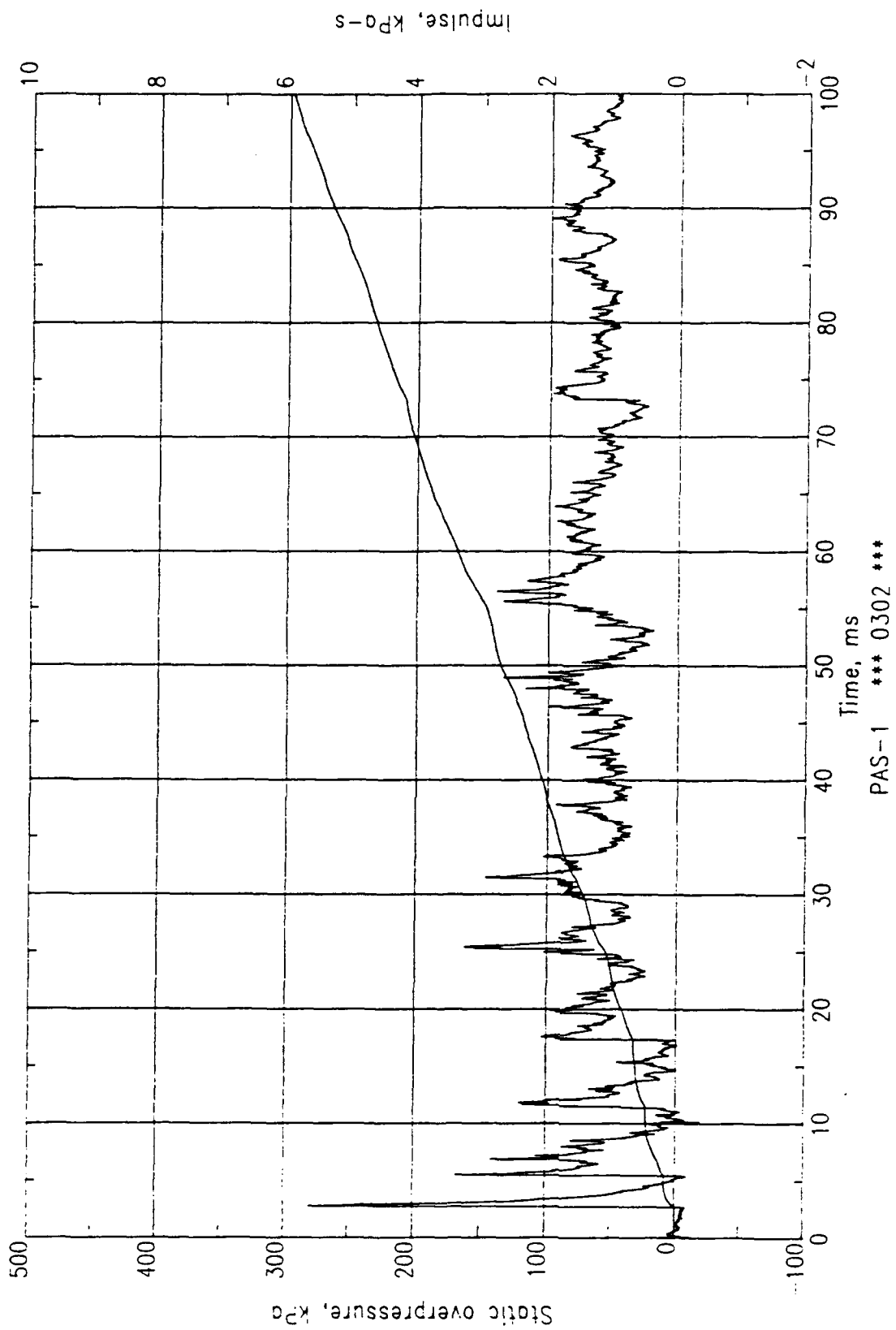


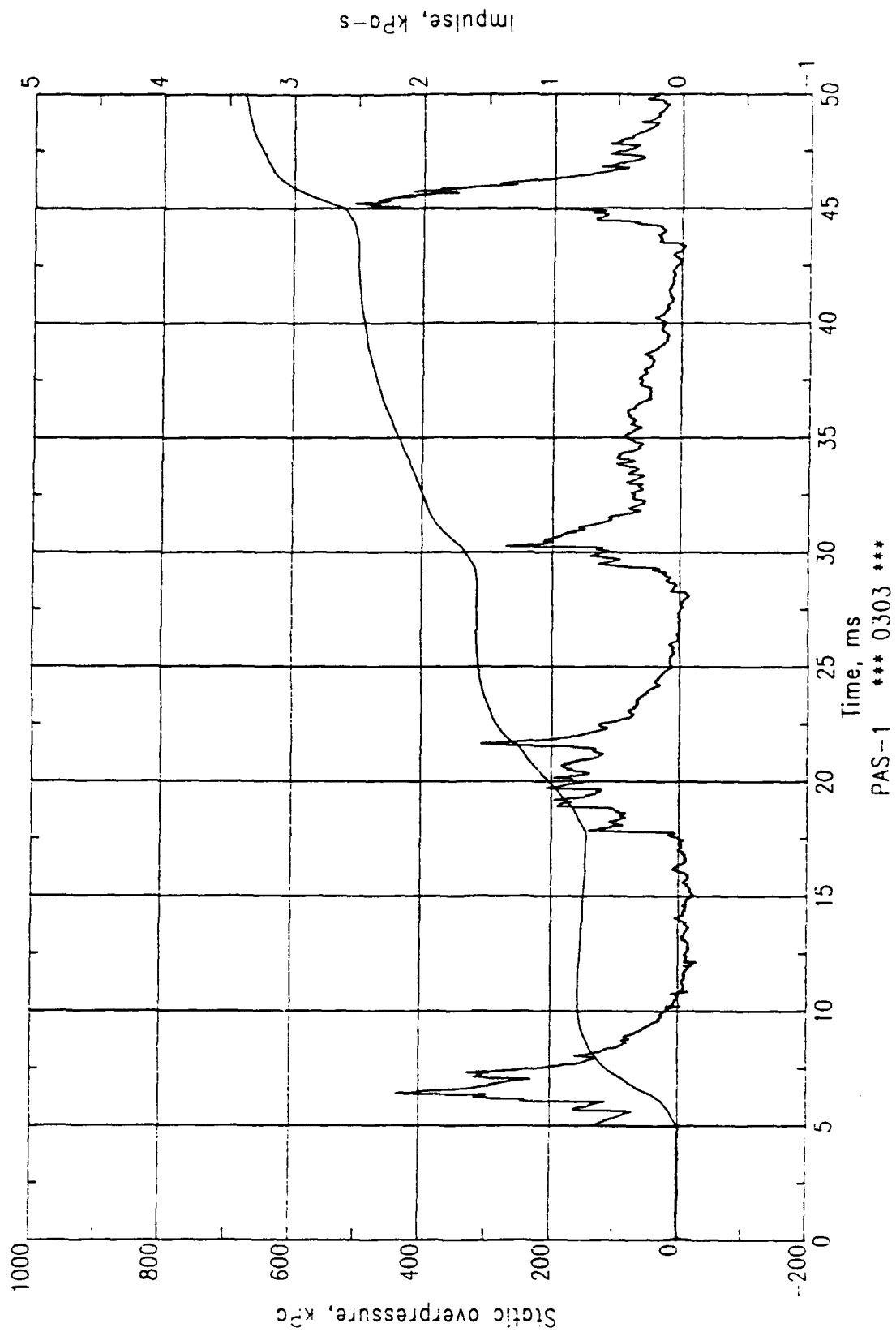


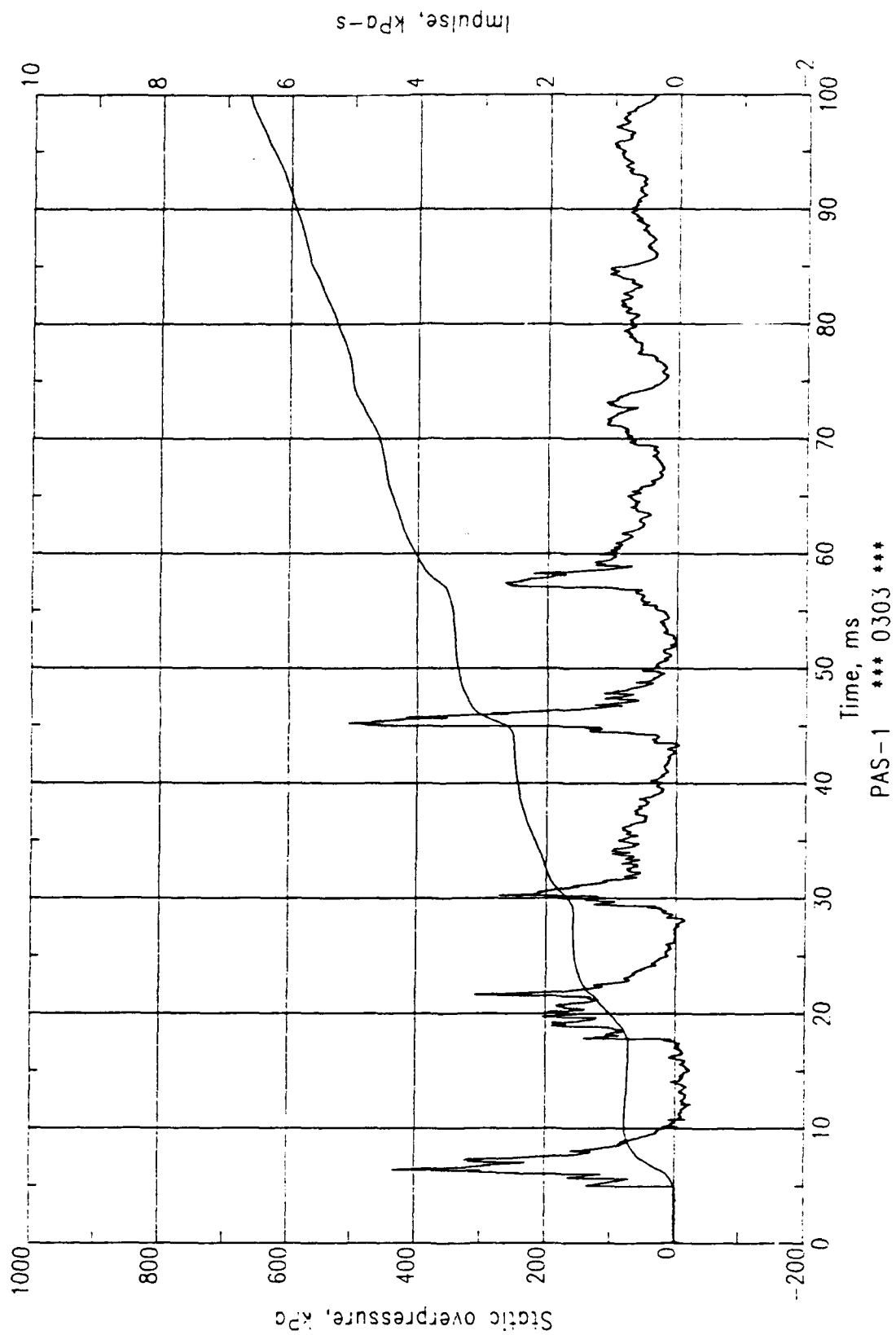


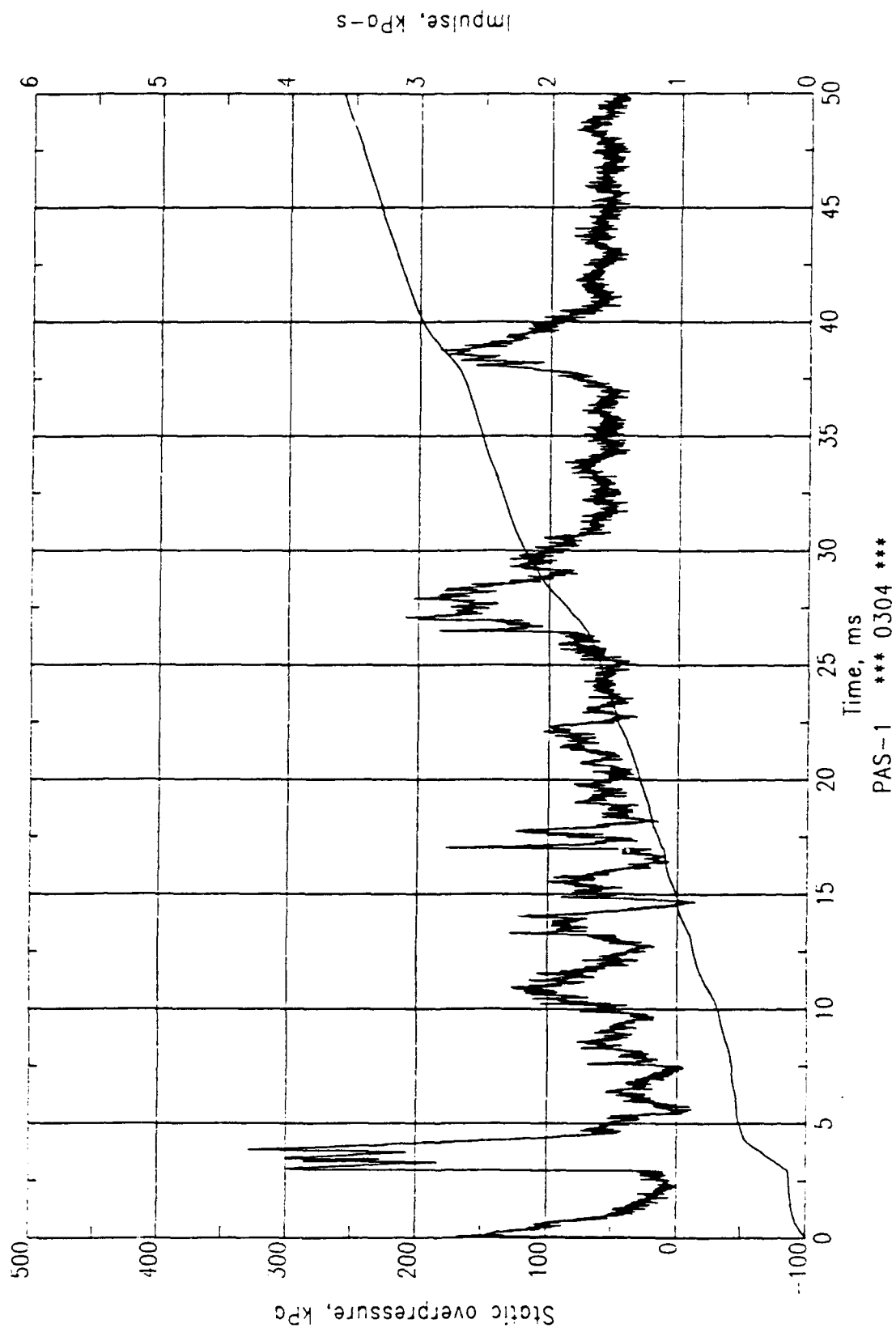


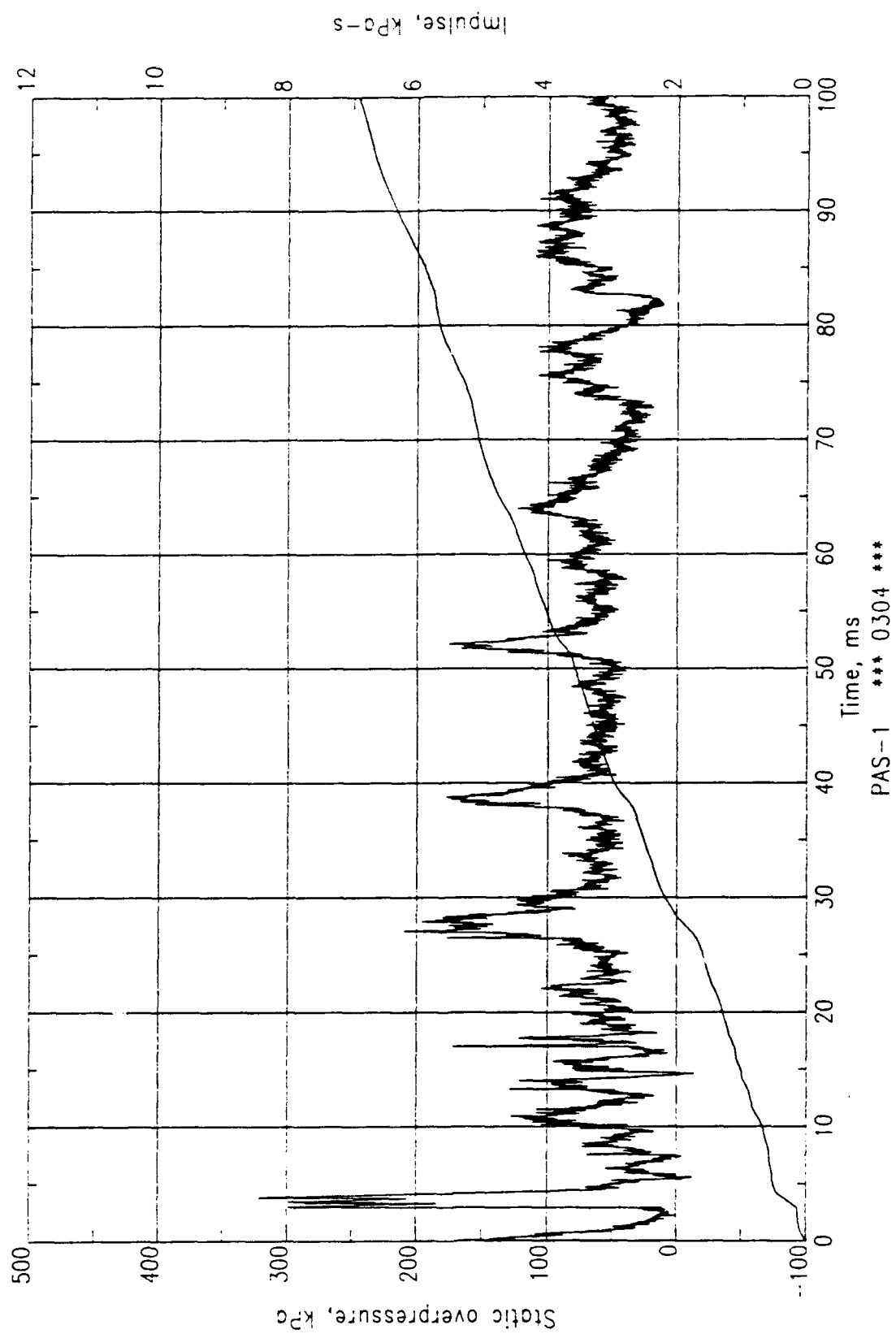


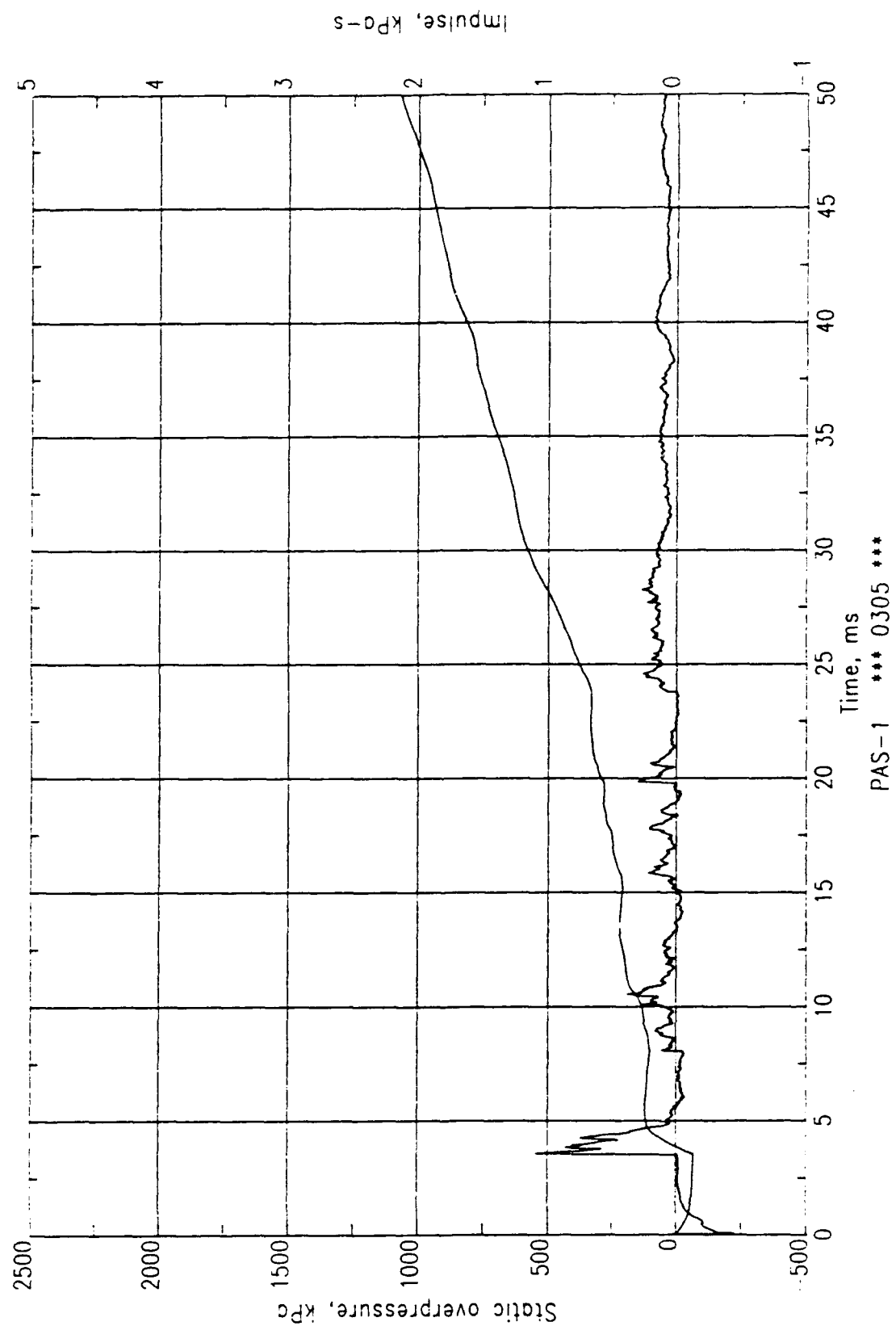


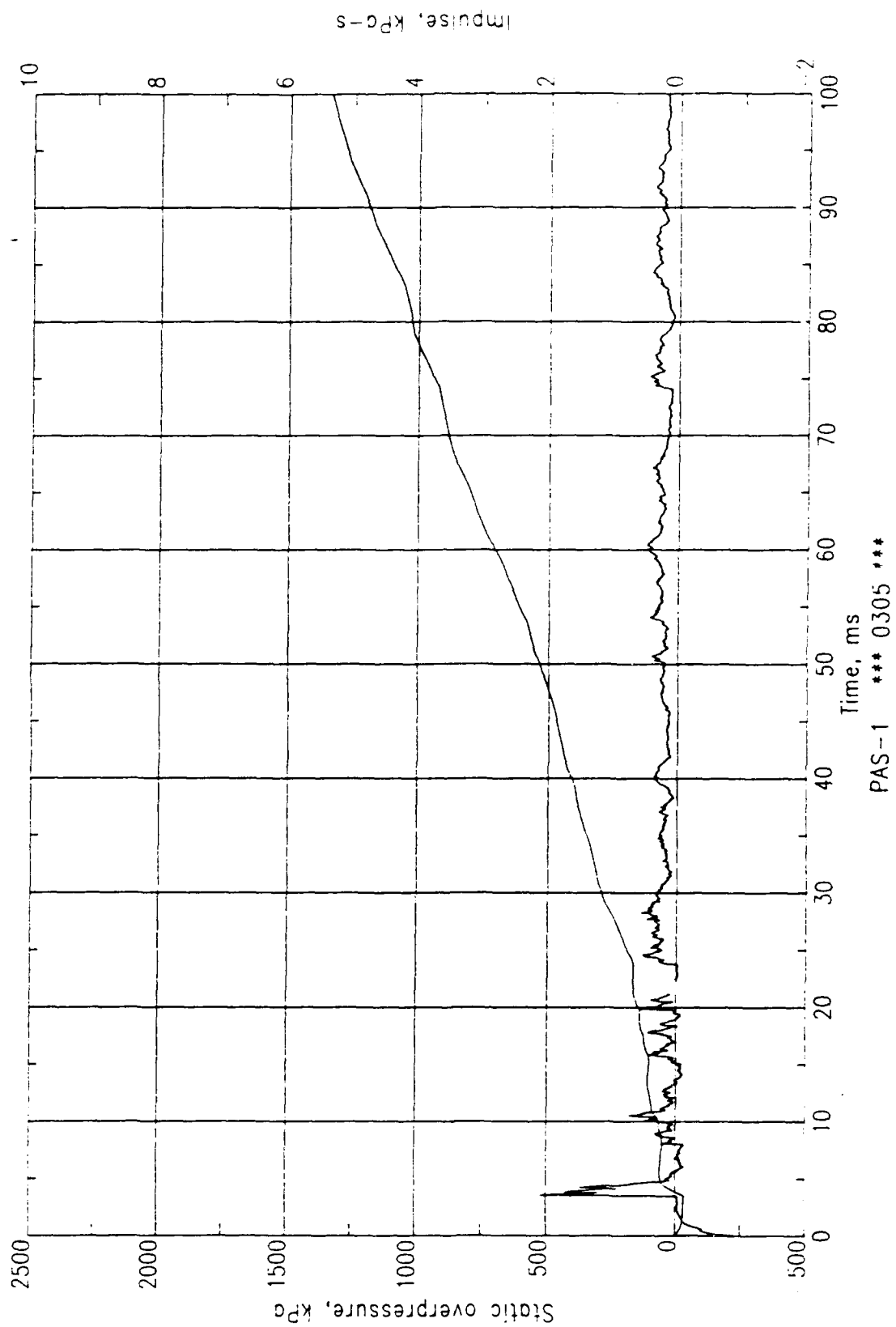


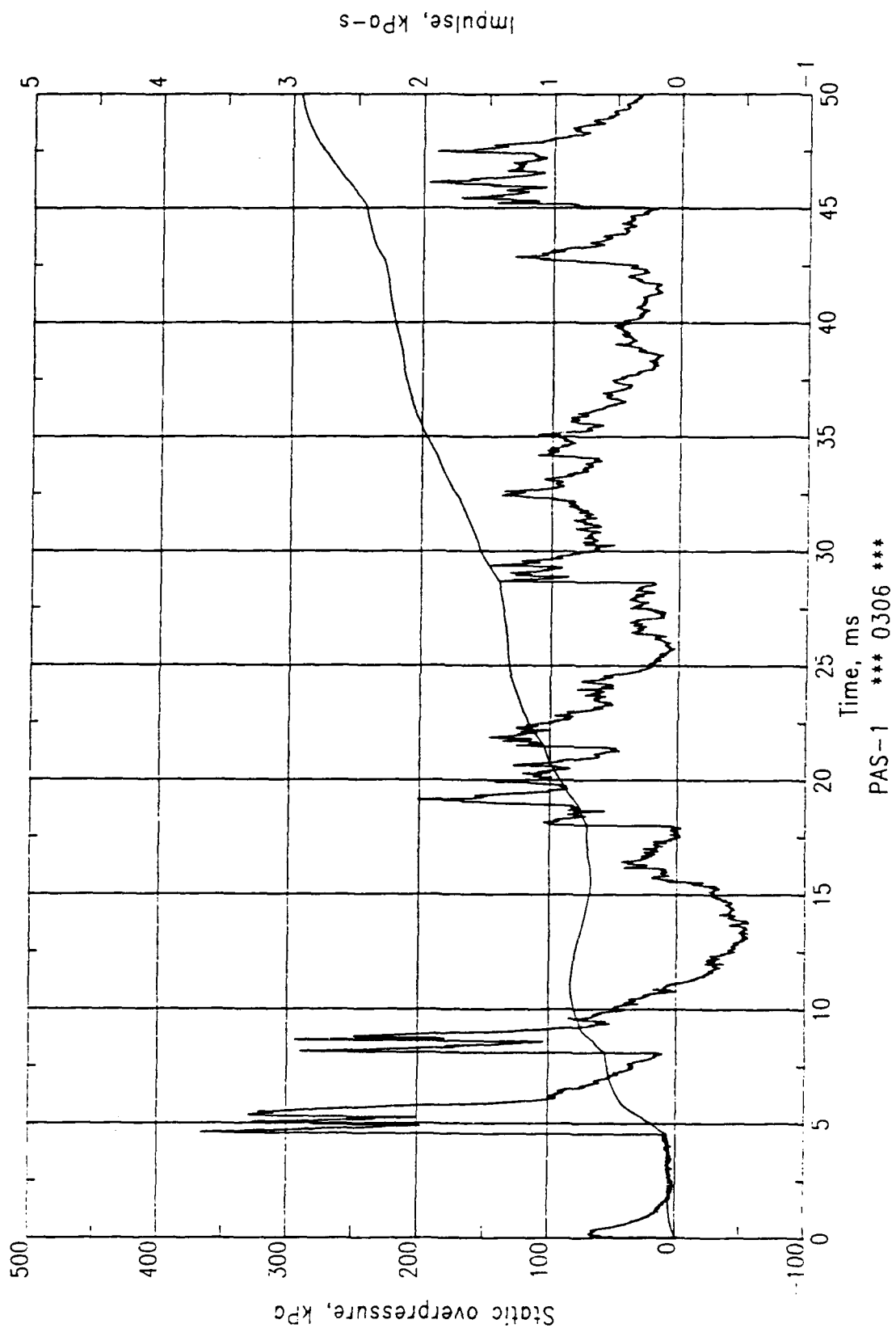


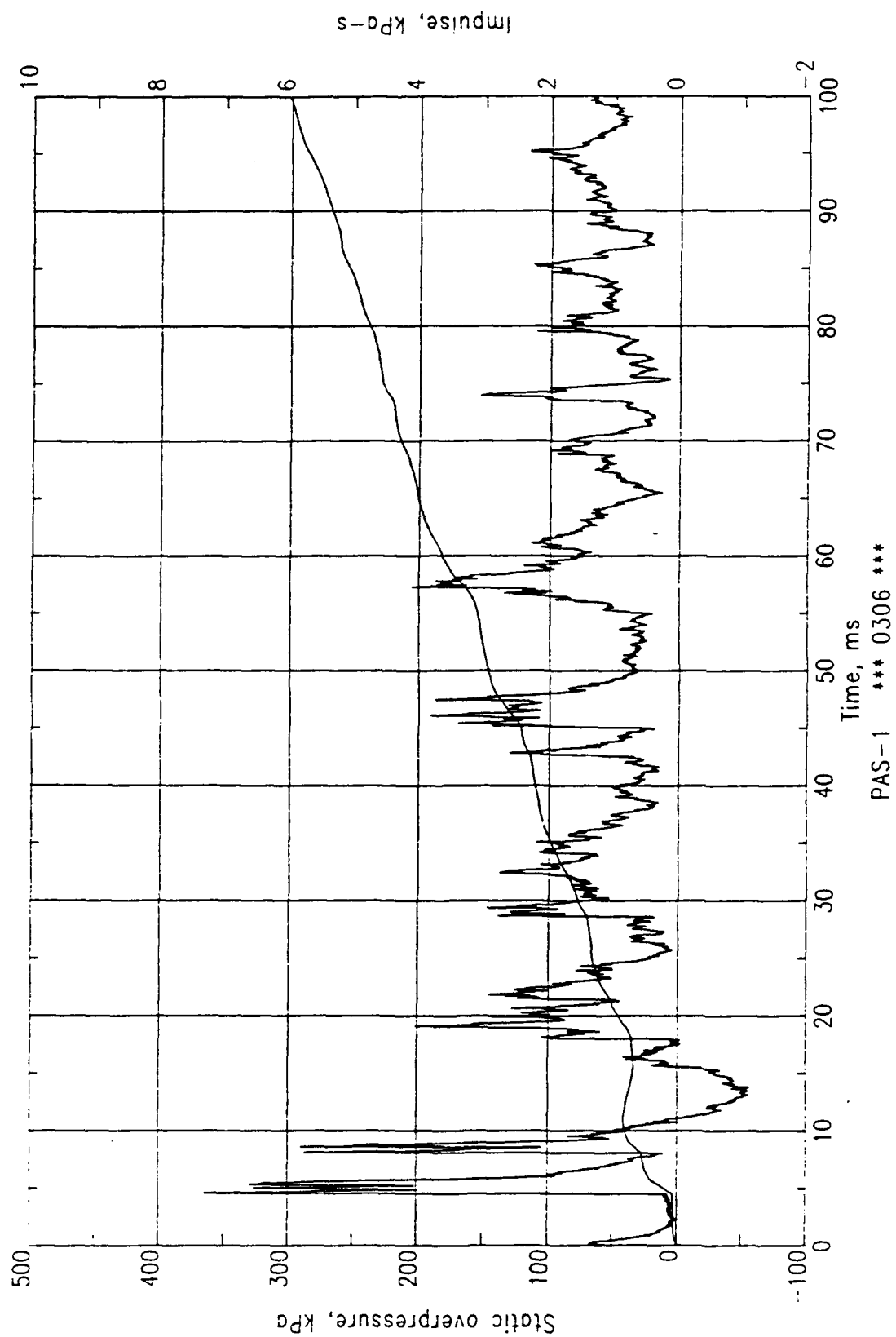


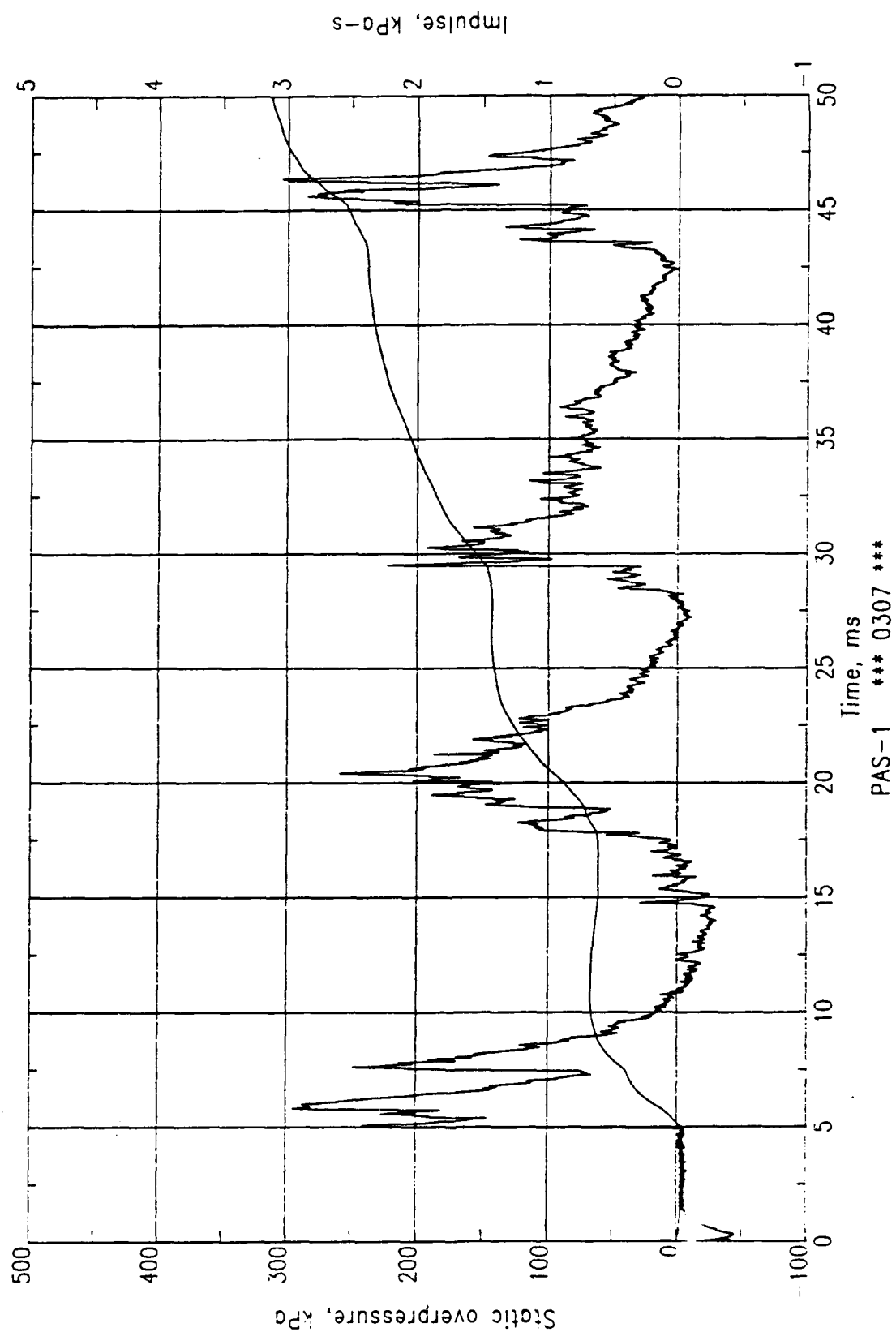




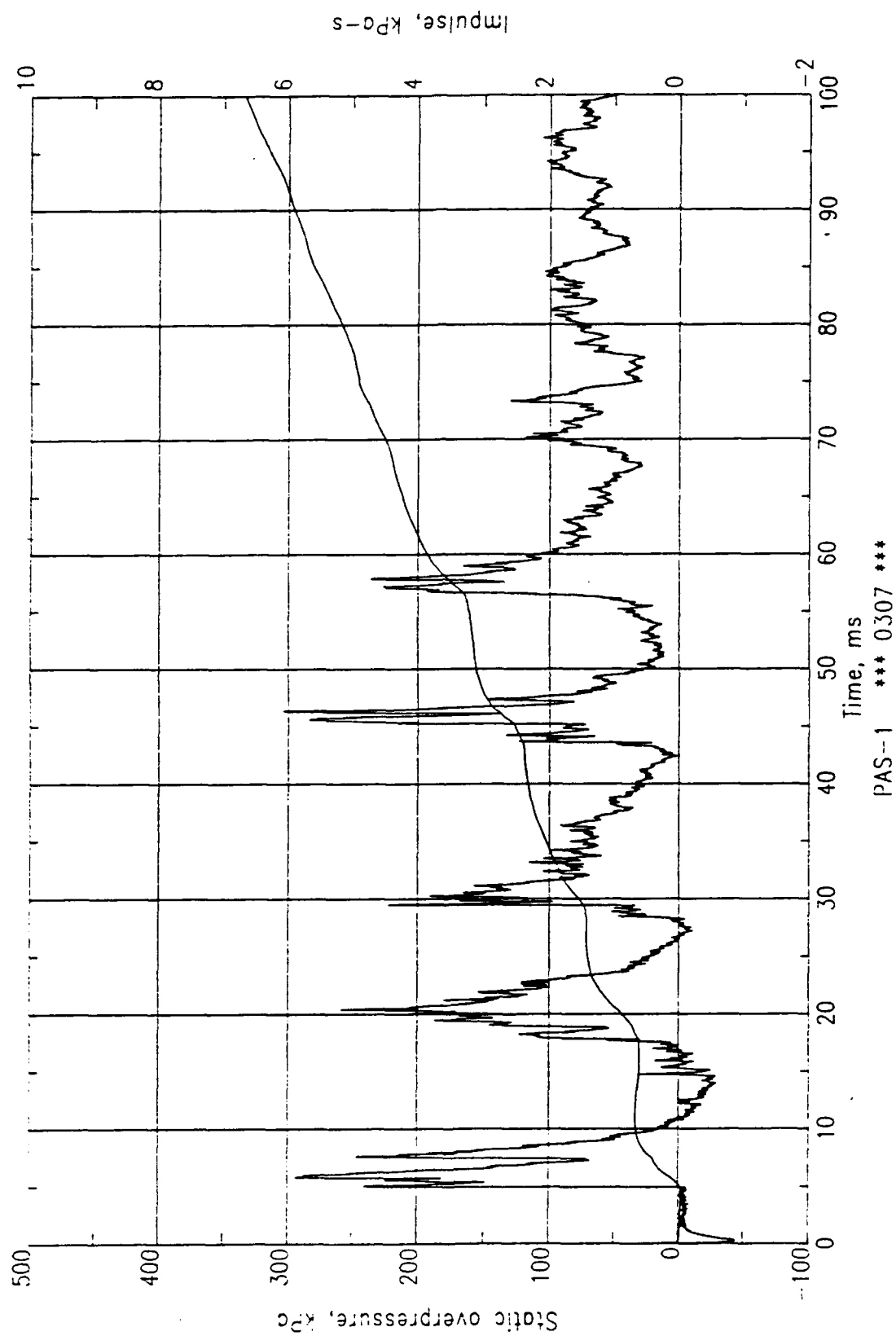


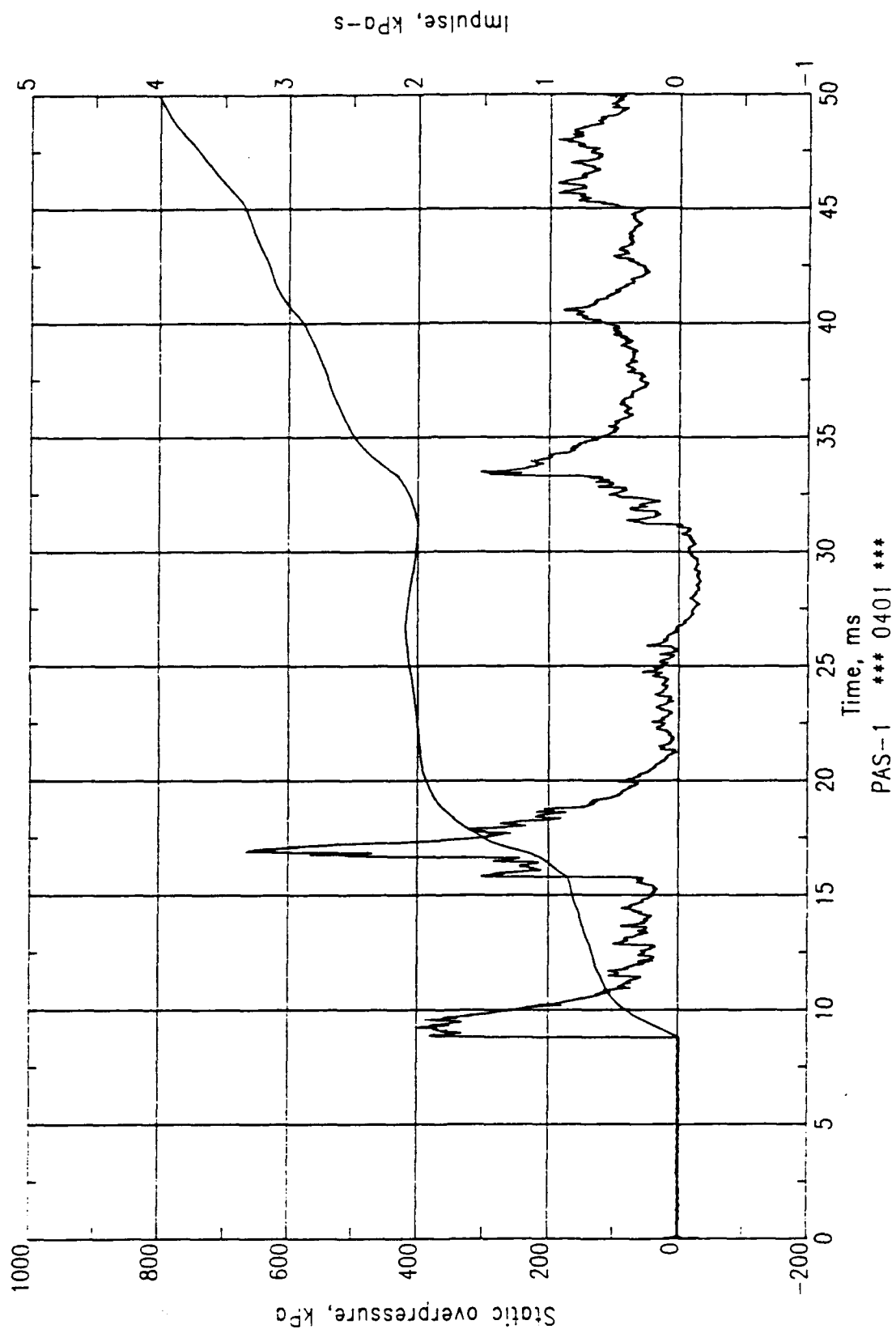


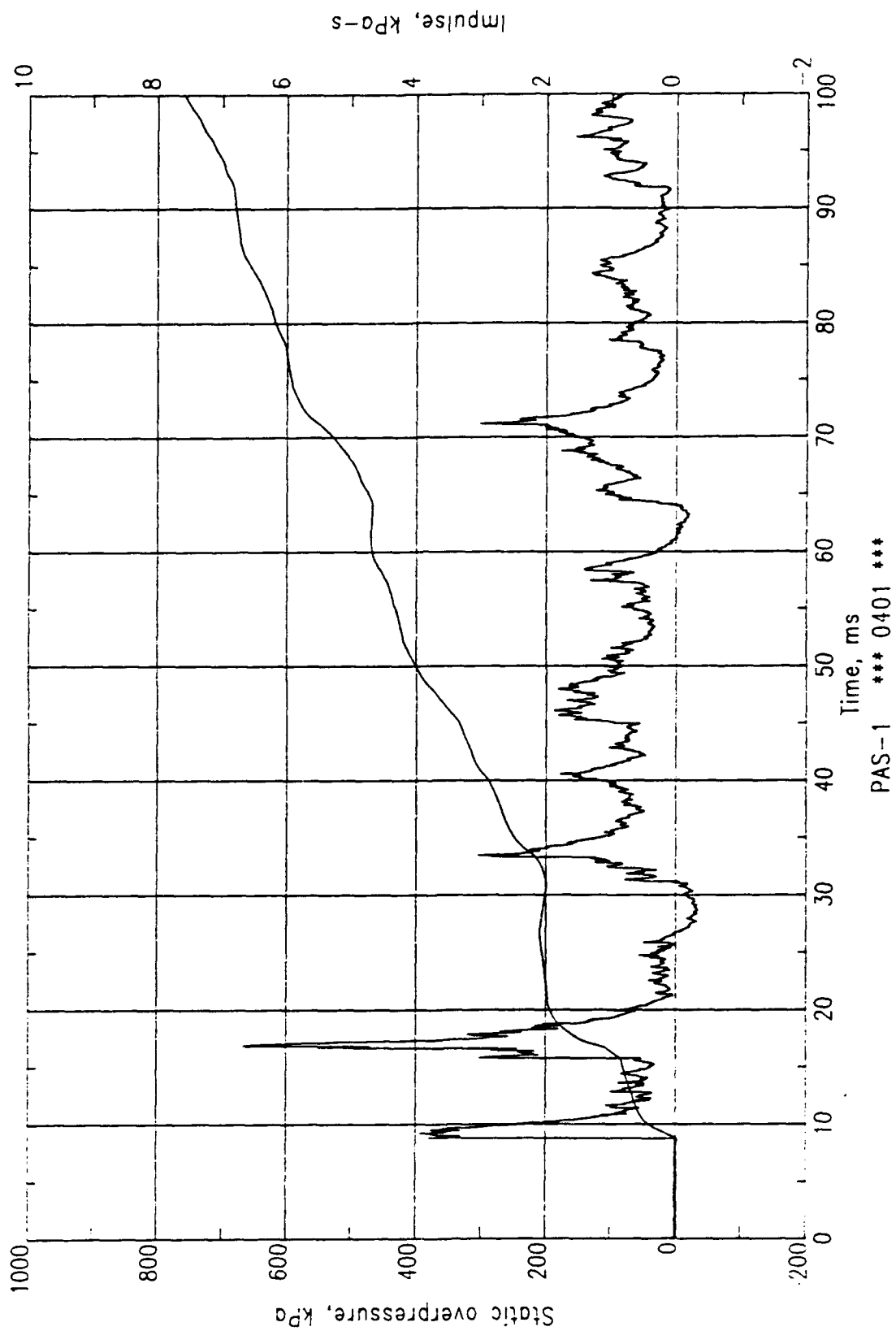


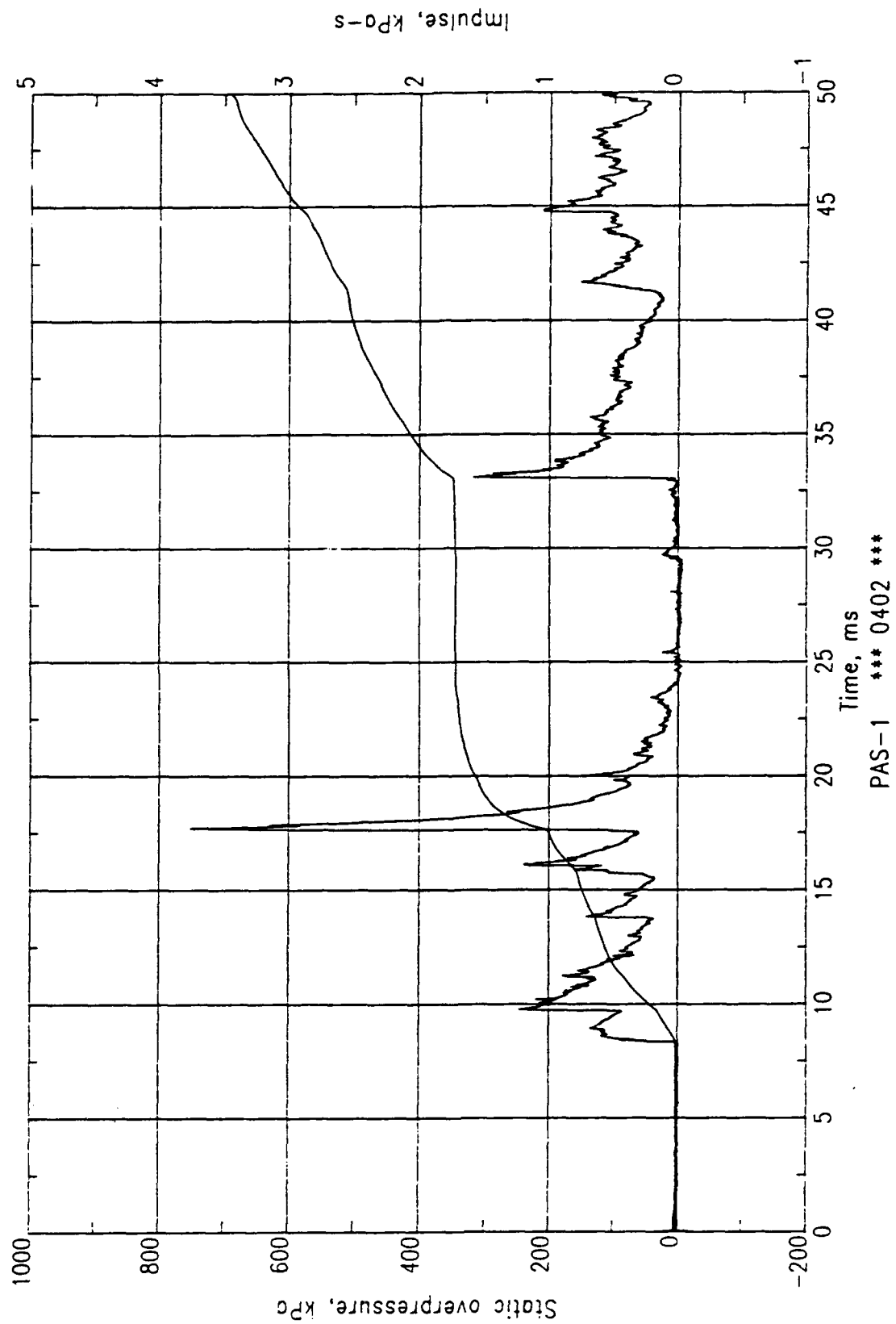


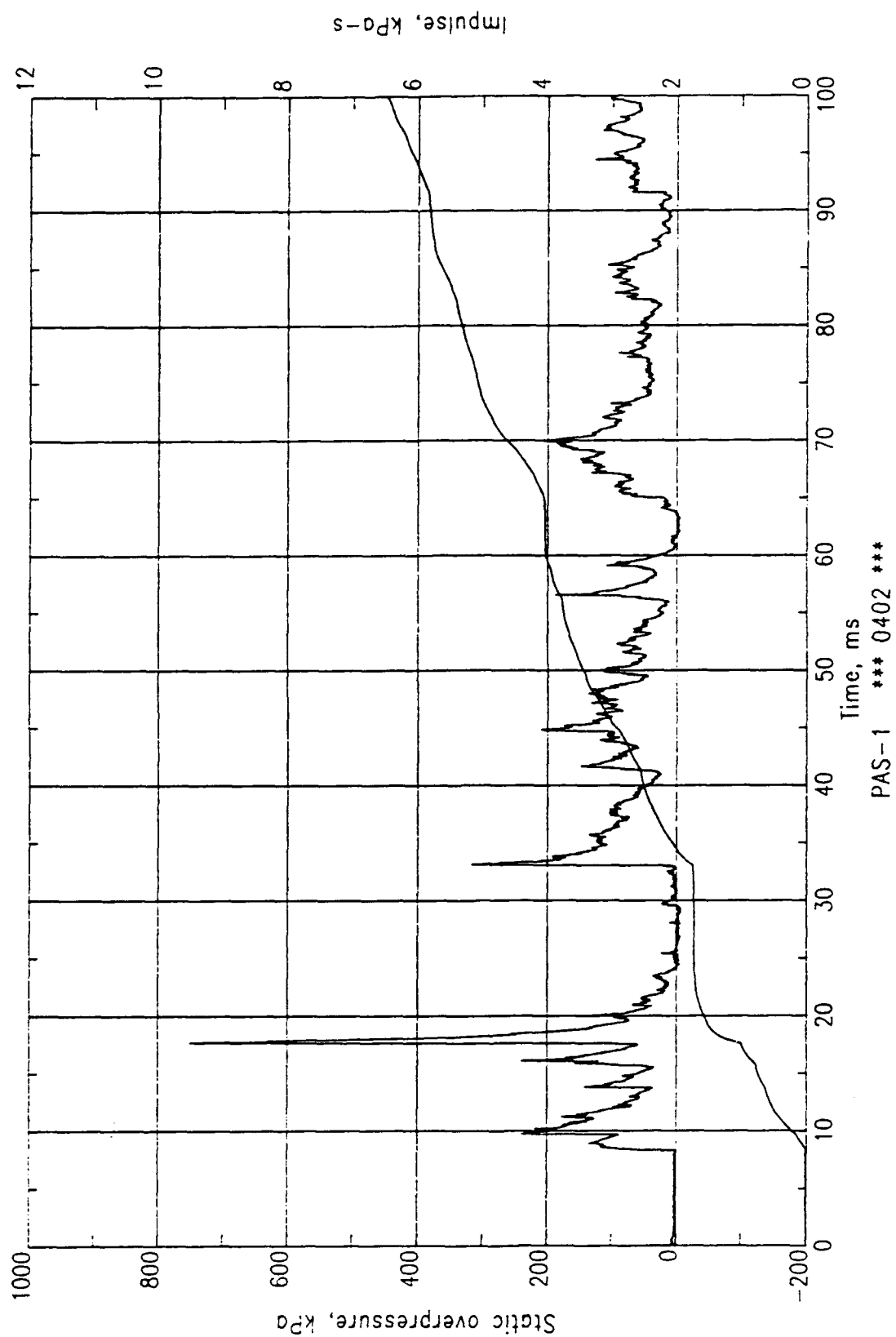
PAS-1 *** 0307 ***

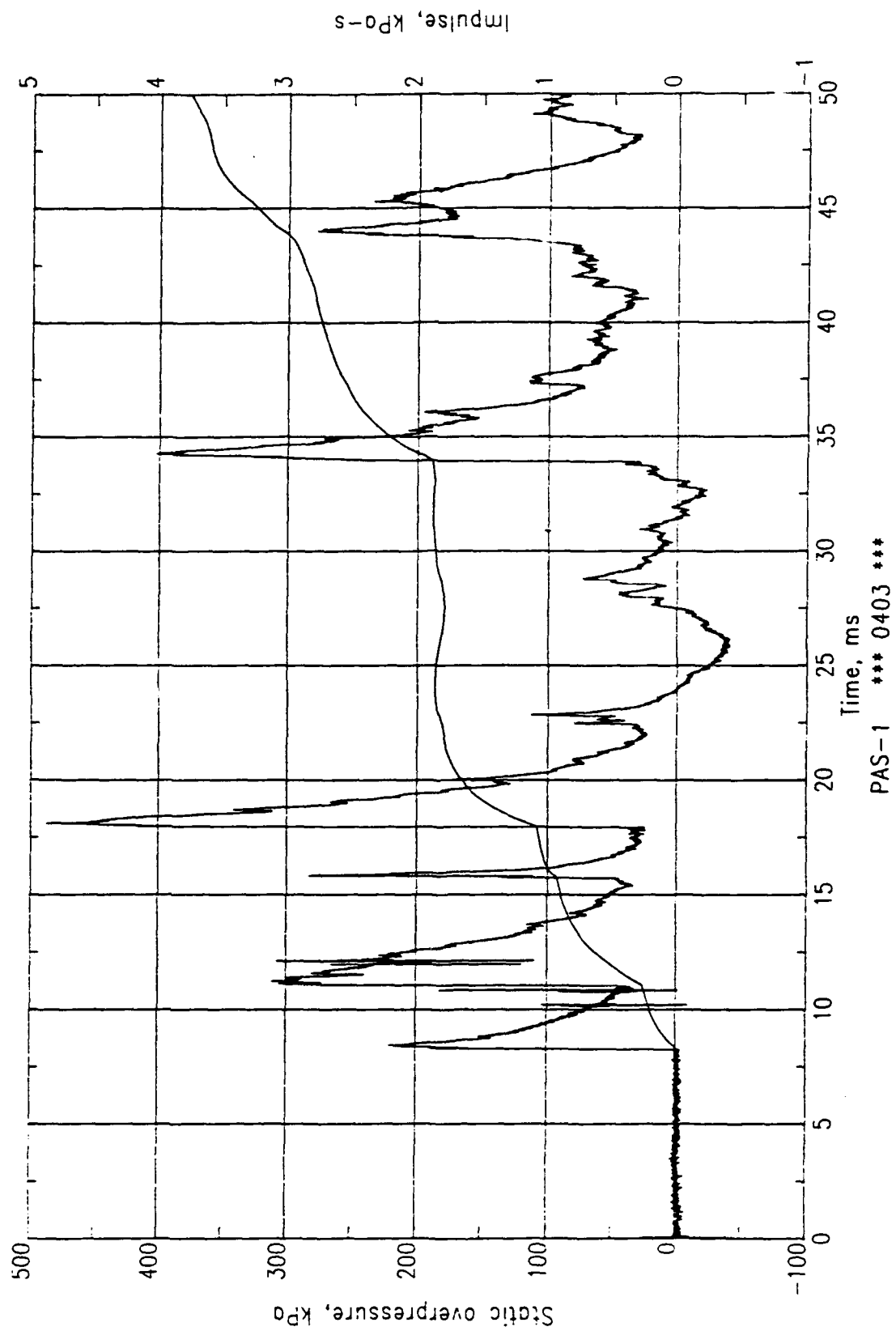


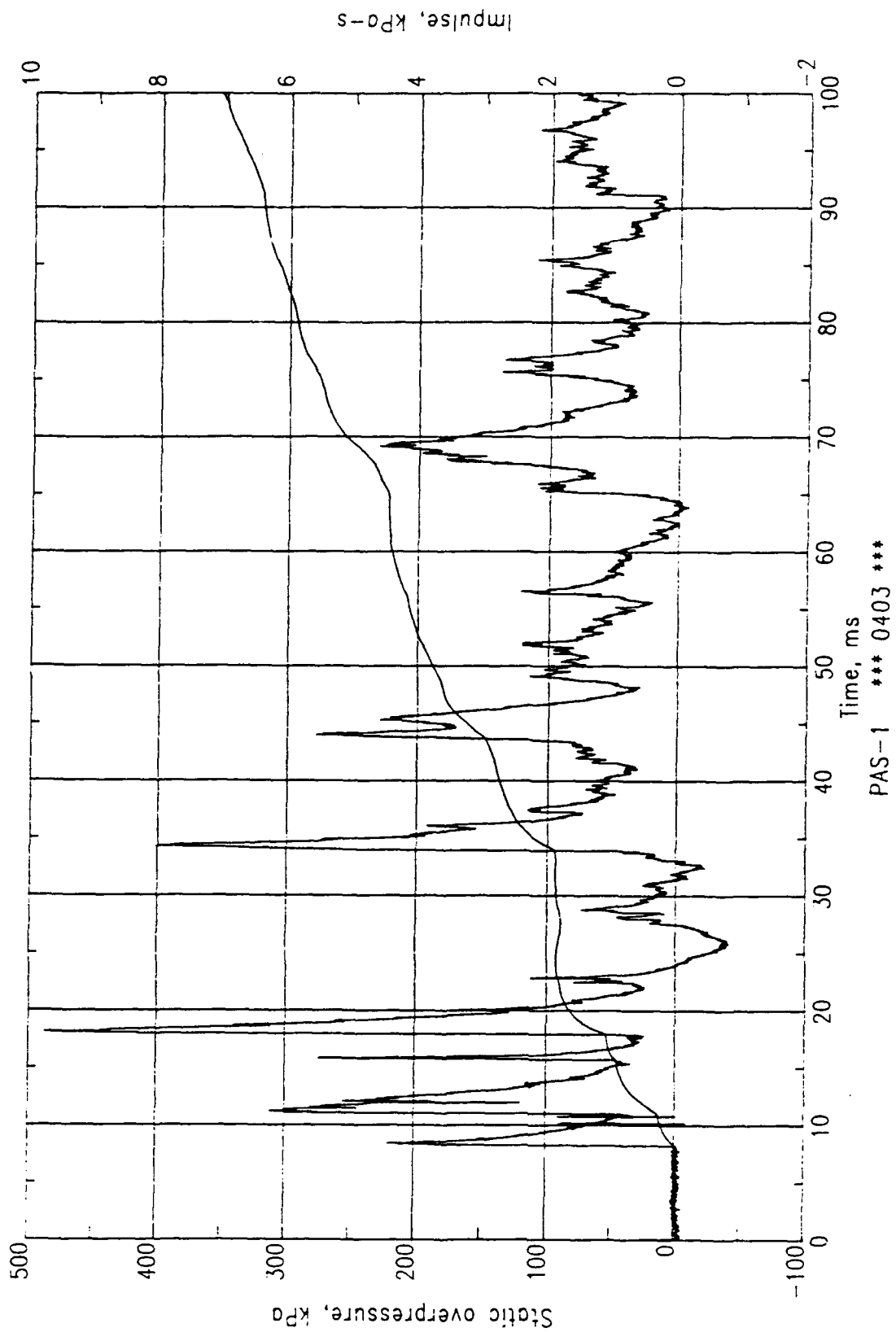


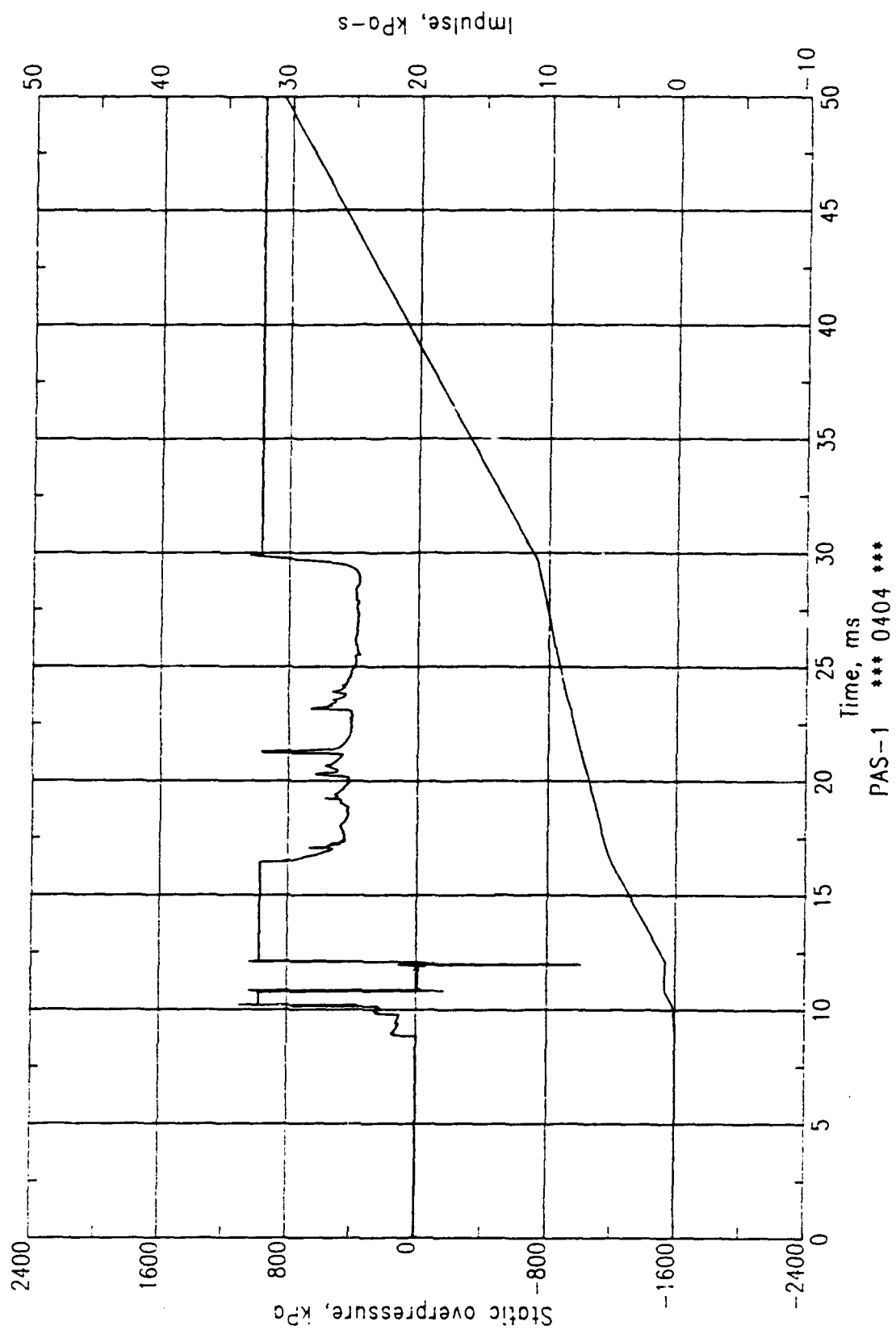


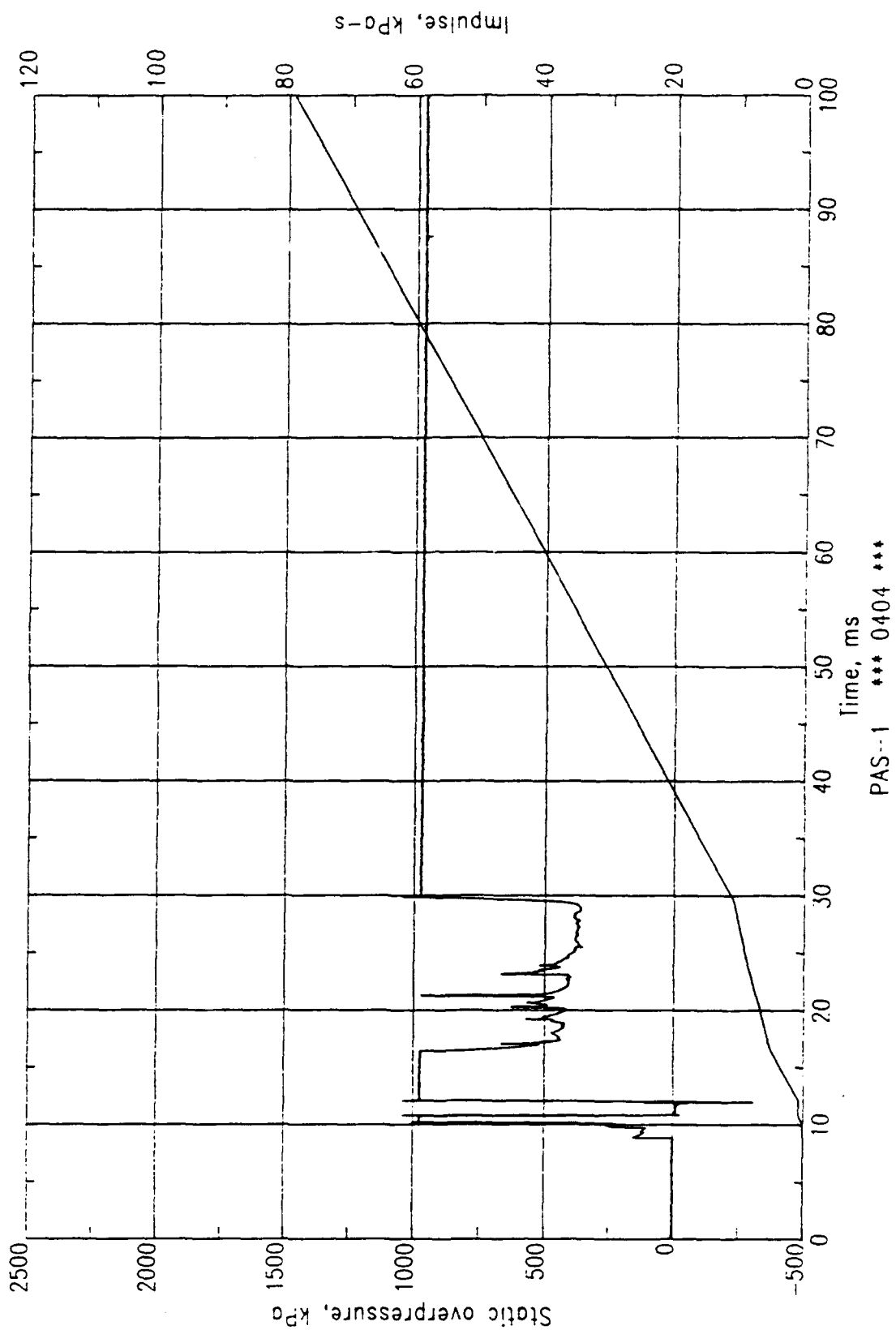


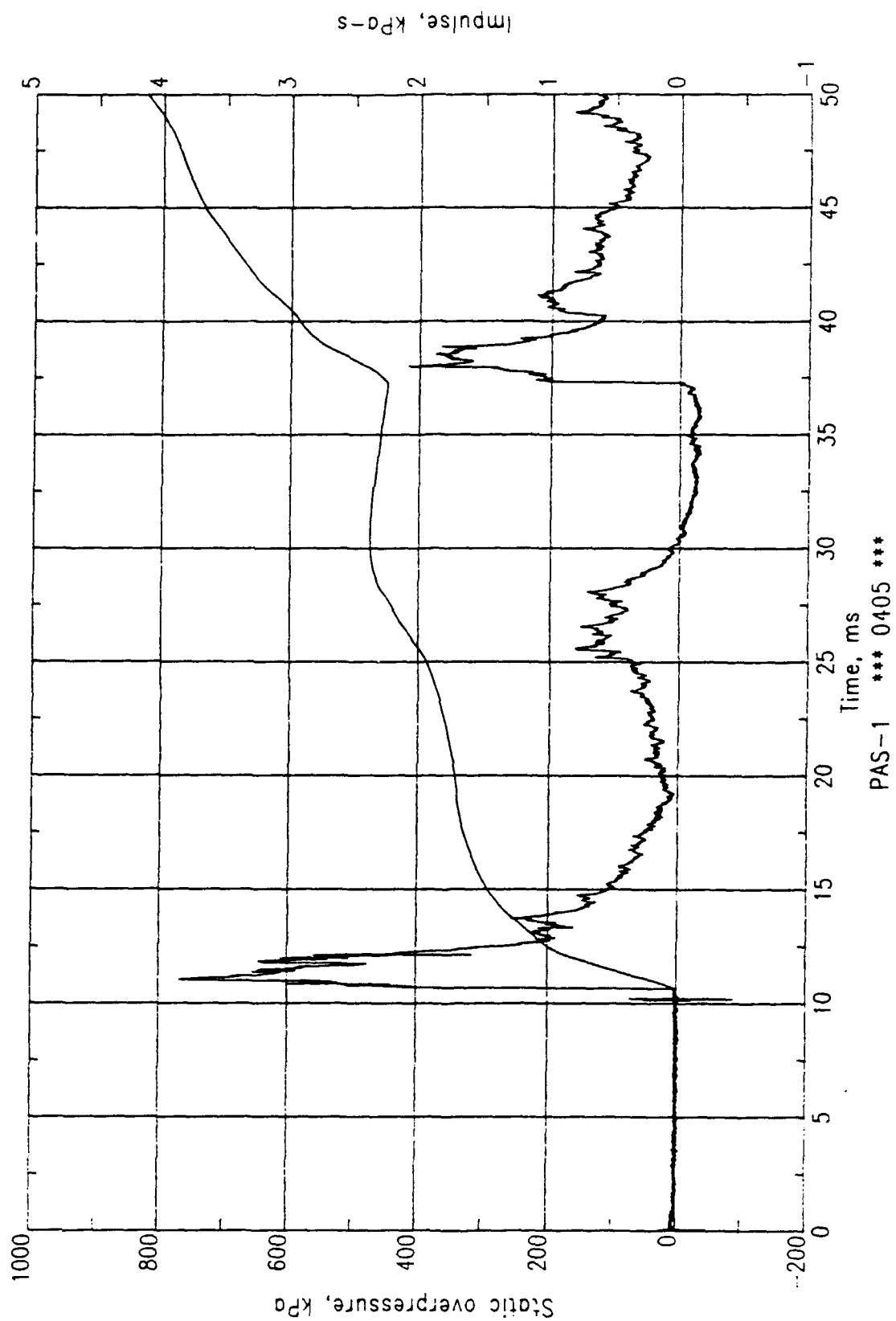


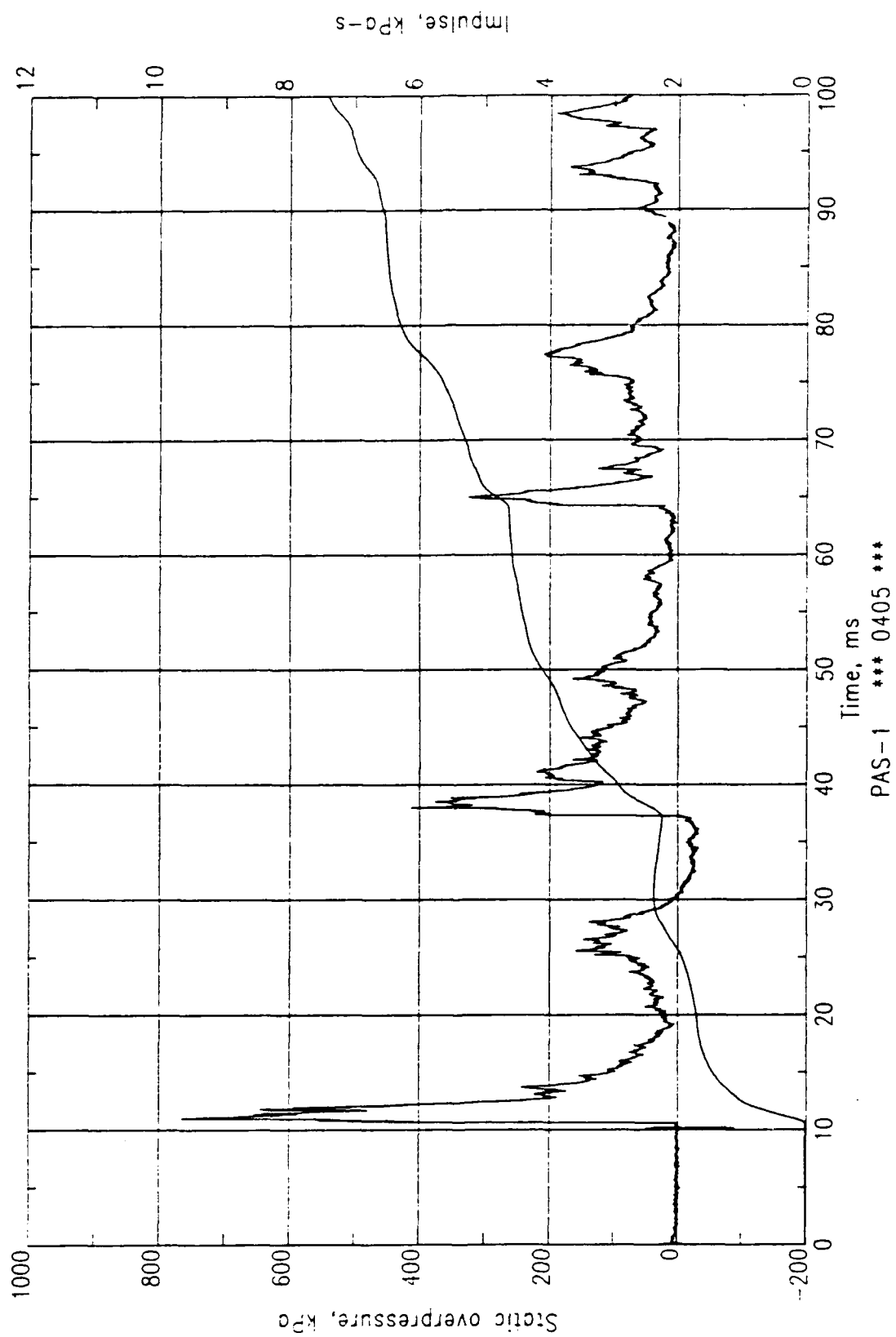


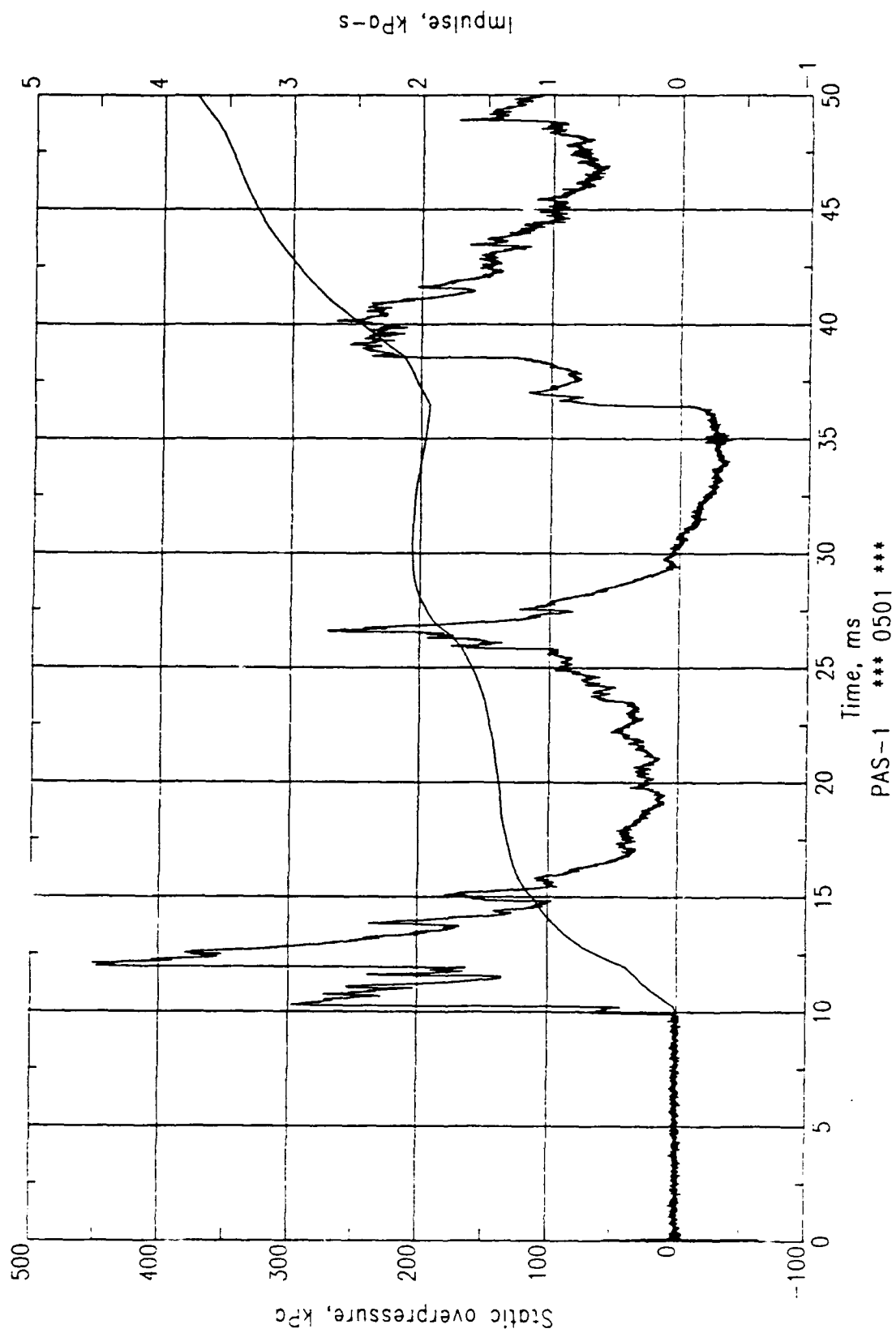


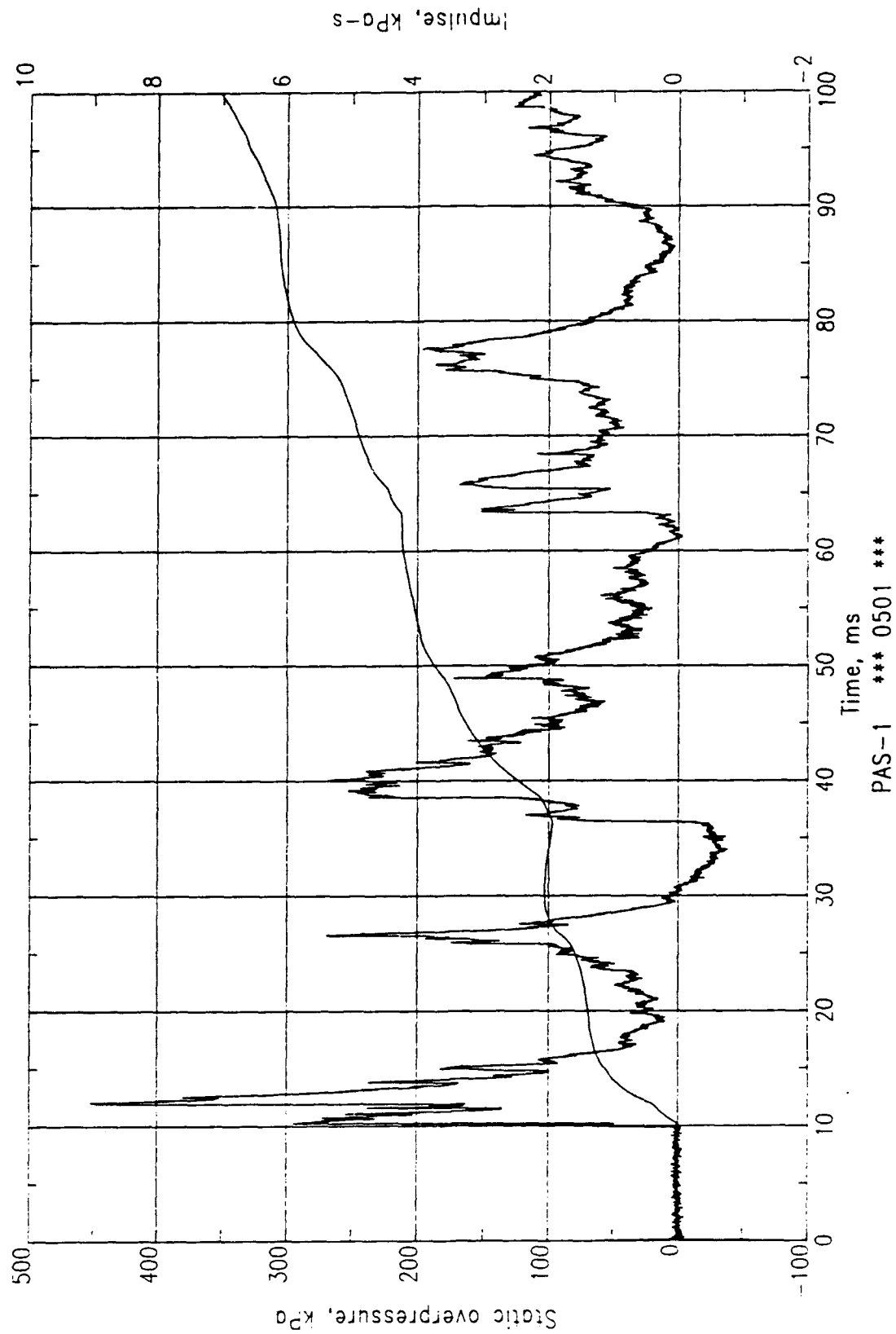




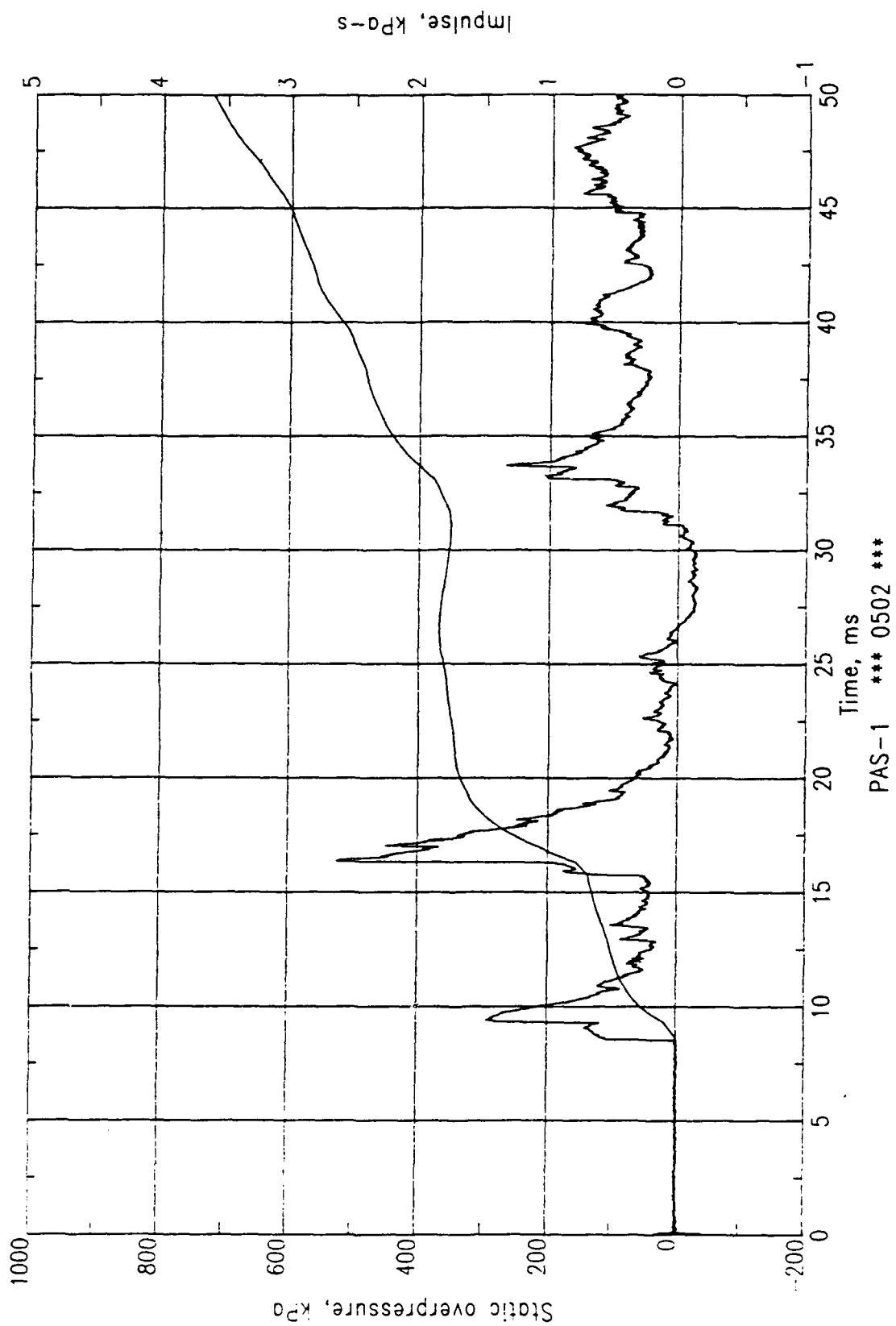


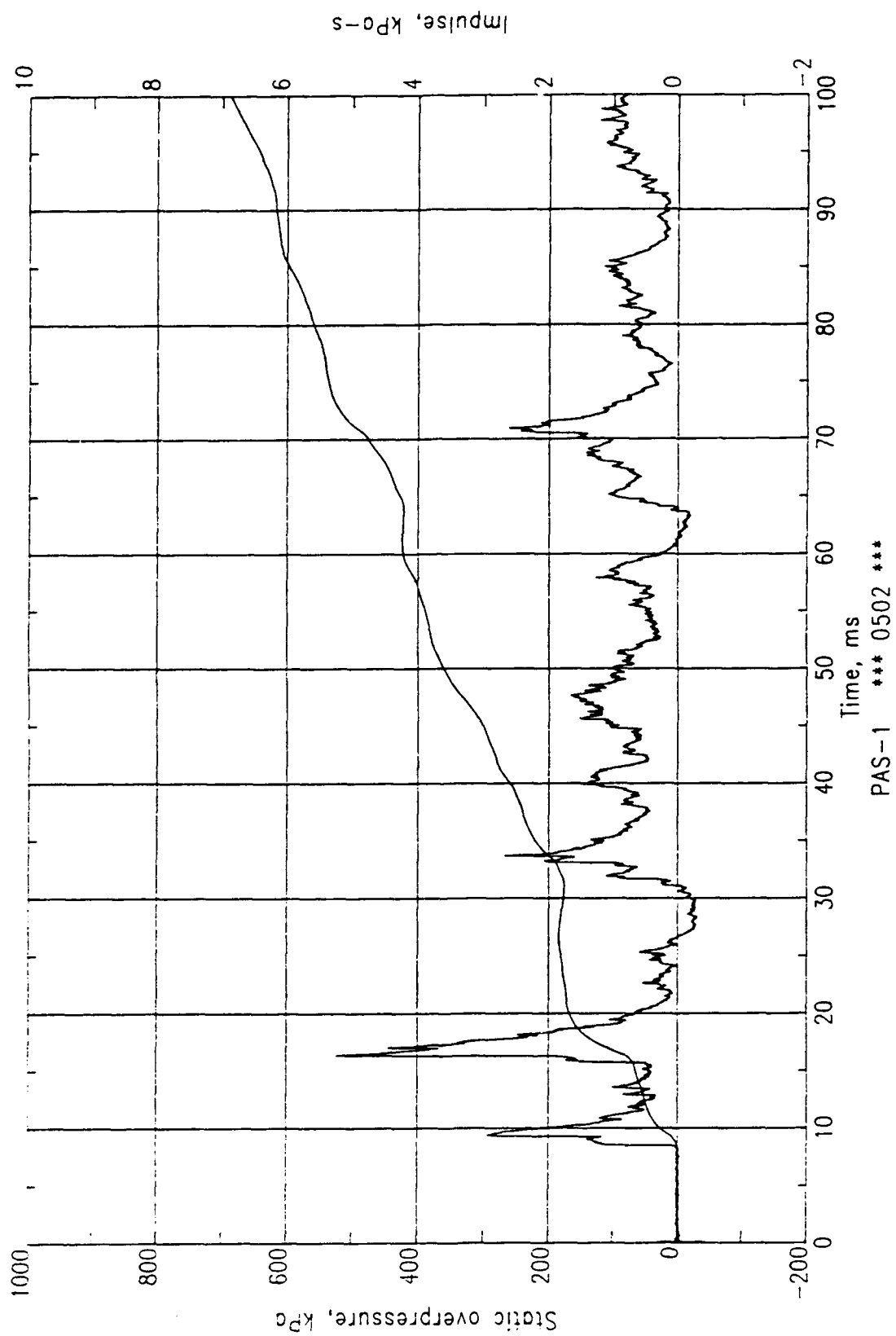


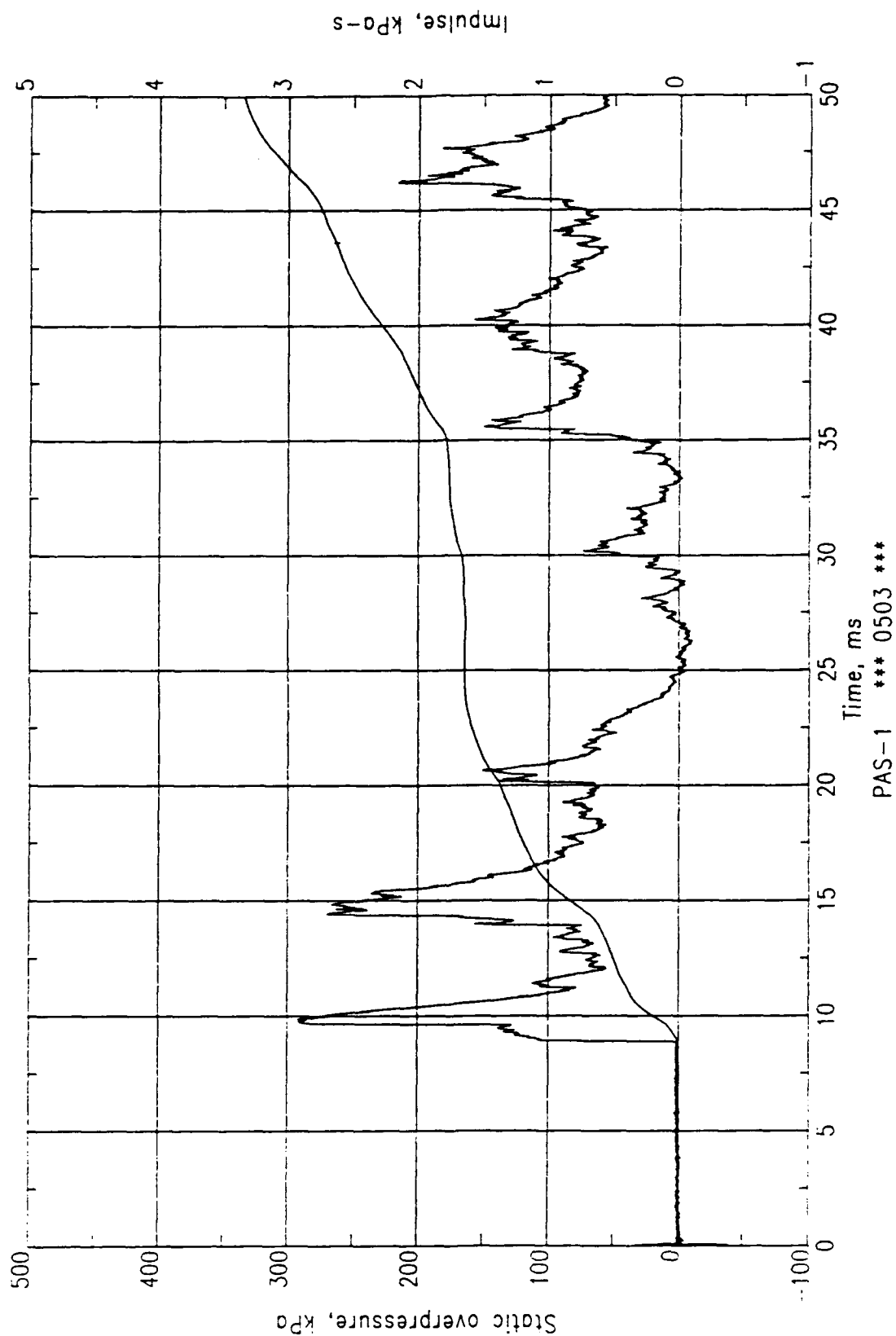


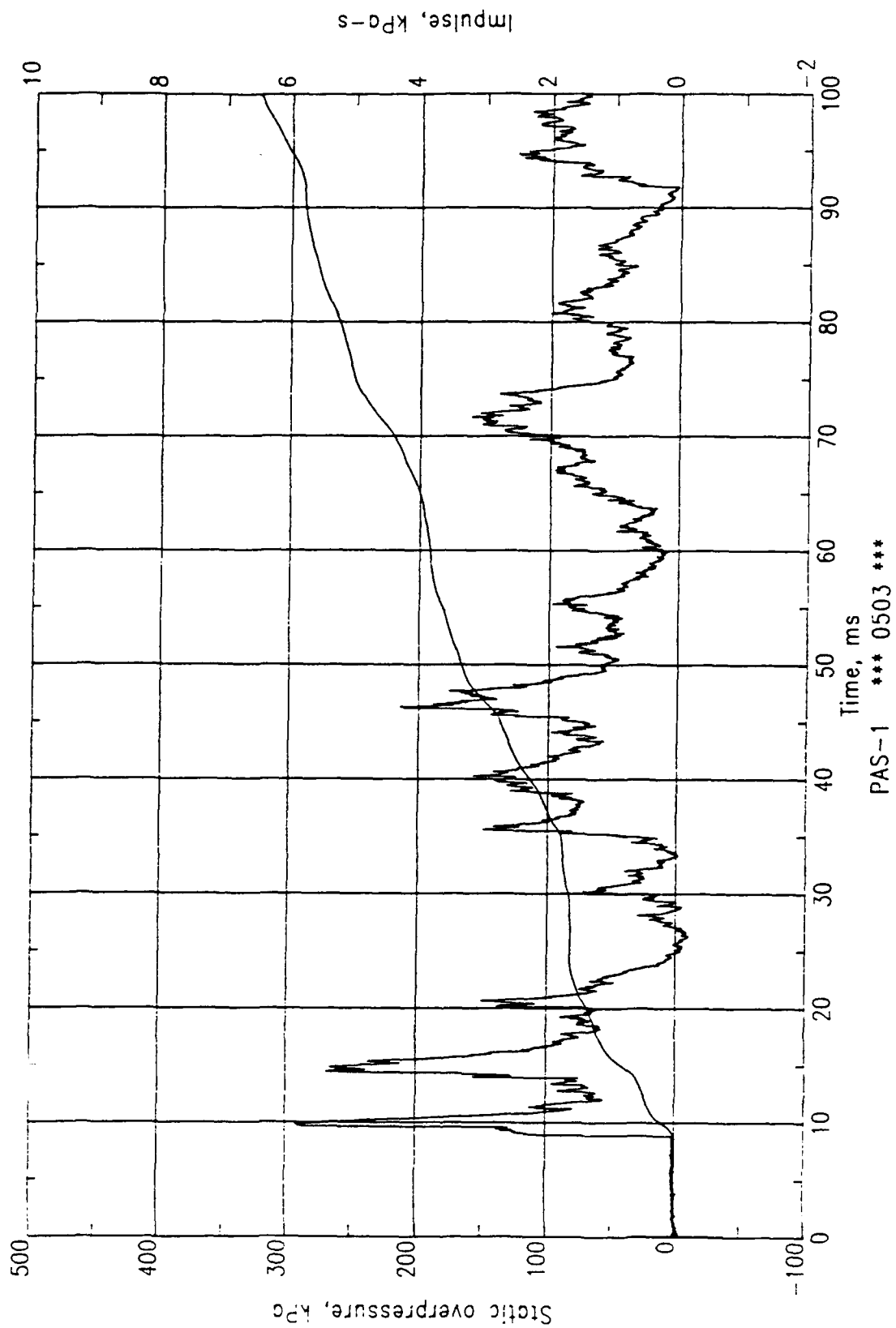


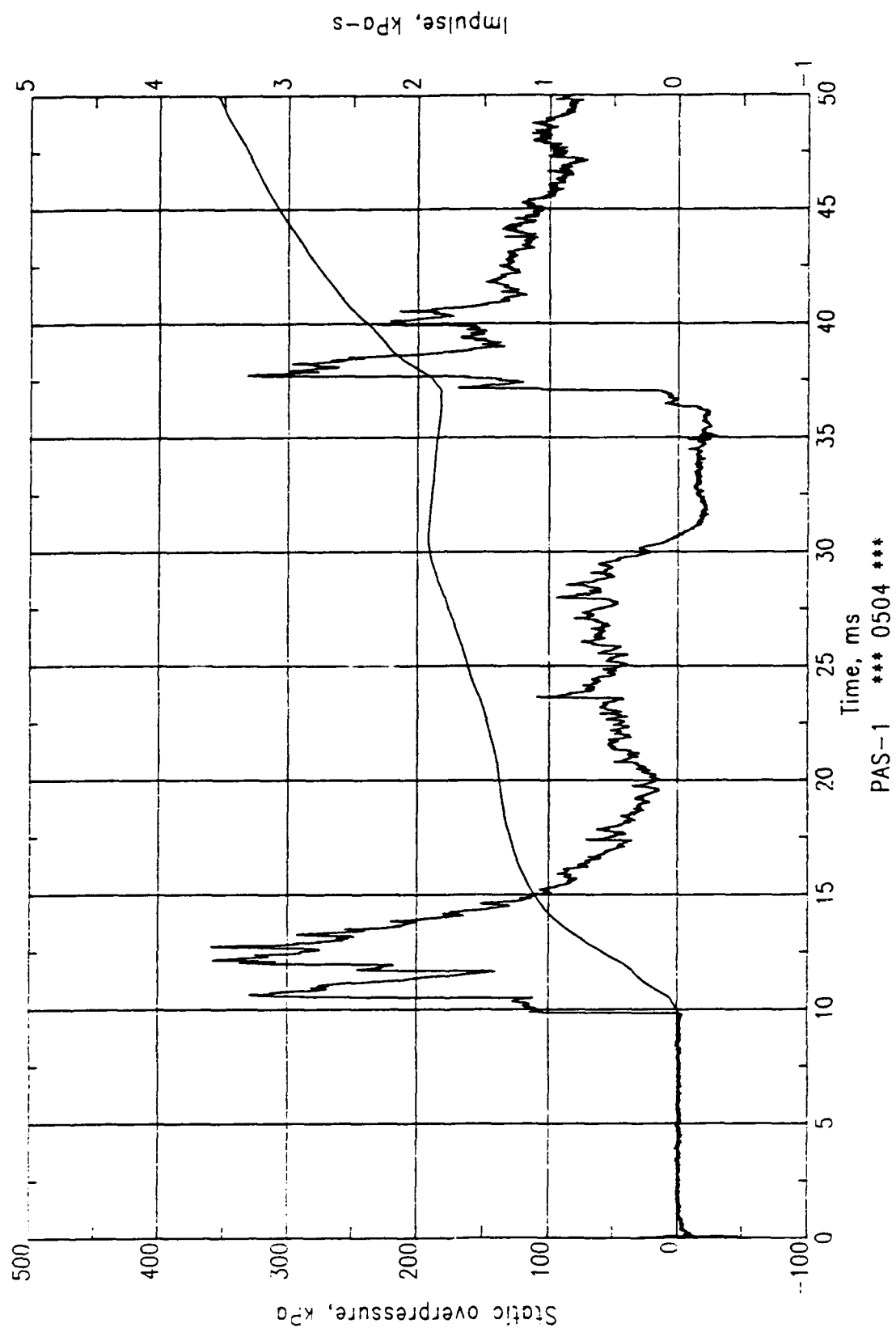
PAS-1 *** 0501 ***

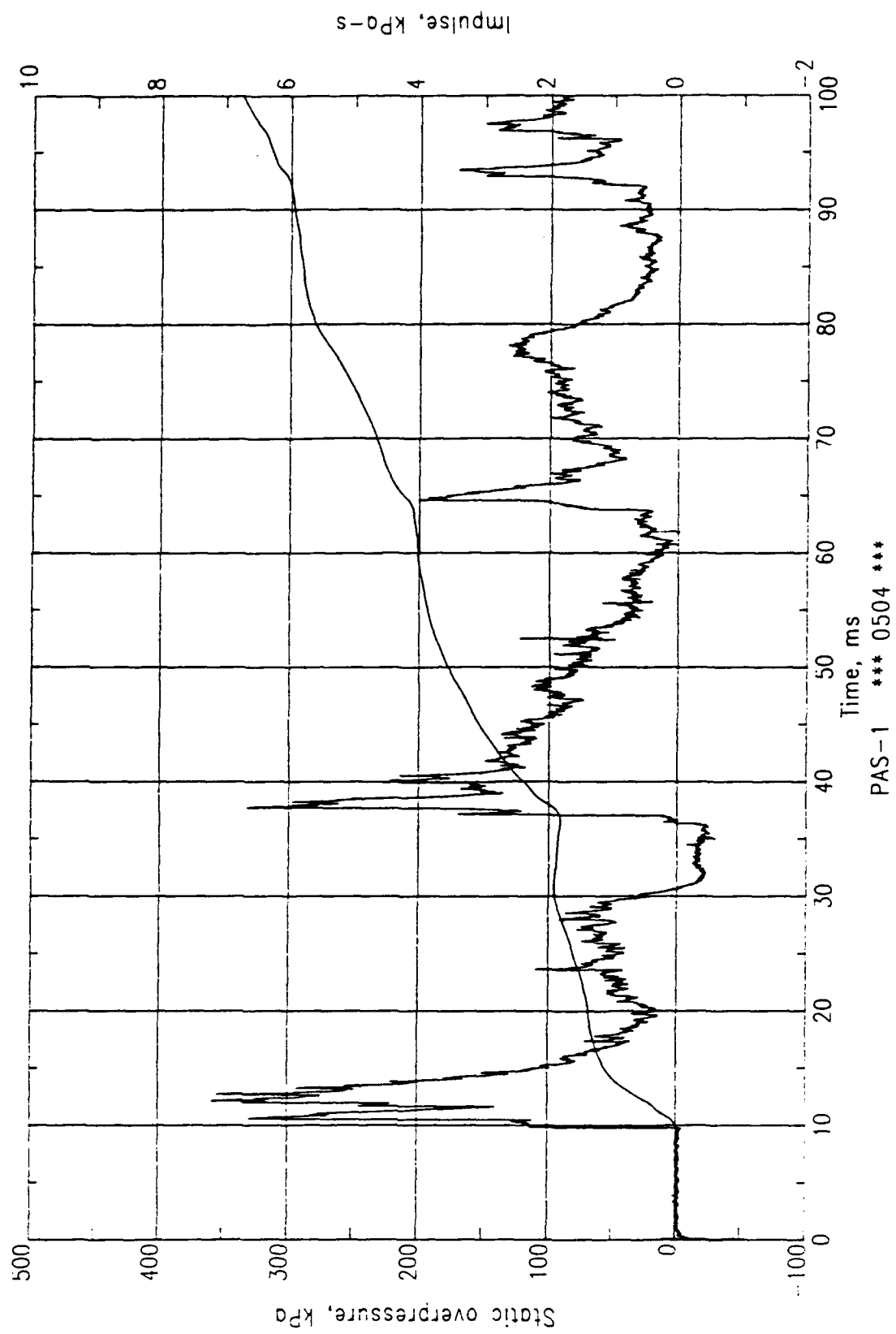


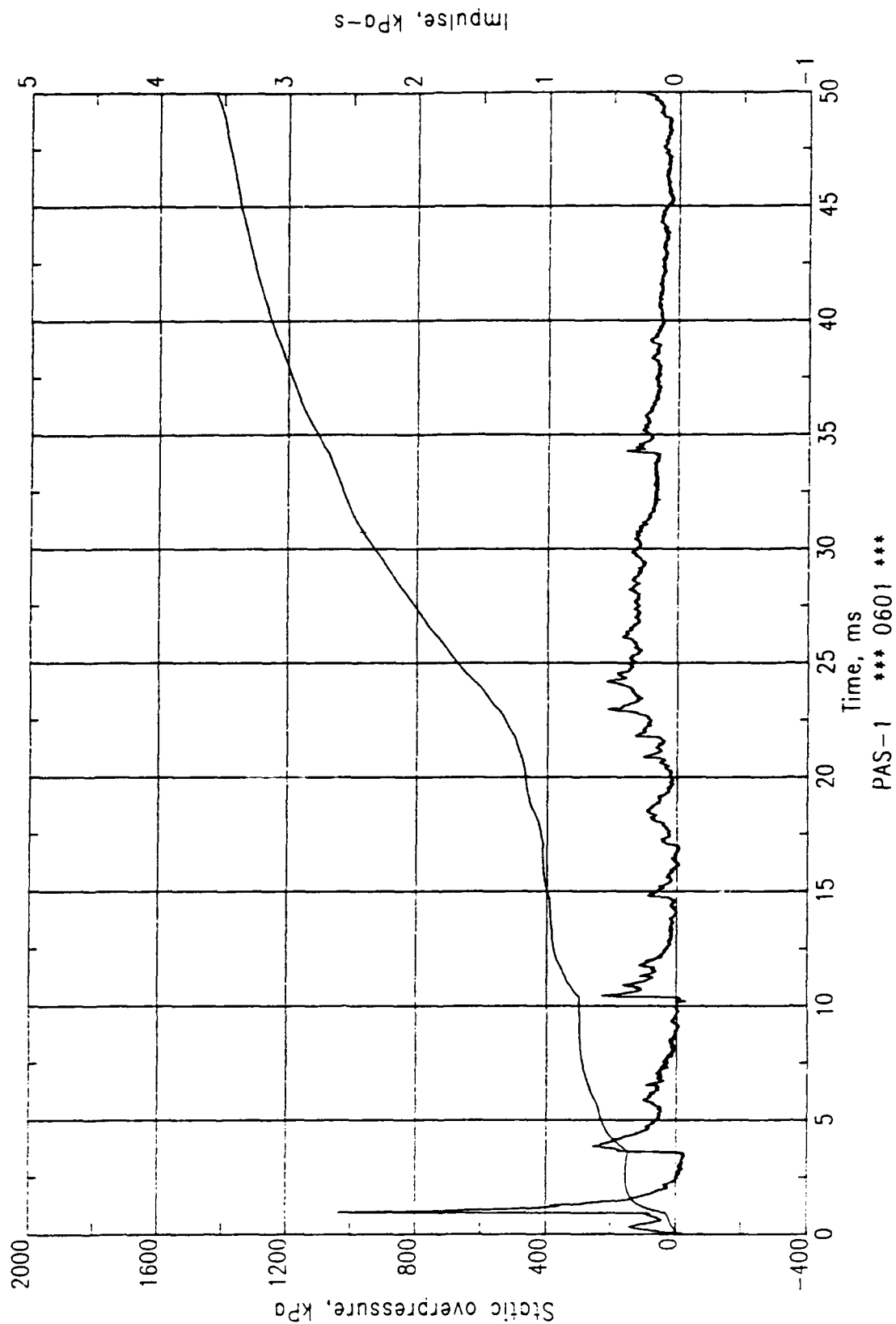


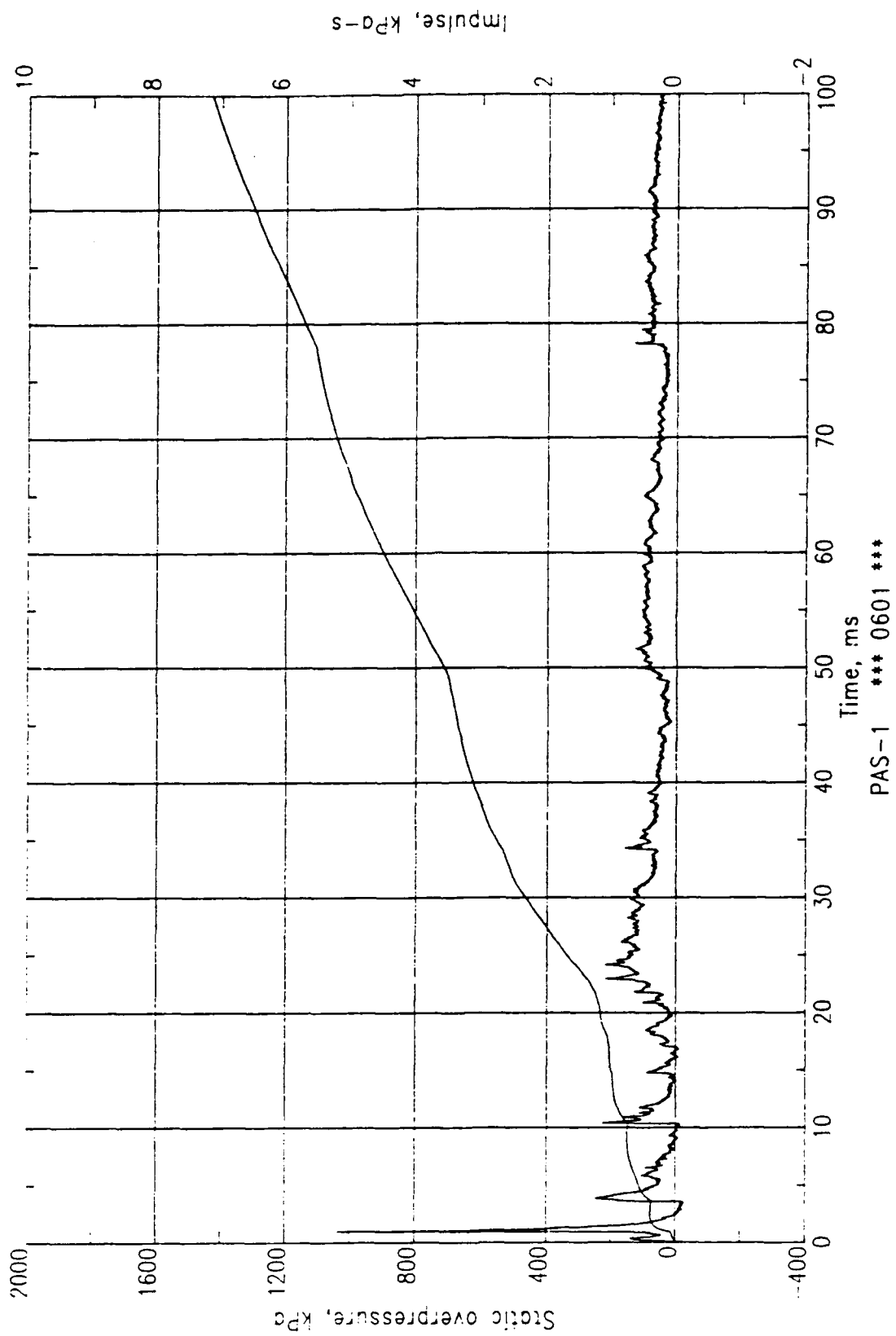


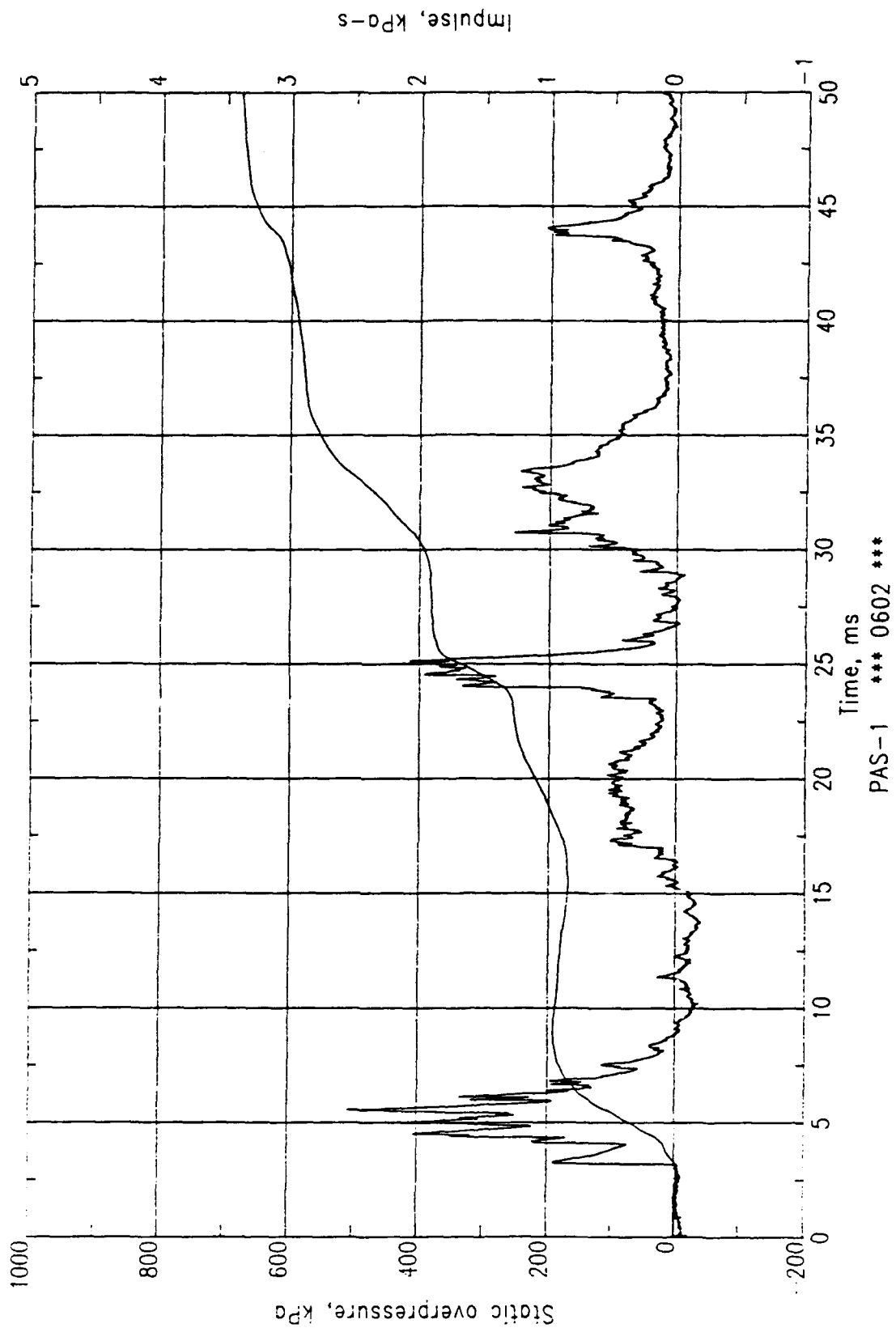


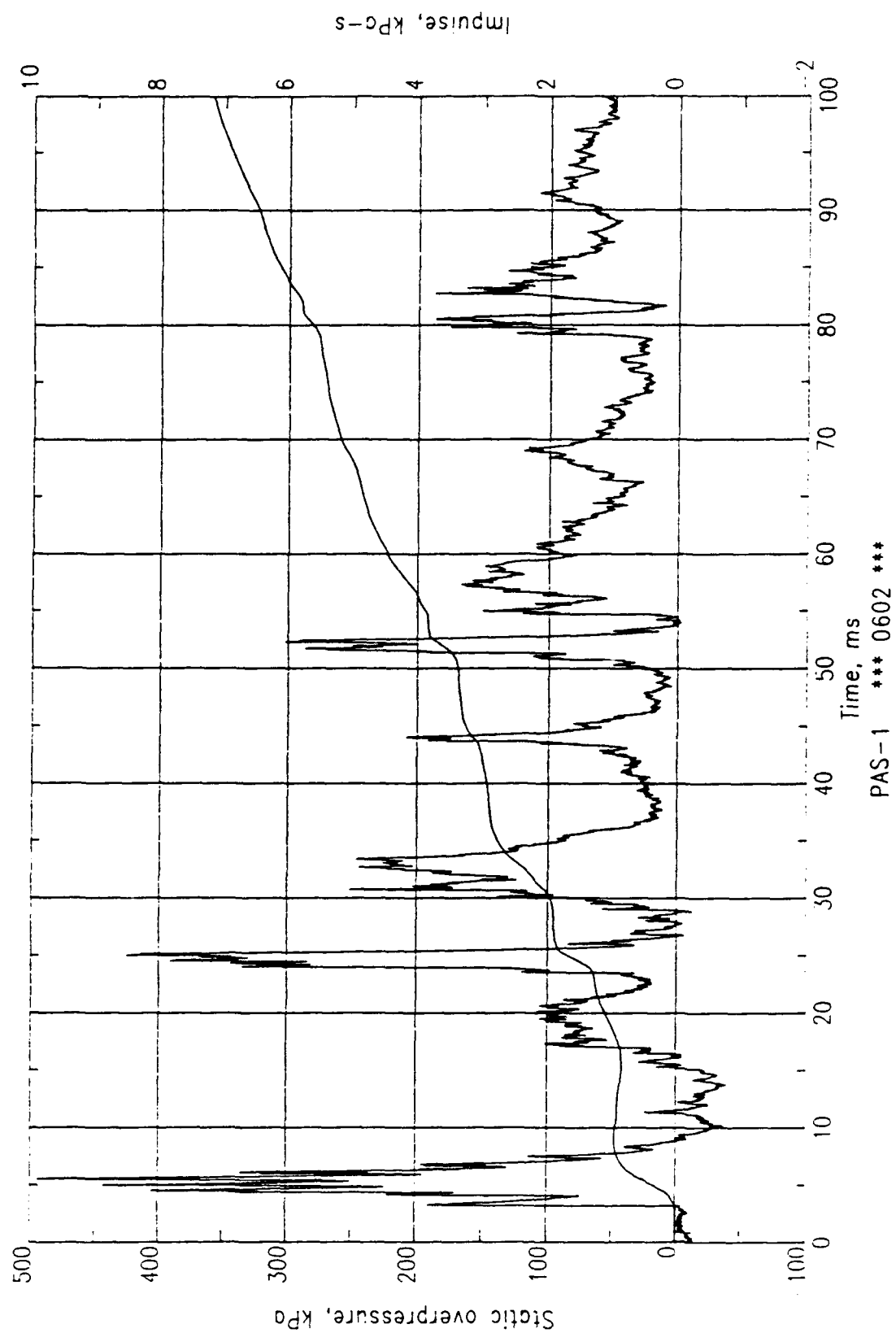


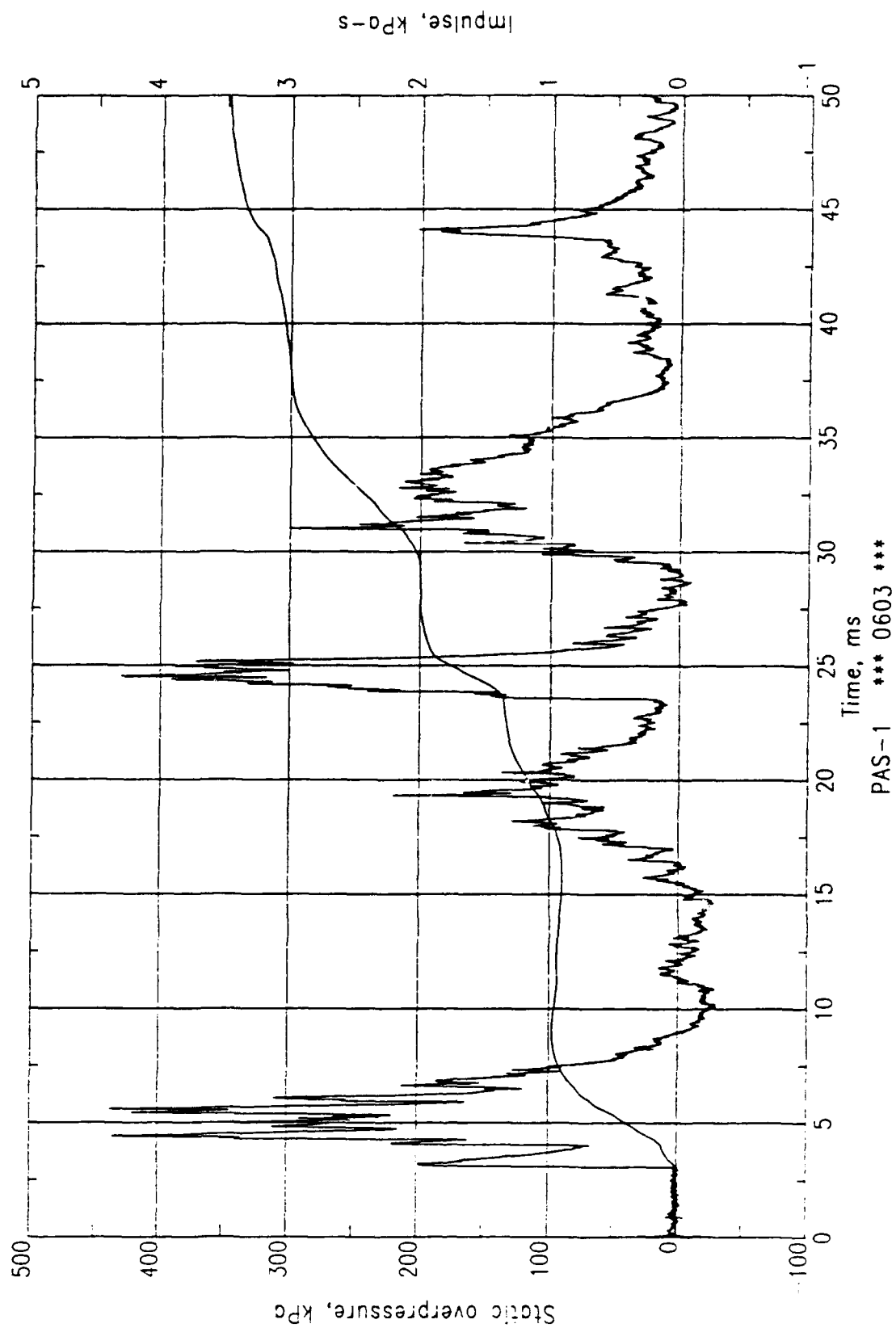


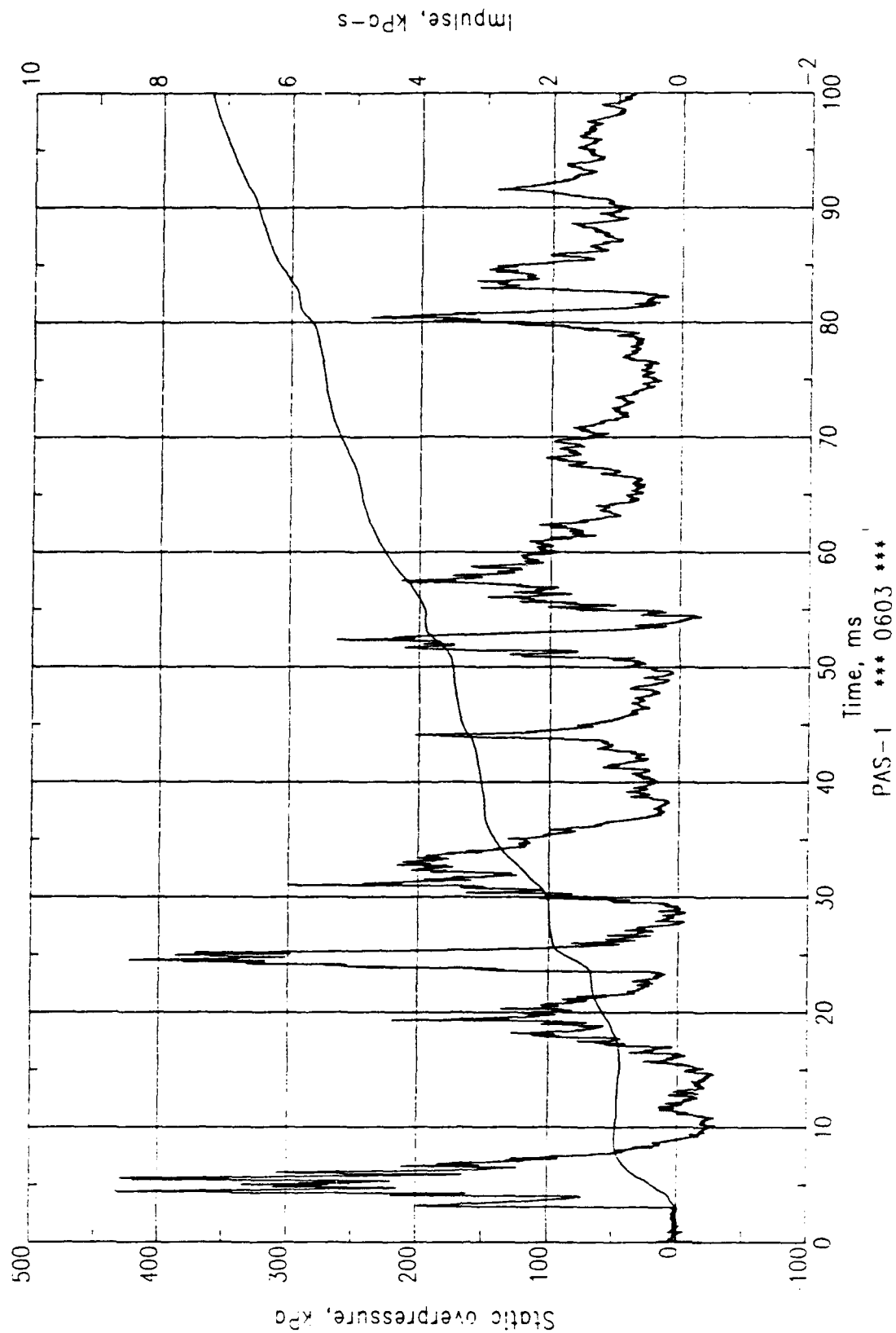


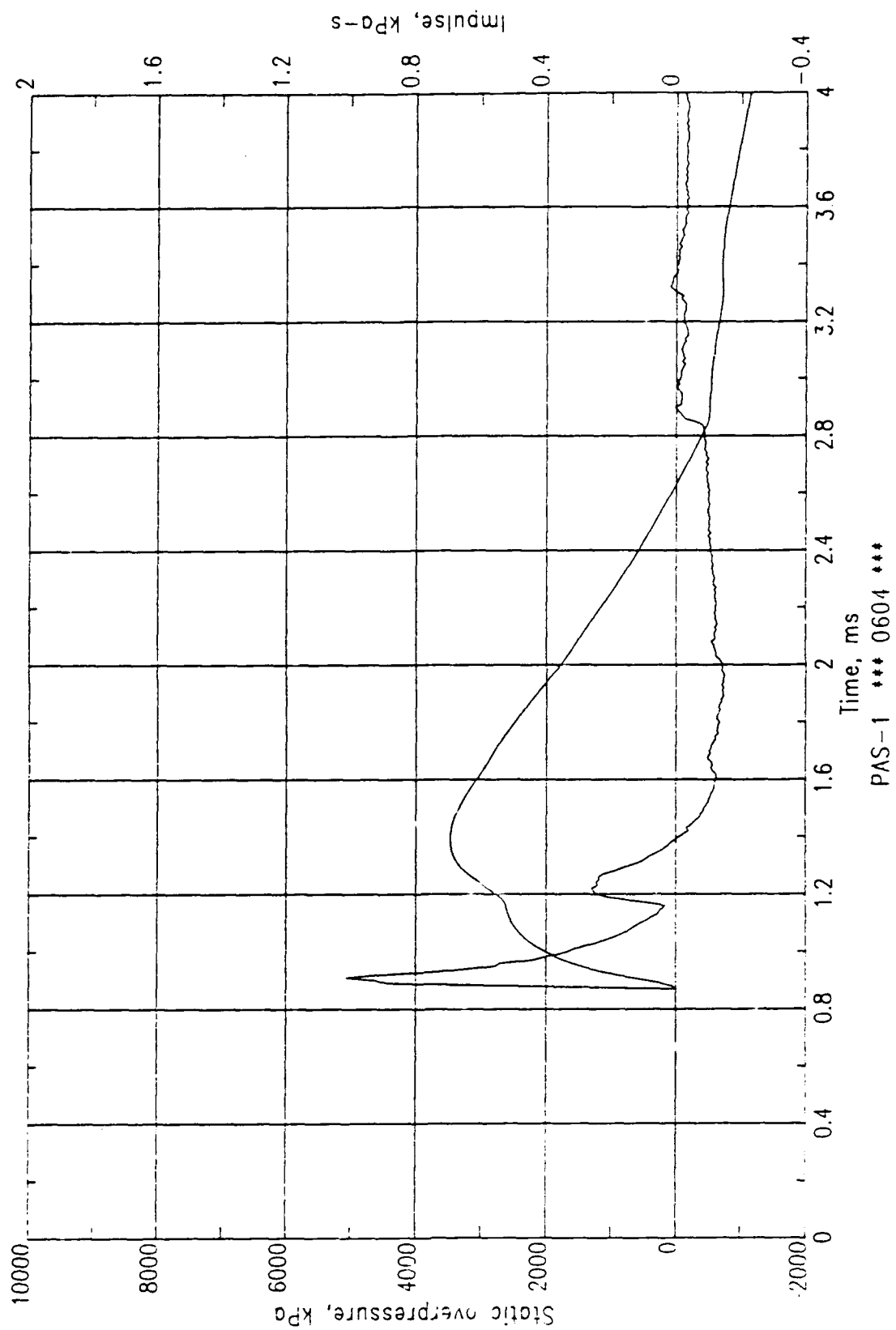


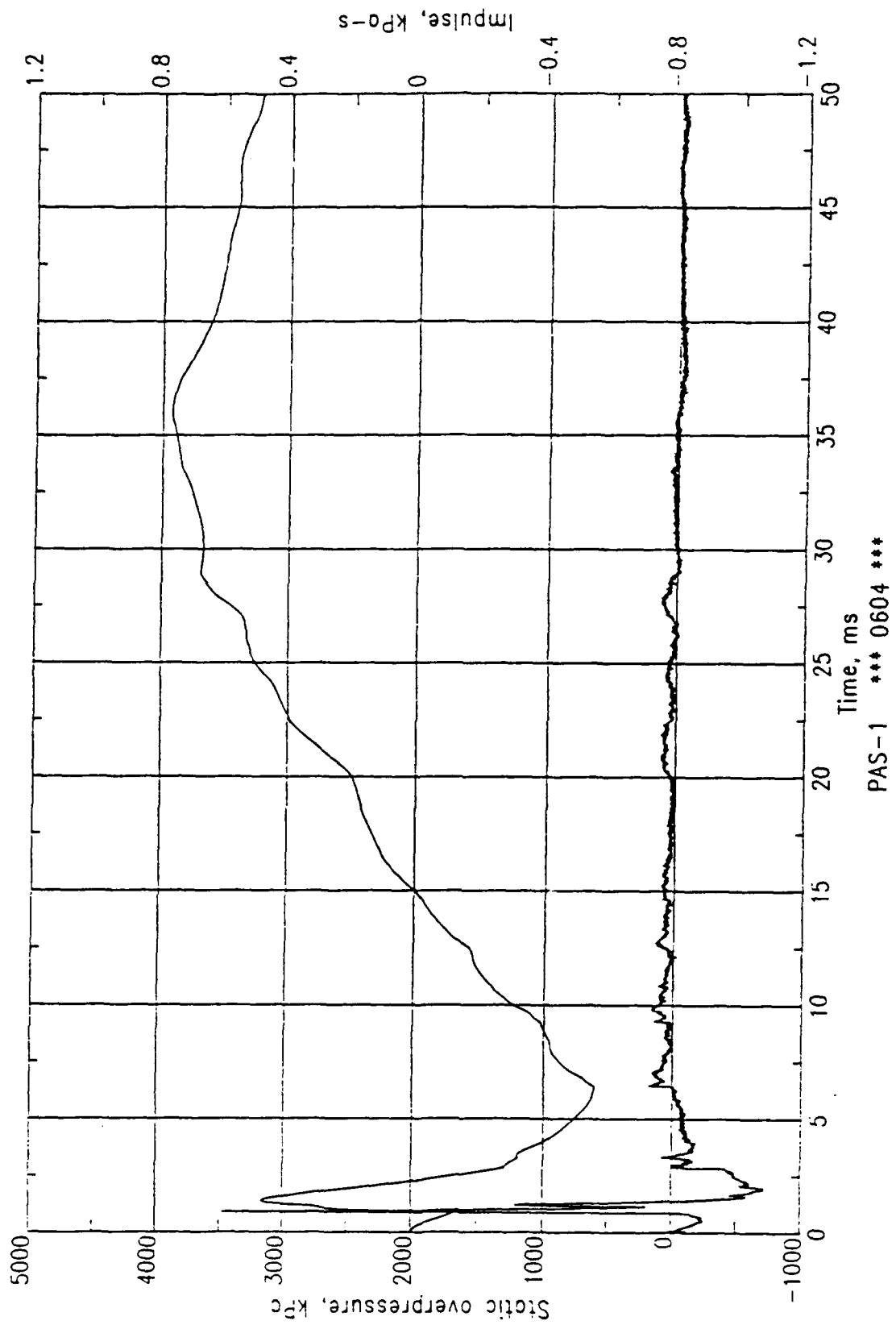


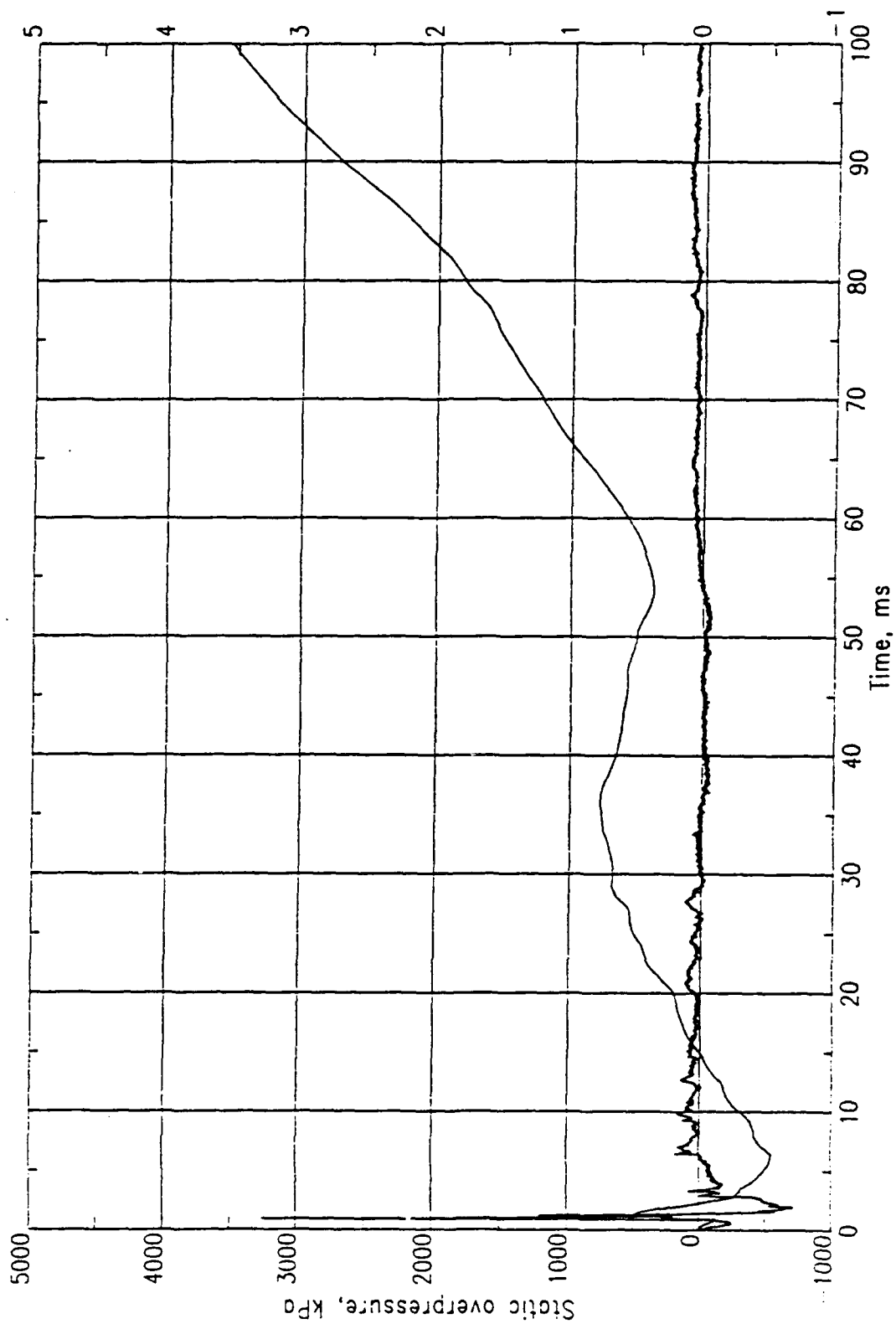




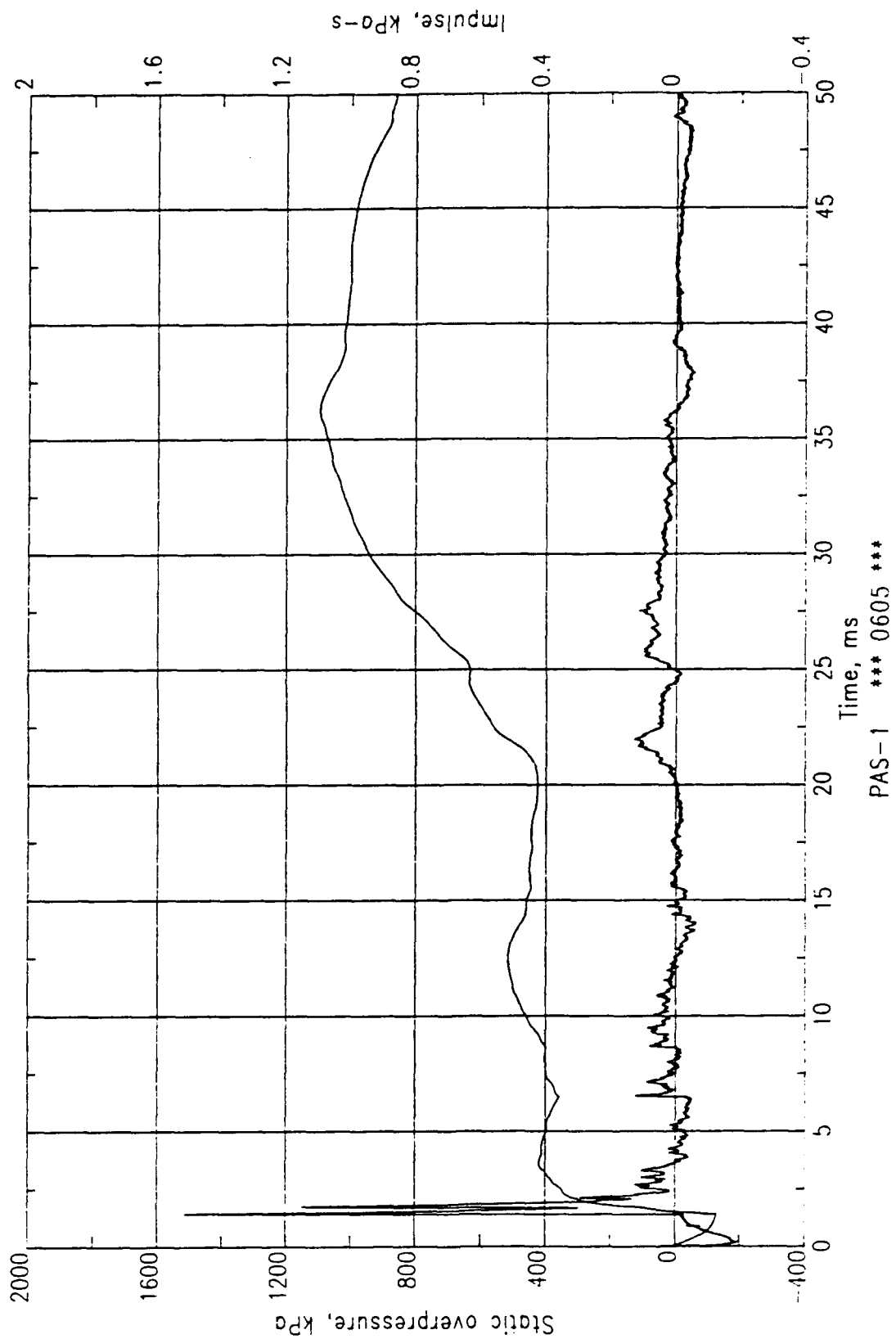


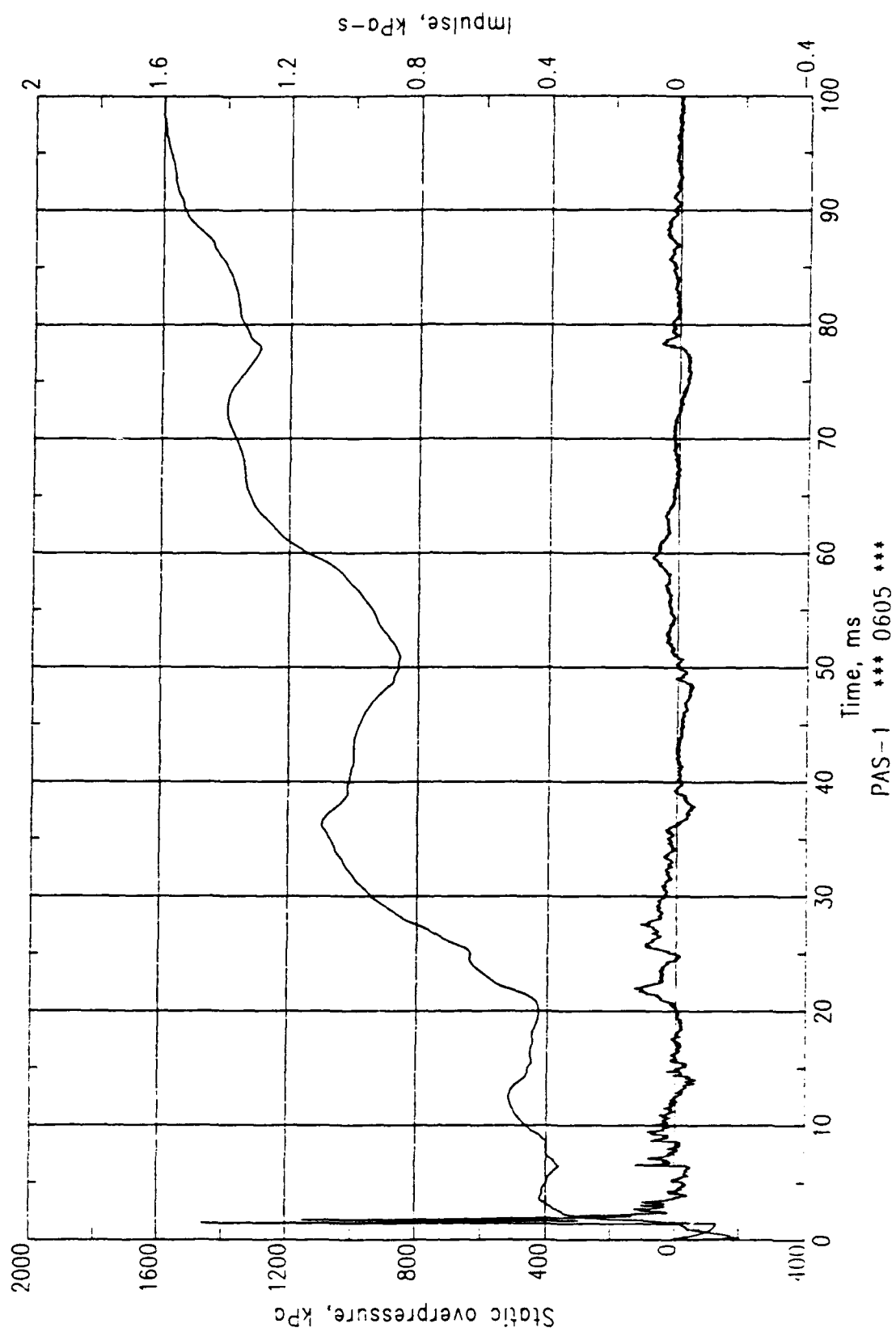


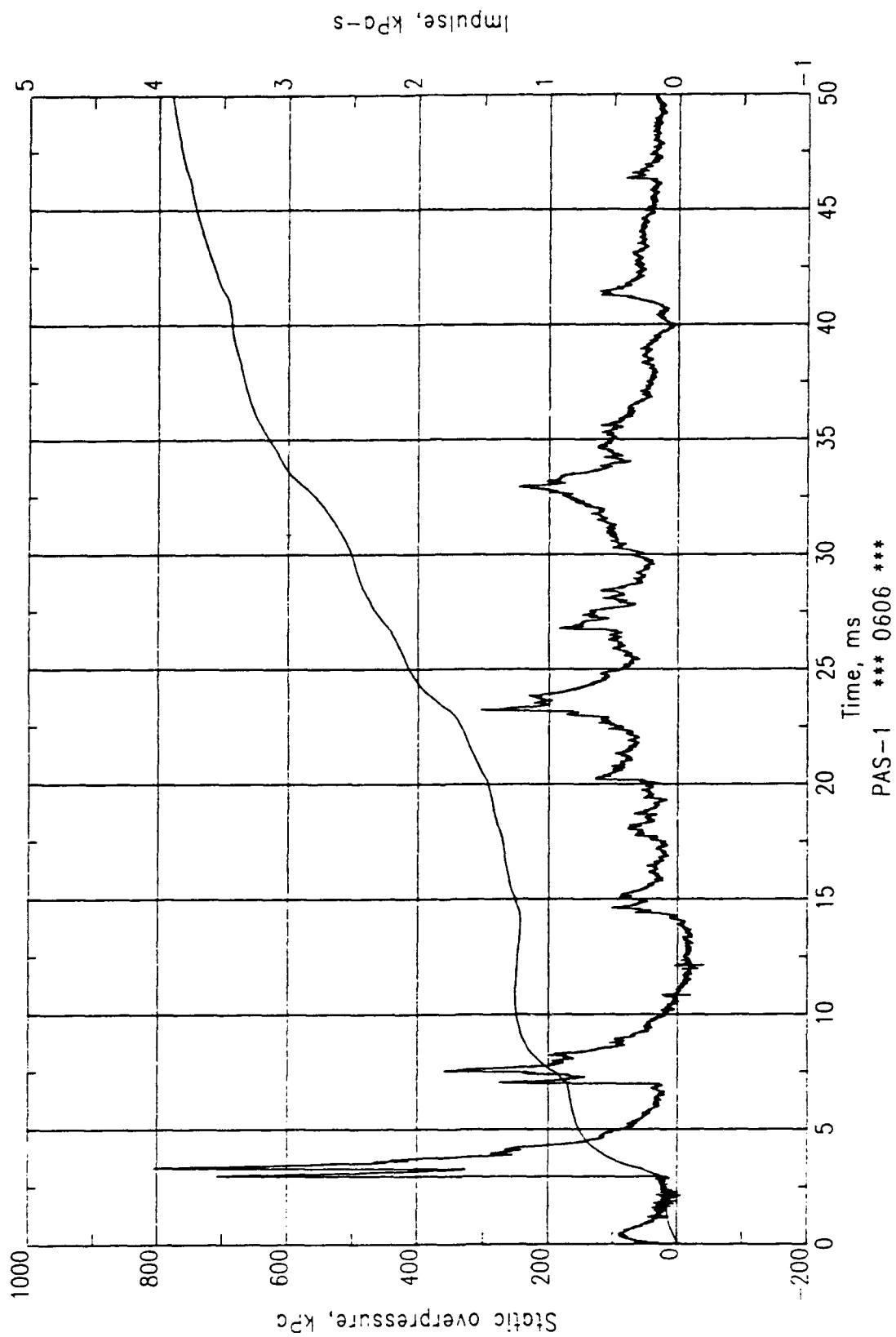


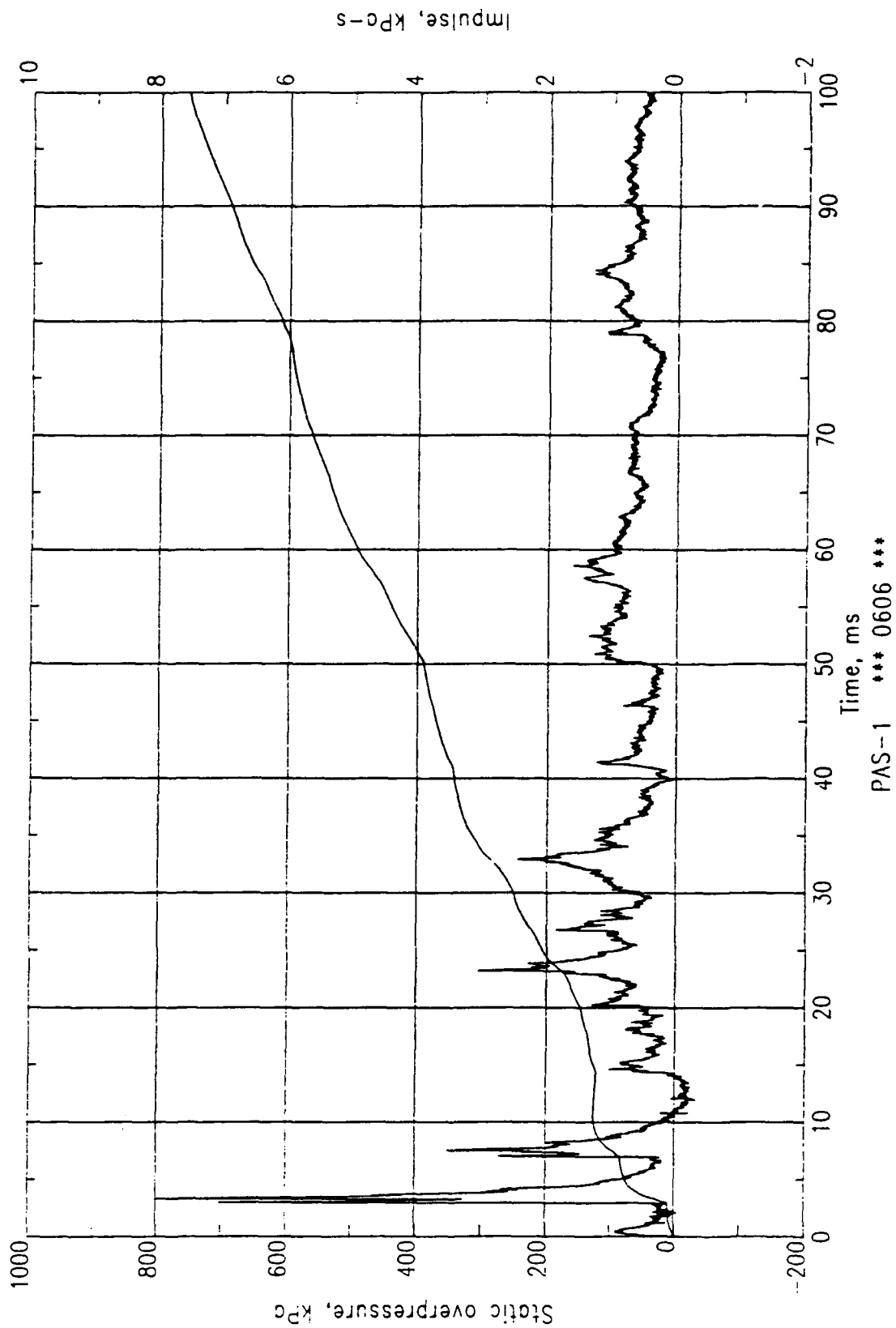


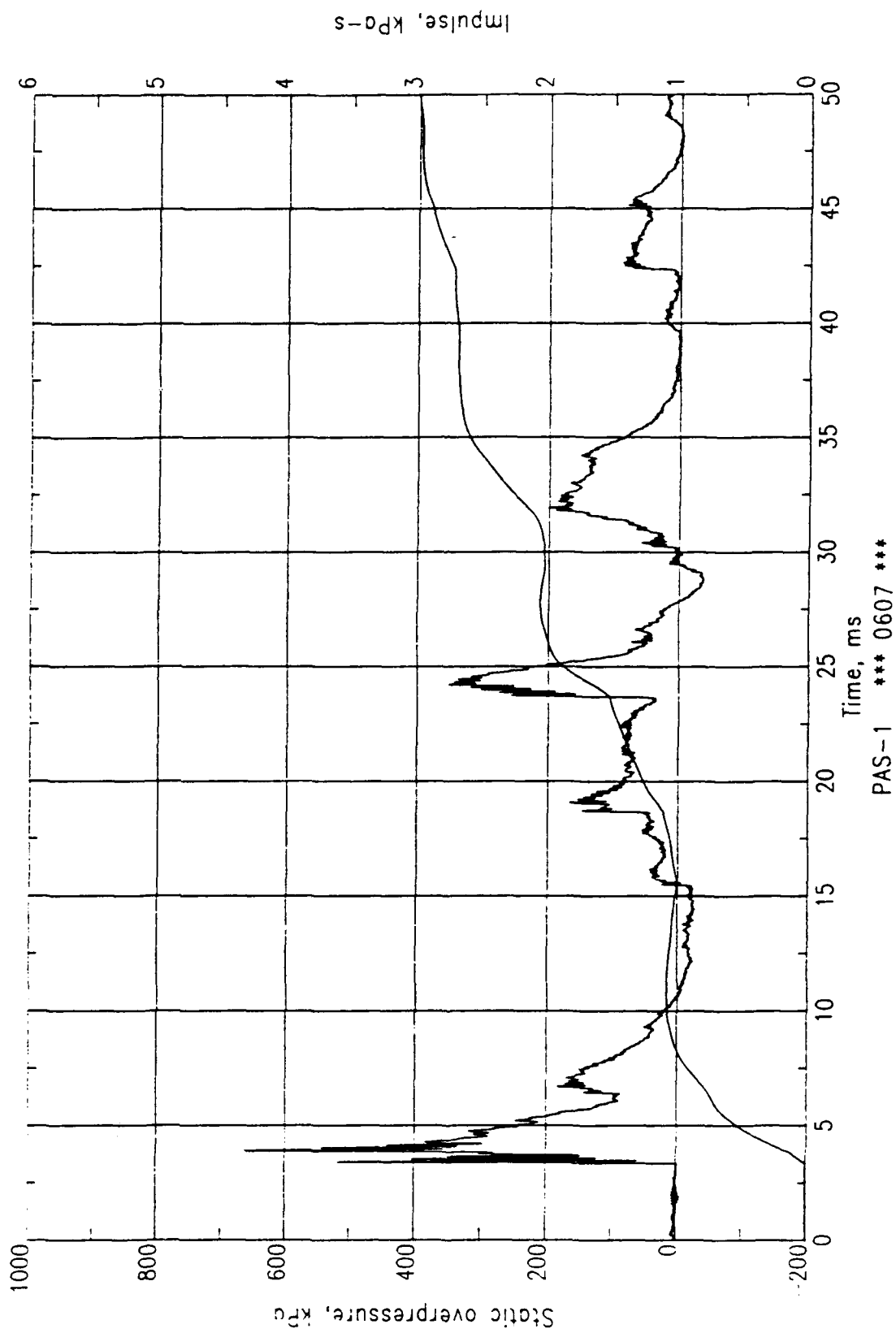
PAS-1 *** 0604 ***

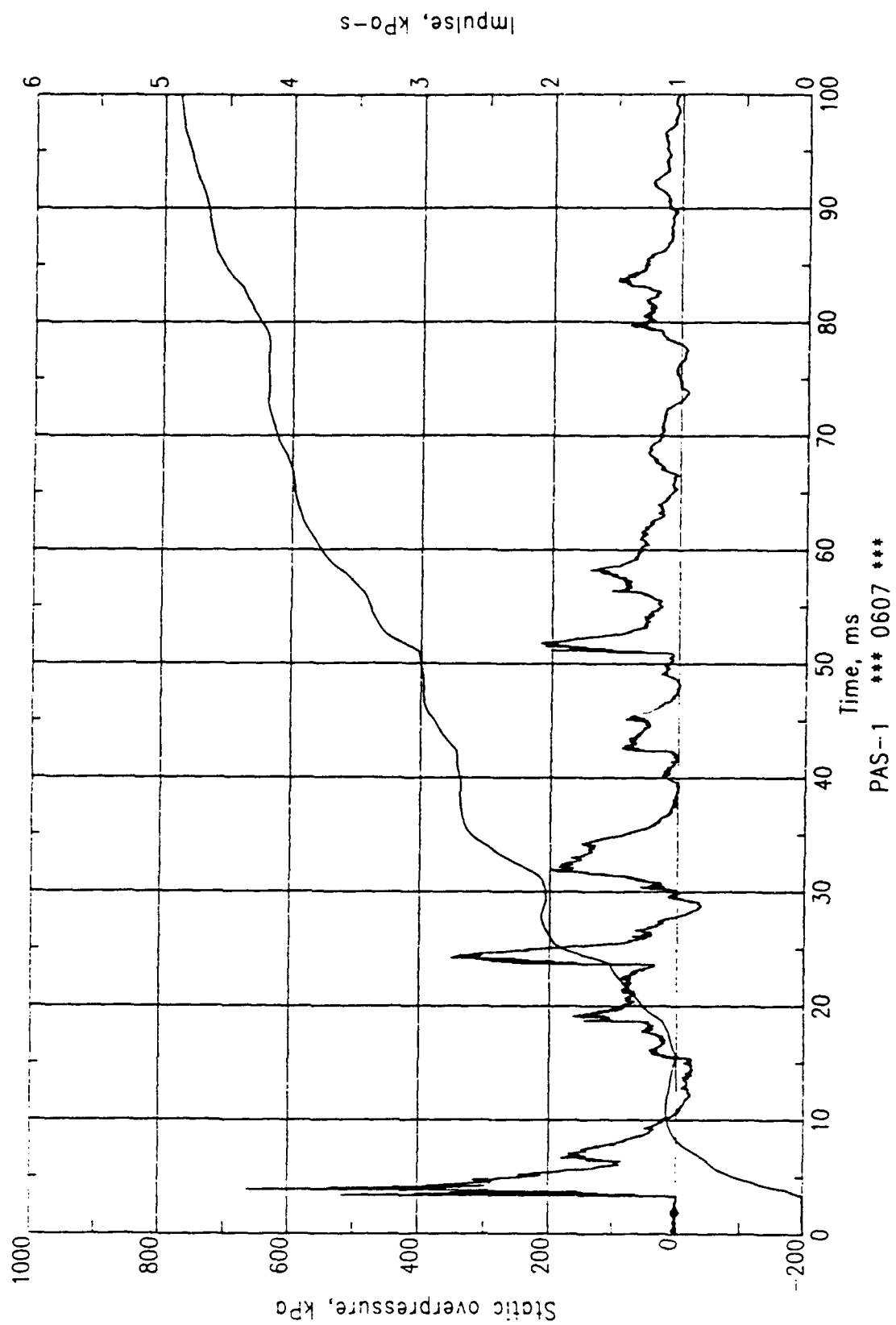


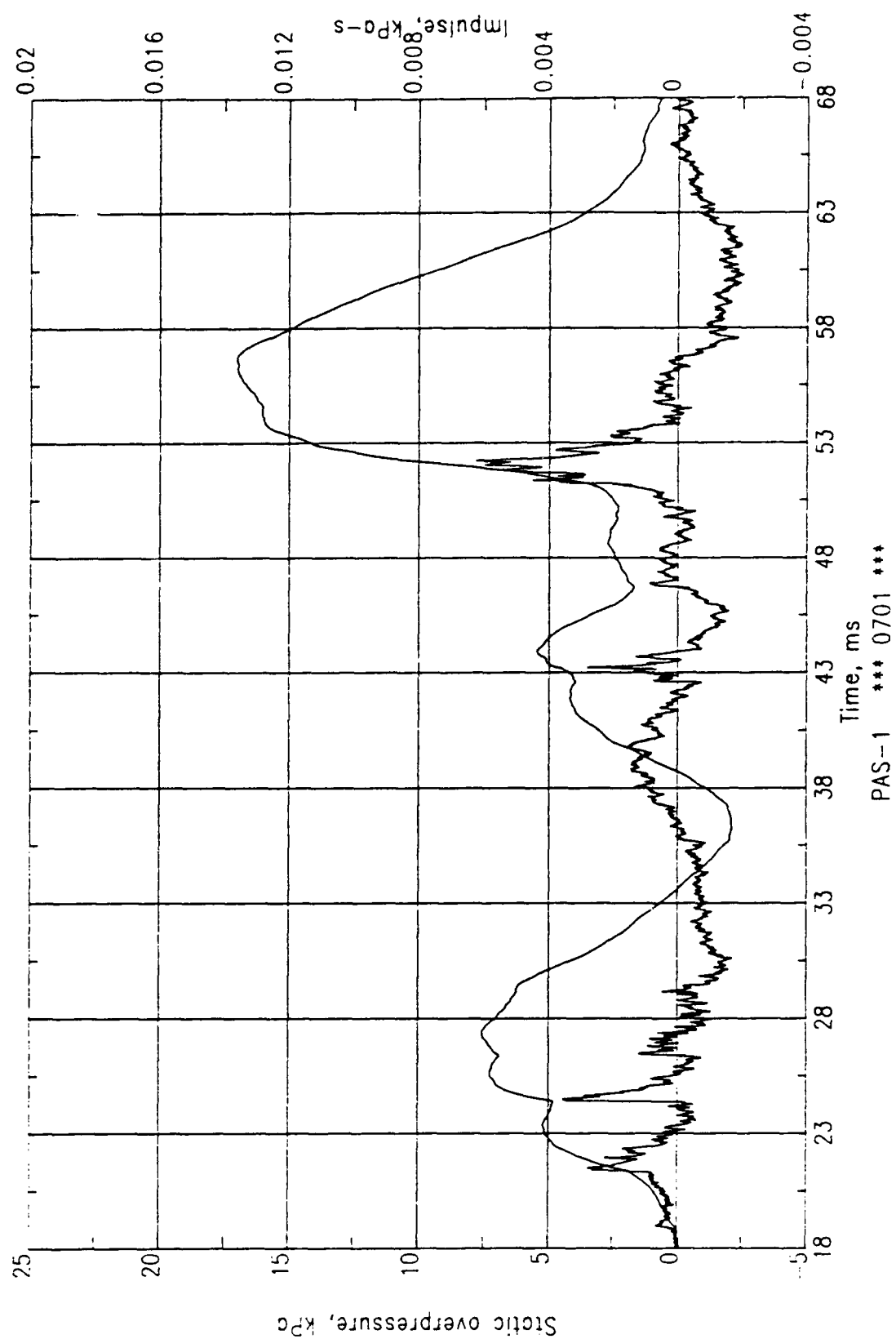




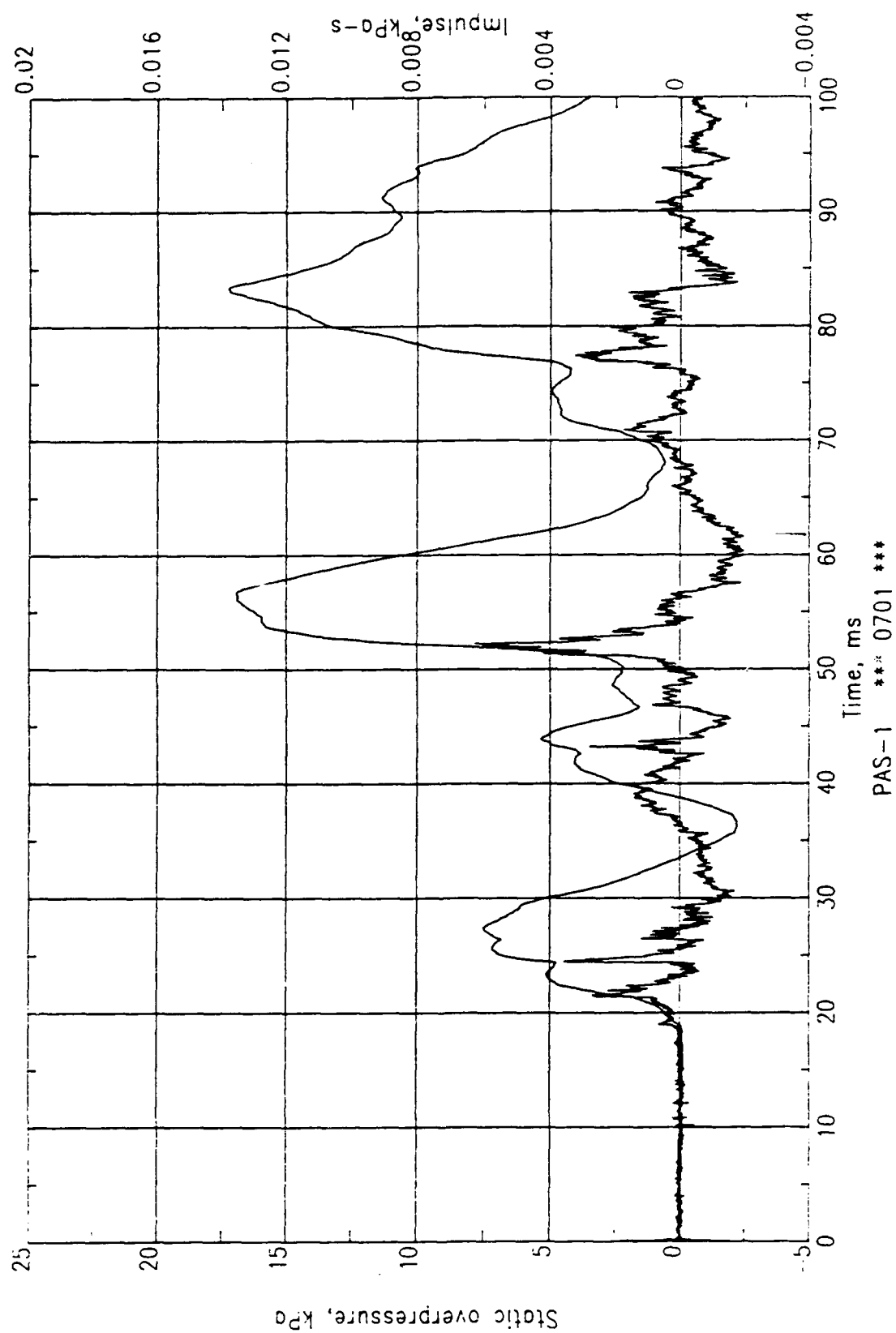


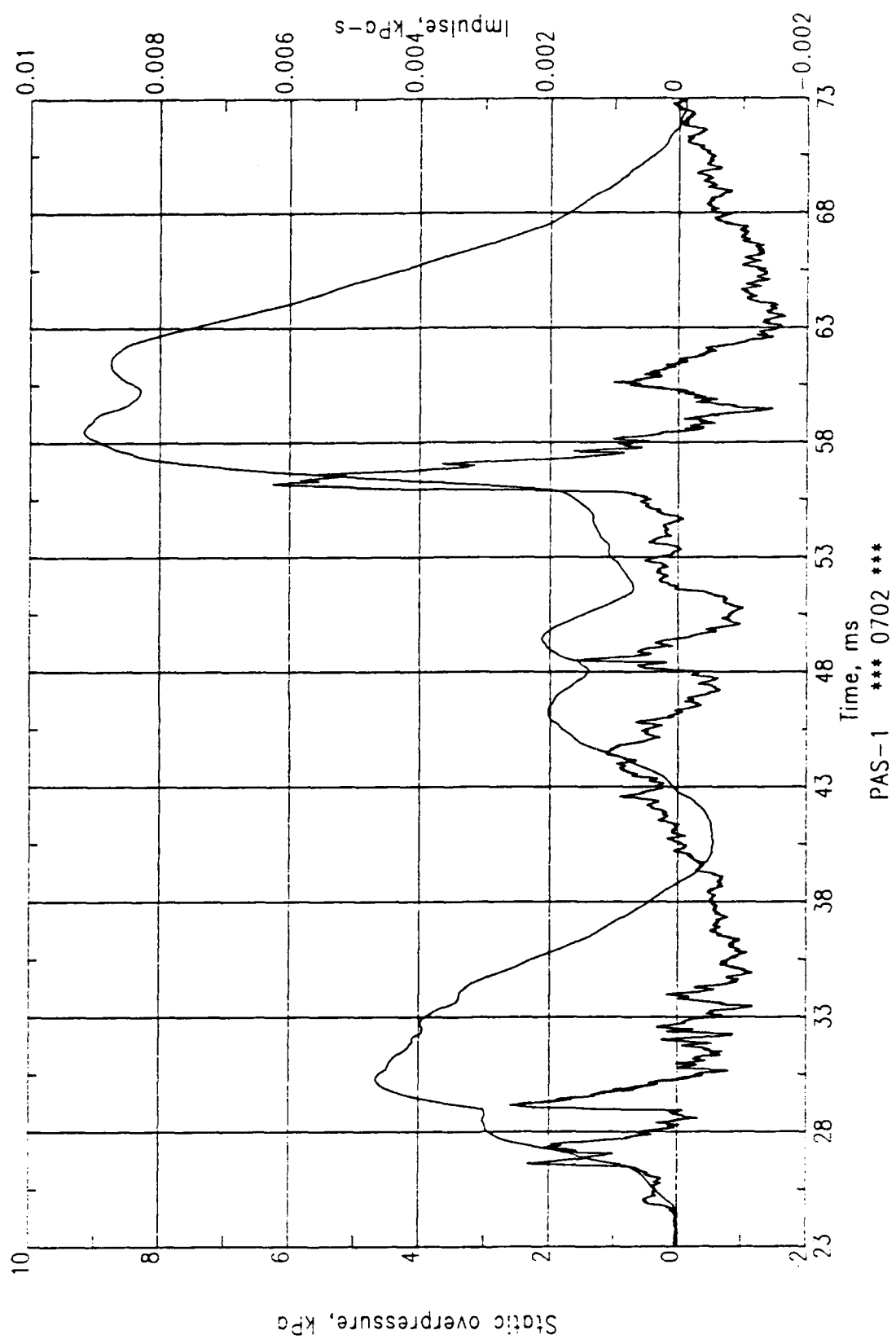


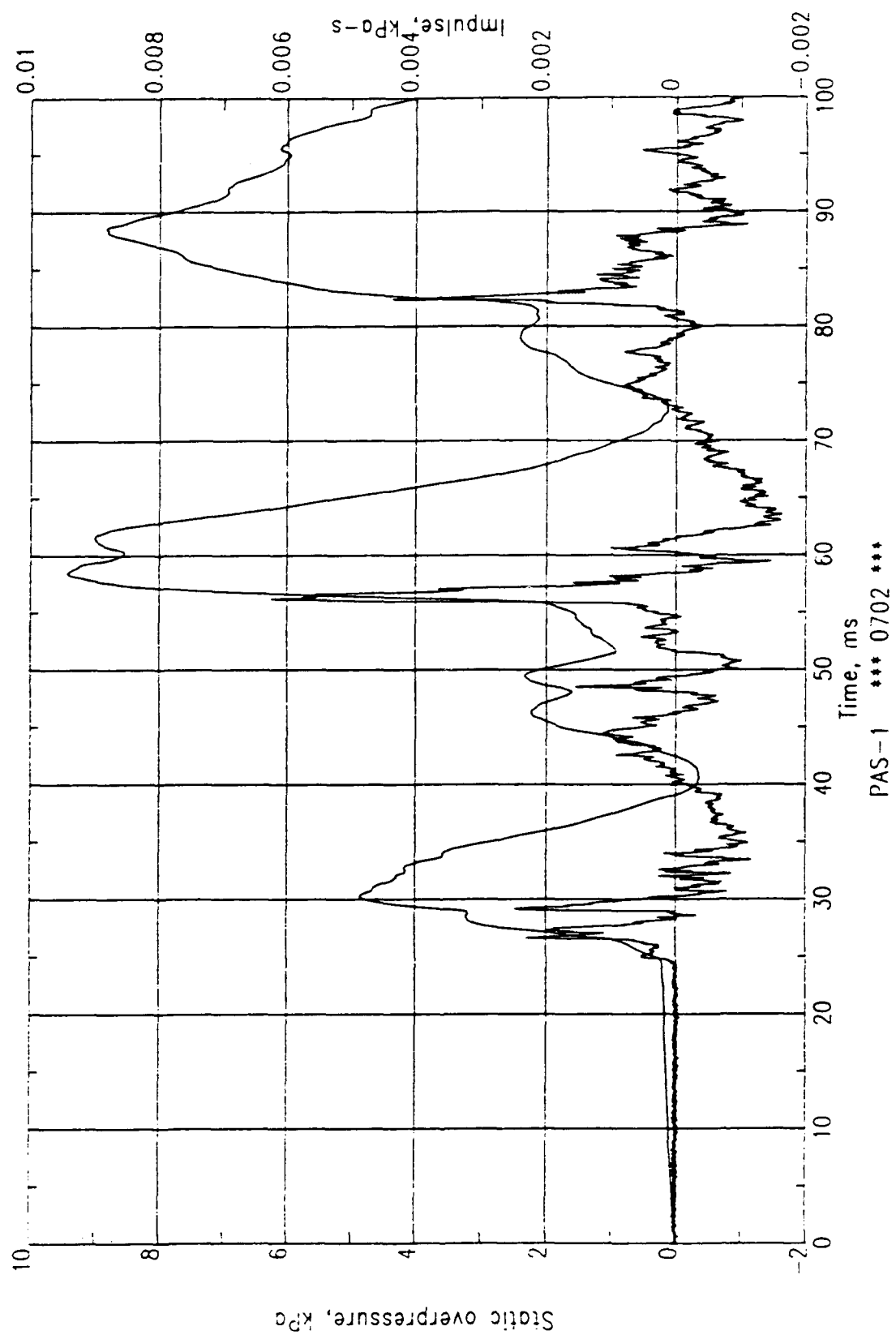


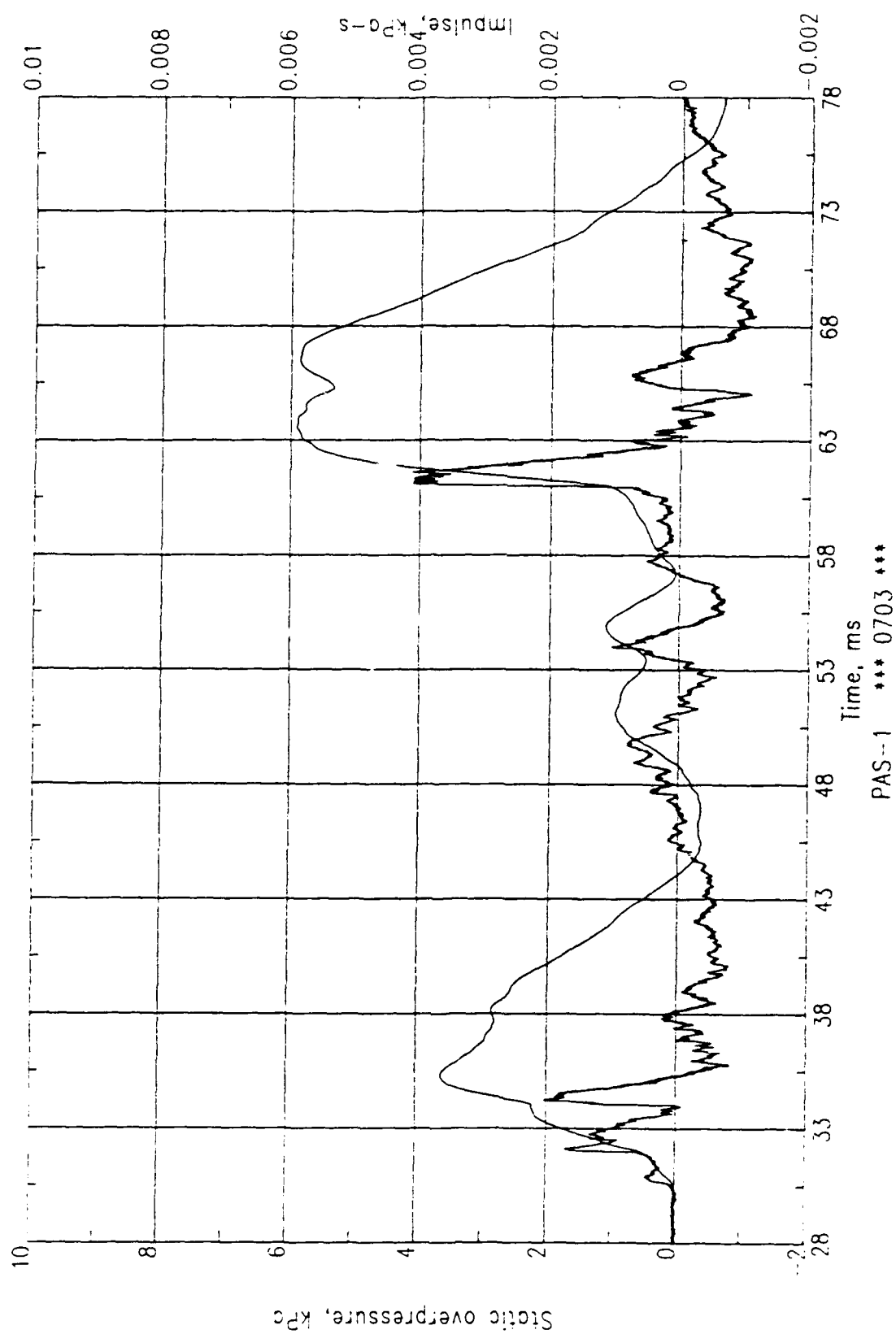


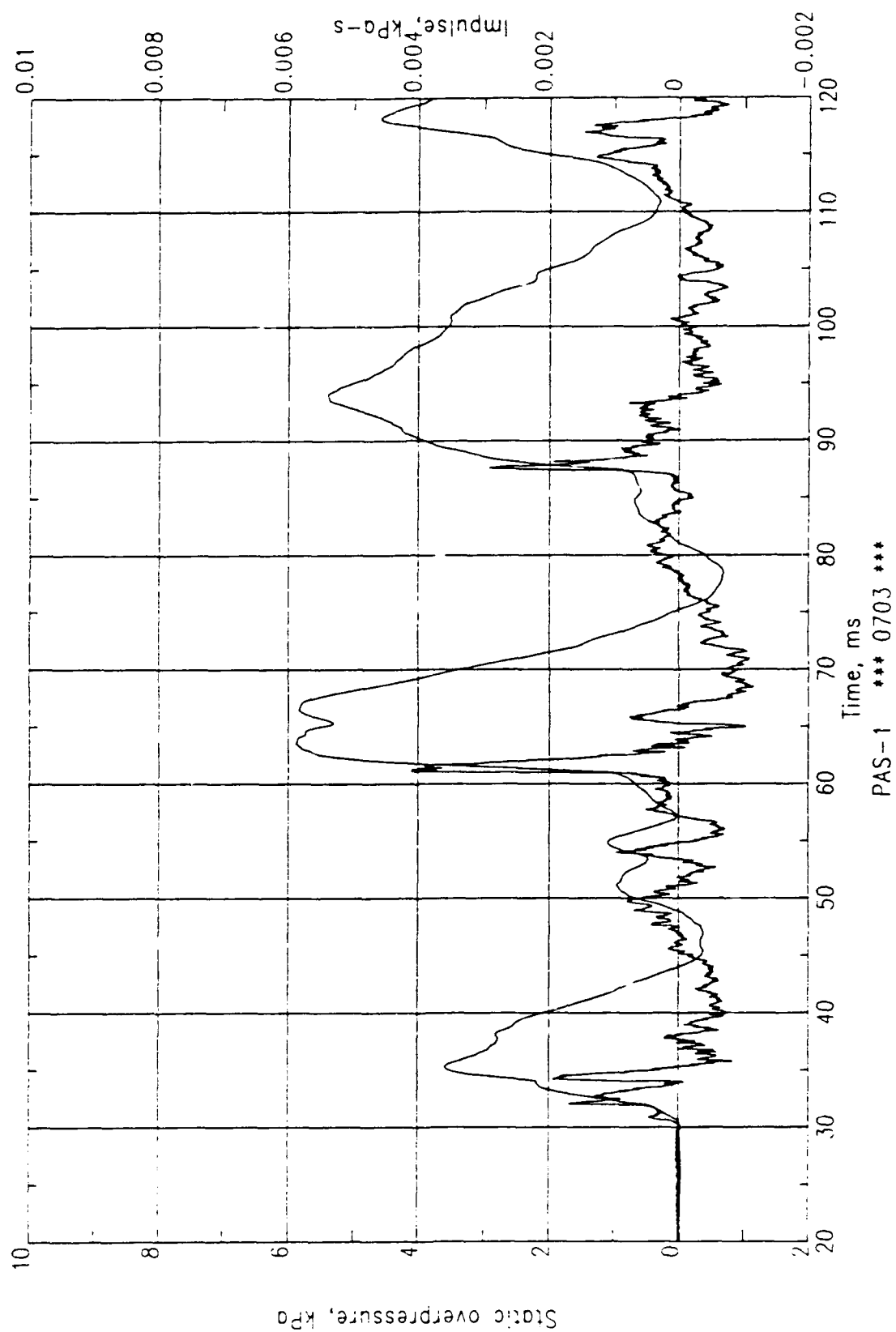
PAS-1 *** 0701 ***

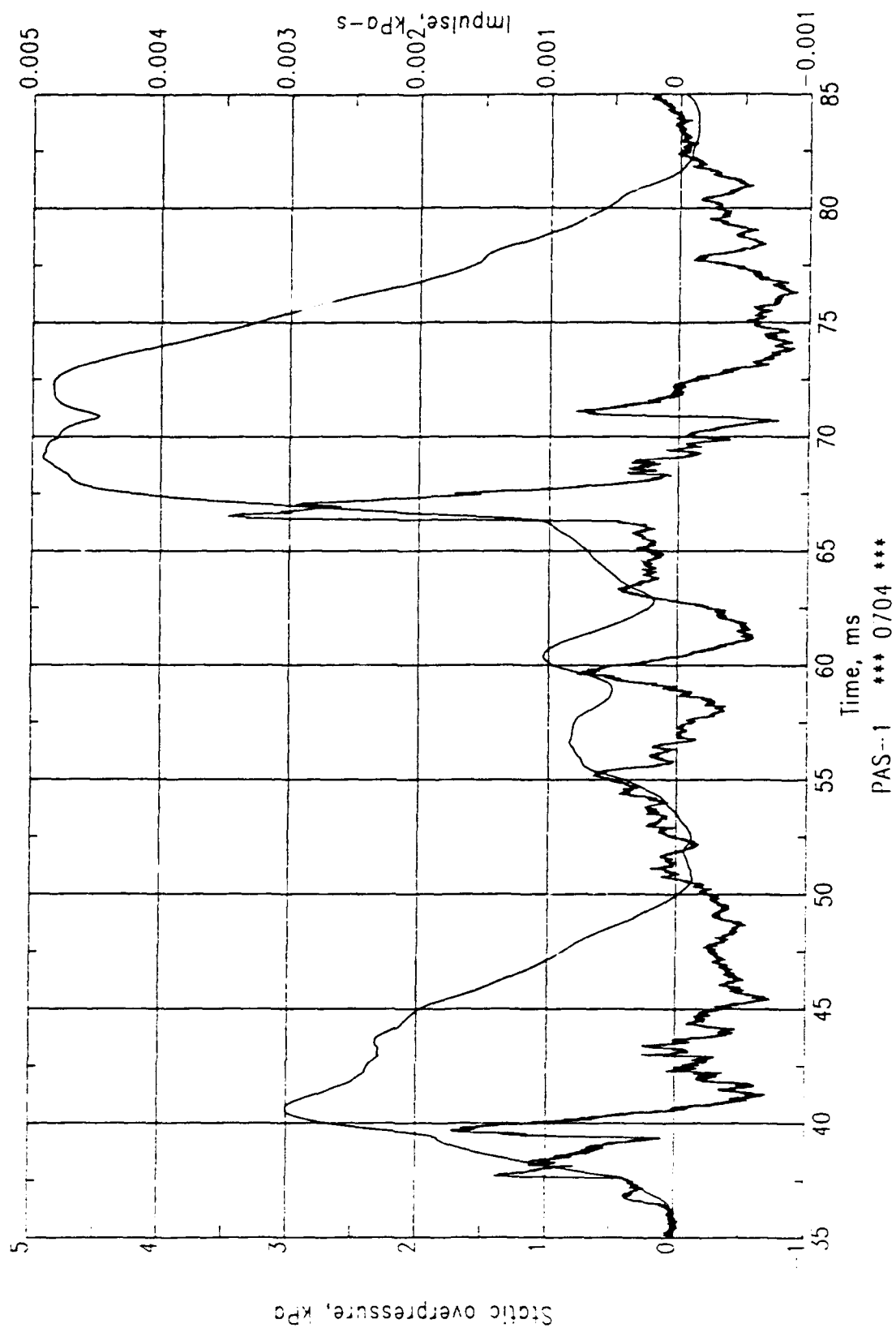


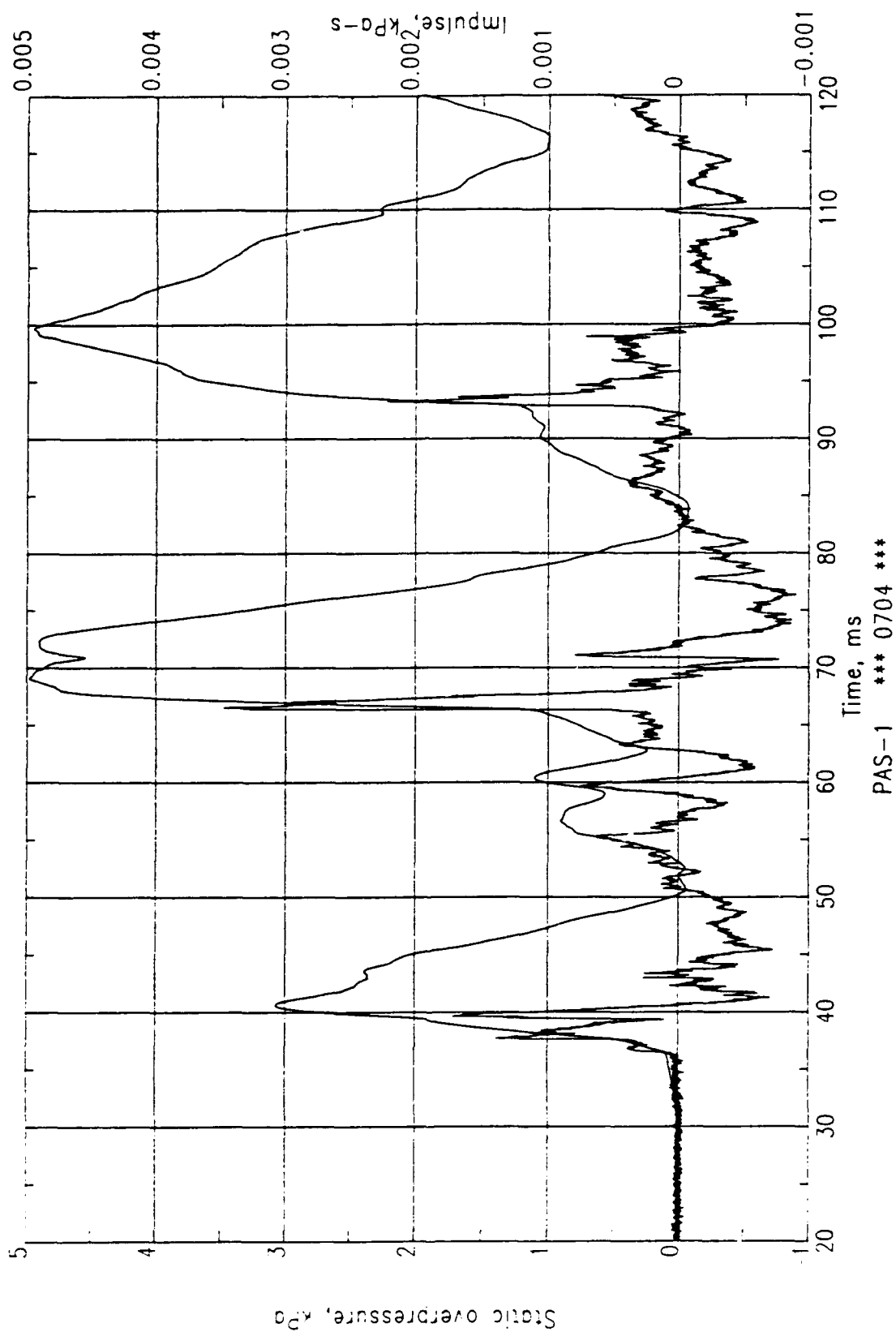


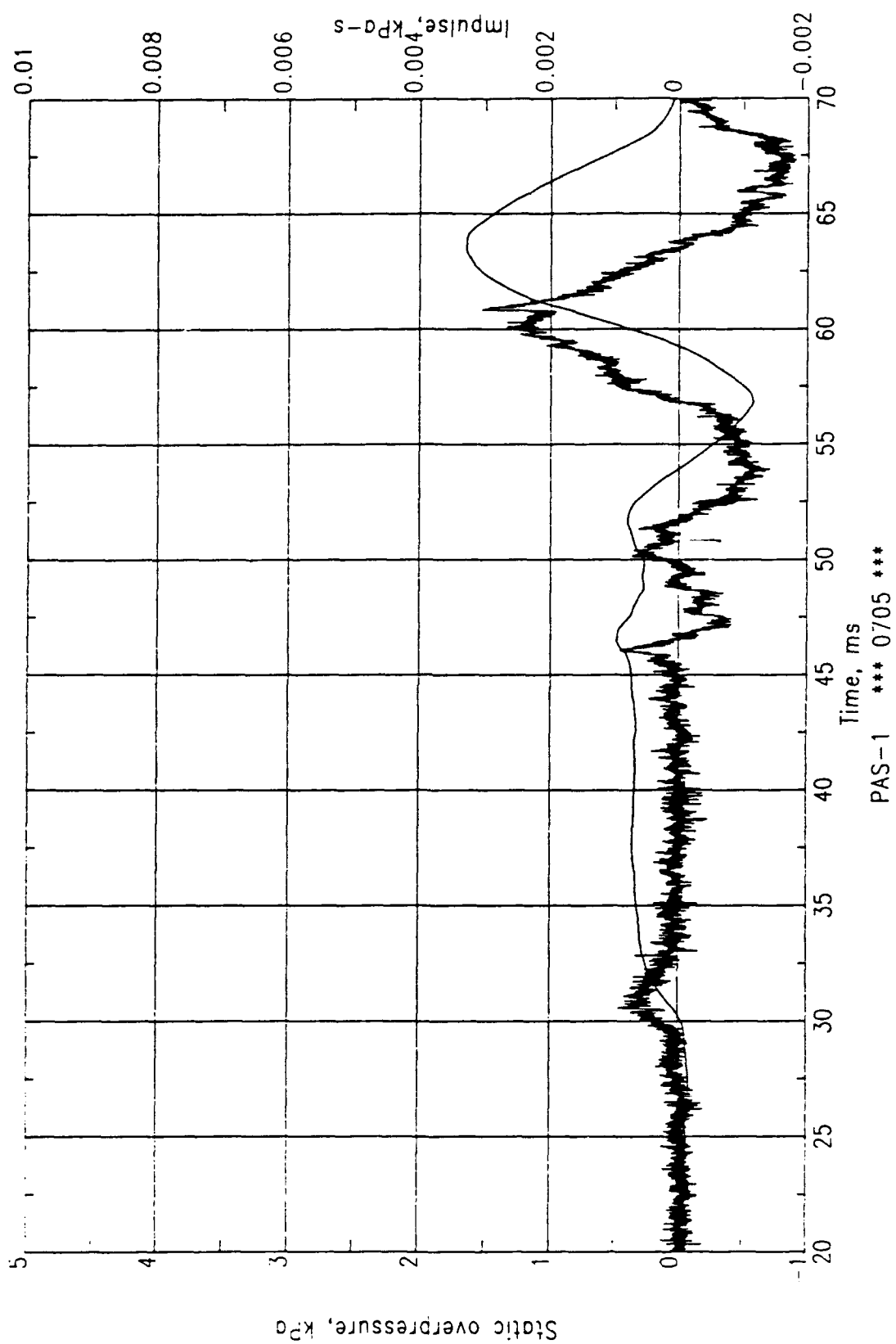


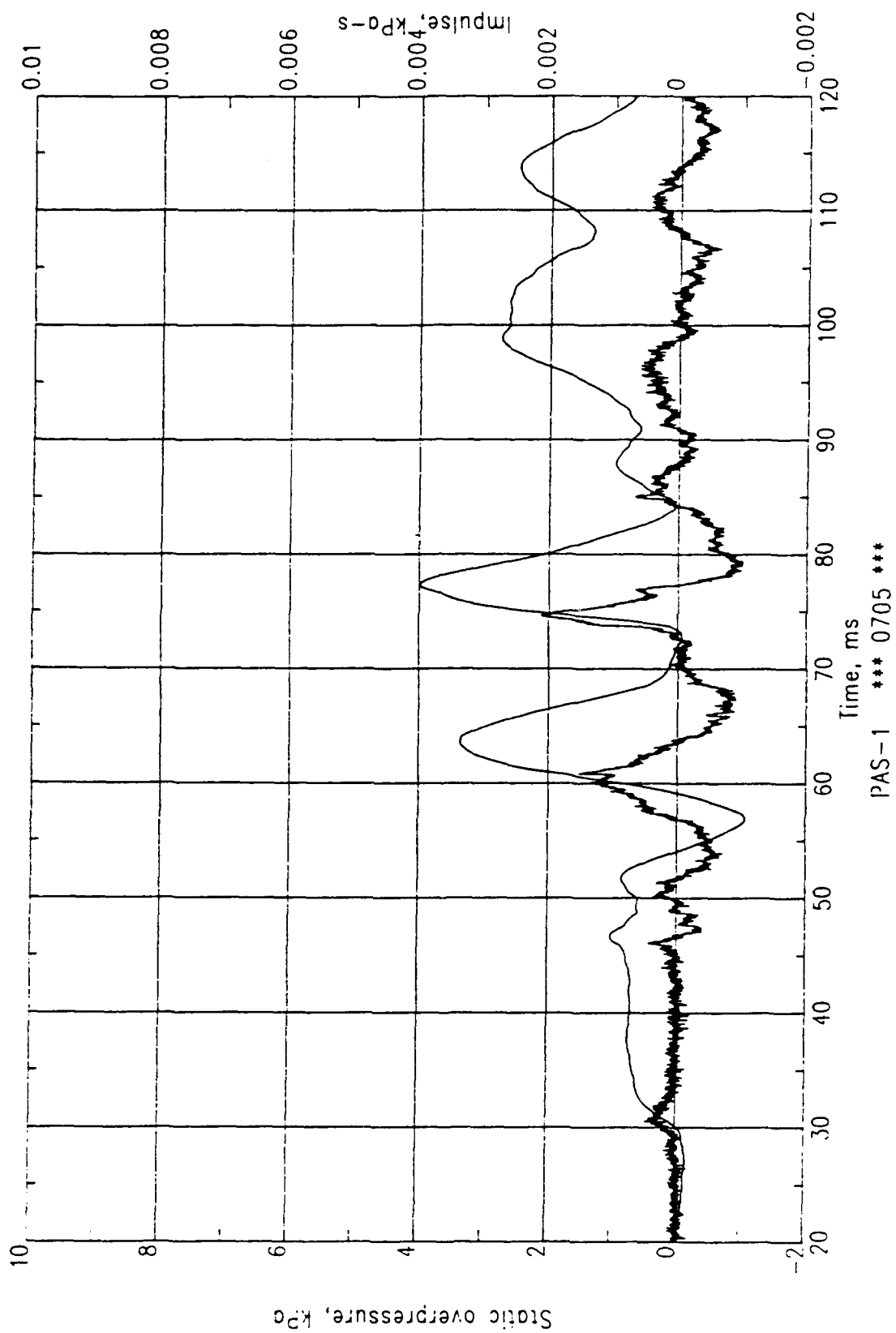


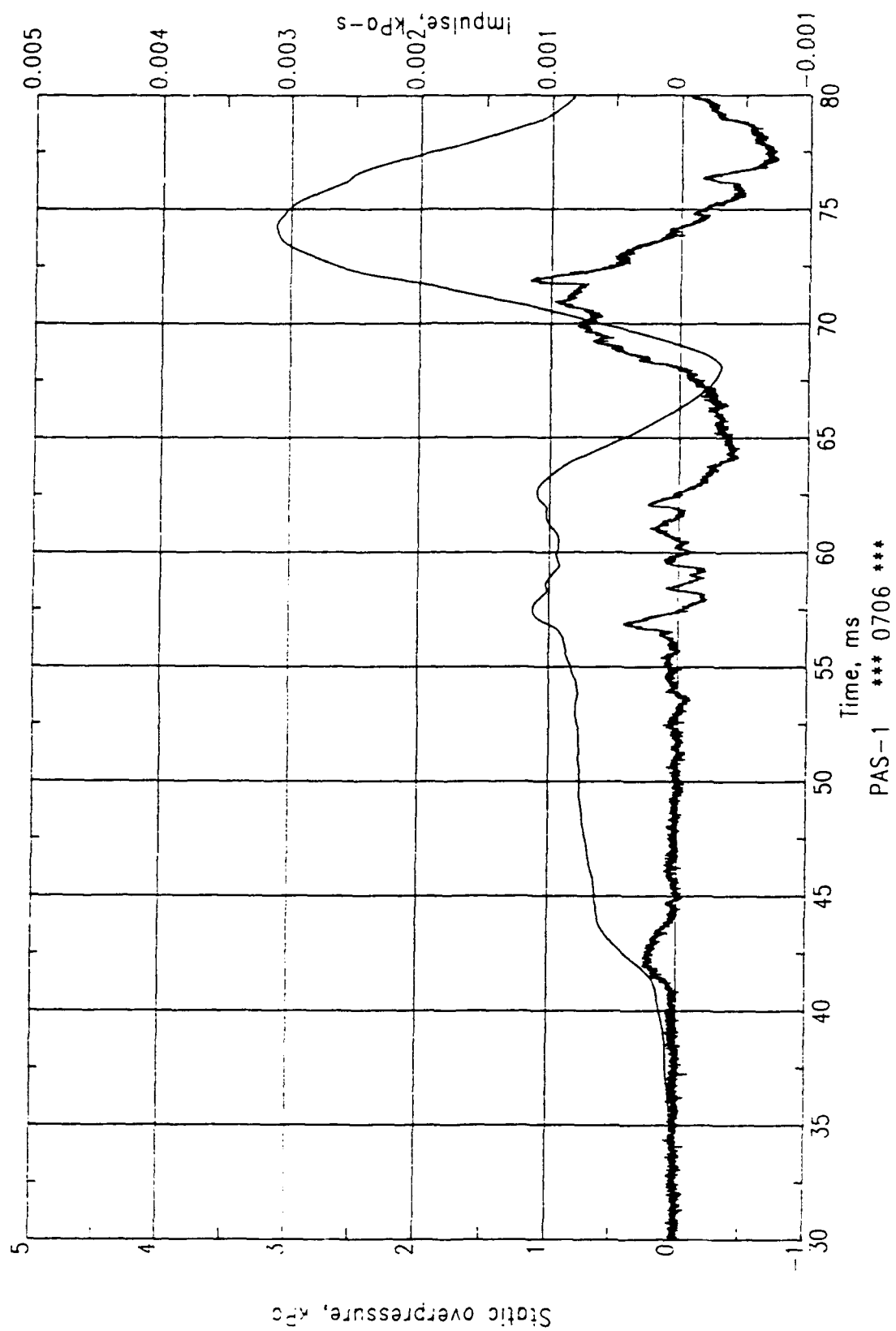


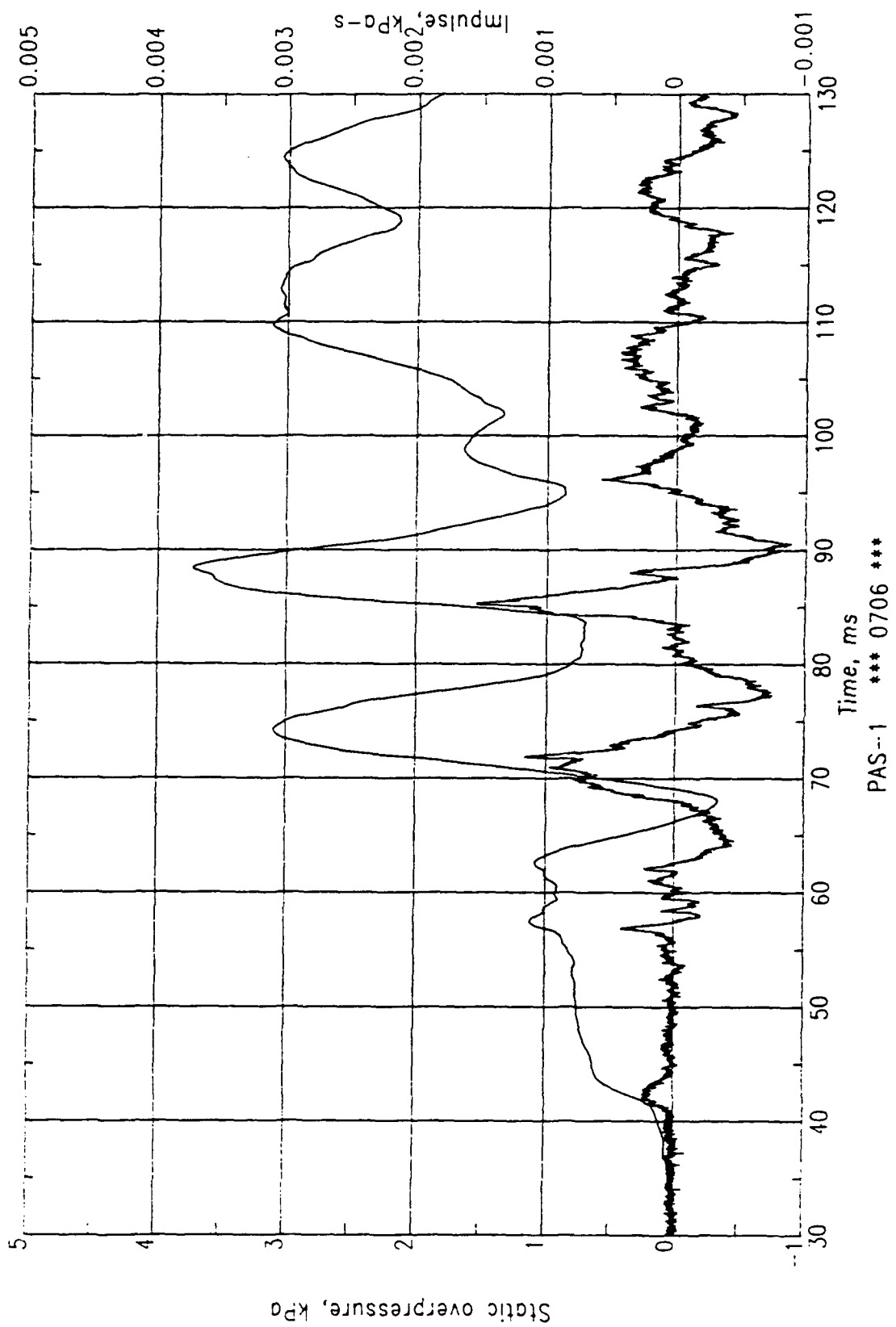


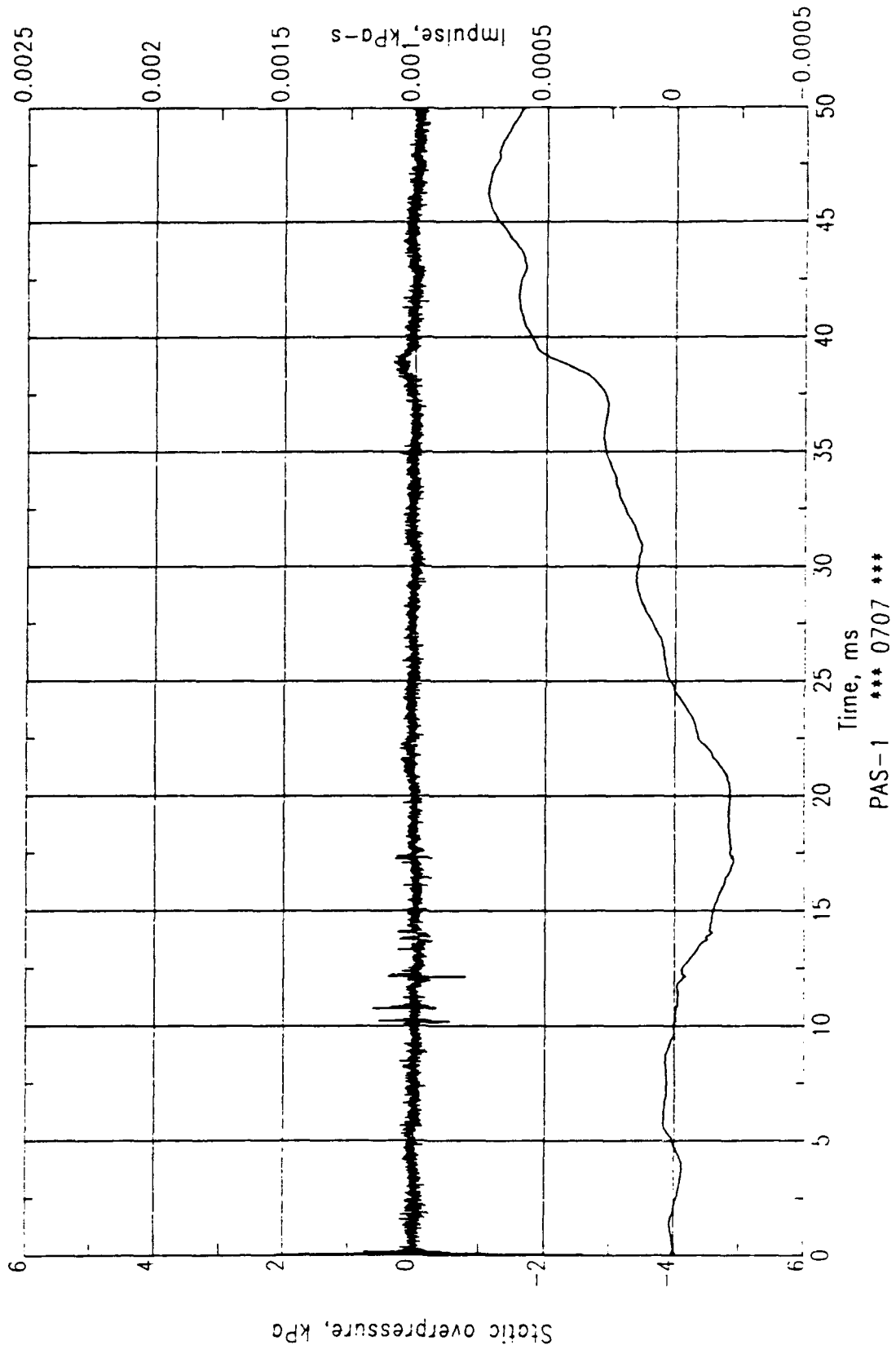


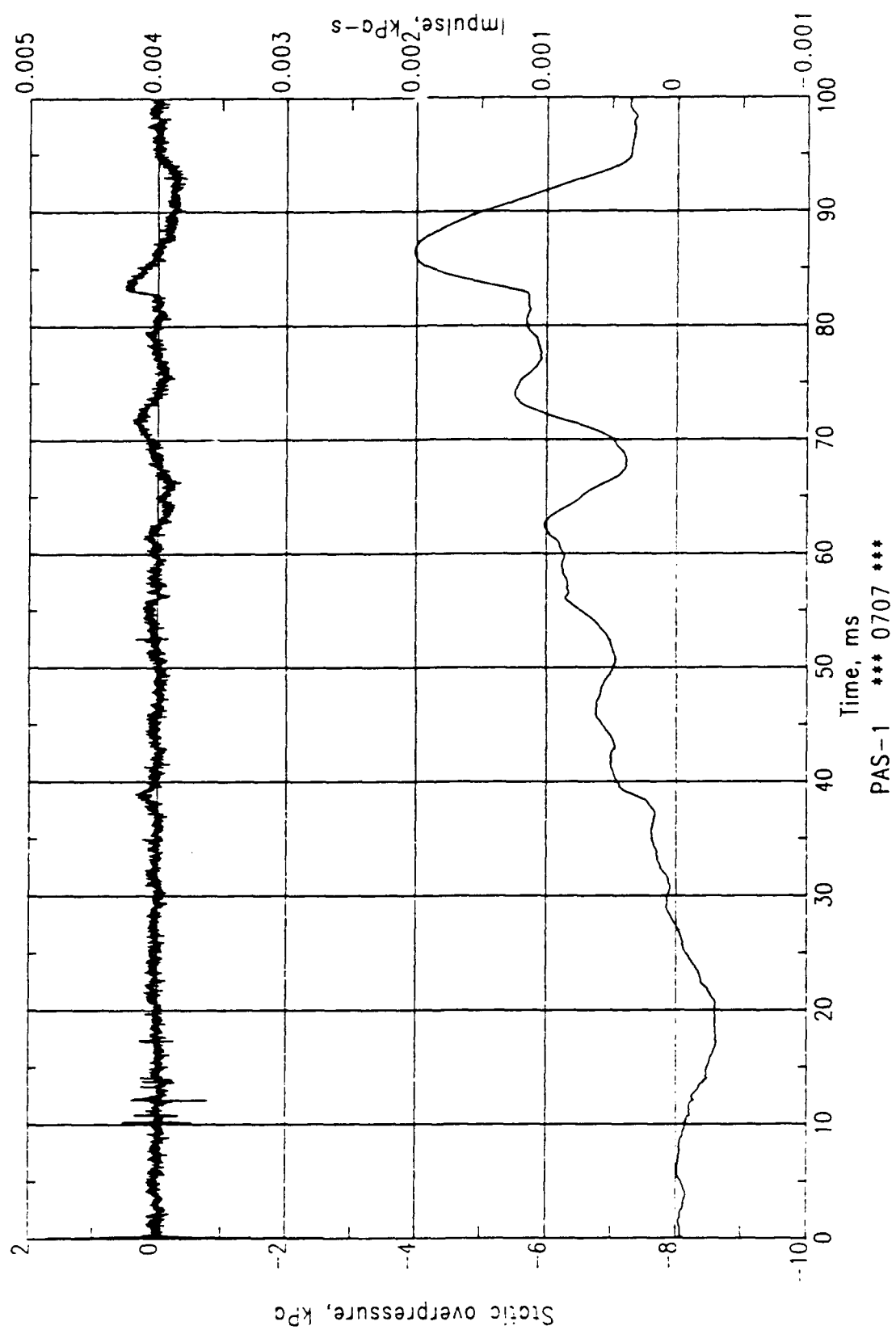


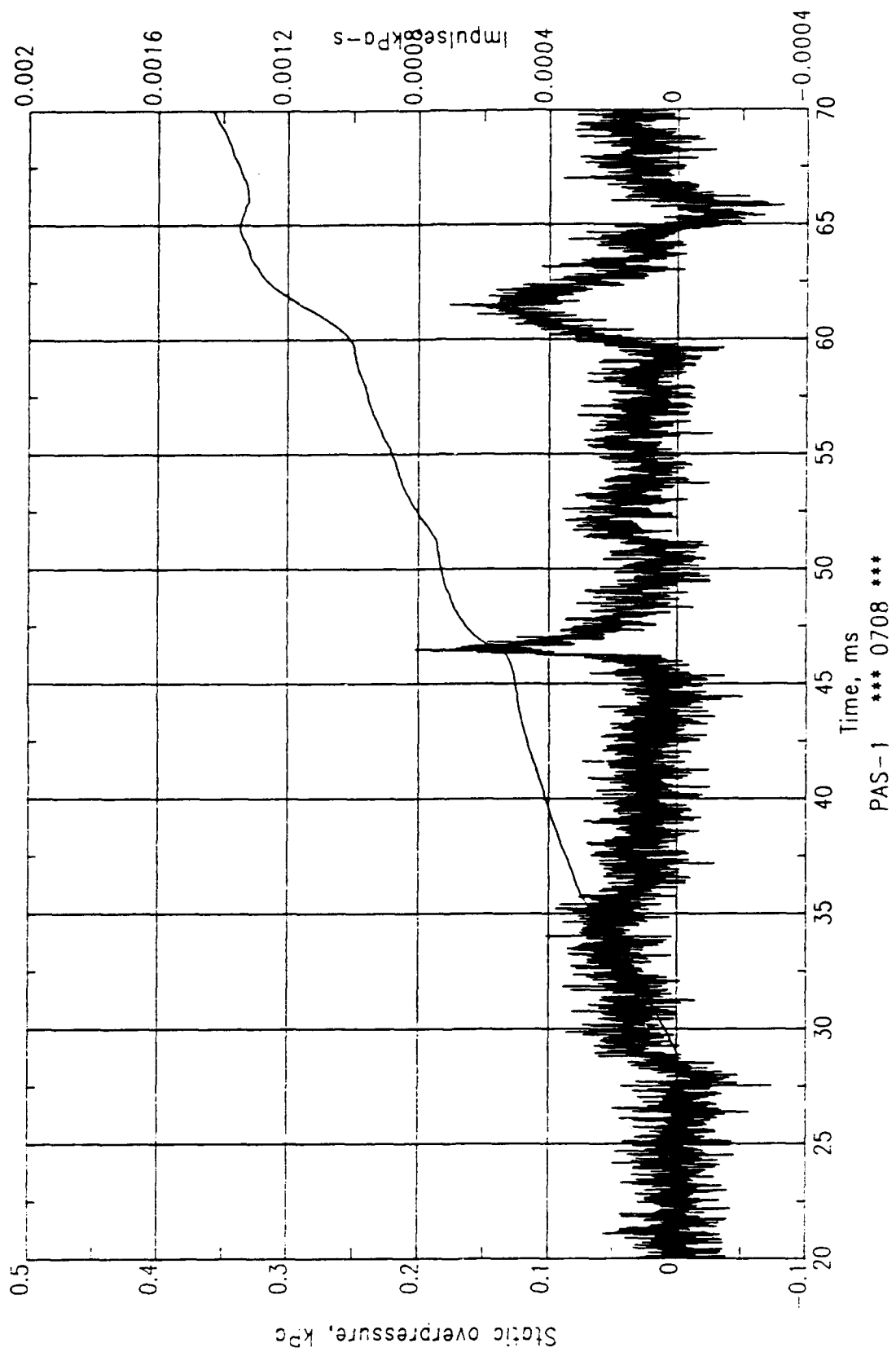


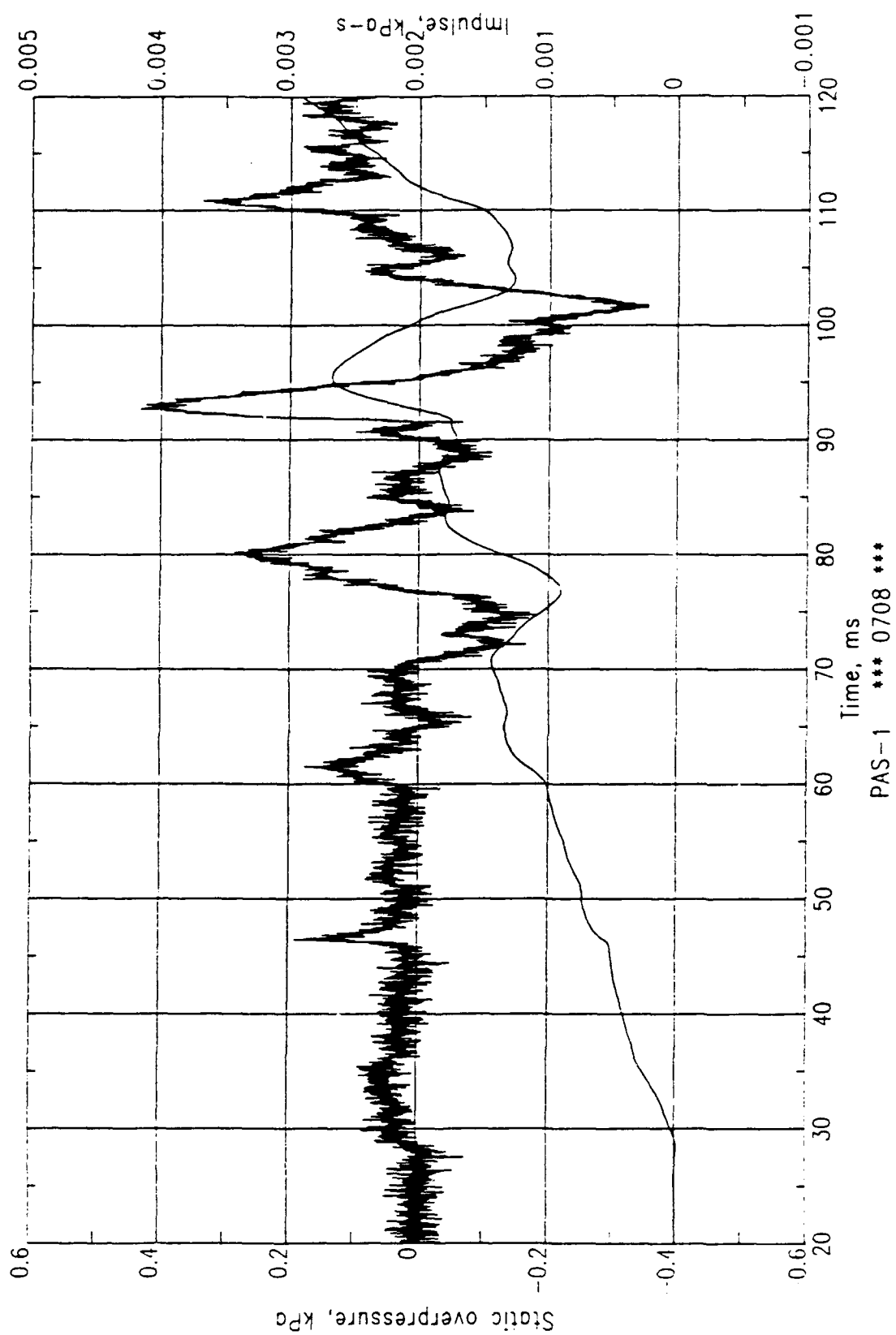


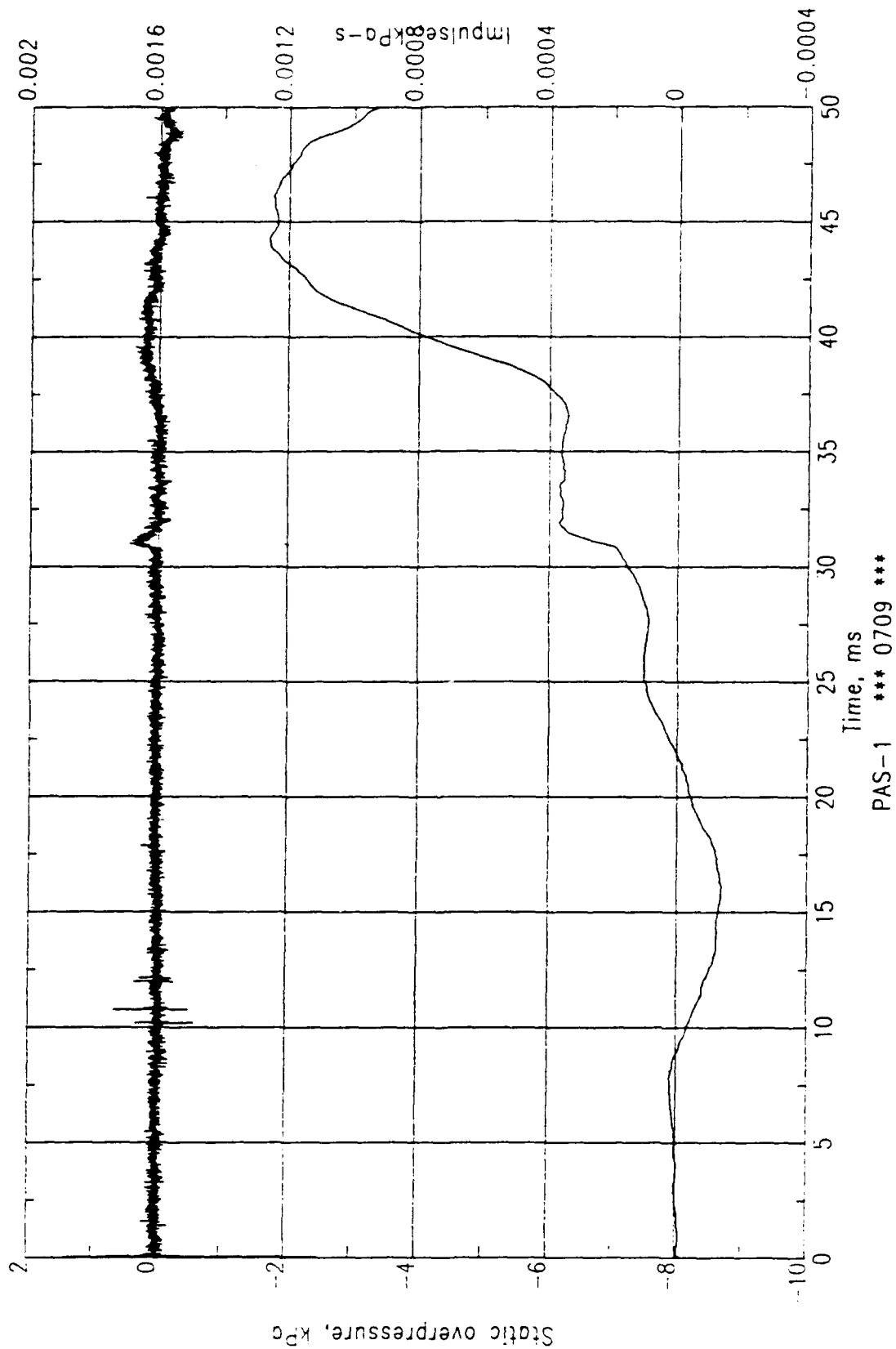


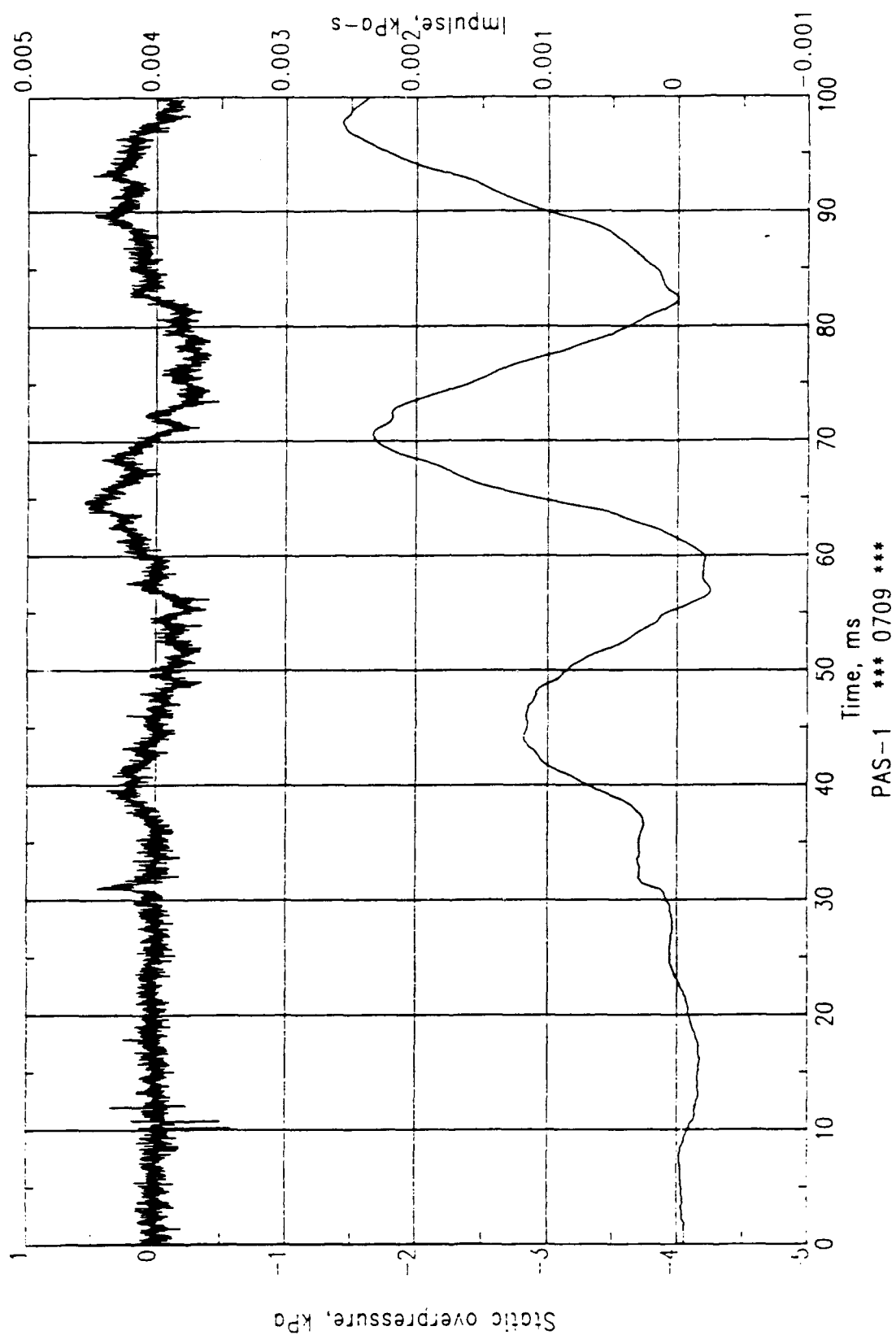


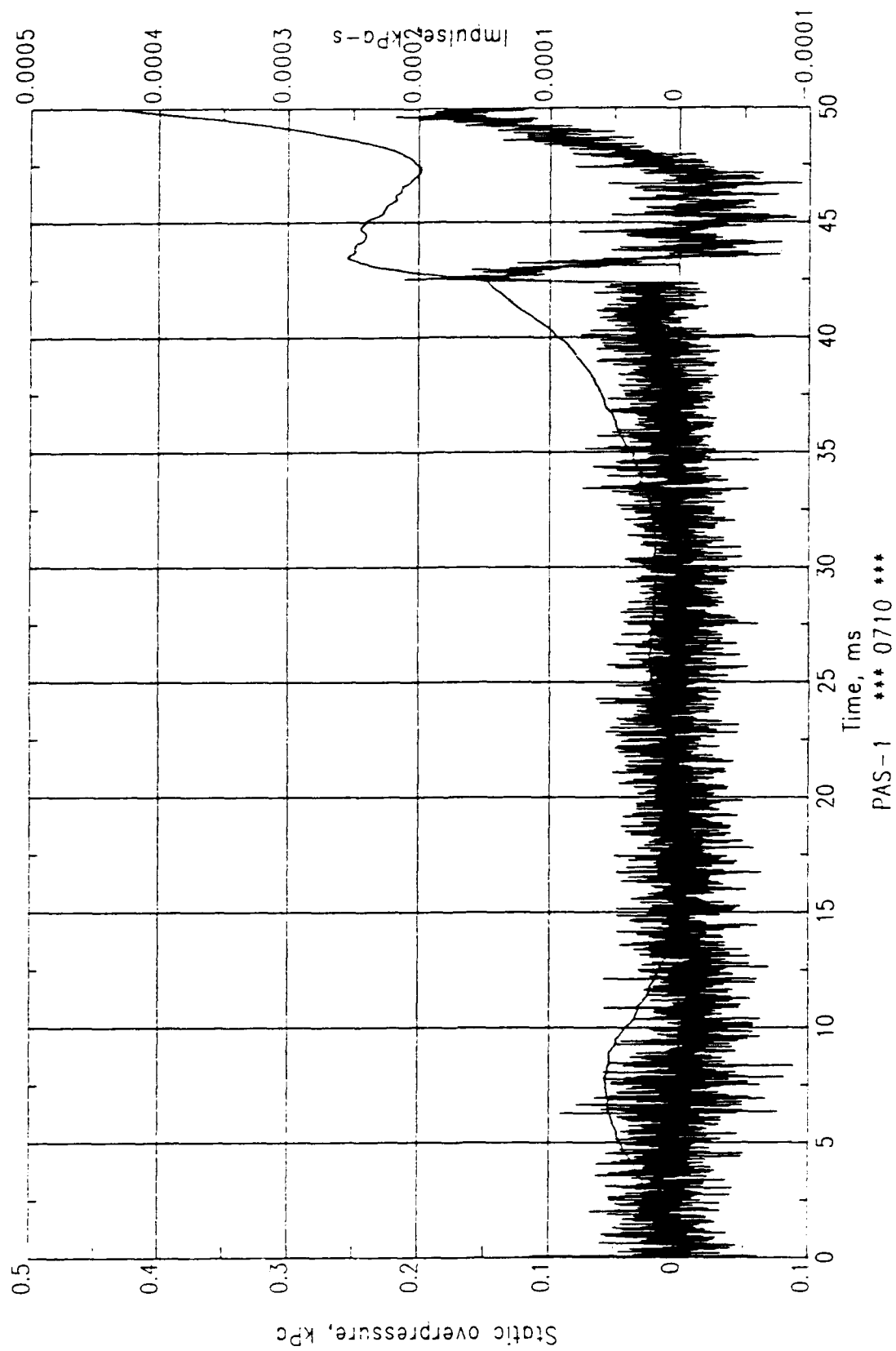


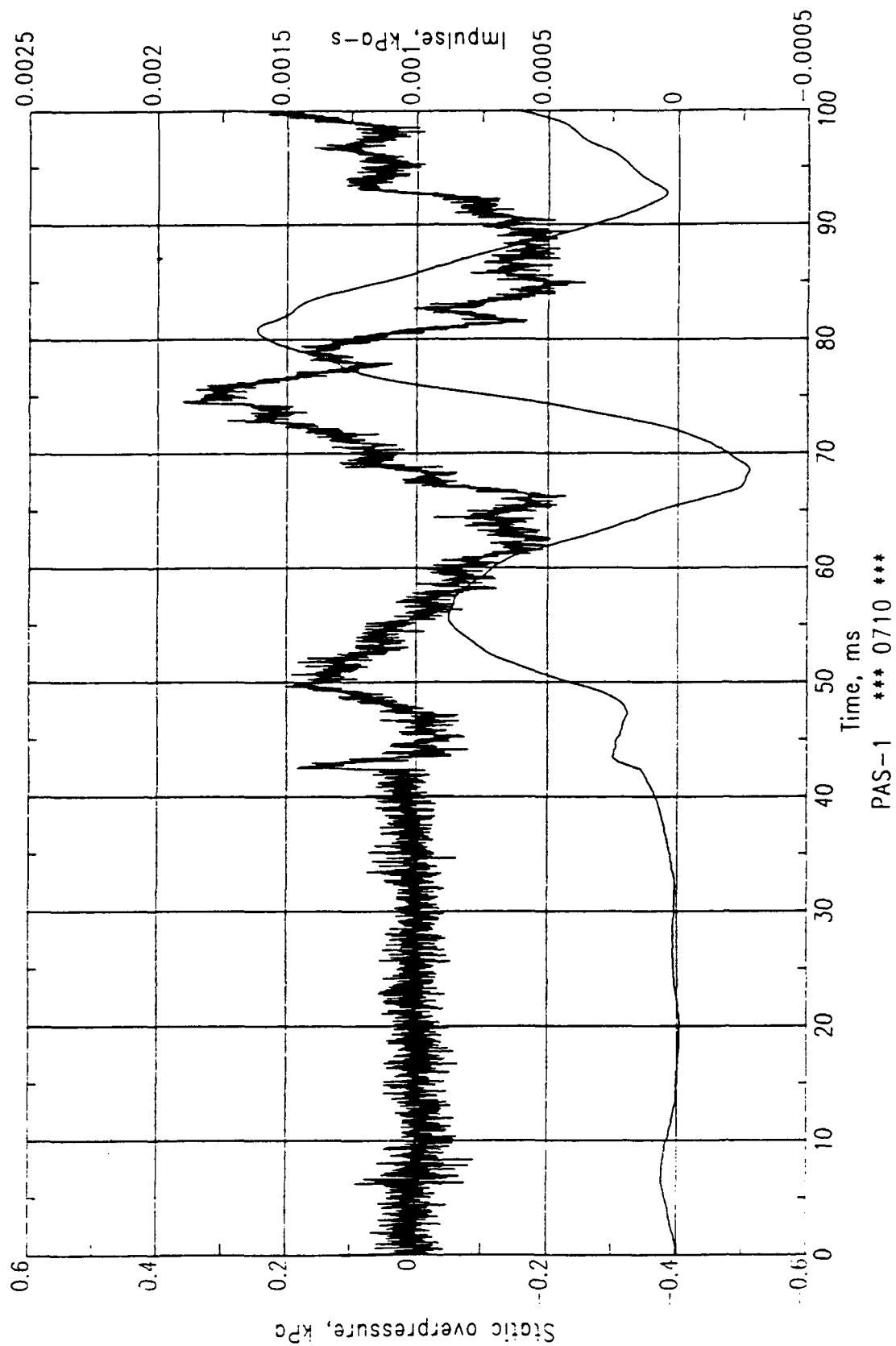


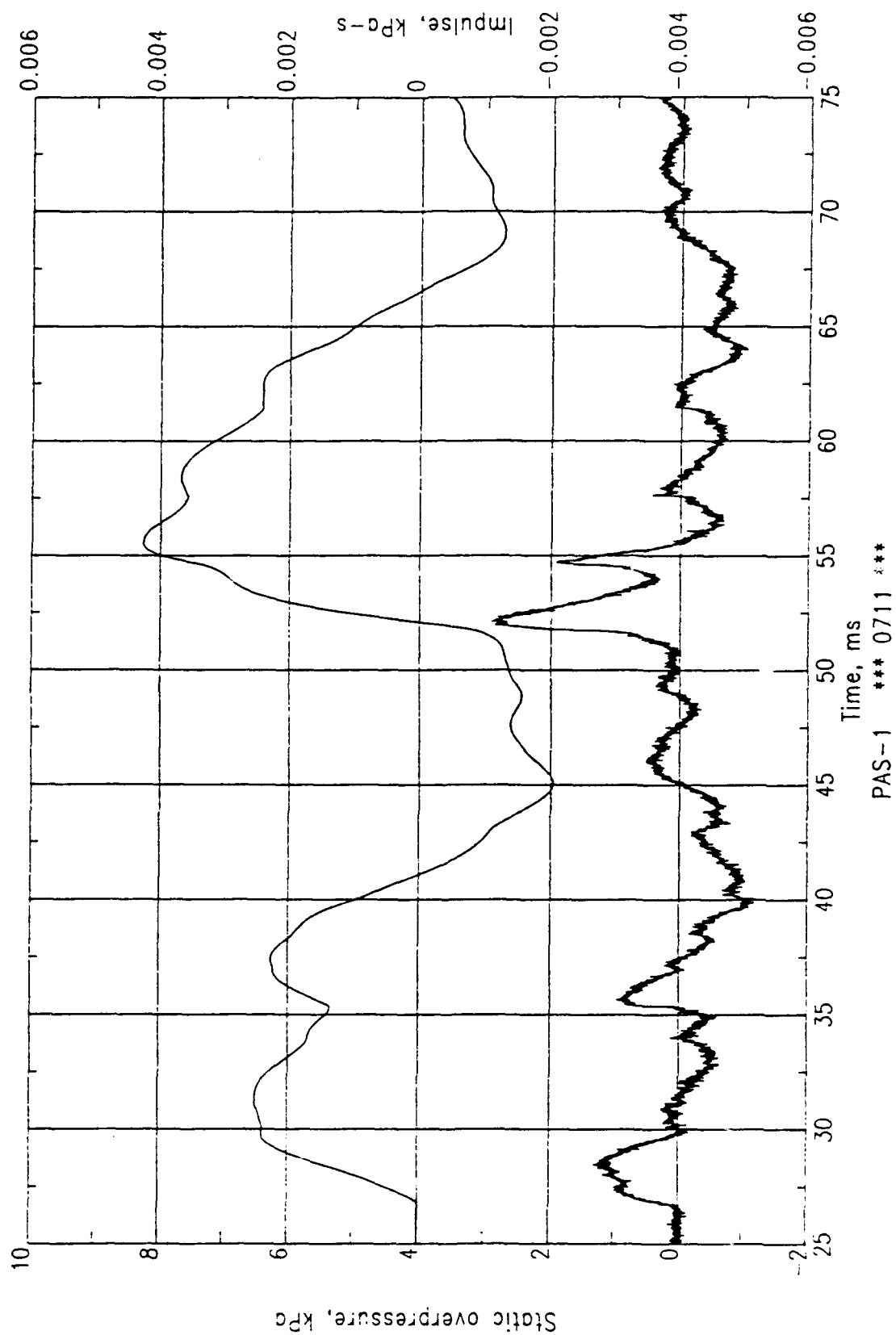


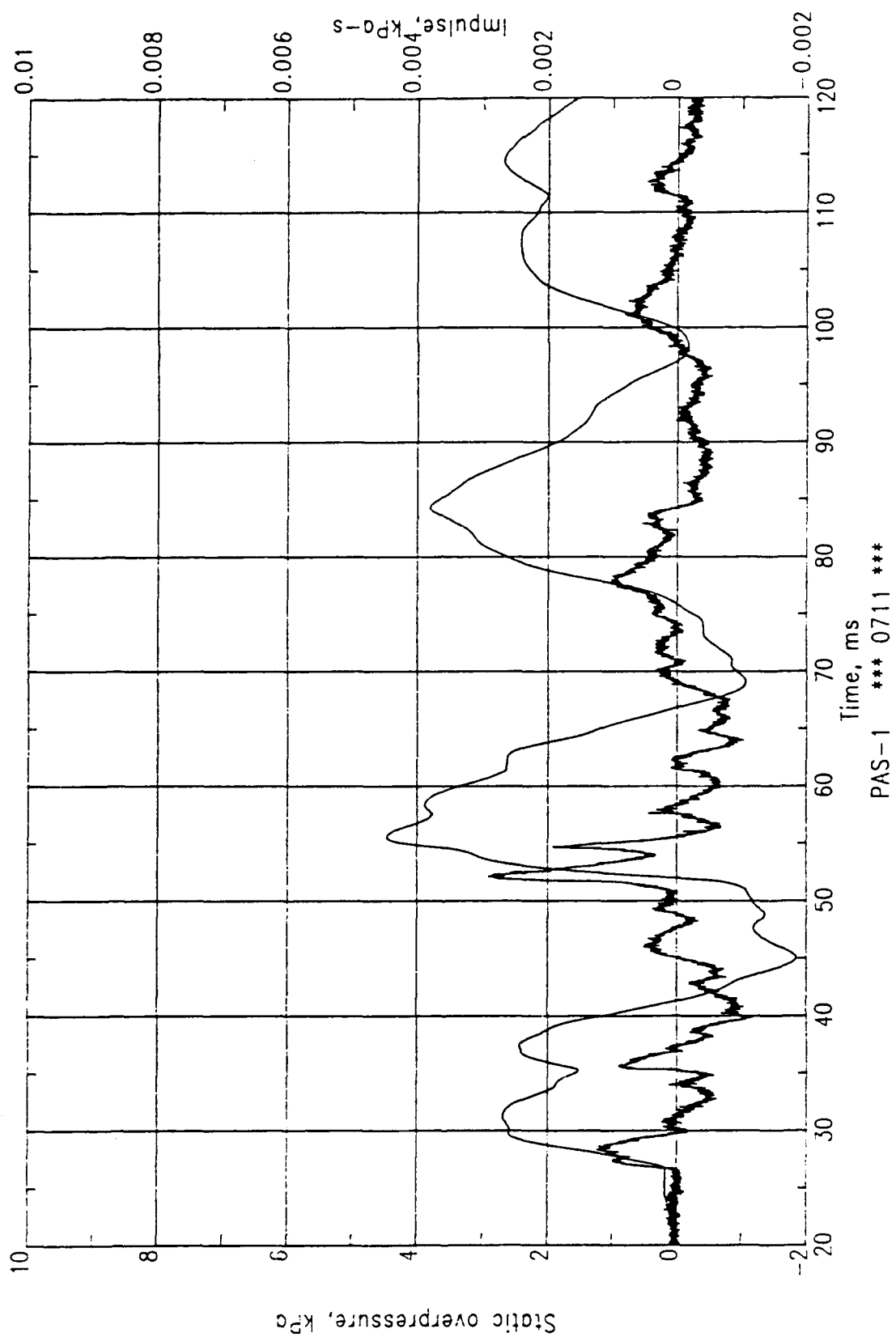


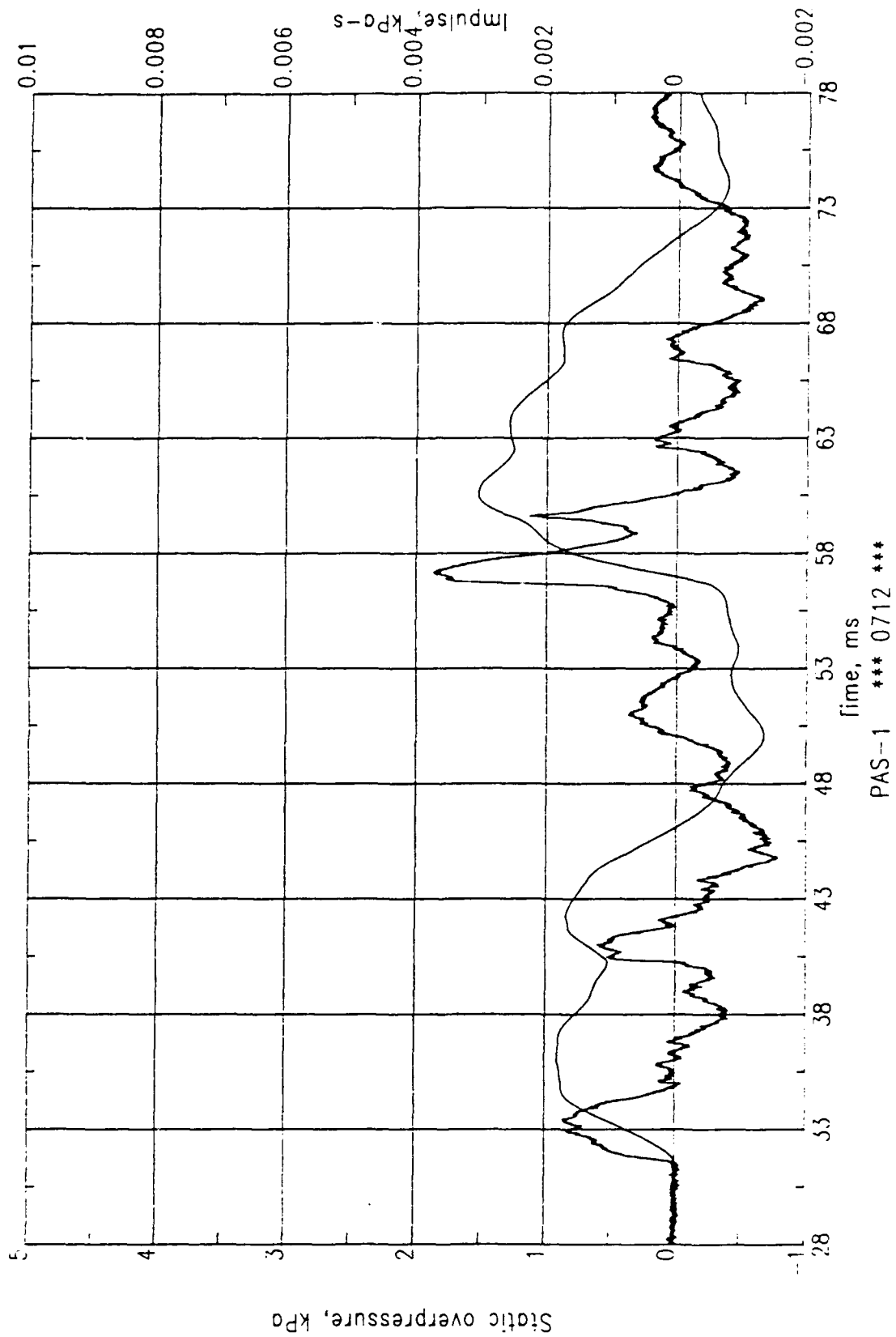


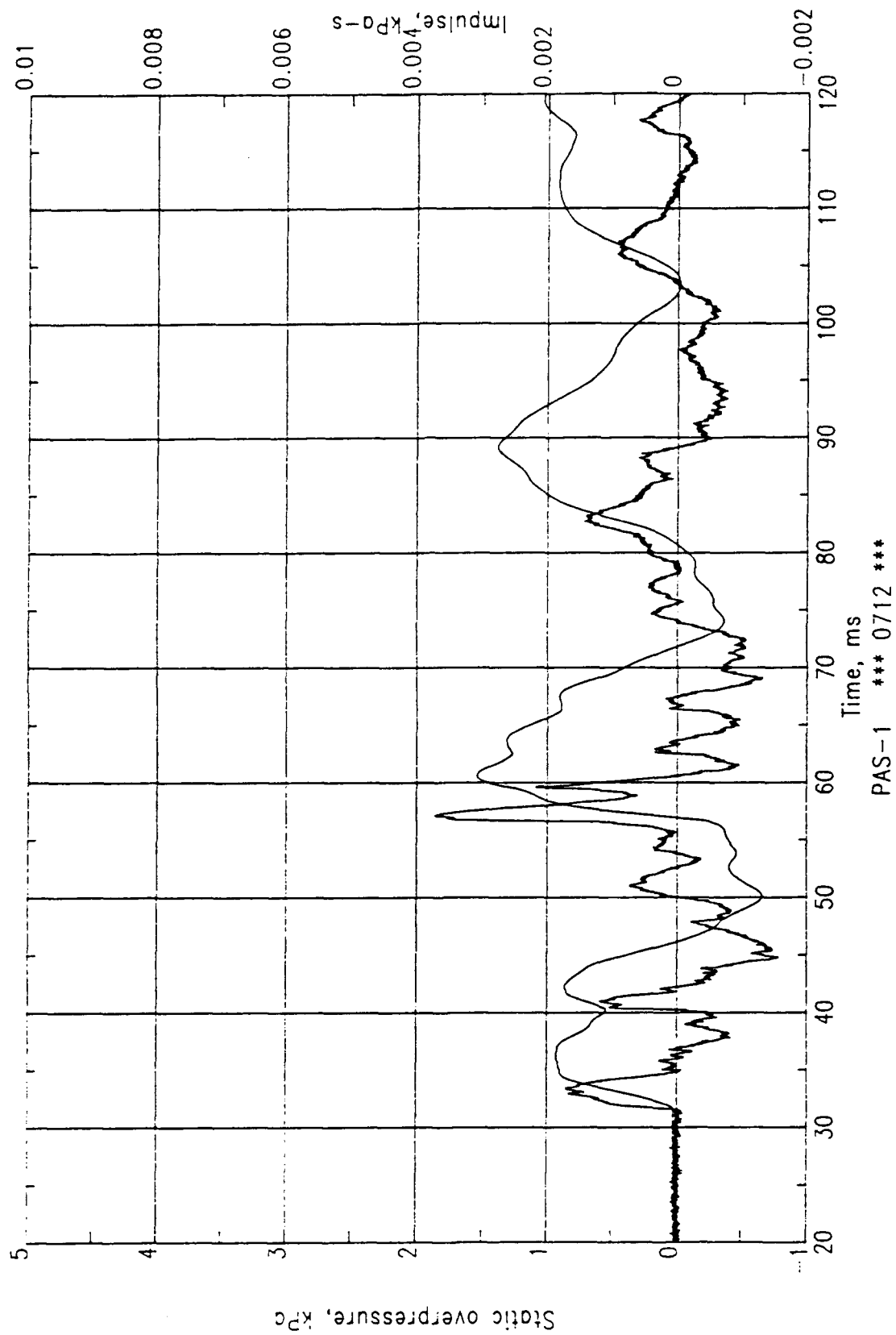


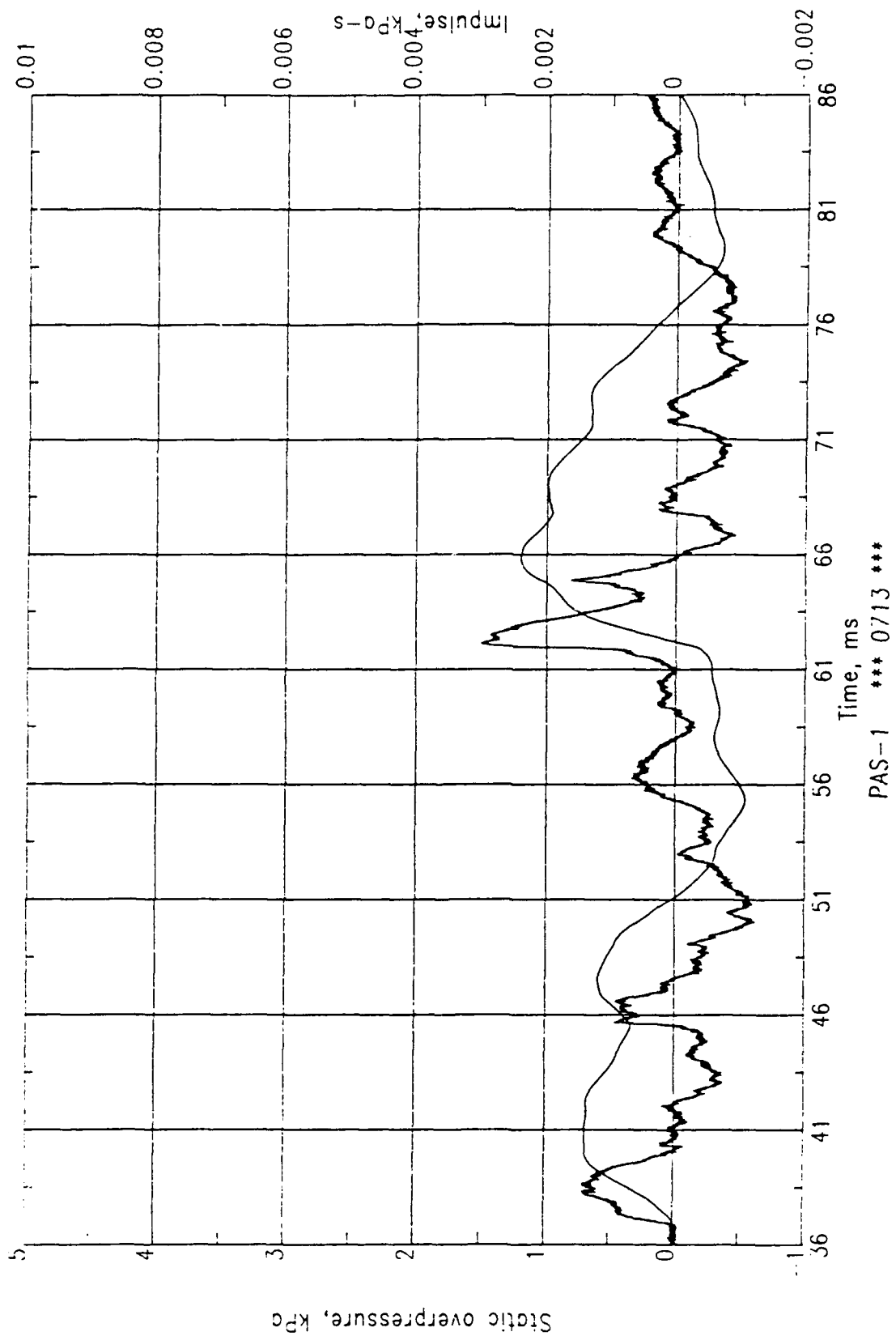


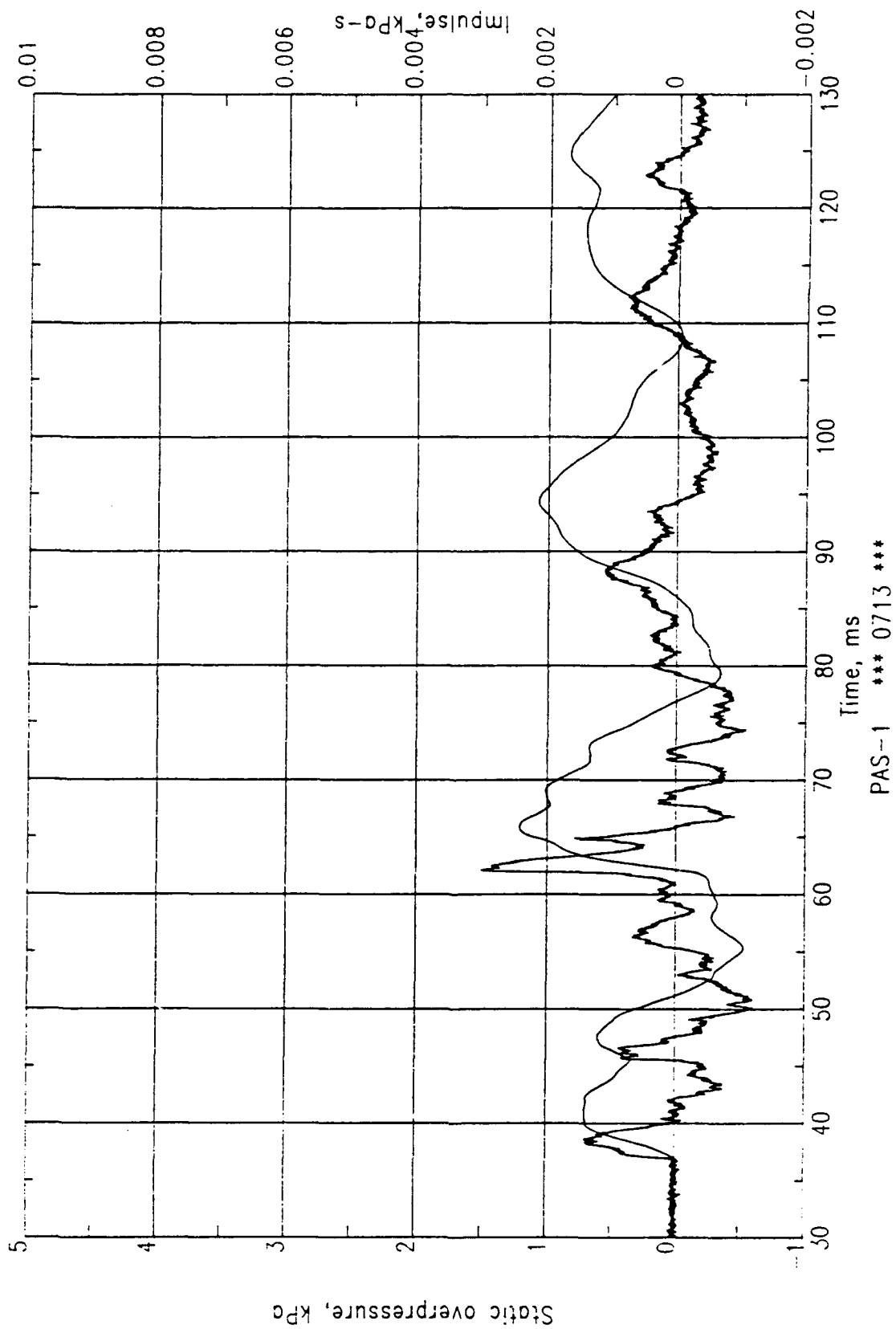


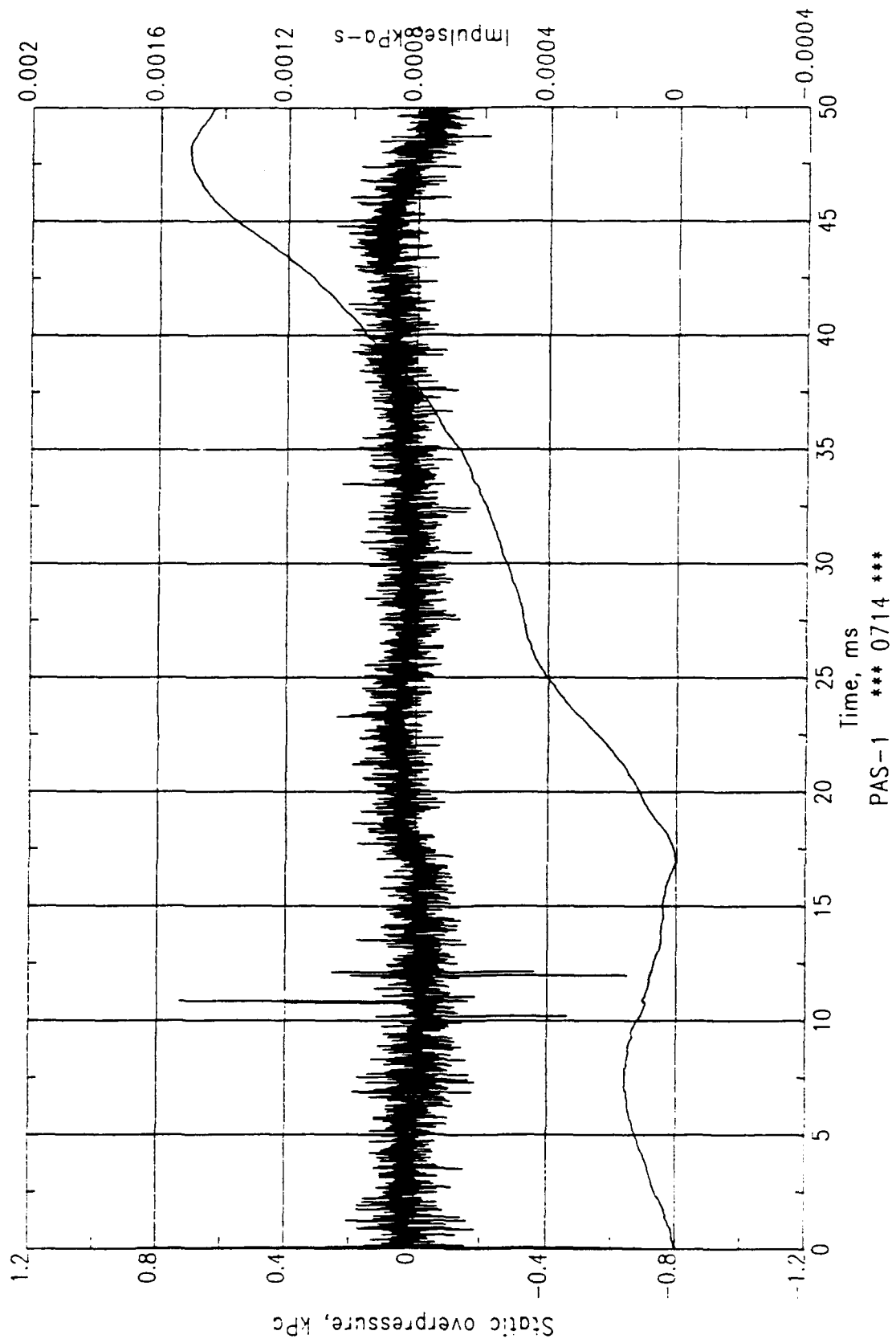


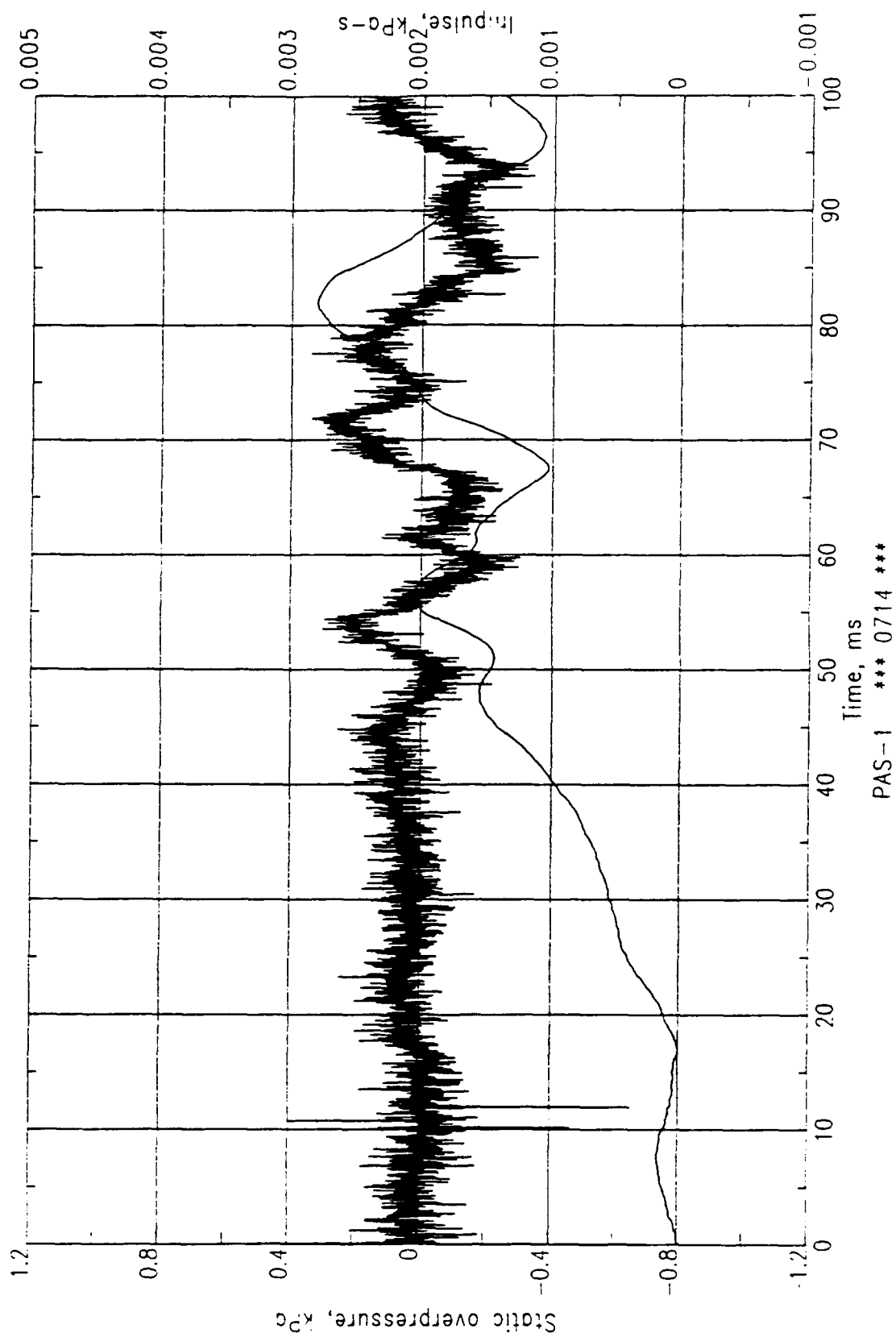


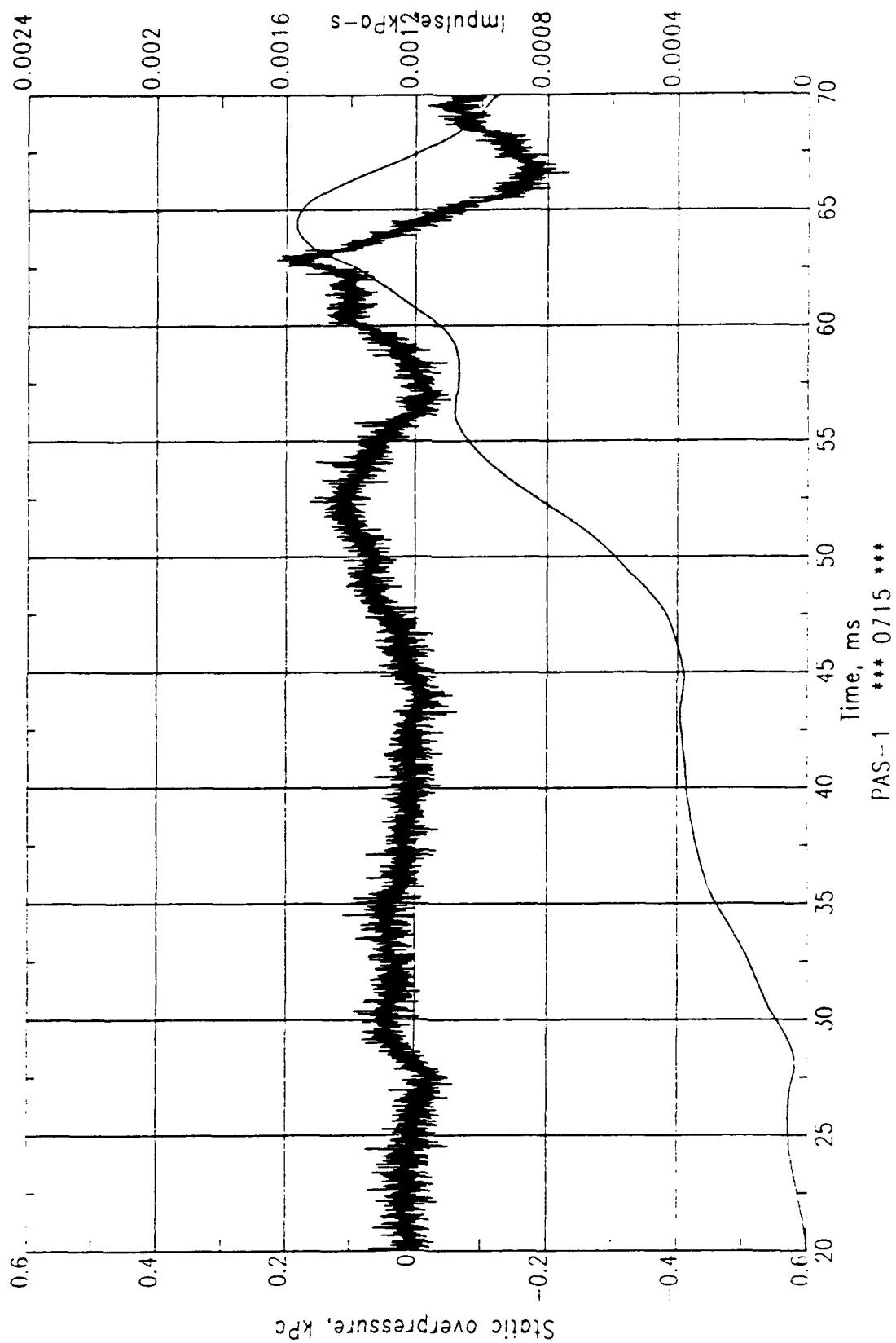


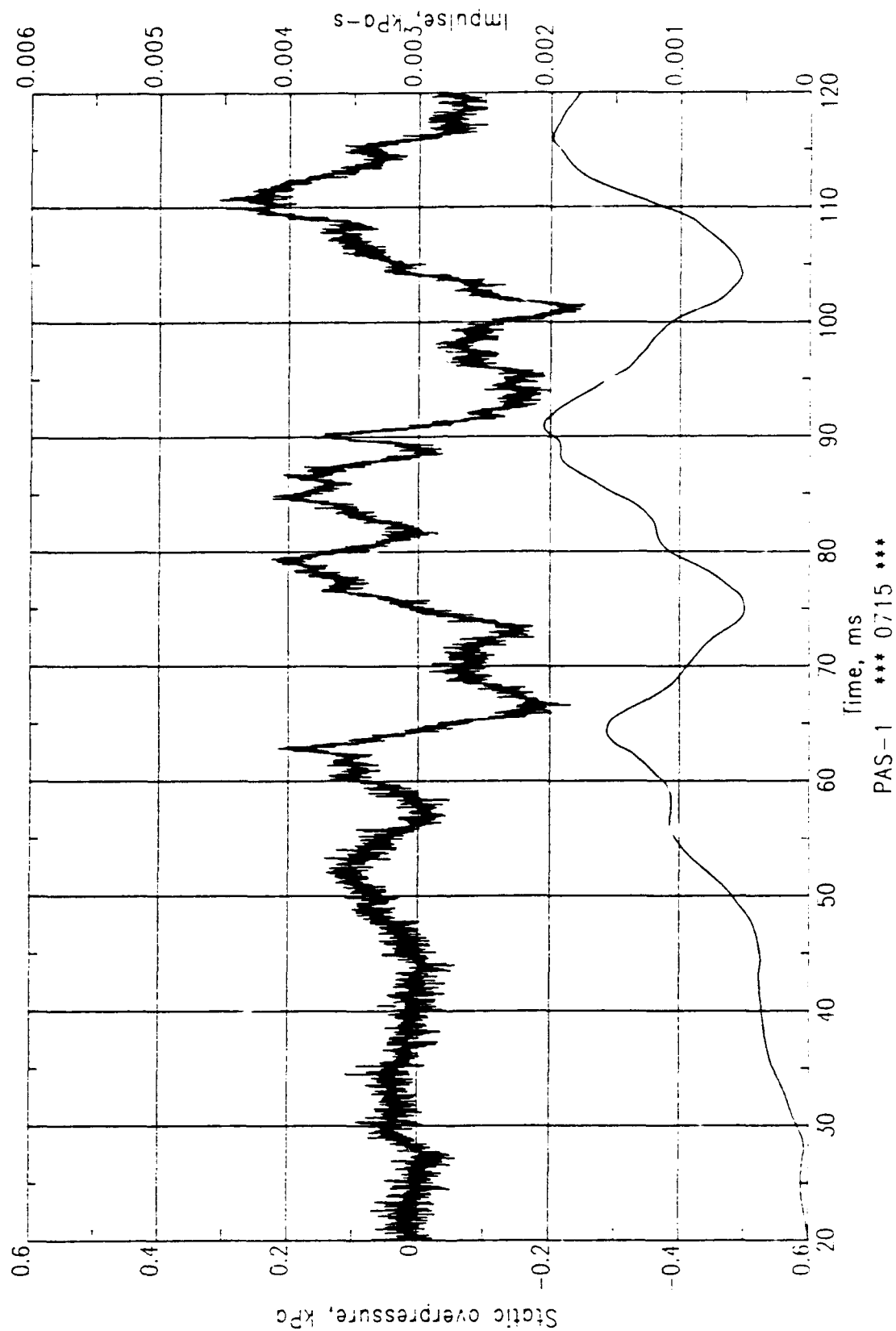




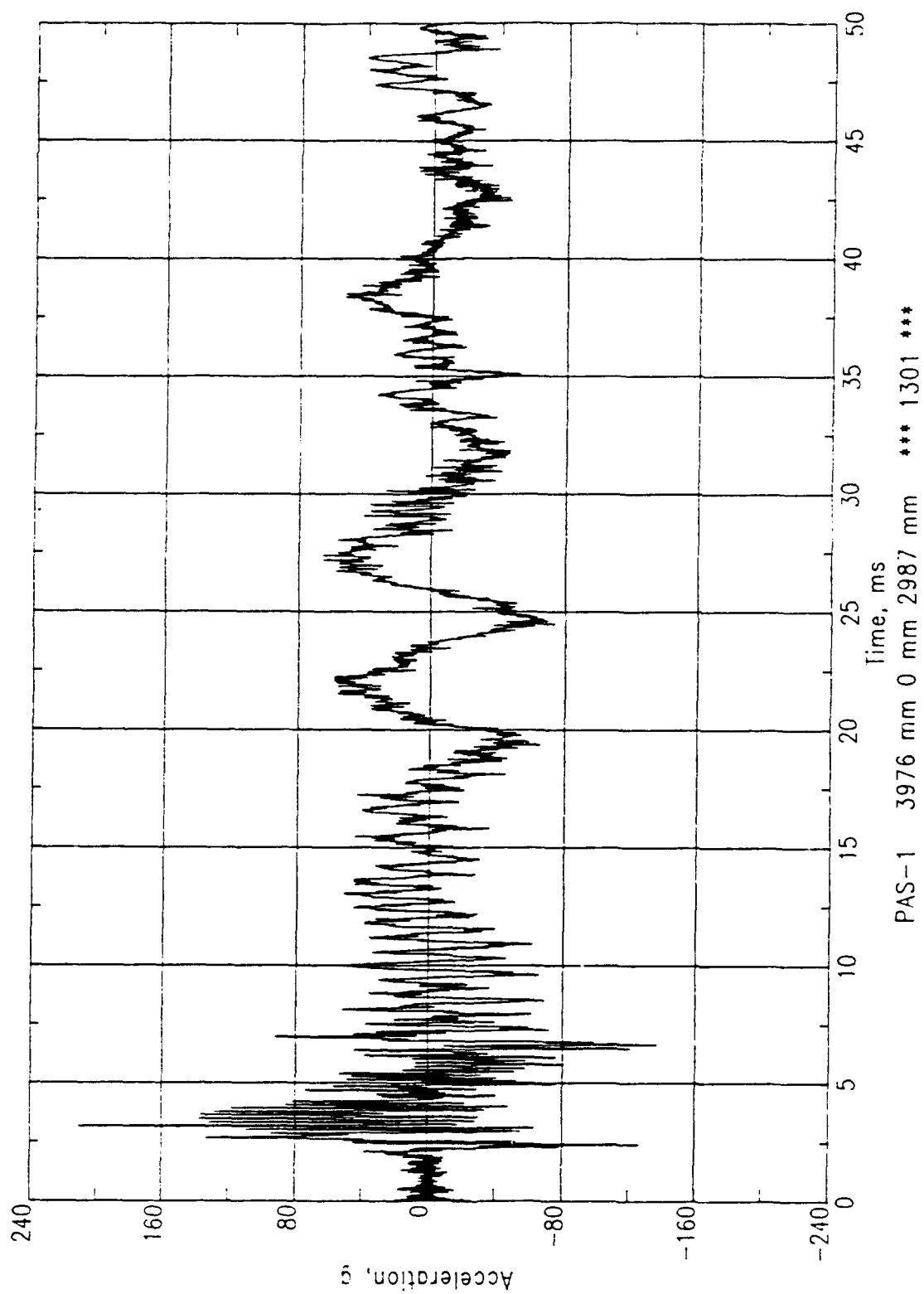


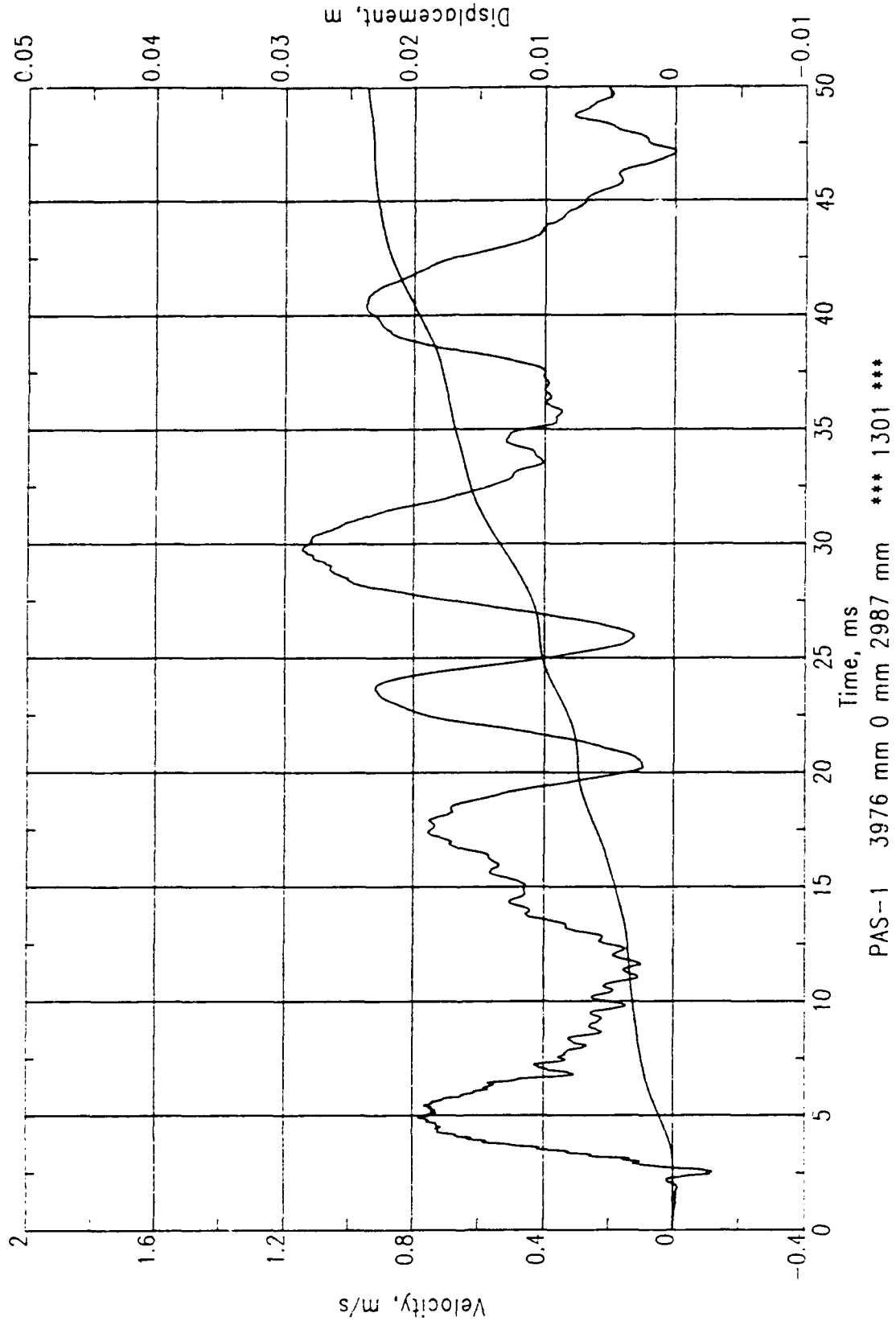


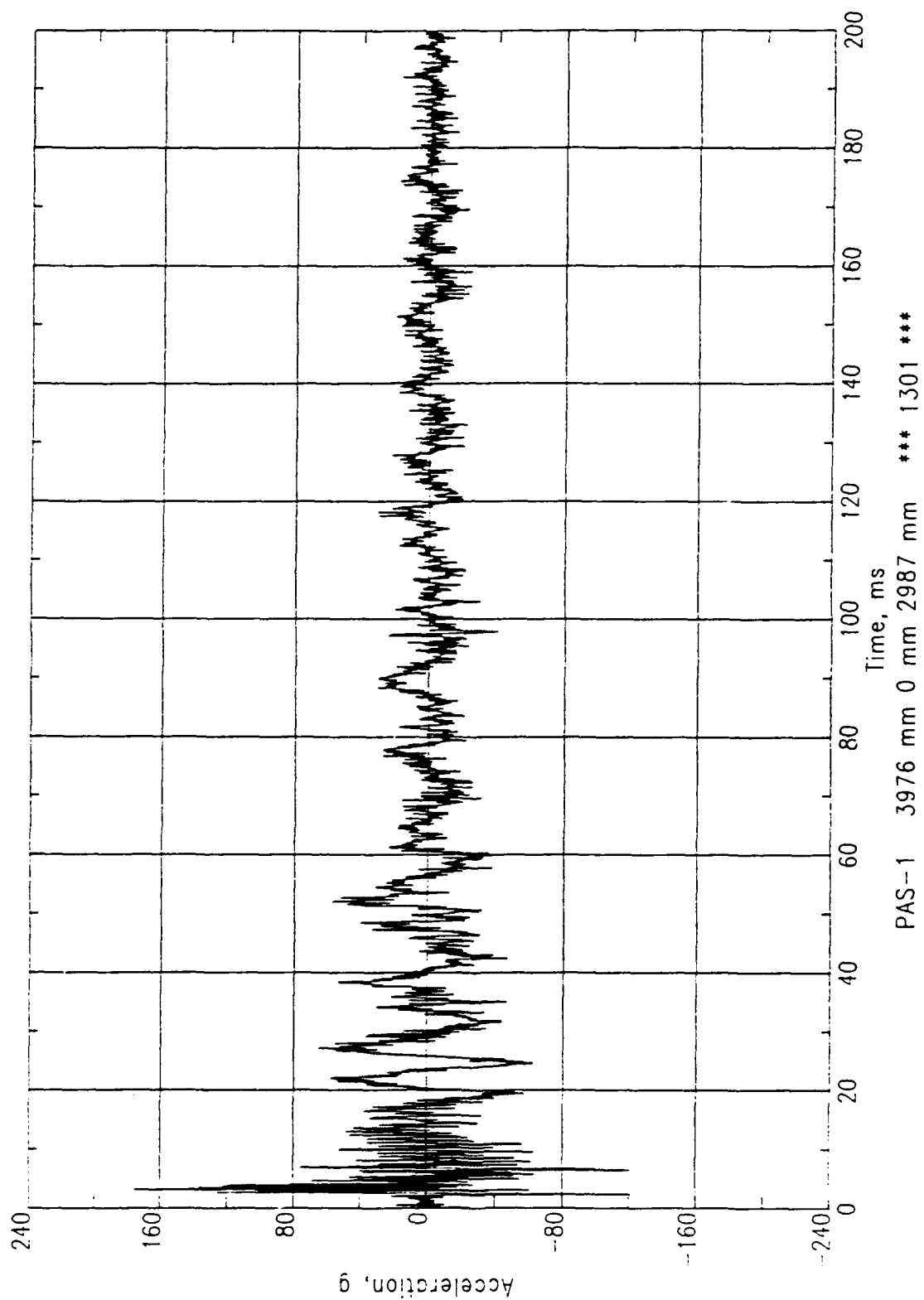


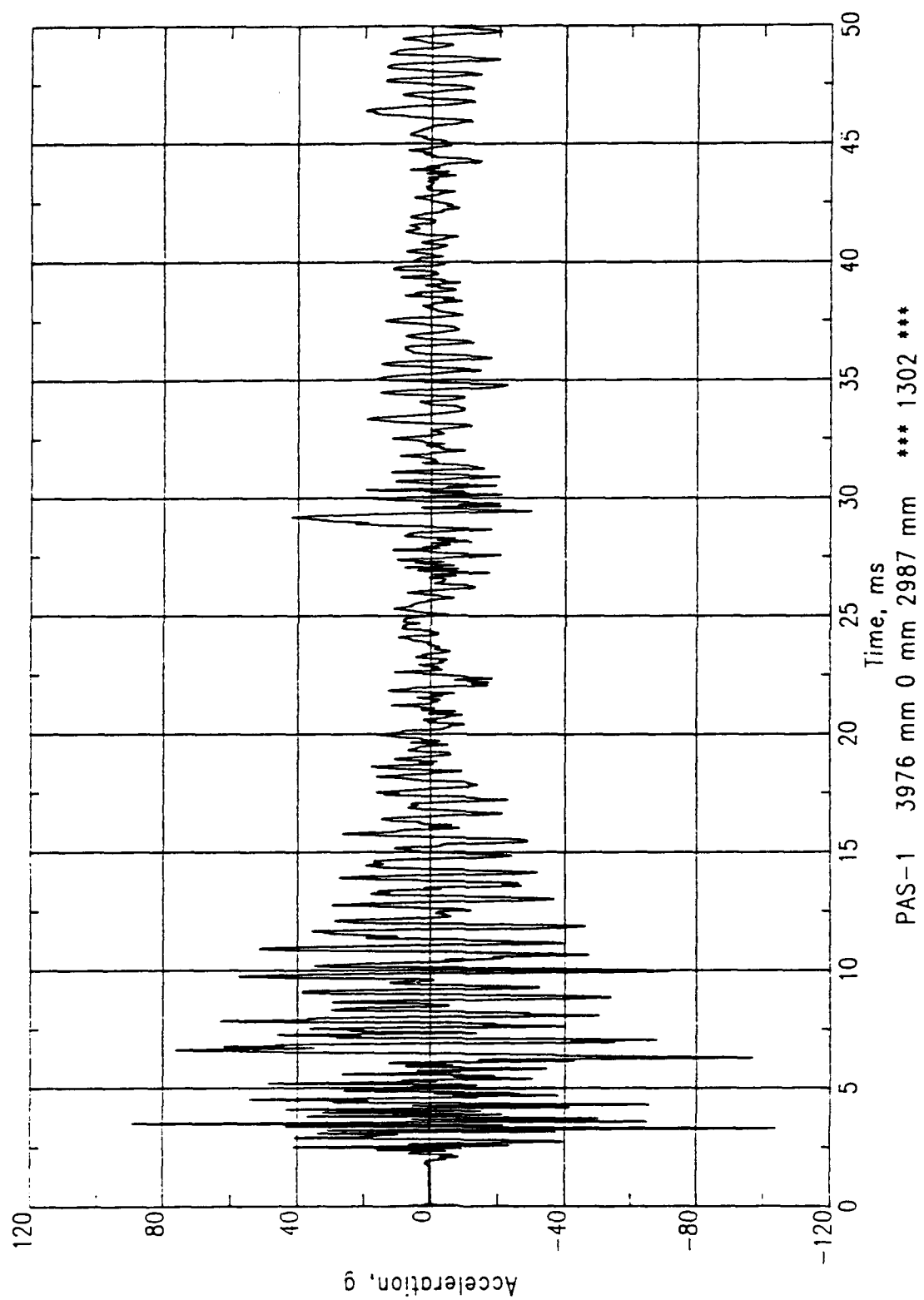


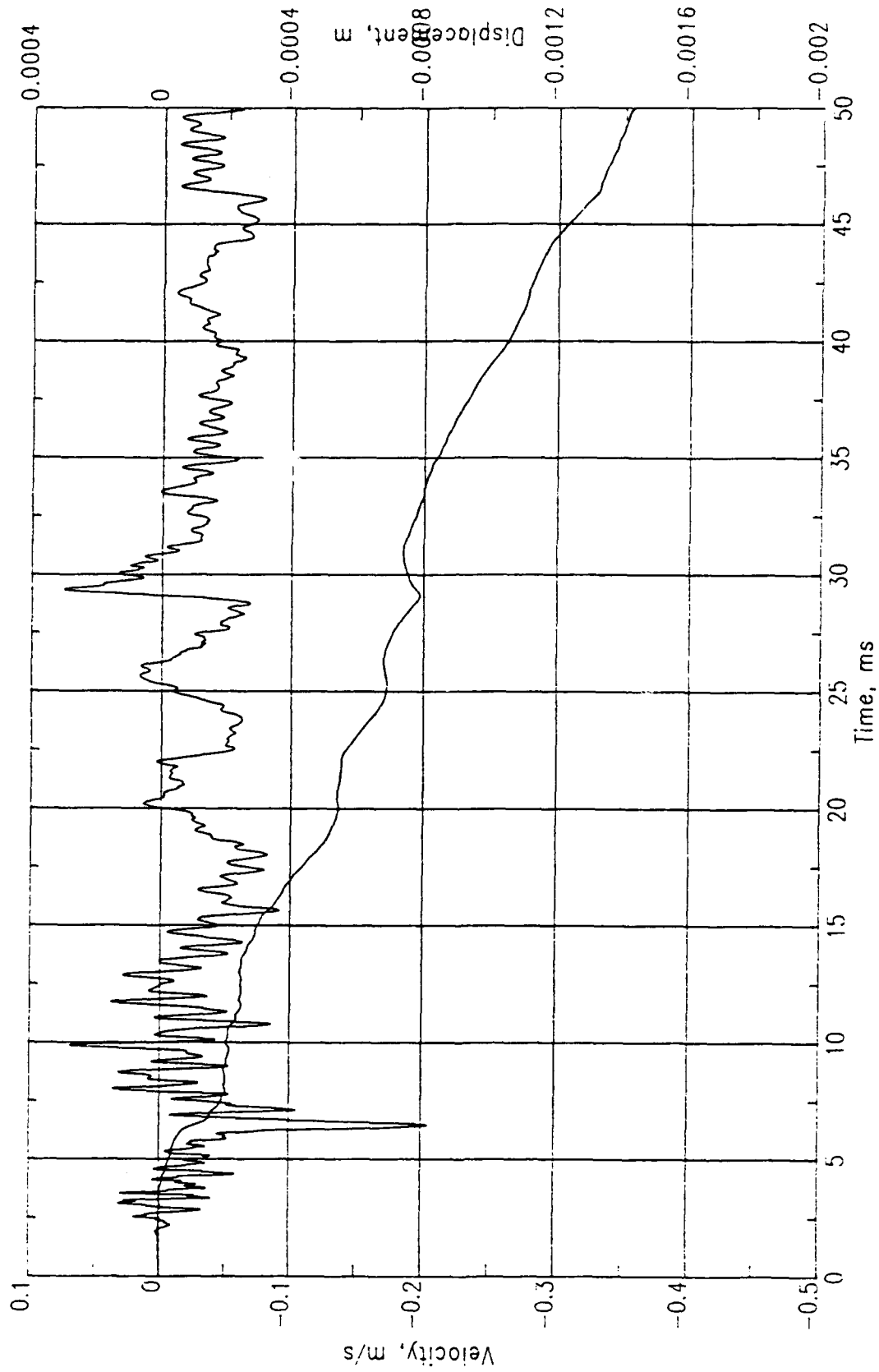
PAS-1 *** 0715 ***



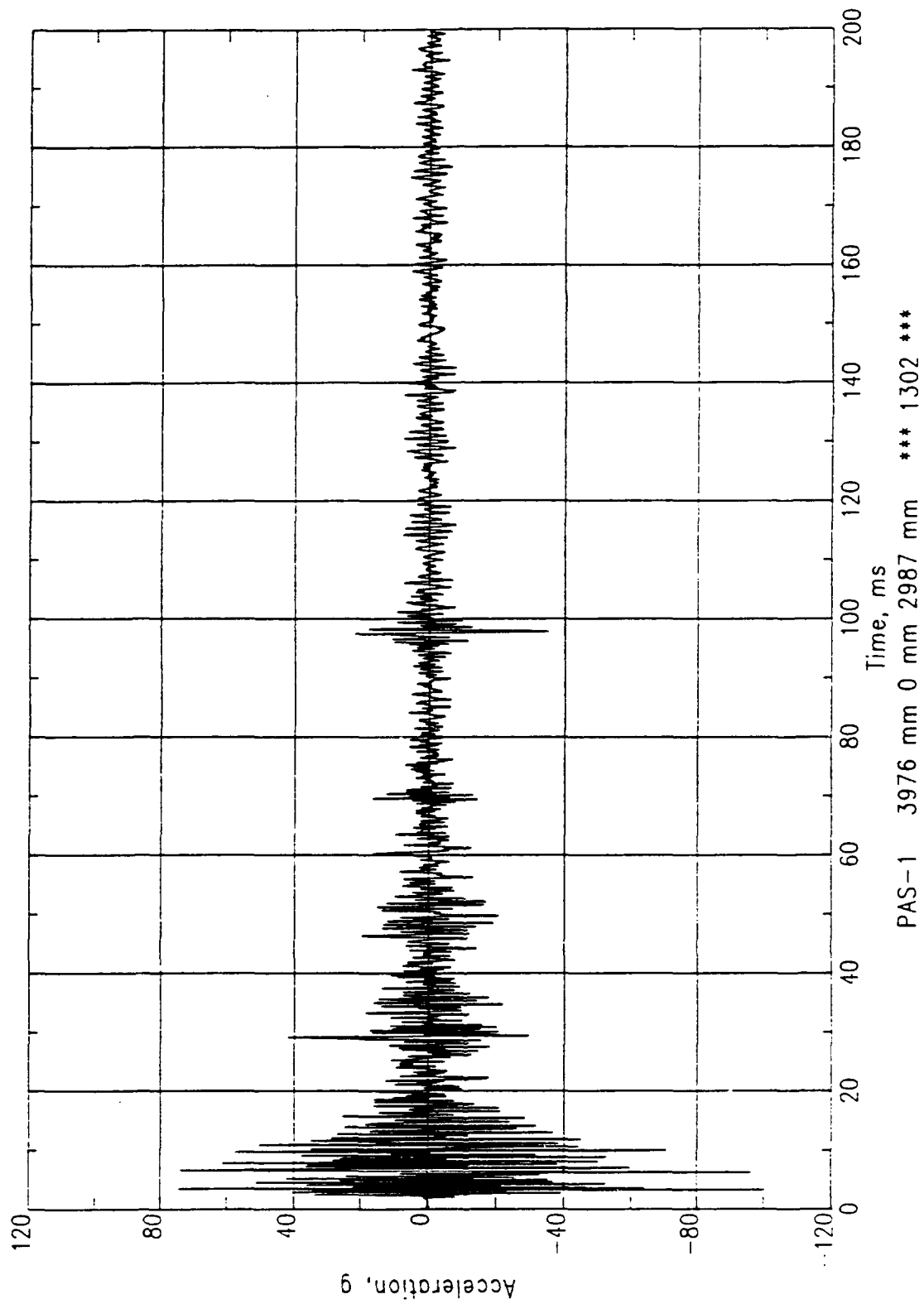


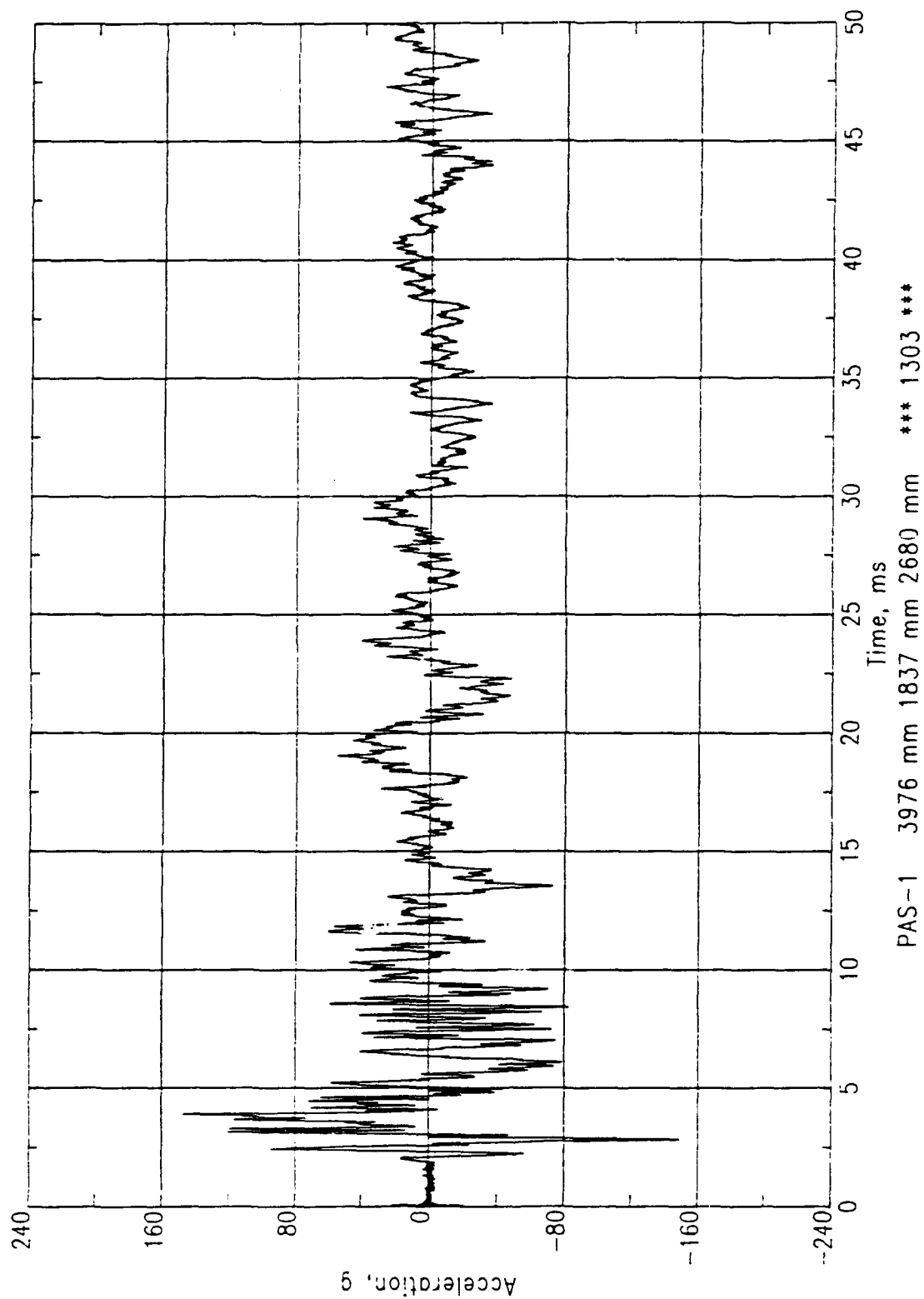


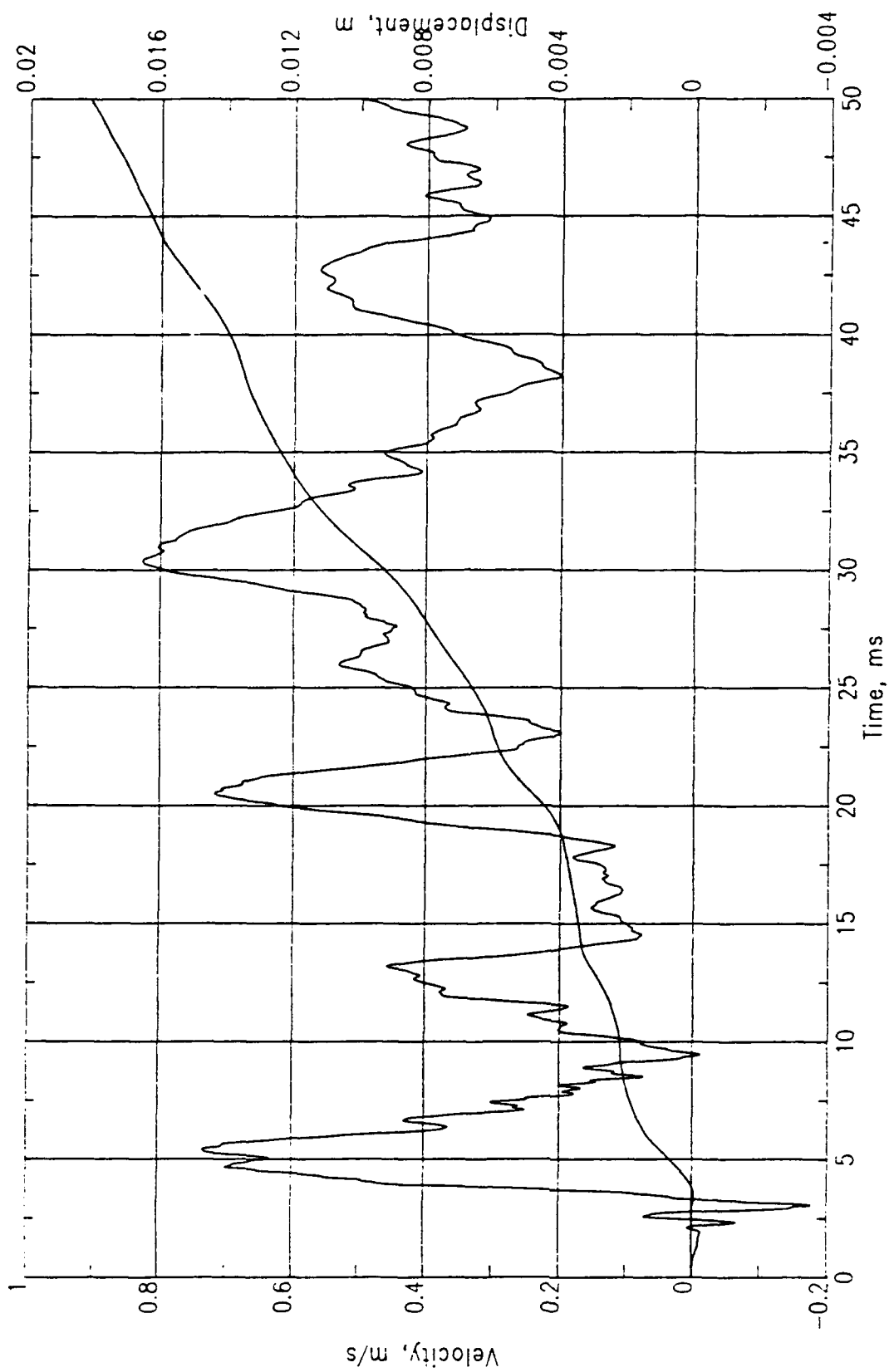




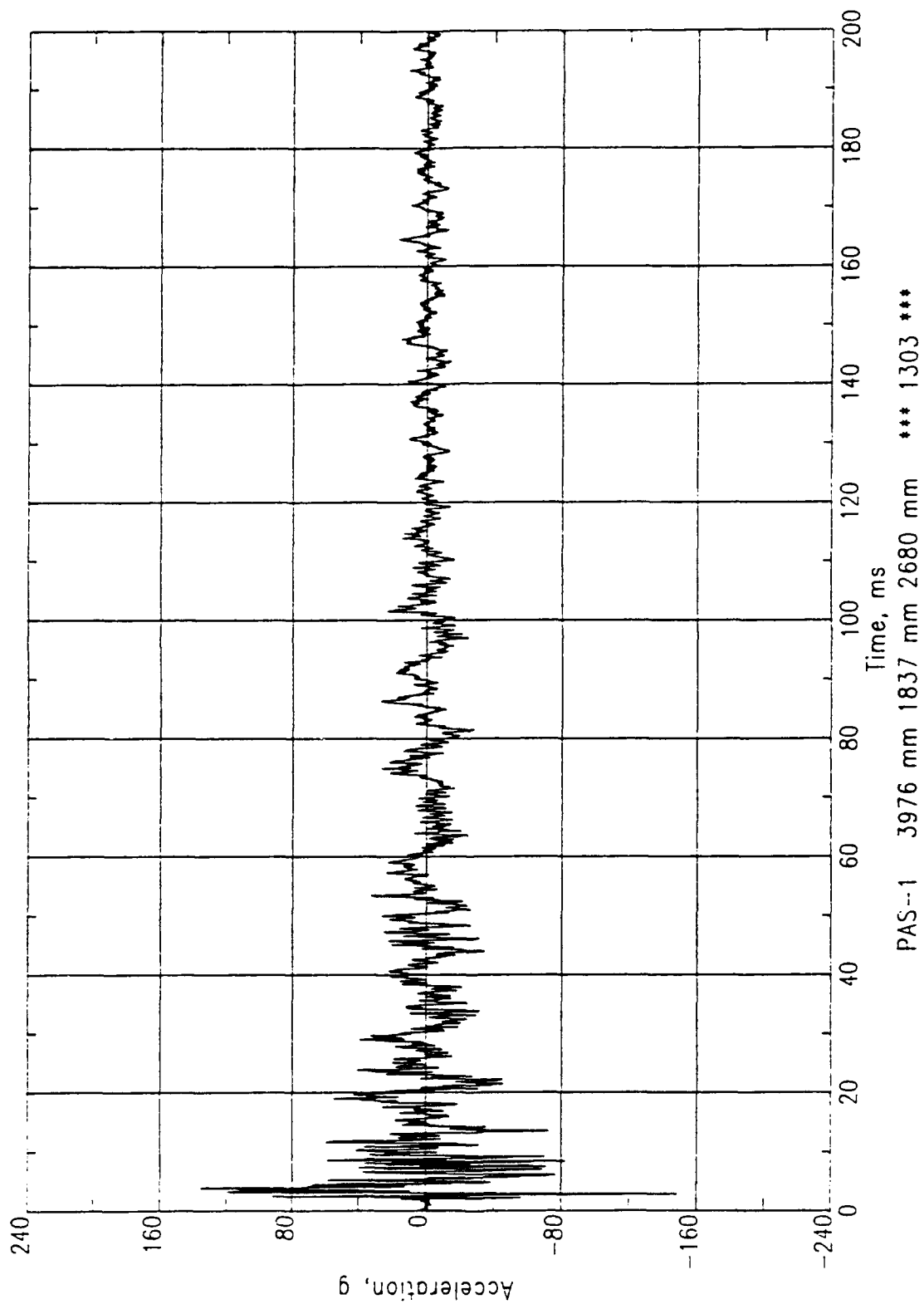
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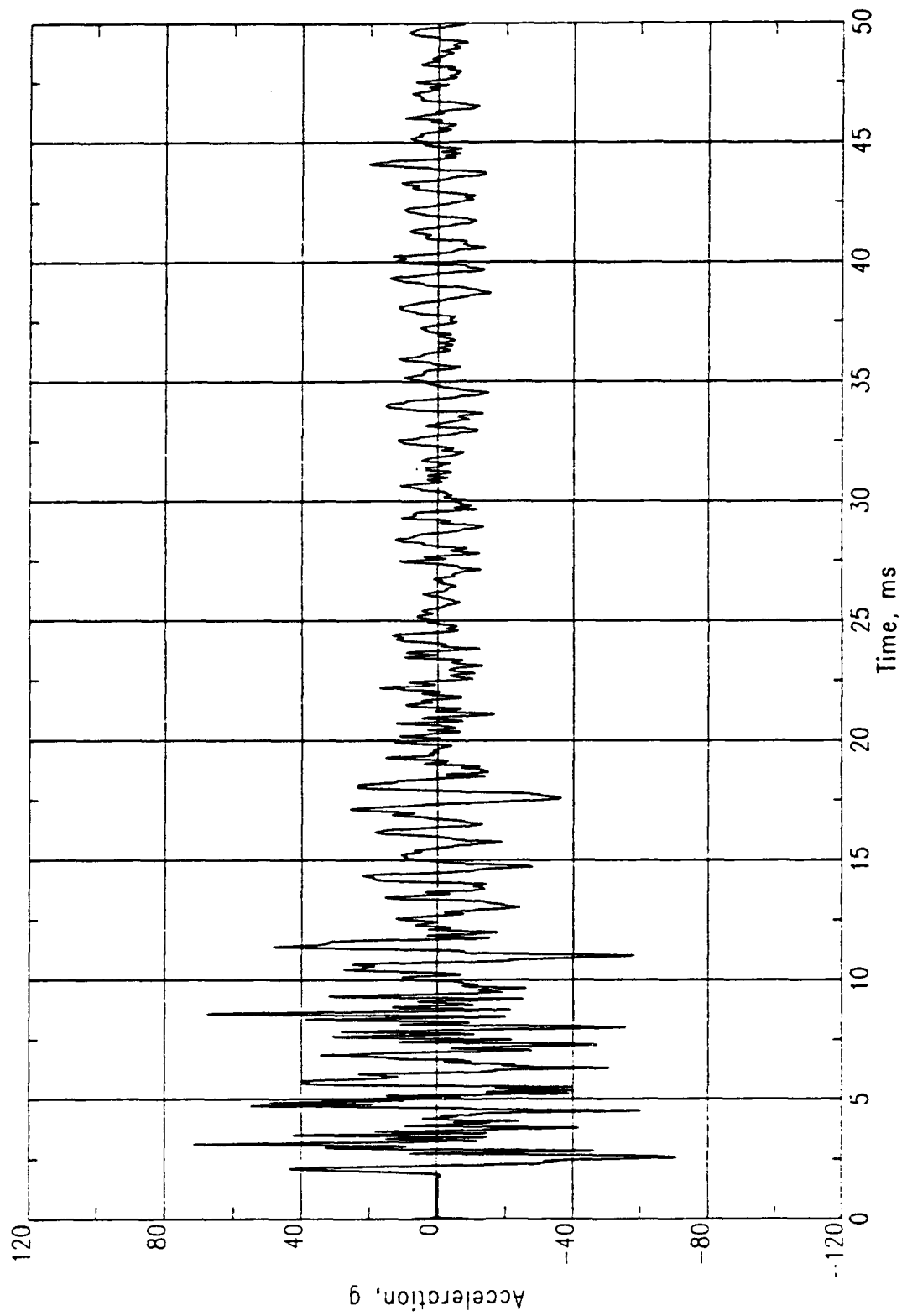




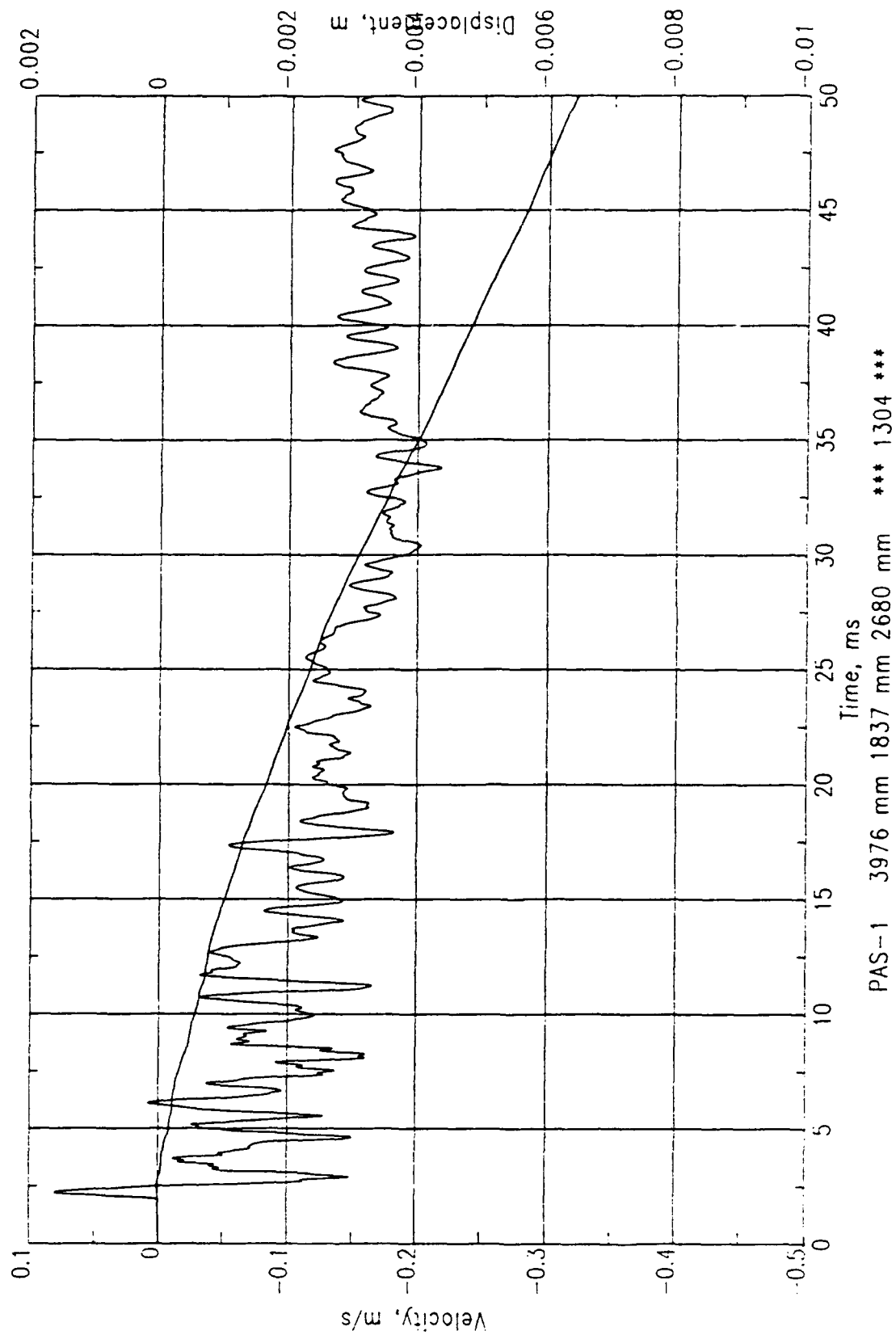


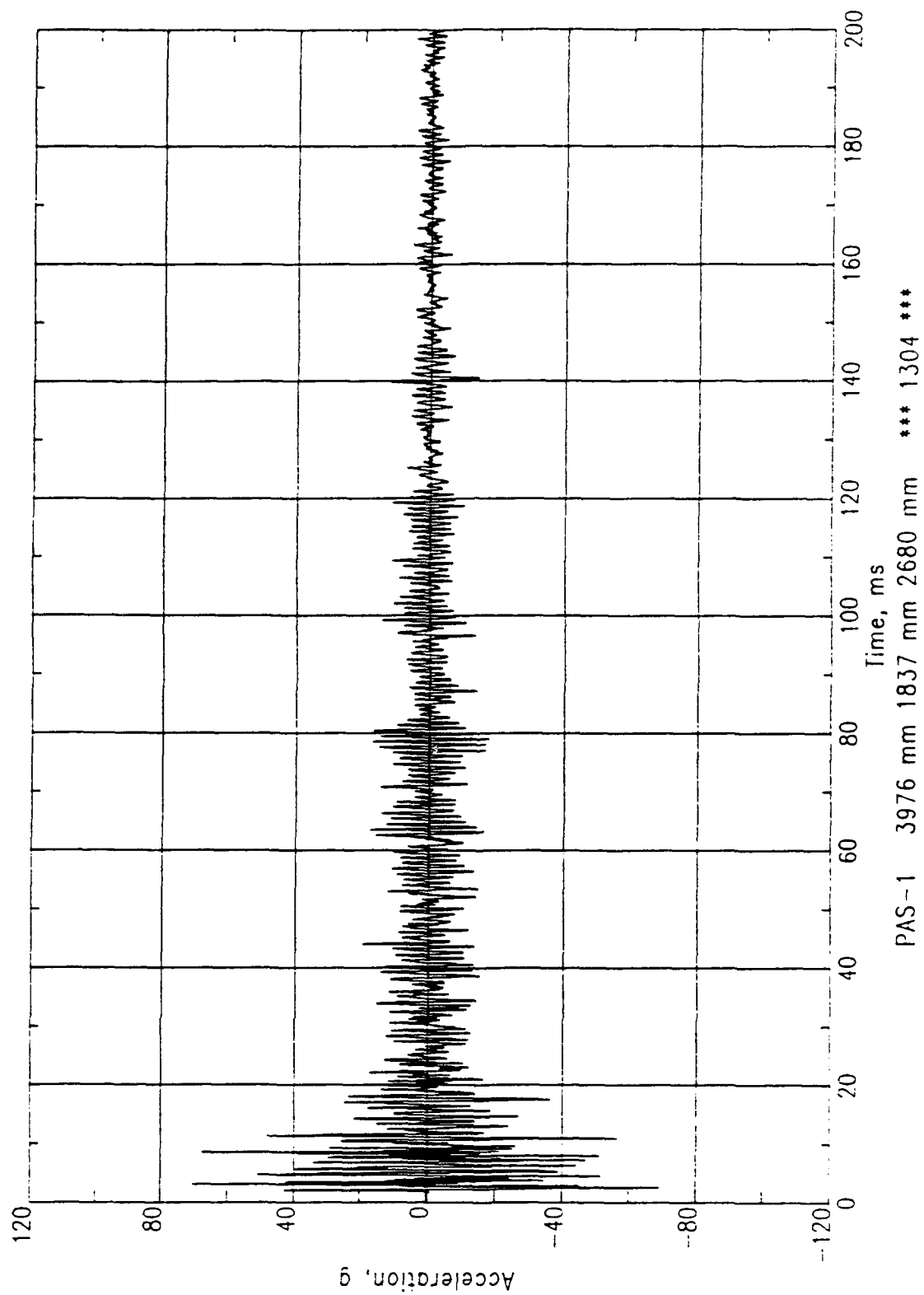
PAS-1 3976 mm 1837 mm 2680 mm *** 1303 ***

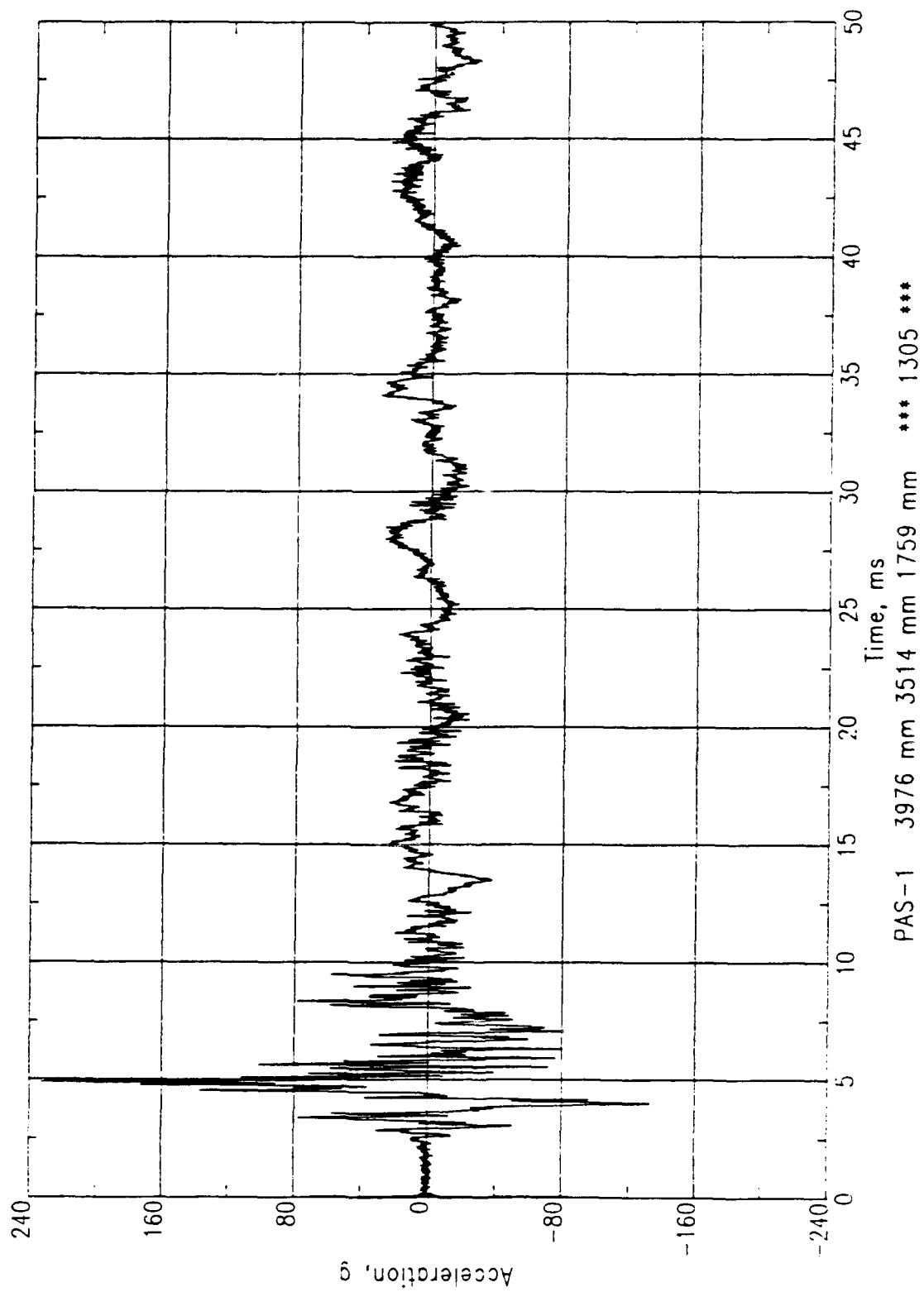


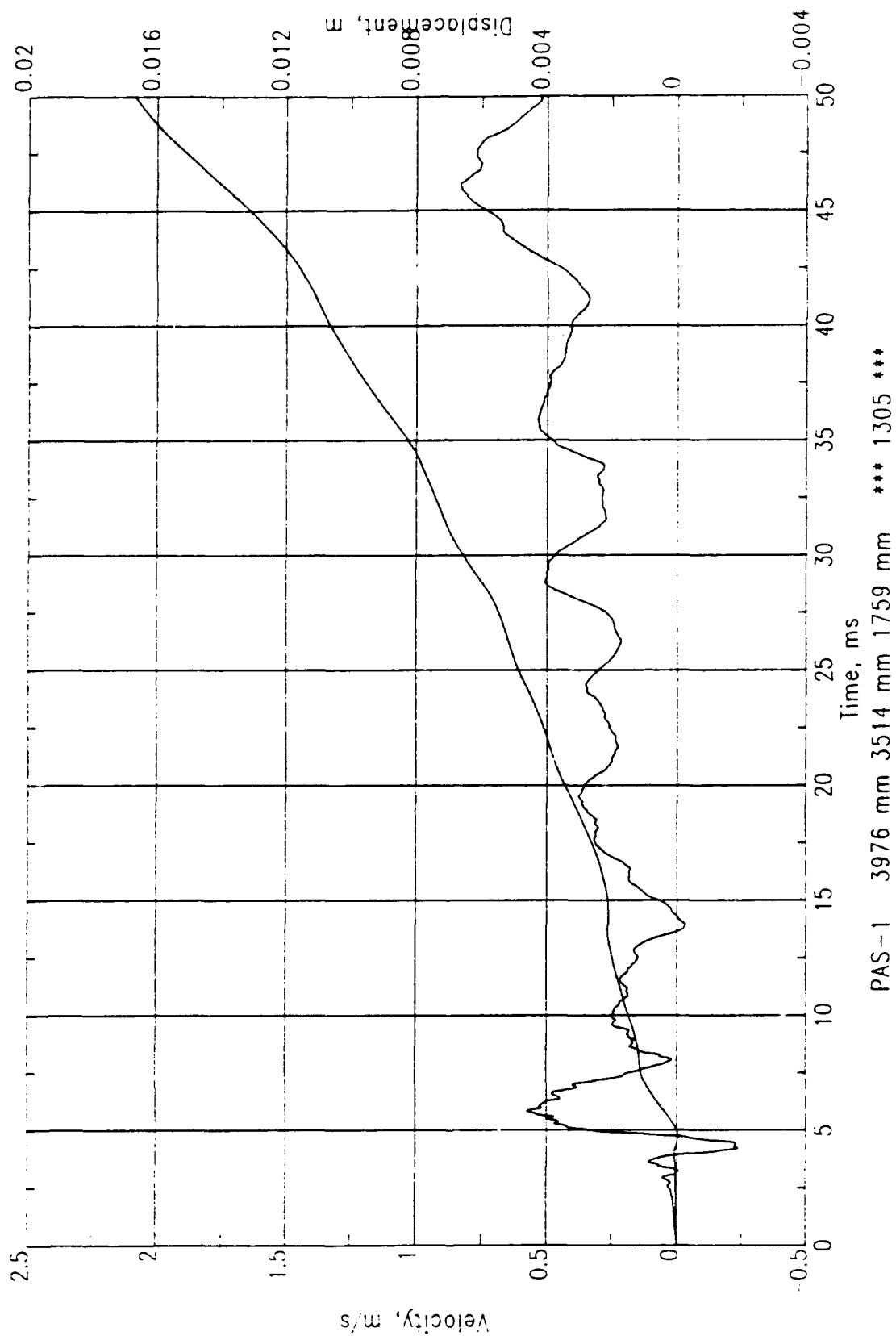


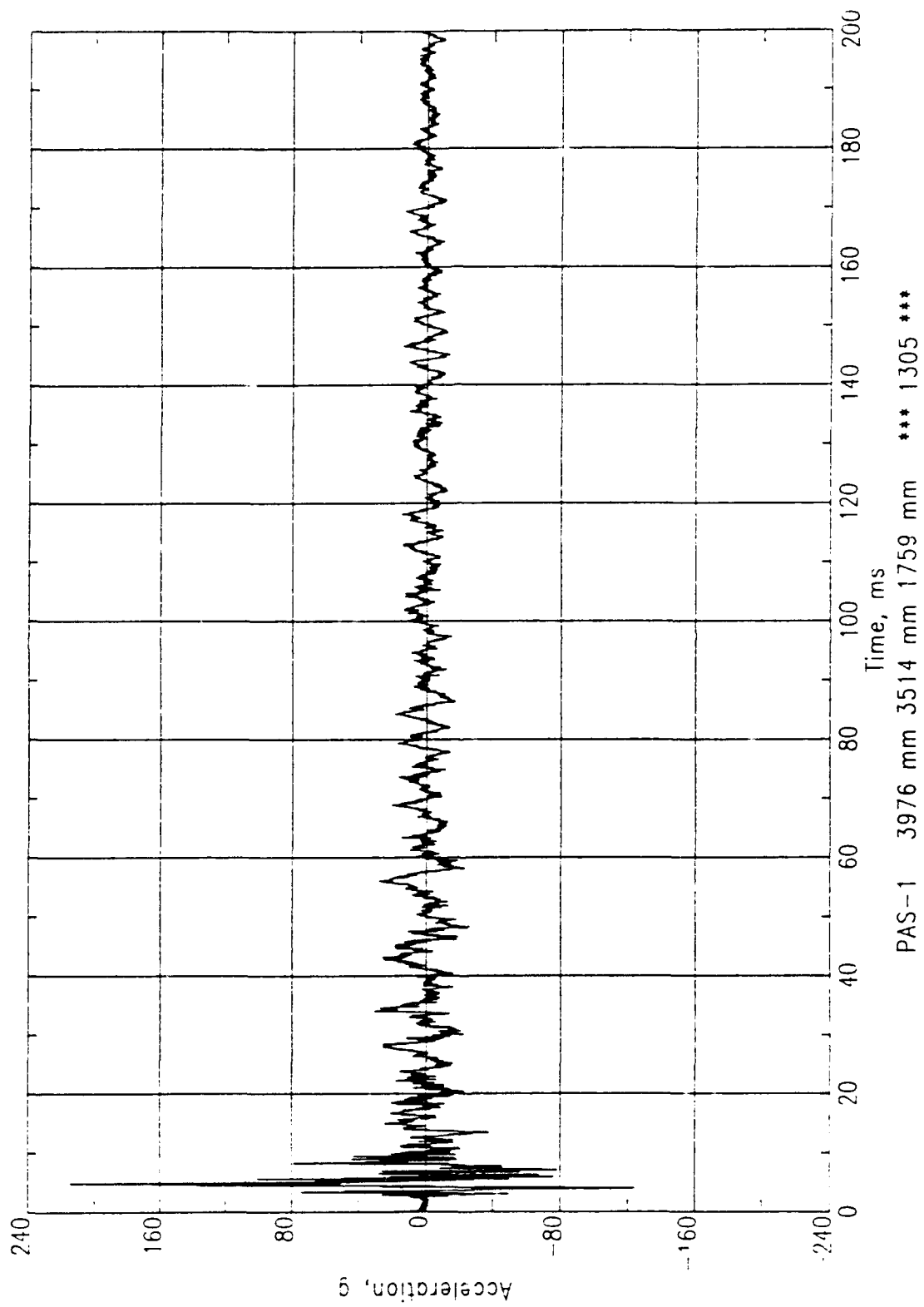
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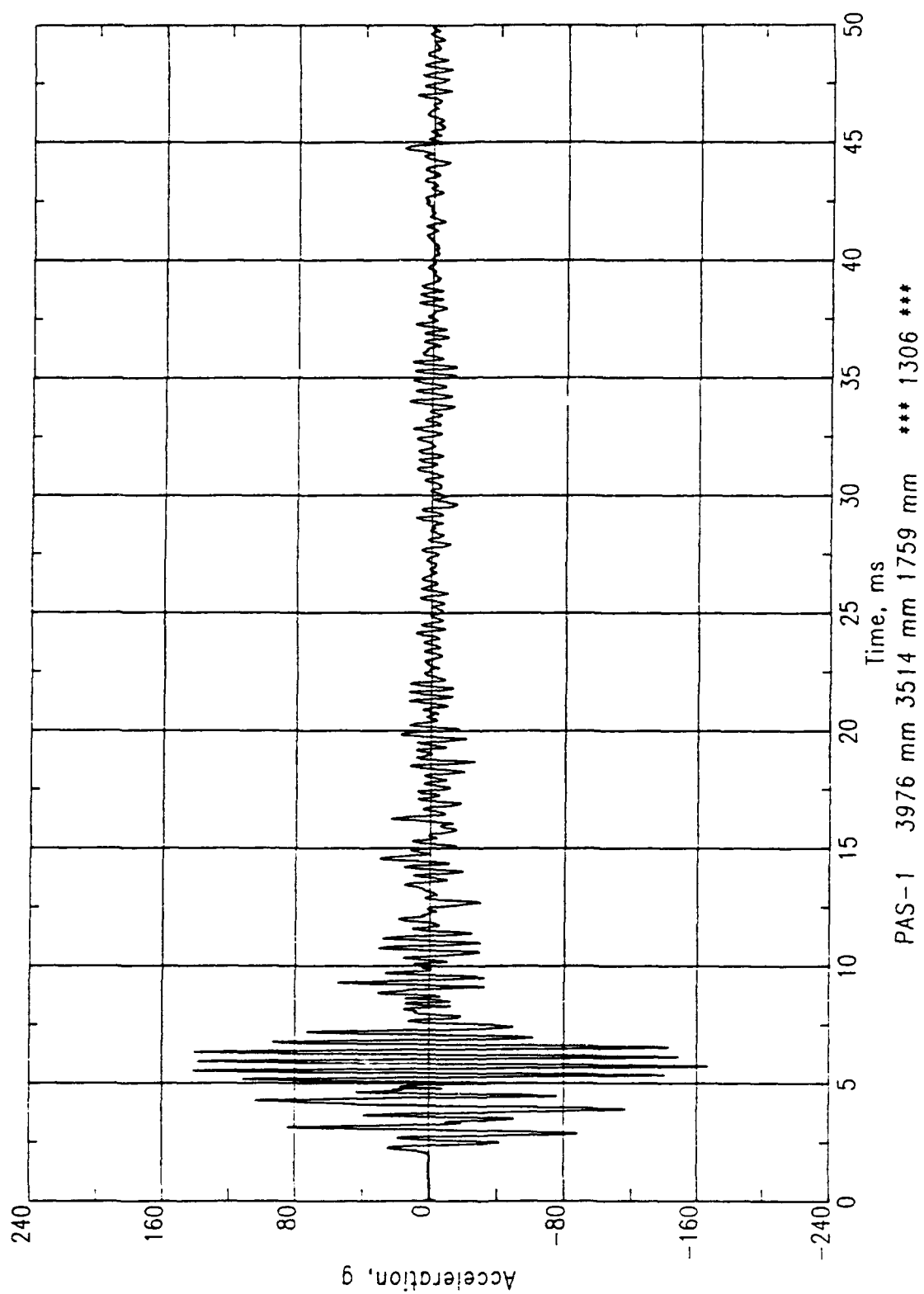


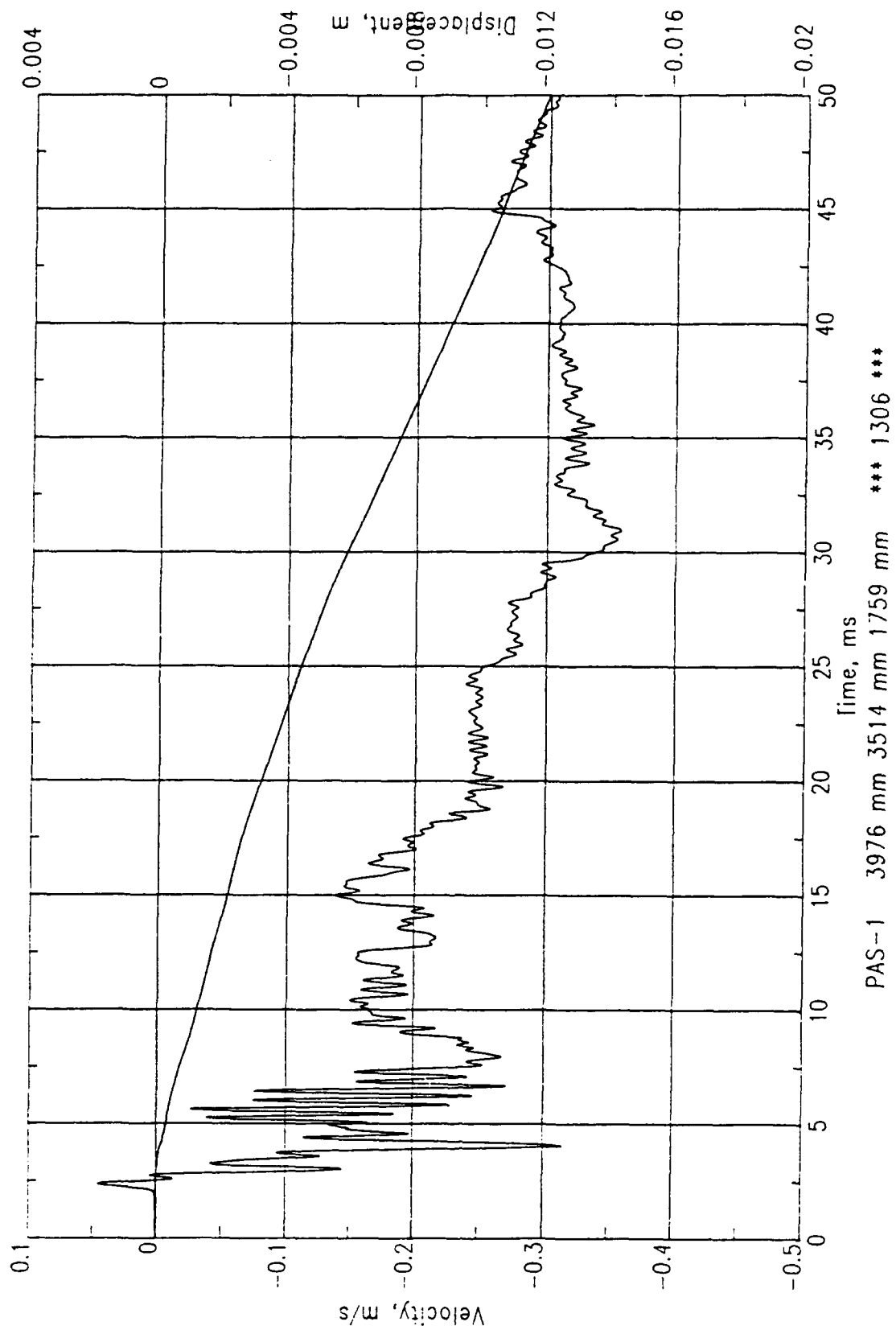


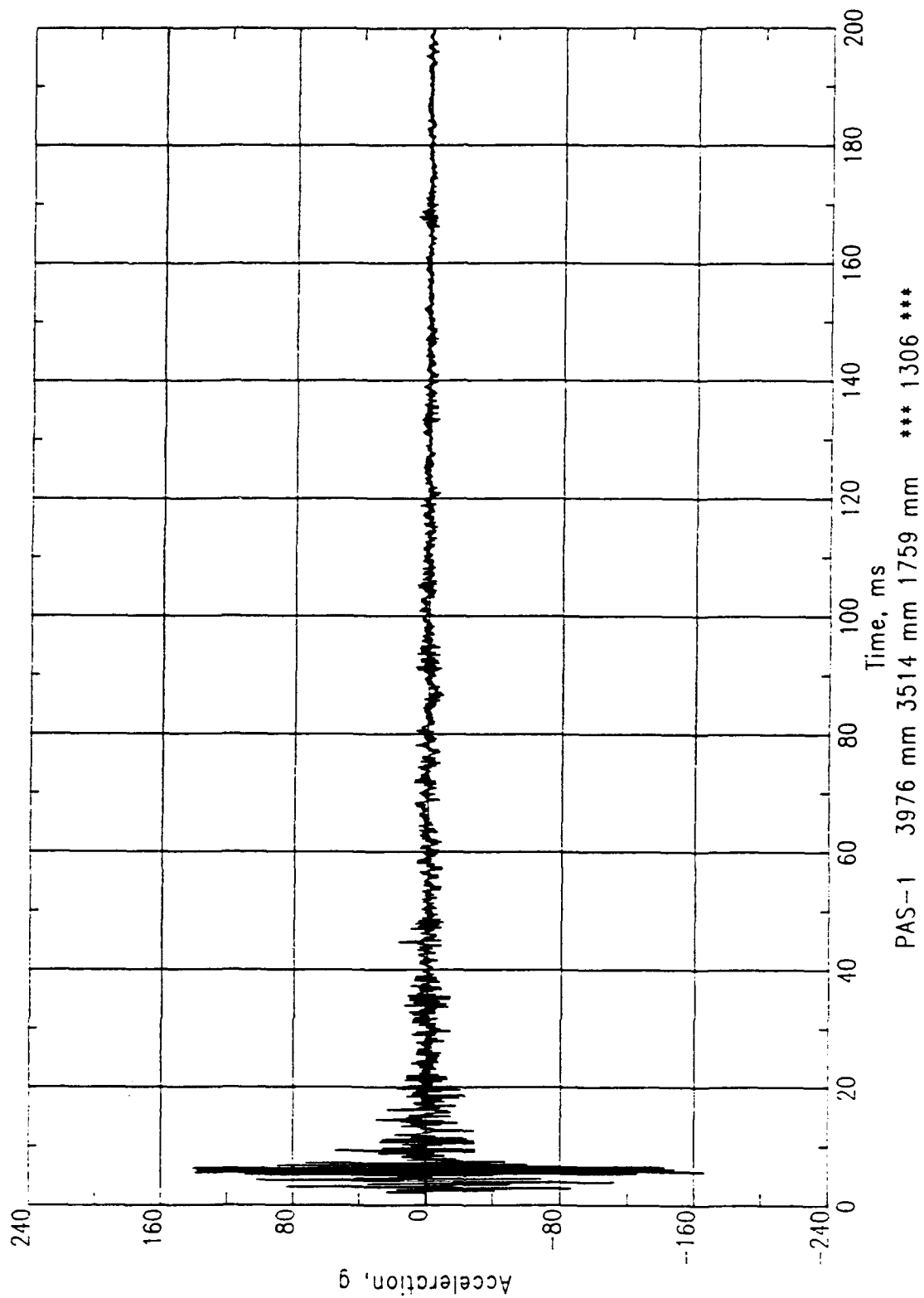


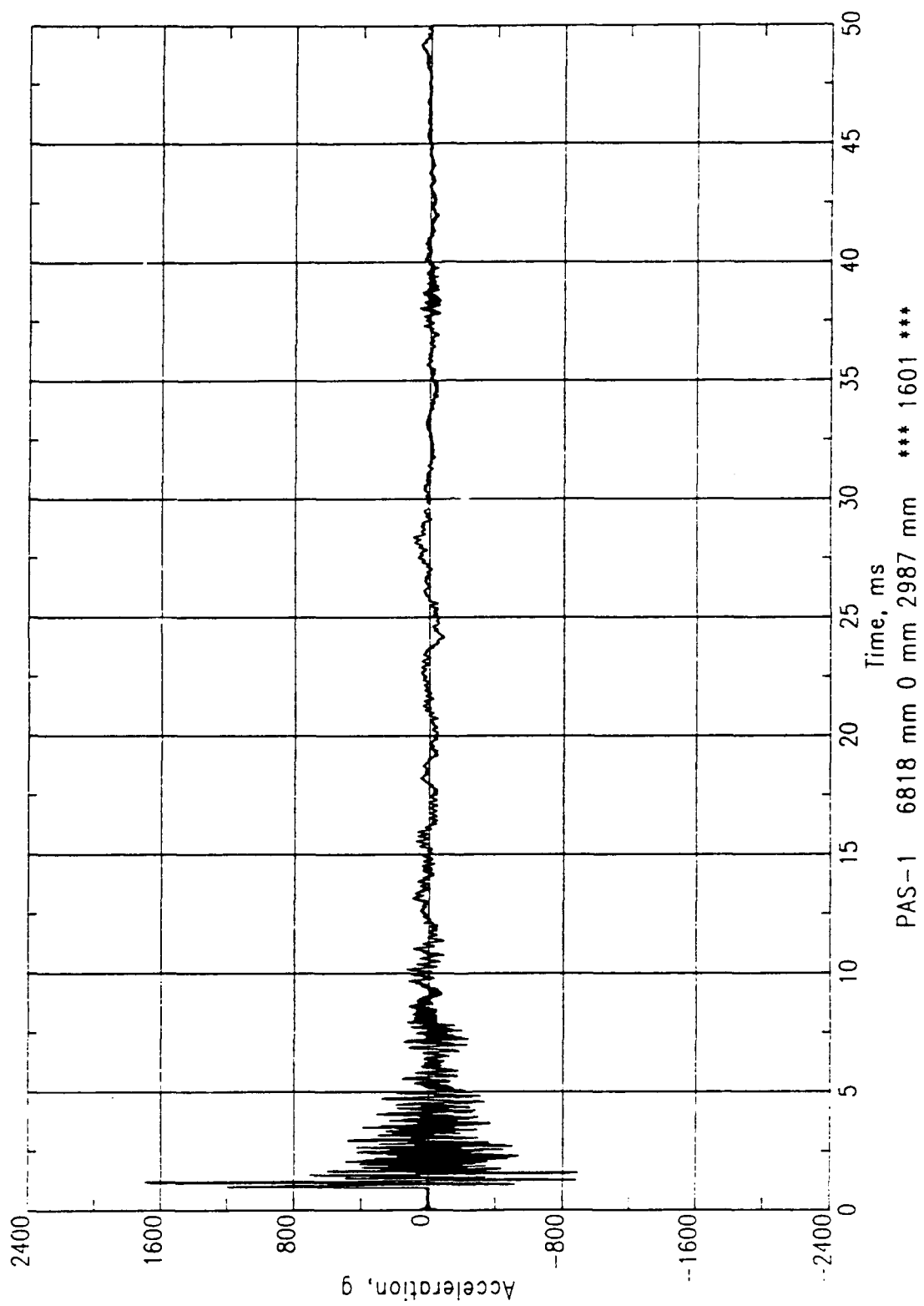


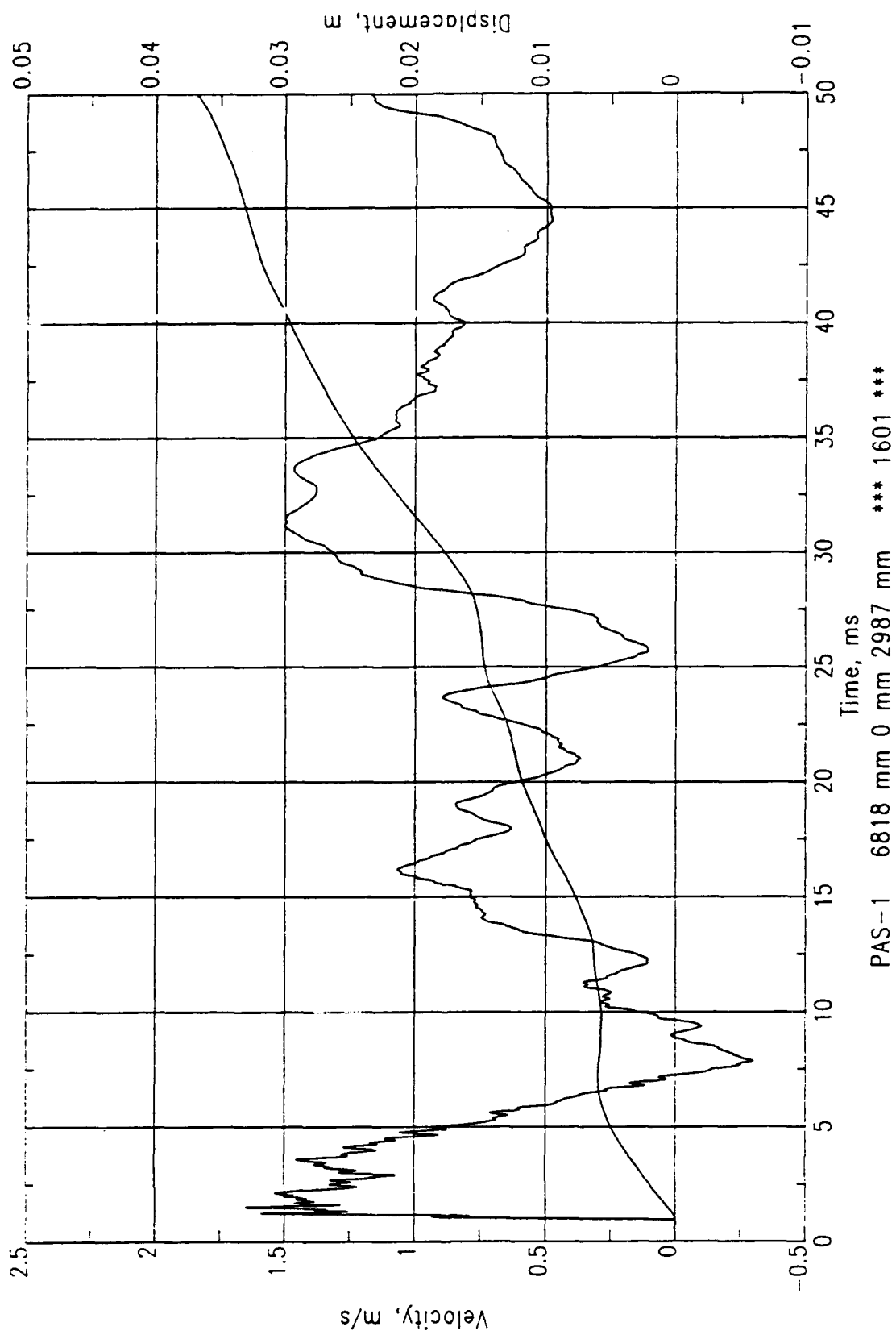


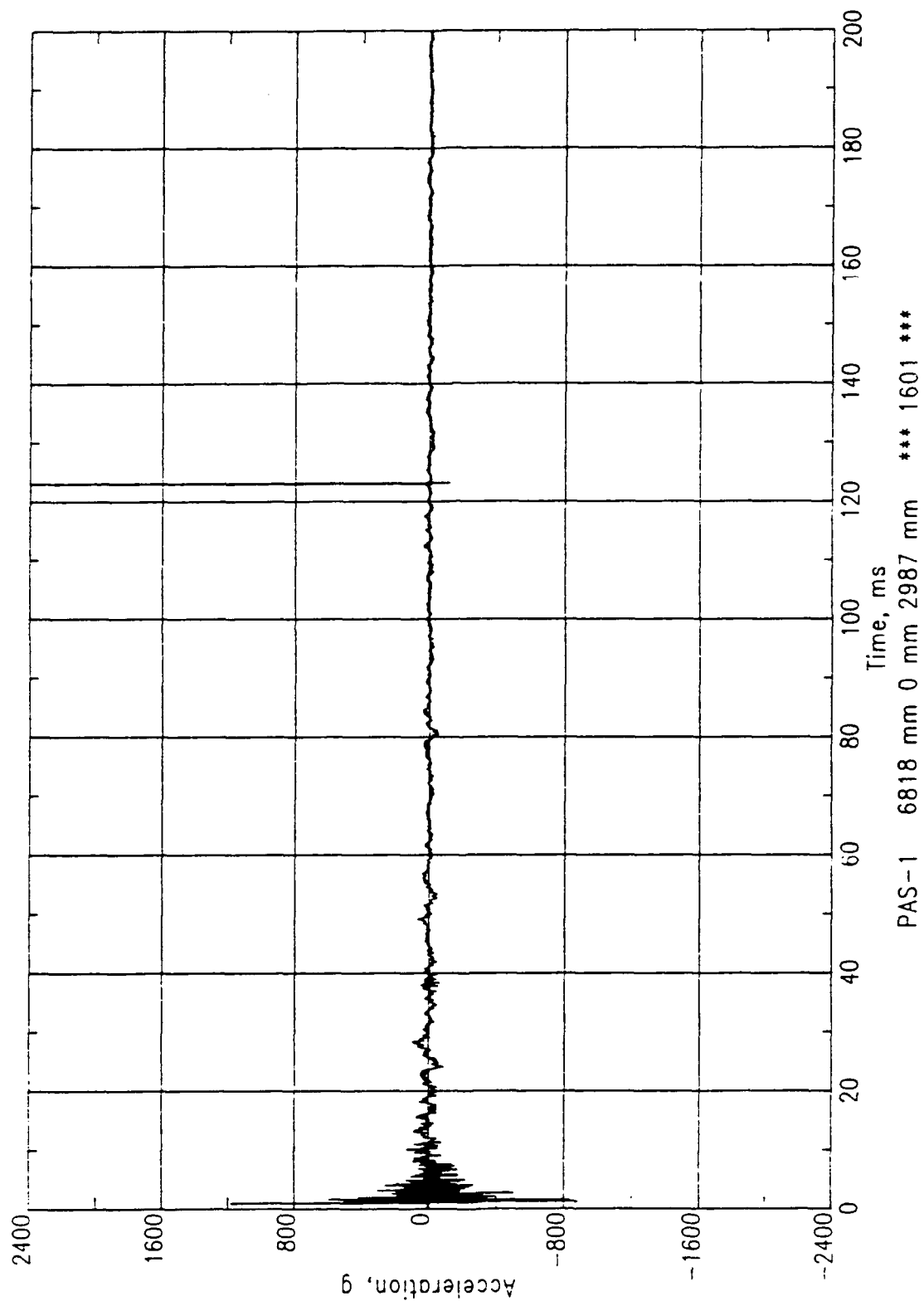


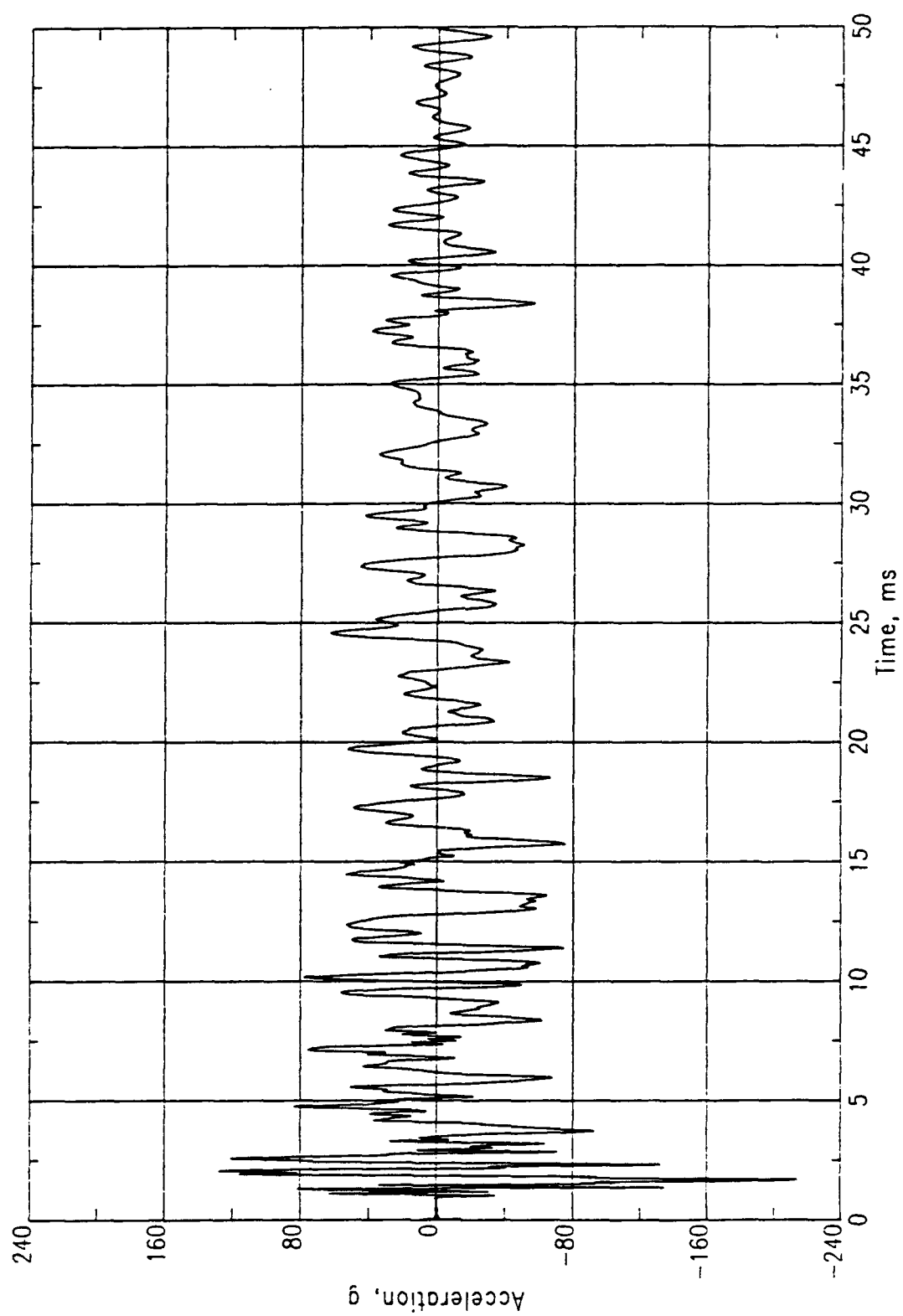




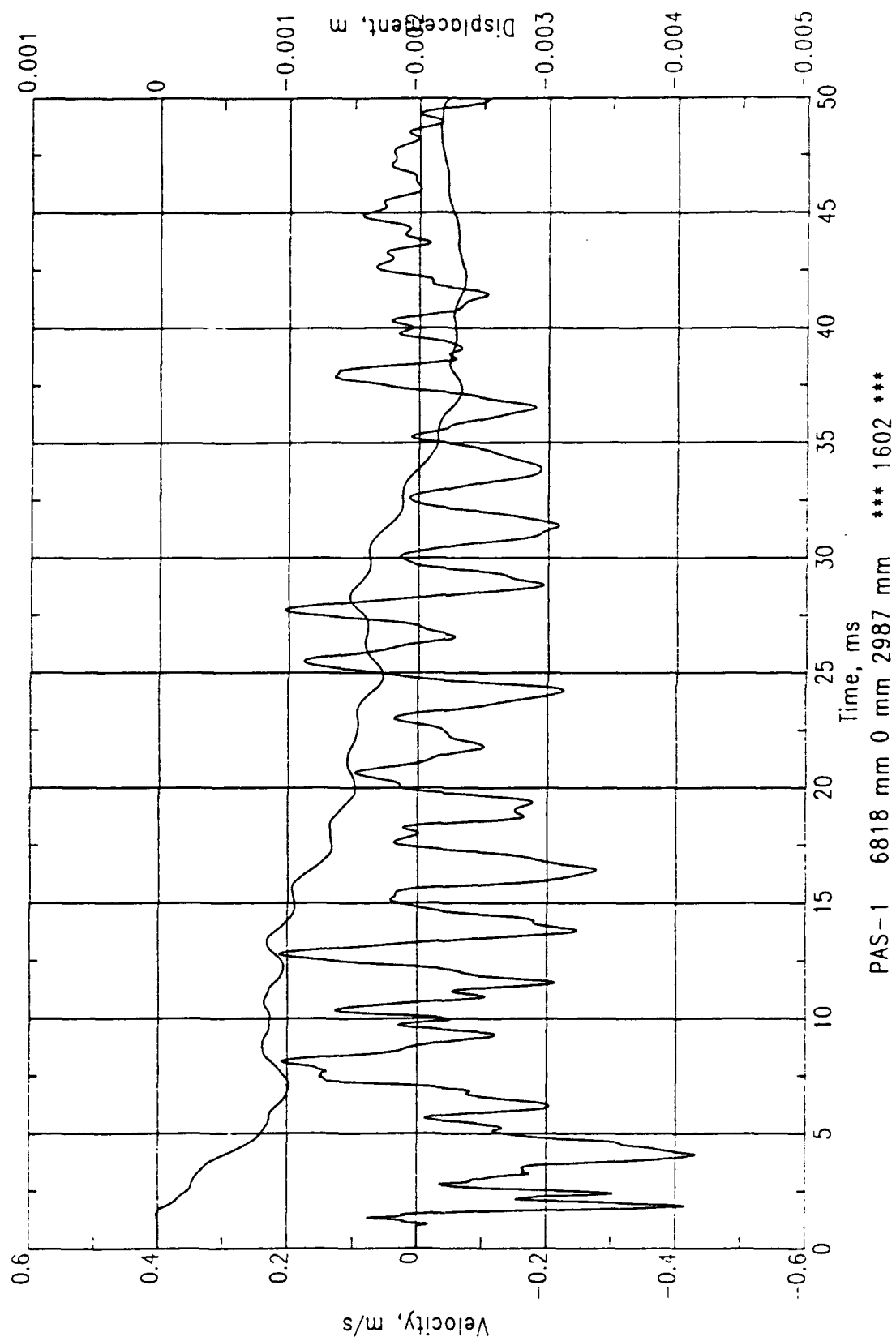


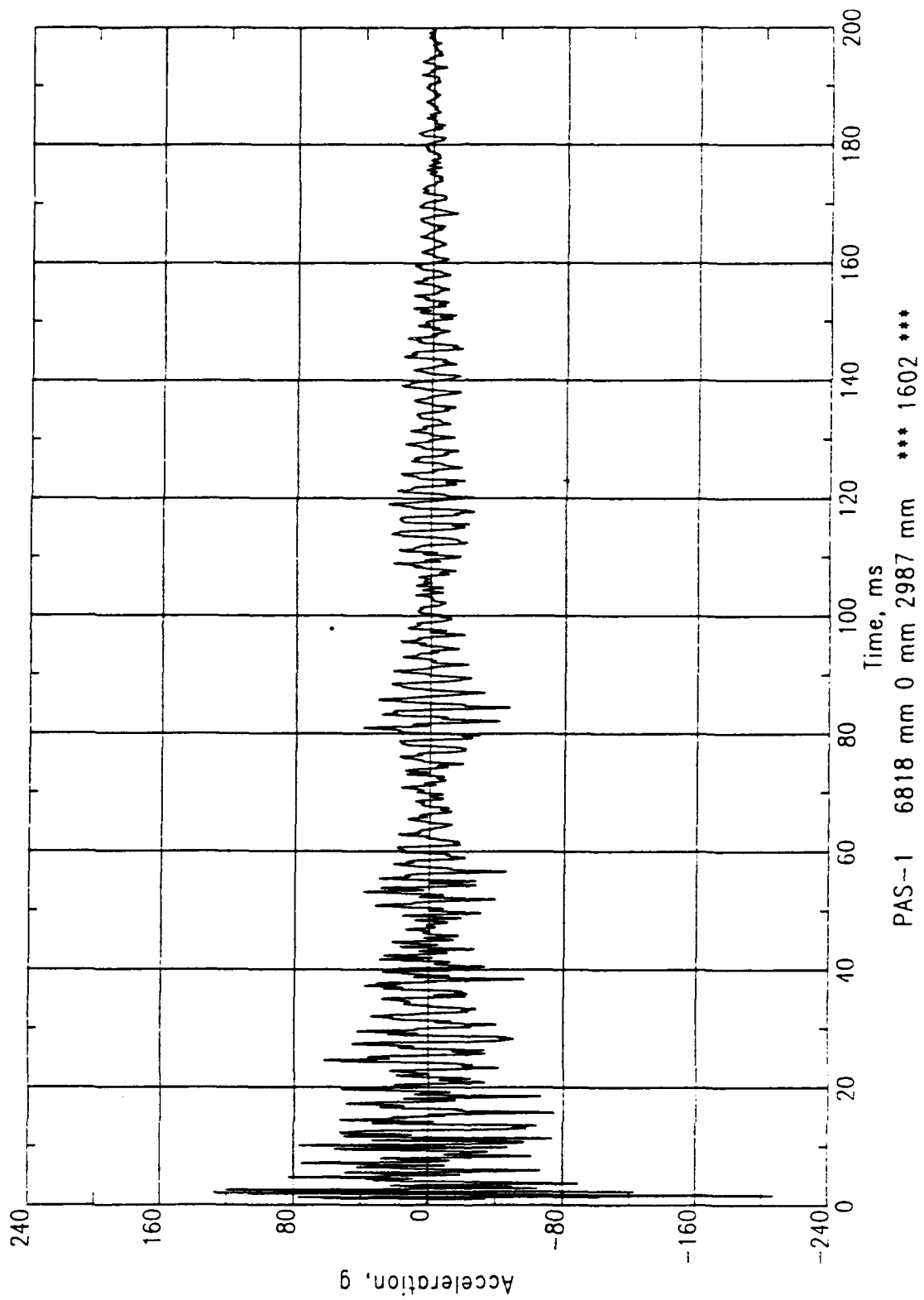


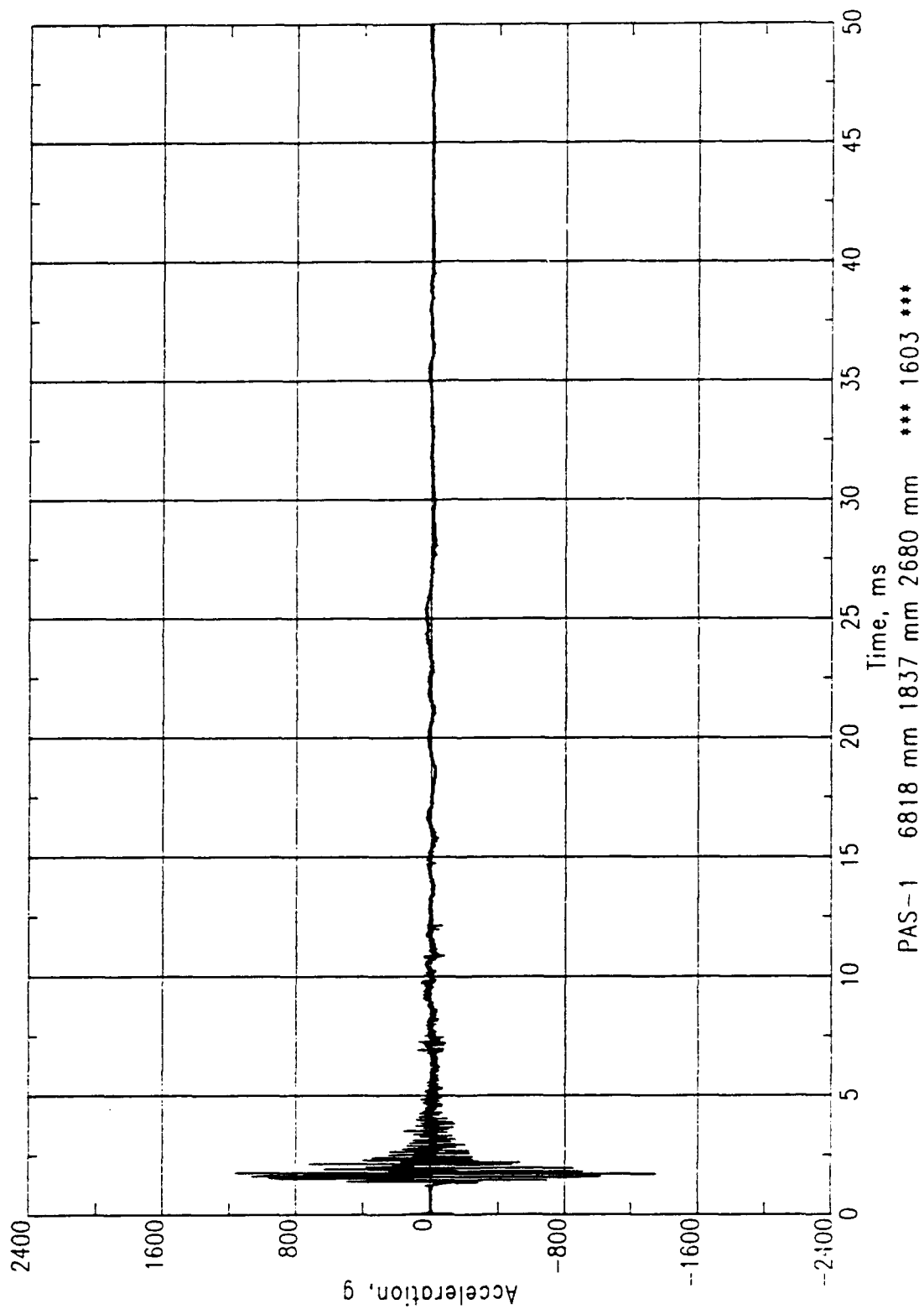


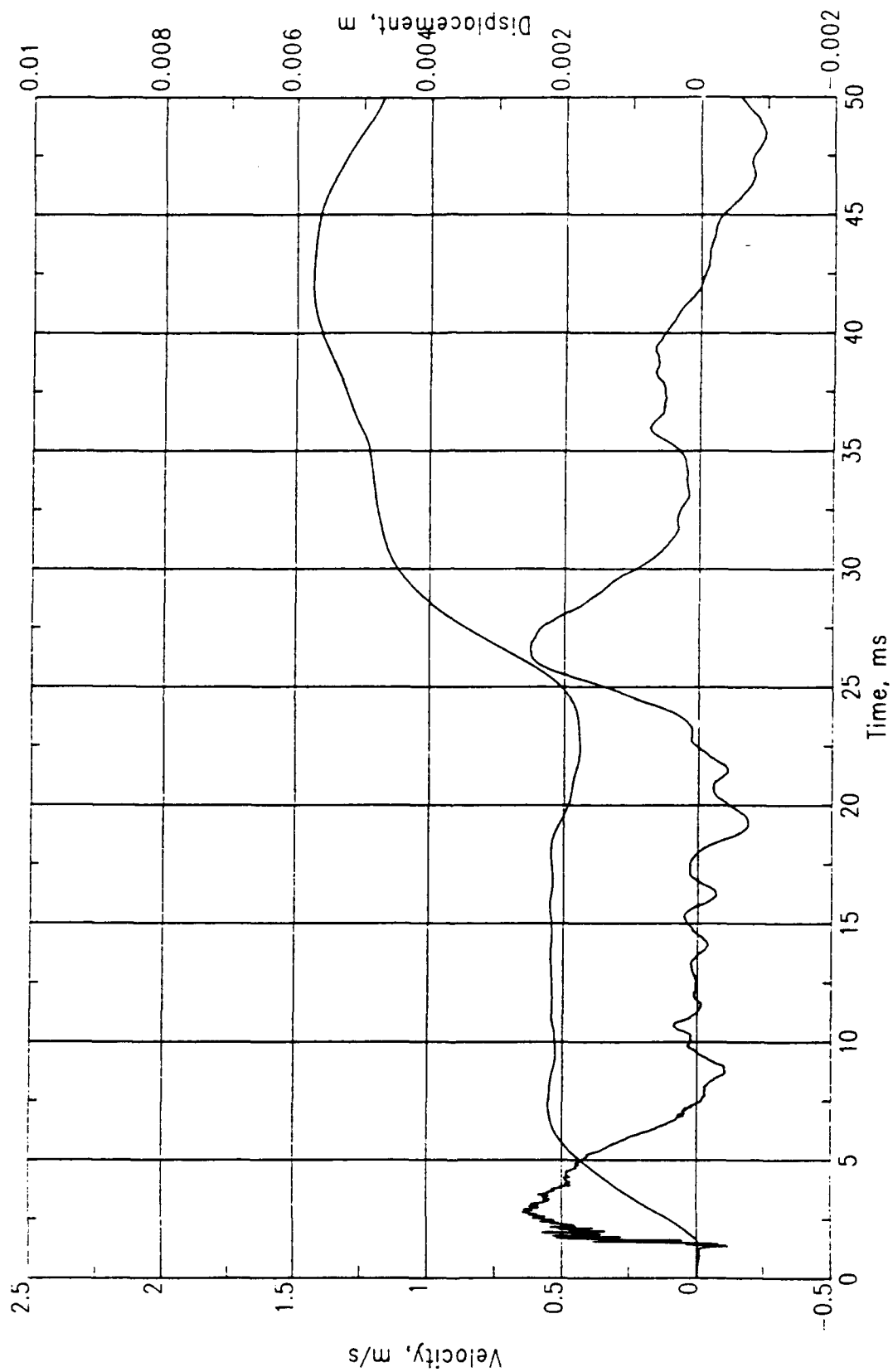


PAS-1 6818 mm 0 mm 2987 mm *** 1602 ***

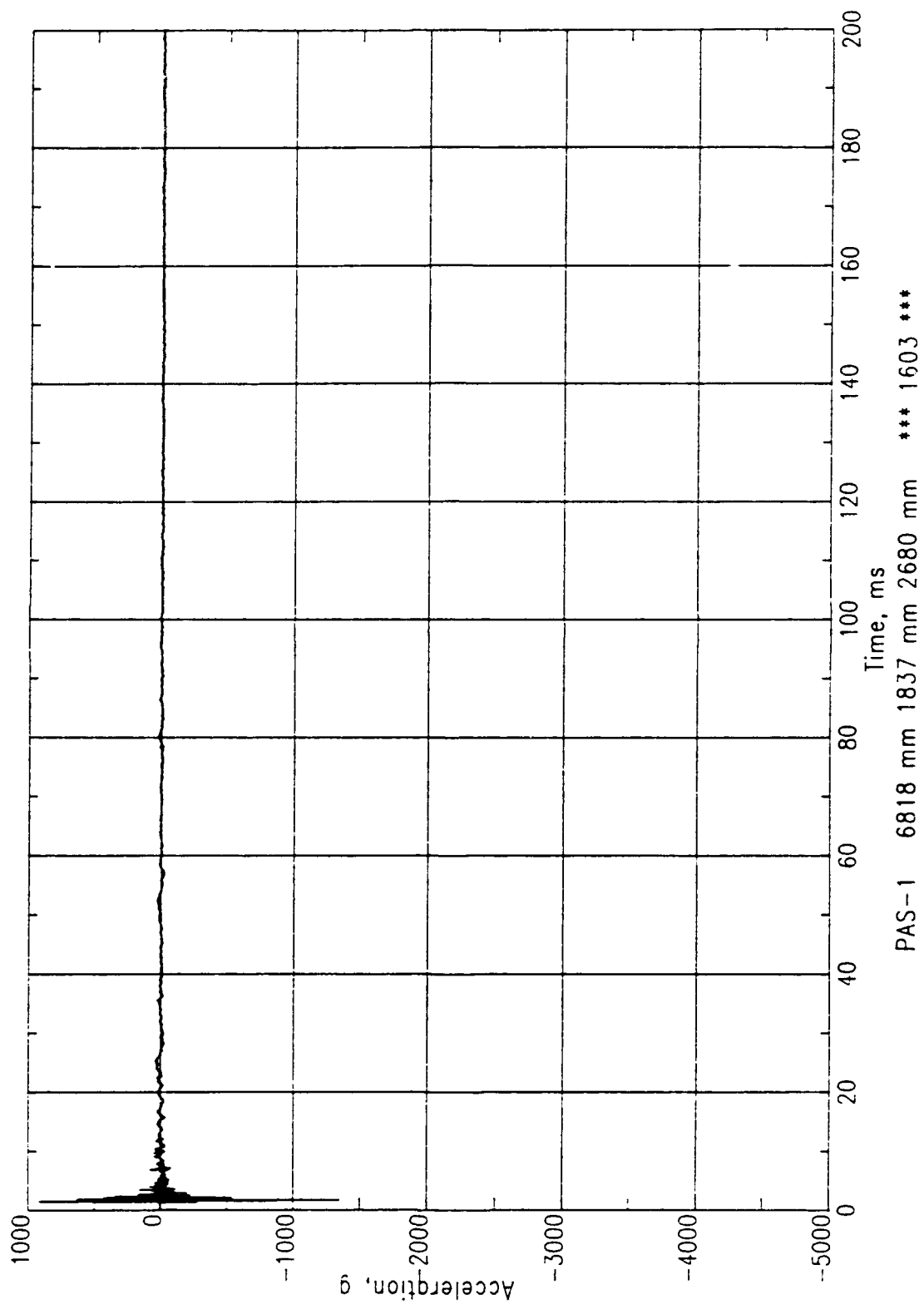


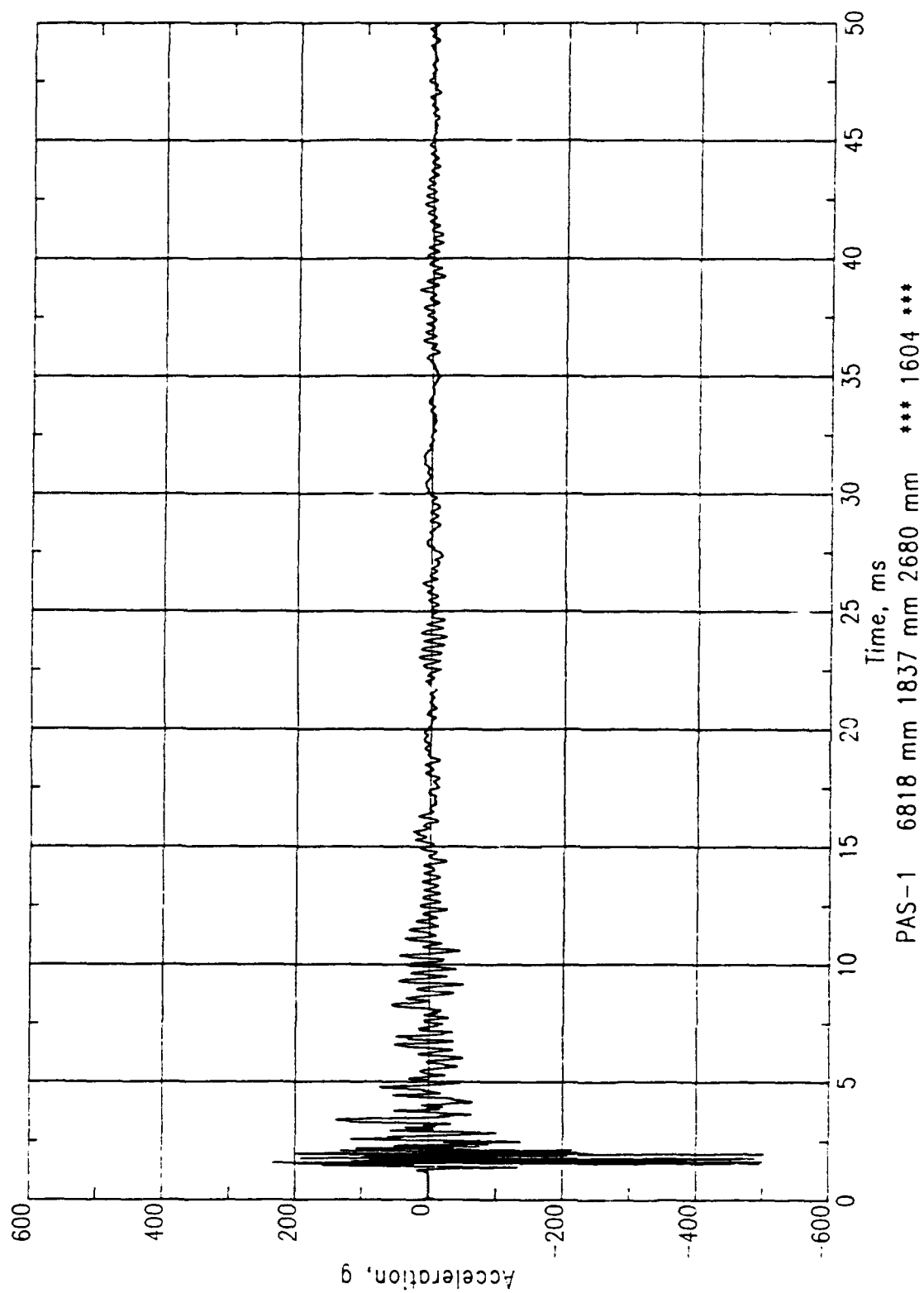


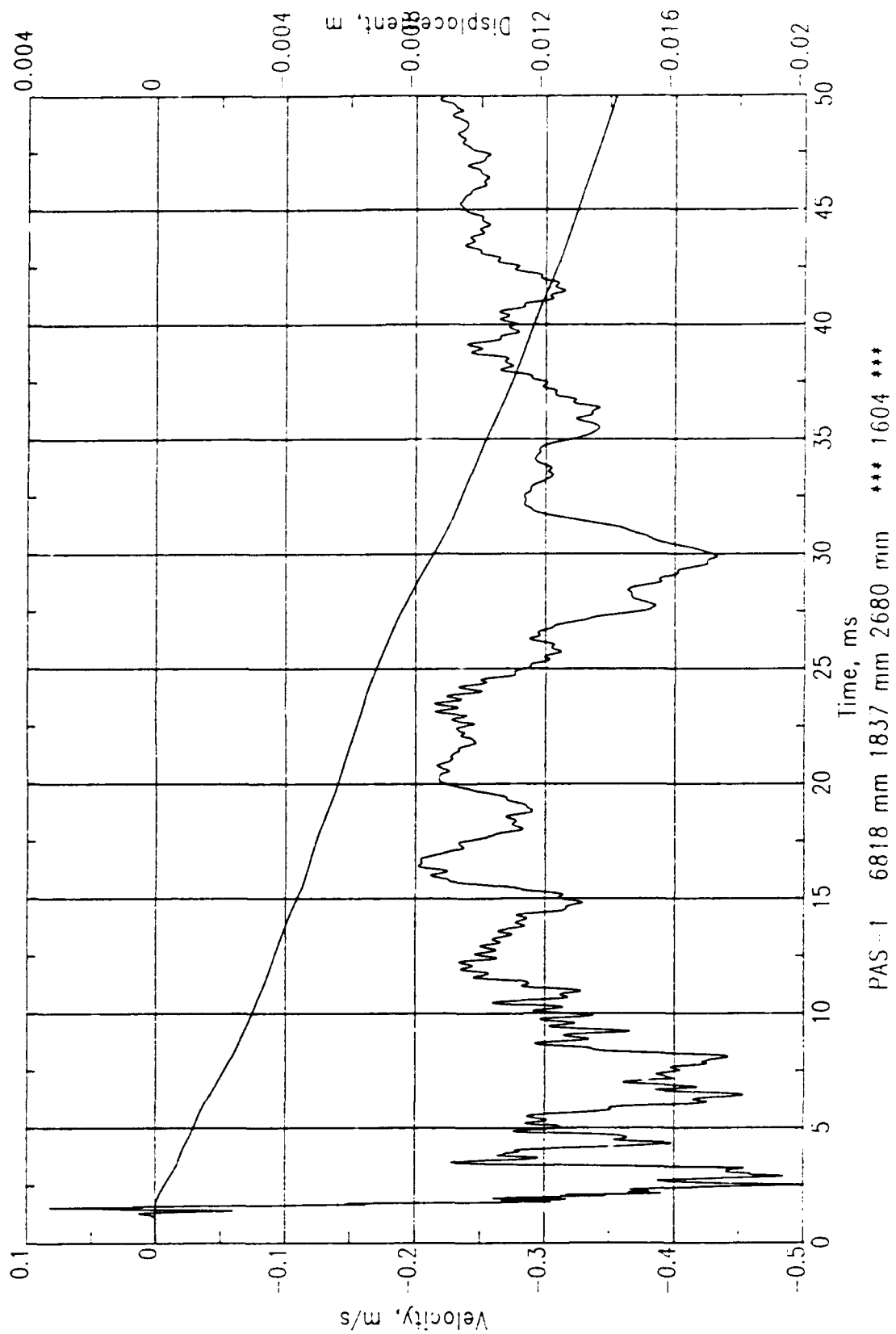


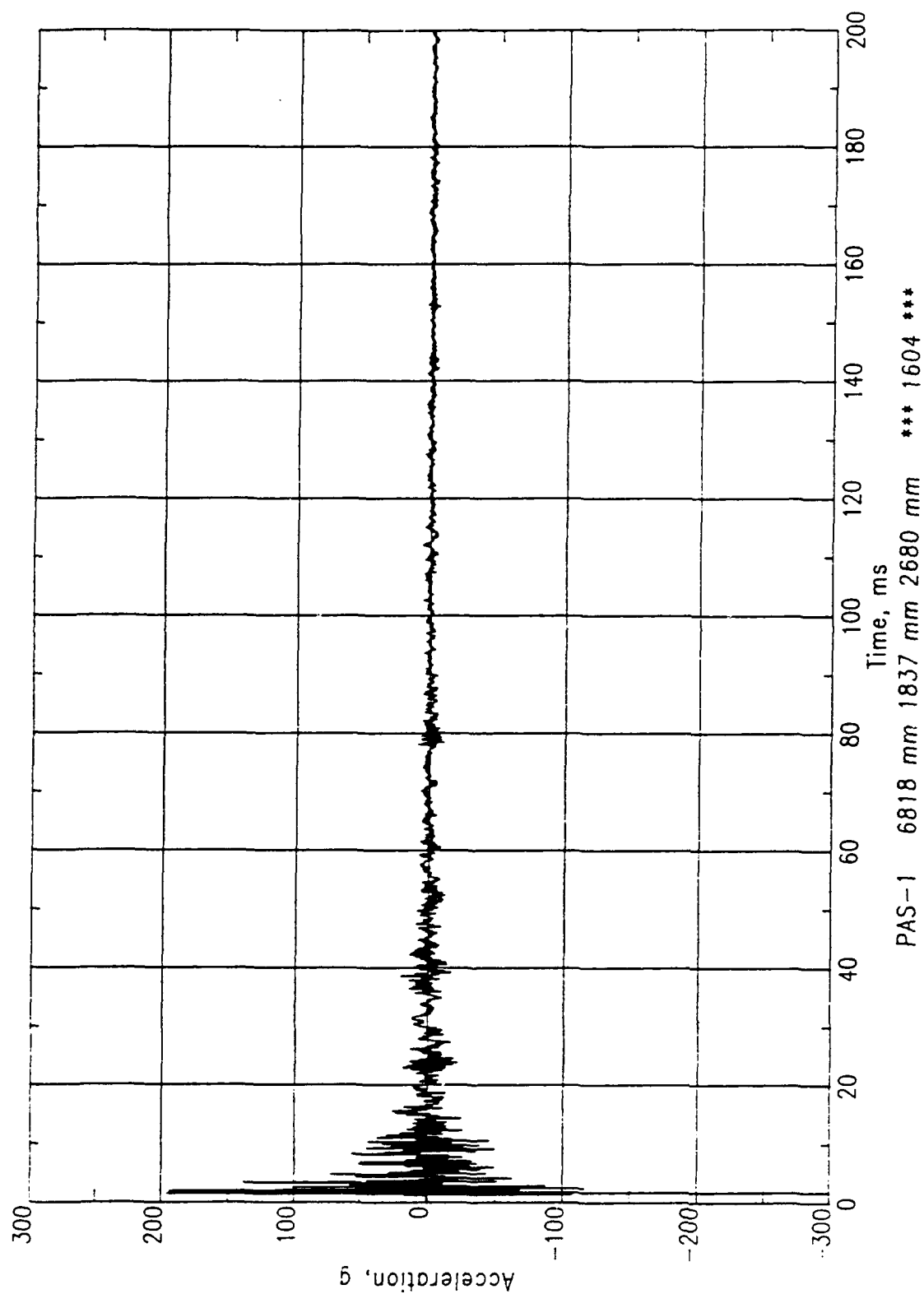


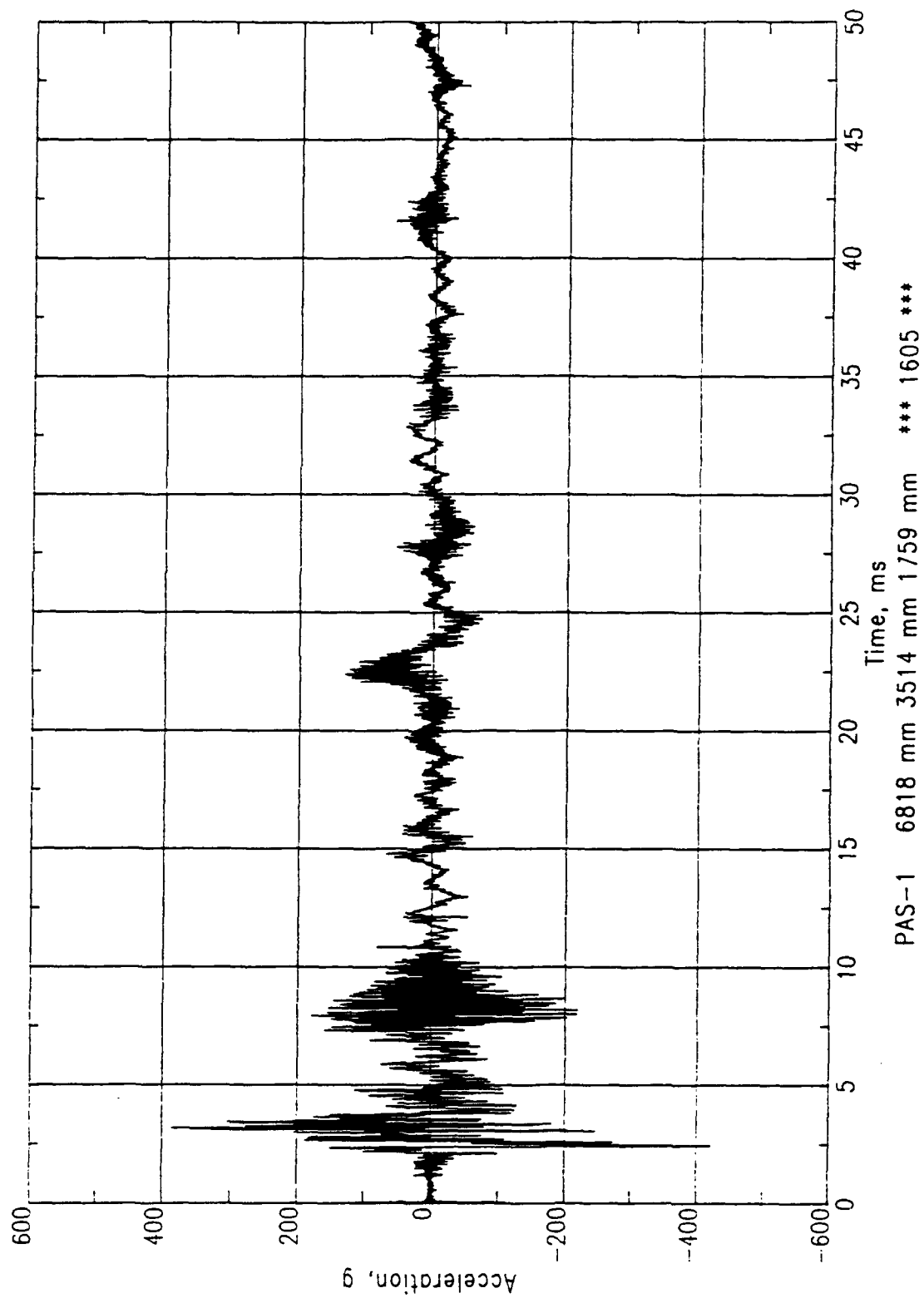
PAS-1 6818 mm 1837 mm 2680 mm *** 1603 ***

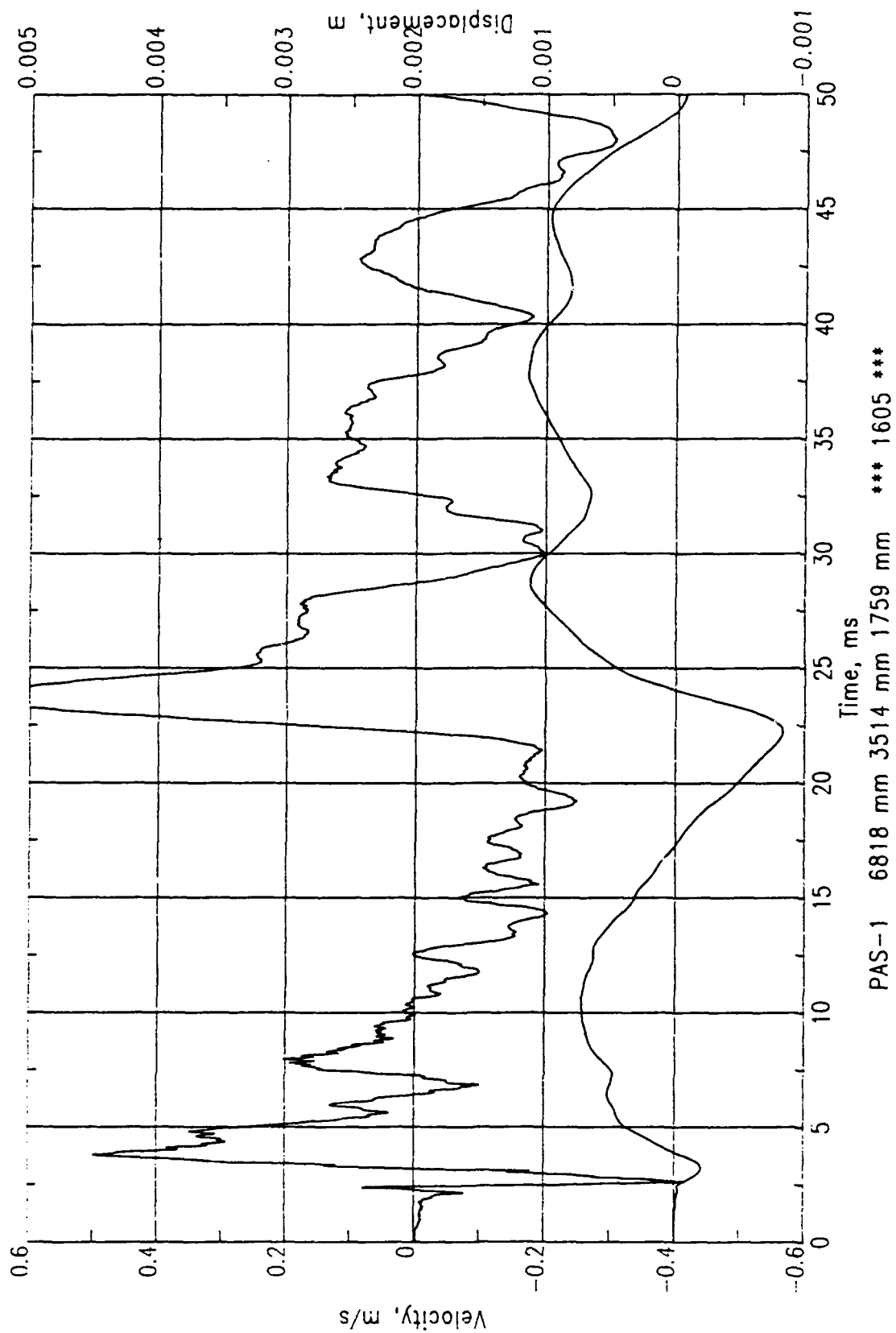


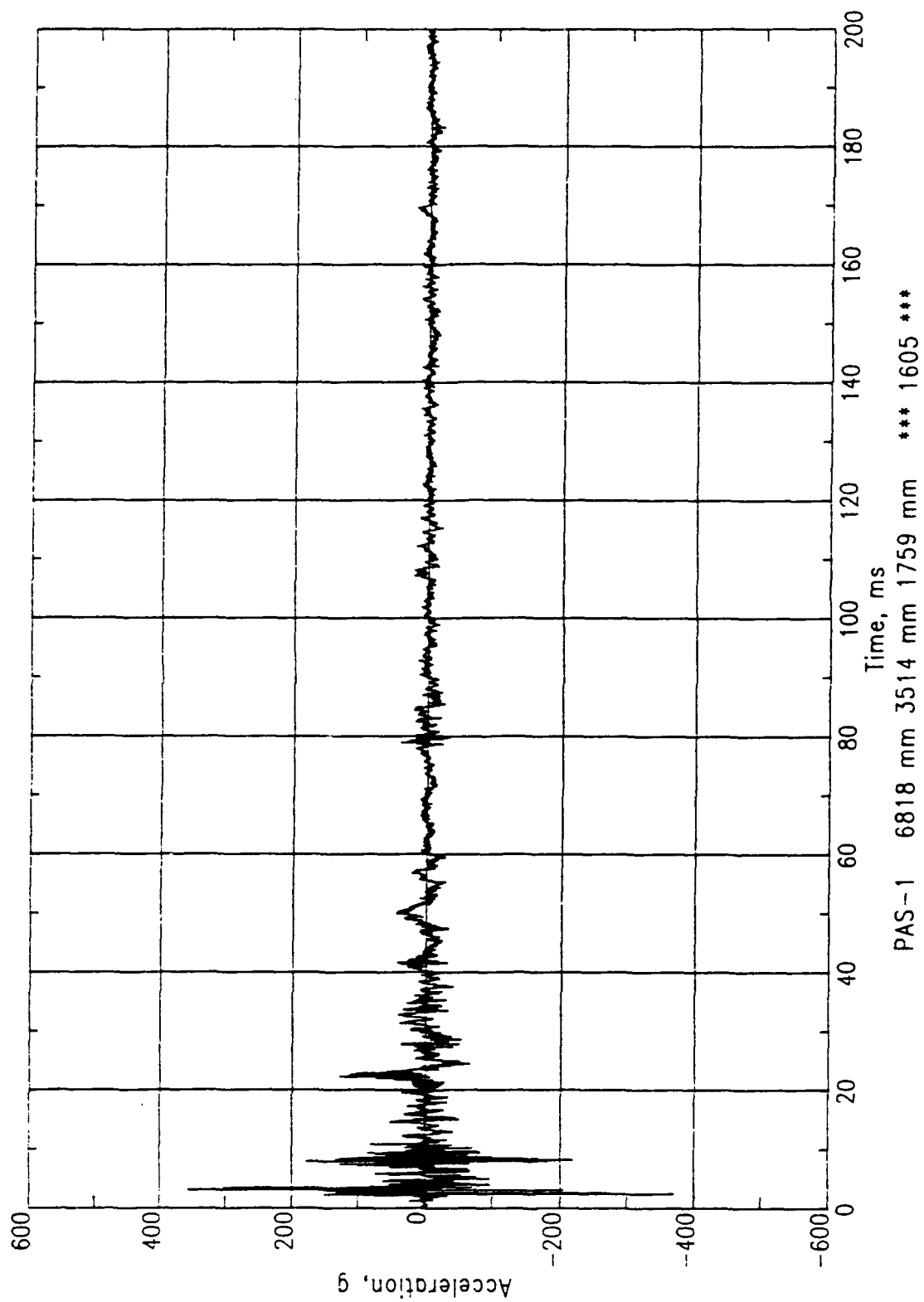


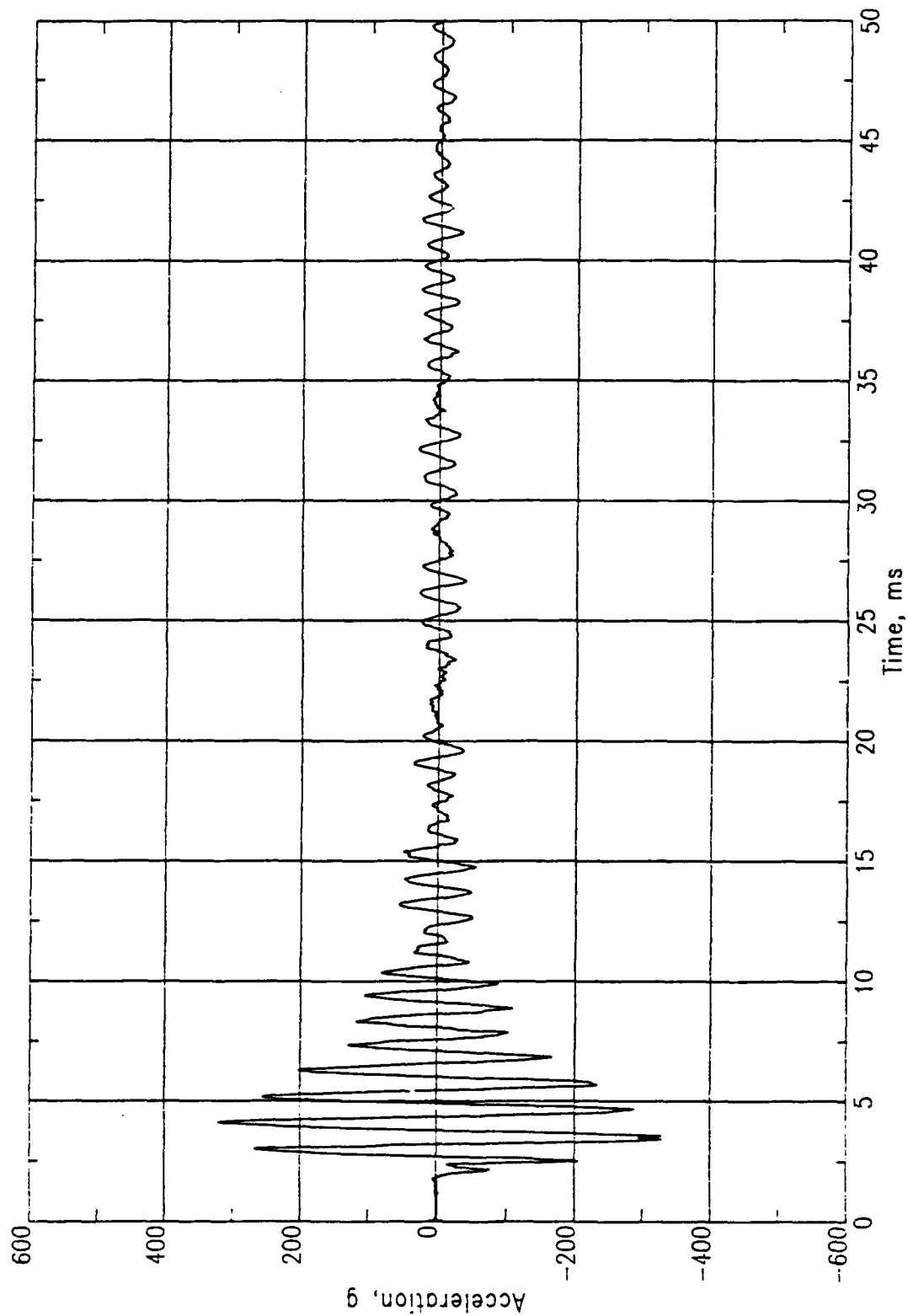




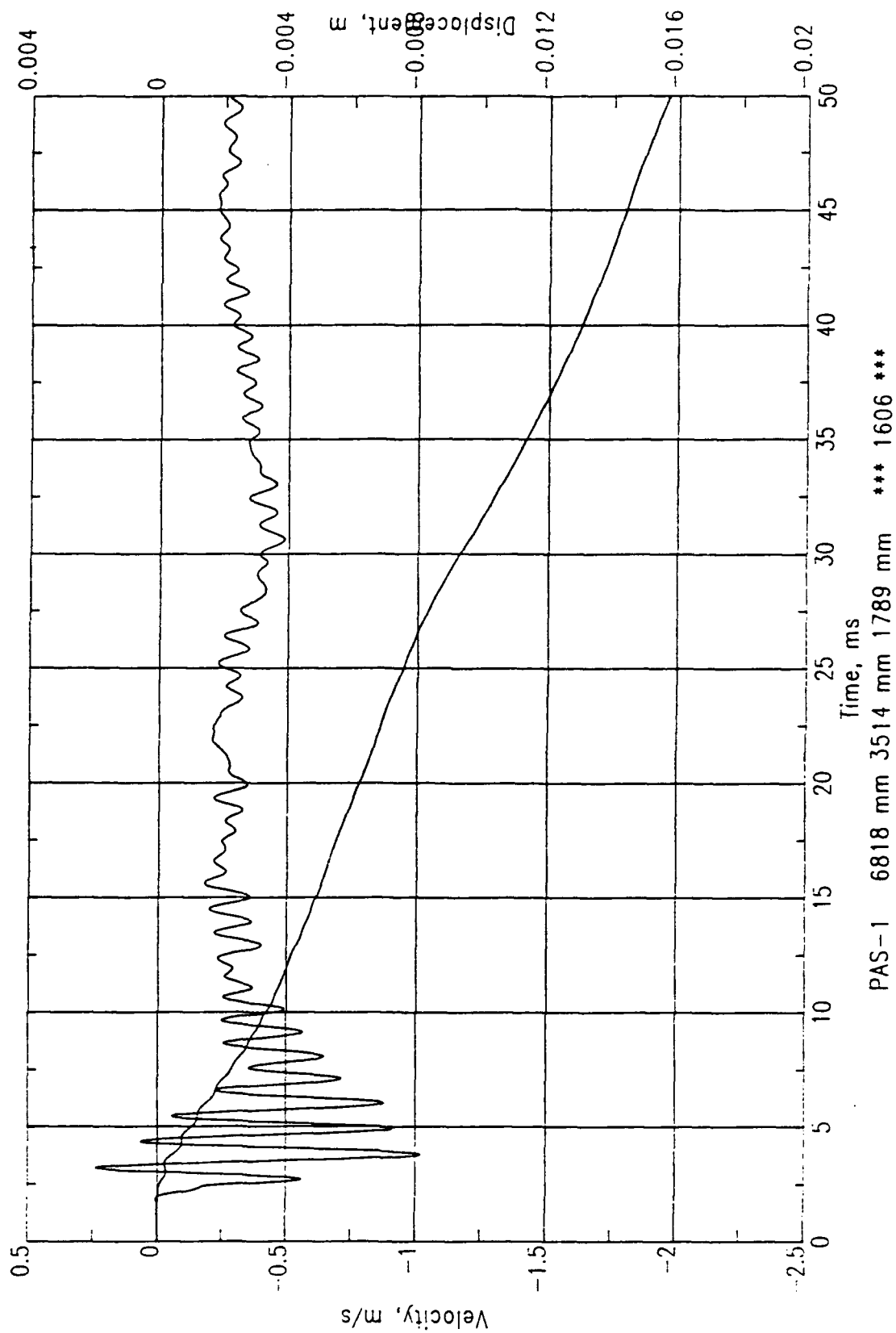


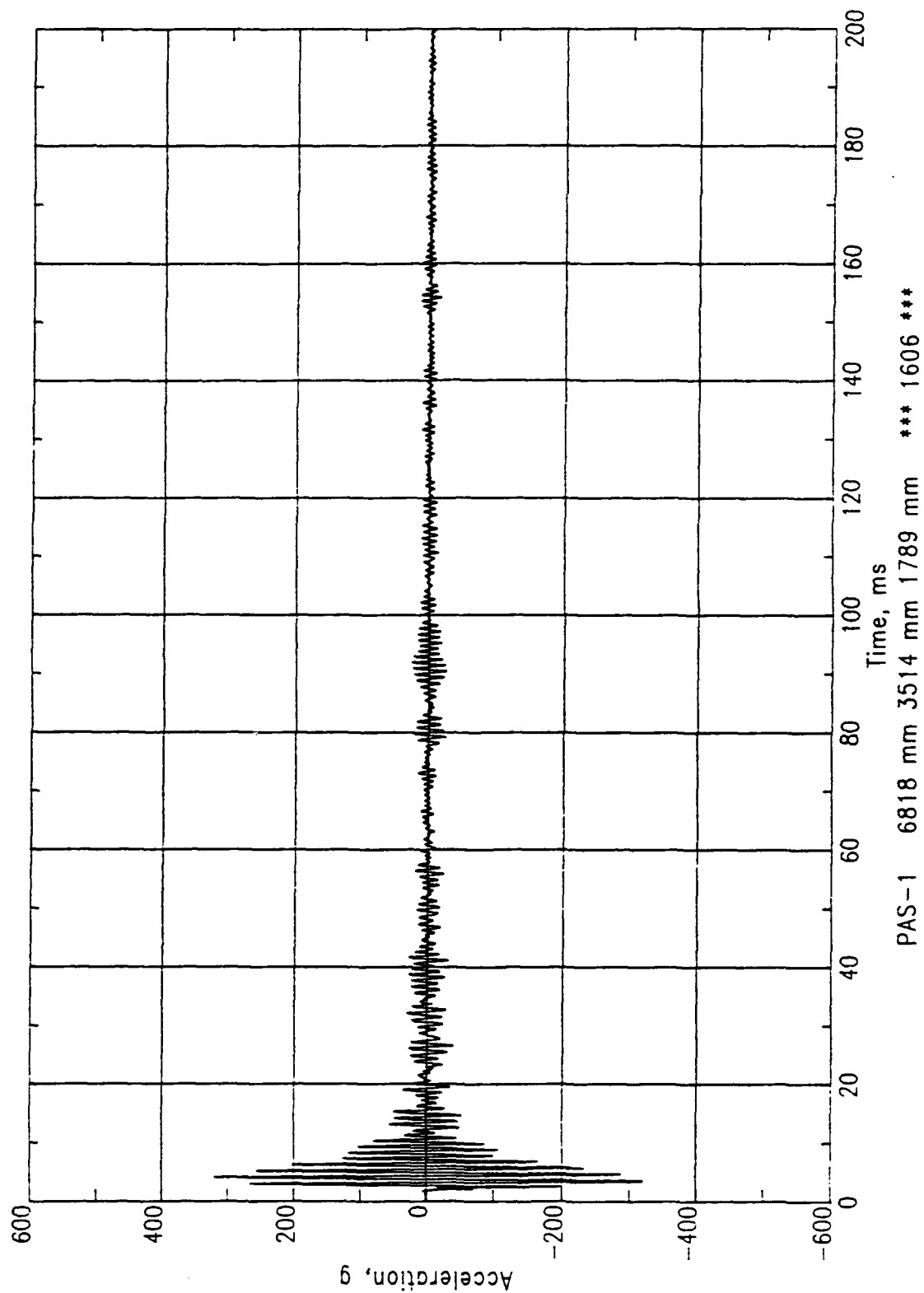


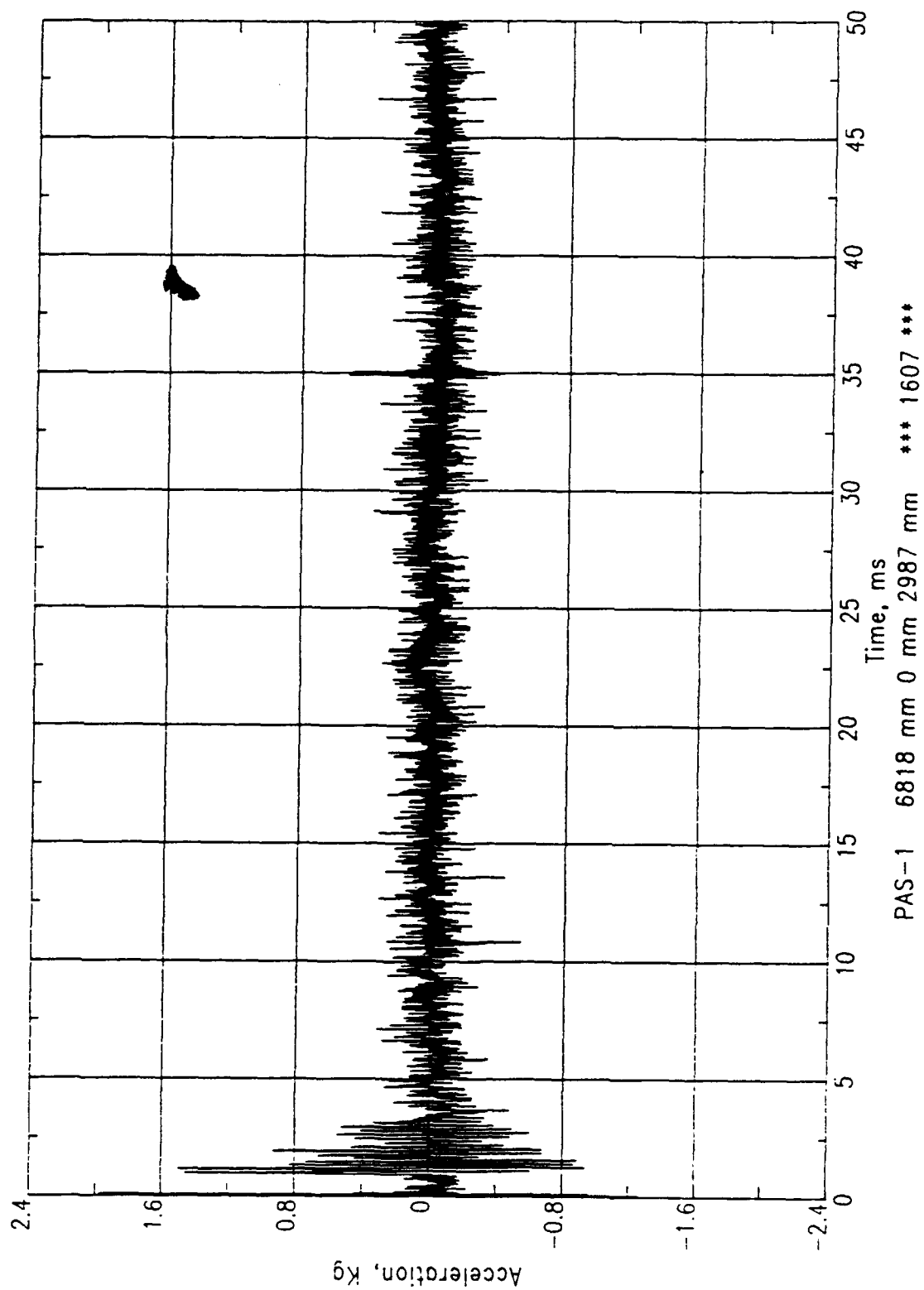


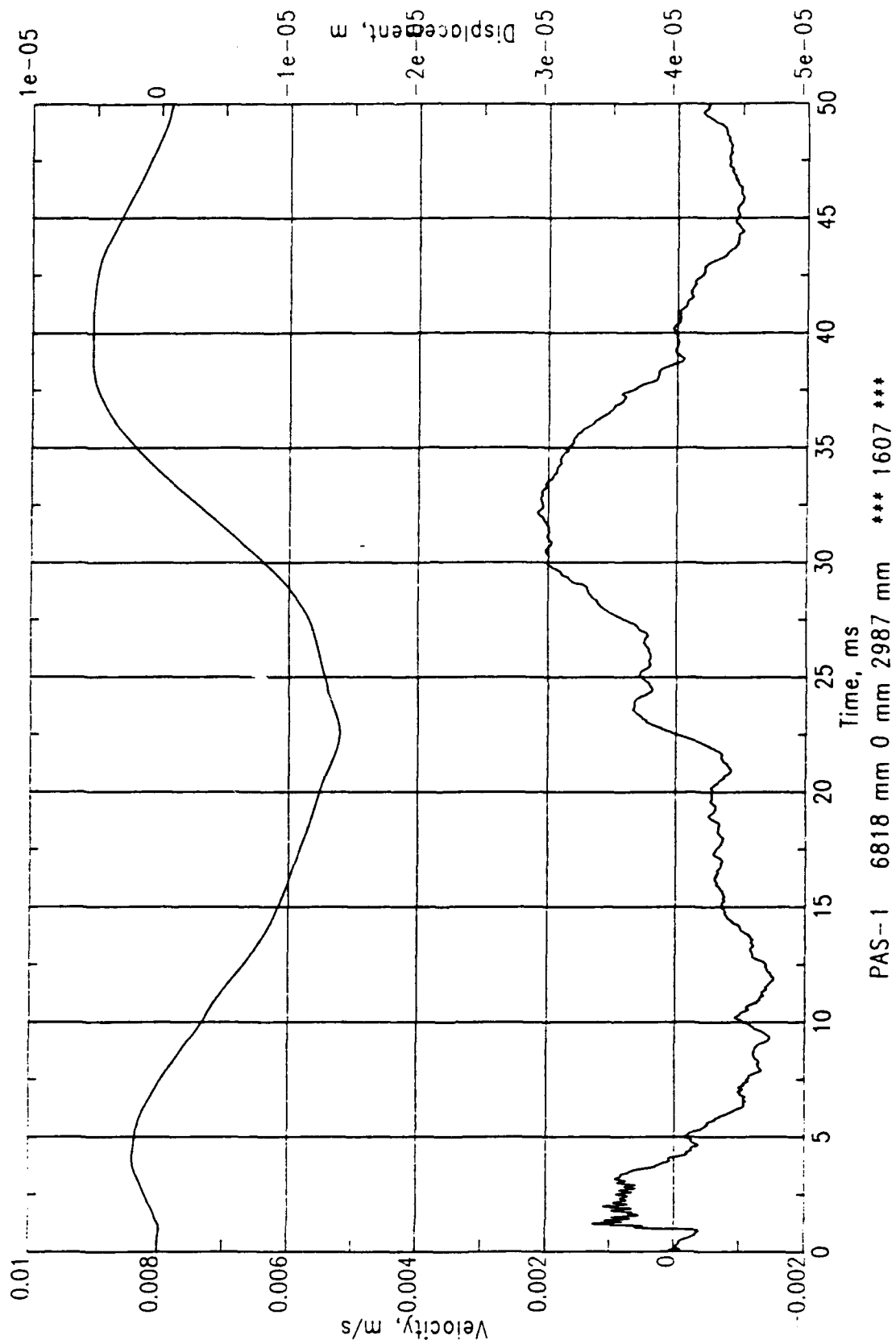


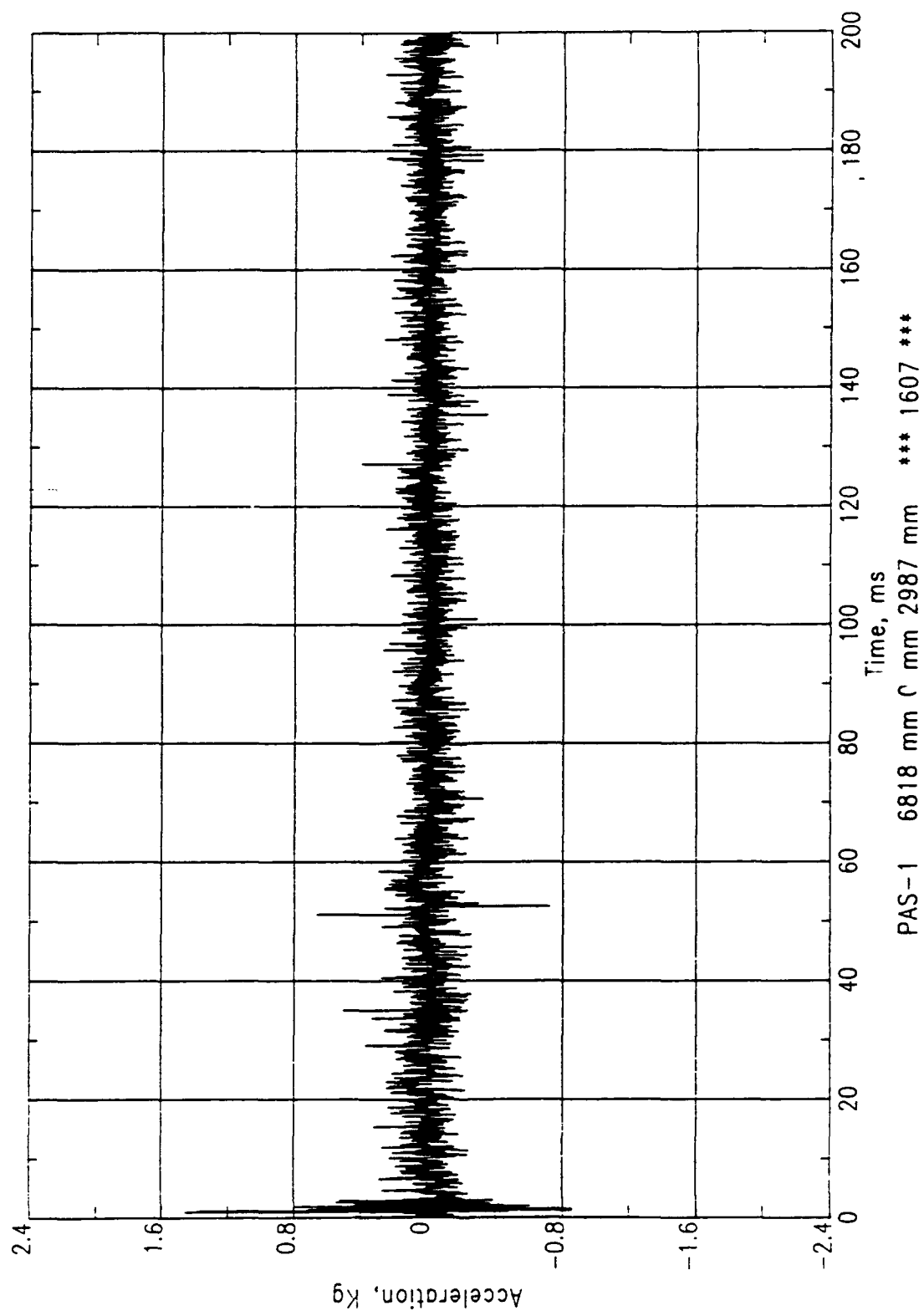
PAS--1 6818 mm 3514 mm 1789 mm *** 1606 ***

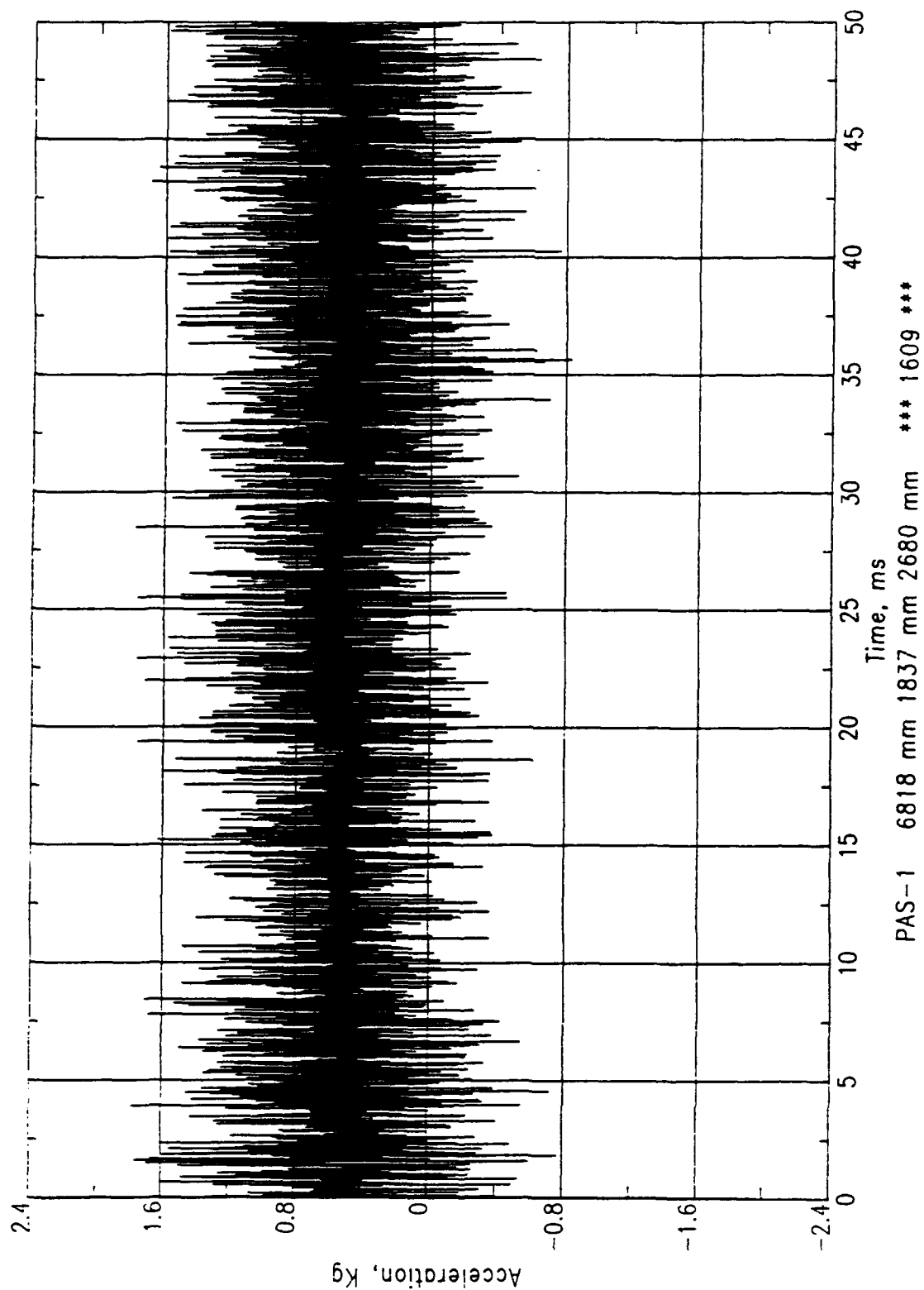


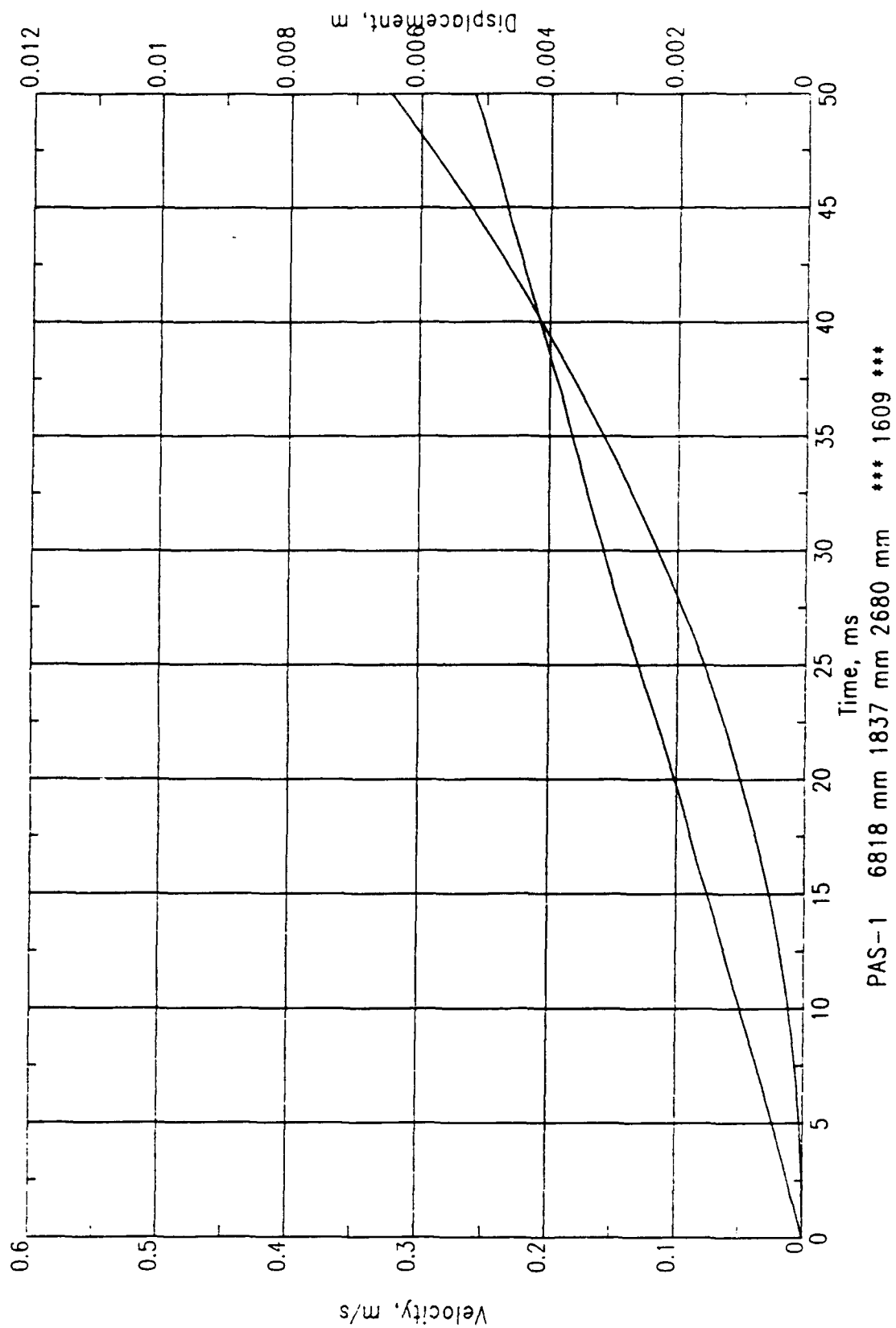


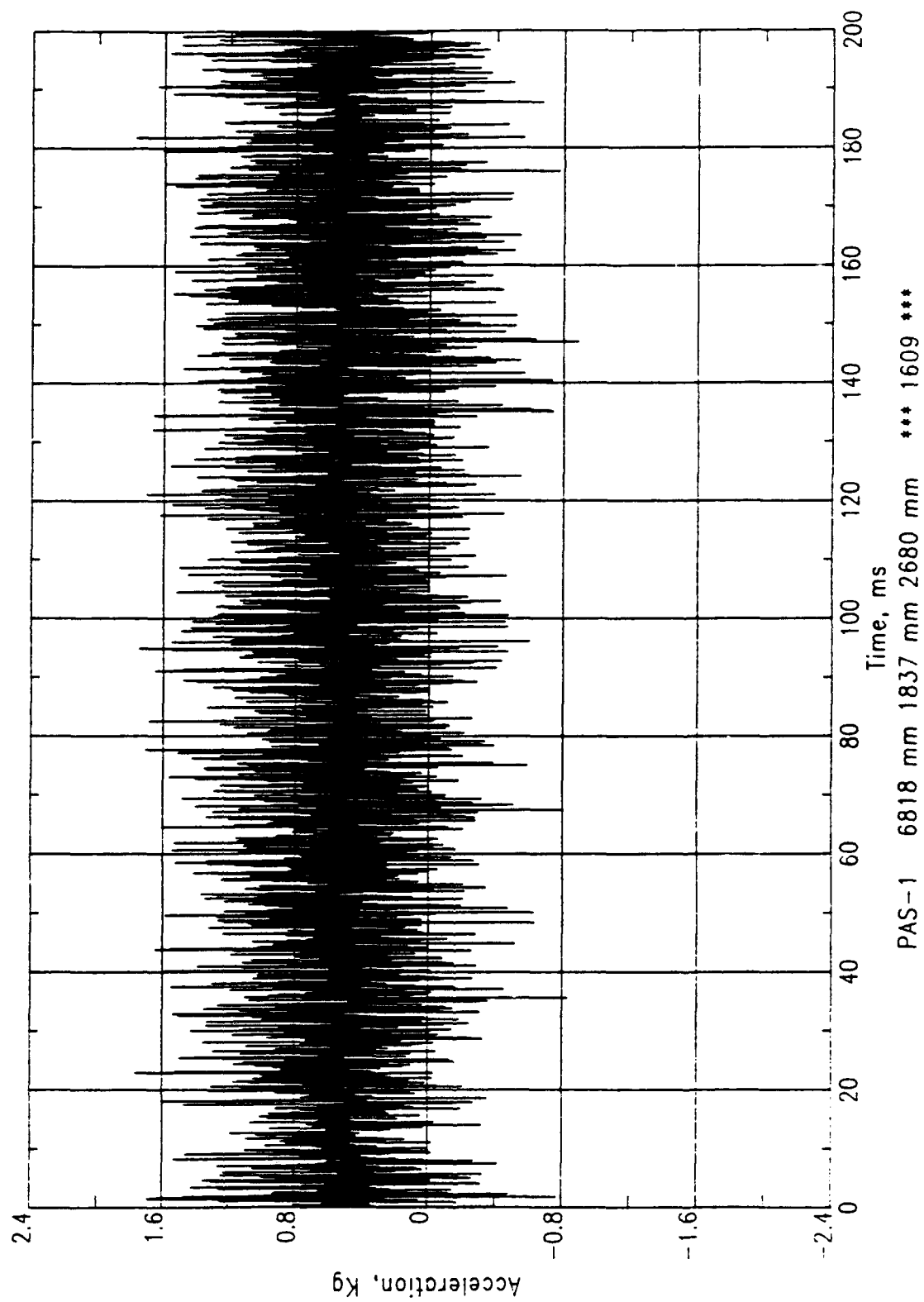


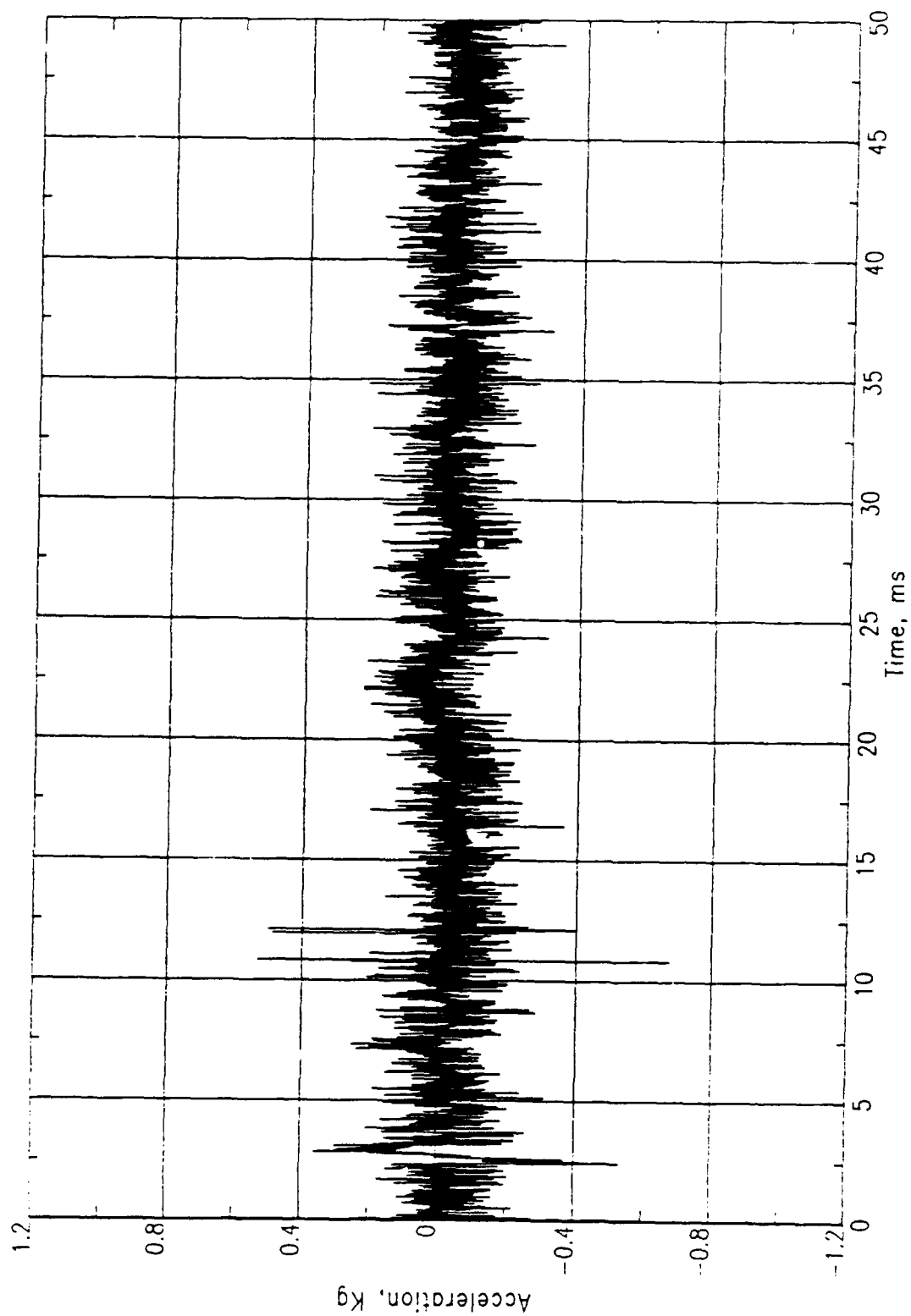




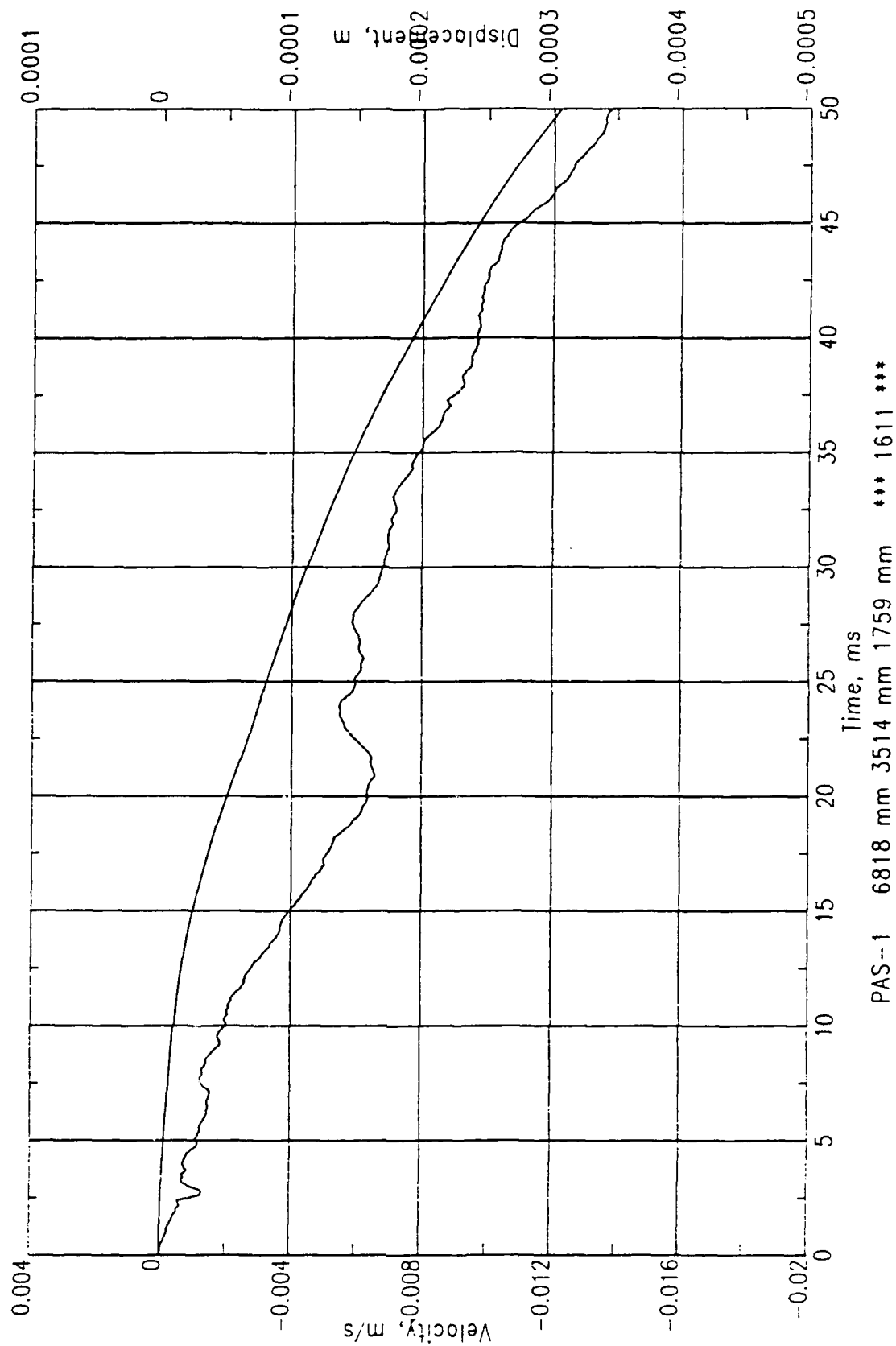


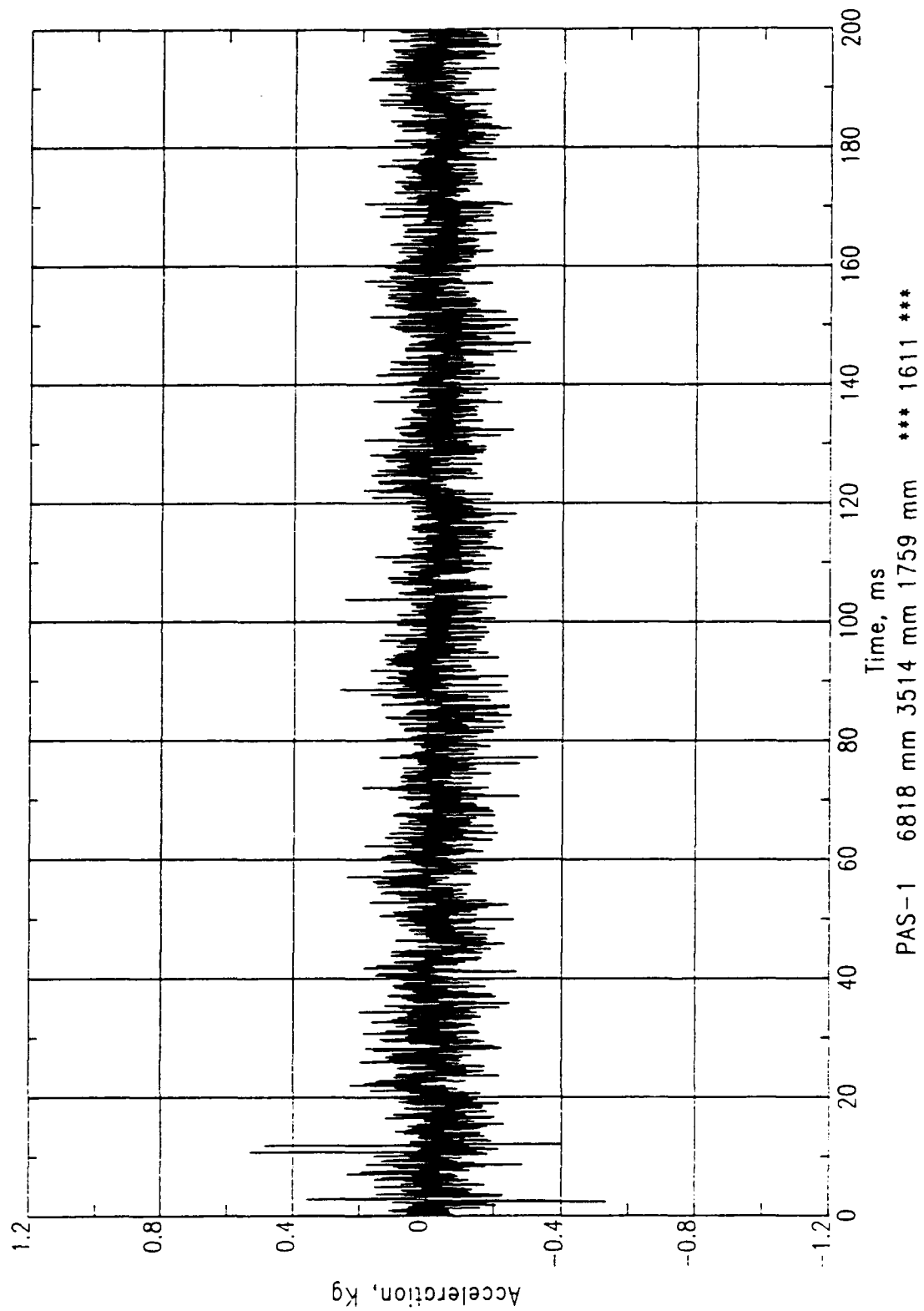


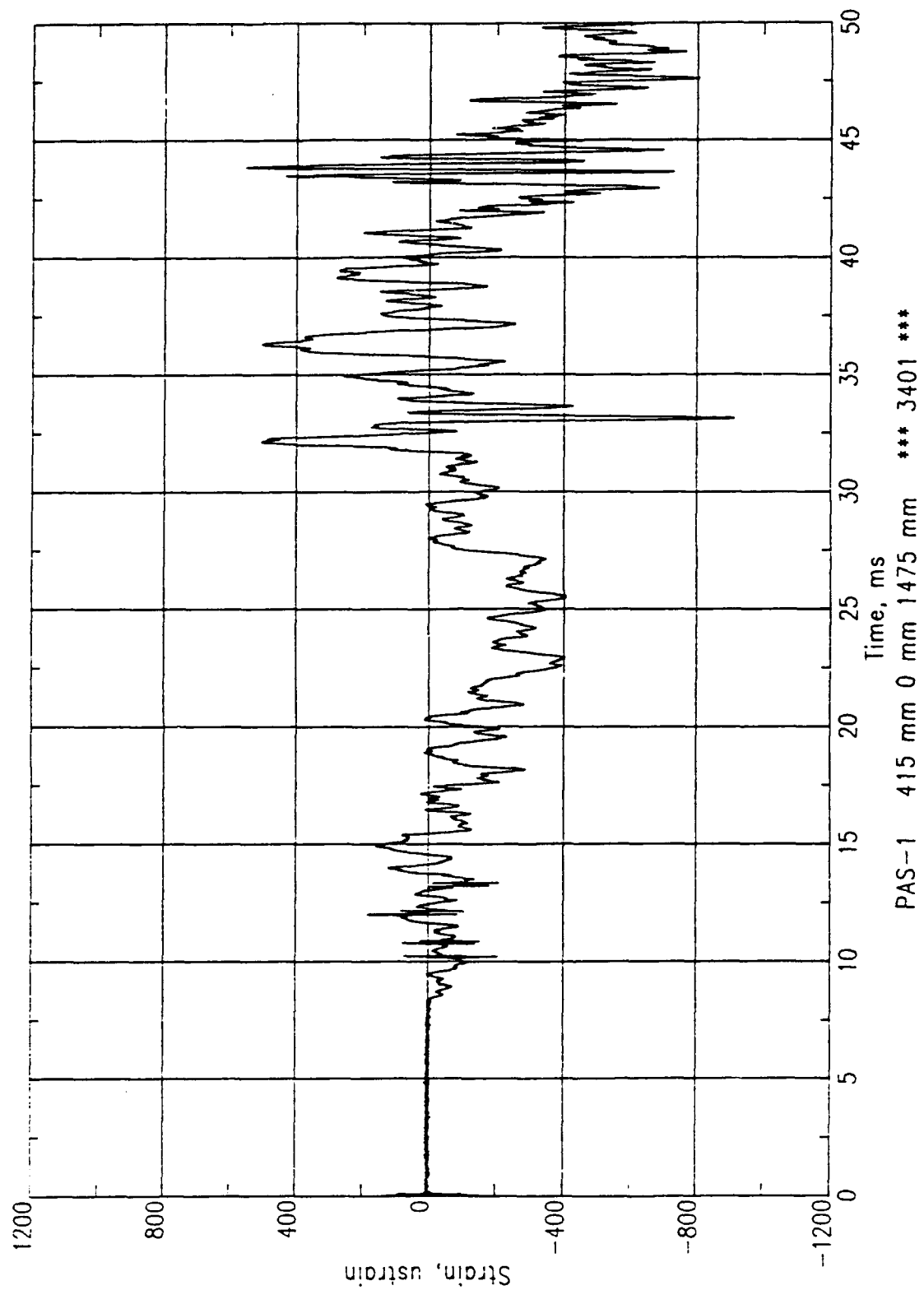


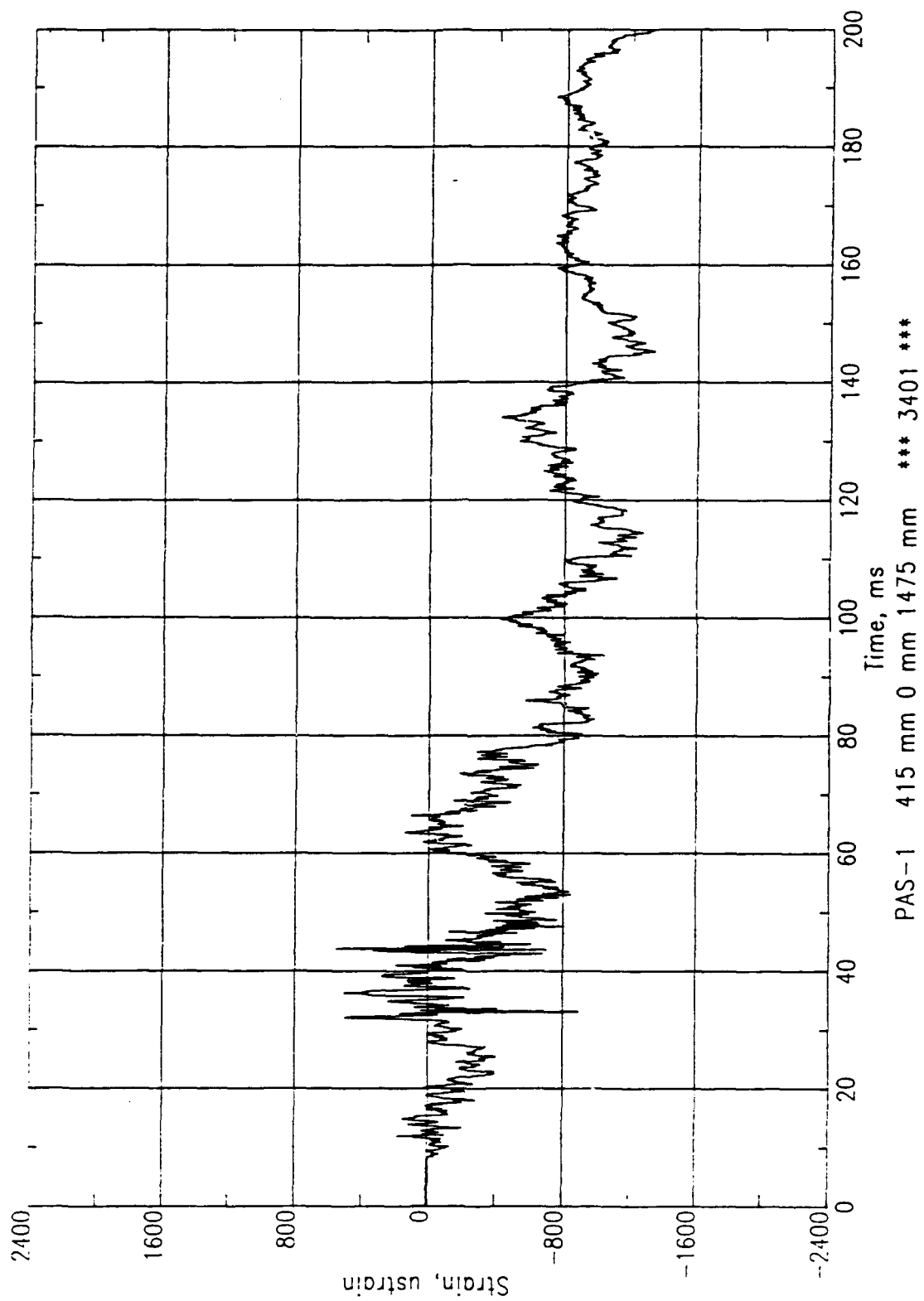


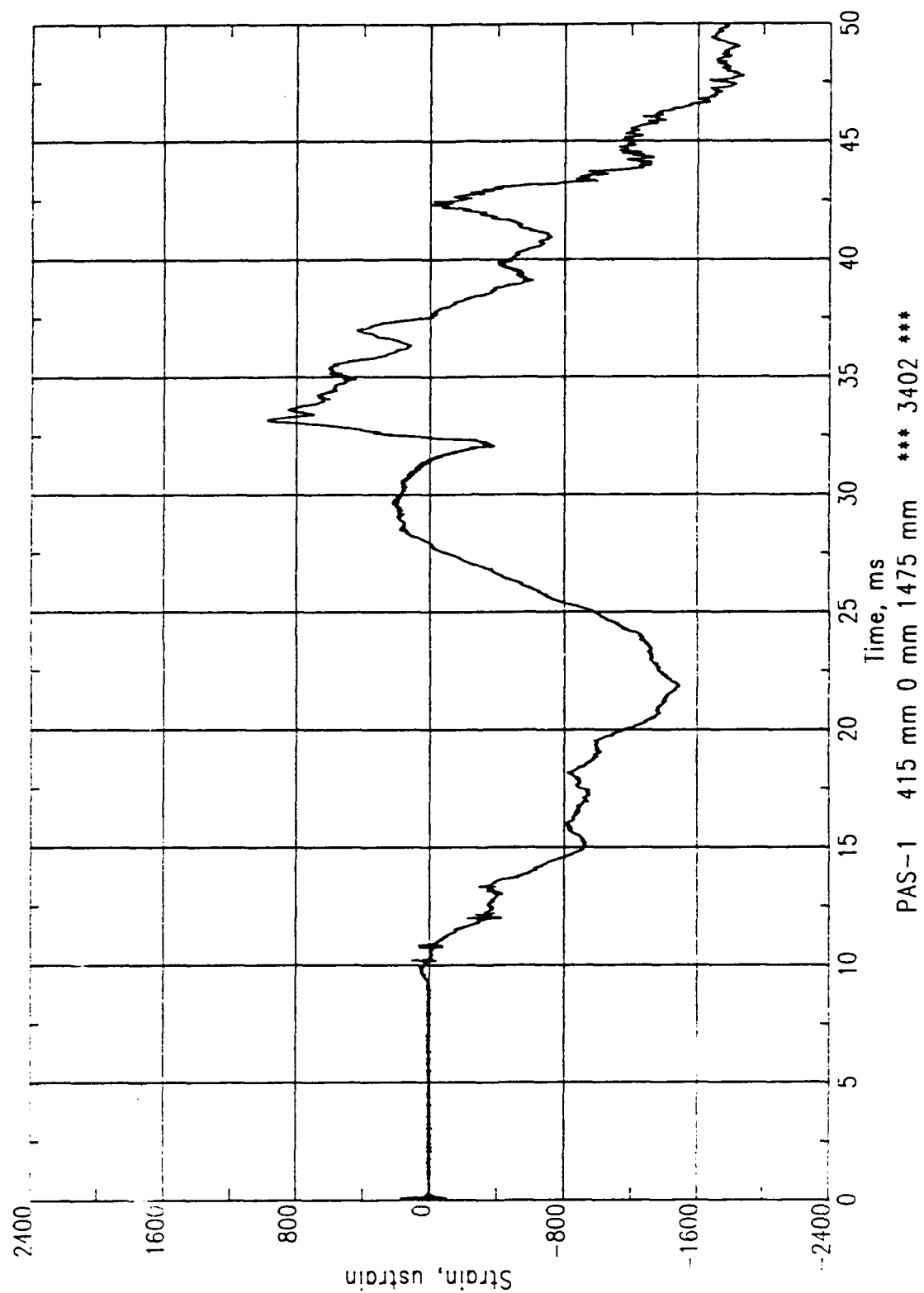
PAS-1 6818 mm 3514 mm 1759 mm *** 1611 ***

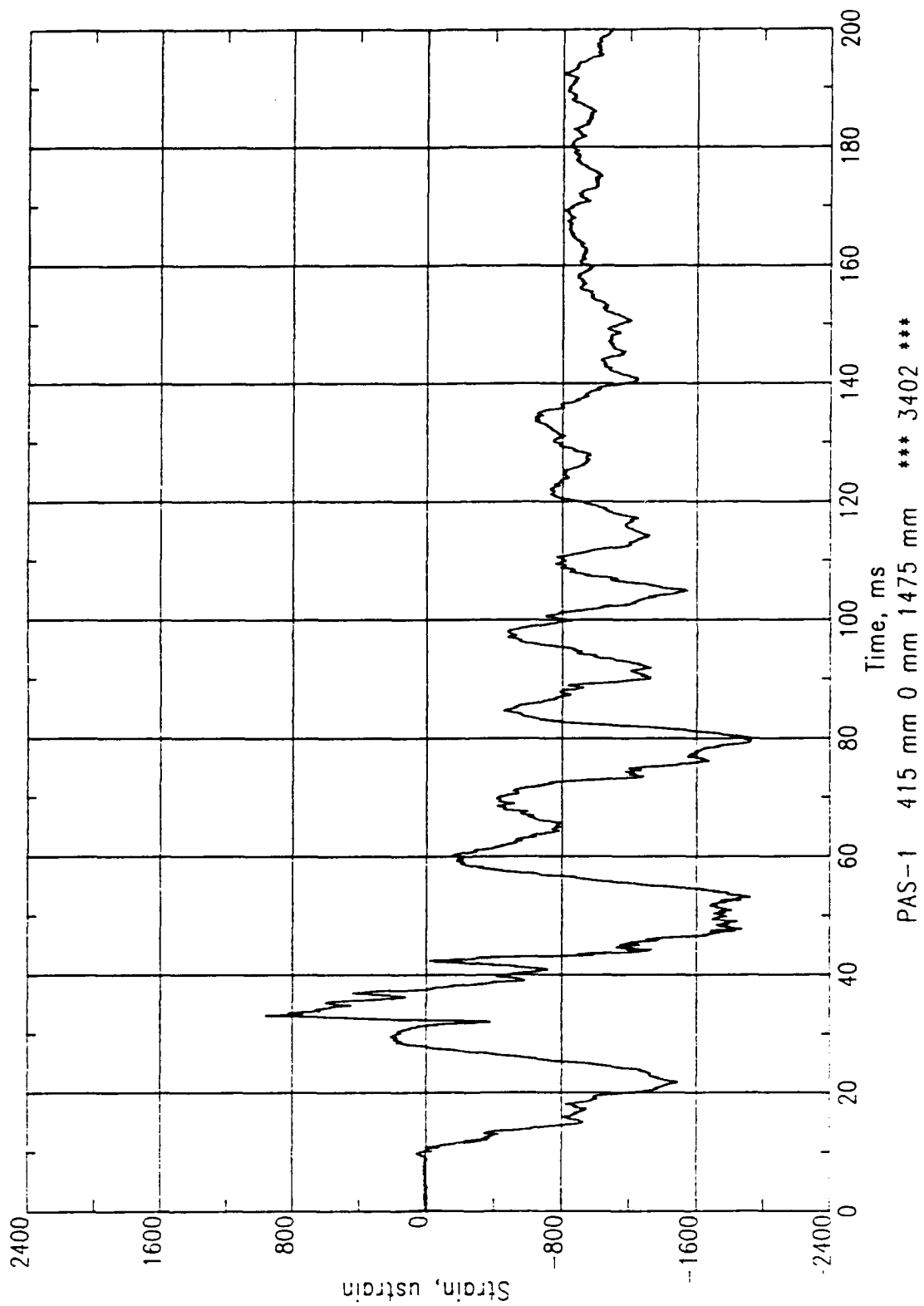


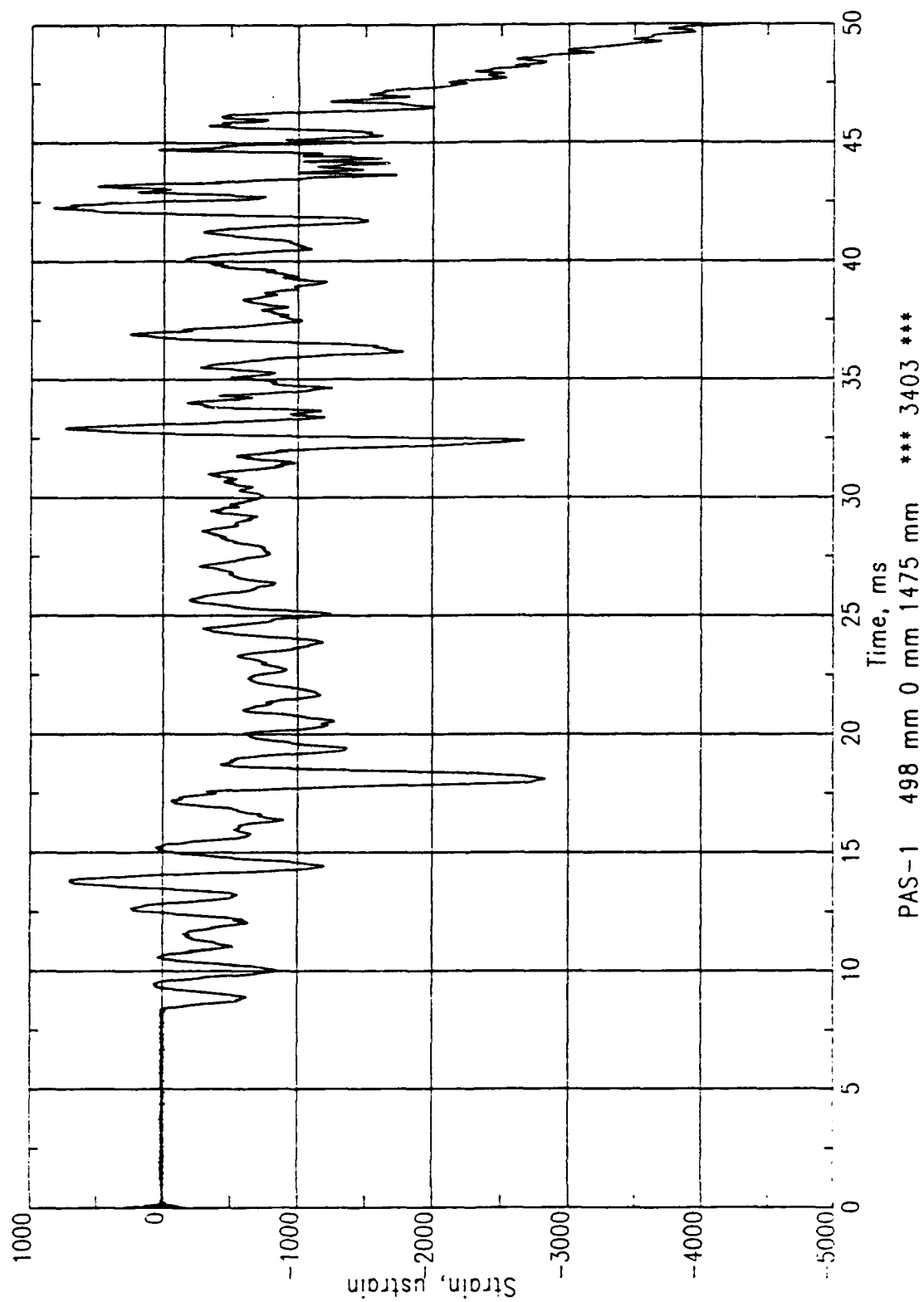


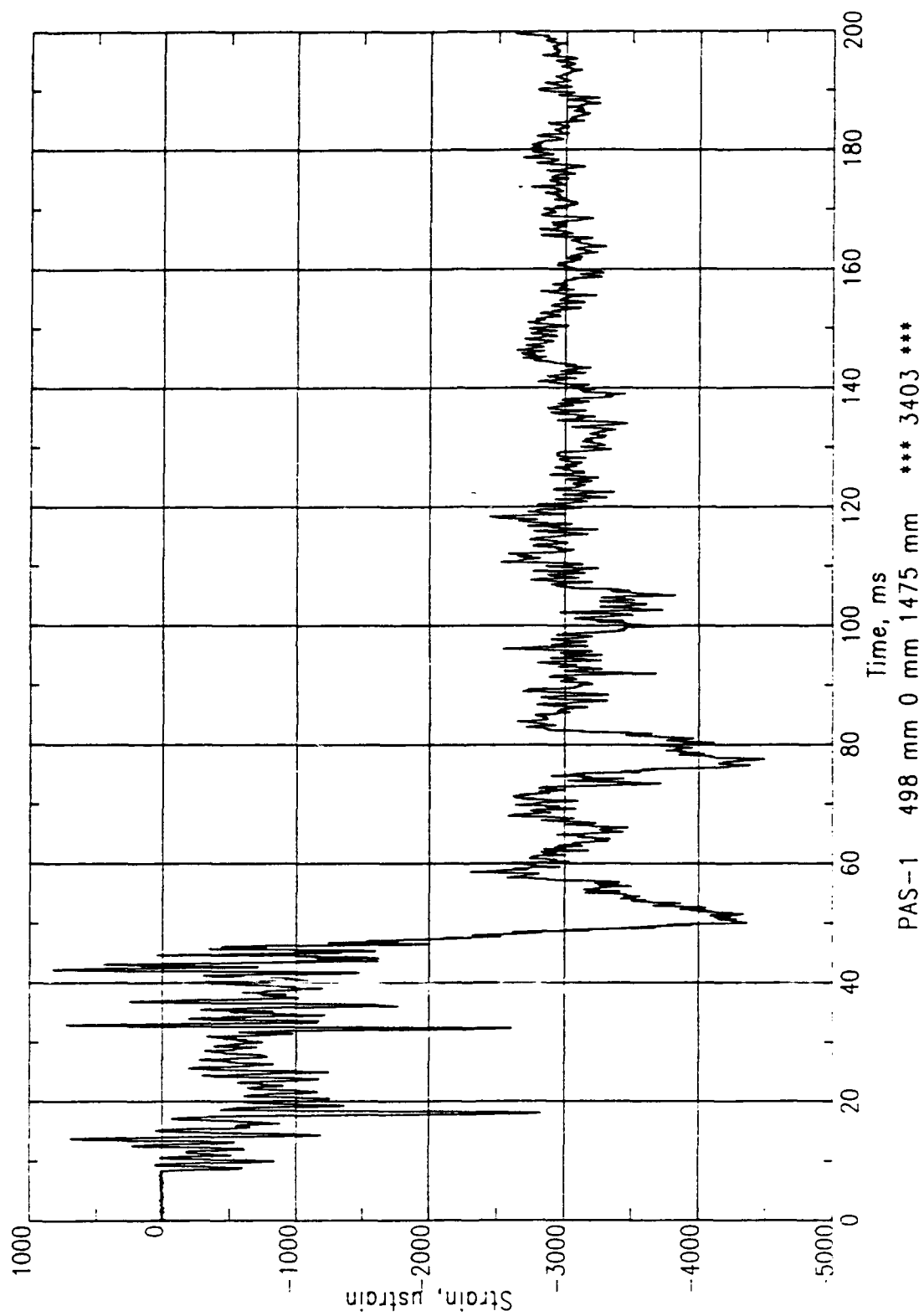


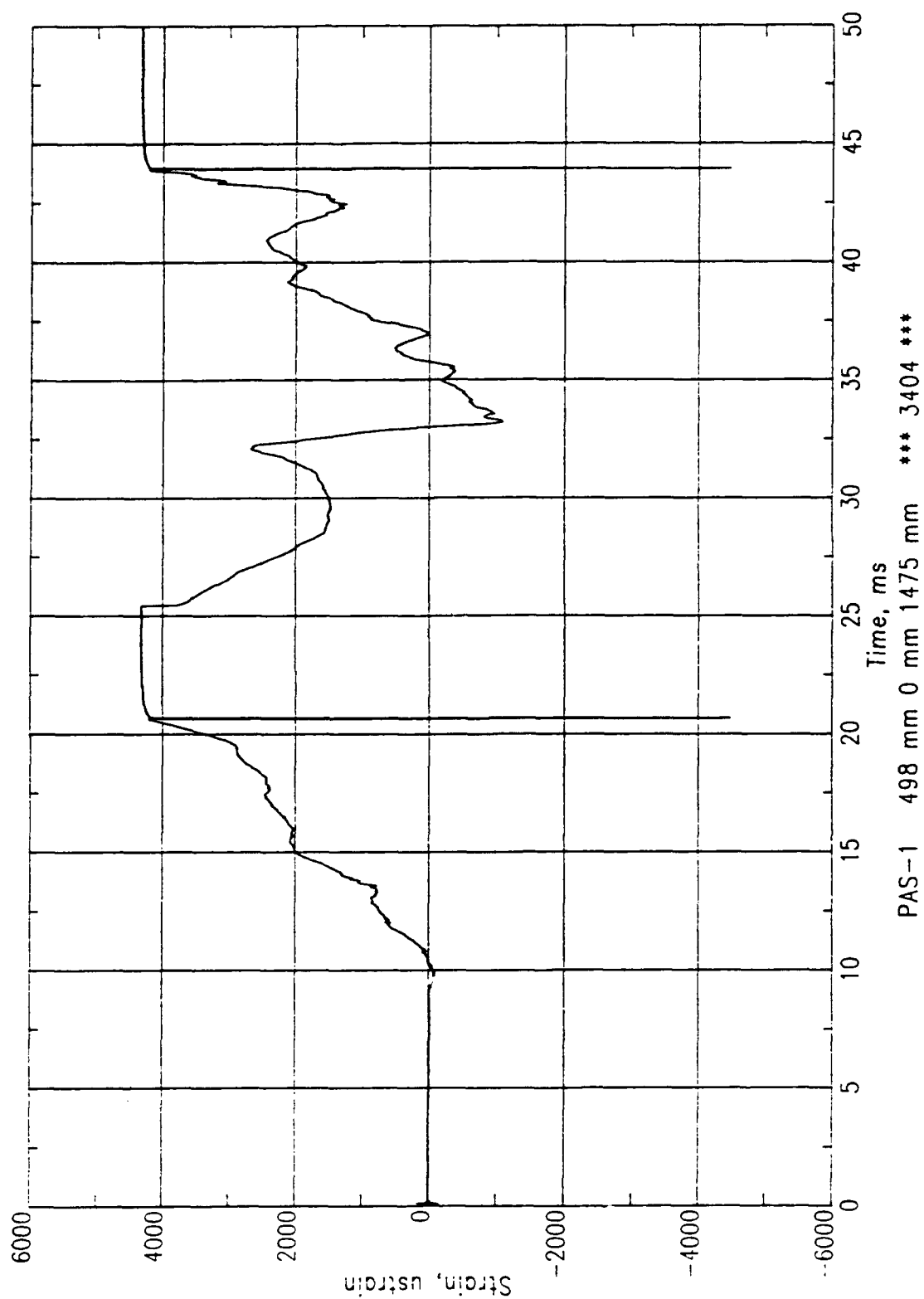


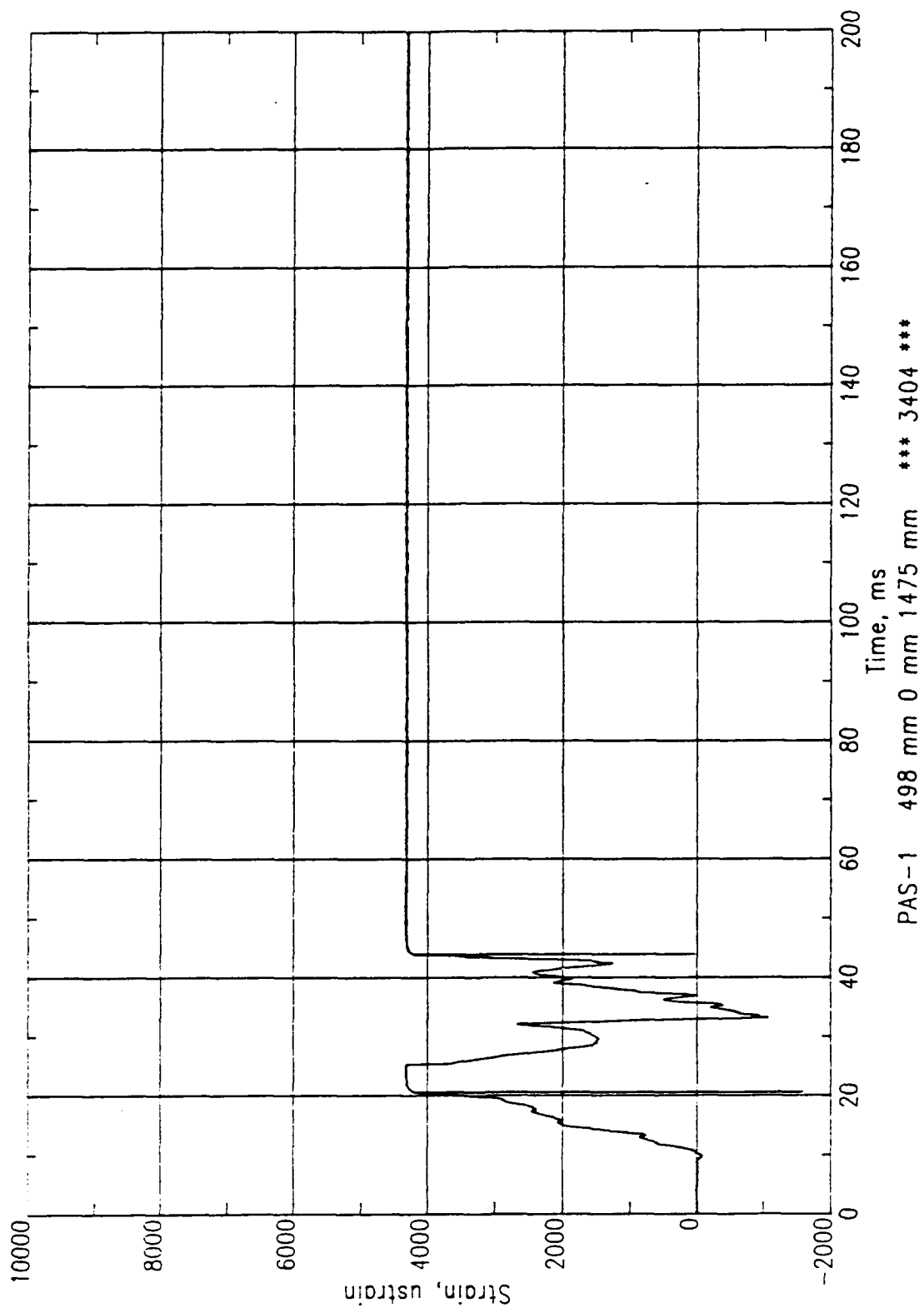


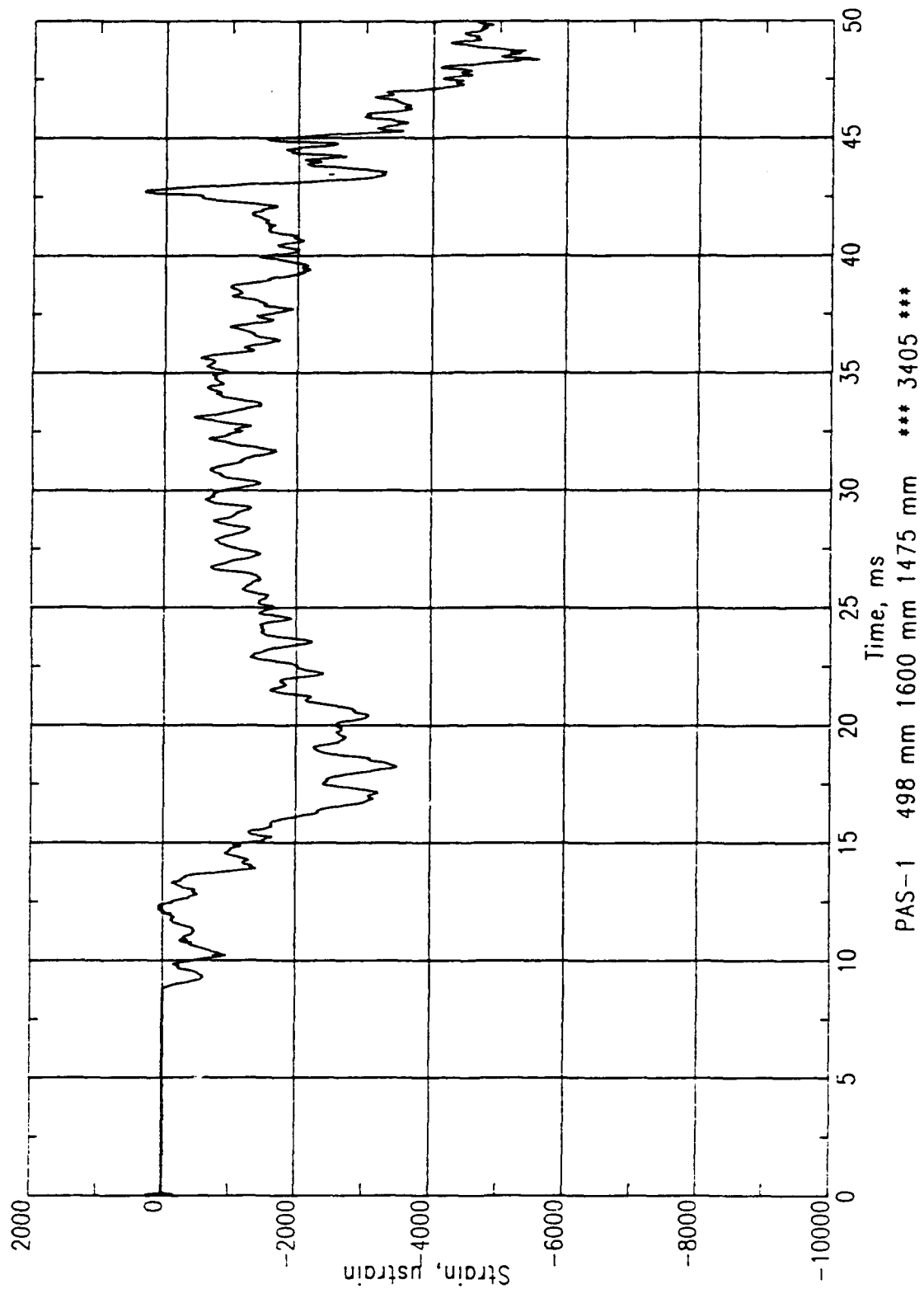


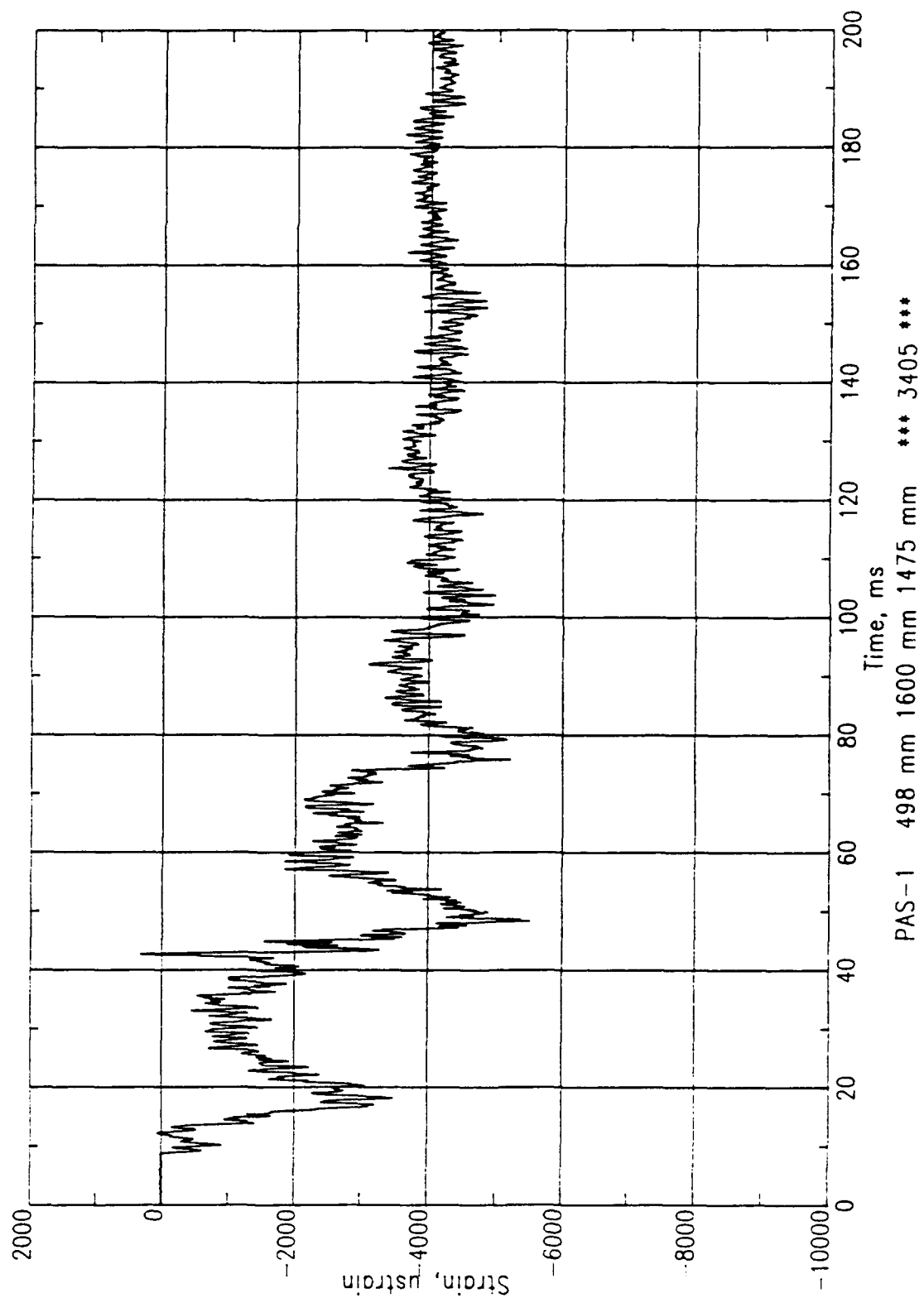


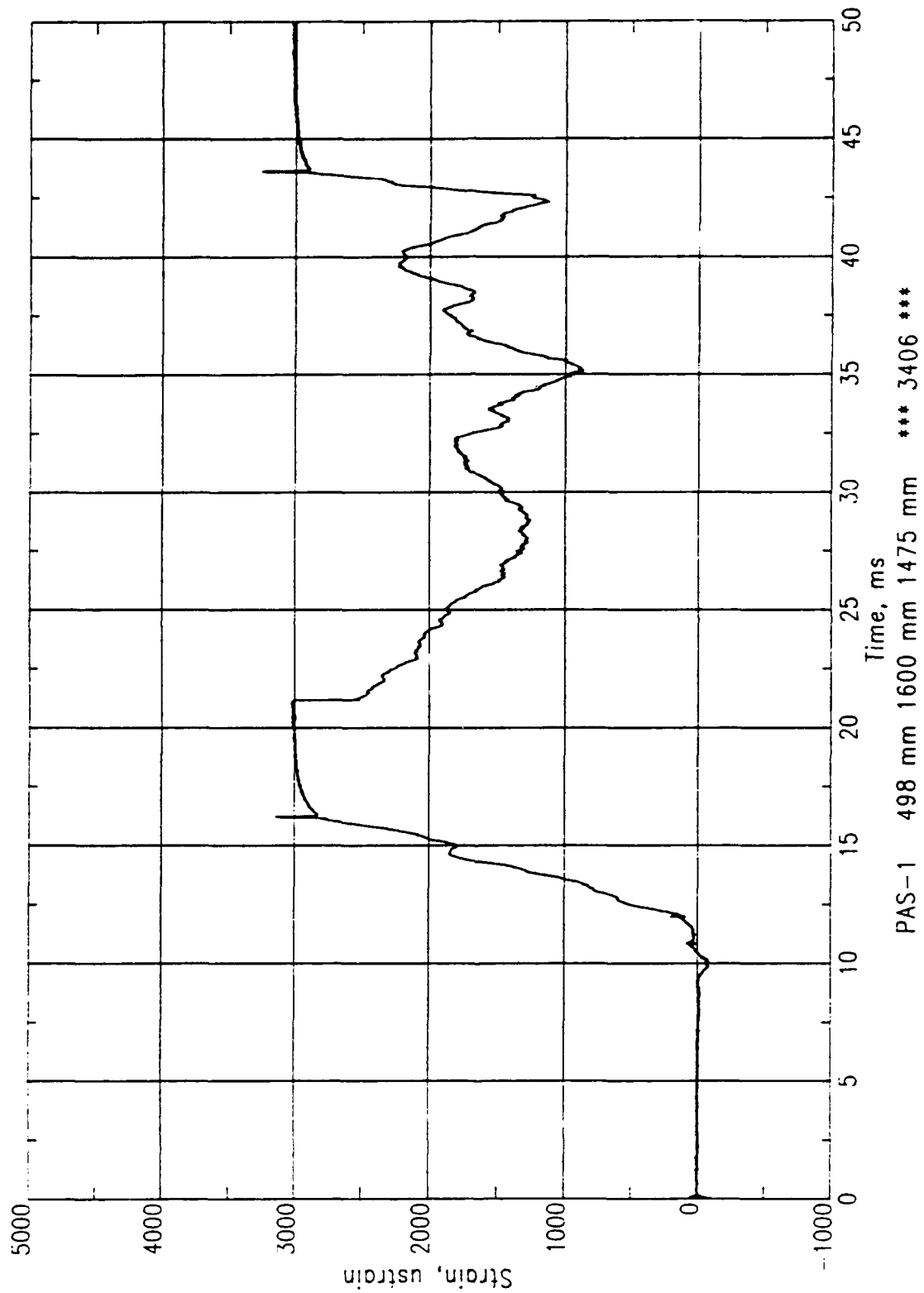




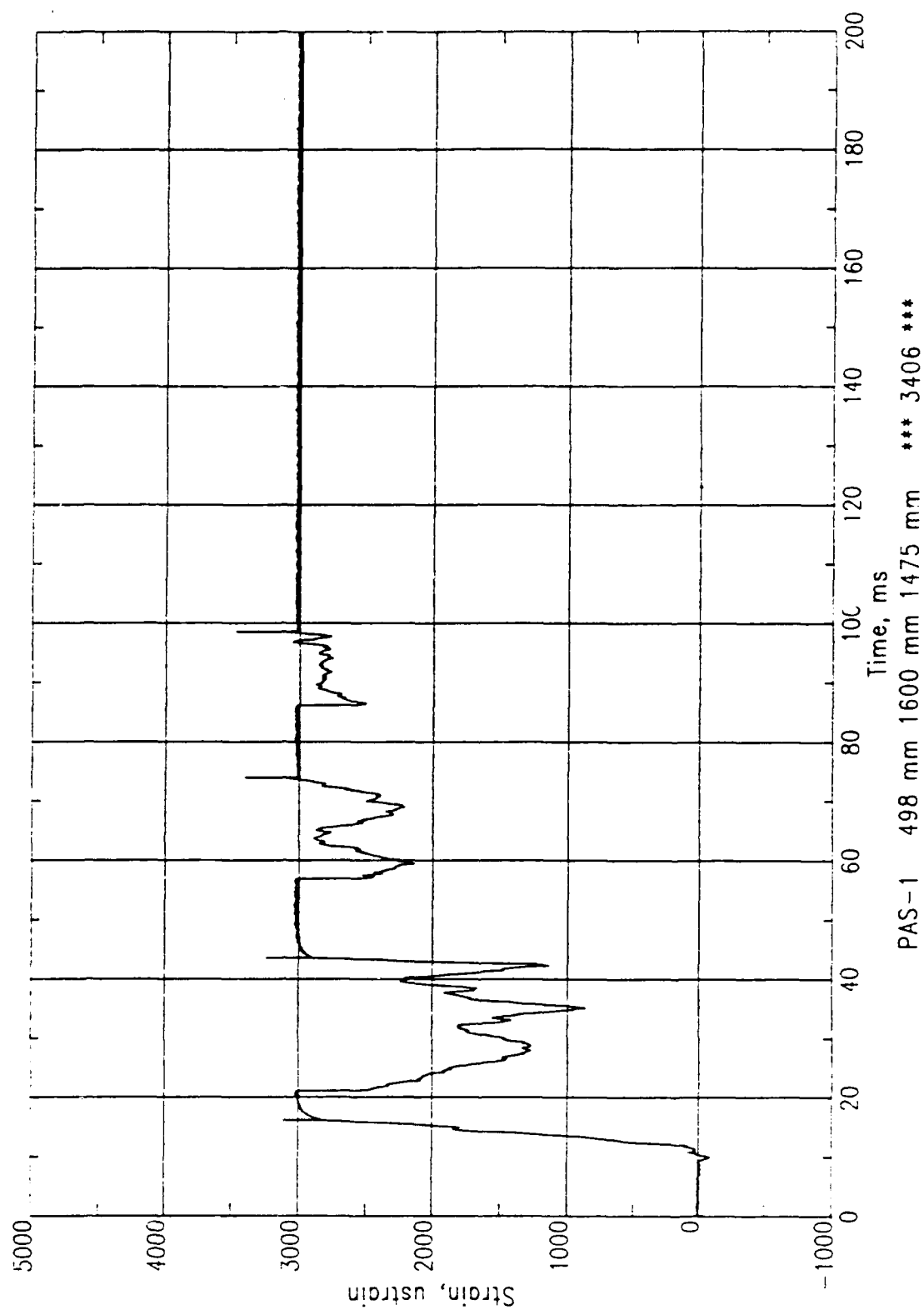


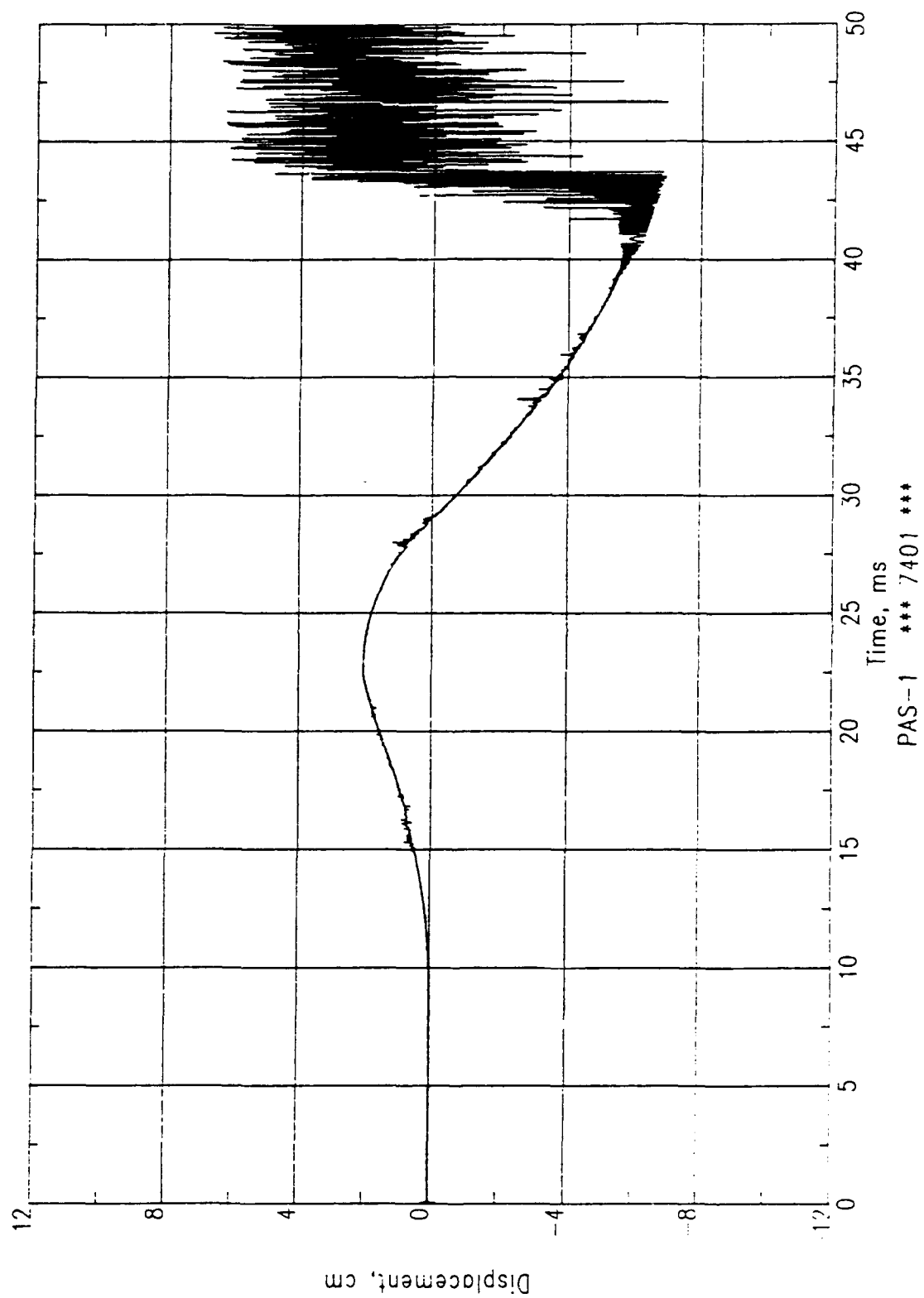


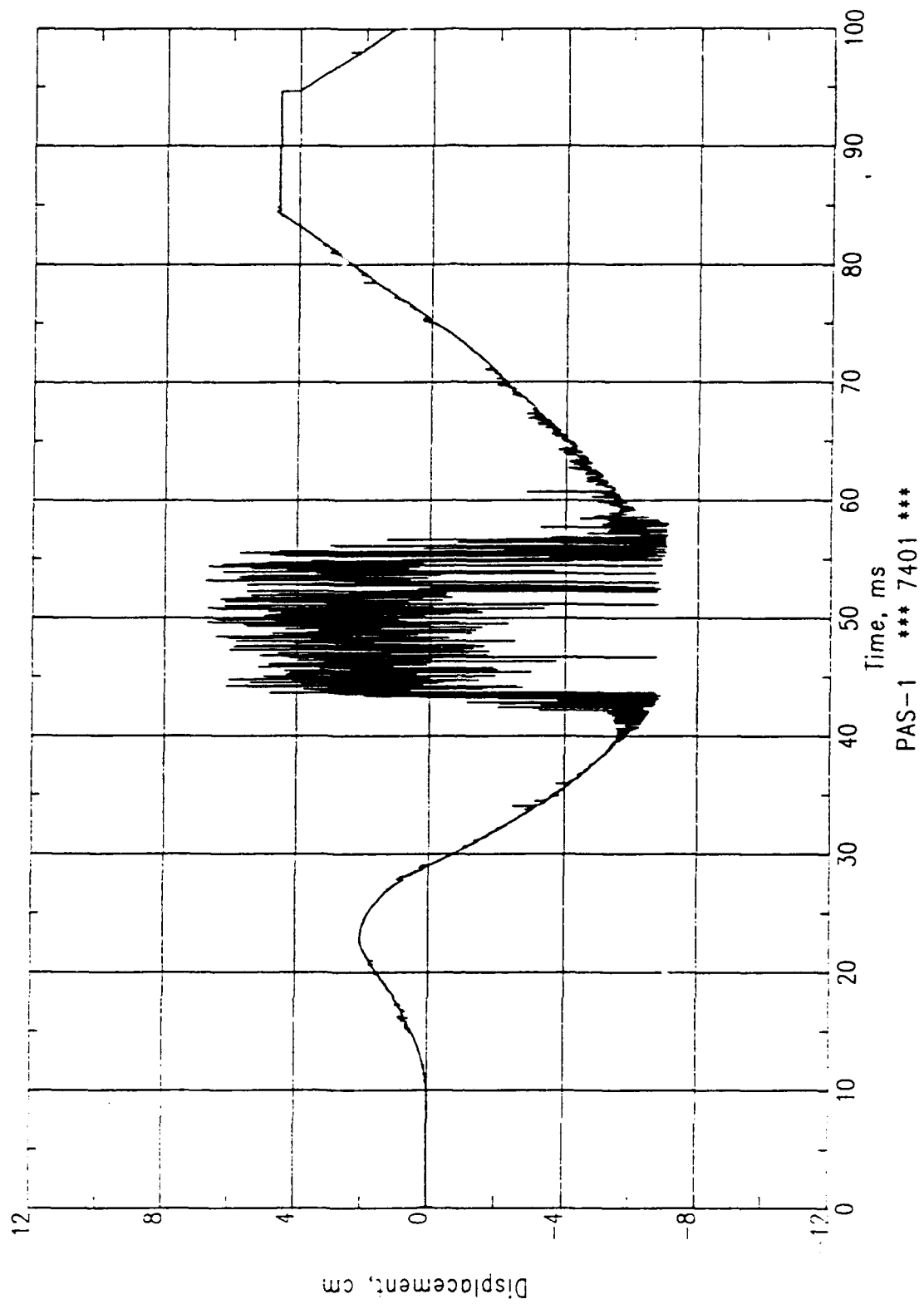


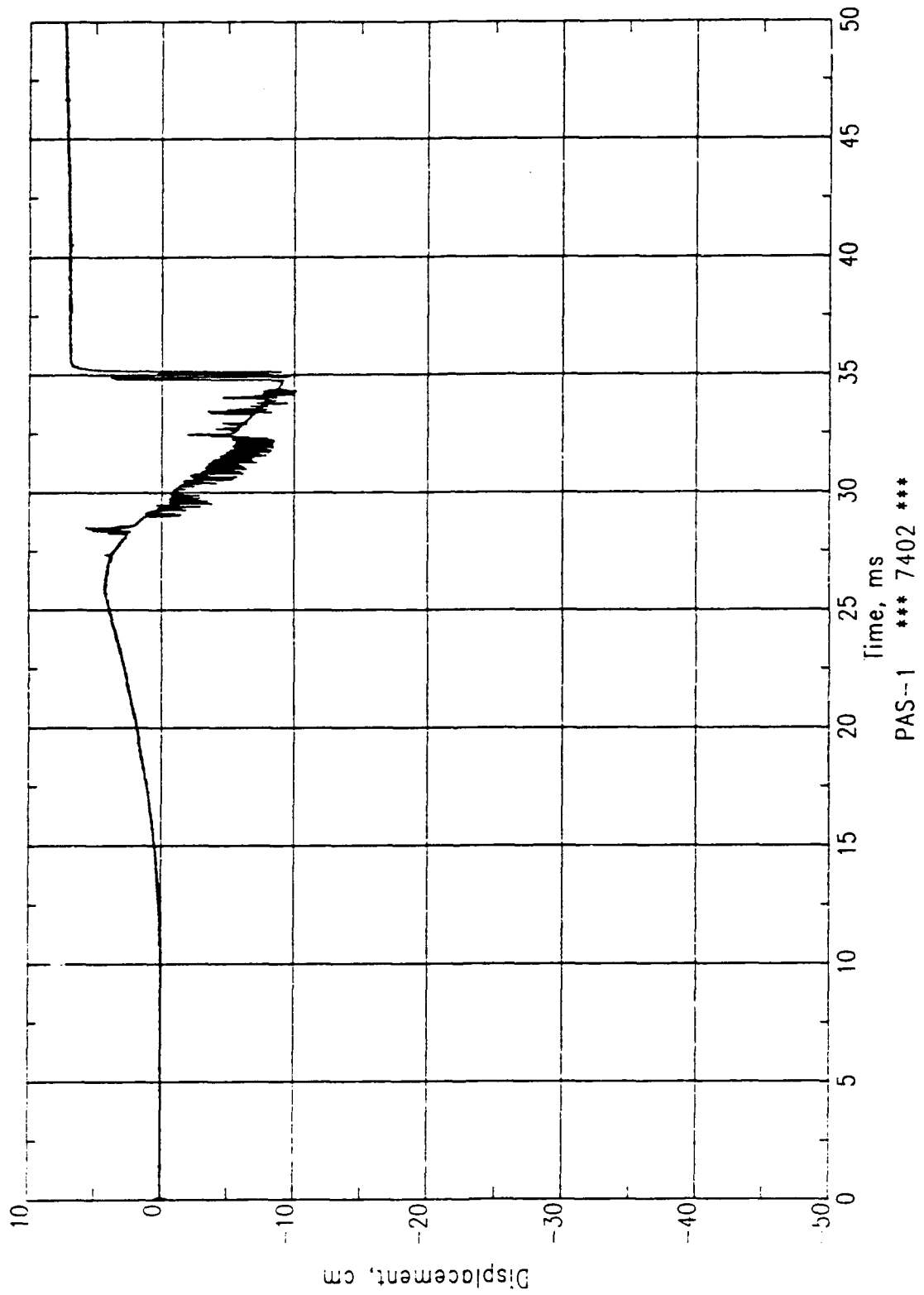


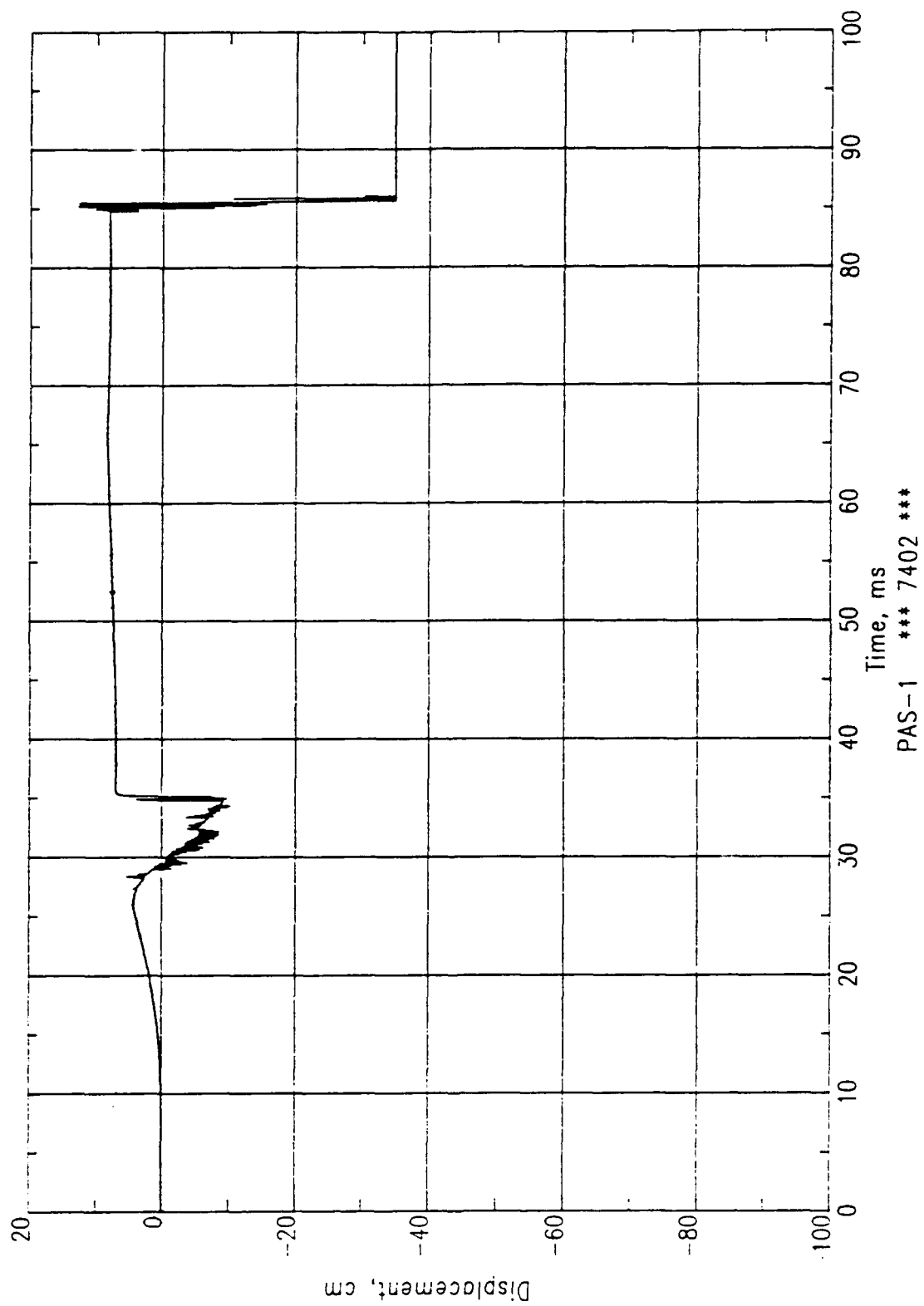
PAS-1 498 mm 1600 mm 1475 mm *** 3406 ***

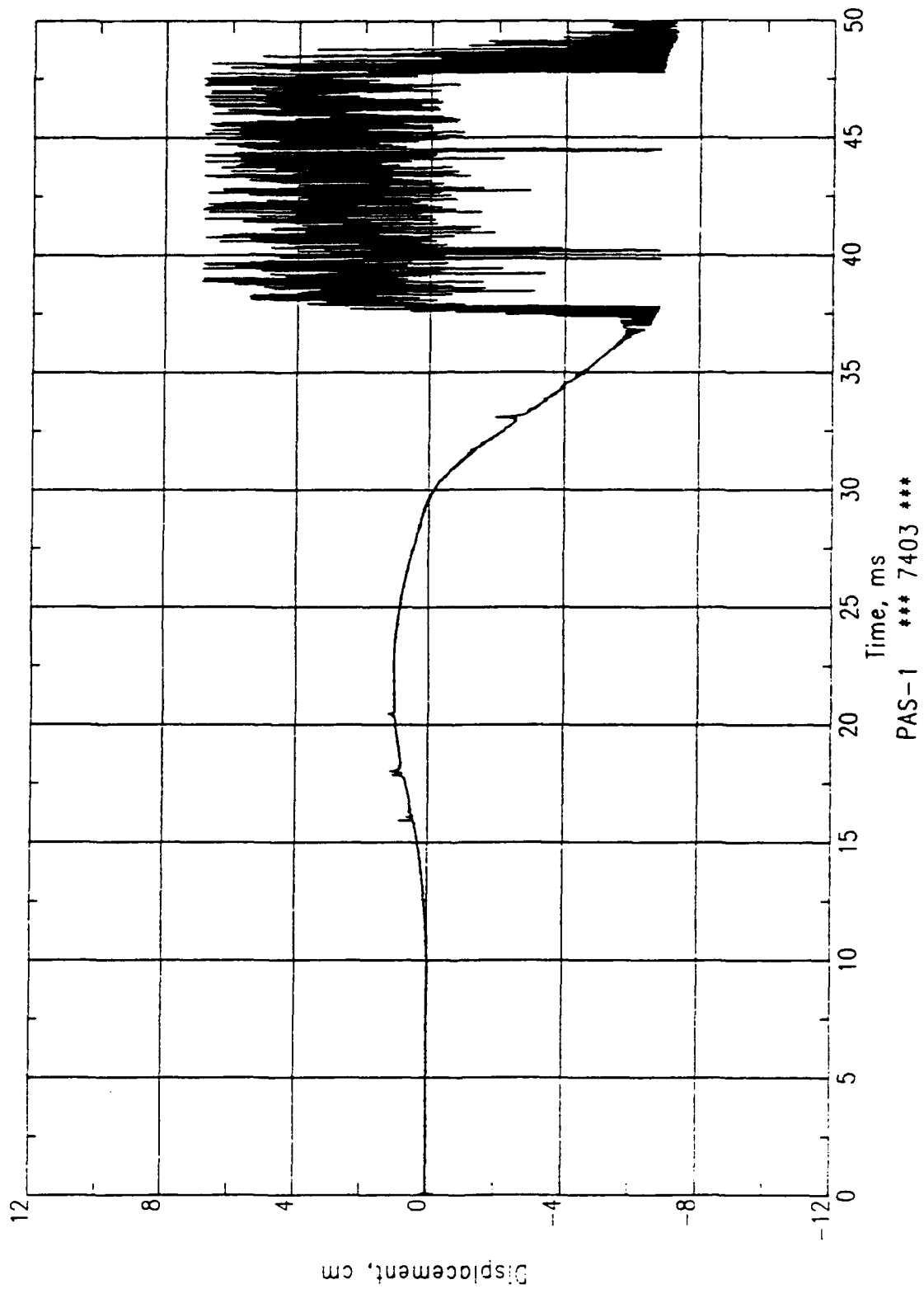


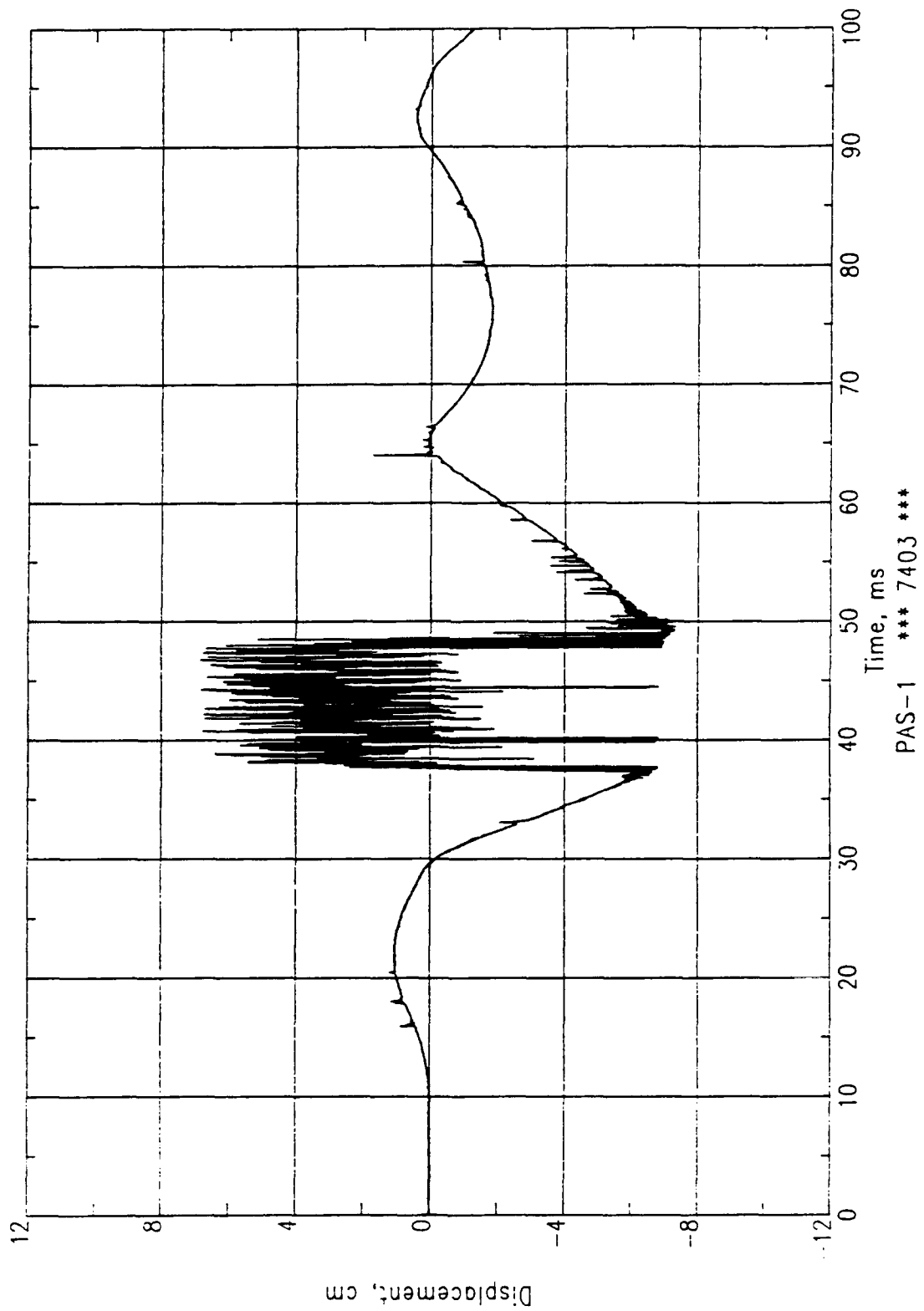


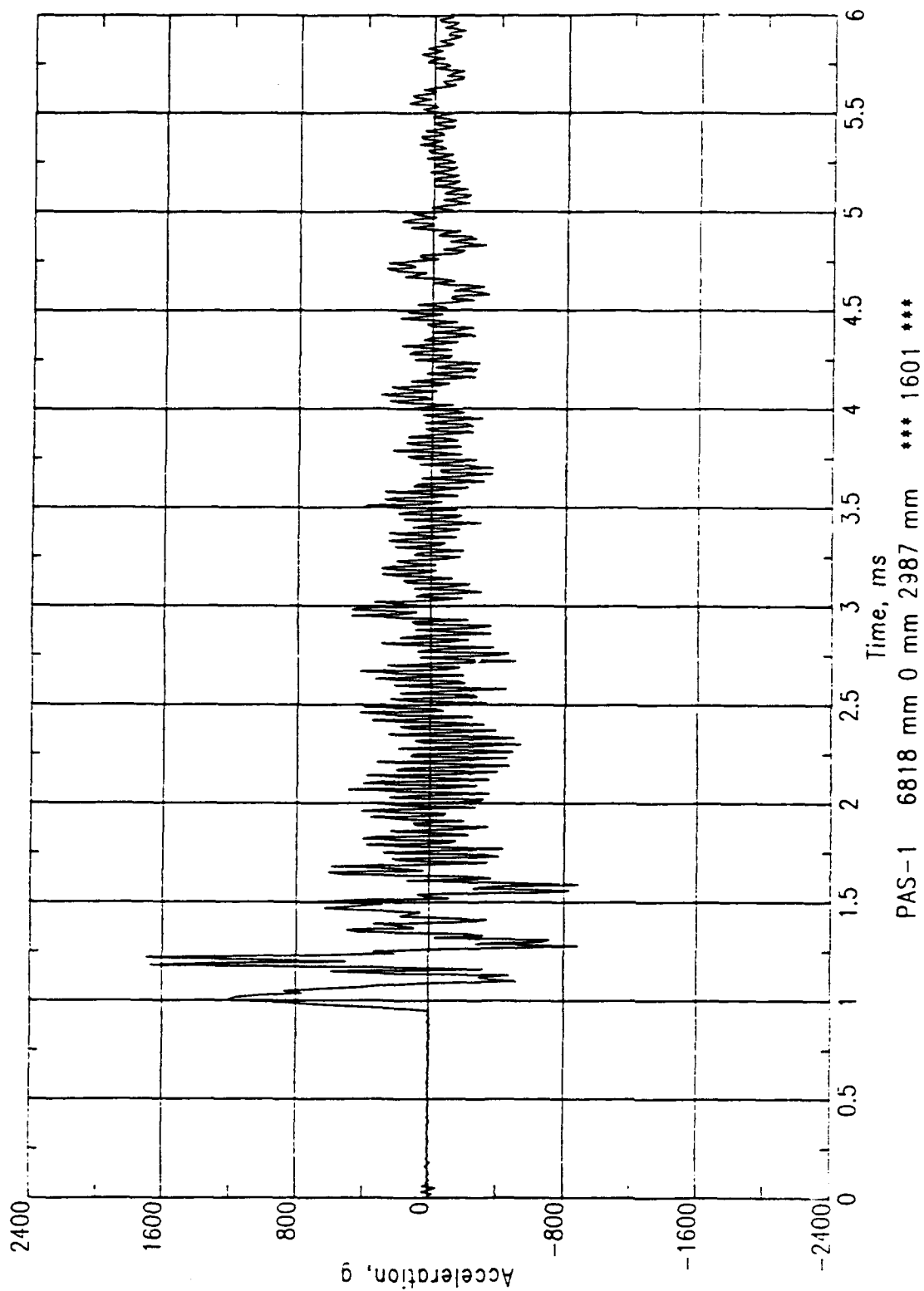


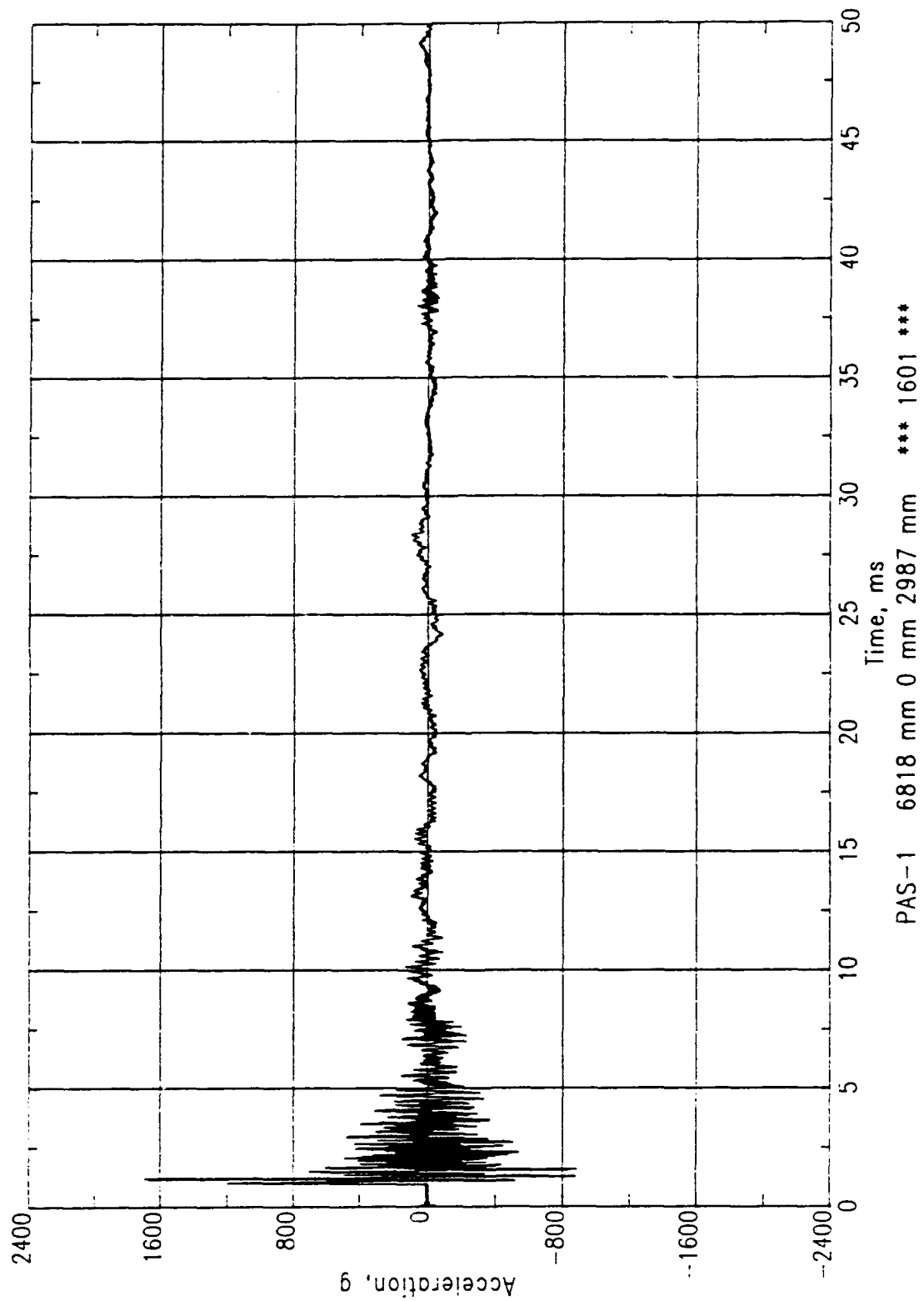


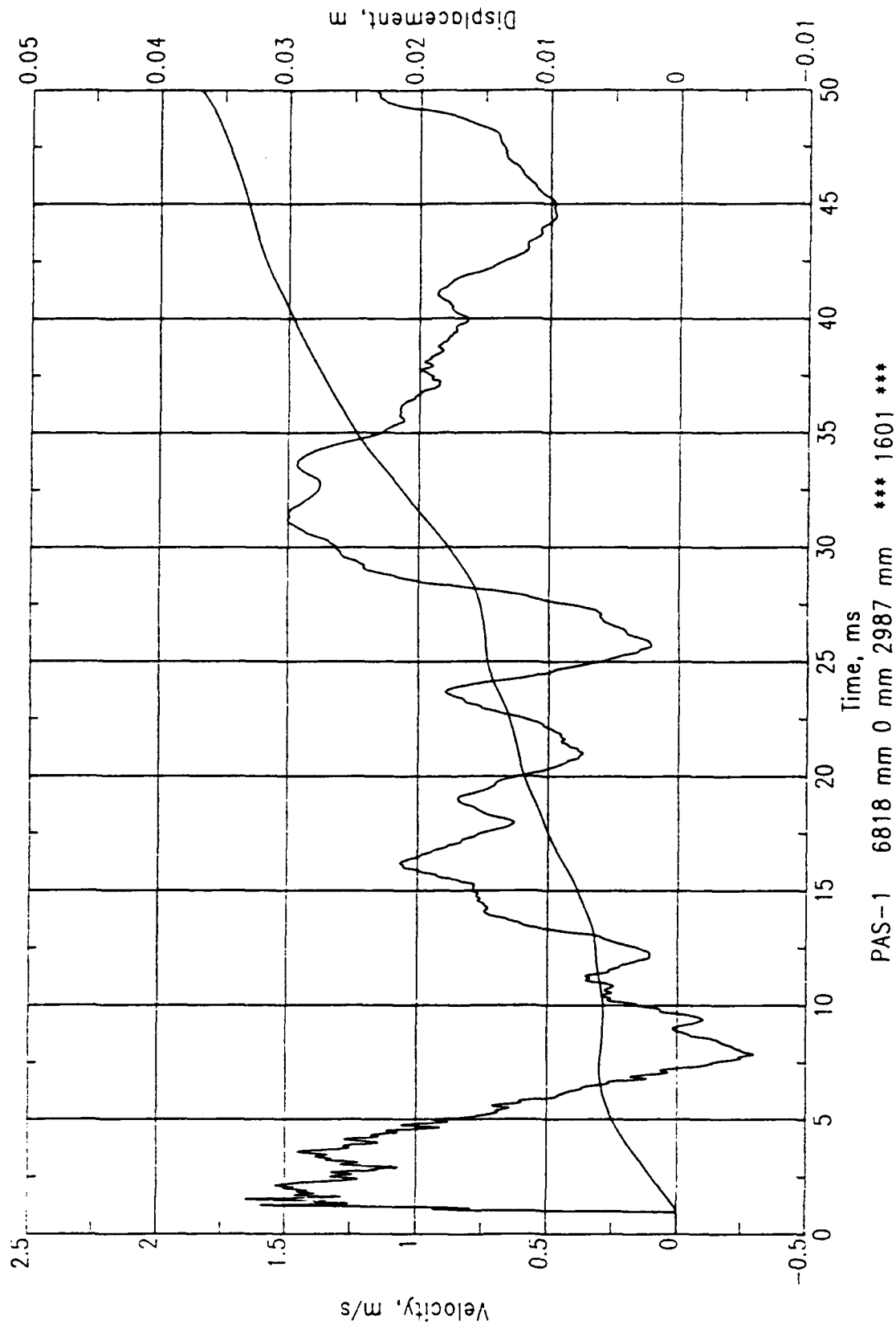


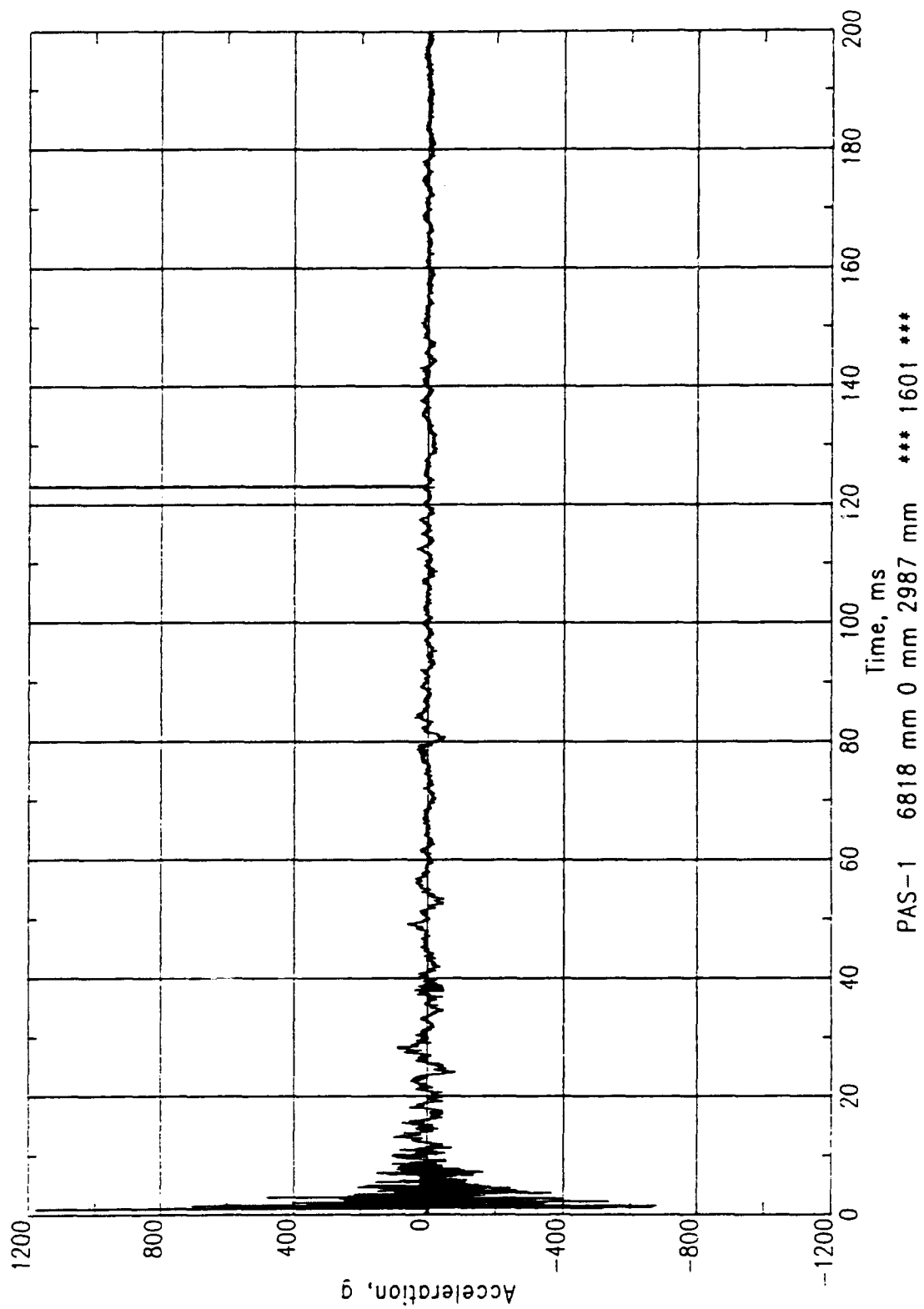


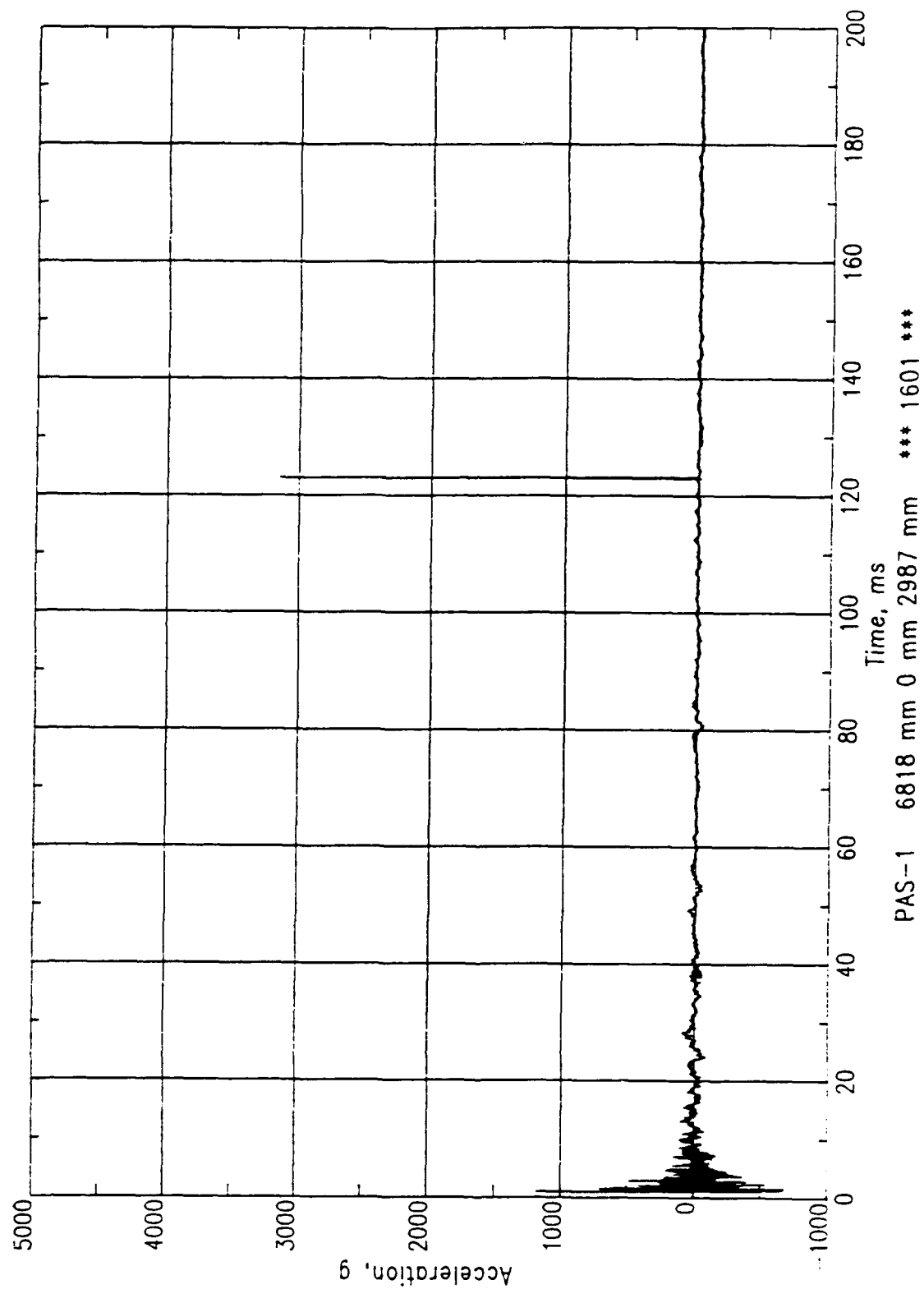


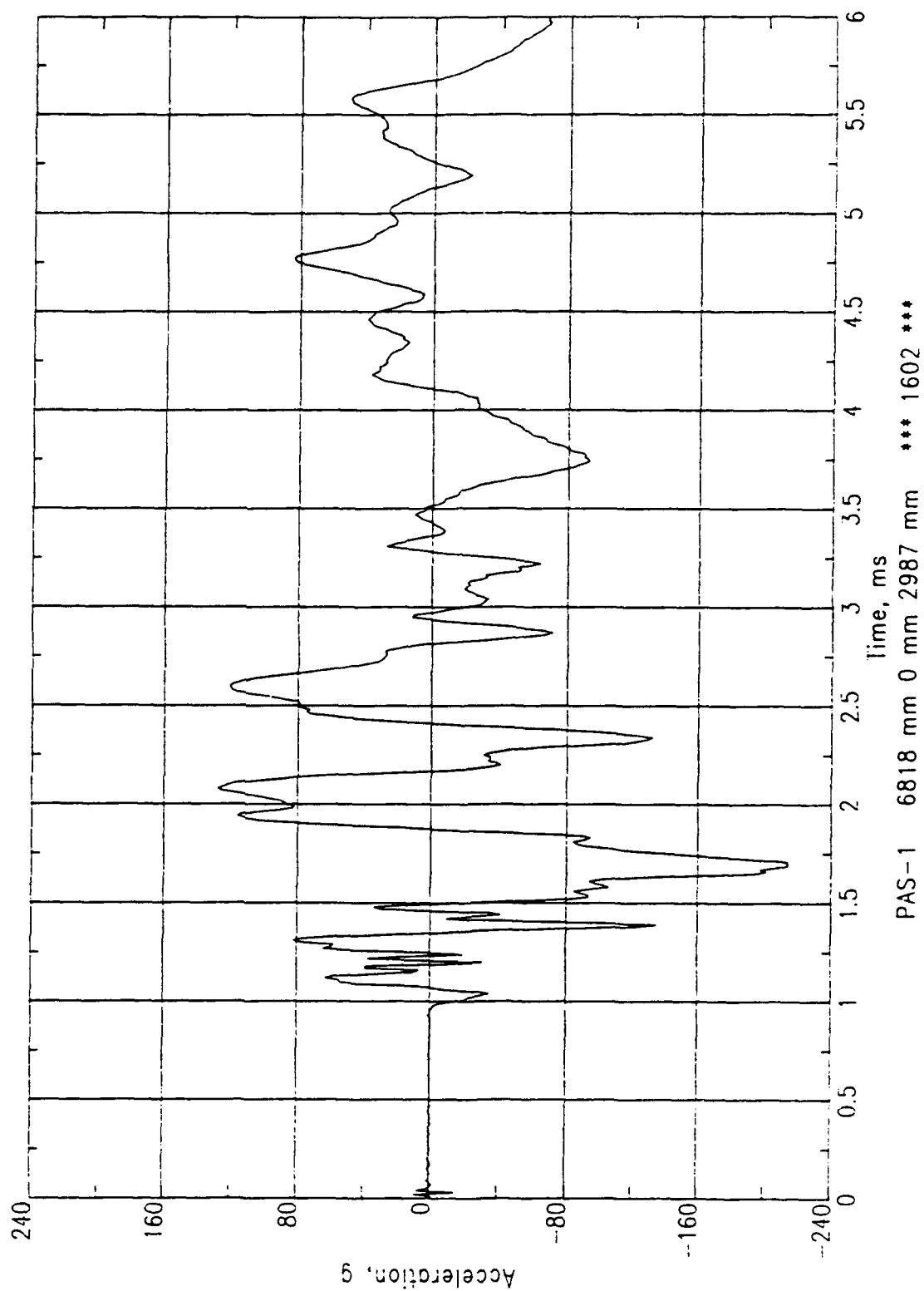


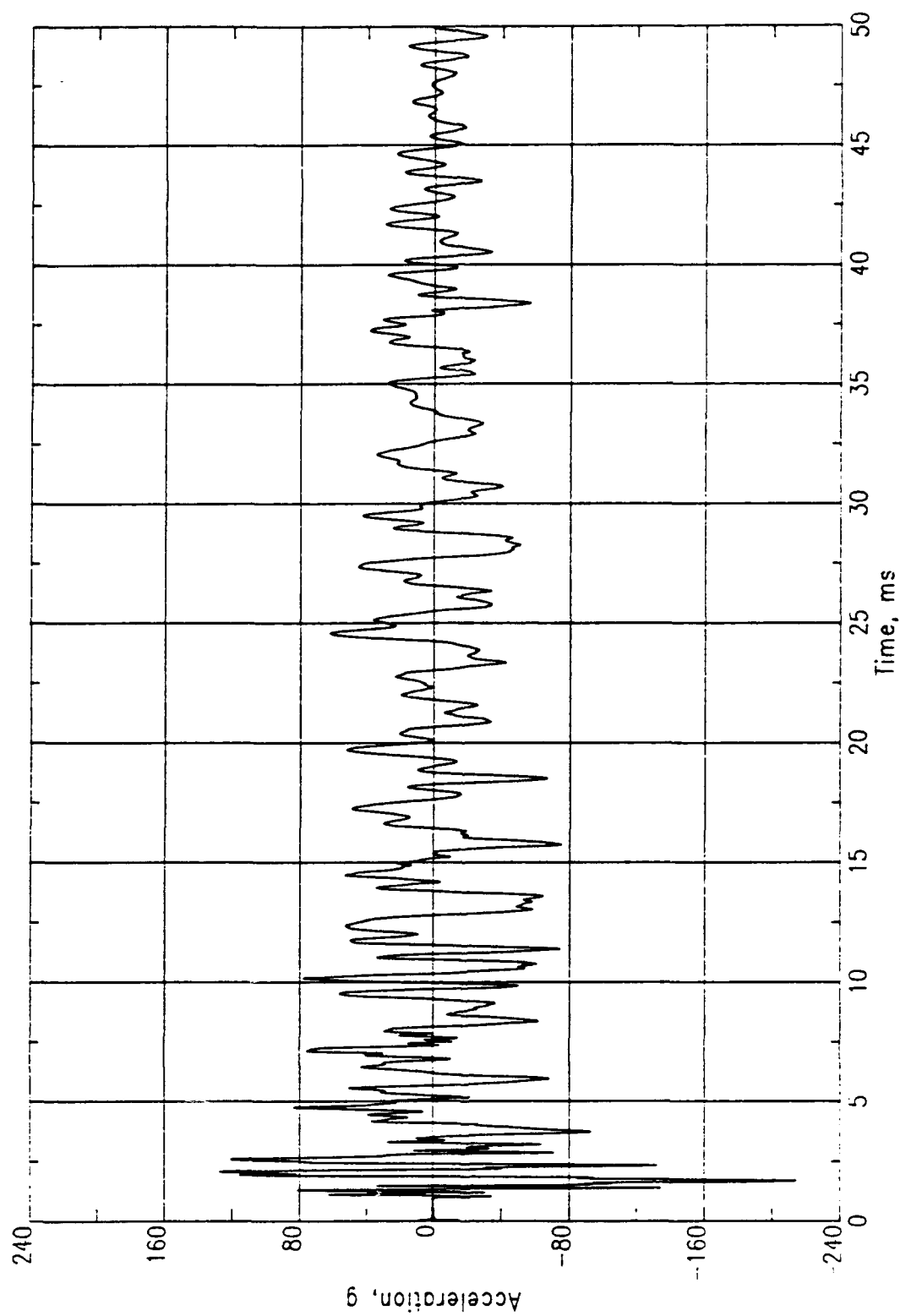




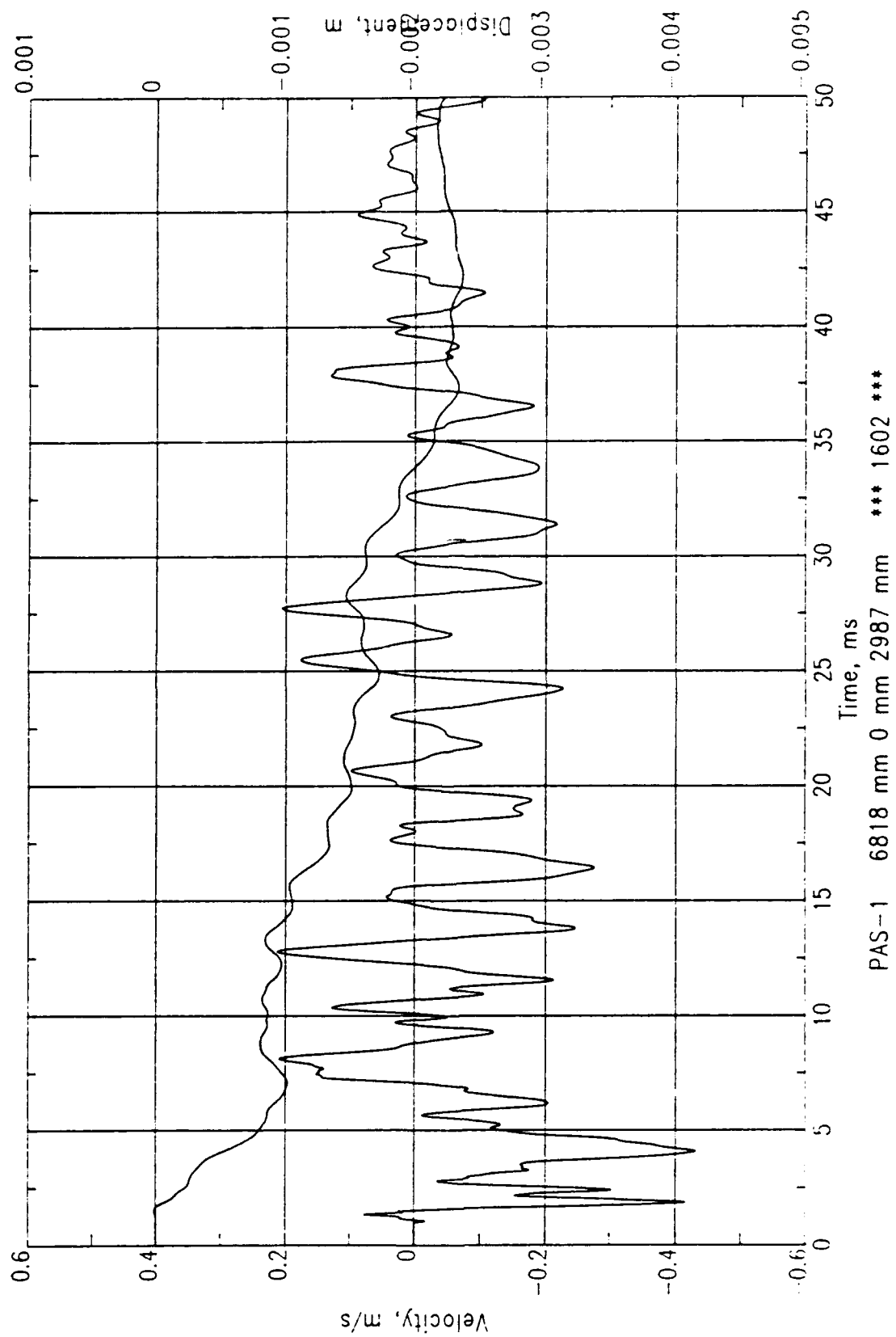


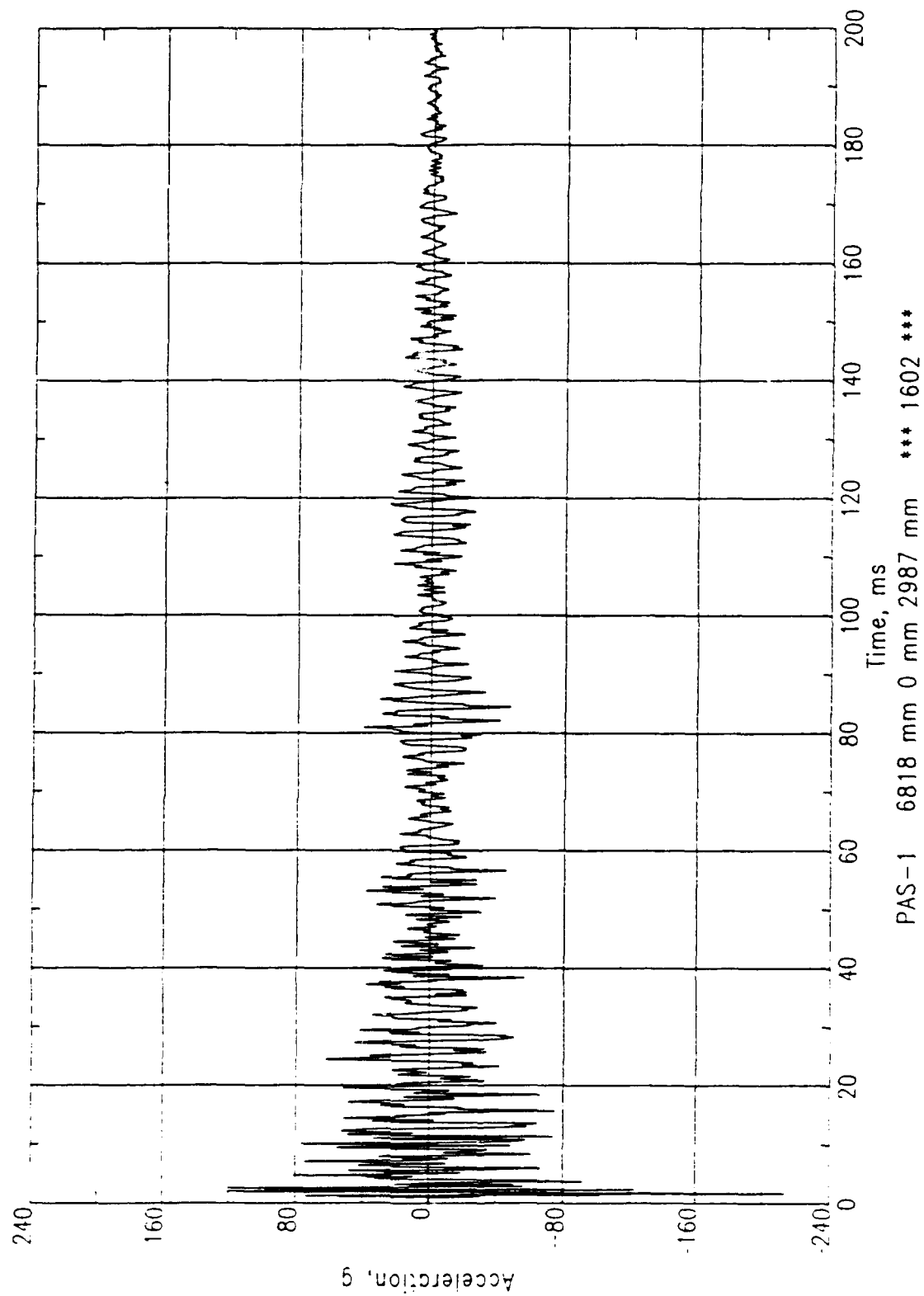


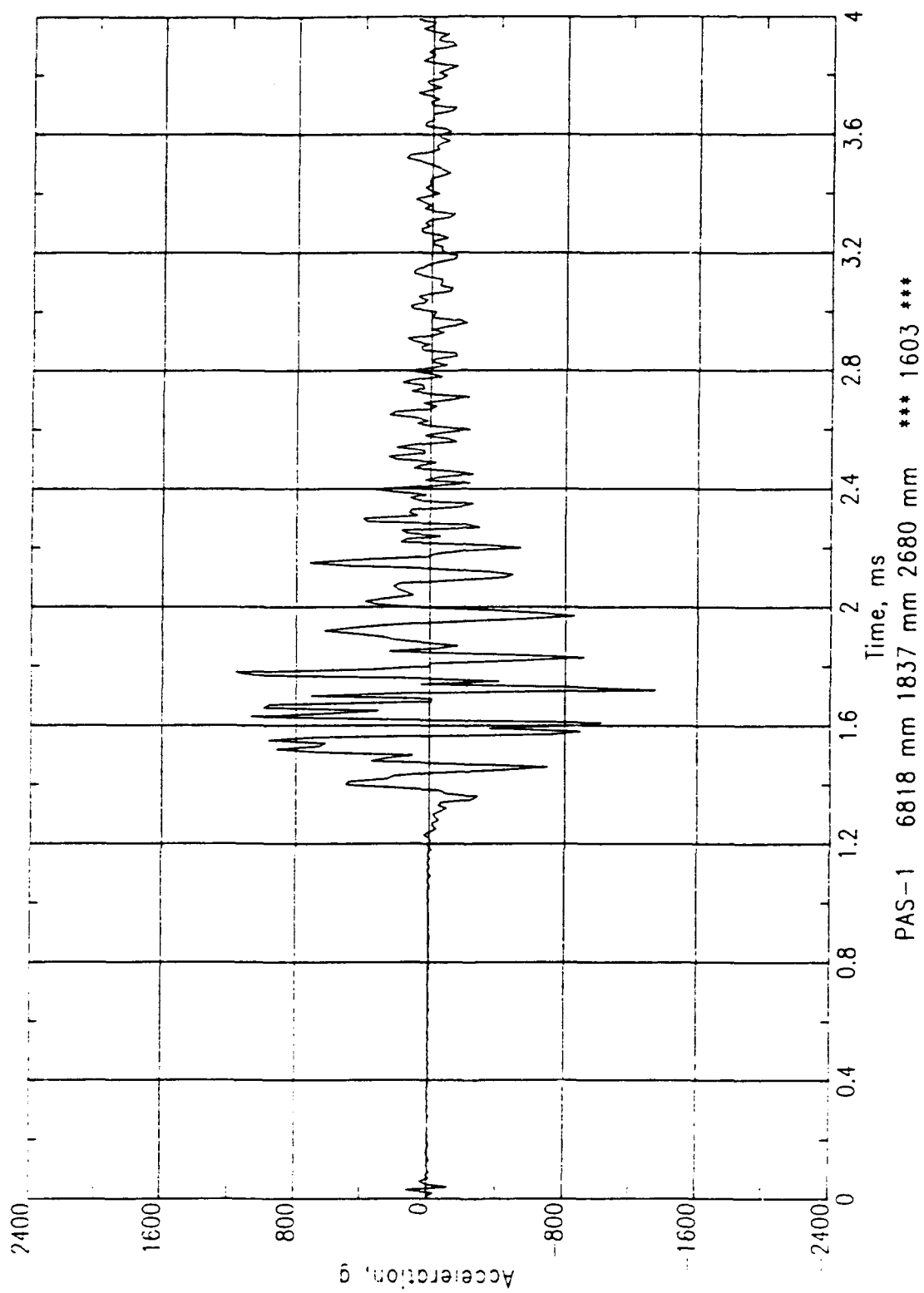


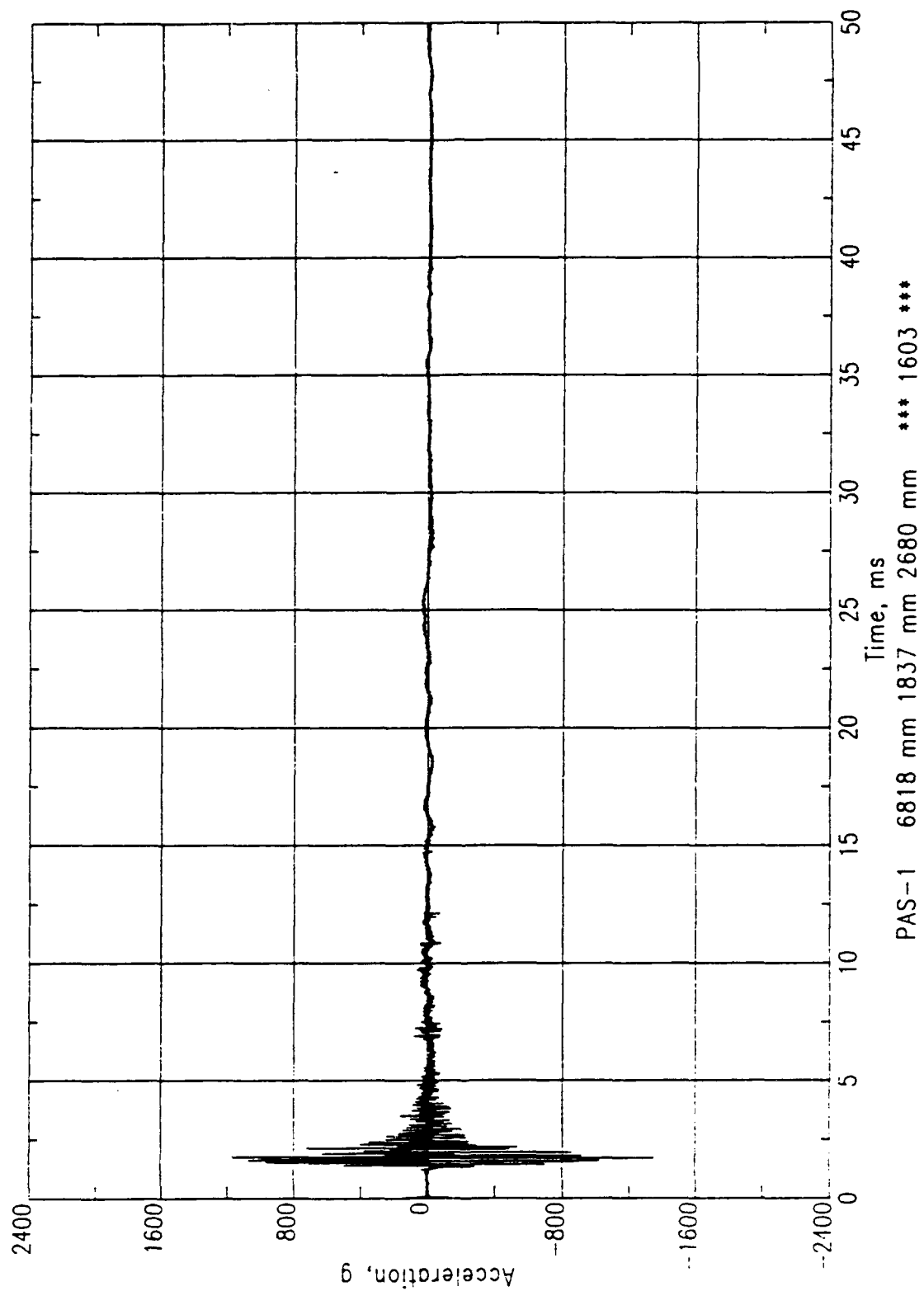


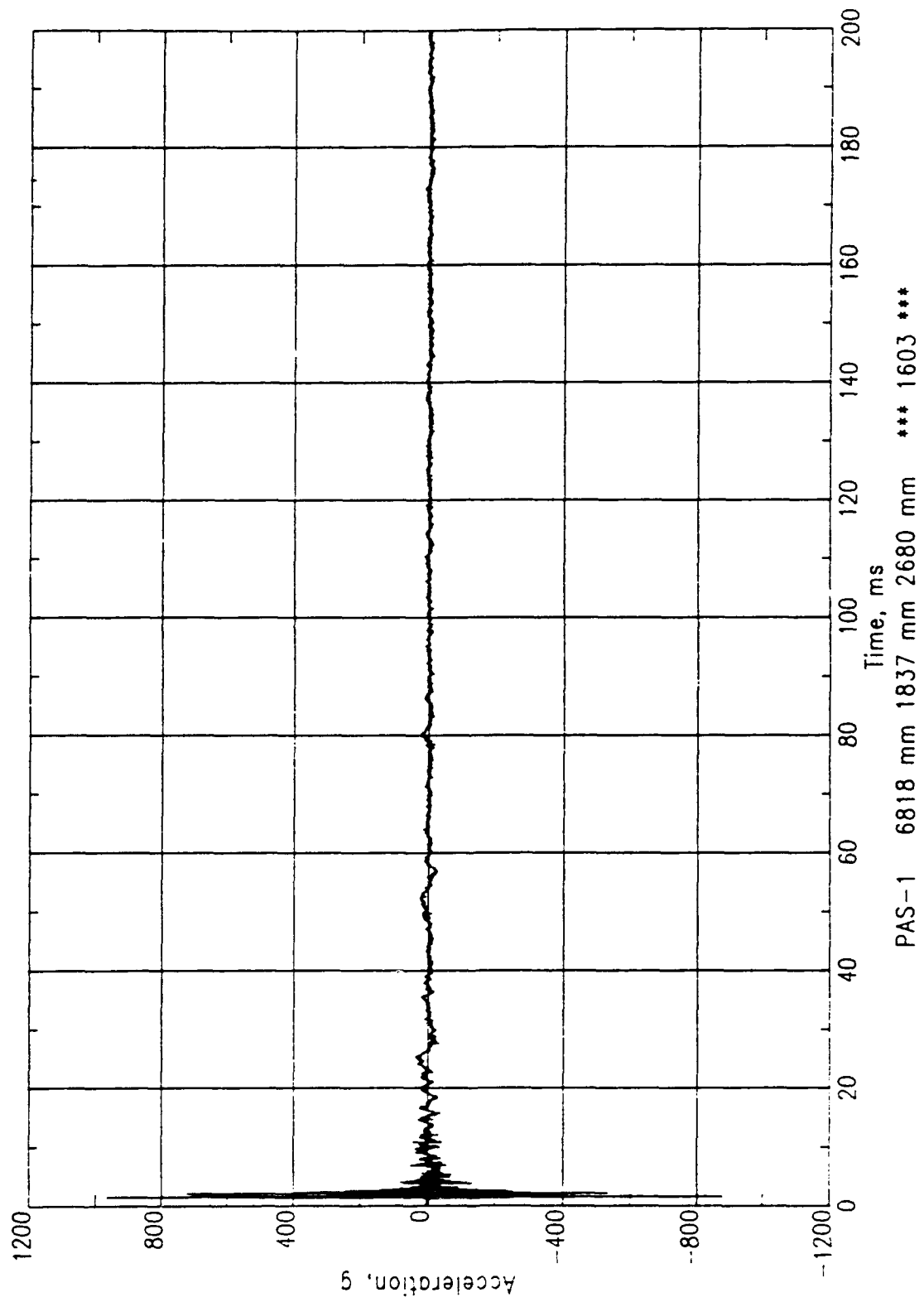
PAS-1 6818 mm 0 mm 2987 mm *** 1602 ***

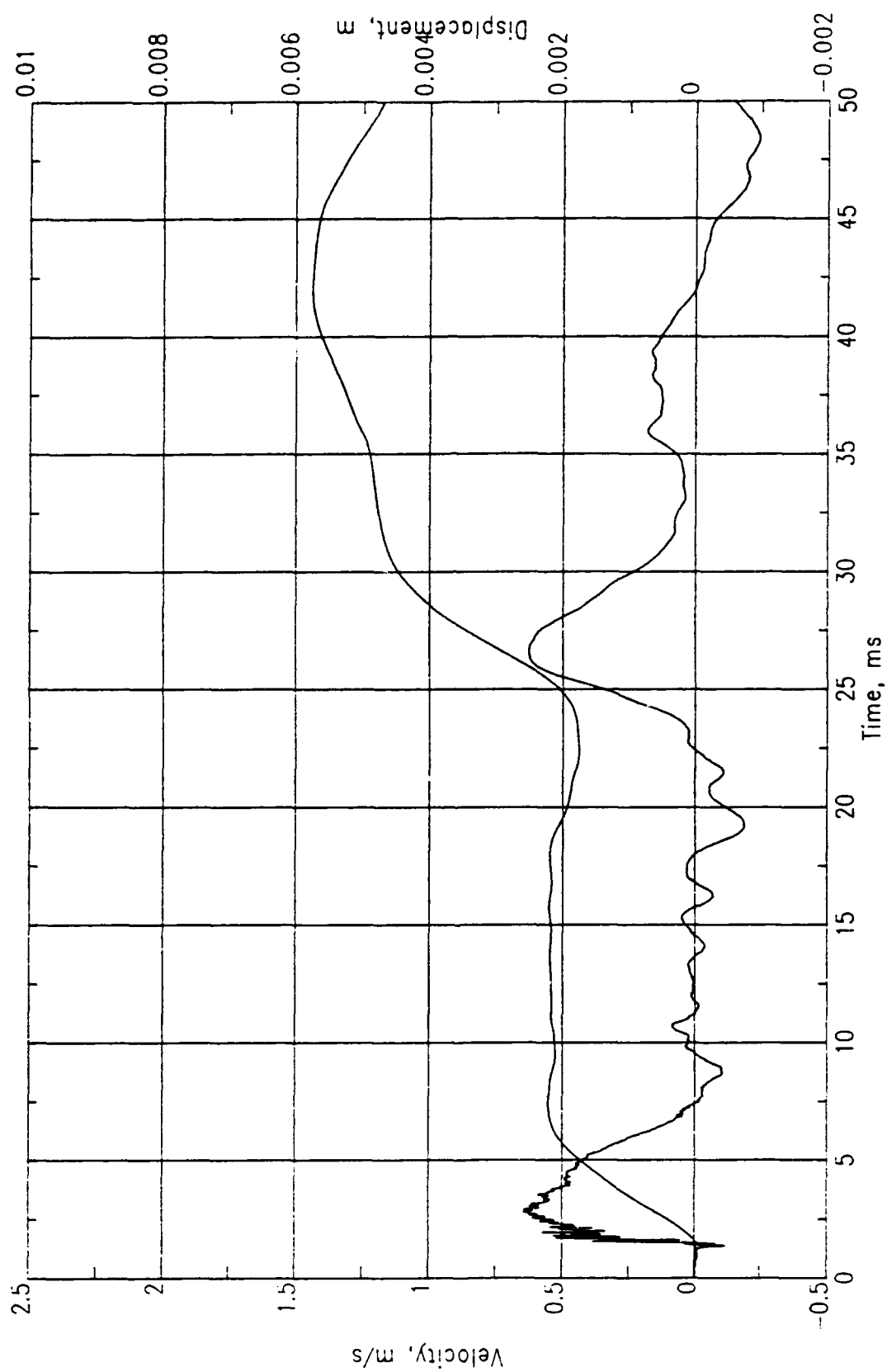












PAS-1 6818 mm 1837 mm 2680 mm *** 1603 ***