

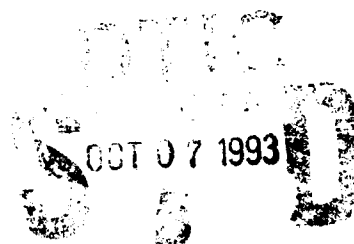


**NORWAY/UNITED STATES DESIGN PROTECTIVE
AIRCRAFT SHELTER (PAS) QUANTITY-DISTANCE
PROGRAM 1/3-SCALE TEST SERIES**

**Volume IV of V
Appendix C: PAS-2**

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Bruce A. Schneider**

**New Mexico Engineering Research Institute
The University of New Mexico
Albuquerque, NM 87131-1376**



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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FOR THE COMMANDER



AARON PEREA
Project Officer



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

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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.

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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 168		16. PRICE CODE
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1.0 PAS-2 ELECTRONIC INSTRUMENTATION, DATA PLOTS

The PAS-2 measurements are listed in Table C-1. The locations of the various on-structure measurements are shown in Figures C-1 through C-8. PAS-2 data plots are presented in sequential order by measurement number. The measurement number is centered below the plot; that is, PAS-2 *** 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 C-1. List of measurements, PAS-2.

MEASUREMENT LIST													
PAS-2							KIRST						
TEST EVENT		LOCATION			SENS		PREC		CONF		TRANSDUCER		CHANGES
MEAS NO.	GEN	X#	Y#	Z#	AXIS	MAX	LEVEL	MODEL	RANGE	TYPE	SERIAL NUMBER	ITEM	
0101-2	SF	12807	0	367	Z	0.896 MPa	50 %	KULITE XT-190	2.068 MPa	(Filter) PRESSURE	(1743-5-46) 6-75		
0102-2	SF	12807	3700	367	Z	2.827 MPa	91 %	HKS-11-375	3.447 MPa	(Filter) PRESSURE	1400-2-16		
0201-2	BW	13010	100	2500	X	1.241 MPa	100 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	C6-19		
0202-2	BW	13010	1700	1475	X	0.689 MPa	85 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-40) Y6-6		
0203-2	BW	13010	3700	930	X	2.137 MPa	61 %	KULITE HKS-11-375	6.895 MPa	(Filter) PRESSURE	117-7-23		
0301-2	SF	3976	0	367	Z	0.931 MPa	90 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-94) Z6-94		
0302-2	SF	3976	1850	367	Z	0.689 MPa	95 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-151) E7-1		
0303-2	SF	3976	3700	367	Z	1.034 MPa	67 %	KULITE XT-190	2.068 MPa	(Filter) PRESSURE	(1743-5-72) D7-54		
0304-2	SC	3976	0	2717	Z	0.724 MPa	79 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-184) G7-37		
0305-2	SC	3976	1749	2424	R1	1.172 MPa	89 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1893-3-31) O7-30		
0306-2	SC	3976	3346	1548	R2	0.965 MPa	75 %	KULITE XT-190	2.068 MPa	(Filter) PRESSURE	(1743-5-116) D7-53		
0307-2	SC	3976	3763	1029	R3	0.896 MPa	88 %	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-222) P7-73		

NOTES: X = Distance in millimeters
 SF = Shelter floor
 BU = Backwall
 SC = Shelter Ceiling

Table C-1. Continued.

MEASUREMENT LIST														DATE	22 MAY 92	PAGE 2 OF 5 PAGES
PAS-2														KIRST		
TEST EVENT	MEAS NO.	LOCATION				SENS AXIS	PREC MAX	CONF LEVEL	TRANSDUCER		RANGE	TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES		
		GEN	X#	Y#	Z#				MODEL					ITEM	AUTH	DATE
	0402-2	FD	498	100	1475	X	0.586 MPa	66	KULITE XT-190	1.379 MPa	(Nylon Mount) PRESSURE	(1893-3-108) X8-86				
	0405-2	FW	498	3700	930	X	2.137 MPa	47	KULITE HKS-11-375	6.895 MPa	(Nylon Mount) PRESSURE	117-7-7				
	0501-2	SF	645	3700	367	Z	2.827 MPa	100	KULITE HKS-11-375	3.447 MPa	(Filter) PRESSURE	2014-3-2				
	0502-2	SC	645	0	2717	Z	1.207 MPa	100	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(543-5-39) M5-84				
	0503-2	SC	645	1749	2424	R1	1.103 MPa	100	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(2200-2-83) G10-98				
	0504-2	SC	645	3346	1548	R2	1.034 MPa	90	KULITE XT-190	2.068 MPa	(Filter) PRESSURE	(1743-5-85) D7-47				
	0601-2	SF	6818	1850	367	Z	2.413 MPa	95	KULITE HKS-11-375	3.447 MPa	(Filter) PRESSURE	2013-2-18				
	0602-2	SF	6818	3700	367	Z	0.827 MPa	69	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-112) D7-39				
	0603-2	SF	6818	3700	367	Z	0.827 MPa	69	KULITE XT-190	1.379 MPa	(Filter) PRESSURE	(1743-5-242) P7-76				
	0604-2	SC	6818	0	2717	Z	3.792 MPa	34	KULITE HKS-11-375	13.79 MPa	(Filter) PRESSURE	118-7-26				
	0605-2	SC	6818	1749	2424	R1	3.999 MPa	93	KULITE HKS-11-375	6.895 MPa	(Filter) PRESSURE	117-7-19				
	0606-2	SC	6818	3346	1548	R2	2.068 MPa	80	KULITE HKS-11-375	3.447 MPa	(Filter) PRESSURE	2013-2-15				
NOTES:														SF = Shelter floor		
														FD = Front Door		
														FH = Front Hall		
														SC = Shelter Ceiling		

NOTES: # = Distance in millimeters
 FD = Front Door
 SF = Shelter Floor
 SC = Shelter Ceiling
 FH = Front Hall

Table C-1. Continued.

MEASUREMENT LIST														DATE	22 MAY 92	PAGE 3 OF 8 PAGES
TEST EVENT		PAS-2				IE		KIRST				CHANGES				
MEAS NO.	GEN	LOCATION			SENS AXIS	PRED MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES				
		X#	Y#	Z#				MODEL	RANGE			ITEM	DATE			
0607-2	SC	6818	3763	1029	R3	1.931 MPa	82 %	KULITE	3.447 MPa	(Filter) PRESSURE	2013-2-13					
0701-2	FF	-5000	0	350	Z	48.264 kPa	70 %	KULITE	172.4 kPa	PRESSURE	(2710-1-15) A9-57	GAGE	J.K. 9/10			
0702-2	FF	-9000	0	350	Z	17.237 kPa	63 %	KULITE	68.95 kPa	PRESSURE	(2907-3-114) K9-35	GAGE	J.K. 9/27			
0703-2	FF	-14000	0	350	Z	8.274 kPa	50 %	KULITE	34.74 kPa	PRESSURE	(1495-7-75) K7-7					
0704-2	FF	-24000	0	350	Z	1.724 kPa	50 %	ENDEVCO	13.79 kPa	PRESSURE	C61M					
0705-2	FF	-3433	8000	350	Z	20.684 kPa	60 %	KULITE	68.95 kPa	PRESSURE	(3827-4-19) L18-92					
0706-2	FF	-6233	10800	350	Z	6.895 kPa	50 %	ENDEVCO	13.79 kPa	PRESSURE	RF93	GAGE	J.K. 9/27			
0707-2	FF	-16433	21000	350	Z	1.724 kPa	50 %	KULITE	34.74 kPa	PRESSURE	(4263-5-135) Y18-25	GAGE	J.K. 9/9			
0708-2	FF	6818	8000	350	Z	6.895 kPa	67 %	KULITE	34.74 kPa	PRESSURE	(1495-7-76) K7-6					
0709-2	FF	6818	12000	350	Z	5.171 kPa	60 %	KULITE	34.74 kPa	PRESSURE	(1491-2-46) U6-16					
0710-2	FF	6818	16000	350	Z	3.447 kPa	50 %	KULITE	34.74 kPa	PRESSURE	(4363-5-139) X18-22	GAGE	J.K. 9/10			
0711-2	FF	6818	24000	350	Z	1.724 kPa	50 %	ENDEVCO	13.79 kPa	PRESSURE	RF87					

NOTES:
= Distance in millimeters
FF = Free Field
SC = Shelter Ceiling

NOTES: # = Distance in millimeters

FF = Free Field

SC = Shelter Ceiling

Table C-1. Continued.

MEASUREMENT LIST																	DATE	22 MAY 92	PAGE 4 OF 8 PAGES	
TEST EVENT		PAS-2				IE		KIRST												
MEAS NO.	GEN	LOCATION			SENS AXIS	PRES MAX	CONF LEVEL	TRANSDUCER		TRANSDUCER TYPE	TRANSDUCER SERIAL NUMBER	CHANGES								
		X#	Y#	Z#				MODEL	RANGE			ITEM	AUTH	DATE						
0712-2	FF	17041	8000	350	Z	5.171 kPa	60 %	KULITE XT-190	34.74 kPa	PRESSURE	(4263-5-140) Y18-26	QAGE	J.K.	6/6						
0713-2	FF	19841	10800	350	Z	3.447 kPa	50 %	KULITE XT-190	34.74 kPa	PRESSURE	{RF91} (4363-5-151) X18-26	QAGE	J.K.	5/27						
0714-2	FF	21000	21000	350	Z	0.689 kPa	33 %	ENDEVCO 8510B	13.79 kPa	PRESSURE	C93M									
0715-2	FF	19000	0	350	Z	6.895 kPa	50 %	ENDEVCO 8510B	34.74 kPa	PRESSURE	RF77									
0716-2	FF	23000	0	350	Z	3.447 kPa	63 %	KULITE XT-190	13.79 kPa	PRESSURE	(4363-5-184) X18-31	QAGE	J.K.	6/10						
0717-2	FF	37000	0	350	Z	1.379 kPa	67 %	ENDEVCO 8510B	13.79 kPa	PRESSURE	WC95									
0718-2	FF	6818	-8000	350	Z	6.895 kPa	67 %	KULITE XT-190	34.74 kPa	PRESSURE	(4363-5-137) K18-21	QAGE	J.K.	6/10						
0719-2	FF	6818	-24000	350	Z	1.724 kPa	50 %	ENDEVCO 8510B	13.79 kPa	PRESSURE	RF86									
1301-2	SR	3976	0	2987	Z	1000 g	50 %	ENDEVCO 2264A	2000 g	ACCELEROMETER	CA90A									
1302-2	SR	3976	0	2987	Y	250 g	100 %	ENDEVCO 2260A	250 g	ACCELEROMETER	AR93F									
1303-2	SR	3976	1837	2680	R1	500 g	50 %	ENDEVCO 2264A	2000 g	ACCELEROMETER	BW72A									
1304-2	SR	3976	1837	2680	T1	150 g	60 %	ENDEVCO 2260A	250 g	ACCELEROMETER	AR80F									

NOTES:

= Distance in millimeters

FF = Free Field

SR = Structure Roof

NOTES: # = Distance in millimeters

Ff = Free Field

SR = Structure Roof

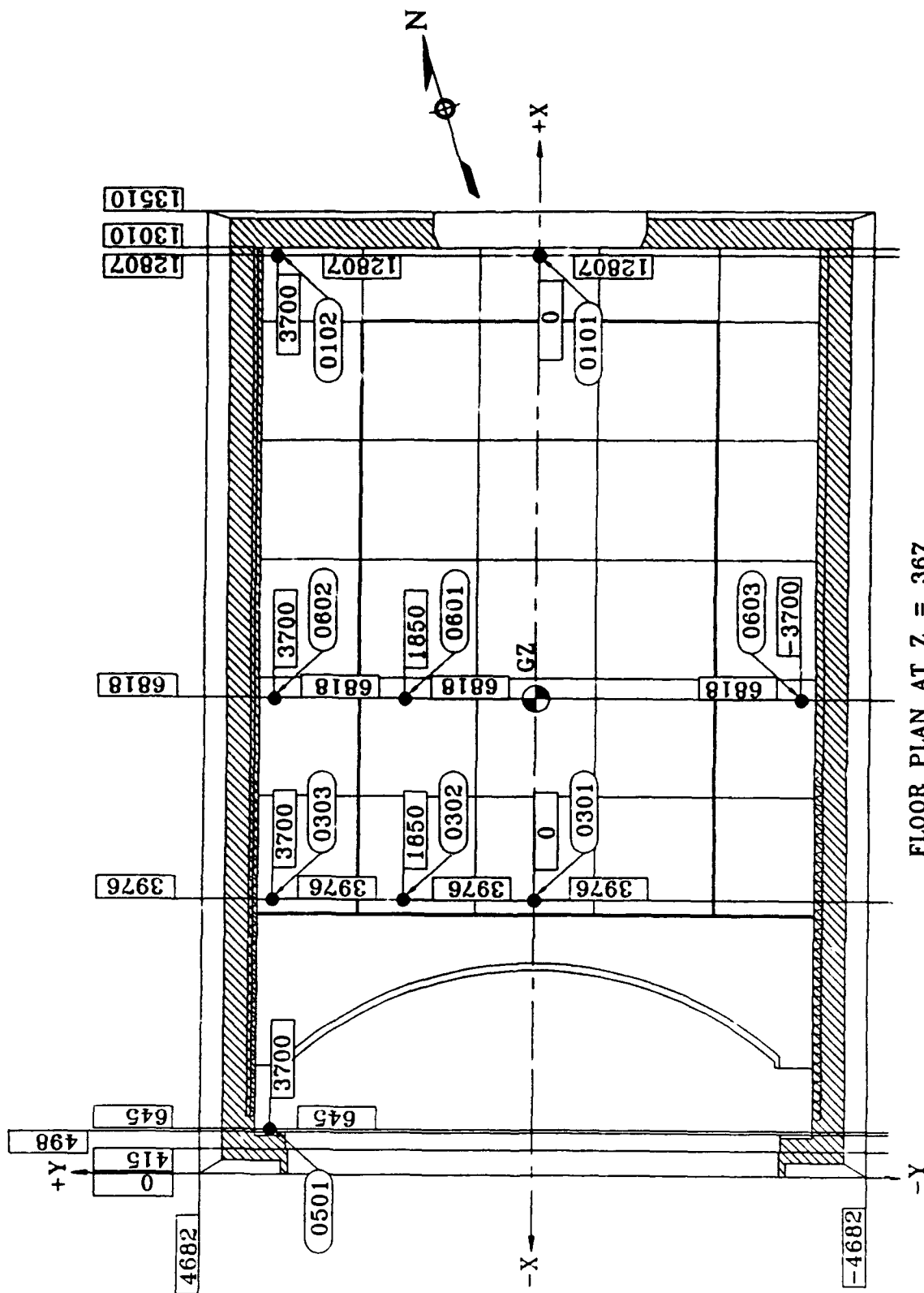
Table C-1. Concluded.

MEASUREMENT LIST													
PAS-2													
TEST EQUIP	LOCATION			SENS AXIS	PRED MAX	CONF LEVEL	TRANSducer		TRANSducer TYPE	TRANSducer SERIAL NUMBER	CHANGES		
	GEN	X#	Y#	Z#			MODEL	RANGE			ITEM	AUTH	DATE
1305-2	SR	3976	3514	1759	R2	500 g	50	ENDEVCO 2264A	2000 g	ACCELEROMETER	CA65A		
1306-2	SR	3976	3514	1759	T2	150 g	60	ENDEVCO 2260A	250 g	ACCELEROMETER	AQ95F		
1601-2	SR	6818	0	2987	Z	3500 g	70	ENDEVCO 2264A	5000 g	ACCELEROMETER	BY90B		
1602-2	SR	6818	0	2987	Y	500 g	50	ENDEVCO 2262C	1000 g	ACCELEROMETER	KT55		
1603-2	SR	6818	1837	2680	R1	1500 g	50	ENDEVCO 2264A	5000 g	ACCELEROMETER	CA20B		
1604-2	SR	6818	1837	2680	T1	300 g	50	ENDEVCO 2262C	1000 g	ACCELEROMETER	KA17		
1605-2	SR	6818	3514	1759	R2	1000 g	50	ENDEVCO 2264A	5000 g	ACCELEROMETER	BT06A		
1606-2	SR	6818	3514	1759	T2	250 g	50	ENDEVCO 2262C	1000 g	ACCELEROMETER	KA38		
3401-2	FD	415	0	1475	Z	5000 msn	25	AILTECH SG159-11-10-6S	+/-20000 msn	STRAIN GAGE	N/A		
3402-2	FD	415	0	1475	Z	5000 msn	25	AILTECH SG159-11-10-6S	+/-20000 msn	STRAIN GAGE	N/A		
3403-2	FD	498	0	1475	Z	5000 msn	25	AILTECH SG159-11-10-6S	+/-20000 msn	STRAIN GAGE	N/A		
3404-2	FD	498	0	1475	Z	5000 msn	25	AILTECH SG159-11-10-6S	+/-20000 msn	STRAIN GAGE	N/A		

NOTES: * = Distance in millimeters msn = microstrains

SR = Shelter Roof

FD = Front Door



FLOOR PLAN AT Z = 367
Figure C-1. Instrumentation in floor of structure, PAS-2.

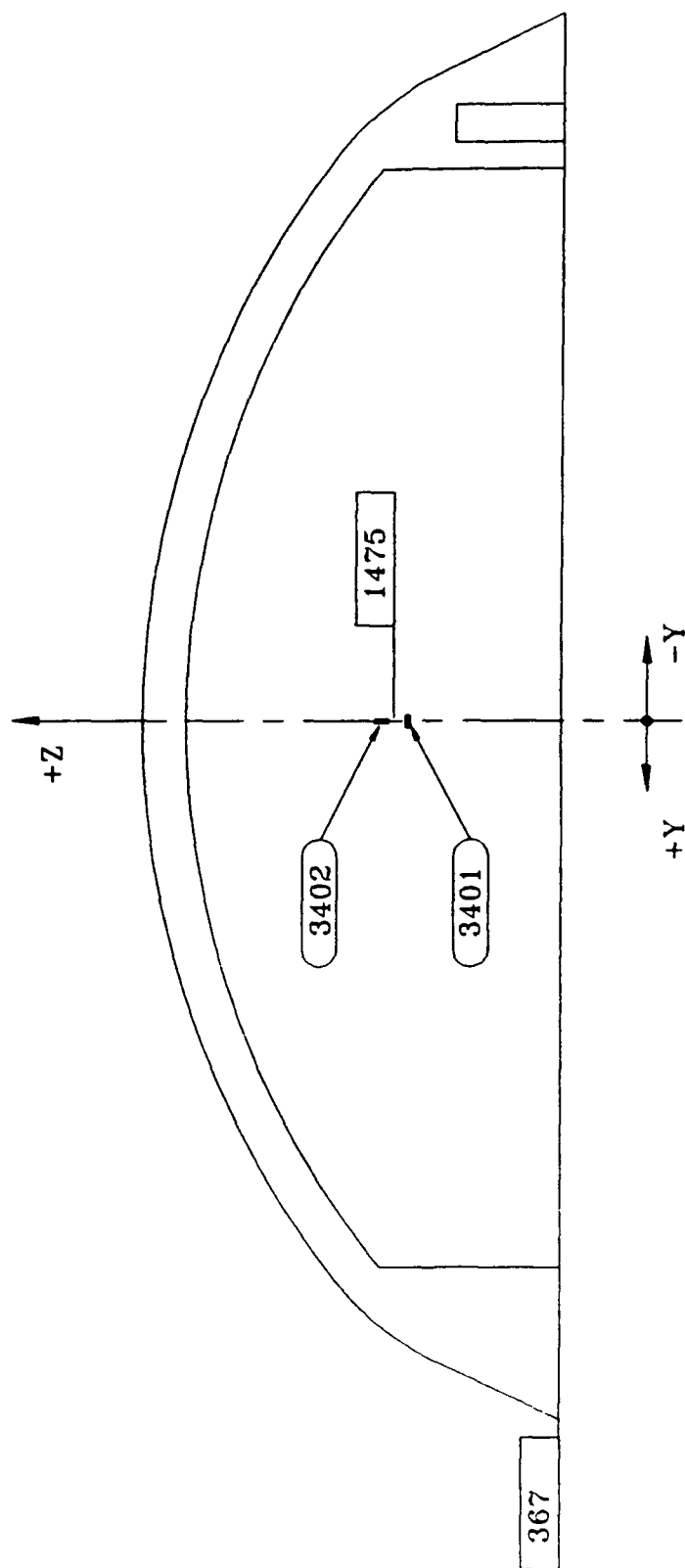


Figure C-2. Instrumentation on outside of front door at $X = 415$, PAS-2.

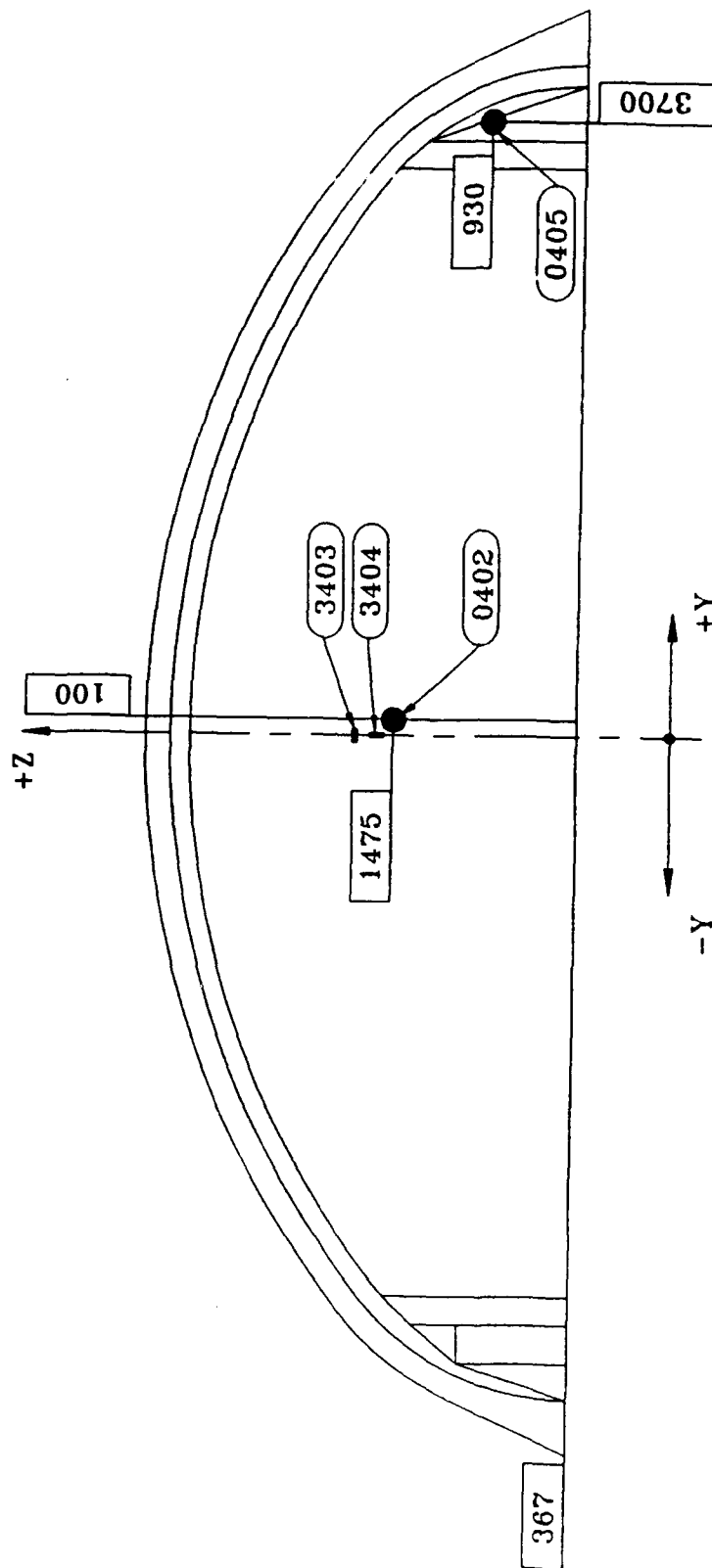


Figure C-3. Instrumentation on inside surface of front door at X = 498, PAS-2.

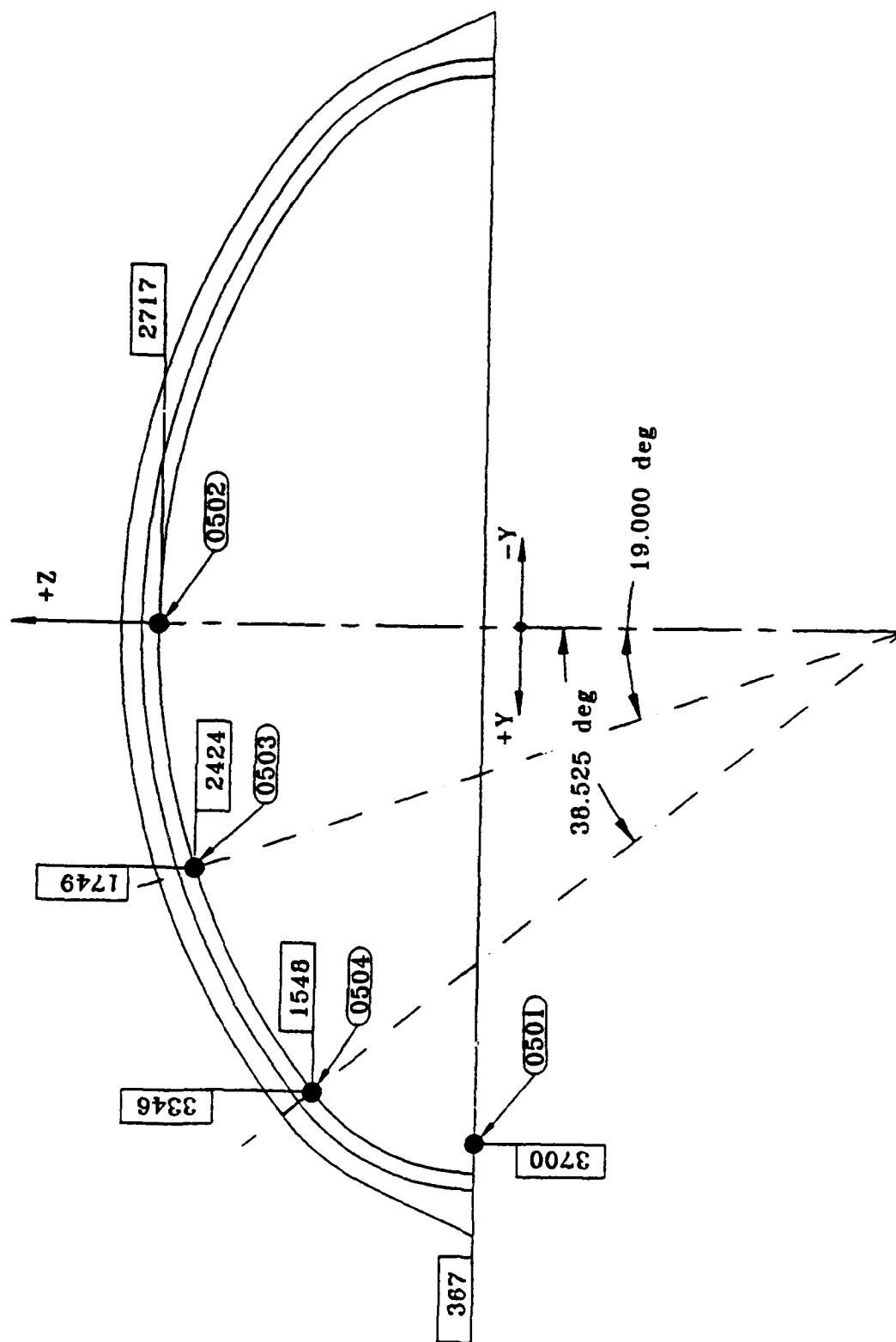


Figure C-4. Instrumentation on arch at X = 645, PAS-2.

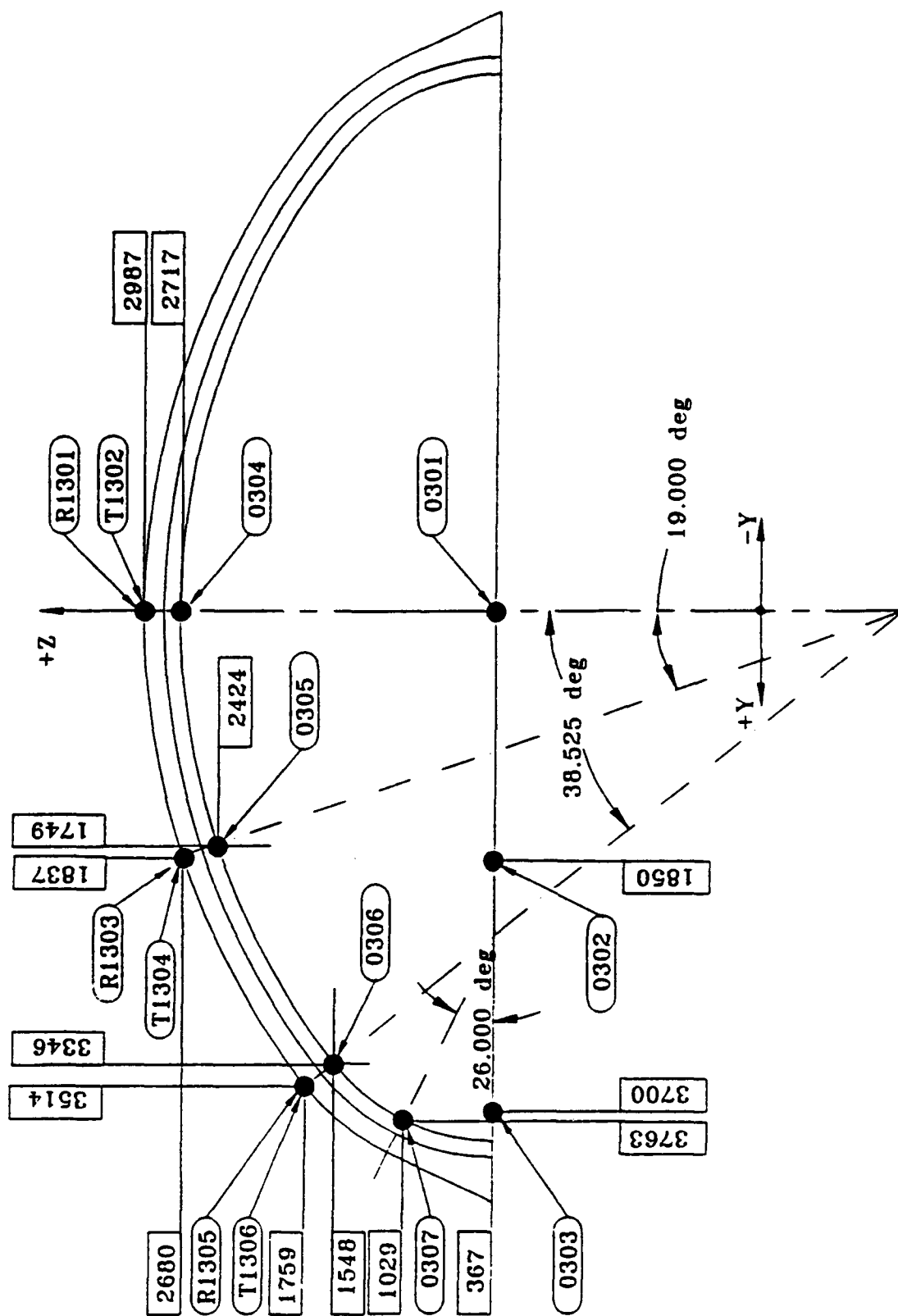


Figure C-5. Instrumentation on arch at X = 3976, PAS-2.

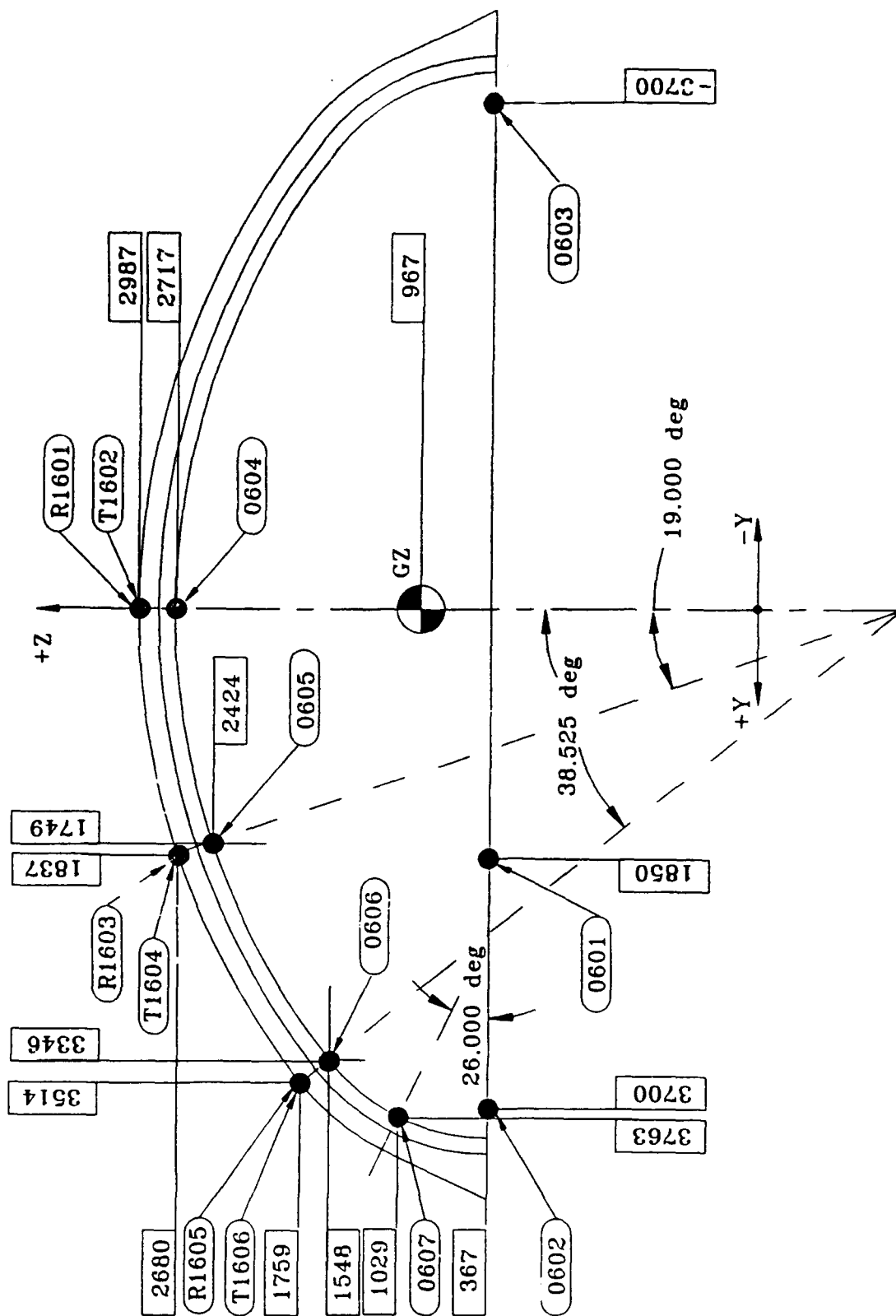


Figure C-6. Instrumentation on arch at X = 6818, PAS-2.

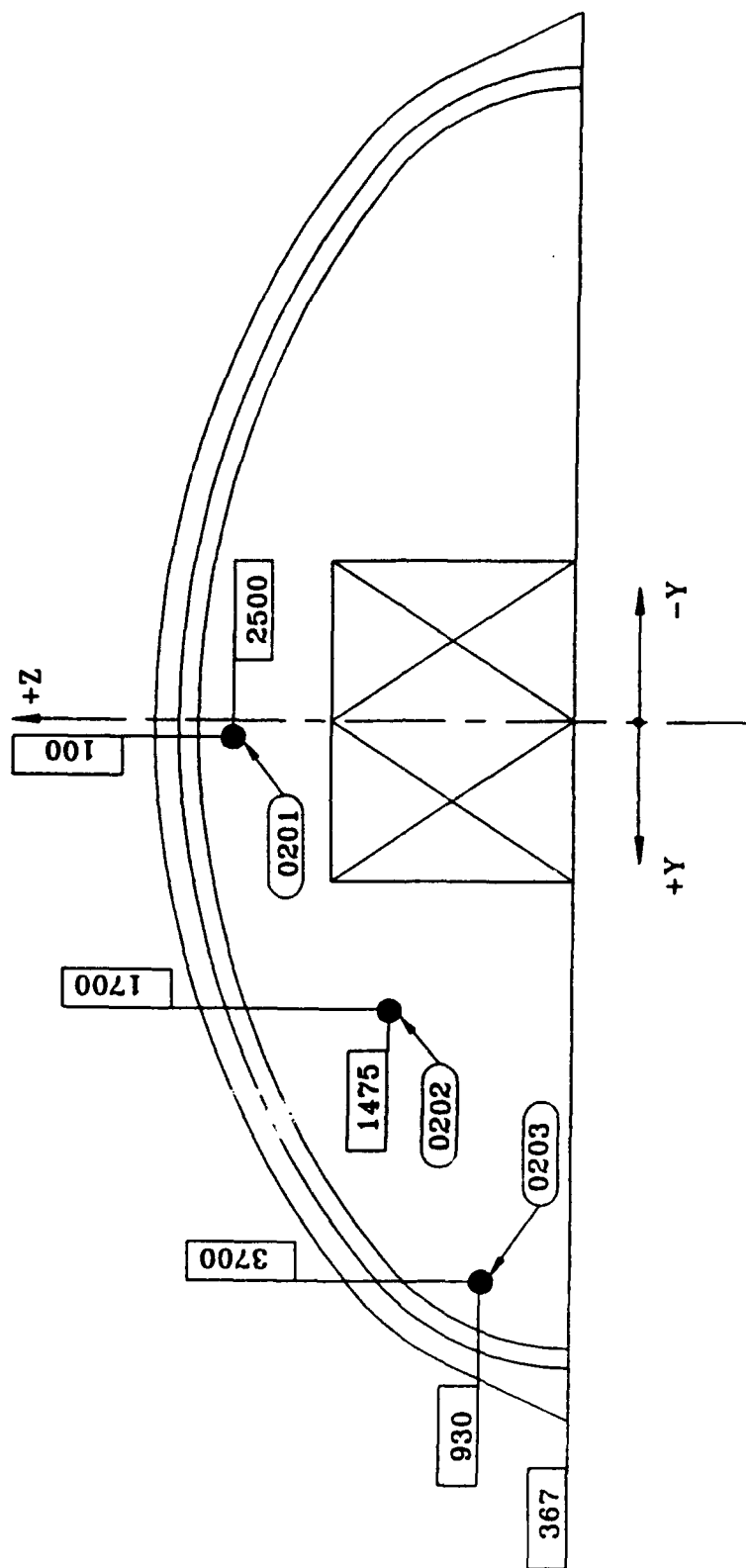


Figure C-7. Instrumentation on inner surface of backwall at X = 13010, PAS-2.

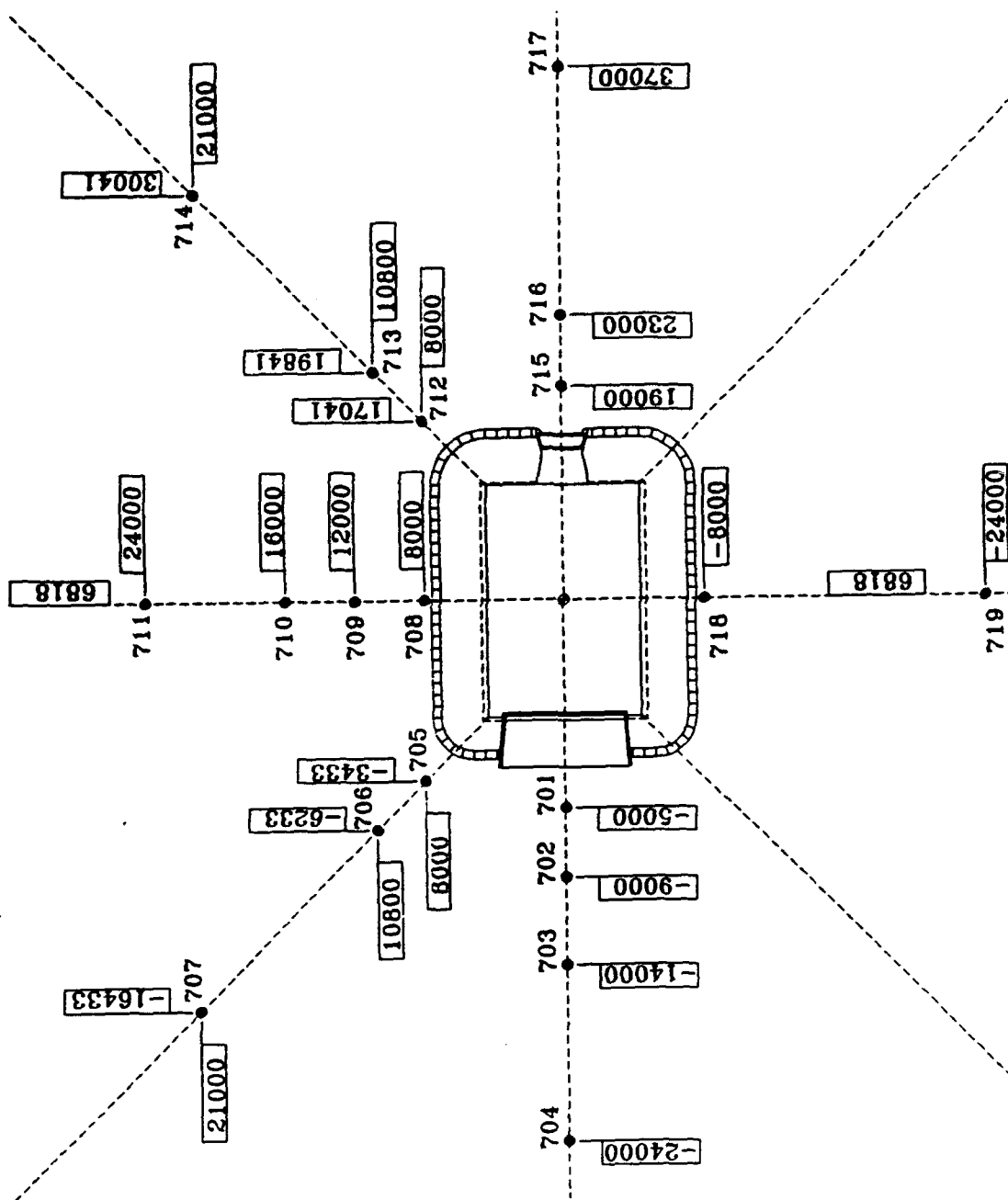
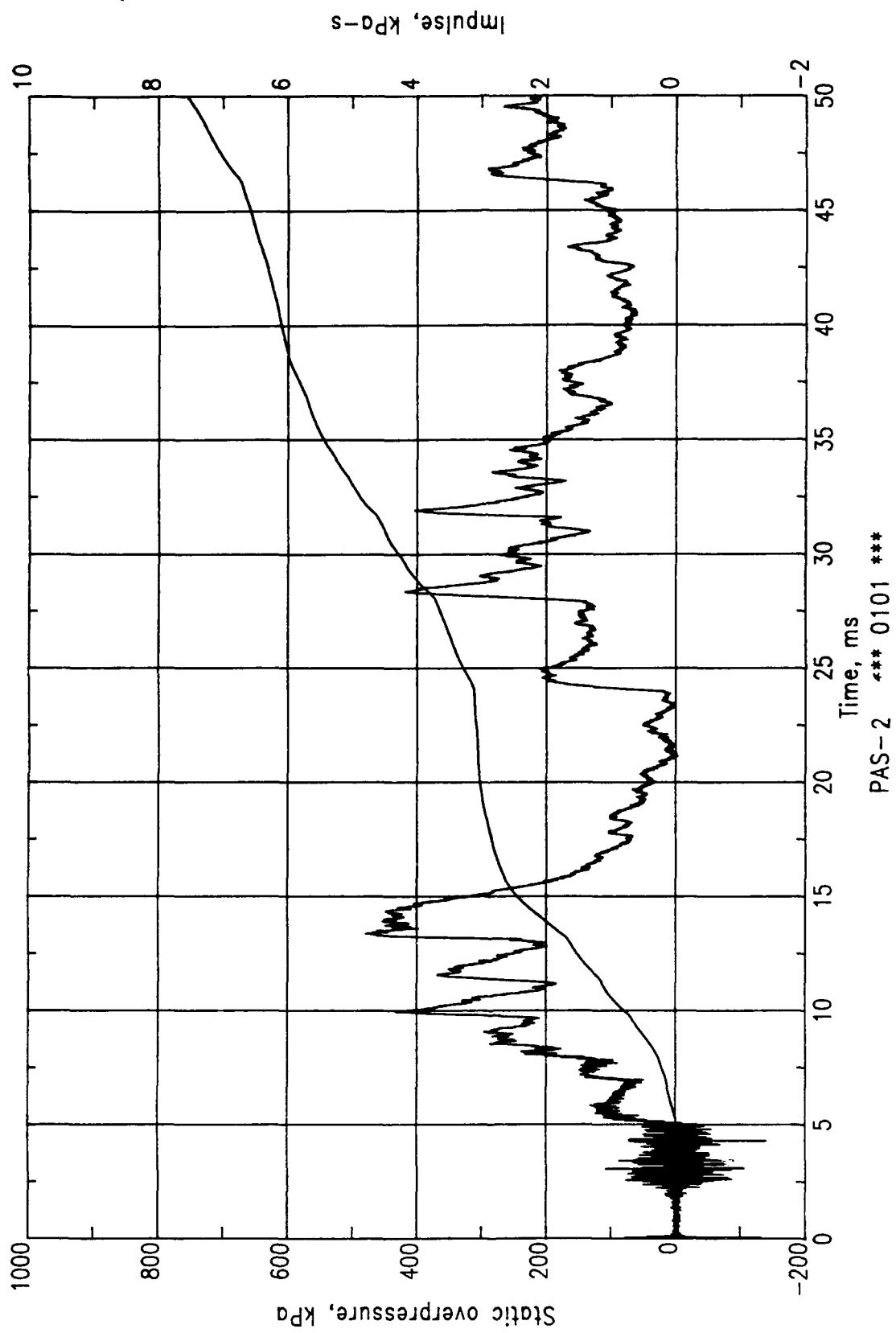
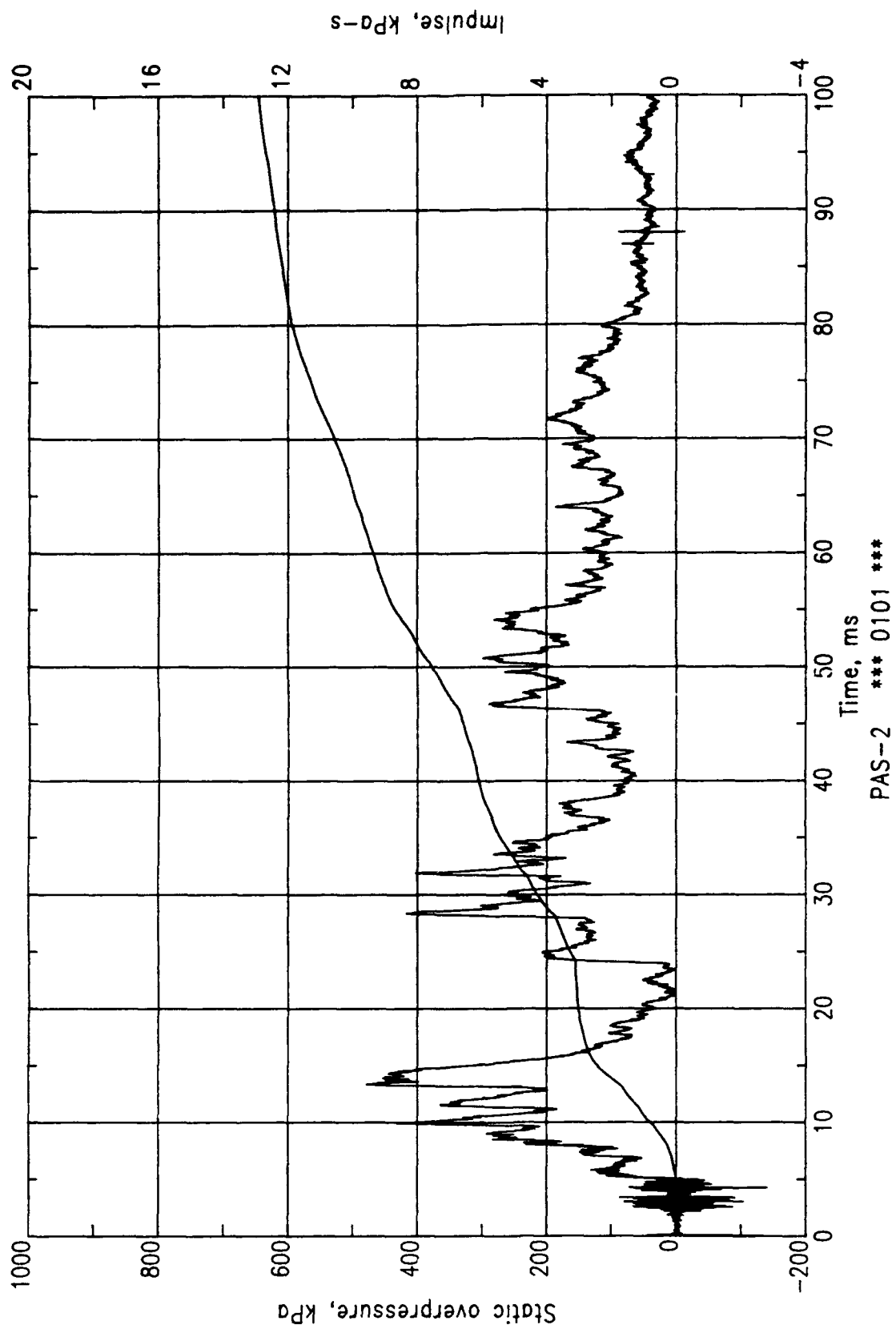
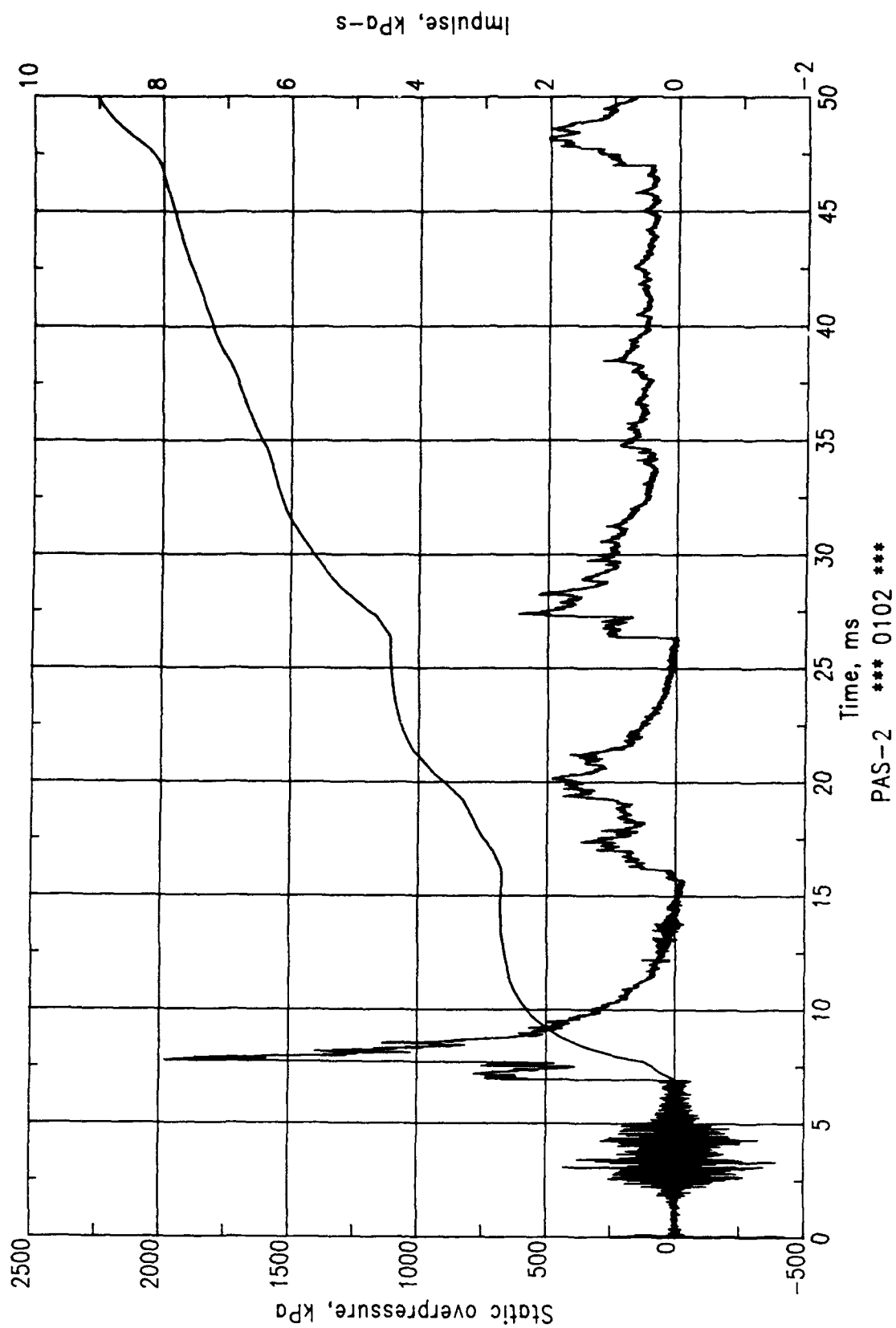
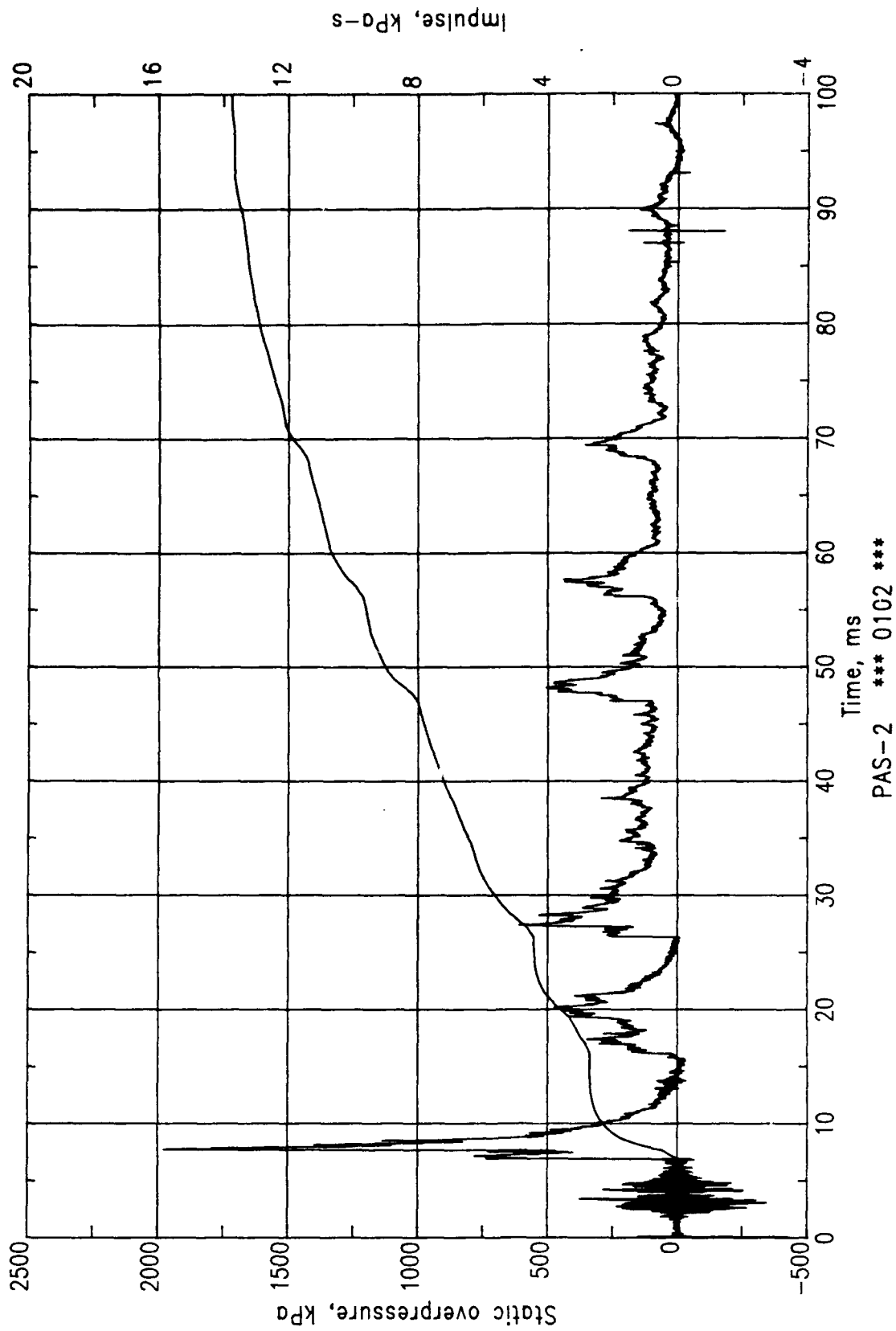


Figure C-8. Free-field airblast gage locations, PAS-2.

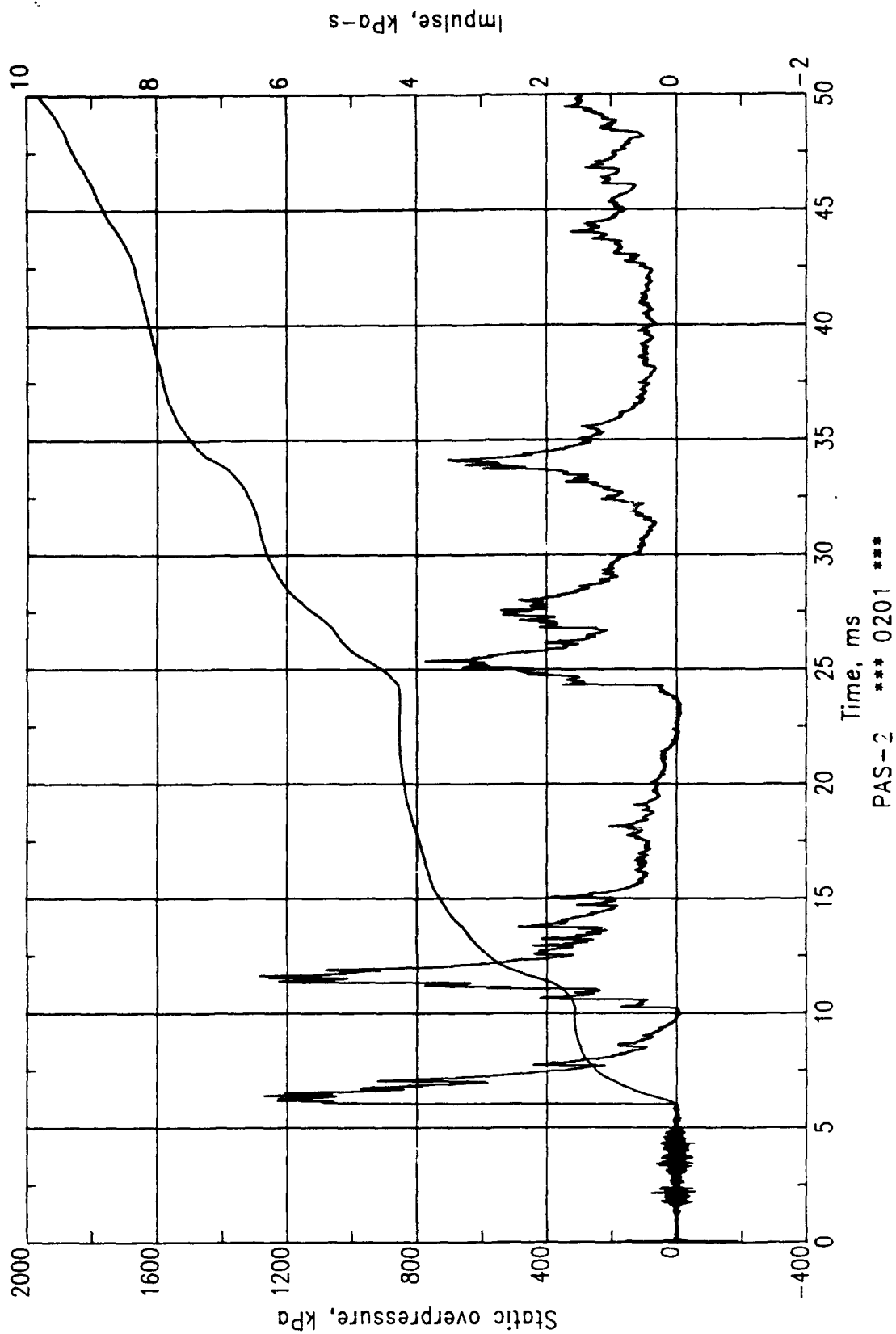


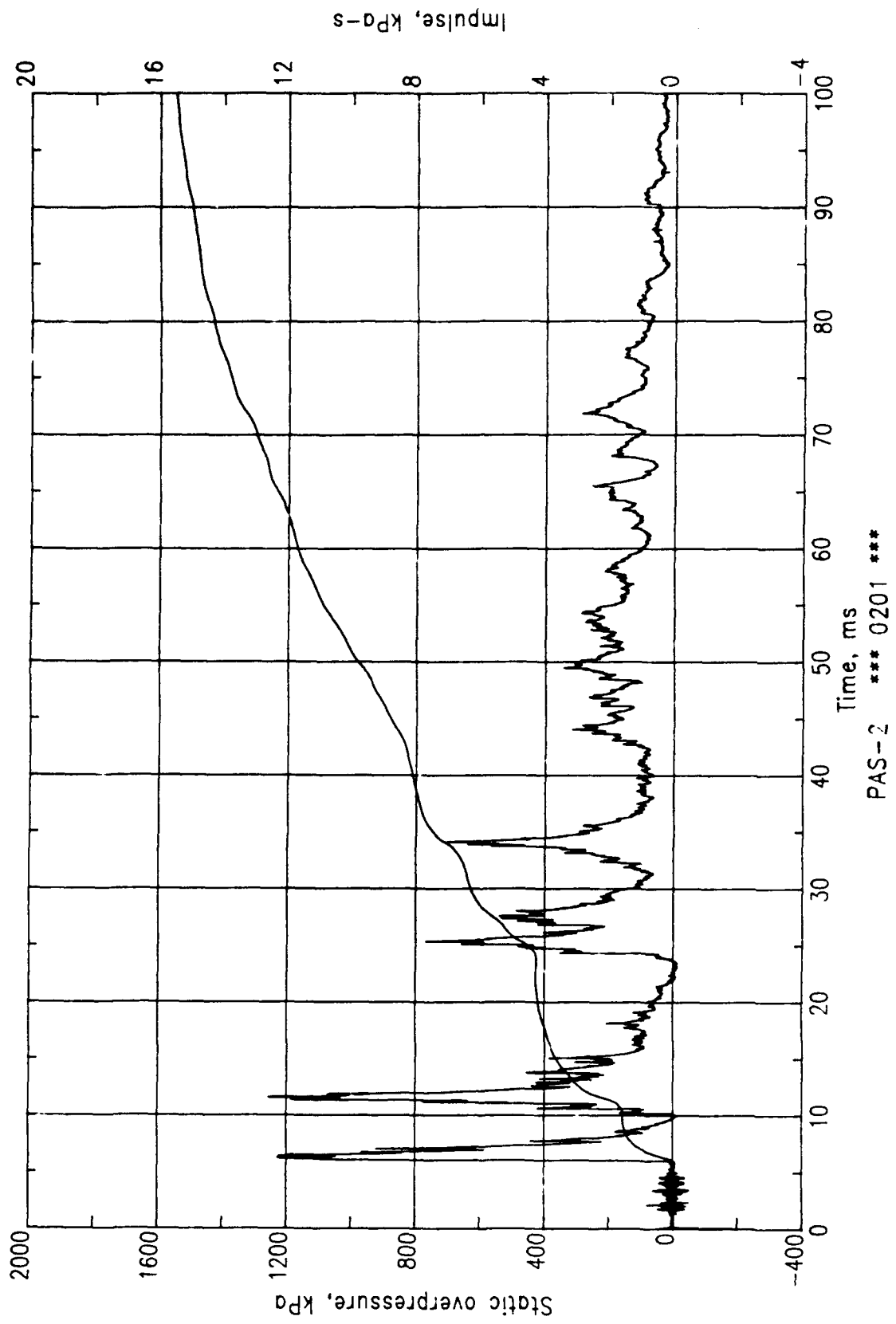




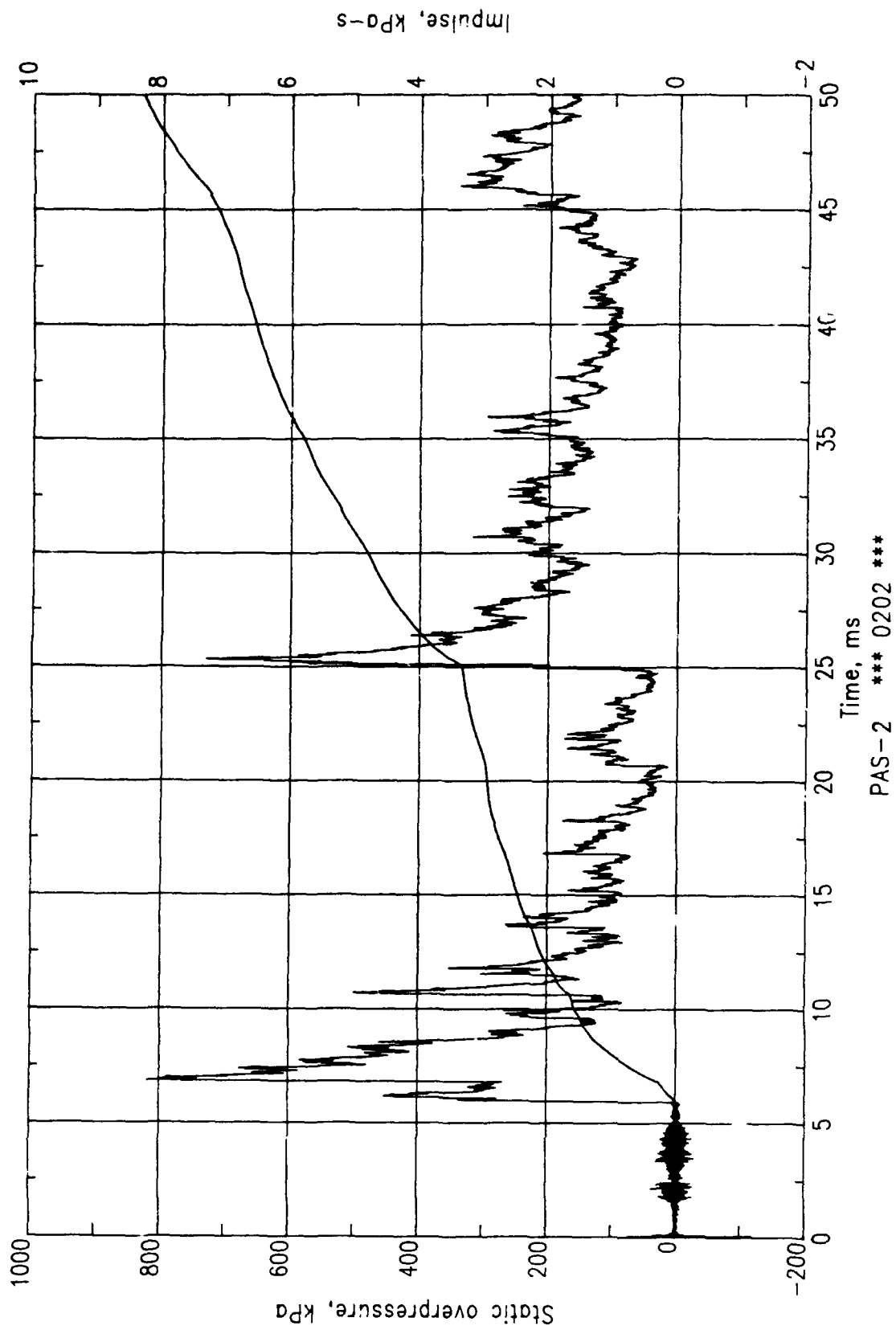


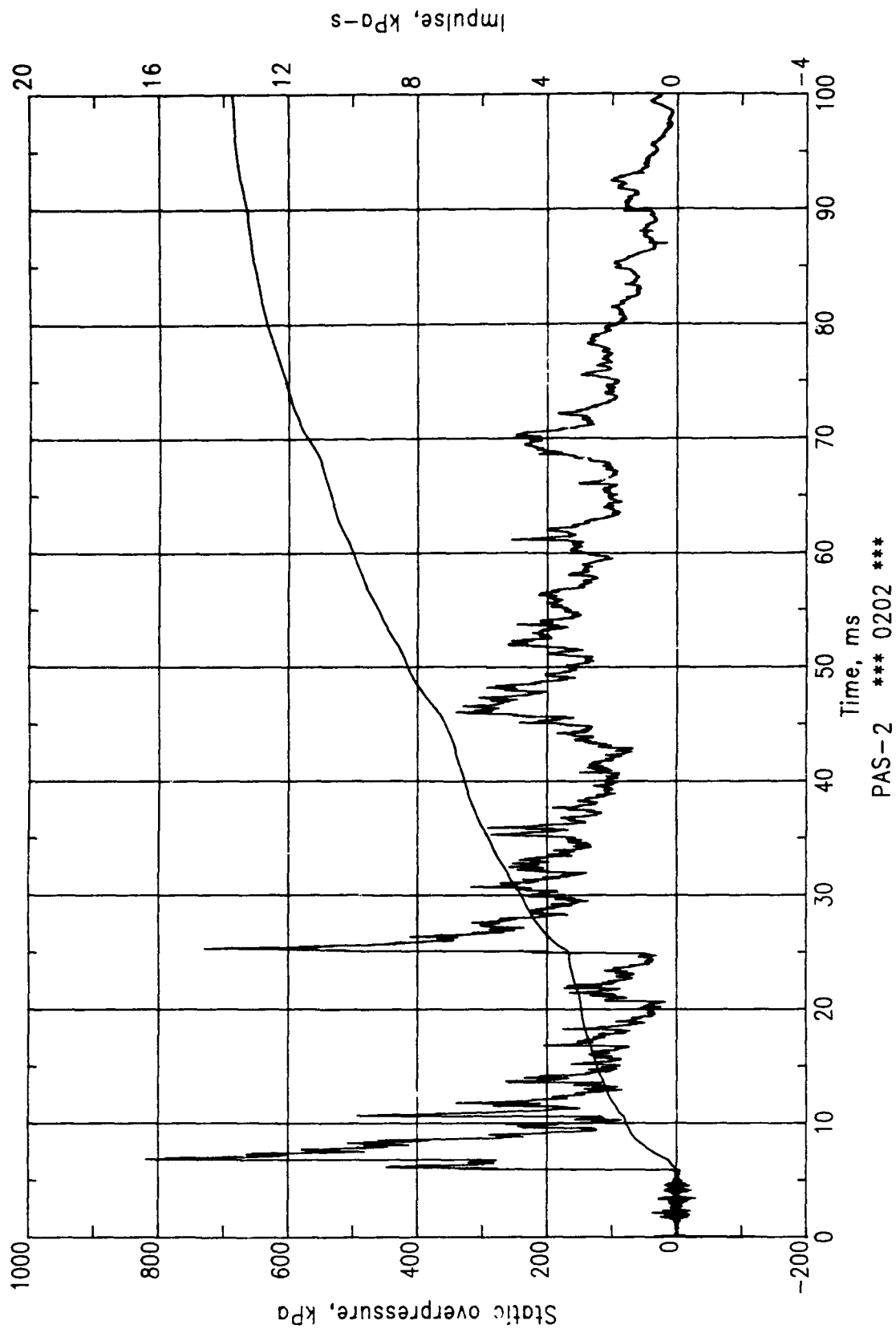
PAS-2 *** 0102 ***

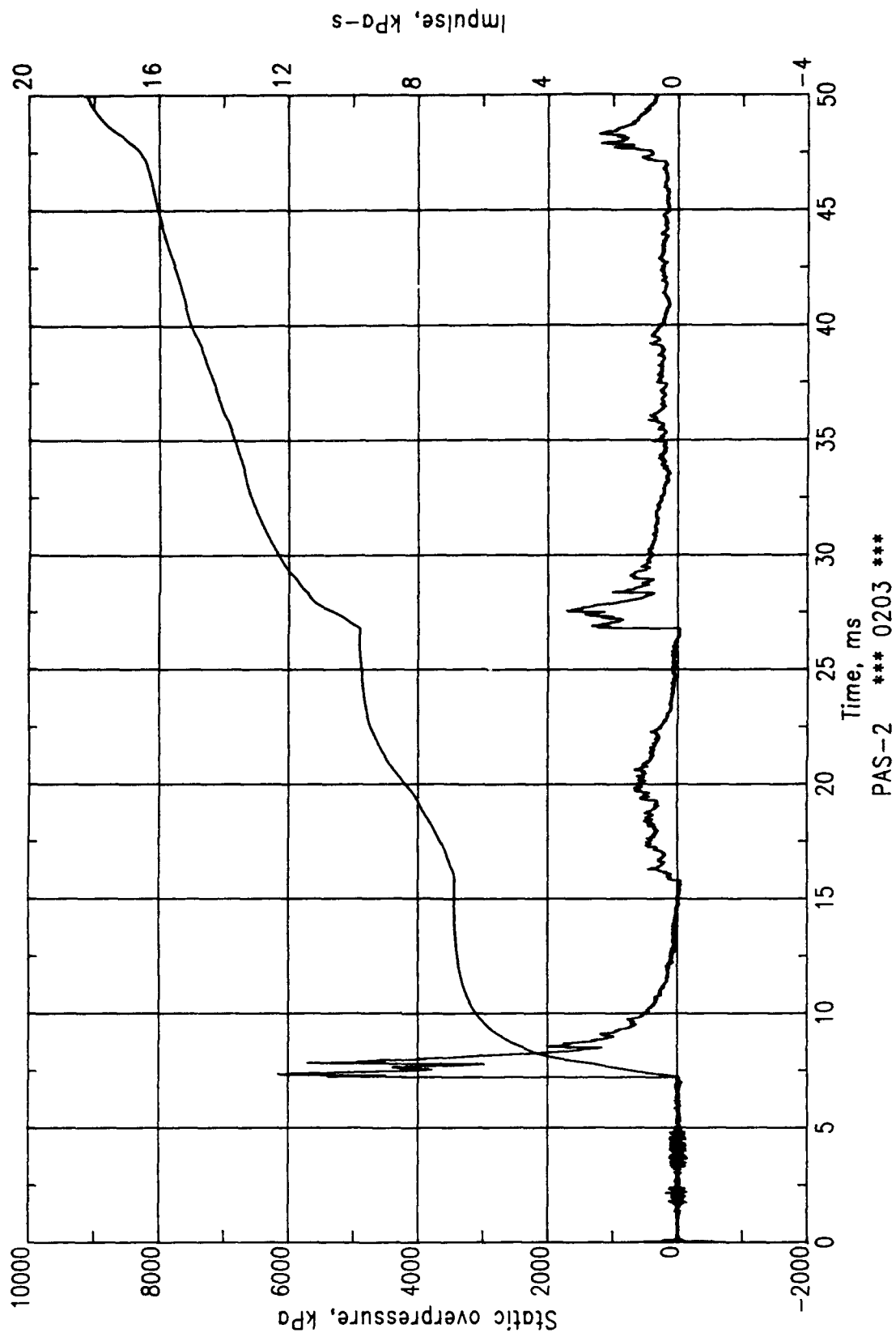


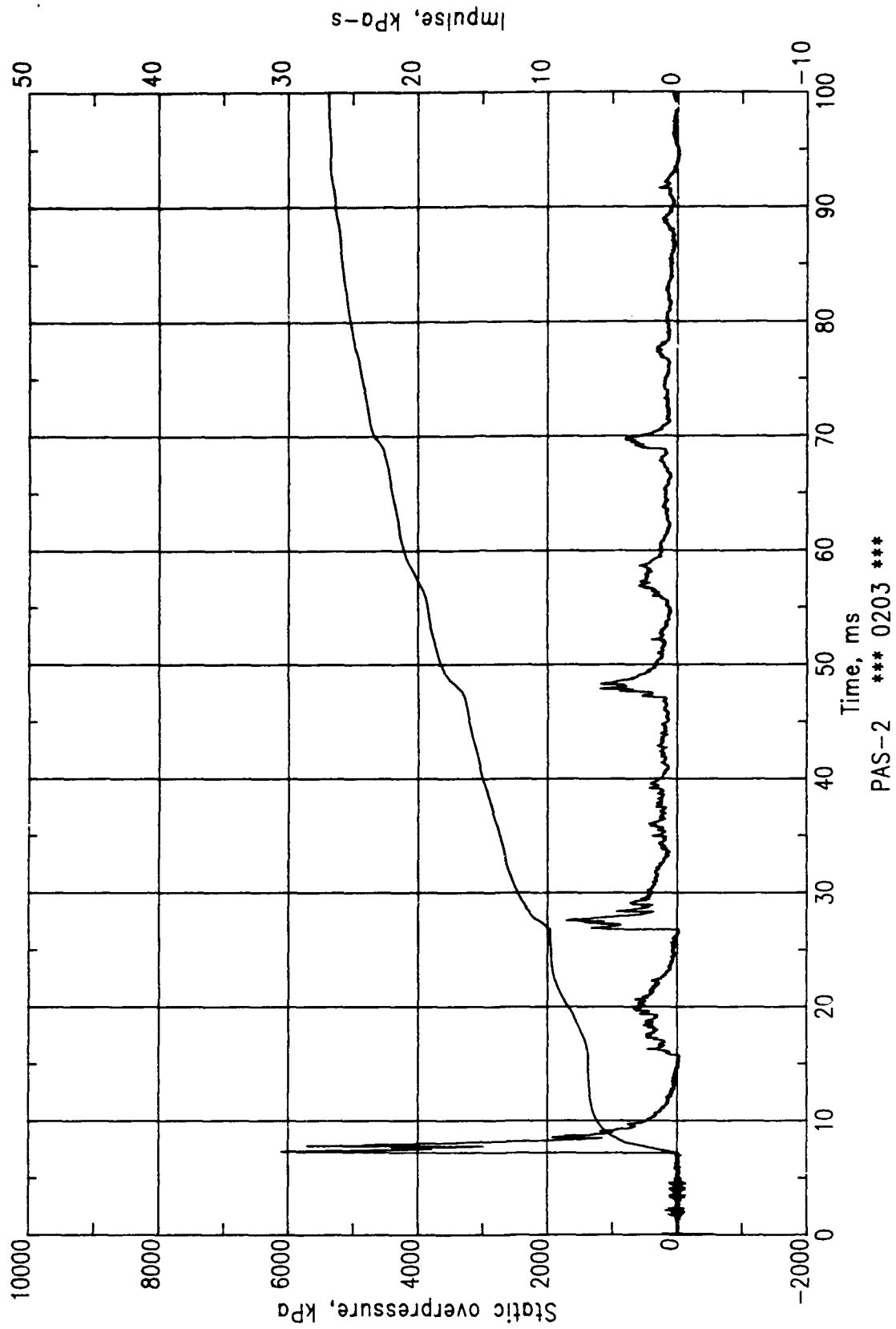


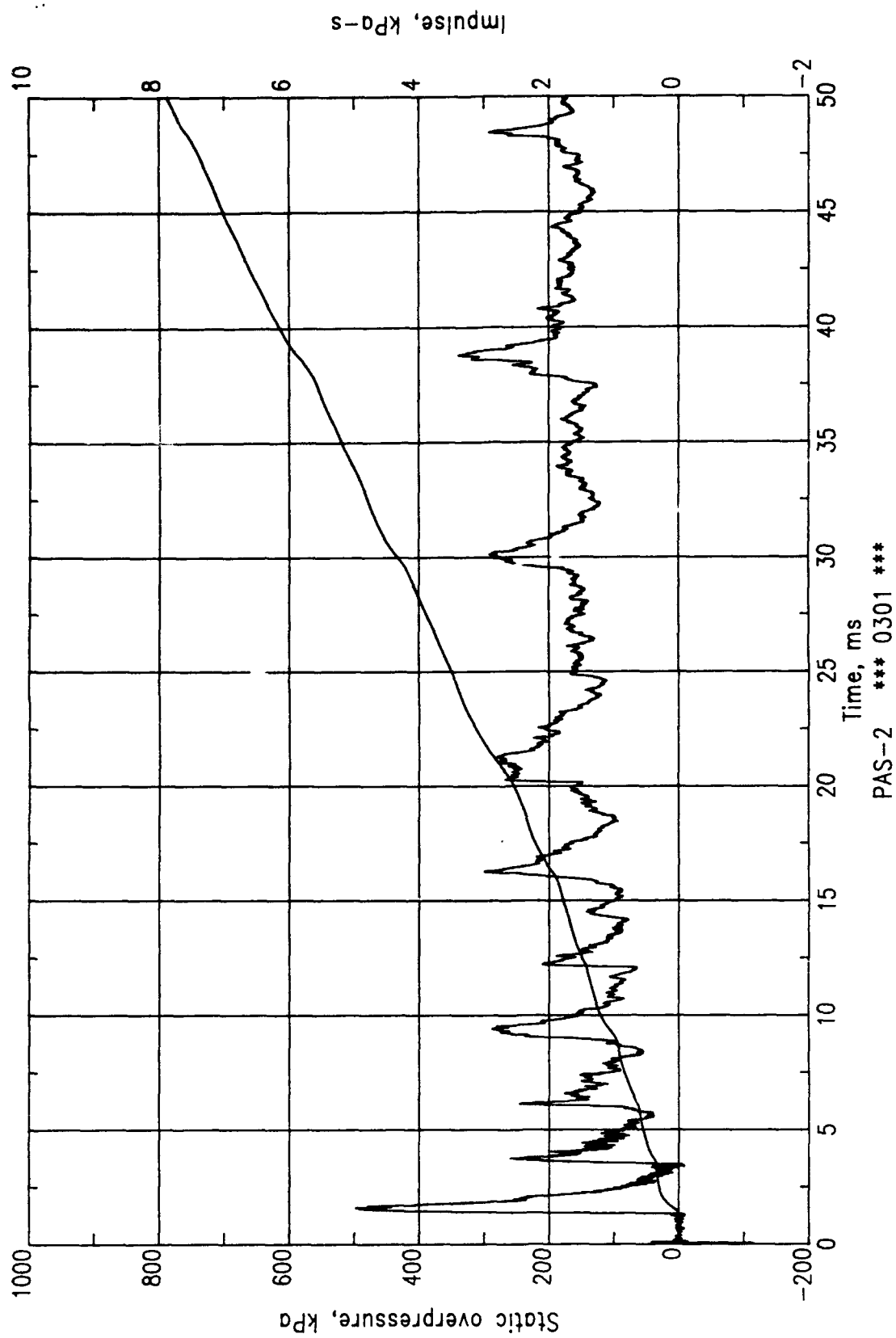
PAS-2 *** 0201 ***

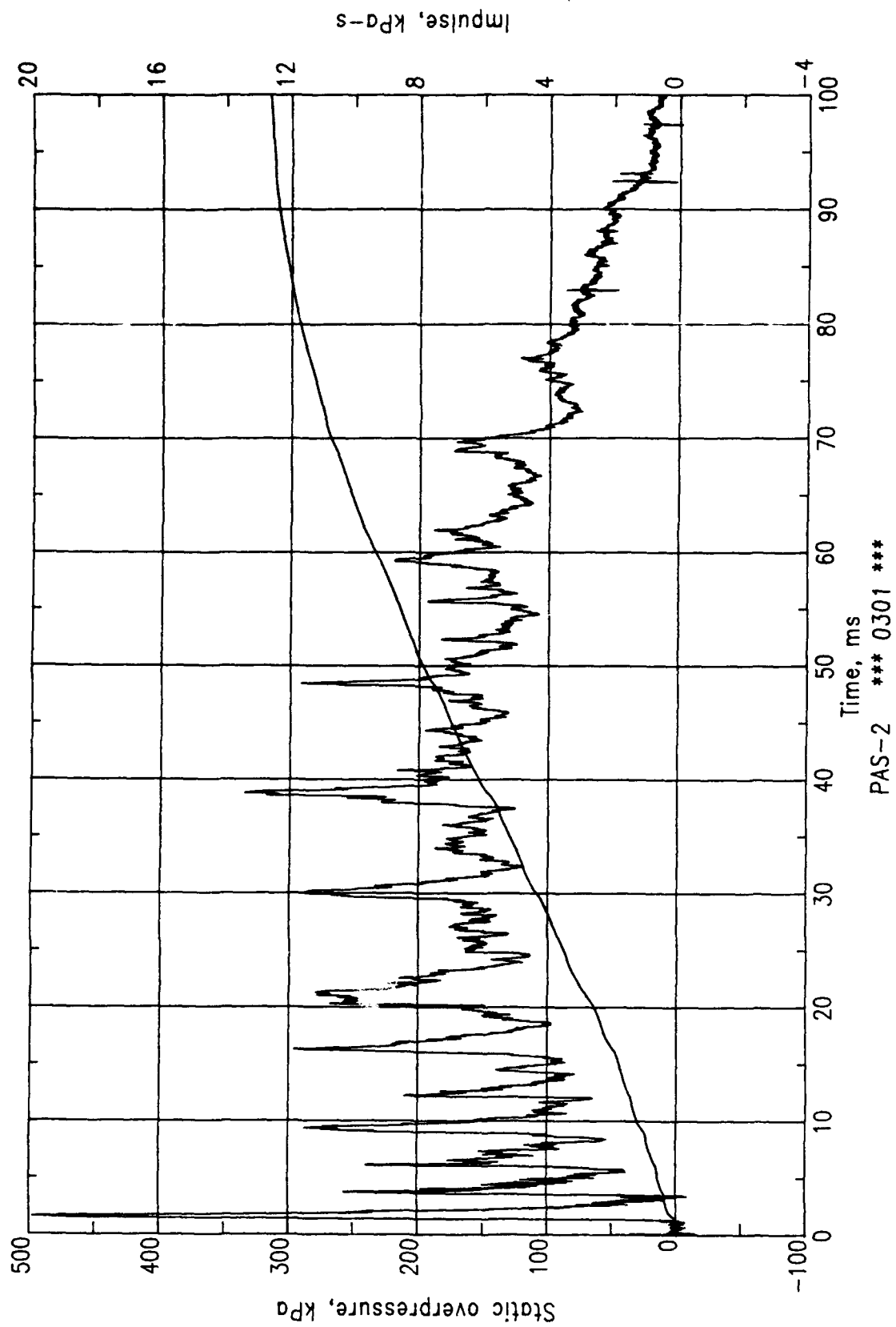


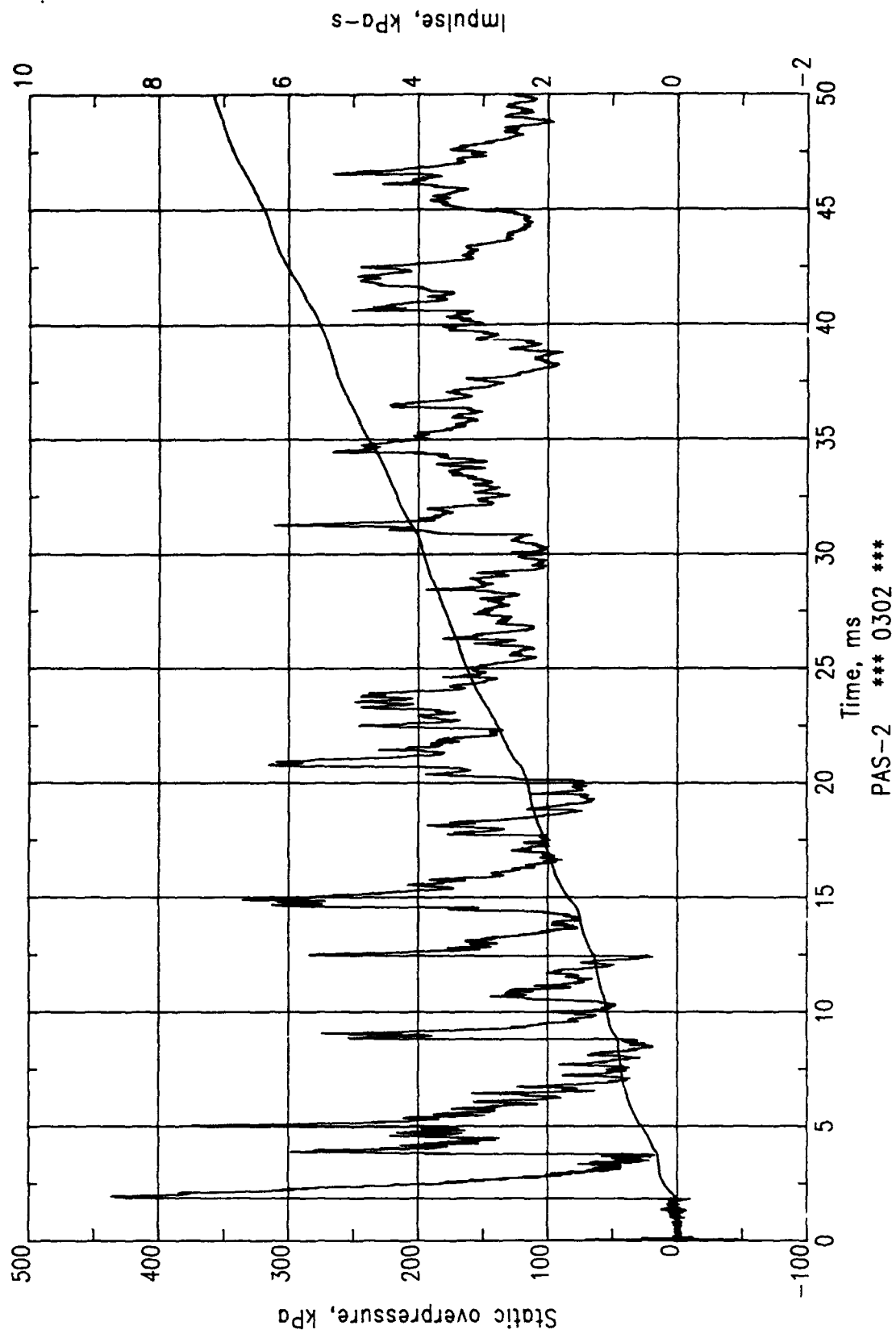


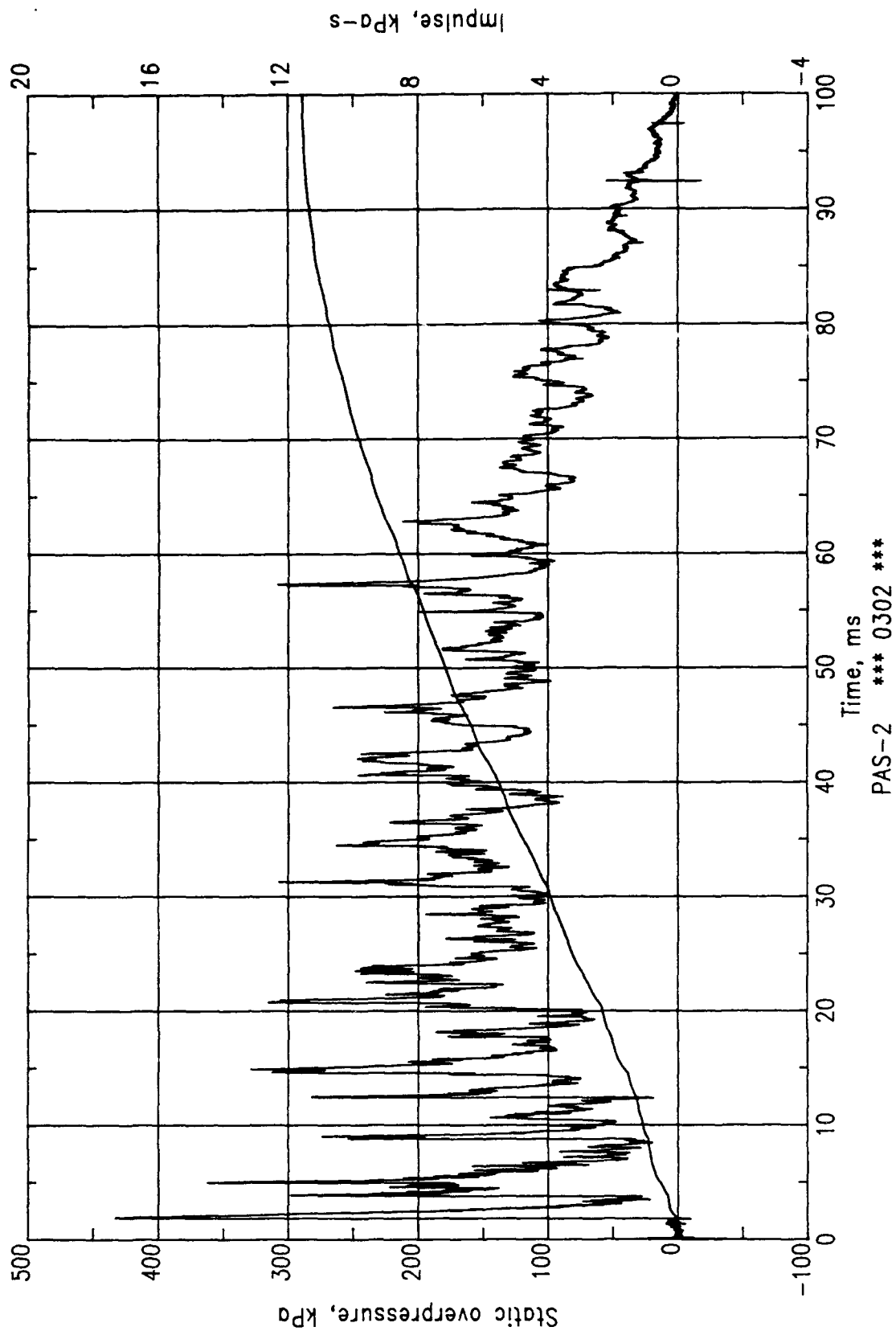


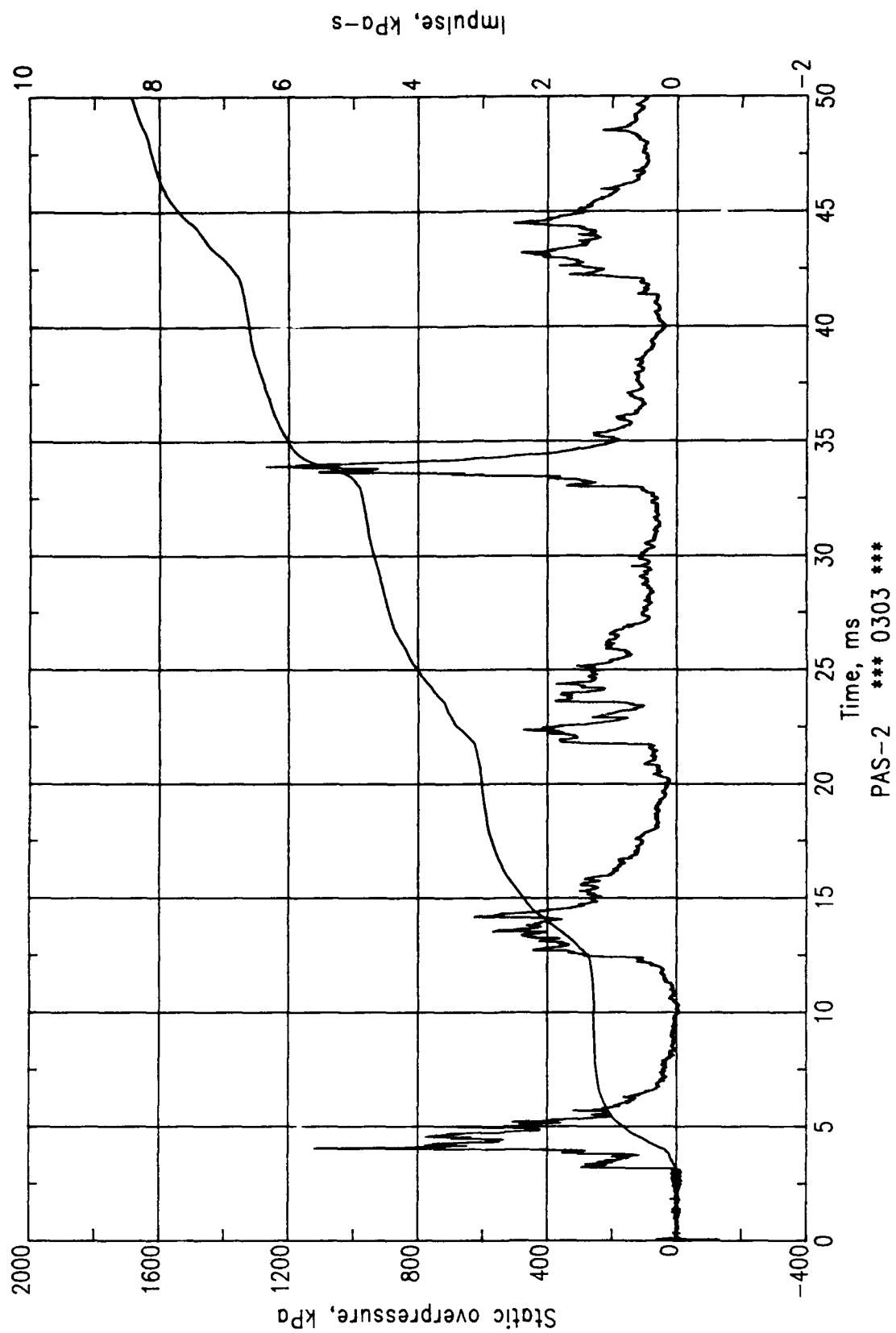


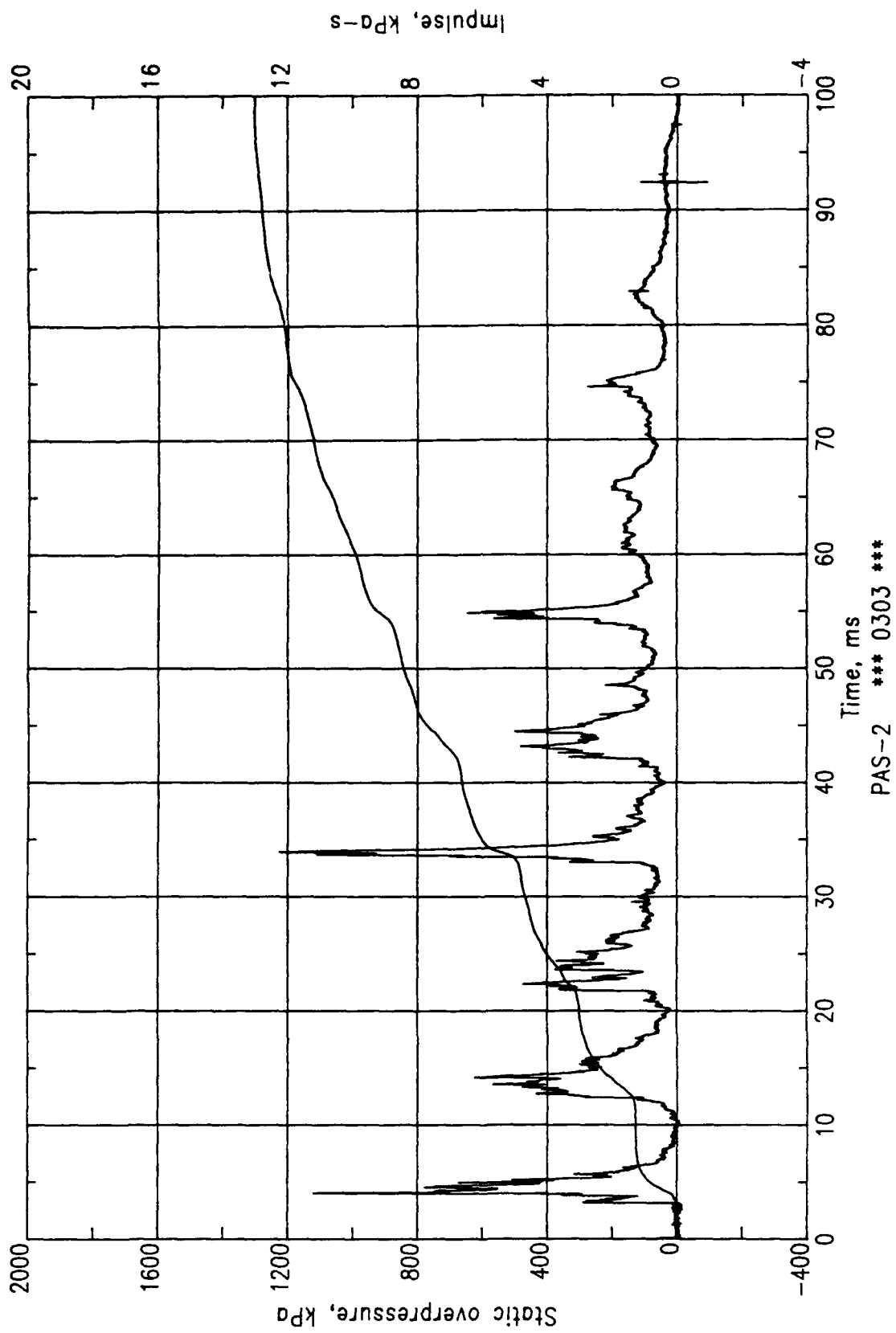


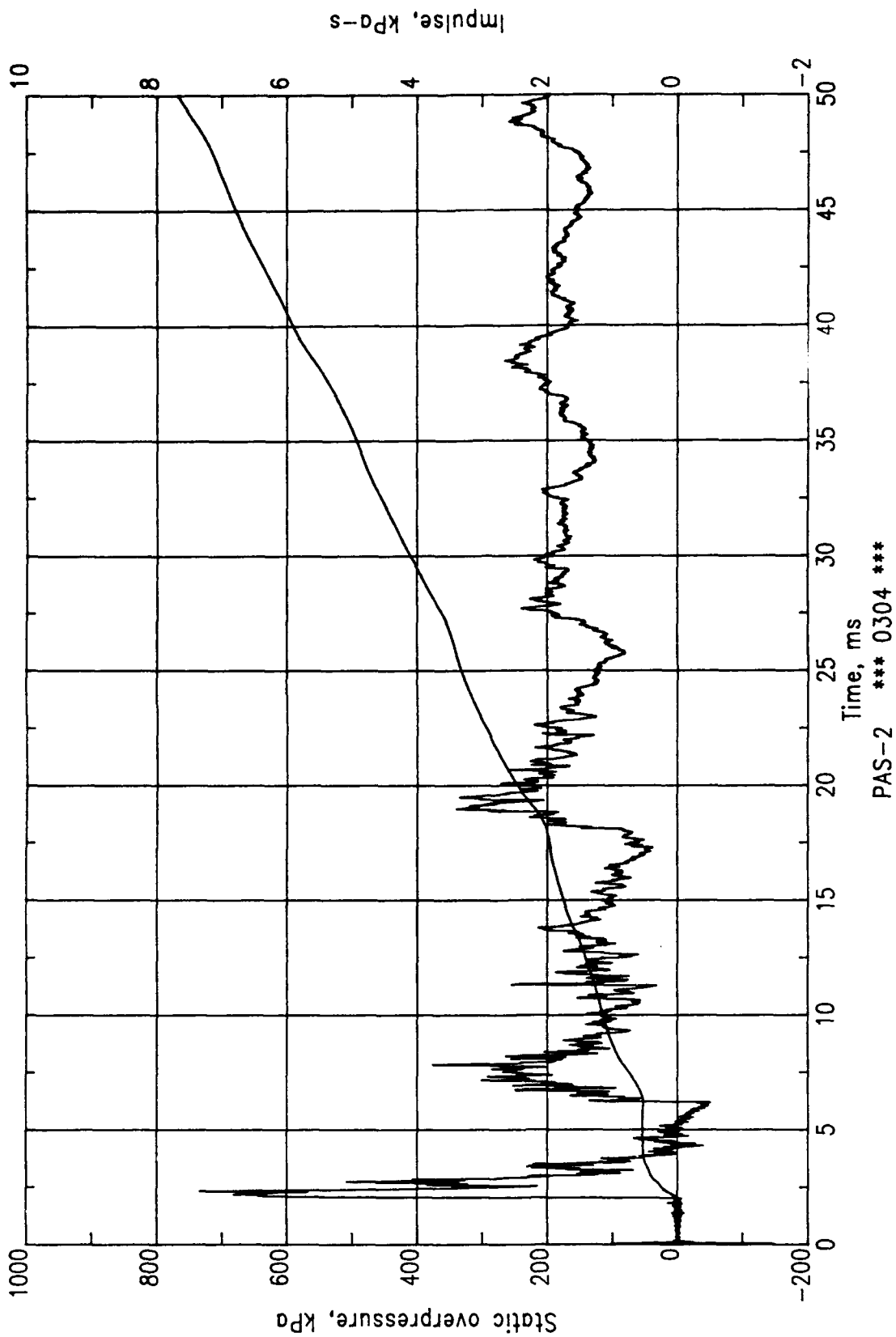


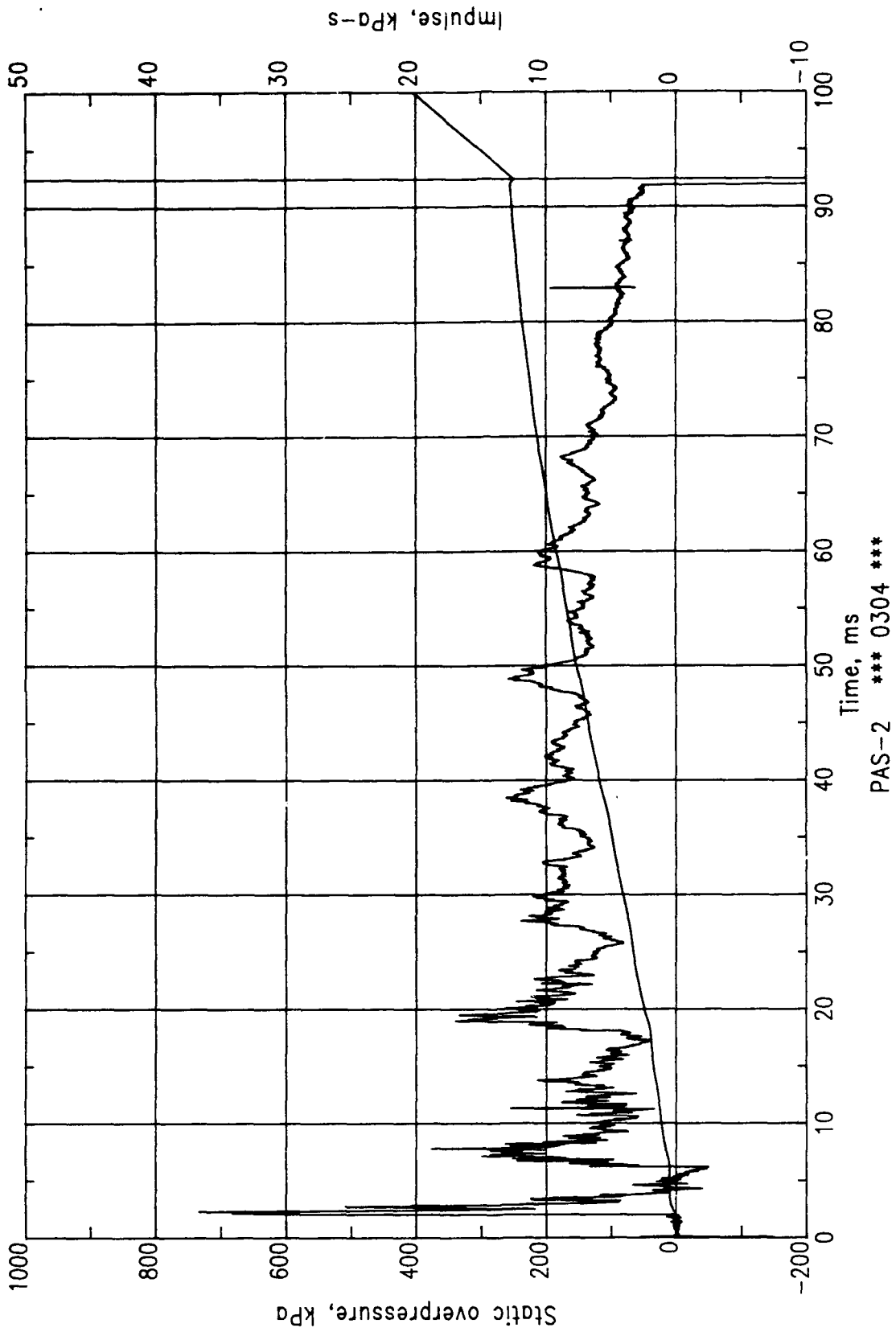


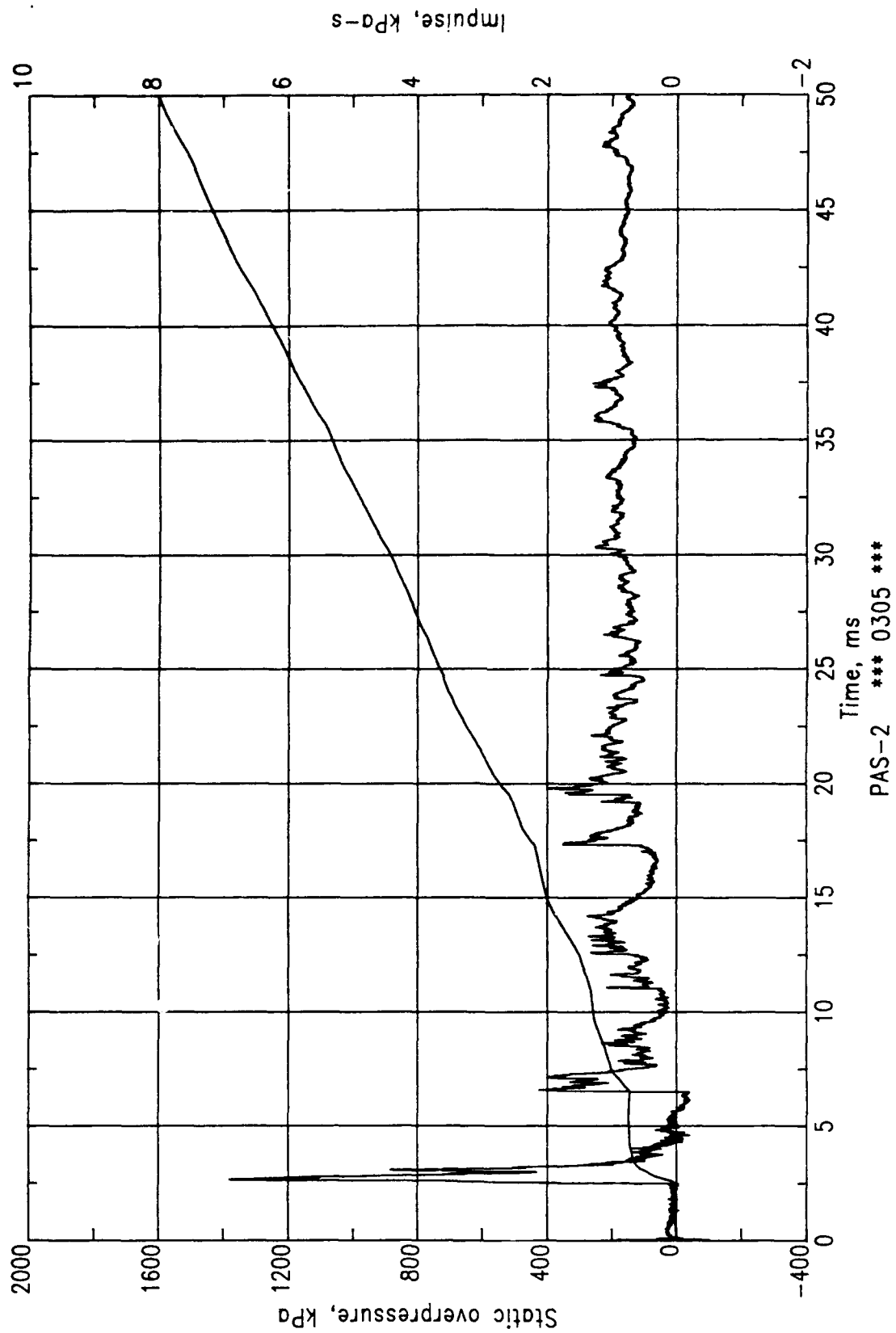


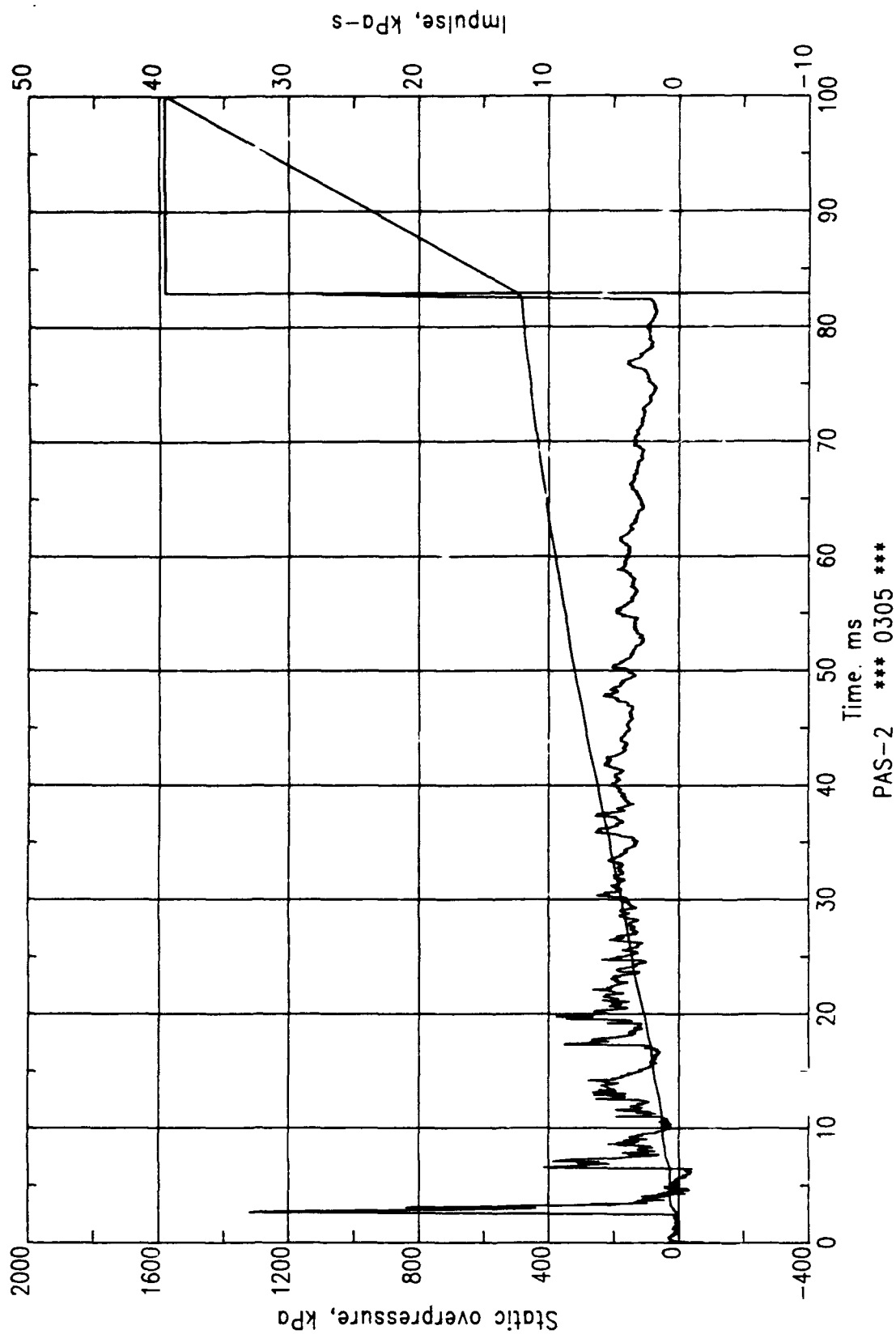


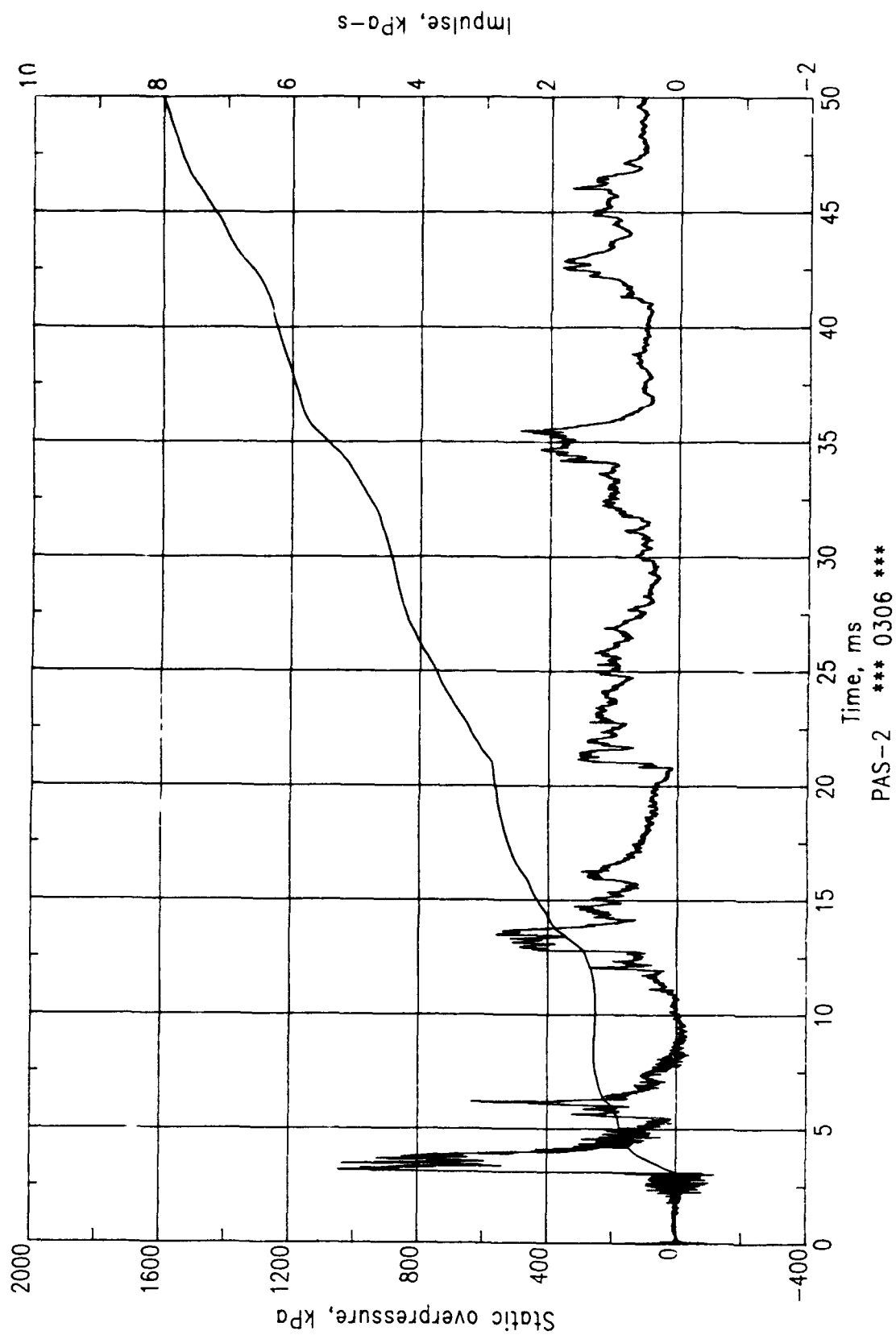


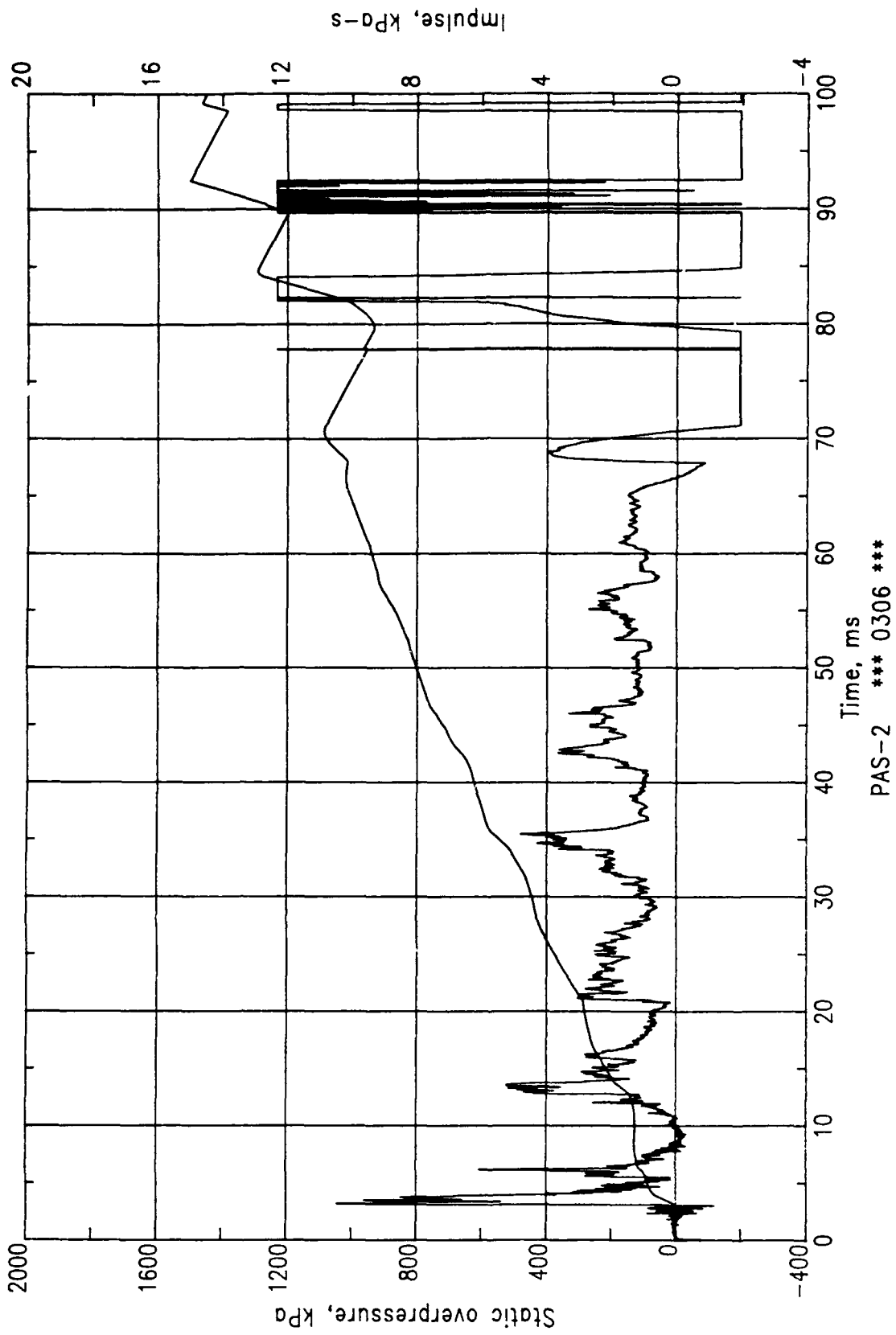


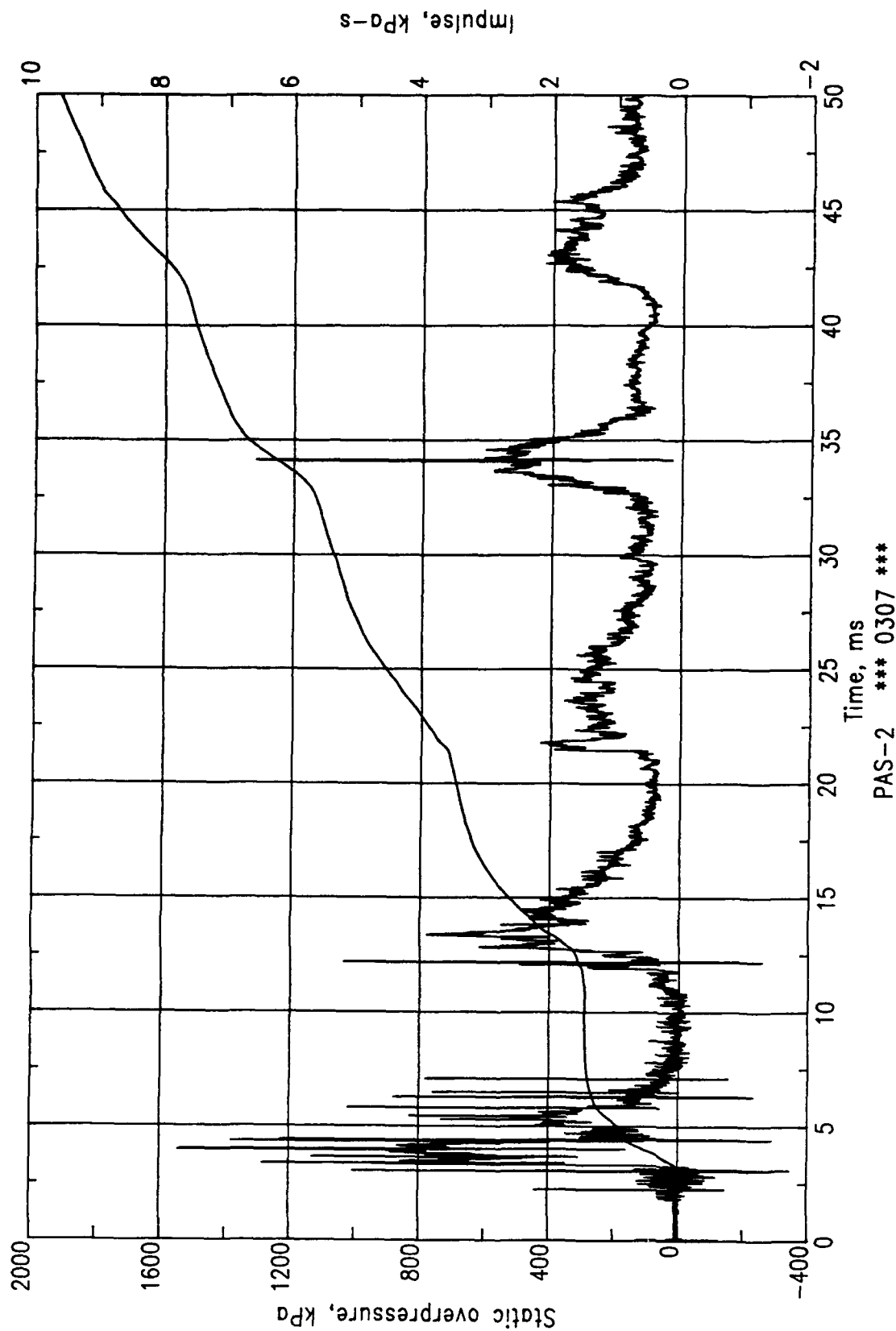


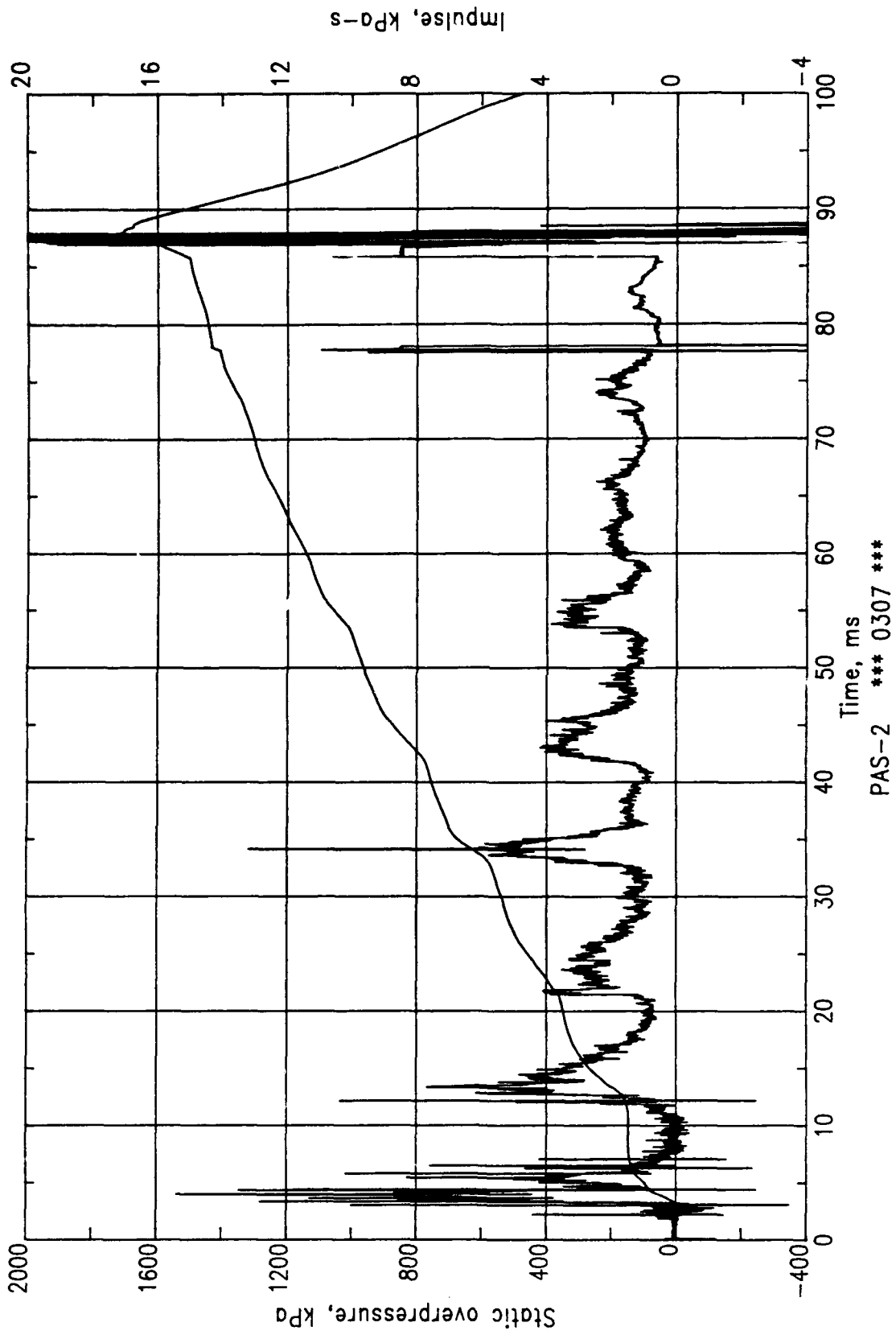


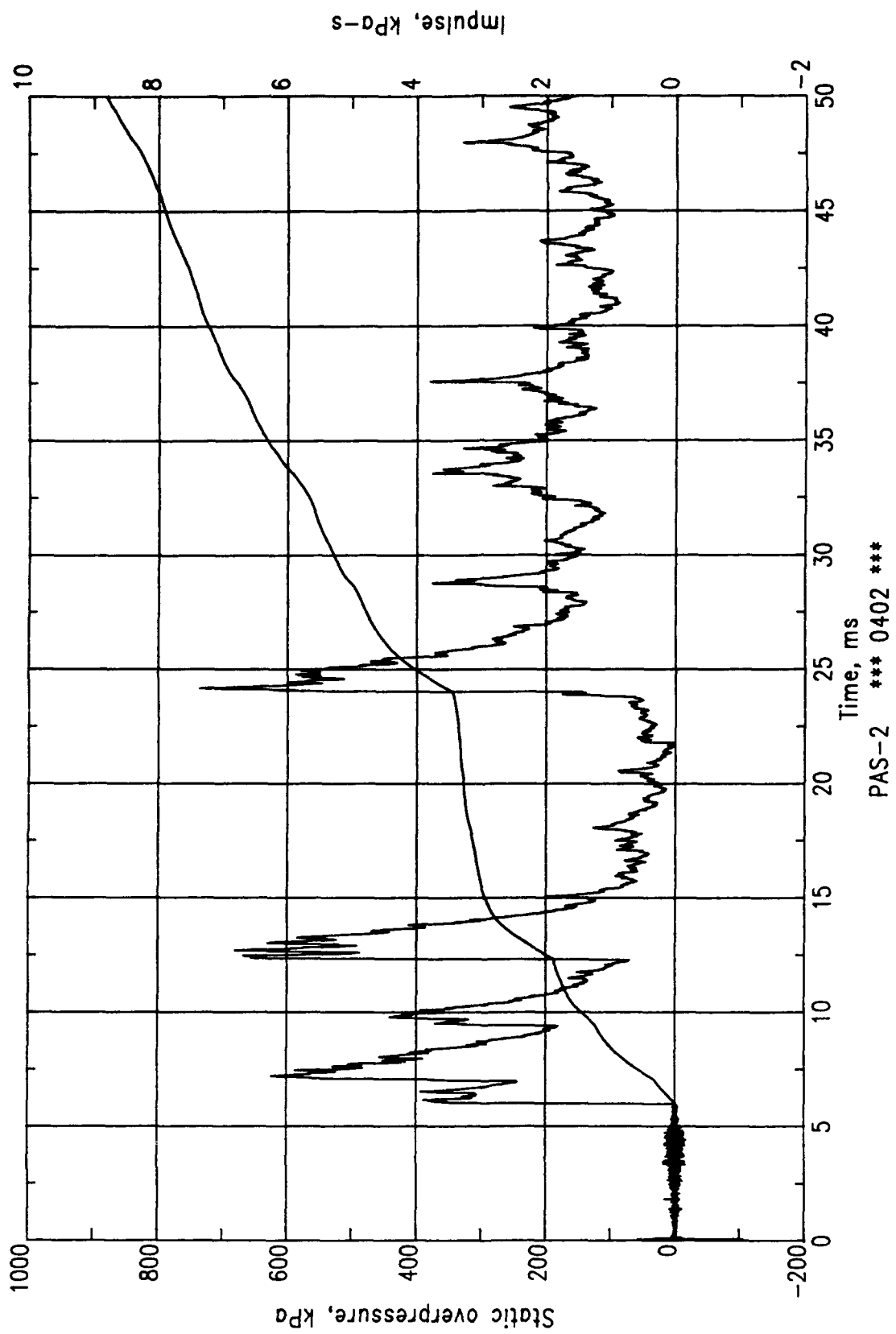


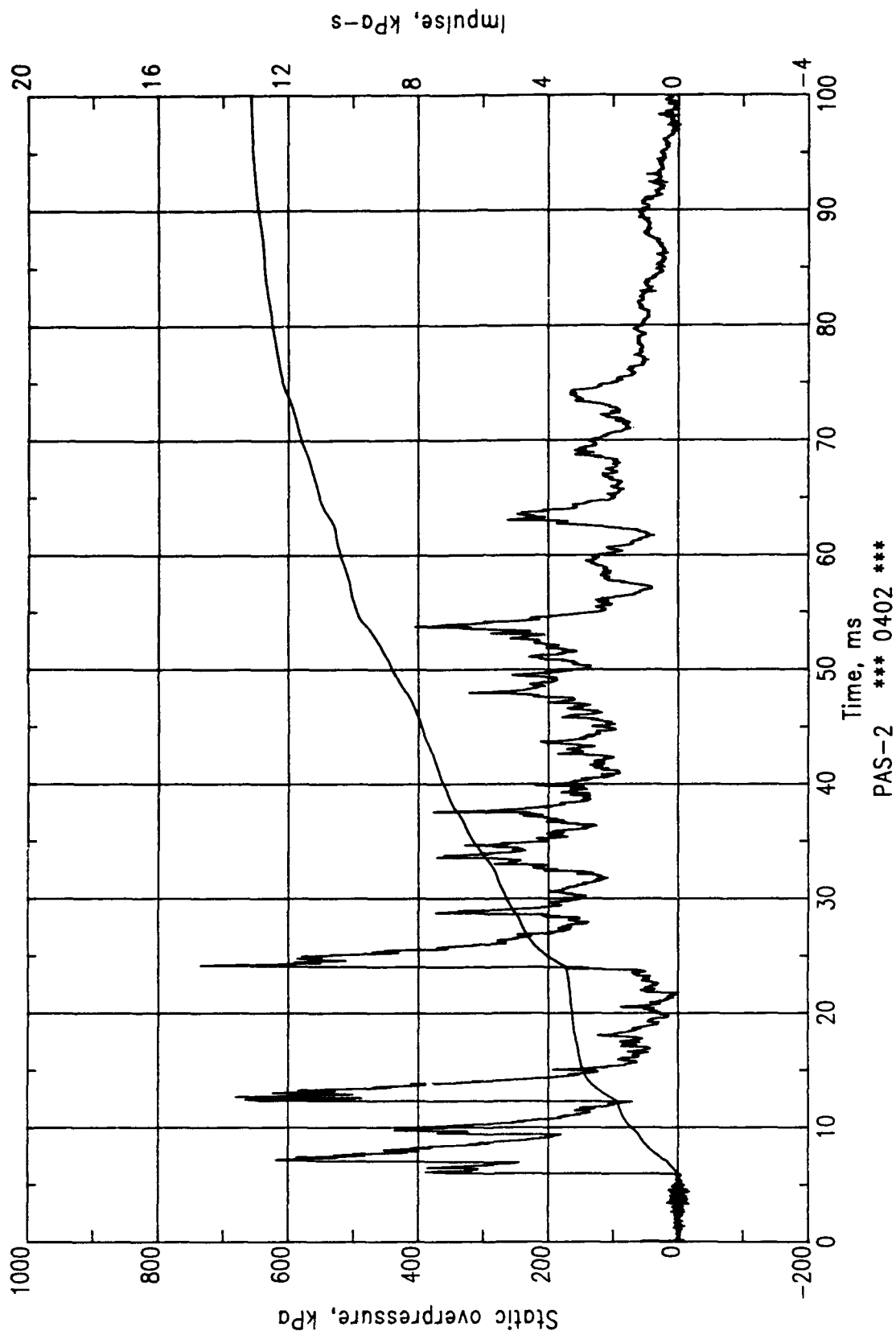


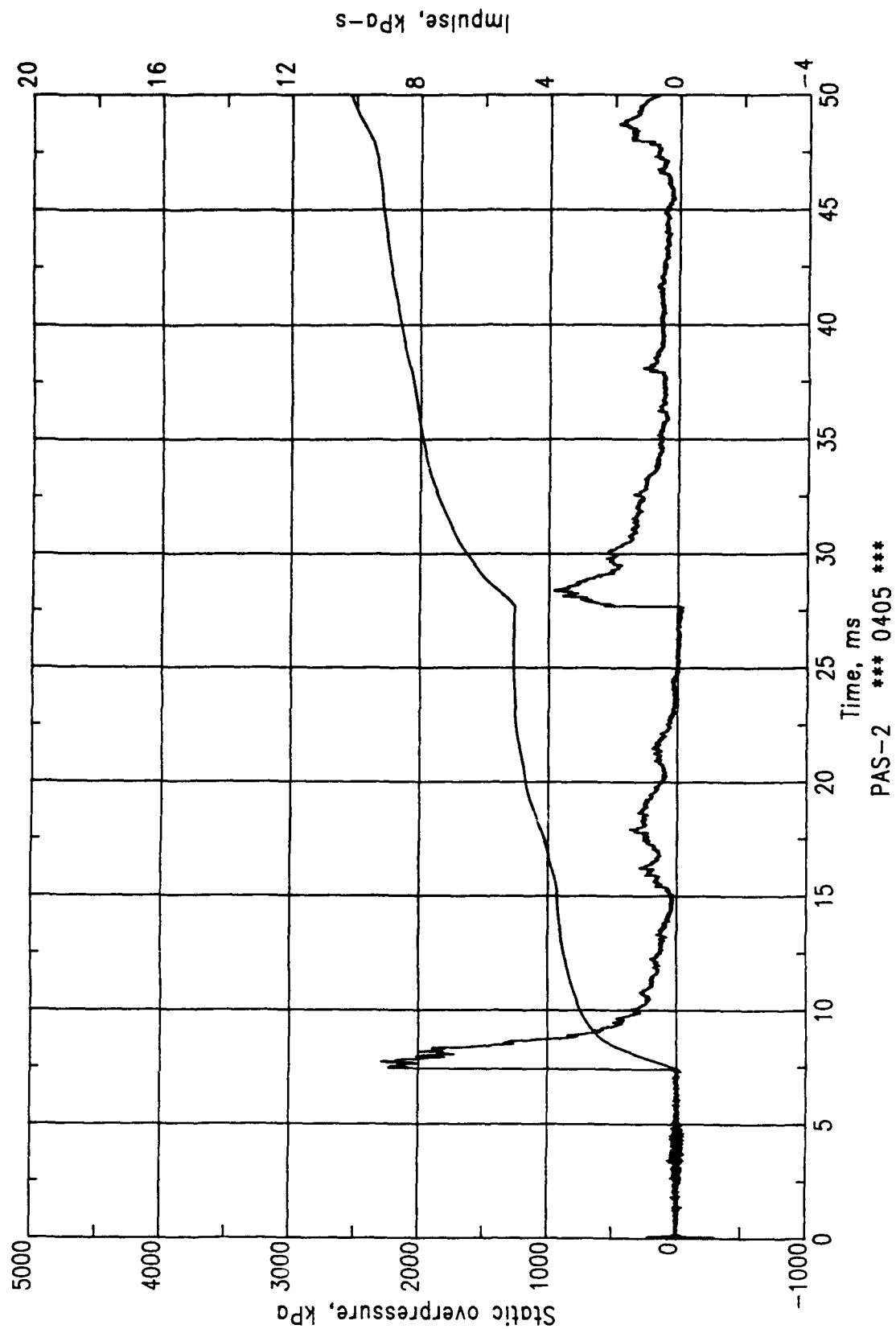


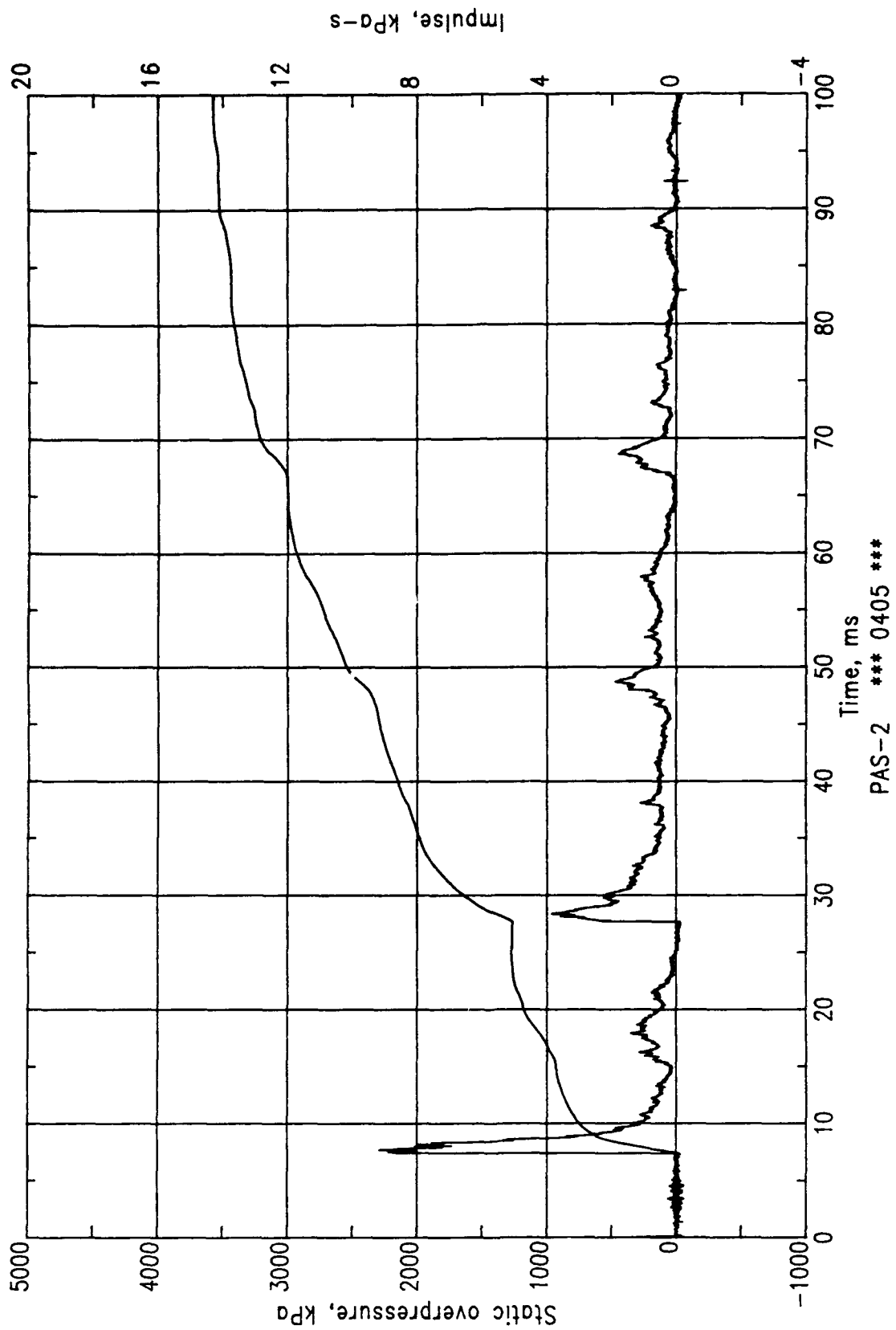


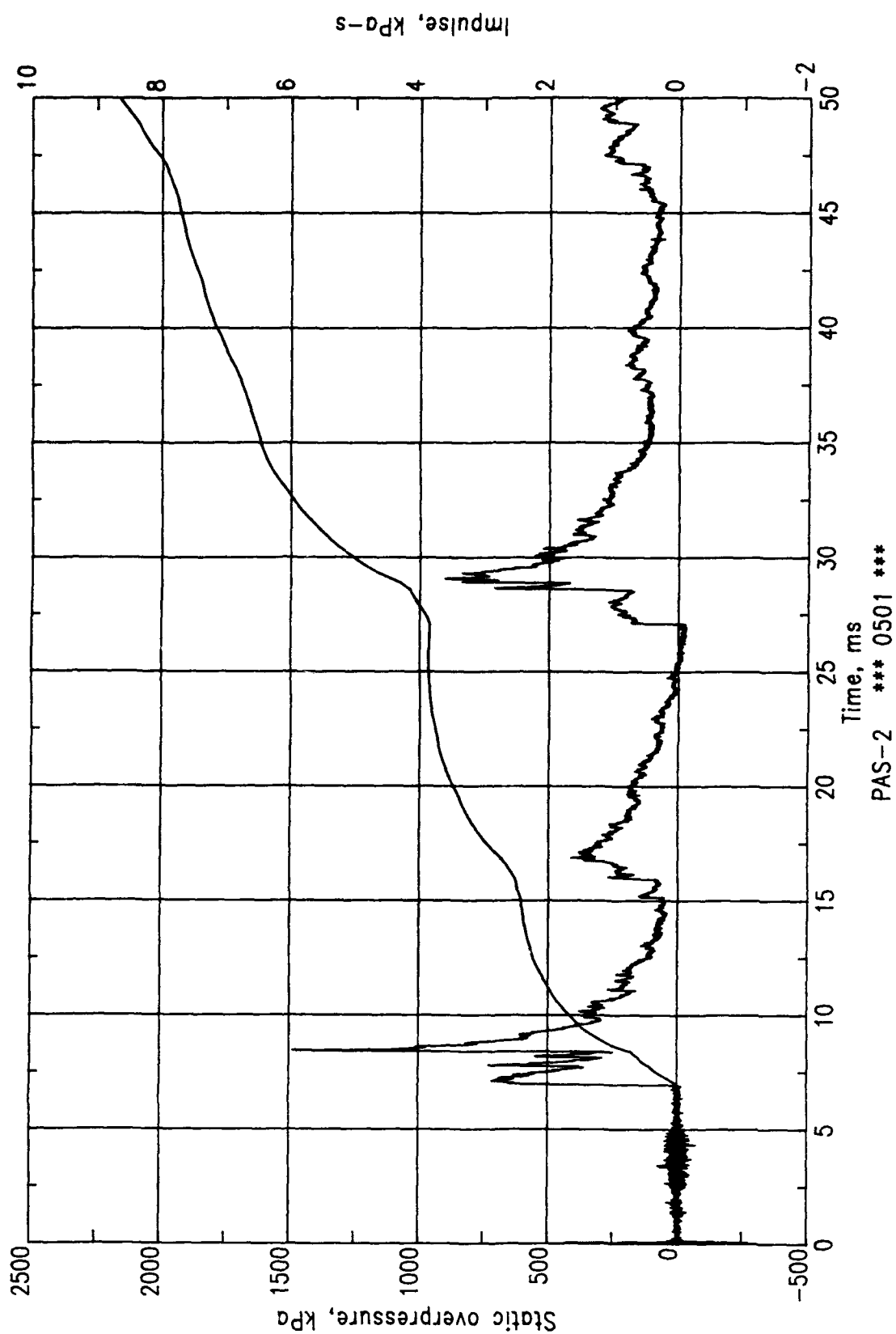


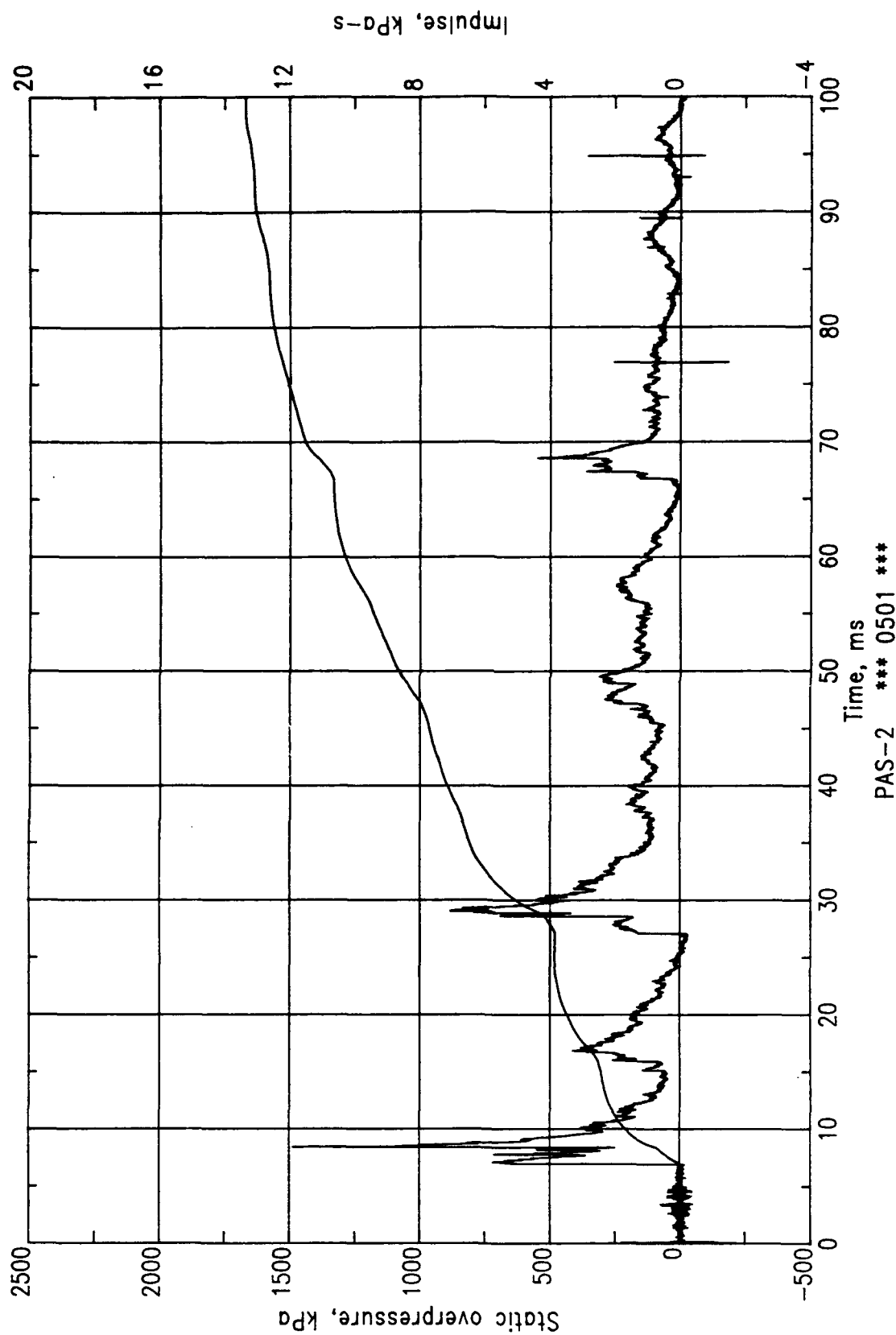


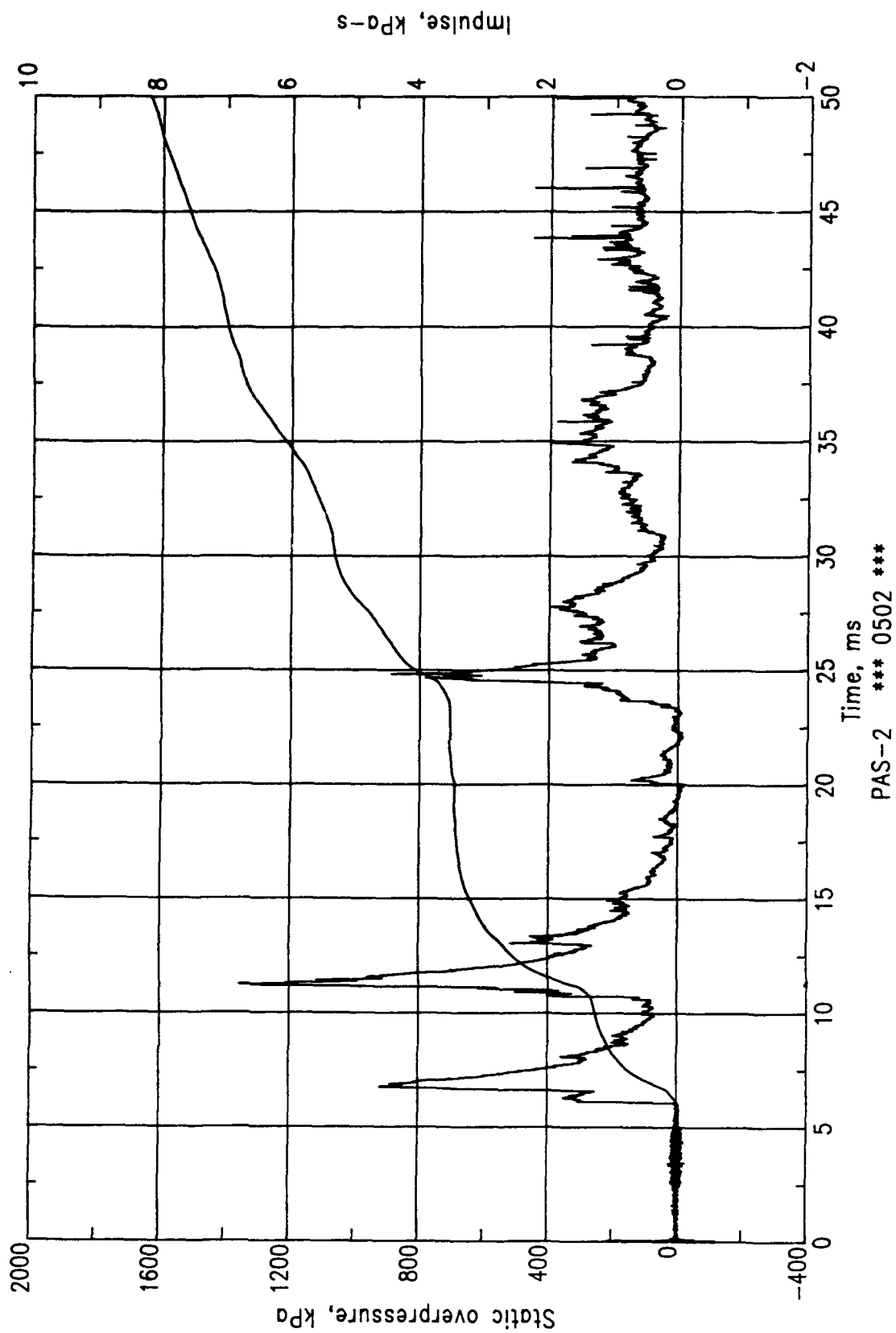


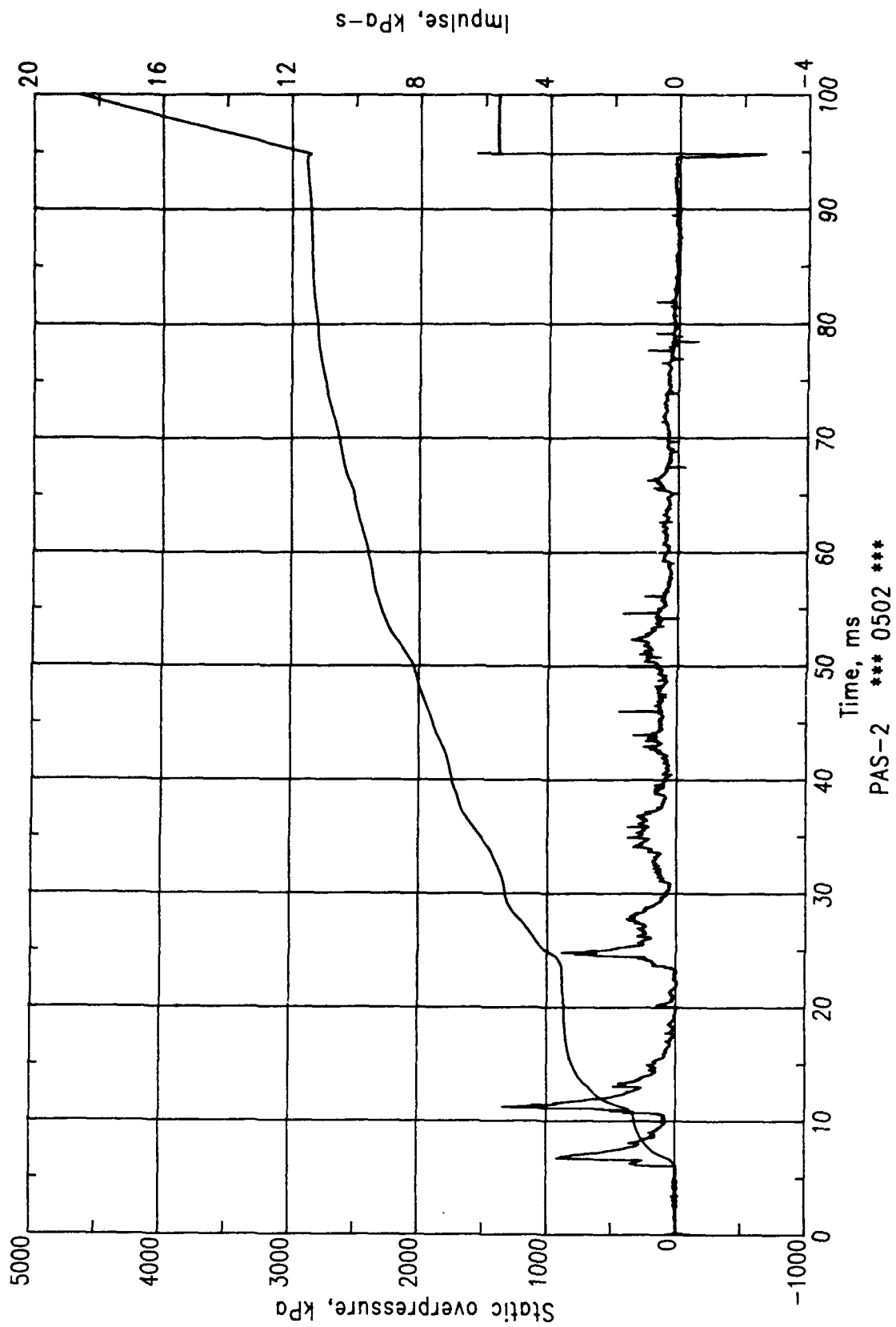


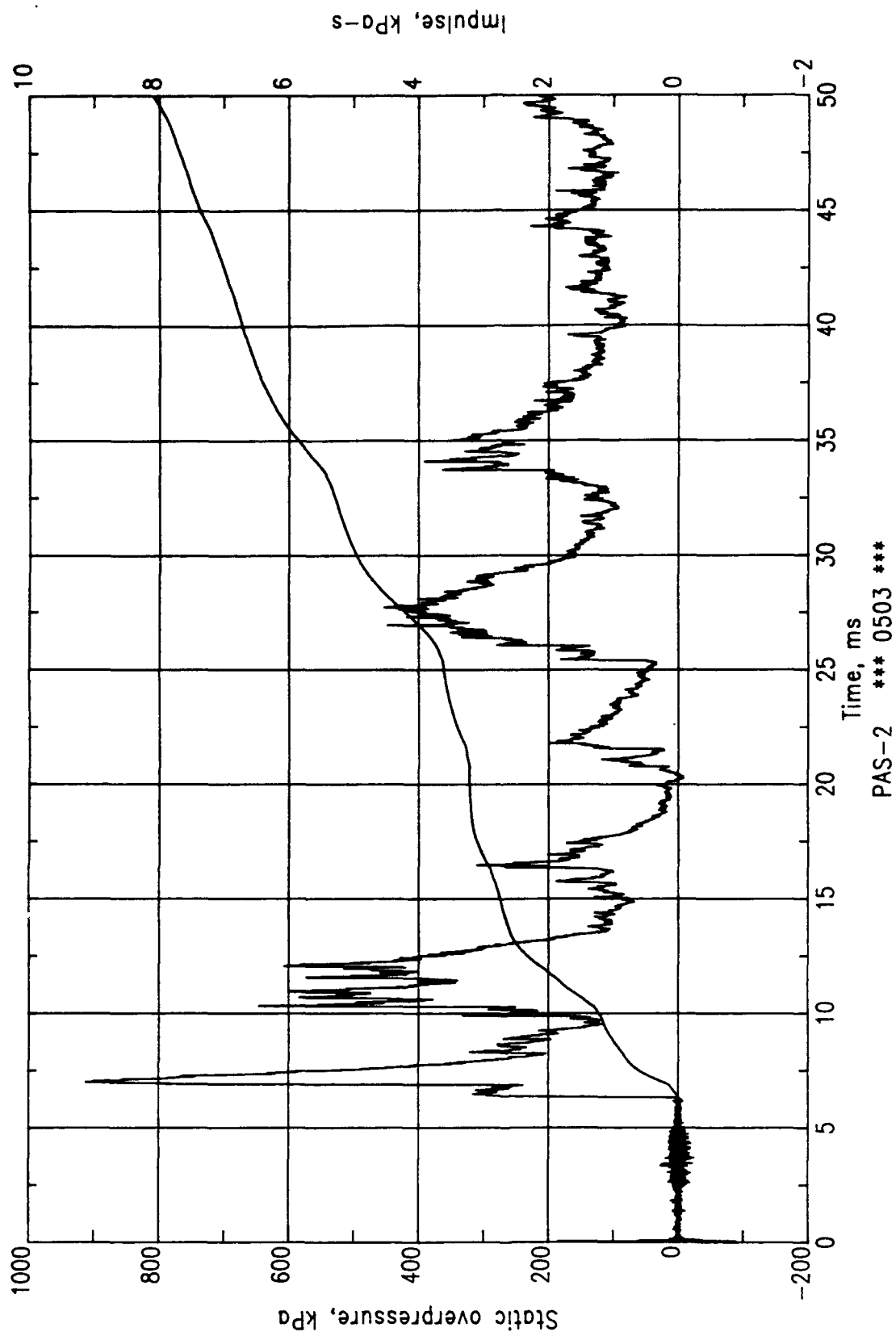


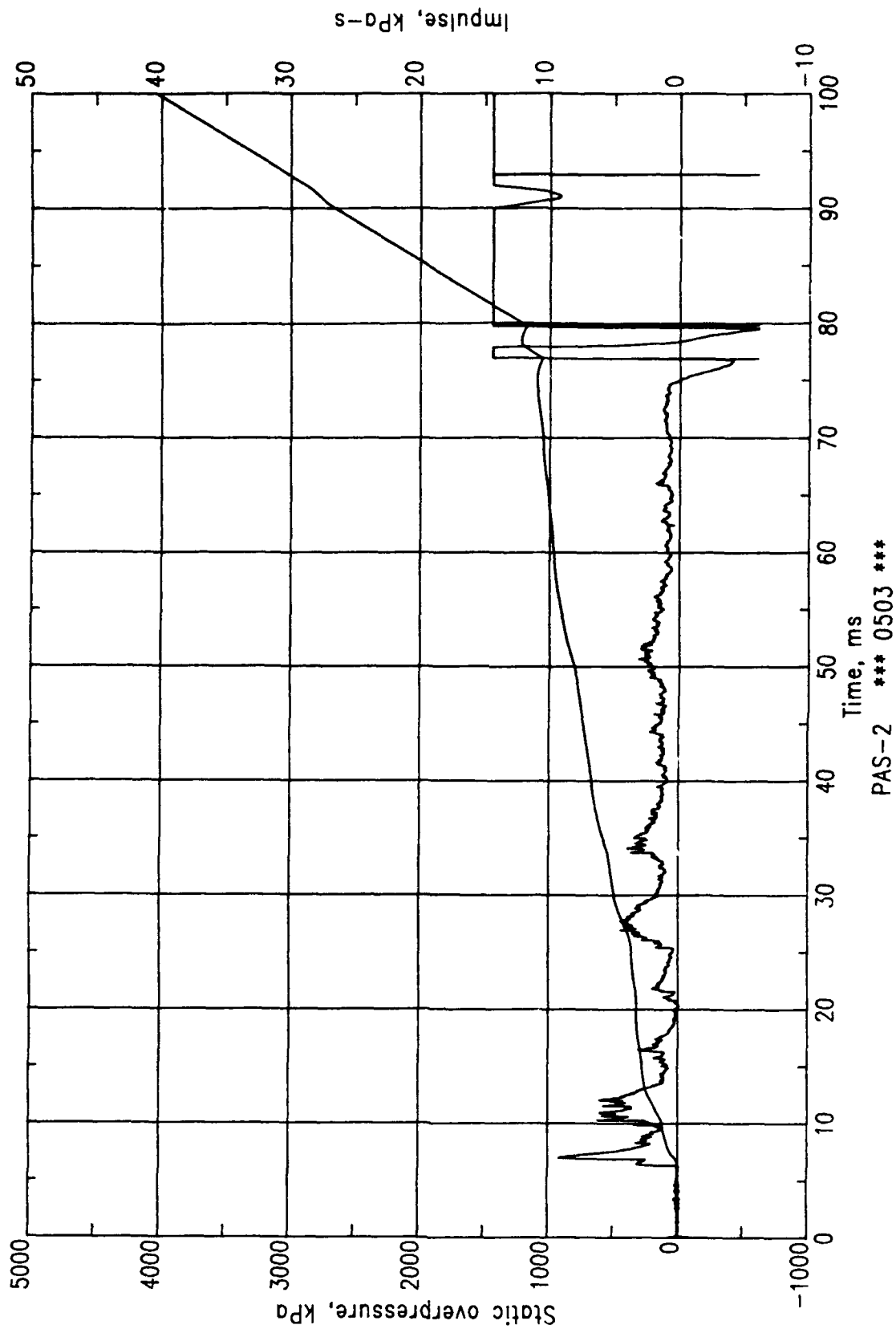


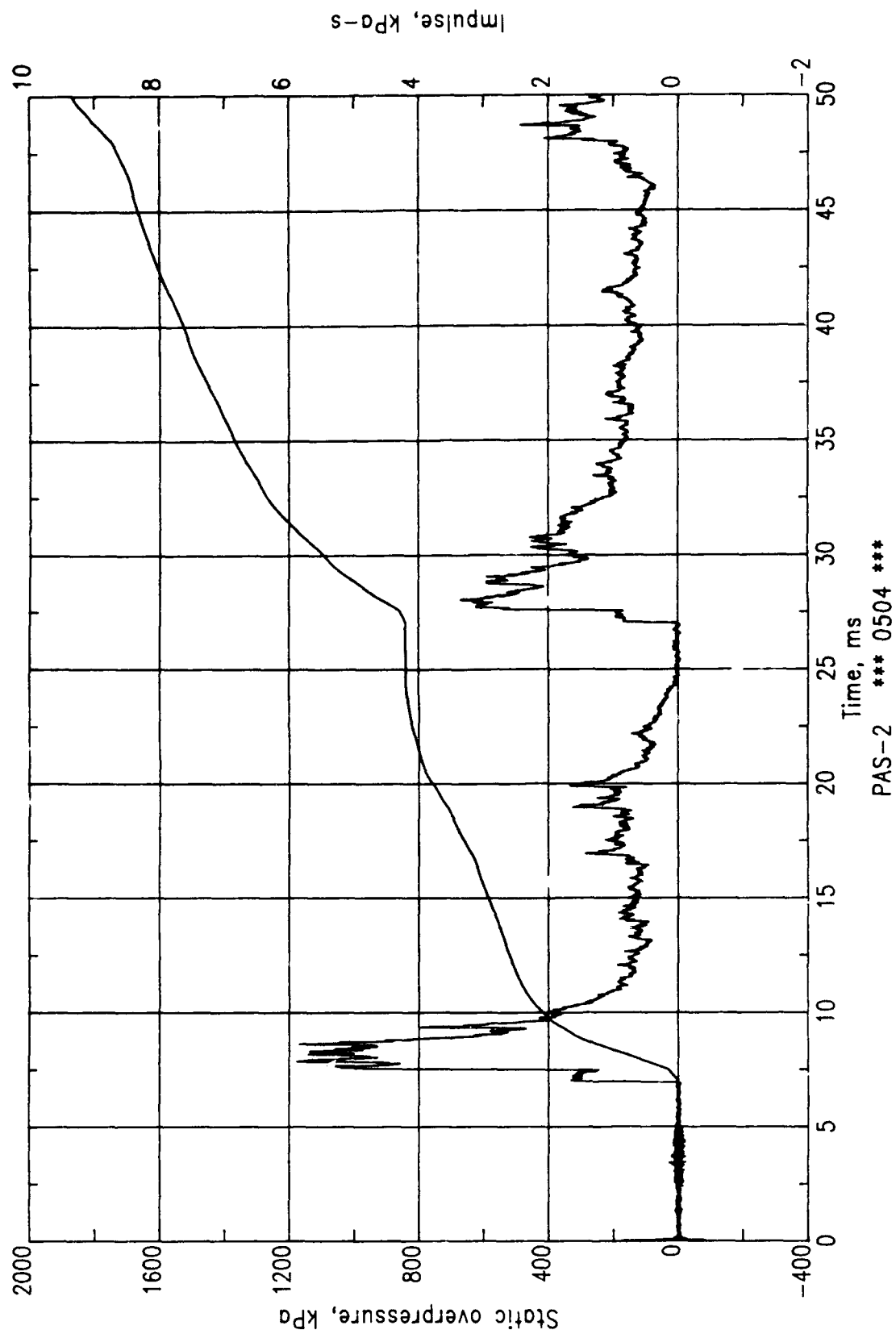


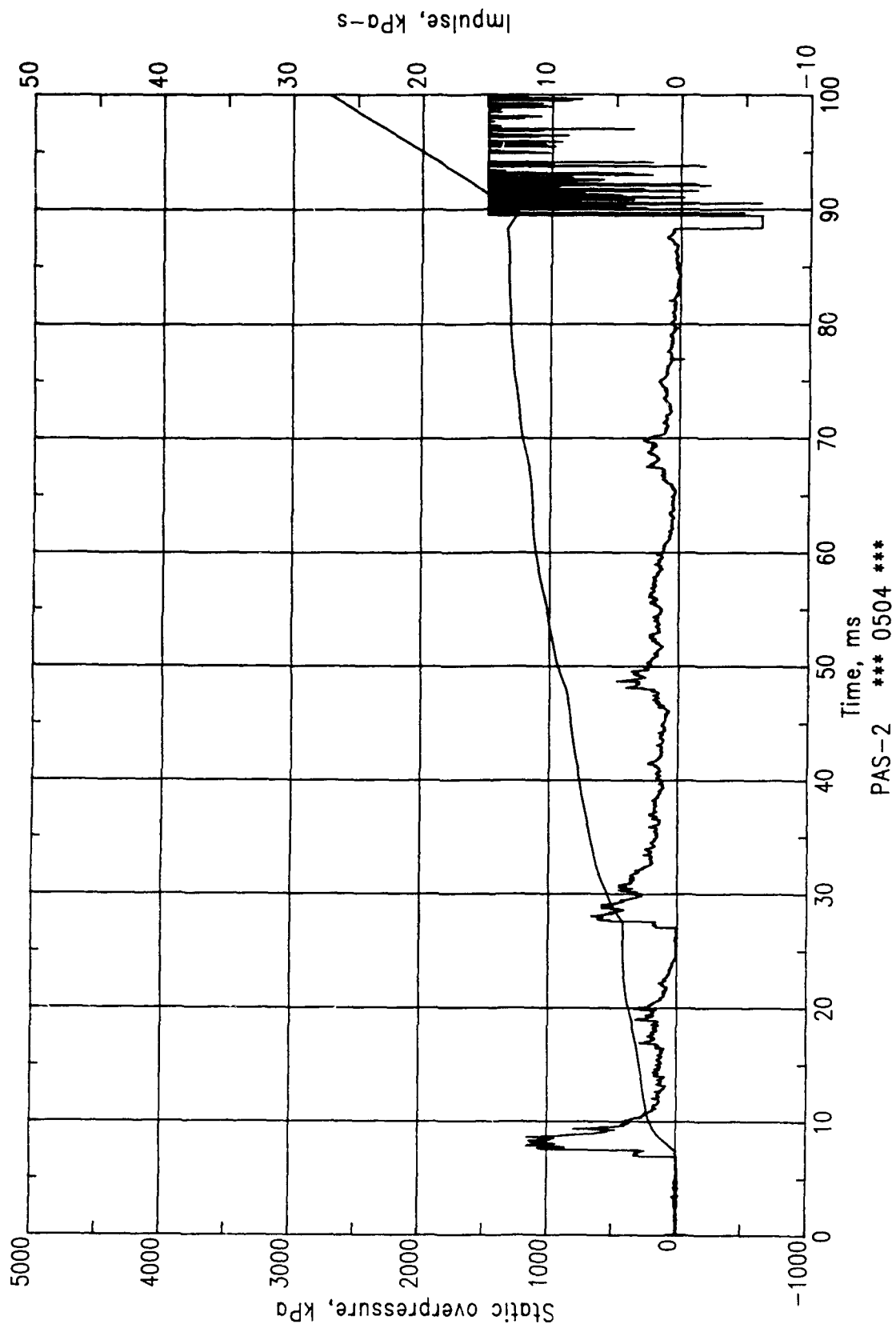


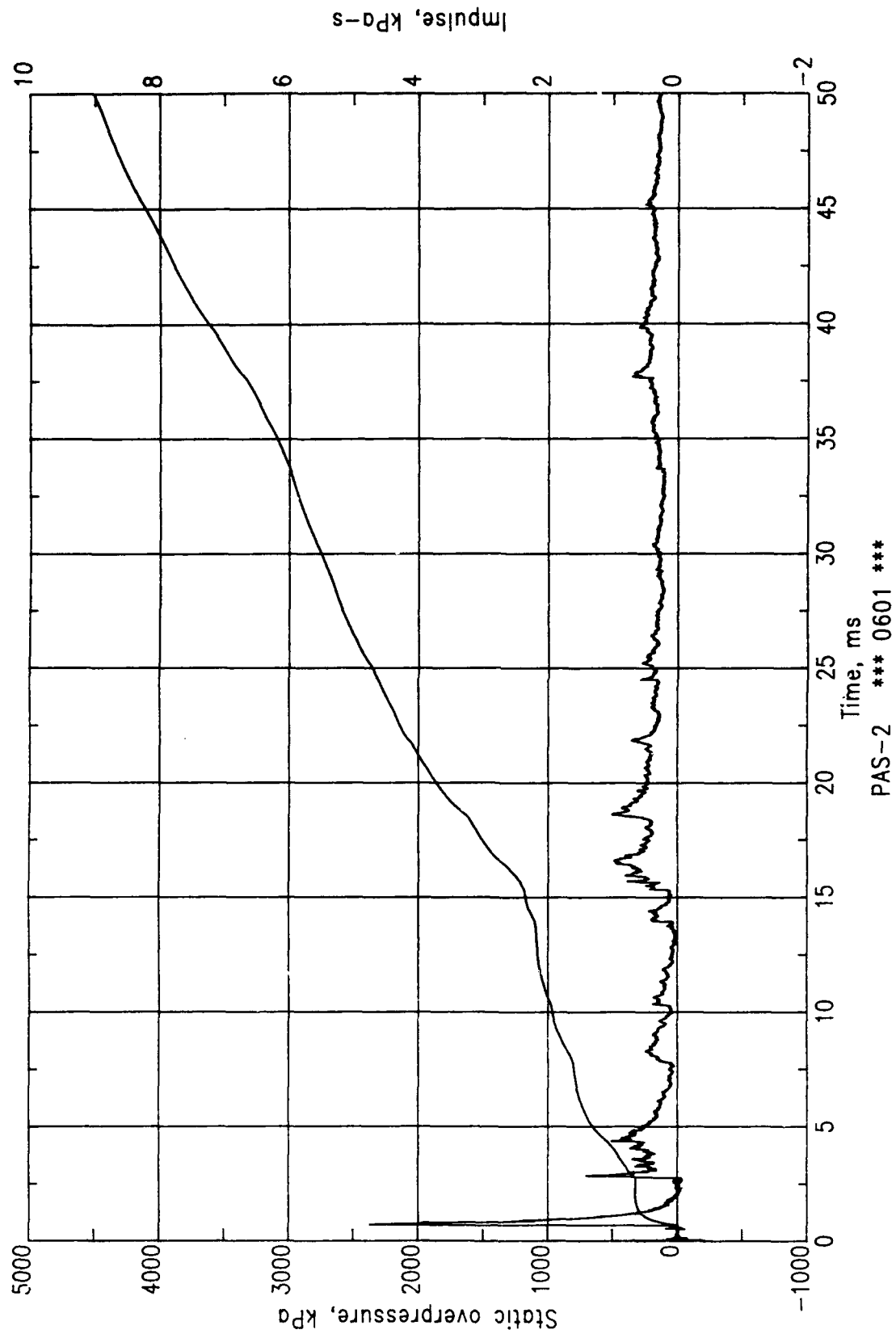


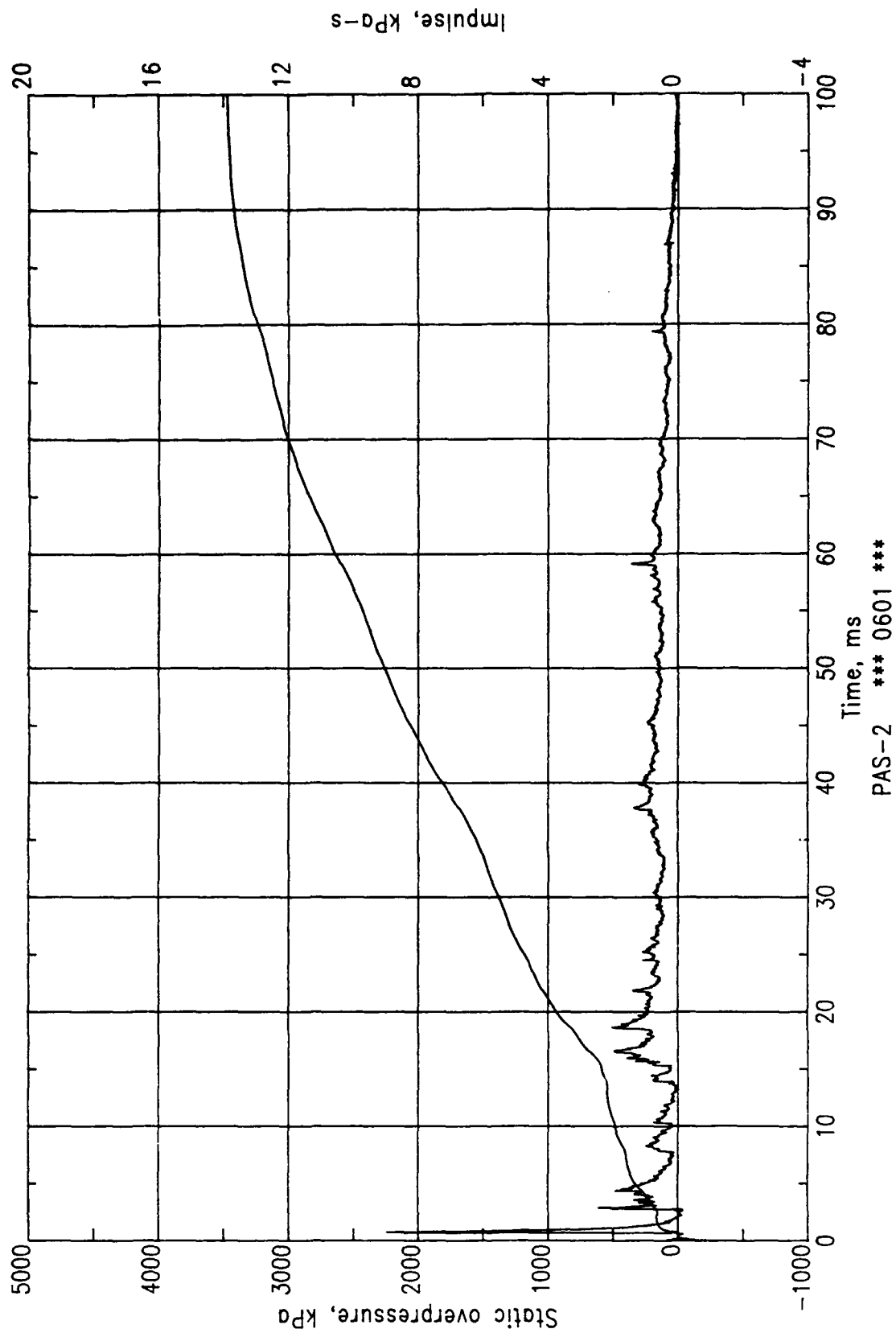


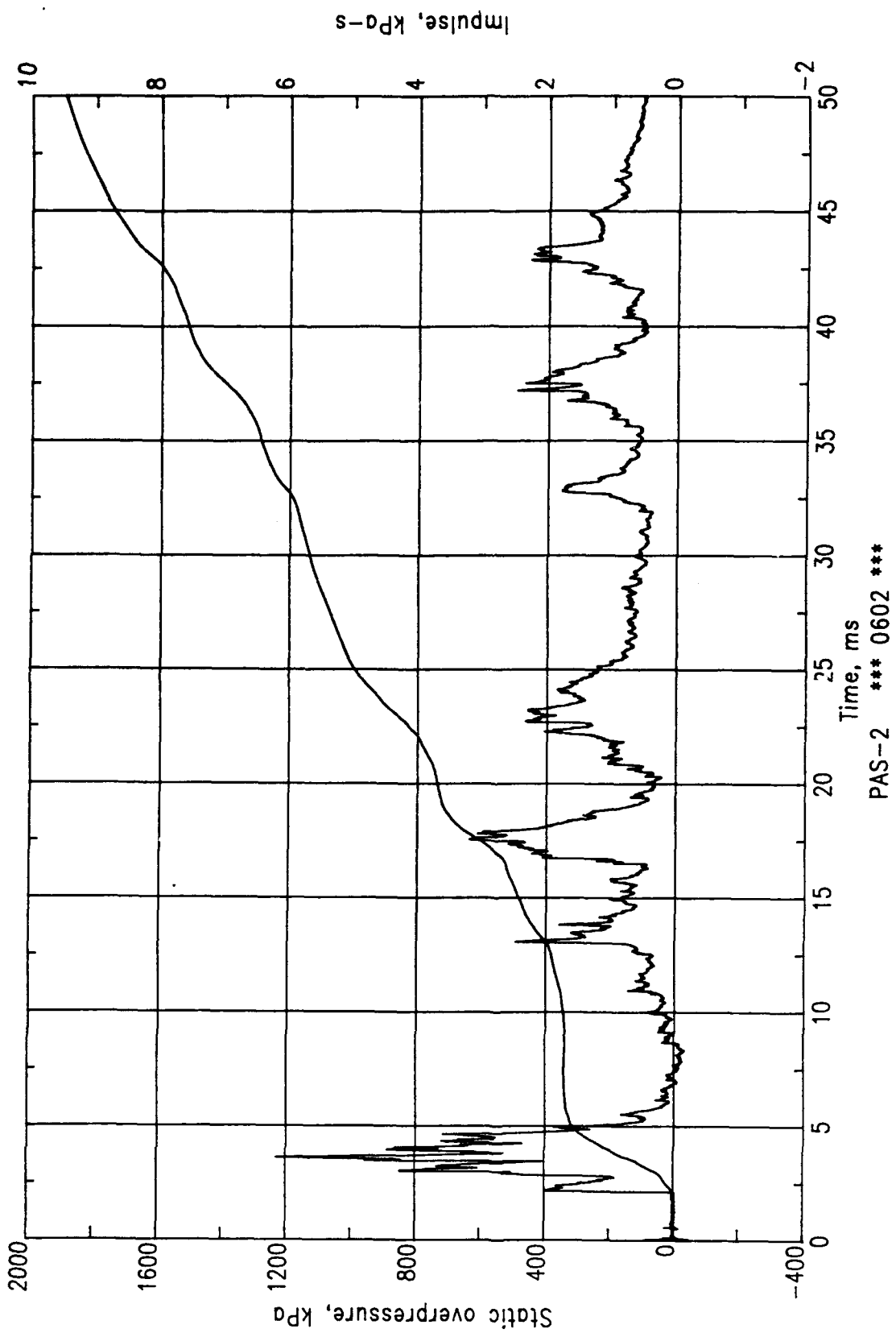


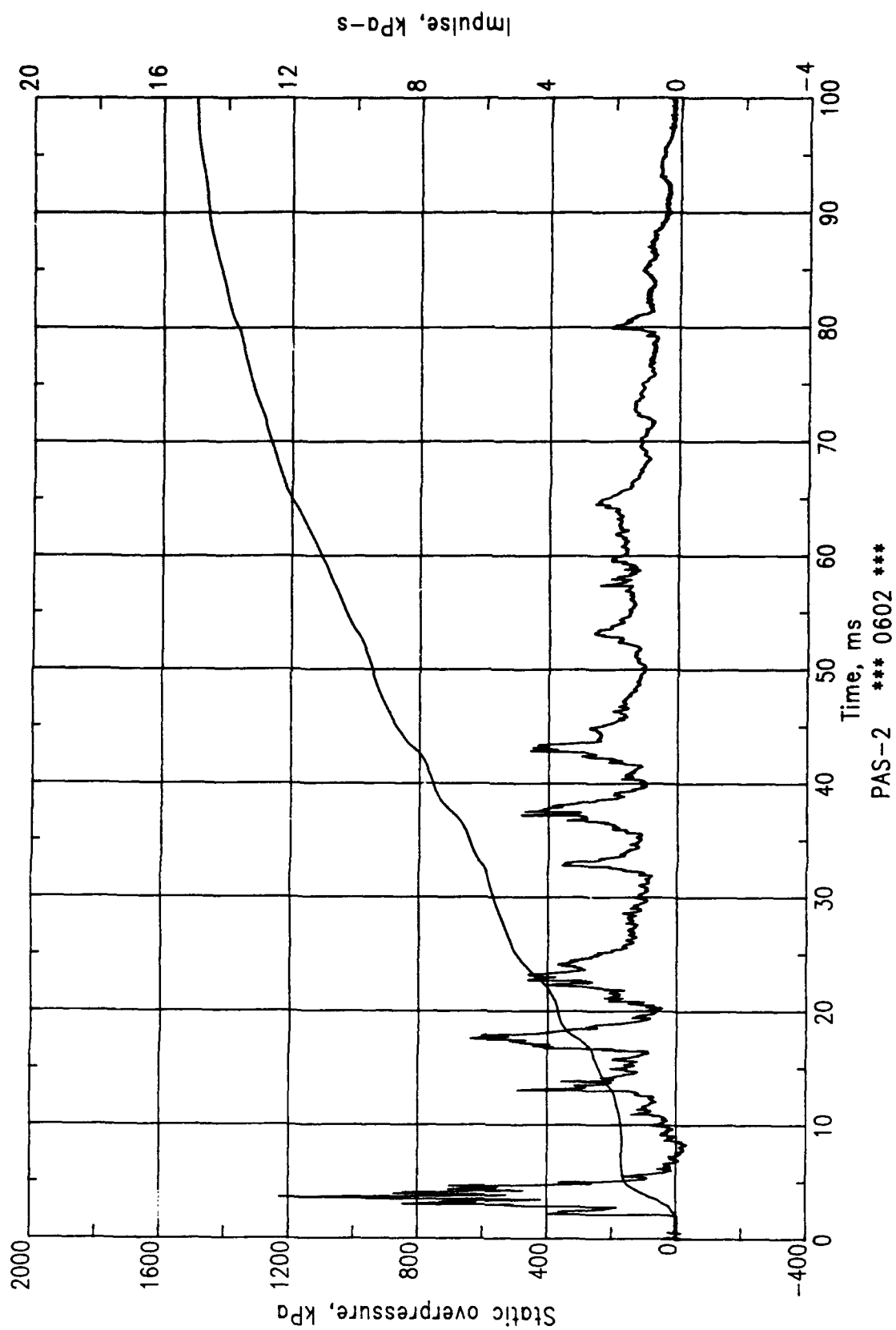


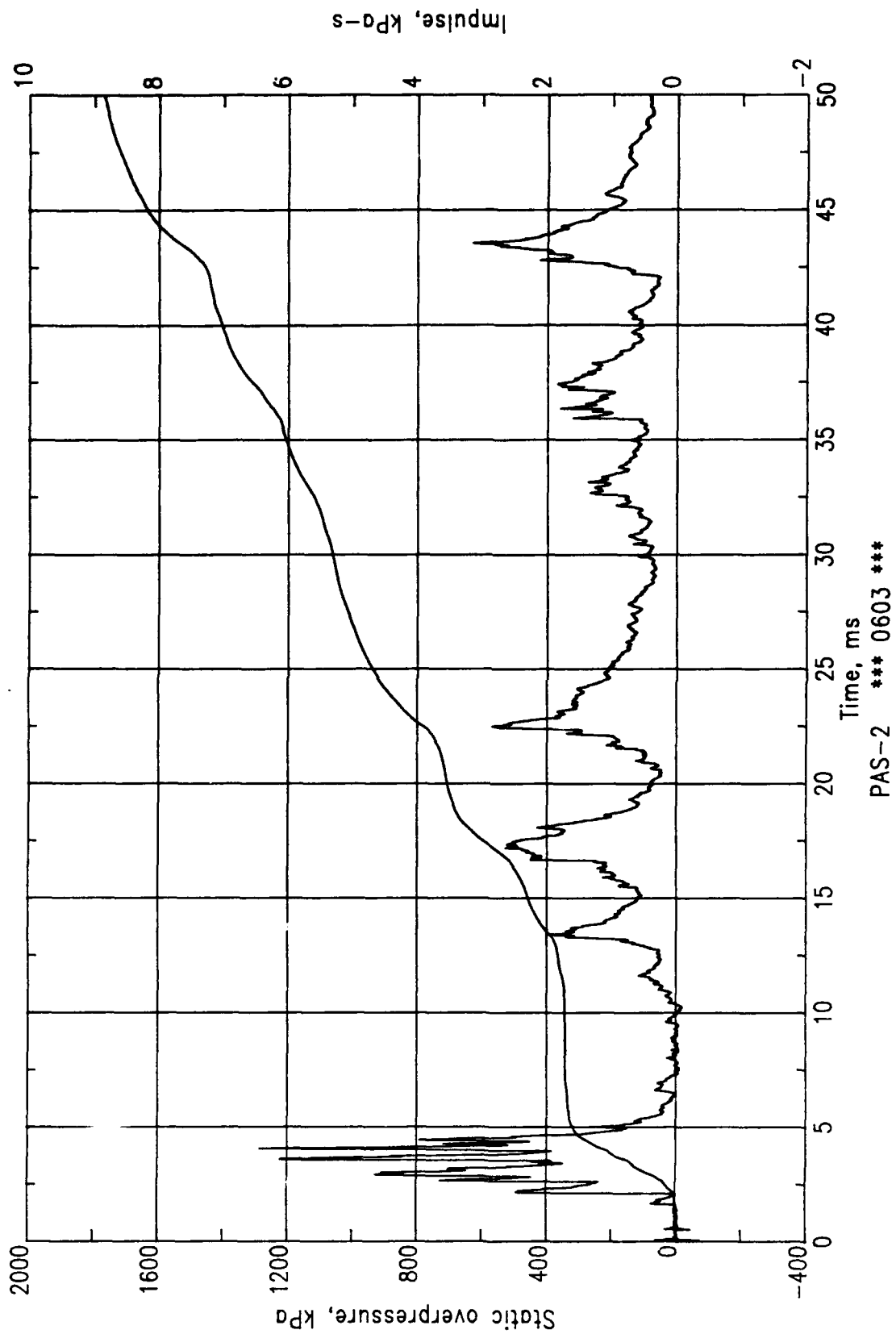


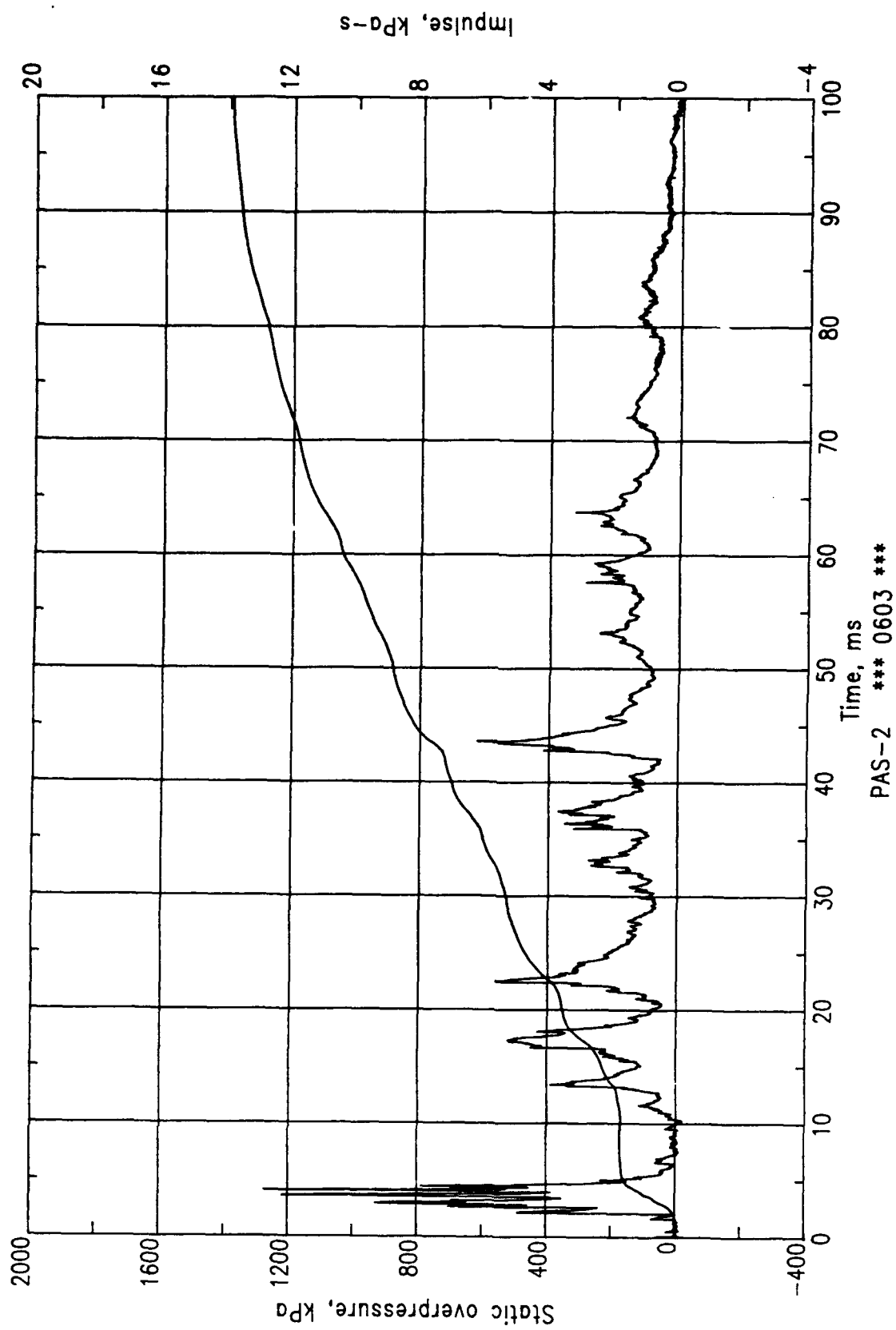


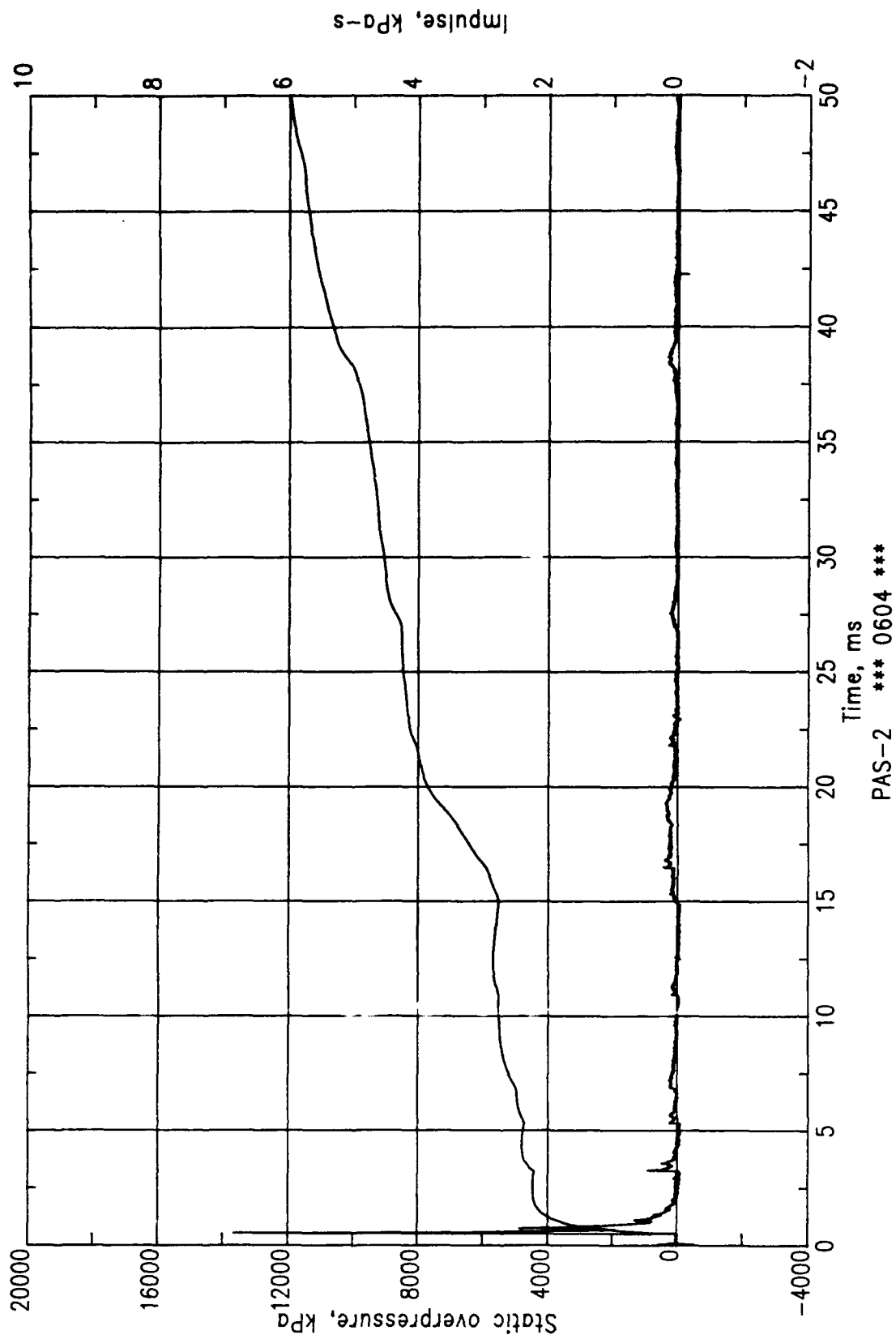


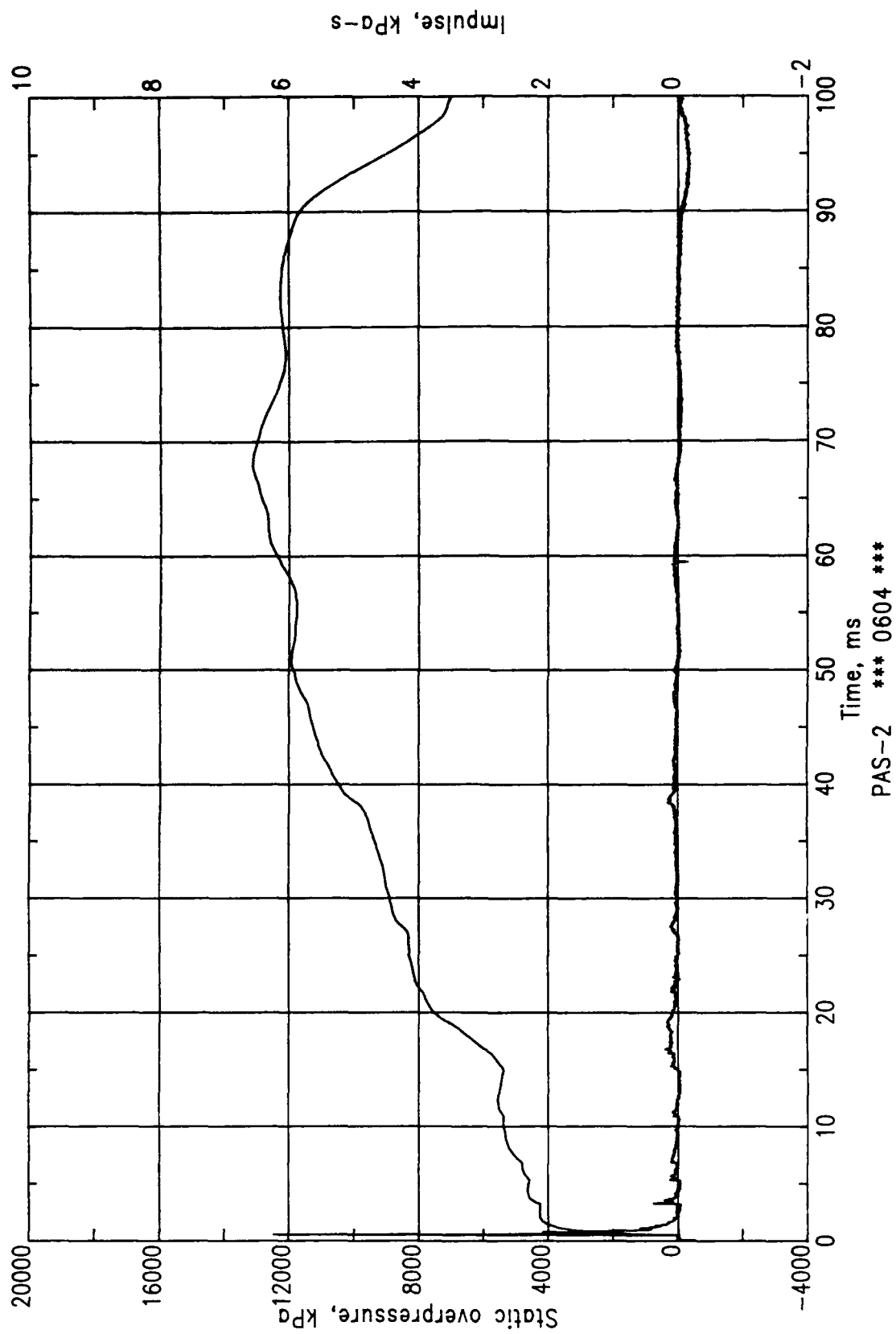


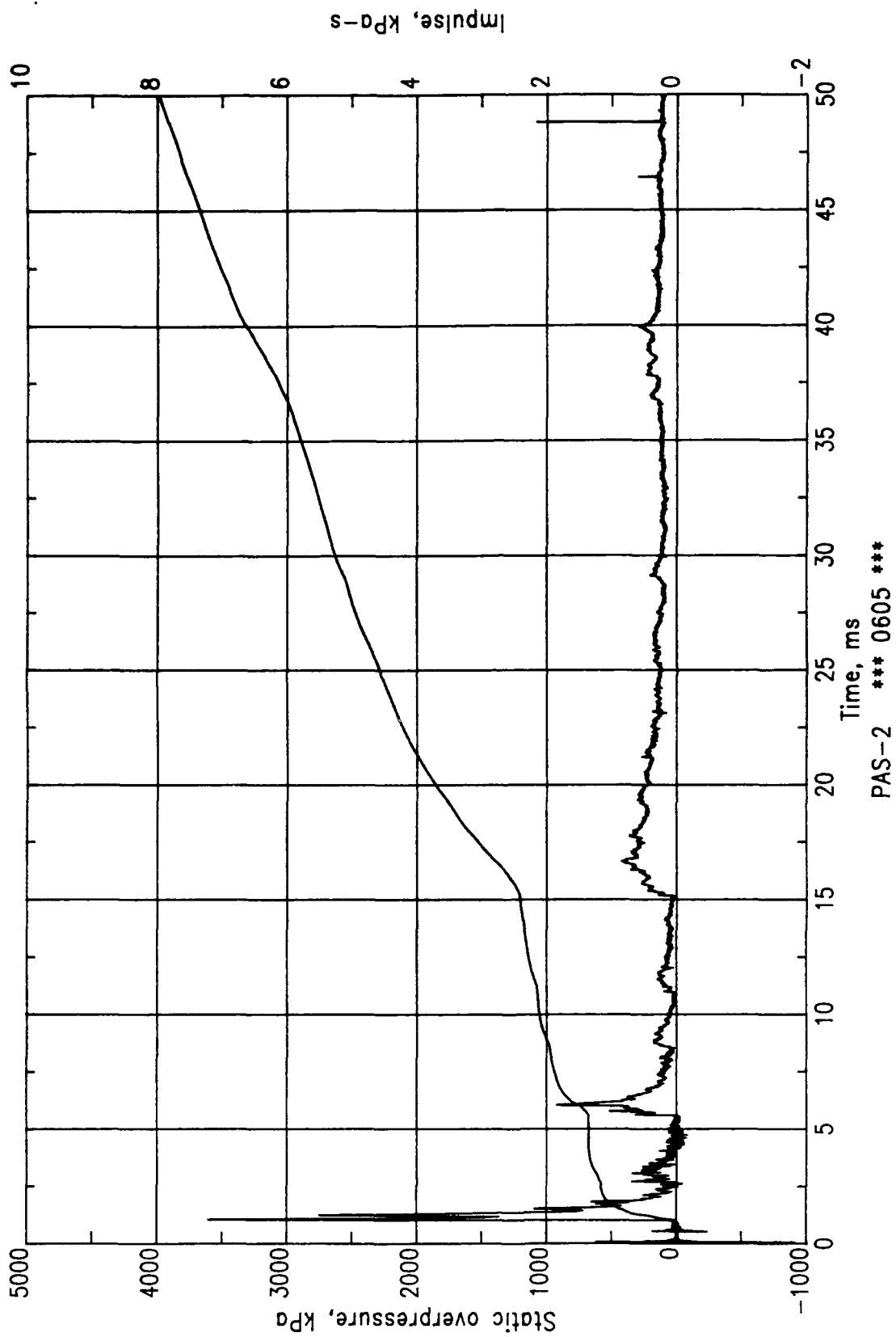


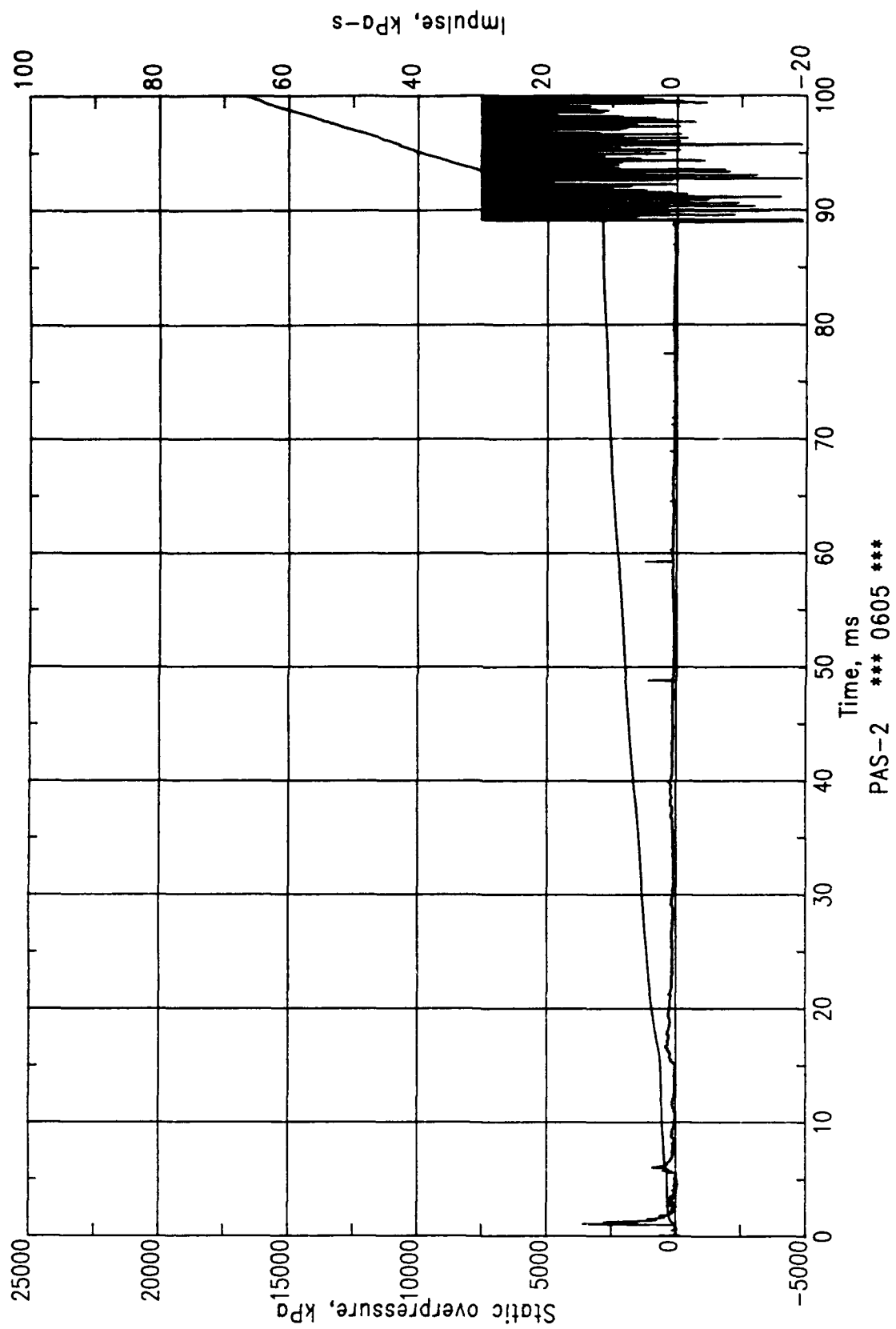


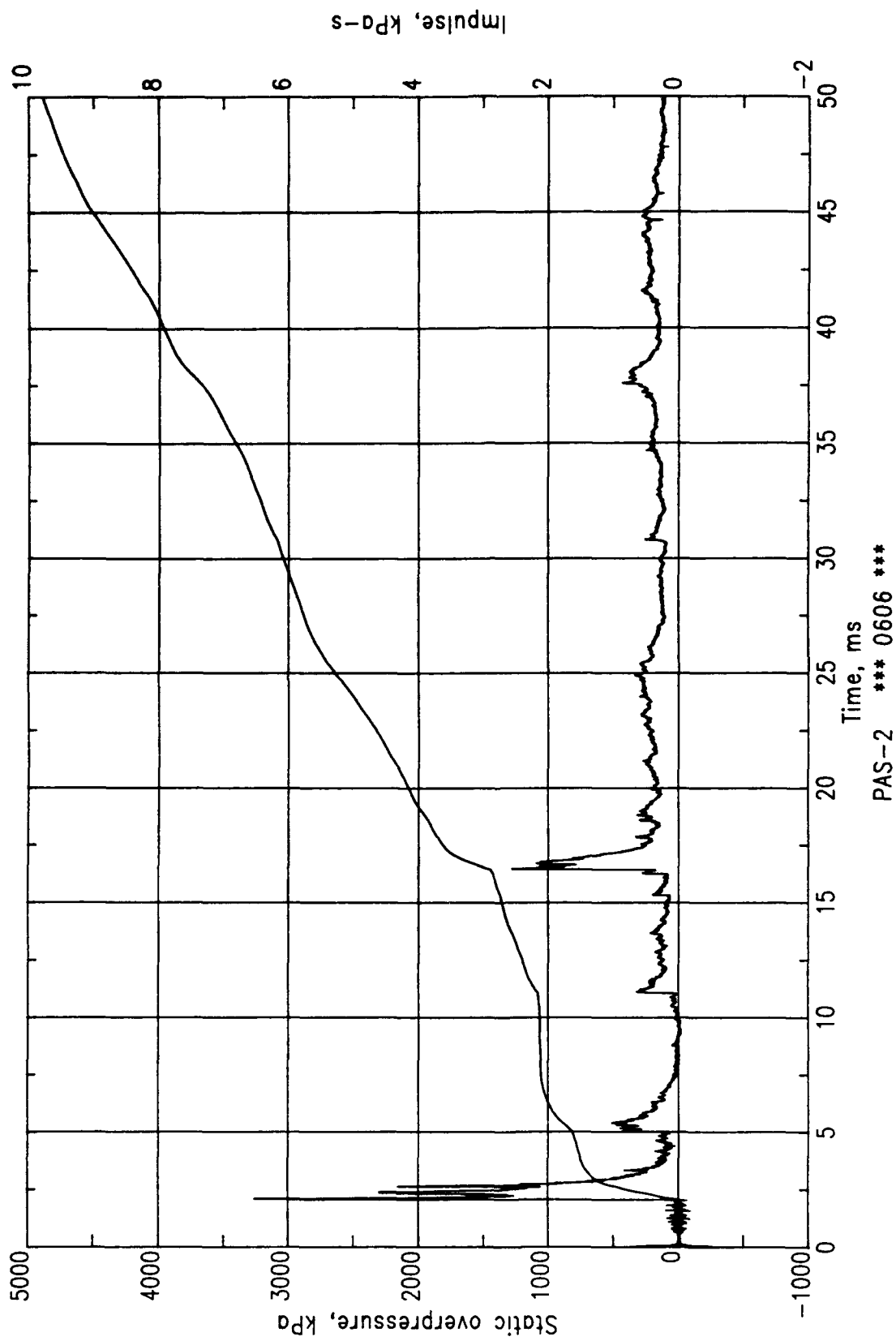


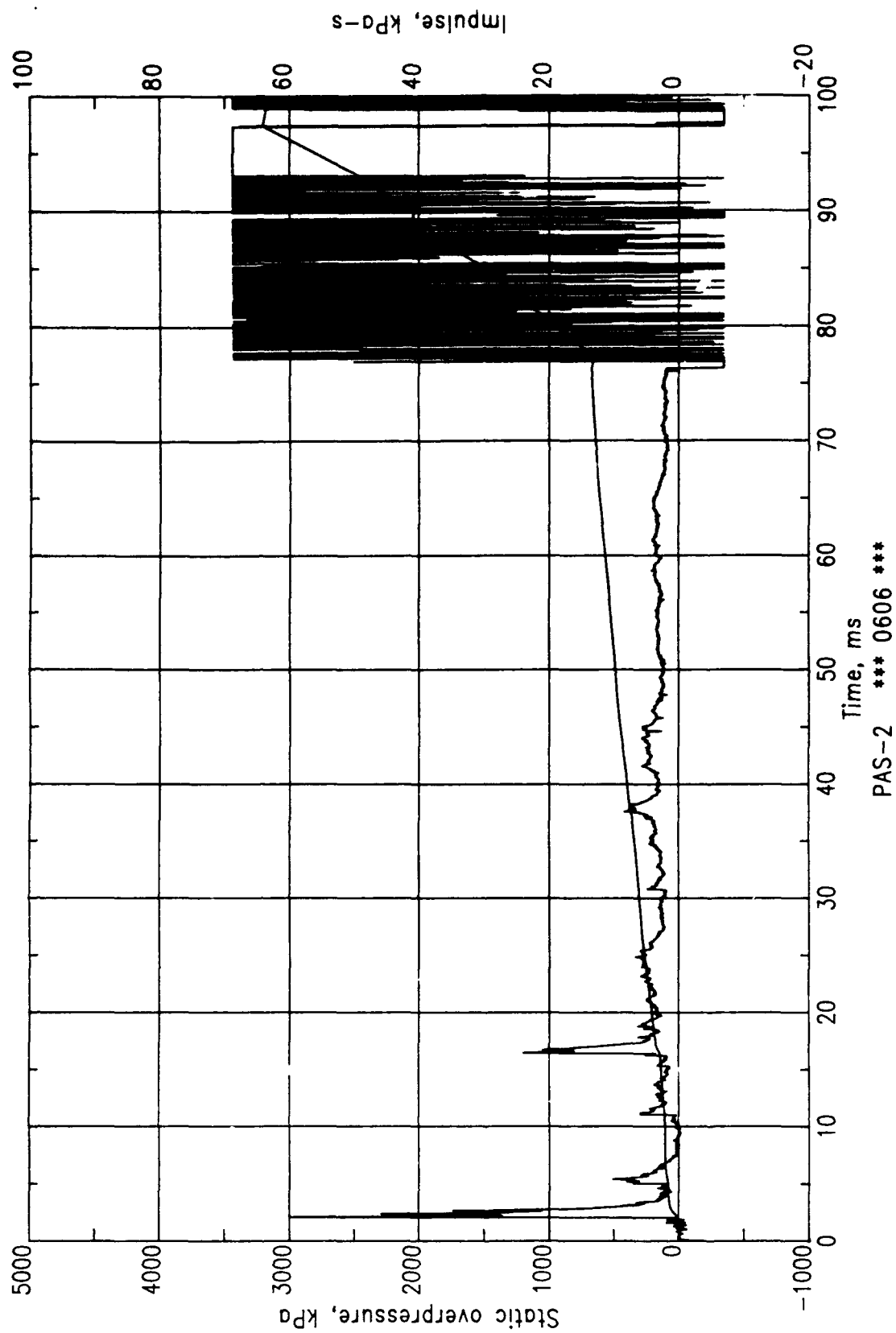


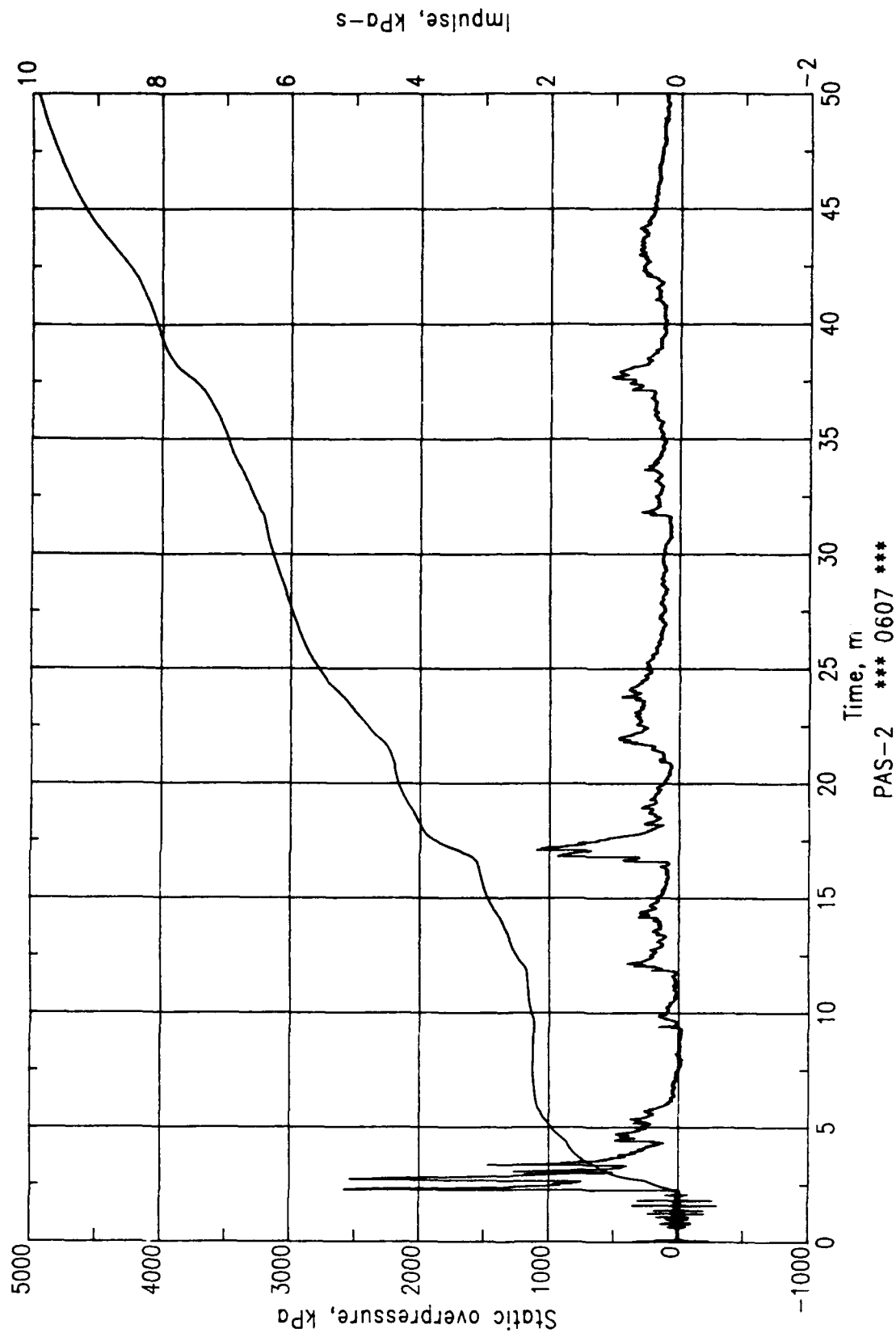


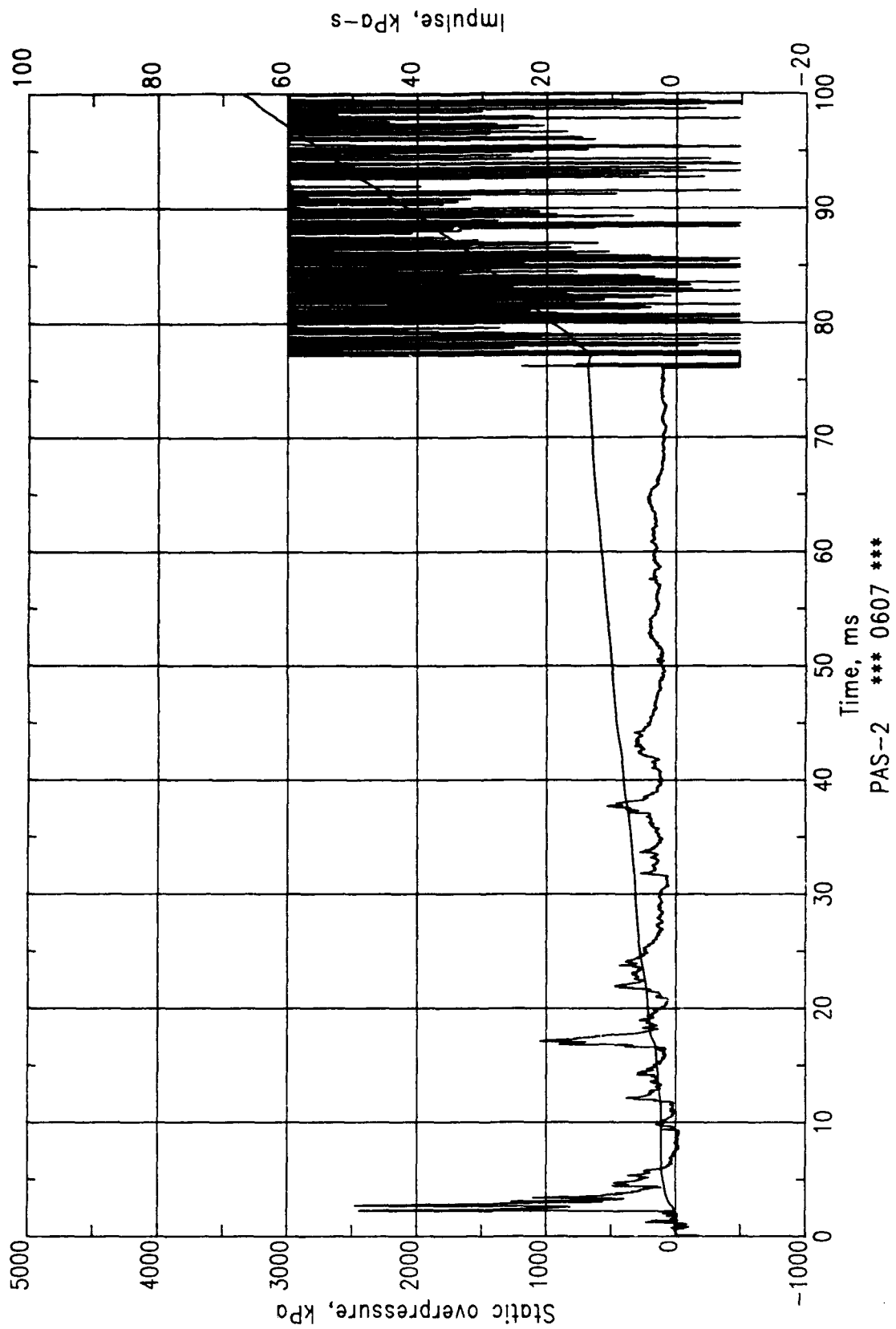


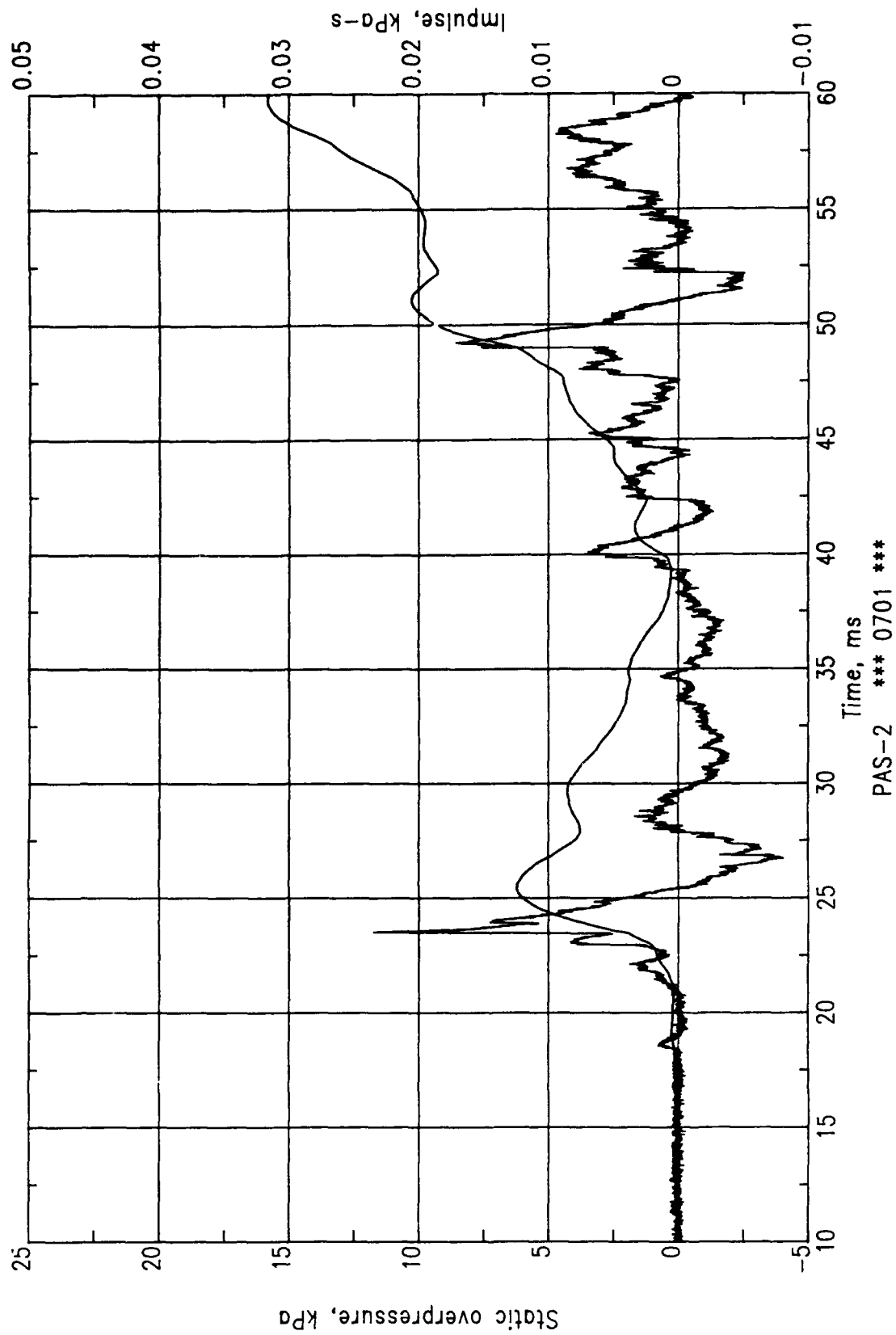


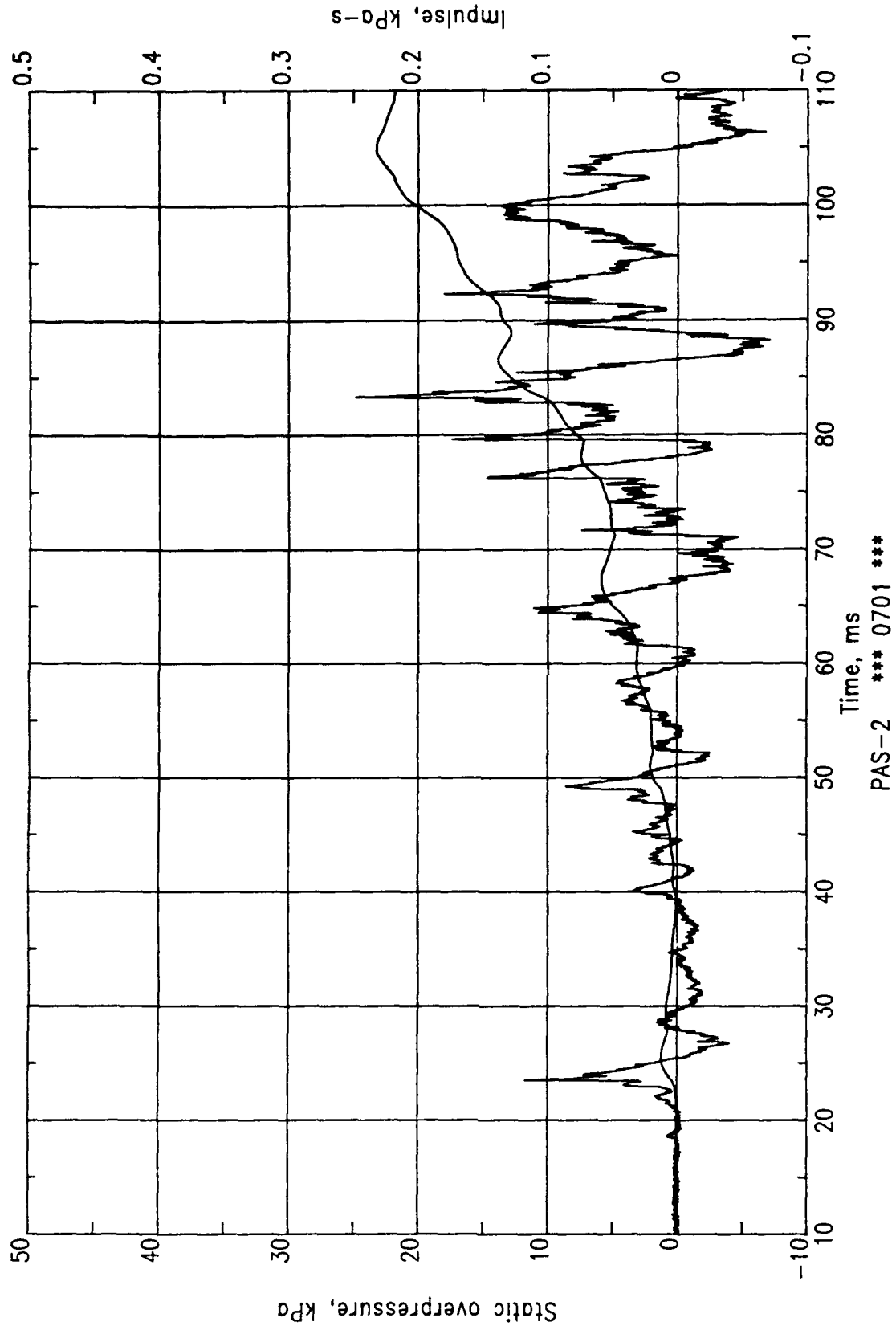


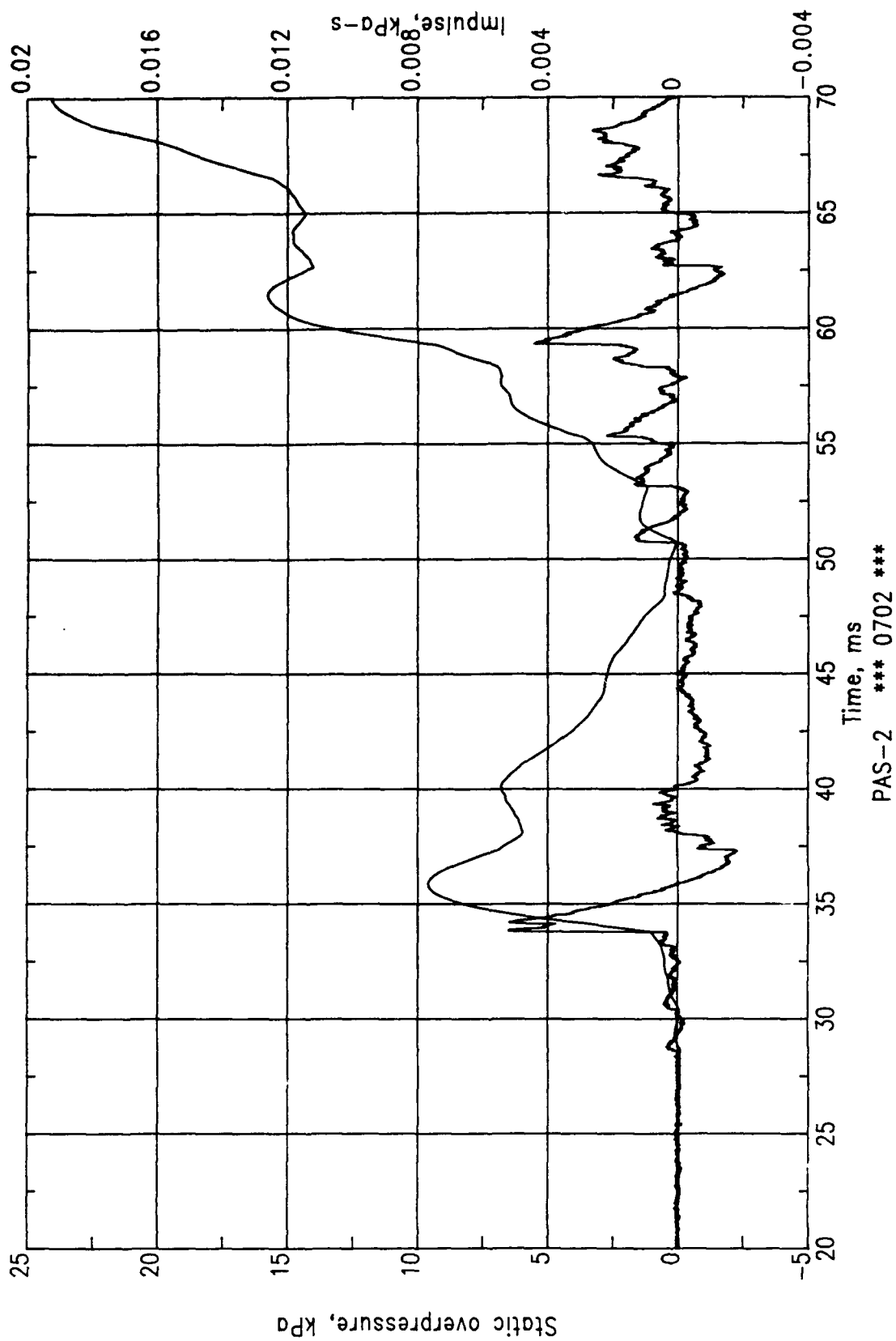


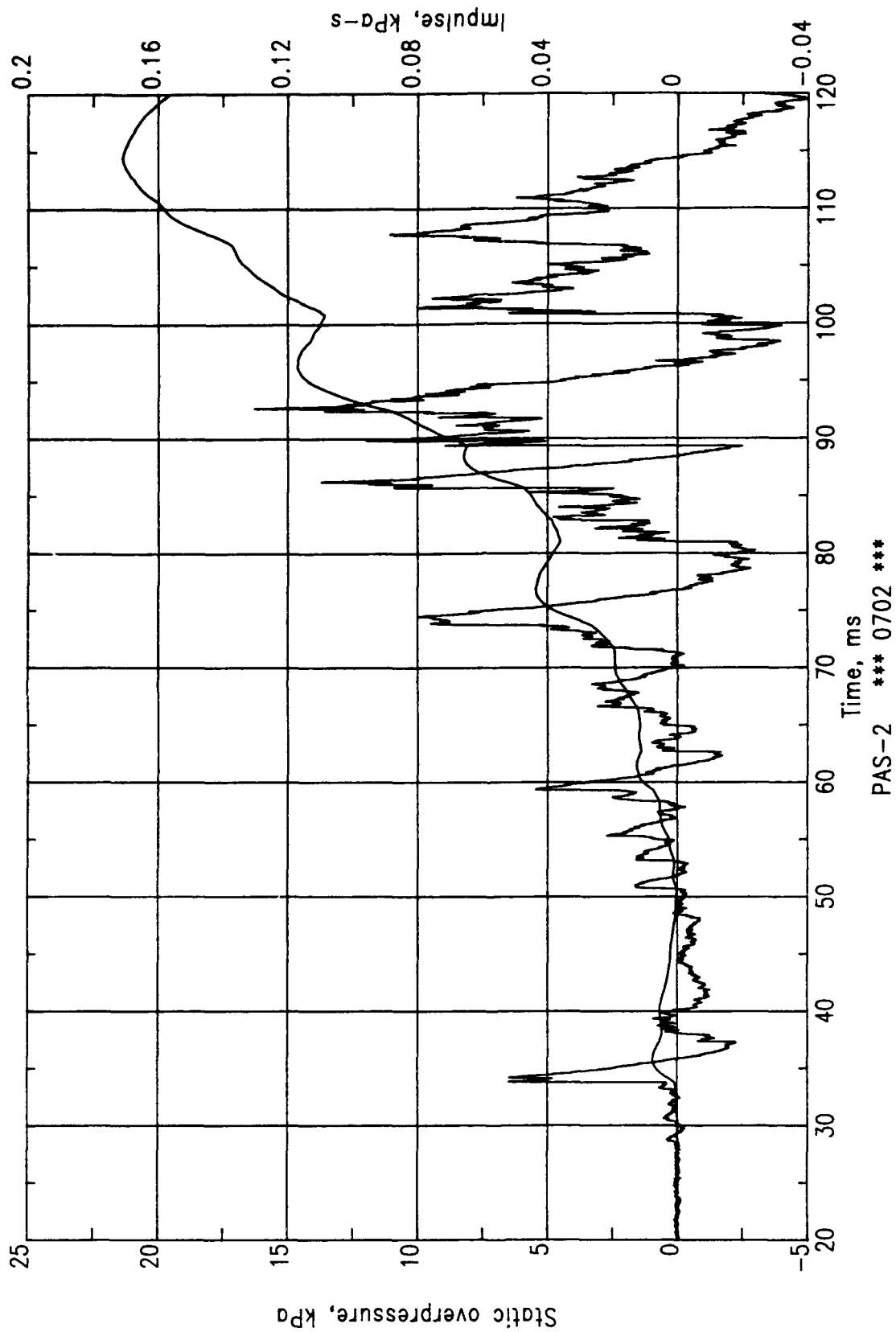


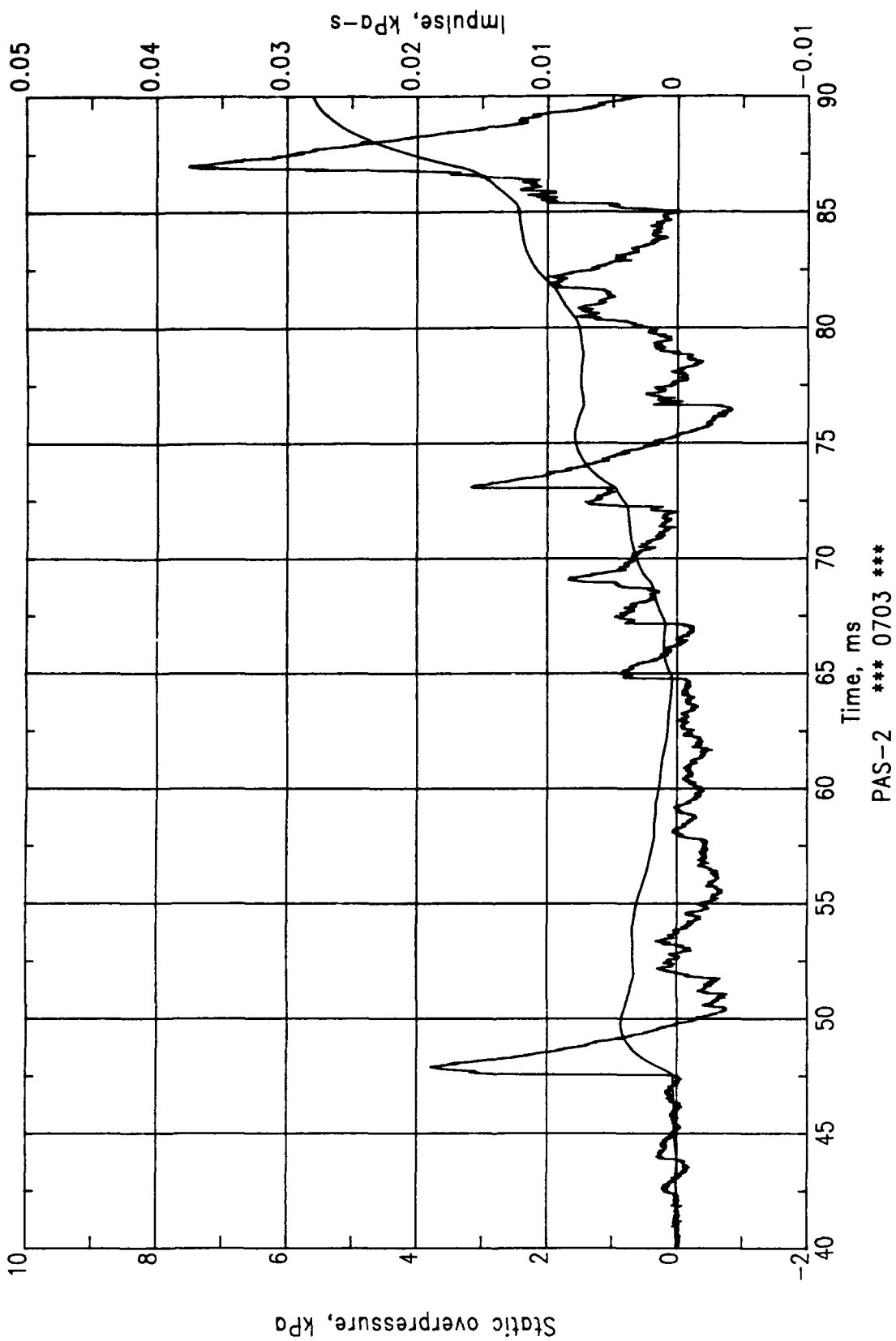


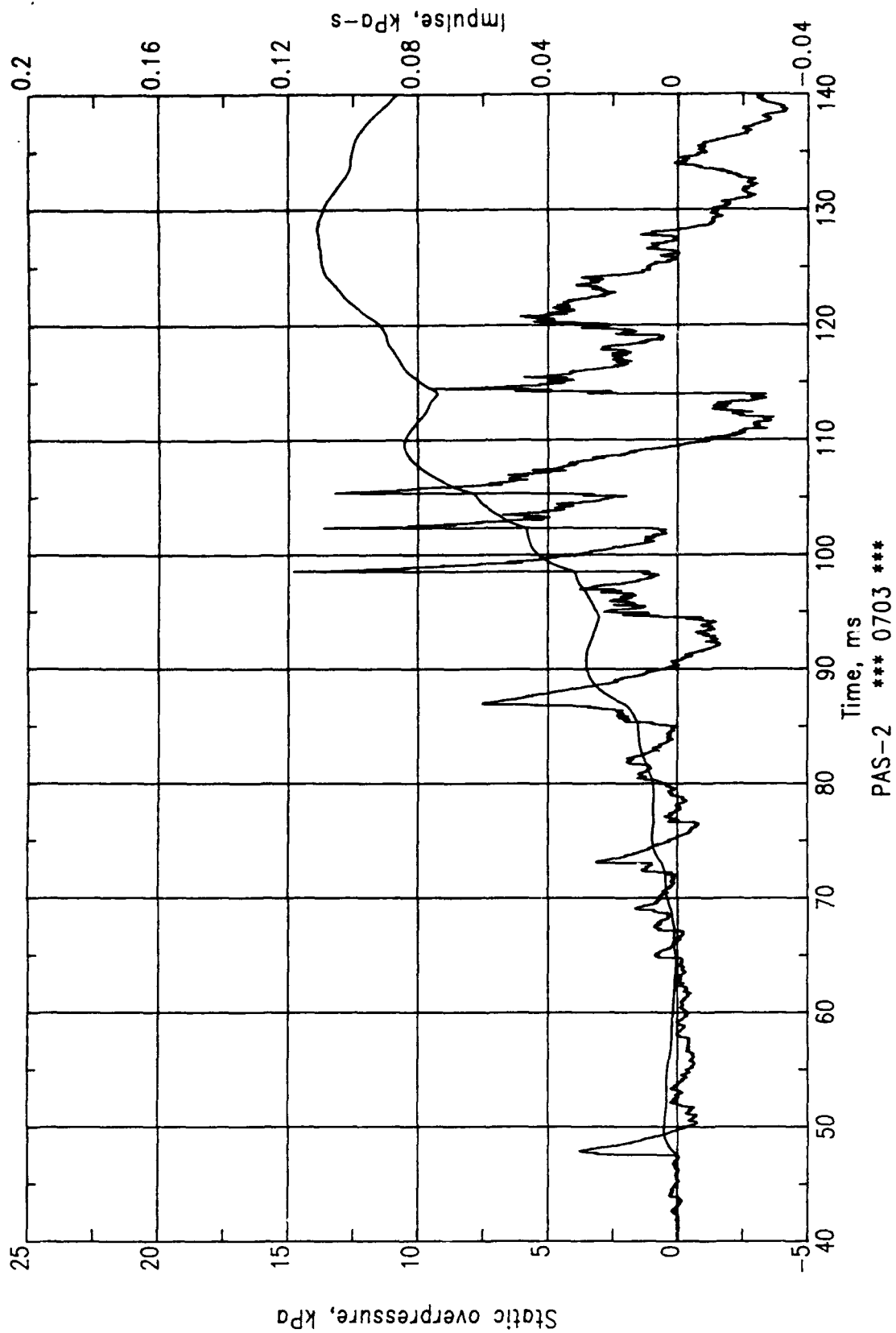


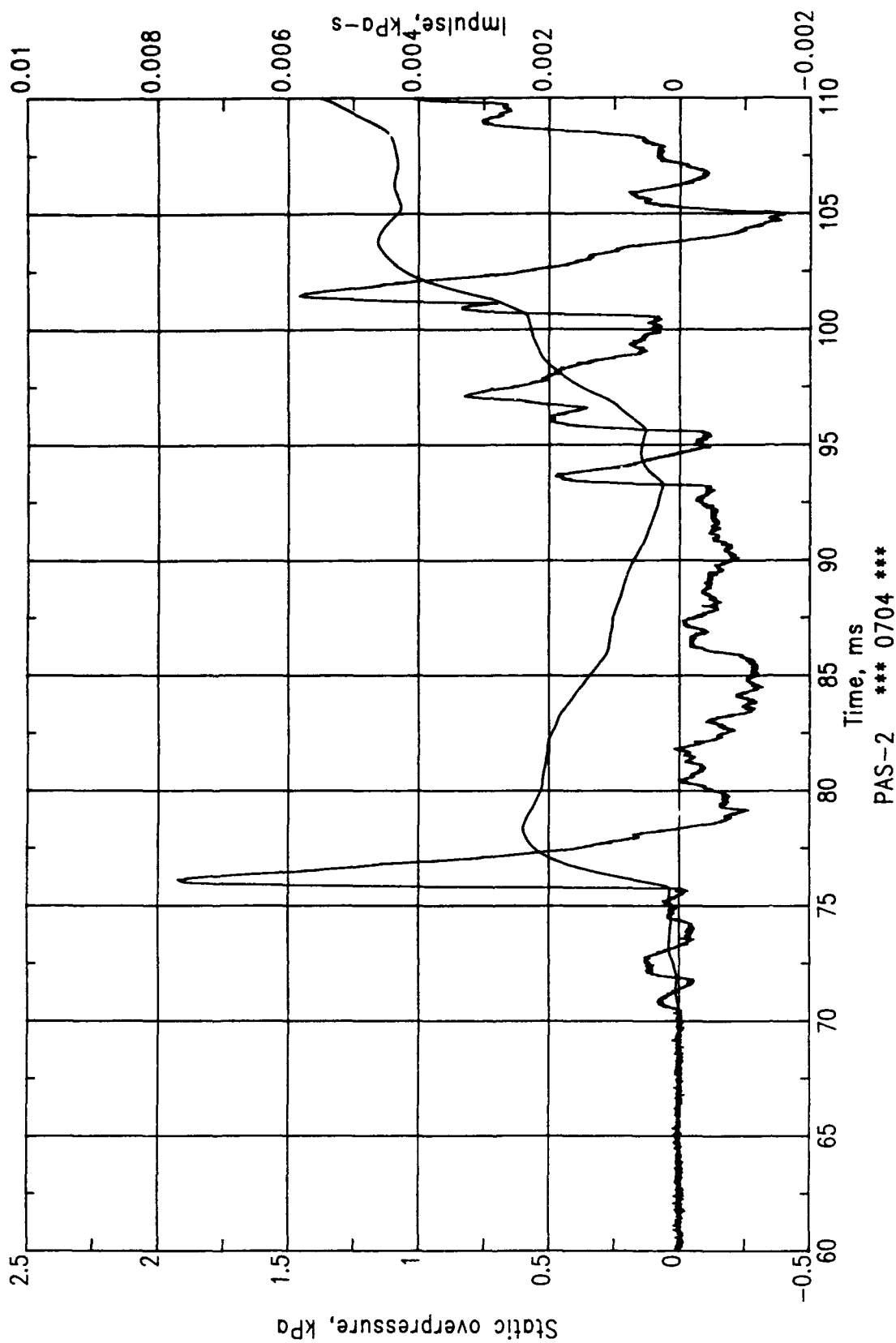


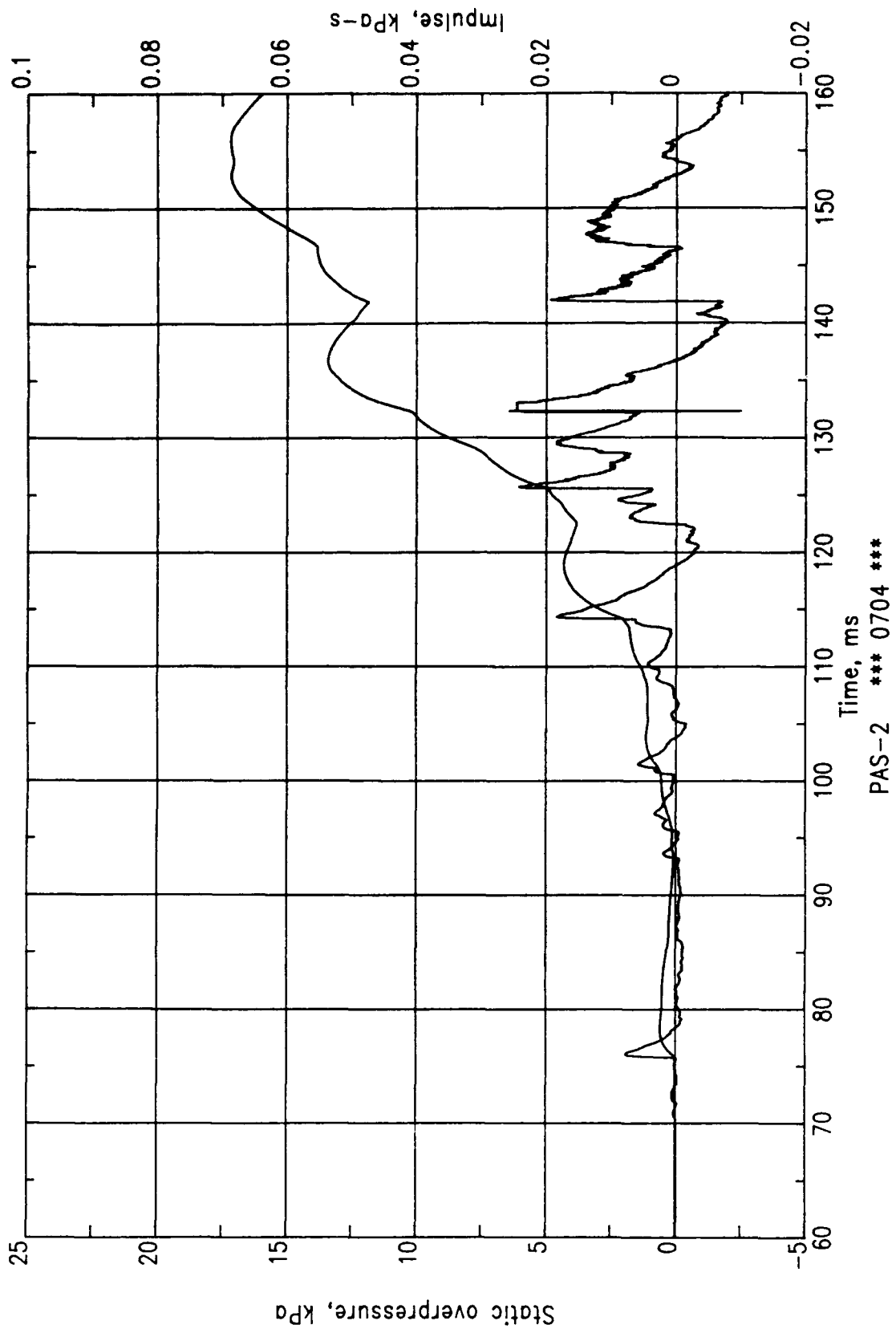


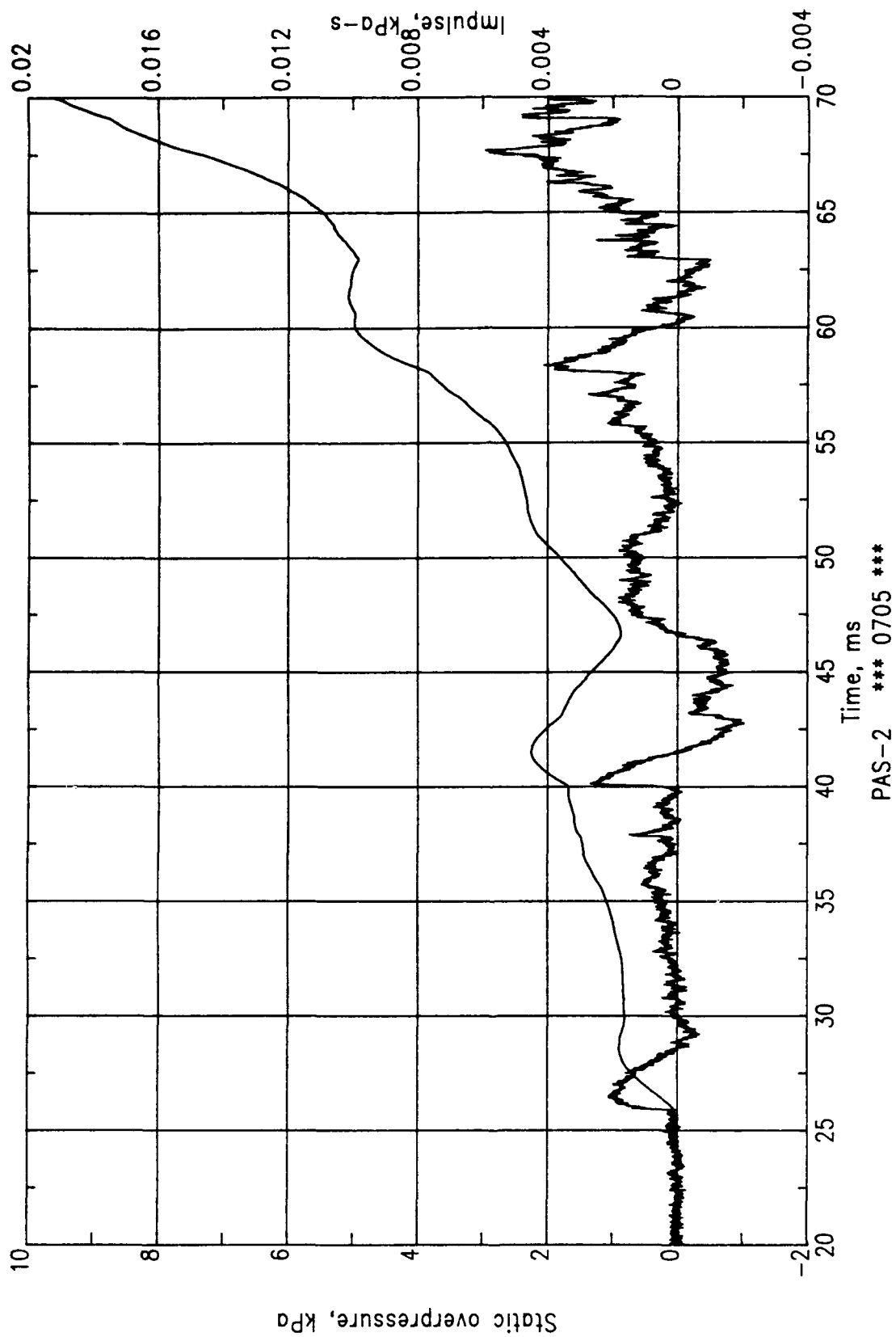


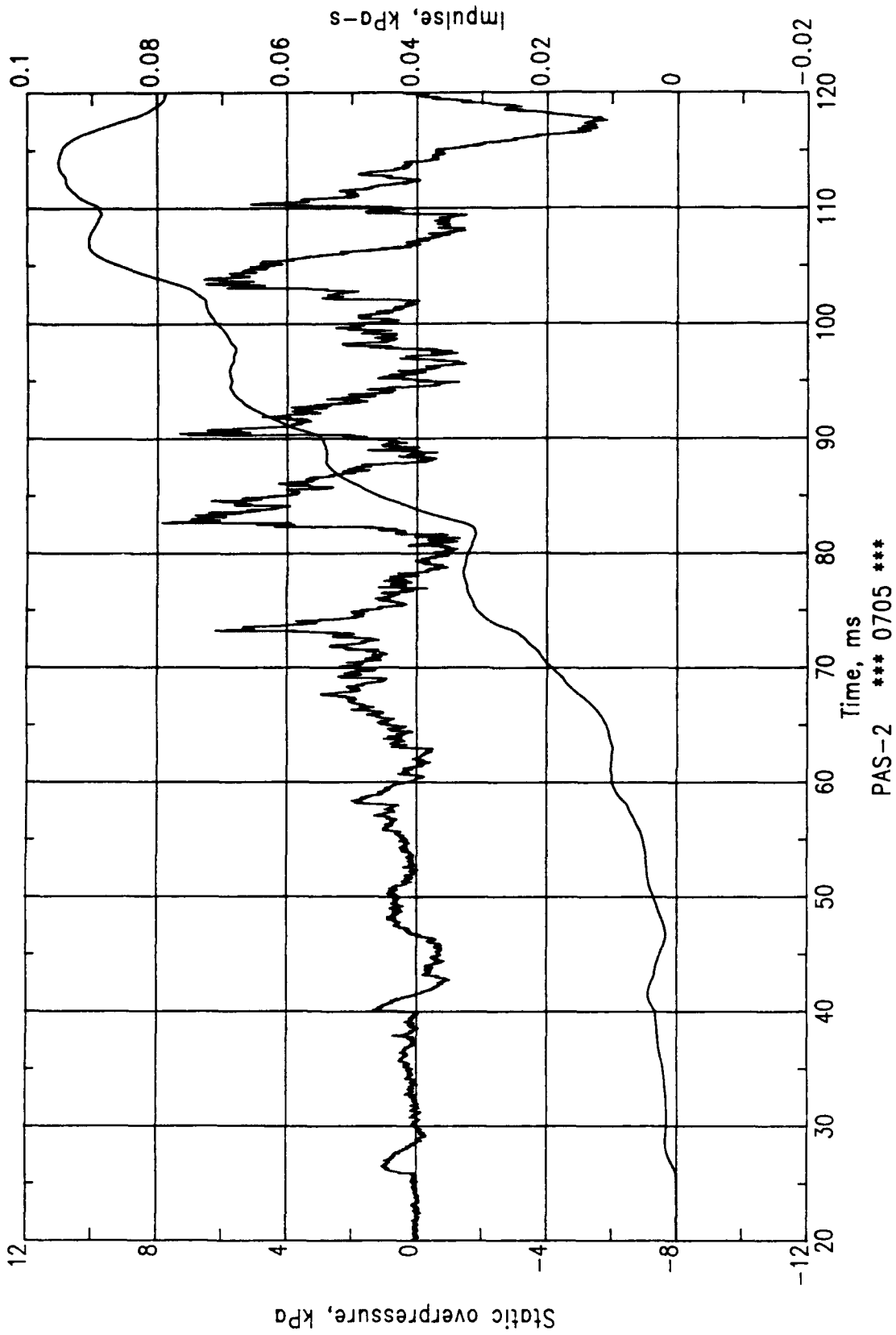


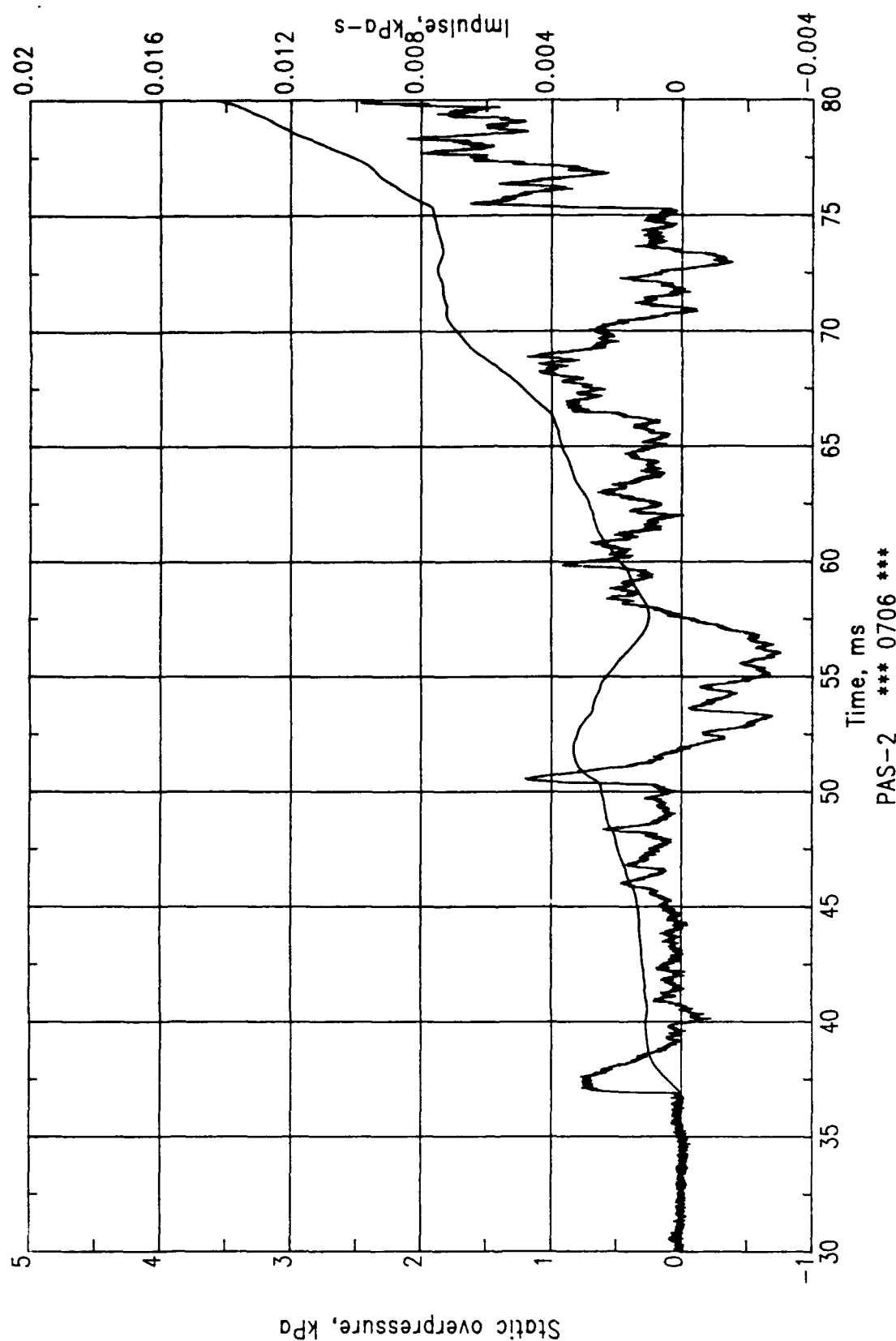




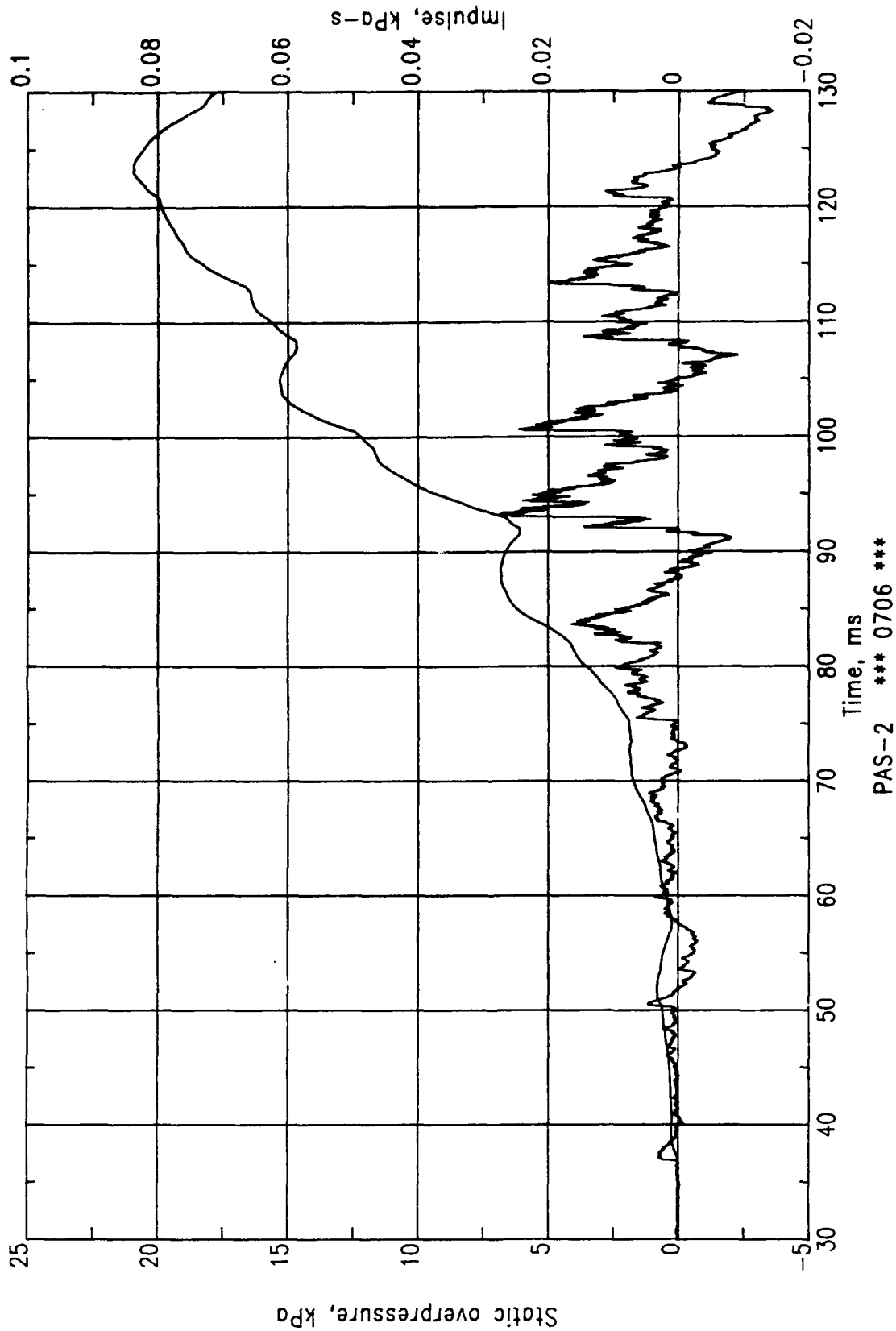


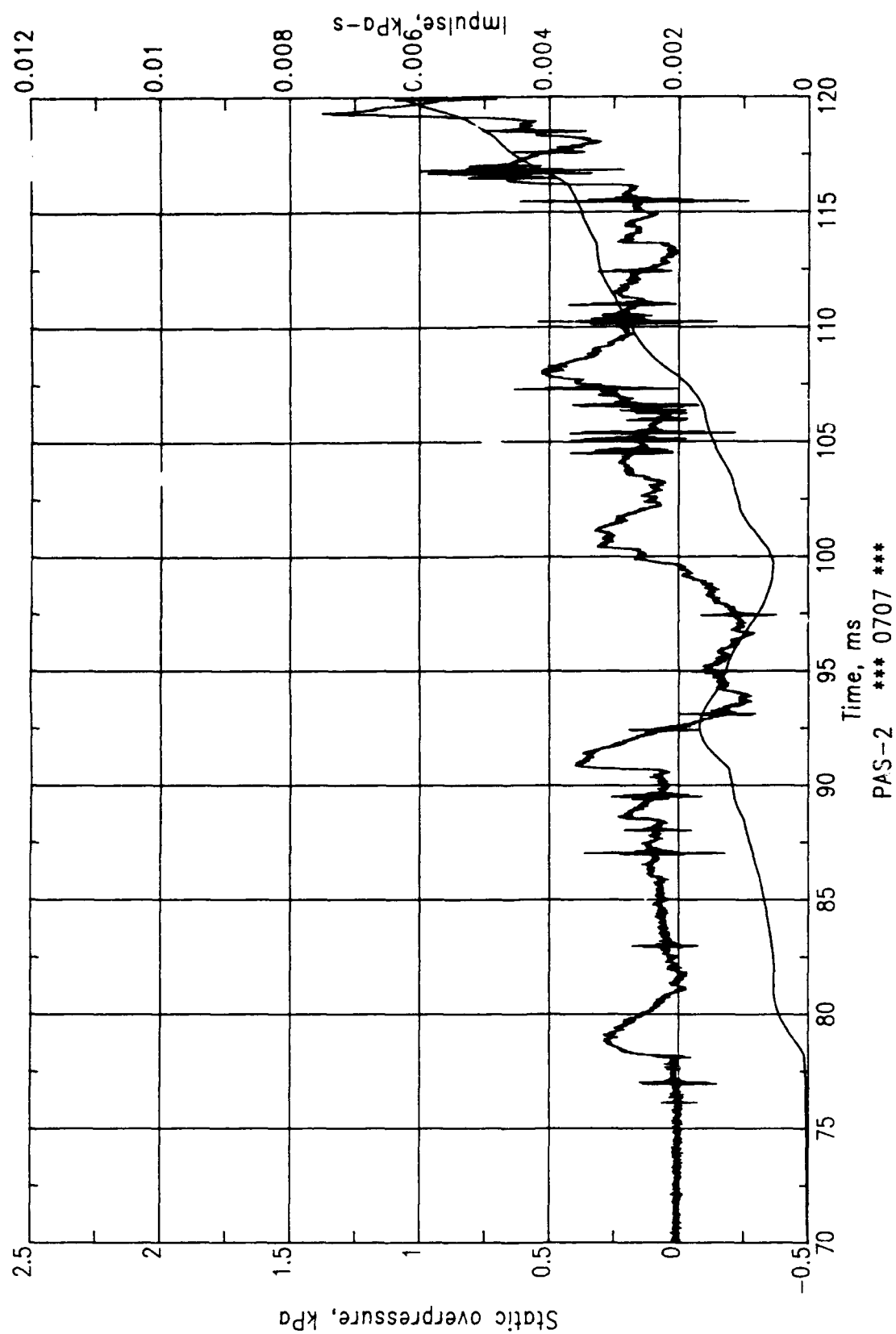


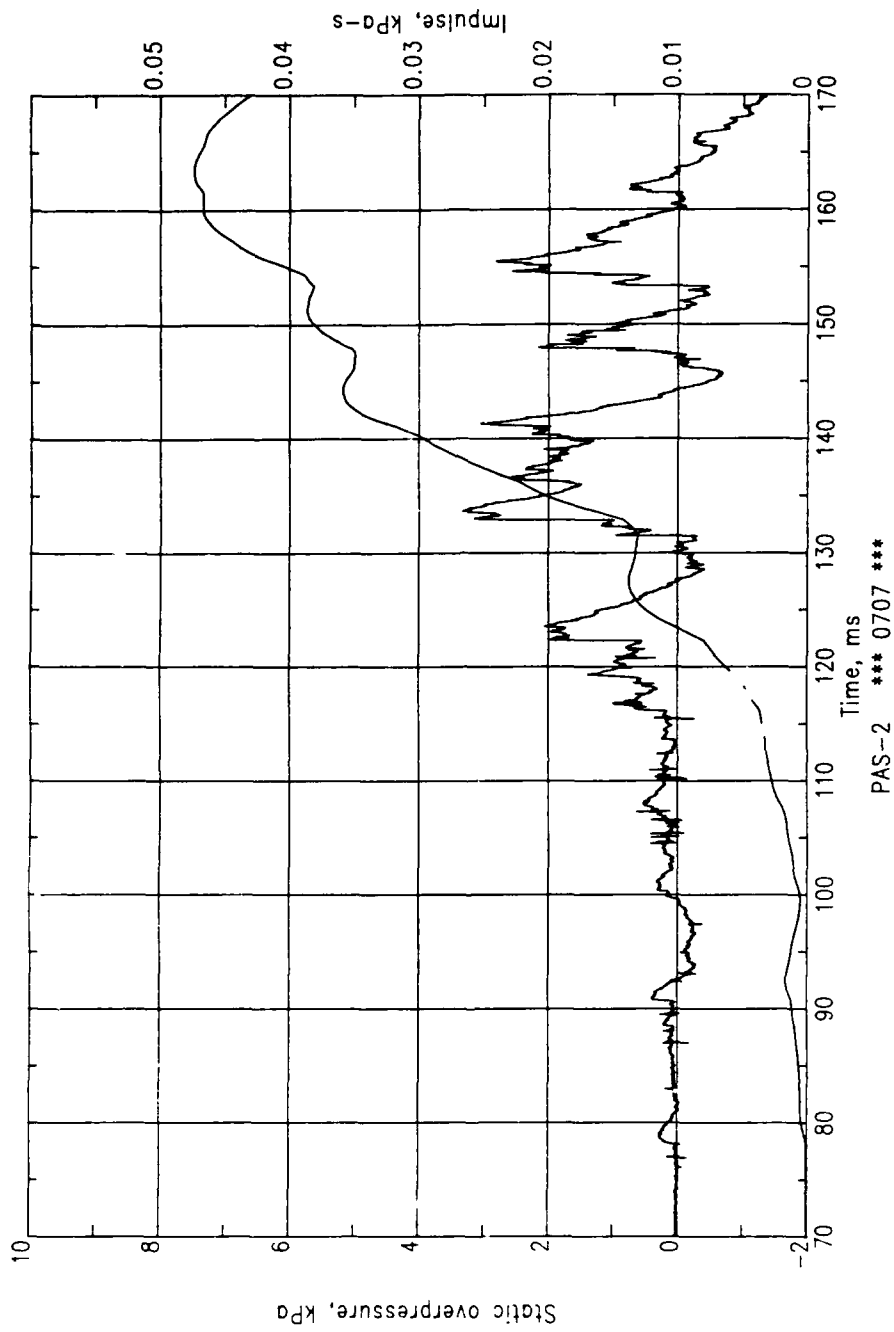


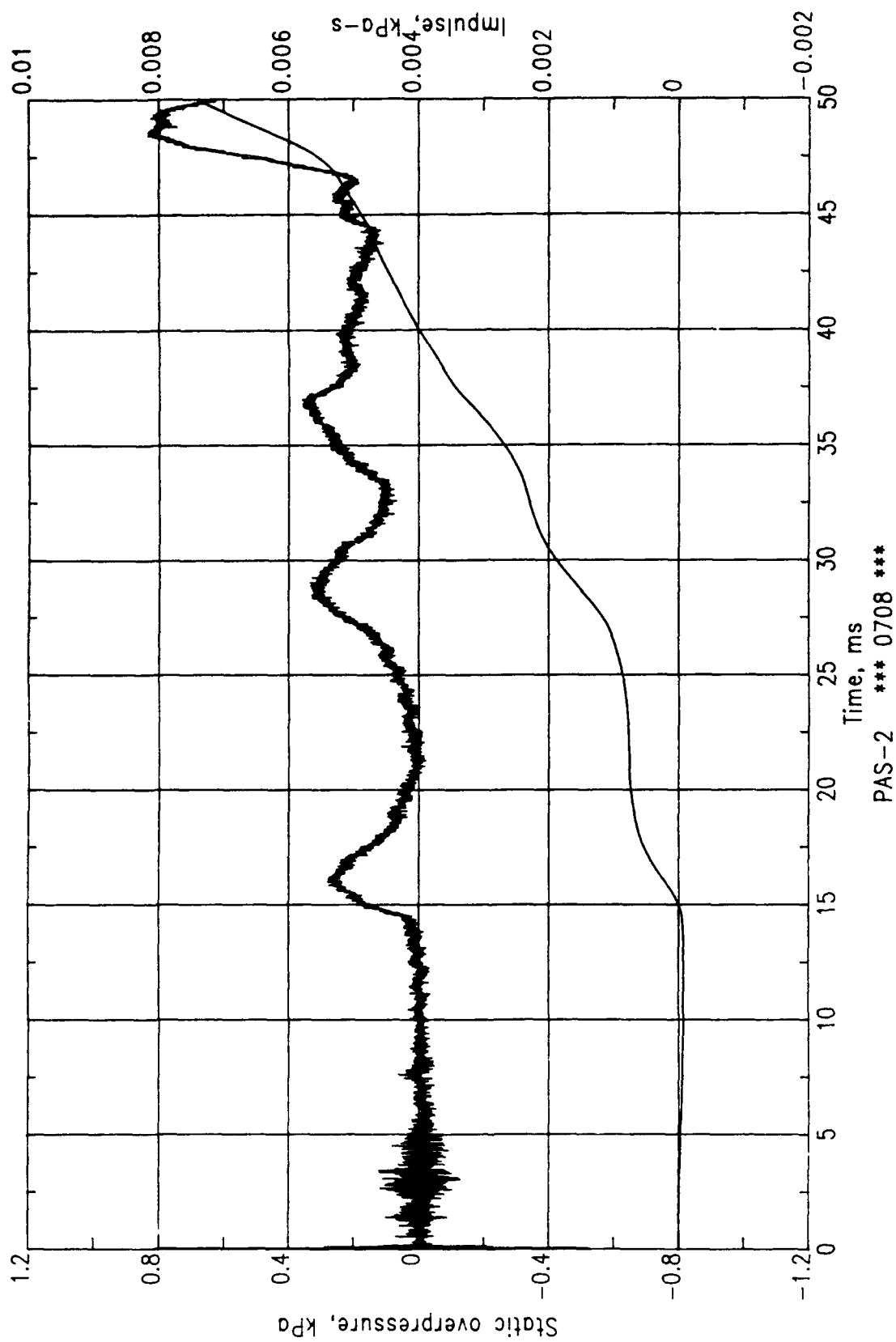


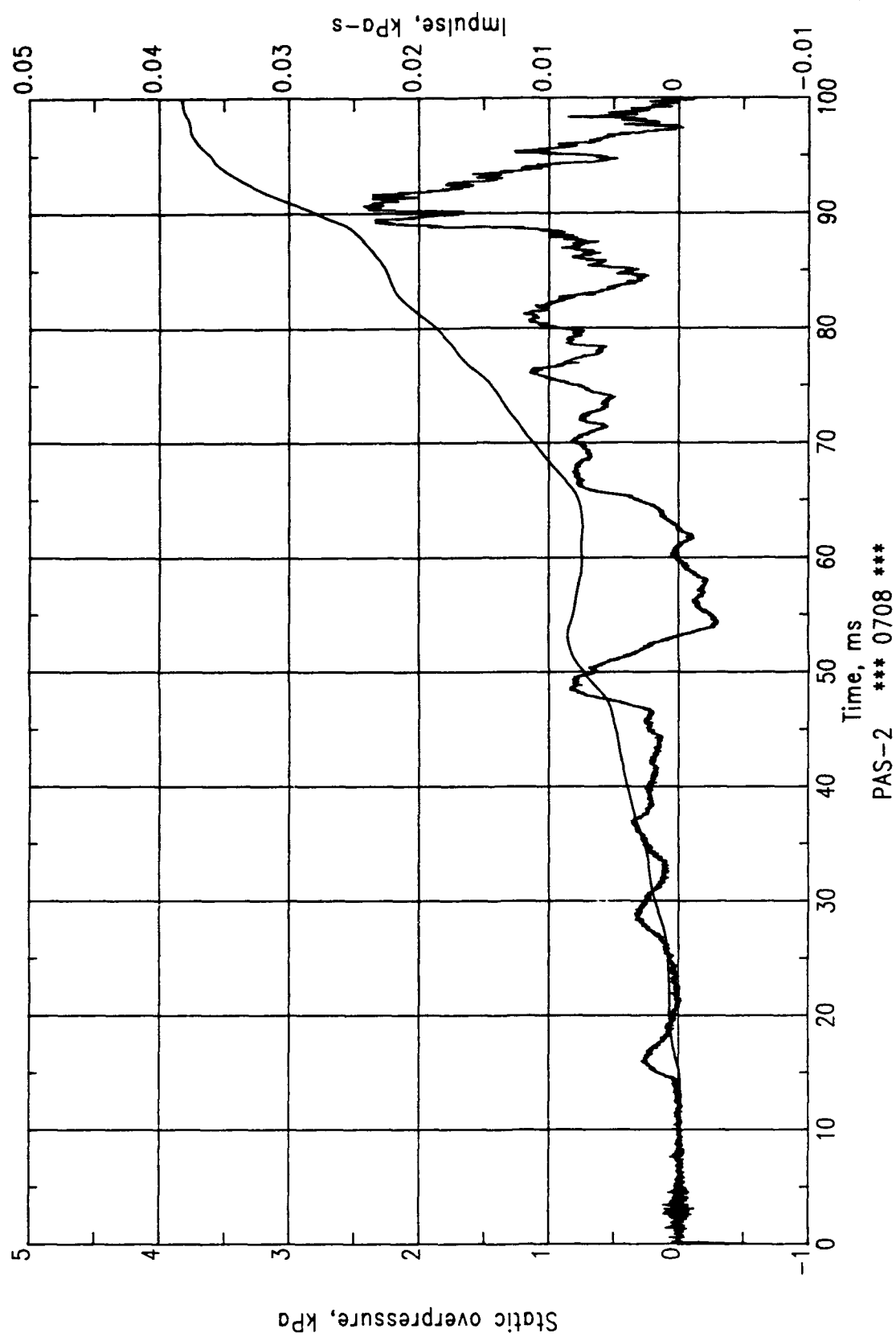
PAS-2 *** 0706 ***

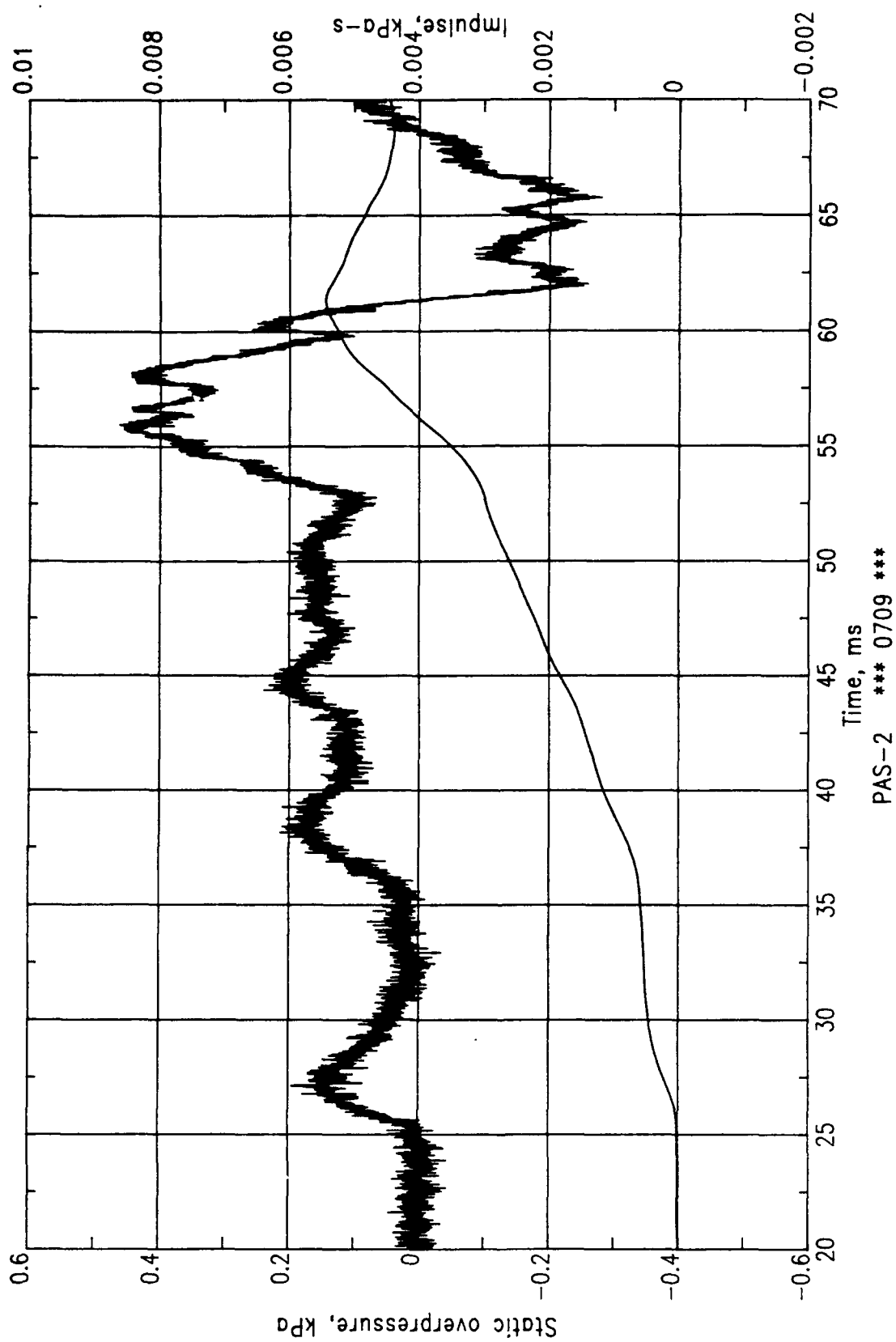


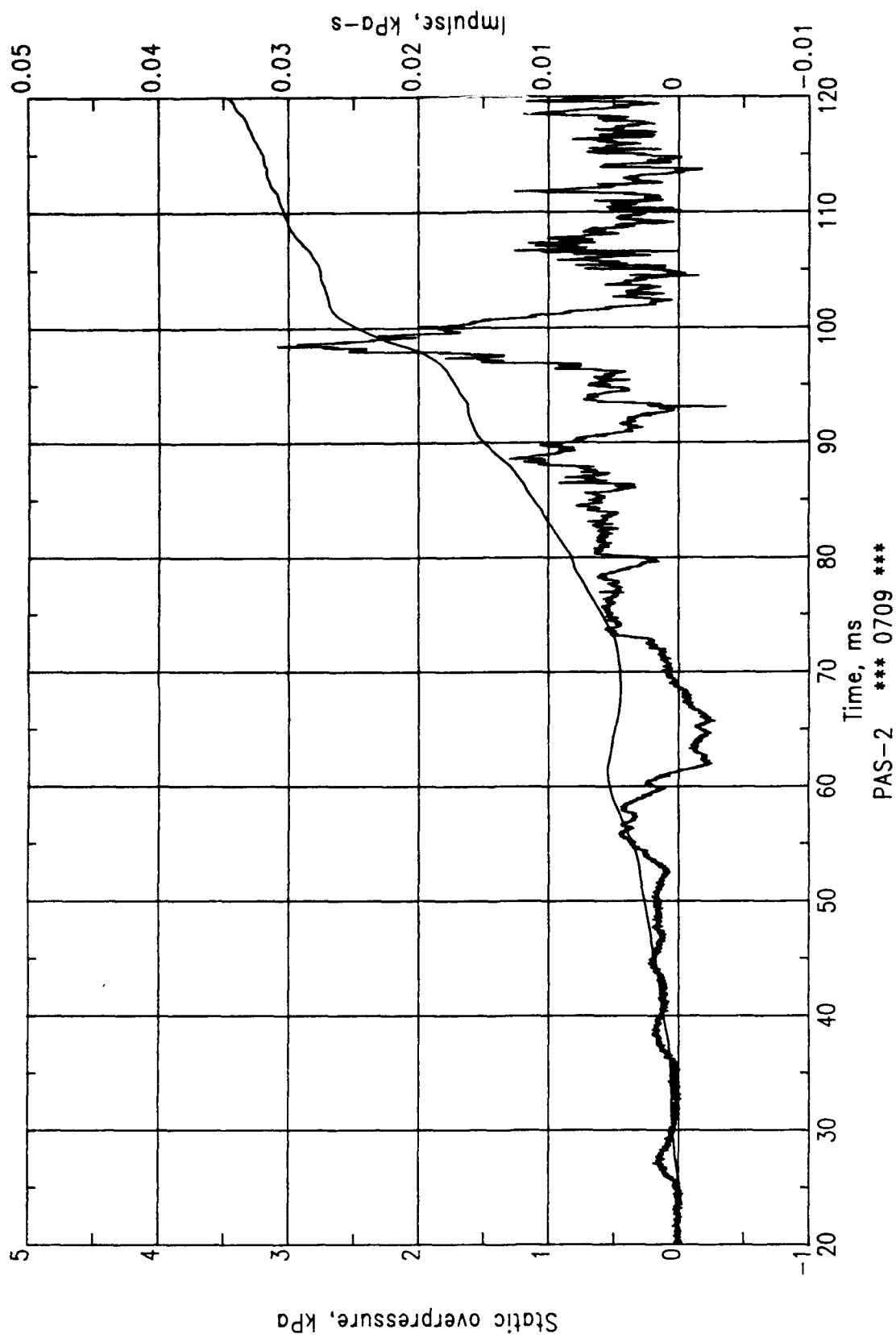


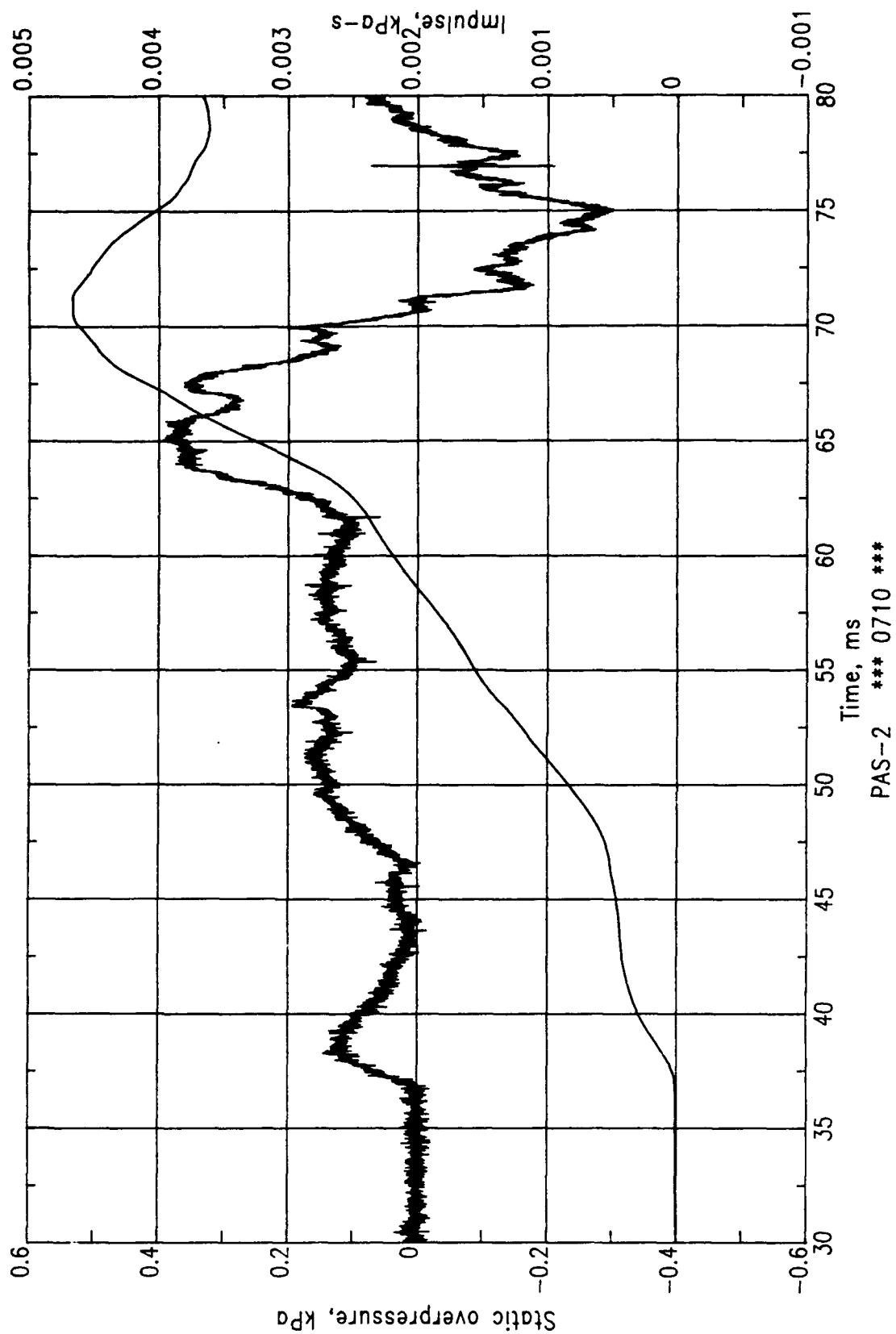




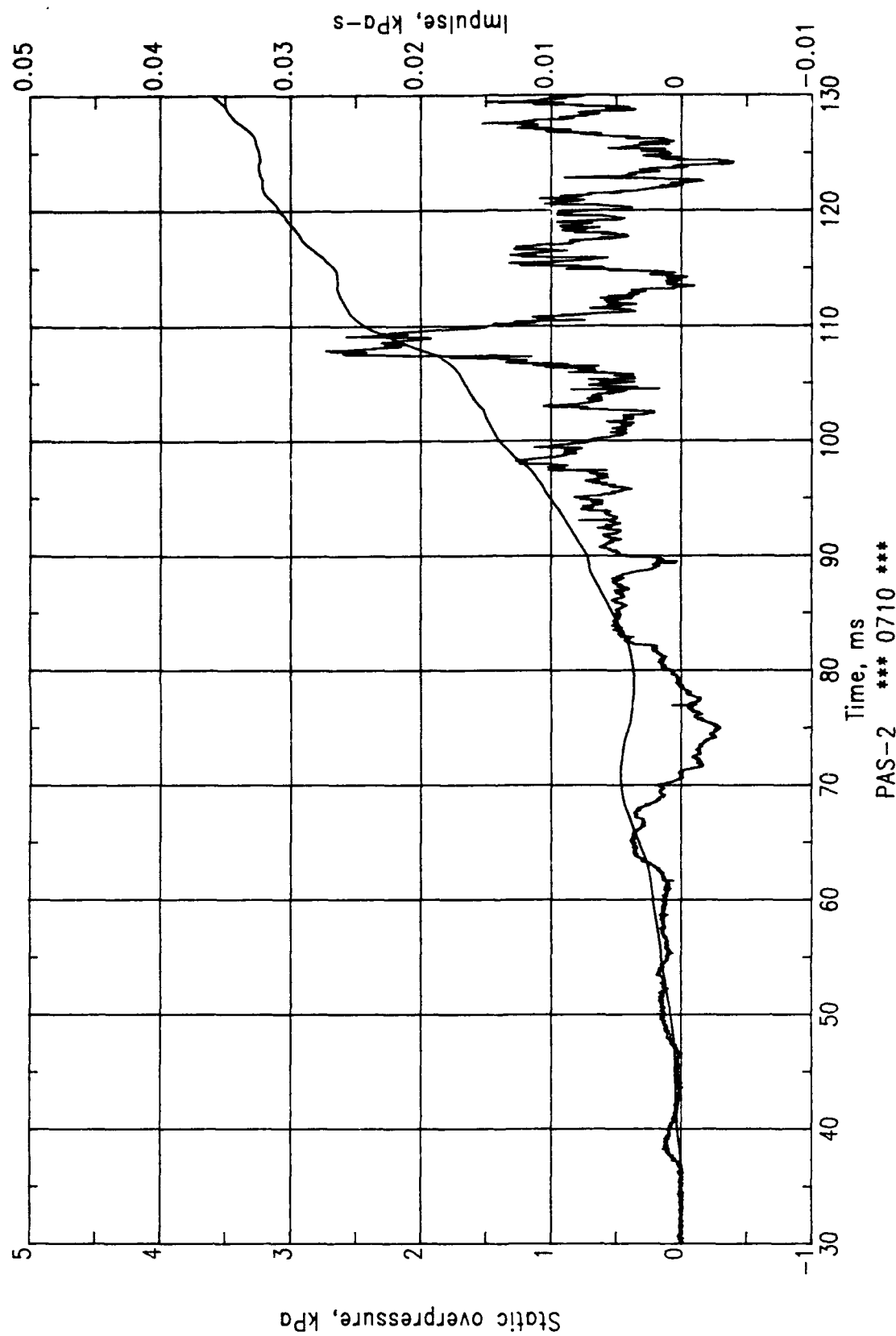


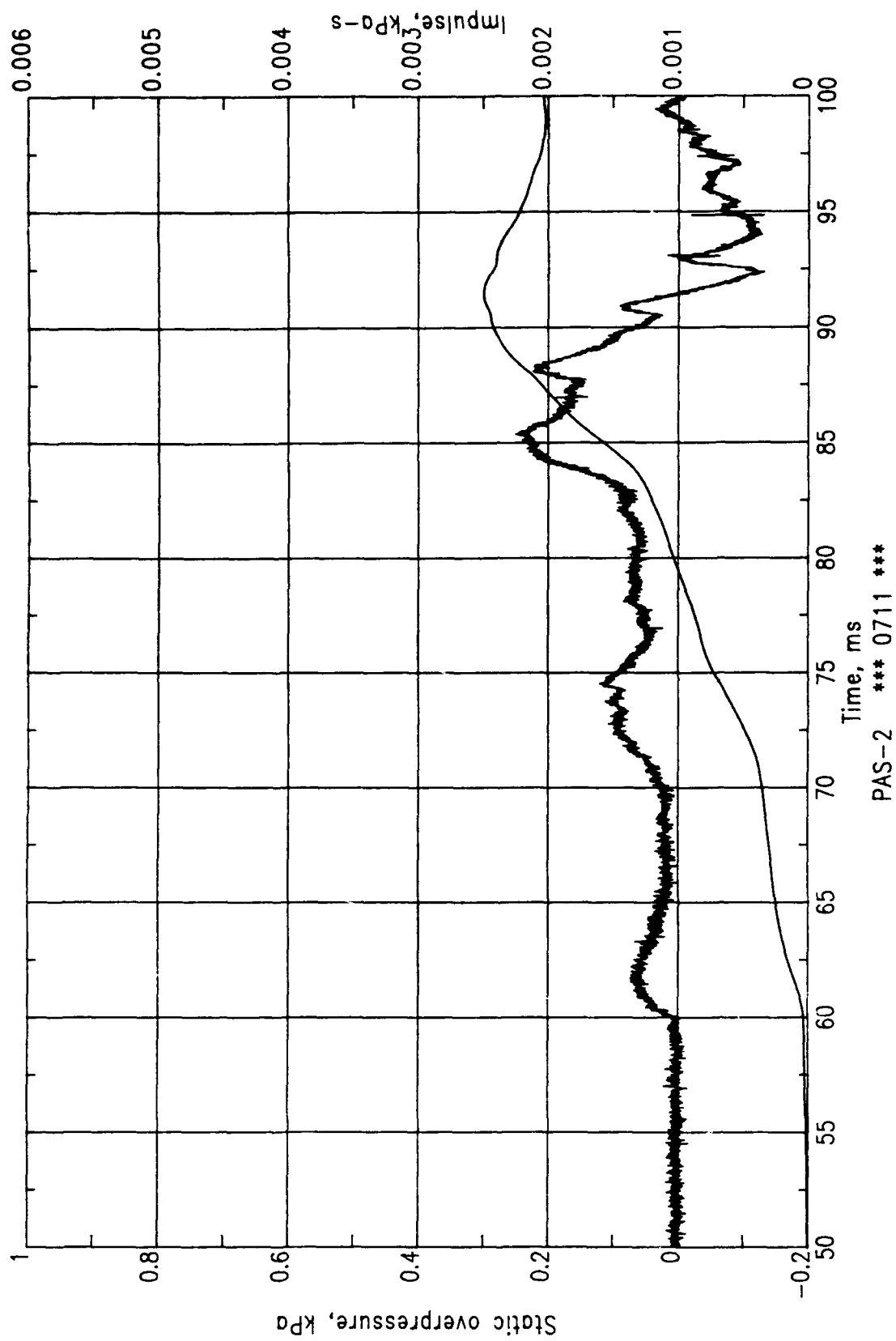




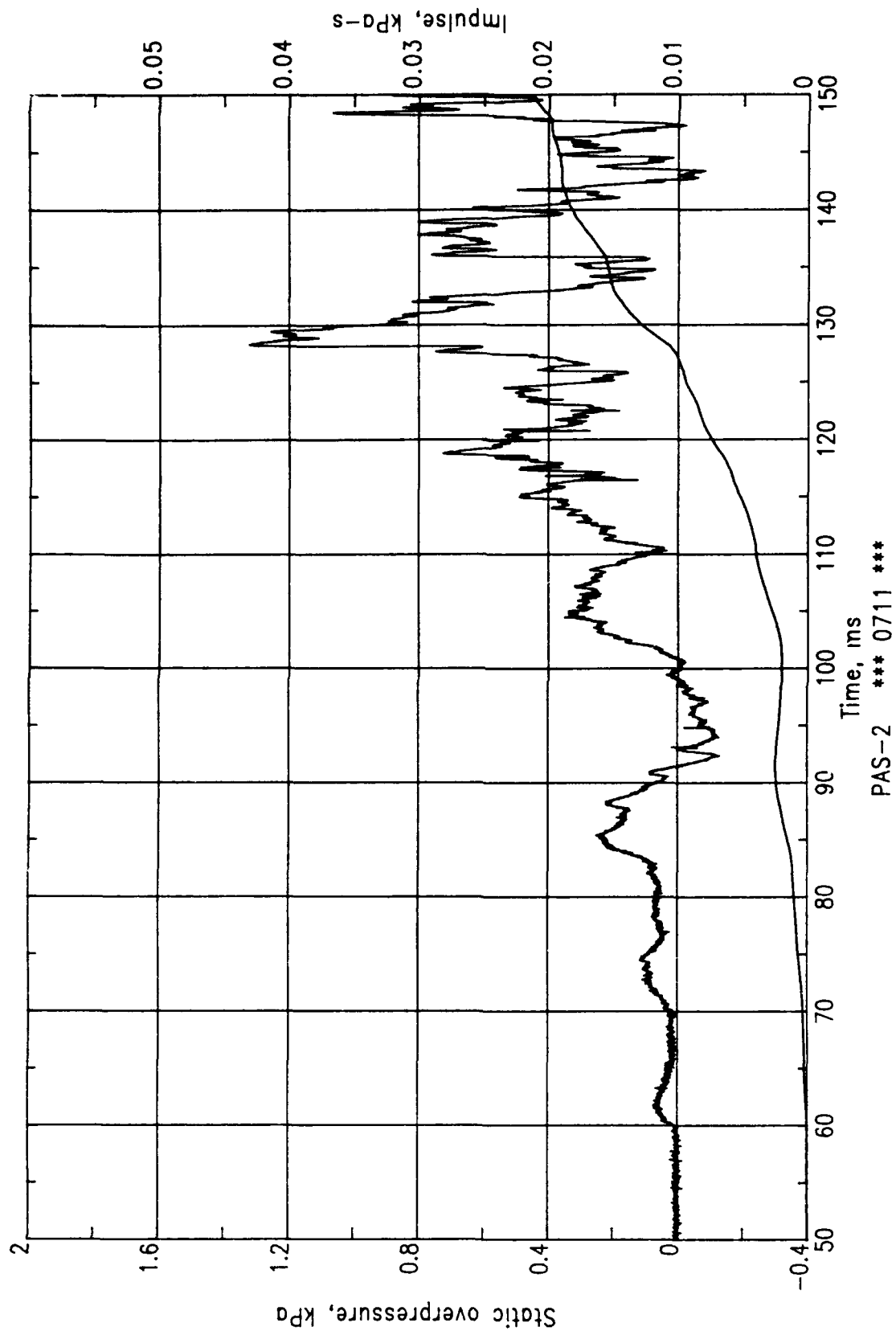


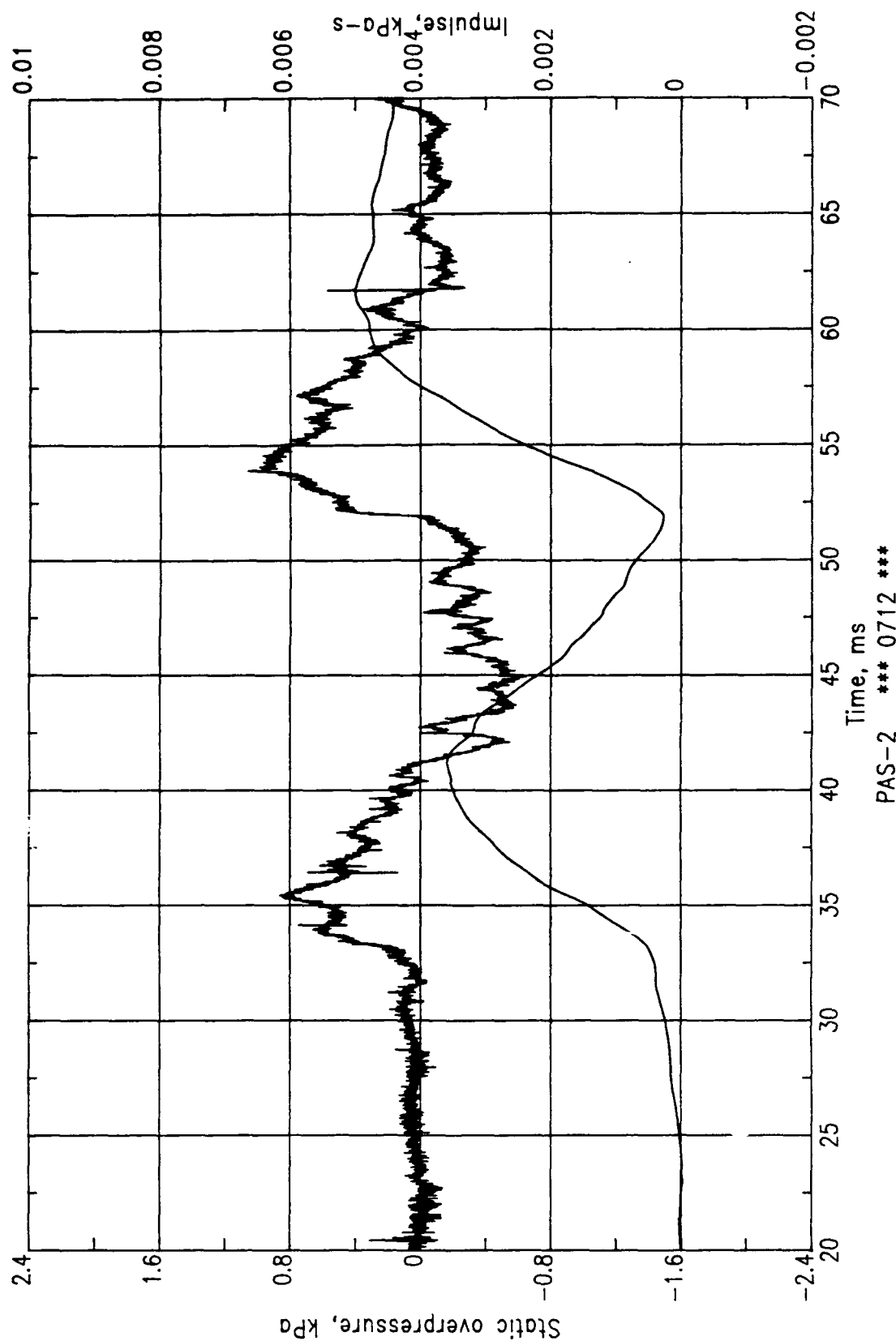
PAS-2 *** 0710 ***

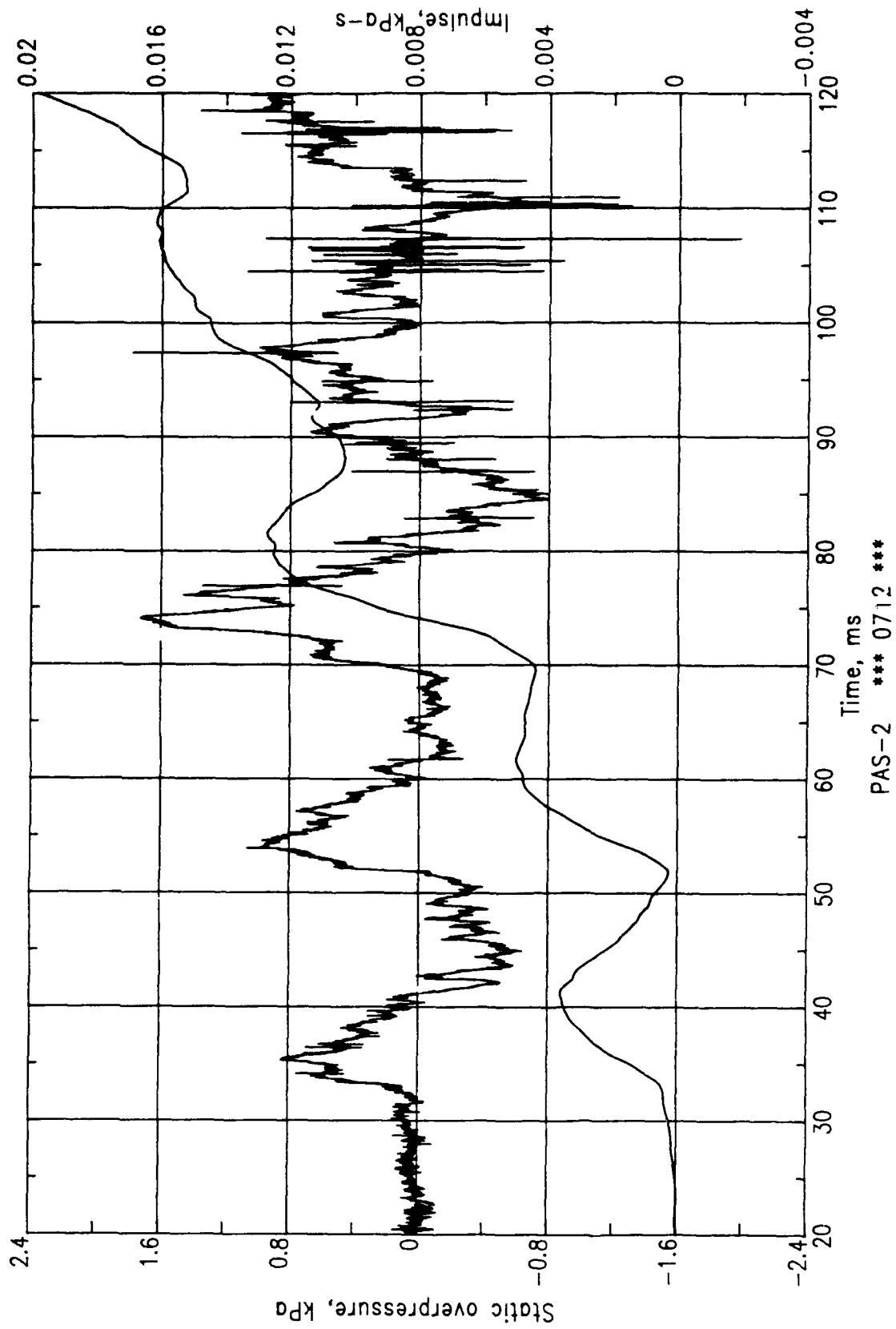


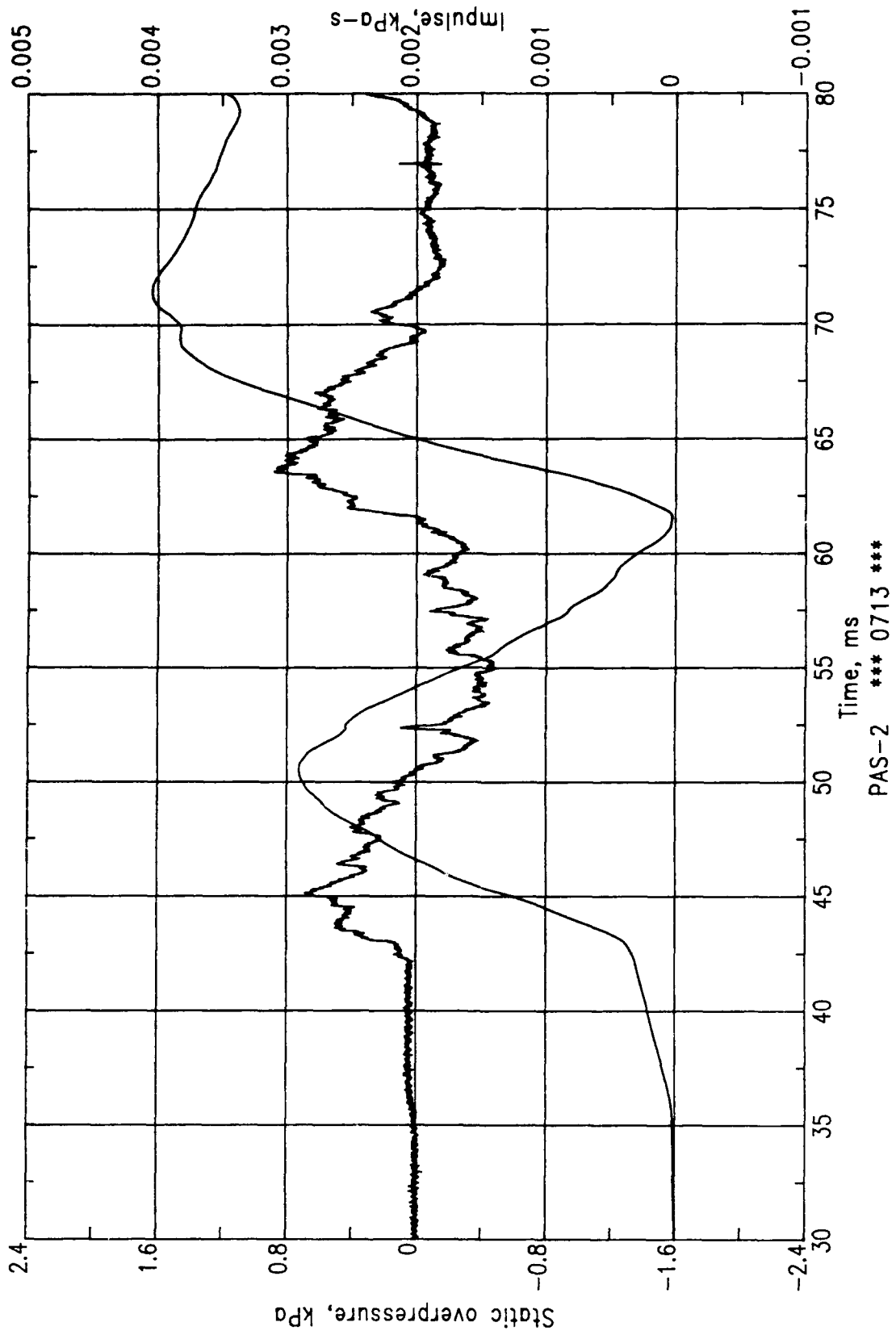


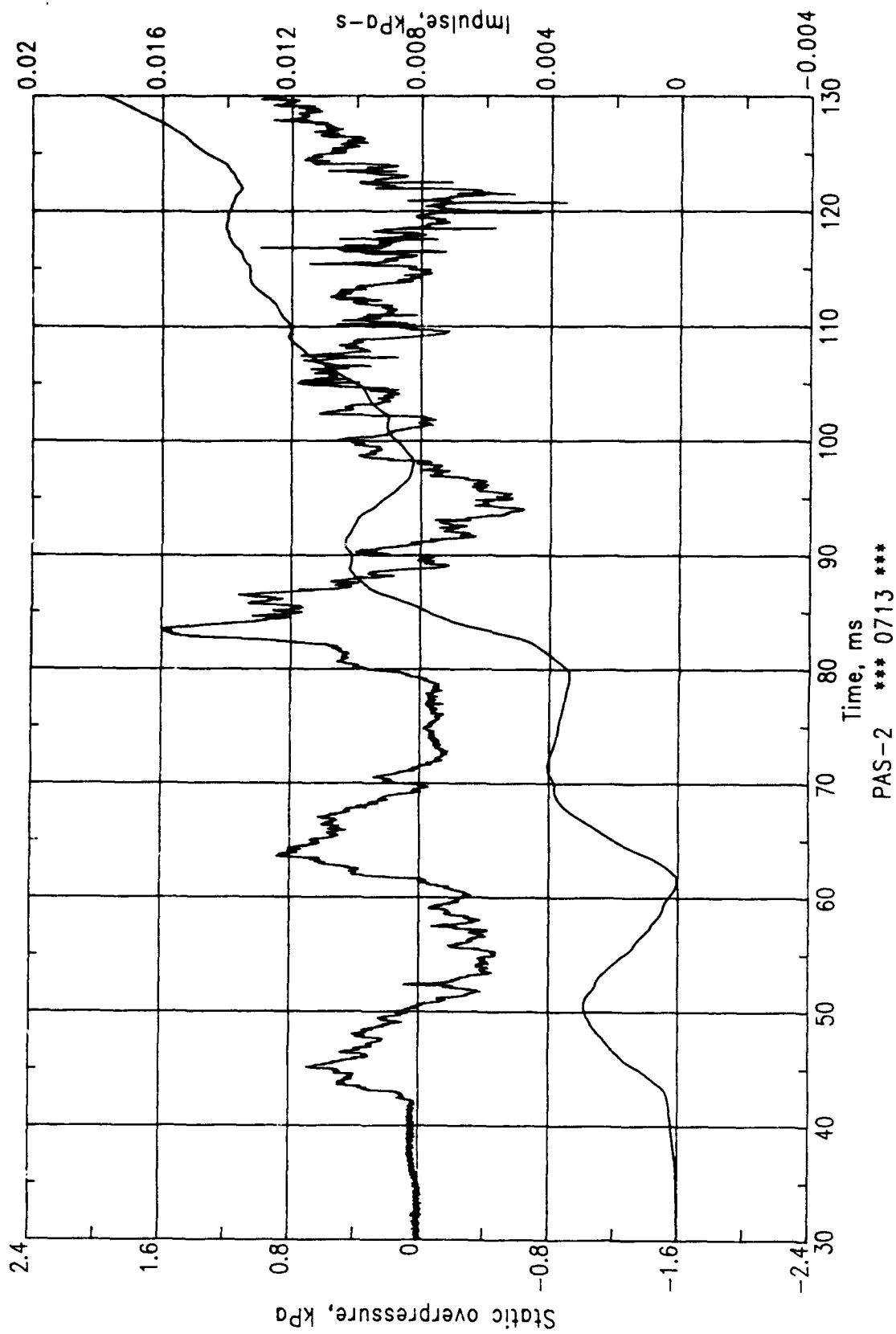
PAS-2 *** 0711 ***

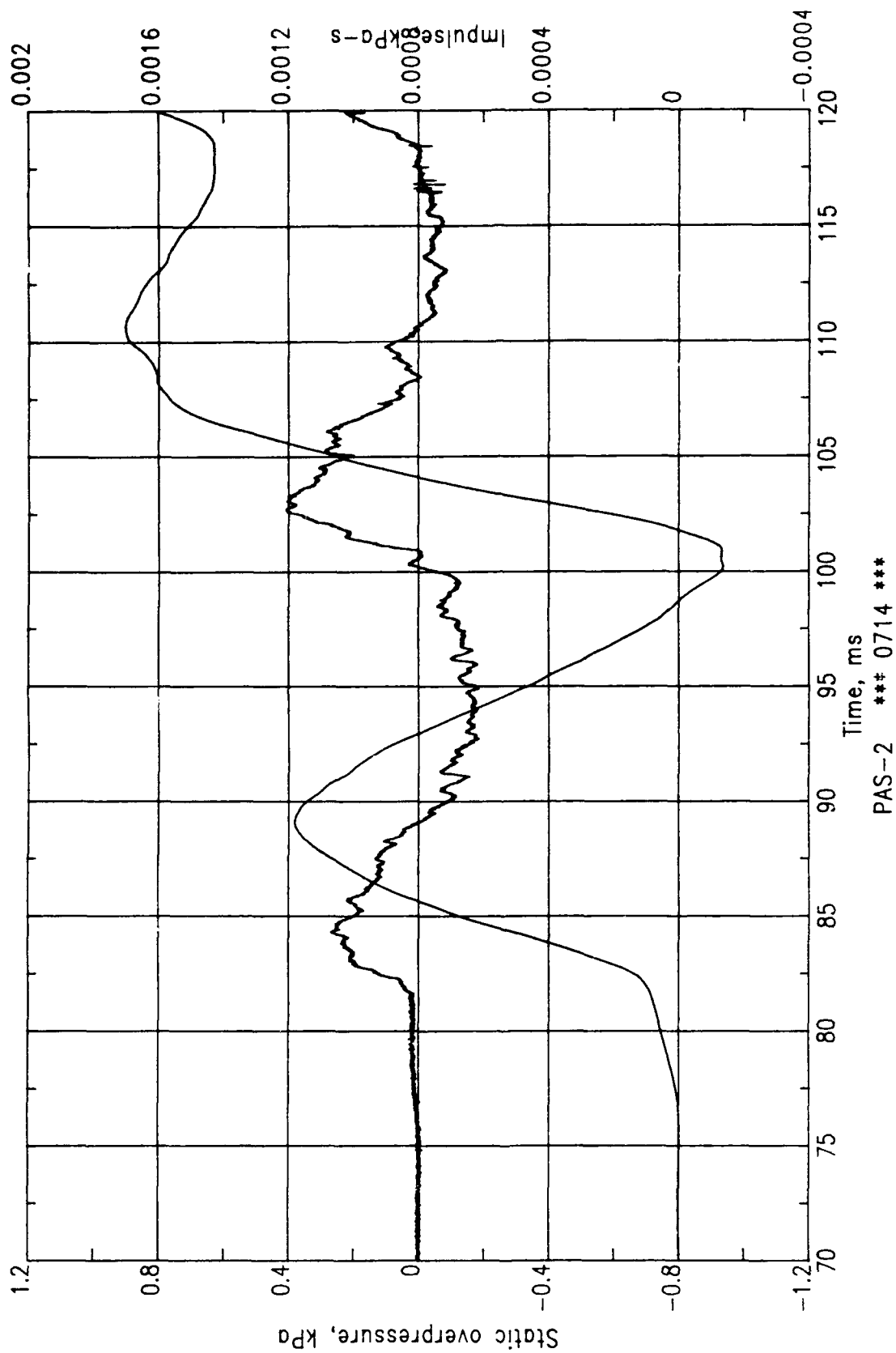


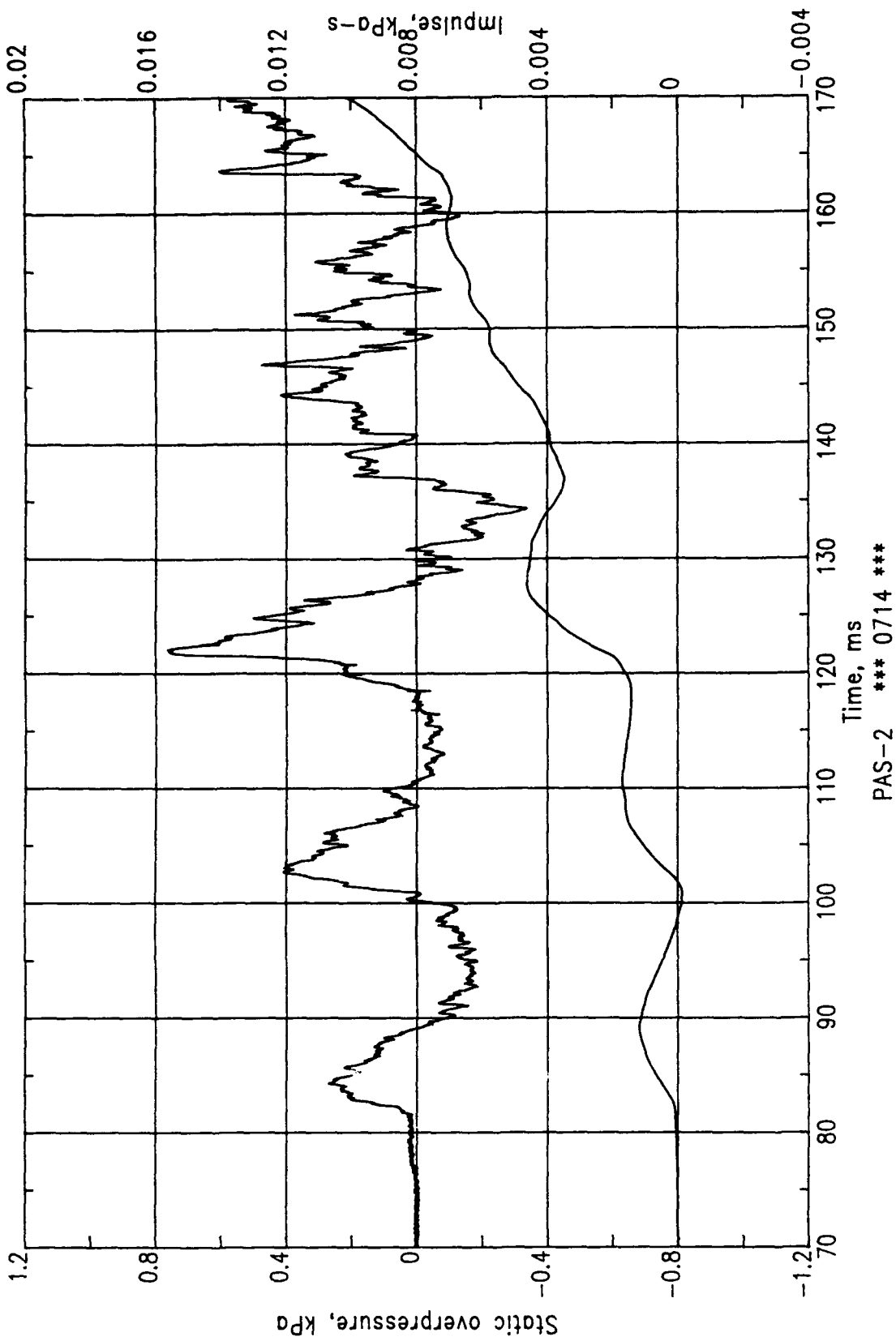


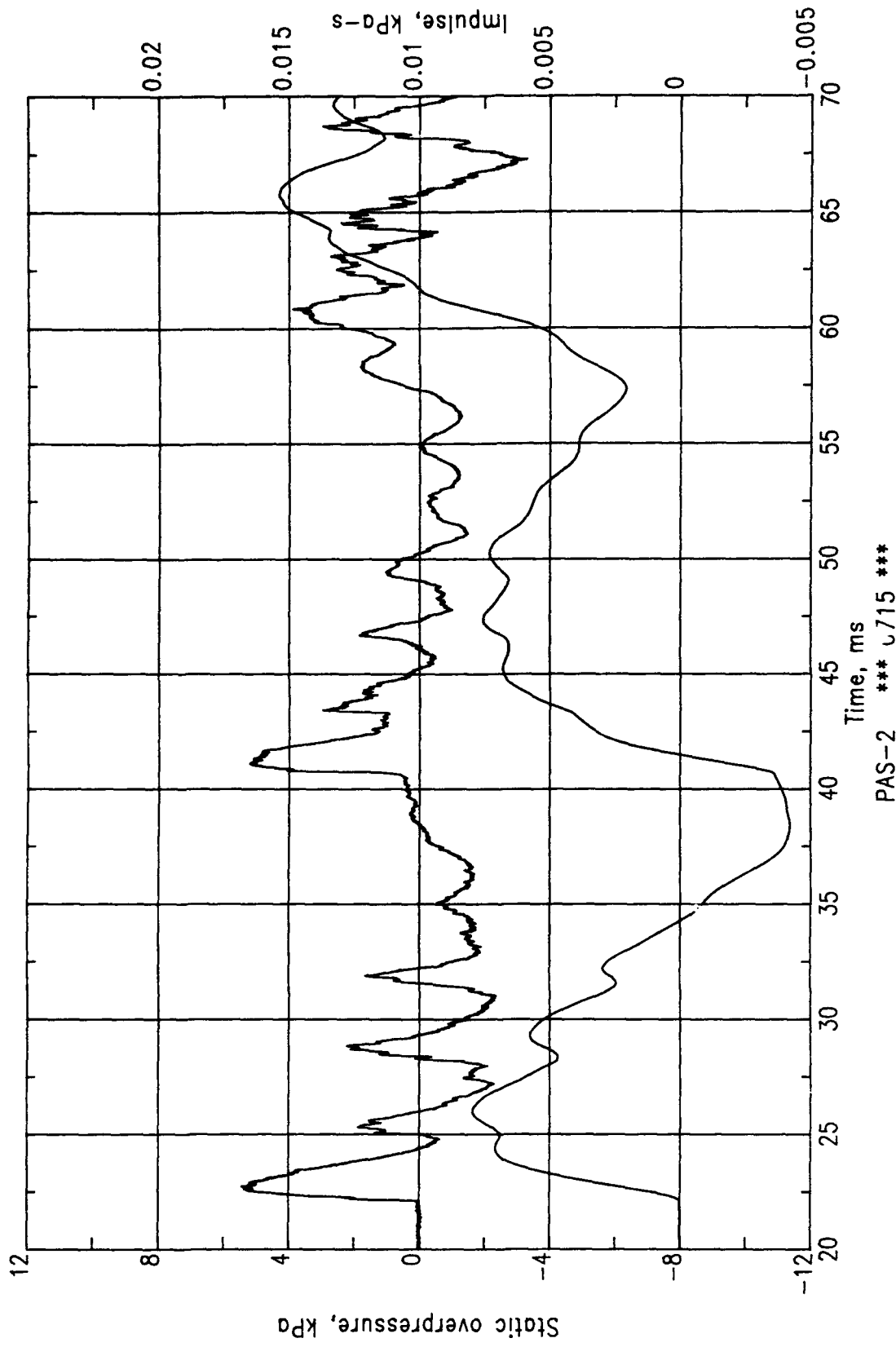


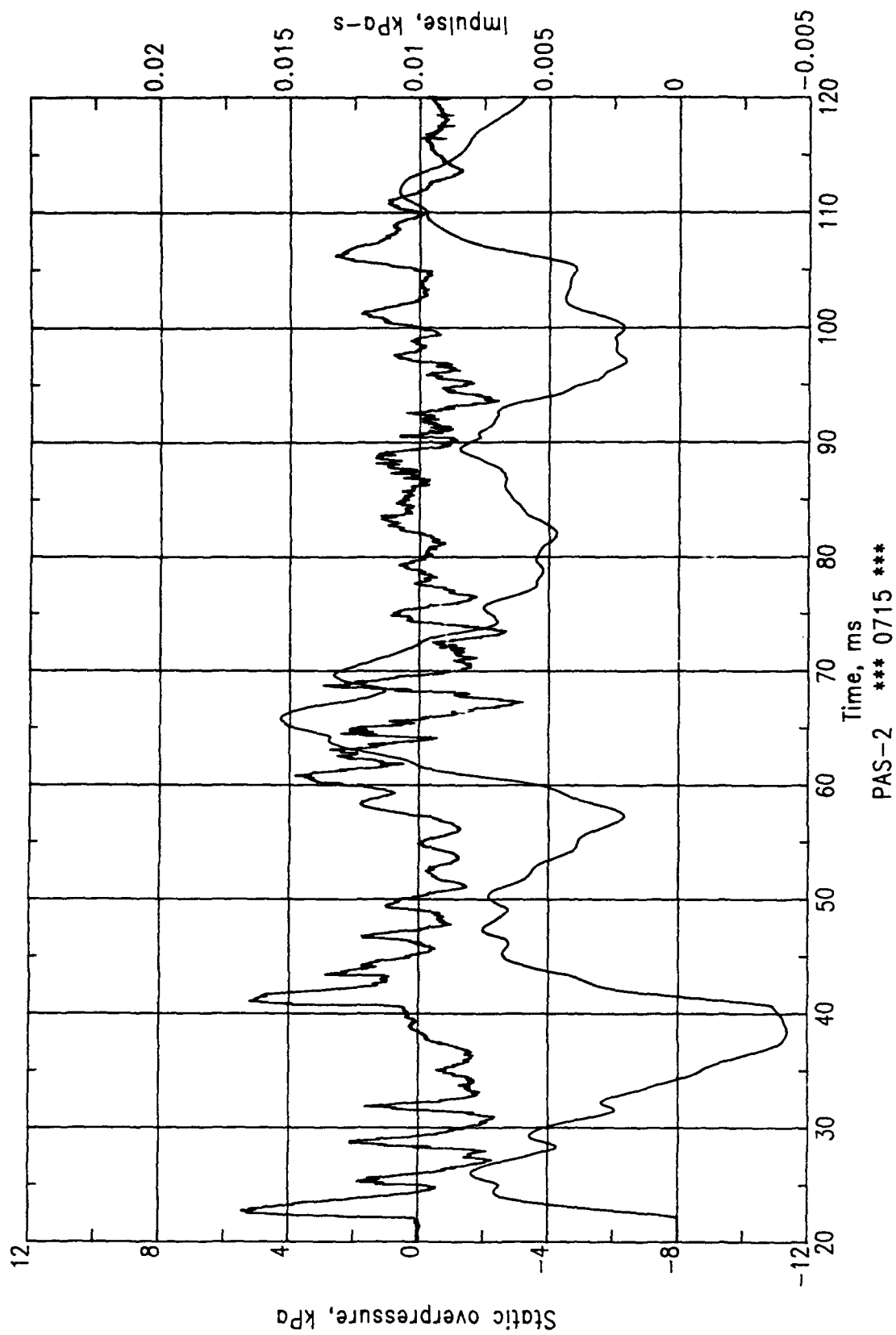


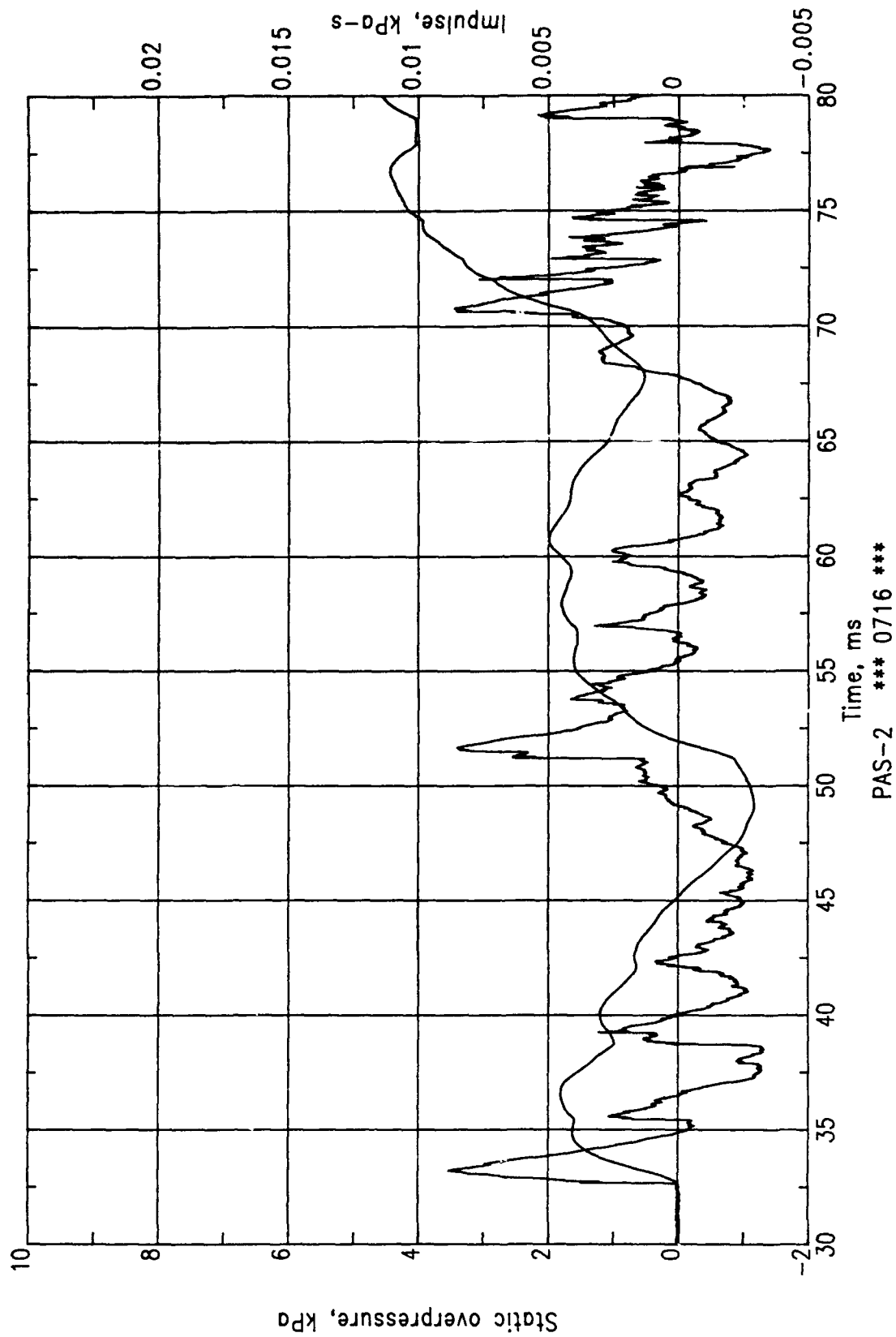


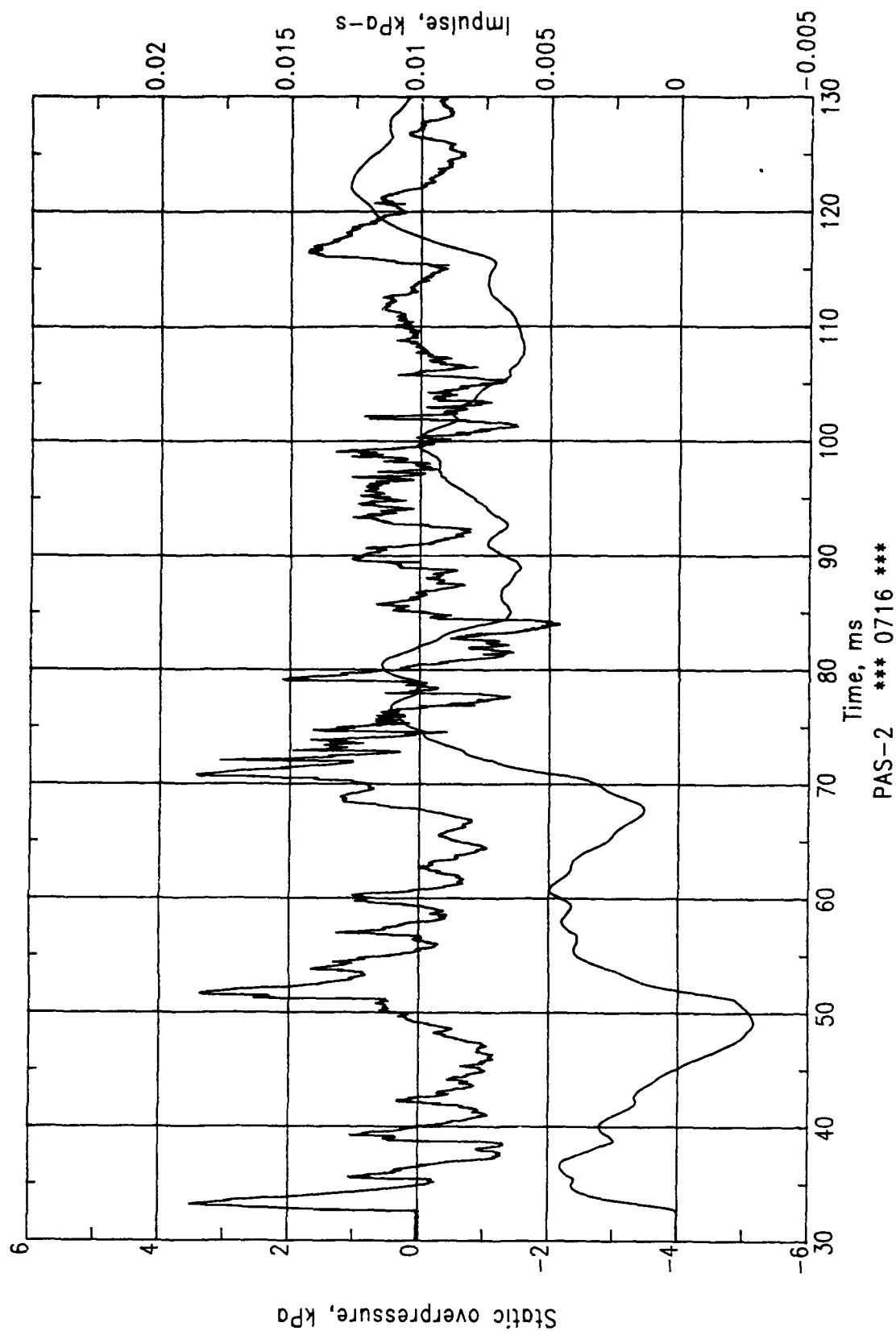


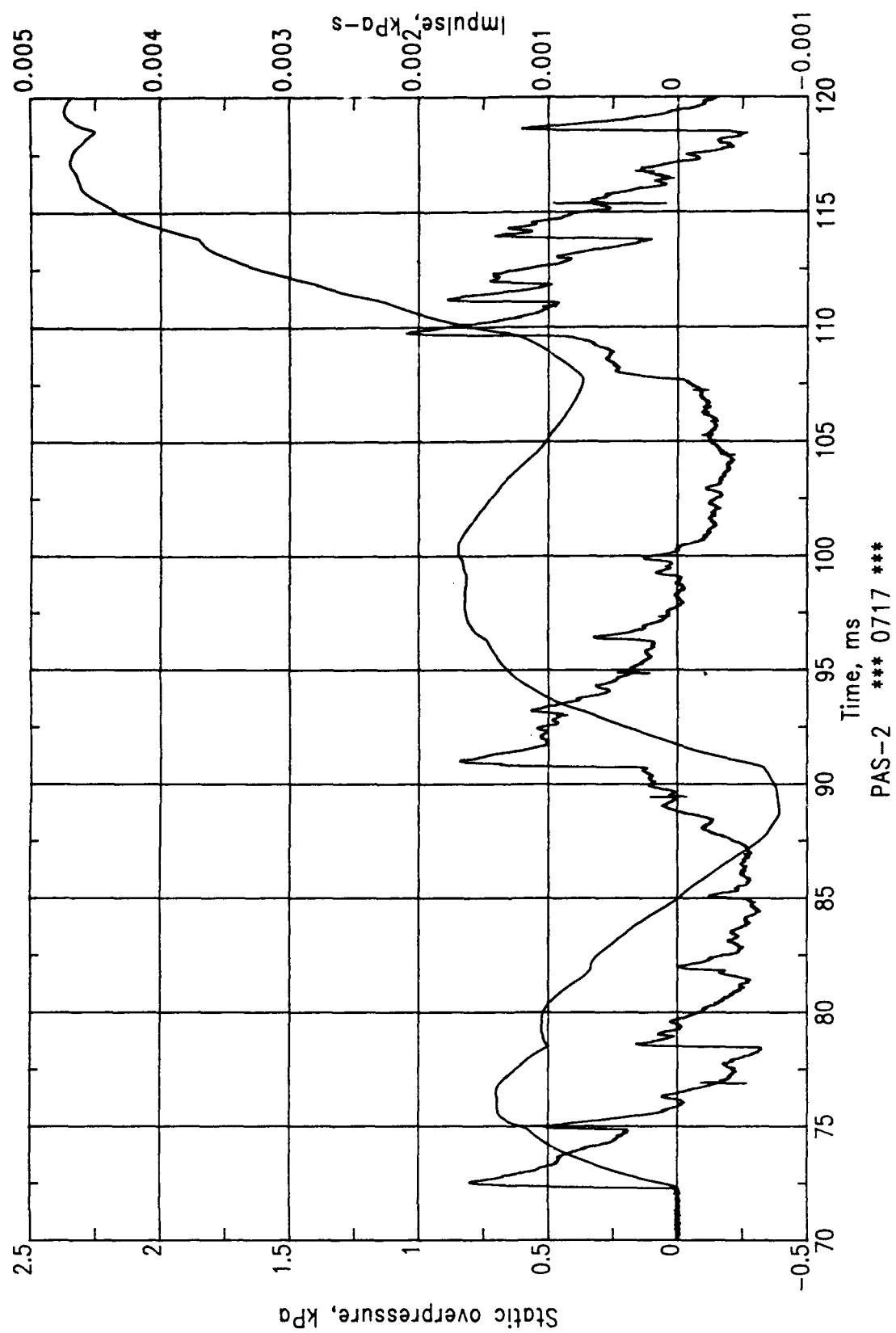


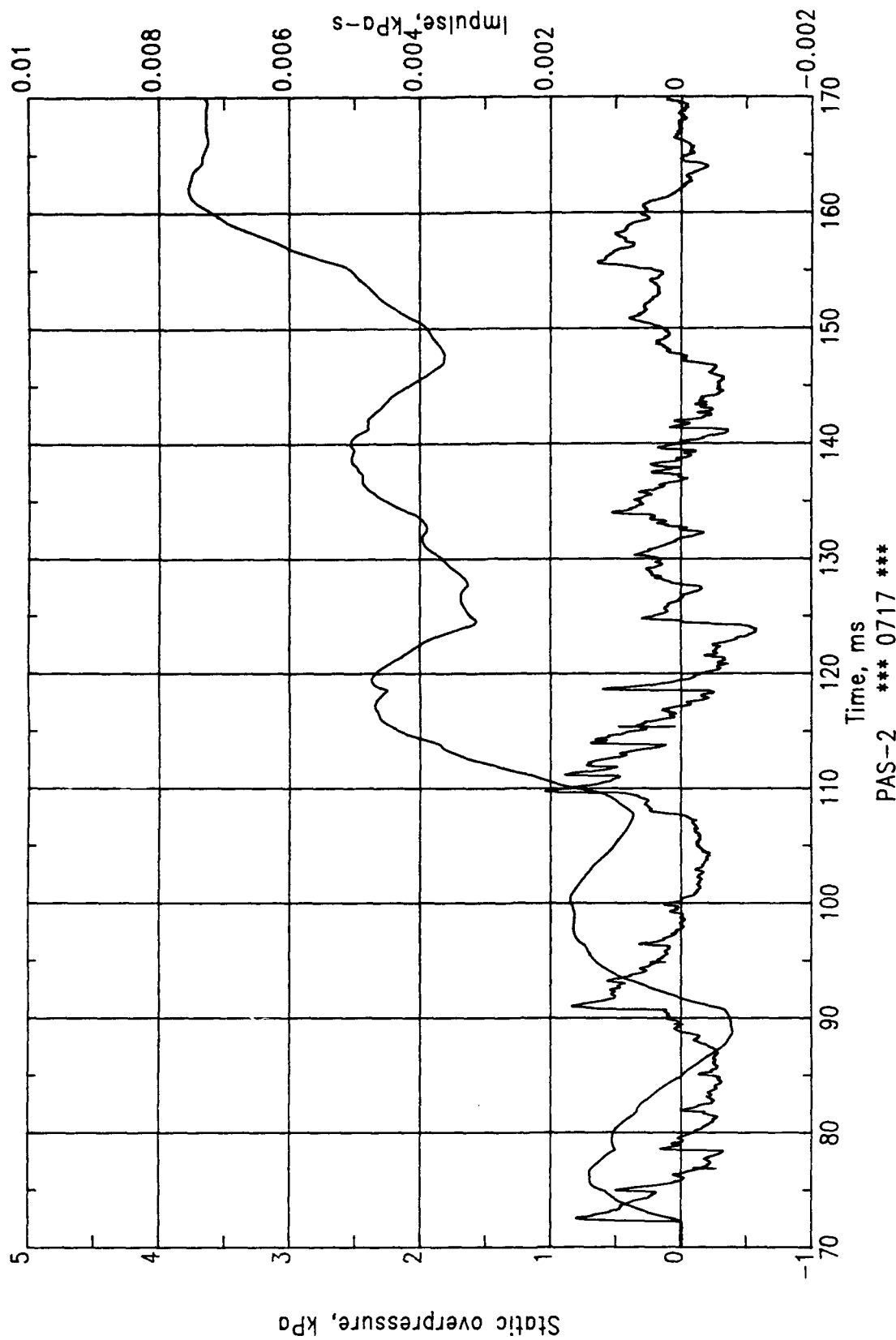


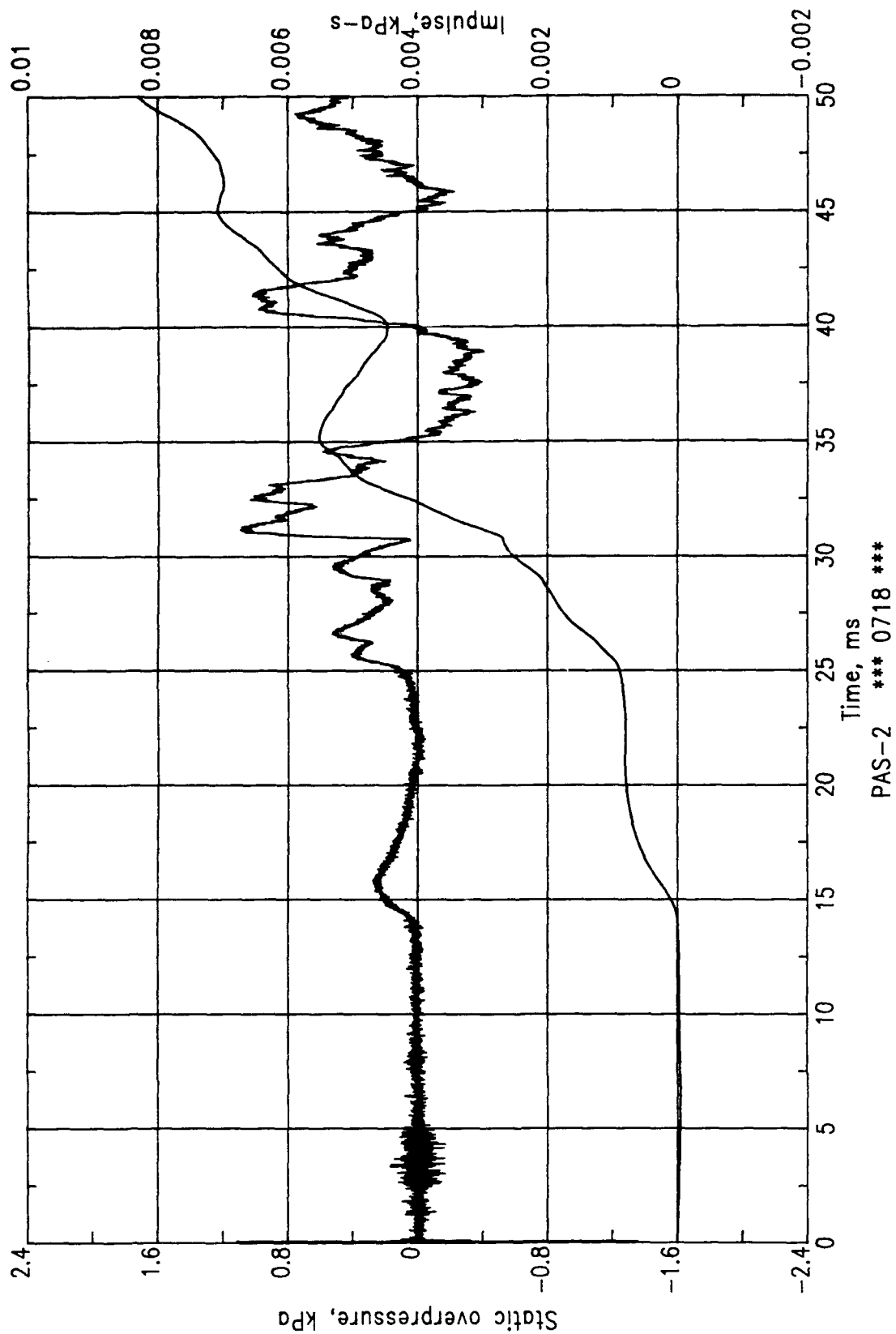


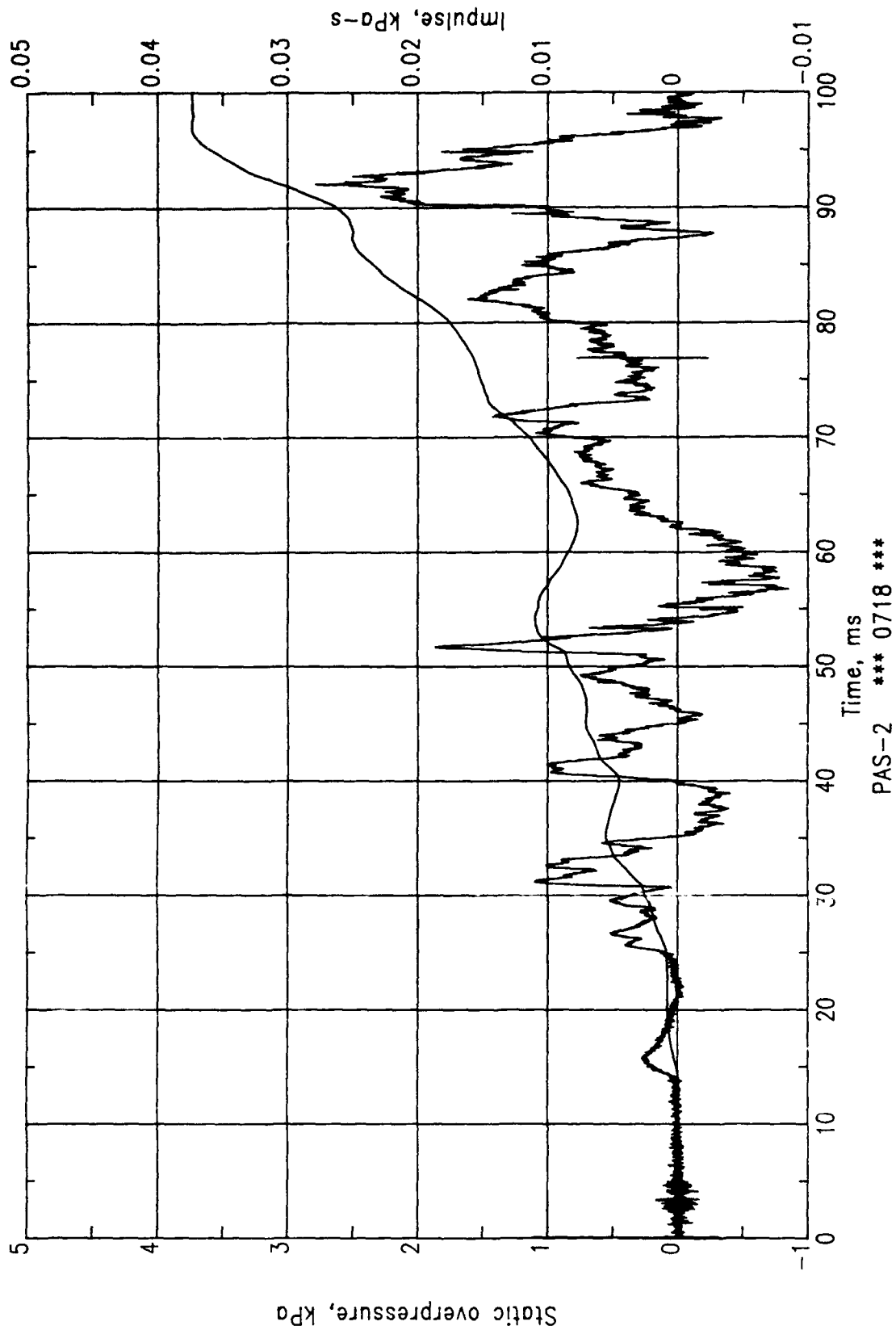


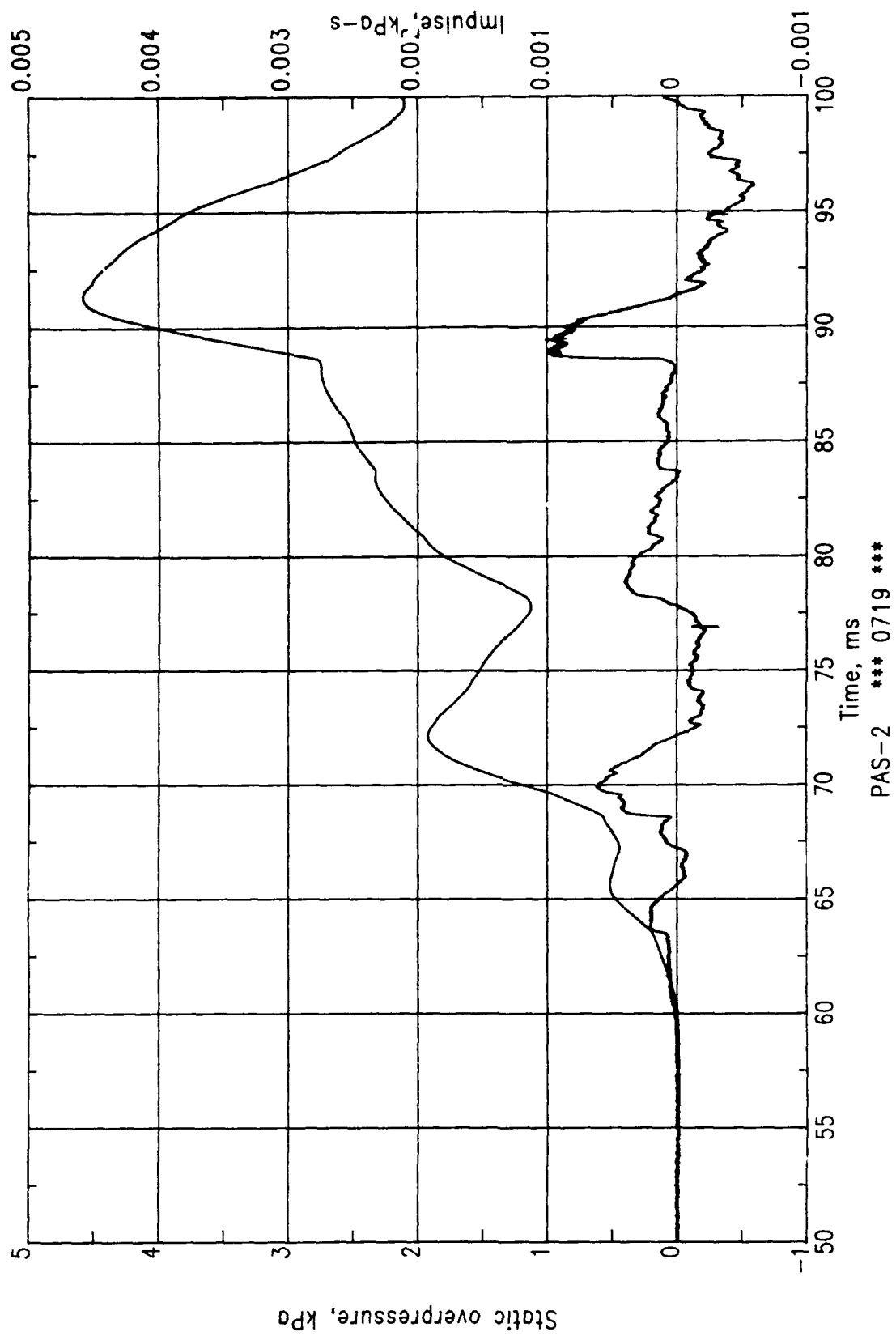


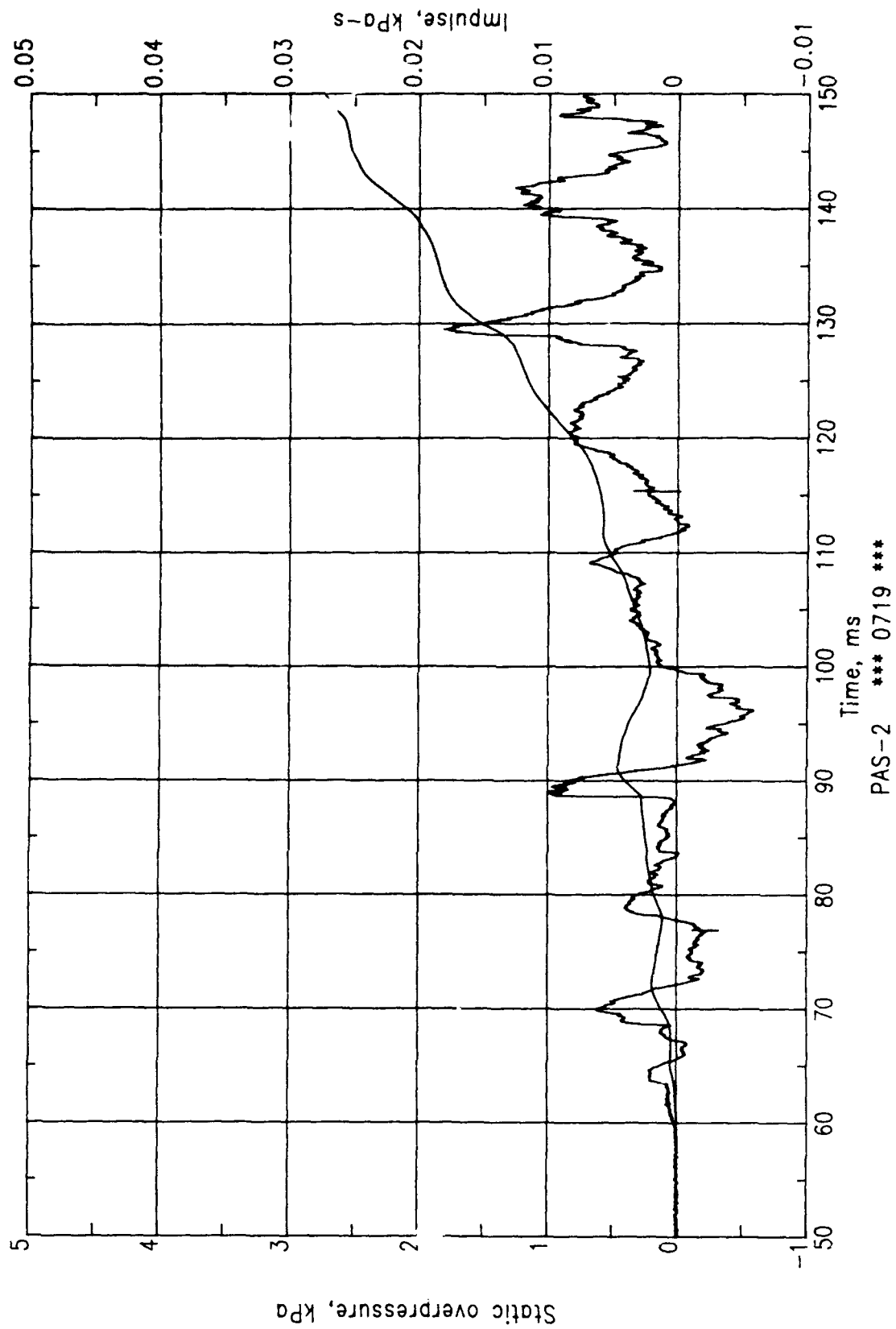


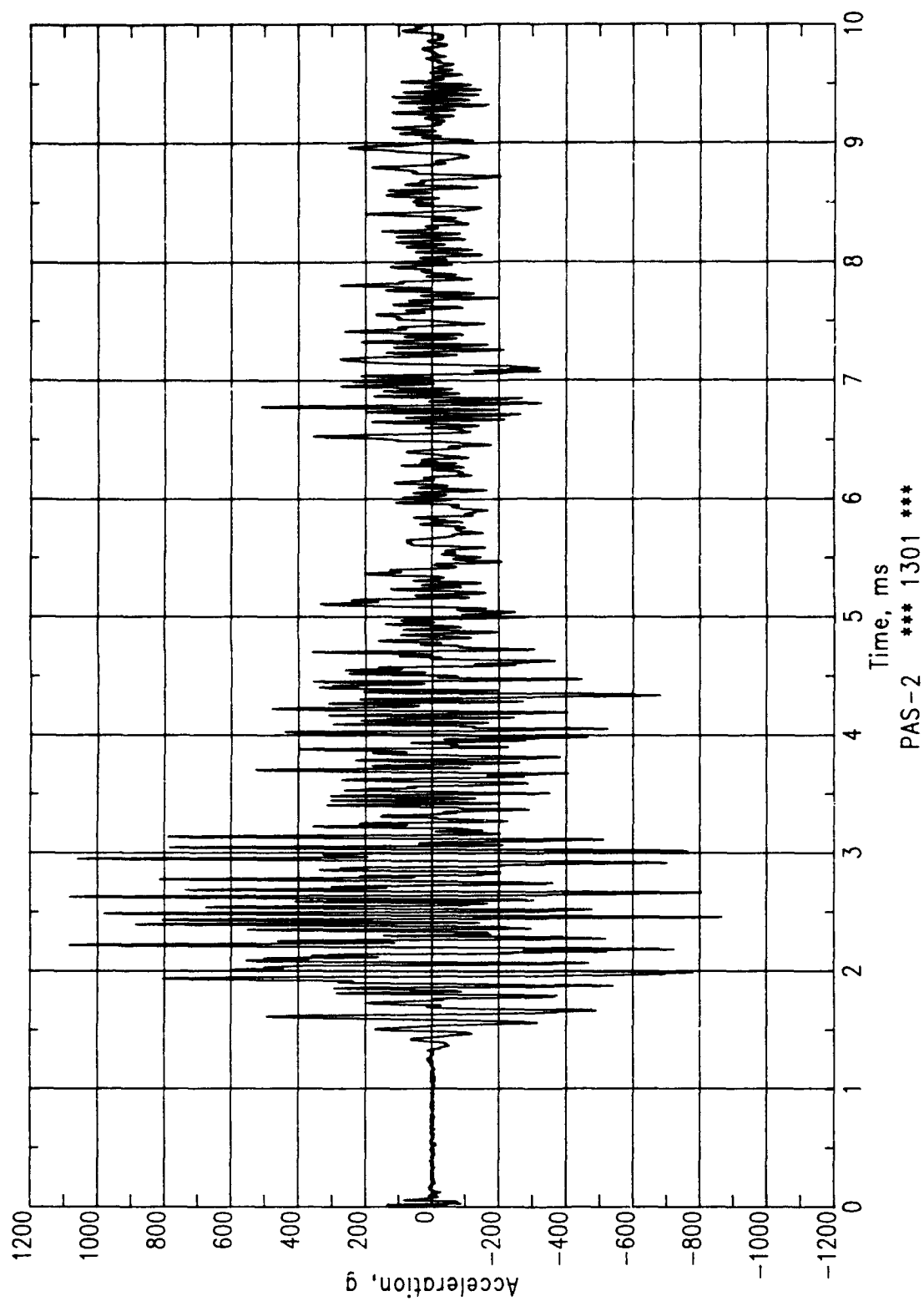


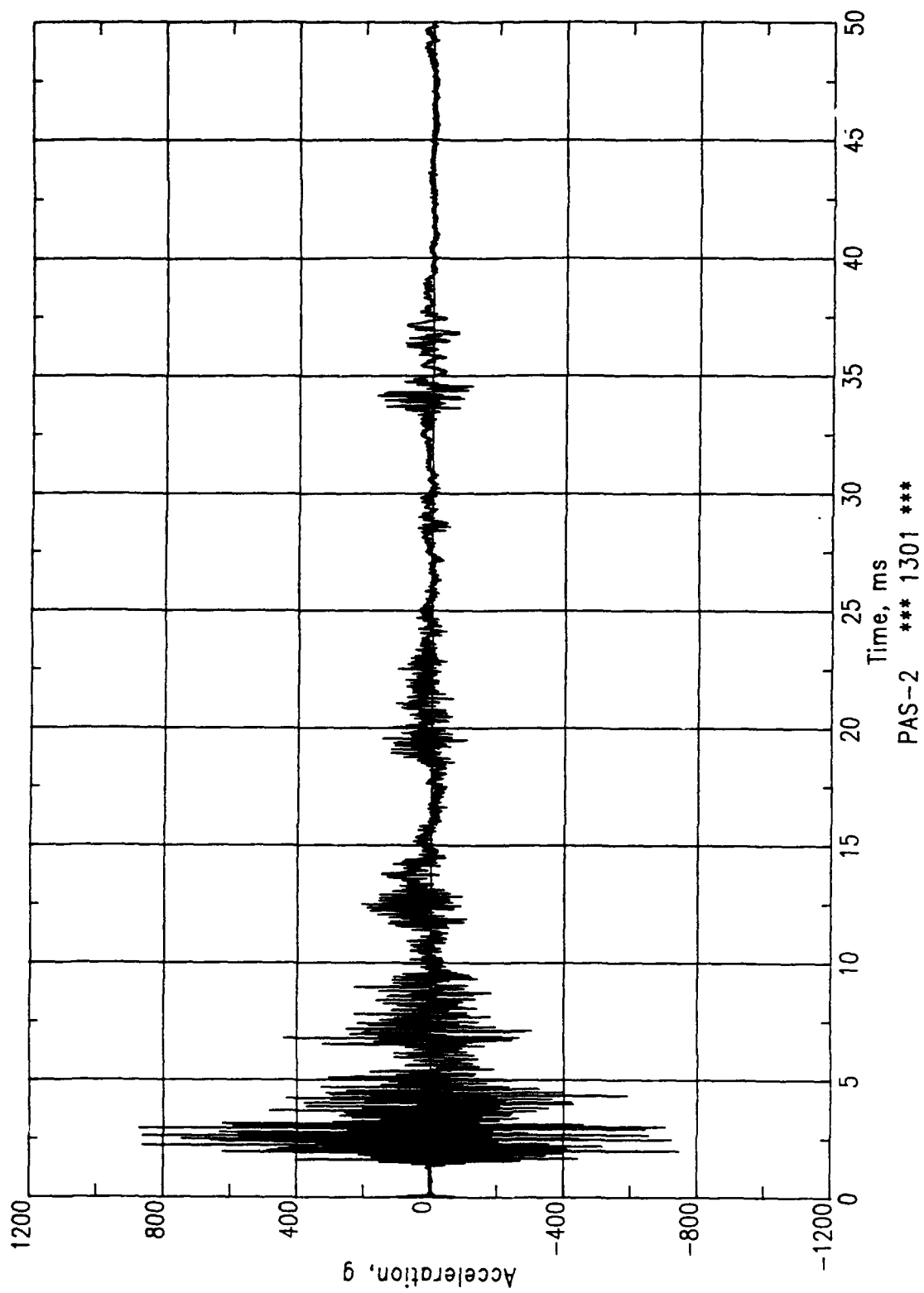


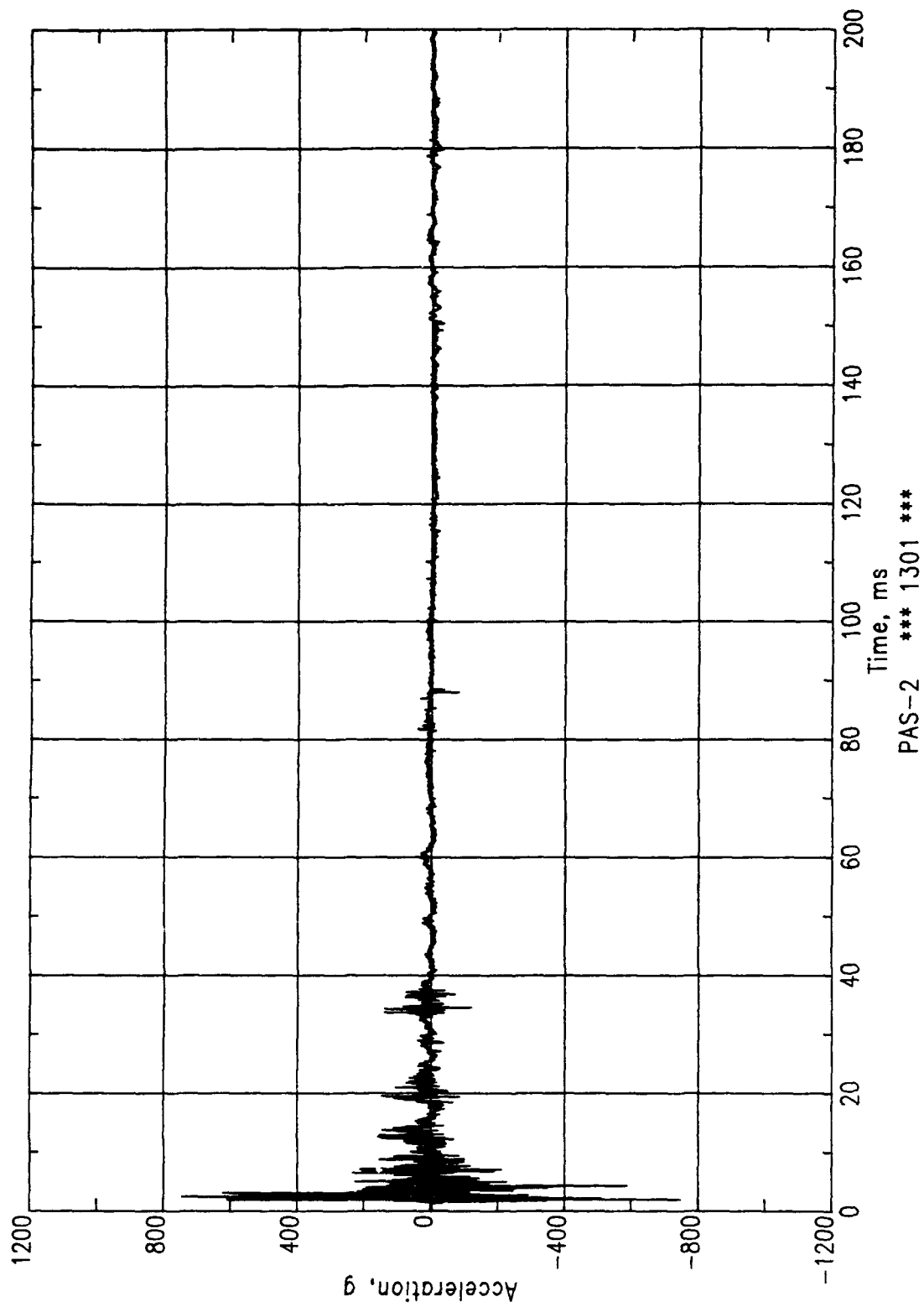


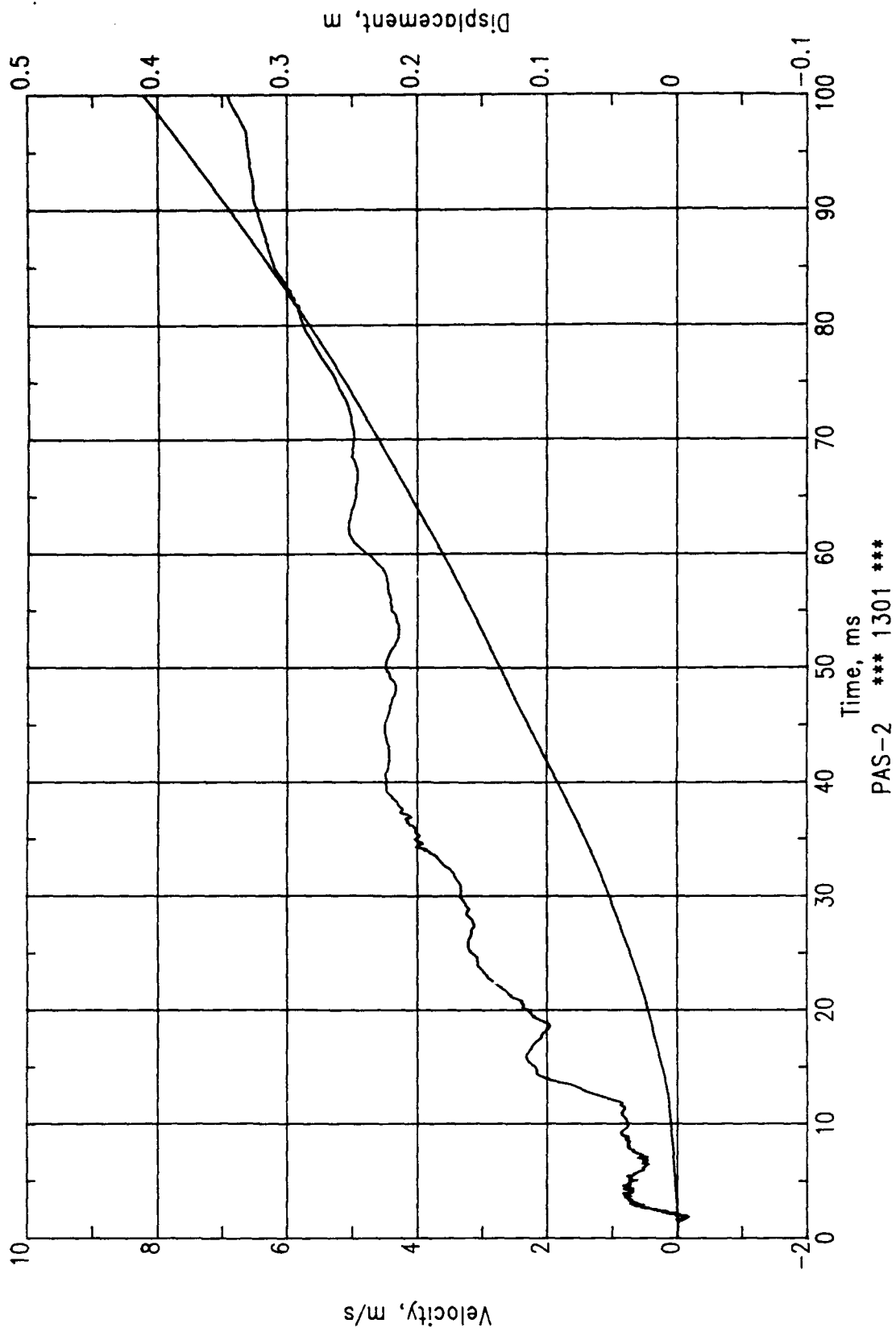


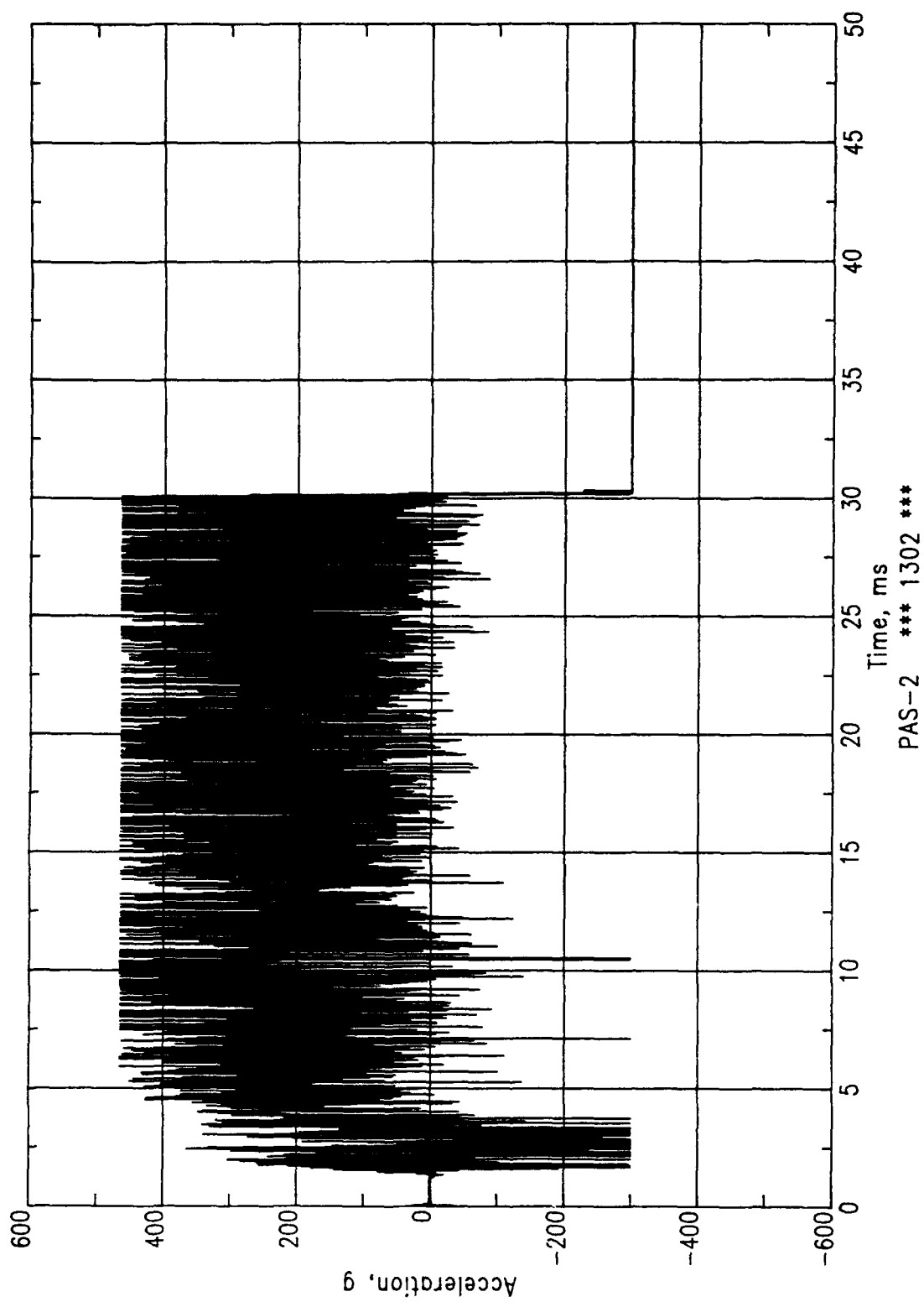


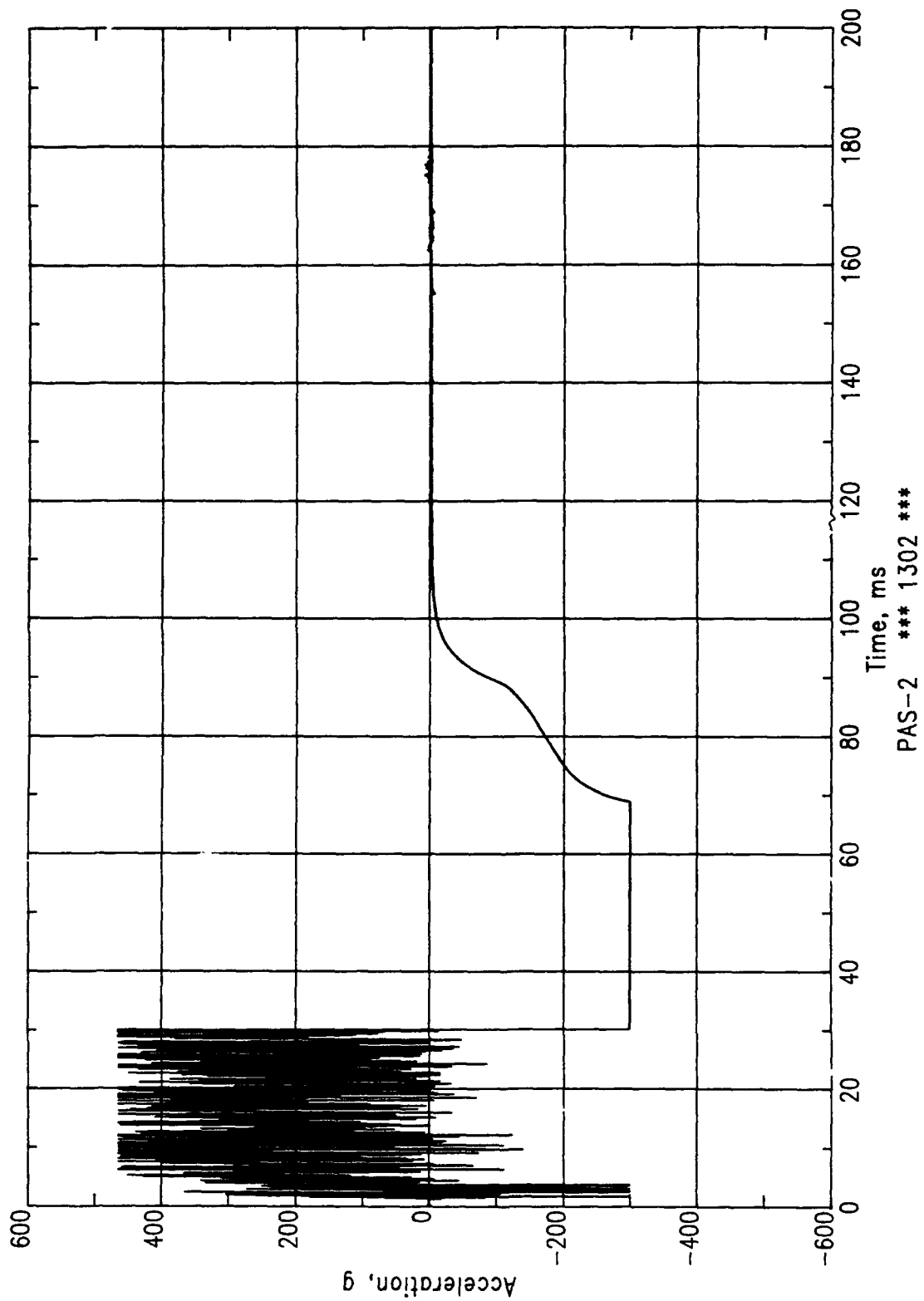


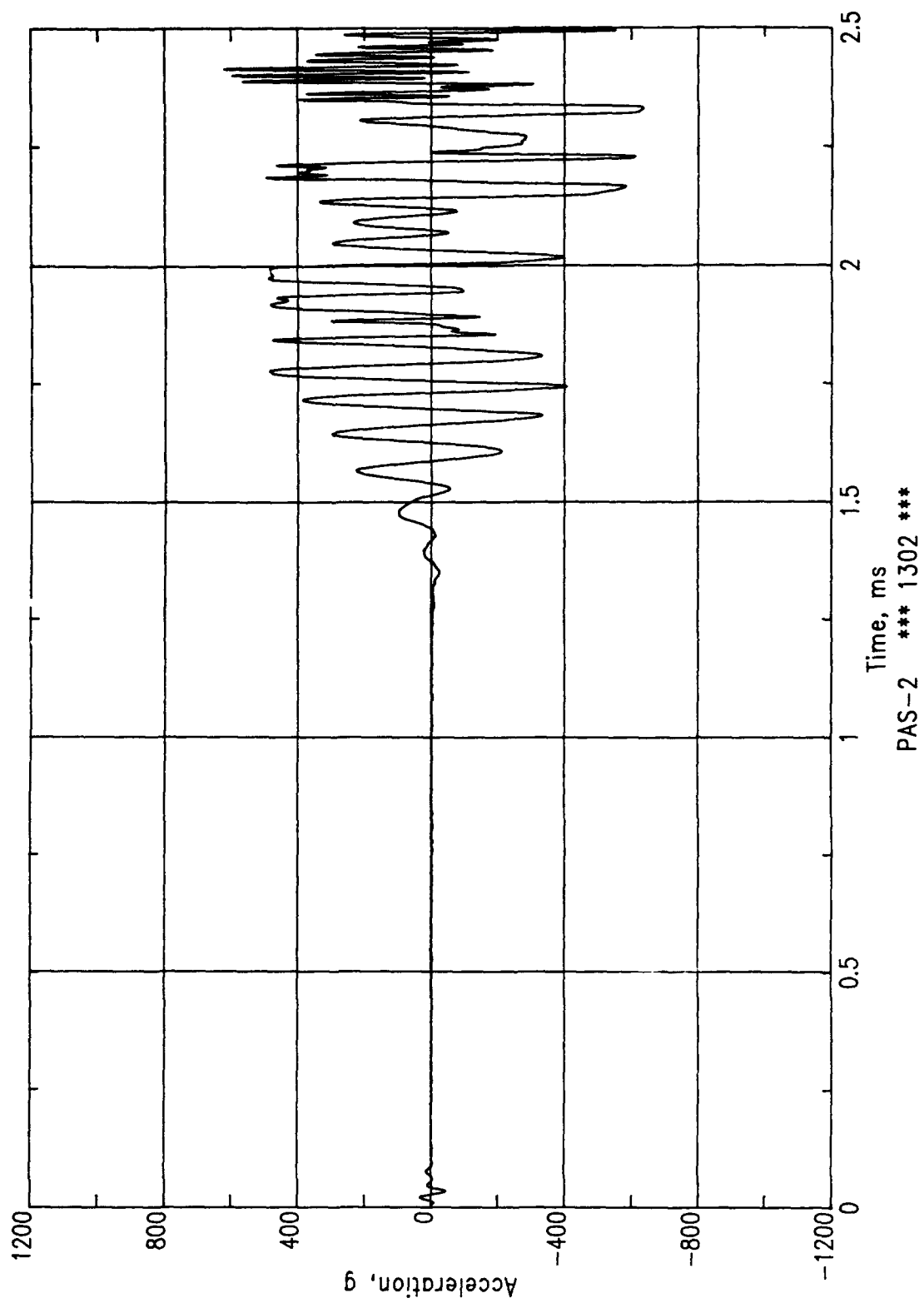


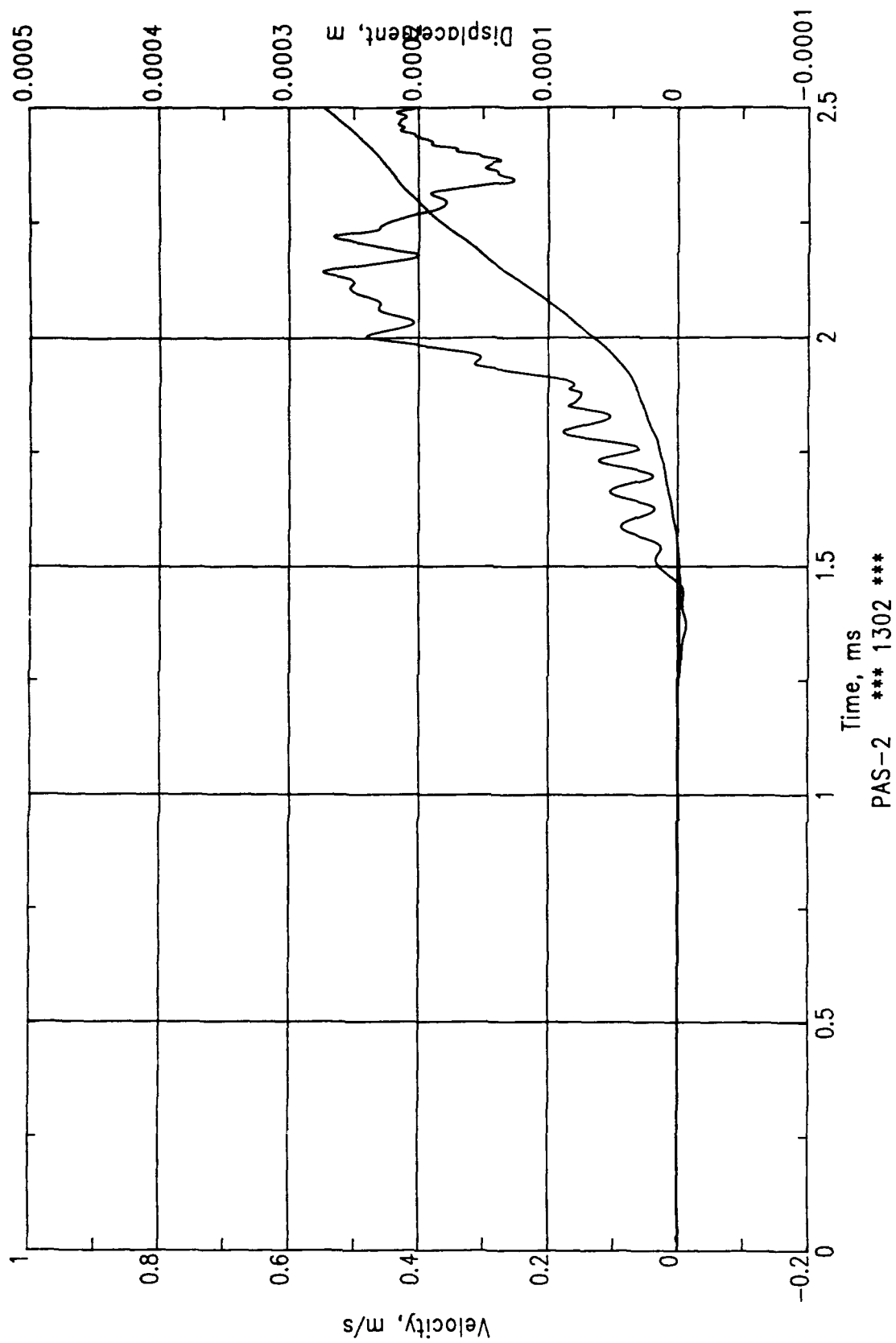


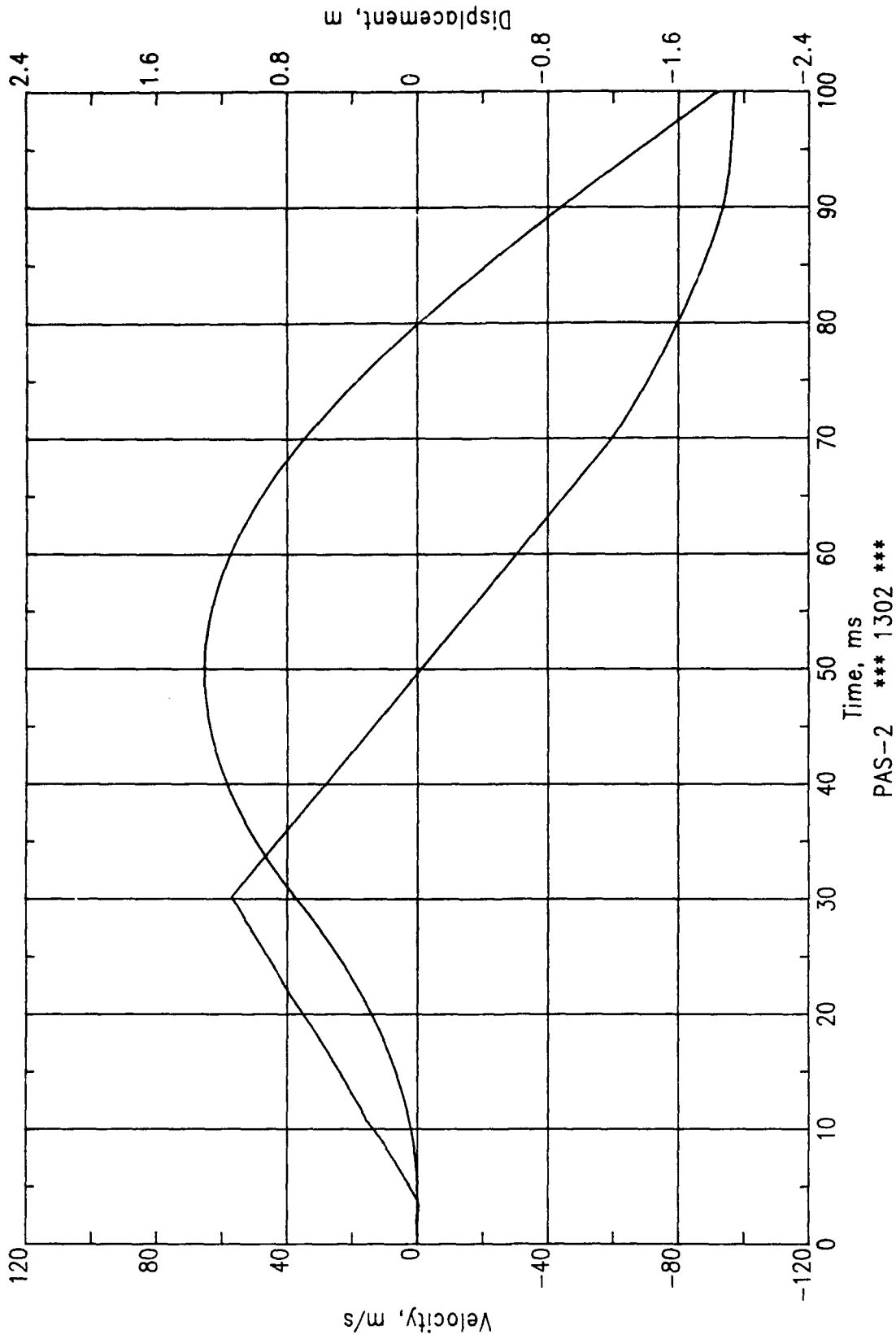




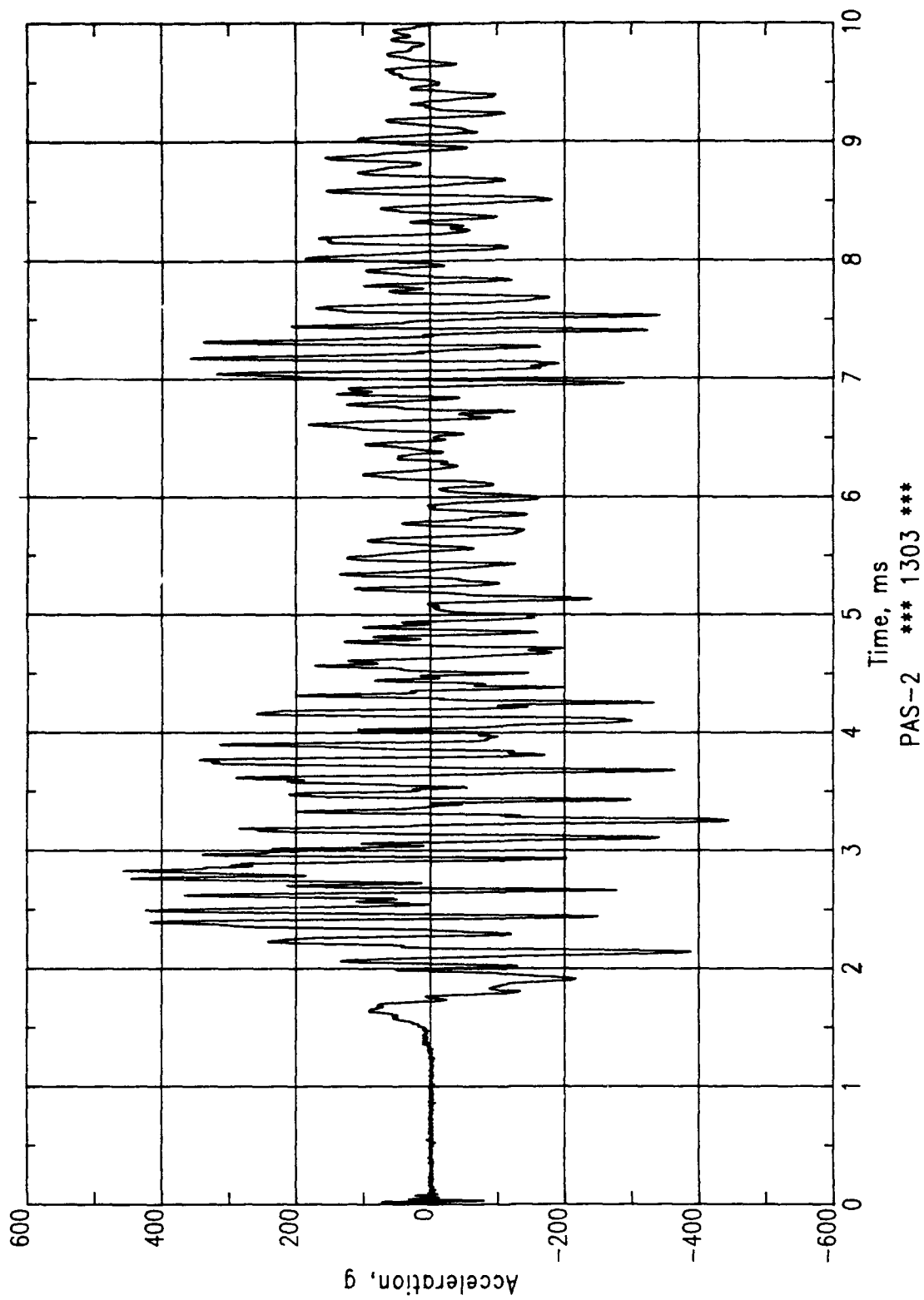


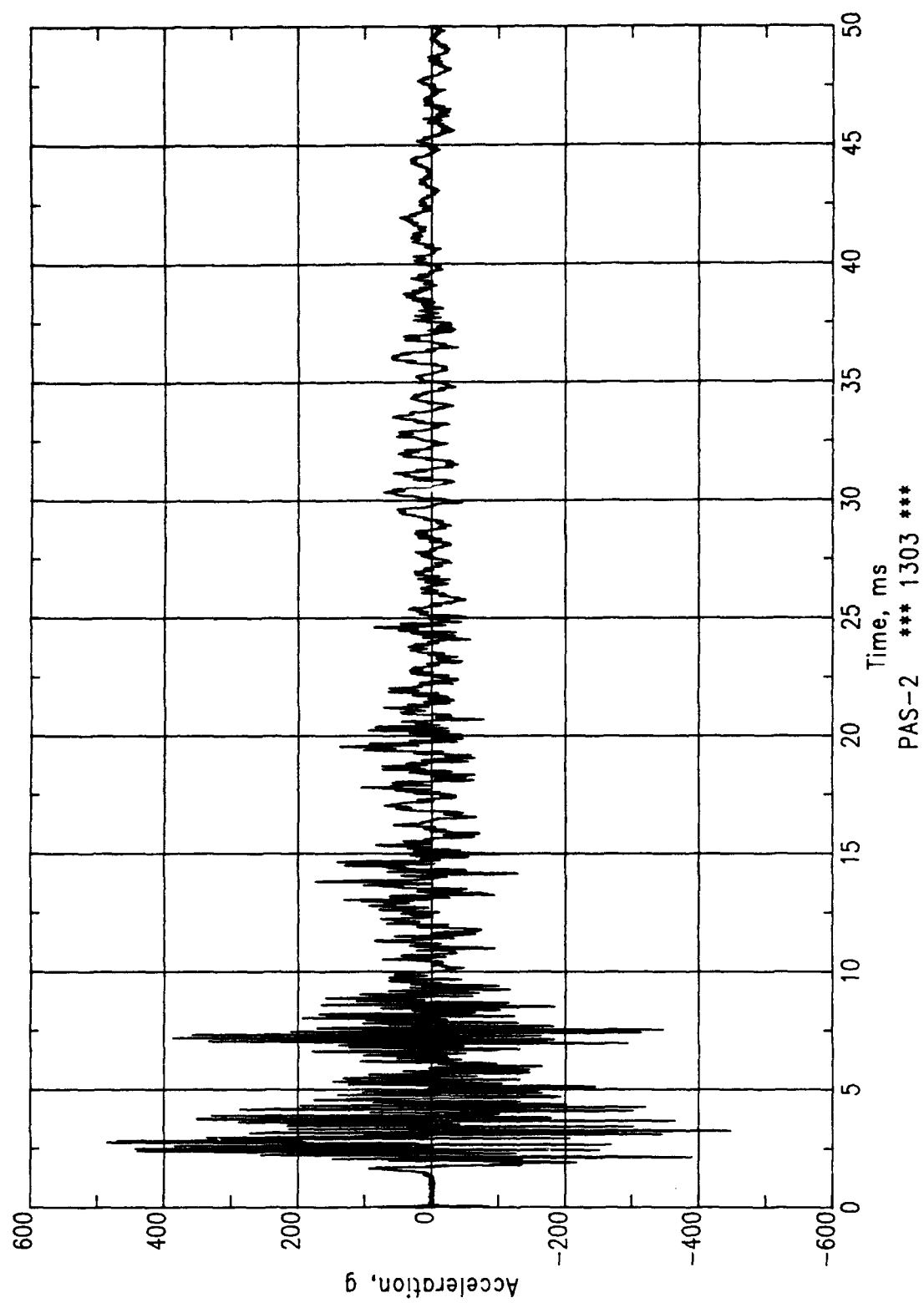


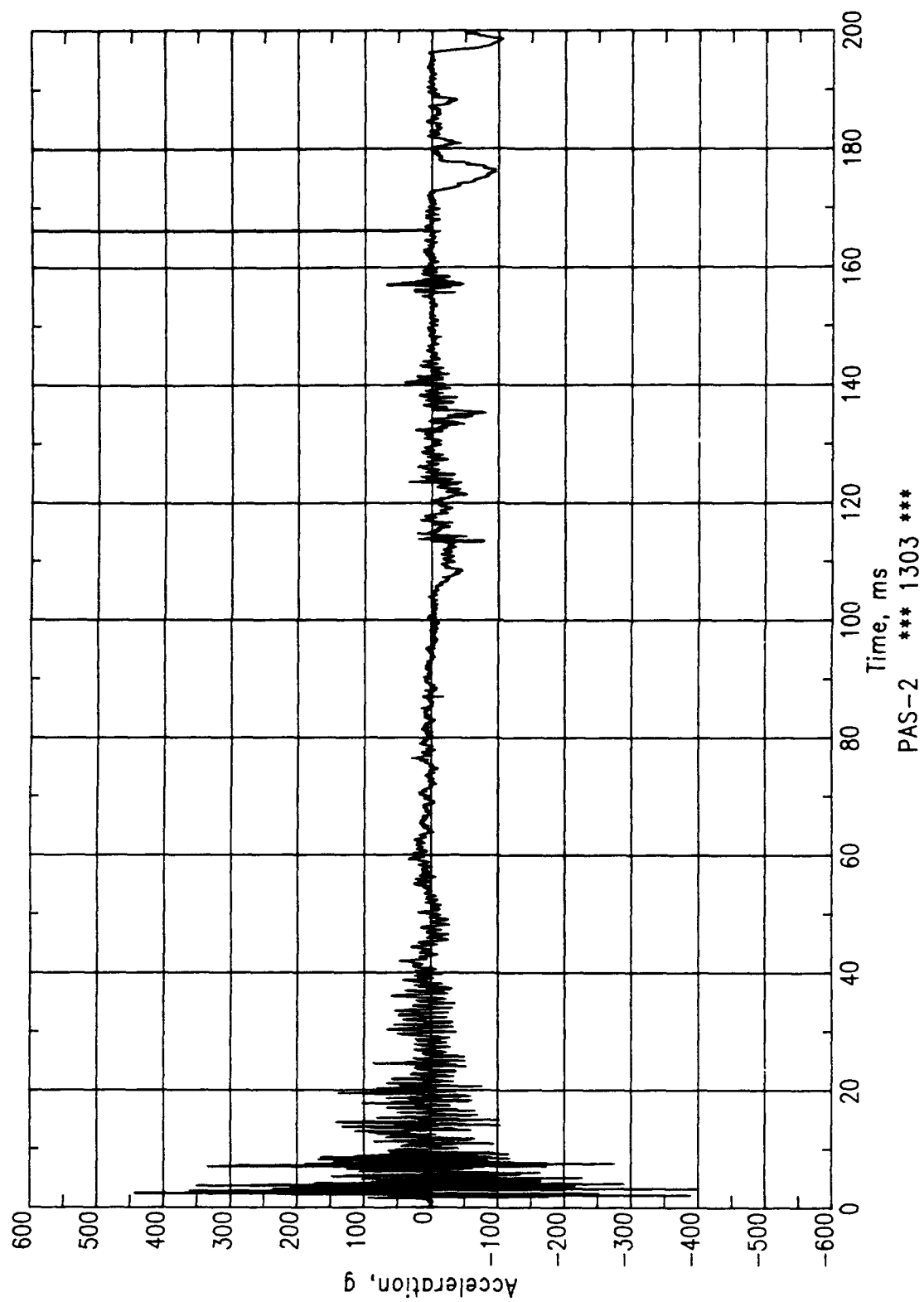


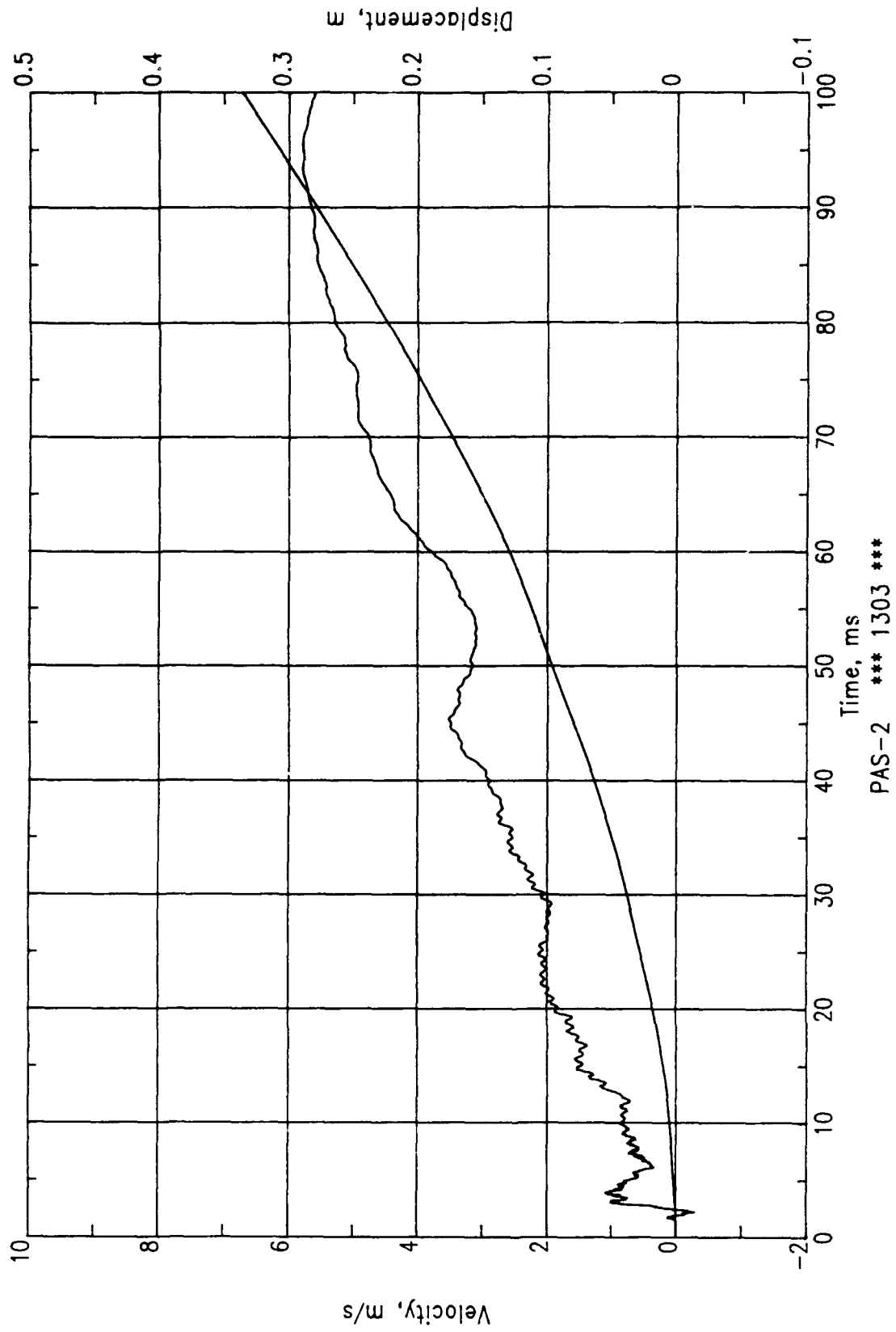


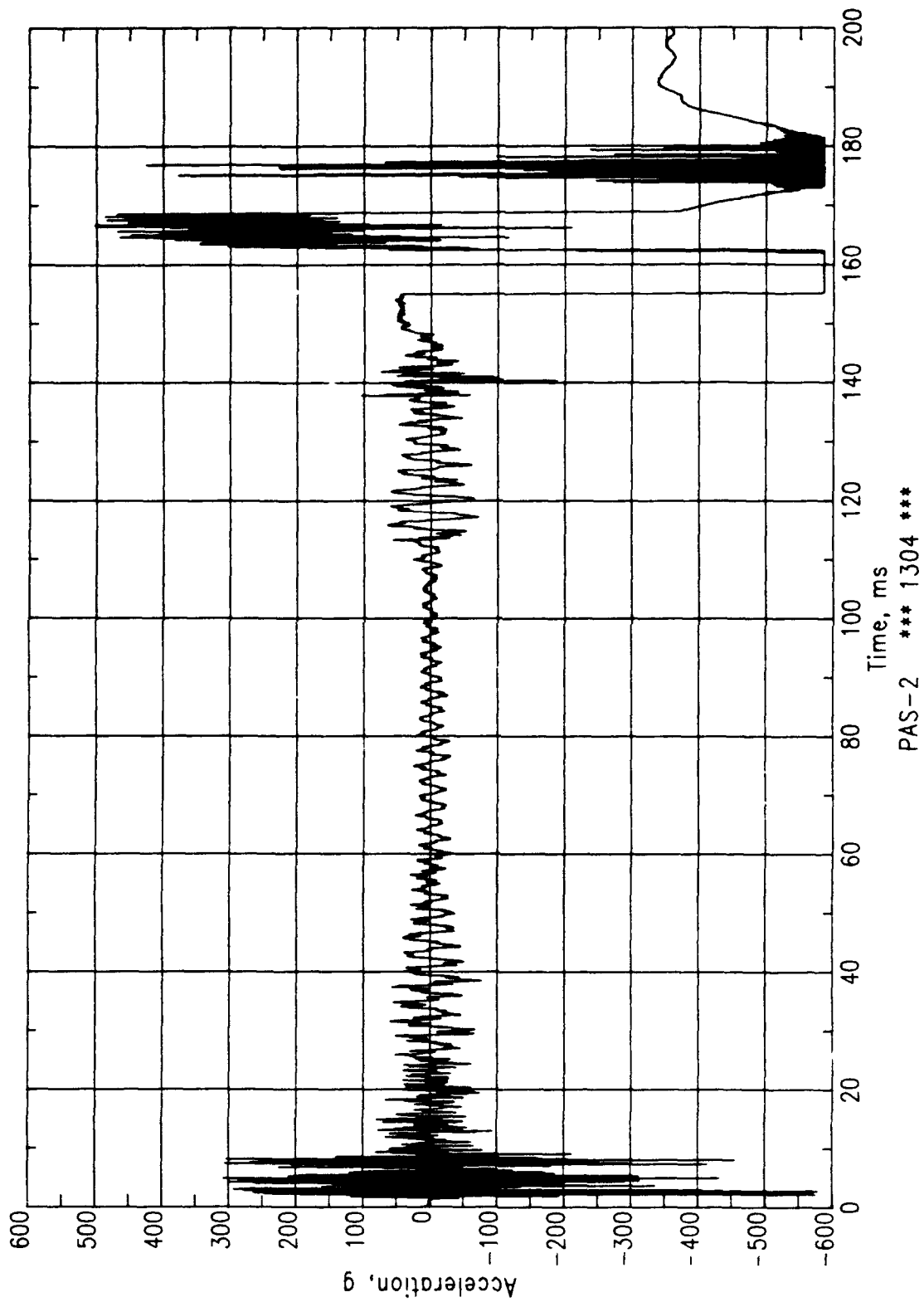
PAS-2 *** 1302 ***

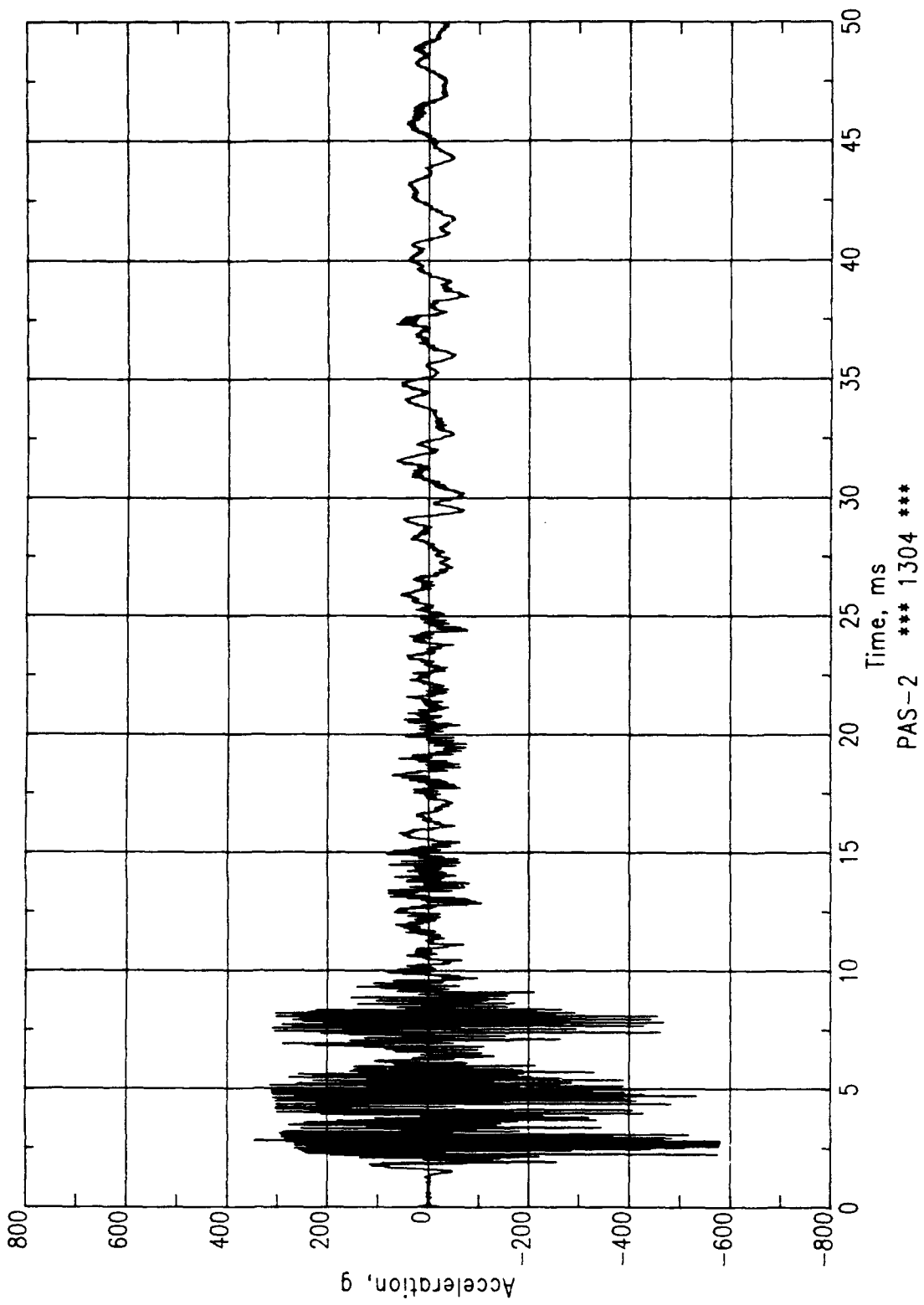


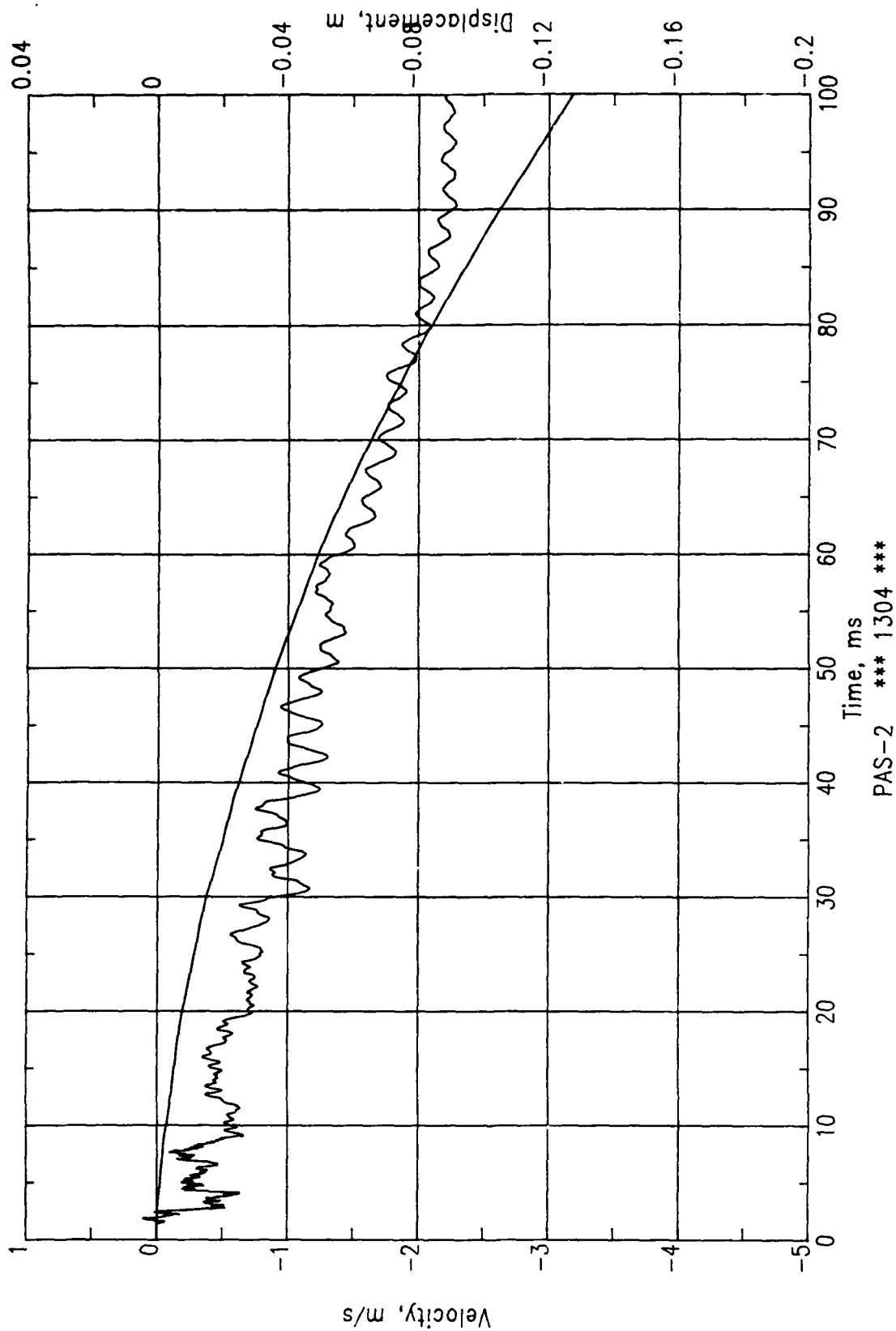


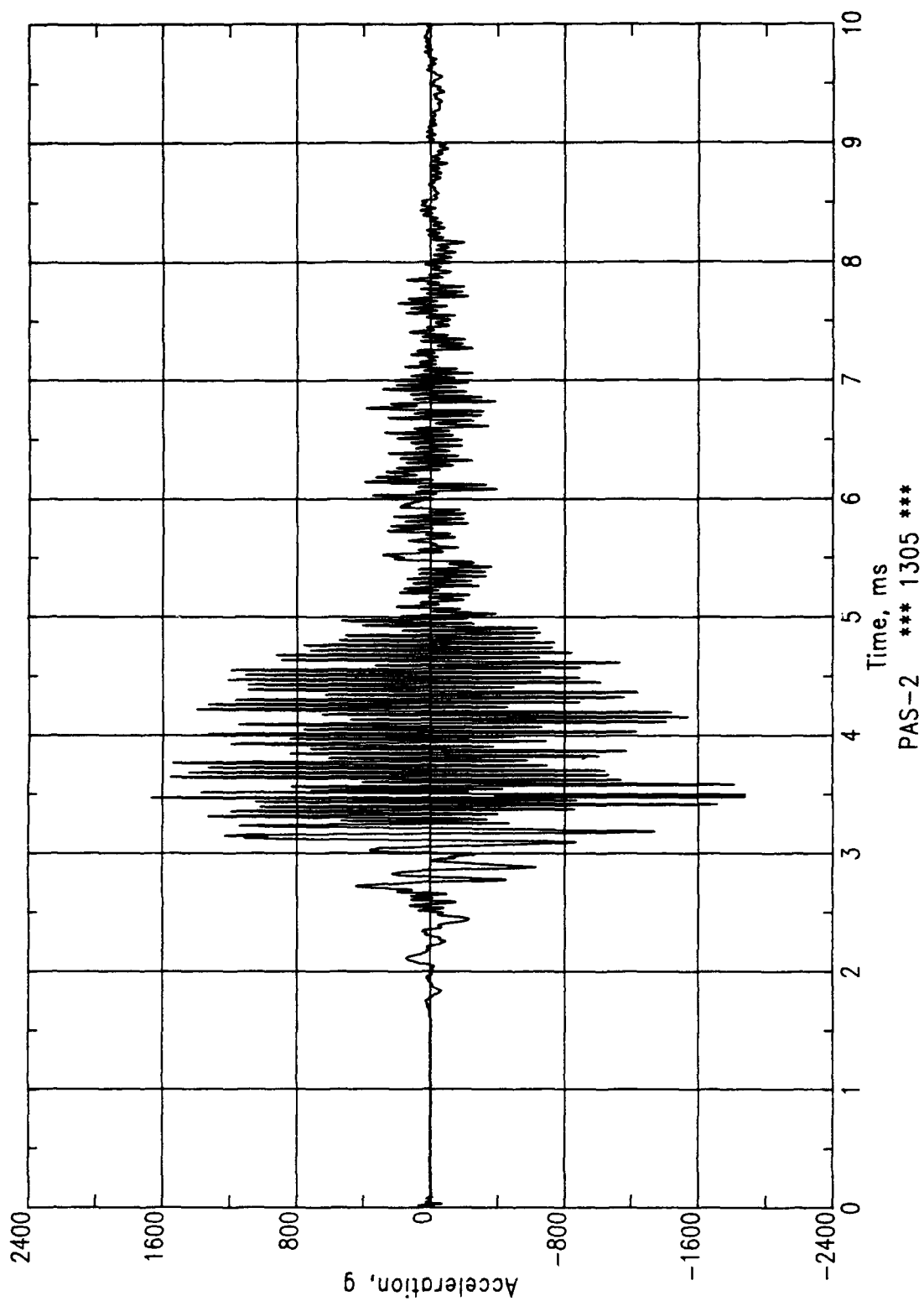


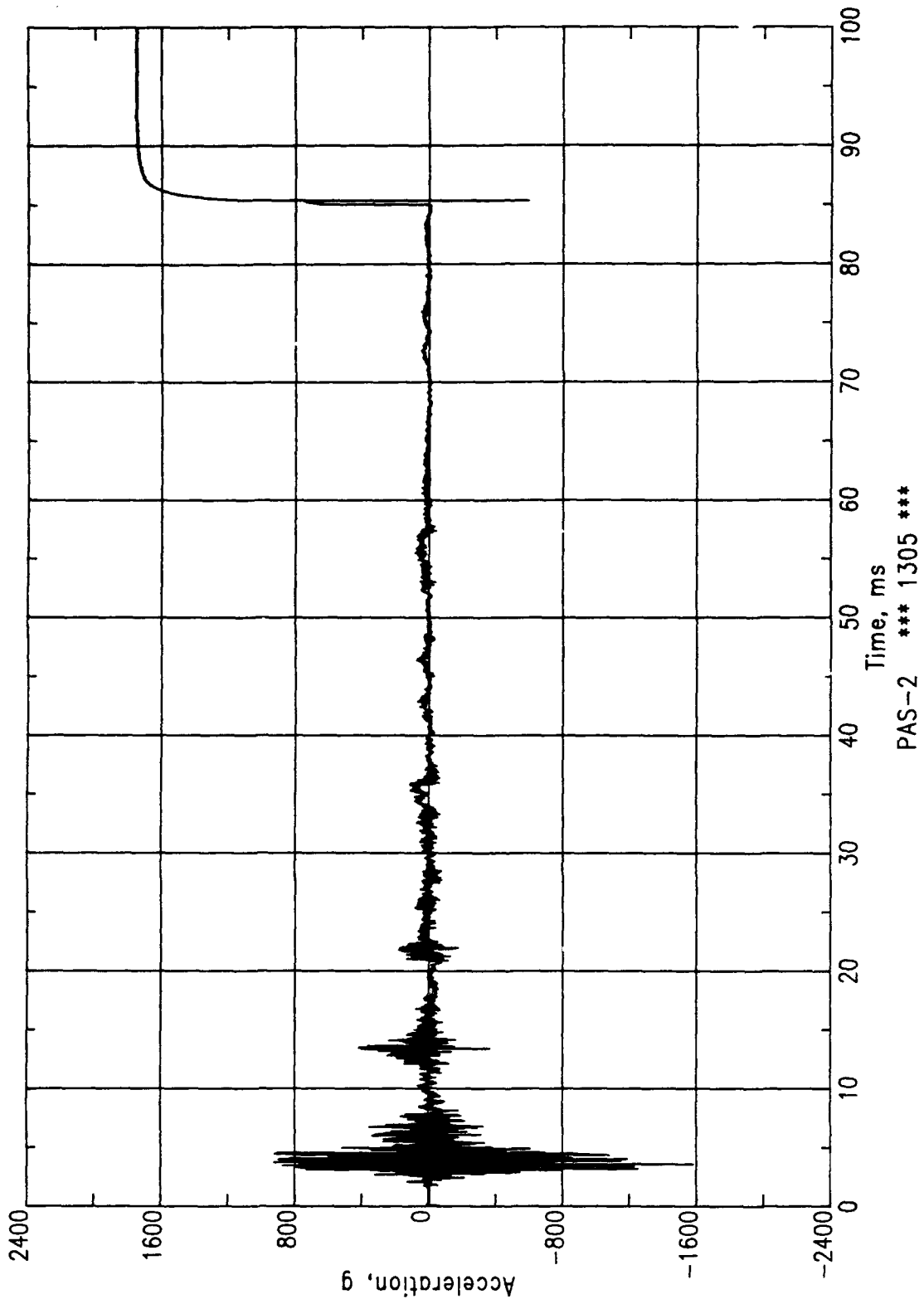


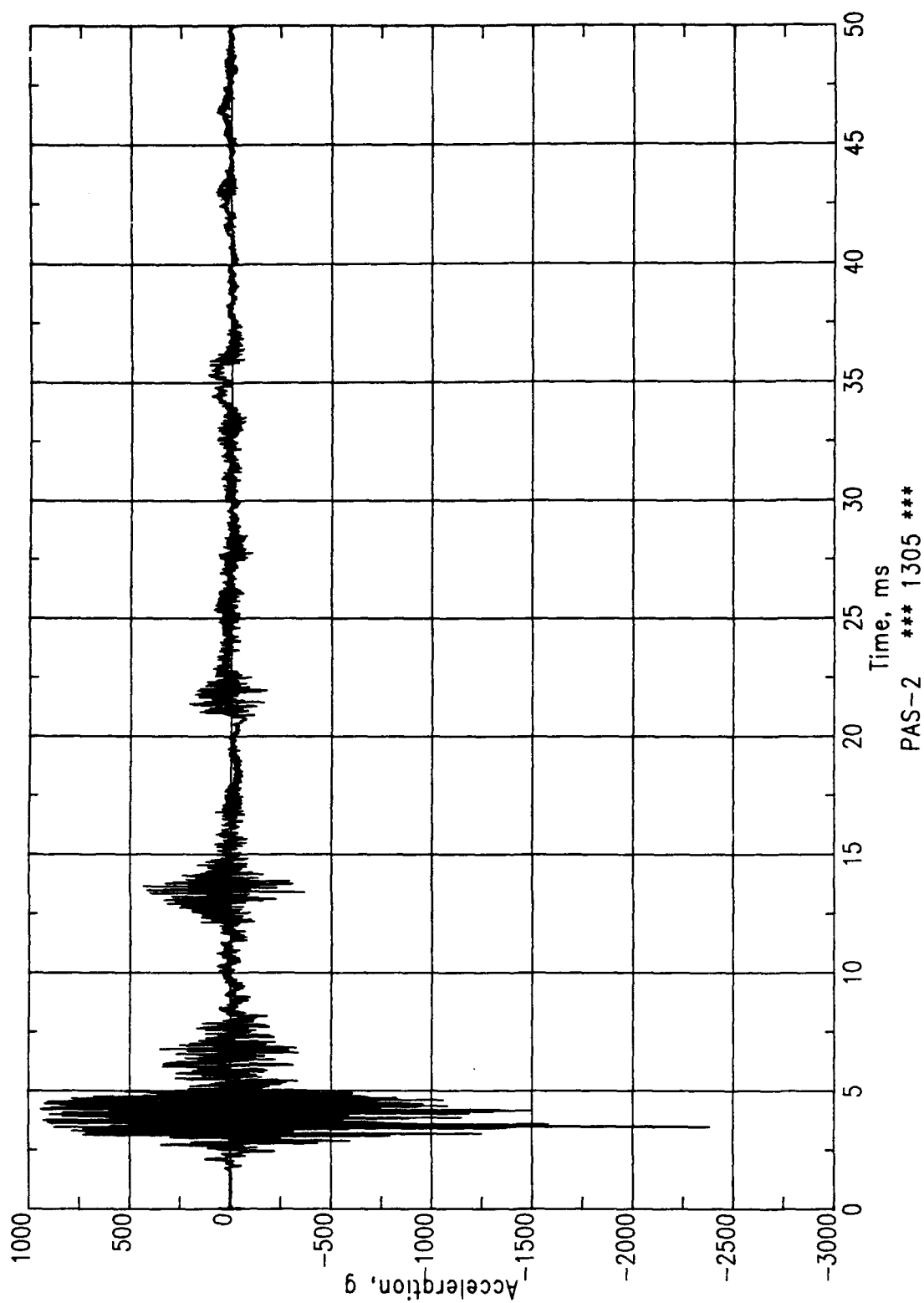


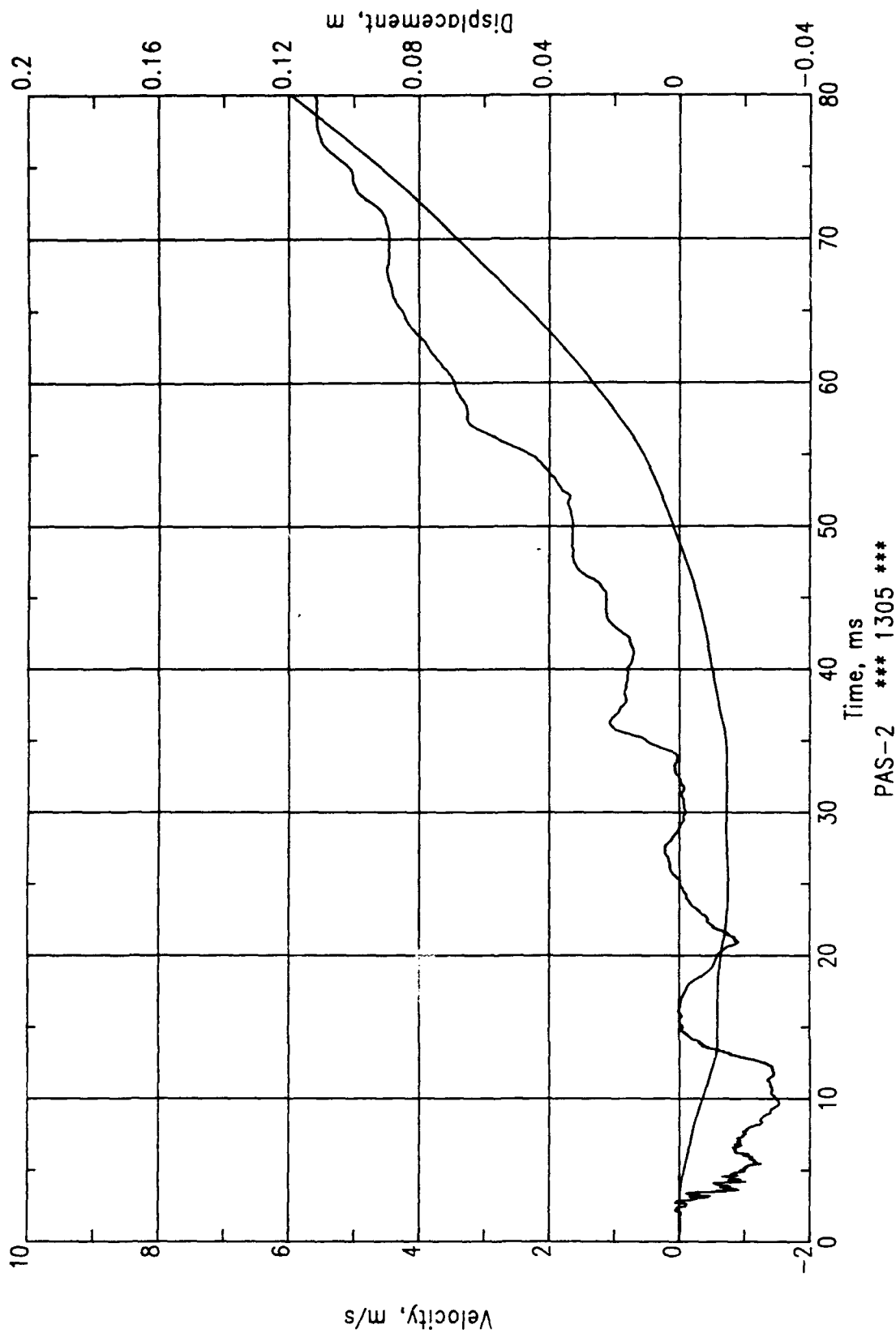


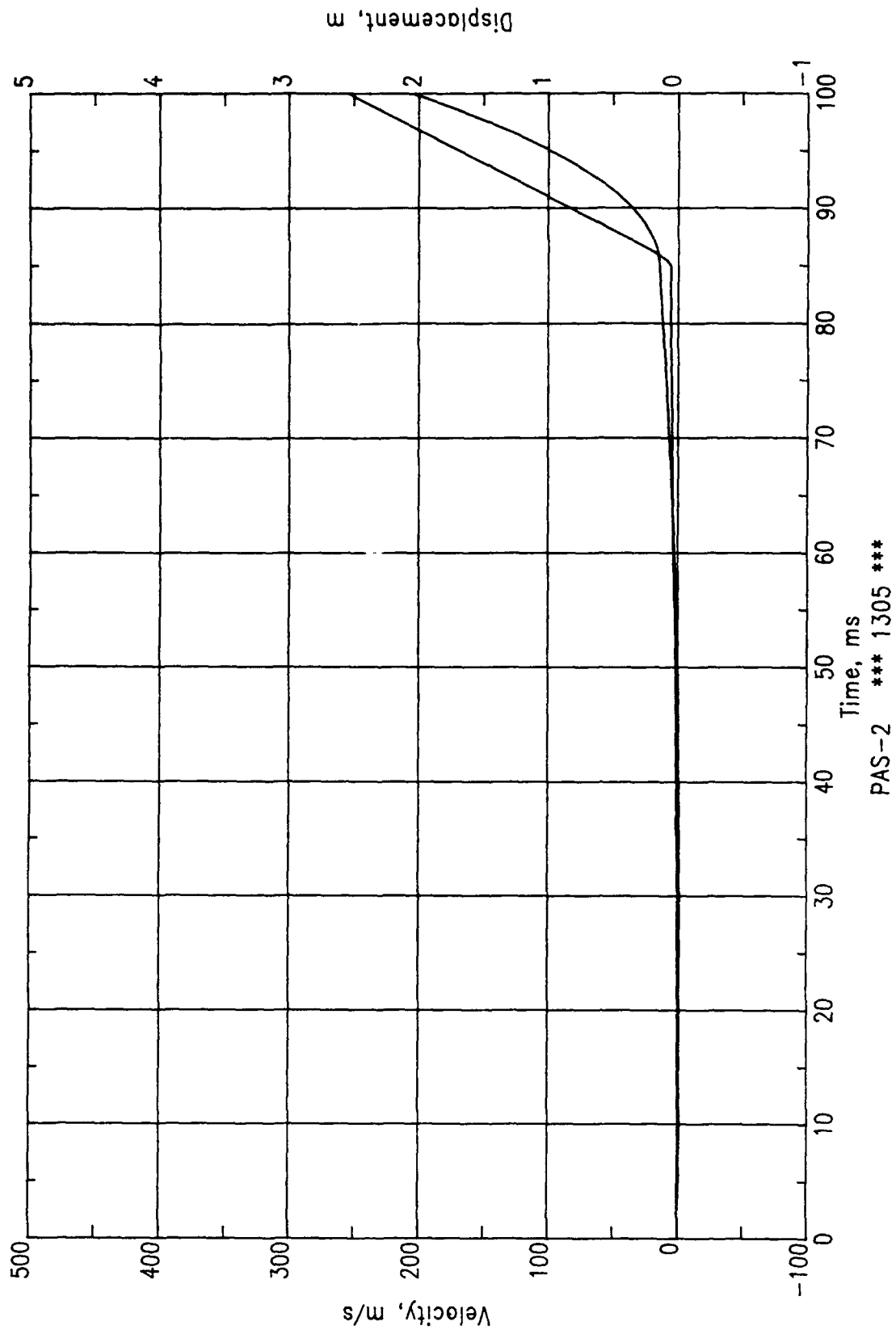


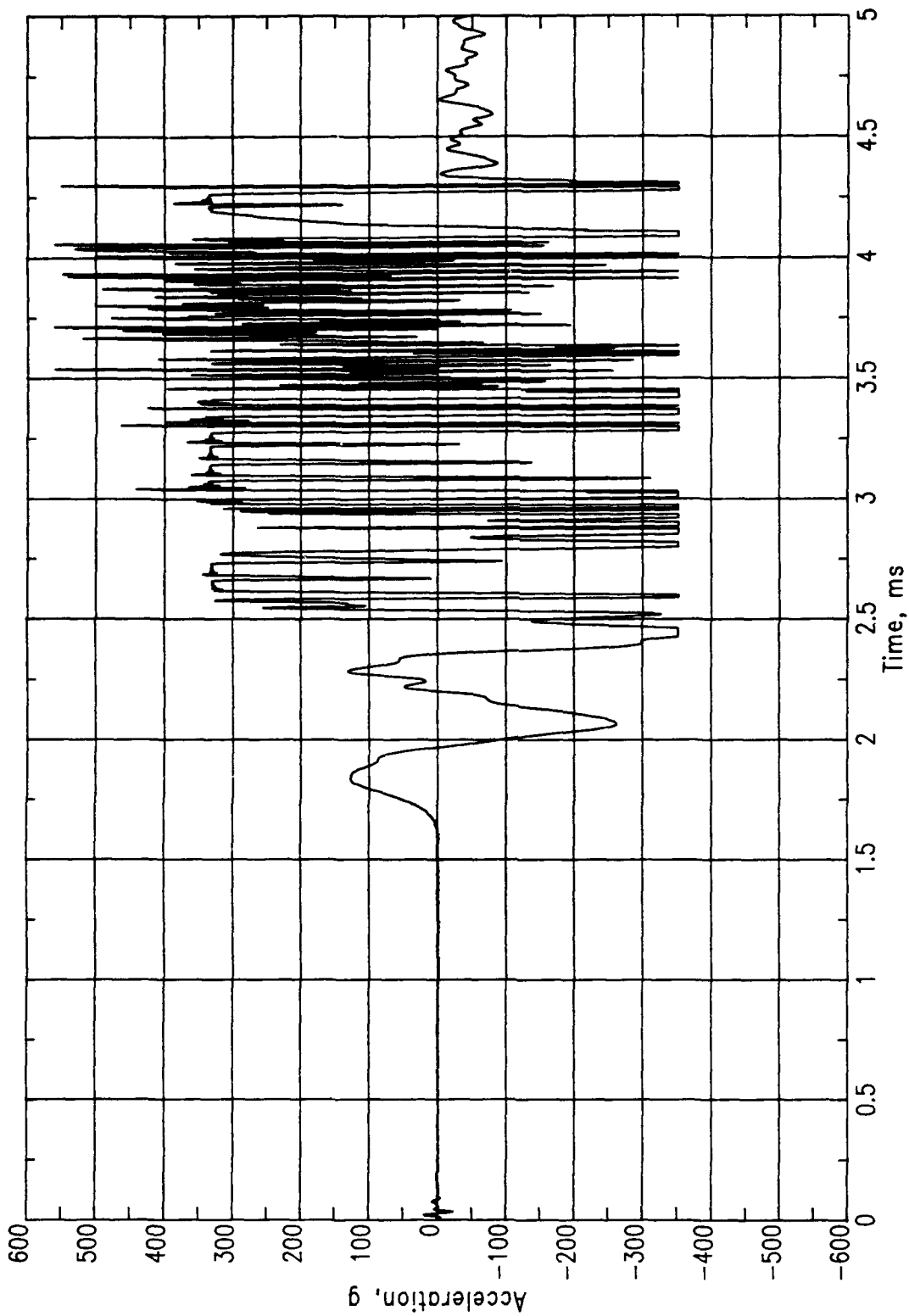












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