EDWARDS UNDERGROUND
WATER DISTRICT

Report 92-01

Blasting Effects on Engineered Structures

Appendices A - G

List of Appendices

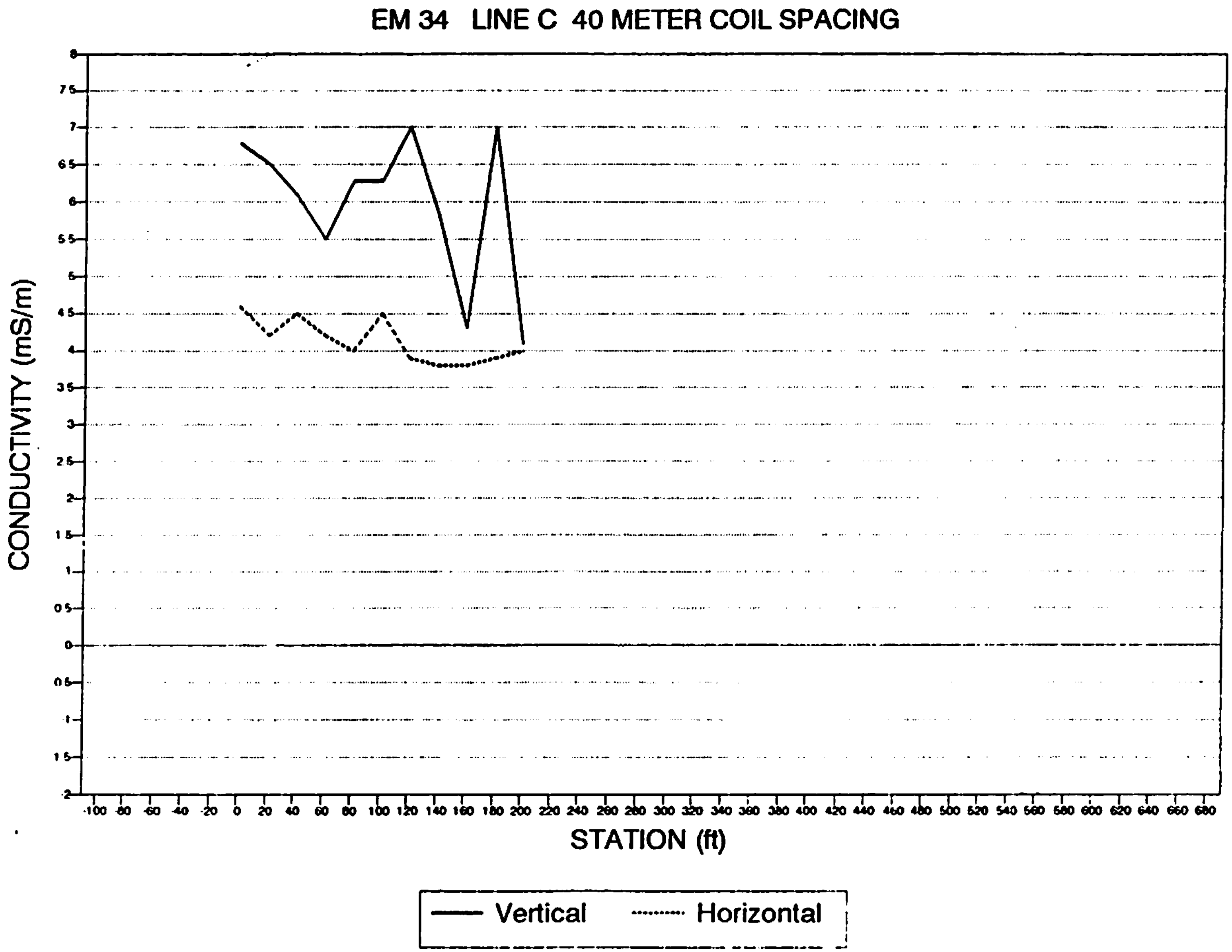


Figure A.2i - EM 34 Line C Survey: 40 Meter Coil Spacing

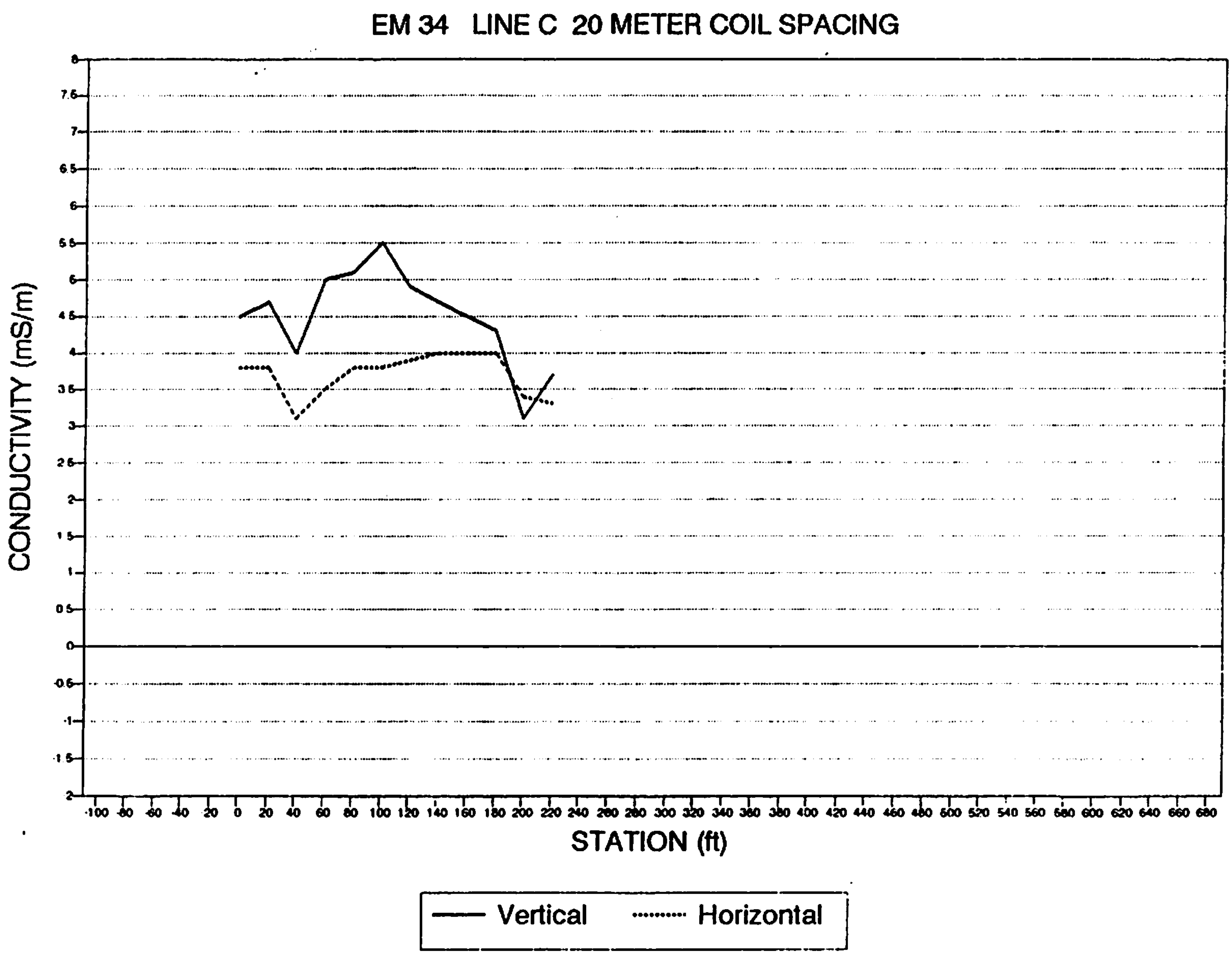


Figure A.2h - EM 34 Line C Survey: 20 Meter Coil Spacing

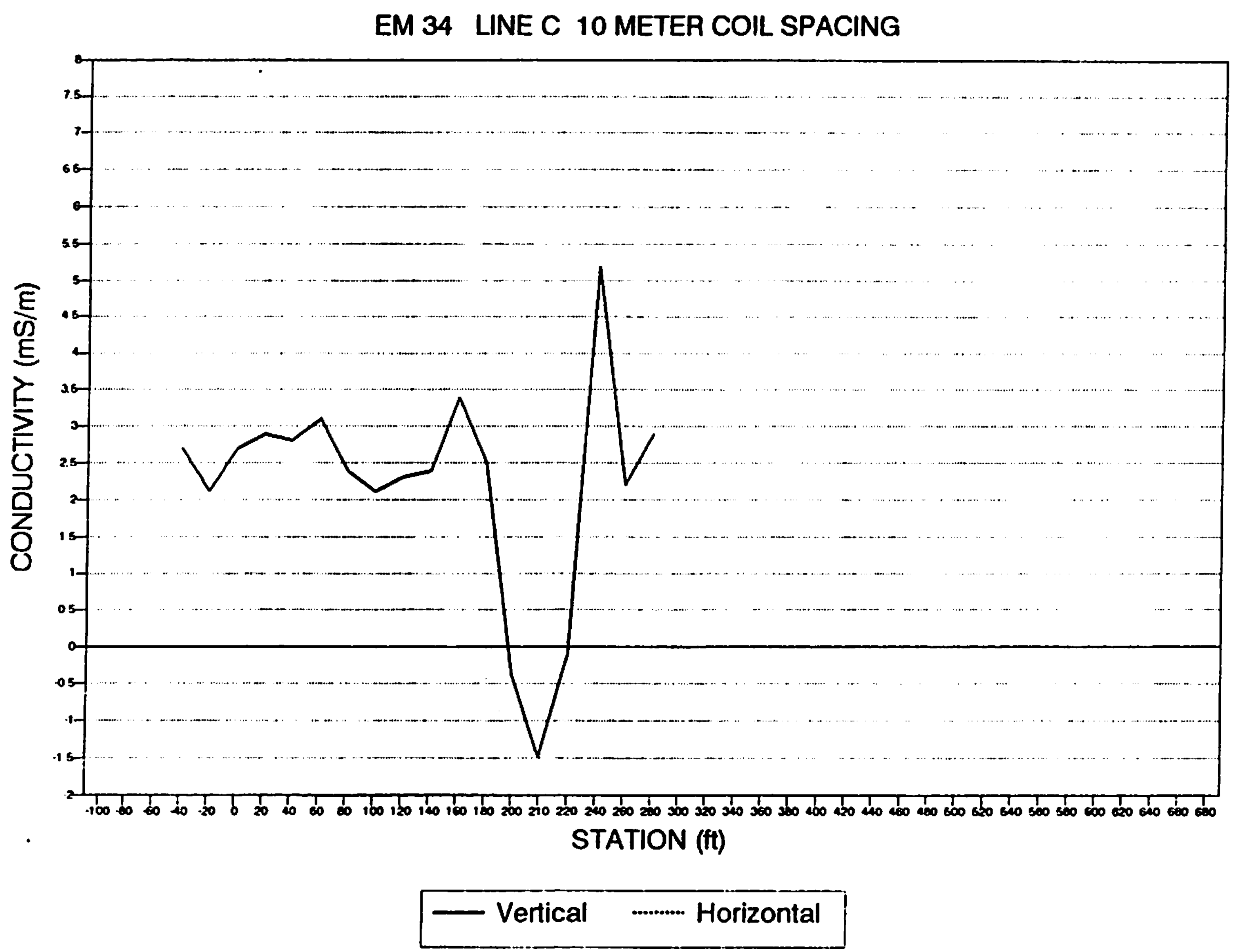


Figure A.2g - EM 34 Line C Survey: 10 Meter Coil Spacing

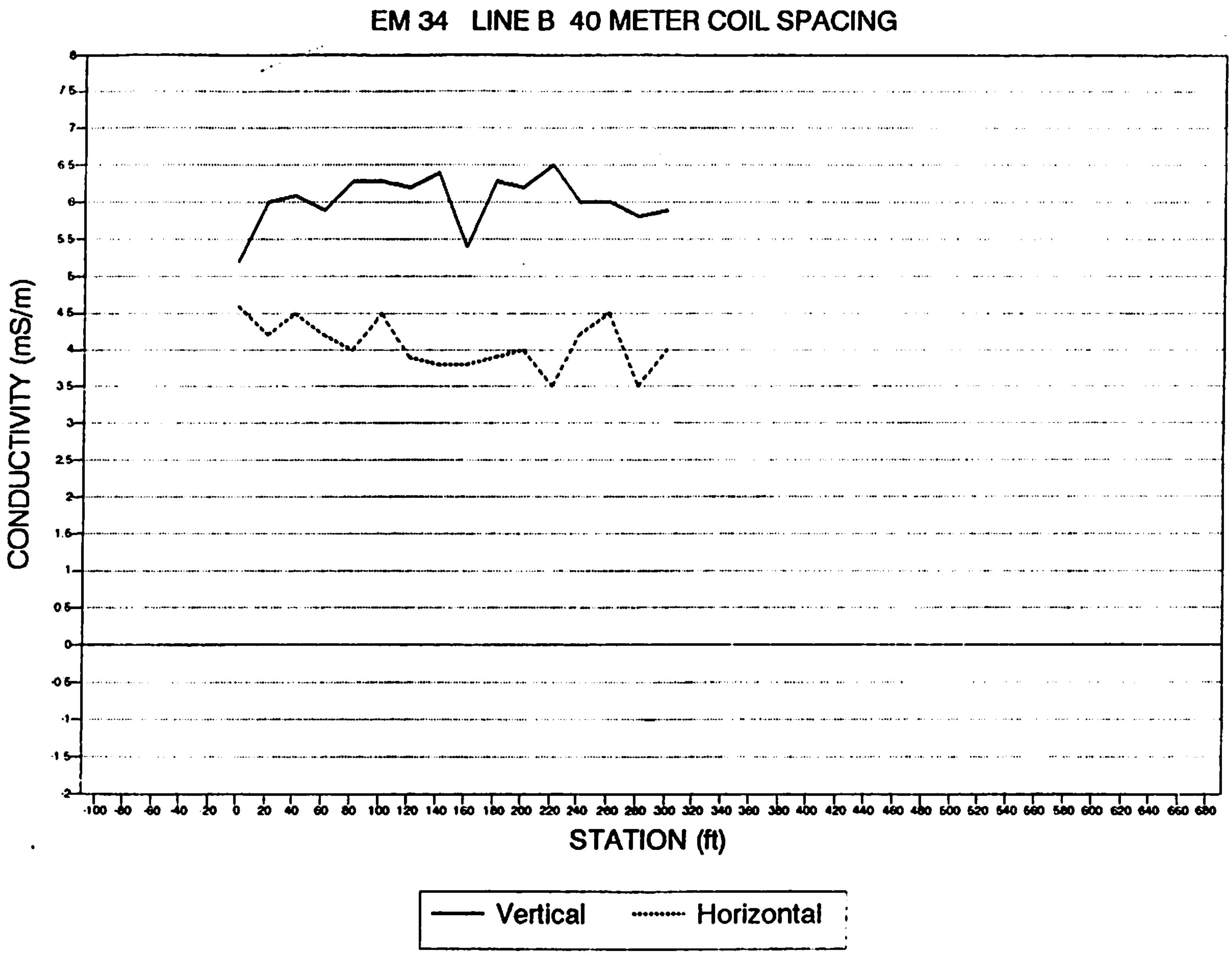


Figure A.2f - EM 34 Line B Survey: 40 Meter Coil Spacing

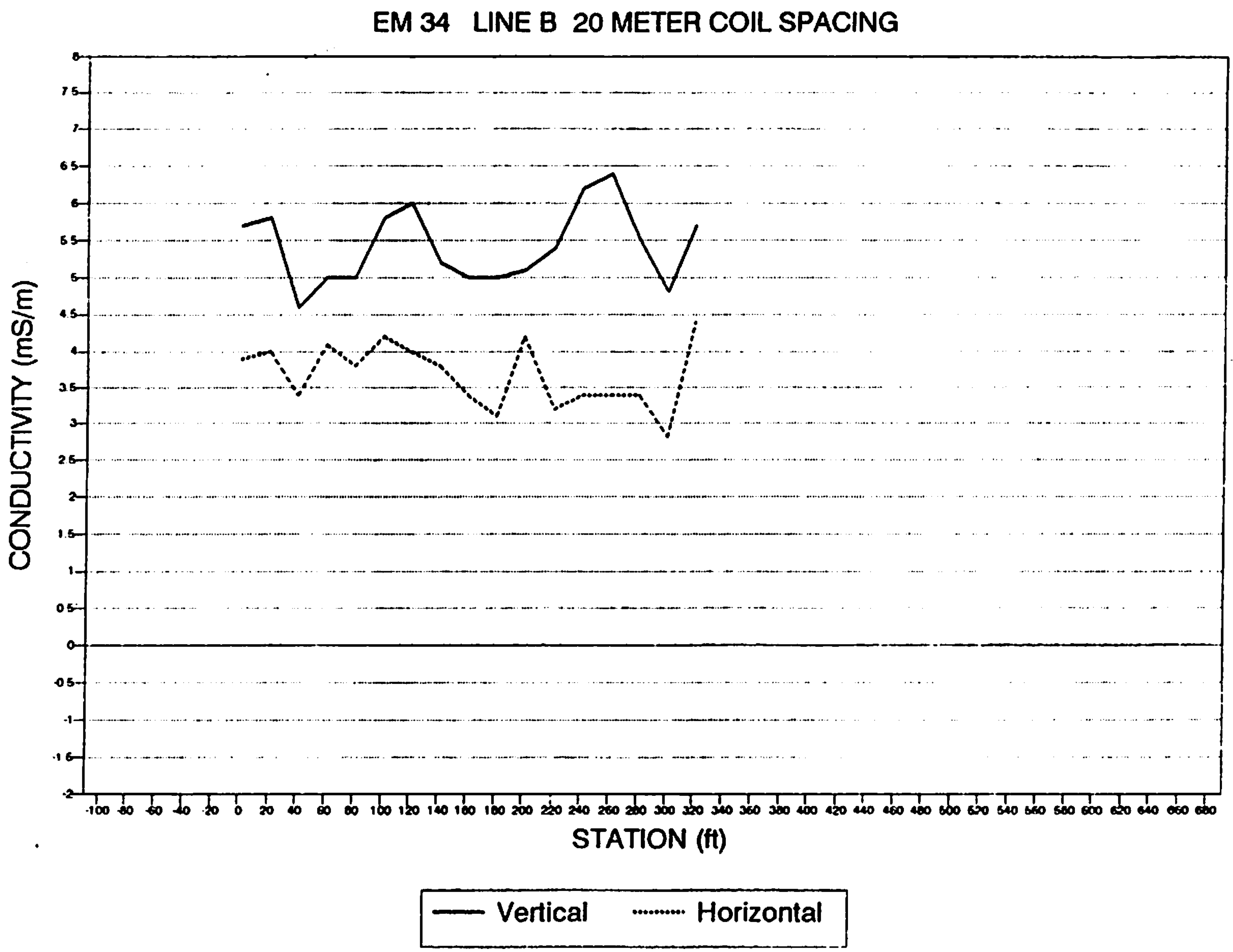


Figure A.2e - EM 34 Line B Survey: 20 Meter Coil Spacing

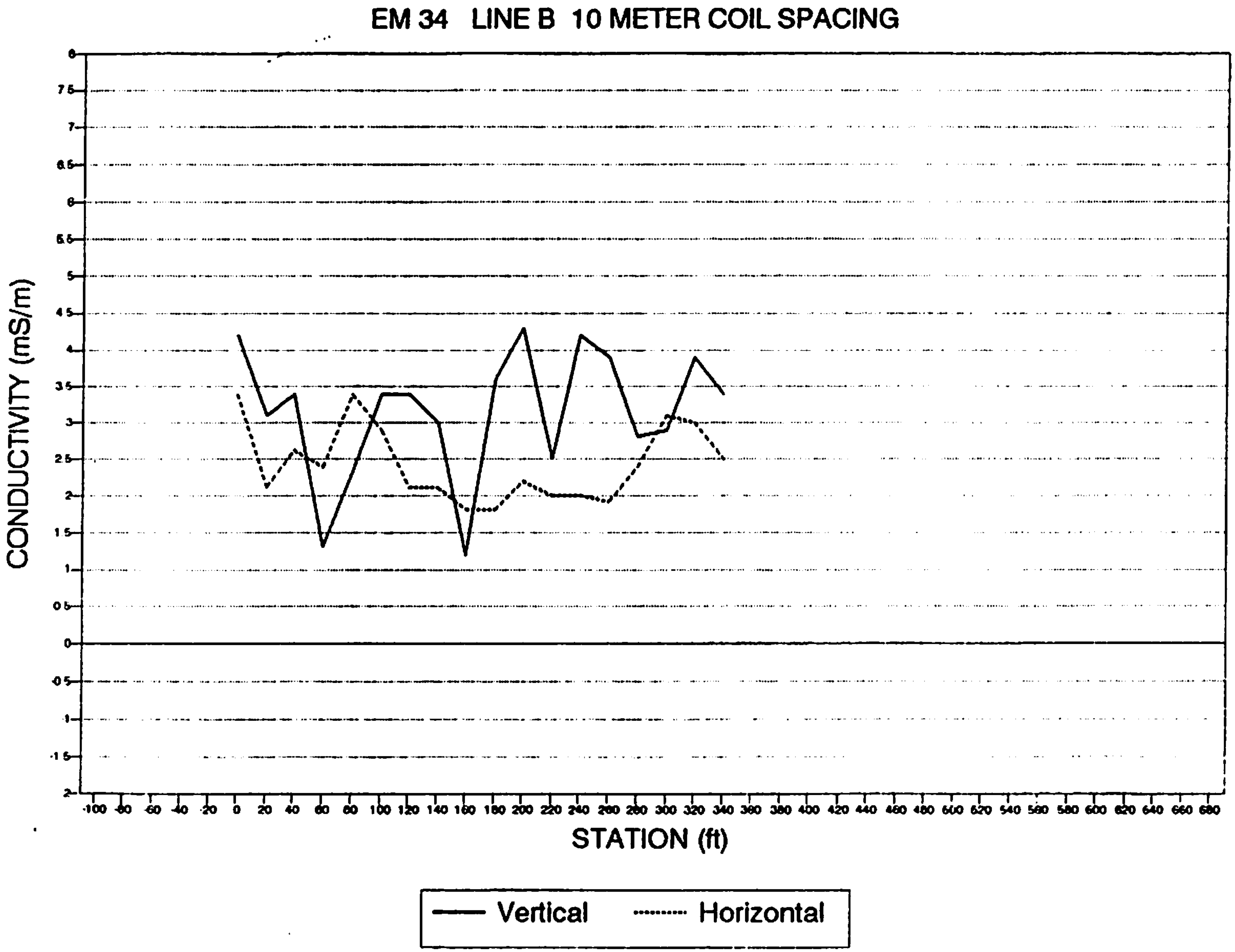


Figure A.2d - EM 34 Line B Survey: 10 Meter Coil Spacing

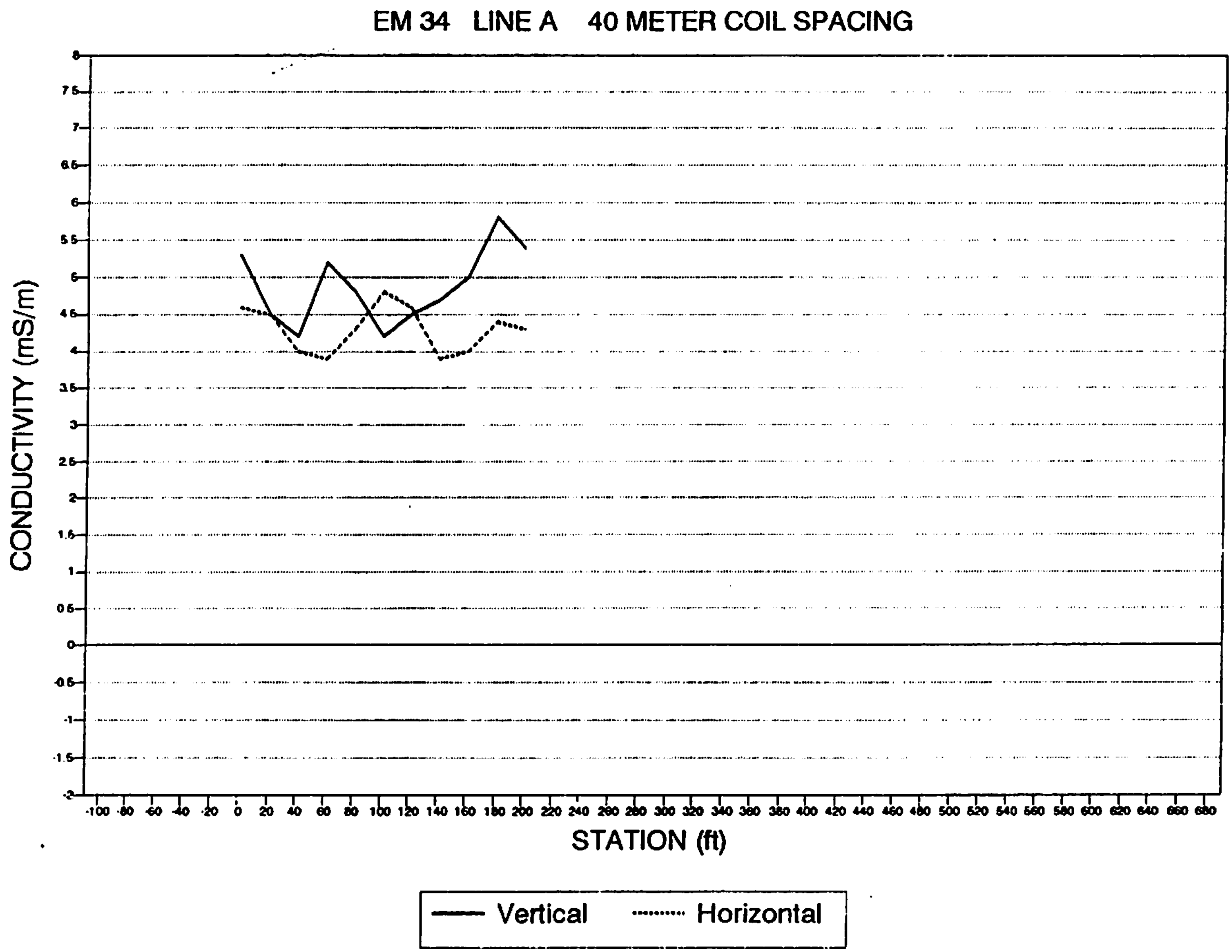


Figure A.2c - EM 34 Line A Survey: 40 Meter Coil Spacing

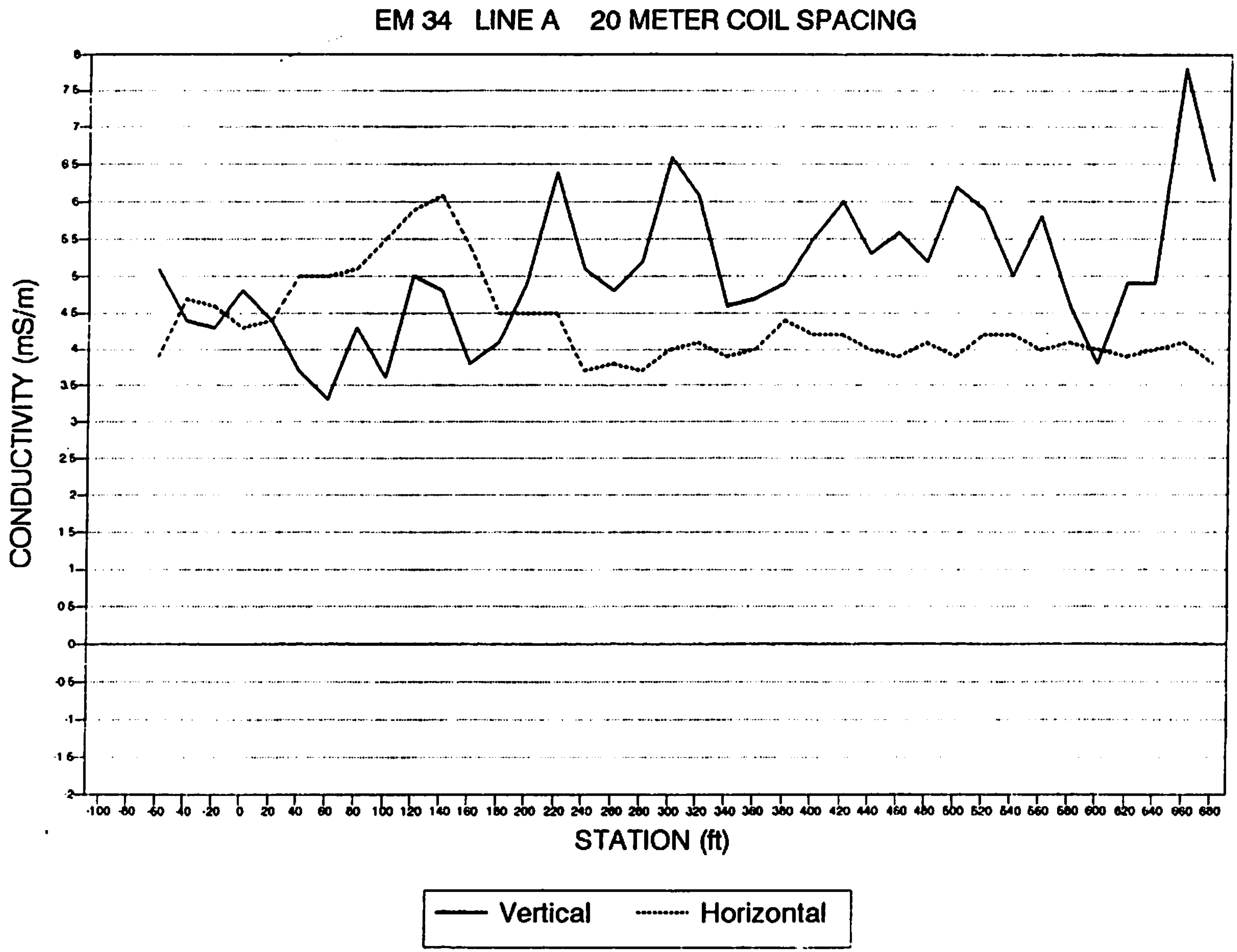


Figure A.2b - EM 34 Line A Survey: 20 Meter Coil Spacing

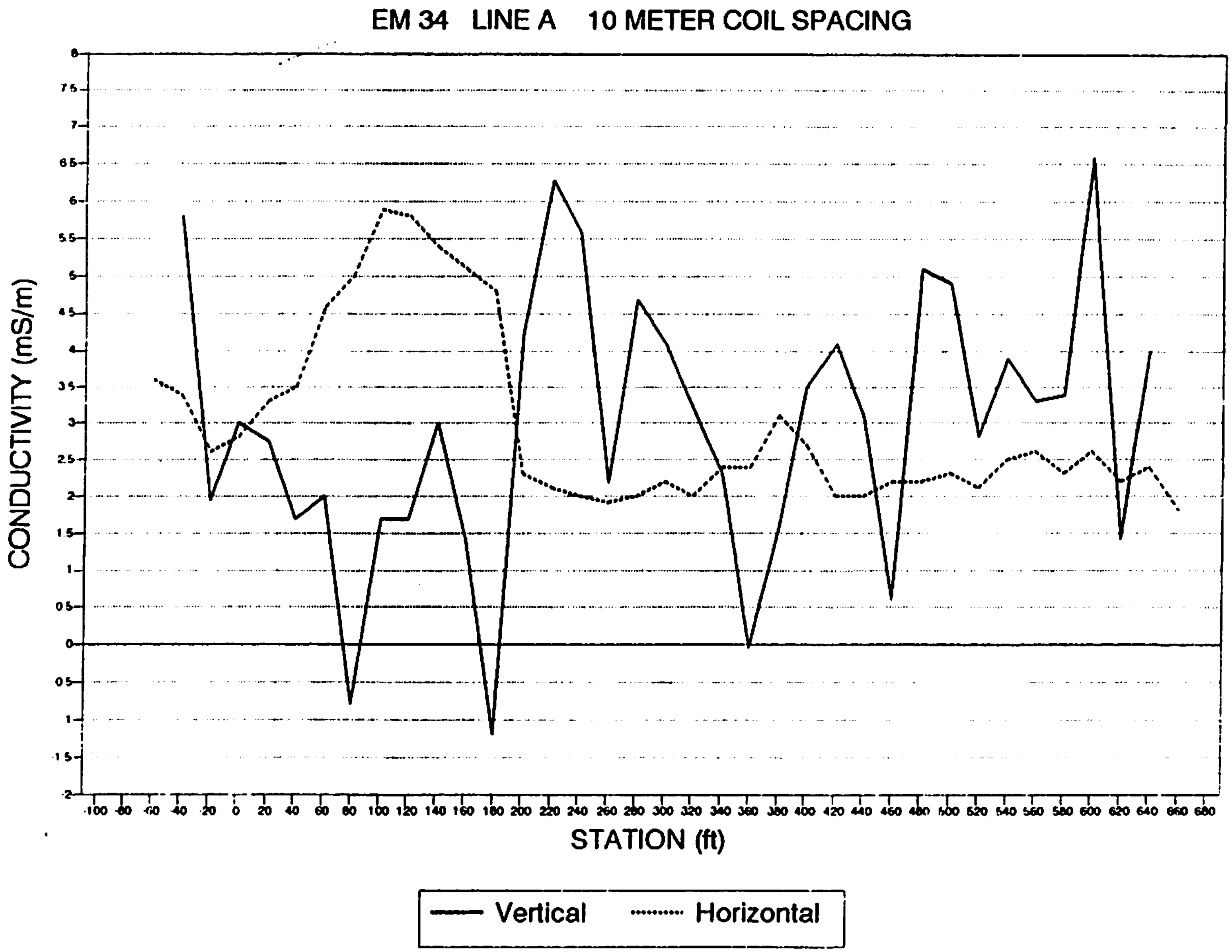


Figure A.2a - EM 34 Line A Survey: 10 Meter Coil Spacing

EM GEOPHYSICAL SURVEY DATA

Technical specification

Primary field	Magnetic components of the EM field emanating from an already-existing VLF transmitter.
Measured parameters	Vertical and horizontal in-phase and out-of-phase components.
Displayed parameter	Vertical in-phase field expressed as percentage of the horizontal field and recalculated as "current density". Alternatively, any of the 4 measured parameters can be displayed.
Station selection	Automatic (scans and tunes onto the most suitable station) or manual (station frequency entered from keyboard).
Frequency range	15-30 kHz in steps of 100 Hz.
Display	Easy-to-read LCD, 150 x 40 mm.
Languages	English/Spanish. English/French. English/German. English/Swedish. (More versions available soon).
Help key	Pressing this key together with any other key provides context-sensitive help.
Diagnostics	Four-option service menu: — Inclinometer calibration. — Change of language. — Memory test. — Internal voltages check.
Inclinometer range	—10° to +10°.
Inclinometer precision	0.2%.
Maximum sensitivity	Better than 100 nanoamp/m.
Minimum sensitivity	500 milliamp/m.
Transmitter range	The WADI can normally be used at distances ranging from 75-100 km to about 10 000 km from a powerful transmitter.
Memory capacity	Data from about 6000 measuring stations.
Data output	Via serial RS232C interface to standard dot matrix printer (PRINT F0 OR PRINT F1) or modem (SEND DATA).
Power	9 V from 6 standard D-cells, or (optionally) rechargeable cells.
Battery life	Approximately 2 weeks of field work.
Ambient temperature range	—20°C – +50°C. (Built-in heater warms display).
Net weight	Hand-held controller unit 1.6 kg Entire system 6 kg
Shipping weight	10 kg

Items to be ordered

Item	Description	Order Code	Qty	Item	Description	Order Code	Qty
1	**WADI basic system**	9133 0018 05	1		**Optional accessories**		
	Controller unit						
	Interconnect cable			2.1	Rechargeable batteries	9139 0400 23	6
	Antenna unit			2.2	Battery charger 220 V	9133 0018 45	1
	Measuring/battery unit			2.3	WADI-to-printer cable	9136 0001 58	1
	Carrying belt			2.4	Dot-matrix printer 80 c	9139 9100 04	1
	Six 1.5 V batteries						
	Two Instruction manuals						

Remember to specify your WADI's language when placing an order.

ABEM products undergo continuous development. Write or call today for the latest technical information and prices.

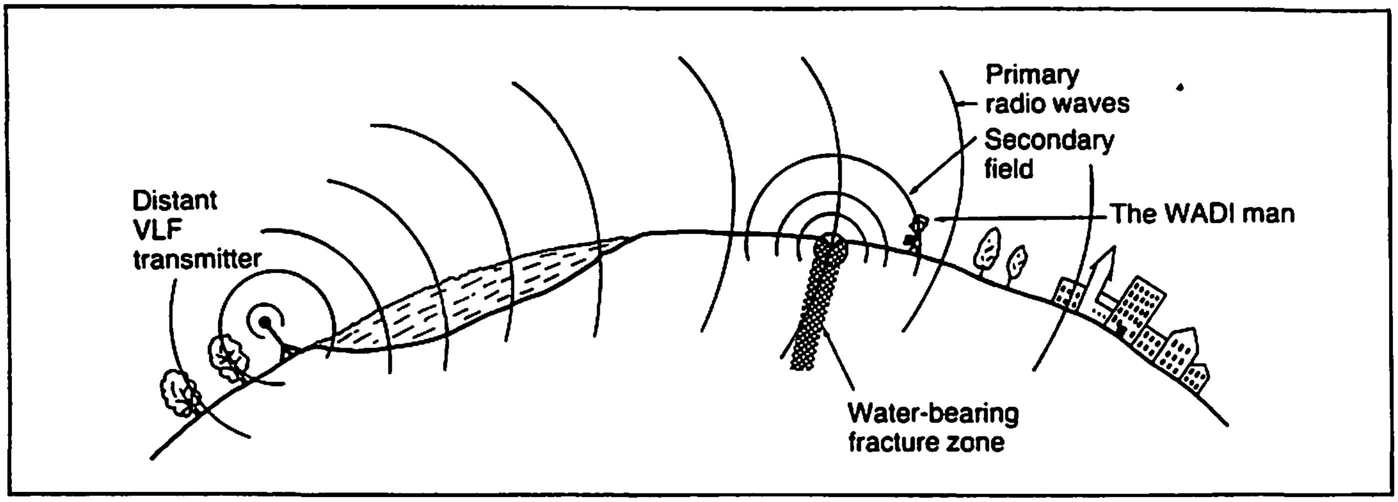
Atlas Copco

Atlas Copco ABEM AB

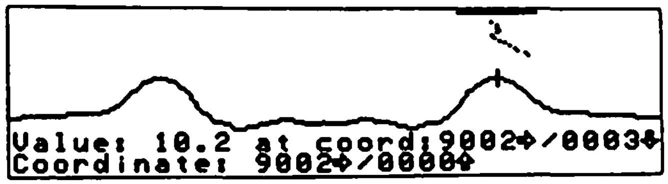
Your distributor

 SALES. SERVICE. RENTALS

THE VLF PRINCIPLE



The WADI utilizes the magnetic components of the electromagnetic field generated by already-existing radio transmitters in the VLF (Very Low Frequency) band. These transmittters are used for long-distance communication (see map), and they operate at 10-30 kHz. Conductive structures on the surface or underground, even when covered with thick overburden, affect locally the direction and strength of the field generated by the transmitted radio signal. The WADI measures the radio signal distorsion and presents the result directly on a display screen.



When the surveyor passes over a conductive structure, the WADI displays a peak on a normally straight line. By pressing a key, the WADI will indicate the depth to the conductive zone and its dip.

Some VLF Transmitters

VLF Stations that can be used with the WADI include:

	Frequency (kHz)	Power (kW)
Bordeaux, France (FUO)	15.1	500
Rugby, Great Britain (GBR)	16.0	750
Hegeland, Norway (JXZ)	16.4	350
Gorki, USSR (ROR)	17.0	315
Moscow, USSR (UMS)	17.1	1000
Yosamai, Japan (NDT)	17.4	50
Oxford, Great Britain (GBZ)	19.6	
Annapolis, USA (NSS)	21.4	400
Northwest Cape, Australia (NWC)	22.3	1000
Laulualei, Hawaii, USA (NPM)	23.4	600
Buenos Aires, Argentina (LPZ)	23.6	
Cutler, Maine, USA (NAA)	24.0	1000
Seattle, Washington, USA (NLK)	24.8	125
Aguada, Puerto Rico (NAU)	28.5	100

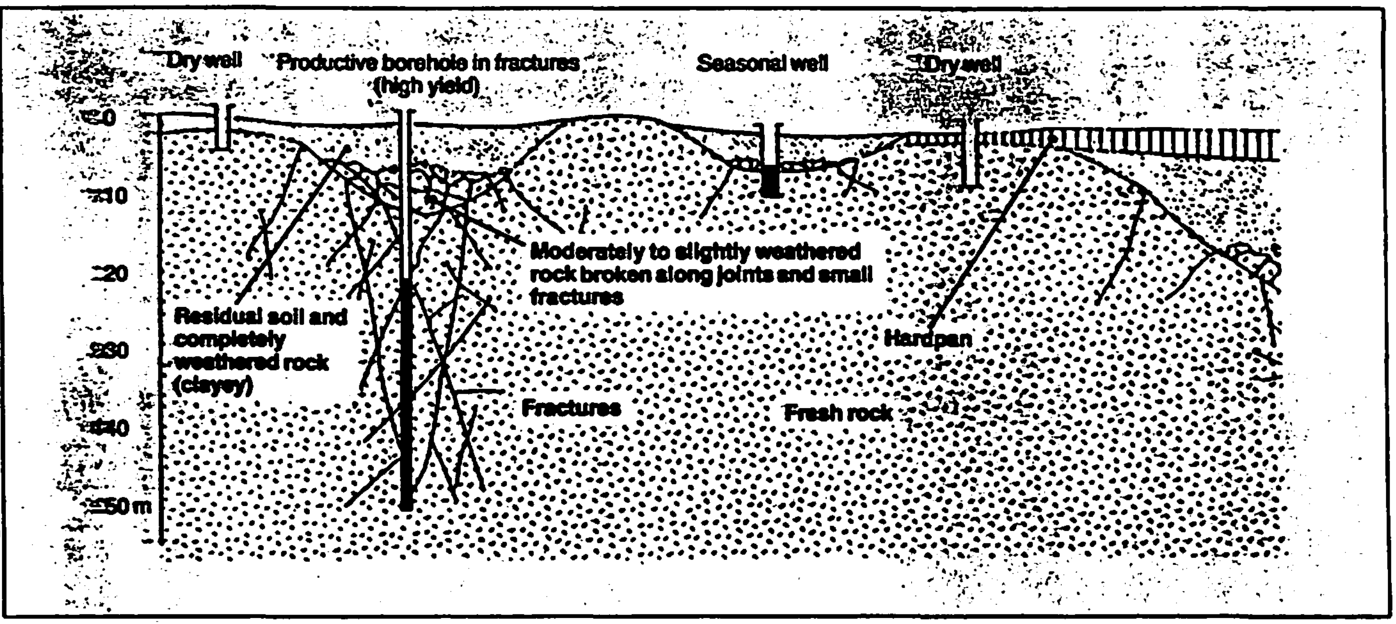
The WADI tunes in automatically on the most suitable transmitter located roughly perpendicular to your survey line. You will see the frequency on the display. If a weaker, local transmitter (not listed above) is in operation, the WADI tunes in on it since it is more suitable. It's also possible to set the WADI to a specific frequency from the keyboard.

HOW THE WADI FINDS WATER

Good drinking water can be obtained from hard rock. But drilling without previous site investigation seldom yields water in useful quantities. Effective water development programs must include carefully conducted geological and geophysical investigations. The WADI finds structures where useful quantities of underground water may be trapped in rock fractures and cavities, thus enabling drillers to select the most promising sites for their wells.

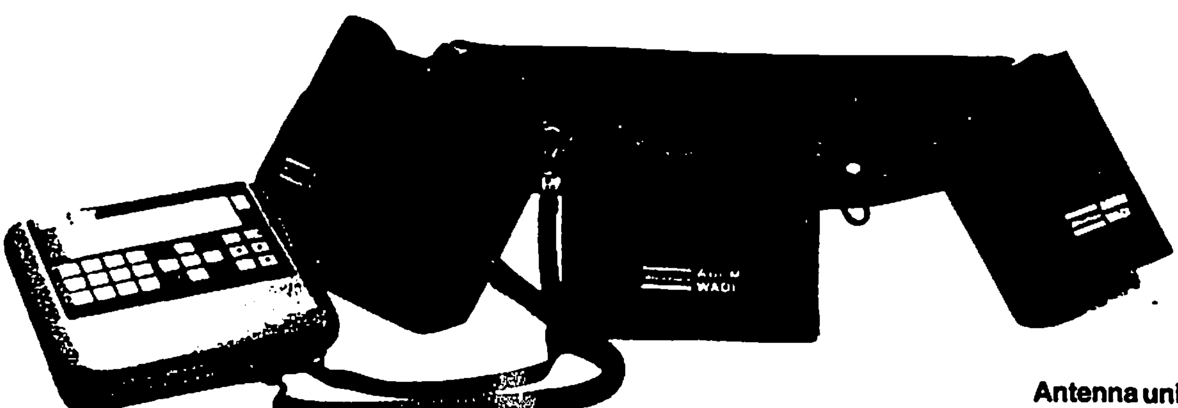
The WADI combines state-of-the-art geophysics with forked-stick simplicity. But unlike the divining rod, the WADI's results are convincingly consistent. And unlike most geophysical instruments, the WADI presents your answer on site without requiring complicated interpretation.

However, the WADI simply finds physical structures. It cannot guarantee that they contain water (such structure might comprise an orebody for example). Nonetheless, the VLF principle on which the WADI is based has an excellent track record when it comes to finding useful quantities of water in hard rock.



The WADI finds structures where water may be trapped.

THE WADI IN A NUTSHELL



Antenna unit

Hand-held controller unit (with strap-type handle)

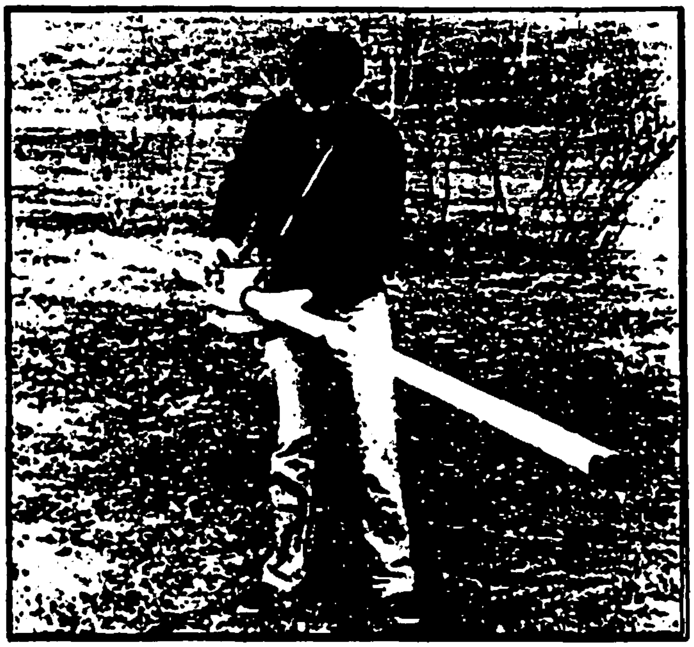
Measuring unit with battery compartment

ABEM WADI

Simple, state-of-the-art water prospecting instrument

ONE MAN

CONTINUOUS READING



EM31-D

The Geonics EM31 provides a measurement of terrain conductivity without ground electrodes or contact using a patented electromagnetic inductive technique.

This instrument is direct reading in millisiemens per meter and, over a uniform half space reads identically with conventional resistivity instruments with fixed array spacings. Using the inductive method, surveys are readily carried out in regions of high resistivity such as sand, gravel, permafrost and bedrock.

The effective depth of exploration is about six meters making it ideal for many geotechnical and ground water contaminant surveys. Other important advantages of the EM31 over conventional methods are the speed with which surveys can be conducted, the precision with which small changes in conductivity can be measured and the continuous readout while traversing the survey area. The new EM31-DL provides an analog output of both the quadrature-phase and inphase components which can be recorded continuously (on a digital or dual channel analog recorder). The inphase component is especially useful for detecting small, shallow ore bodies and, in waste site surveys buried metal drums.

Specifications

MEASURED QUANTITY	Apparent conductivity of the ground in mS/m
PRIMARY FIELD SOURCE	Self-contained dipole transmitter
SENSOR	Self-contained dipole receiver
INTERCOIL SPACING	3.66 meters
OPERATING FREQUENCY	9.8 kHz
POWER SUPPLY	8 disposable alkaline 'C' cells (approx. 20 hrs life continuous use)
CONDUCTIVITY RANGES	3, 10, 30, 100, 300, 1000 mS/m
MEASUREMENT PRECISION	±2% of full scale
MEASUREMENT ACCURACY	±5% at 20 mS/m
NOISE LEVEL	<0.1 mS/m
OPERATOR CONTROLS	● Mode Switch ● Conductivity Range Switch ● Phasing Potentiometer ● Coarse Inphase Compensation ● Fine Inphase Compensation
DIMENSIONS	Boom : 4.0 meters extended 1.4 meters stored Console : 24 x 20 x 18 cm Shipping Case : 145 x 38 x 23 cm
WEIGHT	Instrument Weight : 11 kg Shipping Weight : 26 kg

TWO MAN

VARIABLE DEPTH

EM34-3

Operating on the same principles as the EM31-DL, the EM34-3 is designed to achieve a substantially increased depth of exploration and more information about the vertical conductivity profile.

Simple operation, survey speed and straight forward data interpretation makes the EM34-3 a versatile and cost effective tool for the engineering geophysicist.

The underlying principle of operation of this patended non-contacting method of measuri... ...rain conductivity is that the depth of penetration is independent of terrain conductivity and is determined solely by the intercoil spacing and coil orientation. The EM34-3 can be us... ... three fixed spacings of 10, 20 or 40 meters and in the vertical coplanar (as shown) or horizont... ...planar modes, sensing to approx. 0.75 and 1.5 times the intercoil spacing respectively.

For surveys in regions of particularly high cultural and atmospheric noise the high powere... ...4-3XL reduces the noise at the 40m spacing by a factor of 10 and by a factor of 4 at the 10m and 20... ...cings.

Specifications

MEASURED QUANTITY	Apparent conductivity of the ground in mS/m
PRIMARY FIELD SOURCE	Self-contained dipole transmitter
SENSOR	Self-contained dipole receiver
REFERENCE CABLE	Lightweight, 2 wire shielded cable
INTERCOIL SPACING & OPERATING FREQUENCY	● 10 meters at 6.4 kHz ● 20 meters at 1.6 kHz ● 40 meters at 0.4 kHz
POWER SUPPLY	Transmitter : 8 disposable 'D' cells Receiver : 8 disposable 'C' cells
CONDUCTIVITY RANGES	3, 10, 30, 100, 300 mS/m
MEASUREMENT PRECISION	±2% of full scale deflection
MEASUREMENT ACCURACY	±5% at 20 mS/m
NOISE LEVEL	<0.2 mS/m
DIMENSIONS	Receiver Console : 19.5 x 13.5 x 26cm Transmitter Console : 15 x 8 x 26cm Coils : 63cm diameter
WEIGHTS	Receiver Console : 3.1 kg Receiver Coil : 5.6 kg Transmitter Console : 3.0 kg Transmitter Coil : 8.8 kg Shipping Weight : 43 kg

CATALOG

GEONICS LIMITED

LEADERS IN ELECTROMAGNETICS

GEOPHYSICAL
INSTRUMENTATION

GEOPHYSICAL EQUIPMENT SPECIFICATIONS

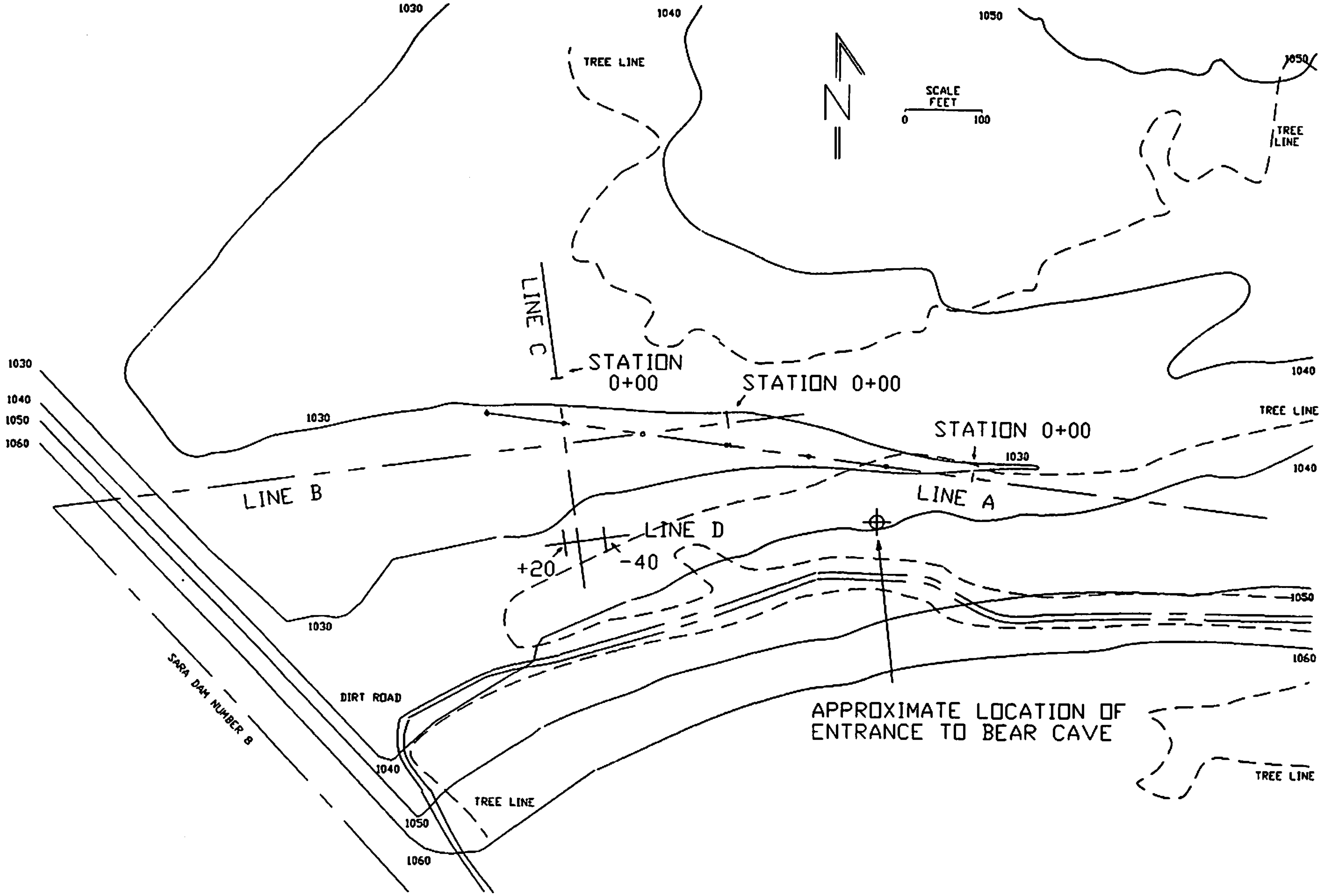


Figure A.1 Geophysical Survey Plan

seized and sheared at a depth of approximately 5 feet. The barrel was later recovered during excavation operations.

Borings B-9 and B-10 were excavated to a depth of approximately 50 feet to complete the geologic profile, to probe for the top of the Glen Rose formation and to provide locations for subsurface instruments during blast monitoring. Boring B-10 was air drilled with a 6 inch bit to provide better access for instrument installation, and no cores were recovered. Voids were encountered at a depth of approximately 30 feet in both holes. Later, as water receded from the flooded site, horizontally flowing water was observed in the voids, indicating an underground drainage system.

A.3 Down-Hole Logs

Caliper and Gamma logs were taken by EUWD staff to reinforce the results of the geophysics and boring programs. Of particular interest are the pronounced voids and gamma log anomalies at approximately 30 feet below the ground surface in borings B-9 and B-10, which are associated with lateral ground-water flow at this depth. Shallow gamma log signatures are similar for all the borings, with a peak at a depth of approximately 15 feet, reflecting the horizontal continuity of the geologic strata.

area. This observation was later confirmed during site clearing and construction activities.

The EM devices, which induce and then measure the amplitude of current eddies in the ground, produced more positive results. The amplitude of induced current eddies is determined by the distribution of conductivity in the ground, and thus is indicative of the presence and extent of highly-conductive clay seams. The clay seams, in turn, are often associated with sink holes and/or caves. The conductivity profile for line A (Figure A.2a) clearly shows an increase in amplitude in the vecinity of Cub Cave. Another anomaly at the southwest end of the line is associated with near-surface clay seams which caused the loss of the drilling subcontractor's core bit in boring B-3, as described in the following section. This same anomaly is reflected more strongly by the readings at the southwest end of line B. High conductivities were also measured at the intersections of lines C and D, where clay-filled caverns were later discovered in boring B-8 and during drilling and blasting operations along this line.

A.2 Borings

A total of ten borings were excavated to depths ranging from 5 to 50 feet (See boring logs and Figure A.3). Initially, shallow borings 2 1/2 inches in diameter were taken over a wide area to determine the nature of the bedrock to a depth of 15 feet. Continuous cores were recovered and stored for later analysis. The rock strata were continuous horizontally, however the degree of weathering varied from one location to another. Hard layers of crystaline limestone alternating with seams of red clay and clay-gravel mix. Numerous crystal-filled vugs and solution channels reflected the effects of water percolating through the limestone. Thicker and more numerous stiff clay seams were encountered in borings B-8 and in boring B-3, where the core barrel

Geotechnical Site Investigation

The subsurface conditions at the site were investigated in detail to provide information for selection of test blast locations and to test the accuracy of state-of-the-art subsurface exploration techniques. A flat area with few trees was initially selected for ease of access and operation of heavy equipment. Preliminary geophysical surveys were conducted to confirm the subsurface continuity of the relatively uniform geologic conditions encountered on the surface. Shallow borings were taken at key locations to test the accuracy of the geophysical surveys and obtain direct measurements of rock quality (RQD, hardness, etc.). Finally caliper and gamma logs were taken in the boreholes to confirm the location of voids and measure rock characteristics associated with specific strata in situ. The quality of predictions of subsurface conditions was later confirmed by direct observation of rock conditions during the blasting and excavation operations.

A.1 Geophysical Surveys

The main base line ("Line A, Figure A.1) was laid out along the axis of the stream bed that appeared initially to be the most likely location for the blasting operations. Geophysical profiles were recorded along line A and subsequently along lines B, C and D which were laid out as the surveys progressed. Data was recorded on Geonics EM-31, EM-34 terrain conductivity meters and an ABEM Wadi VLF (very low frequency) receiver (see enclosed product literature).

The Wadi data fluctuated considerably along each of the lines, but no clear trend in the data was detected. This instrument is most sensitive to vertical discontinuities such as clay-filled faults, and the lack of major anomalies indicated that no major displacements were present in the immediate

APPENDIX A

GEOTECHNICAL SITE INVESTIGATION

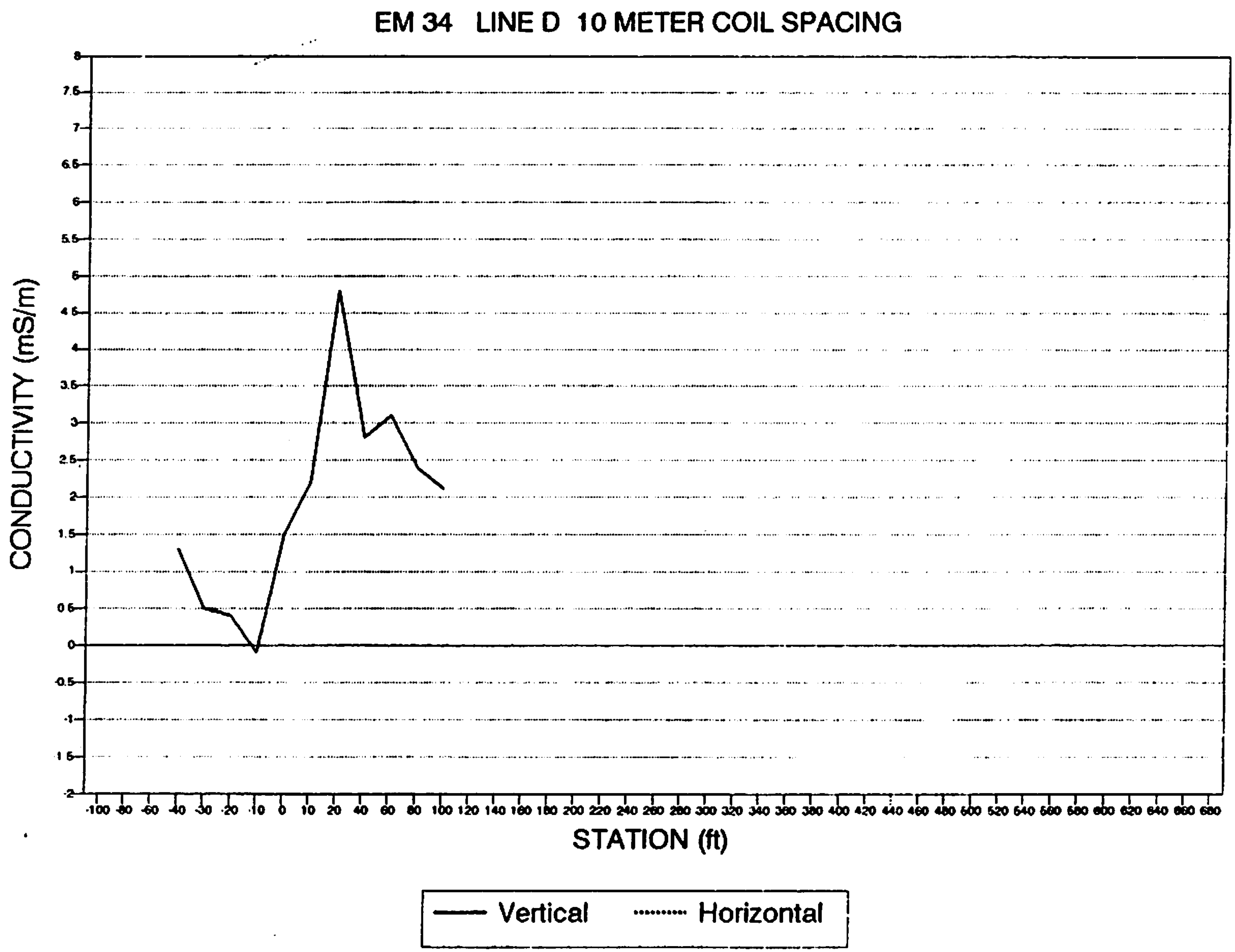


Figure A.2j - EM 34 Line D Survey: 10 Meter Coil Spacing

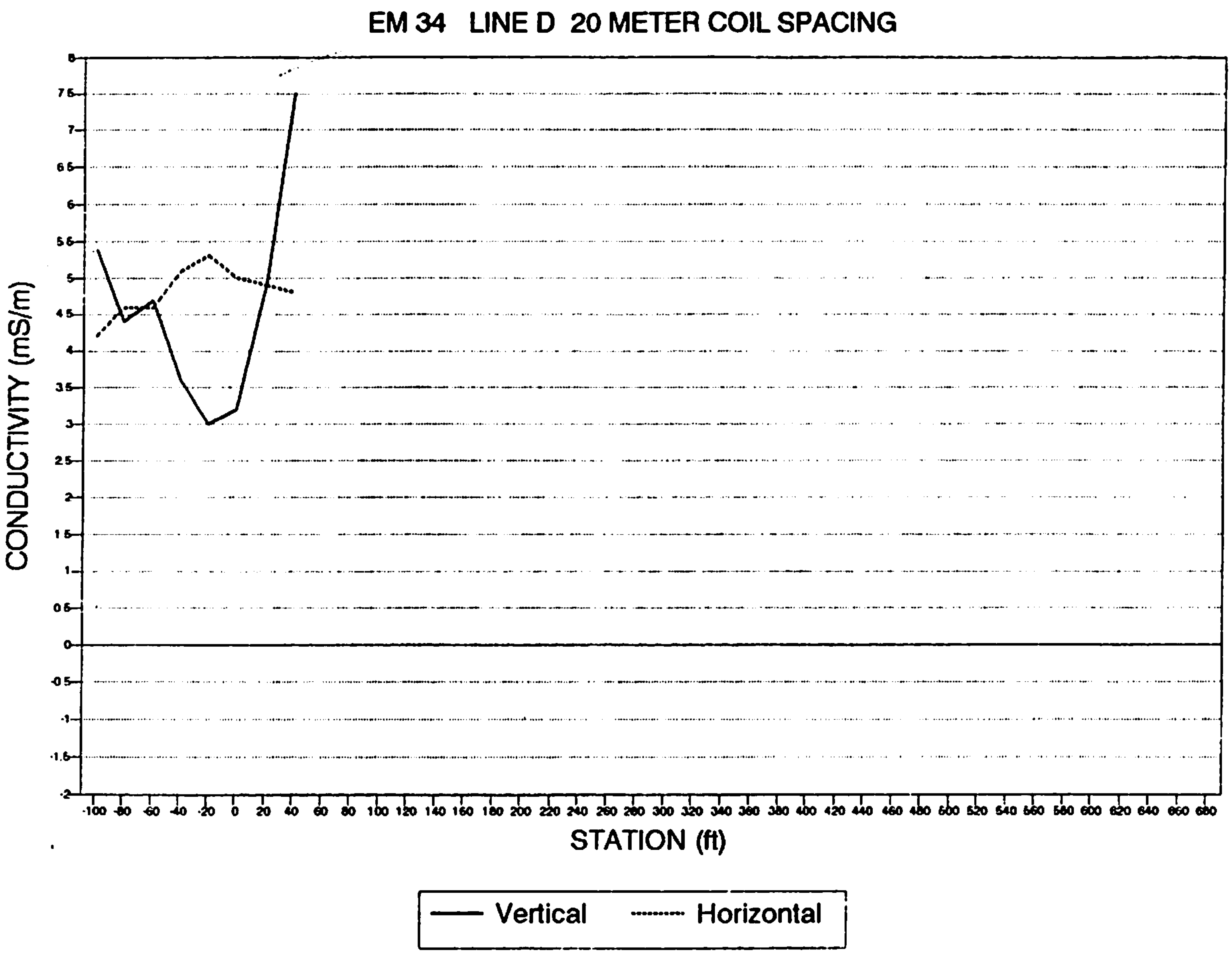


Figure A.2k - EM 34 Line D Survey: 20 Meter Coil Spacing

BORING LOGS

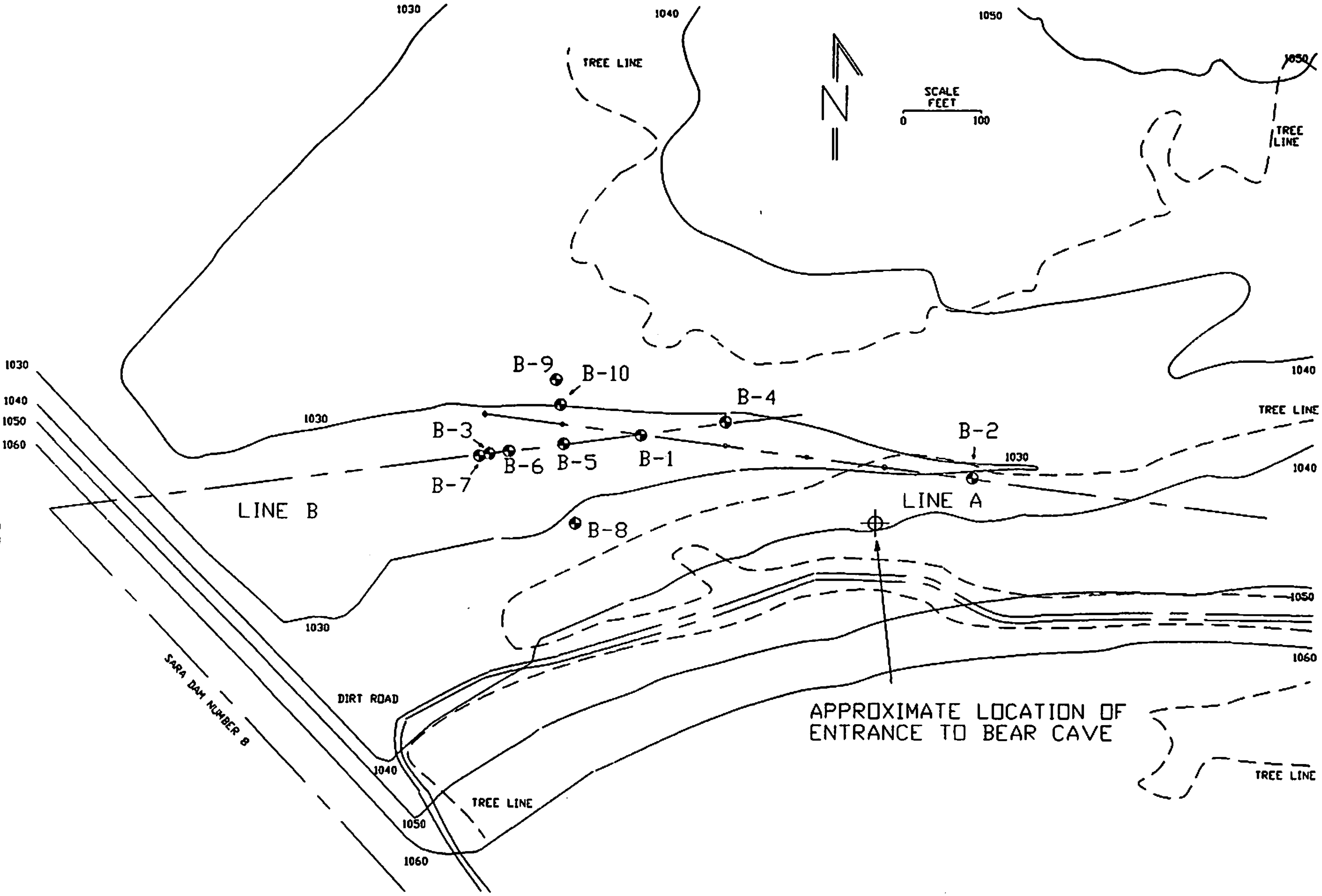


Figure A.3 Boring Location Plan

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-1

SURFACE ELEVATION 1026 FT | SHEET 1 OF 2

NOTES
ROTARY DRILLER CME55, 2½ INCH CORE BARREL
DRILLER - DAN COSTILLO
GEOLOGIST - MICHAEL HOLDSWORTH

RUN #/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①							HARD, DENSE LIMESTONE WITH RECRYST-	
					0		ALIZATION IN VUGS, LOW POROSITY	
				0.8			EXCEPT IN VECINITY OF NEARLY HORO-	
				0.1			ZONTAL FLOW CHANNELS	SOLUTION?
				0.6	1.0		LIMONITIC, SIDERITIC SECONDARY	
							DEPOSITIONS IN VUGS	
					2.0			
				1.5				
				0.4	3.0		VOID (?)	
				0.75	4.0			
4.85	(100)	90%						
②	4.85			0.15' 0.1'				
				0.4' 0.32'	5.0			
							(RED CLAY IN VOID)	
					6.0			
				1.45'				
					7.0		LOST H20 @ ≃ 7.0 FT (≃30 GAL LOSS)	
							BIT DROPPED 4". BROUGHT WATER TRUCK	
				0.18'			RESUMED DRILLING, LOSS ≃5 TO 10 GAL/	
					8.0		MIN; REDDISH COLORED RETURN FLOW,	
				0.97'			THEN WHITE	
				0.38'	9.0		LIMESTONE	
				0.70'				
	5.1	73%			10.0			
10.3'	(93)			0.22' 0.06'				
③							(VUG)	
				1.25'	11.0			

FIELD BORING LOG (ROCK)

UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-1

SURFACE ELEVATION | SHEET 2 OF 2

NOTES
ROTARY DRILLER CME55, 2½ INCH CORE BARREL
DRILLER - DAN COSTILLO
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
					11.0			
							RED CLAY IN SEAM	
				0.45'				
				0.2'	12.0			
				0.25'			LIMESTONE	
				0.19'				
				0.80'	13.0		2" DROP IN BIT AT 13 FT, WATER LOSS	
							VUGS, NO CLAY	
				1.7'	14.0			
	(100)							
15.1	4.8	88%			15.0			
							B.O.H. = 15.1 FT	

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS PROJECT Nº 59- BORING B-2

SURFACE ELEVATION 1030 FT SHEET 1 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN COSTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN Ⓝ/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①							HARD DENSE LIMESTONE	
				(.06)	0		LOW POROSITY WITH EXCEPTION OF VERY	
				.48			VUGULAR ZONE FROM ½' TO 1 3/4', RED-	
				.78			BROWN CLAY IN VOID @ 2.85'	
					1.0		VUGGY, 2"DROP	
				.38			WATER FLOWING TO SURFACE 1½'	
				1.15	2.0		FROM CORE HOLE	
				(.2)			RED CLAY AND GRAVEL	
				(.2)	3.0			
				(.25)			4" DROP	
				(.15)	4.0			
	(92)			.6				
4.8	4.4	71	TOTAL	3.39	5.0			
②				(.21)				
				(.27)				
				(.10)	6.0			
				(.13) (.10)				
				.38	7.0			
				(.17)			VUGGY IN THIS INTERVAL WITH SOME	
				1.8			RECRYSTALIZATION & REPLACEMENT	
				(.16)	8.0		(4" DROP) WITH SIDERITIC MINERALS	
				.4				
				.7	9.0			
	(98)							
9.7	4.8	67	TOTAL	3.28				
③				(.16')	10.0			
				1.17	11.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS

PROJECT Nº

BORING B-2

SURFACE ELEVATION

SHEET 2 OF 2

NOTES
ROTARY DRILLER CME55, 2½ INCH CORE BARREL
DRILLER - DAN COSTILLO
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
(3)								
					11.0			
				.9			LIMESTONE WITH RECRYSTALIZATION	
				(.17)			VUGS; LIMONITIC	
				(.2)	12.0			
				1.22				
				.47	13.0			
				.45				
				.33				
	(100)		TOTAL	4.54	14.0			
14.7	5.0	91					B.O.H= 14.7'	
					15.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS	PROJECT Nº	BORING B-3
	SURFACE ELEVATION 1026 FT	SHEET 1 OF 2

NOTES
ROTARY DRILLER CME55, 2½"CORE BARREL
DRILLER - DAN COSTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN ⓝ/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①								
					0		0.0-2.0' SOILS DRILLED BY 8" AUGER	
							AND CONDUCTOR CASING SET PRIMARILY	
					1.0		CLAY; LIMESTONE WEATHERING PRODUCTS	
							LIMESTONE: DENSE, HARD, RECRYSTAL-	
					2.0		IZED VUGS.	
							PALEO SOIL "TERRA ROSA" CLAYEY,	
				(.31)			RED, SOME LENSES OF DETRITUS	
				.42	3.0			
				(.17)				
				(.32)	4.0		2" DROP	
				(.23)				
4.9	50	90.0		.72	5.0		CORE BARREL SEIZED IN HOLE	
				.33			(5 FT TO 8 FT - TERRA ROSA)	
②								
				.87	6.0			
				(.25)				
			TOTAL	2.34	7.0			
					8.0		B.O.H. = 8.0 FT	
					9.0			
					10.0			
					11.0			

BORING Nº 3
PAGE

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-4

SURFACE ELEVATION 1026FT | SHEET 1 OF 2

NOTES
ROTARY DRILLER CME55, 2½" CORE BARREL
DRILLER - DAN COSTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①							
					0	0.0 - 0.6'	
				(.15)		LIMESTONE, VERY FRACTURED, VERT. & HORIZ.	
				(.30) (.25)		0.6'-2.3' (WELL DEFINED CONTACT @0.6')	
					1.0	VERY WEATHERED, CLAYEY, NO RECOVERY	
				(1.7		IN THIS INTERVAL, WASHED OUT "GRITTY" BUFF-TAN	
				GONE)	2.0	2.3 - 3.2	
				(.25)		LIMESTONE, VUGULAR, W/RECRYSTALIZATION	
				(.14)		IN VUGS, SOME RED STAINING ($FeCO_2$)?	RESIDUAL PALEO SOIL
				(.07)	3.0	2.3 - 4.96'	
				.40		LIMESTONE DENSE, SOME VERTICAL FRACT-	
				.56	4.0	URING, NO VUGS	
	(67)			1.2			
4.96	3.32	44					
②					5.0	4.96 - 6.2 LIMESTONE DENSE, HARD	
				.44			
				.79	6.0	RED CLAY @ 6.2', THIN SEAM (PINK RETURN FLOW)	
				(.27)		LIMESTONE, VUGULAR, @ 7.0' VUGS ARE	
				(.08)	7.0	LARGE, UPTO 1.5" LINED W/ CALCITE	
				.60		CRYSTALS, BY 8.3' VUGS DIMINISH,	
				(.22)		LIMESTONE IS DENSE, UNIFORM	
				1.19	8.0		
				1.4			
						HOLE TAKING WATER, PROBABLY IN 7-8'	
					9.0	ZONE	
9.7		93					
③				(.15)	10.0	LIMESTONE DENSE, VUGS FILLED BUT	
				(.09)		STILL VISIBLE	
				.94	11.0		

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-4

SURFACE ELEVATION | SHEET 2 OF 2

NOTES
ROTARY DRILLER CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO , SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN ⓝ/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
③								
					11.0			
				1.54				
				.48			VUG FILLED WITH RED CLAY AND LIME-	
				1.56	12.0		STONE, FRAGMENTS OF DETRITUS	
			TOTAL	4.76	13.0		HORIZONTAL SEAM W/ RED CLAY	
							RECRYSTALIZED VUGS FROM 14.3 TO 15.0'	
					14.0			
	4.76						VOID	
15.0	(90)	85			15.0		NO FLOW RETURN BELOW 15.0'	
④				.62				
				.50				
				1.17	16.0			
				.50				
				2.22	17.0		AT 17.0', VUGS FILLED W/ 1/8 TO 1/10 "	
							CALCITE CRYSTALS, MANY VUGS HAVE	
	(100)						RED STAINED WALLS W/ GRITTY TEXTURES	
20.0	5.01	100	TOTAL	5.01	18.0		IN GENERAL, VUGS ARE MORE ABUNDANT.	
					19.0			
							B.O.H. = 20.0 FT	
					20.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT N° | BORING B-5

SURFACE ELEVATION 1026 FT | SHEET 1 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK-HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①								
					0		LIMESTONE, DENSE, GREY VUGGY IN	
				.42			UPPER 1.5'	
				.48			RED CLAY IN LARGE VUG	
				(.28)	1.0			
				.73				
				.50	2.0			
				.83				
				1.5				
				(.07)	3.0			
				(.31)				
			TOTAL	4.46	4.0			
4.6	512	96					TERRA ROSA (RED CLAY), GRAVELLY,	
②				(.14)	5.0		SANDY	
				(.14)			VUGGY FROM 5.0' TO 6.8'	
				.64	6.0			
				.52			RED CLAY	
				.33			PINK FLOW RETURNED @ 6.5 - 9.0'	
				.85	7.0		LARGE VUGS @ 6.2 W/ RED CLAY	
				(.23)			FILLING. /@ 6.5' BREAK W/ RED CLAY	
				1.03	8.0		AND LARGE CALCITE CRYSTALS	
				(.18)			.5' VERTICAL FRACTURES AT ABOUT 7'.	
				.84				
			TOTAL	4.9	9.0			
	(98)							
101	4.9	85			10.0			
					11.0			

BORING N° 5
PAGE 1

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS PROJECT N° BORING . B-5

SURFACE ELEVATION SHEET 2 OF 2

NOTES
ROTARY DRILLER CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (N°)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
(3)								
				1.0	11.0			
				.5				
				1.4				
					12.0			
				1.33				
				(.22)			VERY LARGE VUG AT 14.2'	
				.35	13.0		CALCITE LINED	
			TOTAL	4.8	14.0			
	(94)							
15.2	4.8	90			15.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-6

SURFACE ELEVATION 1026 FT | SHEET 1 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①								
					0			
				(.16)			UNCONSOLIDATED, WASHED OUT, NO REC-	
				(.09)			OVERY IN THIS INTERVAL, LOST CIRCUL-	
				.62	1.0		ATION FOR 0.5'	
				.58			LIMESTONE, DENSE, LIGHT GREY, FEW	
				2.11	2.0		VUGS	
				.42				
					3.0			
					4.0			
	(81)						CLAYEY, SAND SIZE LIMESTONE PART-	
4.9	3.98	76					ICLES, FAIRLY WELL CEMENTED	
②				(.27)	5.0			
				(.25)				
				(.29)	6.0			
				(.30)			RED CLAY, LOST WATER RETURN AT 6.5	
				(.30)			TO 7.0'. WATER FLOWED TO SURFACE	
				(.23)	7.0		FROM MUD PIT.	
				.42				
				.63	8.0		LIMESTONE, MODERATELY VUGGY	
				1.48			SOME VUGS FILLED BUT VISIBLE	
				.61				
					9.0			
	(99)							
9.75	4.78	65						
③				.82	10.0		LIMESTONE AS ABOVE	
				.70				
				.40	11.0			
				1.23				

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-6

SURFACE ELEVATION | SHEET 2 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (B)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
					11.0			
				(.25)				
				.46				
				1.0	12.0			
					13.0			
	(94)						13.5': LOST RETURN FLOW COMPLETELY	
149	186	90					IN THIS ZONE, VERY VUGGY W/ SOME	
					14.0		RECRYSTALIZATION	
					15.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS PROJECT Nº

BORING B-7

SURFACE ELEVATION 1026 FT

SHEET 1 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO
ENGINEER - DAVID LELAND

RUN (#) / END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
							NOTE: AIR DRILLED 0 TO 8.09 FT.	
					0			
							(0 FT TO 5 FT, SAME AS BORING #3)	
					1.0			
					2.0			
					3.0			
					4.0			
					5.0		5 FT TO 8 FT - TERRA ROSA	
					6.0			
					7.0			
①					8.0			
							LIMESTONE: HARD DENSE, MICRO CRYSTALLINE, NO OPEN VUGS.	
					9.0			
				.65				
				1.1	10.0			
10.4	(100)	(100)		.66				
②			TOTAL	2.41	11.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-7

SURFACE ELEVATION | SHEET 2 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO
ENGINEER - DAVID LELAND

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
(2)							
					11.0		
				.70			
				.43			
				.42	12.0		
				(.20)			
				.39	13.0	LIMESTONE AS ABOVE	
				1.39			
				1.50		AT 13.7', BEGAN TAKING WATER	
				(.17)	14.0		
			TOTAL	5.2		LIMESTONE, VUGGY, FROM 13.7' DOWN-	
15.7	100	93			15.0	WARD. REMINERALIZED VUG FILLINGS,	
						DECAYED LIMESTONE, SOME CALCITE	

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS PROJECT Nº 8 BORING B-8

SURFACE ELEVATION SHEET 1 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
ENGINEER - DAVID LELAND

RUN (#) / END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
(1)								
					0		SMALL ROCK FRAGMENTS (2").	
							VOID	
							LIMESTONE WITH SECONDARY DEPOSITION	
					1.0		IN VOIDS, NUMEROUS SMALL VOIDS,	
							RED SILTY CLAY (TERRA ROSA)	
					2.0			
							LIMESTONE W/ VOIDS	
							LIMESTONE FRAGMENTS LOSING WATER,	
					3.0		(VOID?), WATER RETURNING TO SURFACE	
							THROUGH CRACKS.	
					4.0		LIMESTONE COMPETENT FOR ABOUT 11.0" THEN LG. VOIDS W/ SM. CRYSTALS & RED STAIN.	
	2.9						LOSING WATER DOWN HOLE;CLAY (TERRA ROSA)	
5.0	(58)	48					LIMESTONE W/ VOIDS, SECONDARY DEPOSITION	
(2)					5.0		LIMESTONE POROUS, SM. VOIDS, TERRA ROSA STAIN	
							VOID?	
					6.0		LIMESTONE; COMPETENT	
							LIMESTONE W/ CRYSTAL-FILLED VOID	
					7.0		VOID?	
							LIMESTONE; COMPETENT	
					8.0			
	4.6				9.0		LIMESTONE, POROUS, W/ CRYSTAL FILL-	
9.6	(100)	96					ED VOIDS	
(3)					10.0		LIMESTONE WITH VOIDS (SMALL TO MED)	
							W/ TERRA ROSA DEPOSITS W/ SMALL	
							CRYSTALS	
					11.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-8

SURFACE ELEVATION | SHEET 2 OF 2

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO
ENGINEER - DAVID LELAND

RUN Ⓝ/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
					12.0		LIMESTONE, COMPETENT W/ SOME POROUS ZONES	
					13.0			
					14.0			
	5.8							
15.4	(100)	100			15.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-9

SURFACE ELEVATION | SHEET 1 OF 5

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN ⓝ /END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
①								
							LIMESTONE, HARD, DENSE, LT. GREY,	
				.30) .54'			MICROCRYSTALINES, VUGGY W/ RED STAIN	
				.38'			ON VUG SURFACES	
				.73'	1.0			
				.46'				
				.33'	2.0			
				.50'				
				.17'			REMINERALIZED, CLAYEY, CRUMBLY	
				.13'	3.0		NO RECOVERY OF CLAY IN THESE ZONES	
				.38'			(CALLED BY DRILLER) TAKING WATER @ 3'	
	3.92		TOTAL	3.92	4.0			
4.3	(91)	84					DECREASING VUGS IN SECOND RUN	
②								
					5.0			
				.94'			VOID @ 5.3' SEEMS TO BE TAKING WATER	
				.88'				
				1.75'	6.0			
				.48'				
				1.08'	7.0			
			TOTAL	5.13'				
					8.0			
					9.0			
9.75	(94)	94						
③				(.25)	10.0			
				(.08)				
				.97	11.0			

FIELD BORING LOG (ROCK)

UTSA - CENTER FOR WATER RESEARCH

PROJECT: UTSA CHAMPIONS | PROJECT Nº: | BORING: B-9

SURFACE ELEVATION: | SHEET 2 OF 5

NOTES:
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
					11.0			
				1.27			LIMESTONE HARD, DENSE, MICROCRYSTALS	
				.63			VERY FEW OPEN VUGS IN RUN 3	
				.46	12.0		RED CLAY	
				1.5				
			TOTAL	5.16	13.0			
14.92	(99.8)	93					AT 14.0' SUDDEN COMPLETE LOSS OF	
					14.0		WATER	
					15.0			
(4)								
				(.13)				
				1.15	16.0		(NO RETURNS OF WATER)	
				(.10)				
				1.0	17.0			
				.60				
				.88				
				.75	18.0			
				.38				
5.08				.42	19.0			
			TOTAL	4.51				
20.0	(89)	82					REMINERALIZED, SOFT, YELLOW, BOY-	
(5)					20.0		TROYDAL	
				..12				
				.12	21.0			
				.38				
				.33				
				.65	22.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-9

SURFACE ELEVATION | SHEET 3 OF 5

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
OGIST -- MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
				.88			
				(.13)	22.0	LIMESTONE HARD, DENSE, LT. GREY	
				.54		OCCASIONAL LAMINAE OF RED, VUGS UPTO	
				(.12)		1.5" LINED W/ CALCITE CRYSTALS	
				(.12)	23.0		
				(.13)			
				(.12)	24.0		
				(.14)			
				(.12)			
251				(.12)	25.0		
(6)				(.12)			
				(.12)	26.0		
	(83)	55	TOTAL	4.26			
					27.0		
				.63			
				1.0	28.0		
				.96			
				(.08)			
			TOTAL	2.67	29.0		
303	(51)	50			30.0		
(7)							
				.75			
				(.30)	31.0		
				(.19)			
				.63	32.0		
				(.17)			
				(.16)			
					33.0		

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-9

SURFACE ELEVATION | SHEET 4 OF 5

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
				(.06)	33.0			
				(.08)			LIMESTONE, HARD, DENSE, LT. GREY	
				.38			OCCASIONAL RED LAMINAS	
				.81	34.0		FOSSILIFEROUS, UNIDENTIFIED	
				.48			SHELL FRAGMENTS	
35.4				.71	35.0			
(8)				.40				
	(100)	82	TOTAL	5.12				
					36.0		LIMESTONE, HARD, DENSE, LT. GREY	
				(.13)			VUGS FILLED W/ DECAYED LIMESTONE	
				1.33	37.0		SCATTERED RED LAMINAS,	
				.33			FOSSILFEROUS	
				1.02				
				.33	38.0			
				2.06			LIMESTONE, HARD, DENSE, VERY VUGGY	
			TOTAL	5.2	39.0		FILLED W/ DECAYED LIMESTONE	
					40.0			
40.6	(100)	98						
(9)								
				.17	41.0			
				.75				
				.17	42.0			
				.66				
				.54				
				.79	43.0			
				.71				
					44.0			

FIELD BORING LOG (ROCK) UTSA - CENTER FOR WATER RESEARCH

PROJECT UTSA CHAMPIONS | PROJECT Nº | BORING B-9

SURFACE ELEVATION | SHEET 5 OF 5

NOTES
ROTARY DRILL CME55, 2½" CORE BARREL
DRILLER - DAN CASTILLO, SWL
GEOLOGIST - MICHAEL HOLDSWORTH

RUN (#)/END OF RUN, FT	RUN RECOVERY, FT (%)	RQD (%)	ROCK HARDNESS	SEGMENT RECOVERY LENGTH, FT	DEPTH-FEET	ROCK LEGEND	ROCK TEXTURE, COLOR, TYPE, WEATHERING, FRACTURE TYPE, SPACING, DIP, ETC	NOTES
				.33	44.0			
				.96				
45.8	(100)	91		.17			LIMESTONE AS ABOVE	
					45.0			
(10)								
				.17	46.0			
				.83				
				1.5				
					47.0			
				.31				
				.38				
				.29	48.0			
				.60				
				.50				
					49.0			
				.17				
			TOTAL	4.75				
50.1	(103)	88			50.0		B.O.H. AT 50.1 FT.	

GAMMA AND CALIPER DOWN-HOLE LOGS

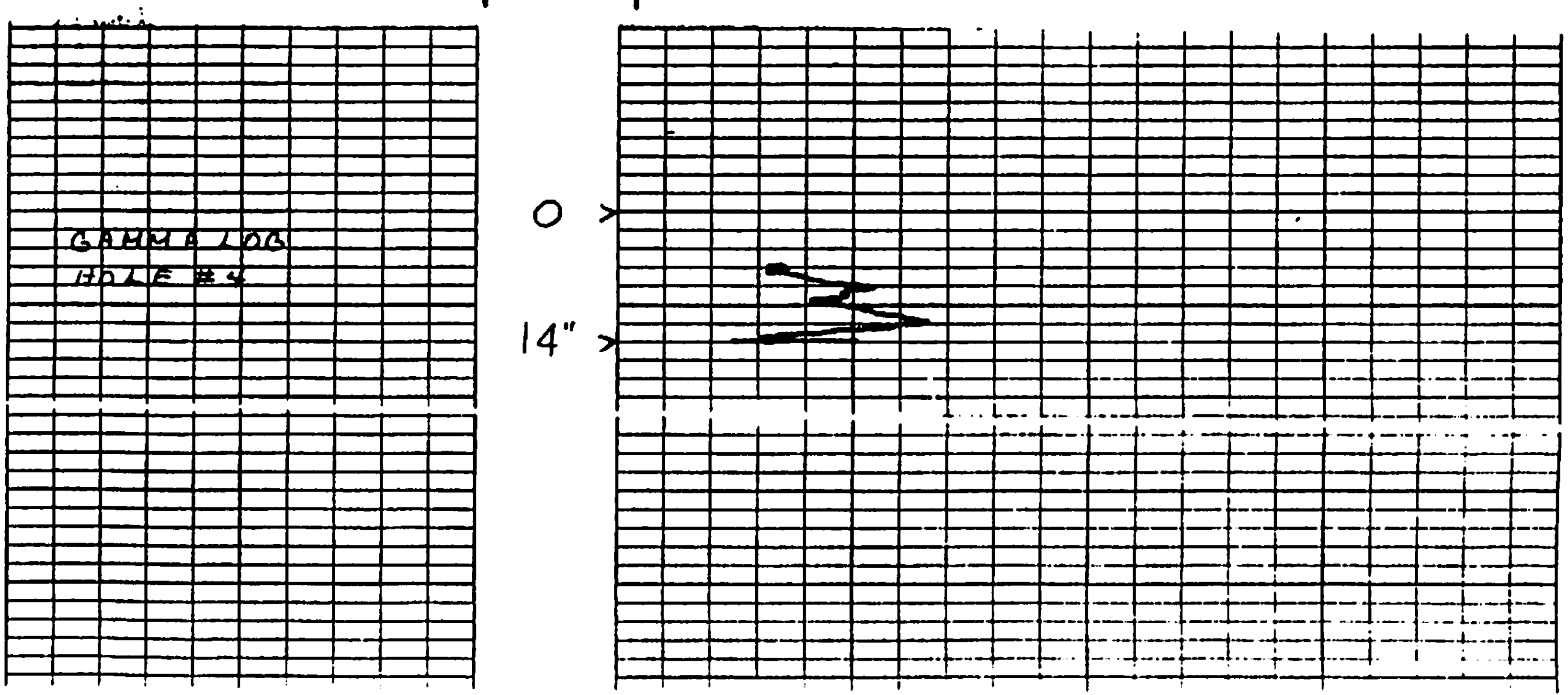
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 4 (AY-68-21) WELL DEPTH: 15.0 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY

CASING:	(1) DIA: 3.00	FROM: 0.00	TO: 15.00	(DIA=ID in INCHES)
	(2) DIA: 0.00	FROM: 0.00	TO: 0.00	(DEPTHS = FEET)
HOLE:	(1) DIA: 0.00	FROM: 0.00	TO: 0.00	
	(2) DIA: 0.00	FROM: 0.00	TO: 0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1025
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-1 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->

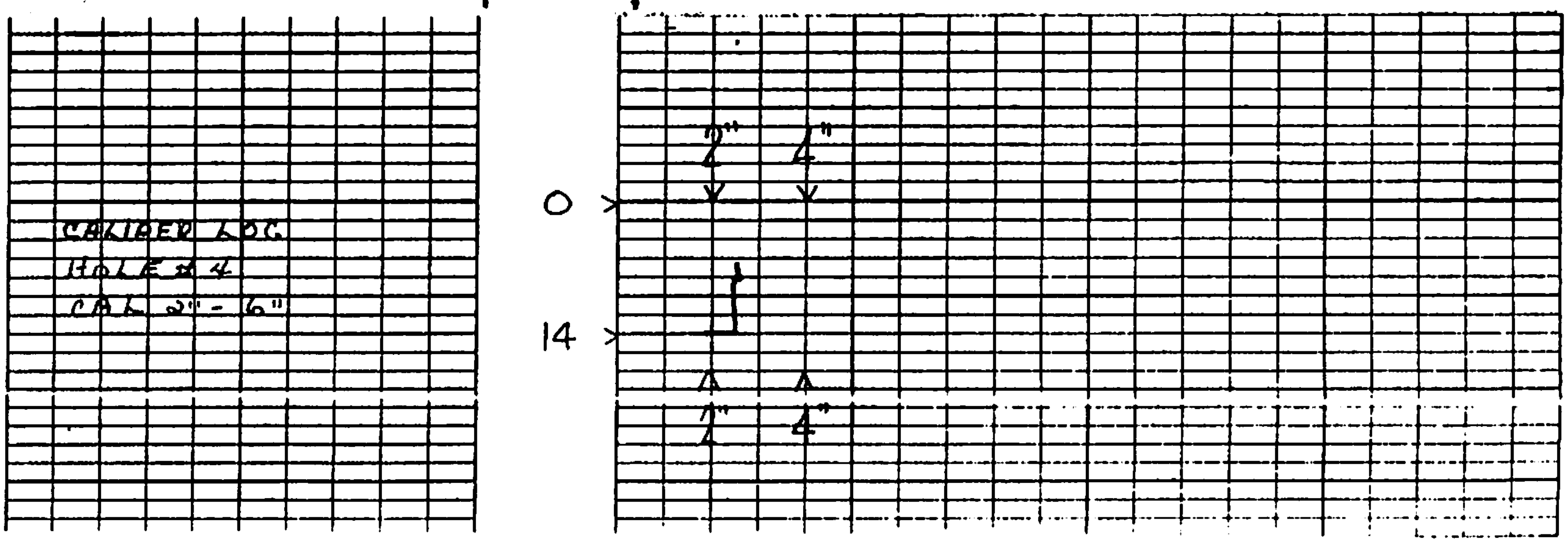


EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 4 WELL DEPTH: 15.0 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.000 FROM: 0.000 TO: 15.0 (DIA=ID in INCHES)
(2) DIA: 0.000 FROM: 0.000 TO: 0.0 (DEPTHS = FEET)
HOLE: (1) DIA: 0.000 FROM: 0.000 TO: 0.0
(2) DIA: 0.000 FROM: 0.000 TO: 0.0
LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1025
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 2" TO: 6" (INCHES)
COMMENTS: UTSA BOREHOLE # B-1 AT CHAMPIONS

DEPTH | CALIPER LOG
DIAMETER OF HOLE INCREASES-------------->

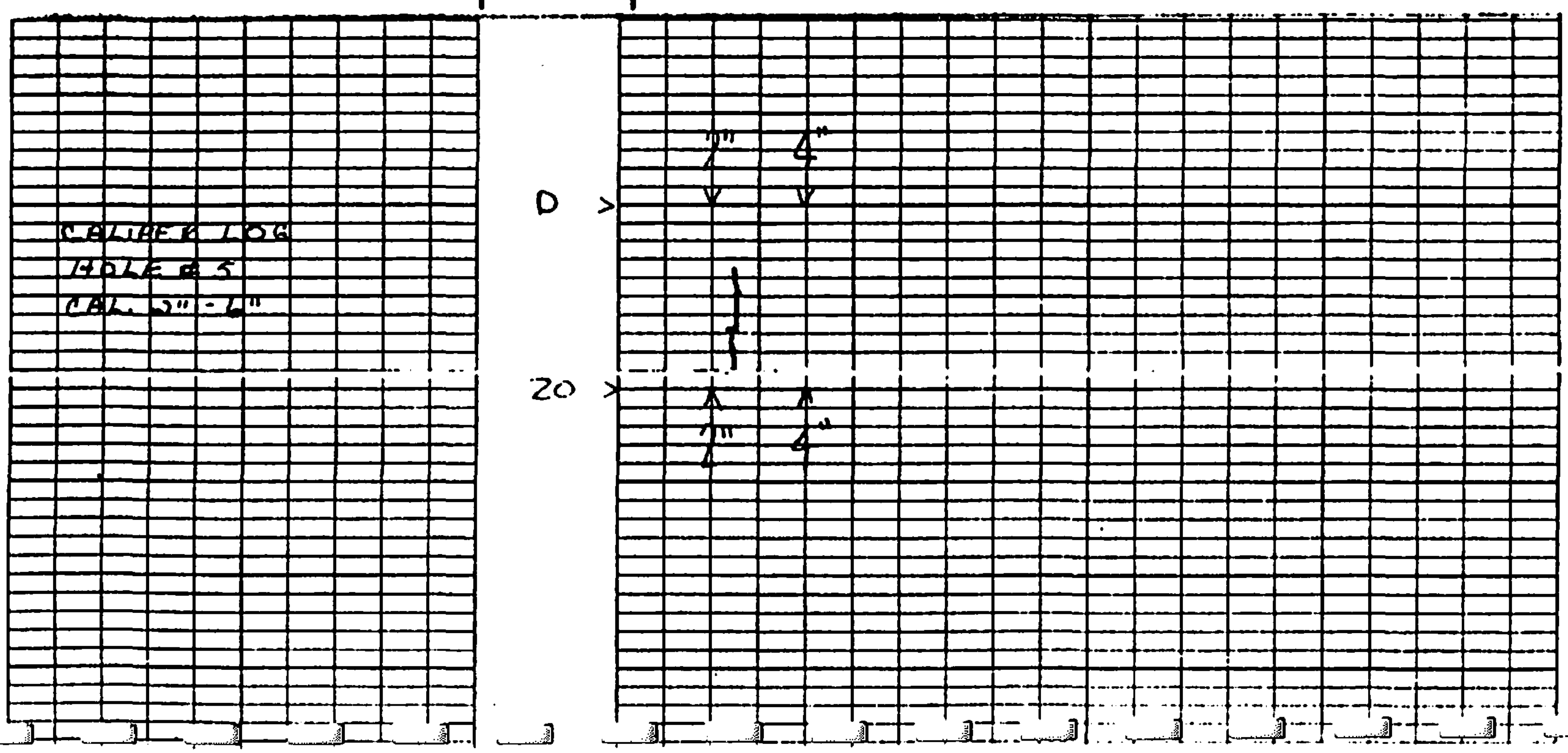


EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 5 WELL DEPTH: 20.0 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.000 FROM: 0.000 TO: 20.0 (DIA=ID in INCHES)
(2) DIA: 0.000 FROM: 0.000 TO: 0.0 (DEPTHS = FEET)
HOLE: (1) DIA: 0.000 FROM: 0.000 TO: 0.0
(2) DIA: 0.000 FROM: 0.000 TO: 0.0
LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 2" TO: 6" (INCHES)
COMMENTS: UTSA BOREHOLE # B-4 AT CHAMPIONS

DEPTH | CALIPER LOG
DIAMETER OF HOLE INCREASES---------->



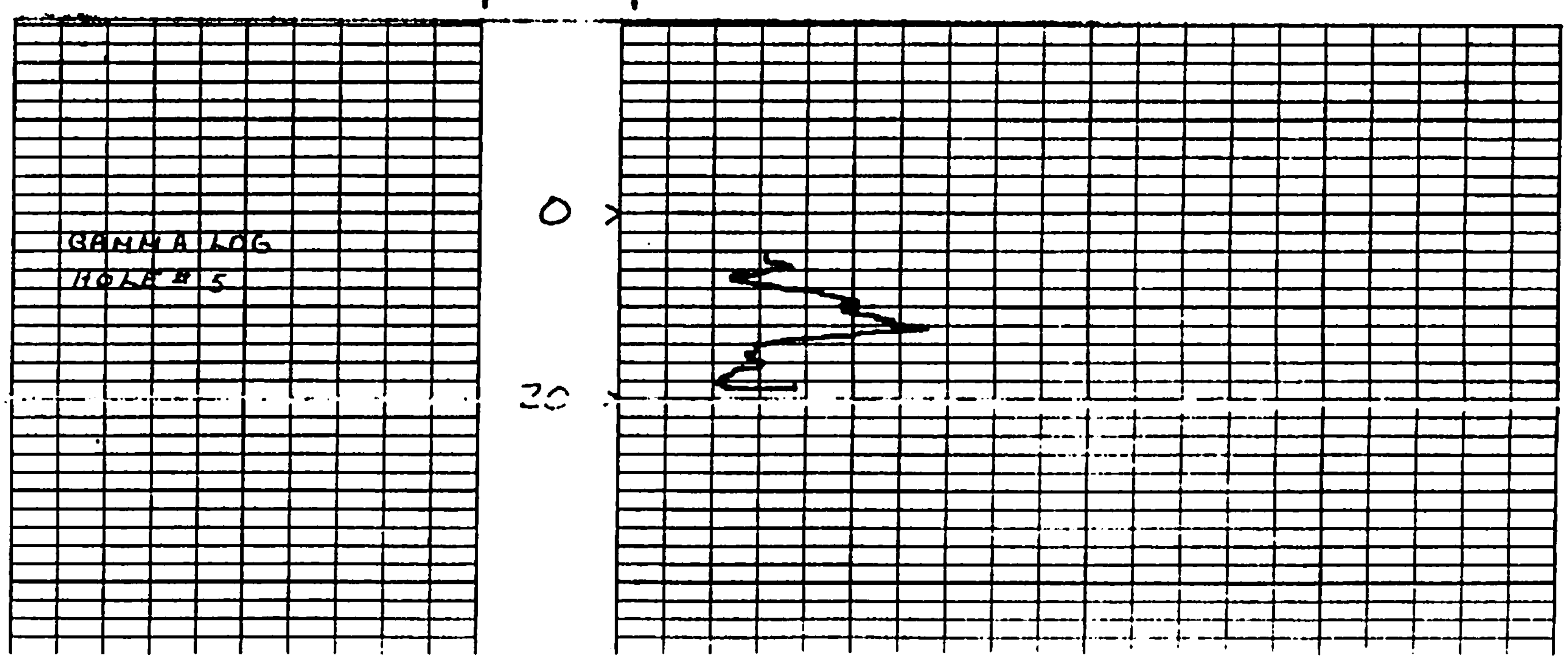
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 5 (AY-68-21) WELL DEPTH: 20.0 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY

CASING:	(1) DIA:	3.00	FROM:	0.00	TO:	20.00	(DIA=ID in INCHES)
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	(DEPTHS = FEET)
HOLE:	(1) DIA:	0.00	FROM:	0.00	TO:	0.00	
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-4 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->

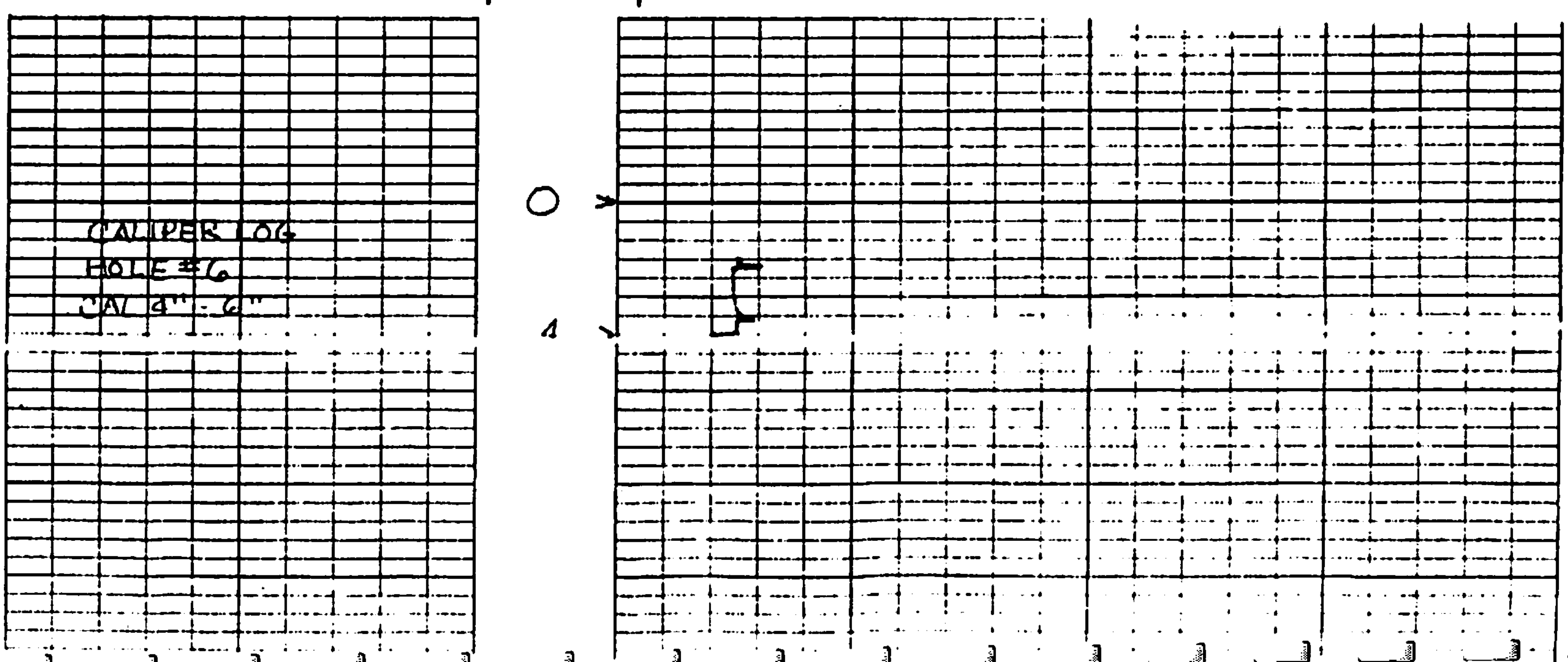


EDWARDS UNDERGROUND WATER DISTRICT

CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 6 (AY-68-21) WELL DEPTH: 15.2 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.00 FROM: 0.00 TO: 15.20 (DIA=ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE: (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1024
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
CALIPER CALIBRATED FROM: 4 TO: 8 (INCHES)
COMMENTS: UTSA BOREHOLE # B-5 AT CHAMPIONS.

DEPTH | CALIPER LOG
DIAMETER OF HOLE INCREASES---------->



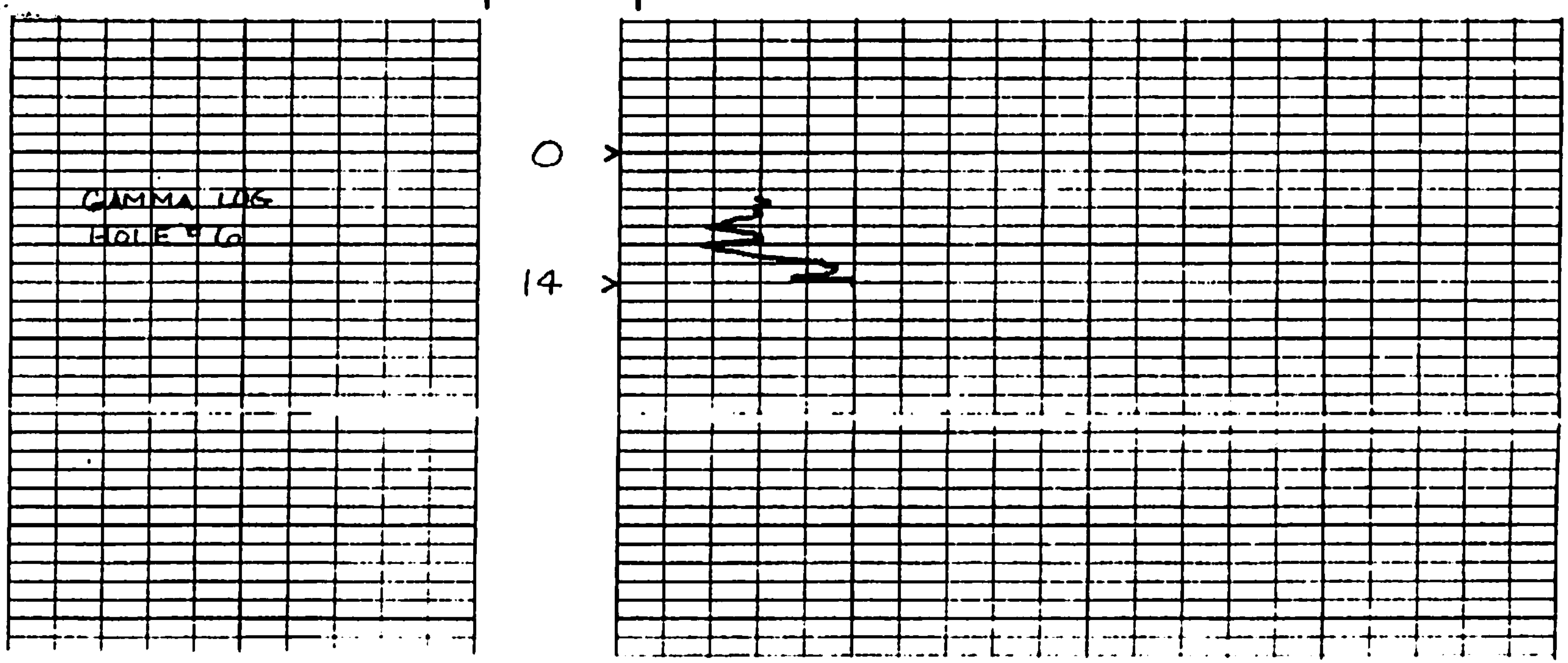
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 6 (AY-68-21)　　WELL DEPTH: 15.2　　(BELOW LSD)
LATITUTE: 29-38-54　　LONGITUDE: 98-29-51　　(D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS.　　DRILLING METHOD: MUD ROTARY

CASING:	(1) DIA:	3.00	FROM:	0.00	TO:	15.20	(DIA=ID in INCHES)
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	(DEPTHS = FEET)
HOLE:	(1) DIA:	0.00	FROM:	0.00	TO:	0.00	
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	

LOG OPERATOR: DRP　　LOG MP:　　LOG TD:　　LSD: 1024
GAMMA LOG: YES　CALIPER LOG: YES　ELECTRIC LOG: NO　　(LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN)　　VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2　　COUNTS/SECOND: 100 / 20　　(CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-5 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->



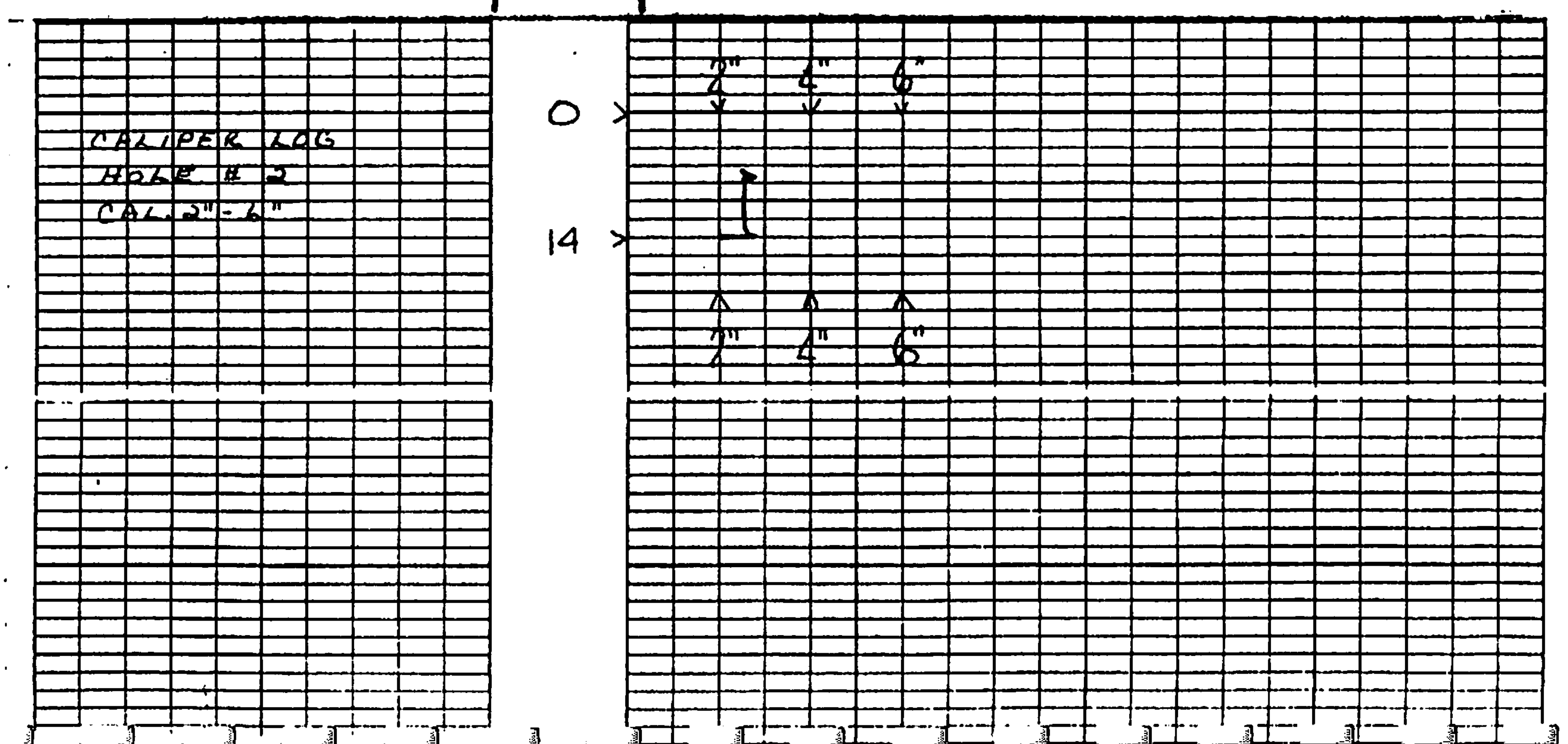
EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 2 (AY-68-21)   WELL DEPTH: 14.8   (BELOW LSD)
LATITUTE: 29-38-54   LONGITUDE: 98-29-48   (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.7 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.000   FROM: 0.000   TO: 14.8   (DIA=ID in INCHES)
(2) DIA: 0.000   FROM: 0.000   TO: 0.0   (DEPTHS = FEET)
HOLE: (1) DIA: 0.000   FROM: 0.000   TO: 0.0
(2) DIA: 0.000   FROM: 0.000   TO: 0.0
LOG OPERATOR: DRP   LOG MP: LOG TD: LSD: 1030
GAMMA LOG: YES   CALIPER LOG: YES   ELECTRIC LOG: NO   (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN)   VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 2" TO: 6" (INCHES)
COMMENTS: UTSA BOREHOLE # B-2 AT CHAMPIONS

DEPTH

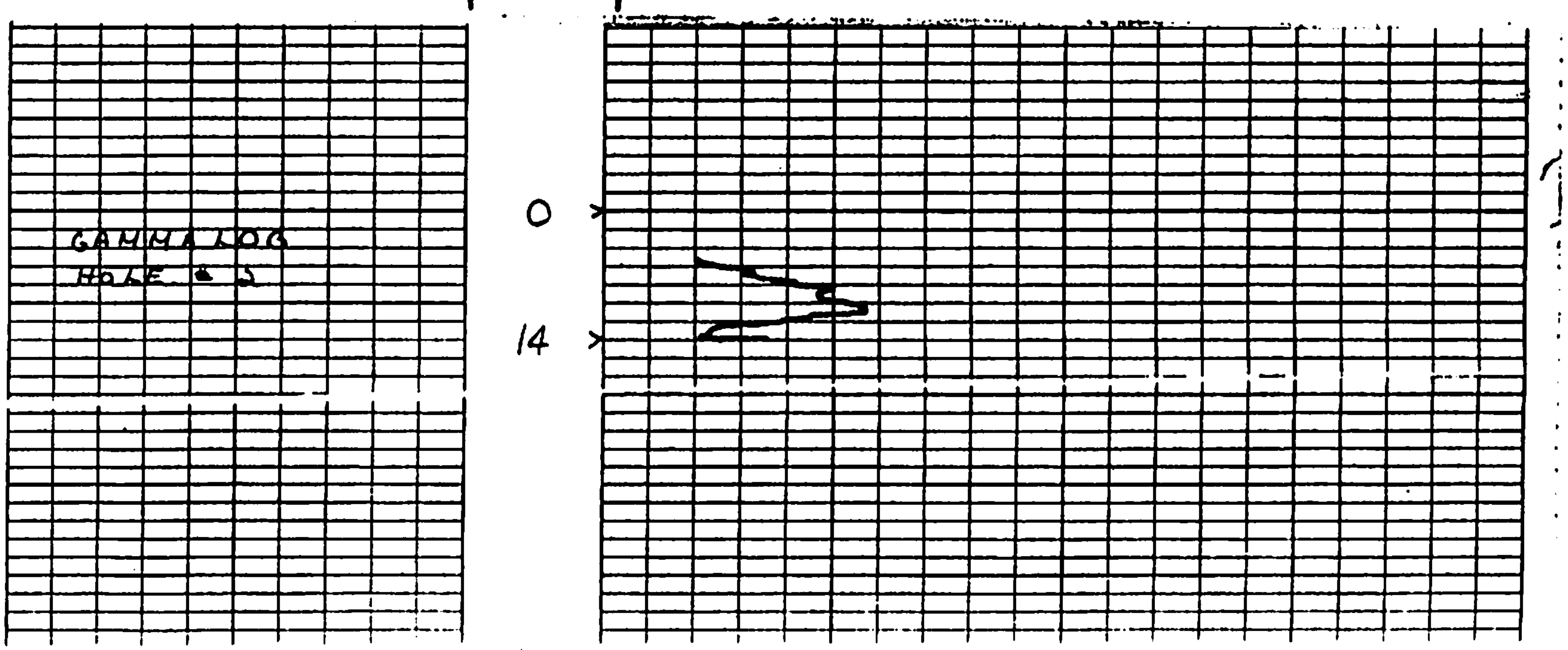
CALIPER LOG
DIAMETER OF HOLE INCREASES---------->



EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 2 (AY-68-21) WELL DEPTH: 14.8 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-48 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.70 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY
CASING: (1) DIA: 3.00 FROM: 0.00 TO: 14.80 (DIA=ID in INCHES)
(2) DIA: 0.00 FROM: 0.00 TO: 0.00 (DEPTHS = FEET)
HOLE: (1) DIA: 0.00 FROM: 0.00 TO: 0.00
(2) DIA: 0.00 FROM: 0.00 TO: 0.00
LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1030
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-2 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->



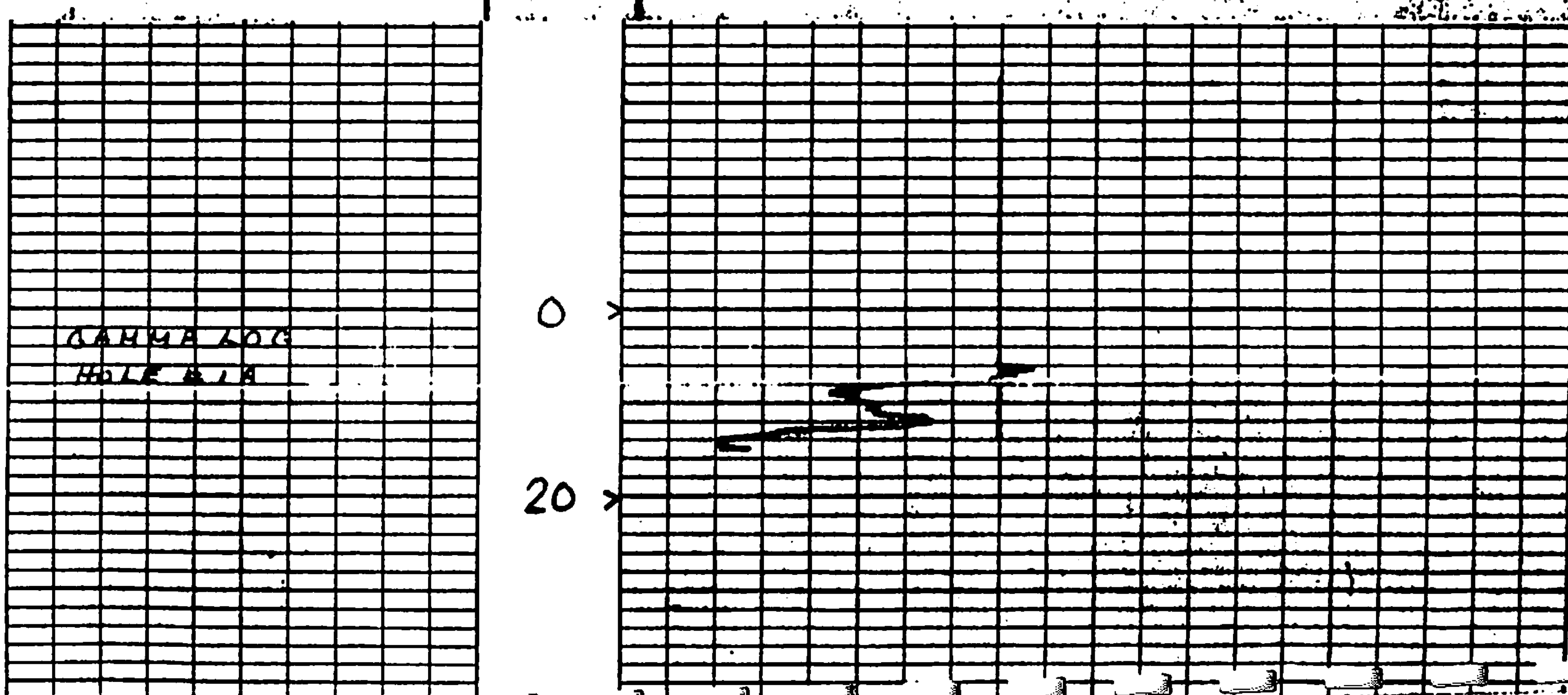
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 1 A (AY-68-21) WELL DEPTH: 15.0 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-54 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.60 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: DRILLING METHOD:

CASING:	(1)	DIA: 3.00	FROM: 0.00	TO: 15.00	(DIA=ID in INCHES)
	(2)	DIA: 0.00	FROM: 0.00	TO: 0.00	(DEPTHS = FEET)
HOLE:	(1)	DIA: 0.00	FROM: 0.00	TO: 0.00	
	(2)	DIA: 0.00	FROM: 0.00	TO: 0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-6 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->



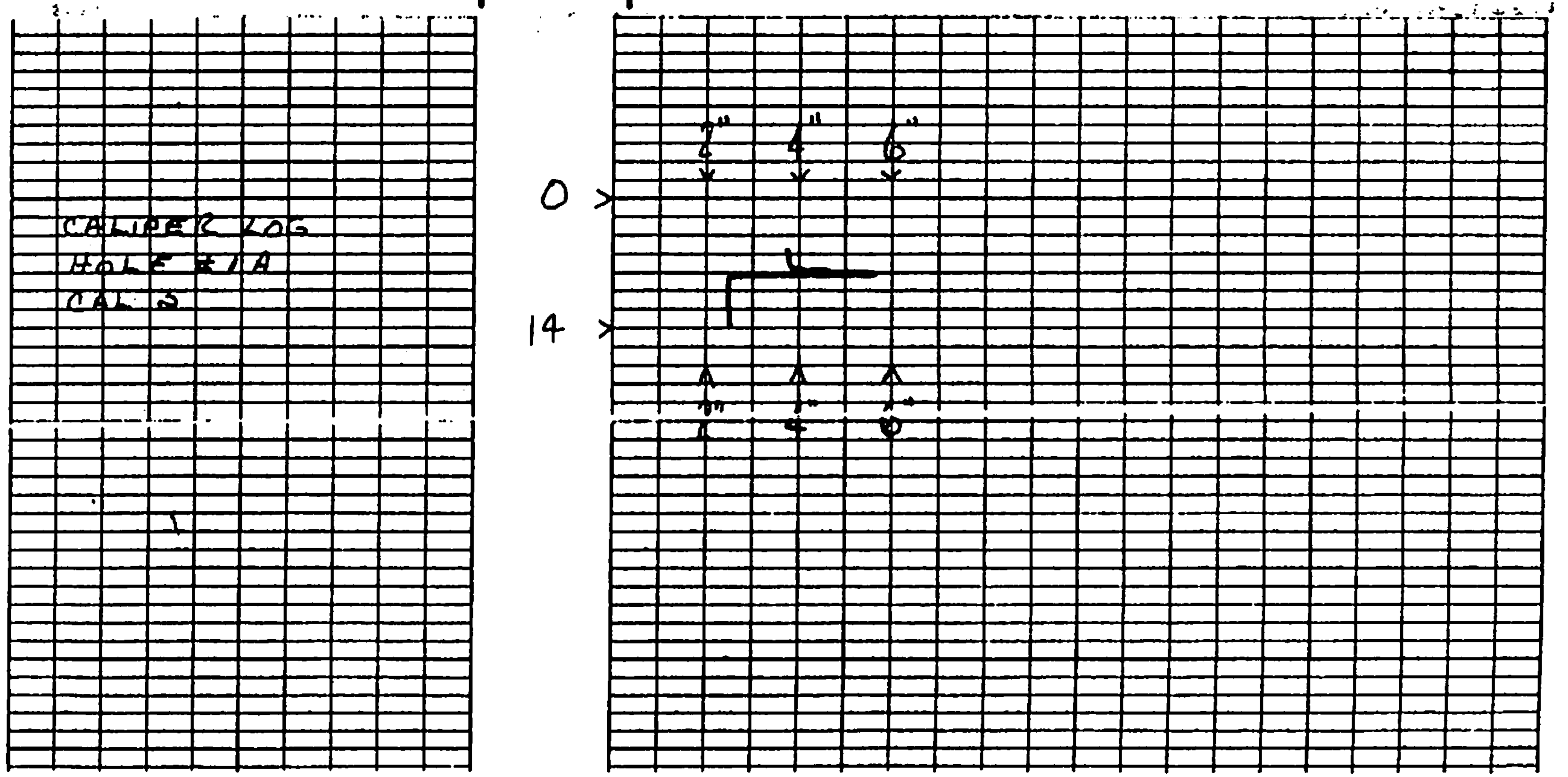
EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 1 A (AY-68-21)   WELL DEPTH: 15.0   (BELOW LSD)
LATITUTE: 29-38-54   LONGITUDE: 98-29-54   (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.6 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.000 FROM: 0.000 TO: 15.0 (DIA=ID in INCHES)
(2) DIA: 0.000 FROM: 0.000 TO: 0.0 (DEPTHS = FEET)
HOLE: (1) DIA: 0.000 FROM: 0.000 TO: 0.0
(2) DIA: 0.000 FROM: 0.000 TO: 0.0
LOG OPERATOR: DRP   LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO   (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN)   VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 2" TO: 6" (INCHES)
COMMENTS: UTSA BOREHOLE # B-6 AT CHAMPIONS

DEPTH

CALIPER LOG
DIAMETER OF HOLE INCREASES ------>



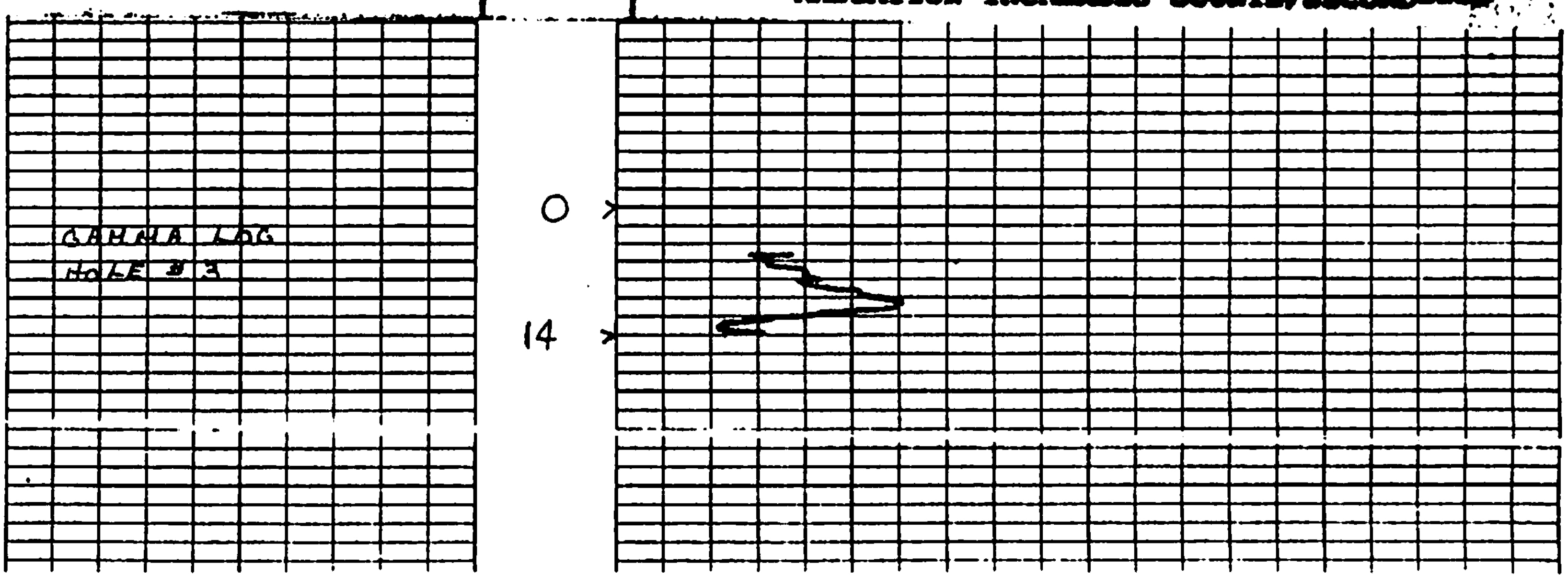
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 3 (AY-68-21) WELL DEPTH: 15.3 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-54 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.60 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY

CASING:	(1)	DIA:	3.00	FROM:	0.00	TO:	15.30	(DIA=ID in INCHES)
	(2)	DIA:	0.00	FROM:	0.00	TO:	0.00	(DEPTHS = FEET)
HOLE:	(1)	DIA:	0.00	FROM:	0.00	TO:	0.00	
	(2)	DIA:	0.00	FROM:	0.00	TO:	0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-7 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->



EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 3 (AY-68-21) WELL DEPTH: 15.3 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-54 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.6 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

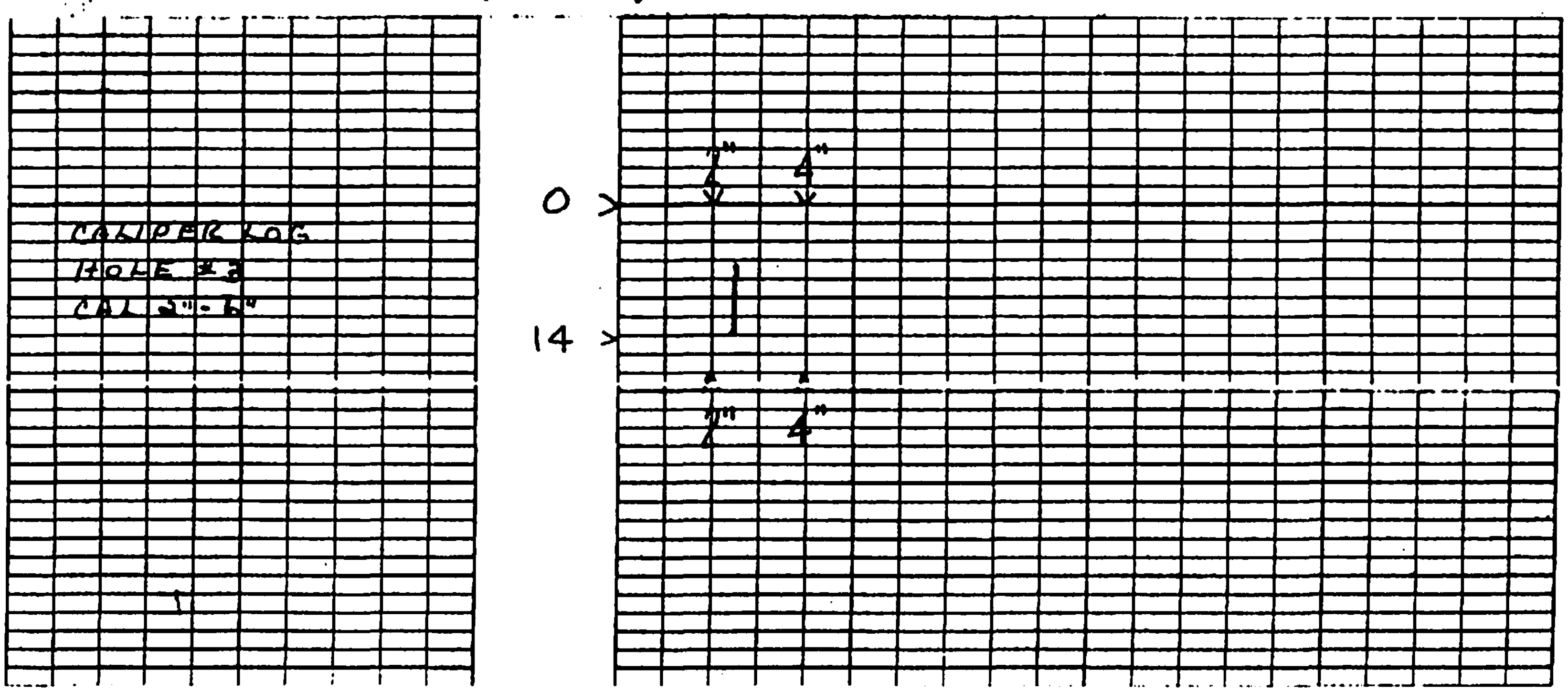
DRILLER: DRILLING METHOD:

CASING:	(1) DIA: 3.000	FROM: 0.000	TO: 15.3	(DIA=ID in INCHES)
	(2) DIA: 0.000	FROM: 0.000	TO: 0.0	(DEPTHS = FEET)
HOLE:	(1) DIA: 0.000	FROM: 0.000	TO: 0.0	
	(2) DIA: 0.000	FROM: 0.000	TO: 0.0	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1026
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 2" TO: 6" (INCHES)
COMMENTS: UTSA BOREHOLE # B-7 AT CHAMPIONS

DEPTH

CALIPER LOG
DIAMETER OF HOLE INCREASES---------->



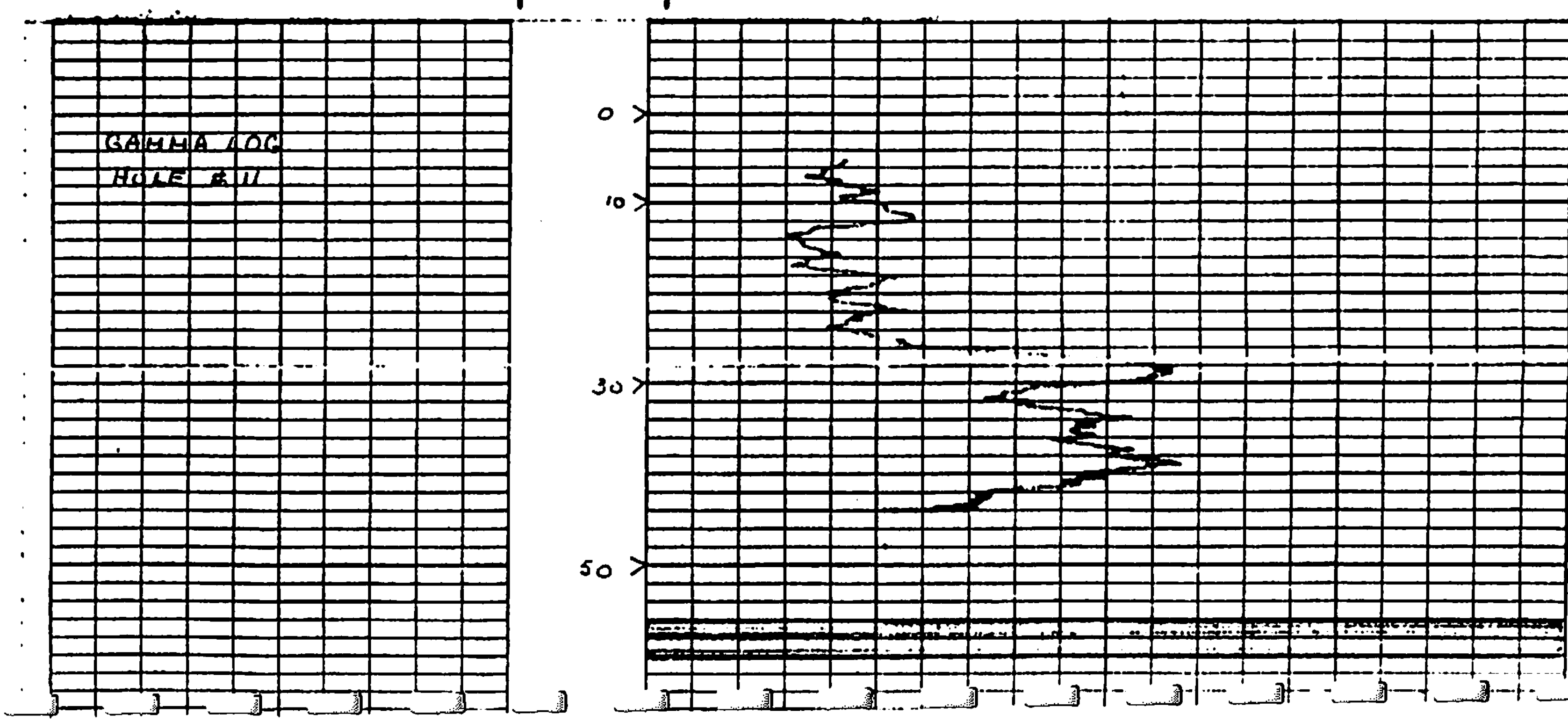
EDWARDS UNDERGROUND WATER DISTRICT
NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91
WELL NO: 11 (A4-68-21) WELL DEPTH: 44.6 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.
DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY

CASING:	(1) DIA:	3.00	FROM:	0.00	TO:	44.60	(DIA=ID in INCHES)
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	(DEPTHS = FEET)
HOLE:	(1) DIA:	0.00	FROM:	0.00	TO:	0.00	
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: 44.0 LSD: 1029
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)
TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)
COMMENTS: UTSA BOREHOLE # B-10 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->

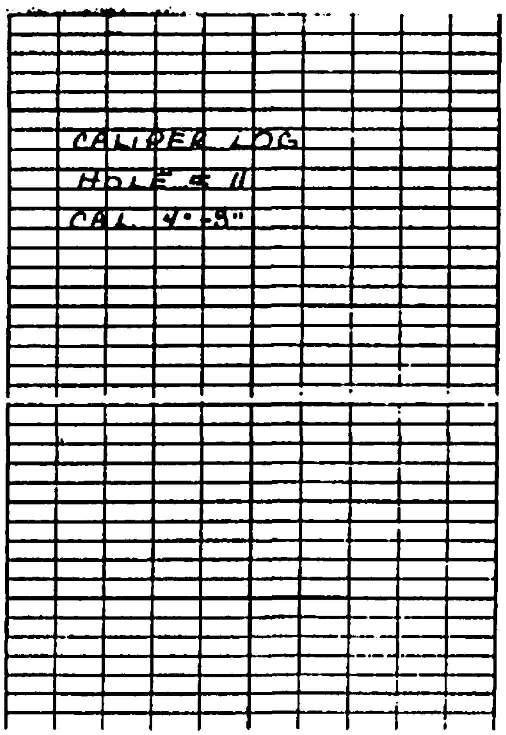


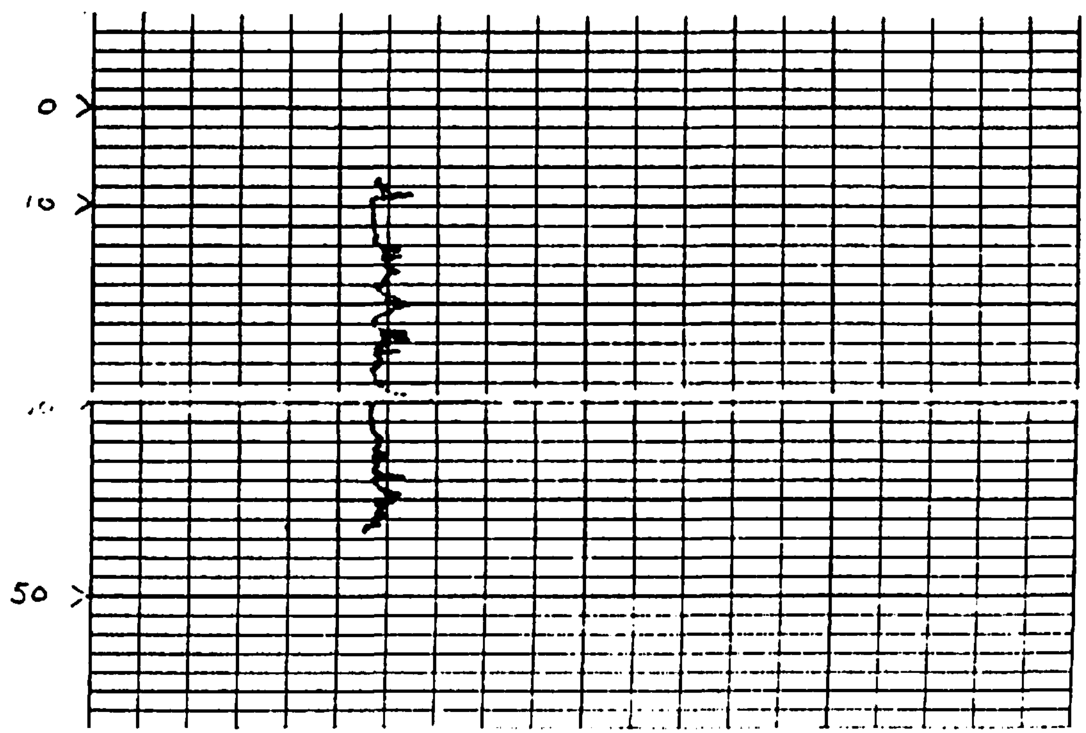
EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 11 (AY-68-21) WELL DEPTH: 44.6 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 5.500 FROM: 0.000 TO: 44.6 (DIA=ID in INCHES)
(2) DIA: 0.000 FROM: 0.000 TO: 0.0 (DEPTHS = FEET)
HOLE: (1) DIA: 0.000 FROM: 0.000 TO: 0.0
(2) DIA: 0.000 FROM: 0.000 TO: 0.0
LOG OPERATOR: DRP LOG MP: LOG TD: 43.0 LSD: 1029
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 4" TO: 8" (INCHES)
COMMENTS: UTSA BOREHOLE # B-10 AT CHAMPIONS

DEPTH | CALIPER LOG
DIAMETER OF HOLE INCREASES---------->





EDWARDS UNDERGROUND WATER DISTRICT

NATURAL GAMMA AND CASING COLLAR LOG

DATE: 27 FEBRUARY 91

WELL NO: 10 (AY-68-21) WELL DEPTH: 50.1 (BELOW LSD)

LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)

OWNER: UTSA/DR. BLANEY

LOCATION: 1.65 miles from WEST line and 1.60 miles from SOUTH line on map AY 68-21.

DRILLER: SOUTHWESTERN LABS. DRILLING METHOD: MUD ROTARY

CASING:	(1) DIA:	3.00	FROM:	0.00	TO:	50.10	(DIA=ID in INCHES)
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	(DEPTHS = FEET)
HOLE:	(1) DIA:	0.00	FROM:	0.00	TO:	0.00	
	(2) DIA:	0.00	FROM:	0.00	TO:	0.00	

LOG OPERATOR: DRP LOG MP: LOG TD: LSD: 1033

GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)

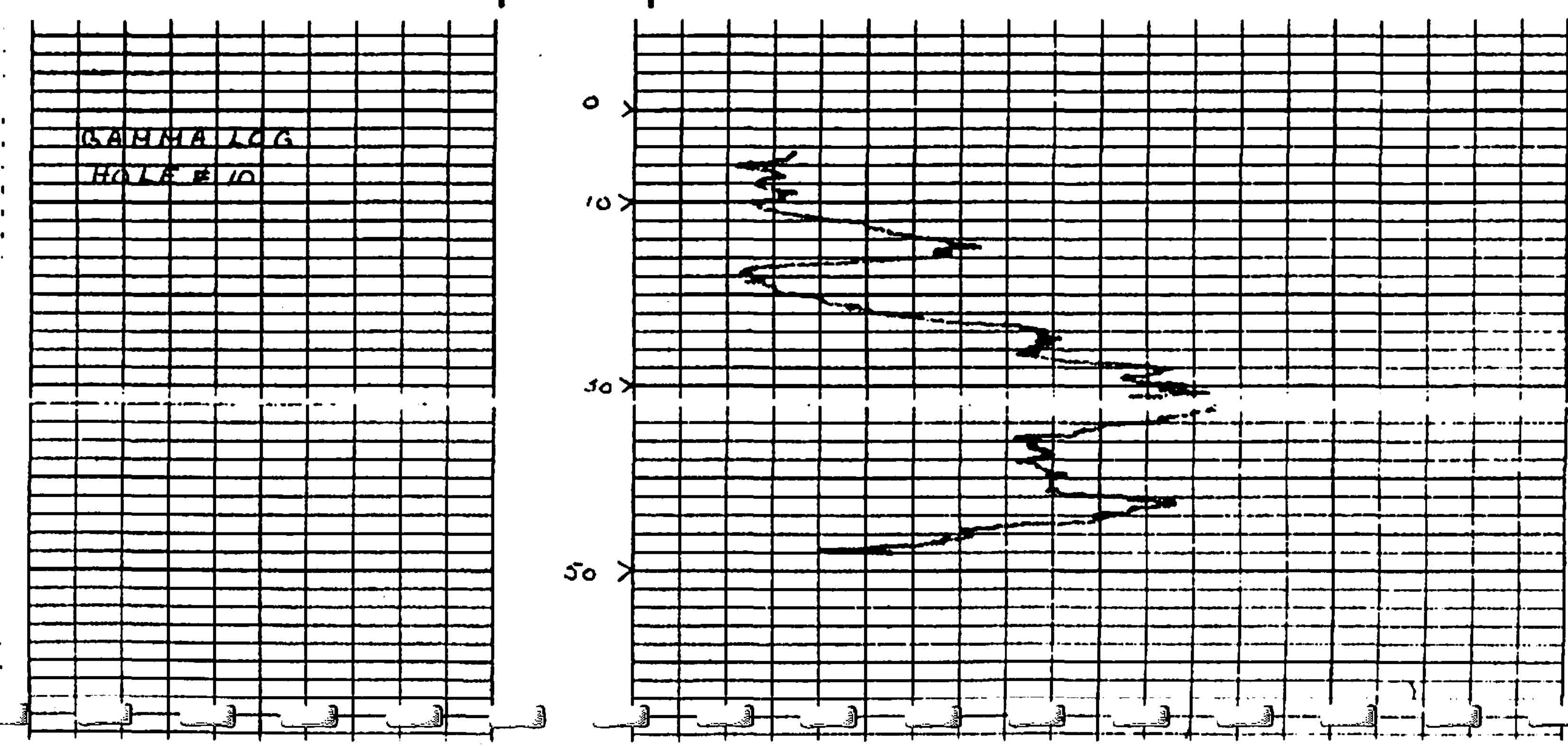
WATER LEVEL (below LSD): 0.00

LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5.0 (INCHES/100FT)

TIME CONSTANT: 2 COUNTS/SECOND: 100 / 20 (CHART DIVISIONS)

COMMENTS: UTSA BOREHOLE # B-9 AT CHAMPIONS.

CASING COLLAR LOG | DEPTH | GAMMA LOG
RADIATION INCREASES COUNTS/SECOND--->

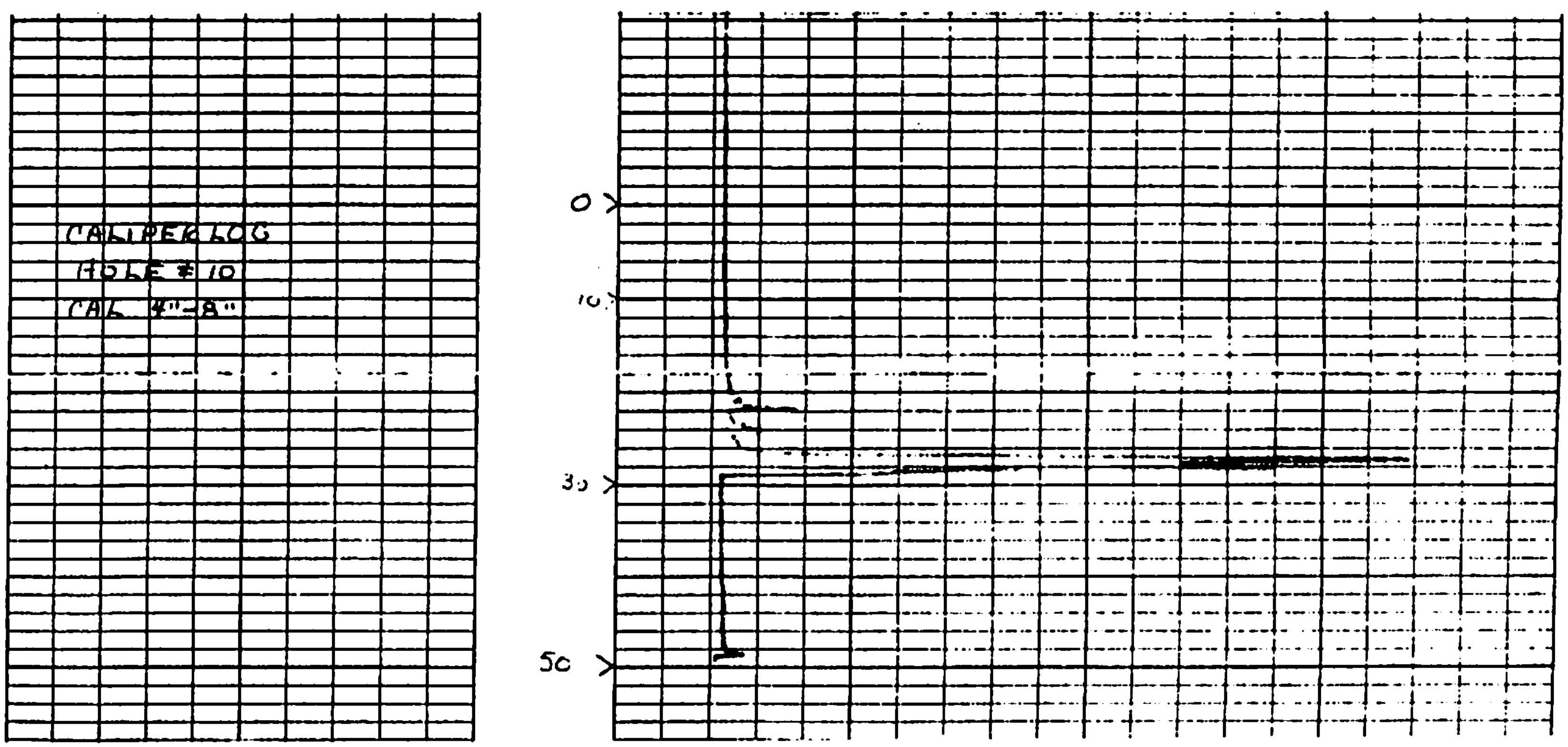


EDWARDS UNDERGROUND WATER DISTRICT
CALIPER LOG

DATE: 27 FEBRUARY 91
WELL NO: 10 WELL DEPTH: 50.1 (BELOW LSD)
LATITUTE: 29-38-54 LONGITUDE: 98-29-51 (D-M-S)
OWNER: UTSA/DR. BLANEY
LOCATION: 1.65 MILES FROM W LINE AND 1.6 MILES FROM S LINE ON AY 68-21

DRILLER: DRILLING METHOD:
CASING: (1) DIA: 3.000 FROM: 0.000 TO: 50.1 (DIA=ID in INCHES)
(2) DIA: 0.000 FROM: 0.000 TO: 0.0 (DEPTHS = FEET)
HOLE: (1) DIA: 0.000 FROM: 0.000 TO: 0.0
(2) DIA: 0.000 FROM: 0.000 TO: 0.0
LOG OPERATOR: DRP LOG MP: LOG TD: 49.0 LSD: 1033
GAMMA LOG: YES CALIPER LOG: YES ELECTRIC LOG: NO (LSD fr TOPO sht)
WATER LEVEL (below LSD): 0.00
LOG SPEED: 30 (FT/MIN) VERTICAL SCALE: 5 (INCHES/100FT)
CALIPER CALIBRATED FROM: 4" TO: 8" (INCHES)
COMMENTS: UTSA BOREHOLE # B-9 AT CHAMPIONS

DEPTH | CALIPER LOG
DIAMETER OF HOLE INCREASES---------->



APPENDIX B

TRANSDUCERS

Transducers

B.1 Transducer Specifications

One transducer type was employed throughout the project for uniformity an economy. The Mark Products L-410 geophone is a rugged (4 year warranty), high-output (0.874 volts/inch/sec +/- 10 %), miniature (0.88 inches in diameter, 1.3 inches high, 1,6 ounces) unit. A detailed description of the unit is given in the enclosed product literature. The resonance frequency of 10 Hertz was chosen to assure that all significant energy from each blast would be recorded. With 11.8 K Ohm shunt resistors, the total instrument damping is 58.9 %, the response is flat to approximately 15 Hertz, with a roll-off of approximately 20 % at 10 Hertz. The instrument units are waterproof.

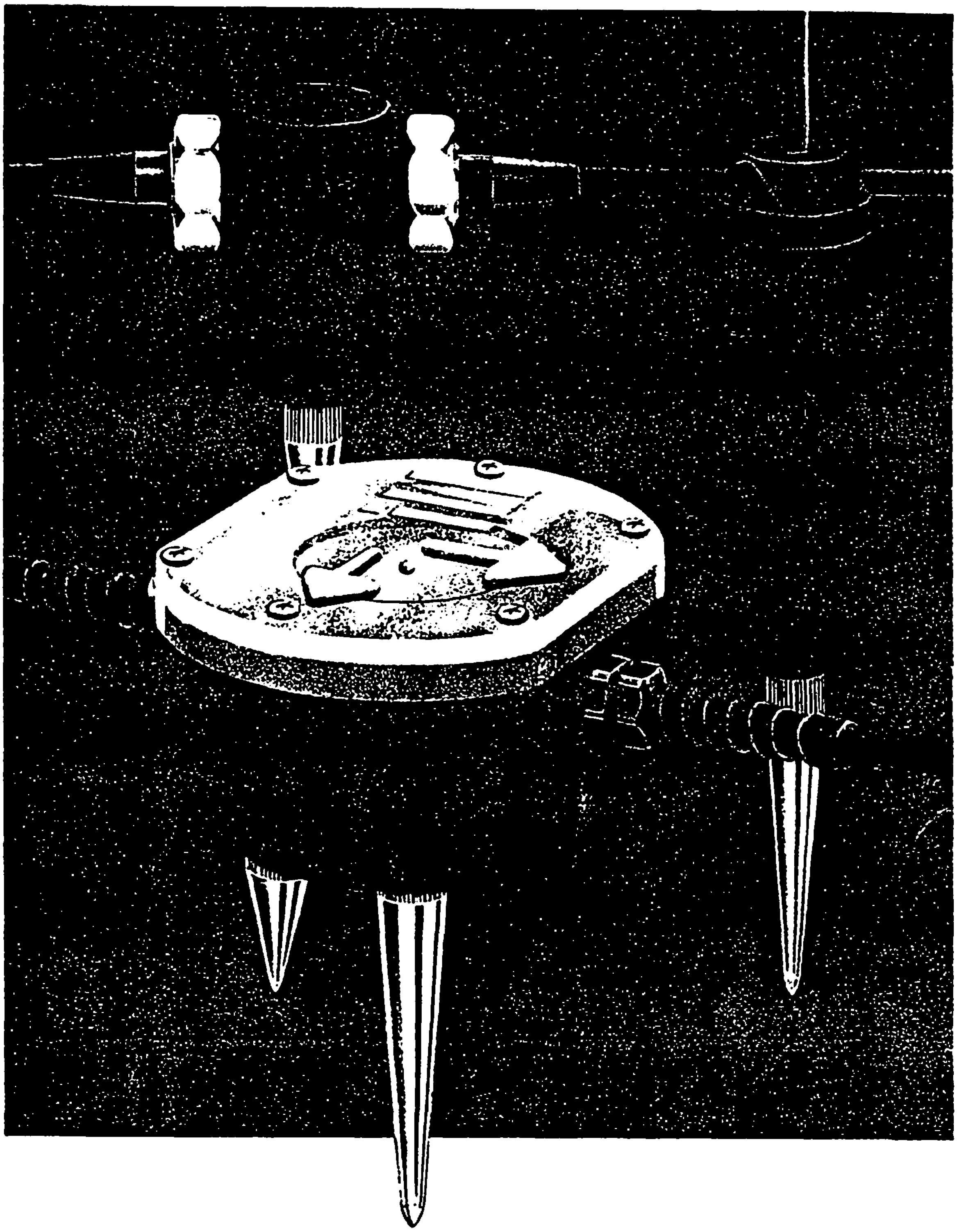
B.2 Transducer Installation

Seven vertical geophones and fourteen horizontal geophones were installed in aluminum blocks to make seven three-dimensional instrument-packages. Instrument cables were 26 gage twisted pairs with a rugged, waterproof jacket. The packages were clamped in the test pipes and the borehole by inflating a rubber bladder. The orientation of the packages in the pipes and borehole was confirmed by observation of LED's installed on the front (top) of each package. For tank (submerged) applications, the aluminum blocks were clamped inside waterproof PVC cases, which were fixed in place on the bottom of the tank with adhesive and bags of lead shot (Figure B.1). Other packages were connected to the lifting loops and manway covers on the outside of the tank.

GEOPHONE SPECIFICATIONS

L-400 Series

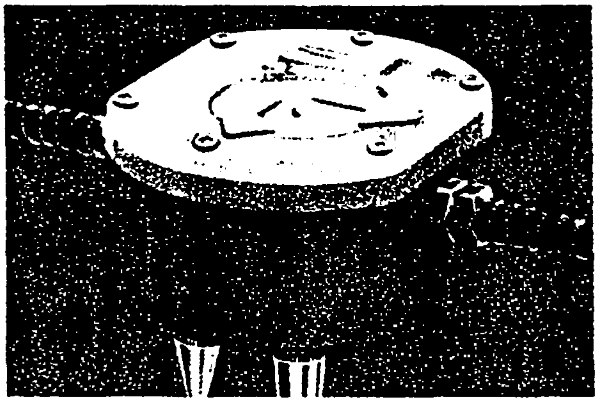
Unique Innovations from Mark Products for Greater Results in the Field



L-400 Series

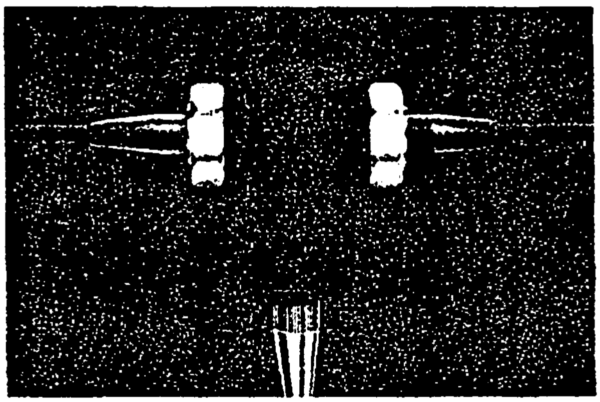
The L-400 Series is a complete new product line offering customers lightweight, subminiature construction, an extremely low distortion index, and the broadest frequency response in the industry (spurious clean band response to over 350 Hz).

The ruggedized water-proof geophone employed in the 400 Series is specifically designed for three-component recording, shear wave recording and P-wave recording. The uniqueness of the 410 unit lies in its compactness and its wide spurious-free band pass. The L-410 is engineered for ideal open circuit damping at 0.475 of critical. This permits the customer the choice of damping to abate or enhance low frequencies. Additionally, the L-410's offset terminals assure uniform polarity. The anchor used in the takeout holds the leader wire firmly in place, transmitting no stress to the geophone. Mark Products is so confident of its endurance that a 4-year warranty is provided.



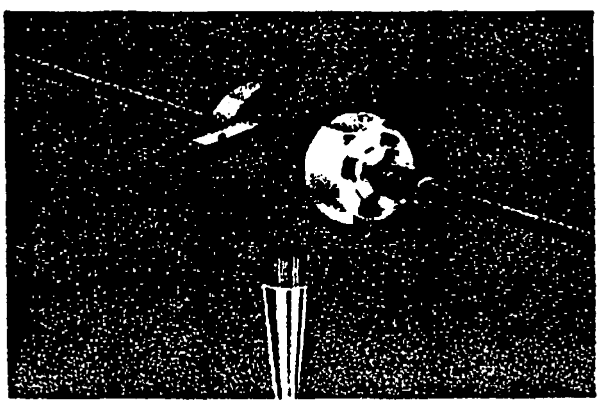
L-400 3-D AMPHIB CASE

The rugged three-directional land case features a high visibility ball-level indicator, making planting easier and quicker. The case's dual spike configuration enhances ground coupling and prevents rotation of the unit. The 3-D Land Case is constructed in three simple parts for easy maintenance in the unlikely event of needed repairs. The unit is fully O-ring sealed for watertight integrity requiring no potting compounds or sealants. Cable life is prolonged by a spiral device that effects gradual bend of cable.



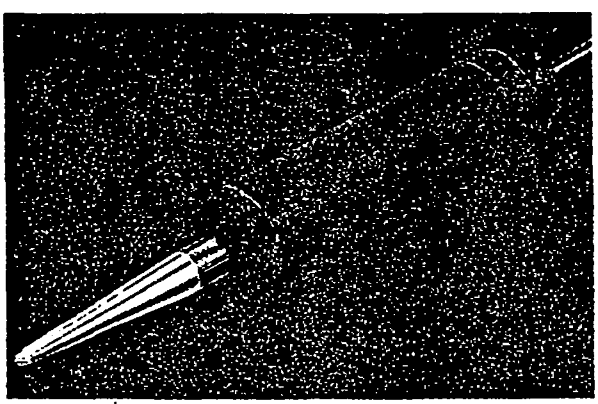
L-400 V and L-400 H AMPHIB CASES

These units are compact, lightweight and contain no screws, utilizing instead a convenient hex-nut assembly. The molded header employed renders the case water-proof and eliminates the need for sealants and potting compounds. As in all 400 series cases, the take-out anchor is polarized to match the L-410 offset terminals. The Horizontal Land Case has all the water-proof features of the Vertical Land Case with one important difference: the horizontal case incorporates a unique ball-leveling configuration. The ball-leveling device, unlike the obsolete bubble design, can be seen from several meters. In addition to the features introduced in these cases they offer the usual dependable qualities that have made Mark cases a leader in the field.



L-400 M AMPHIB CASE

The sturdy and compact marsh case features a unique Thread Lok assembly which prevents cable loosening. A special anchor design assures that no cable stress is transmitted to the watertight seal. The unit is fully water-proof and contains no potting compound. In fact, its rugged case and O-ring seal make it totally field repairable with no special tools required. The Amphib Marsh Case is the only one on the market which features a *complete* water block.



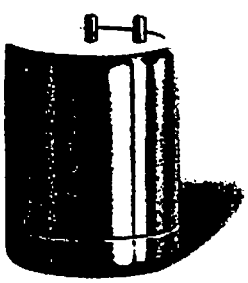
Features described are covered by U.S. Patent 4438292 or patents pending.

L-410 Geophone

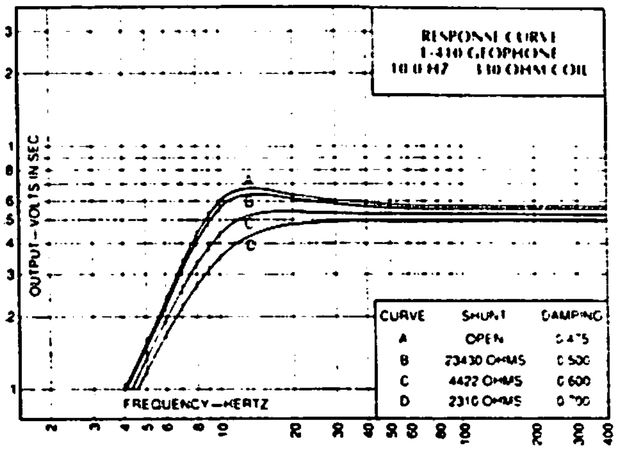
SPECIFICATIONS

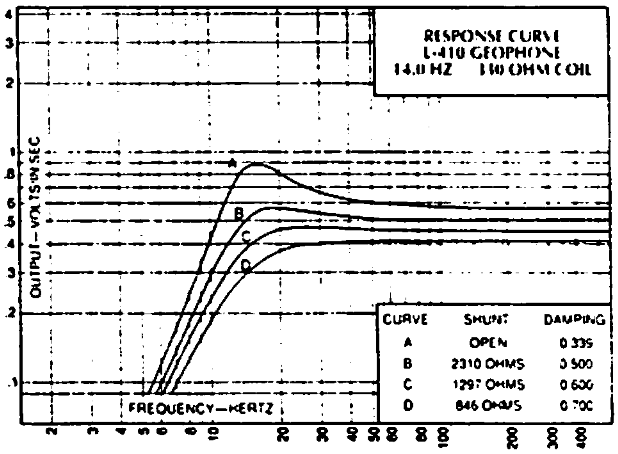
Standard Frequency, Hertz Tolerance, +/- 5%	10, 14, 28
Standard Coil Resistance, Ohms Tolerance, %	330, 510, 795 7.5, 7.5, 10
Maximum Distortion % @1.8 cm/sec (@0.7 in/sec) @ 12 Hertz or Resonance if Greater Than 12 Hertz	0.2
Transduction Constant +/-10% v/cm/sec (v/in/sec)	 0.0122 √Rc (0.031 √Rc)
Open Circuit Damping	$\frac{4.75}{Fo}$
Coil Current Damping	$\frac{18.00\ Rc}{Fo\ (Rc+Rs)}$
Suspended Mass grams (ounces)	 7.0 (0.25)
Power Sensitivity mw/cm/sec (mw/in/sec)	 0.378 (0.960)
Case to Coil Motion cm P-P (ins P-P)	 0.20 (0.080)
Basic Unit Dia. cm (ins)	 2.23 (0.88)
Basic Unit Ht. cm (ins)	 3.30 (1.3)
Basic Unit wt. grams (oz)	 45.3 (1.6)
Min. Spurious Resonance	350 Hertz
Warranty (Damage from physical abuse and high voltage excepted)	4 Years

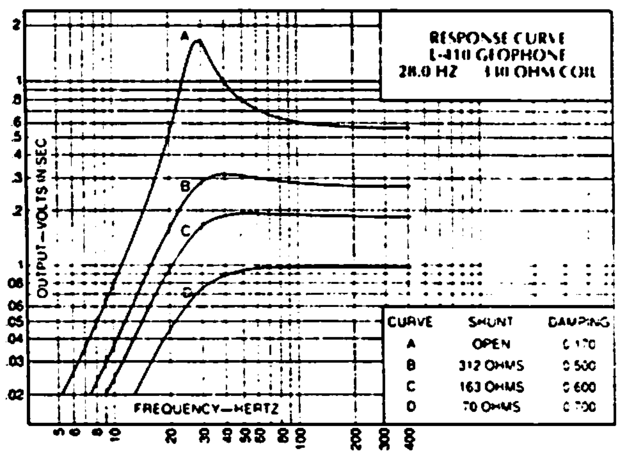
Specifications are subject to change without notice



L-410 Geophone
Actual Size







Mark Products, Inc. • 10502 Fallstone Road • Houston, Texas 77099 • (713) 498-0600 • Telex 76-2069
Mark Products, Ltd. • 1108 55th Ave., N.E. • P.O. Box 73, Station M • Calgary, Alberta, T2P 2G9 Canada • (403) 275-3544

2M587

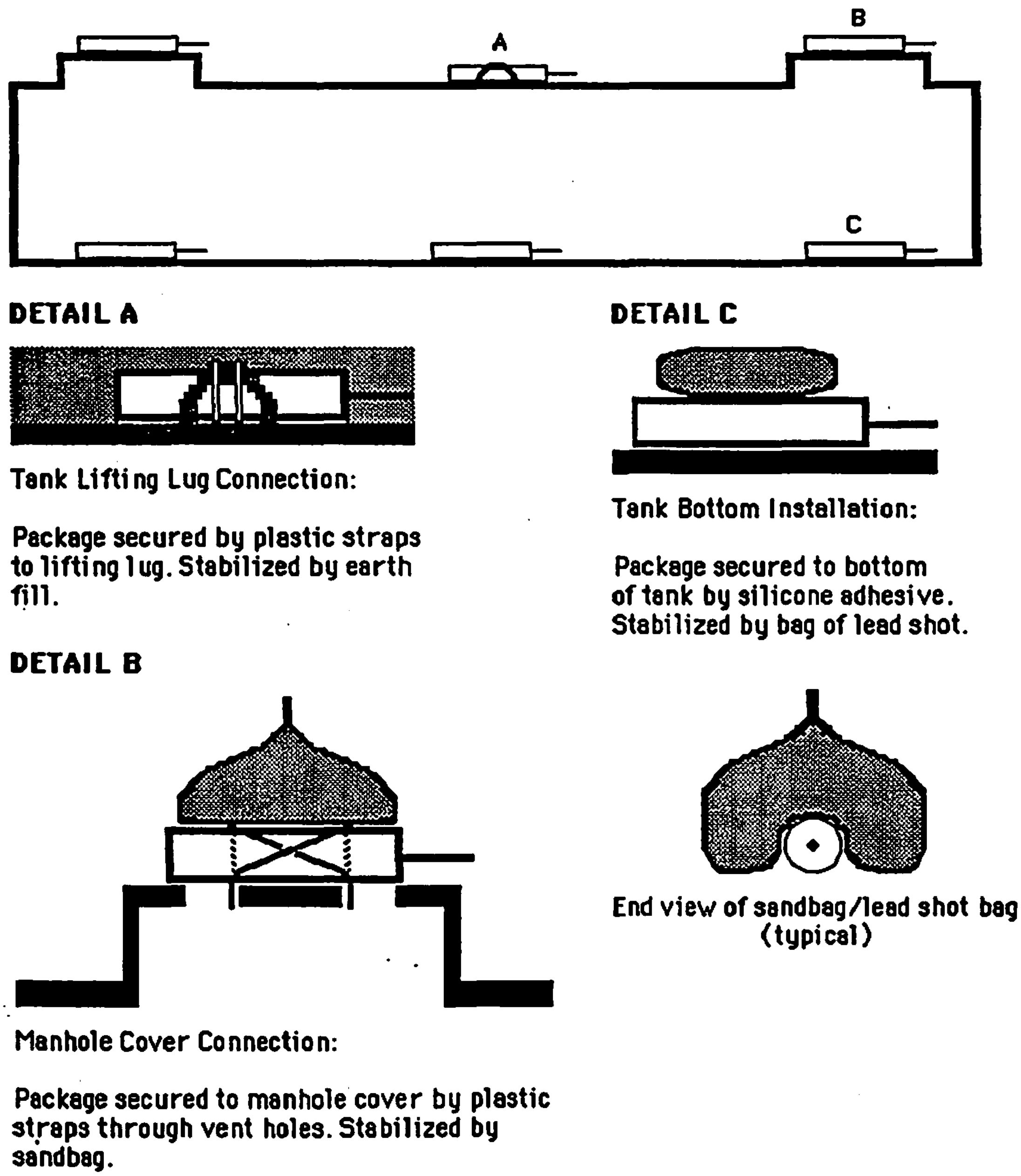


Figure B.1 Instrument Package Locations And Installation.

Techniques In Storage Tanks

APPENDIX C

DATA AQUISITION SYSTEM

Data Acquisition System

The data was acquired on a PC-based system assembled by CWR staff from state-of-the-art hardware and software components. When subjected to vibratory loads, the velocity sensors (geophones) generated a time-varying voltage linear with the ground motion velocity (Appendix B). This signal was carried over twelve-conductor-pair cables to the preconditioning unit, where each channel of analog signal was amplified at a user-selected descrete level between 1 and 1000 (Figure C.1, Table C.1). The conditioned signal then passed to the acquisition boards, where data from each channel was multiplexed and digitized.

The sampling rate specified for each channel was 1024 samples per second, allowing signal discrimination to above 500 Hz. The cut-off frequency was more than adequate, because the geophones were only calibrated by the manufacturer to 400 Hz. Most of the ground motion energy was transmitted at frequencies below 200 Hz. The acquisition board functions were controled by dedicated software (Figure C-2). The digital data was stored on a 160 megabyte hard disk, then demultiplexed and stored as individual channels of digital data. The data was reviewed in the field to assure proper function of the acquisition system and to confirm proper ampifier gain settings for each channel.

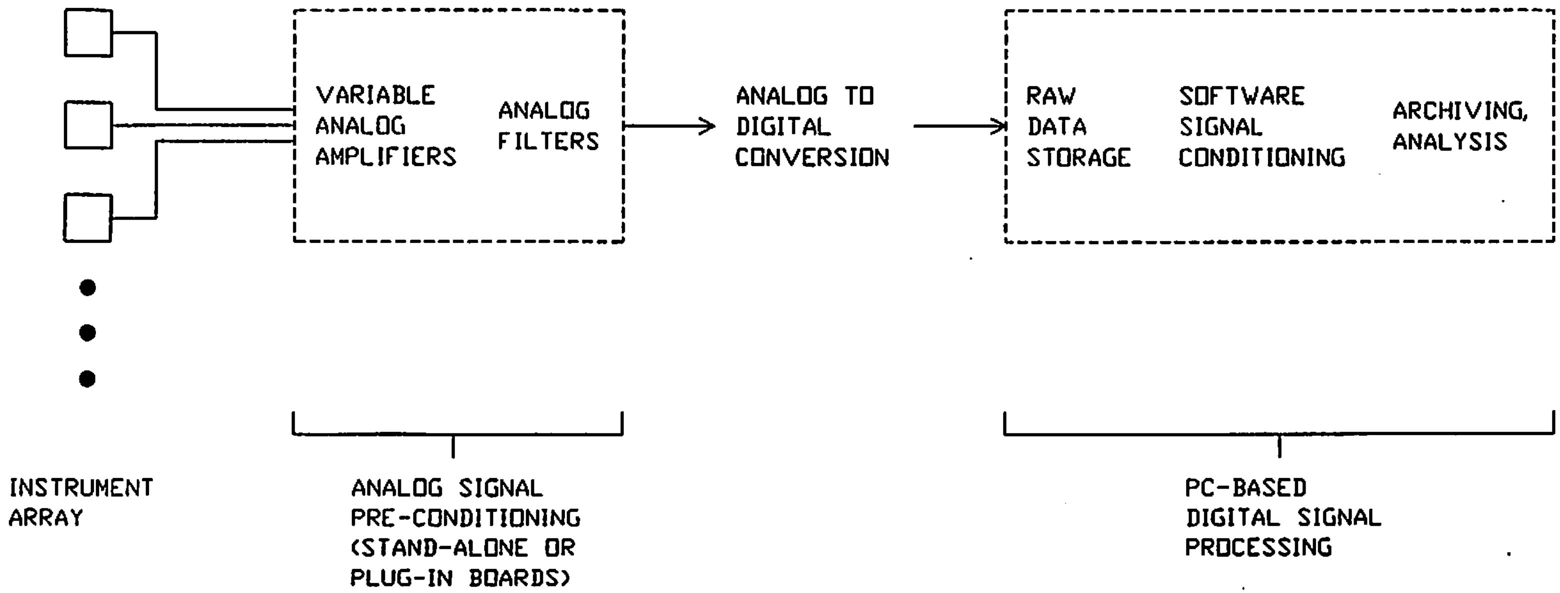
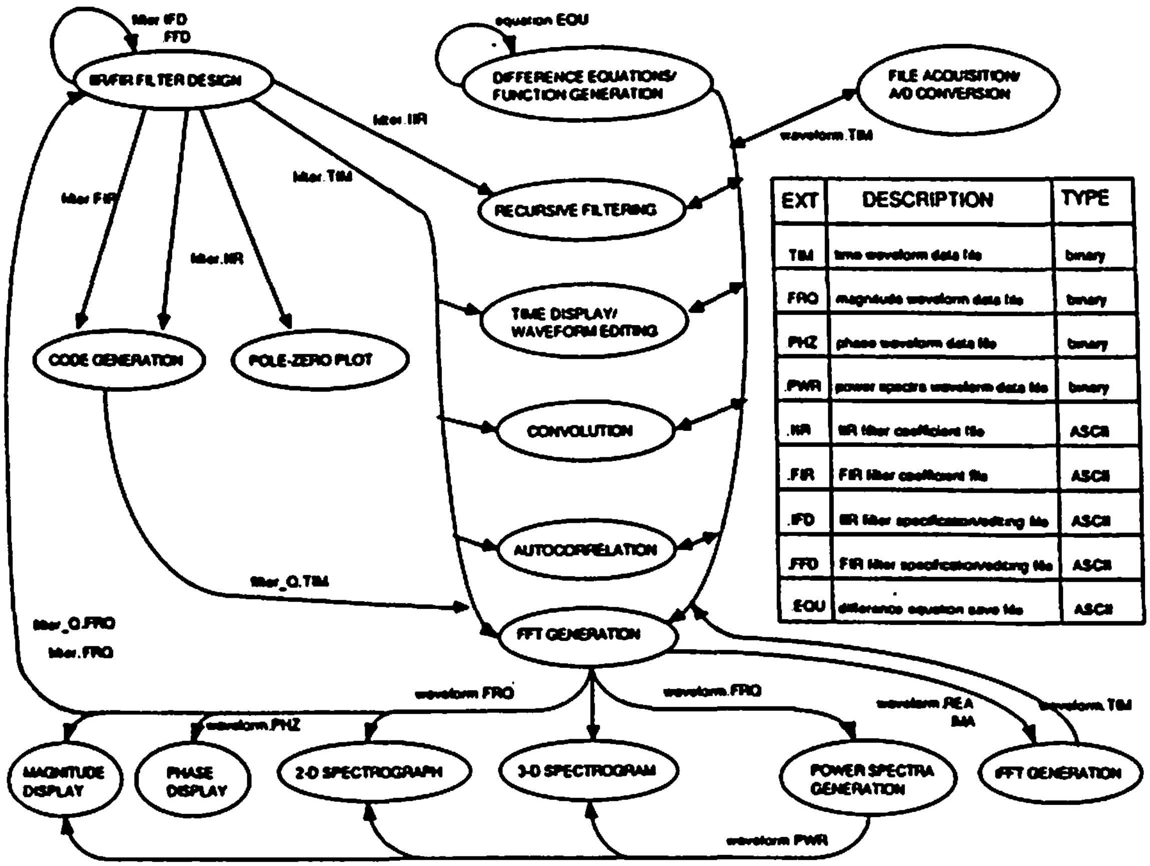


Figure C.1 PC-Based Data Acquisition System

Table C.1 - Available Gain Values

SWITCH POSITION	RESISTOR VALUE	GAIN 1:X
1	OPEN	1.00
2	22 Kohm	2.00
3	5.6 Kohm	4.93
4	4.7 Kohm	5.68
5	2.2 Kohm	11.00
6	470 ohm	47.81
7	330 ohm	67.67
8	220 ohm	101.00
9	47 ohm	469.09
10	22 ohm	1001.00



EXT	DESCRIPTION	TYPE
.TIM	time waveform data file	binary
.FRQ	magnitude waveform data file	binary
.PHZ	phase waveform data file	binary
.PWR	power spectra waveform data file	binary
.IIR	IIR filter coefficient file	ASCII
.FIR	FIR filter coefficient file	ASCII
.IFD	IIR filter specification/editing file	ASCII
.FFD	FIR filter specification/editing file	ASCII
.EQU	difference equation save file	ASCII

Figure C.2 Analytical Capabilities For Data Acquisition And Reduction Software System

APPENDIX D

DATA REDUCTION PROCEDURES

Data Reduction Procedures

D.1 Preliminary Analysis

The individual time histories of digital data, recorded as described in Appendix C, were first converted from system units of amplitude to units of ground motion velocity, as described in "Time History Reduction Procedure." The converted data was then transformed to the frequency domain by standard signal conditioning techniques. The Fourier Transform plots generated by this technique indicate the distribution of velocity amplitude (ground motion) as a function of frequency, and are valuable in assessing the type of waves generating the recorded motion and the possible effects of the motion on the ground and structures.

The basic reduced data included the time history and the frequency response plots on a single computer screen or page (Appendix E). From this information, preliminary estimates of the data quality (signal-to-noise ratio), signal duration, amplitude distribution and frequency content were obtained to provide direction for further analysis.

The recorded data was generally of good quality. Some D.C. shifting was encountered in the data with low signal level and high analog amplification. This shifting was corrected in the reduction process. A few of the records showed clipping due to excessively high signal level and/or high amplifier setting, while several others had a low signal-to-noise level due to weak signal and/or low analog amplification. Some signal distortion in the frequency domain plots was generated by overdriving. One record was lost due to electronics malfunction. A total of over 330 events were recorded and reduced with 10,560 data traces from individual instruments (21,628,880 data points).

D.2 Secondary Analysis

Several higher-level displays were obtained from the preliminary data.

Frequency domain response data for each record (blast event) were separated by direction of motion (vertical, longitudinal, transverse) and plotted in a three-dimensional display of amplitude versus frequency and channel (Appendix E). Three plots were made per blast. Two-dimensional color contour plots of the same data were also generated. The two sets of plots complemented each other, in that the three-dimensional plots demonstrated the continuity of energy from one trace (location) to the next at a given frequency, while the two dimensional plots allowed determination of exact frequency and amplitude at any point on the plot.

Additional functions were generated from the data after analysis of the plots described above. These plots related response amplitude to charge weight at a given surface location, and amplitude to depth within a given ground profile. The application of these plots is explained in Section 7, and sample plots are displayed in Appendix E. In addition, the relationship between predominant frequency and charge weight was plotted (Appendix E).

TIME HISTORY REDUCTION PROCEDURE

The initial form for each time history is a record of 12 bit samples. Each sample represents 1 of 4096 discreet voltage levels (hereafter called units) over a range of +/- 10 volts (20 volts peak-to-peak). Consecutive units differ from each other by:

20 volts/4096 units ==> 0.004883 volts/unit.

Since the digitizer can only sense signals at discreet voltage levels, signals smaller than this constant may not be picked up by the digitizer at all. They will "fall between the cracks". Low level signals at amplitudes approaching this constant in peak to peak voltage will be severely distorted, hence the need for an amplifier prior to digitizing the signal. Also, the number of units which correspond to 1 volt is:

4096 units/20 volts ==> 204.8 units/volt.

Reduction of sample records to a useable format and to velocity units of inches/second follows five steps:

1. All time histories in a blast record are input to the data reduction software as a signal matrix of dimensionless NUMBER- OF-SAMPLES by NUMBER-OF-CHANNELS. Each time history is converted from its native integer form to floating point representation during the input process.

2. Any DC shift present in a time history is removed. The shift is calculated as the average of the last 512 samples in a time history. The average is taken from the end of the time history (recorded data) to allow for the transient signal to settle to what is supposed to be a zero signal level. The average taken is assumed to be the DC shift of the signal;

DC shift = mean (time history)

It is subtracted from each sample of the time history.

sample = sample - DC shift

3. Each time history sample is converted from dimensionless system units to volts using the following formula:

$$\text{sample} = \frac{\text{sample}}{204.8 \text{ units/volt}}$$

4. Each time history sample is converted from volts to velocity in inches/second using the following formula:

$$\text{sample} = \frac{\text{sample}}{0.874 \text{ volts/inch/second}}$$

This geophone response constant was obtained from the Mark Products, Inc. L-410 Geophone specifications. The following formula was provided:

transduction constant = 0.031 * sqrt(standard coil resistance)

where: standard coil resistance = 795 Ohms, and the transduction constant is measured in volts/inch/second.

5. Each time history is corrected for any gain introduced by the signal amplifier, by the following formula:

$$\text{sample} = \frac{\text{sample}}{\text{channel-gain}}$$

The vertical time histories in the Judson/1604 and SARA blast series were recorded using vertical geophones with improper shunt resistors installed at the factory. For these blast records, the transduction constant was approximately 10 percent lower than expected and this resulted in recorded vertical time history amplitudes of 90 percent of the actual signal. After reduction, each of these blast records was adjusted by multiplying the vertical time history amplitudes by the constant 1.1.

TIME HISTORY REDUCTION PROCEDURE

(1) CONVERT RAW INTEGER DATA TO FLOATING POINT

(2) REMOVE DC SHIFT

time history amplitude - mean(time history amplitude)

(3) CONVERT SYSTEM AMPLITUDE TO VOLTS

time history amplitude / 204.8 units/volt

(4) CONVERT VOLTS TO INCHES-PER-SECOND OF GROUND RESPONSE

time history amplitude / 0.874 volts/inch/second

(5) AMPLIFIER GAIN CALIBRATION

time history amplitude / amplifier channel gain

APPENDIX E

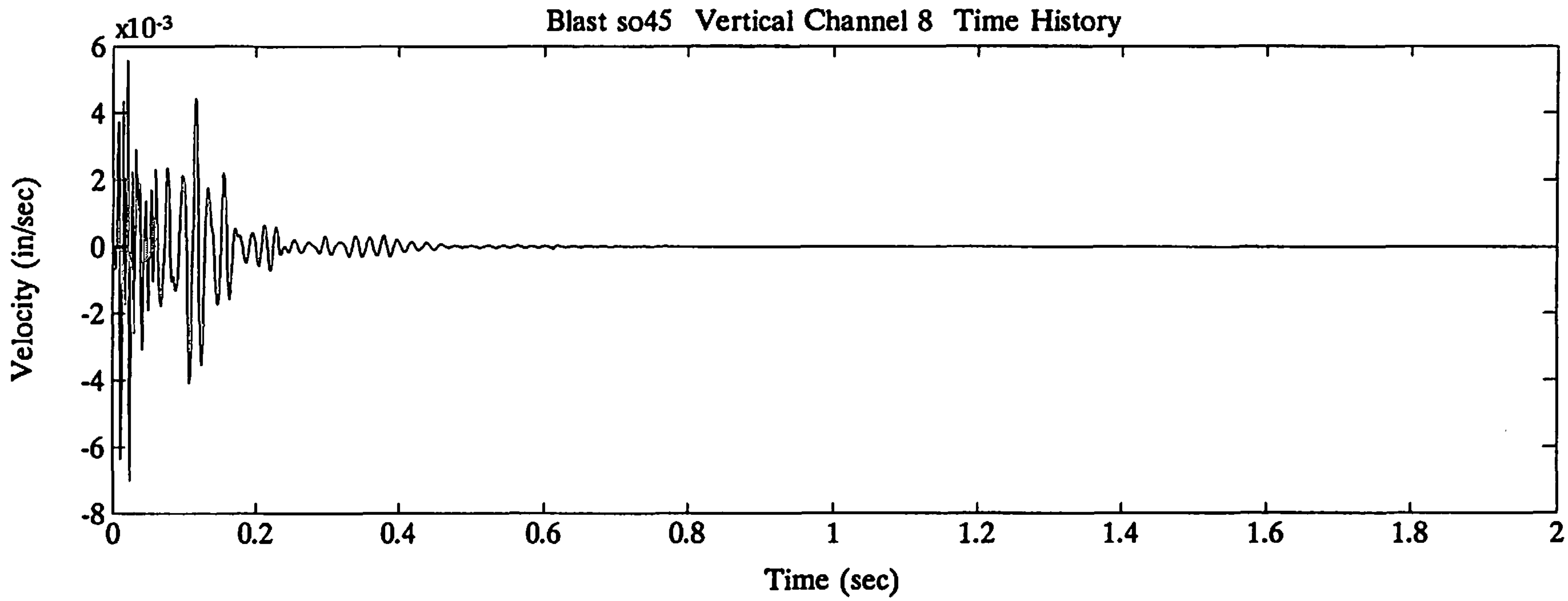
SAMPLE REDUCED DATA

SECTION E-1

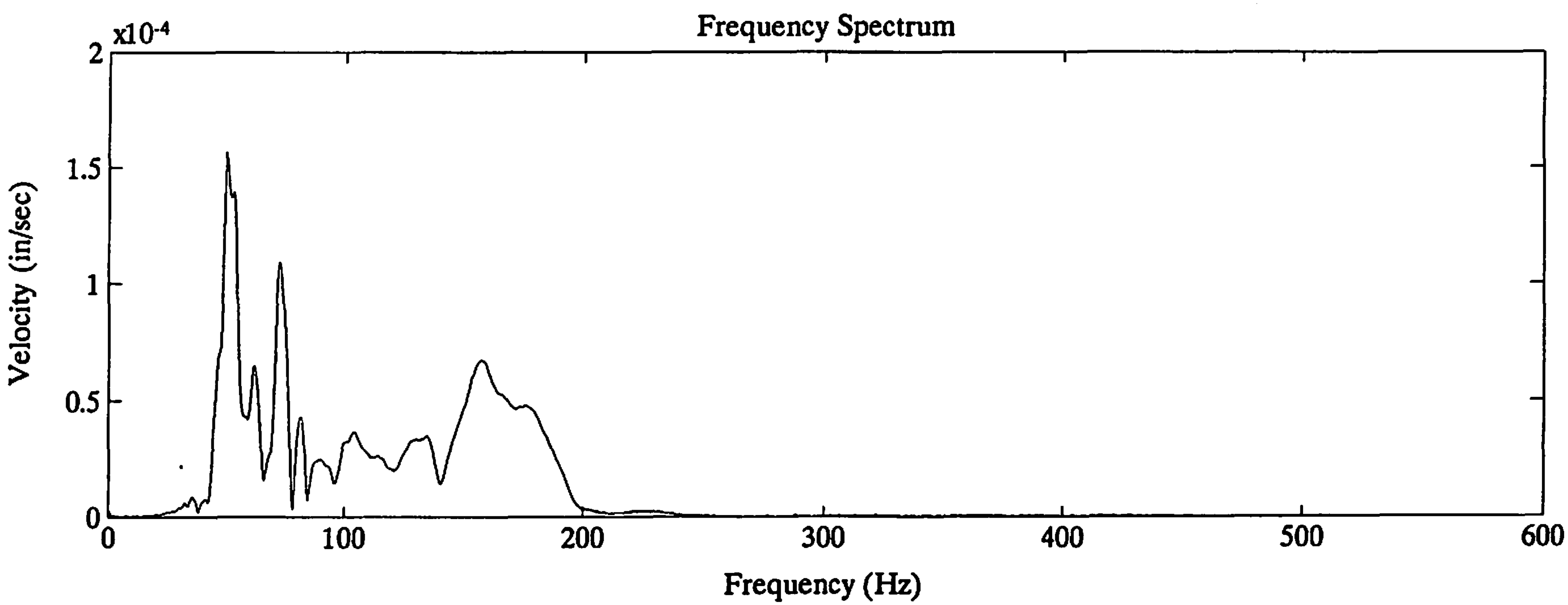
TIME HISTORIES AND FOURIER TRANSFORMS

FOR

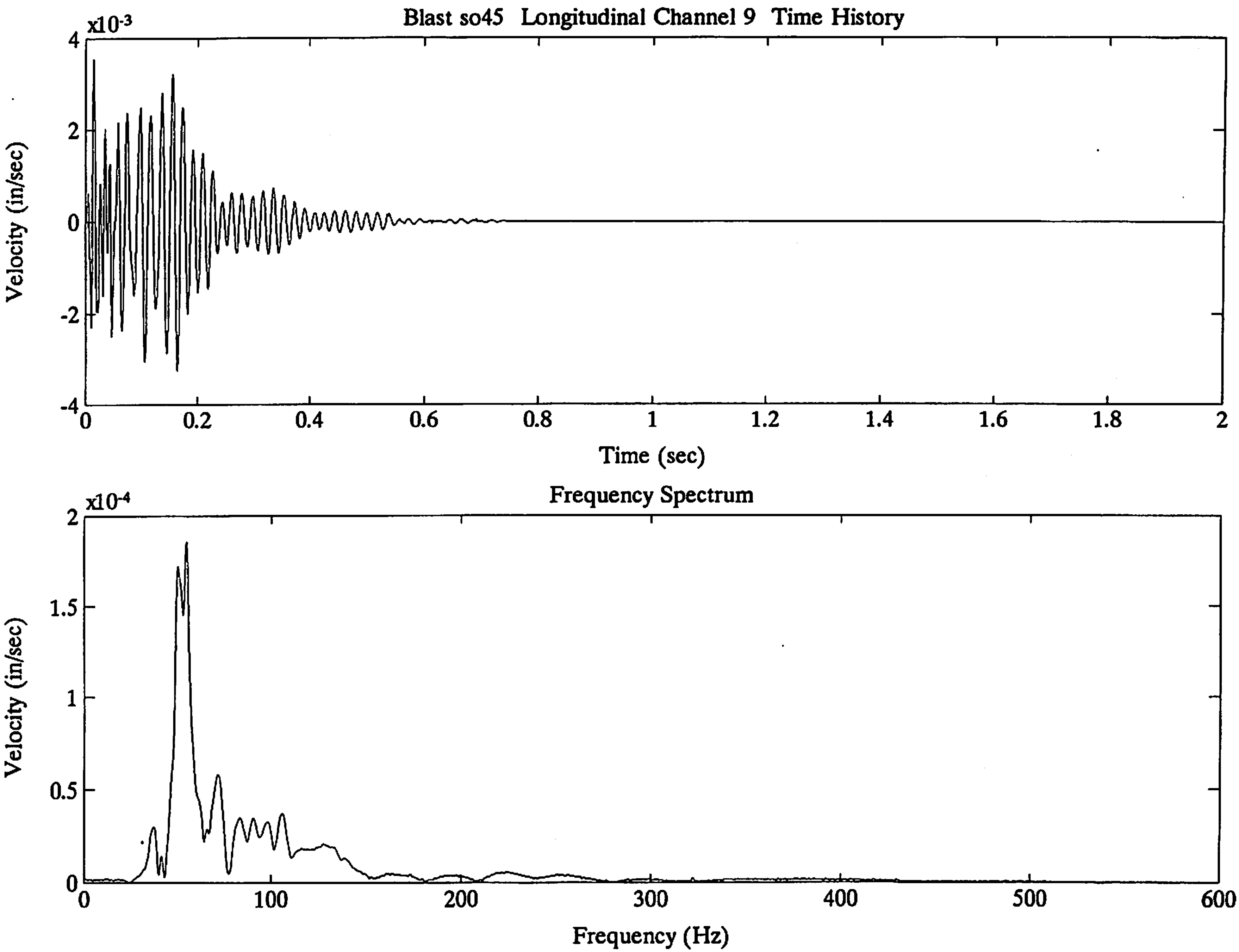
INDIVIDUAL INSTRUMENTS IN SEQUENCE S04



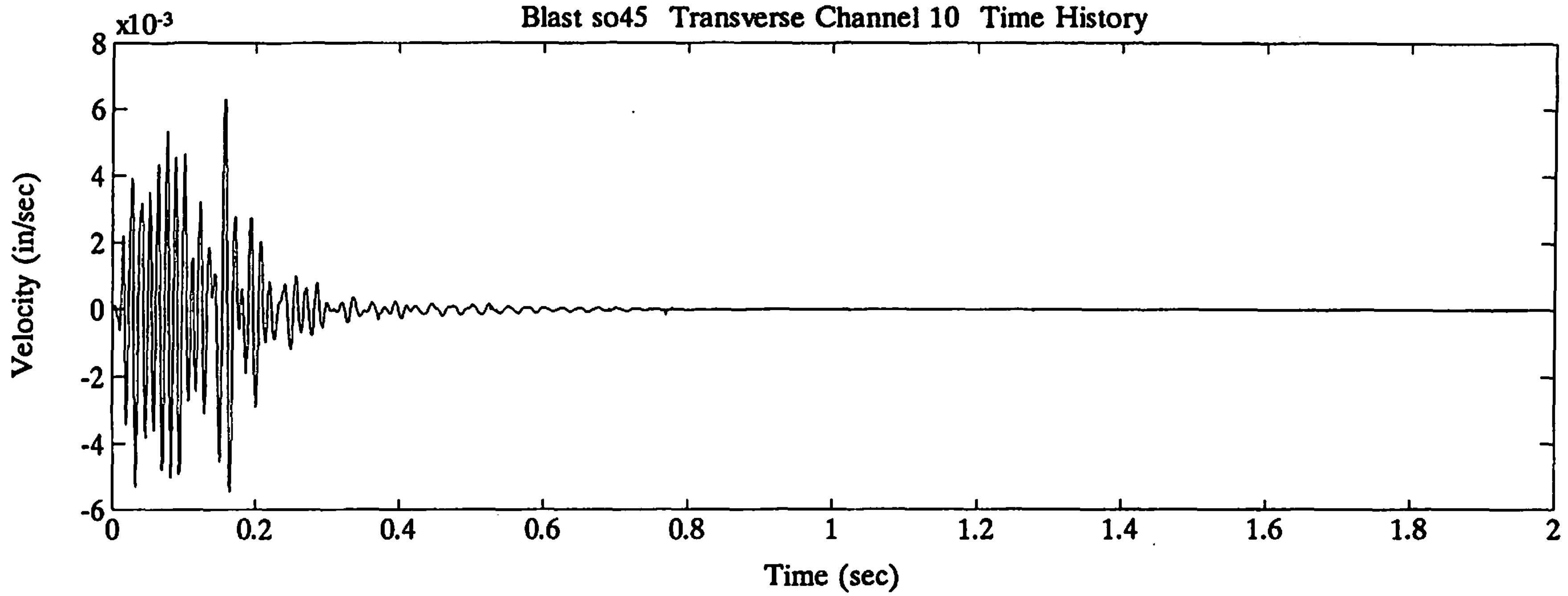
Blast so45 Vertical Channel 8 Time History
x10-3
Velocity (in/sec)
Time (sec)

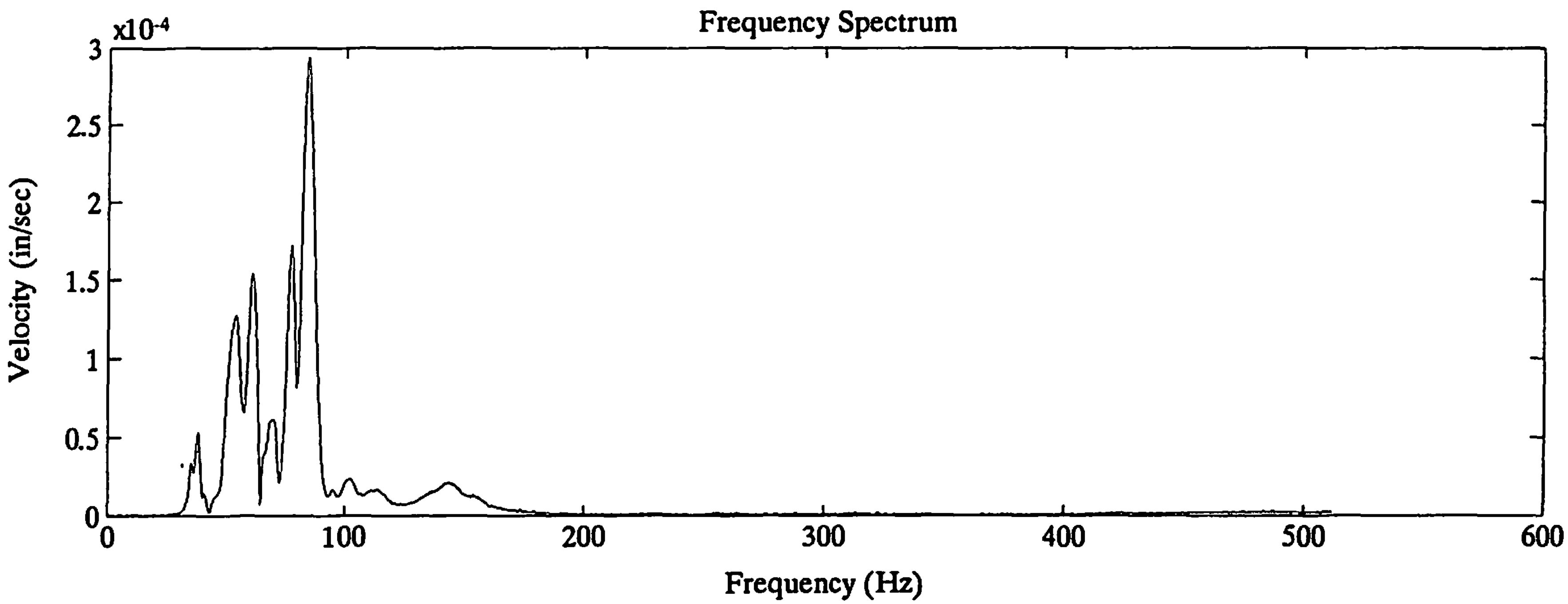


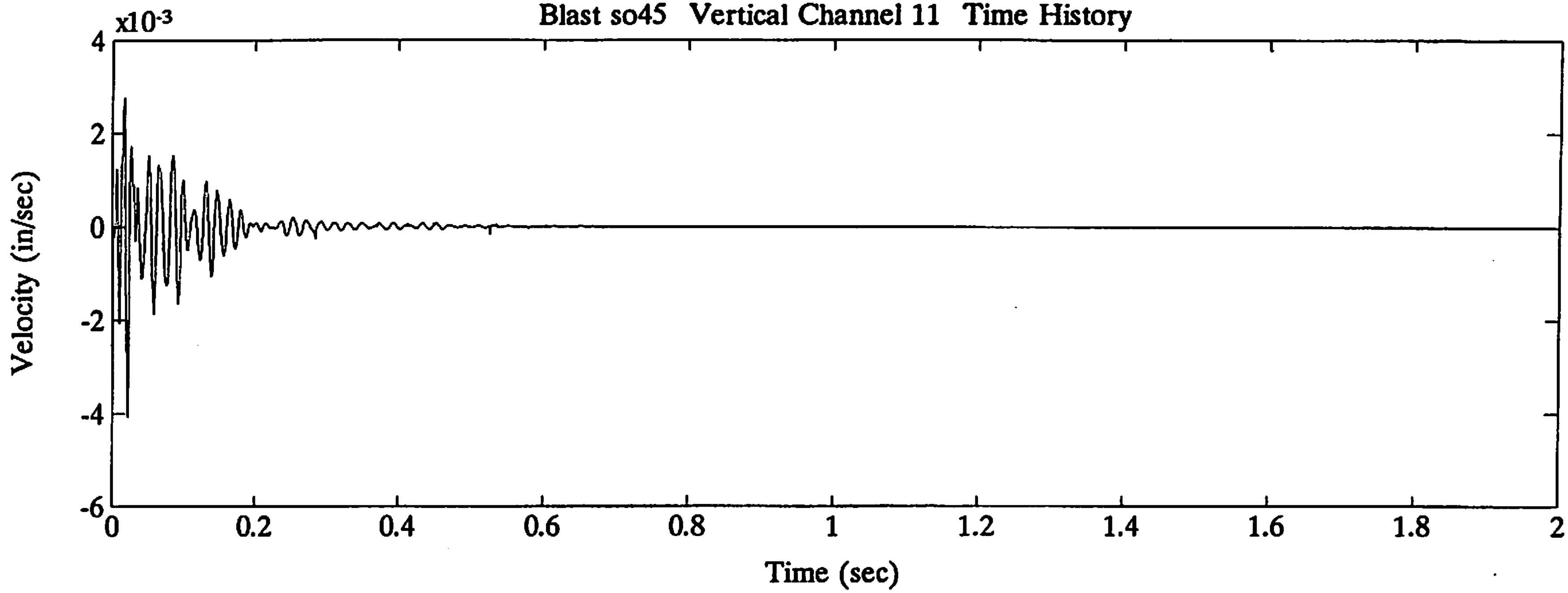
Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)



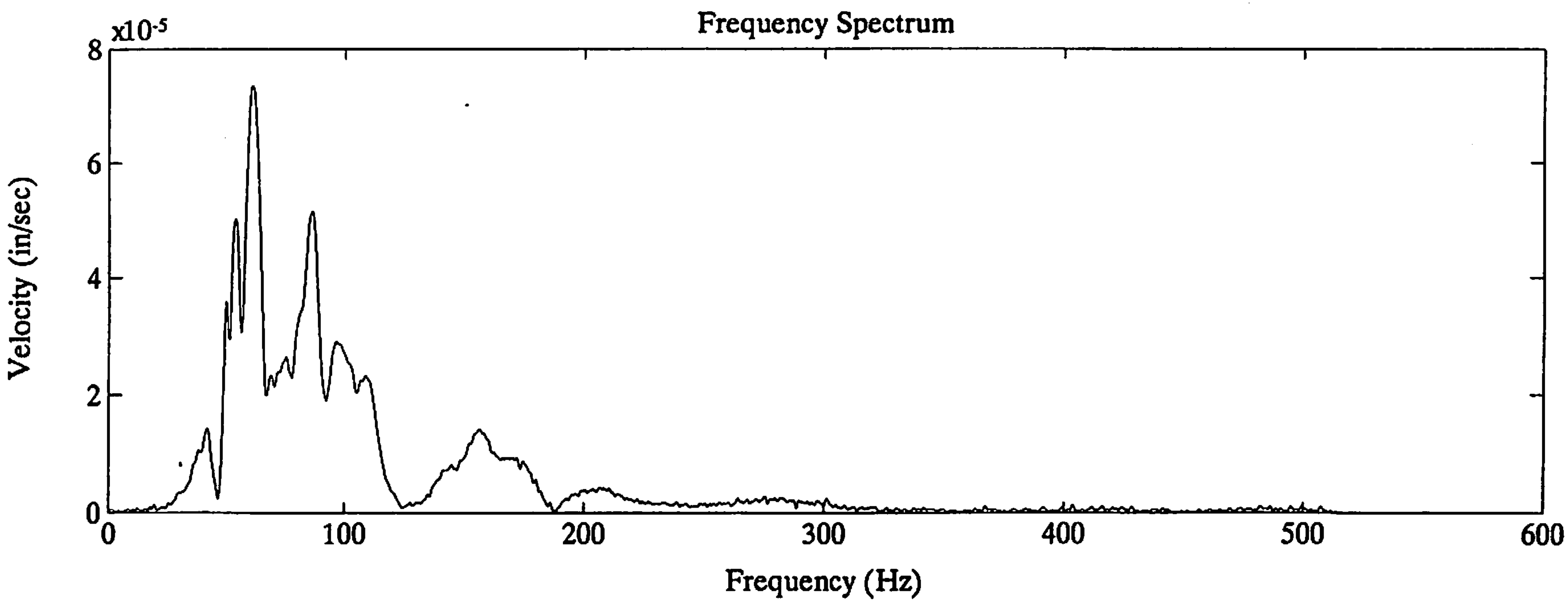
Blast so45 Longitudinal Channel 9 Time History
x10-3
4
2
0
-2
-4
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so45 Transverse Channel 10 Time History
x10-3
Velocity (in/sec)
8
6
4
2
0
-2
-4
-6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

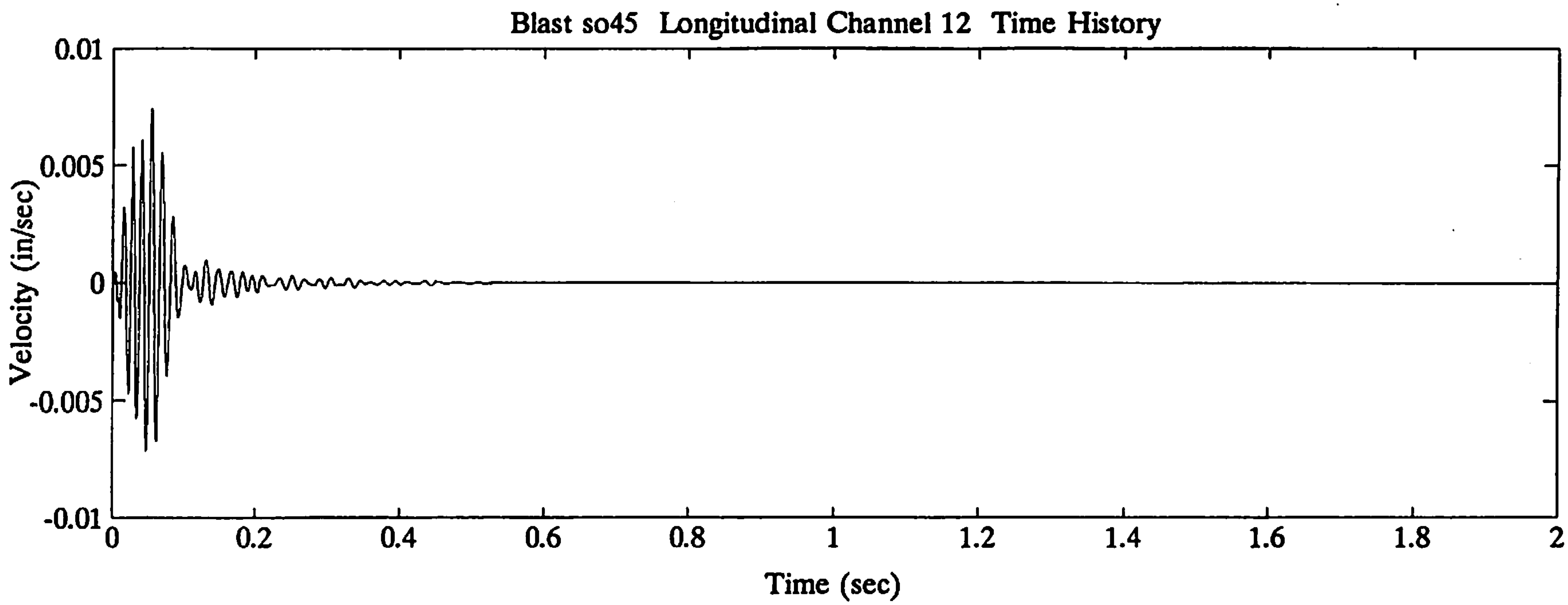

Frequency Spectrum
x10-4
Velocity (in/sec)
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

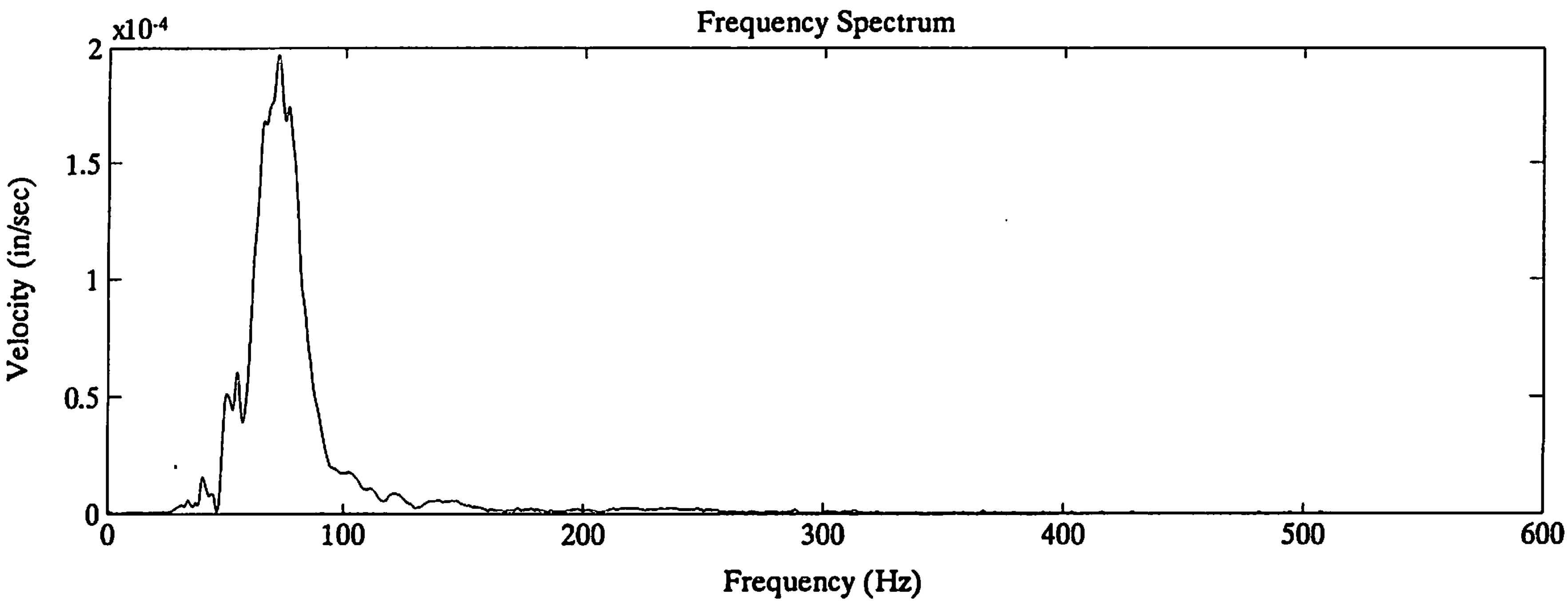


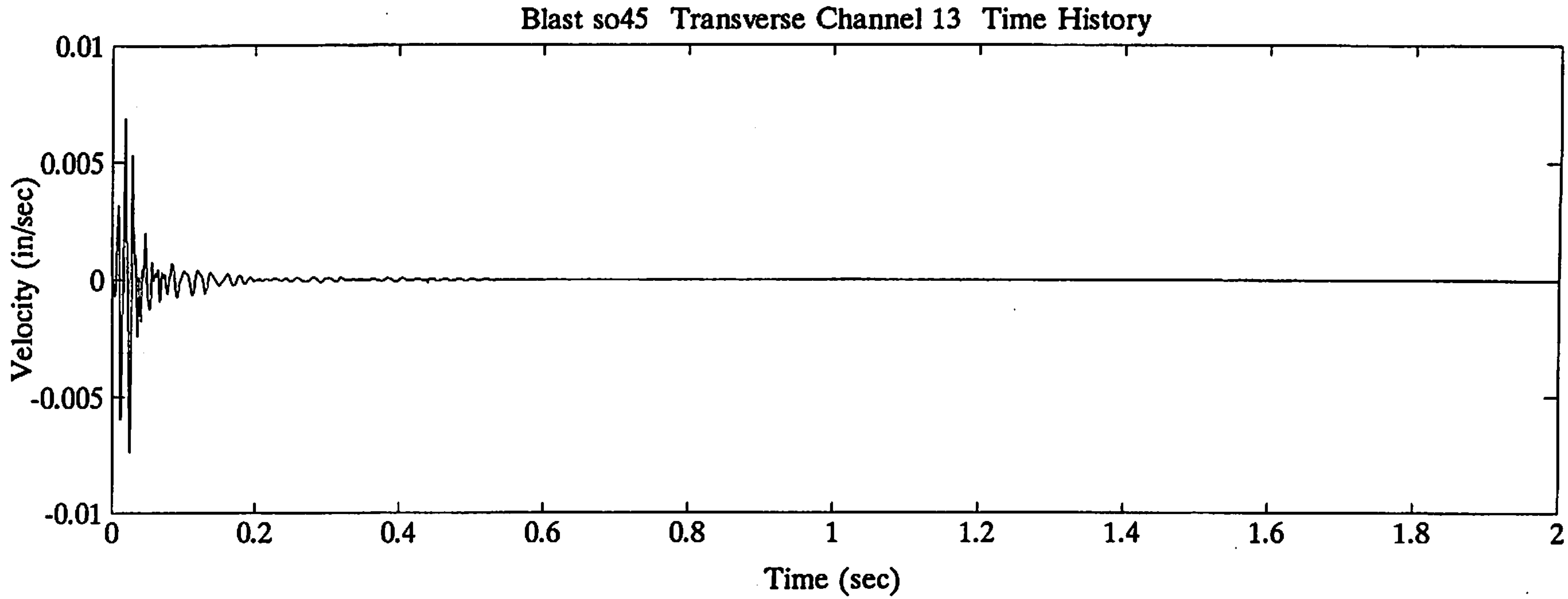
Blast so45 Vertical Channel 11 Time History
x10-3
4
2
0
-2
-4
-6
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

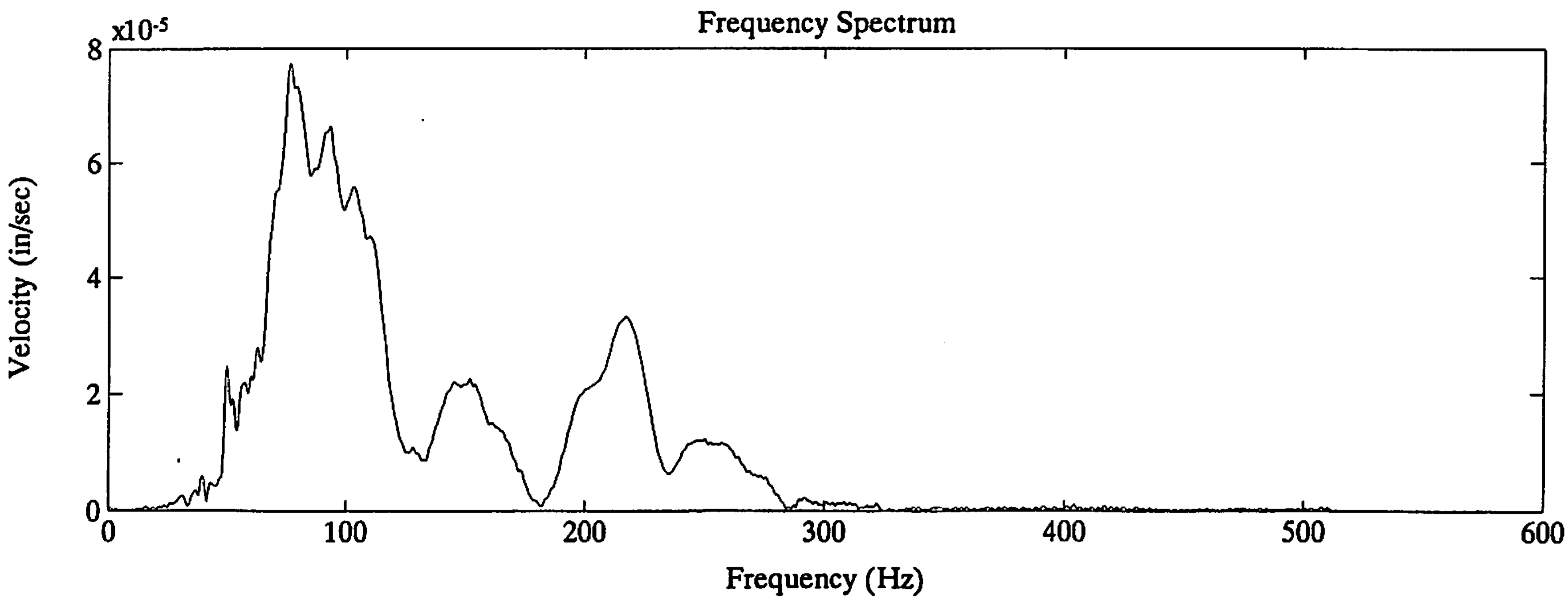


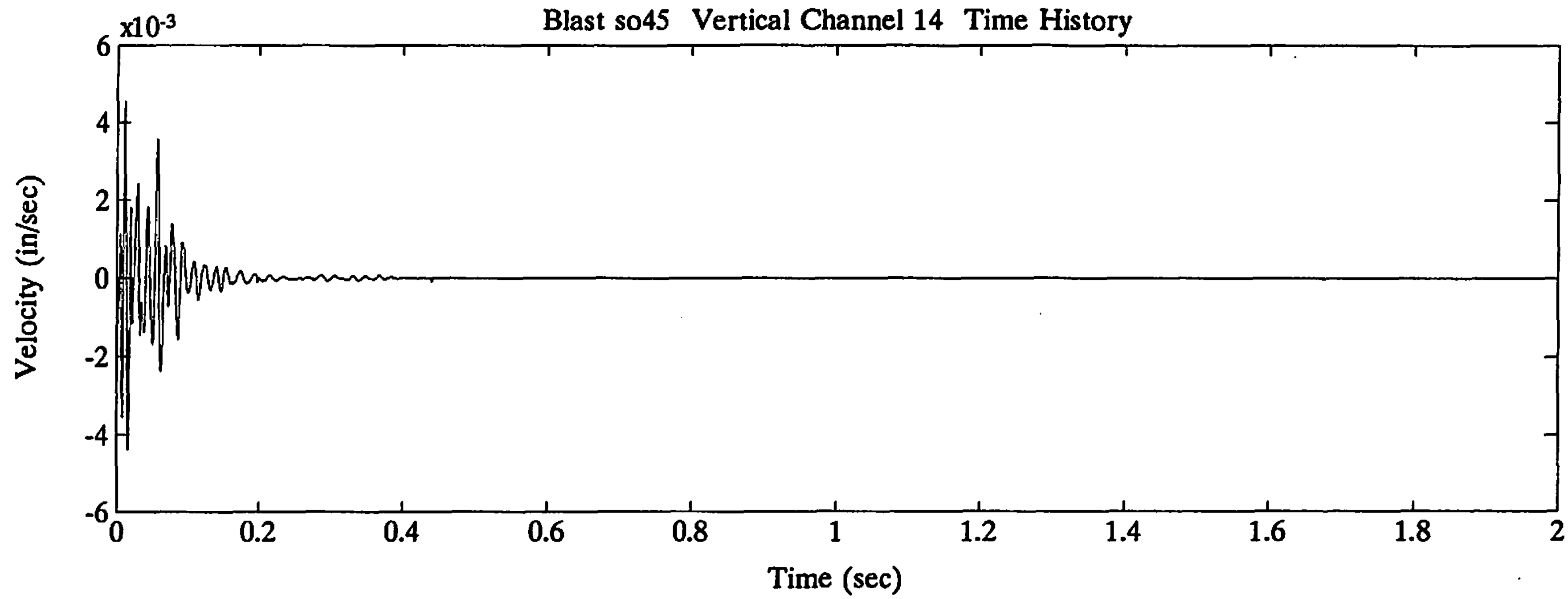
Frequency Spectrum
x10-5
8
6
4
2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

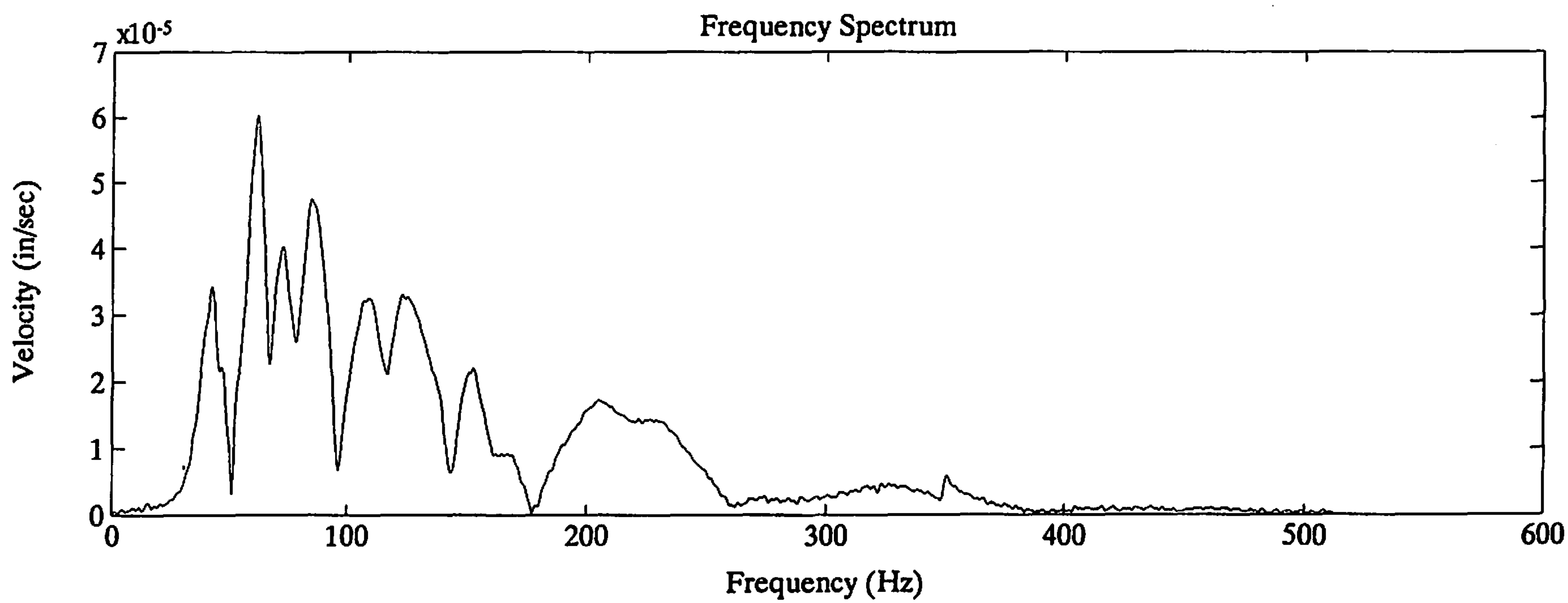

Blast so45 Longitudinal Channel 12 Time History
Velocity (in/sec)
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

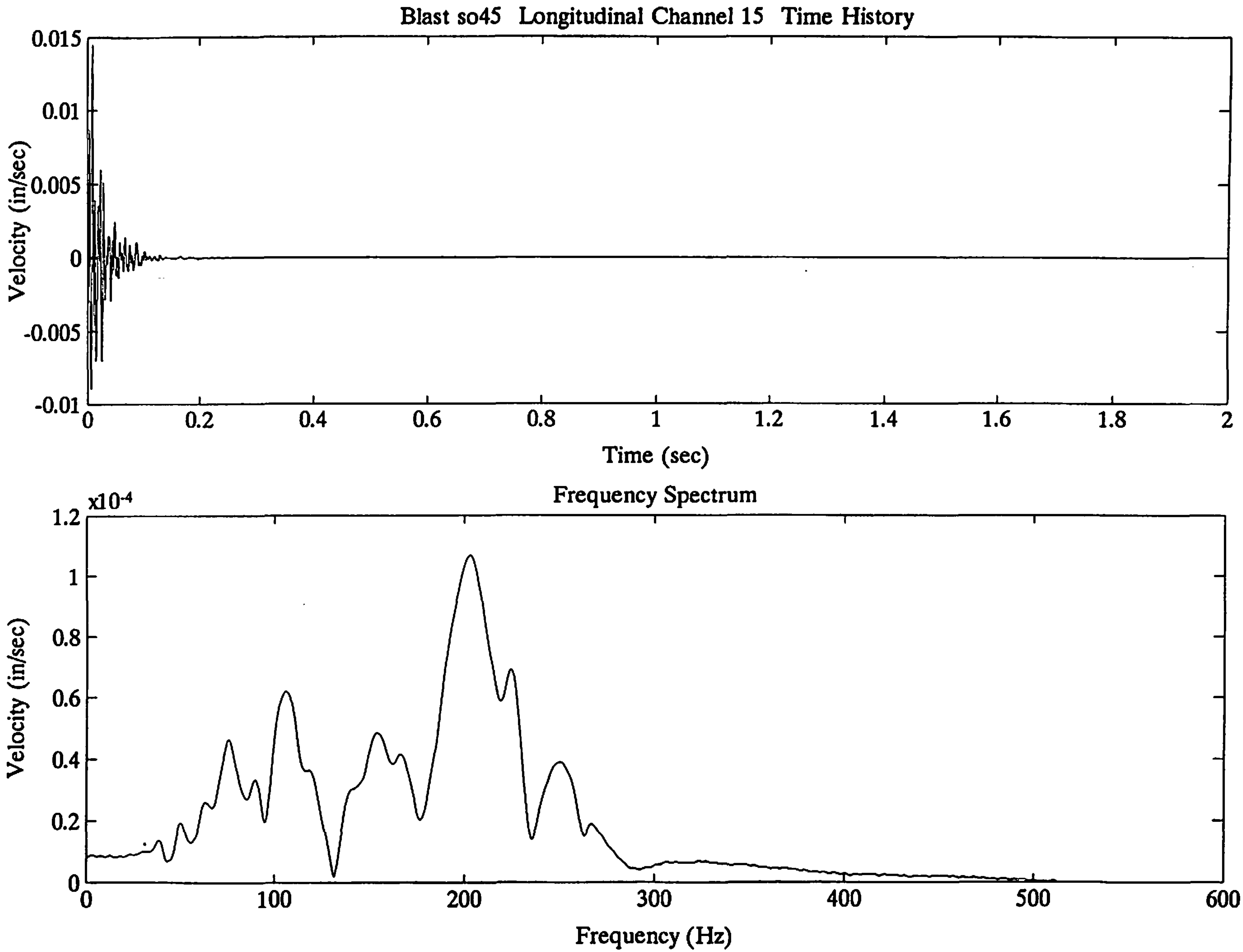

Frequency Spectrum
x10-4
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

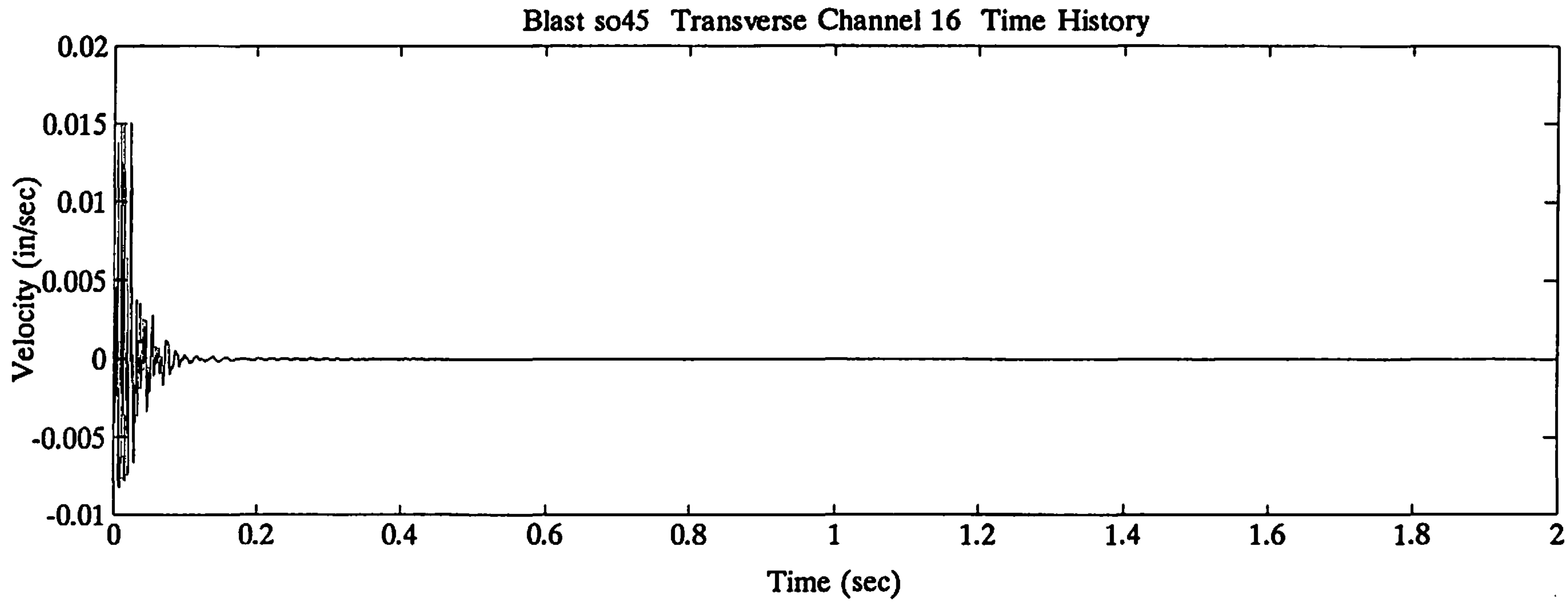

Blast so45 Transverse Channel 13 Time History
Velocity (in/sec)
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

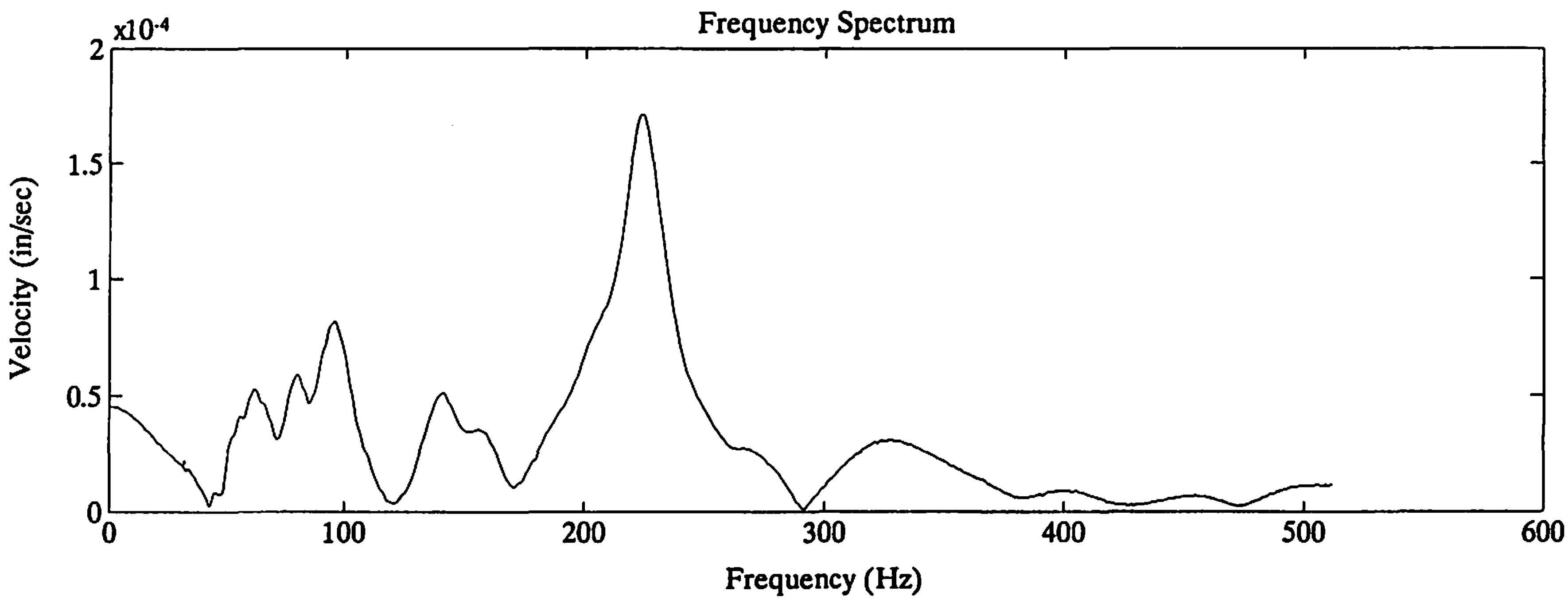

Frequency Spectrum
x10-5
Velocity (in/sec)
8
6
4
2
0
0
100
200
300
400
500
600
Frequency (Hz)

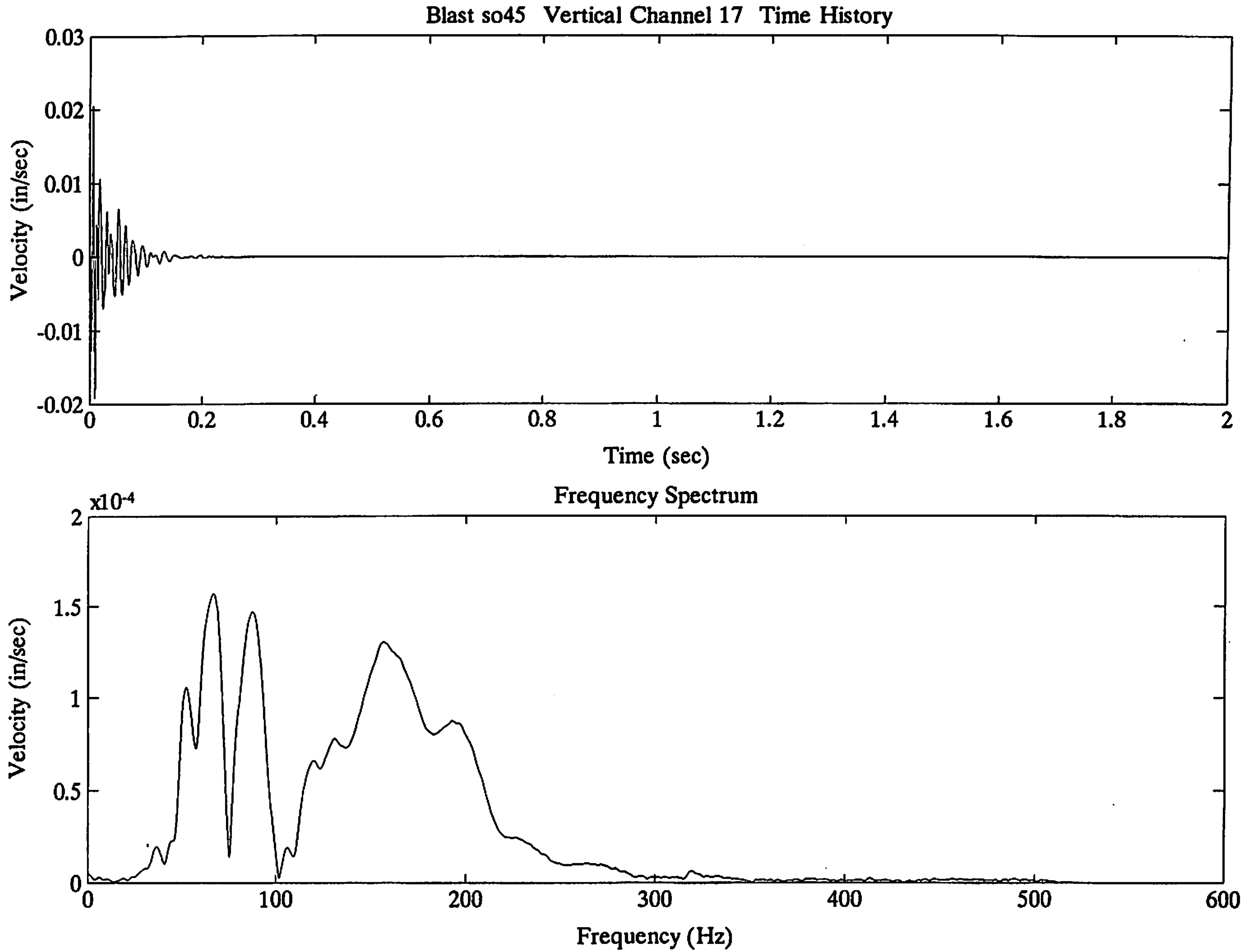

Blast so45 Vertical Channel 14 Time History
x10-3
6
4
2
0
-2
-4
-6
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

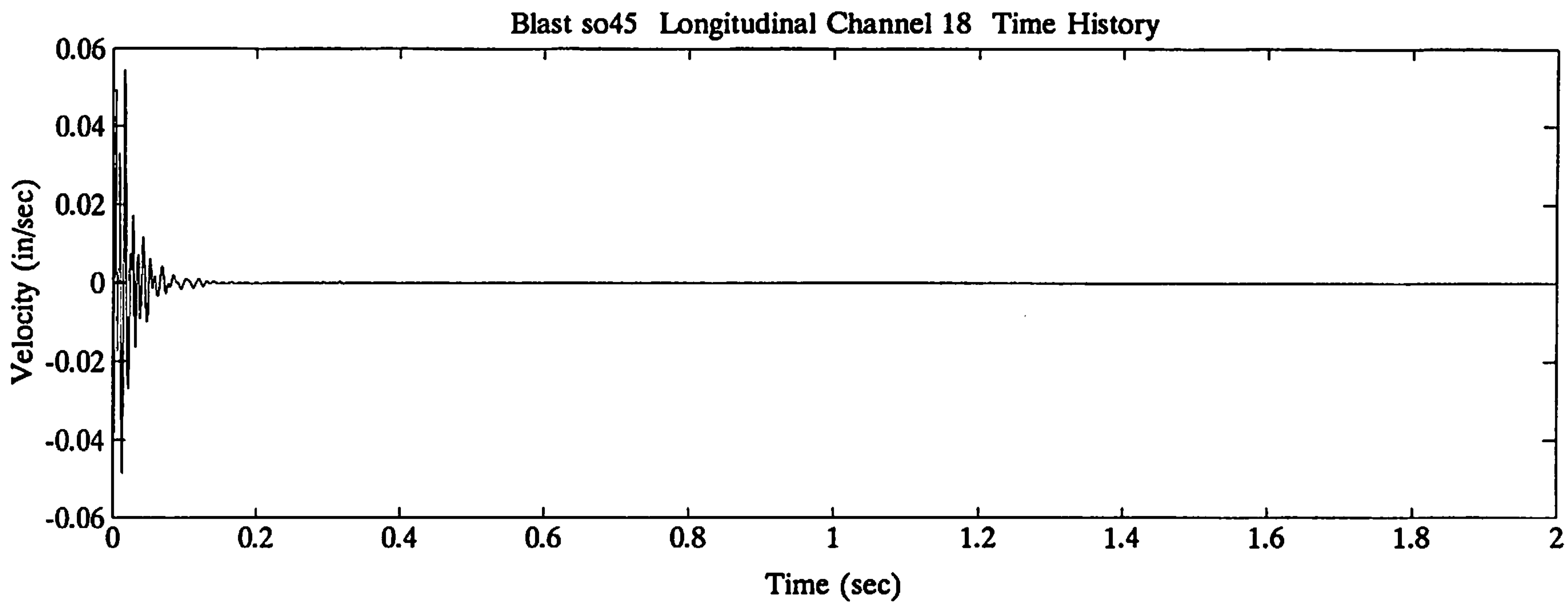

Frequency Spectrum
x10-5
7
6
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so45 Longitudinal Channel 15 Time History
Velocity (in/sec)
0.015
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
100
200
300
400
500
600
Frequency (Hz)

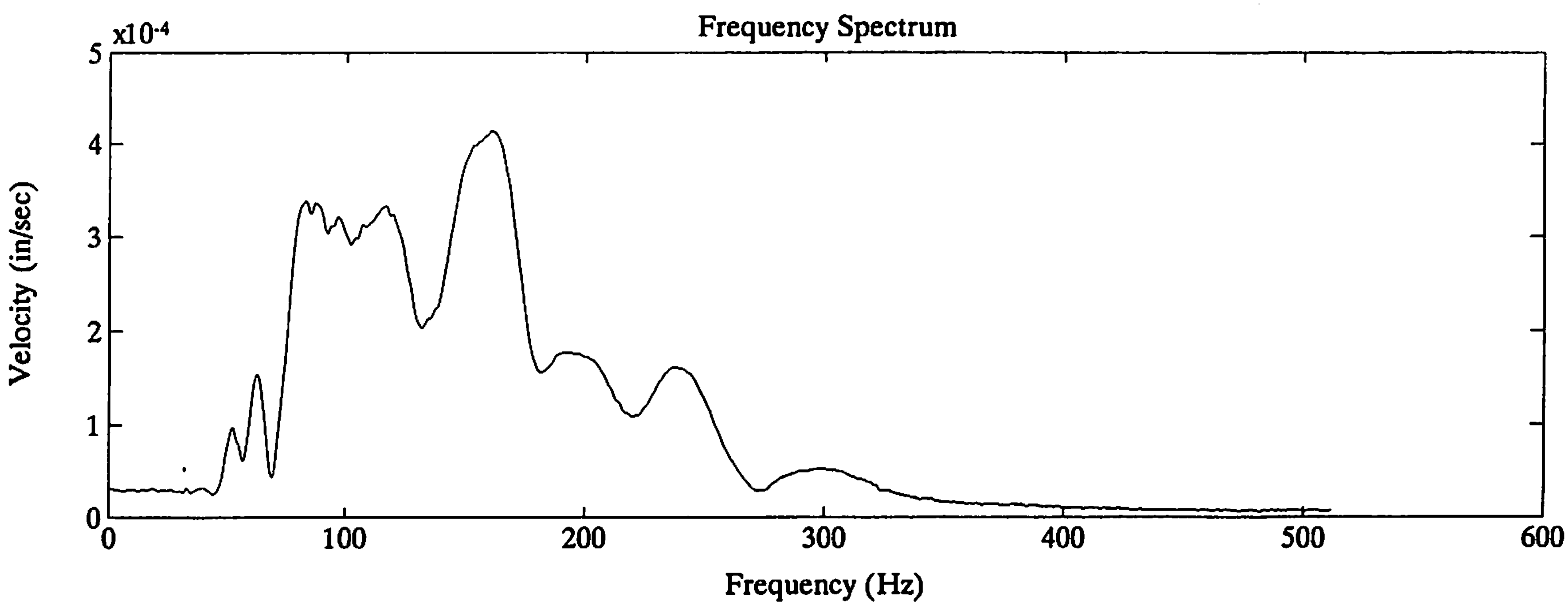

Blast so45 Transverse Channel 16 Time History
Velocity (in/sec)
Time (sec)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)
2
1.5
1
0.5
0
0
100
200
300
400
500
600

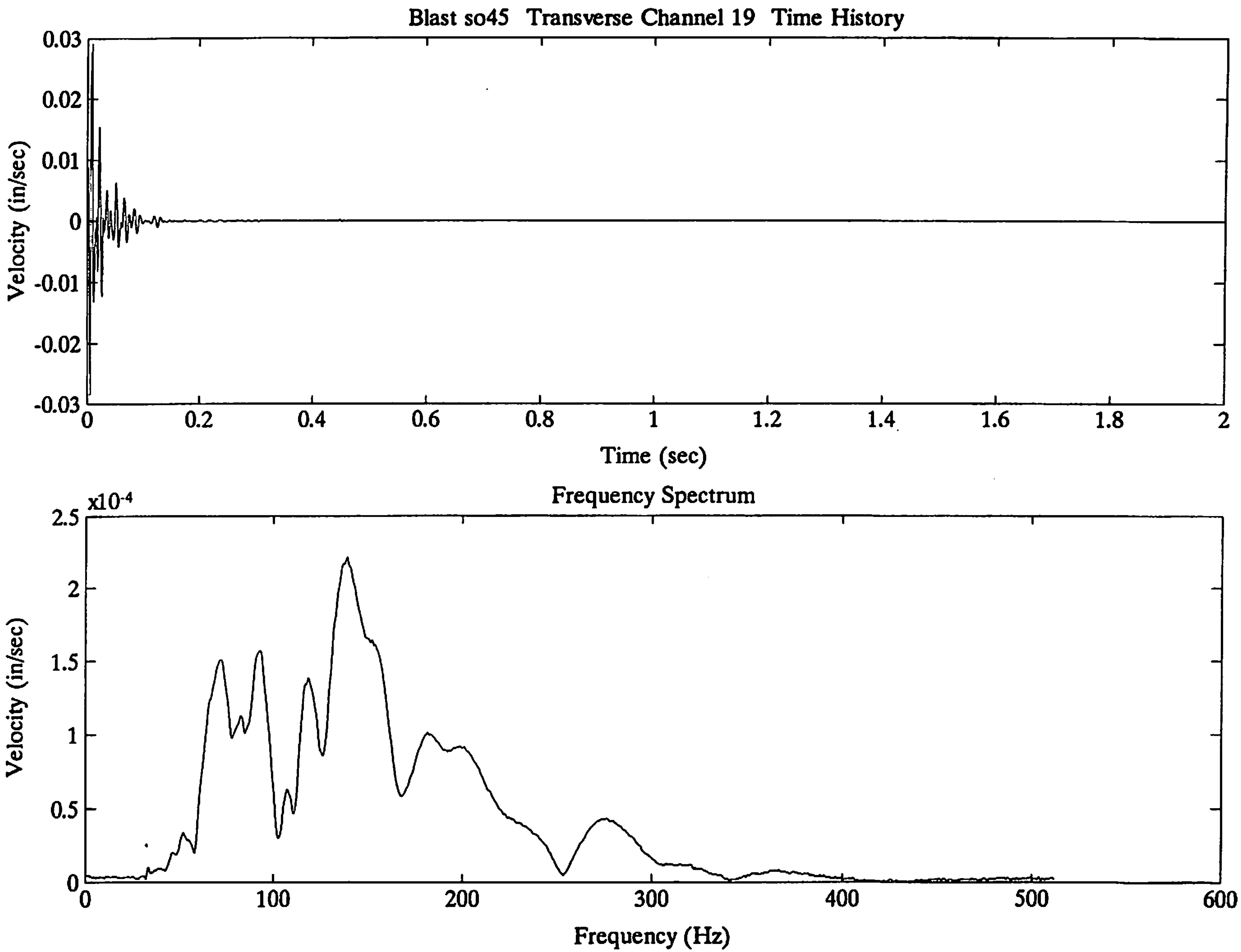

Blast so45 Vertical Channel 17 Time History
Velocity (in/sec)
0.03
0.02
0.01
0
-0.01
-0.02
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10^-4
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)



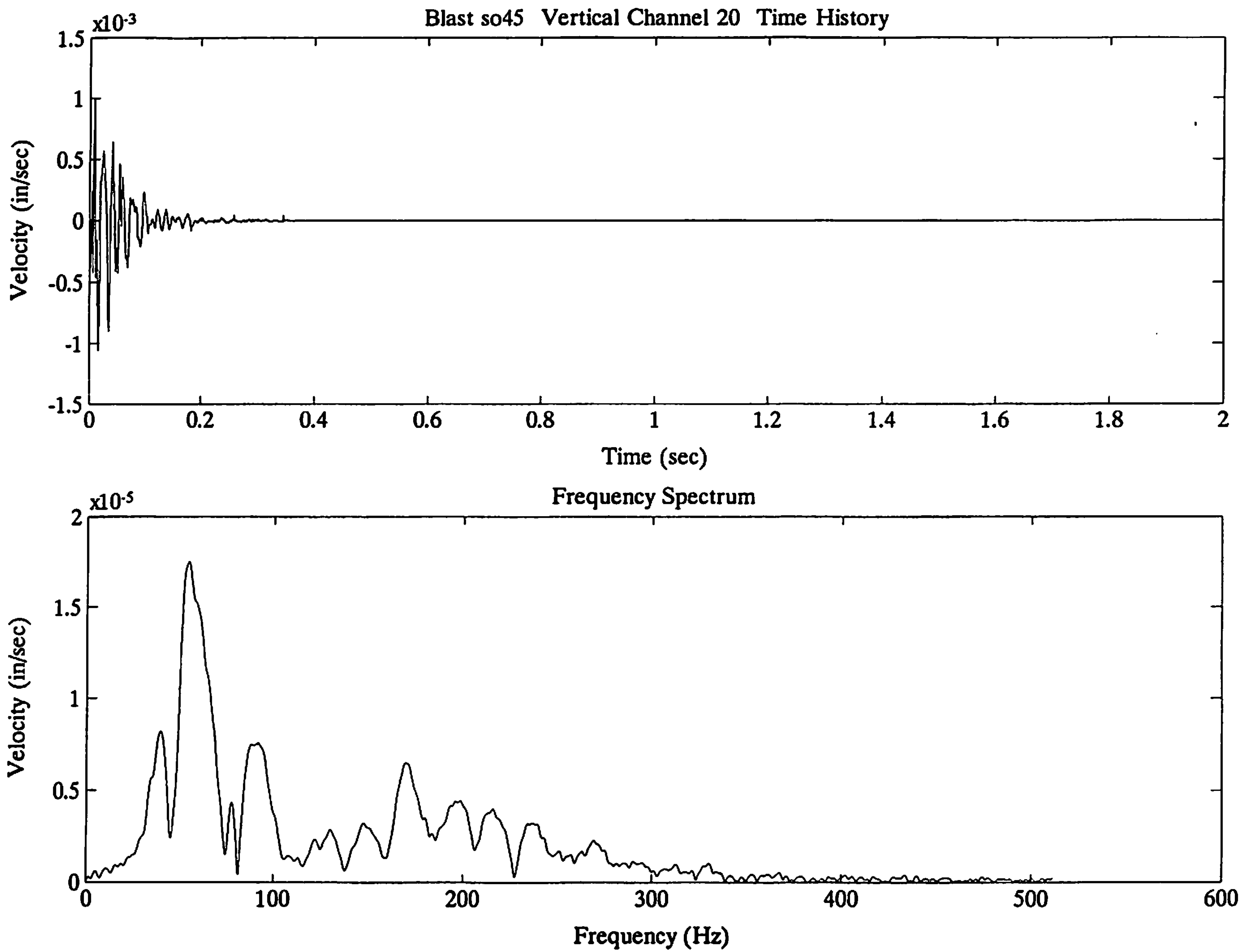
Blast so45 Longitudinal Channel 18 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



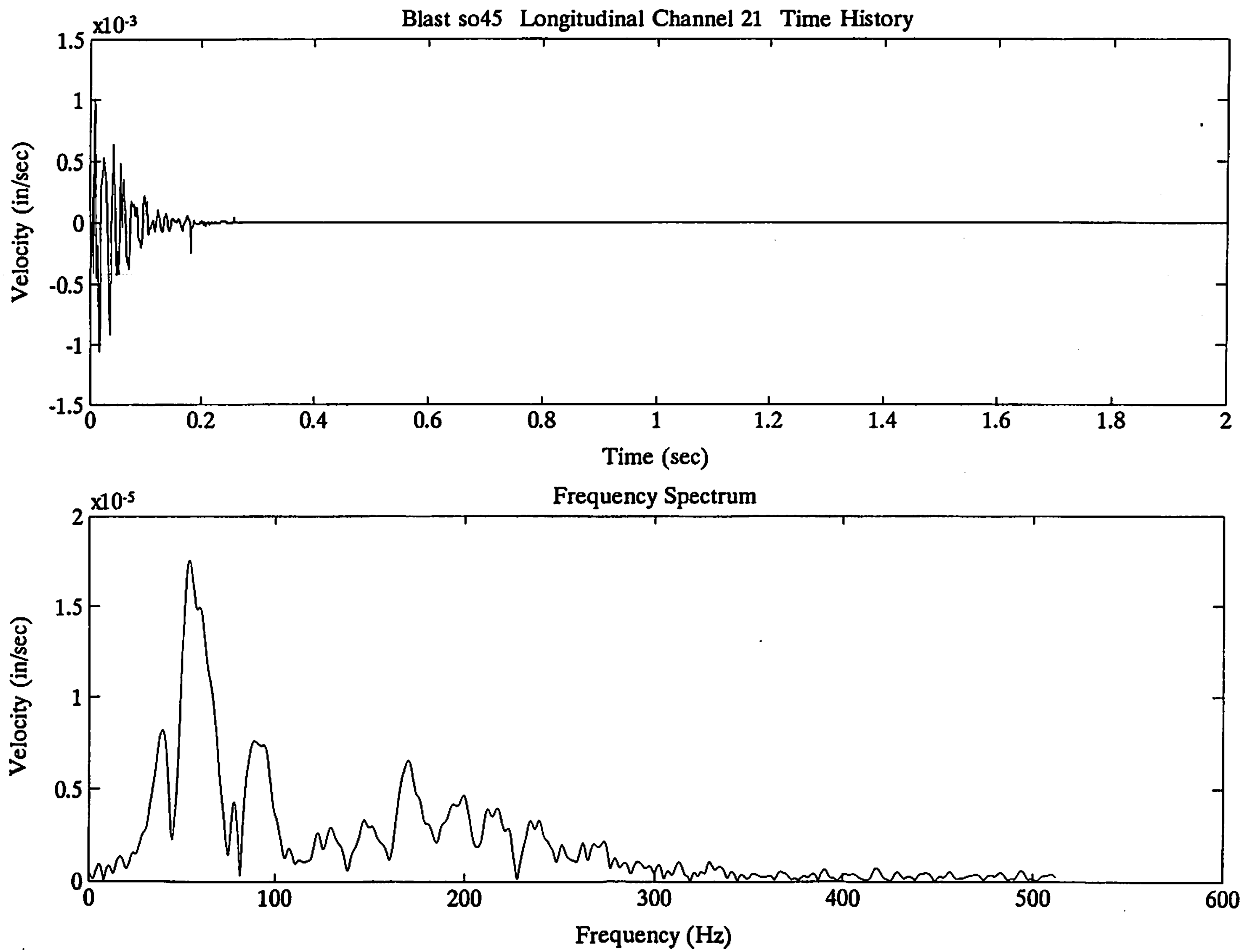
Frequency Spectrum
x10-4
Velocity (in/sec)
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

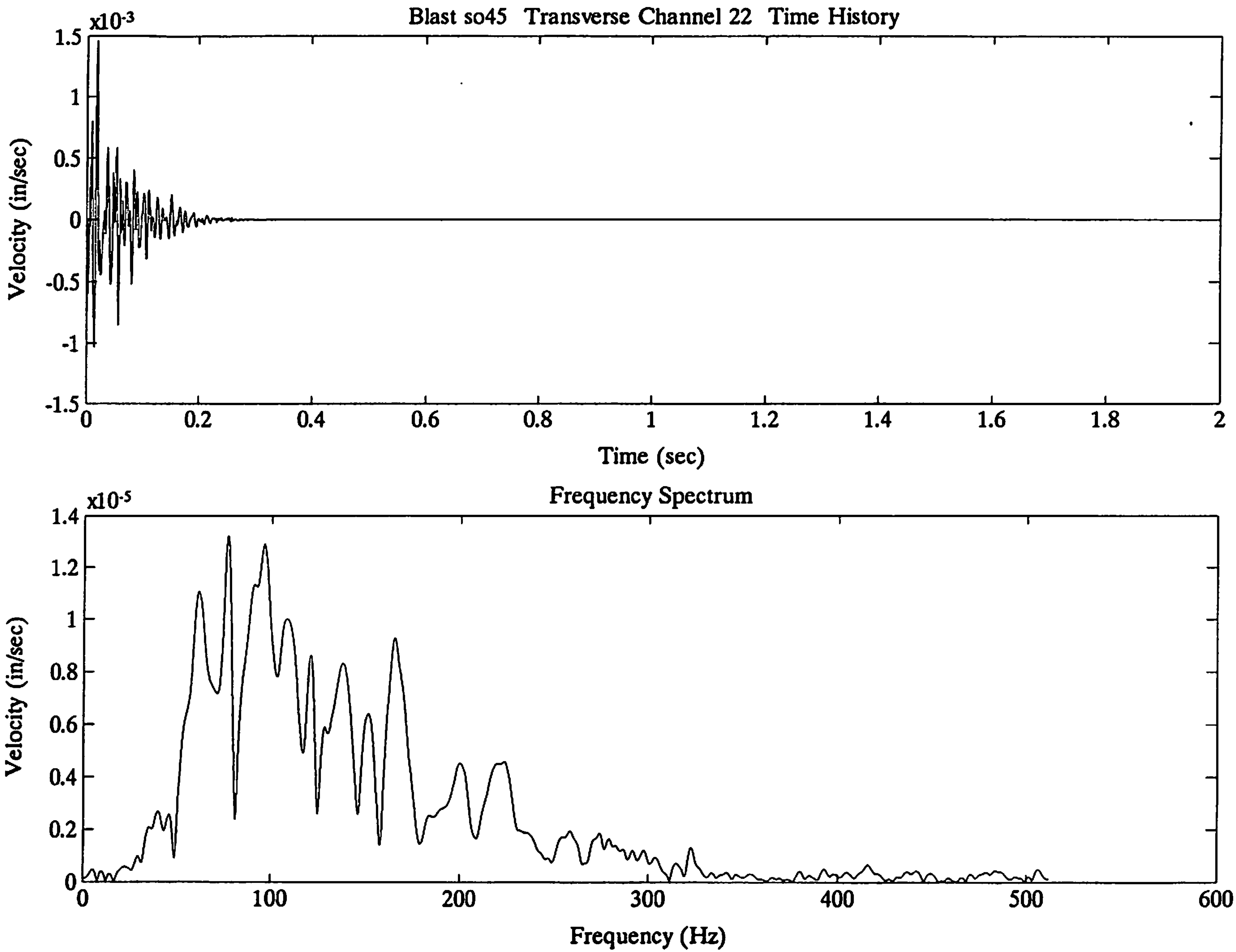


Blast so45 Transverse Channel 19 Time History
Velocity (in/sec)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

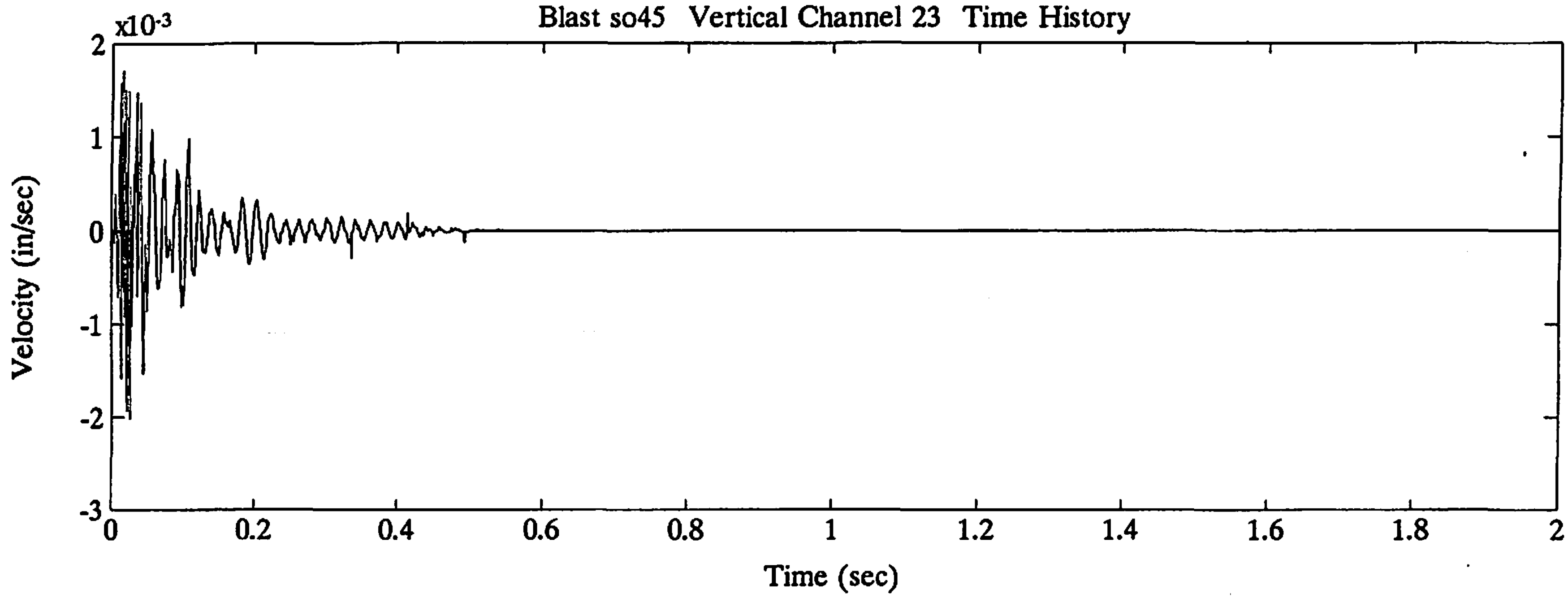


Blast so45 Vertical Channel 20 Time History
x10-3
Velocity (in/sec)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-5
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

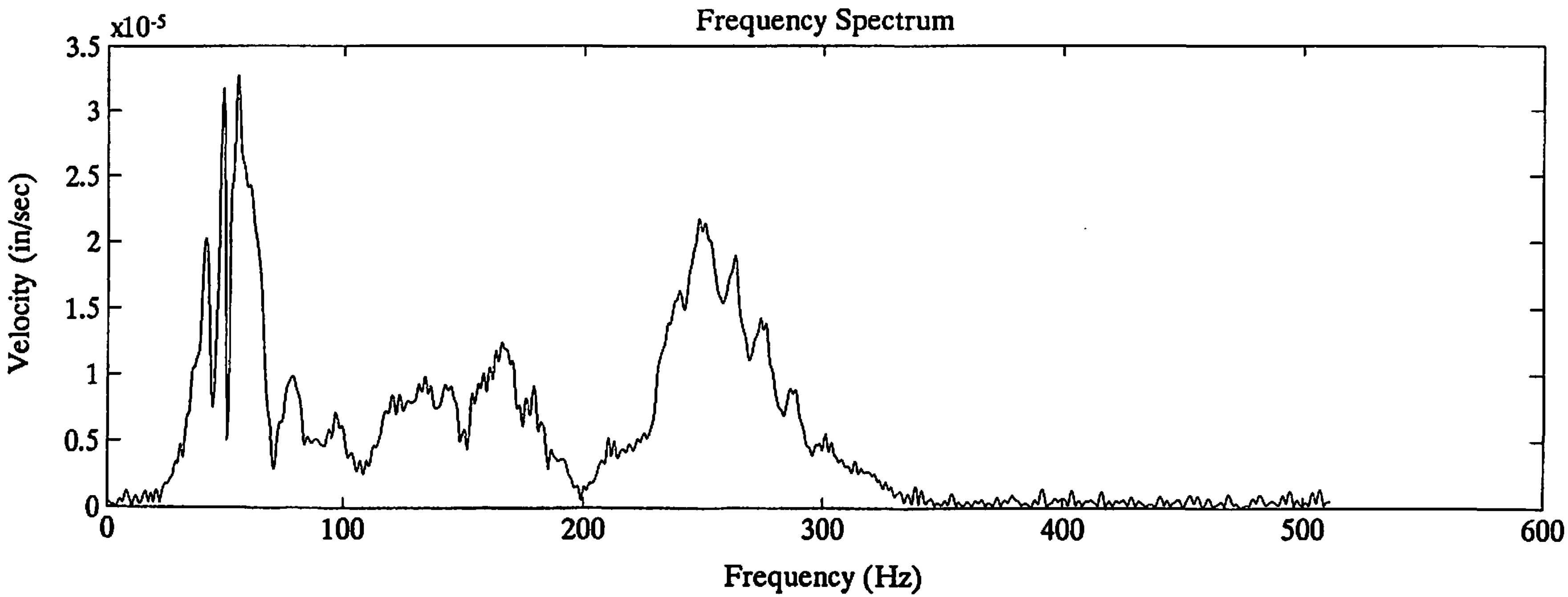

Blast so45 Longitudinal Channel 21 Time History
x10-3
Velocity (in/sec)
Time (sec)
Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)



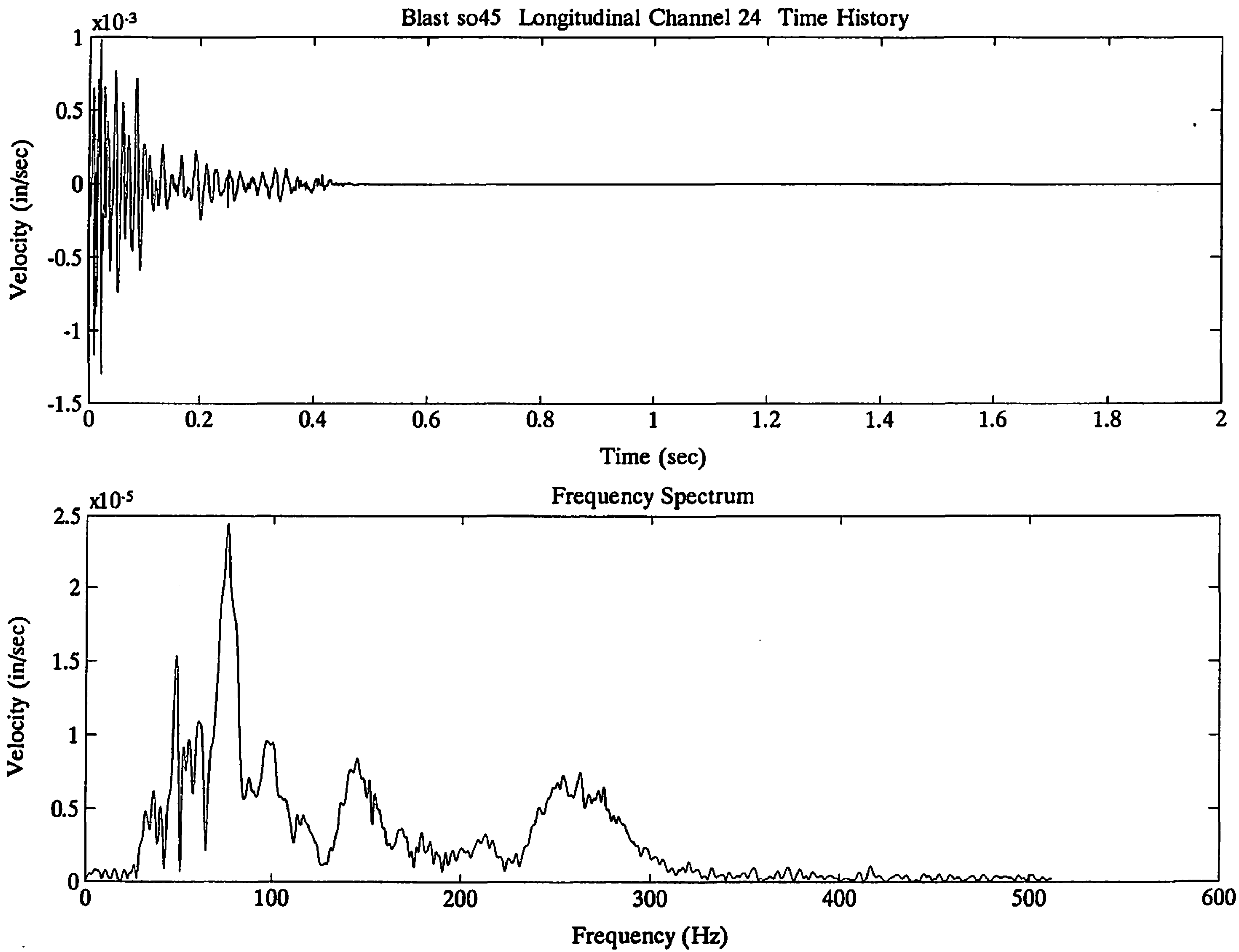
Blast so45 Transverse Channel 22 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-5
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

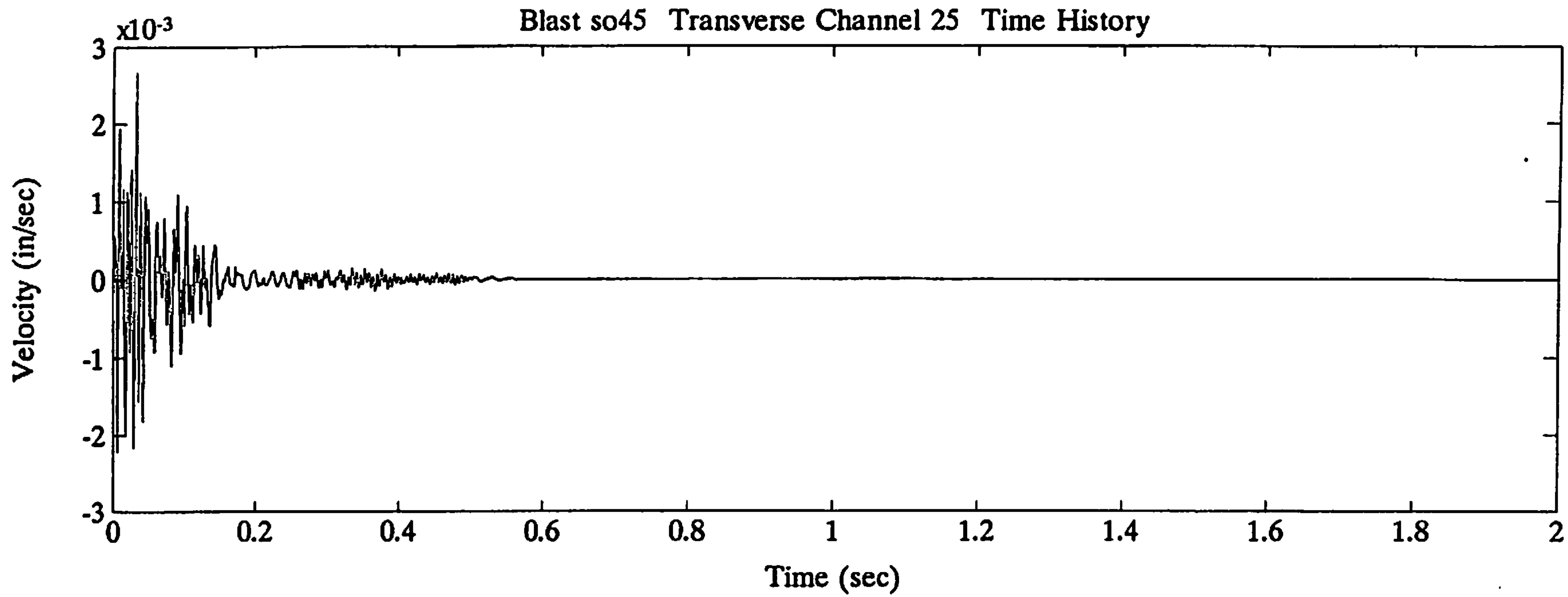


Blast so45 Vertical Channel 23 Time History
x10-3
Velocity (in/sec)
Time (sec)

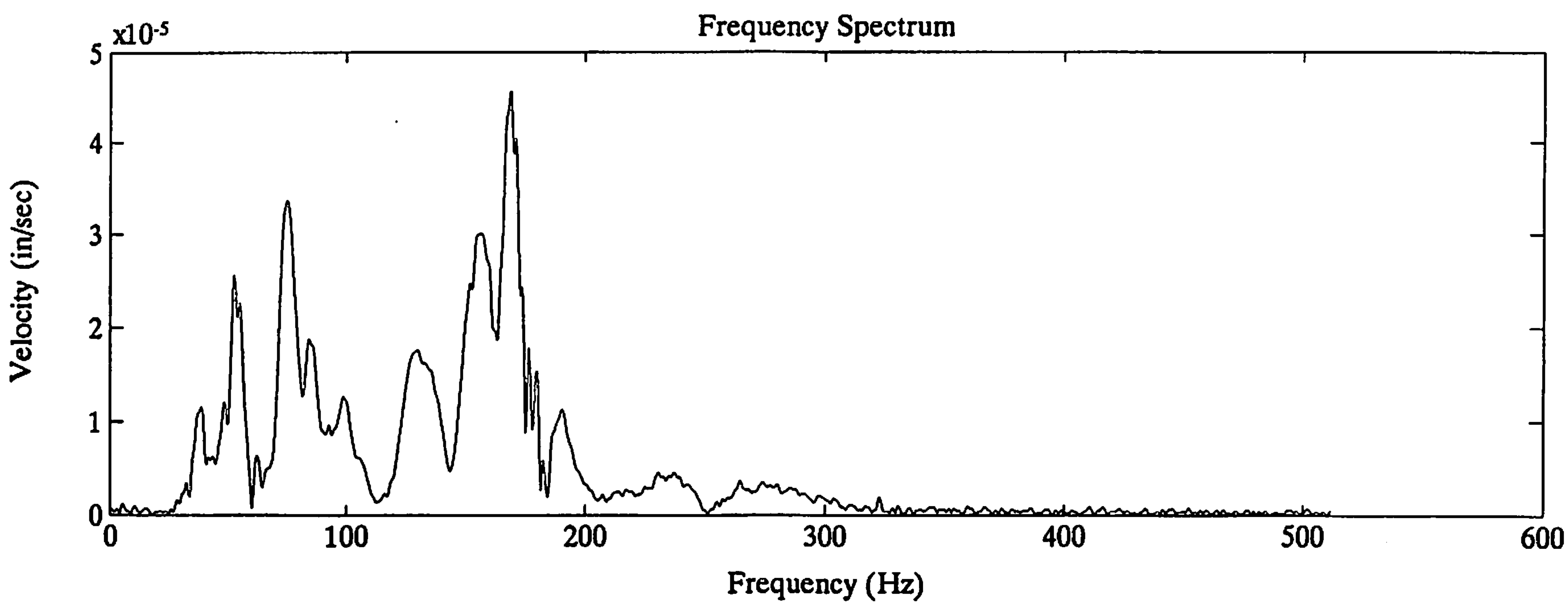


Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)

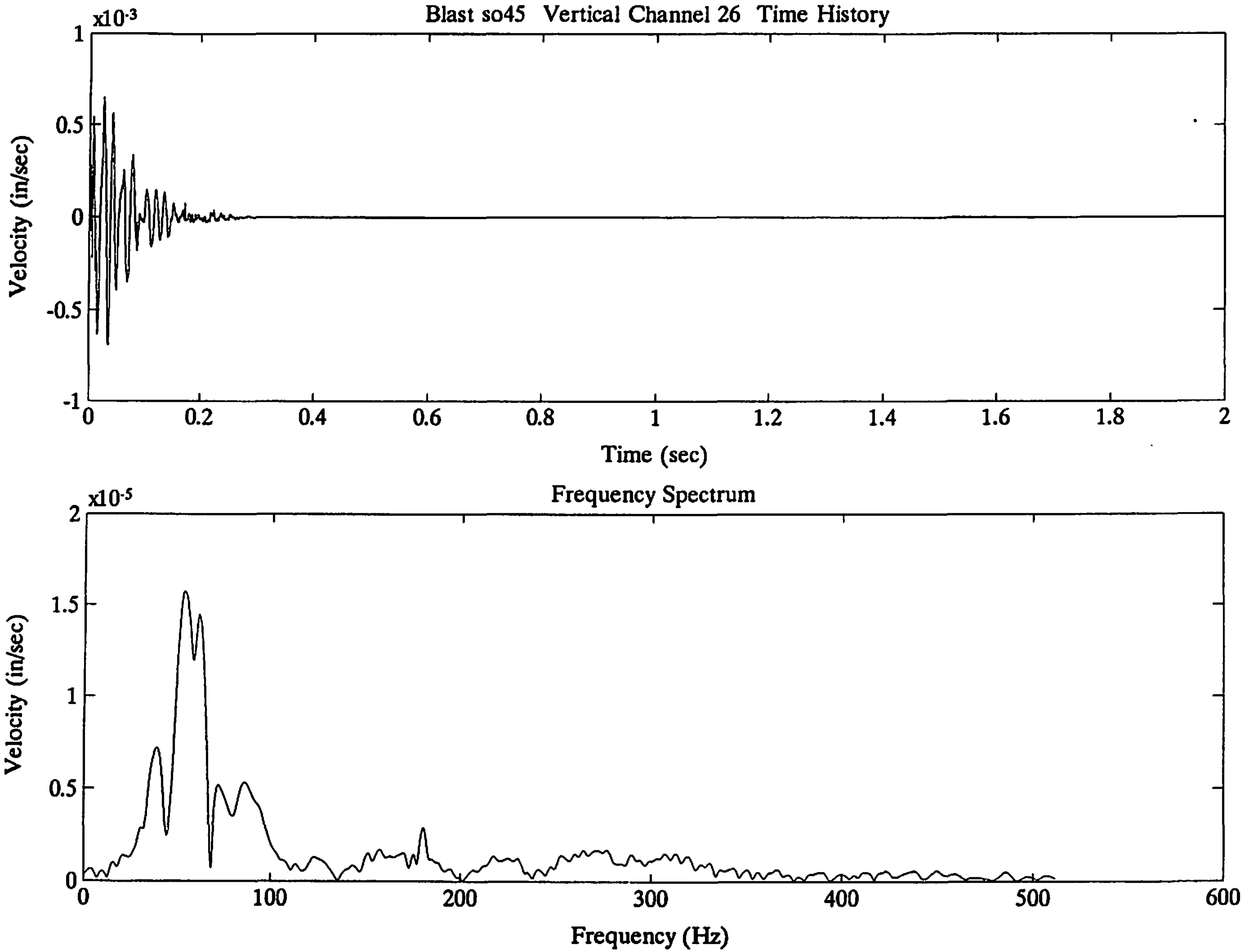

Blast so45 Longitudinal Channel 24 Time History
x10-3
Velocity (in/sec)
Time (sec)
Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)

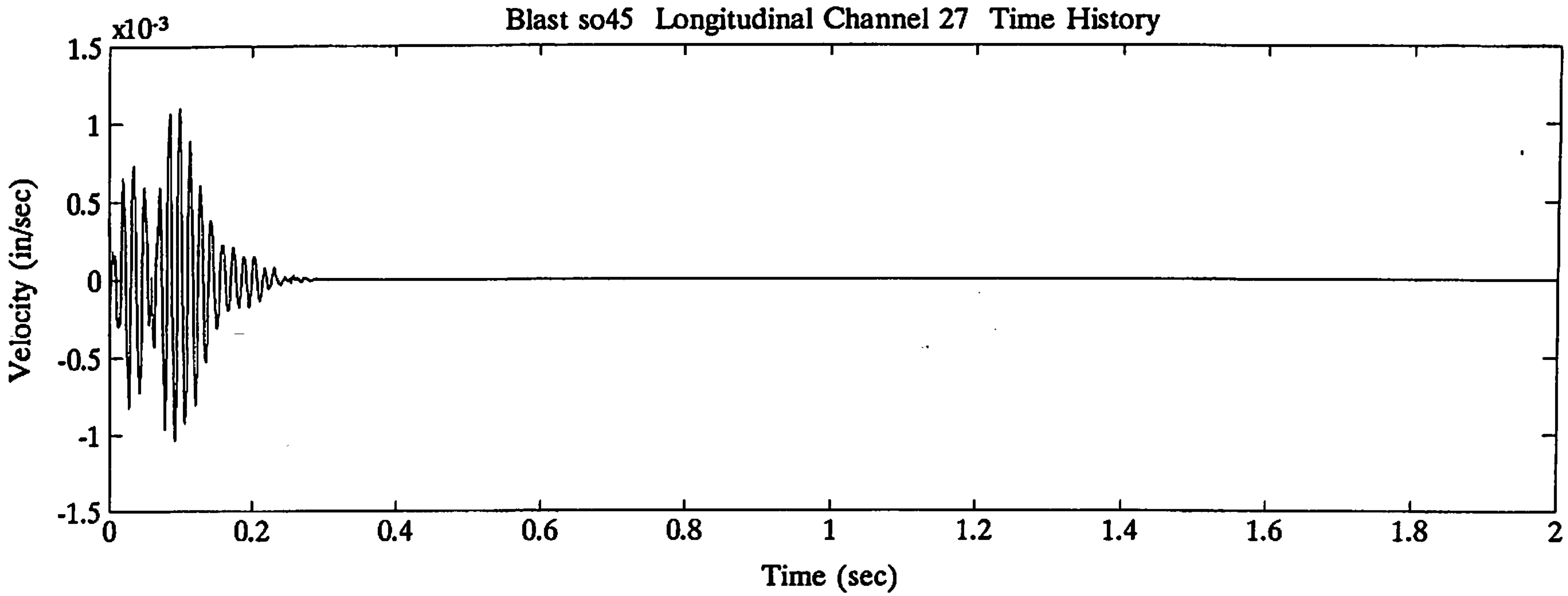


Blast so45 Transverse Channel 25 Time History
x10^-3
3
2
1
0
-1
-2
-3
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

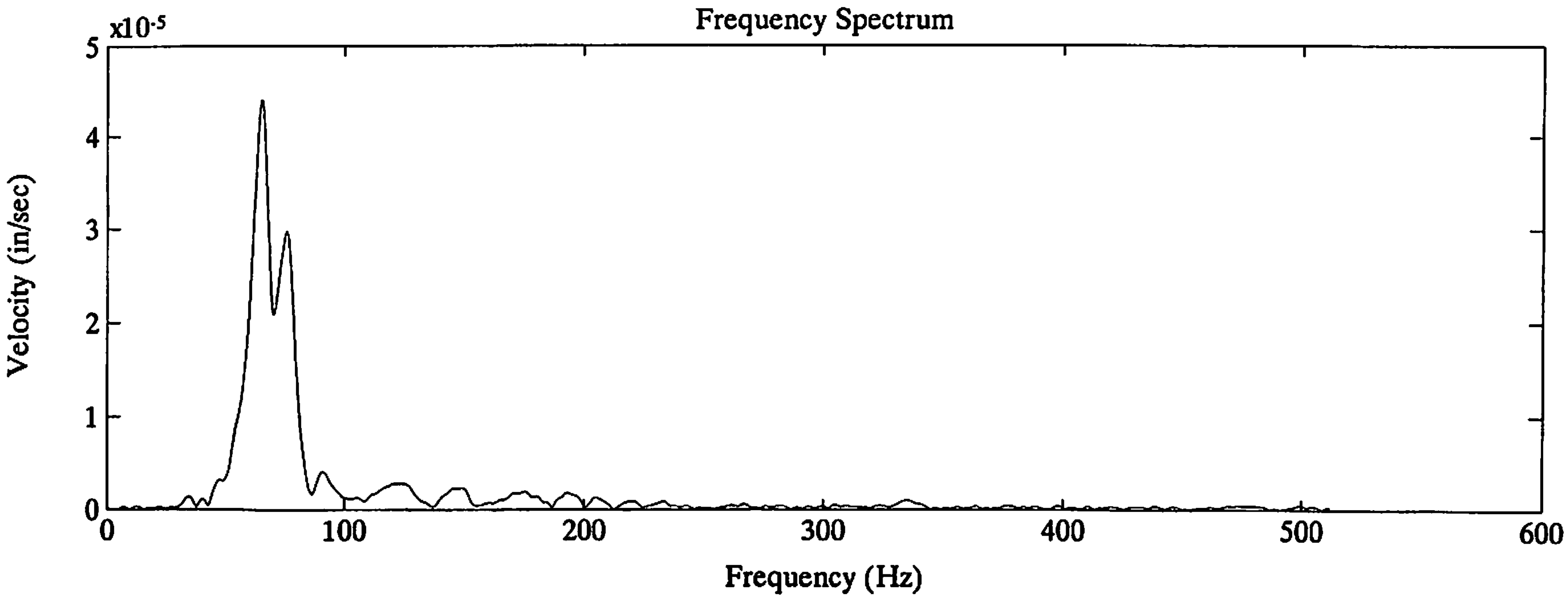


Frequency Spectrum
x10^-5
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

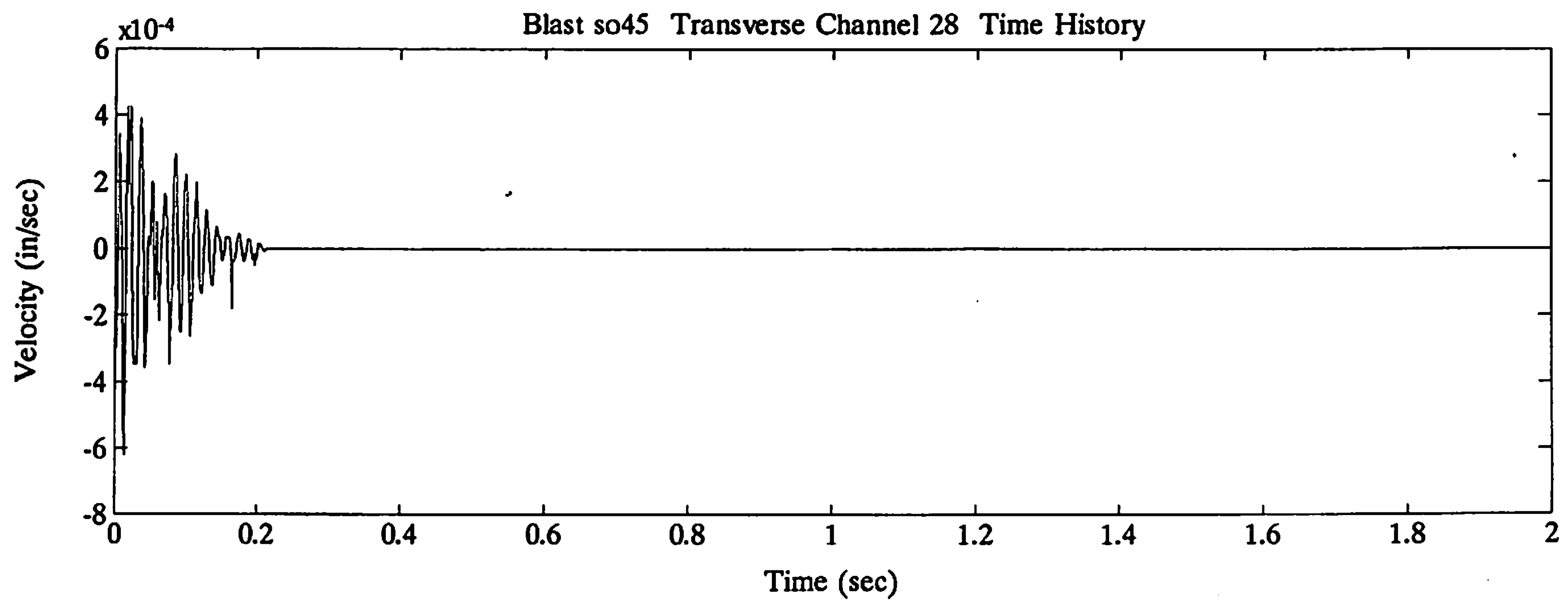

Blast so45 Vertical Channel 26 Time History
x10-3
1
0.5
0
-0.5
-1
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

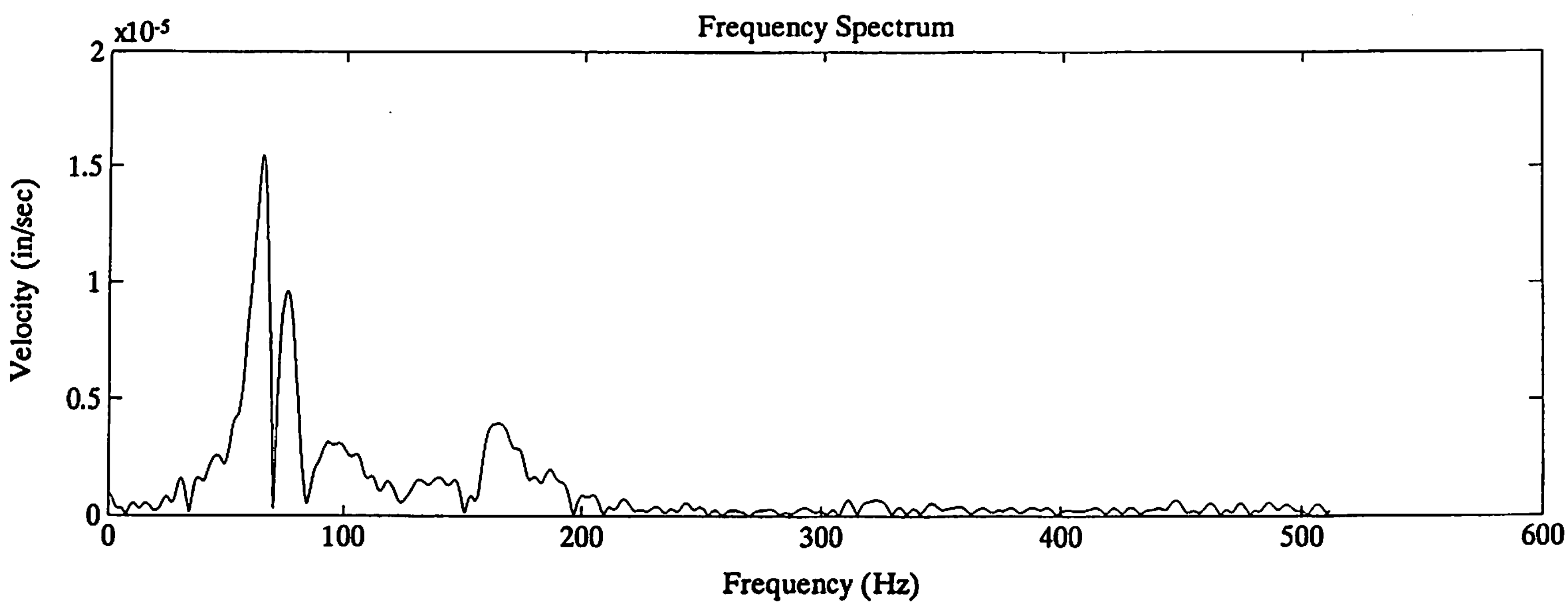


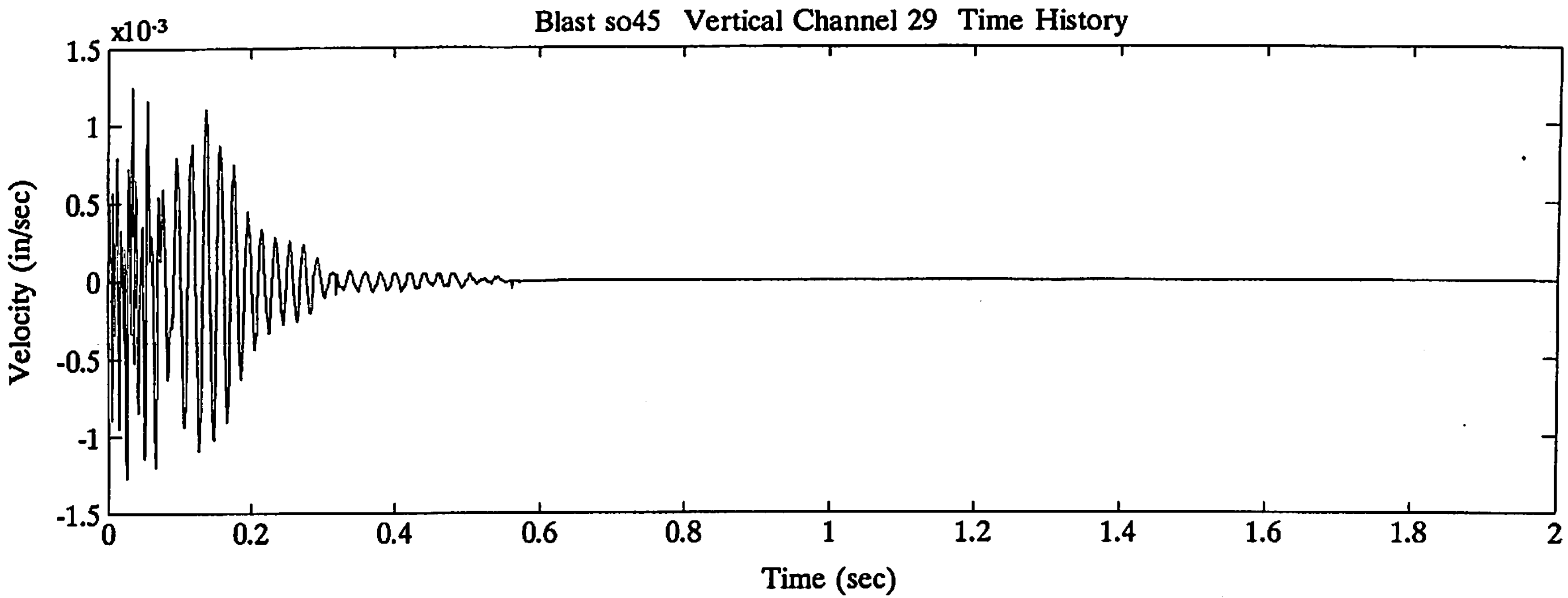
Blast so45 Longitudinal Channel 27 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

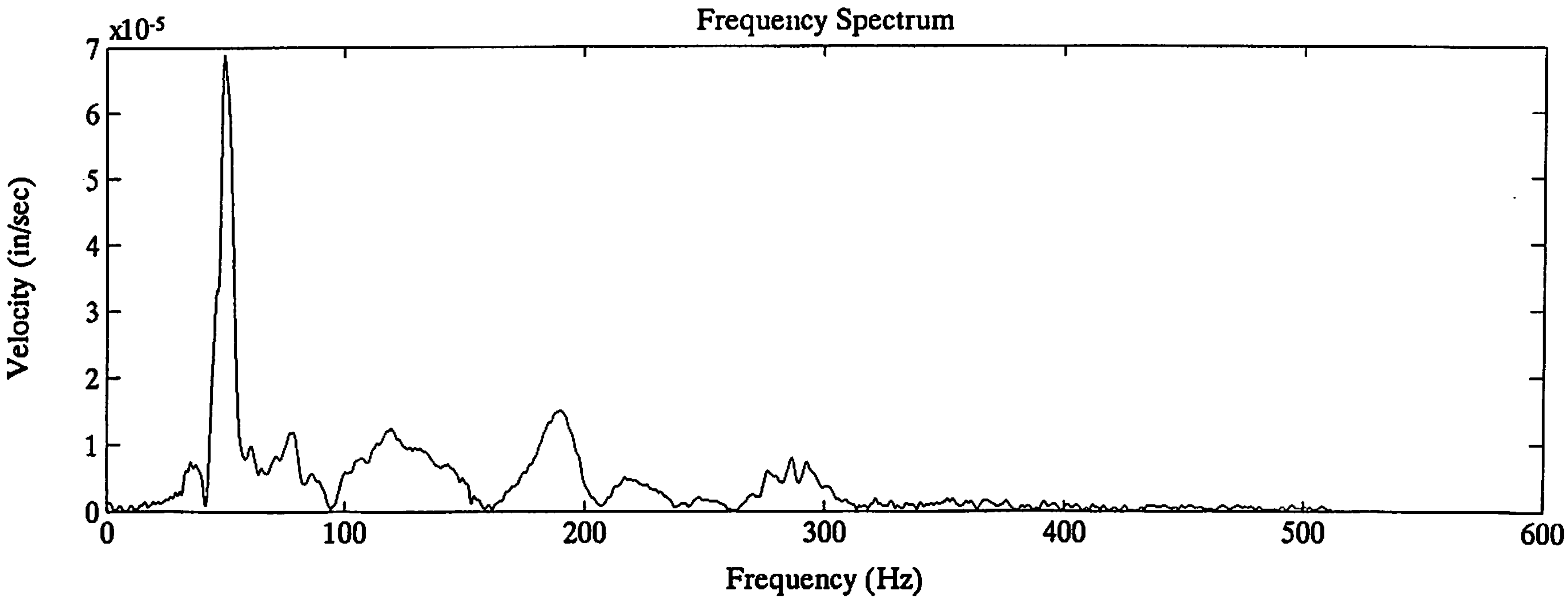


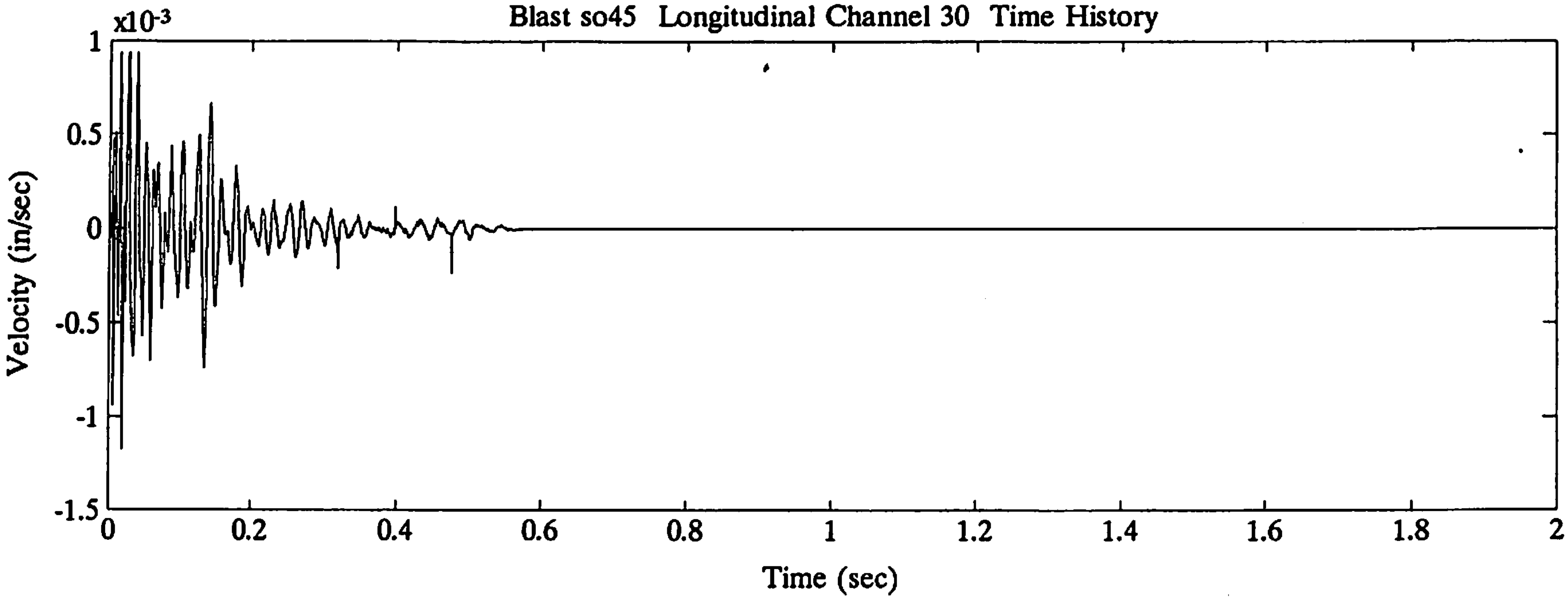
Frequency Spectrum
x10-5
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so45 Transverse Channel 28 Time History
x10-4
Velocity (in/sec)
6
4
2
0
-2
-4
-6
-8
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

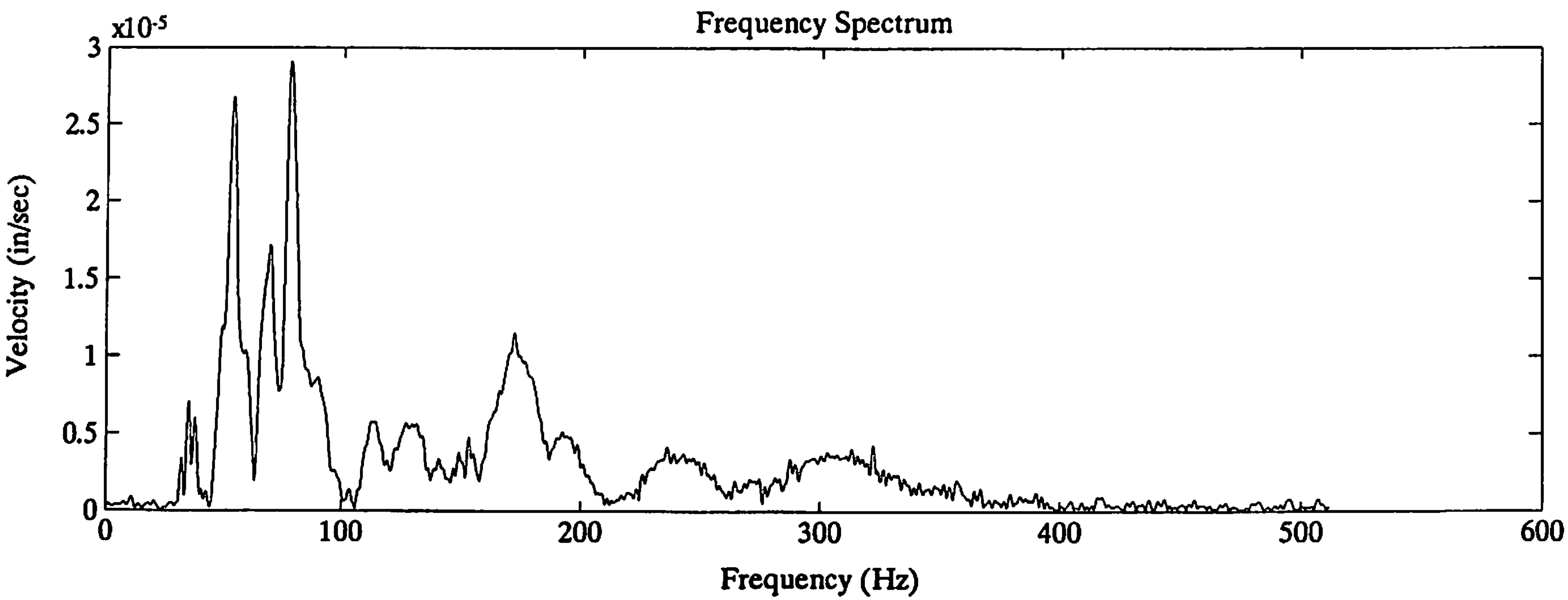

Frequency Spectrum
x10-5
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so45 Vertical Channel 29 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

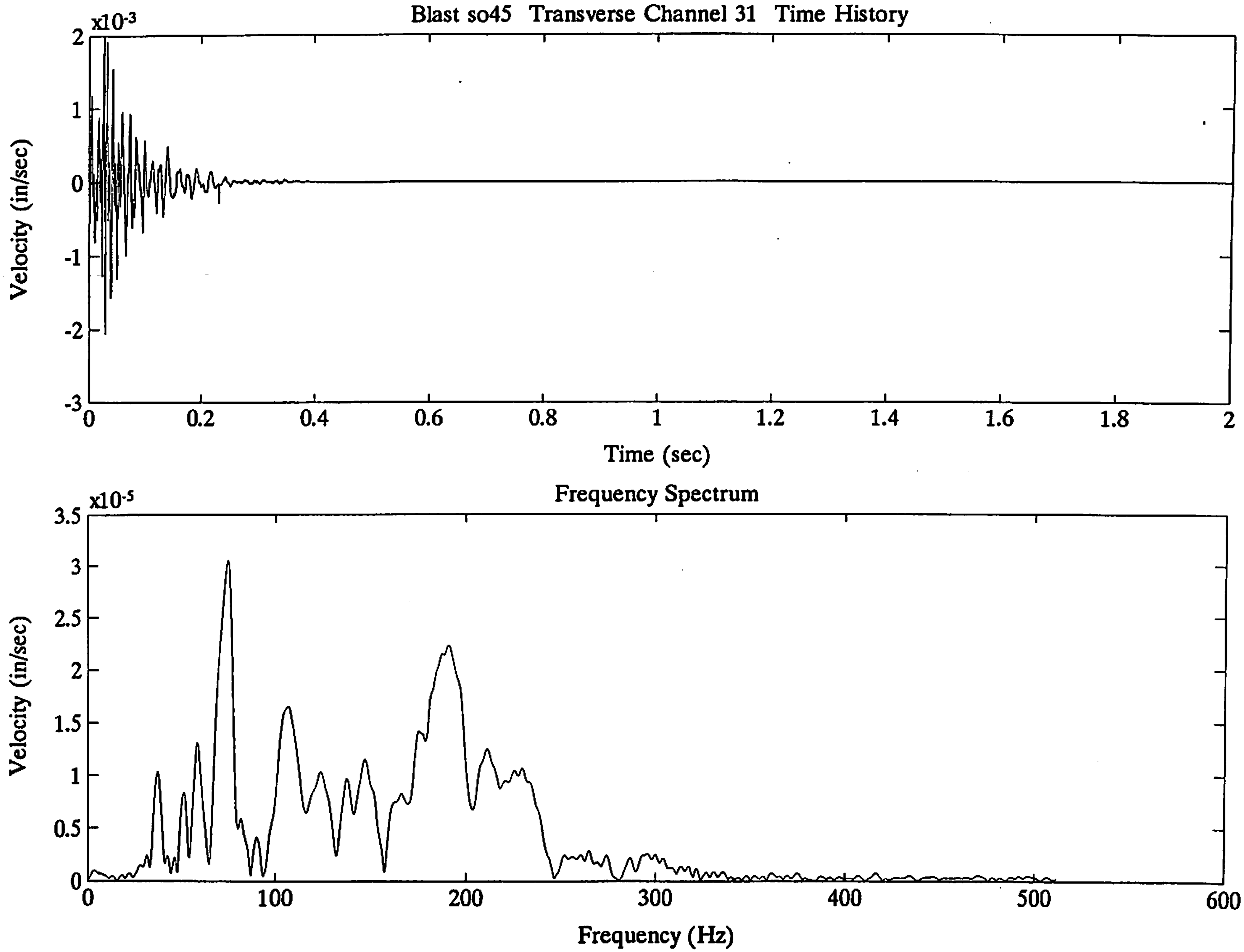

Frequency Spectrum
x10-5
7
6
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

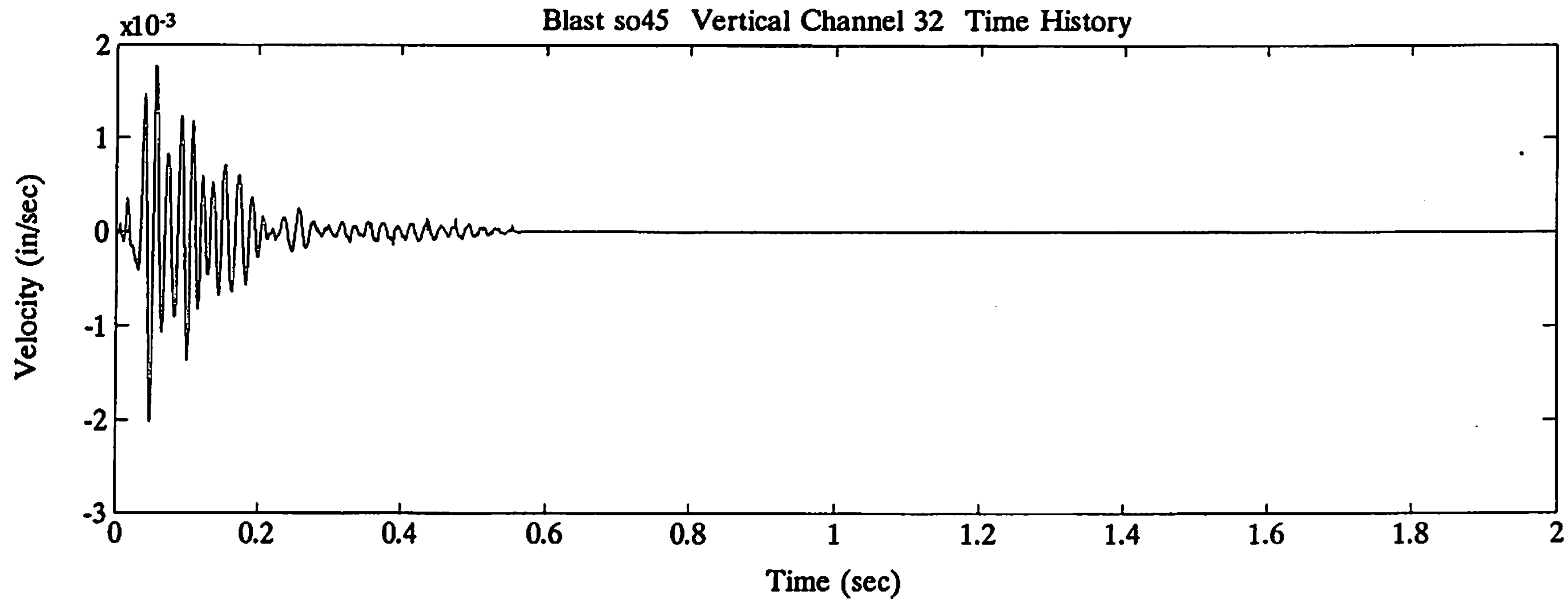


Blast so45 Longitudinal Channel 30 Time History
x10-3
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

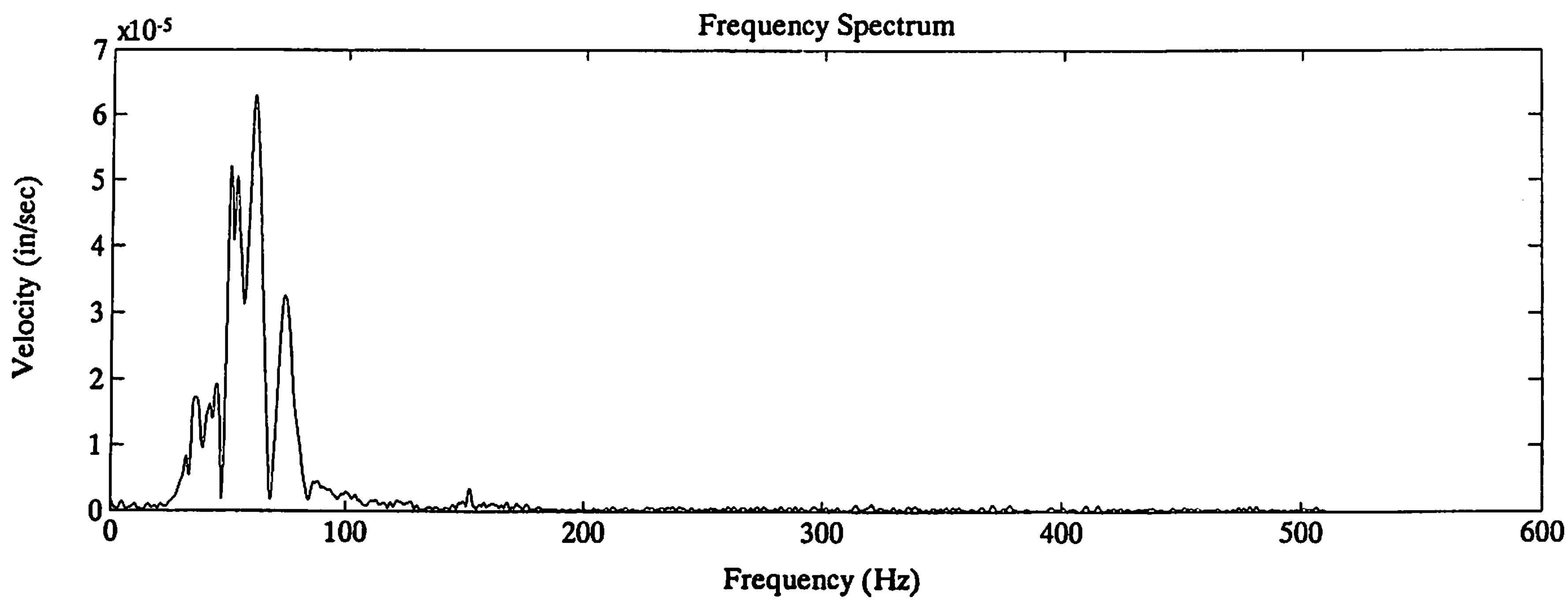


Frequency Spectrum
x10-5
3
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

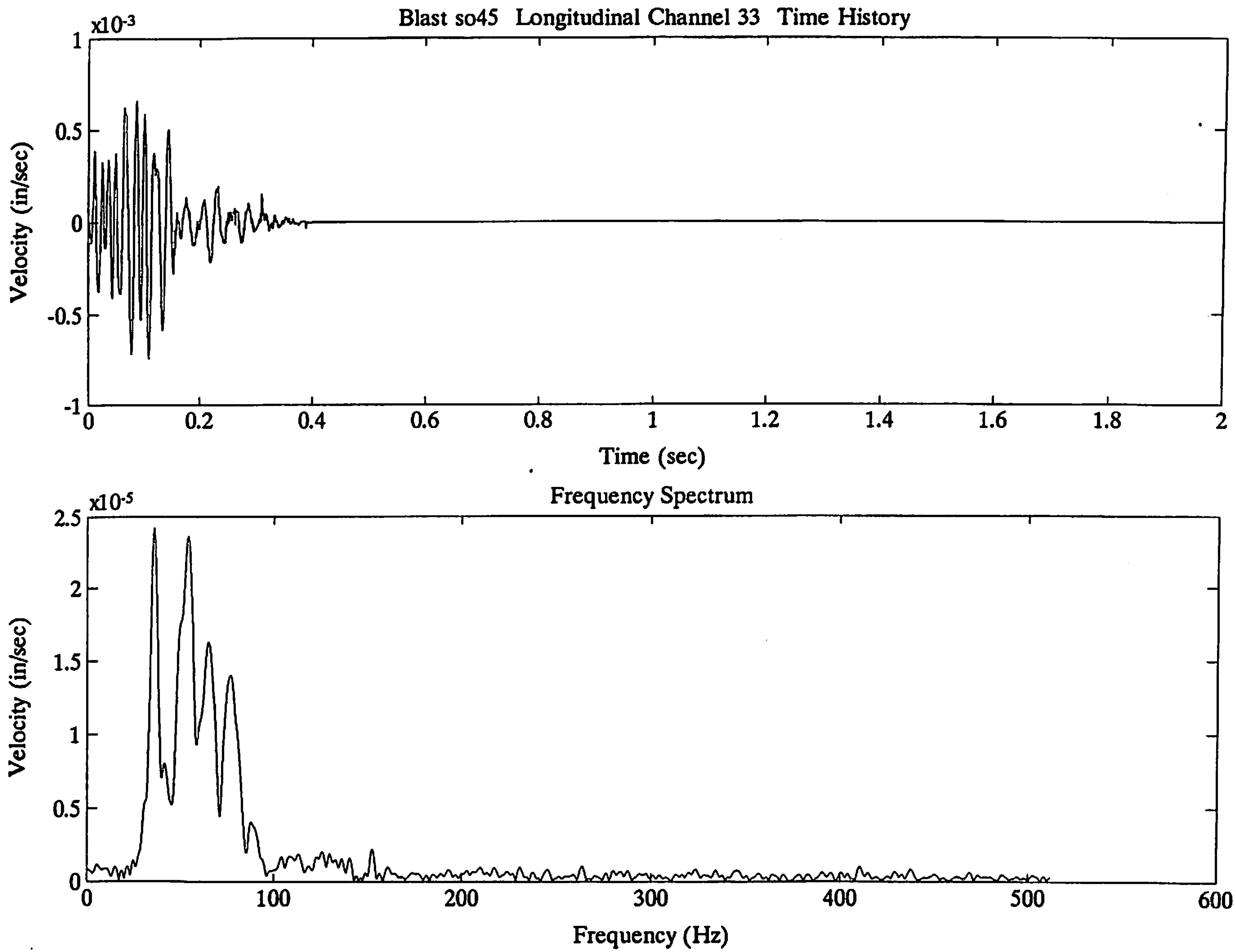

Blast so45 Transverse Channel 31 Time History
x10-3
Velocity (in/sec)
Time (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
-3
-2
-1
1
Frequency Spectrum
x10-5
3.5
3
2.5
2
1.5
0.5
100
200
300
400
500
600
Frequency (Hz)



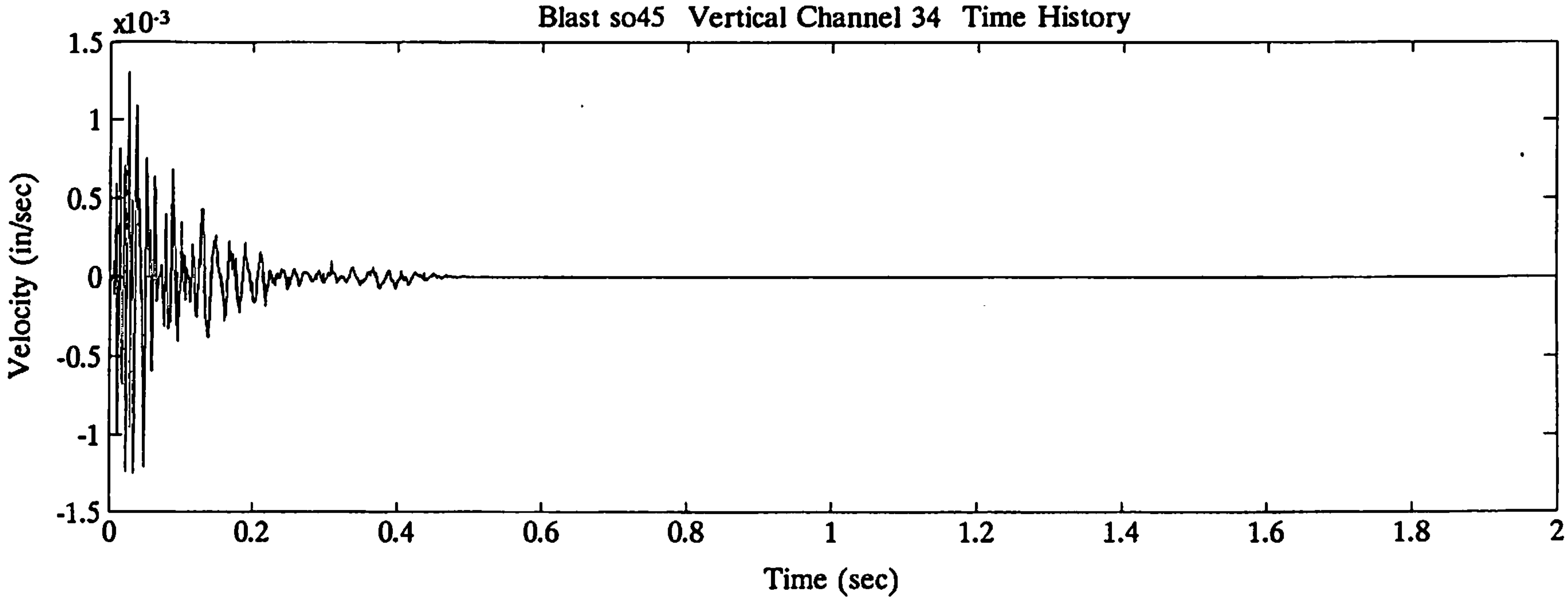
Blast so45 Vertical Channel 32 Time History
x10-3
2
1
0
-1
-2
-3
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



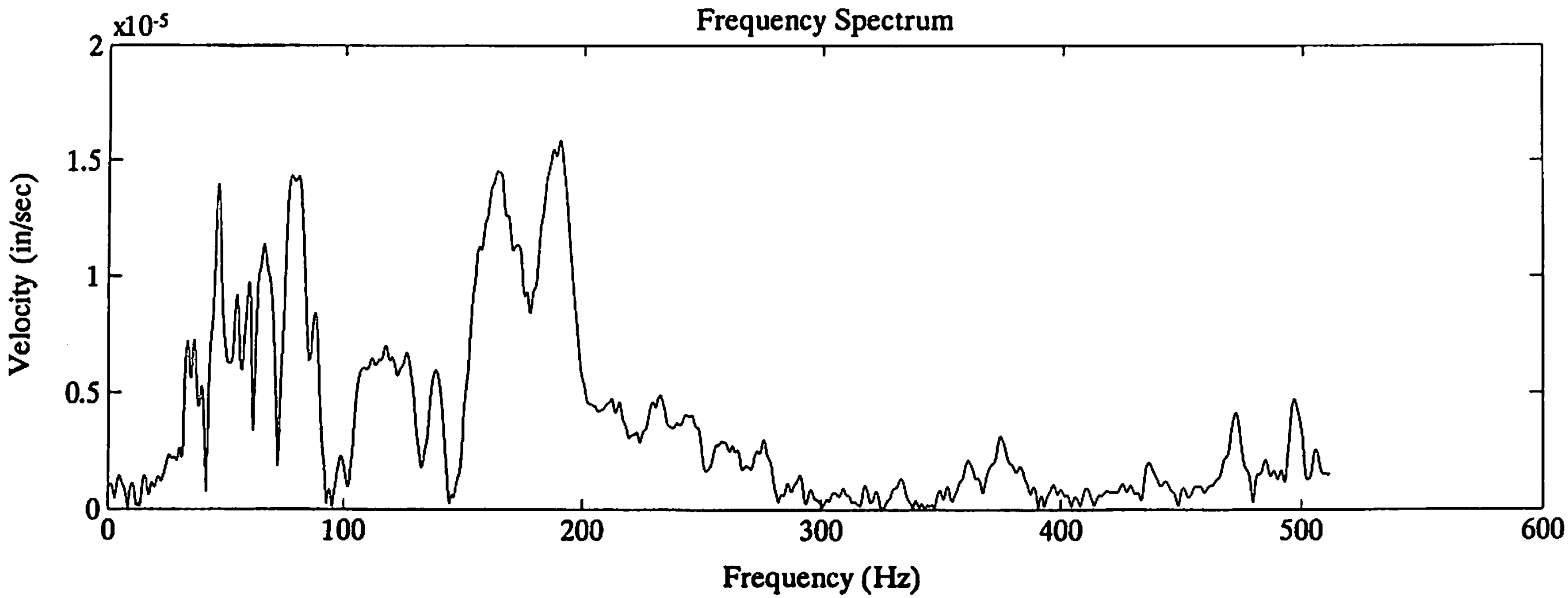
Frequency Spectrum
x10-5
7
6
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)



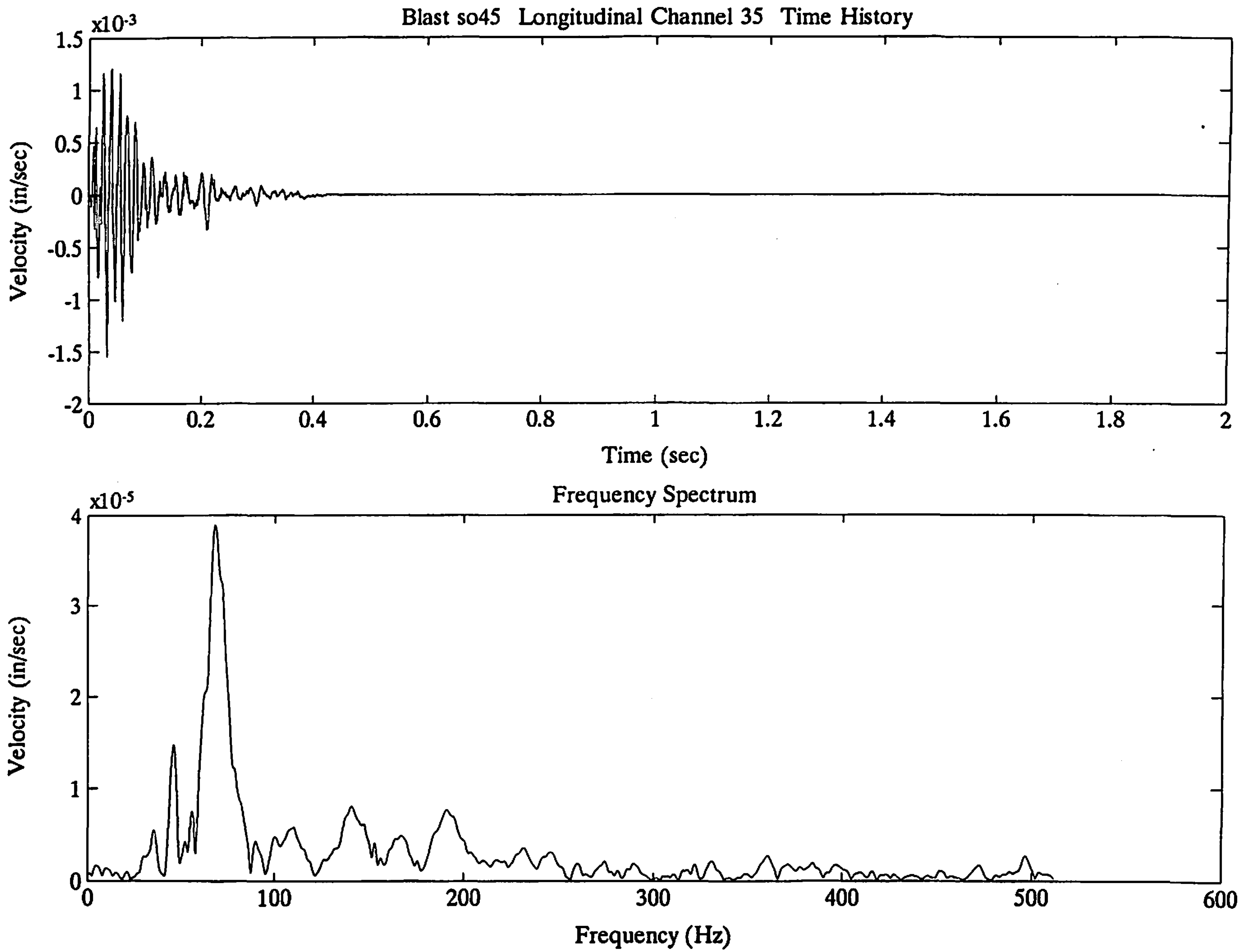
Blast so45 Longitudinal Channel 33 Time History
x10-3
Velocity (in/sec)
Time (sec)
Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)

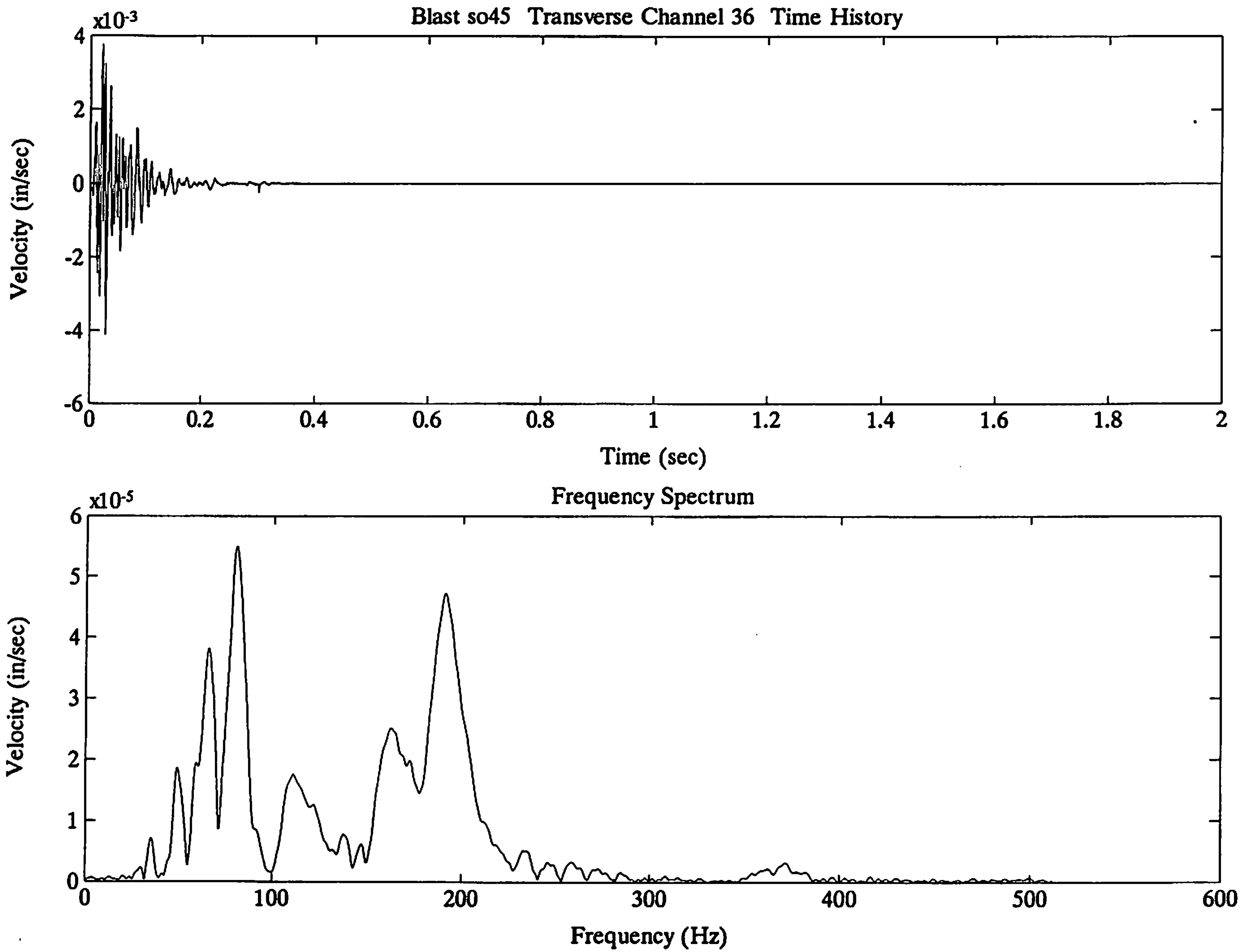


Blast so45 Vertical Channel 34 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

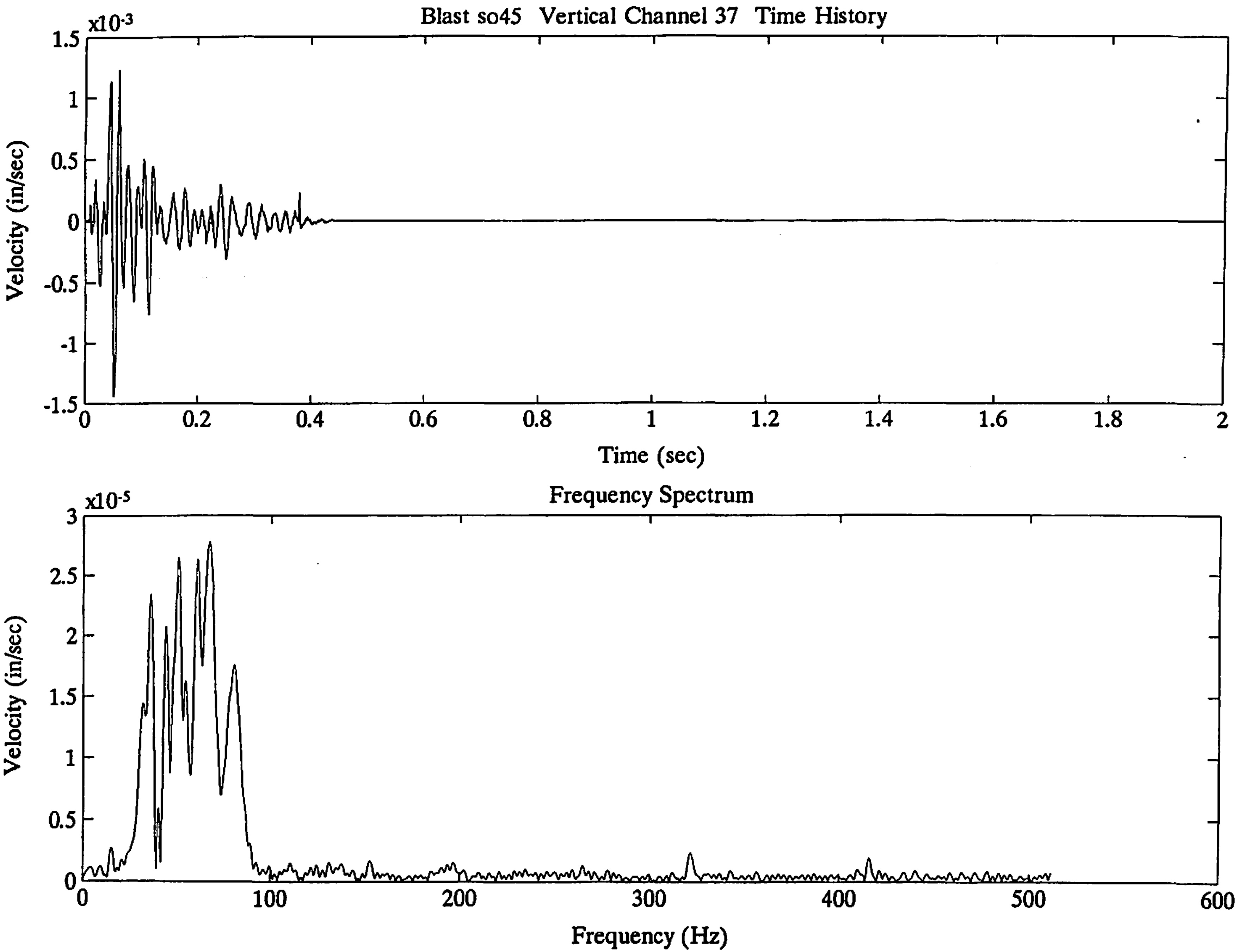


Frequency Spectrum
x10-5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

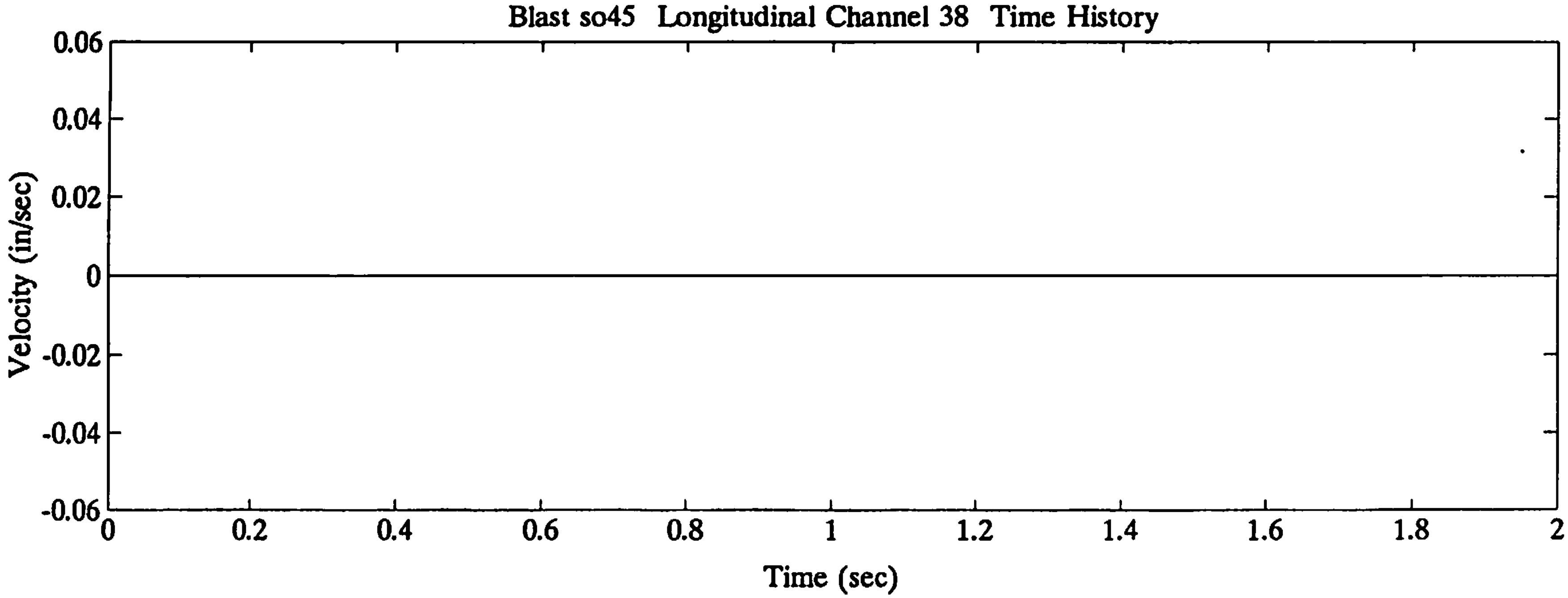

Blast so45 Longitudinal Channel 35 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

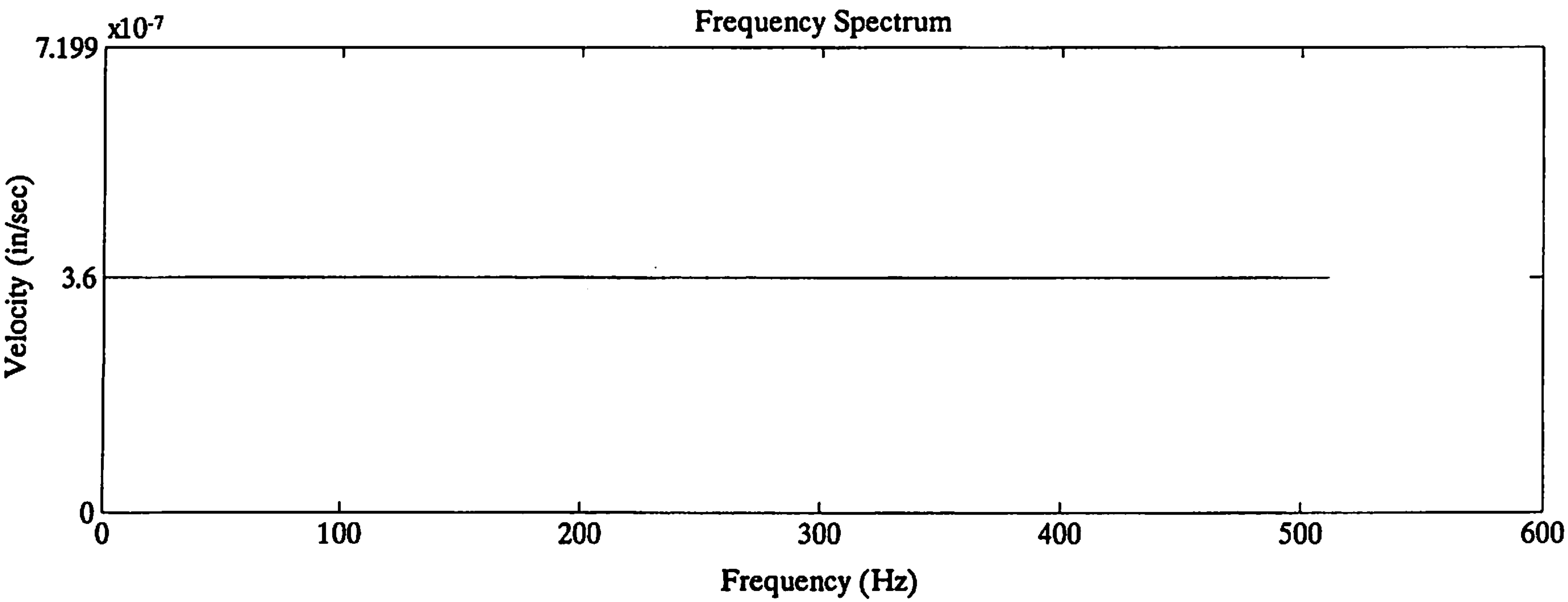


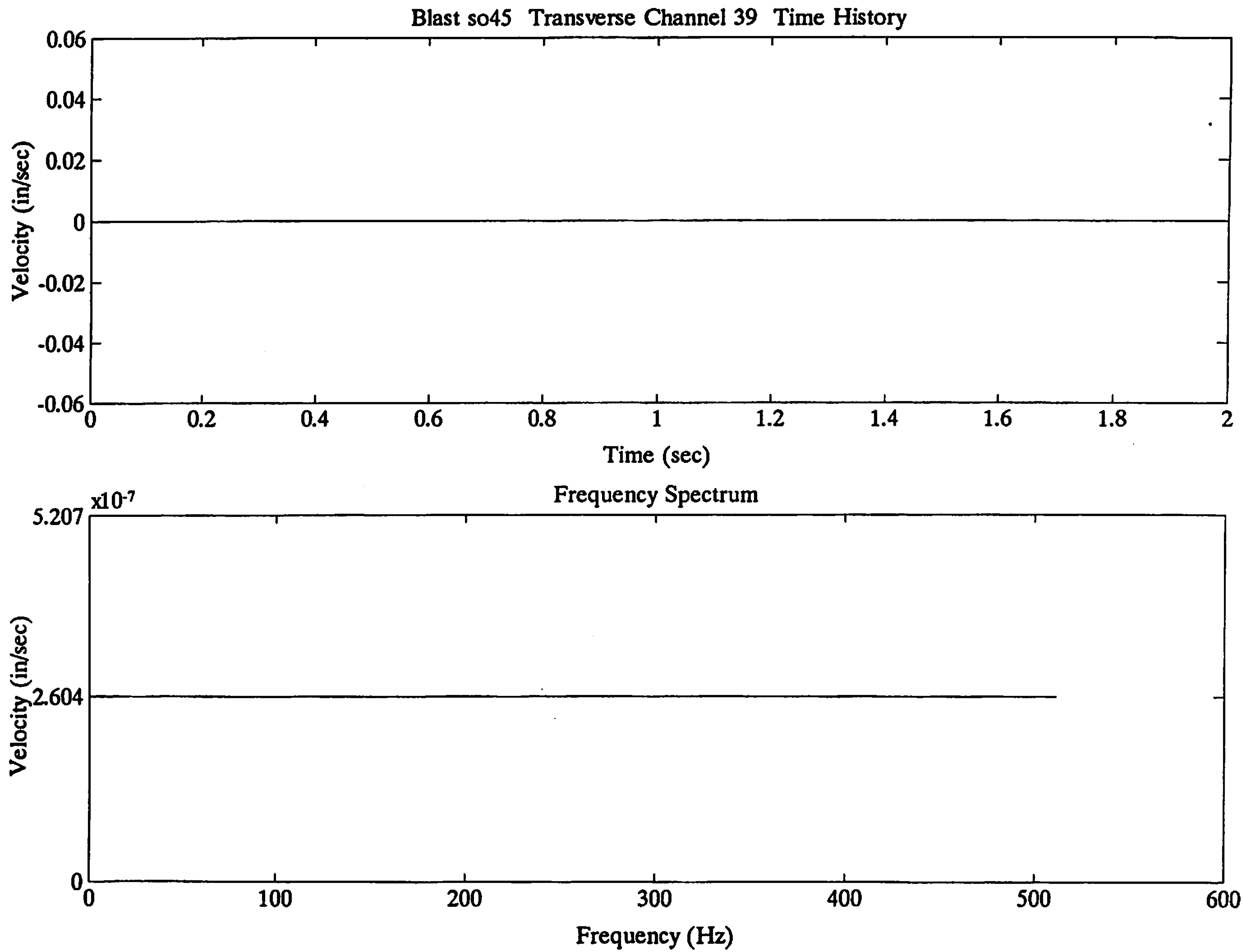
Blast so45 Transverse Channel 36 Time History
x10-3
Velocity (in/sec)
Time (sec)
Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)



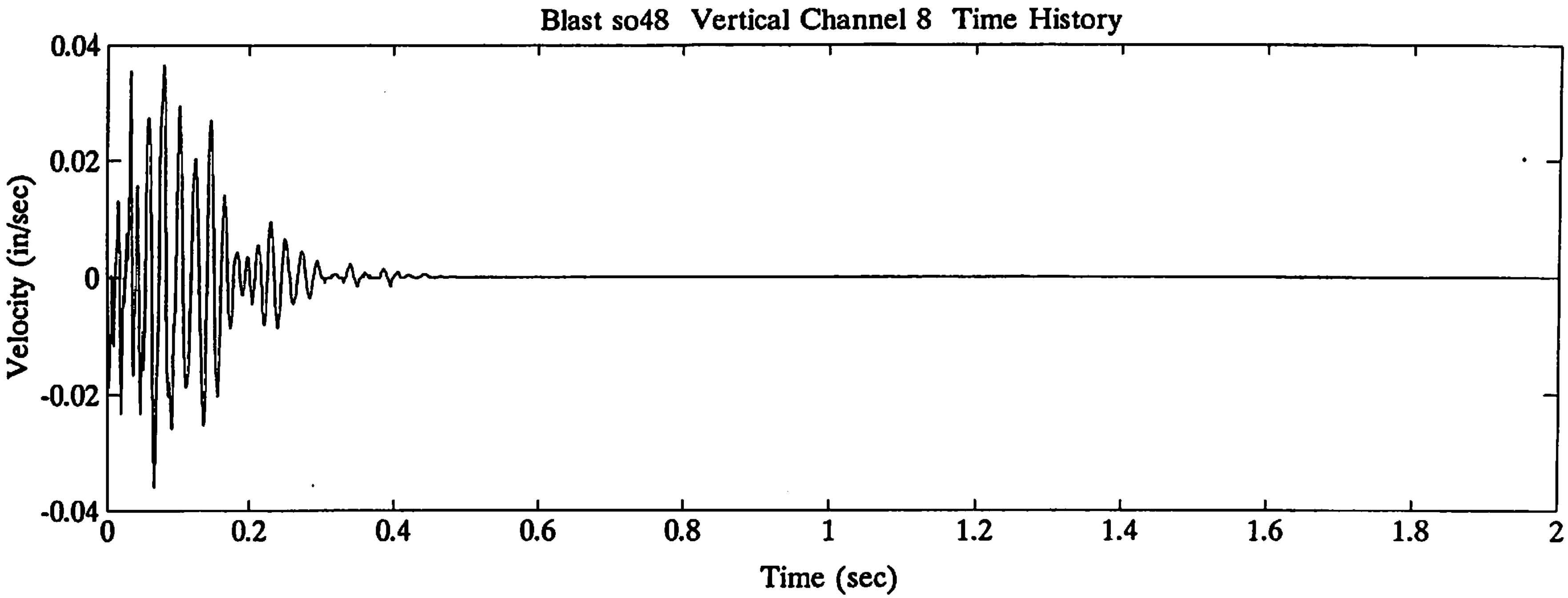
Blast so45 Vertical Channel 37 Time History
x10-3
1.5
1
0.5
0
-0.5
-1
-1.5
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-5
3
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

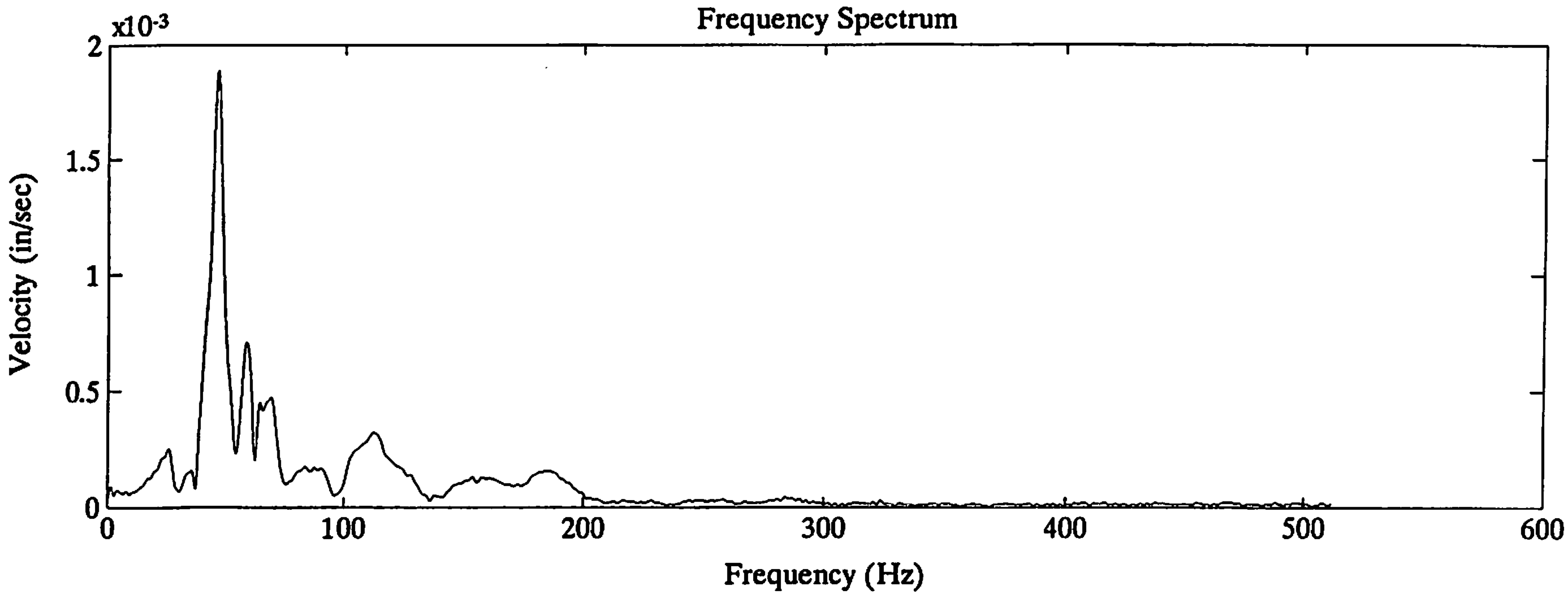

Blast so45 Longitudinal Channel 38 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

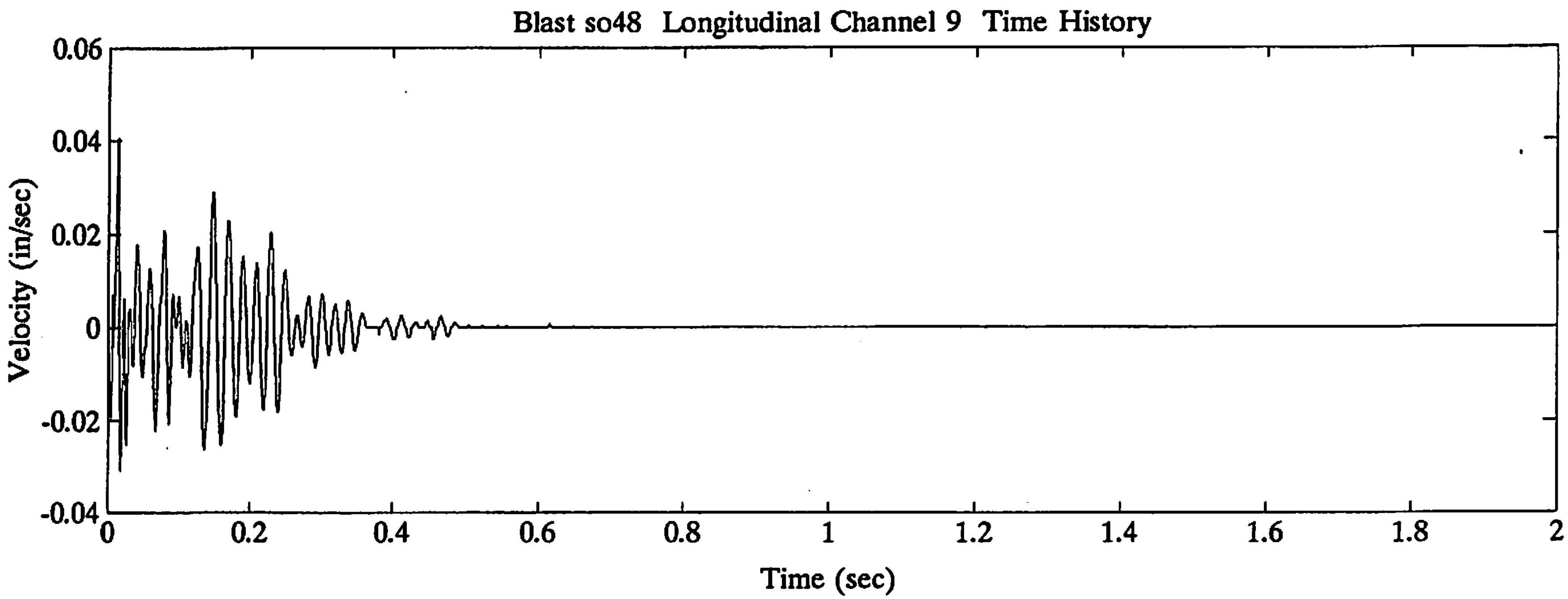

Frequency Spectrum
x10-7
7.199
3.6
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

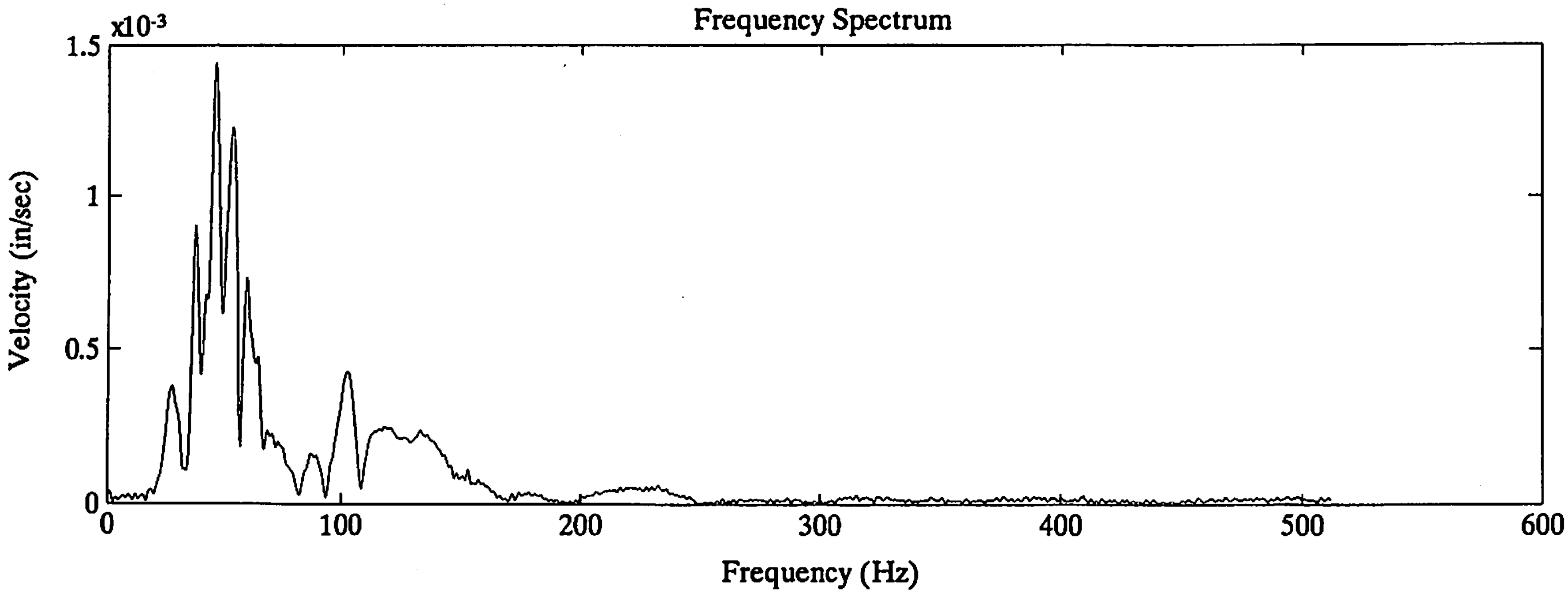


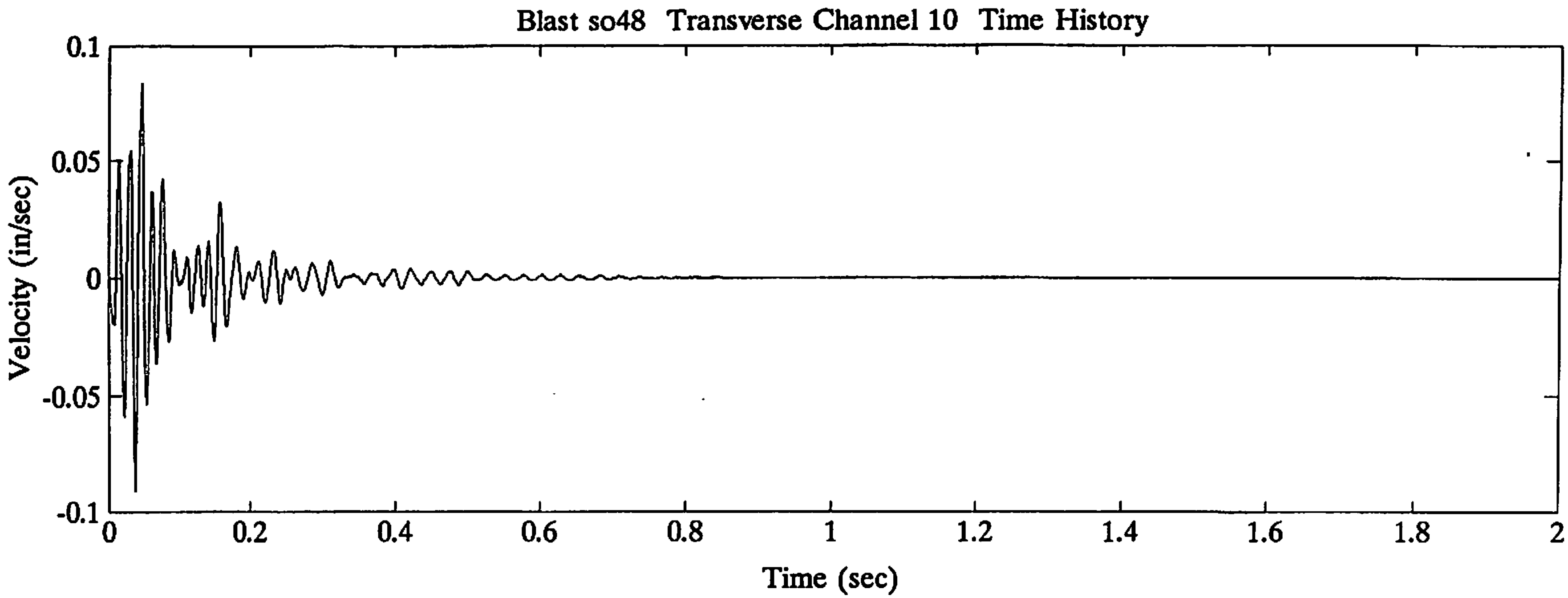
Blast so45 Transverse Channel 39 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-7
5.207
2.604
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

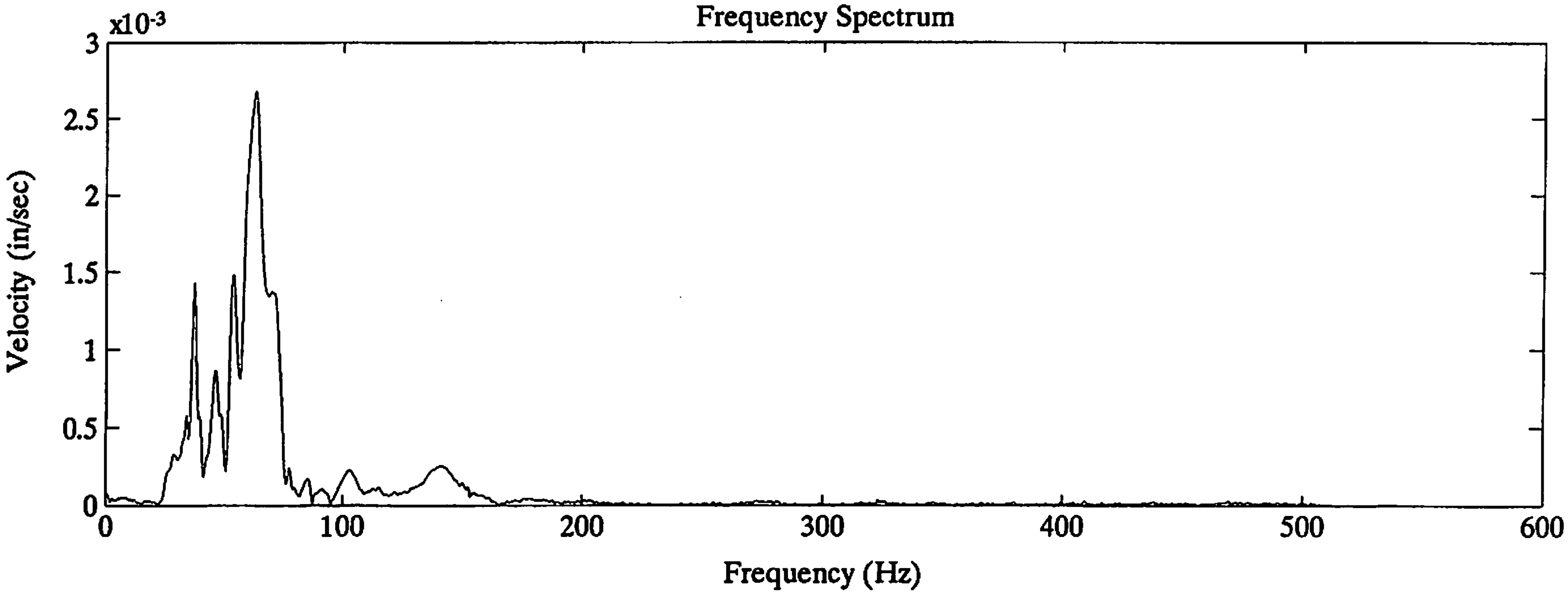

Blast so48 Vertical Channel 8 Time History
Velocity (in/sec)
0.04
0.02
0
-0.02
-0.04
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

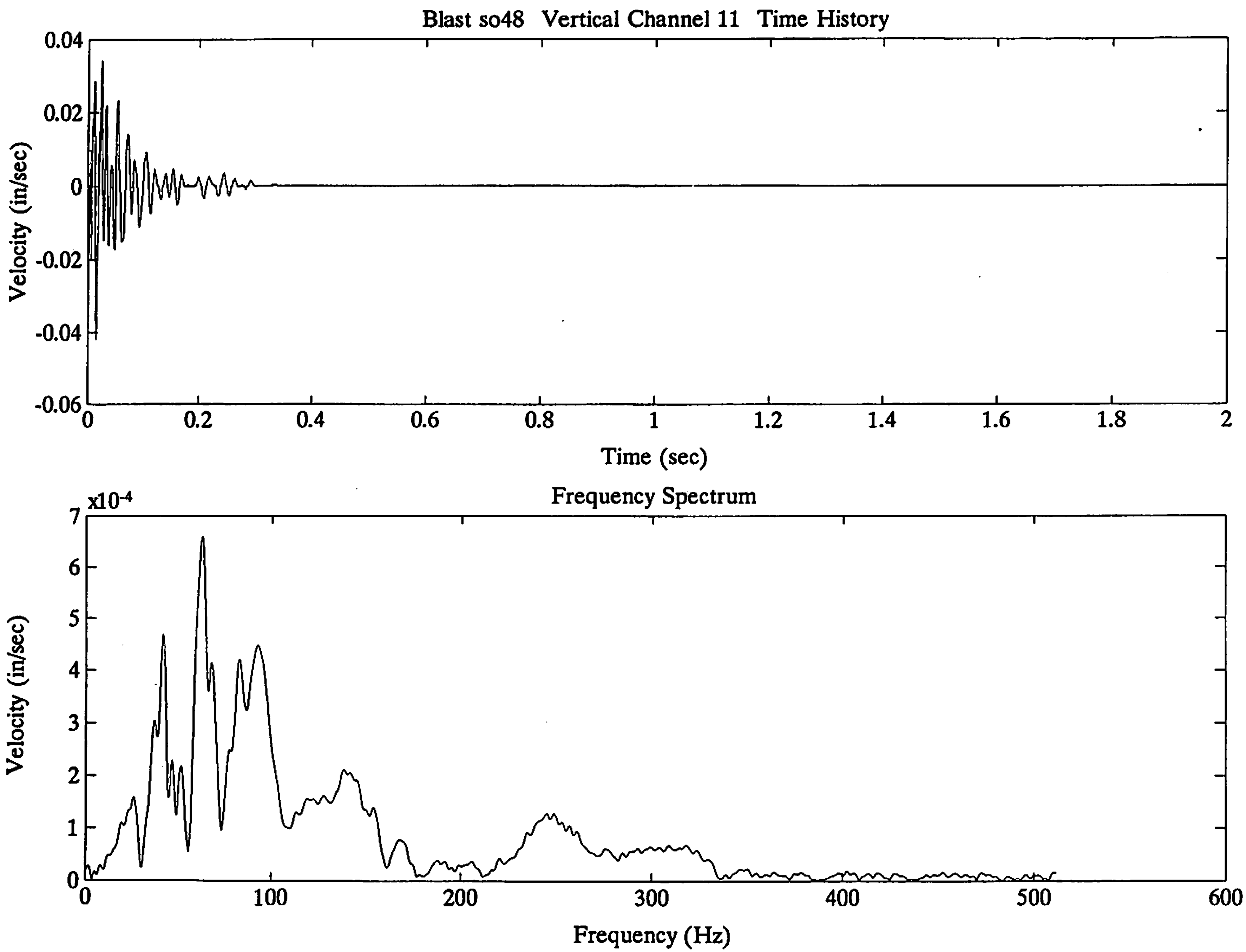

Frequency Spectrum
x10-3
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

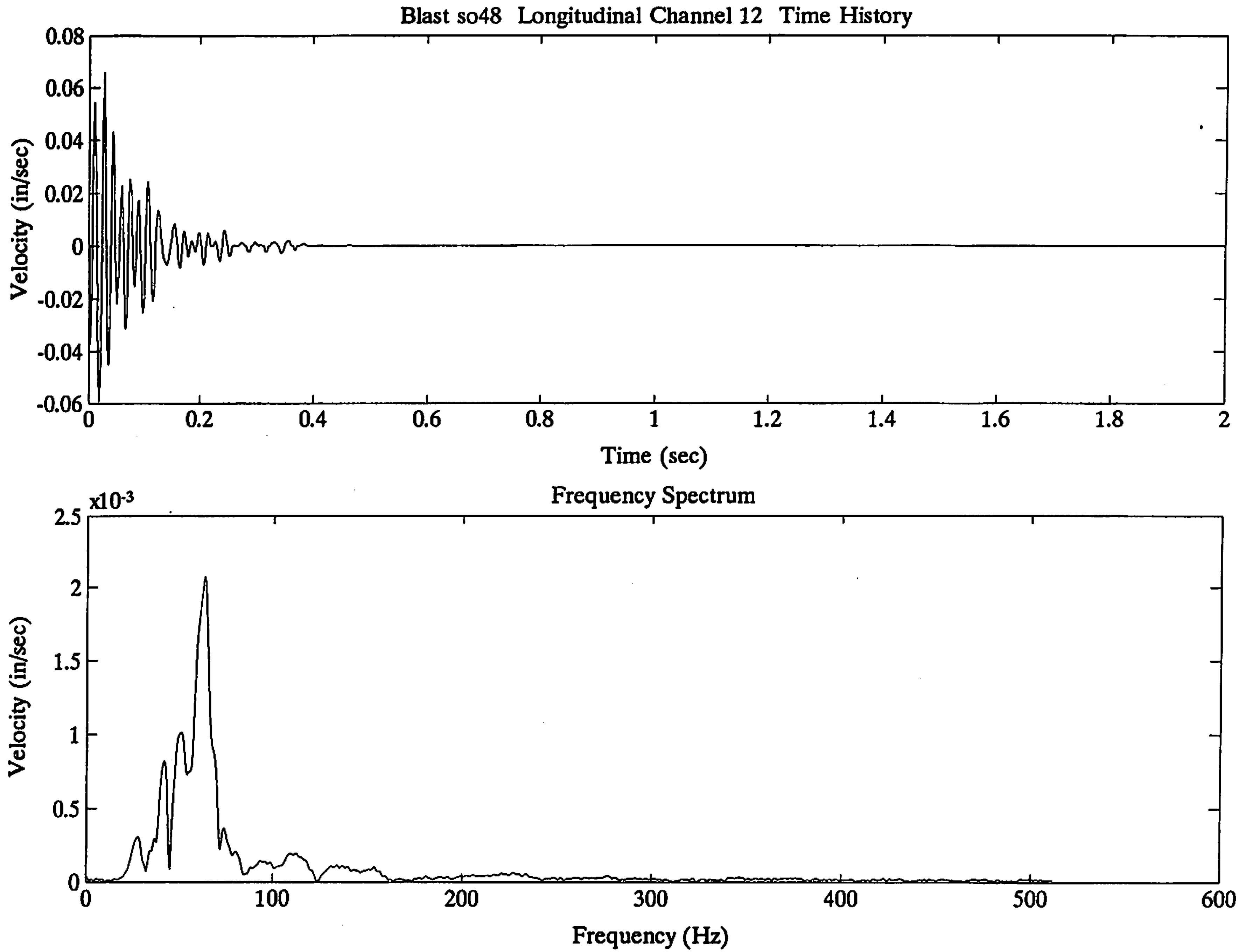

Blast so48 Longitudinal Channel 9 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)


Frequency Spectrum
x10-3
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

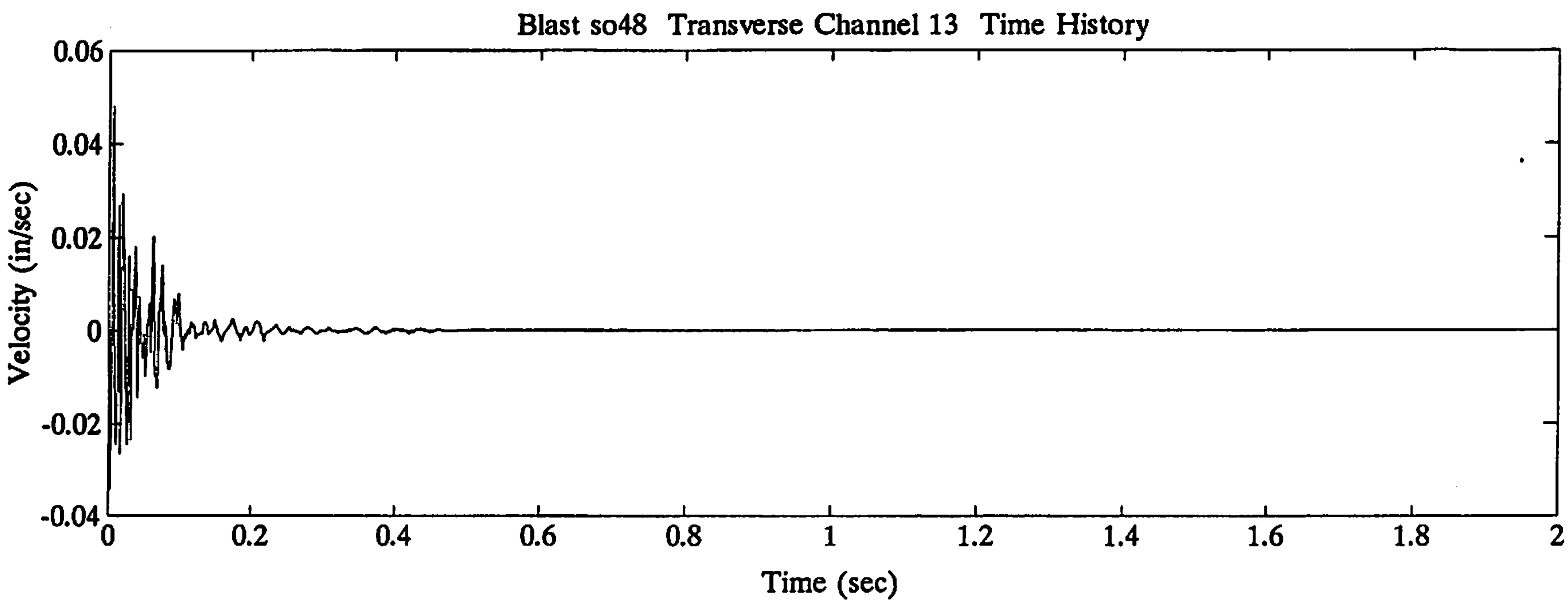

Blast so48 Transverse Channel 10 Time History
Velocity (in/sec)
0.1
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

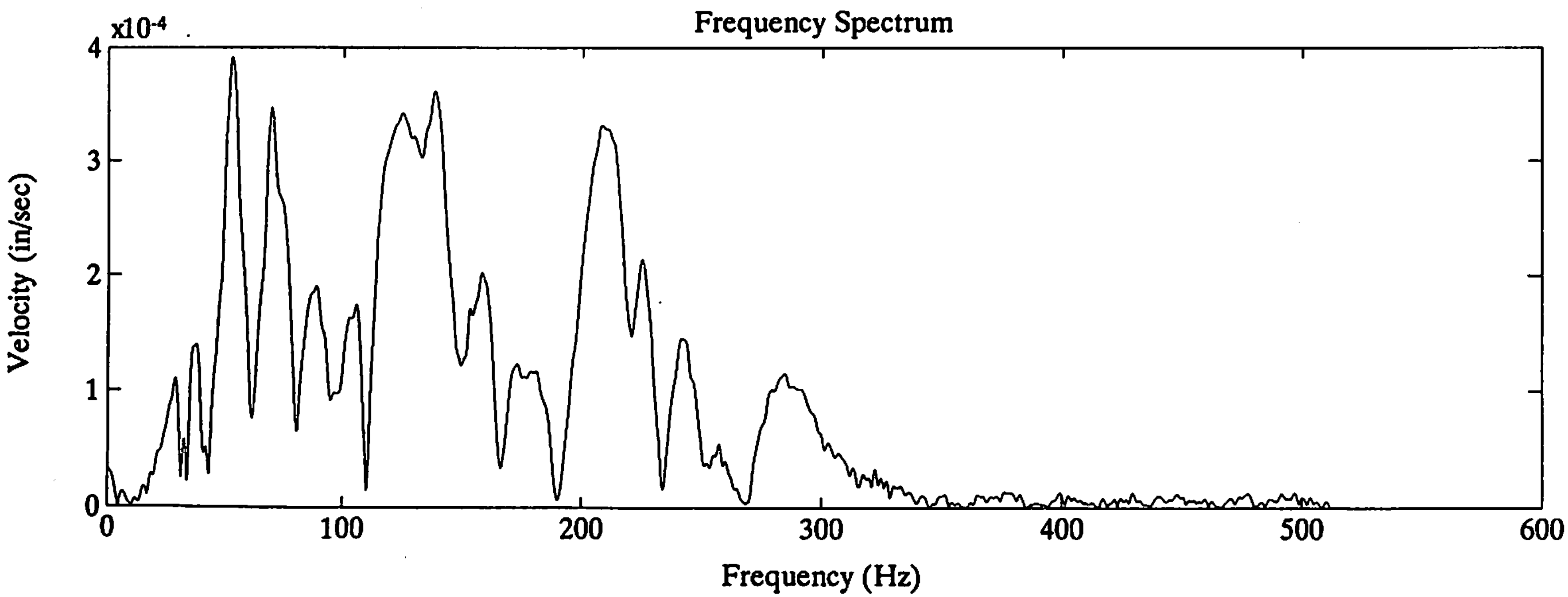

Frequency Spectrum
x10-3
Velocity (in/sec)
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

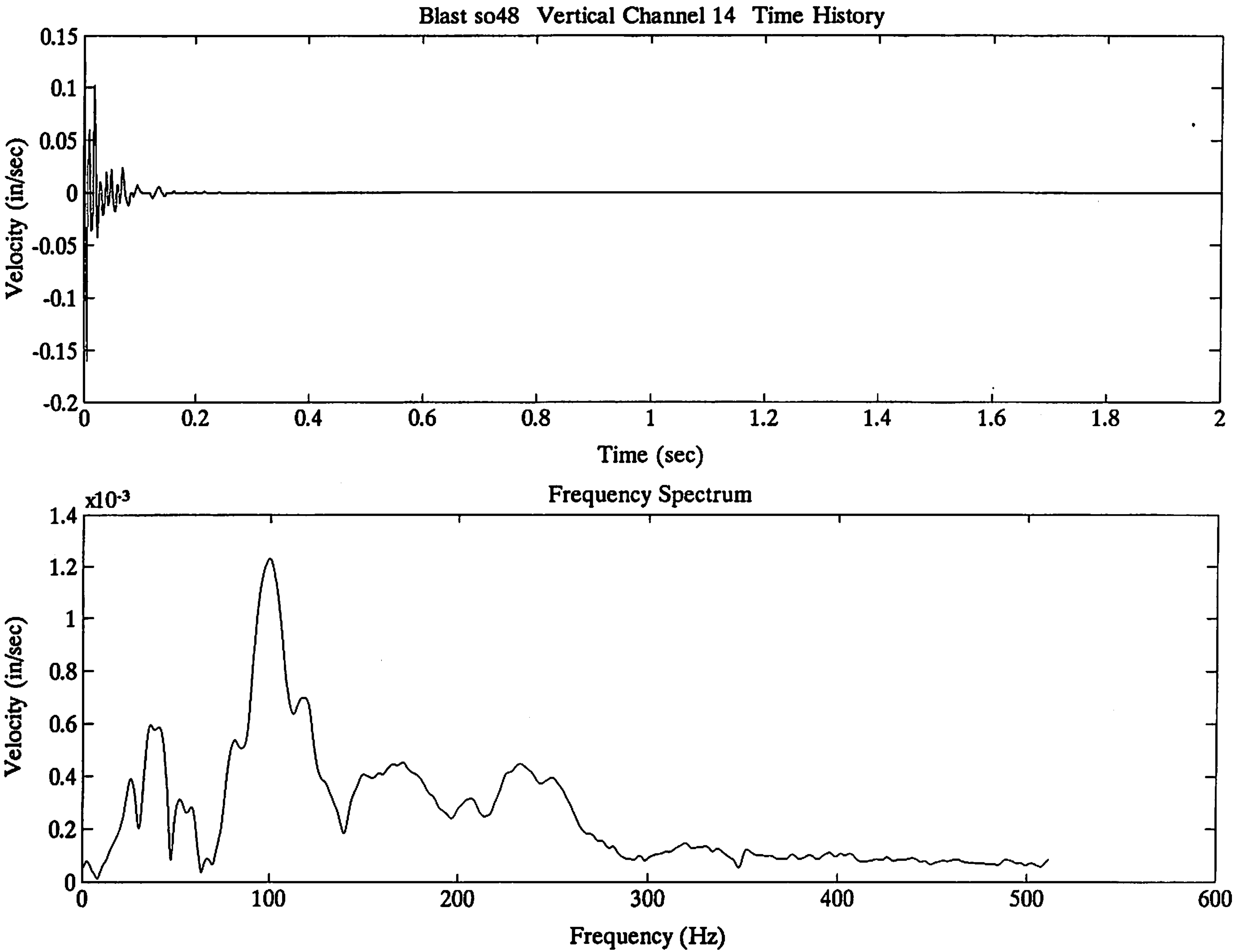

Blast so48 Vertical Channel 11 Time History
Velocity (in/sec)
Time (sec)
Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)



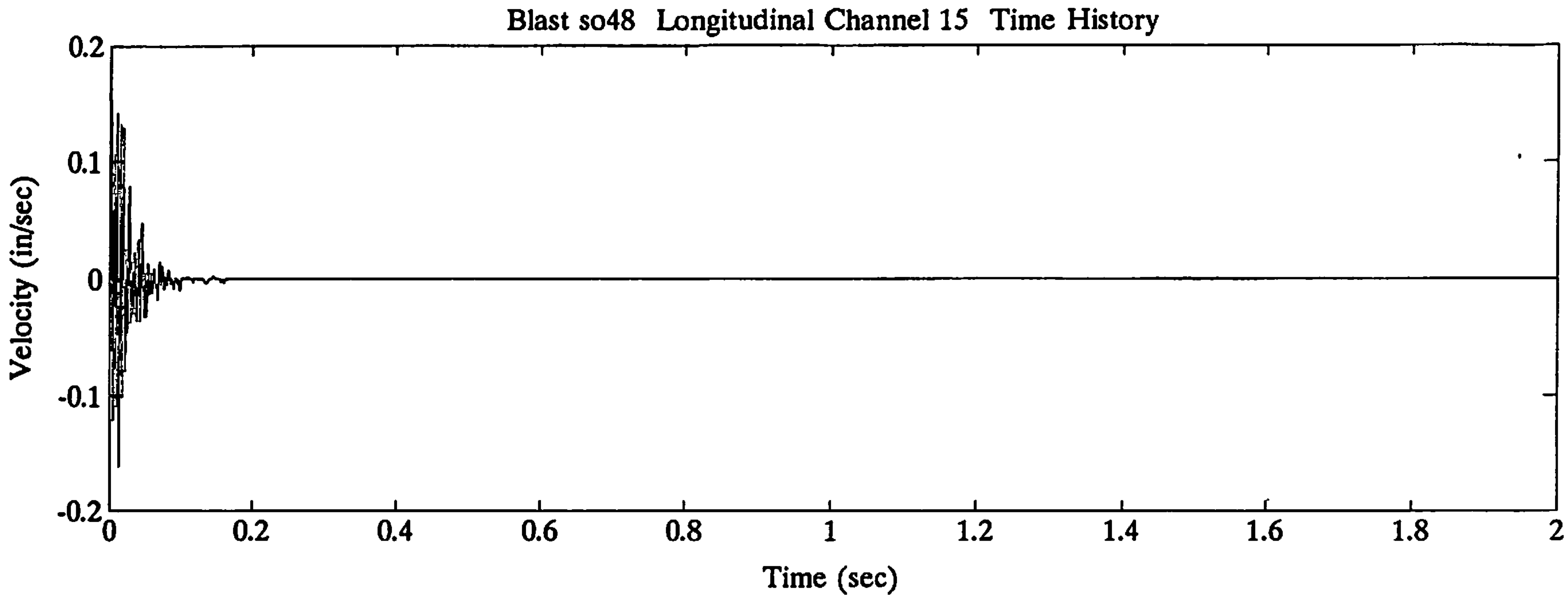
Blast so48 Longitudinal Channel 12 Time History
Velocity (in/sec)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

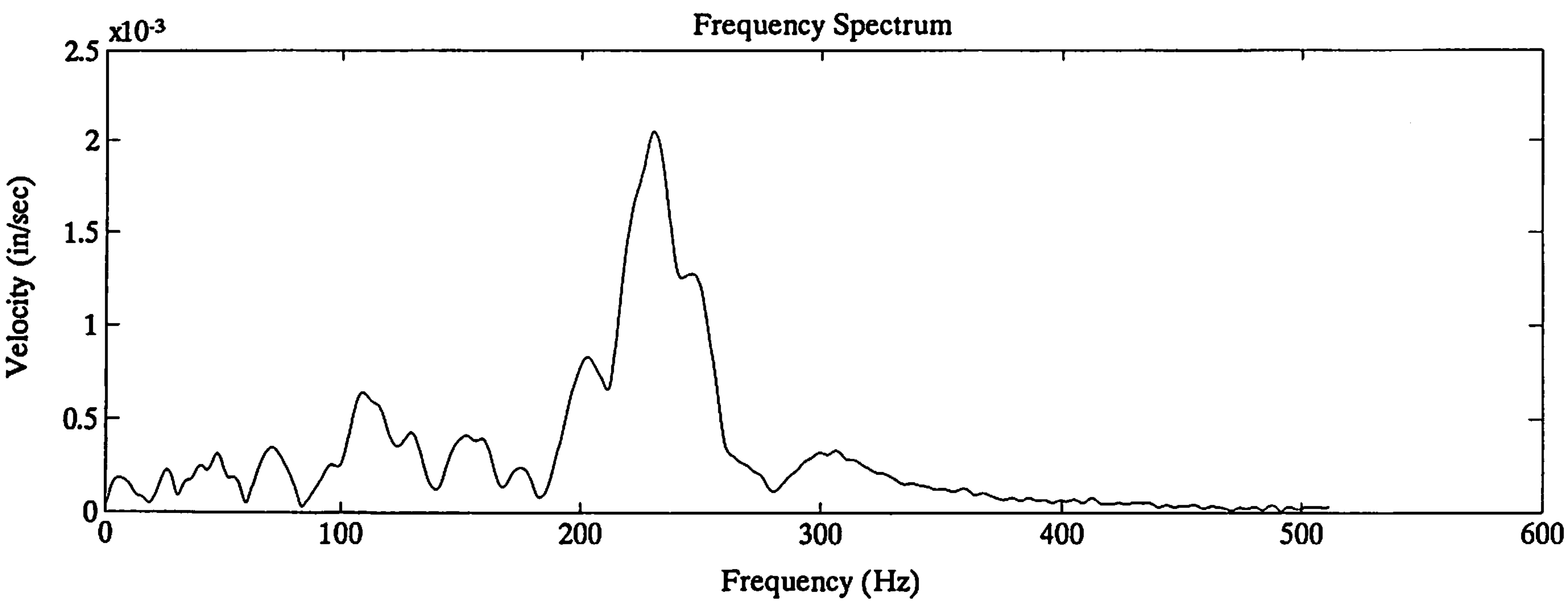

Blast so48 Transverse Channel 13 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

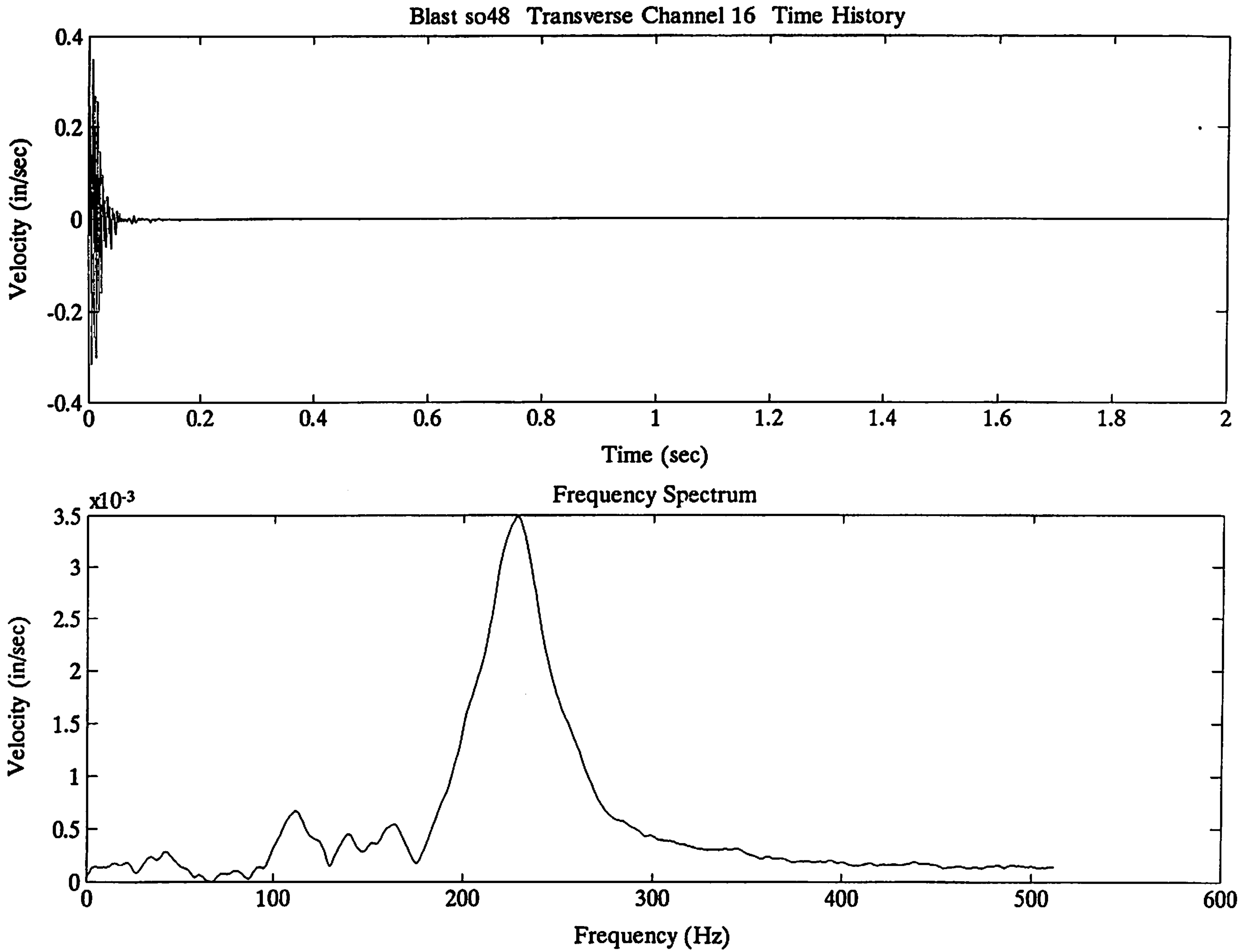

Frequency Spectrum
x10-4
Velocity (in/sec)
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)



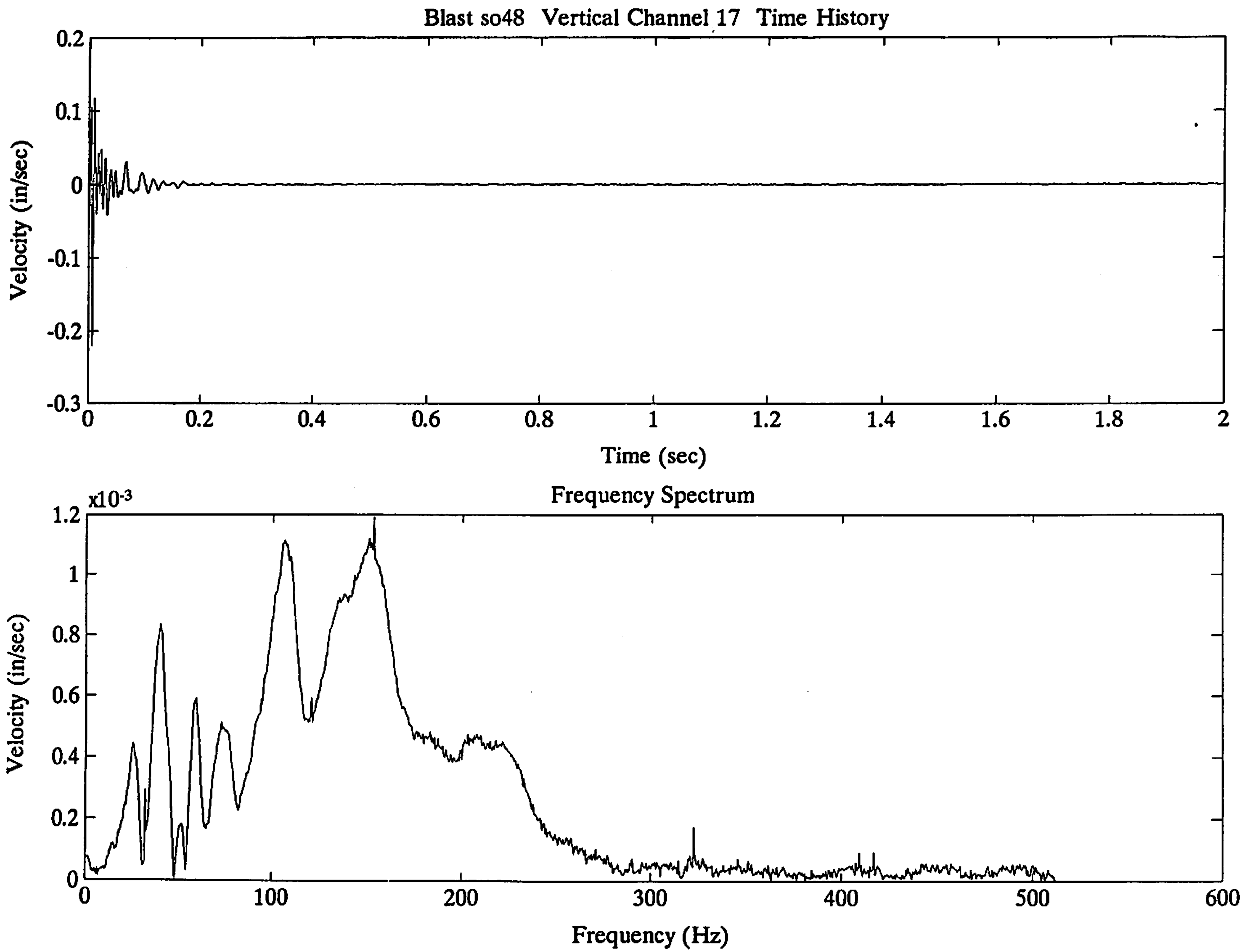
Blast so48 Vertical Channel 14 Time History
Velocity (in/sec)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

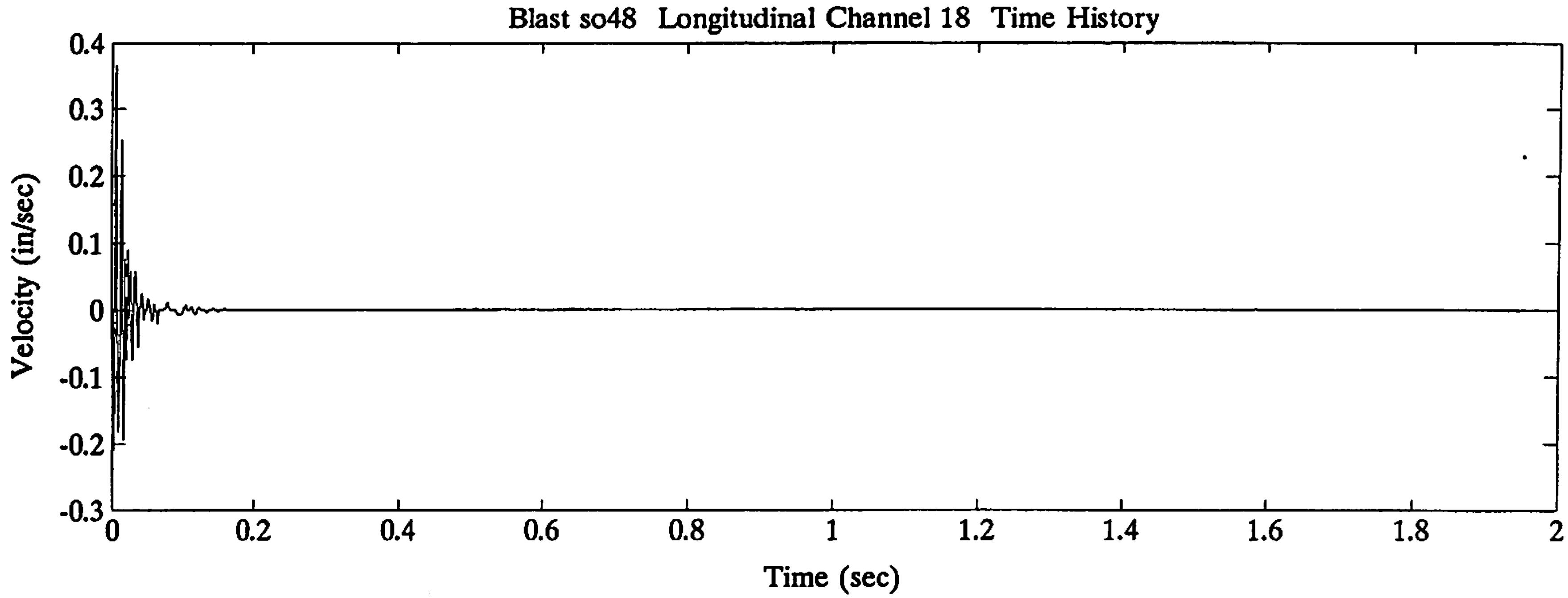

Blast so48 Longitudinal Channel 15 Time History
Velocity (in/sec)
0.2
0.1
0
-0.1
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

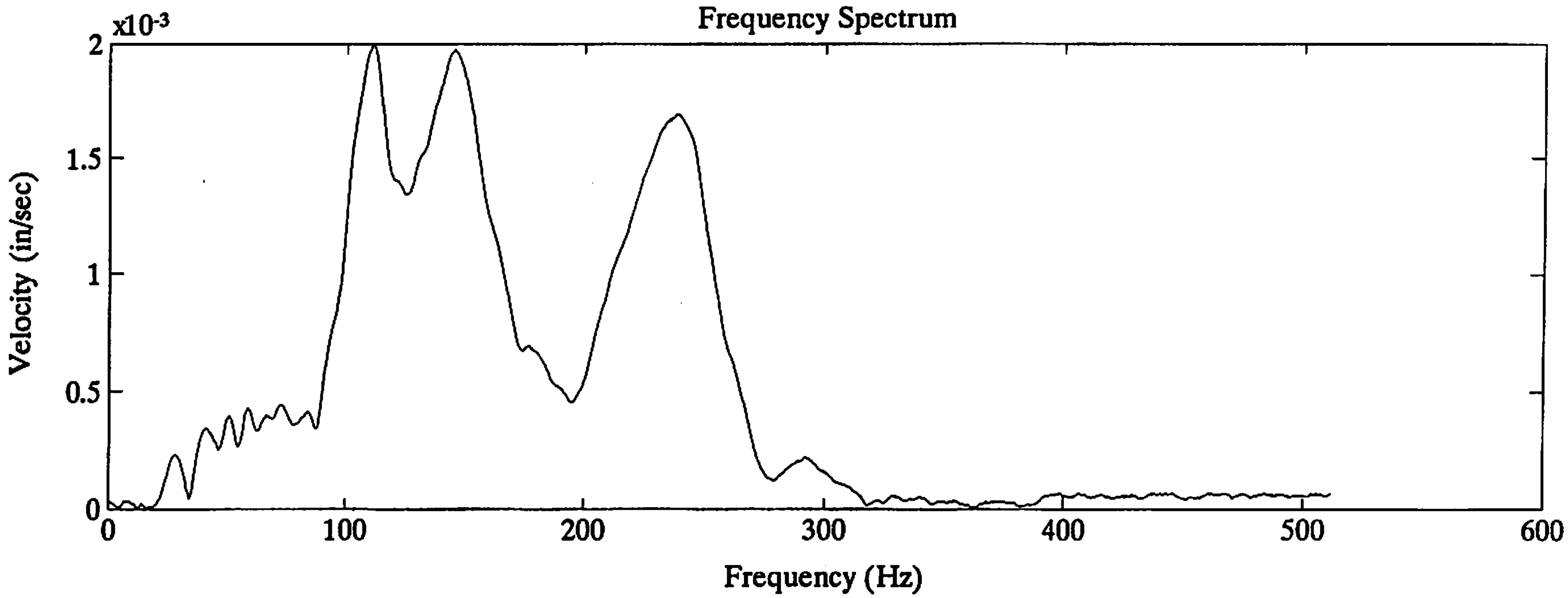

Frequency Spectrum
x10-3
Velocity (in/sec)
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

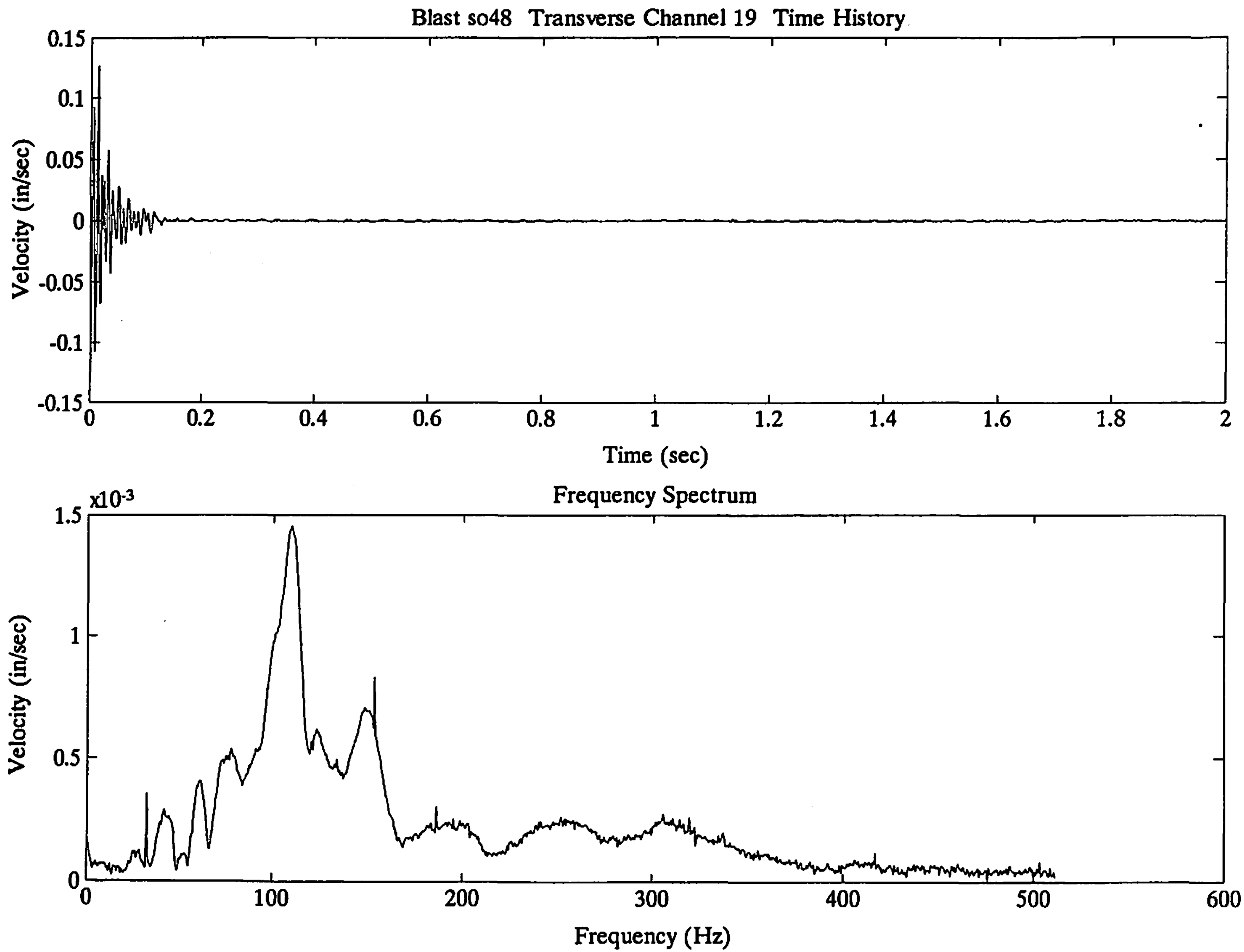


Blast so48 Transverse Channel 16 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
3.5
3
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

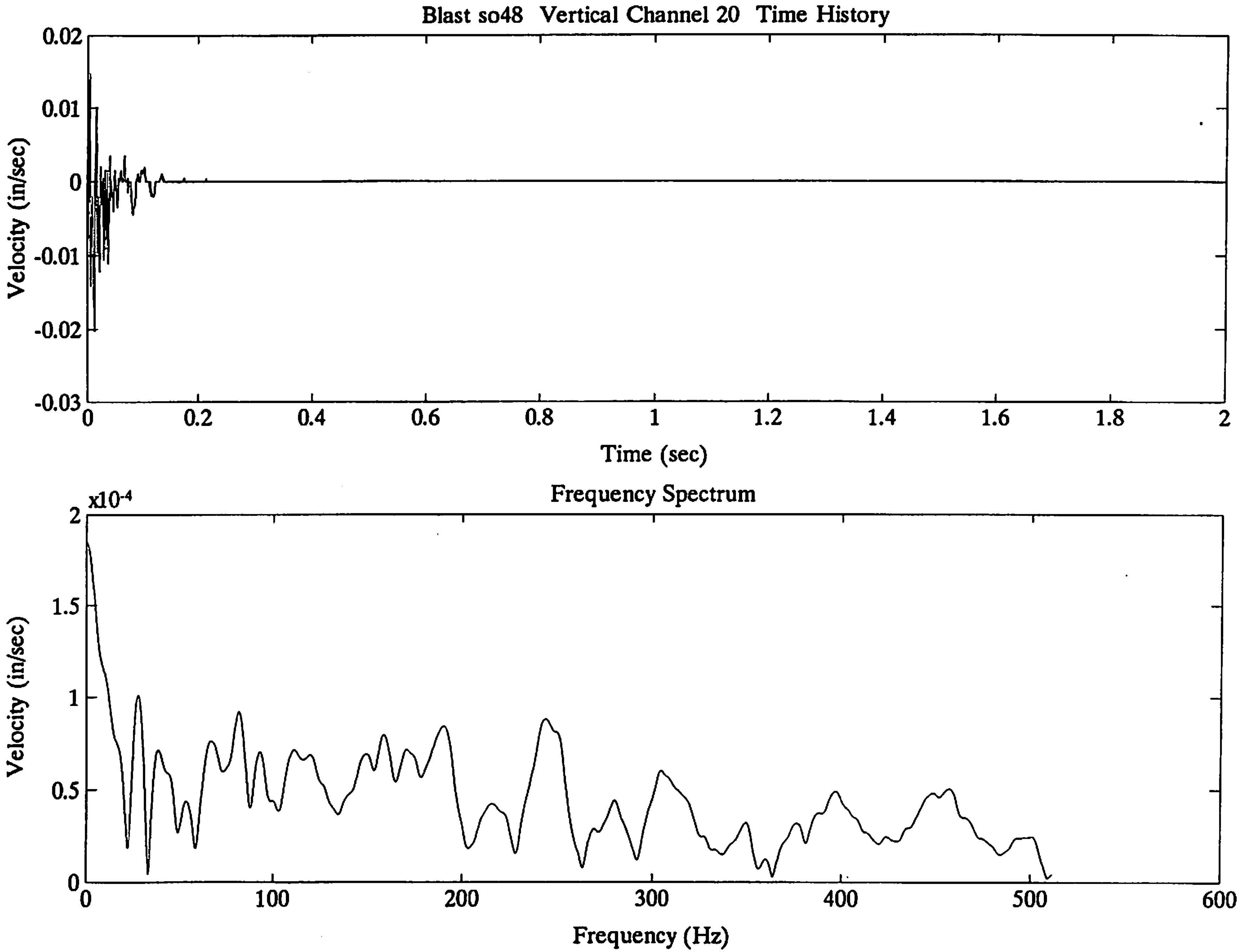

Blast so48 Vertical Channel 17 Time History
Velocity (in/sec)
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so48 Longitudinal Channel 18 Time History
Velocity (in/sec)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

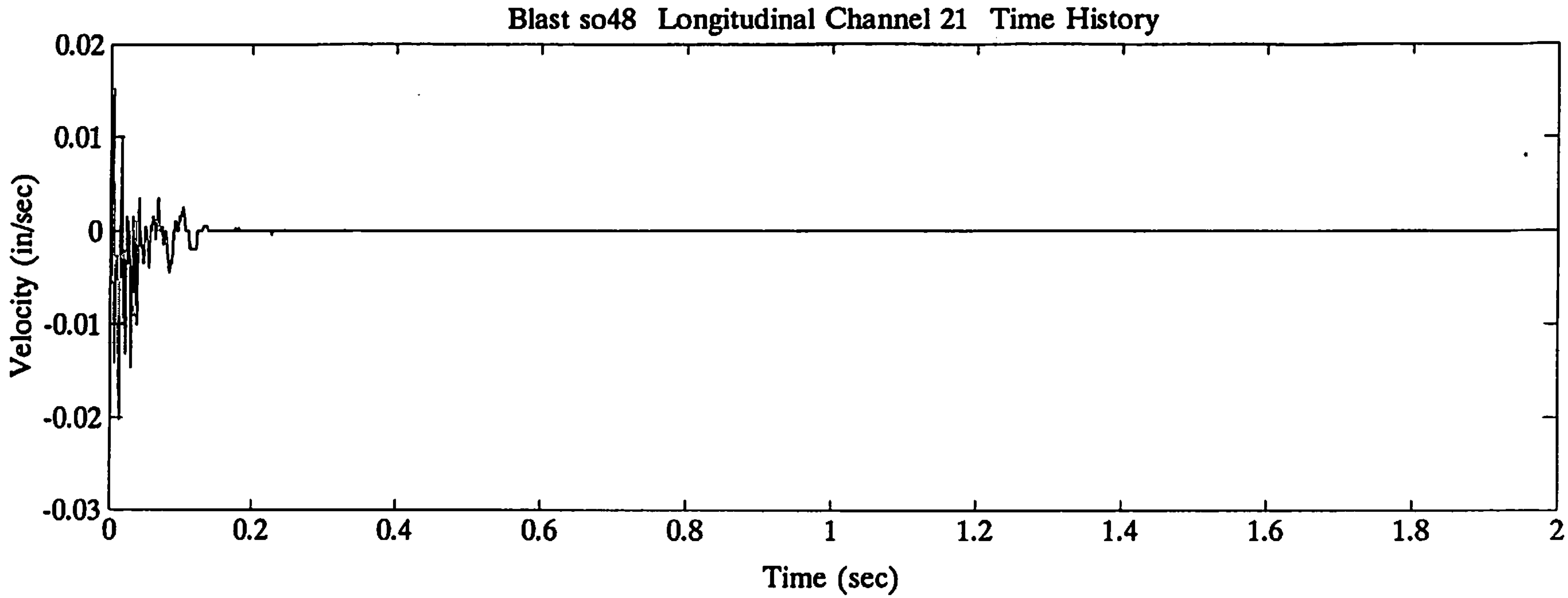

Frequency Spectrum
x10-3
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

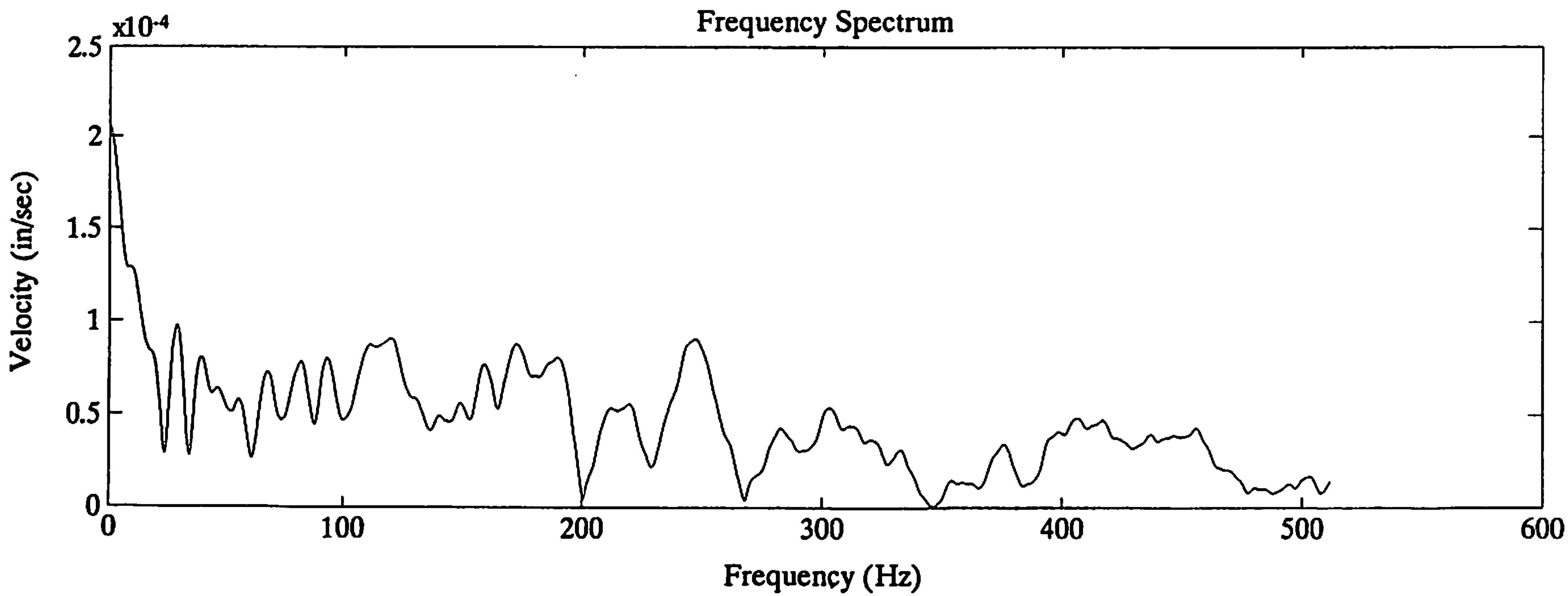


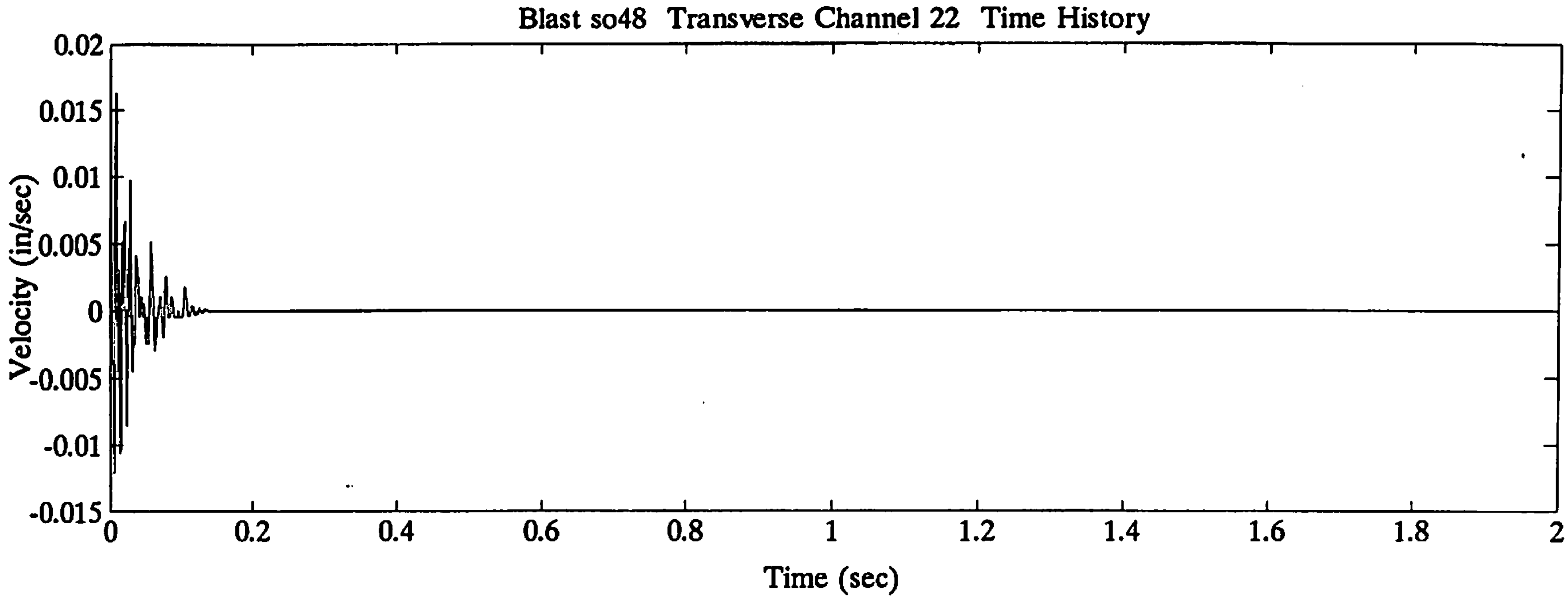
Blast so48 Transverse Channel 19 Time History
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)



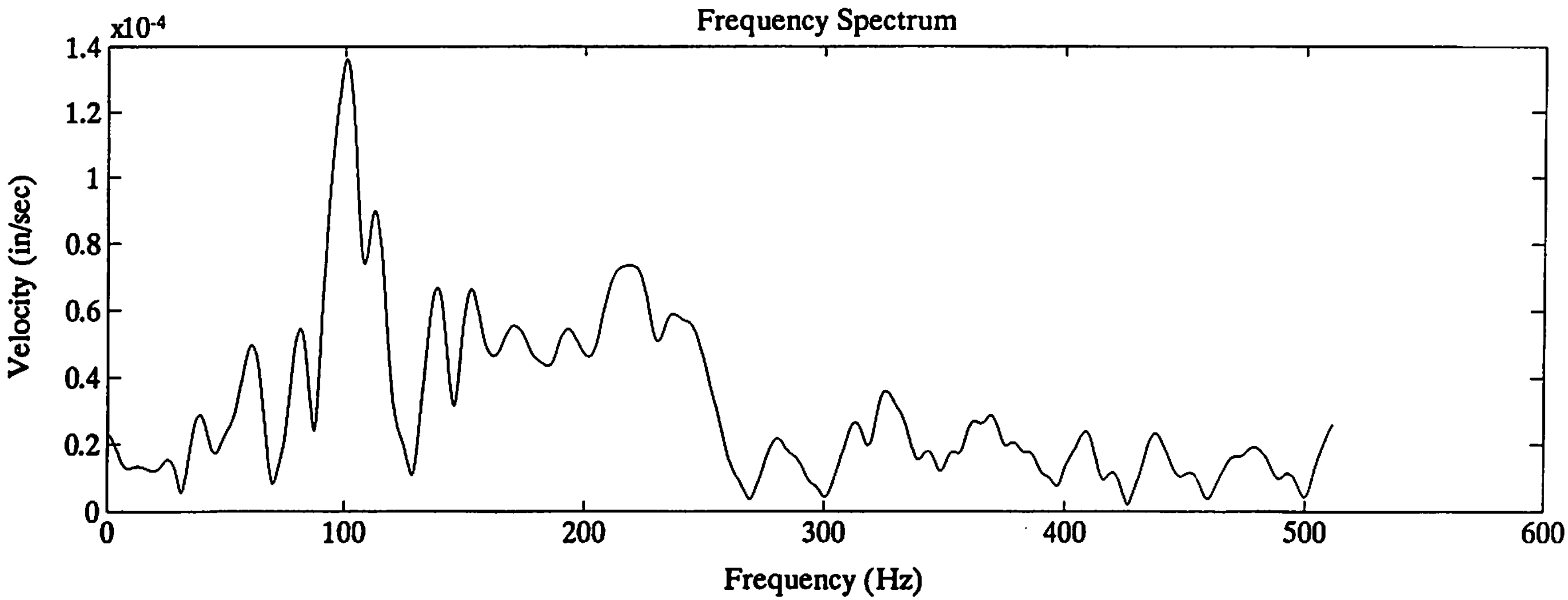
Blast so48 Vertical Channel 20 Time History
Velocity (in/sec)
Time (sec)
0.02
0.01
0
-0.01
-0.02
-0.03
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)
2
1.5
1
0.5
0
0
100
200
300
400
500
600


Blast so48 Longitudinal Channel 21 Time History
Velocity (in/sec)
0.02
0.01
0
-0.01
-0.02
-0.03
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

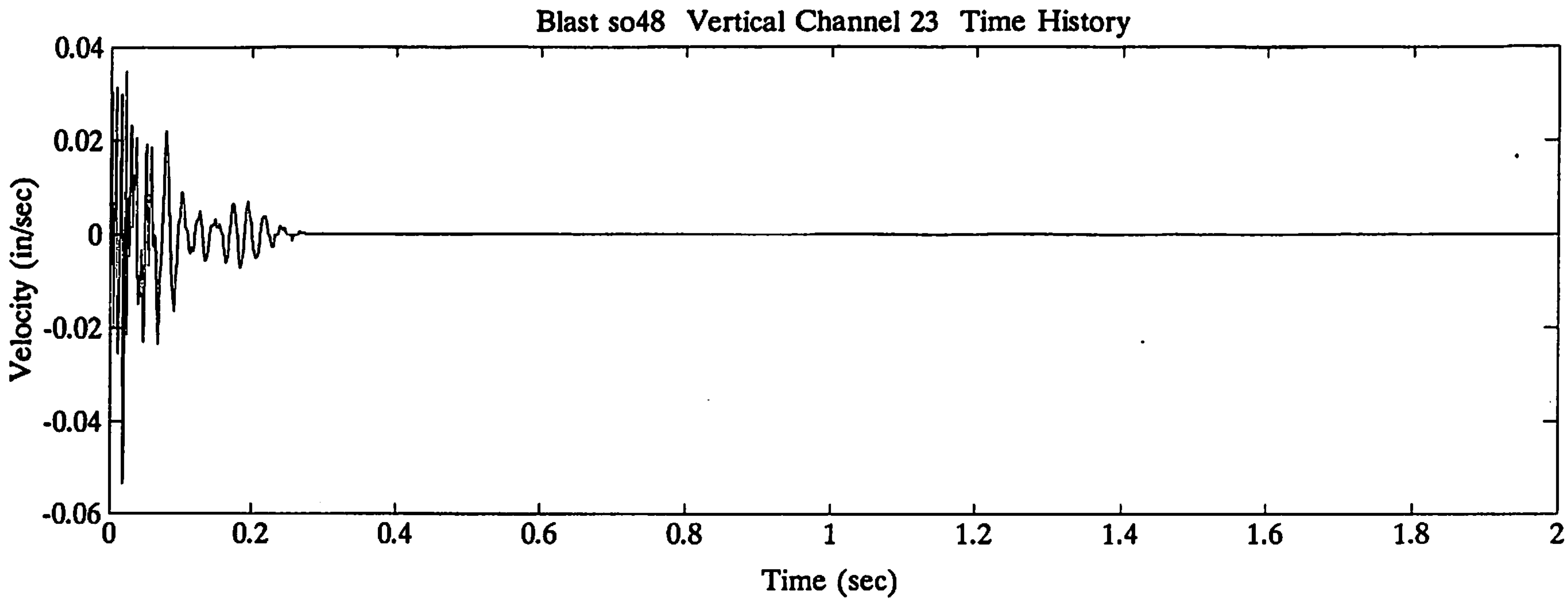

Frequency Spectrum
x10-4
Velocity (in/sec)
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

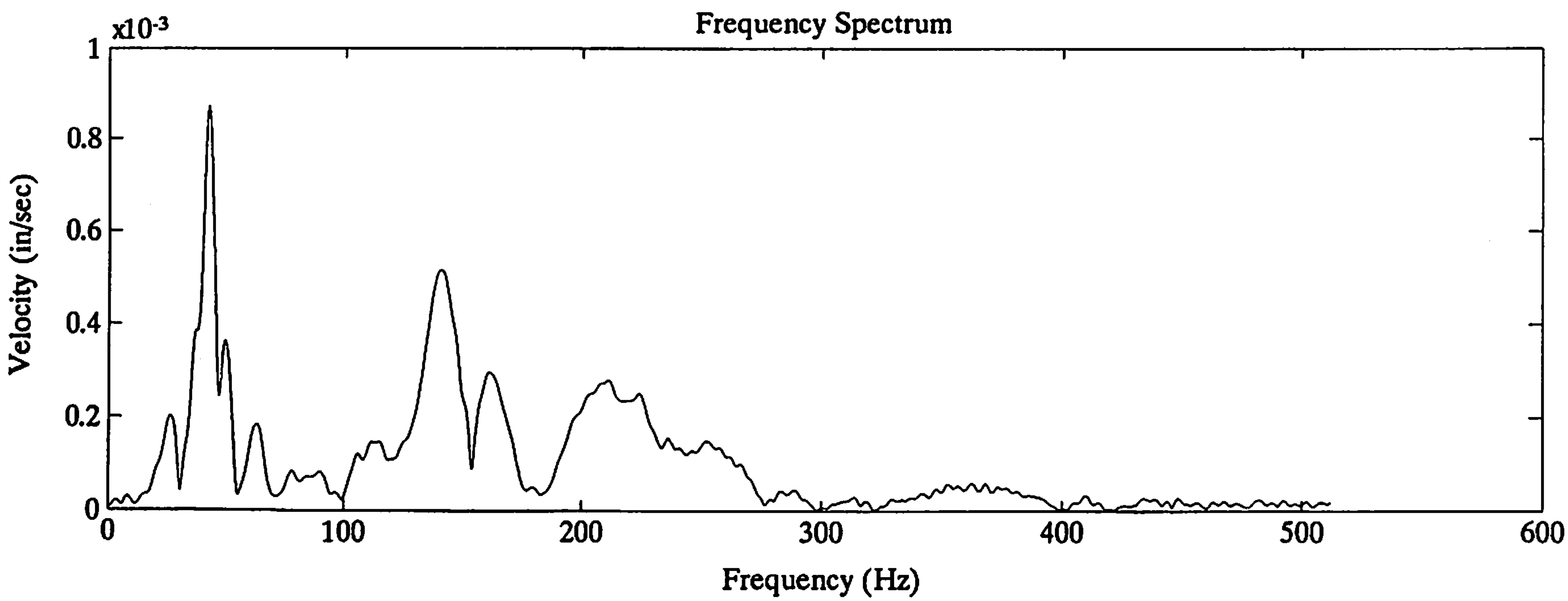


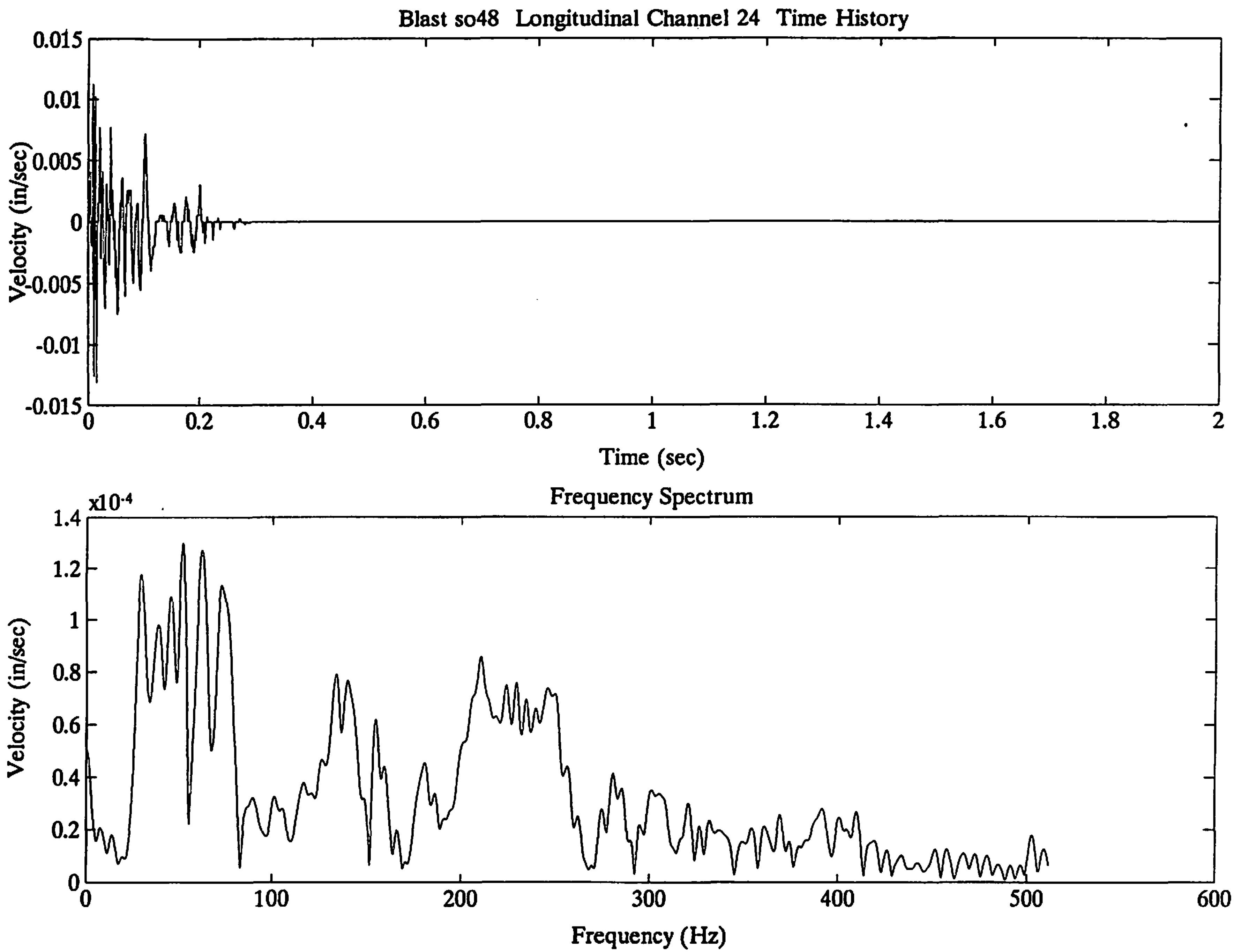
Blast so48 Transverse Channel 22 Time History
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



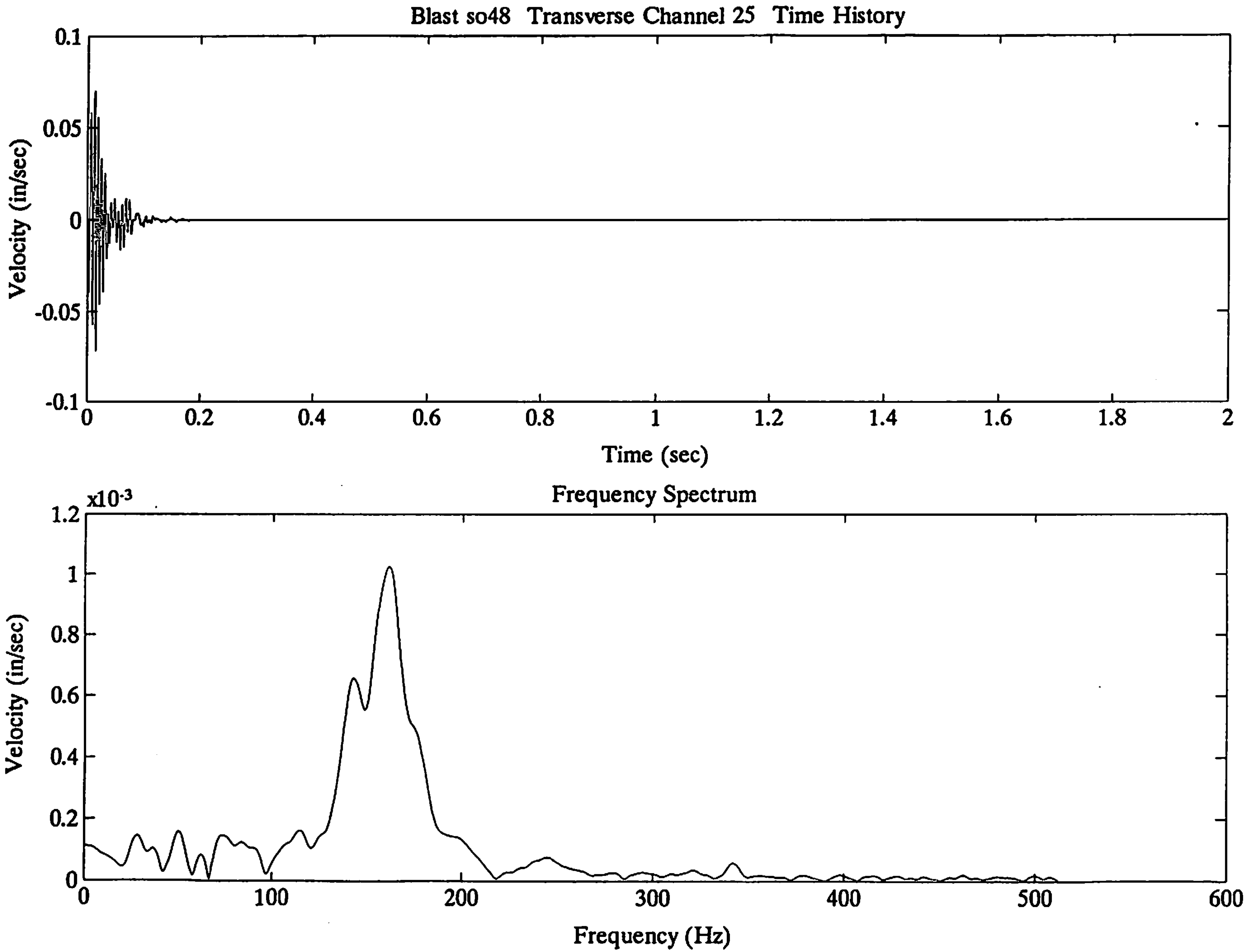
Frequency Spectrum
x10-4
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

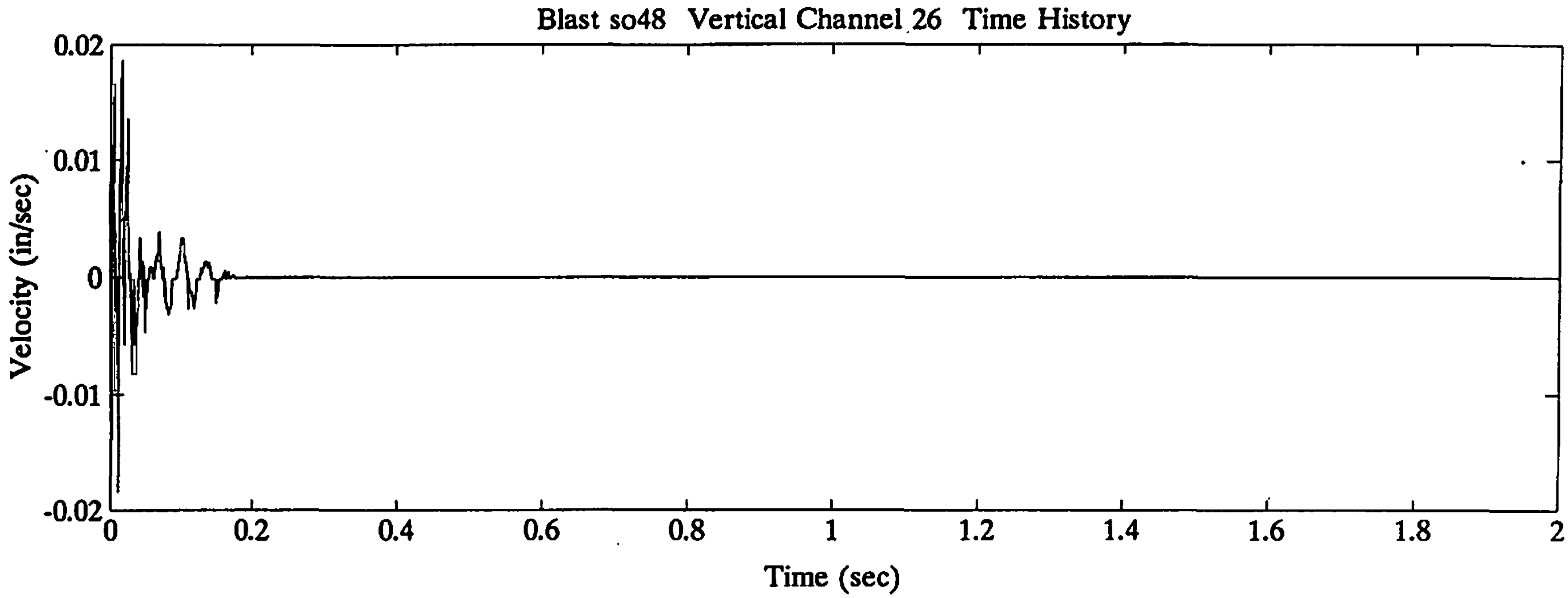

Blast so48 Vertical Channel 23 Time History
Velocity (in/sec)
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

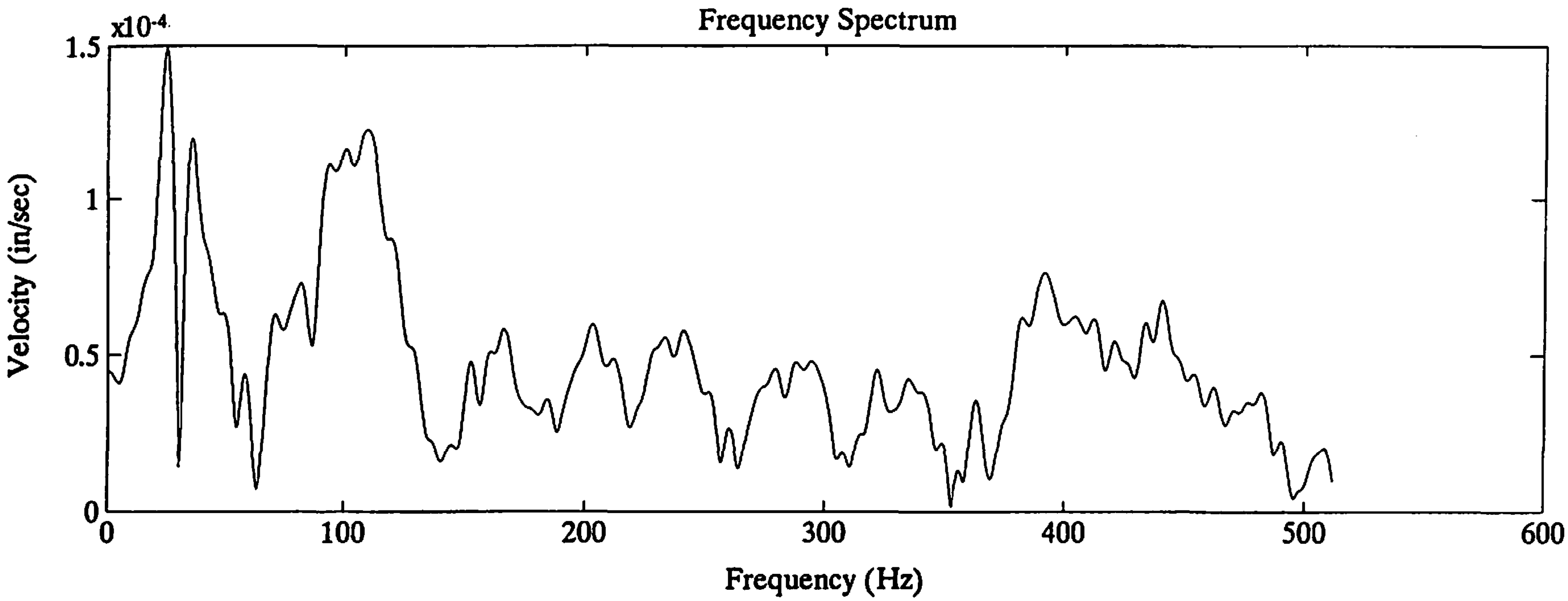

Frequency Spectrum
x10-3
Velocity (in/sec)
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
Frequency (Hz)

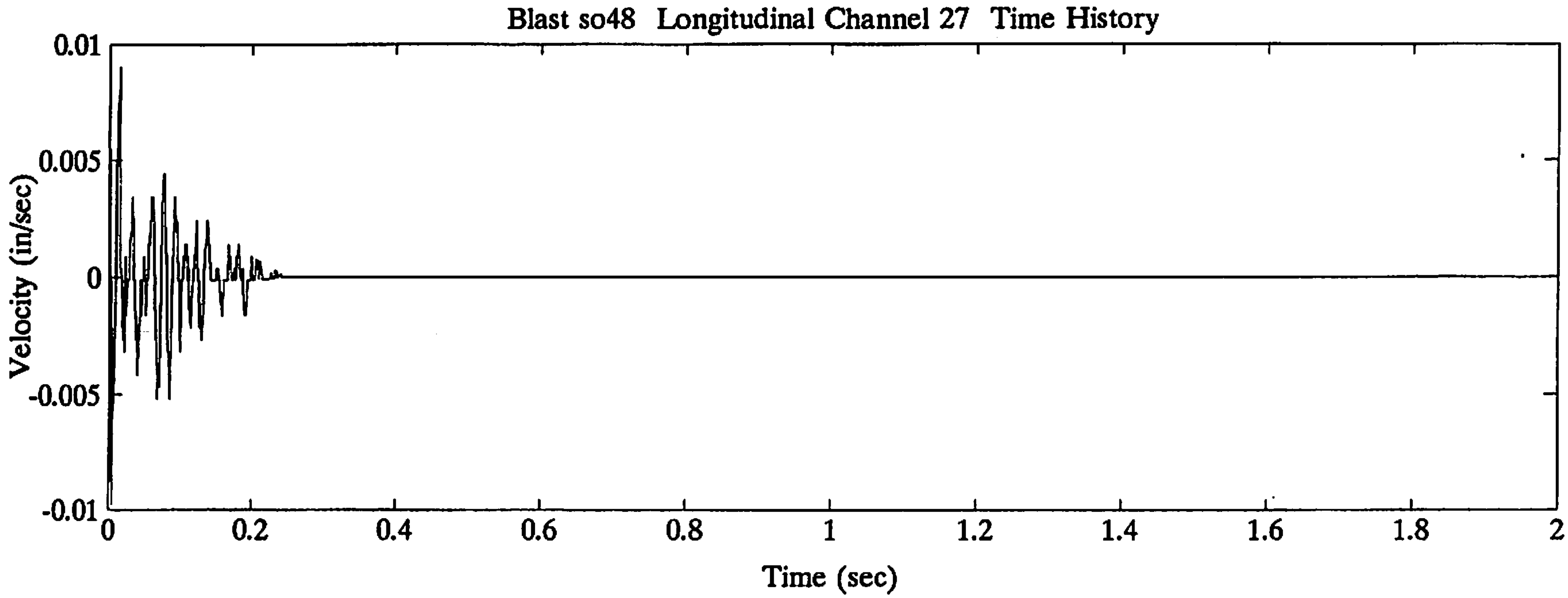


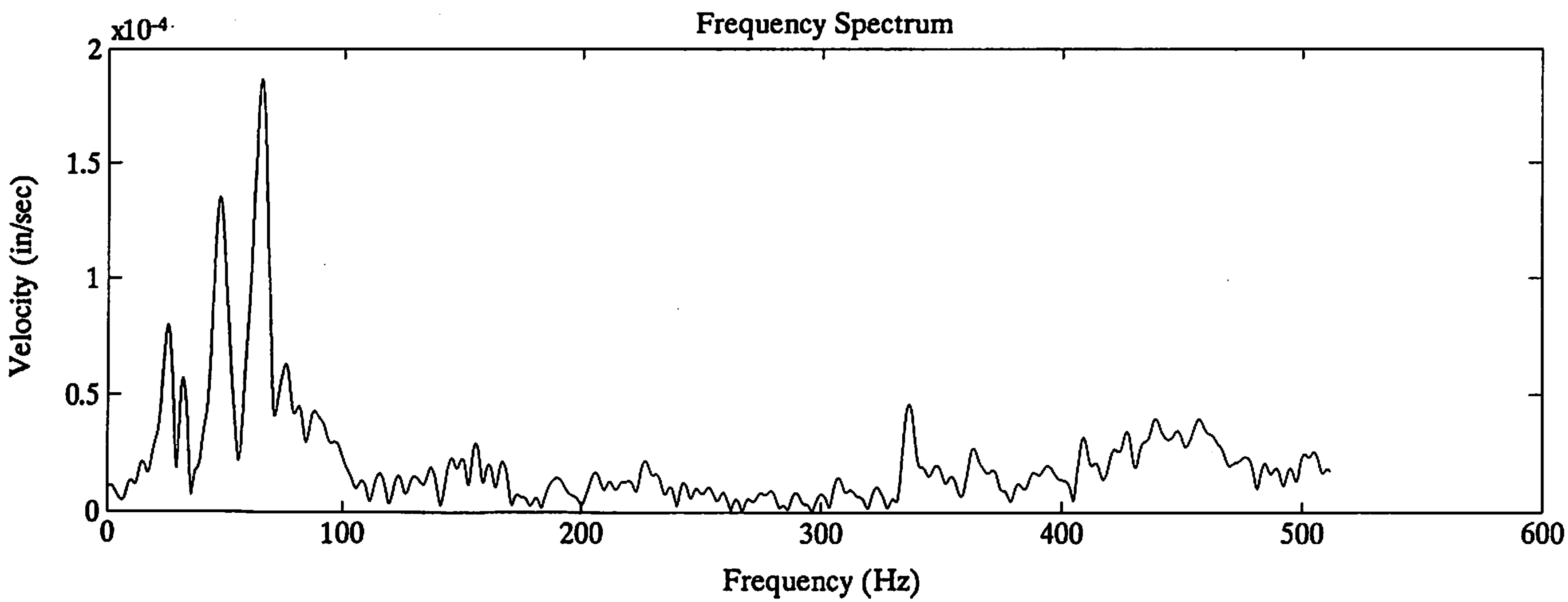
Blast so48 Longitudinal Channel 24 Time History
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

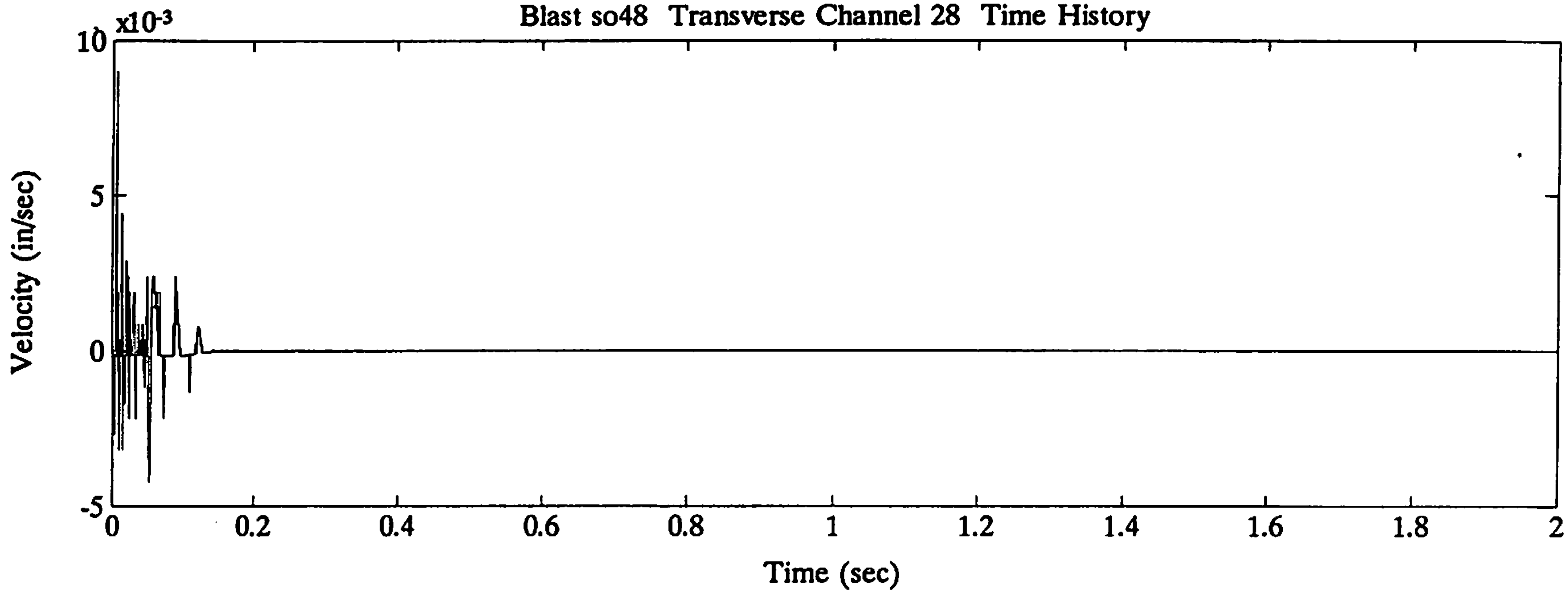

Blast so48 Transverse Channel 25 Time History
Velocity (in/sec)
0.1
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so48 Vertical Channel 26 Time History
Velocity (in/sec)
0.02
0.01
0
-0.01
-0.02
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

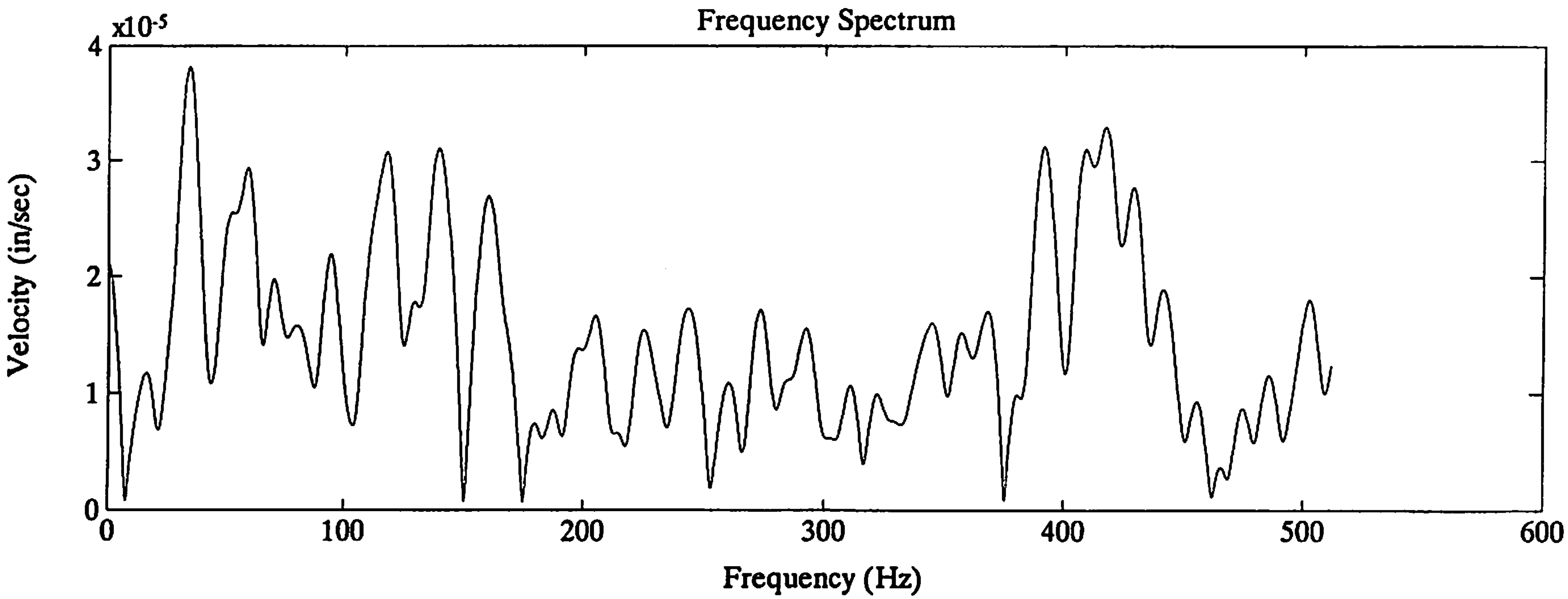

Frequency Spectrum
x10-4
Velocity (in/sec)
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so48 Longitudinal Channel 27 Time History
Velocity (in/sec)
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

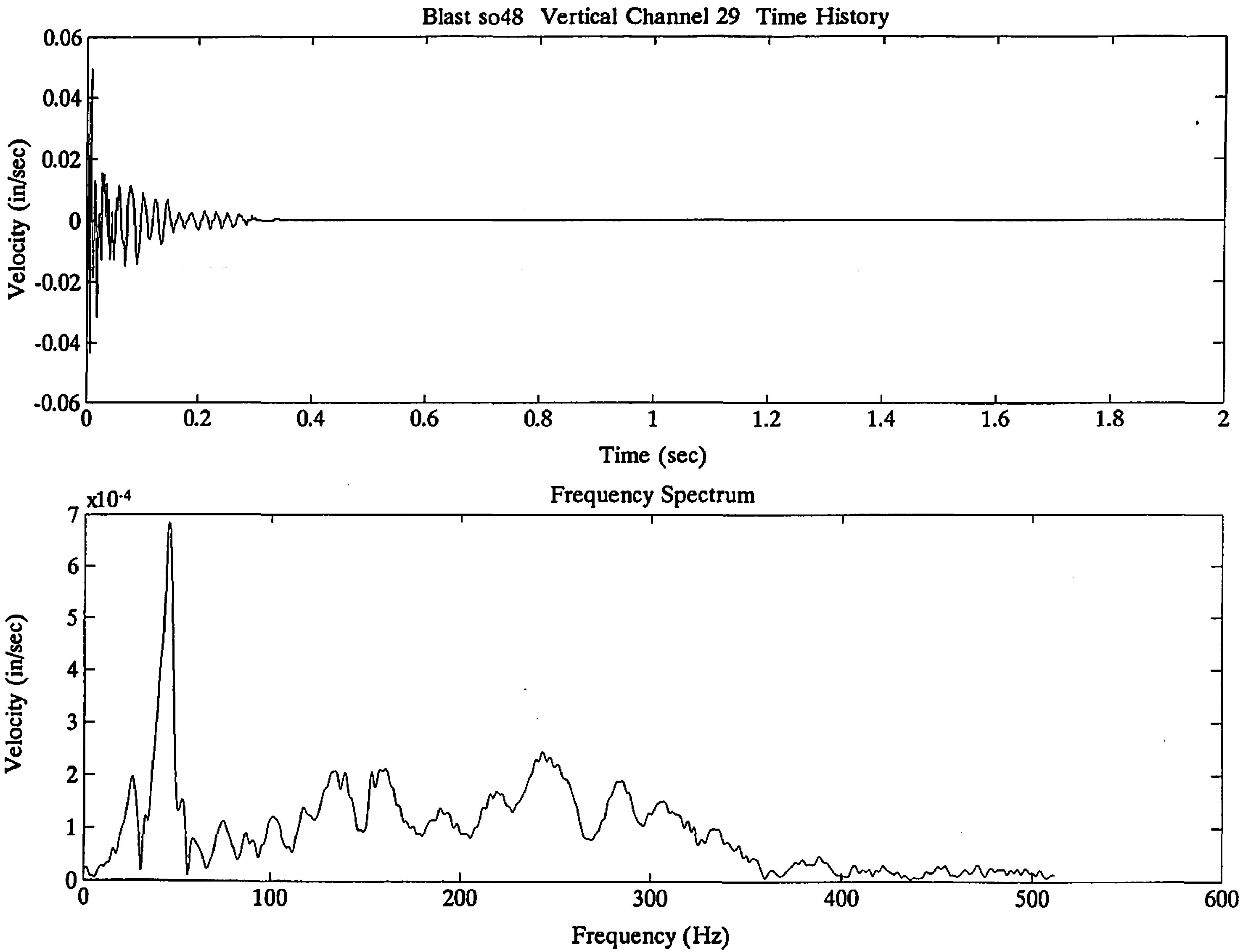

Frequency Spectrum
x10-4
Velocity (in/sec)
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)



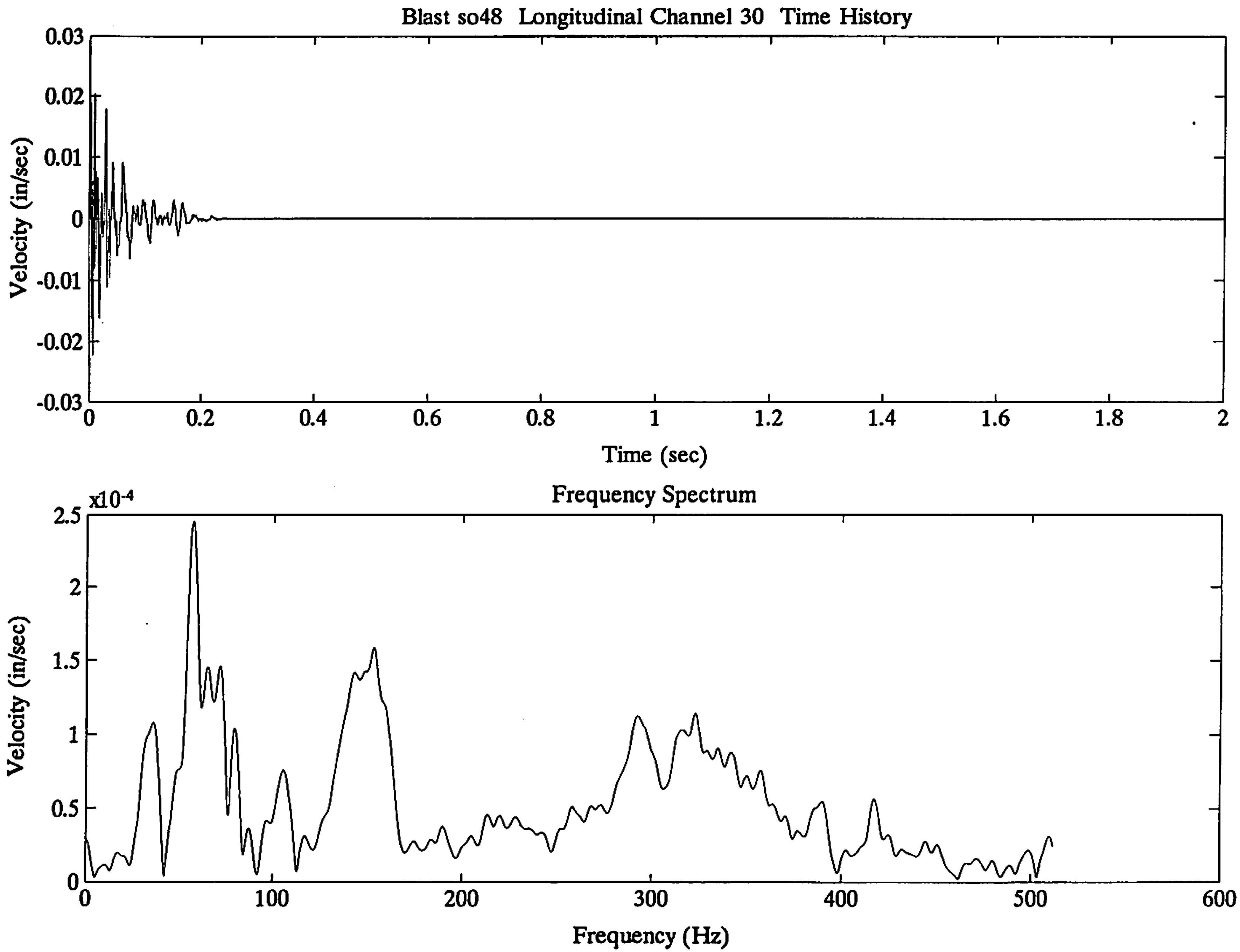
Blast so48 Transverse Channel 28 Time History
x10-3
Velocity (in/sec)
Time (sec)
10
5
0
-5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



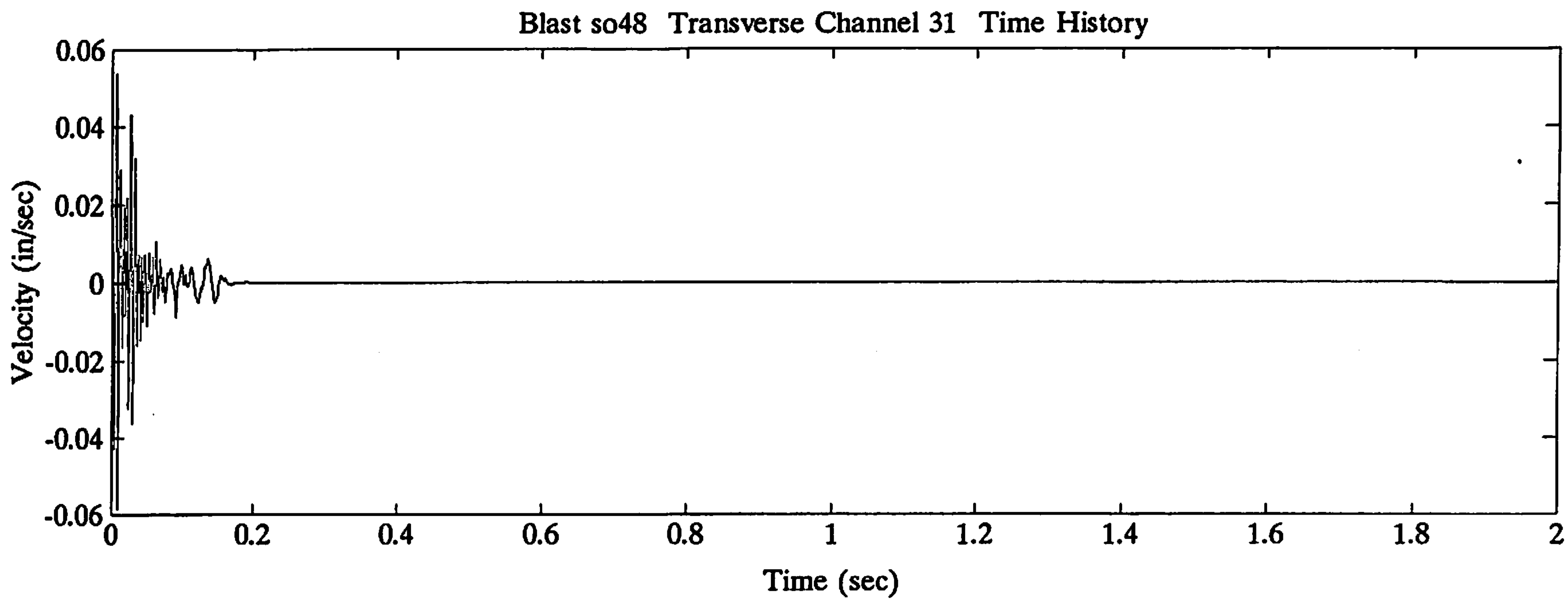
Frequency Spectrum
x10-5
Velocity (in/sec)
Frequency (Hz)
4
3
2
1
0
0
100
200
300
400
500
600

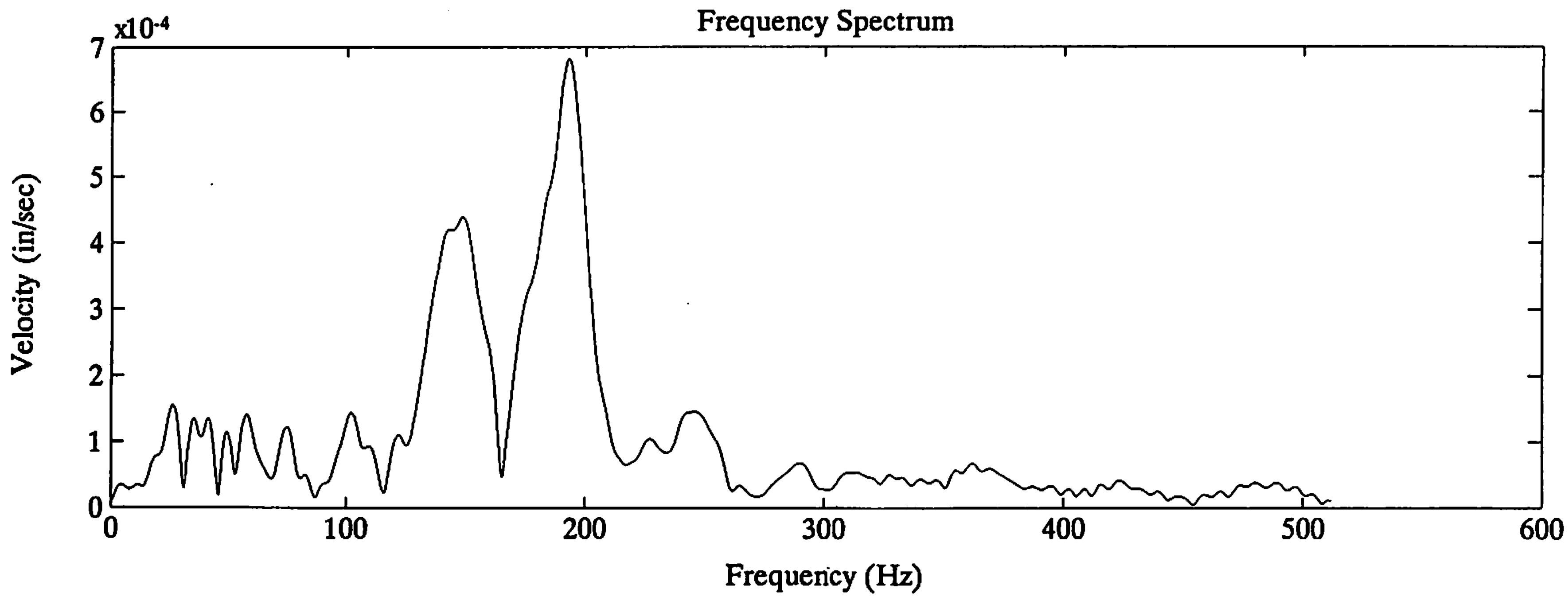


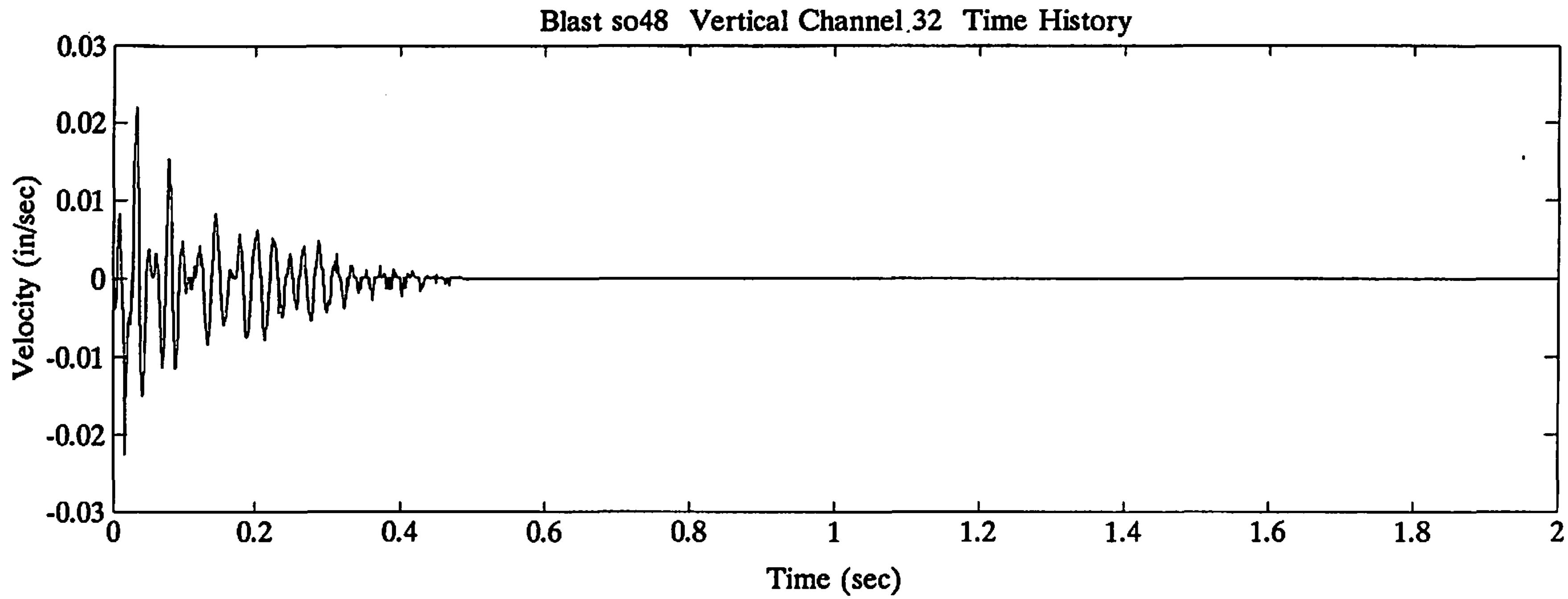
Blast so48 Vertical Channel 29 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
Velocity (in/sec)
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)



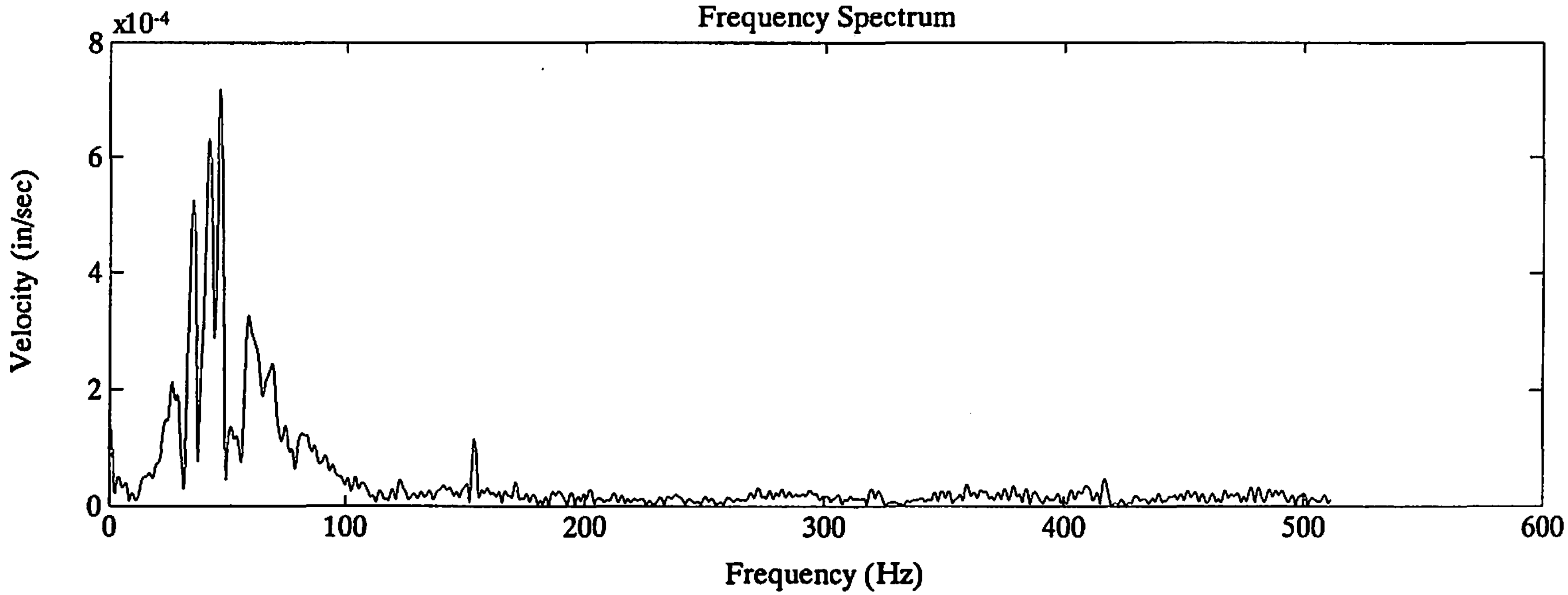
Blast so48 Longitudinal Channel 30 Time History
Velocity (in/sec)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-4
2.5
2
1.5
1
0.5
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so48 Transverse Channel 31 Time History
Velocity (in/sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

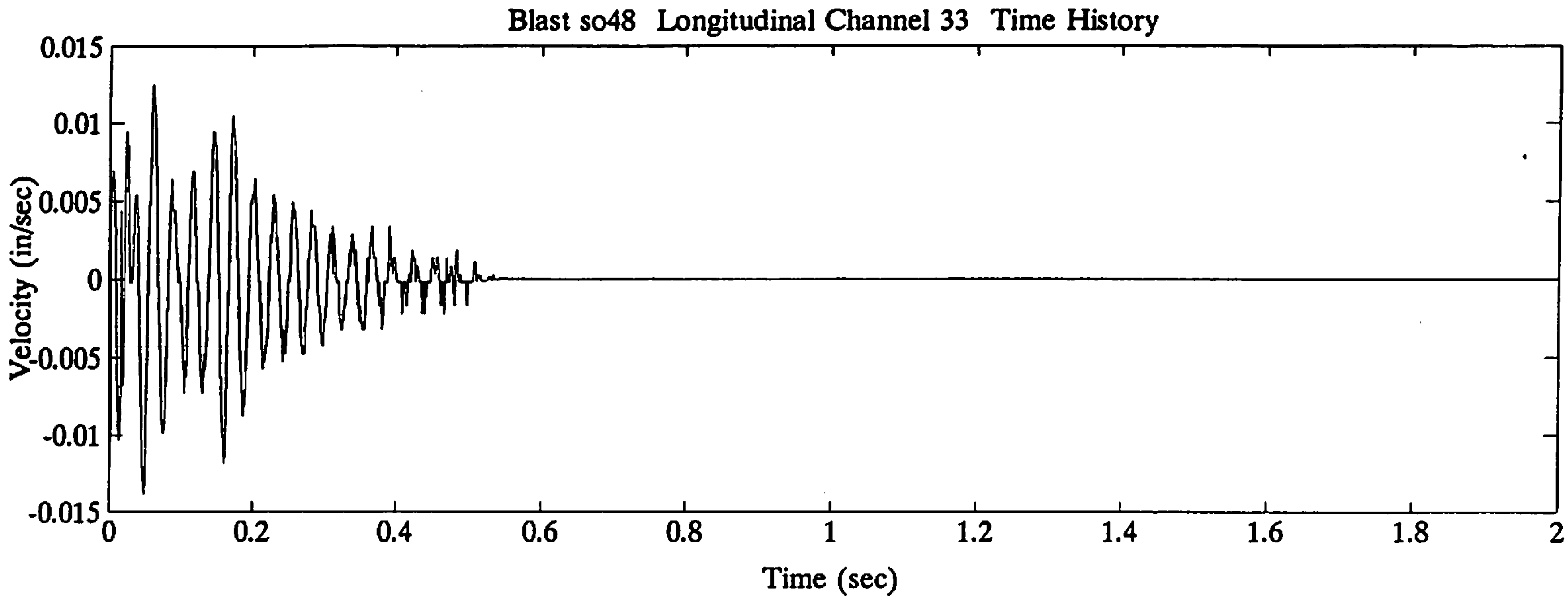

Frequency Spectrum
x10-4
Velocity (in/sec)
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

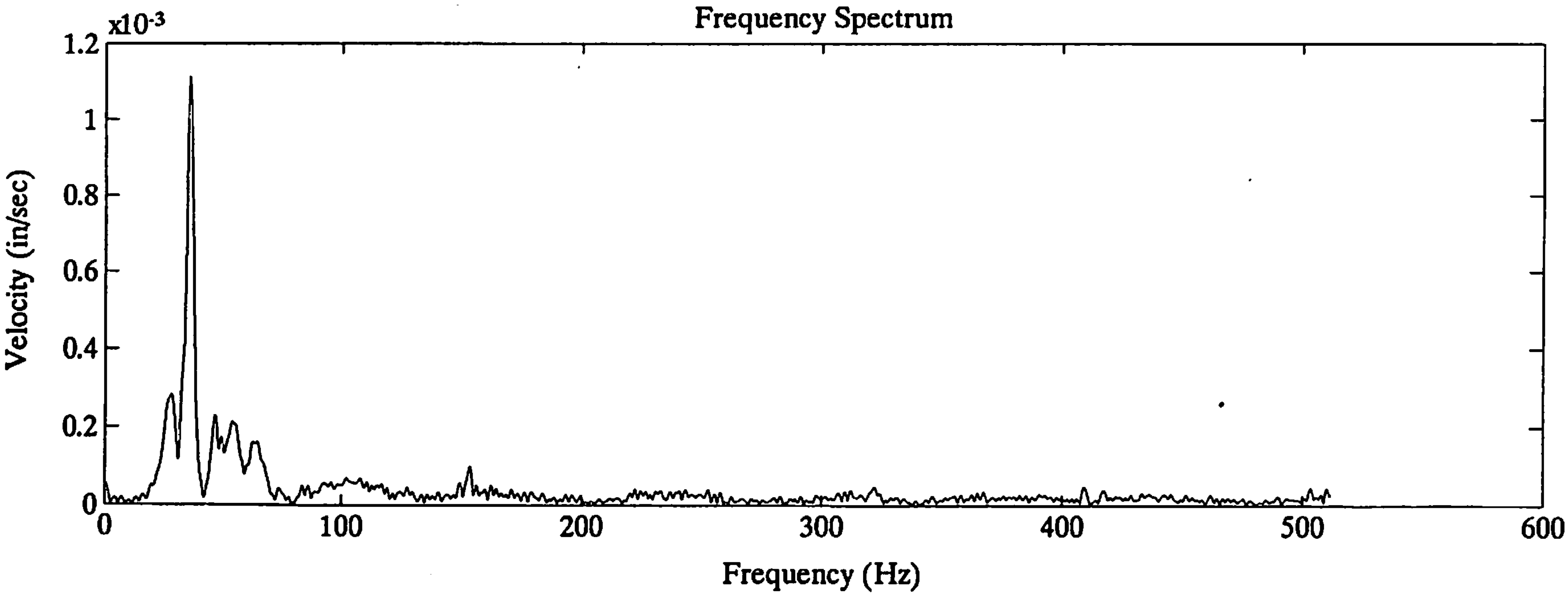


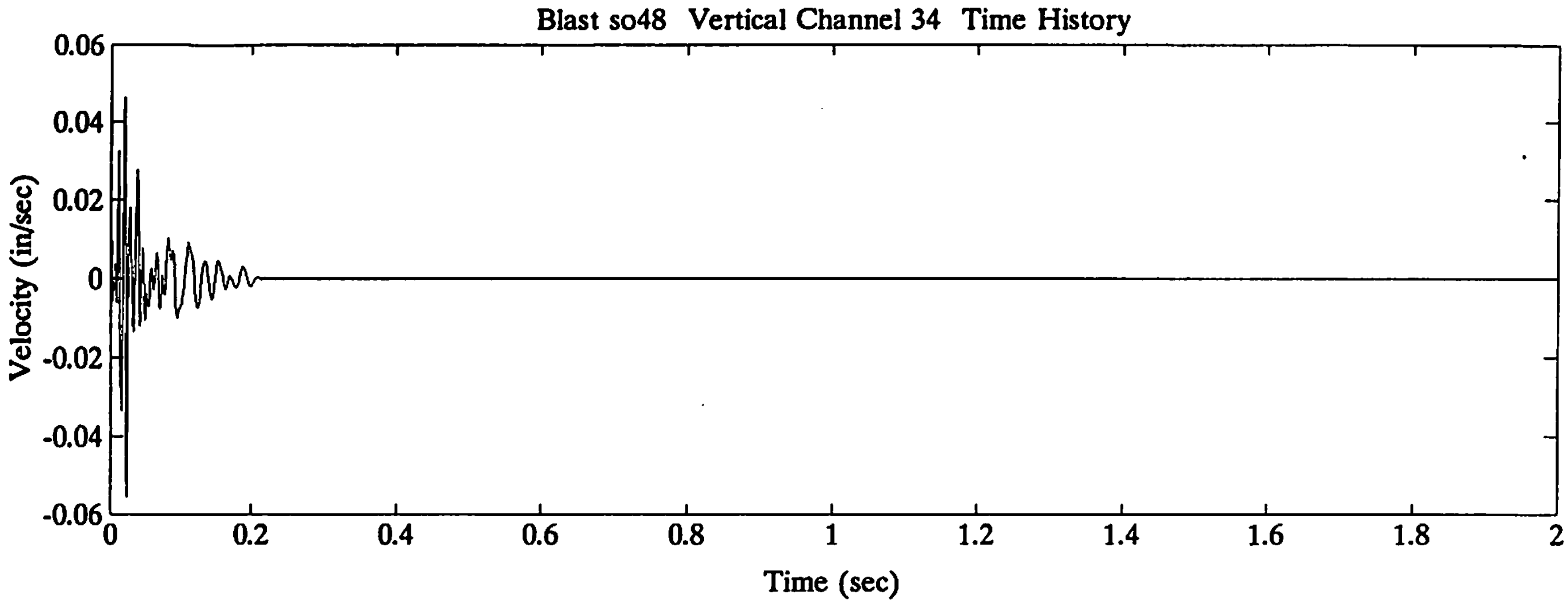
Blast so48 Vertical Channel 32 Time History
Velocity (in/sec)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

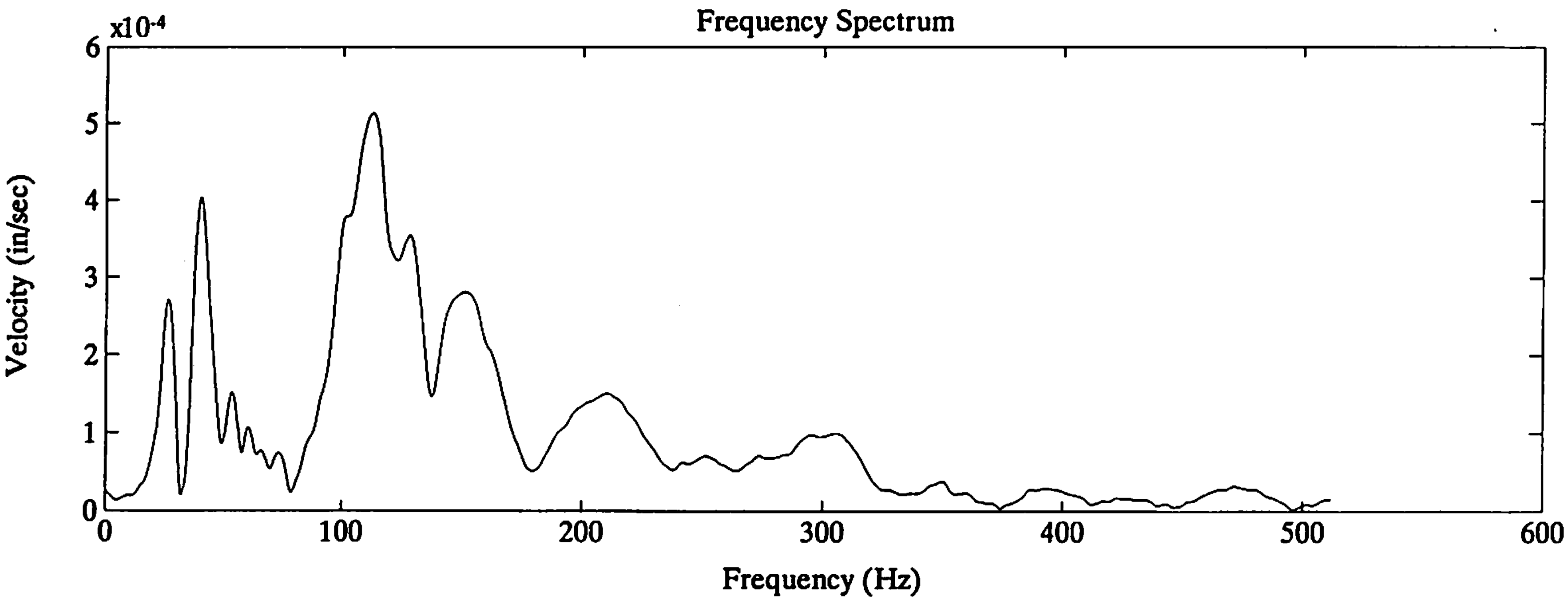


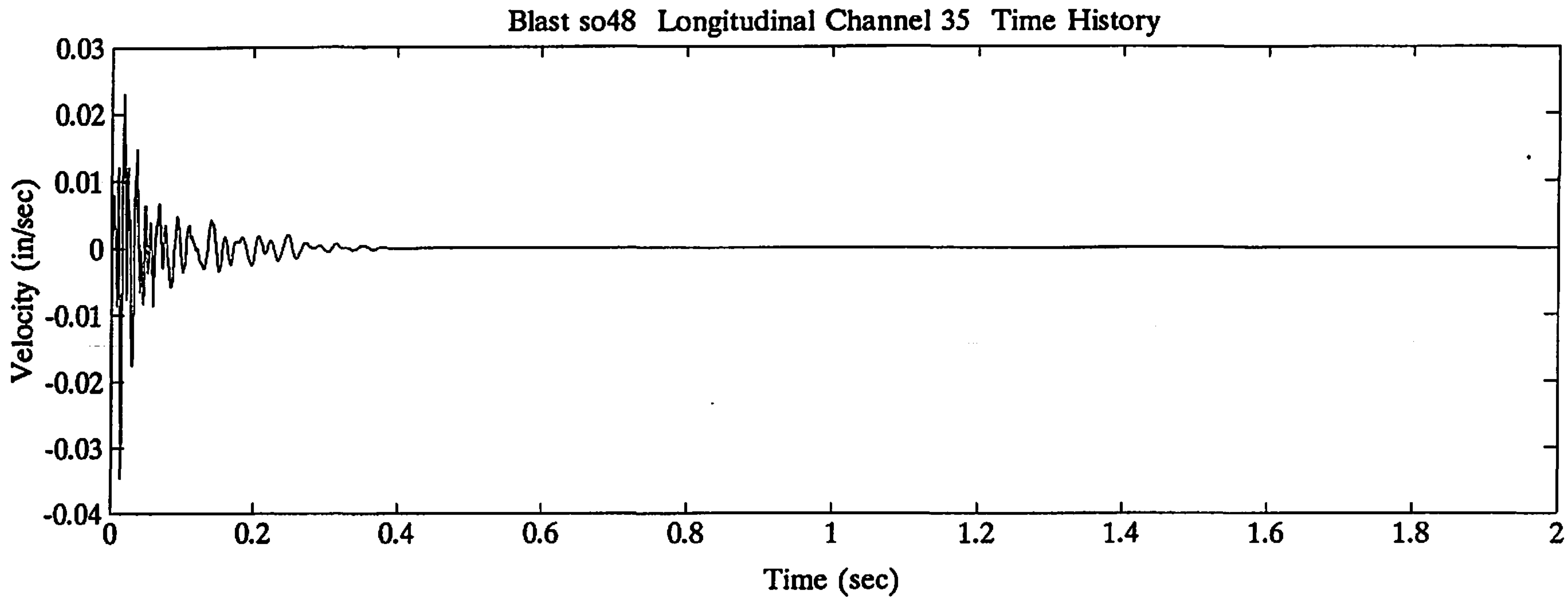
Frequency Spectrum
x10-4
8
6
4
2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

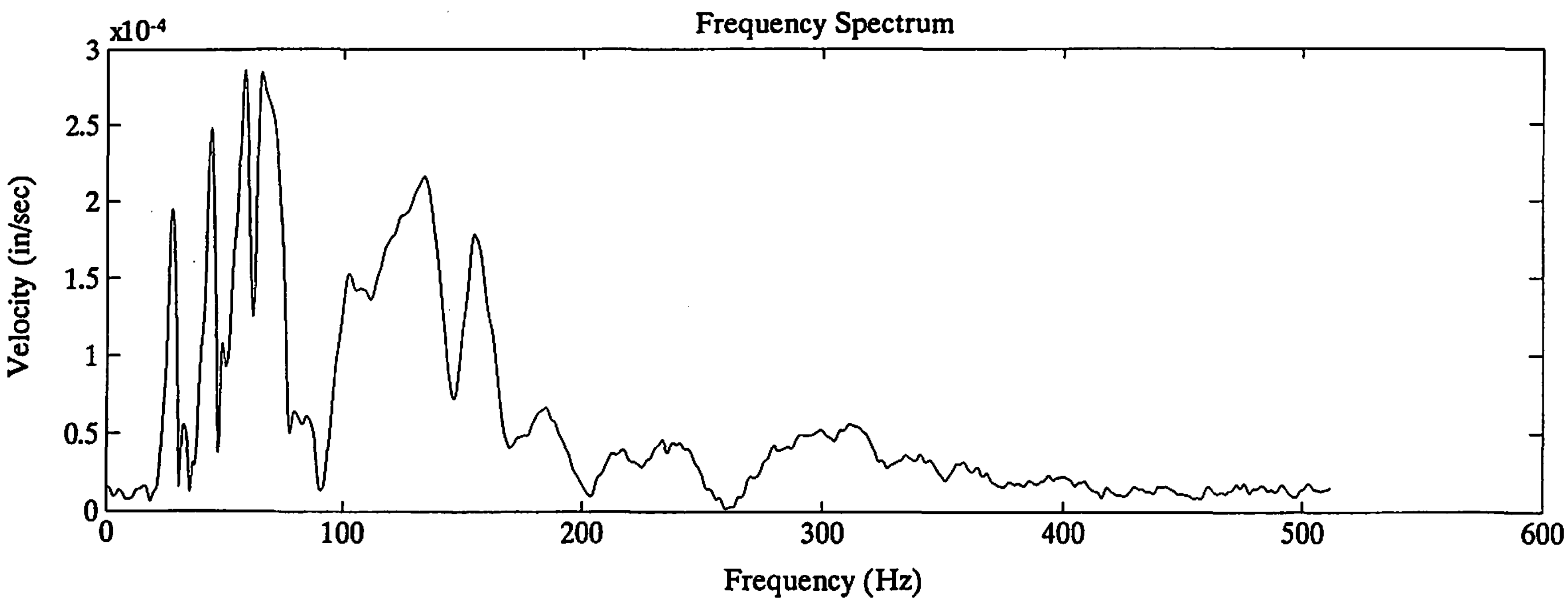

Blast so48 Longitudinal Channel 33 Time History
Velocity (in/sec)
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

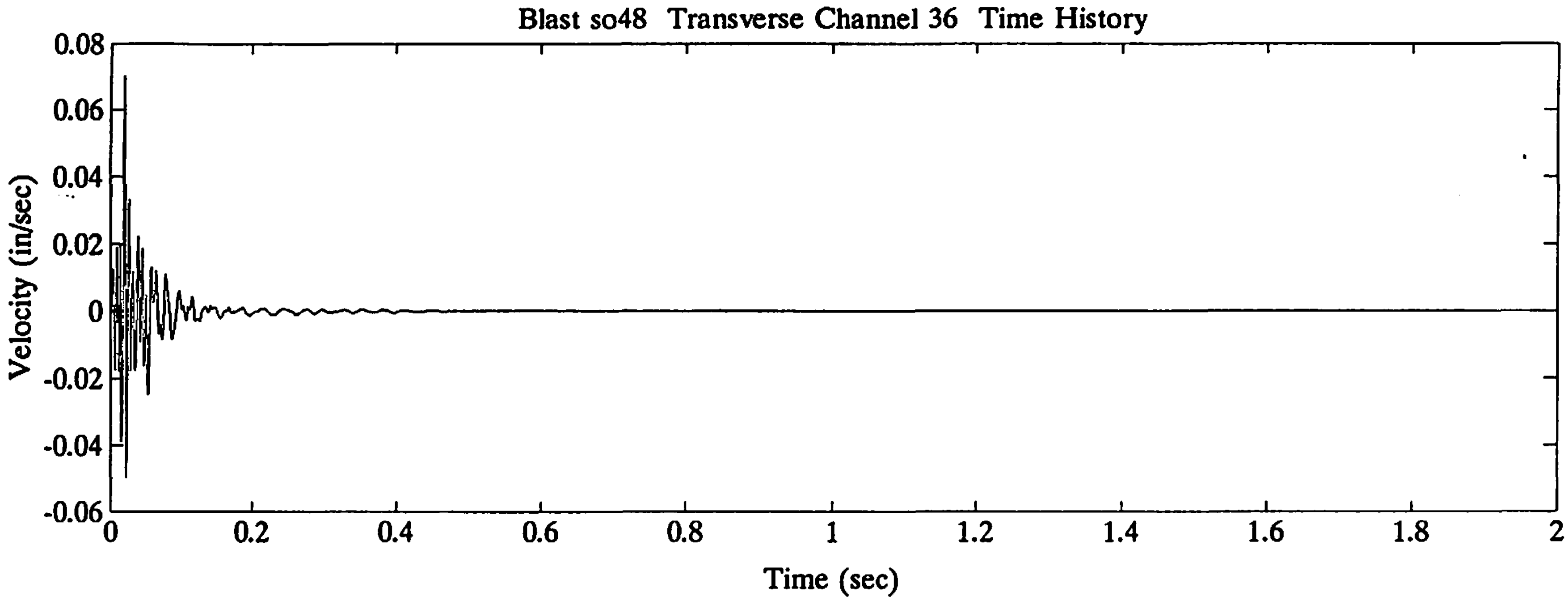

Frequency Spectrum
x10-3
1.2
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)


Blast so48 Vertical Channel 34 Time History
Velocity (in/sec)
Time (sec)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

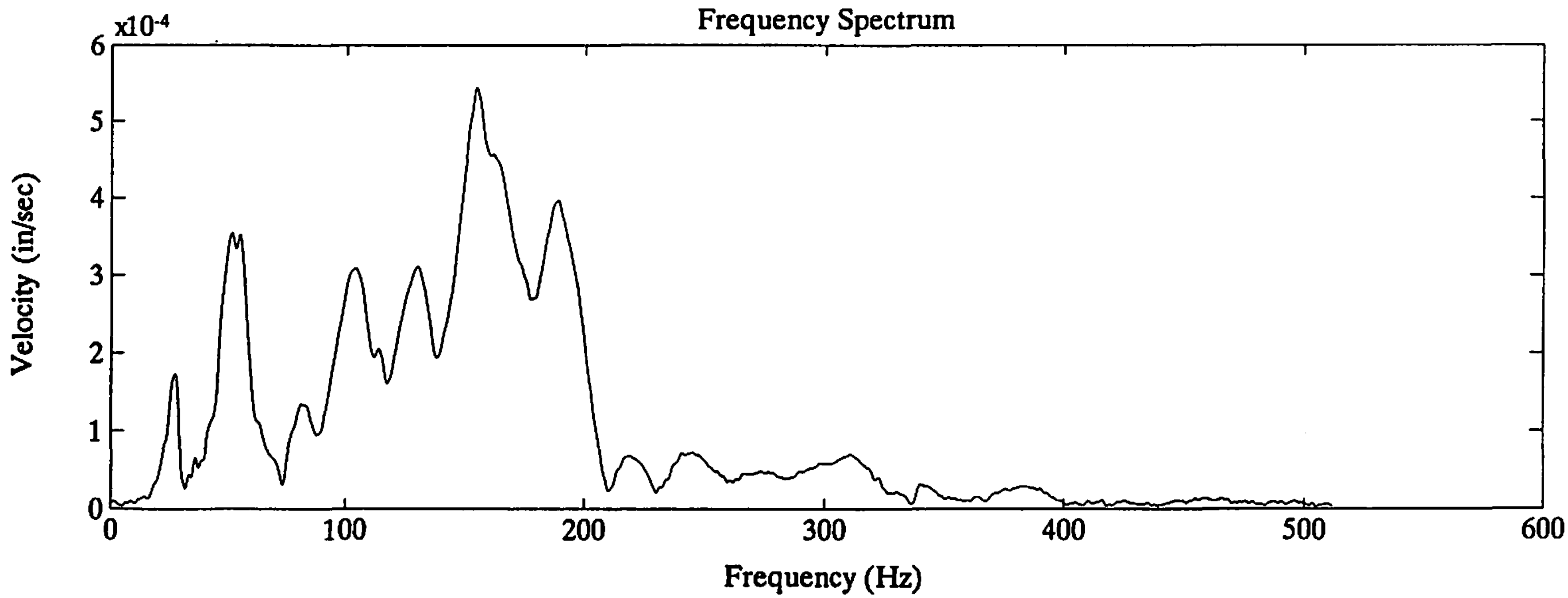

Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)
6
5
4
3
2
1
0
0
100
200
300
400
500
600


Blast so48 Longitudinal Channel 35 Time History
Velocity (in/sec)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

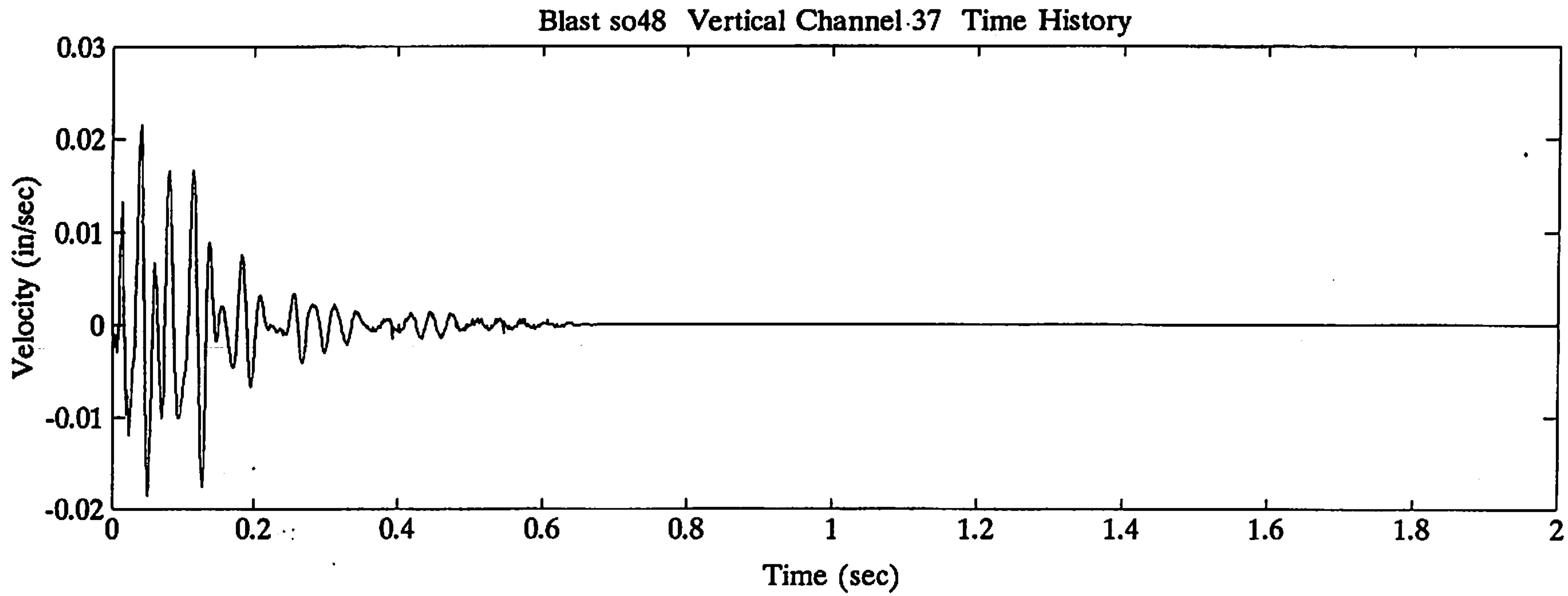

Frequency Spectrum
x10-4
Velocity (in/sec)
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)

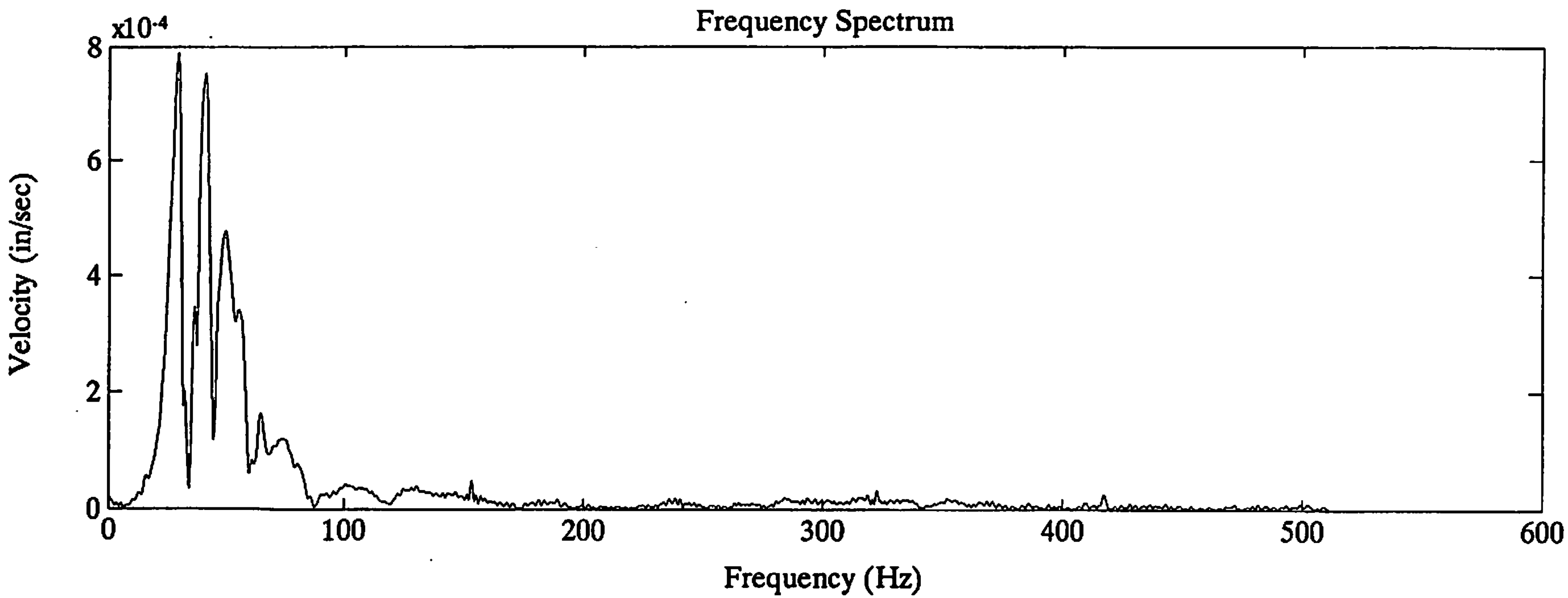


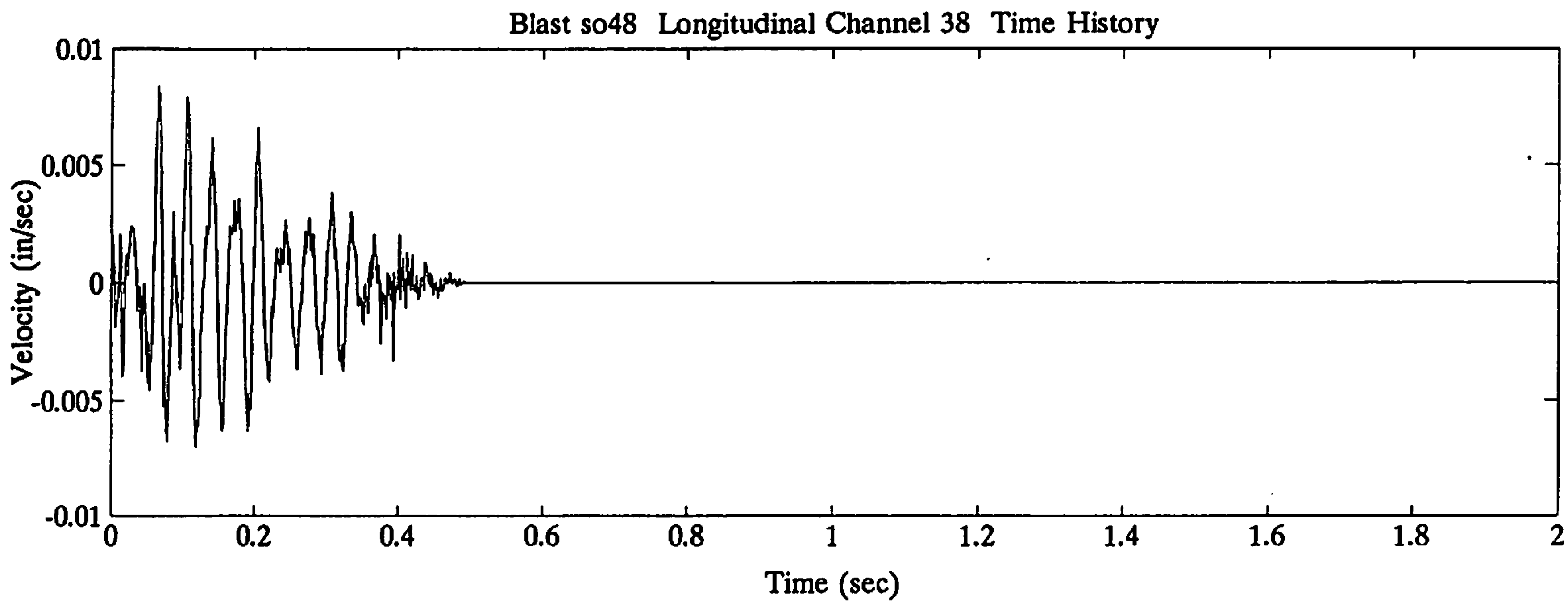
Blast so48 Transverse Channel 36 Time History
Velocity (in/sec)
Time (sec)

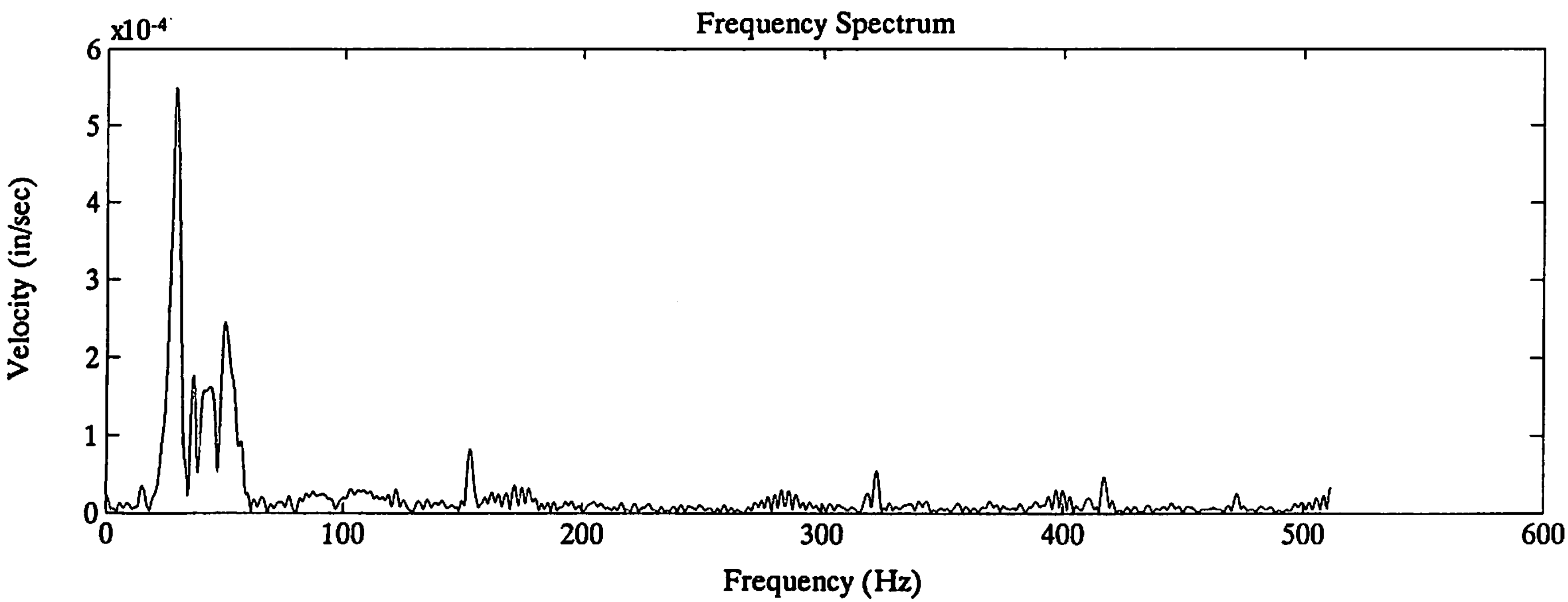


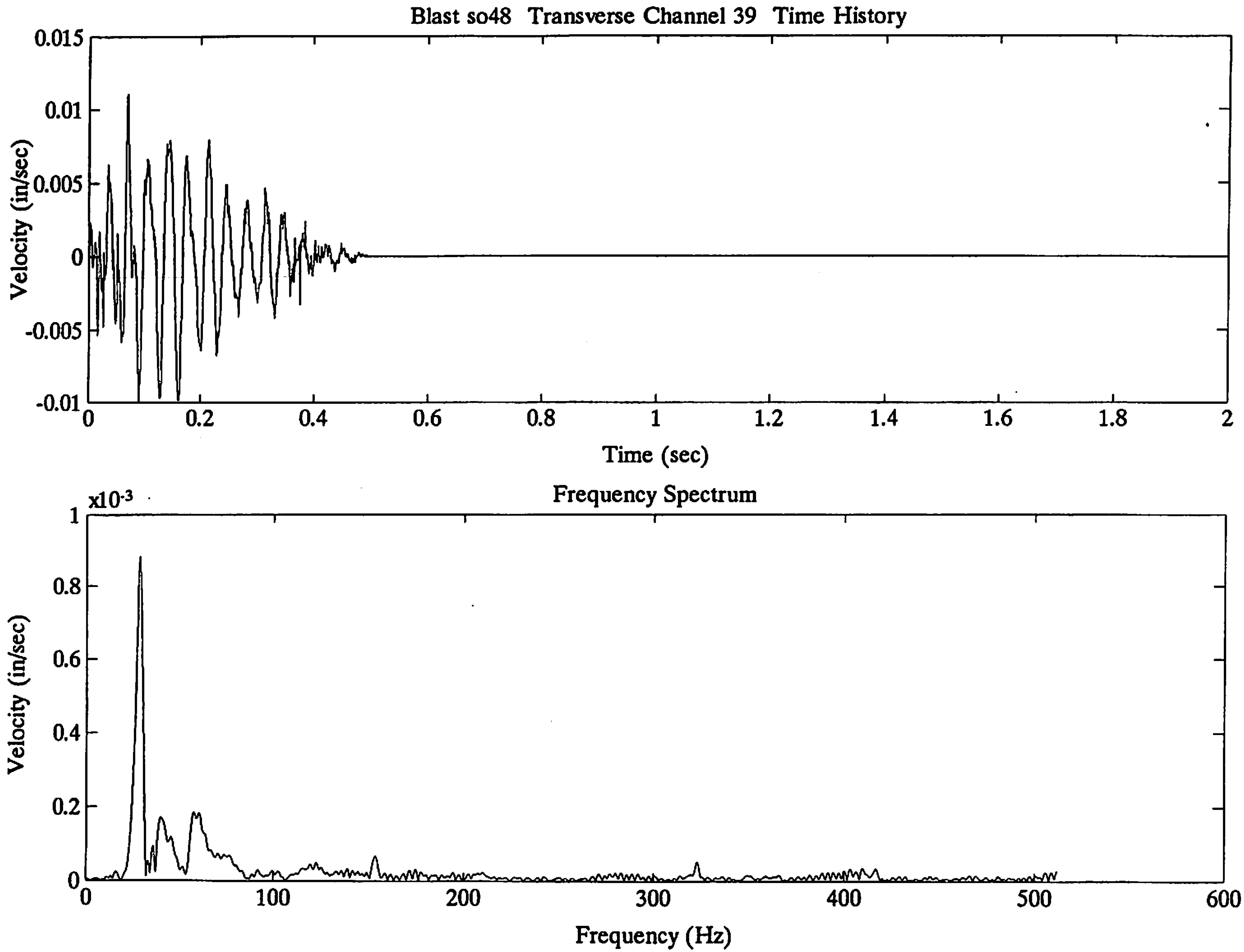
Frequency Spectrum
x10-4
Velocity (in/sec)
Frequency (Hz)


Blast so48 Vertical Channel 37 Time History
0.03
0.02
0.01
0
-0.01
-0.02
Velocity (in/sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

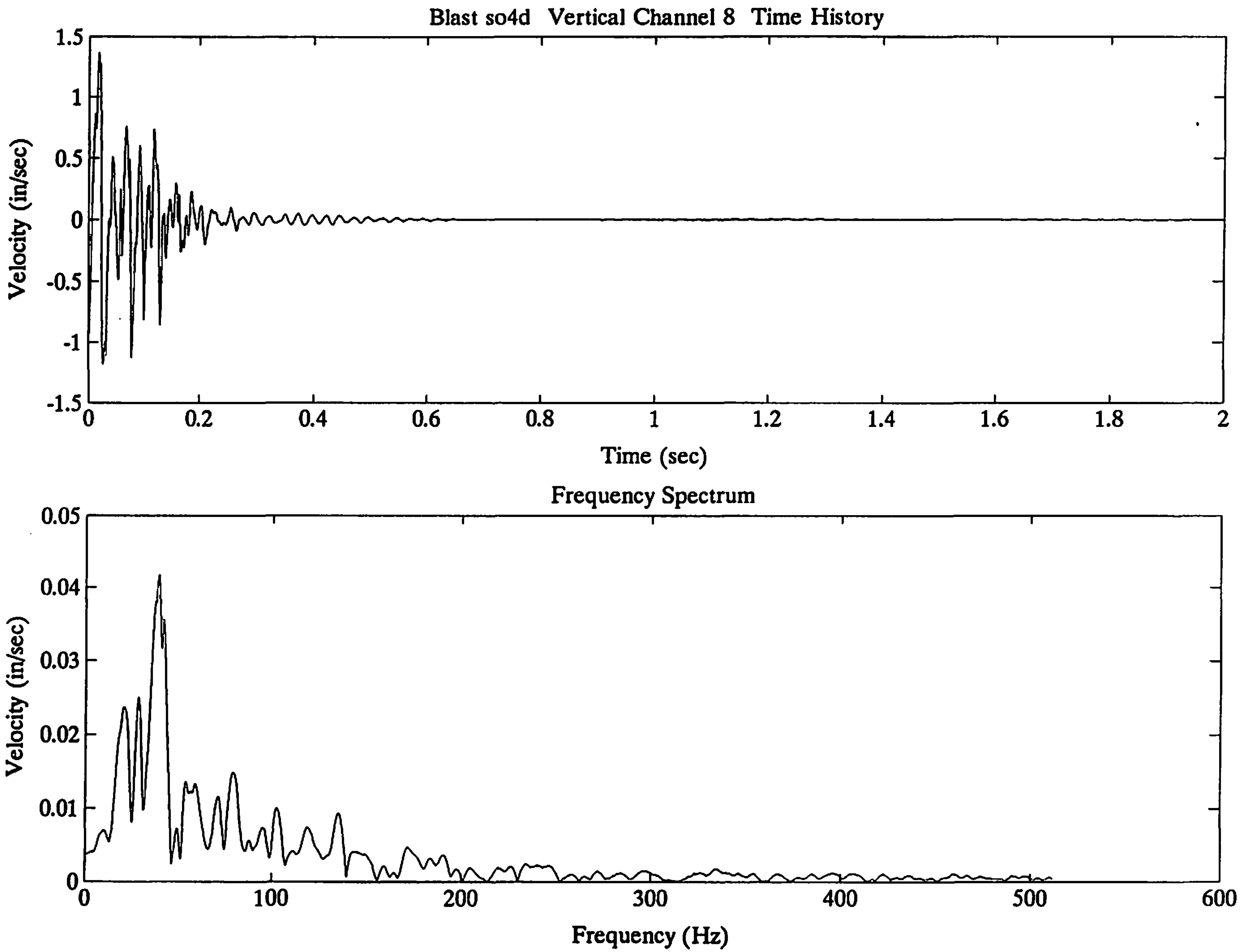

Frequency Spectrum
x10-4
8
6
4
2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

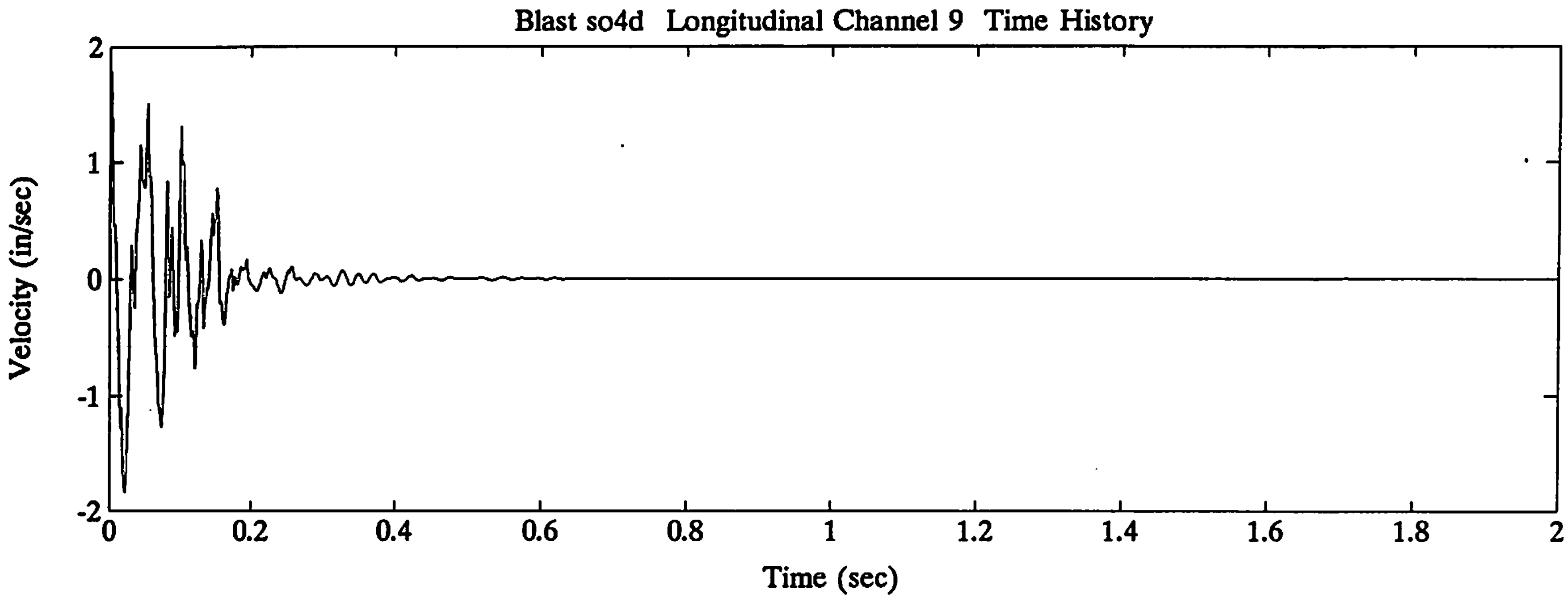

Blast so48 Longitudinal Channel 38 Time History
Velocity (in/sec)
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)


Frequency Spectrum
x10-4
Velocity (in/sec)
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

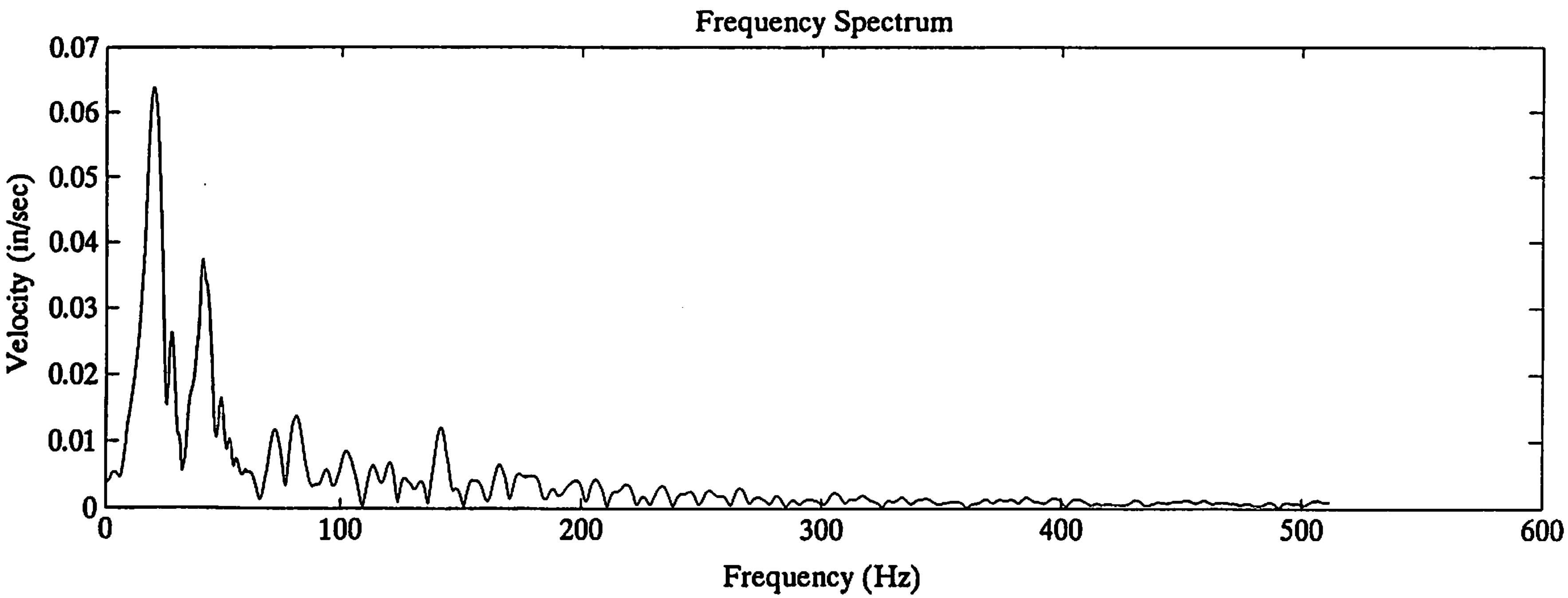


Blast so48 Transverse Channel 39 Time History
Velocity (in/sec)
0.015
0.01
0.005
0
-0.005
-0.01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
1
0.8
0.6
0.4
0.2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

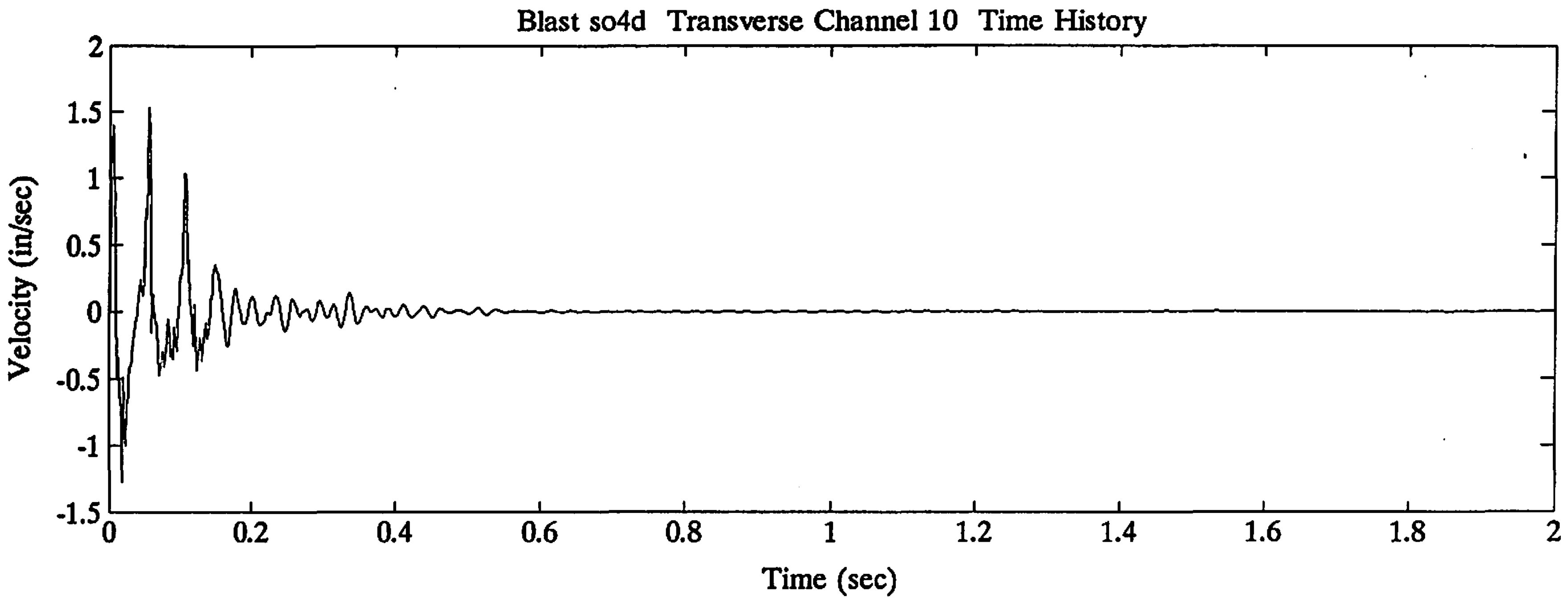

Blast so4d Vertical Channel 8 Time History
Velocity (in/sec)
Time (sec)
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)

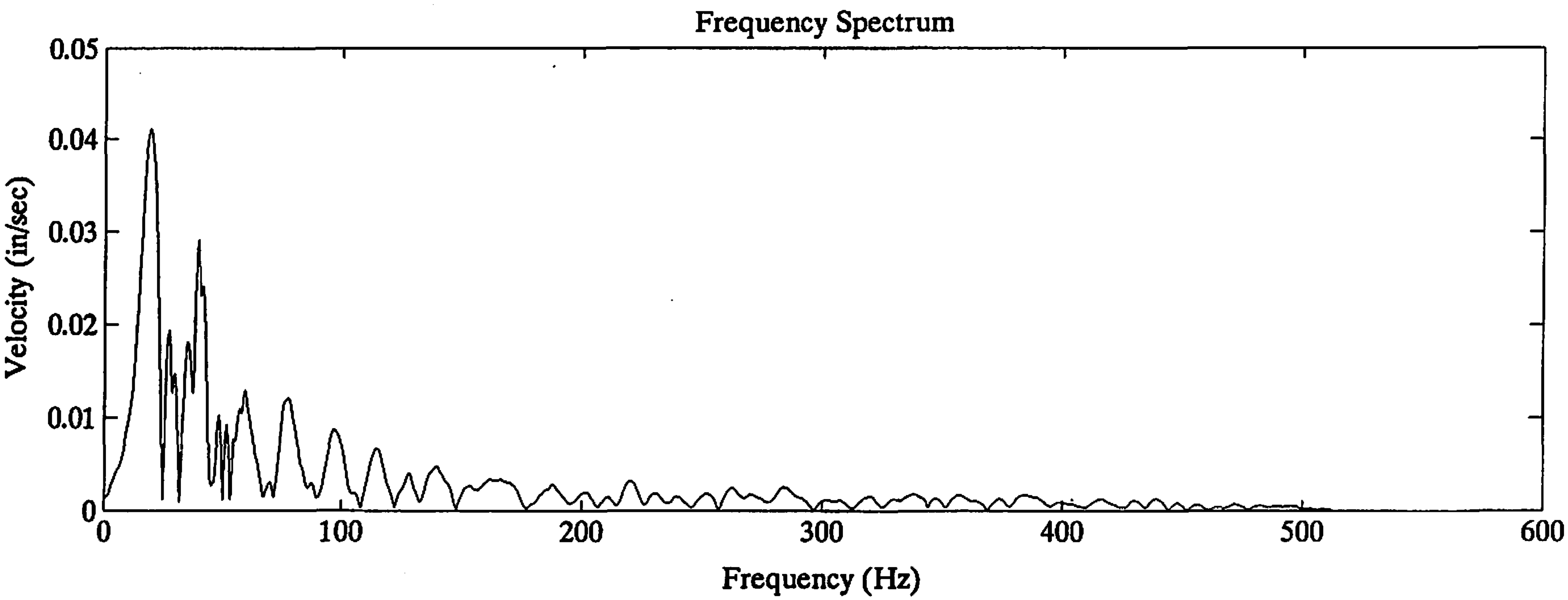


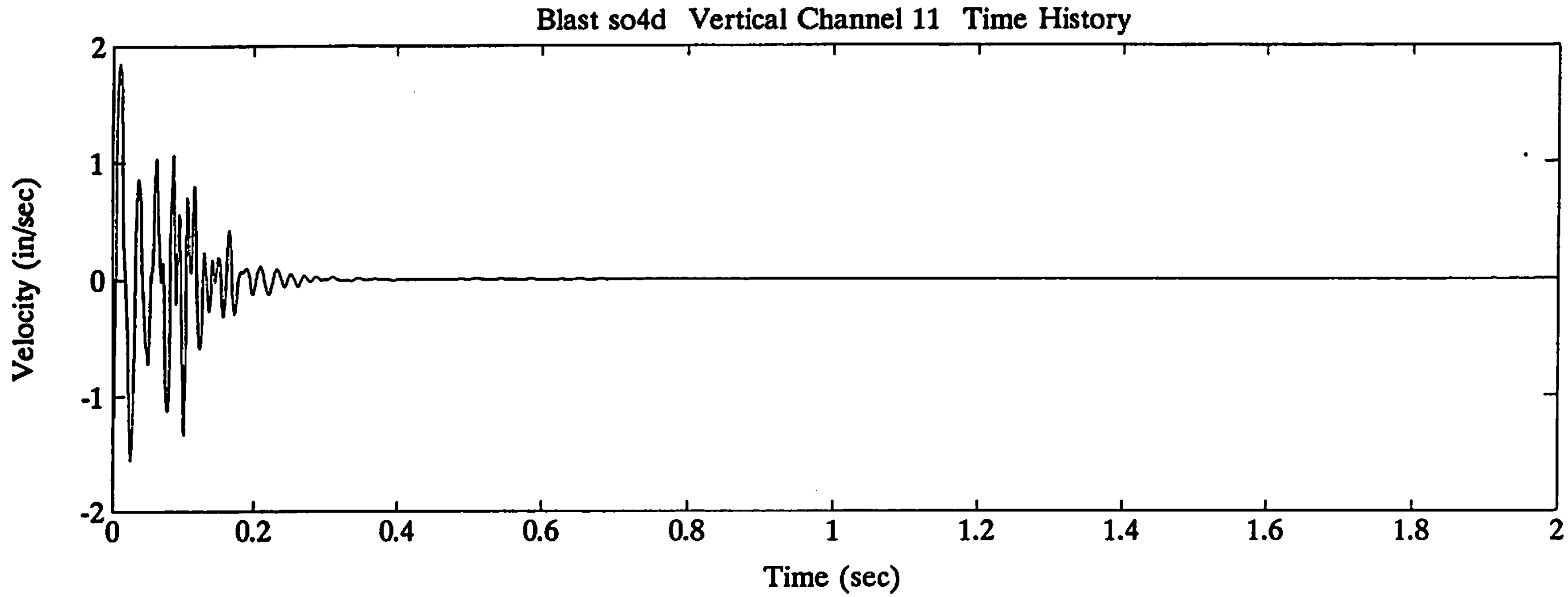
Blast so4d Longitudinal Channel 9 Time History
Velocity (in/sec)
2
1
0
-1
-2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



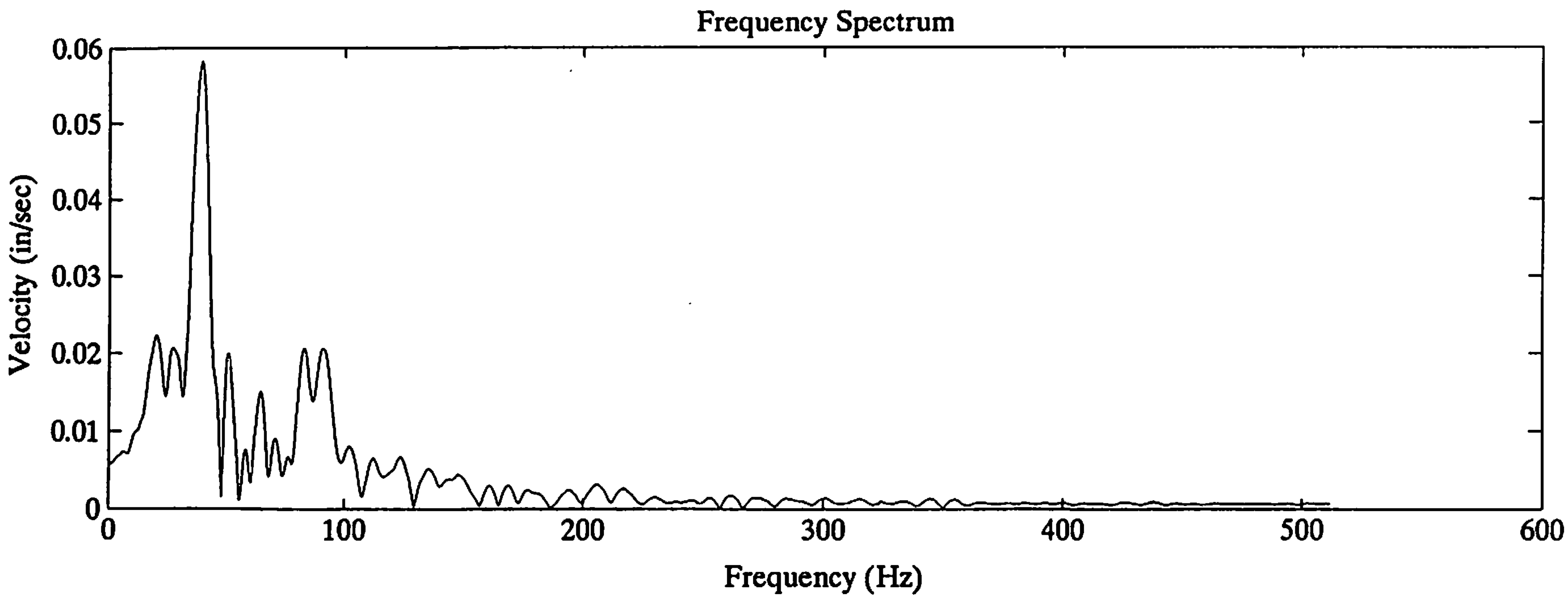
Frequency Spectrum
Velocity (in/sec)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Transverse Channel 10 Time History
Velocity (in/sec)
Time (sec)
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

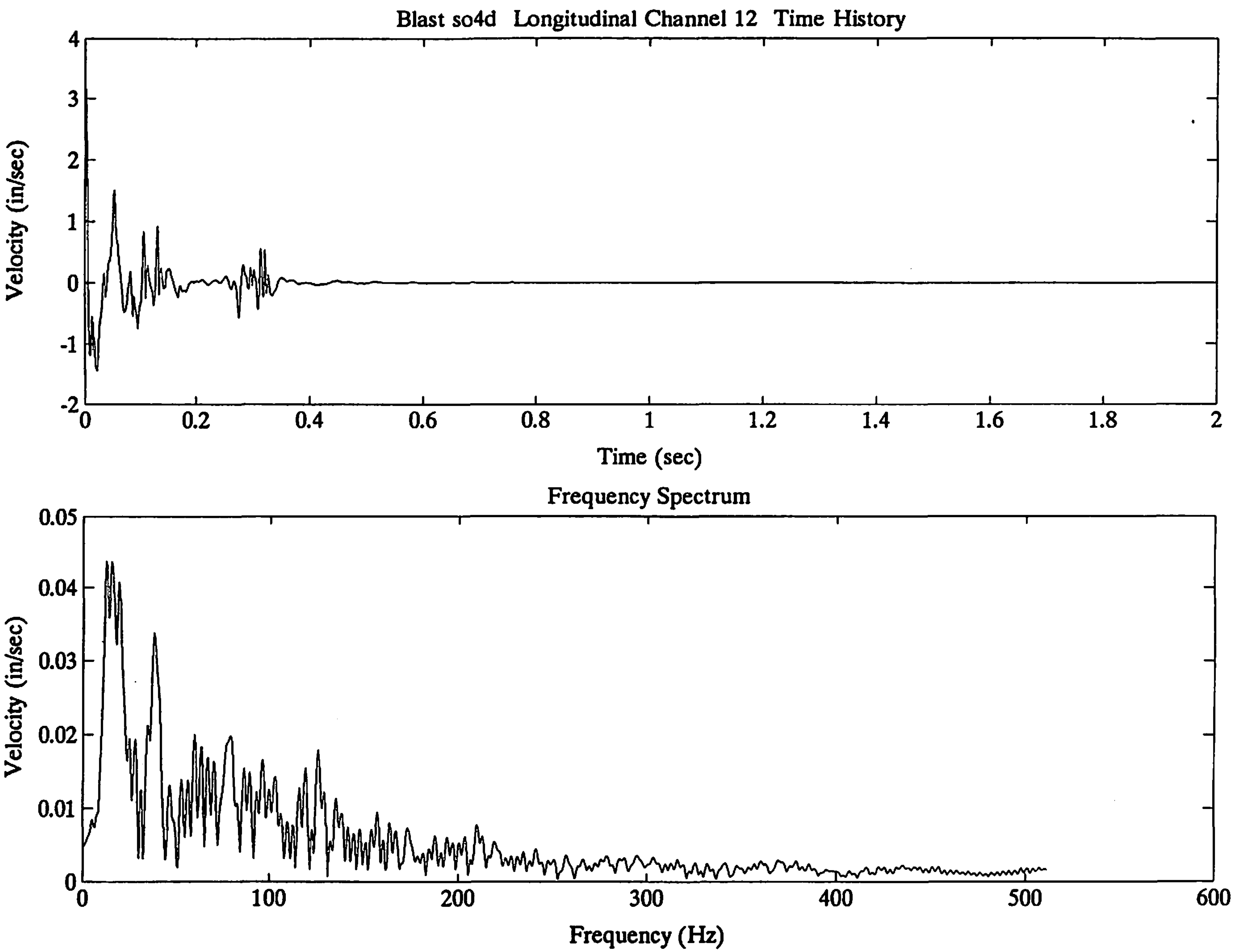

Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600



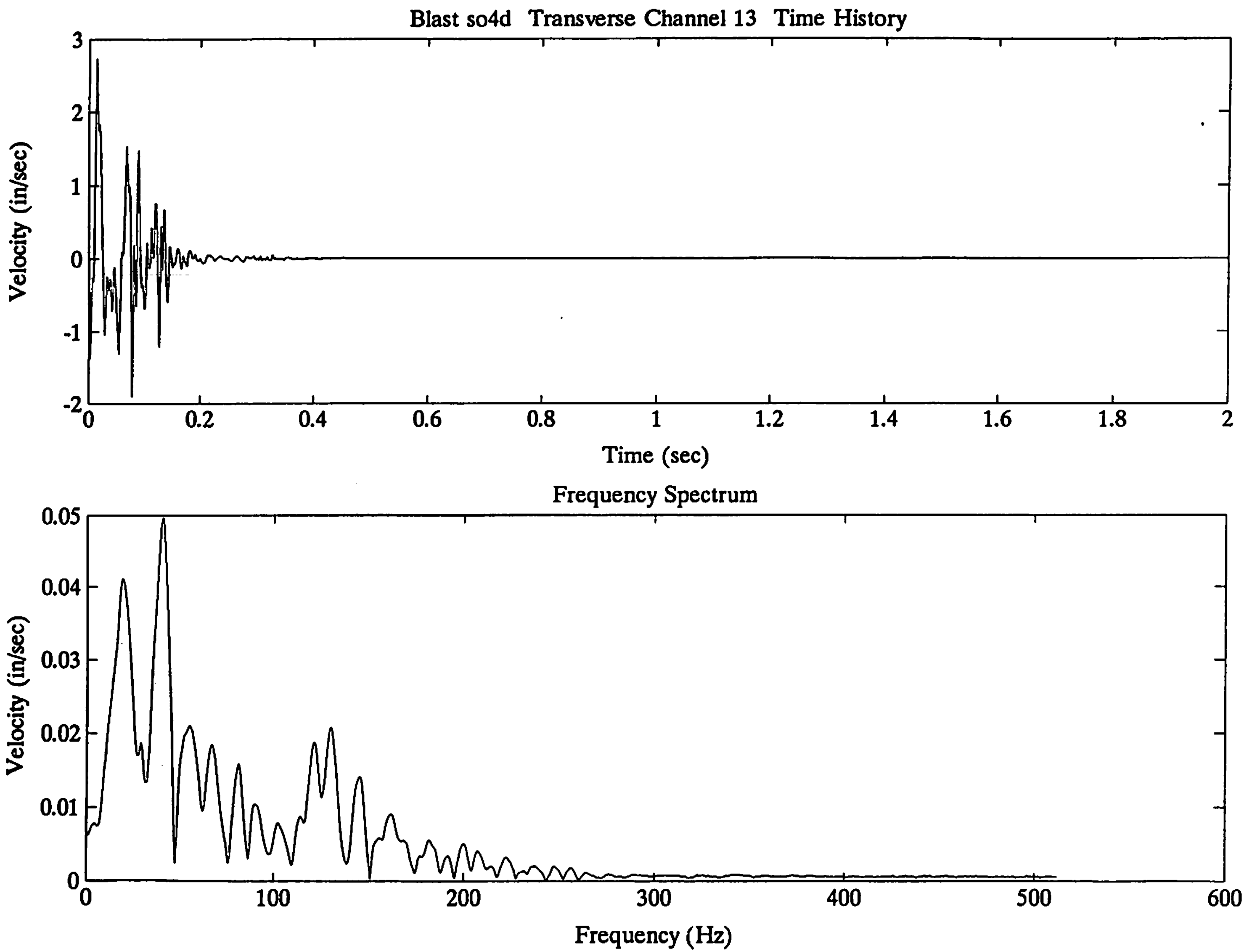
Blast so4d Vertical Channel 11 Time History
Velocity (in/sec)
Time (sec)

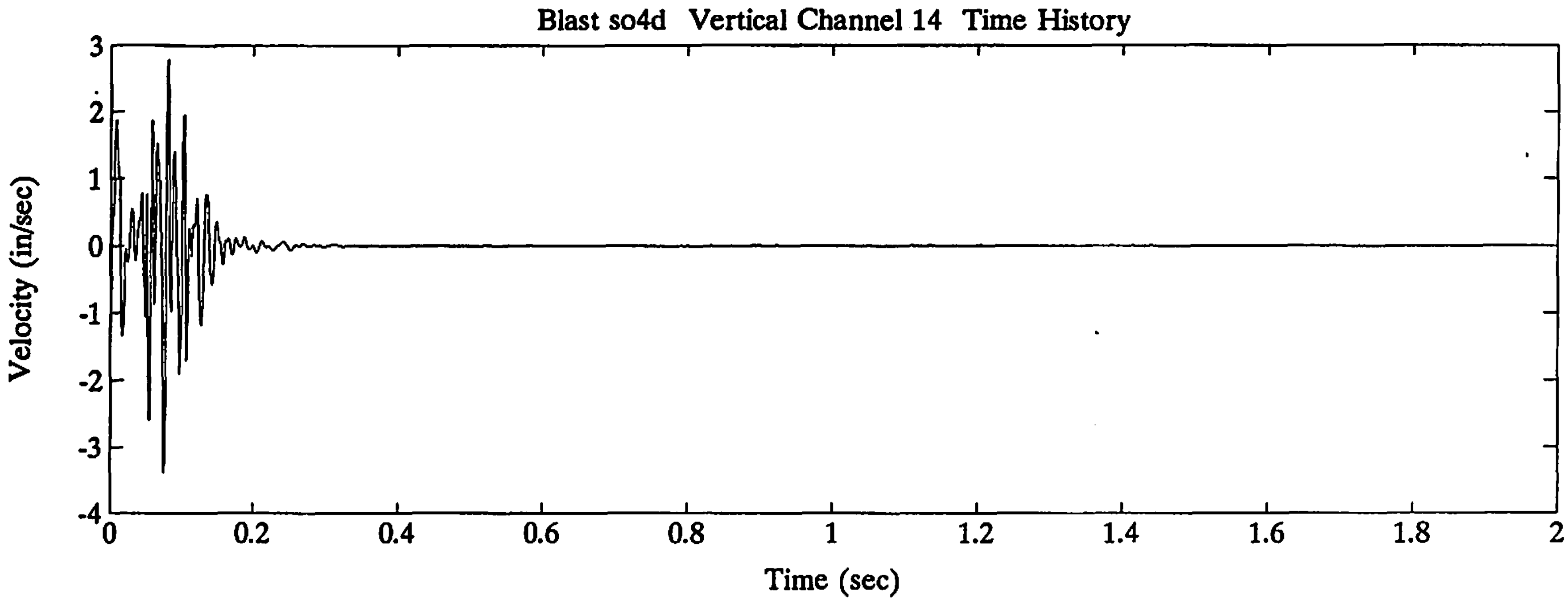


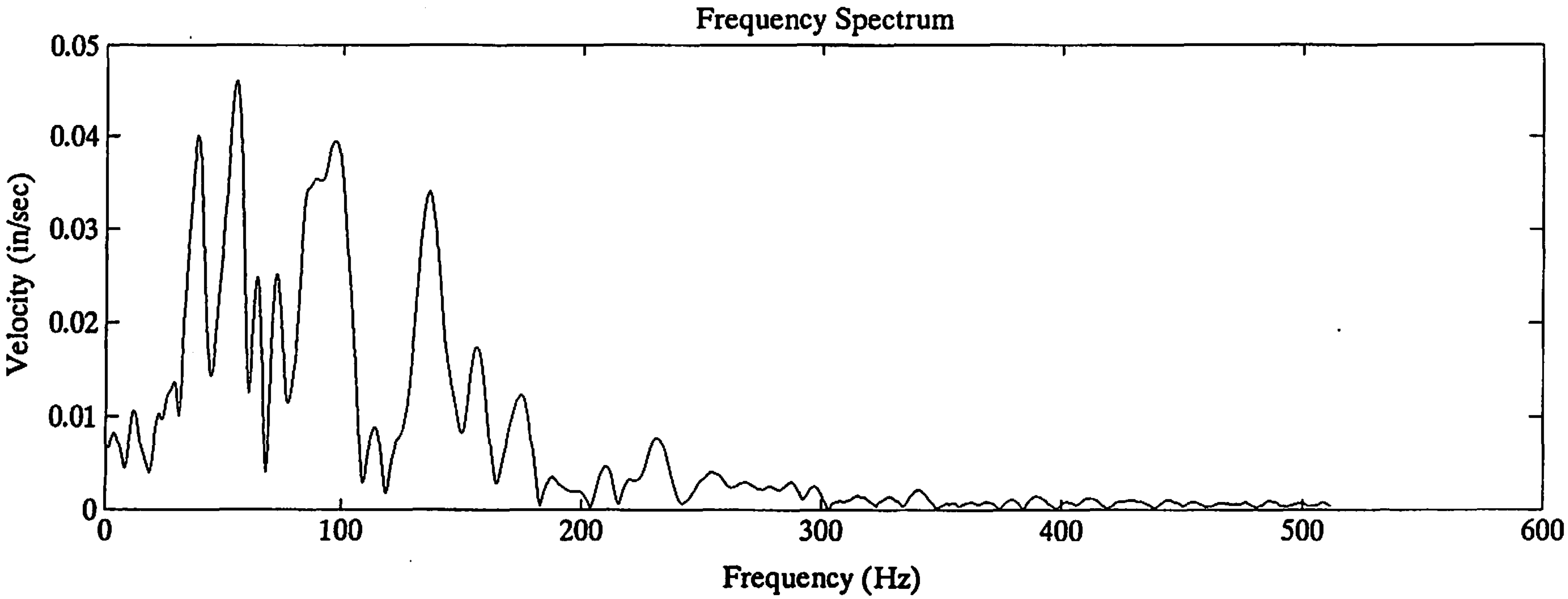
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)

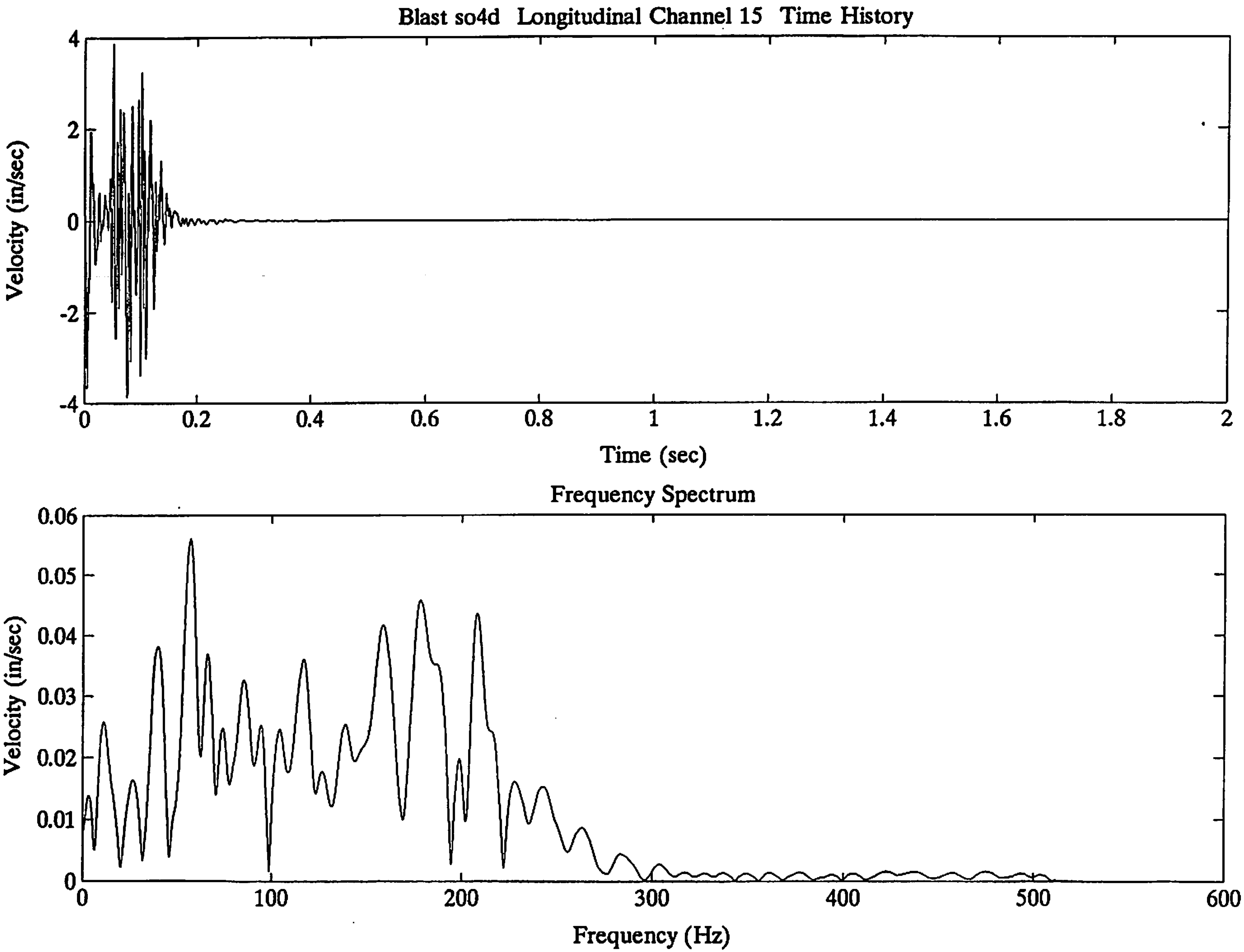


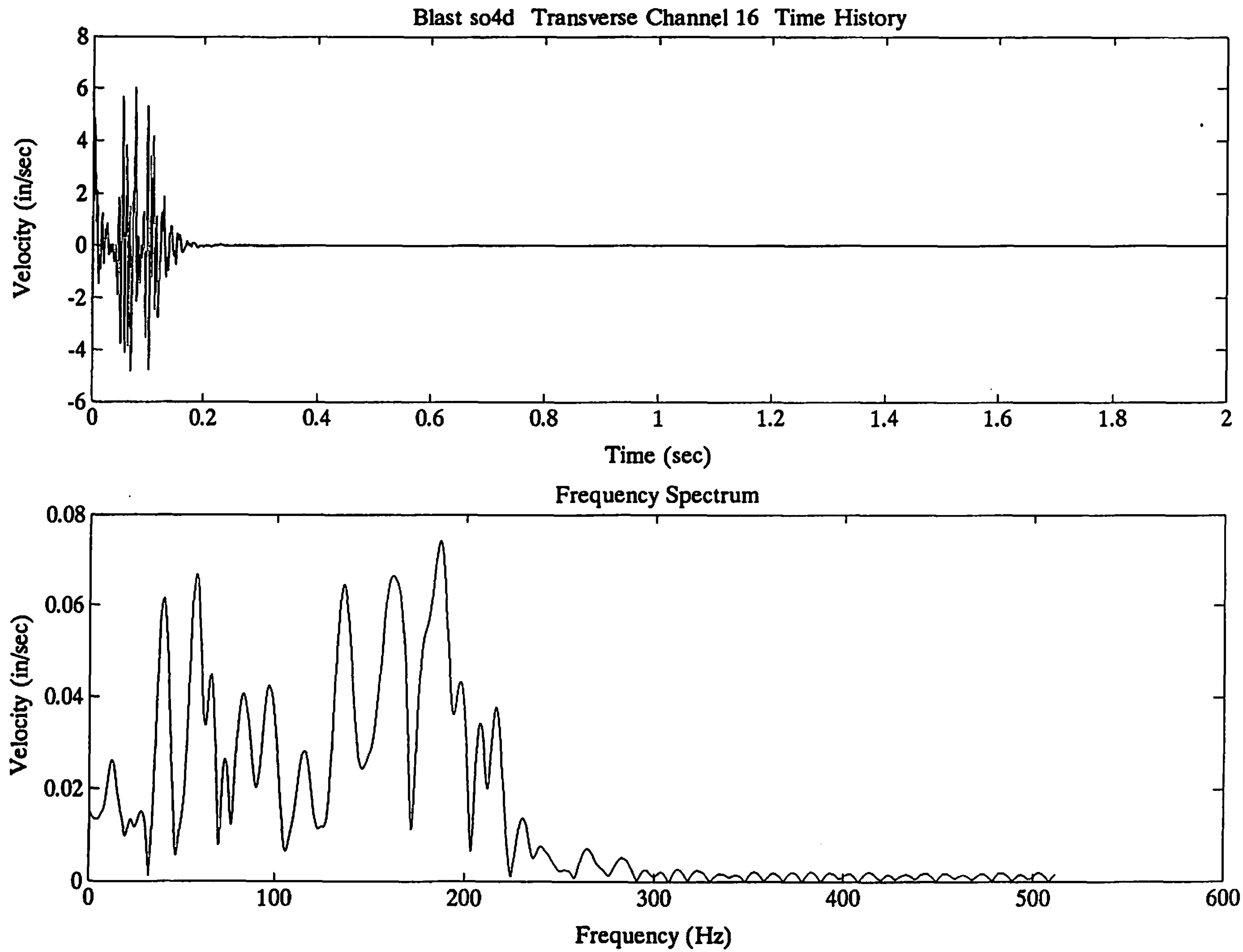
Blast so4d Longitudinal Channel 12 Time History
Velocity (in/sec)
4
3
2
1
0
-1
-2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Transverse Channel 13 Time History
Velocity (in/sec)
3
2
1
0
-1
-2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
Frequency (Hz)

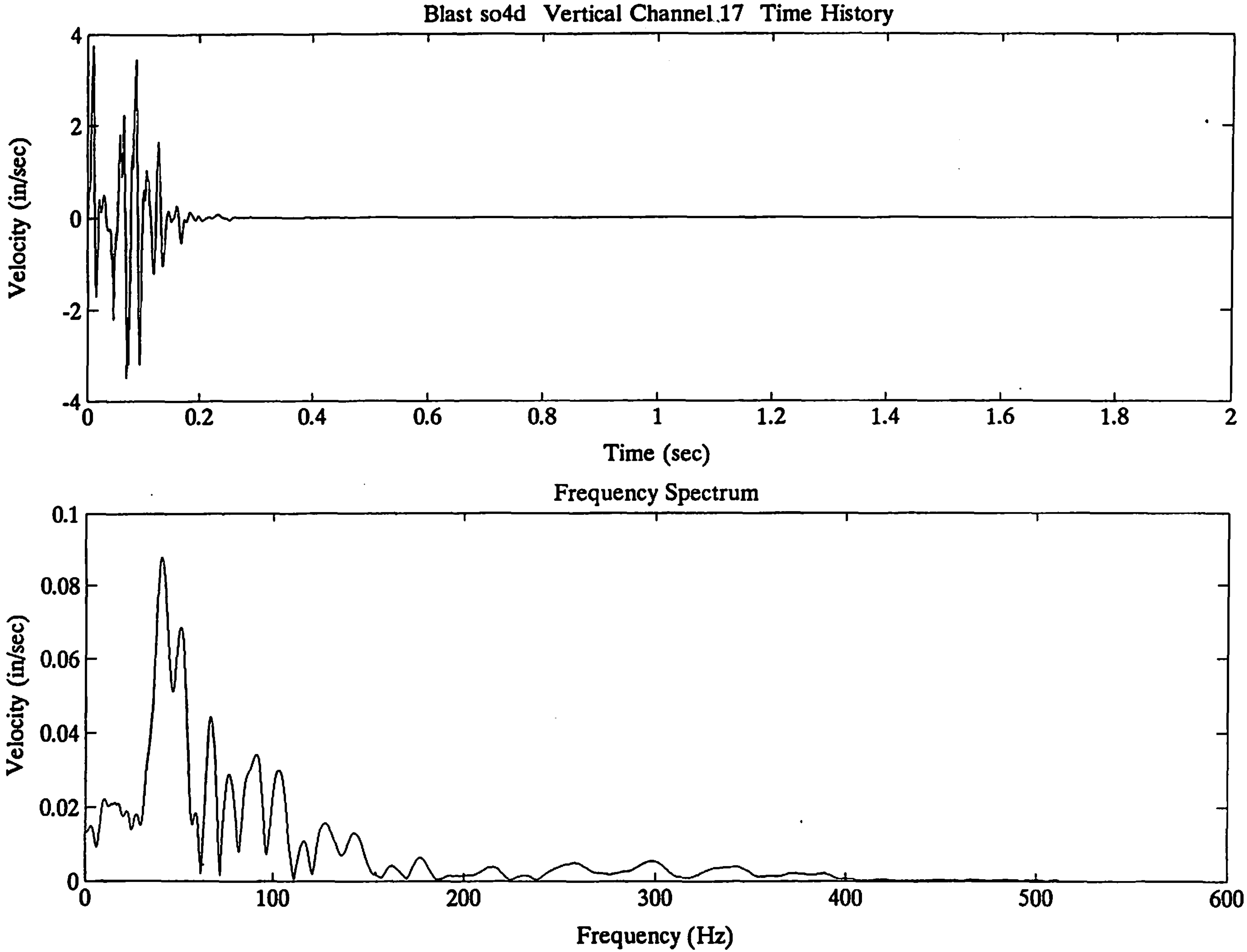

Blast so4d Vertical Channel 14 Time History
Velocity (in/sec)
Time (sec)
3
2
1
0
-1
-2
-3
-4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

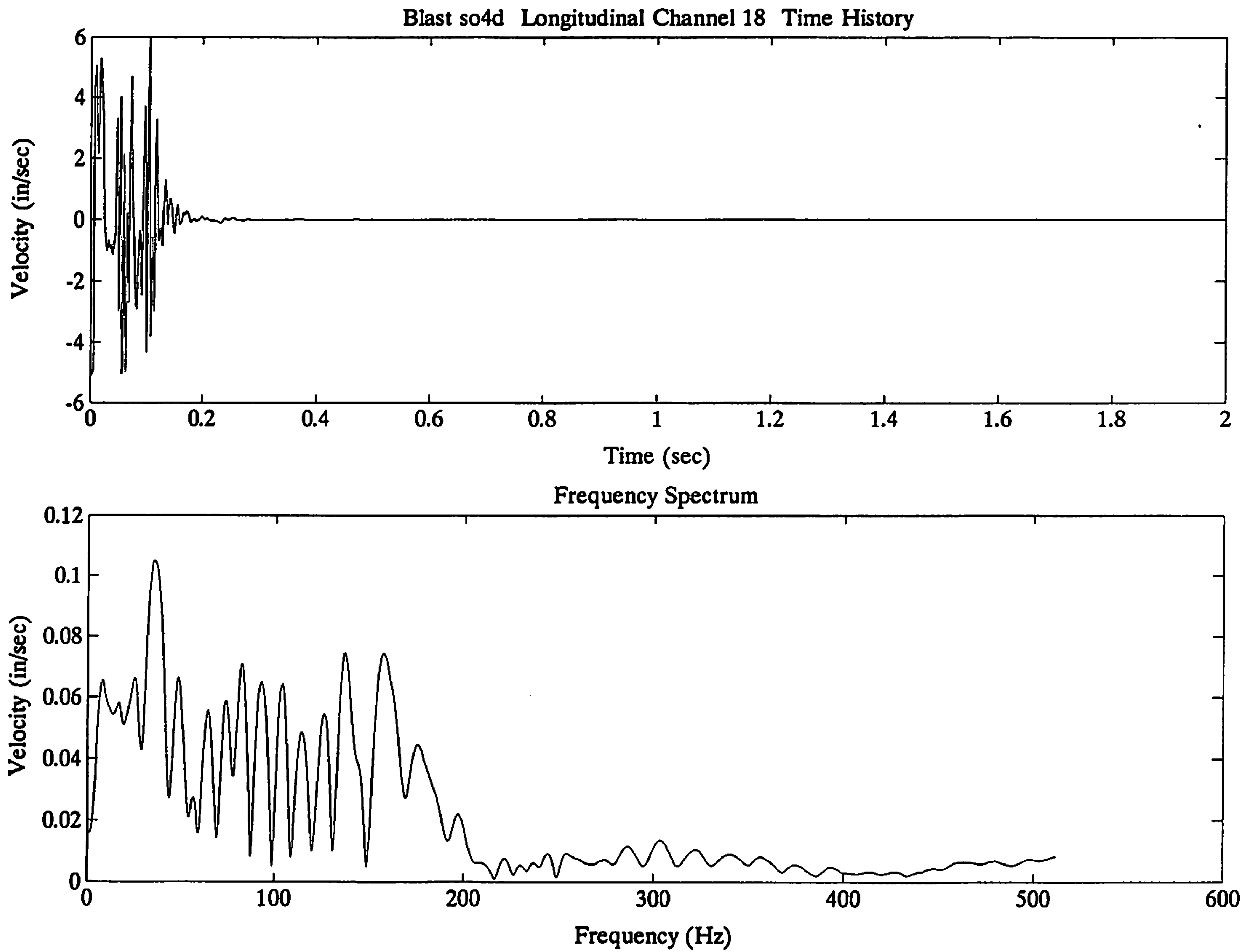

Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600


Blast so4d Longitudinal Channel 15 Time History
Velocity (in/sec)
4
2
0
-2
-4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.06
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
Frequency (Hz)

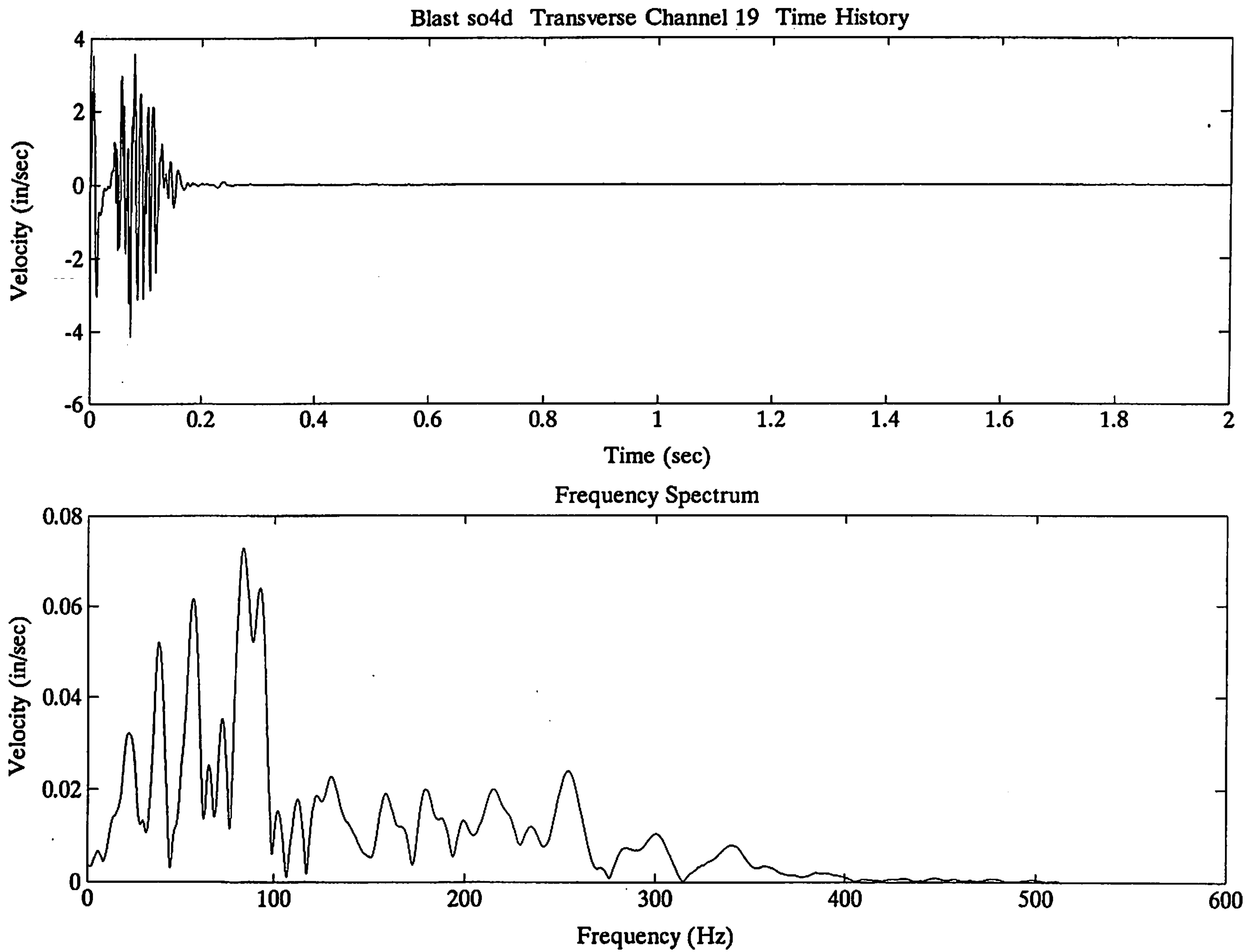


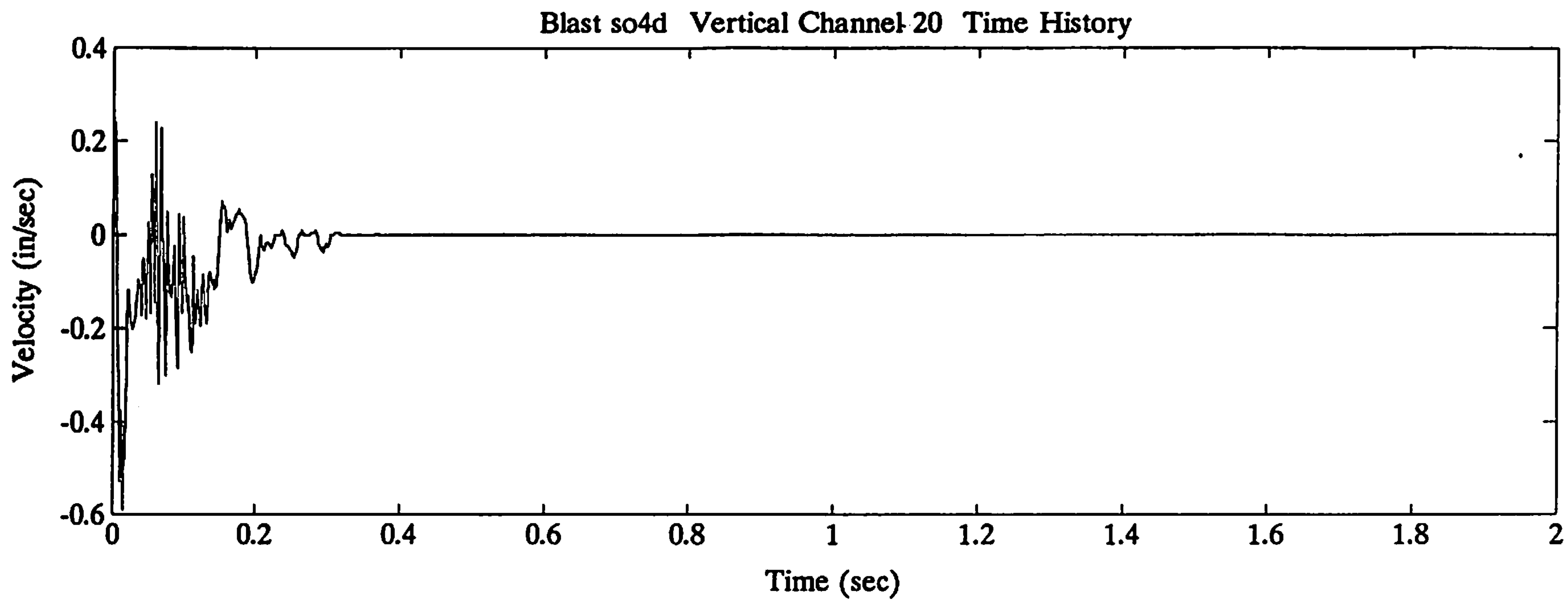
Blast so4d Transverse Channel 16 Time History
Velocity (in/sec)
Time (sec)
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)

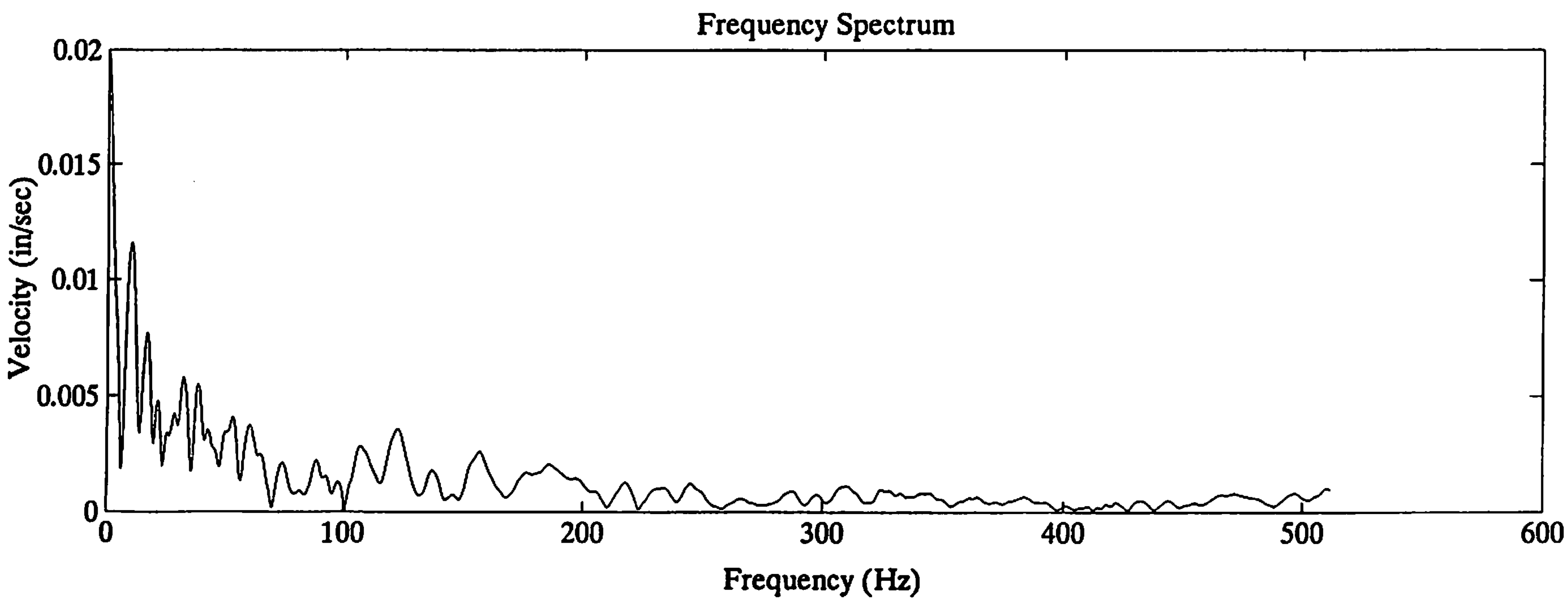

Blast so4d Vertical Channel 17 Time History
Velocity (in/sec)
Time (sec)
4
2
0
-2
-4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)
0.1
0.08
0.06
0.04
0.02
0
0
100
200
300
400
500
600

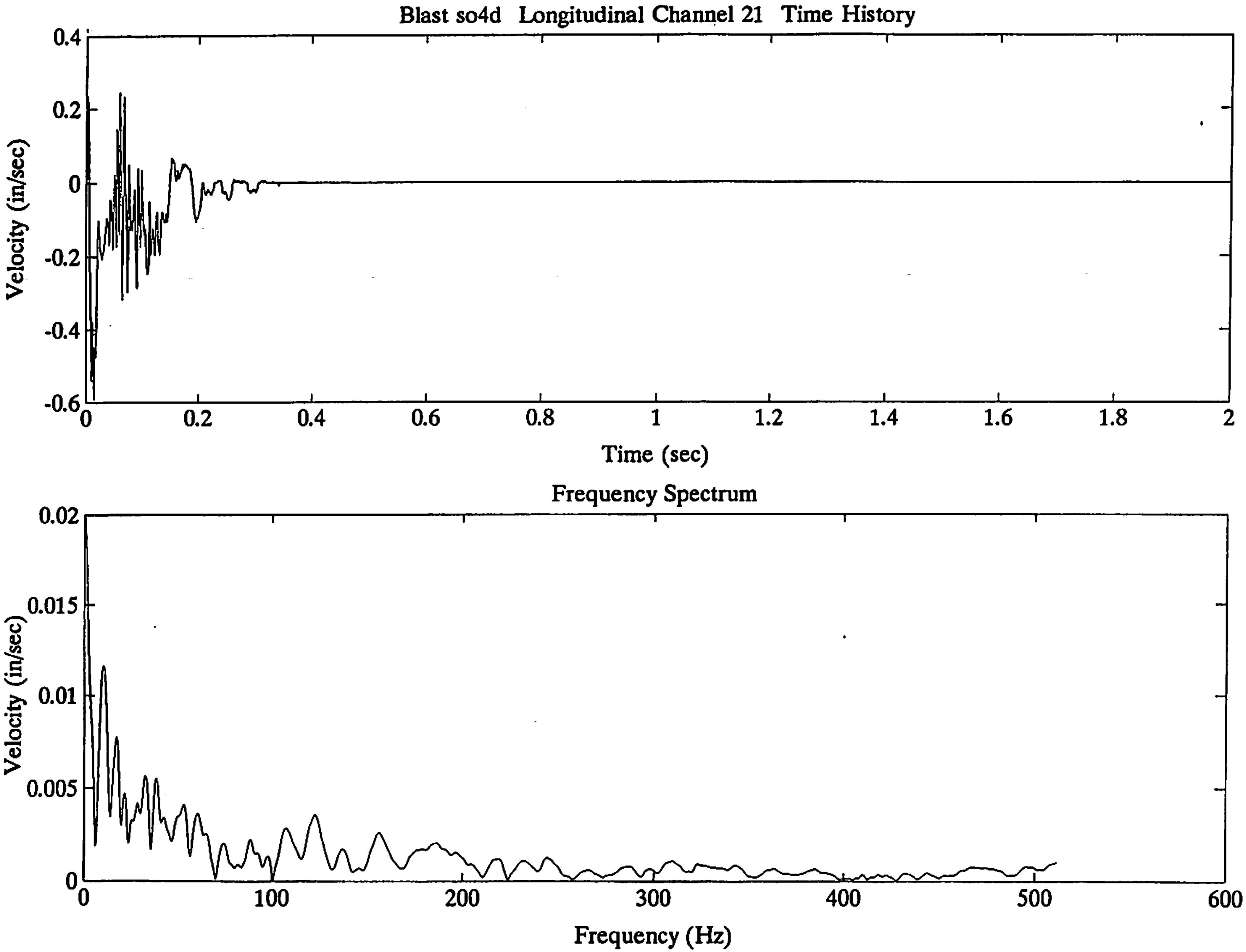


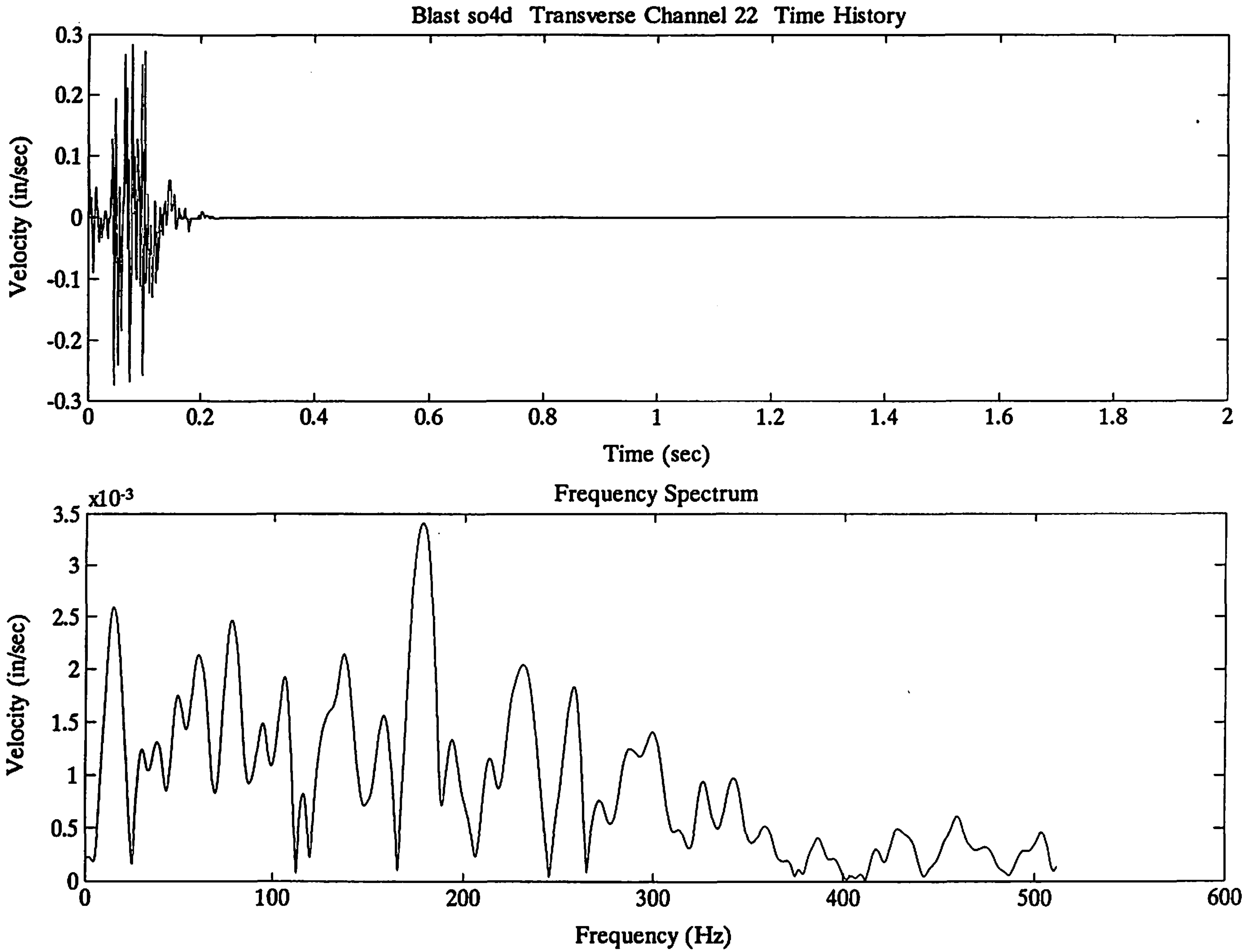
Blast so4d Longitudinal Channel 18 Time History
Velocity (in/sec)
Time (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
6
4
2
0
-2
-4
-6
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)
0
100
200
300
400
500
600
0.12
0.1
0.08
0.06
0.04
0.02
0

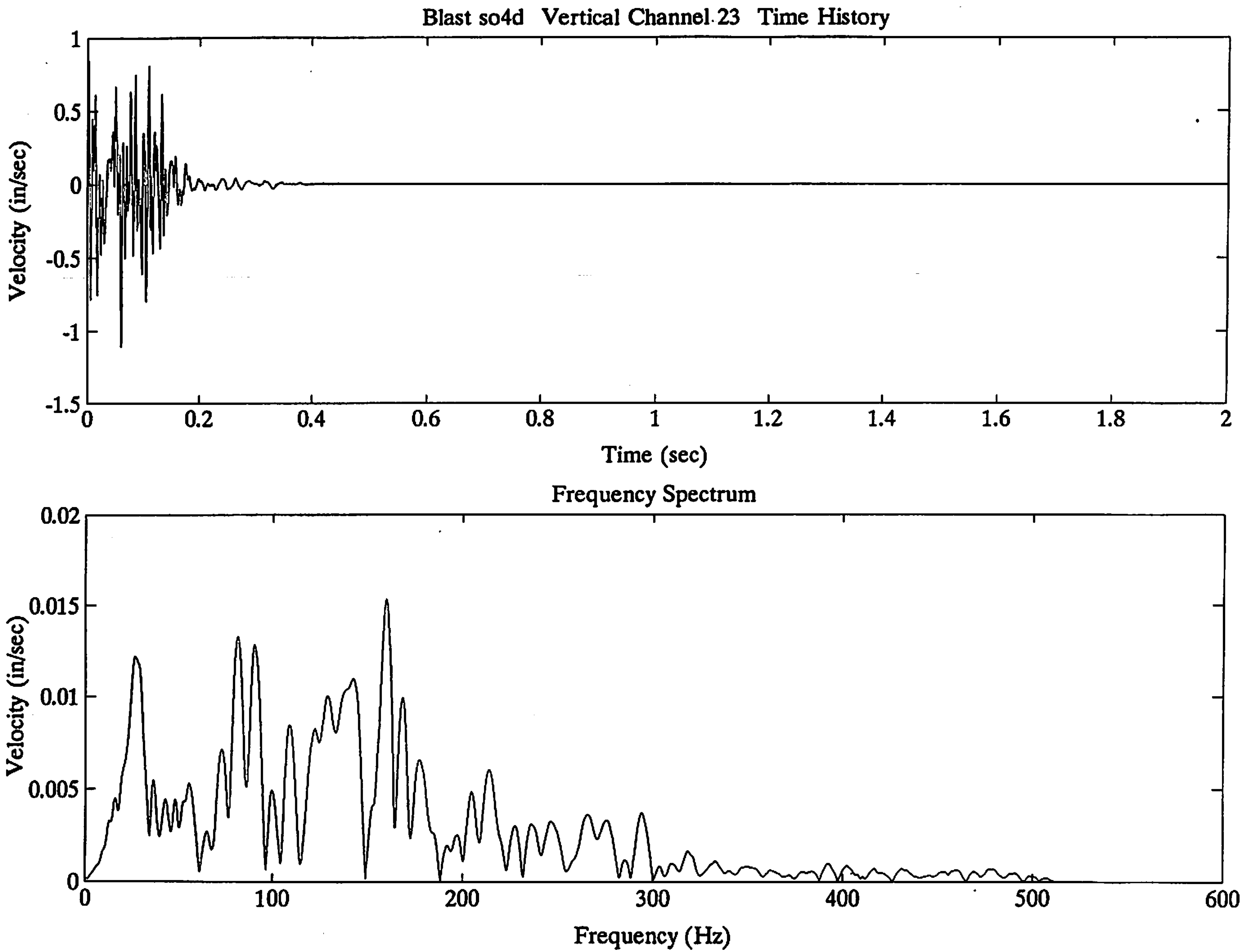

Blast so4d Transverse Channel 19 Time History
Velocity (in/sec)
Time (sec)
Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)

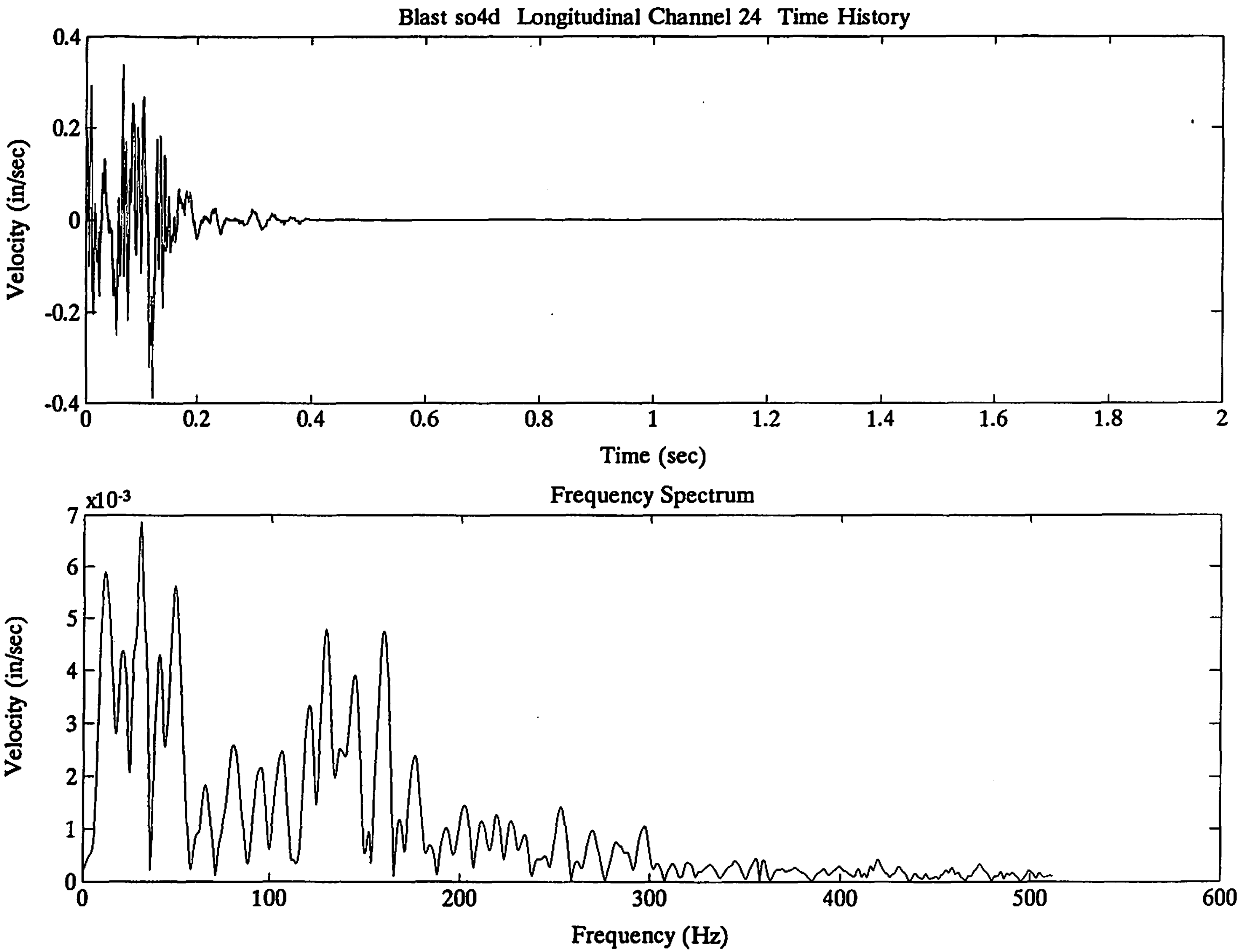

Blast so4d Vertical Channel 20 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

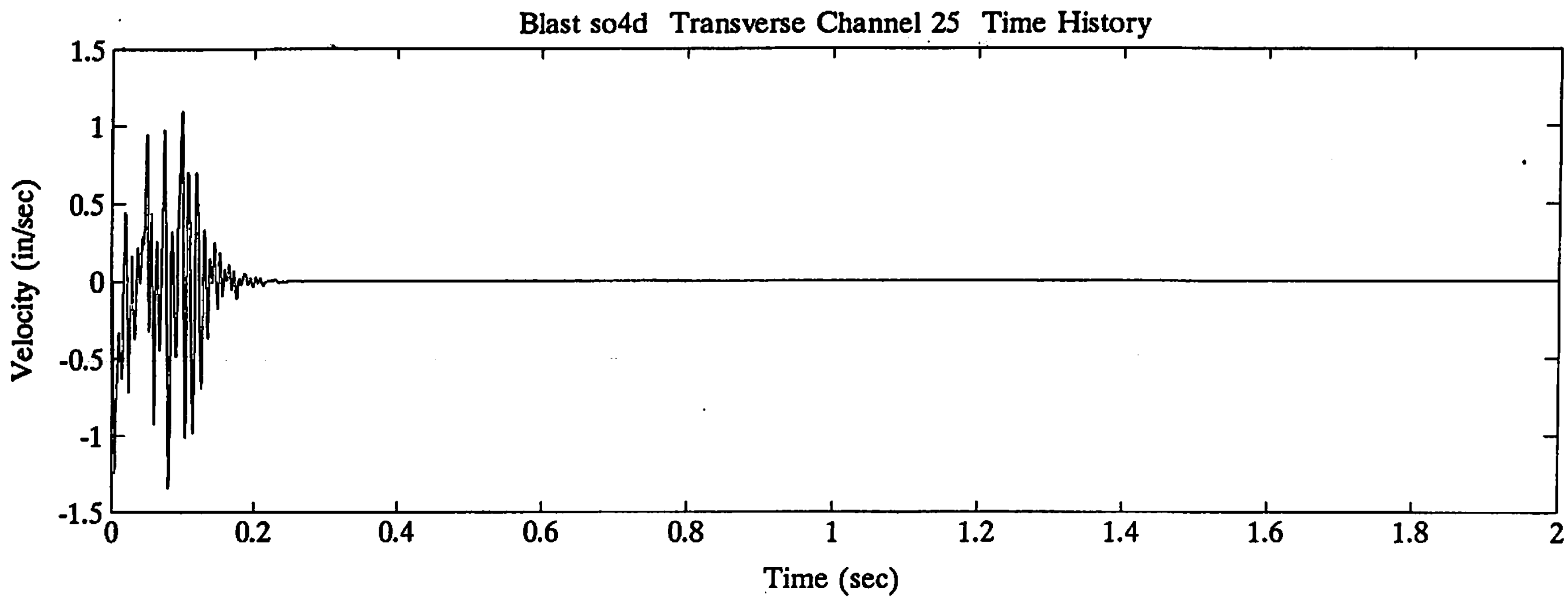

Frequency Spectrum
Velocity (in/sec)
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
Frequency (Hz)

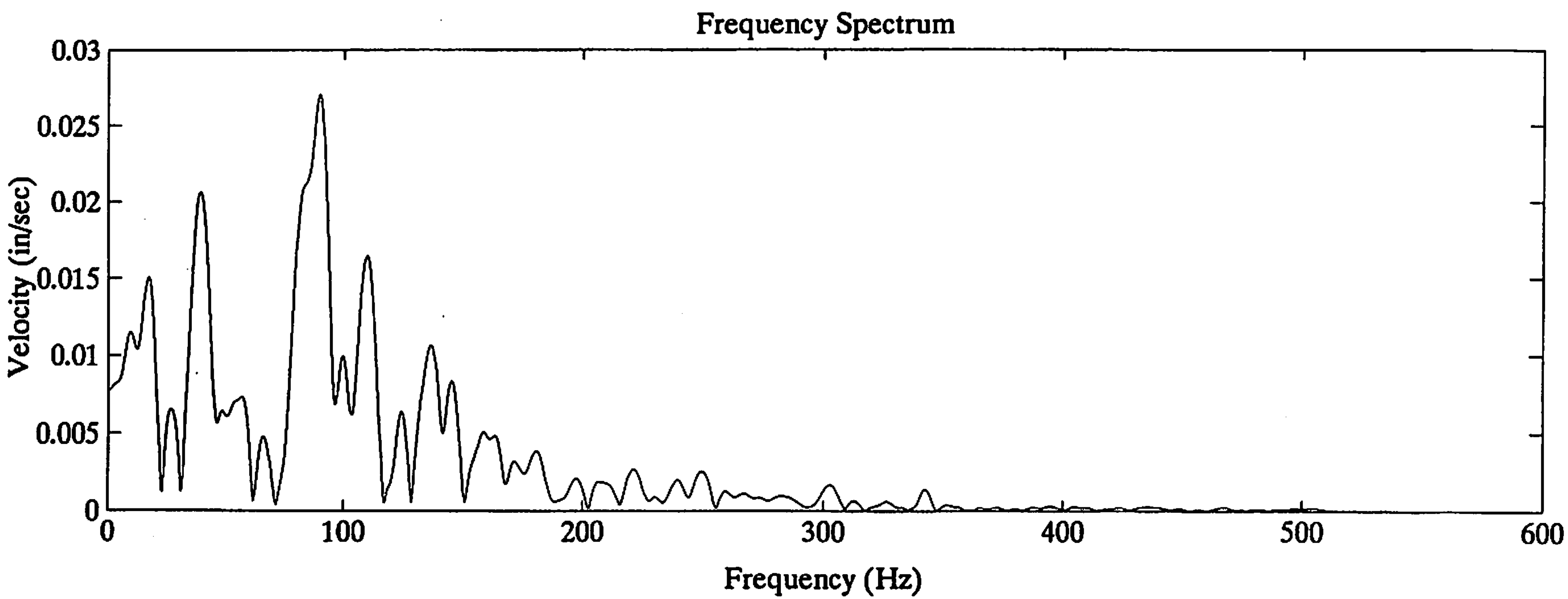

Blast so4d Longitudinal Channel 21 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
Frequency (Hz)

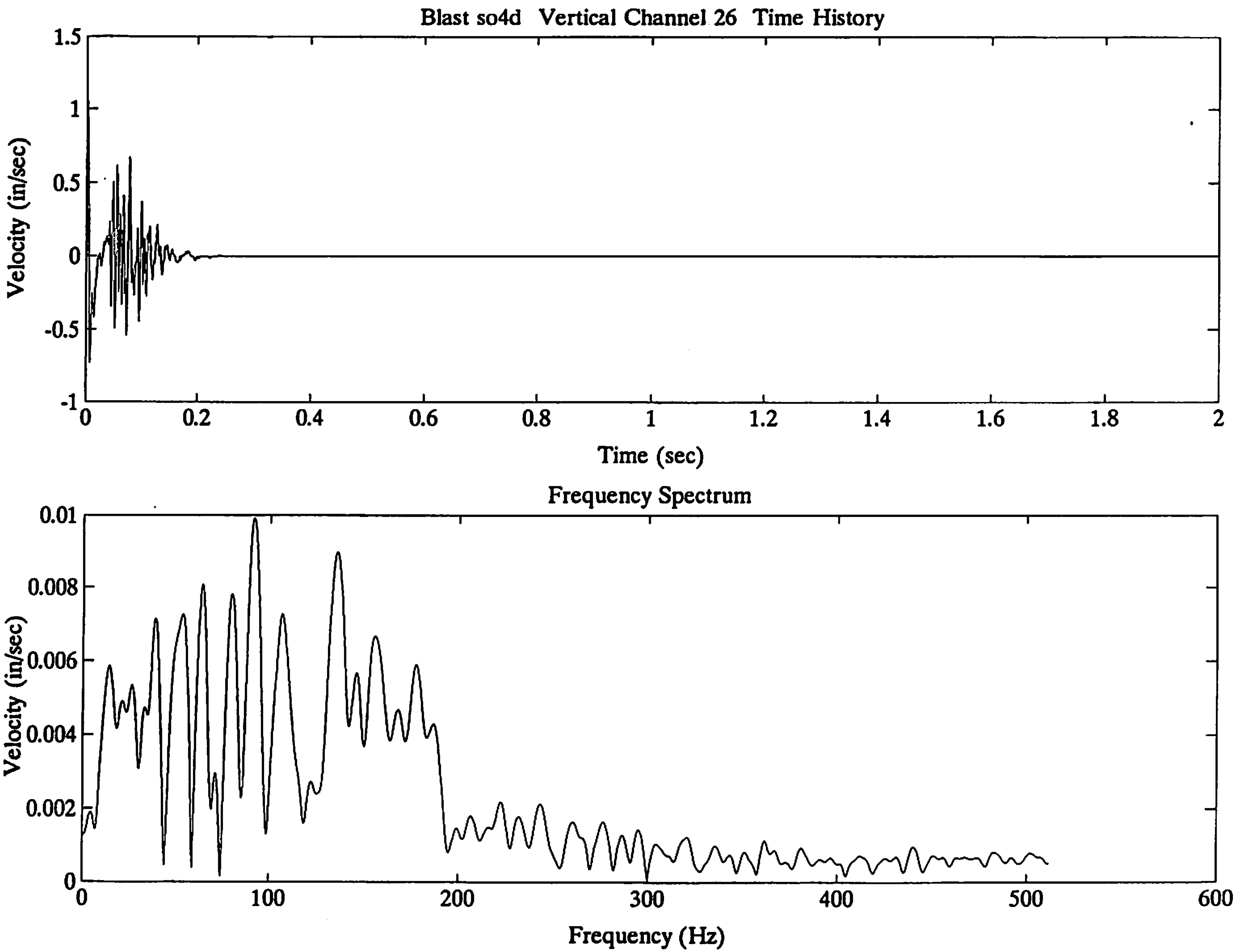

Blast so4d Transverse Channel 22 Time History
Velocity (in/sec)
Time (sec)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Frequency Spectrum
x10-3
Velocity (in/sec)
Frequency (Hz)
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600


Blast so4d Vertical Channel 23 Time History
Velocity (in/sec)
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Longitudinal Channel 24 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
Velocity (in/sec)
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

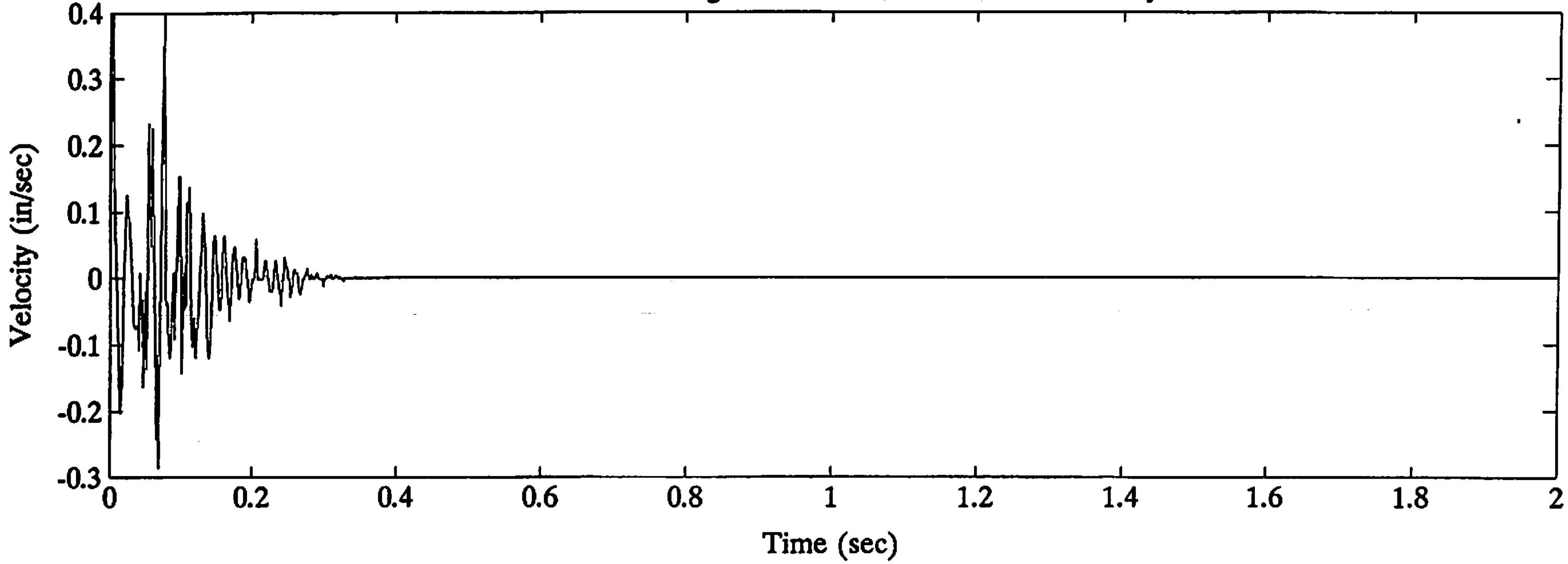

Blast so4d Transverse Channel 25 Time History
Velocity (in/sec)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)


Frequency Spectrum
Velocity (in/sec)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
Frequency (Hz)

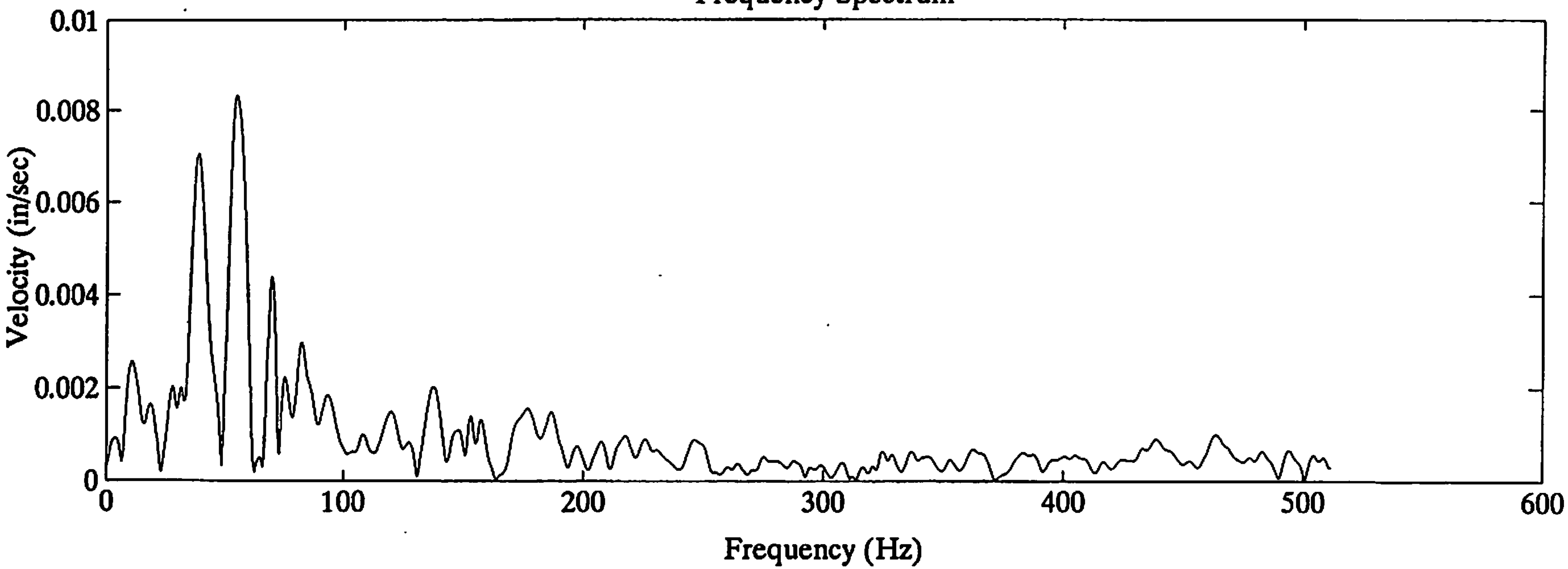


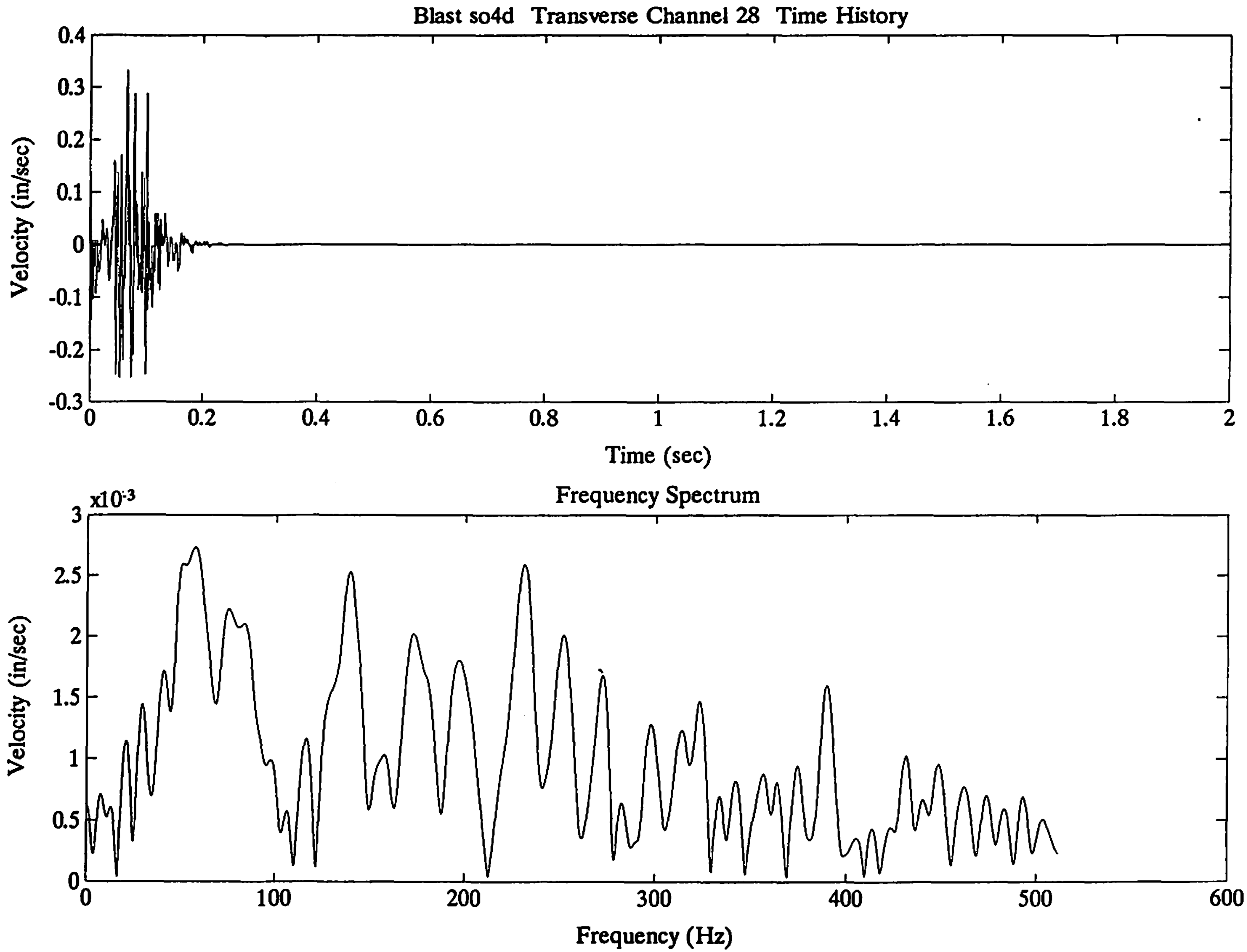
Blast so4d Vertical Channel 26 Time History
Velocity (in/sec)
1.5
1
0.5
0
-0.5
-1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
400
500
600
Frequency (Hz)

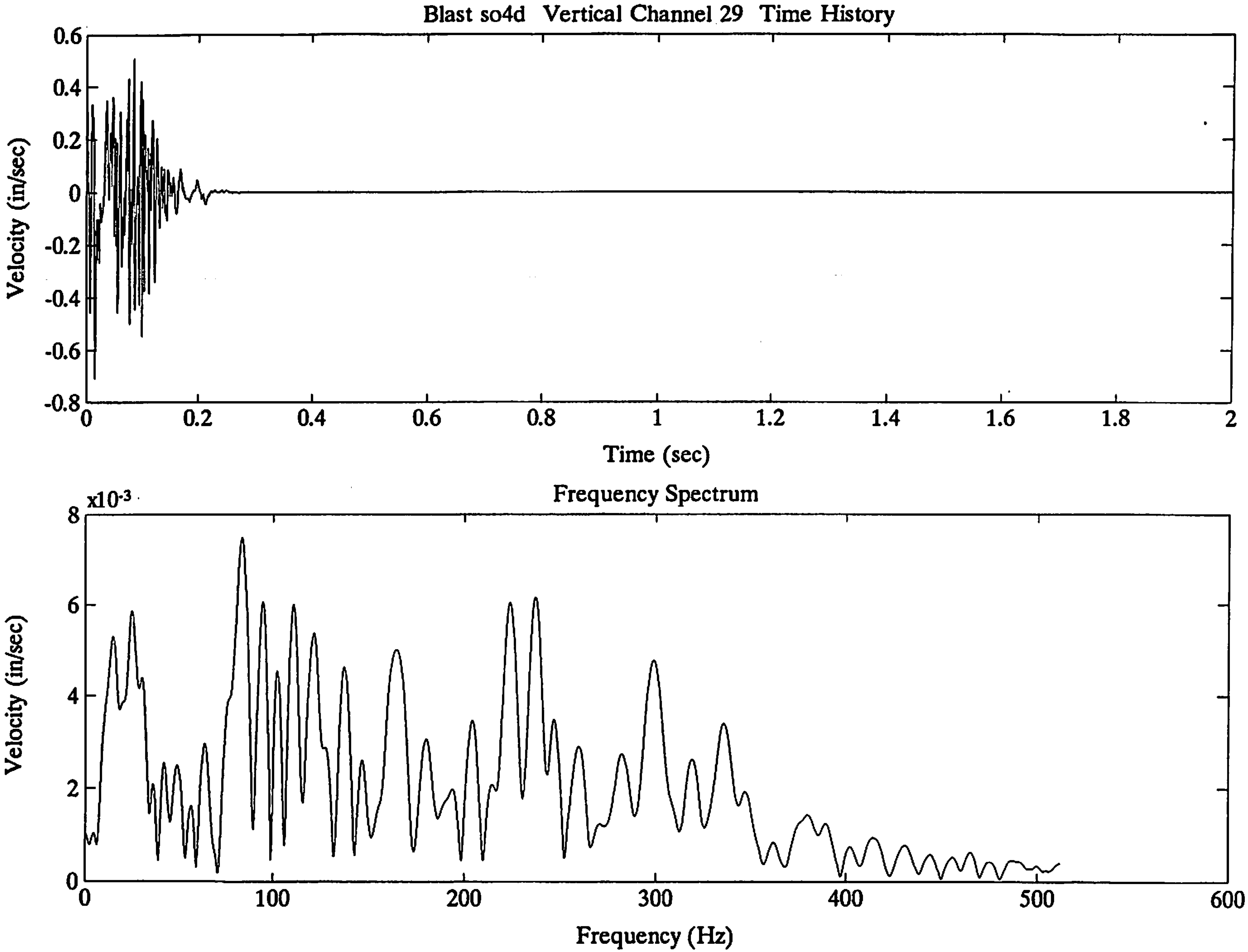
Blast so4d Longitudinal Channel 27 Time History



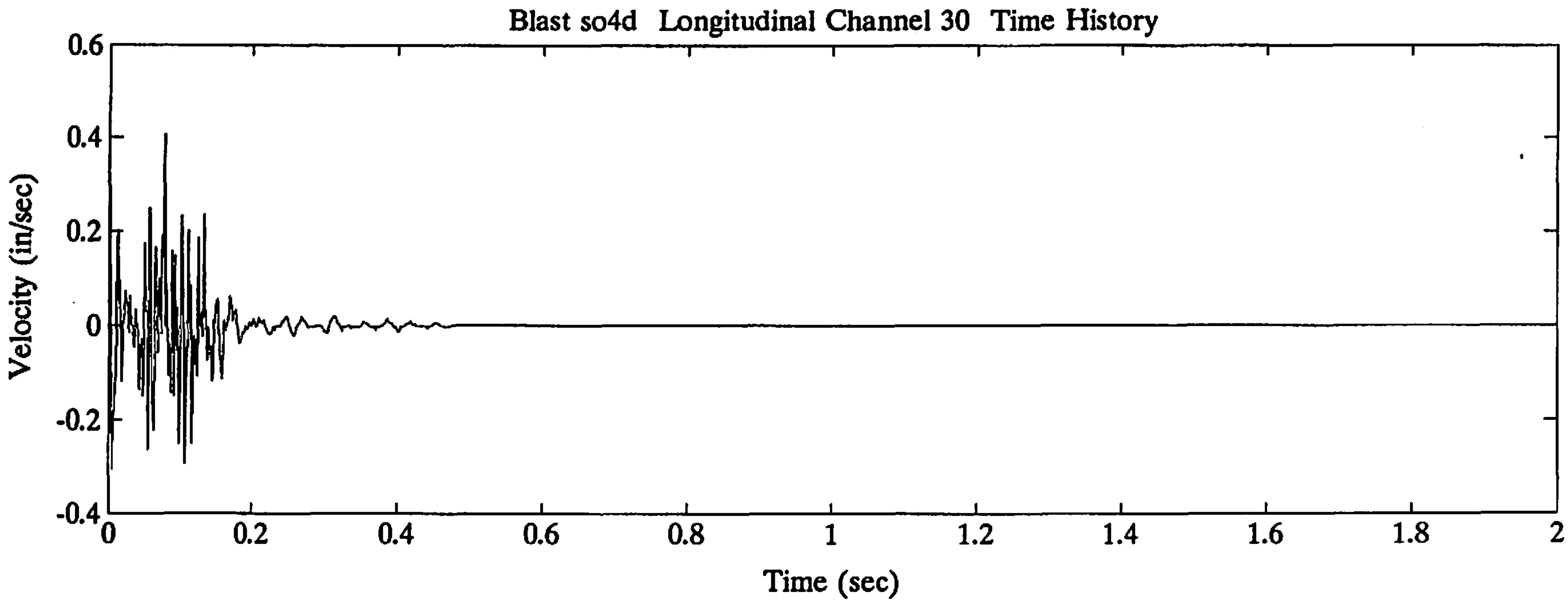
Frequency Spectrum



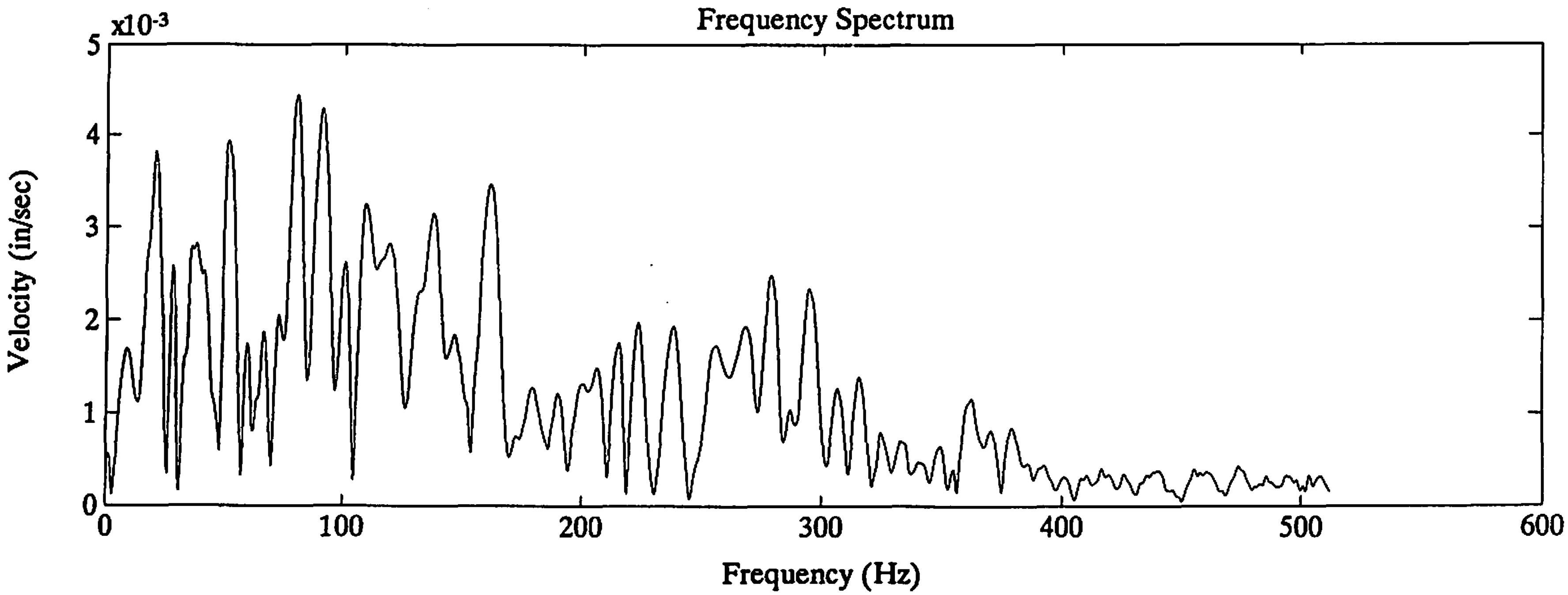

Blast so4d Transverse Channel 28 Time History
Velocity (in/sec)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
Velocity (in/sec)
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
Frequency (Hz)



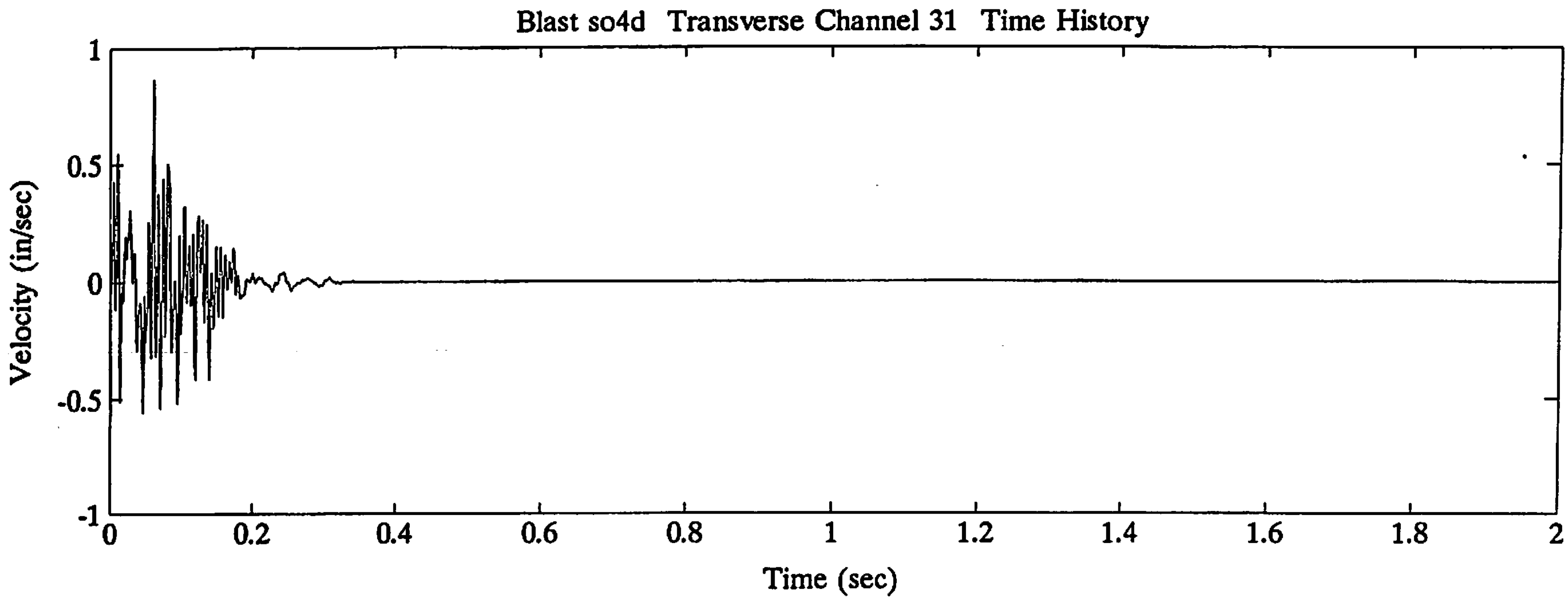
Blast so4d Vertical Channel 29 Time History
Velocity (in/sec)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
8
6
4
2
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

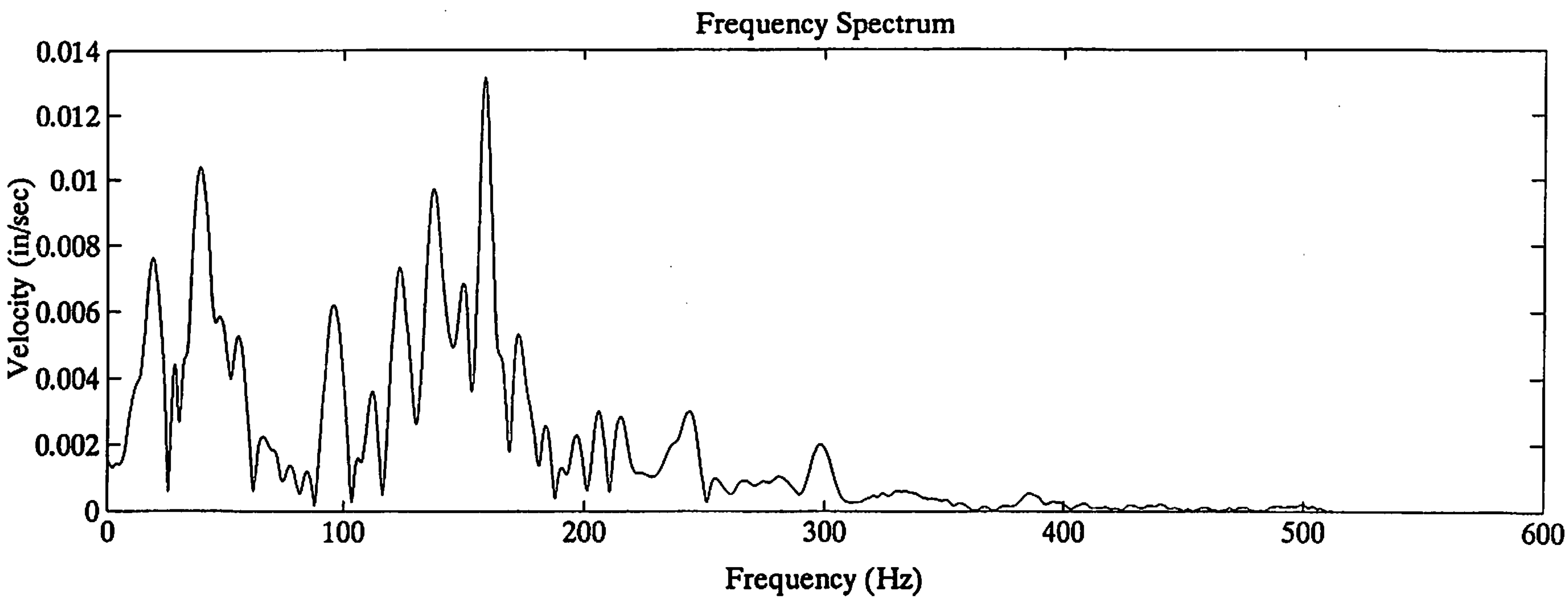


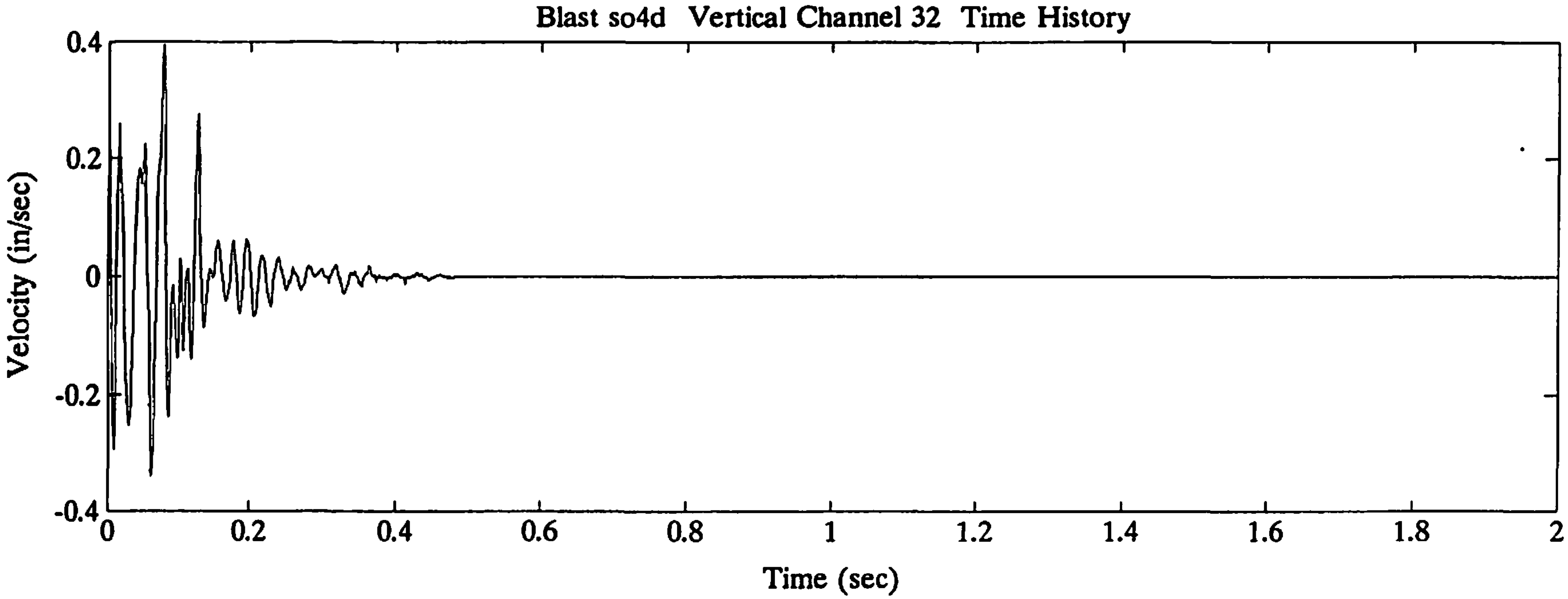
Blast so4d Longitudinal Channel 30 Time History
Velocity (in/sec)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

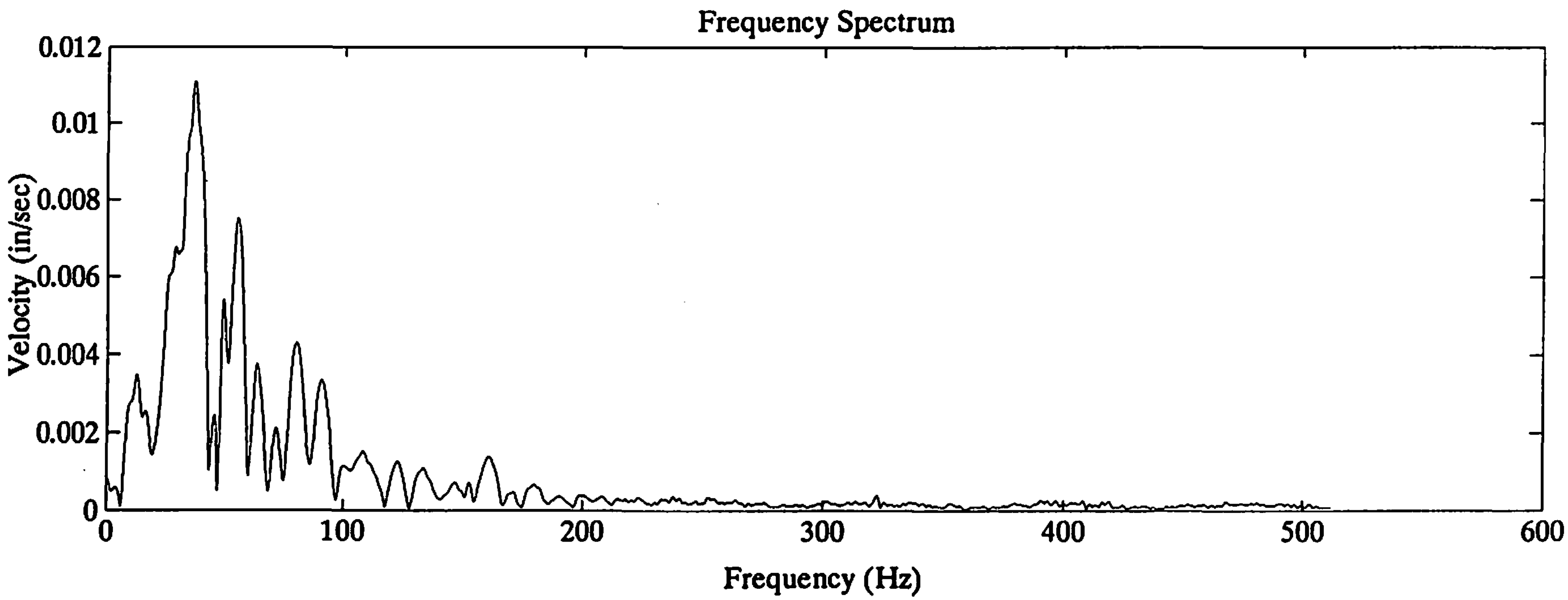


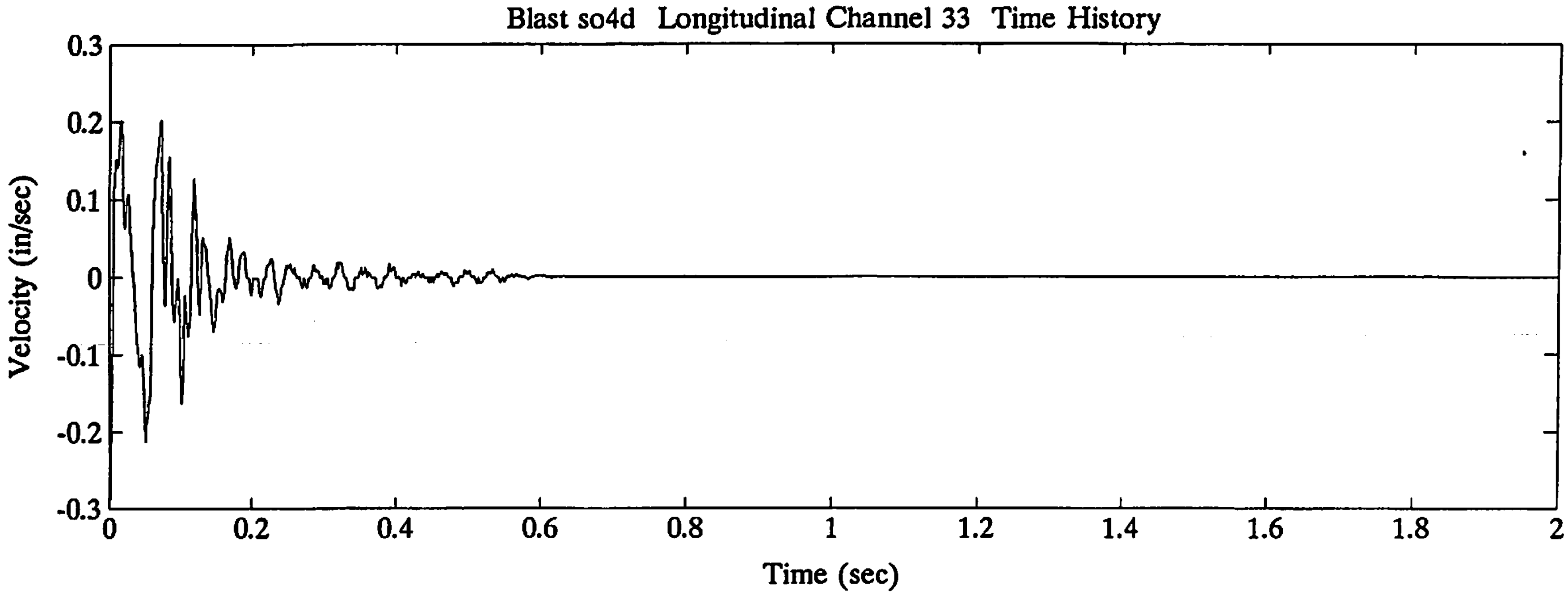
Frequency Spectrum
x10-3
Velocity (in/sec)
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

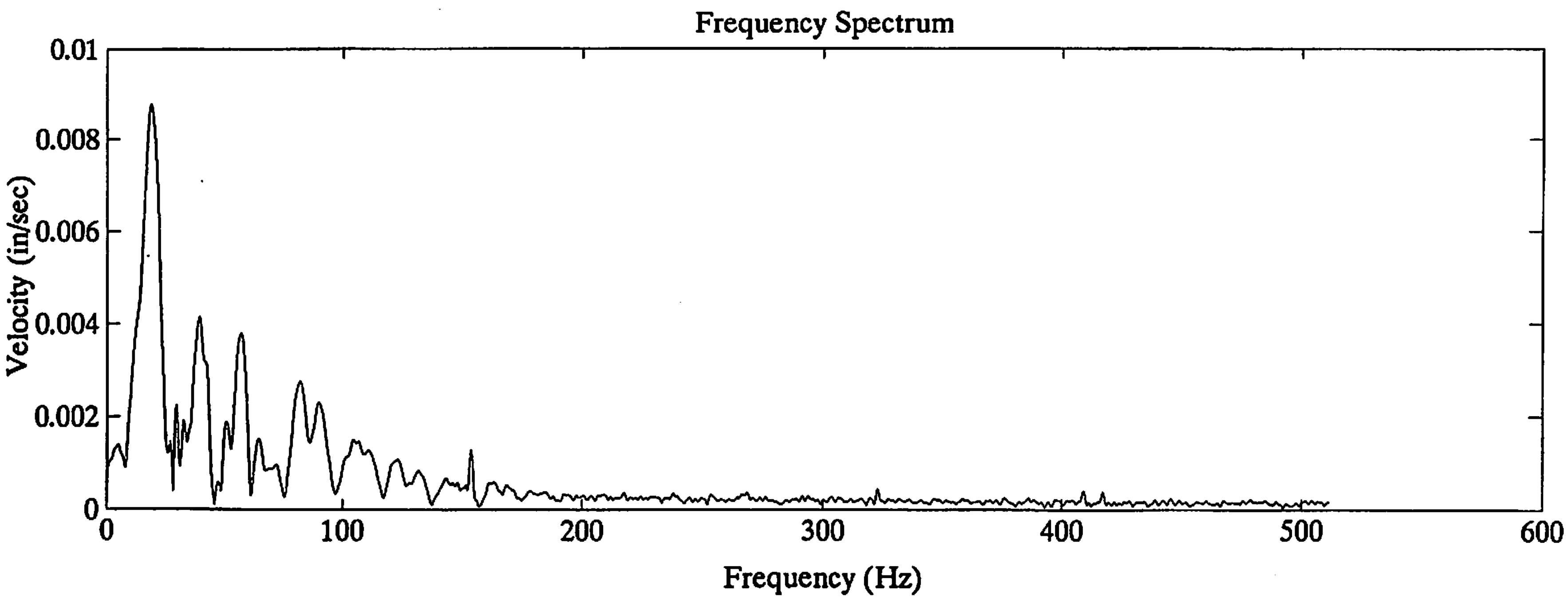

Blast so4d Transverse Channel 31 Time History
Velocity (in/sec)
1
0.5
0
-0.5
-1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

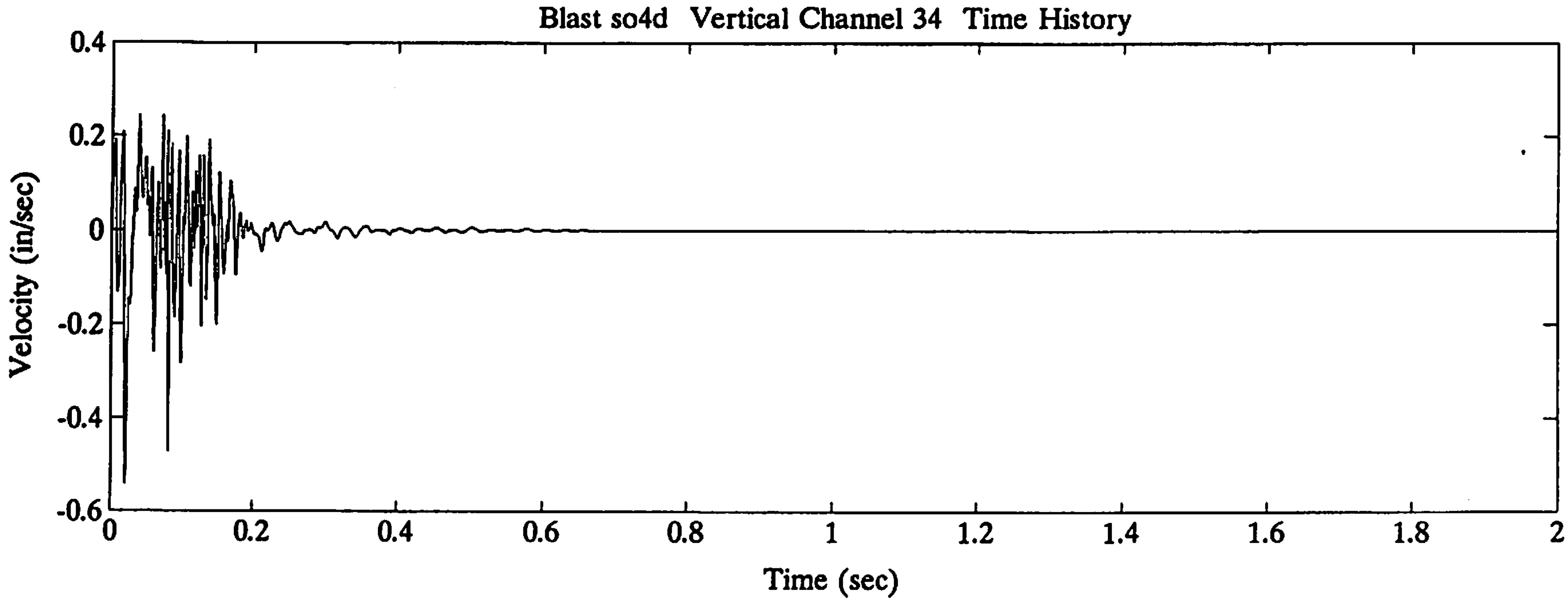

Frequency Spectrum
Velocity (in/sec)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Vertical Channel 32 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

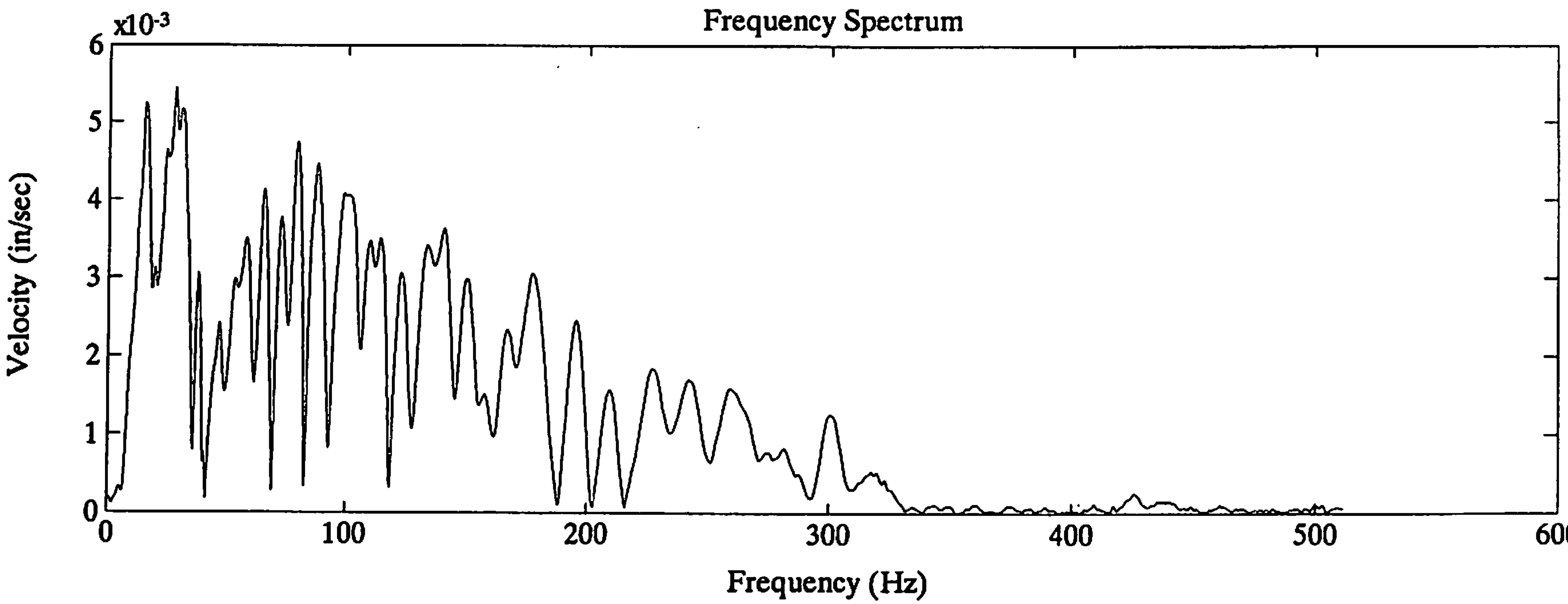

Frequency Spectrum
Velocity (in/sec)
0.012
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Longitudinal Channel 33 Time History
Velocity (in/sec)
Time (sec)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

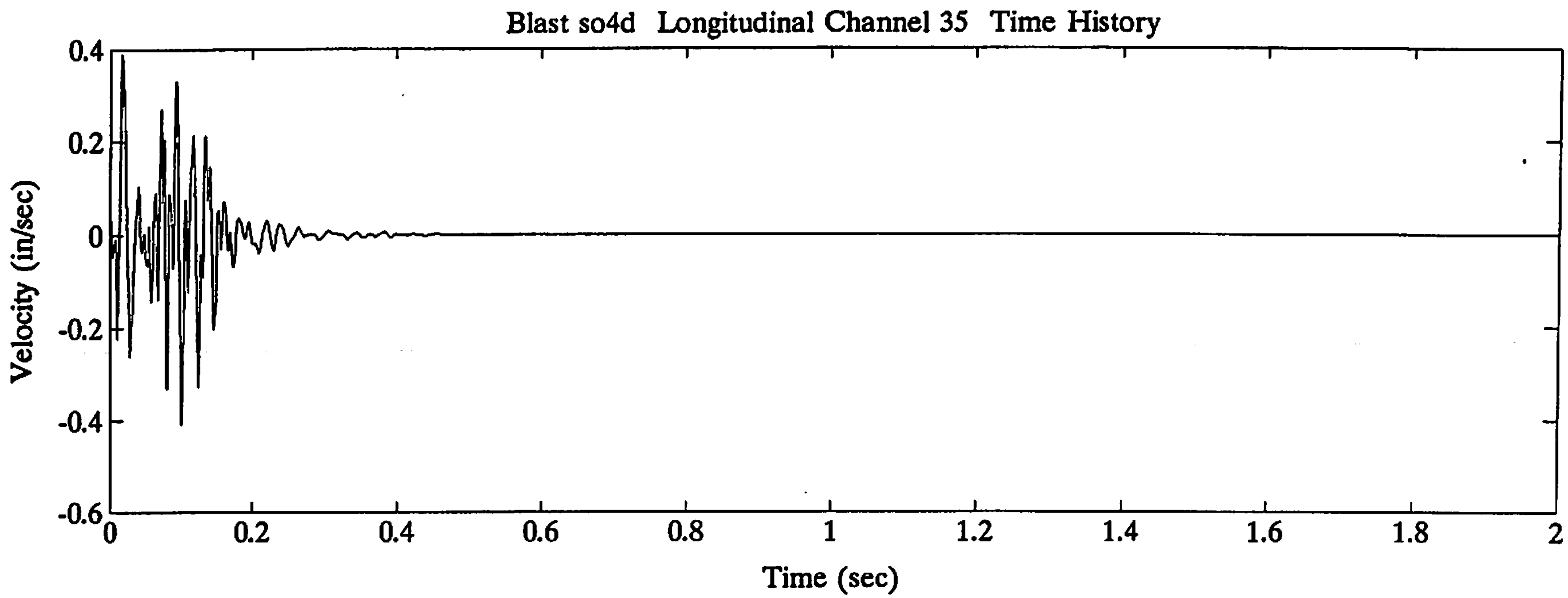

Frequency Spectrum
Velocity (in/sec)
Frequency (Hz)
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
400
500
600

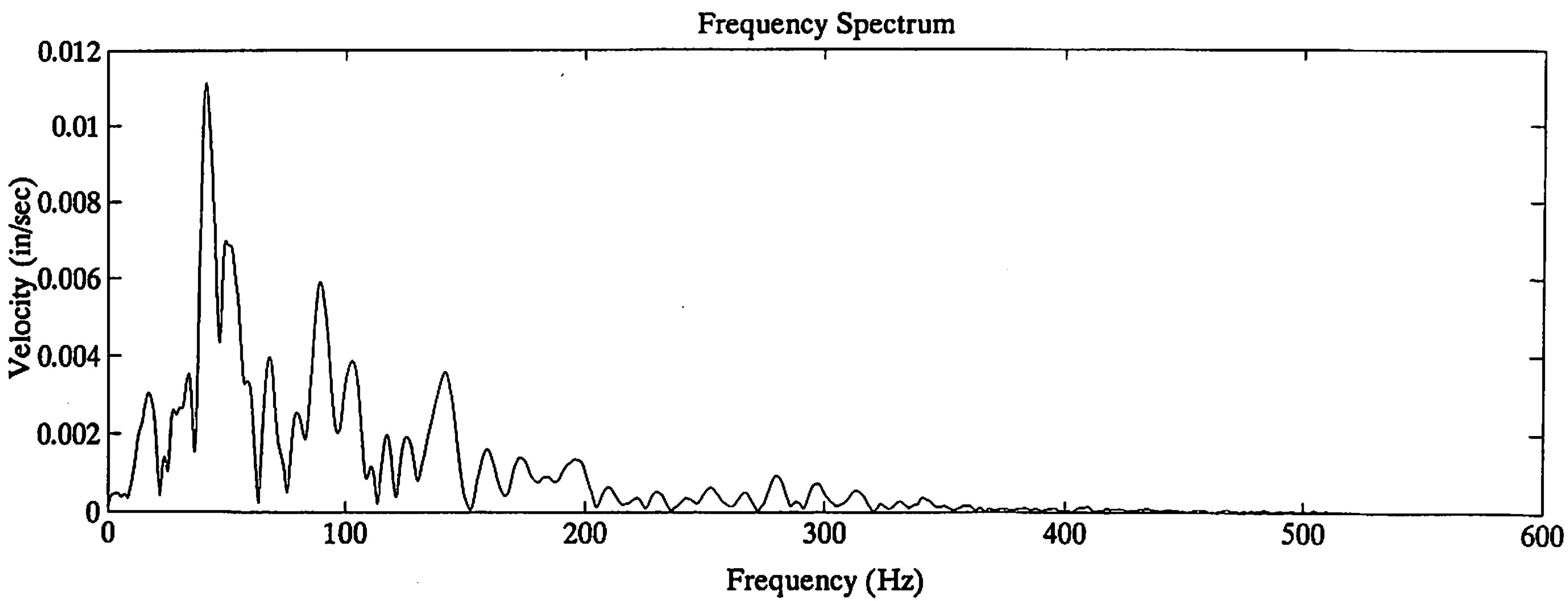


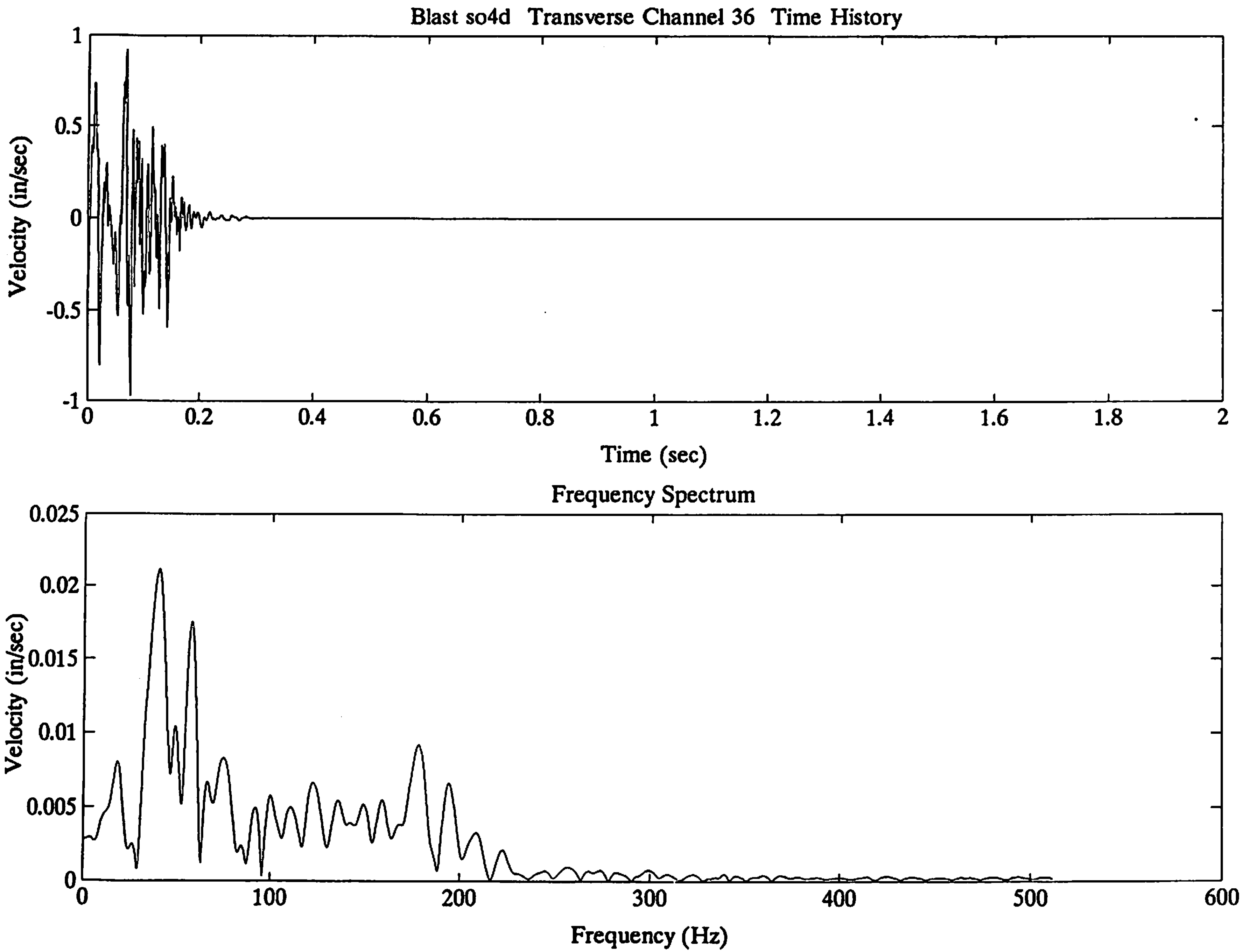
Blast so4d Vertical Channel 34 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



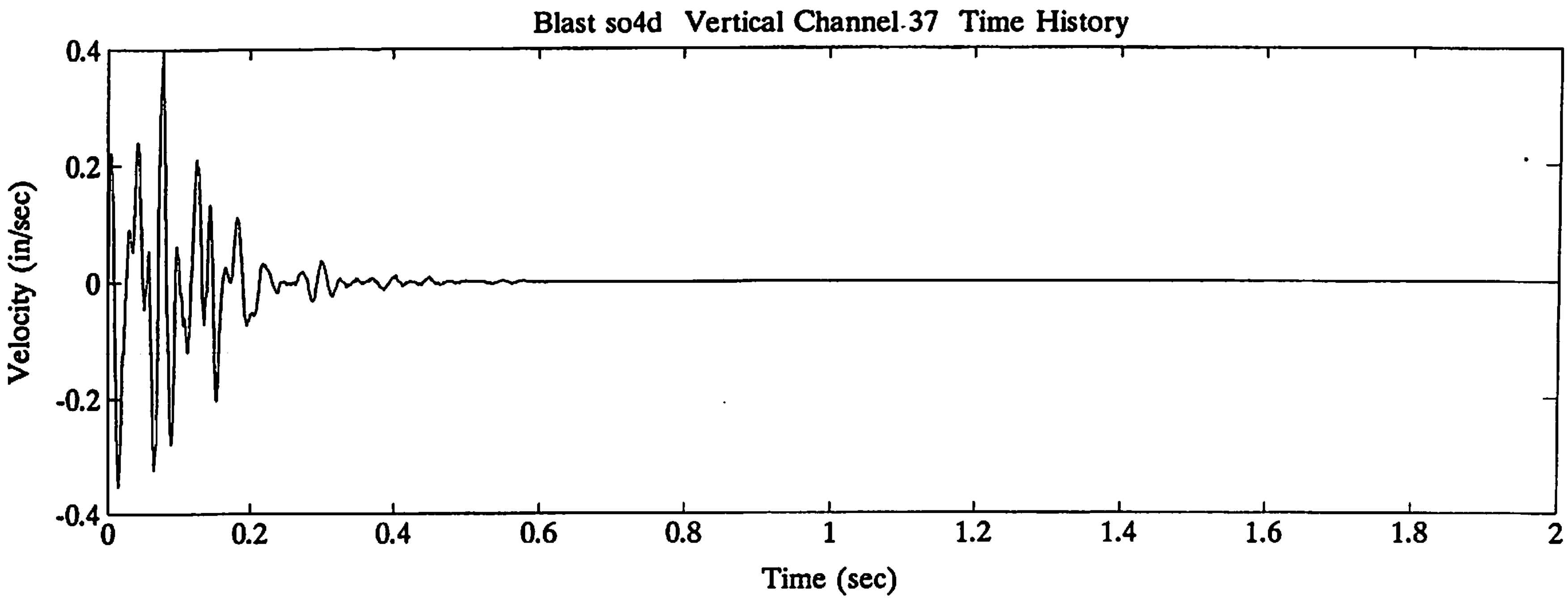
Frequency Spectrum
x10-3
Velocity (in/sec)
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Frequency (Hz)

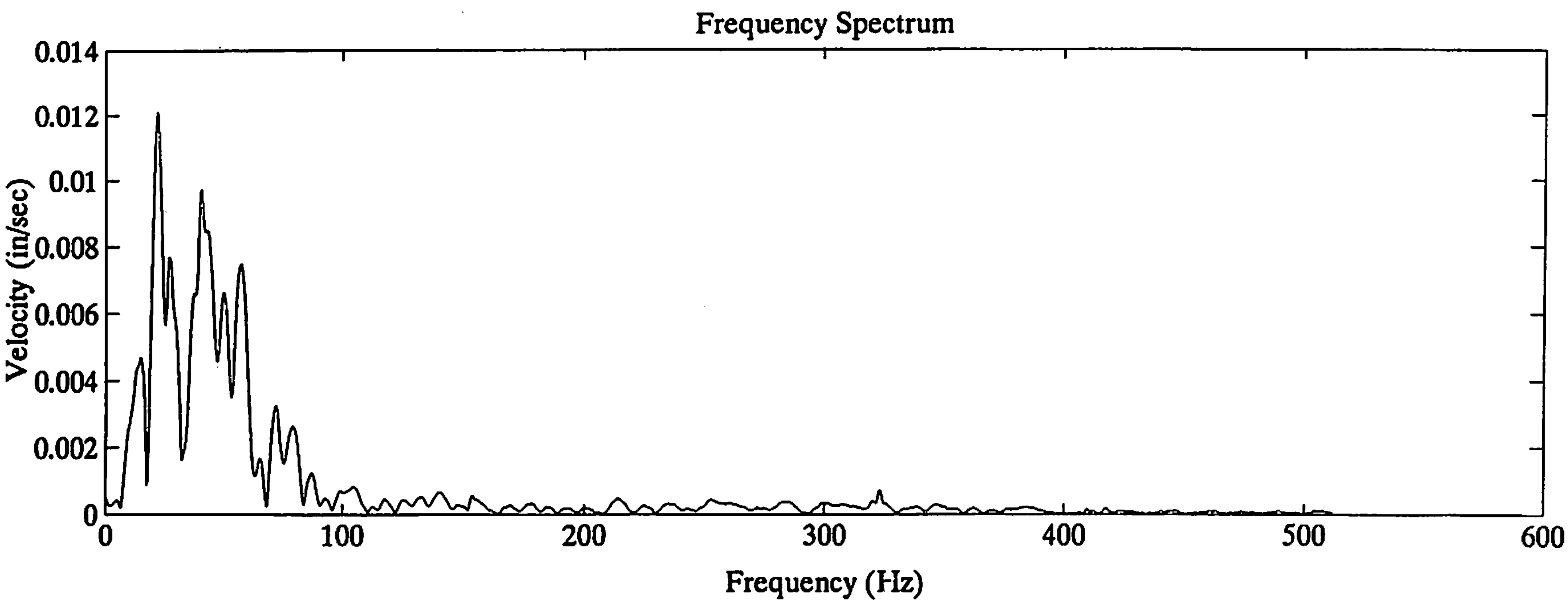

Blast so4d Longitudinal Channel 35 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

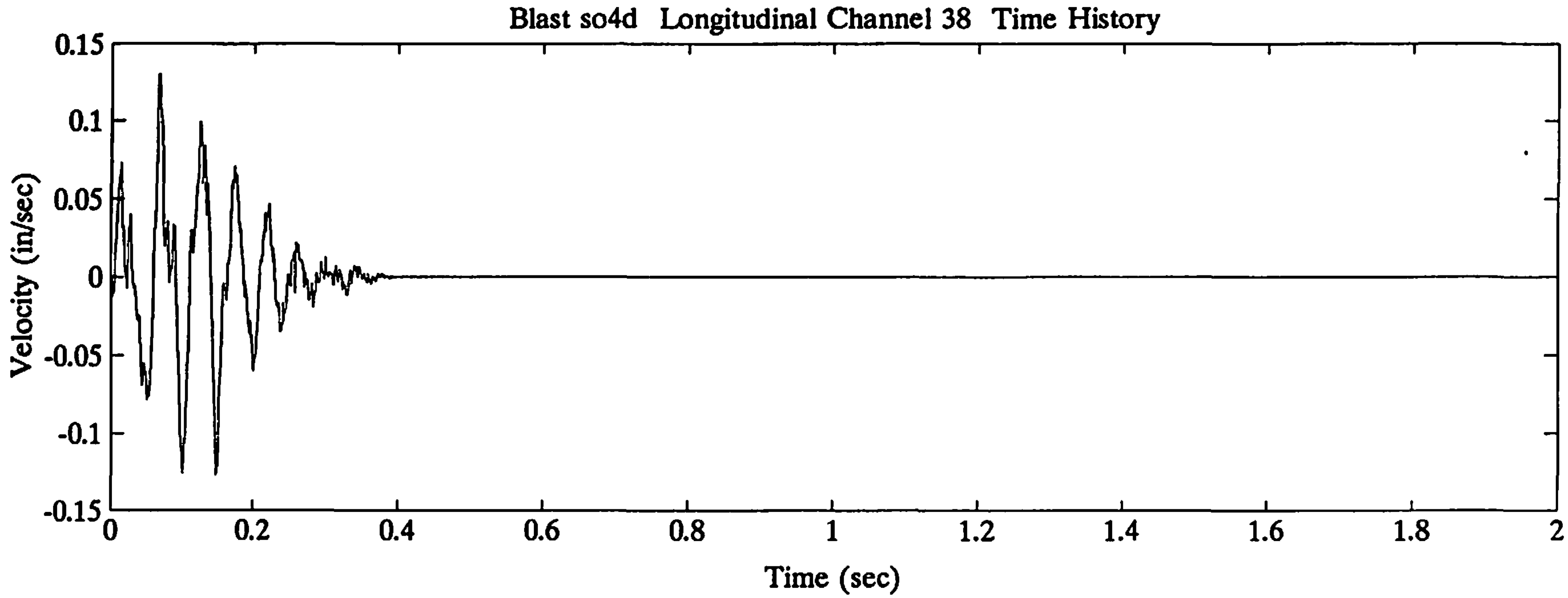

Frequency Spectrum
Velocity (in/sec)
0.012
0.01
0.008
0.006
0.004
0.002
0
0
100
200
300
400
500
600
Frequency (Hz)



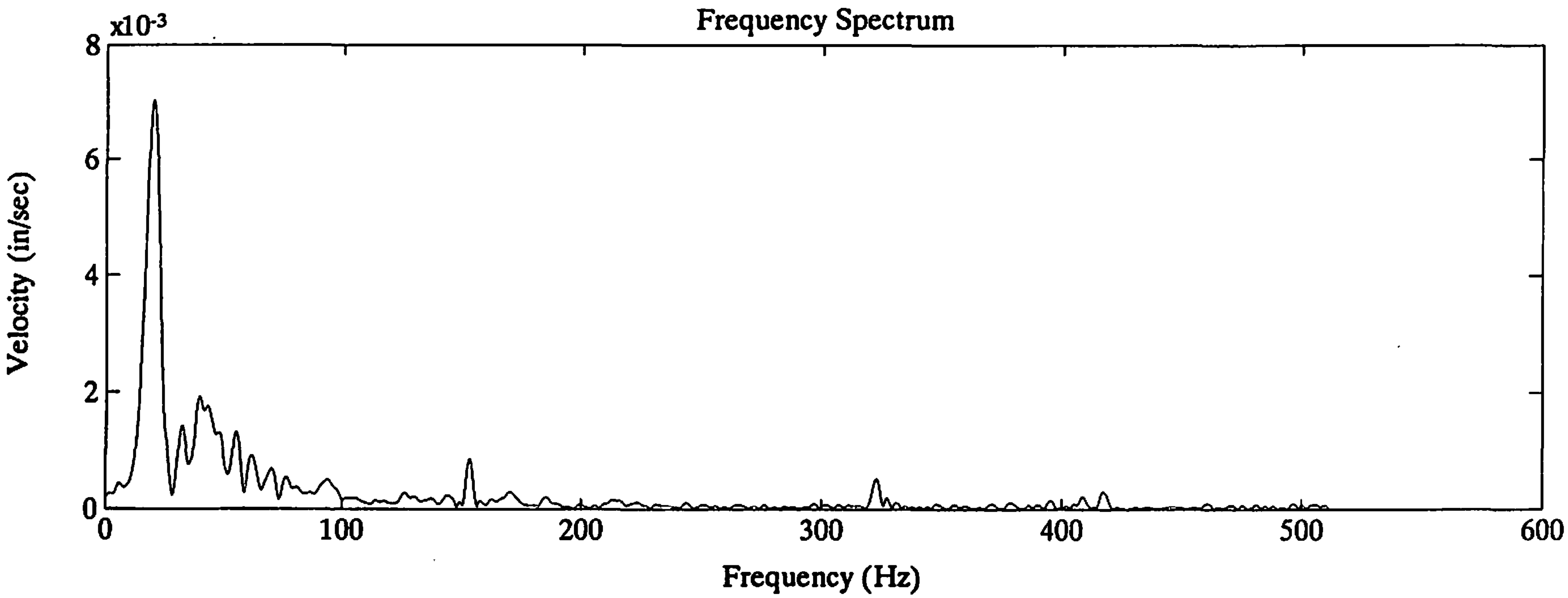
Blast so4d Transverse Channel 36 Time History
Velocity (in/sec)
1
0.5
0
-0.5
-1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
Velocity (in/sec)
0.025
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Vertical Channel 37 Time History
Velocity (in/sec)
0.4
0.2
0
-0.2
-0.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)

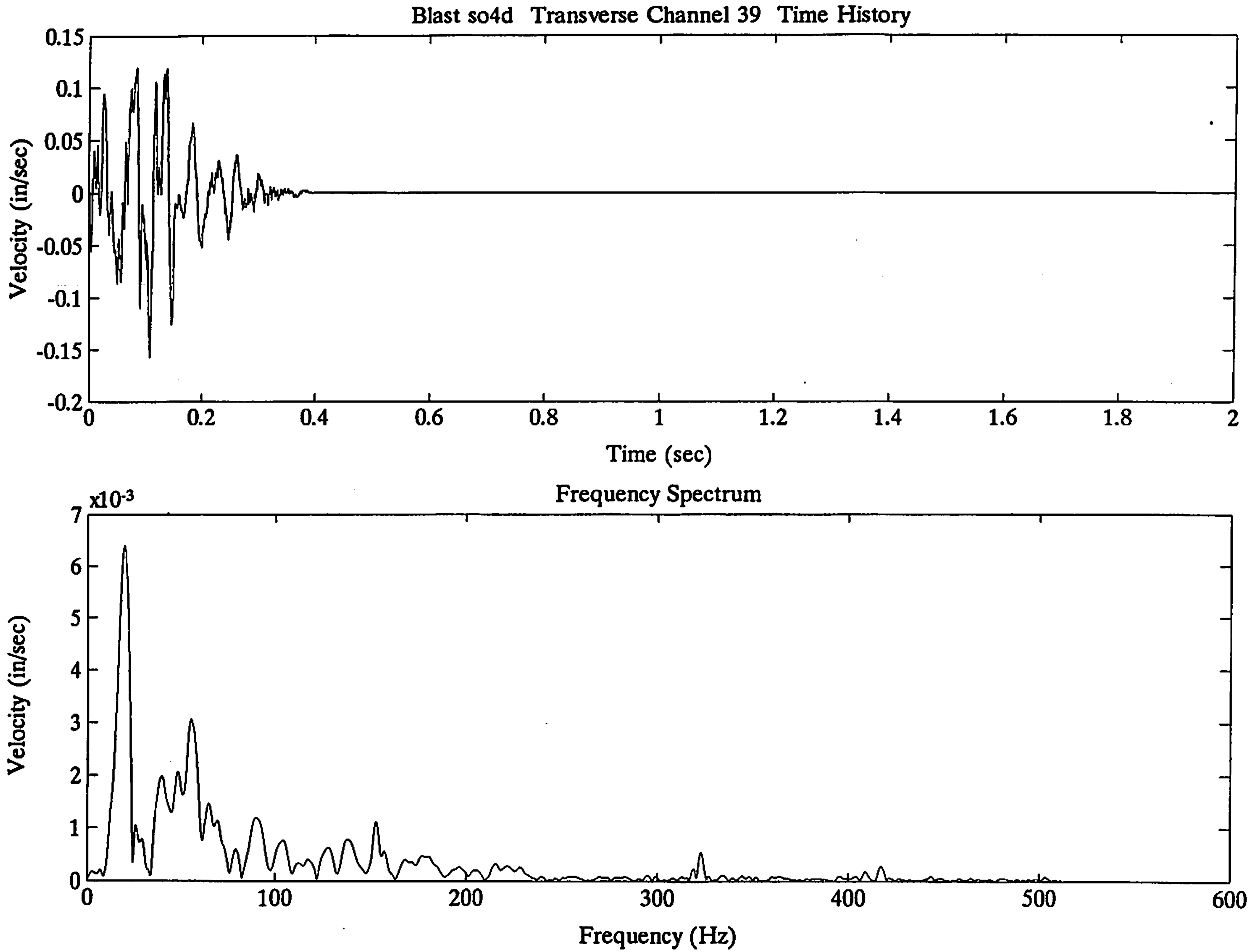

Frequency Spectrum
Velocity (in/sec)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
100
200
300
400
500
600
Frequency (Hz)



Blast so4d Longitudinal Channel 38 Time History
Velocity (in/sec)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)



Frequency Spectrum
x10^-3
Velocity (in/sec)
8
6
4
2
0
0
100
200
300
400
500
600
Frequency (Hz)


Blast so4d Transverse Channel 39 Time History
Velocity (in/sec)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (sec)
Frequency Spectrum
x10-3
7
6
5
4
3
2
1
0
Velocity (in/sec)
0
100
200
300
400
500
600
Frequency (Hz)

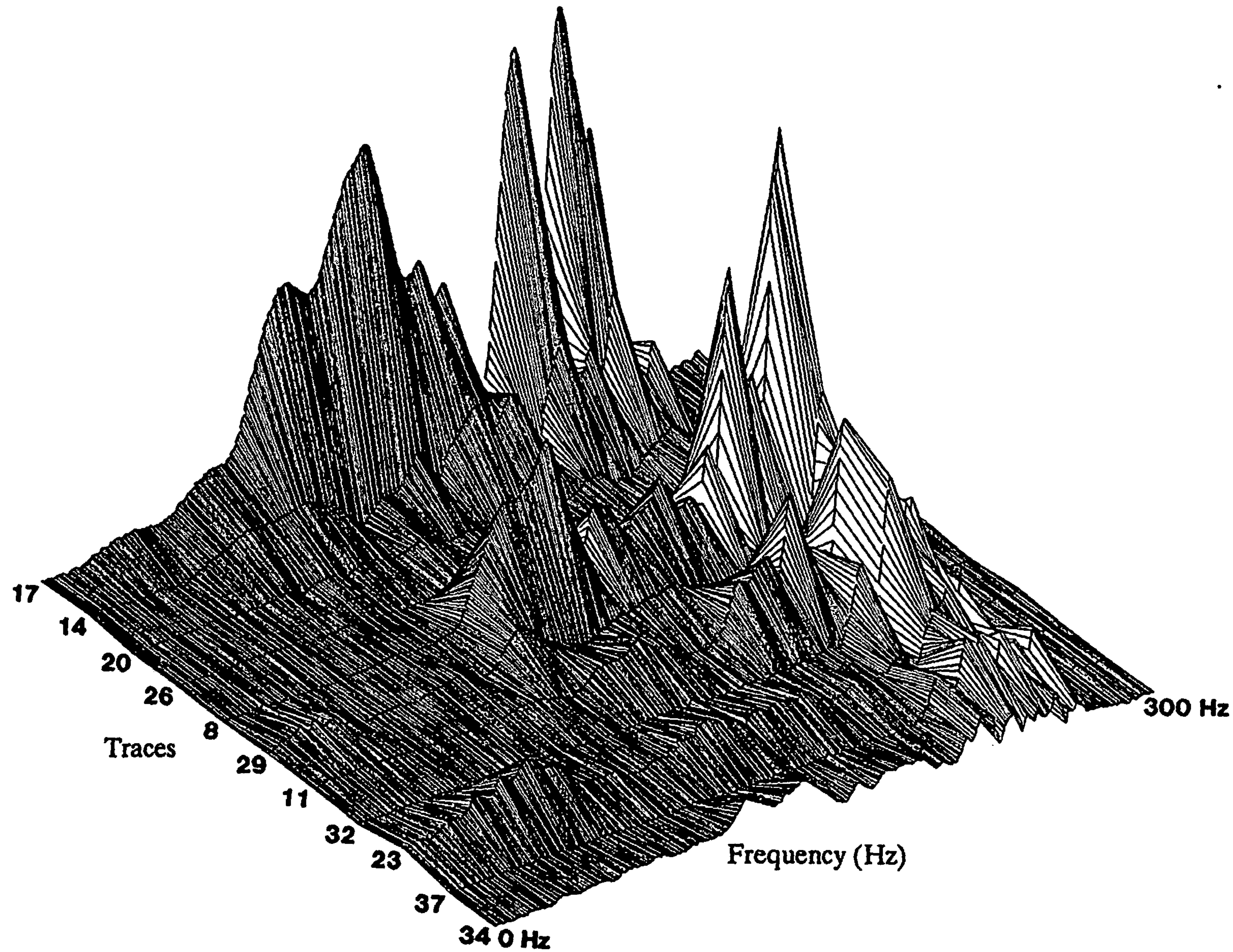
SECTION E-2

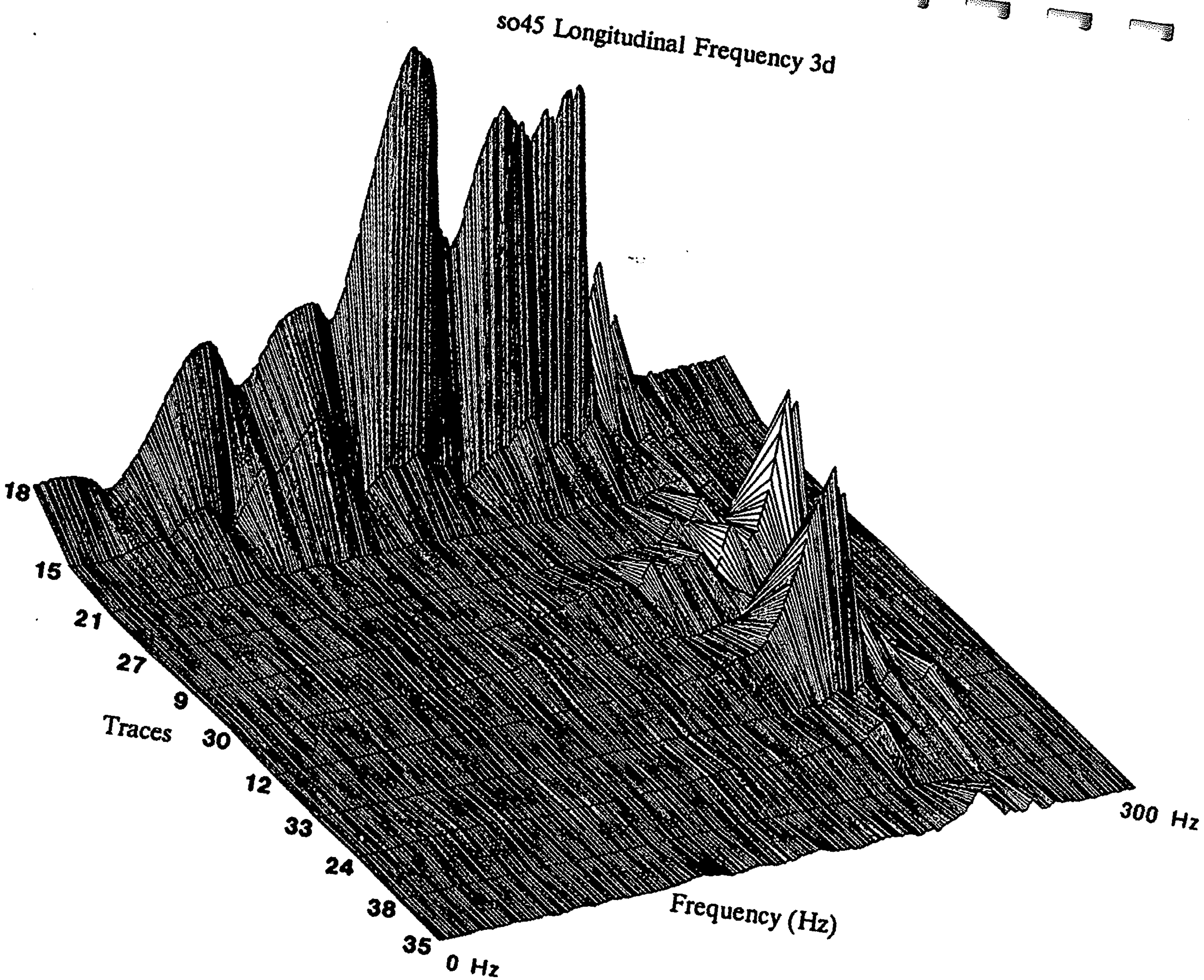
THREE-DIMENSIONAL DISPLAYS OF FOURIER TRANSFORMS

FOR

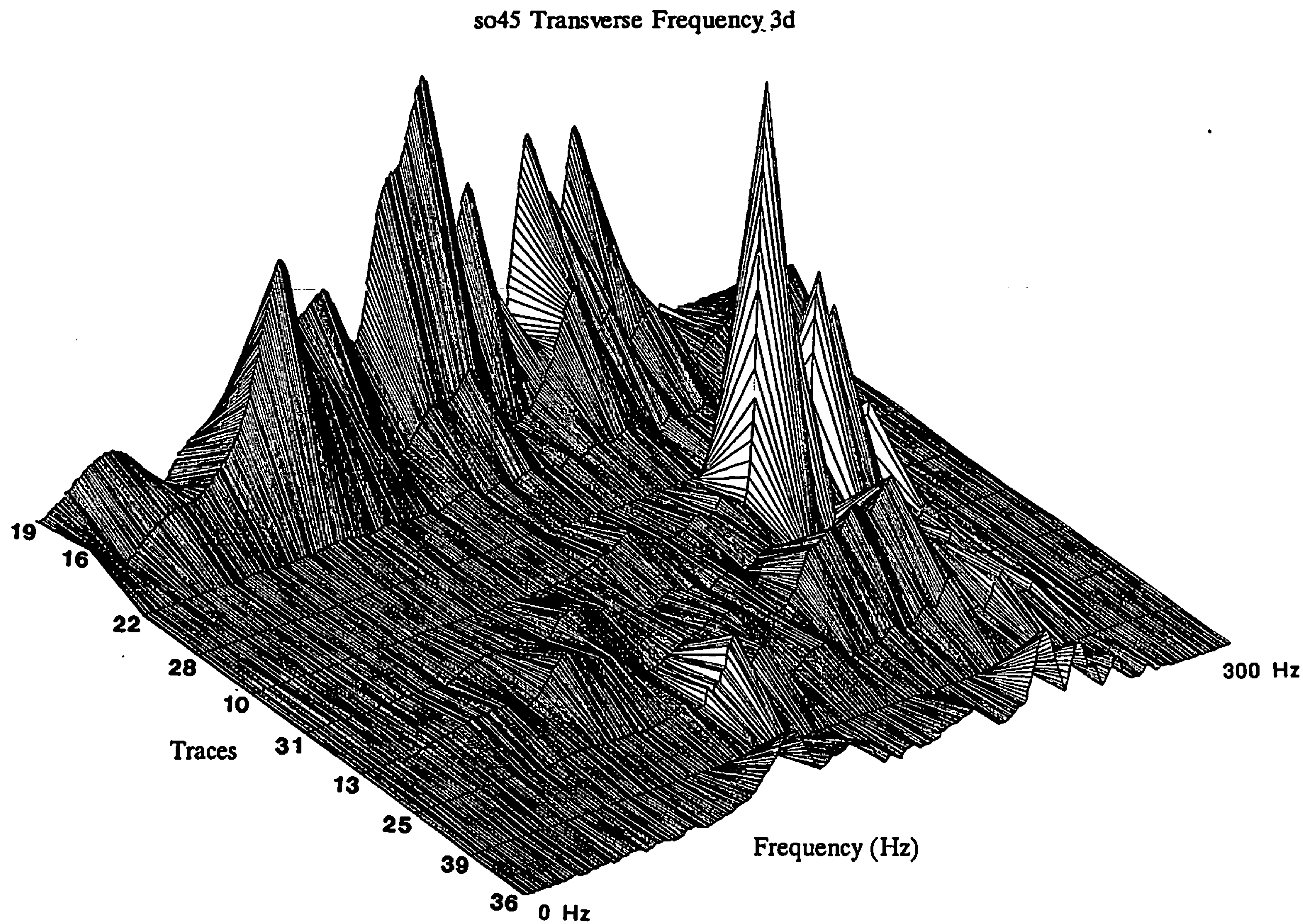
INDIVIDUAL RECORDS IN SEQUENCE S04

so45 Vertical Frequency 3d

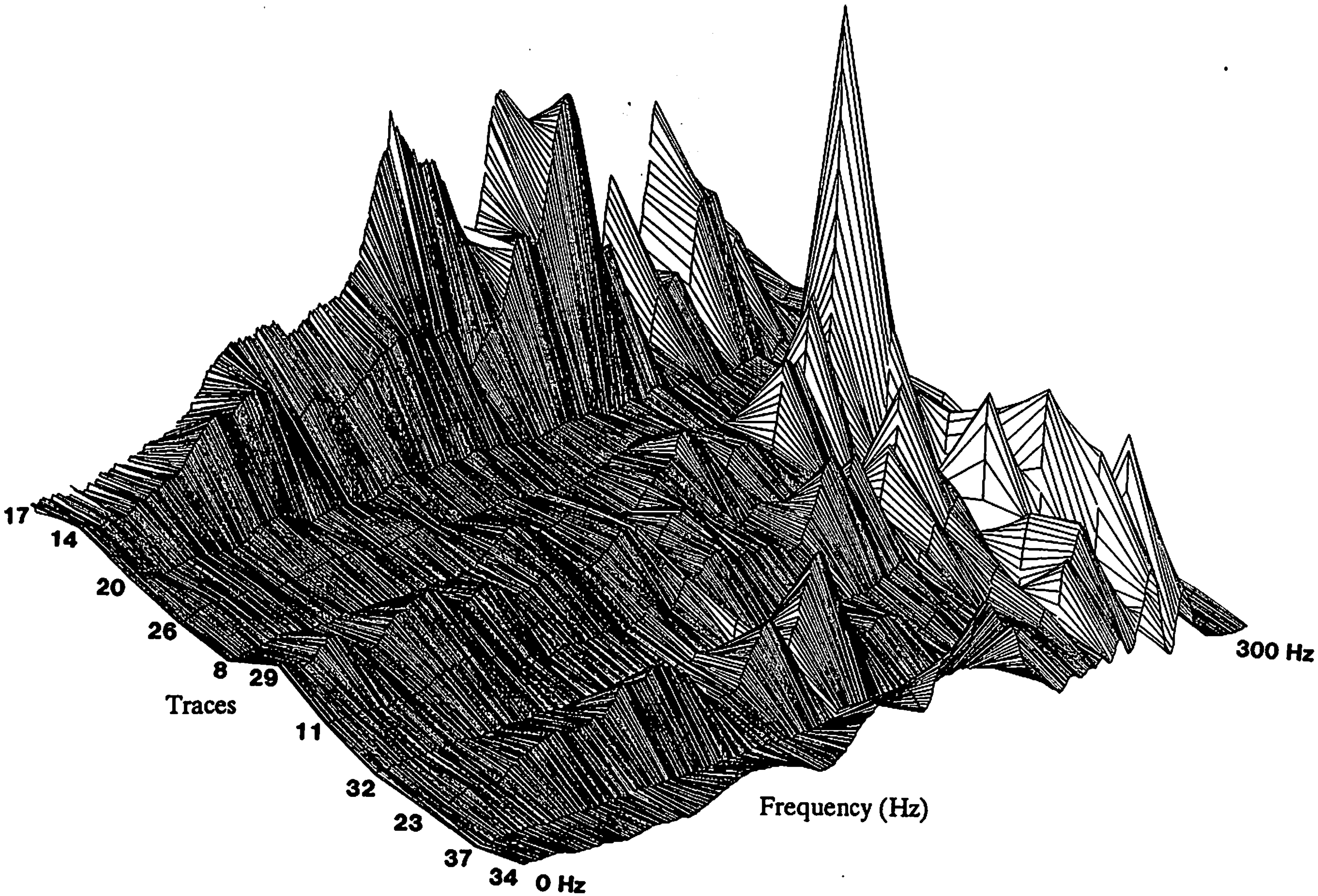


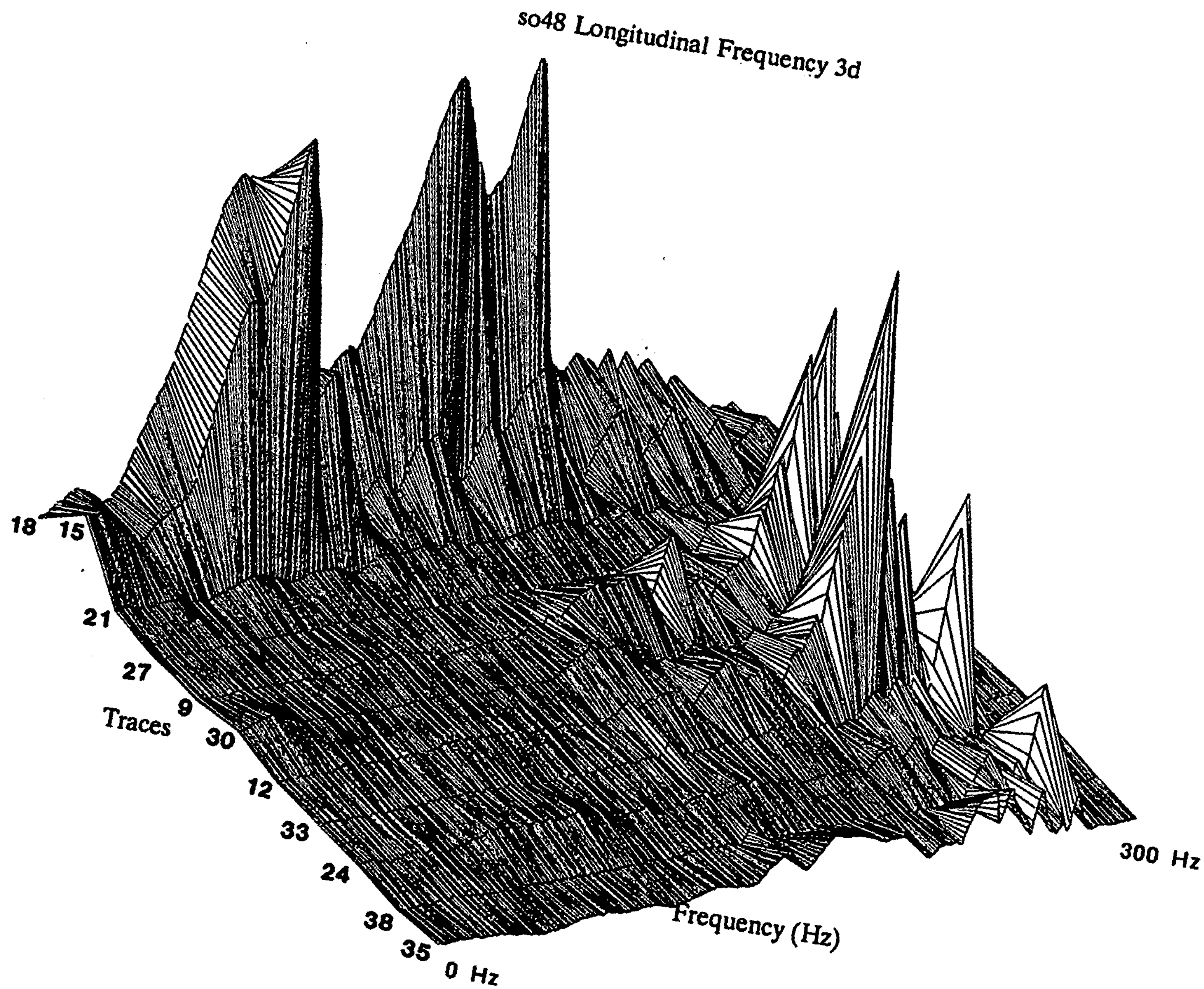


so45 Longitudinal Frequency 3d
18
15
21
27
9
Traces
30
12
33
24
38
35
0 Hz
Frequency (Hz)
300 Hz


so45 Transverse Frequency 3d
19
16
22
28
10
Traces
31
13
25
39
36
0 Hz
Frequency (Hz)
300 Hz

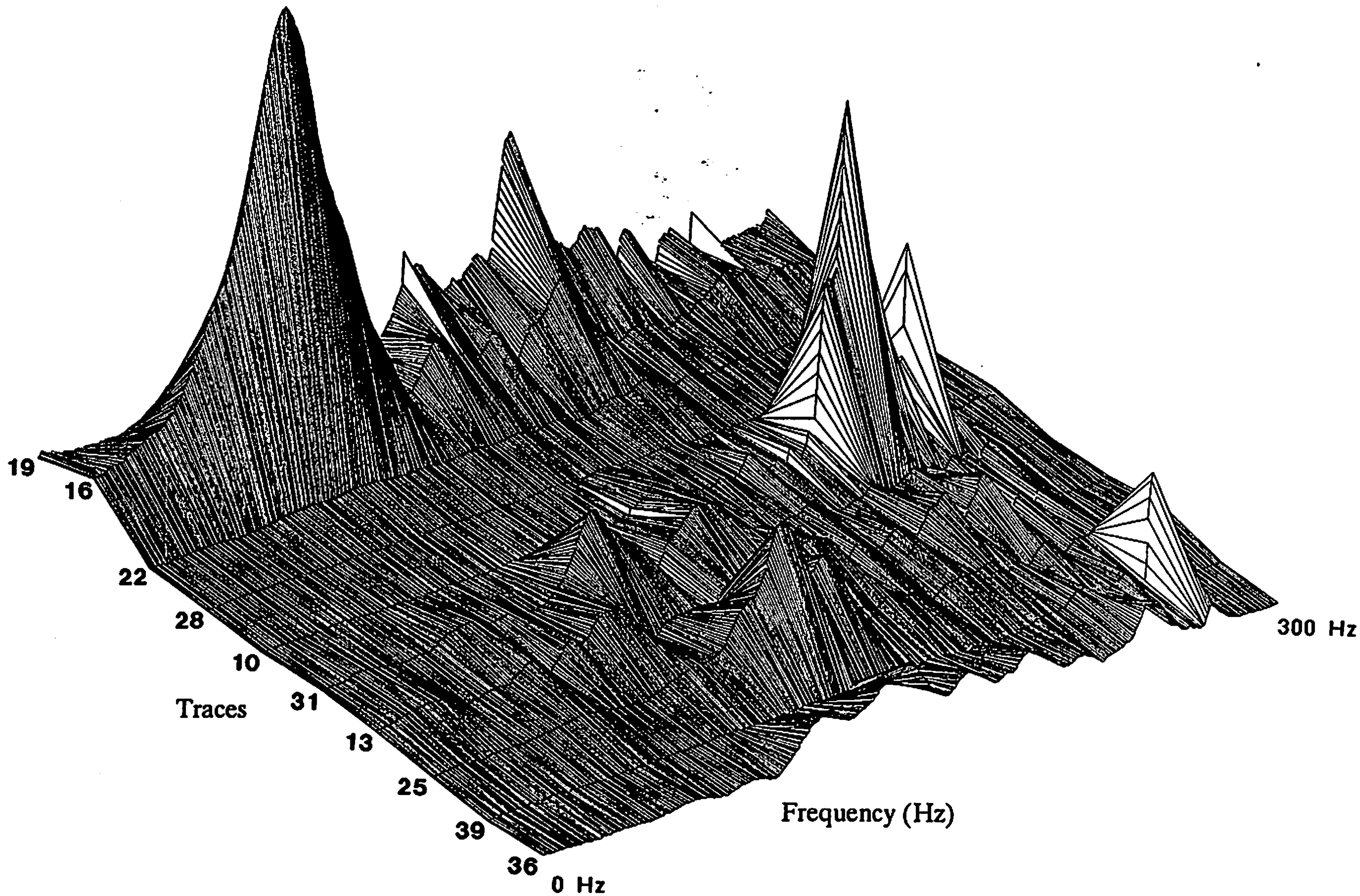
so48 Vertical Frequency 3d



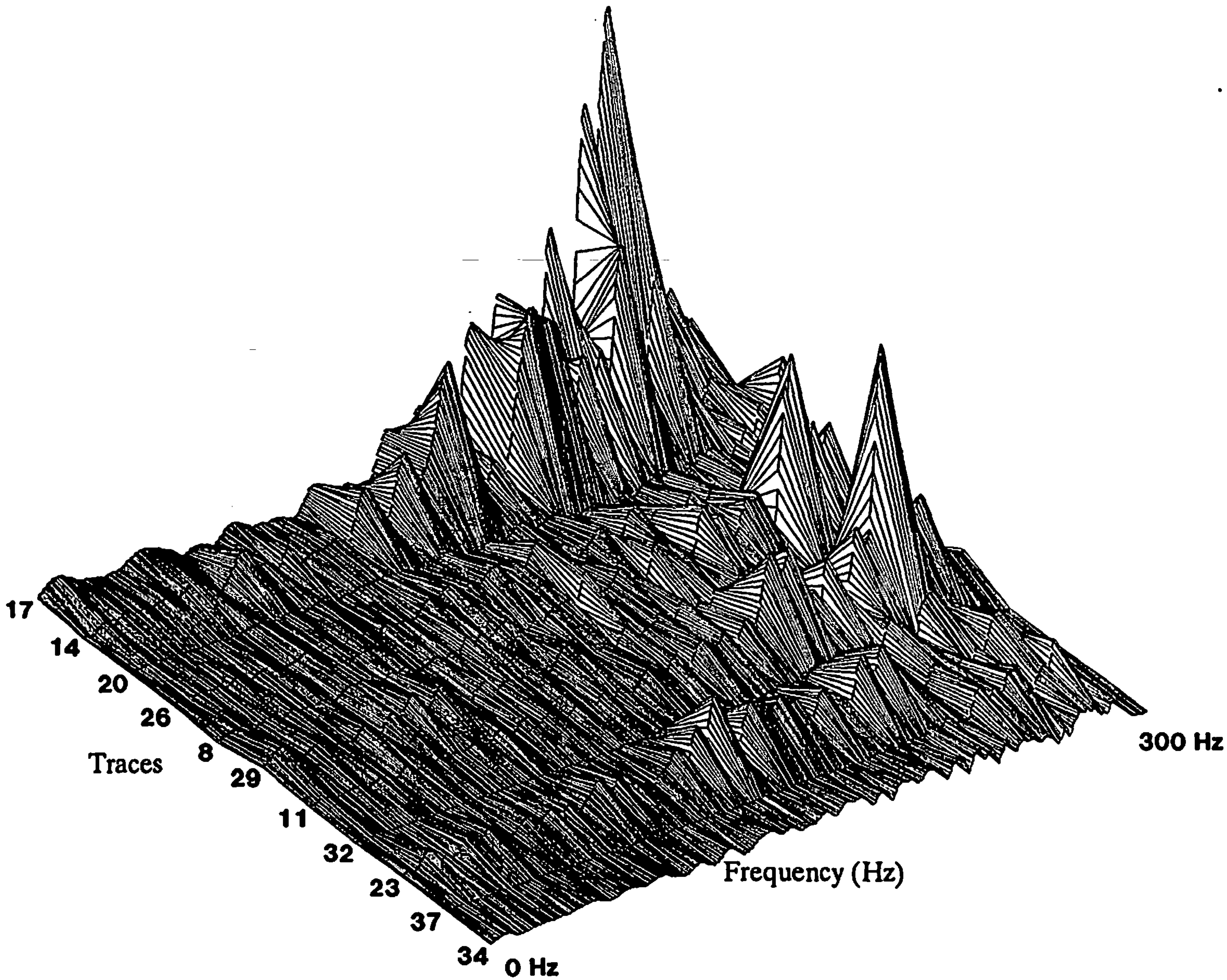


so48 Longitudinal Frequency 3d
18
15
21
27
9
Traces
30
12
33
24
38
35
0 Hz
Frequency (Hz)
300 Hz

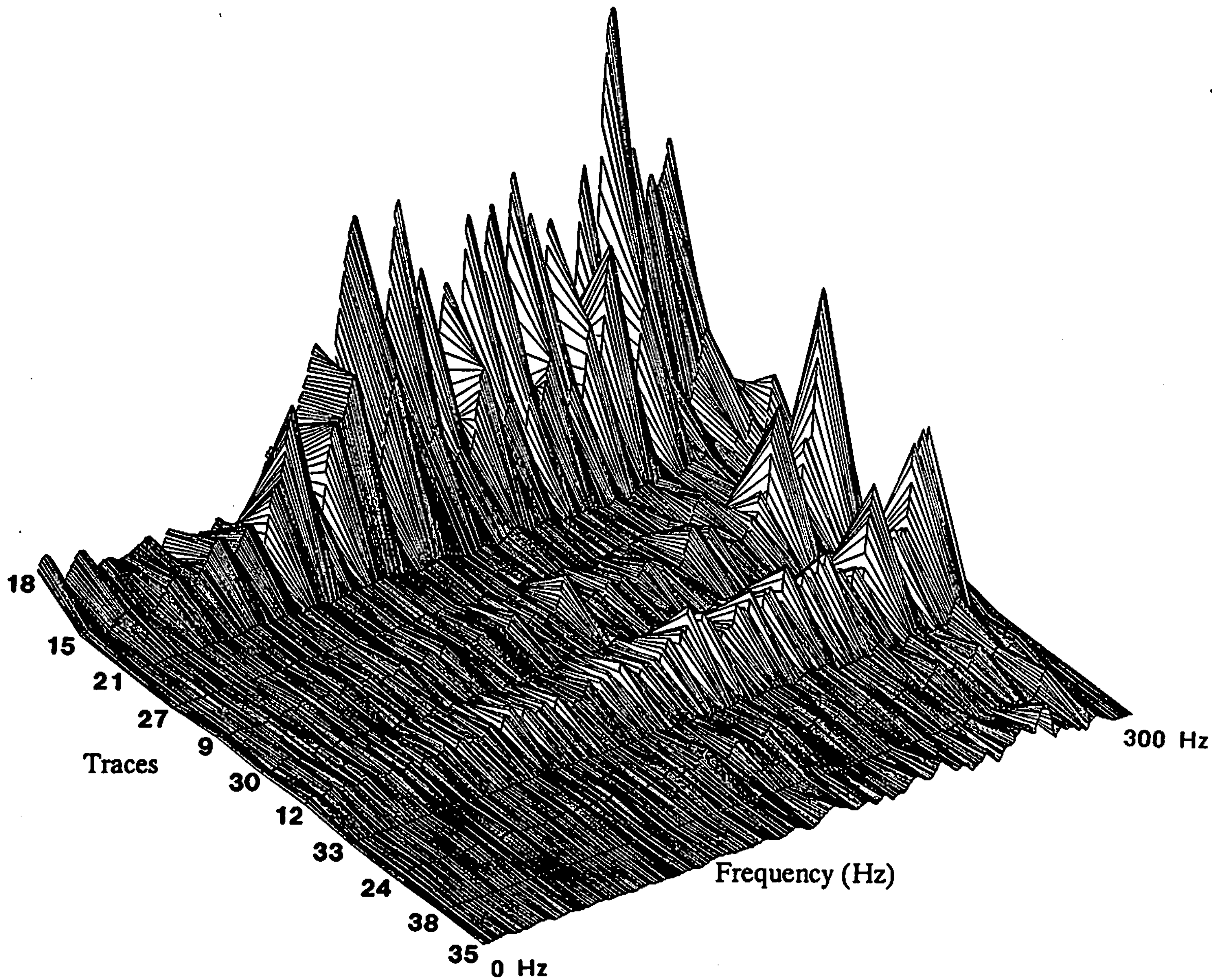
so48 Transverse Frequency 3d

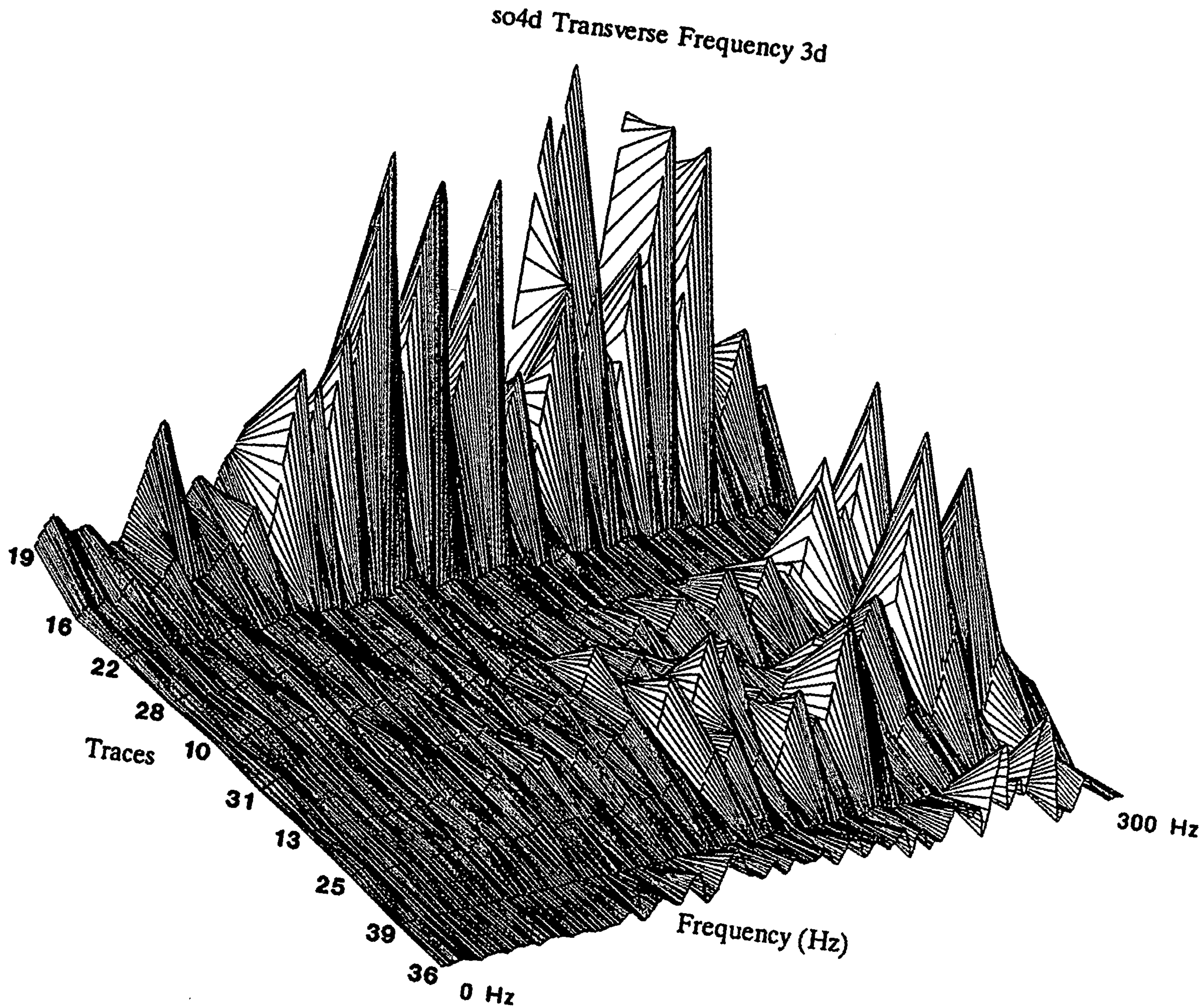


so4d Vertical Frequency.3d



so4d Longitudinal Frequency 3d



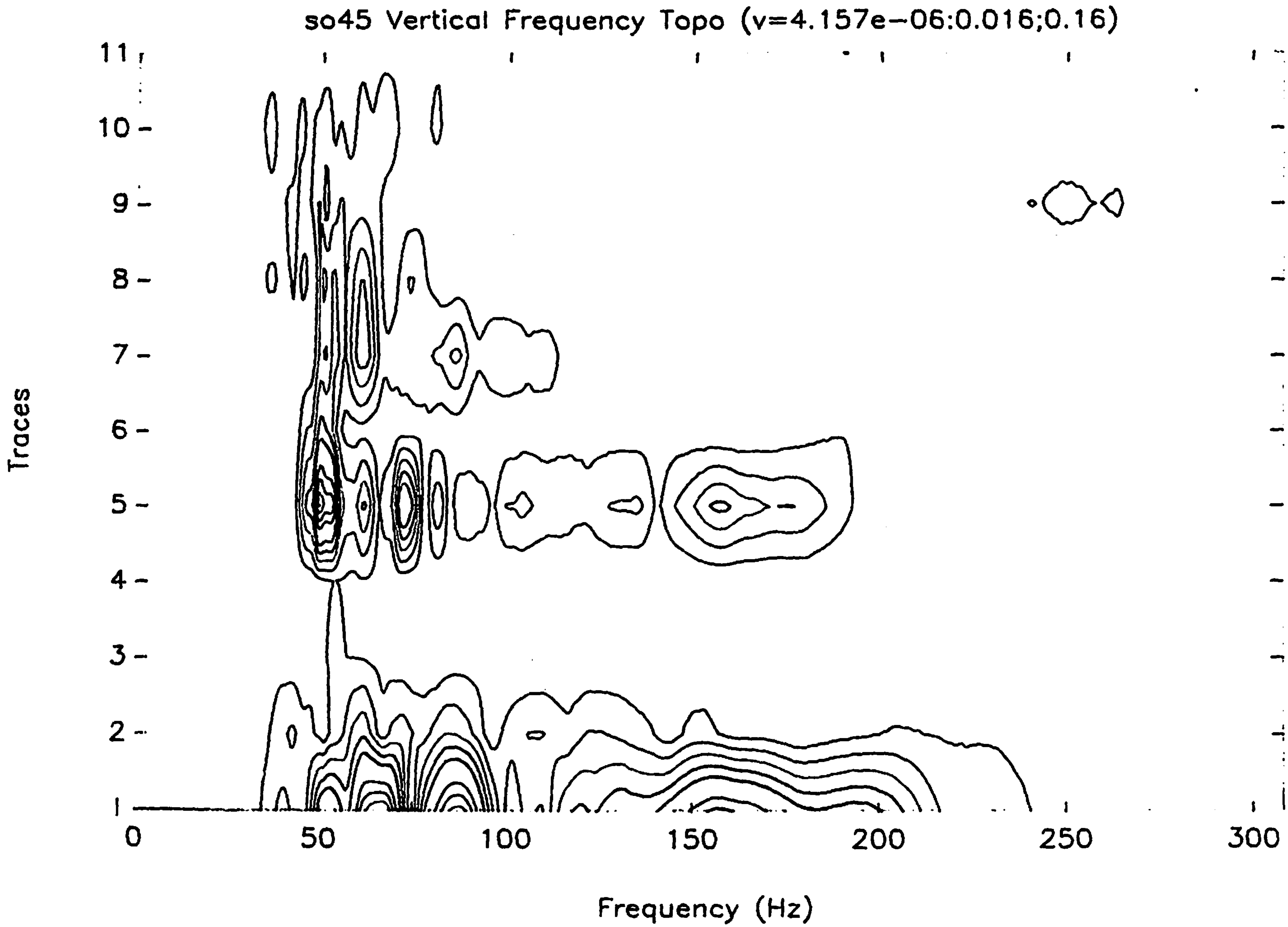

so4d Transverse Frequency 3d
19
16
22
28
Traces
10
31
13
25
39
36
0 Hz
Frequency (Hz)
300 Hz

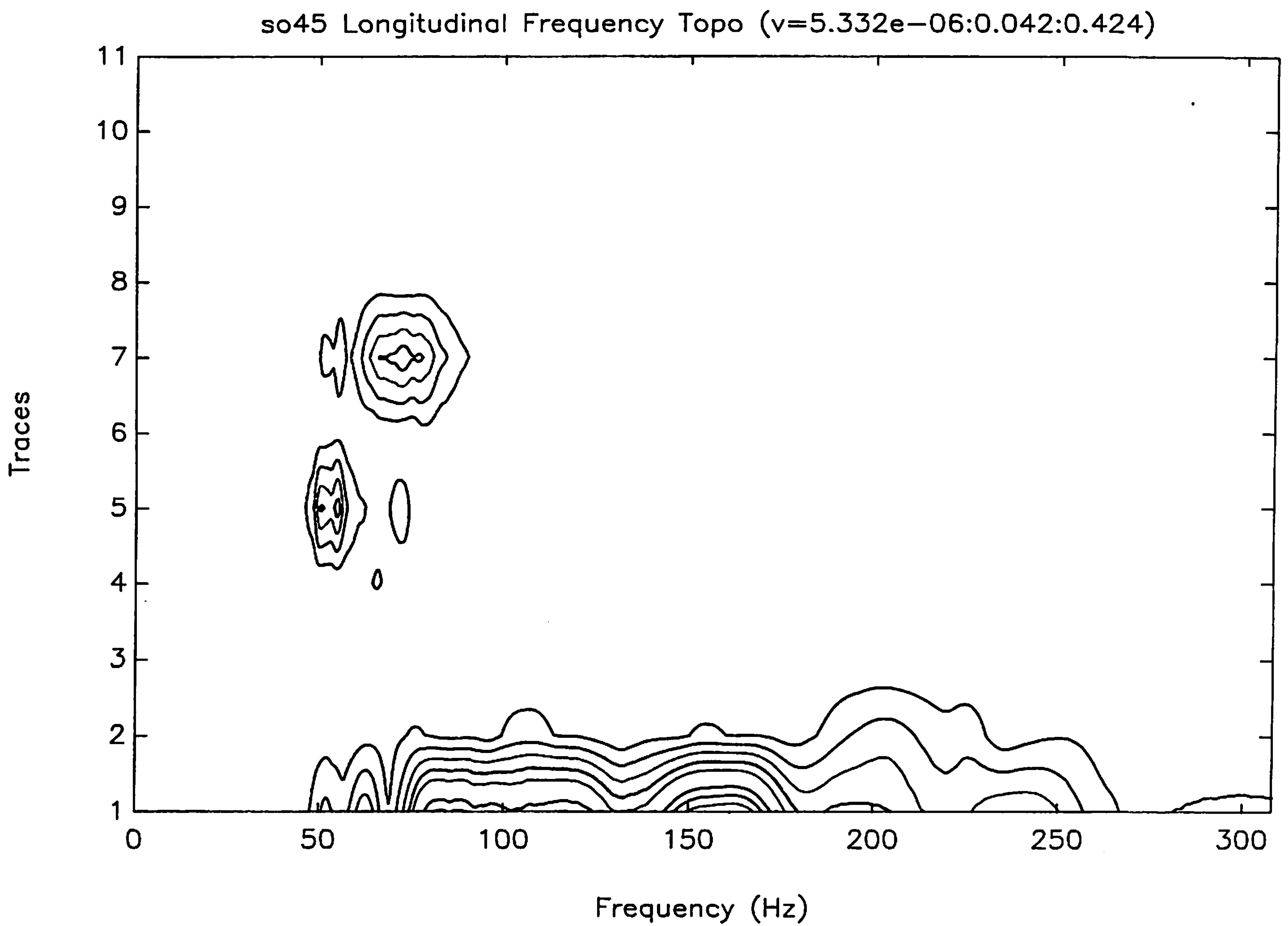
SECTION E-3

TOPOGRAPHIC PLOTS OF FOURIER TRANSFORMS

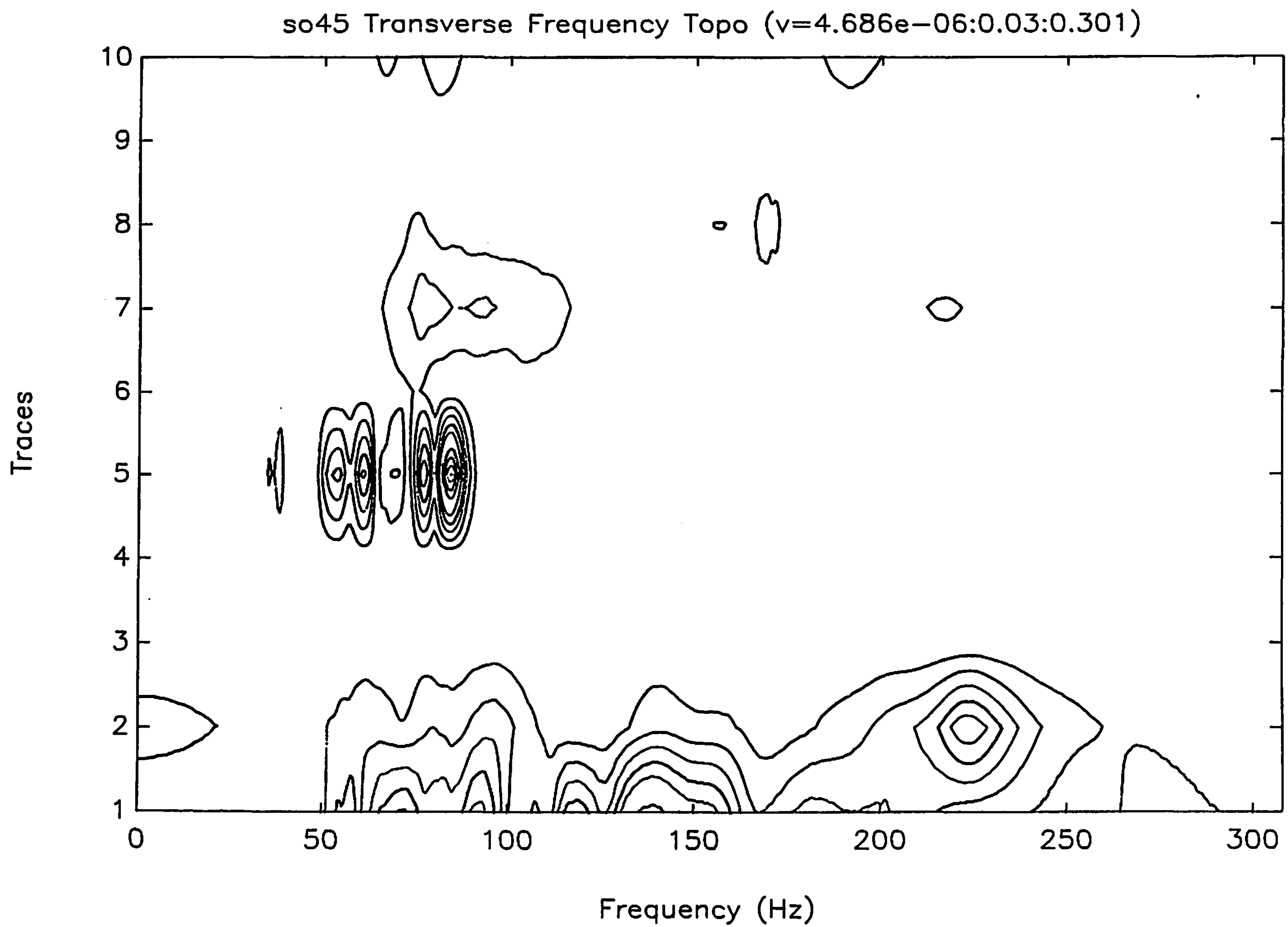
FOR

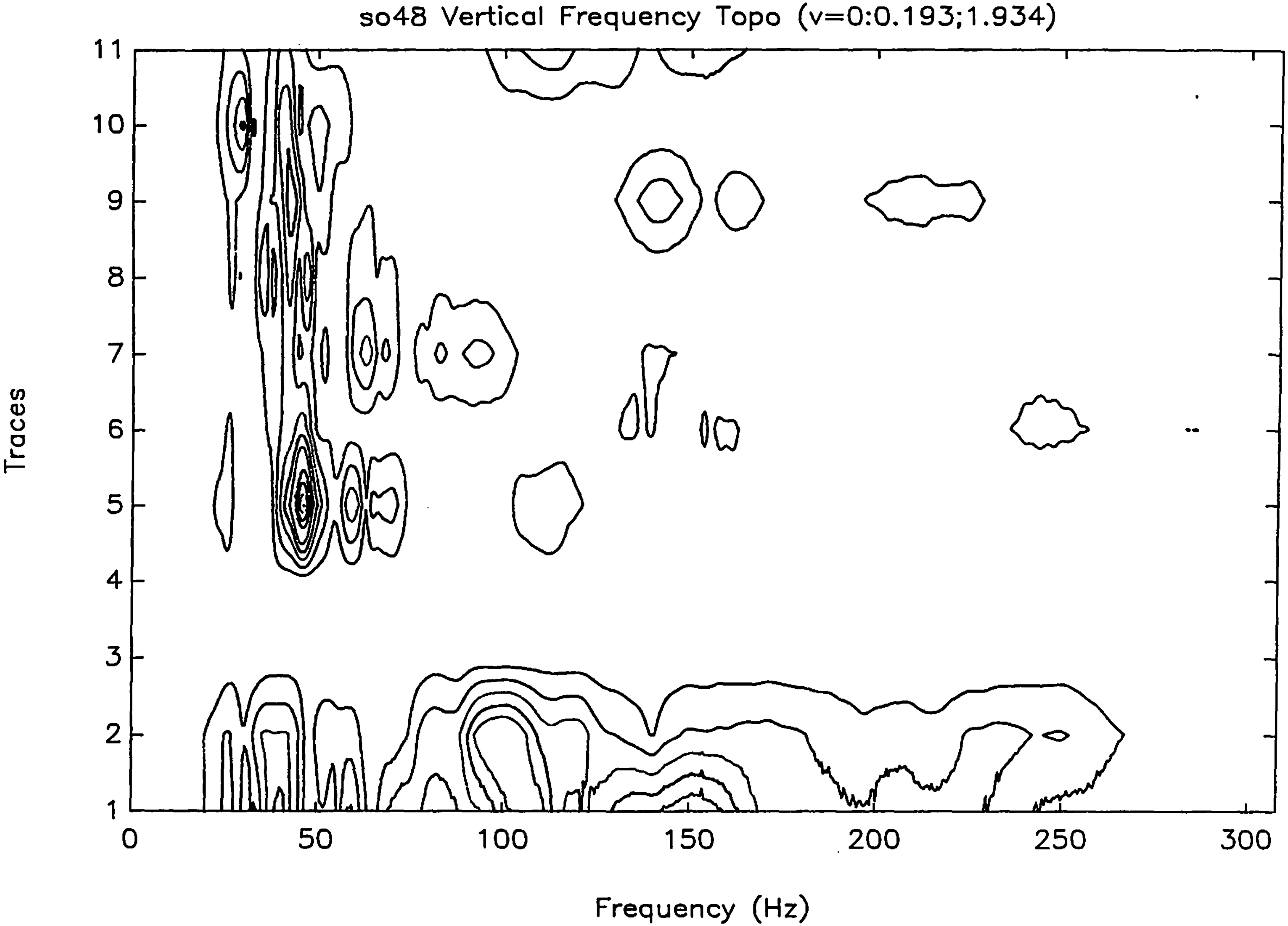
INDIVIDUAL RECORDS IN SEQUENCE S04

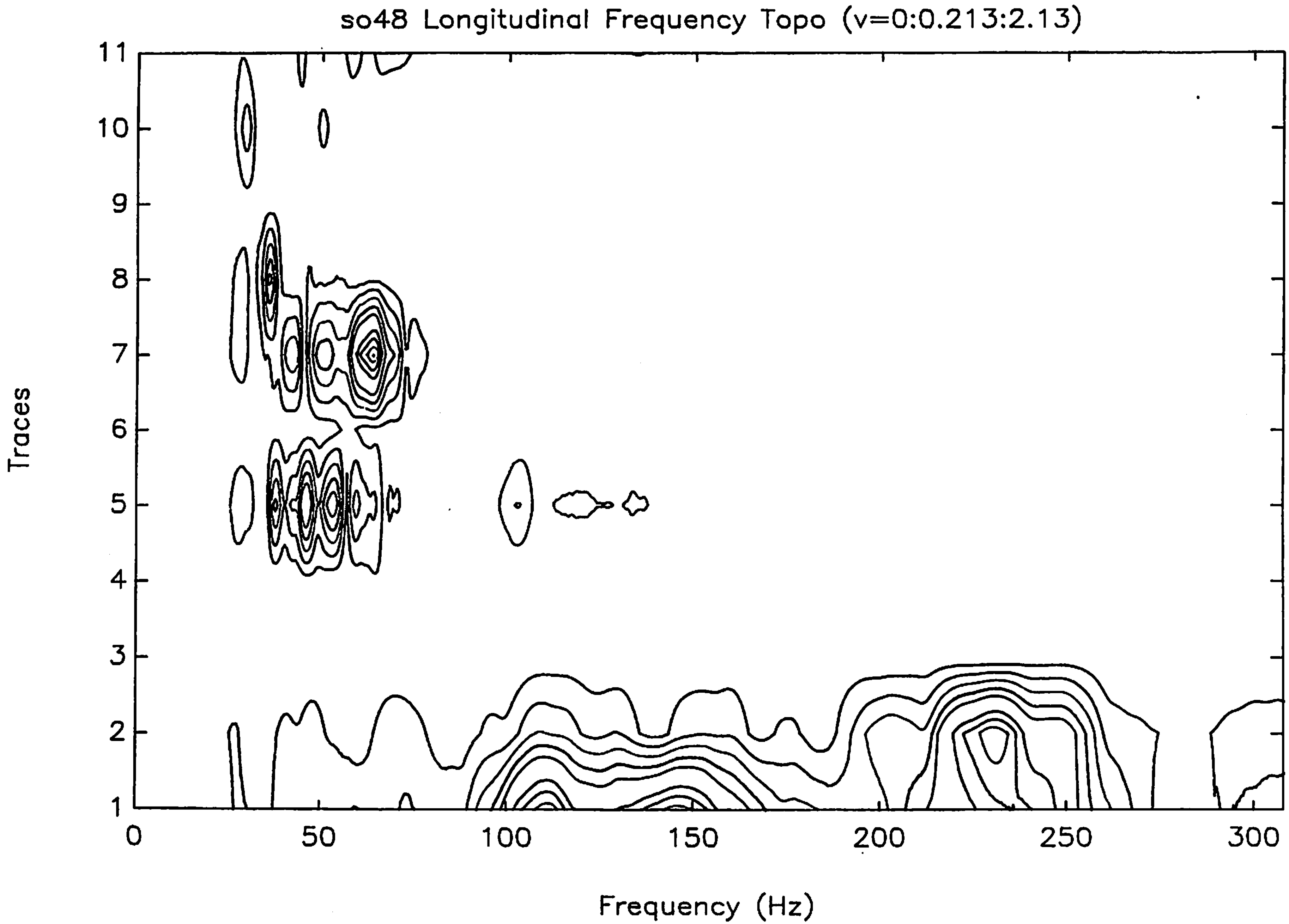

so45 Vertical Frequency Topo (v=4.157e-06:0.016;0.16)
Traces
Frequency (Hz)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11



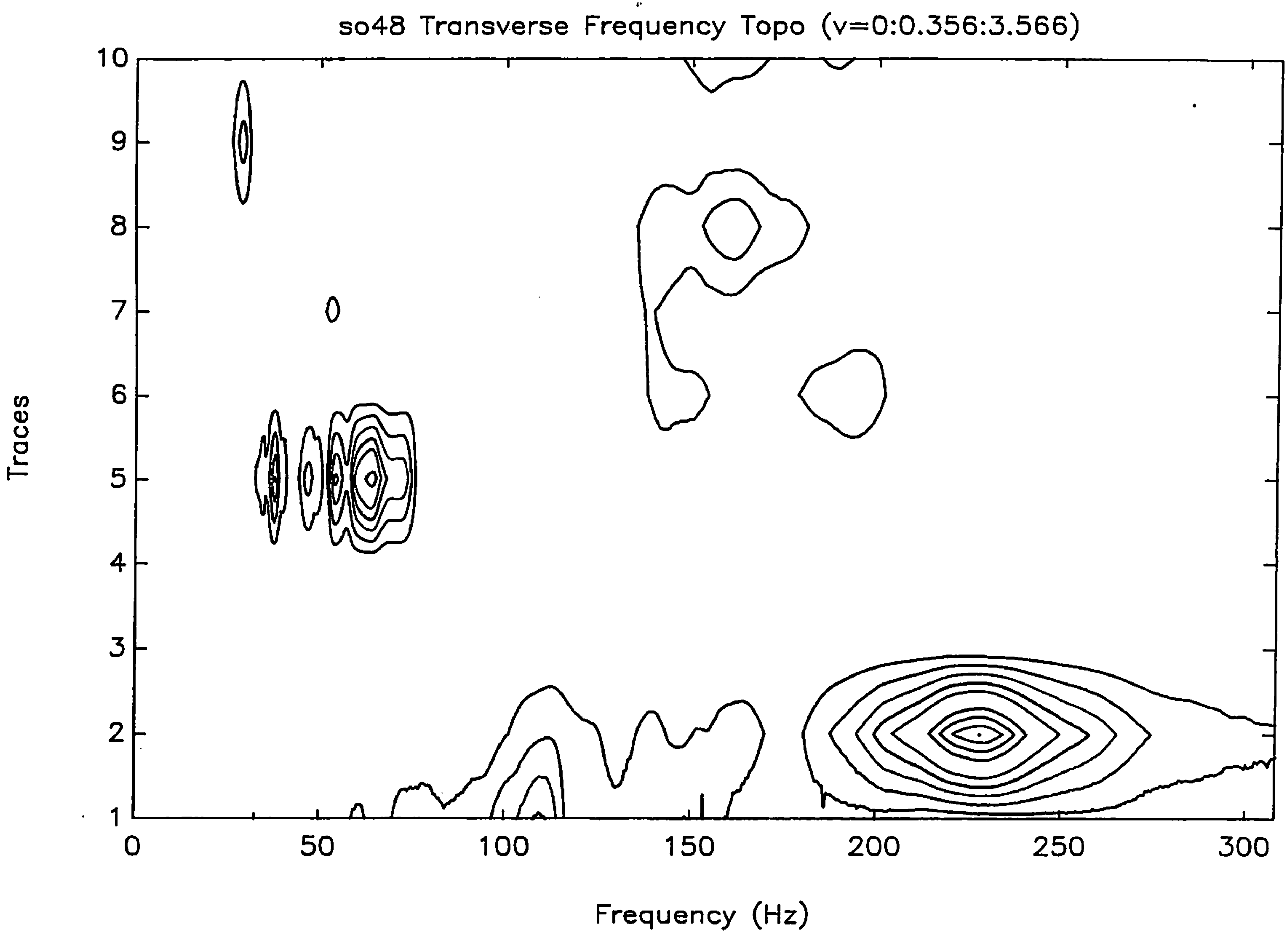
so45 Longitudinal Frequency Topo (v=5.332e-06:0.042:0.424)
Traces
Frequency (Hz)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11


so45 Transverse Frequency Topo (v=4.686e-06:0.03:0.301)
Traces
Frequency (Hz)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10

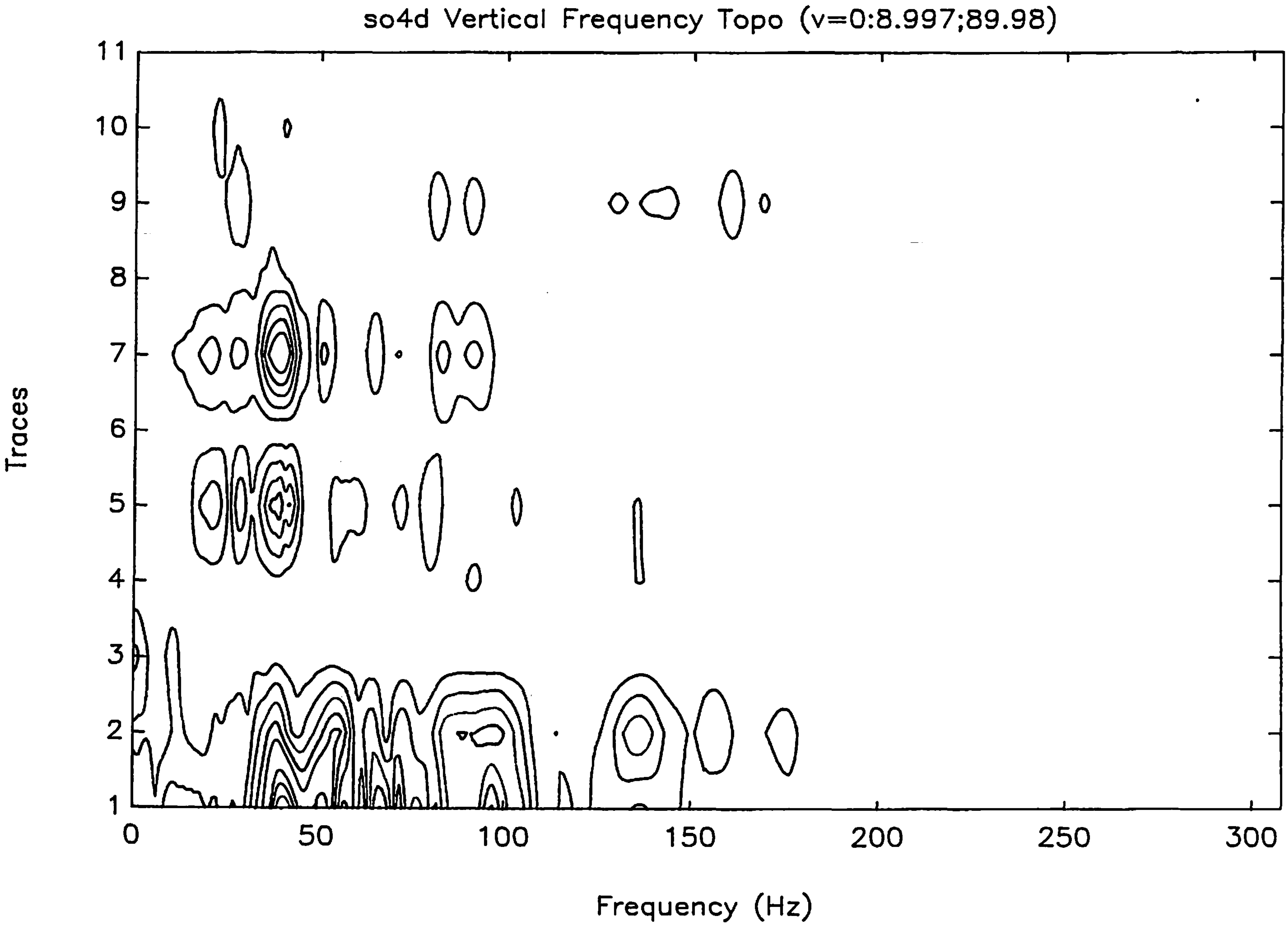

so48 Vertical Frequency Topo (v=0:0.193;1.934)
Traces
Frequency (Hz)
11
10
9
8
7
6
5
4
3
2
1
0
50
100
150
200
250
300

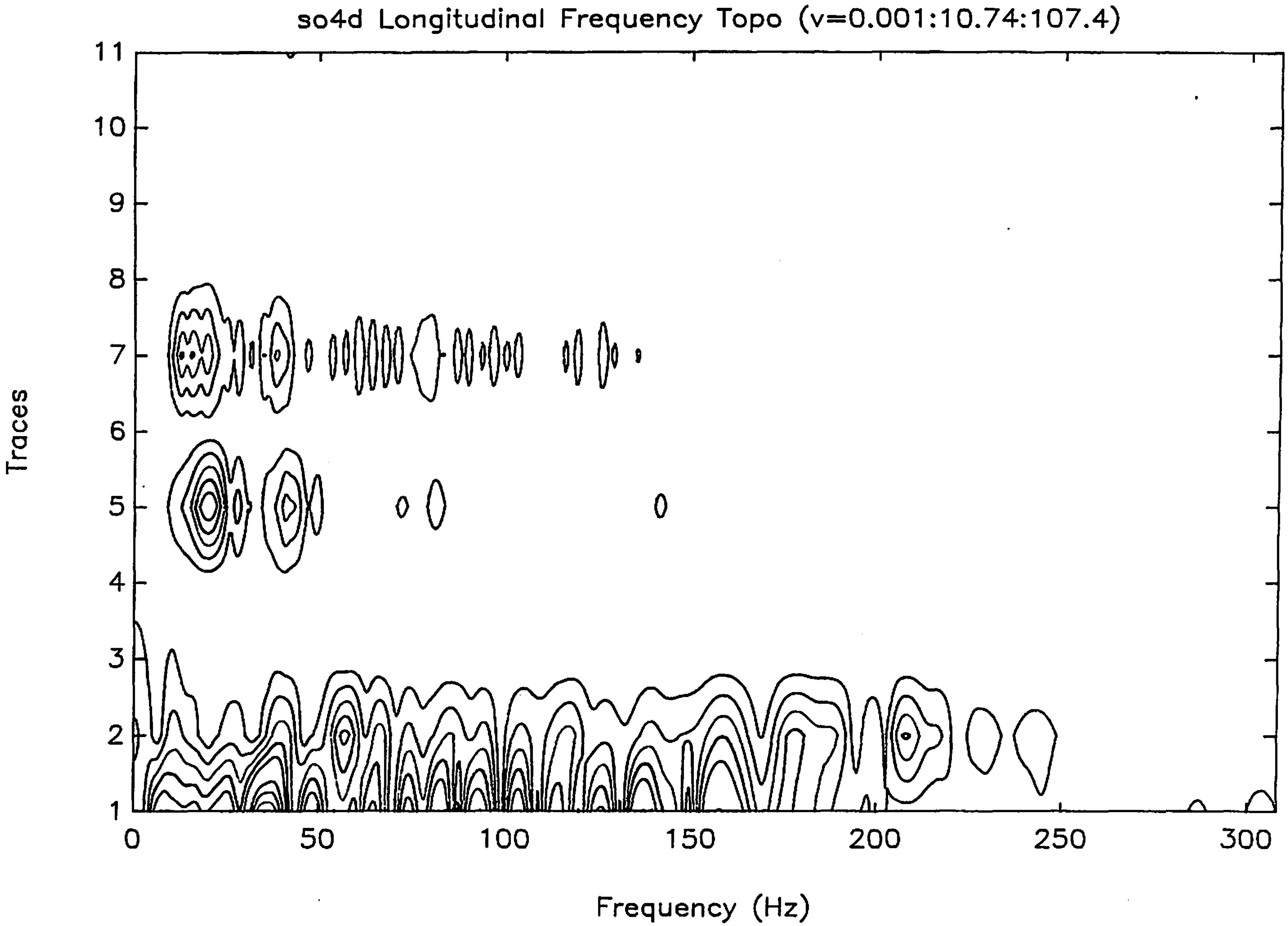


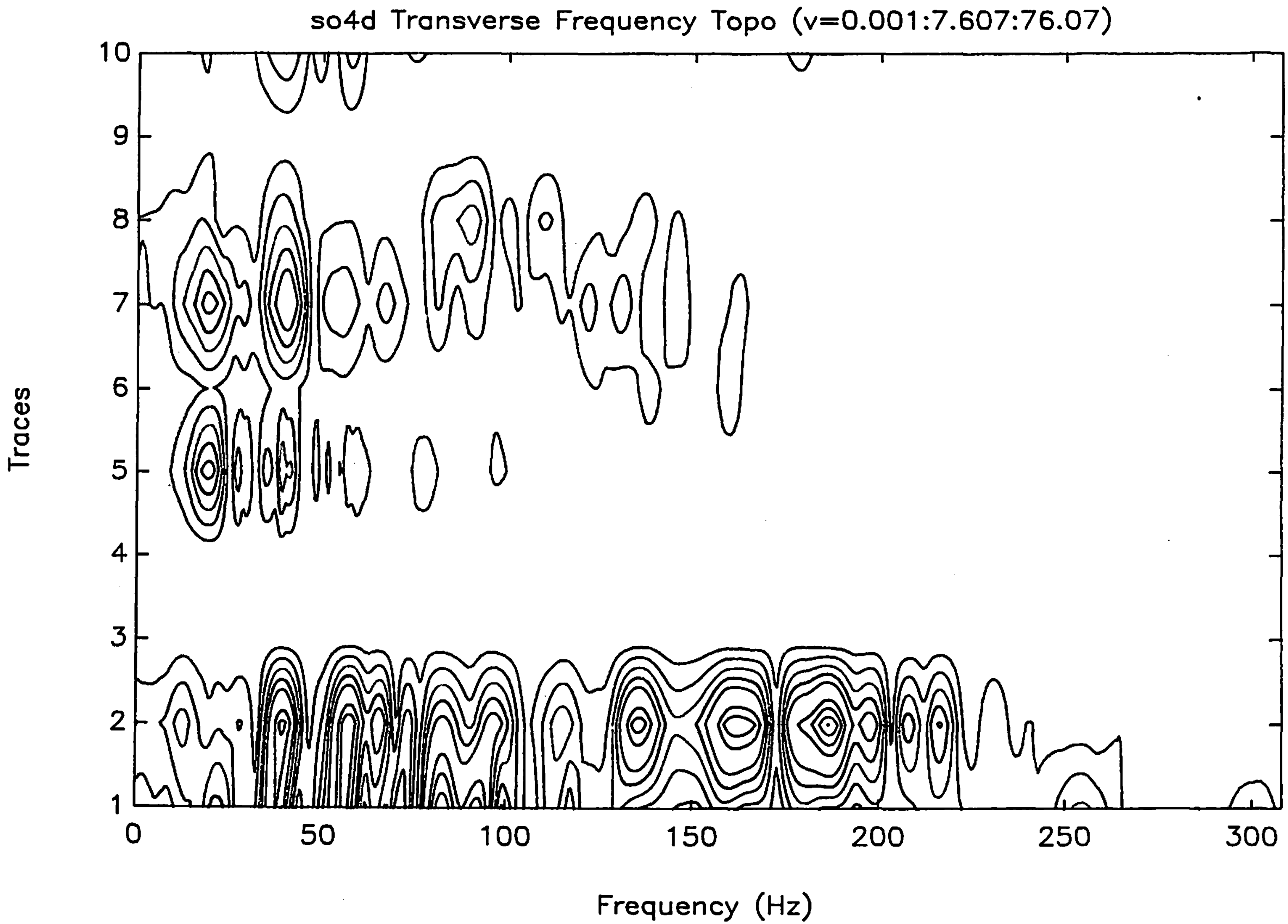
so48 Longitudinal Frequency Topo (v=0:0.213:2.13)
Traces
Frequency (Hz)
1
2
3
4
5
6
7
8
9
10
11
0
50
100
150
200
250
300



so48 Transverse Frequency Topo (v=0:0.356:3.566)
Traces
Frequency (Hz)
10
9
8
7
6
5
4
3
2
1
0
50
100
150
200
250
300


so4d Vertical Frequency Topo (v=0:8.997;89.98)
Traces
Frequency (Hz)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11


so4d Longitudinal Frequency Topo (v=0.001:10.74:107.4)
Traces
Frequency (Hz)
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11


so4d Transverse Frequency Topo (v=0.001:7.607:76.07)
Traces
Frequency (Hz)
10
9
8
7
6
5
4
3
2
1
0
50
100
150
200
250
300

SECTION E-4

PARTICLE VELOCITY REPORTS

FOR

INDIVIDUAL RECORDS IN SEQUENCE S04

Blast so43 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21, 3, 0)	vertical	absolute ppv: 0.1775
9	(21, 3, 0)	longitudinal	absolute ppv: 0.64208
10	(21, 3, 0)	transverse	absolute ppv: 0.64608
11	(21, 7, 0)	vertical	absolute ppv: 0.5534
12	(21, 7, 0)	longitudinal	absolute ppv: 0.69961
13	(21, 7, 0)	transverse	absolute ppv: 0.53955
14	(21,12, 0)	vertical	absolute ppv: 2.00189
15	(21,12, 0)	longitudinal	absolute ppv: 3.38645
16	(21,12, 0)	transverse	absolute ppv: 3.29135
17	(21,17, 0)	vertical	absolute ppv: 2.45084
18	(21,17, 0)	longitudinal	absolute ppv: 6.38467
19	(21,17, 0)	transverse	absolute ppv: 2.71437
20	(16, 8,-10)	vertical	absolute ppv: 0.28534
21	(16, 8,-10)	longitudinal	absolute ppv: 0.28814
22	(16, 8,-10)	transverse	absolute ppv: 0.2393
23	(17, 3, -5)	vertical	absolute ppv: 0.35564
24	(17, 3, -5)	longitudinal	absolute ppv: 0.15294
25	(17, 3, -5)	transverse	absolute ppv: 0.59692
26	(16, 8,-20)	vertical	absolute ppv: 0.14595
27	(16, 8,-20)	longitudinal	absolute ppv: 0.13329
28	(16, 8,-20)	transverse	absolute ppv: 0.13869
29	(21, 3, -5)	vertical	absolute ppv: 0.2116
30	(21, 3, -5)	longitudinal	absolute ppv: 0.12438
31	(21, 3, -5)	transverse	absolute ppv: 0.35891
32	(16, 3, -4)	vertical	absolute ppv: 0.23846
33	(16, 3, -4)	longitudinal	absolute ppv: 0.12447
34	(25, 3, -5)	vertical	absolute ppv: 0.21288
35	(25, 3, -5)	longitudinal	absolute ppv: 0.18175
36	(25, 3, -5)	transverse	absolute ppv: 0.26961
37	(26, 3, -4)	vertical	absolute ppv: 0.23247
38	(26, 3, -4)	longitudinal	absolute ppv: 0.08677
39	(26, 3, -4)	transverse	absolute ppv: 0.07231

Blast so44 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 4.58711e-05
9	(21,25, 0)	longitudinal	absolute ppv: 0.00021
10	(21,25, 0)	transverse	absolute ppv: 0.00033
11	(16,25, 0)	vertical	absolute ppv: 0.00022
12	(16,25, 0)	longitudinal	absolute ppv: 0.0002
13	(16,25, 0)	transverse	absolute ppv: 0.00027
14	(16,30, 0)	vertical	absolute ppv: 0.00019
15	(16,30, 0)	longitudinal	absolute ppv: 0.00097
16	(16,30, 0)	transverse	absolute ppv: 0.00031
17	(21,25, 0)	vertical	absolute ppv: 0.00025
18	(21,25, 0)	longitudinal	absolute ppv: 0.00035
19	(21,25, 0)	transverse	absolute ppv: 0.00021
20	(16,30,-10)	vertical	absolute ppv: 0.0004
21	(16,30,-10)	longitudinal	absolute ppv: 0.00042
22	(16,30,-10)	transverse	absolute ppv: 0.00065
23	(17,25, -5)	vertical	absolute ppv: 0.00048
24	(17,25, -5)	longitudinal	absolute ppv: 0.00038
25	(17,25, -5)	transverse	absolute ppv: 0.0005
26	(16,30,-20)	vertical	absolute ppv: 0.00019
27	(16,30,-20)	longitudinal	absolute ppv: 0.00037
28	(16,30,-20)	transverse	absolute ppv: 0.00025
29	(21,25, -5)	vertical	absolute ppv: 0.00026
30	(21,25, -5)	longitudinal	absolute ppv: 0.00022
31	(21,25, -5)	transverse	absolute ppv: 0.00025
32	(16,25, -4)	vertical	absolute ppv: 0.00063
33	(16,25, -4)	longitudinal	absolute ppv: 0.00052
34	(25,25, -5)	vertical	absolute ppv: 0.00043
35	(25,25, -5)	longitudinal	absolute ppv: 0.00028
36	(25,25, -5)	transverse	absolute ppv: 0.00038
37	(26,25, -4)	vertical	absolute ppv: 0.00032
38	(26,25, -4)	longitudinal	absolute ppv: 0.002
39	(26,25, -4)	transverse	absolute ppv: 0.00241

Blast so45 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.00701
9	(21,25, 0)	longitudinal	absolute ppv: 0.00355
10	(21,25, 0)	transverse	absolute ppv: 0.0063
11	(16,25, 0)	vertical	absolute ppv: 0.00407
12	(16,25, 0)	longitudinal	absolute ppv: 0.00745
13	(16,25, 0)	transverse	absolute ppv: 0.0074
14	(16,30, 0)	vertical	absolute ppv: 0.00457
15	(16,30, 0)	longitudinal	absolute ppv: 0.01452
16	(16,30, 0)	transverse	absolute ppv: 0.01508
17	(21,25, 0)	vertical	absolute ppv: 0.02054
18	(21,25, 0)	longitudinal	absolute ppv: 0.0547
19	(21,25, 0)	transverse	absolute ppv: 0.02918
20	(16,30,-10)	vertical	absolute ppv: 0.00105
21	(16,30,-10)	longitudinal	absolute ppv: 0.00106
22	(16,30,-10)	transverse	absolute ppv: 0.00146
23	(17,25, -5)	vertical	absolute ppv: 0.00202
24	(17,25, -5)	longitudinal	absolute ppv: 0.0013
25	(17,25, -5)	transverse	absolute ppv: 0.00268
26	(16,30,-20)	vertical	absolute ppv: 0.00069
27	(16,30,-20)	longitudinal	absolute ppv: 0.0011
28	(16,30,-20)	transverse	absolute ppv: 0.00062
29	(21,25, -5)	vertical	absolute ppv: 0.00127
30	(21,25, -5)	longitudinal	absolute ppv: 0.00117
31	(21,25, -5)	transverse	absolute ppv: 0.00206
32	(16,25, -4)	vertical	absolute ppv: 0.00202
33	(16,25, -4)	longitudinal	absolute ppv: 0.00074
34	(25,25, -5)	vertical	absolute ppv: 0.0013
35	(25,25, -5)	longitudinal	absolute ppv: 0.00155
36	(25,25, -5)	transverse	absolute ppv: 0.00412
37	(26,25, -4)	vertical	absolute ppv: 0.00144
38	(26,25, -4)	longitudinal	absolute ppv: 0.00036
39	(26,25, -4)	transverse	absolute ppv: 0.00026

Blast so46 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.00639
9	(21,25, 0)	longitudinal	absolute ppv: 0.00387
10	(21,25, 0)	transverse	absolute ppv: 0.00624
11	(16,25, 0)	vertical	absolute ppv: 0.00419
12	(16,25, 0)	longitudinal	absolute ppv: 0.00801
13	(16,25, 0)	transverse	absolute ppv: 0.00801
14	(16,30, 0)	vertical	absolute ppv: 0.00459
15	(16,30, 0)	longitudinal	absolute ppv: 0.01443
16	(16,30, 0)	transverse	absolute ppv: 0.01506
17	(21,25, 0)	vertical	absolute ppv: 0.02153
18	(21,25, 0)	longitudinal	absolute ppv: 0.05681
19	(21,25, 0)	transverse	absolute ppv: 0.03179
20	(16,30,-10)	vertical	absolute ppv: 0.0011
21	(16,30,-10)	longitudinal	absolute ppv: 0.0011
22	(16,30,-10)	transverse	absolute ppv: 0.00163
23	(17,25, -5)	vertical	absolute ppv: 0.00217
24	(17,25, -5)	longitudinal	absolute ppv: 0.00128
25	(17,25, -5)	transverse	absolute ppv: 0.00295
26	(16,30,-20)	vertical	absolute ppv: 0.00076
27	(16,30,-20)	longitudinal	absolute ppv: 0.00111
28	(16,30,-20)	transverse	absolute ppv: 0.0006
29	(21,25, -5)	vertical	absolute ppv: 0.00146
30	(21,25, -5)	longitudinal	absolute ppv: 0.00117
31	(21,25, -5)	transverse	absolute ppv: 0.00254
32	(16,25, -4)	vertical	absolute ppv: 0.00218
33	(16,25, -4)	longitudinal	absolute ppv: 0.00073
34	(25,25, -5)	vertical	absolute ppv: 0.00137
35	(25,25, -5)	longitudinal	absolute ppv: 0.00162
36	(25,25, -5)	transverse	absolute ppv: 0.00449
37	(26,25, -4)	vertical	absolute ppv: 0.00159
38	(26,25, -4)	longitudinal	absolute ppv: 6.47127e-05
39	(26,25, -4)	transverse	absolute ppv: 5.05001e-05

Blast so47 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.00711
9	(21,25, 0)	longitudinal	absolute ppv: 0.00385
10	(21,25, 0)	transverse	absolute ppv: 0.00622
11	(16,25, 0)	vertical	absolute ppv: 0.00441
12	(16,25, 0)	longitudinal	absolute ppv: 0.00765
13	(16,25, 0)	transverse	absolute ppv: 0.00872
14	(16,30, 0)	vertical	absolute ppv: 0.00633
15	(16,30, 0)	longitudinal	absolute ppv: 0.01449
16	(16,30, 0)	transverse	absolute ppv: 0.01505
17	(21,25, 0)	vertical	absolute ppv: 0.02088
18	(21,25, 0)	longitudinal	absolute ppv: 0.05935
19	(21,25, 0)	transverse	absolute ppv: 0.03649
20	(16,30,-10)	vertical	absolute ppv: 0.00111
21	(16,30,-10)	longitudinal	absolute ppv: 0.0011
22	(16,30,-10)	transverse	absolute ppv: 0.00175
23	(17,25, -5)	vertical	absolute ppv: 0.00298
24	(17,25, -5)	longitudinal	absolute ppv: 0.00136
25	(17,25, -5)	transverse	absolute ppv: 0.00323
26	(16,30,-20)	vertical	absolute ppv: 0.00076
27	(16,30,-20)	longitudinal	absolute ppv: 0.00109
28	(16,30,-20)	transverse	absolute ppv: 0.00069
29	(21,25, -5)	vertical	absolute ppv: 0.00152
30	(21,25, -5)	longitudinal	absolute ppv: 0.00154
31	(21,25, -5)	transverse	absolute ppv: 0.00271
32	(16,25, -4)	vertical	absolute ppv: 0.00203
33	(16,25, -4)	longitudinal	absolute ppv: 0.00077
34	(25,25, -5)	vertical	absolute ppv: 0.00137
35	(25,25, -5)	longitudinal	absolute ppv: 0.00178
36	(25,25, -5)	transverse	absolute ppv: 0.00441
37	(26,25, -4)	vertical	absolute ppv: 0.00154
38	(26,25, -4)	longitudinal	absolute ppv: 0.0002
39	(26,25, -4)	transverse	absolute ppv: 0.00011

Blast so48 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.03651
9	(21,25, 0)	longitudinal	absolute ppv: 0.04062
10	(21,25, 0)	transverse	absolute ppv: 0.09165
11	(16,25, 0)	vertical	absolute ppv: 0.04217
12	(16,25, 0)	longitudinal	absolute ppv: 0.06601
13	(16,25, 0)	transverse	absolute ppv: 0.04807
14	(16,30, 0)	vertical	absolute ppv: 0.16092
15	(16,30, 0)	longitudinal	absolute ppv: 0.16205
16	(16,30, 0)	transverse	absolute ppv: 0.34903
17	(21,25, 0)	vertical	absolute ppv: 0.22119
18	(21,25, 0)	longitudinal	absolute ppv: 0.36602
19	(21,25, 0)	transverse	absolute ppv: 0.12663
20	(16,30,-10)	vertical	absolute ppv: 0.02032
21	(16,30,-10)	longitudinal	absolute ppv: 0.02032
22	(16,30,-10)	transverse	absolute ppv: 0.01631
23	(17,25, -5)	vertical	absolute ppv: 0.05352
24	(17,25, -5)	longitudinal	absolute ppv: 0.01314
25	(17,25, -5)	transverse	absolute ppv: 0.07222
26	(16,30,-20)	vertical	absolute ppv: 0.01862
27	(16,30,-20)	longitudinal	absolute ppv: 0.00977
28	(16,30,-20)	transverse	absolute ppv: 0.00898
29	(21,25, -5)	vertical	absolute ppv: 0.04963
30	(21,25, -5)	longitudinal	absolute ppv: 0.0223
31	(21,25, -5)	transverse	absolute ppv: 0.05877
32	(16,25, -4)	vertical	absolute ppv: 0.02268
33	(16,25, -4)	longitudinal	absolute ppv: 0.0139
34	(25,25, -5)	vertical	absolute ppv: 0.05586
35	(25,25, -5)	longitudinal	absolute ppv: 0.03469
36	(25,25, -5)	transverse	absolute ppv: 0.07023
37	(26,25, -4)	vertical	absolute ppv: 0.02156
38	(26,25, -4)	longitudinal	absolute ppv: 0.00838
39	(26,25, -4)	transverse	absolute ppv: 0.01106

Blast so49 Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.02383
9	(21,25, 0)	longitudinal	absolute ppv: 0.02336
10	(21,25, 0)	transverse	absolute ppv: 0.01952
11	(16,25, 0)	vertical	absolute ppv: 0.02032
12	(16,25, 0)	longitudinal	absolute ppv: 0.02132
13	(16,25, 0)	transverse	absolute ppv: 0.042
14	(16,30, 0)	vertical	absolute ppv: 0.10086
15	(16,30, 0)	longitudinal	absolute ppv: 0.07025
16	(16,30, 0)	transverse	absolute ppv: 0.24817
17	(21,25, 0)	vertical	absolute ppv: 0.06366
18	(21,25, 0)	longitudinal	absolute ppv: 0.23345
19	(21,25, 0)	transverse	absolute ppv: 0.0603
20	(16,30,-10)	vertical	absolute ppv: 0.02783
21	(16,30,-10)	longitudinal	absolute ppv: 0.02806
22	(16,30,-10)	transverse	absolute ppv: 0.03122
23	(17,25, -5)	vertical	absolute ppv: 0.04653
24	(17,25, -5)	longitudinal	absolute ppv: 0.0112
25	(17,25, -5)	transverse	absolute ppv: 0.06561
26	(16,30,-20)	vertical	absolute ppv: 0.01128
27	(16,30,-20)	longitudinal	absolute ppv: 0.00925
28	(16,30,-20)	transverse	absolute ppv: 0.00703
29	(21,25, -5)	vertical	absolute ppv: 0.02247
30	(21,25, -5)	longitudinal	absolute ppv: 0.02182
31	(21,25, -5)	transverse	absolute ppv: 0.0352
32	(16,25, -4)	vertical	absolute ppv: 0.00136
33	(16,25, -4)	longitudinal	absolute ppv: 0.00016
34	(25,25, -5)	vertical	absolute ppv: 0.01962
35	(25,25, -5)	longitudinal	absolute ppv: 0.01355
36	(25,25, -5)	transverse	absolute ppv: 0.05222
37	(26,25, -4)	vertical	absolute ppv: 0.00459
38	(26,25, -4)	longitudinal	absolute ppv: 0.00081
39	(26,25, -4)	transverse	absolute ppv: 0.00012

Blast so4a Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.02493
9	(21,25, 0)	longitudinal	absolute ppv: 0.01727
10	(21,25, 0)	transverse	absolute ppv: 0.04652
11	(16,25, 0)	vertical	absolute ppv: 0.01726
12	(16,25, 0)	longitudinal	absolute ppv: 0.01776
13	(16,25, 0)	transverse	absolute ppv: 0.03744
14	(16,30, 0)	vertical	absolute ppv: 0.05666
15	(16,30, 0)	longitudinal	absolute ppv: 0.19491
16	(16,30, 0)	transverse	absolute ppv: 0.10198
17	(21,25, 0)	vertical	absolute ppv: 0.075
18	(21,25, 0)	longitudinal	absolute ppv: 0.09293
19	(21,25, 0)	transverse	absolute ppv: 0.07341
20	(16,30,-10)	vertical	absolute ppv: 0.01172
21	(16,30,-10)	longitudinal	absolute ppv: 0.02069
22	(16,30,-10)	transverse	absolute ppv: 0.01801
23	(17,25, -5)	vertical	absolute ppv: 0.03014
24	(17,25, -5)	longitudinal	absolute ppv: 0.01071
25	(17,25, -5)	transverse	absolute ppv: 0.03515
26	(16,30,-20)	vertical	absolute ppv: 0.01503
27	(16,30,-20)	longitudinal	absolute ppv: 0.00733
28	(16,30,-20)	transverse	absolute ppv: 0.01779
29	(21,25, -5)	vertical	absolute ppv: 0.01916
30	(21,25, -5)	longitudinal	absolute ppv: 0.01576
31	(21,25, -5)	transverse	absolute ppv: 0.02169
32	(16,25, -4)	vertical	absolute ppv: 0.00947
33	(16,25, -4)	longitudinal	absolute ppv: 0.00018
34	(25,25, -5)	vertical	absolute ppv: 0.01728
35	(25,25, -5)	longitudinal	absolute ppv: 0.00712
36	(25,25, -5)	transverse	absolute ppv: 0.03037
37	(26,25, -4)	vertical	absolute ppv: 0.0058
38	(26,25, -4)	longitudinal	absolute ppv: 0.00057
39	(26,25, -4)	transverse	absolute ppv: 3.87988e-05

Blast so4b Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 0.13302
9	(21,25, 0)	longitudinal	absolute ppv: 0.09598
10	(21,25, 0)	transverse	absolute ppv: 0.1115
11	(16,25, 0)	vertical	absolute ppv: 0.10464
12	(16,25, 0)	longitudinal	absolute ppv: 0.1087
13	(16,25, 0)	transverse	absolute ppv: 0.12425
14	(16,30, 0)	vertical	absolute ppv: 0.21983
15	(16,30, 0)	longitudinal	absolute ppv: 1.22387
16	(16,30, 0)	transverse	absolute ppv: 1.00063
17	(21,25, 0)	vertical	absolute ppv: 0.18111
18	(21,25, 0)	longitudinal	absolute ppv: 0.81931
19	(21,25, 0)	transverse	absolute ppv: 0.40542
20	(16,30,-10)	vertical	absolute ppv: 0.06825
21	(16,30,-10)	longitudinal	absolute ppv: 0.06814
22	(16,30,-10)	transverse	absolute ppv: 0.09501
23	(17,25, -5)	vertical	absolute ppv: 0.07128
24	(17,25, -5)	longitudinal	absolute ppv: 0.04677
25	(17,25, -5)	transverse	absolute ppv: 0.17991
26	(16,30,-20)	vertical	absolute ppv: 0.06728
27	(16,30,-20)	longitudinal	absolute ppv: 0.03824
28	(16,30,-20)	transverse	absolute ppv: 0.05476
29	(21,25, -5)	vertical	absolute ppv: 0.09635
30	(21,25, -5)	longitudinal	absolute ppv: 0.11371
31	(21,25, -5)	transverse	absolute ppv: 0.09411
32	(16,25, -4)	vertical	absolute ppv: 0.01589
33	(16,25, -4)	longitudinal	absolute ppv: 0.01506
34	(25,25, -5)	vertical	absolute ppv: 0.04079
35	(25,25, -5)	longitudinal	absolute ppv: 0.02734
36	(25,25, -5)	transverse	absolute ppv: 0.07208
37	(26,25, -4)	vertical	absolute ppv: 0.02166
38	(26,25, -4)	longitudinal	absolute ppv: 0.0084
39	(26,25, -4)	transverse	absolute ppv: 0.0127

Blast so4c Peak Particle Velocity Report

ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 1.24524
9	(21,25, 0)	longitudinal	absolute ppv: 1.2262
10	(21,25, 0)	transverse	absolute ppv: 1.18687
11	(16,25, 0)	vertical	absolute ppv: 1.19889
12	(16,25, 0)	longitudinal	absolute ppv: 1.2034
13	(16,25, 0)	transverse	absolute ppv: 1.27986
14	(16,30, 0)	vertical	absolute ppv: 2.92459
15	(16,30, 0)	longitudinal	absolute ppv: 2.90509
16	(16,30, 0)	transverse	absolute ppv: 3.109
17	(21,25, 0)	vertical	absolute ppv: 2.89061
18	(21,25, 0)	longitudinal	absolute ppv: 2.60357
19	(21,25, 0)	transverse	absolute ppv: 3.05837
20	(16,30,-10)	vertical	absolute ppv: 0.30524
21	(16,30,-10)	longitudinal	absolute ppv: 0.30676
22	(16,30,-10)	transverse	absolute ppv: 0.52574
23	(17,25, -5)	vertical	absolute ppv: 0.97981
24	(17,25, -5)	longitudinal	absolute ppv: 0.28759
25	(17,25, -5)	transverse	absolute ppv: 1.24277
26	(16,30,-20)	vertical	absolute ppv: 0.40798
27	(16,30,-20)	longitudinal	absolute ppv: 0.52044
28	(16,30,-20)	transverse	absolute ppv: 0.34144
29	(21,25, -5)	vertical	absolute ppv: 1.1317
30	(21,25, -5)	longitudinal	absolute ppv: 0.52246
31	(21,25, -5)	transverse	absolute ppv: 0.59817
32	(16,25, -4)	vertical	absolute ppv: 0.23667
33	(16,25, -4)	longitudinal	absolute ppv: 0.27699
34	(25,25, -5)	vertical	absolute ppv: 0.42837
35	(25,25, -5)	longitudinal	absolute ppv: 0.30718
36	(25,25, -5)	transverse	absolute ppv: 0.52912
37	(26,25, -4)	vertical	absolute ppv: 0.30748
38	(26,25, -4)	longitudinal	absolute ppv: 0.07496
39	(26,25, -4)	transverse	absolute ppv: 0.17107

Blast so4d Peak Particle Velocity Report

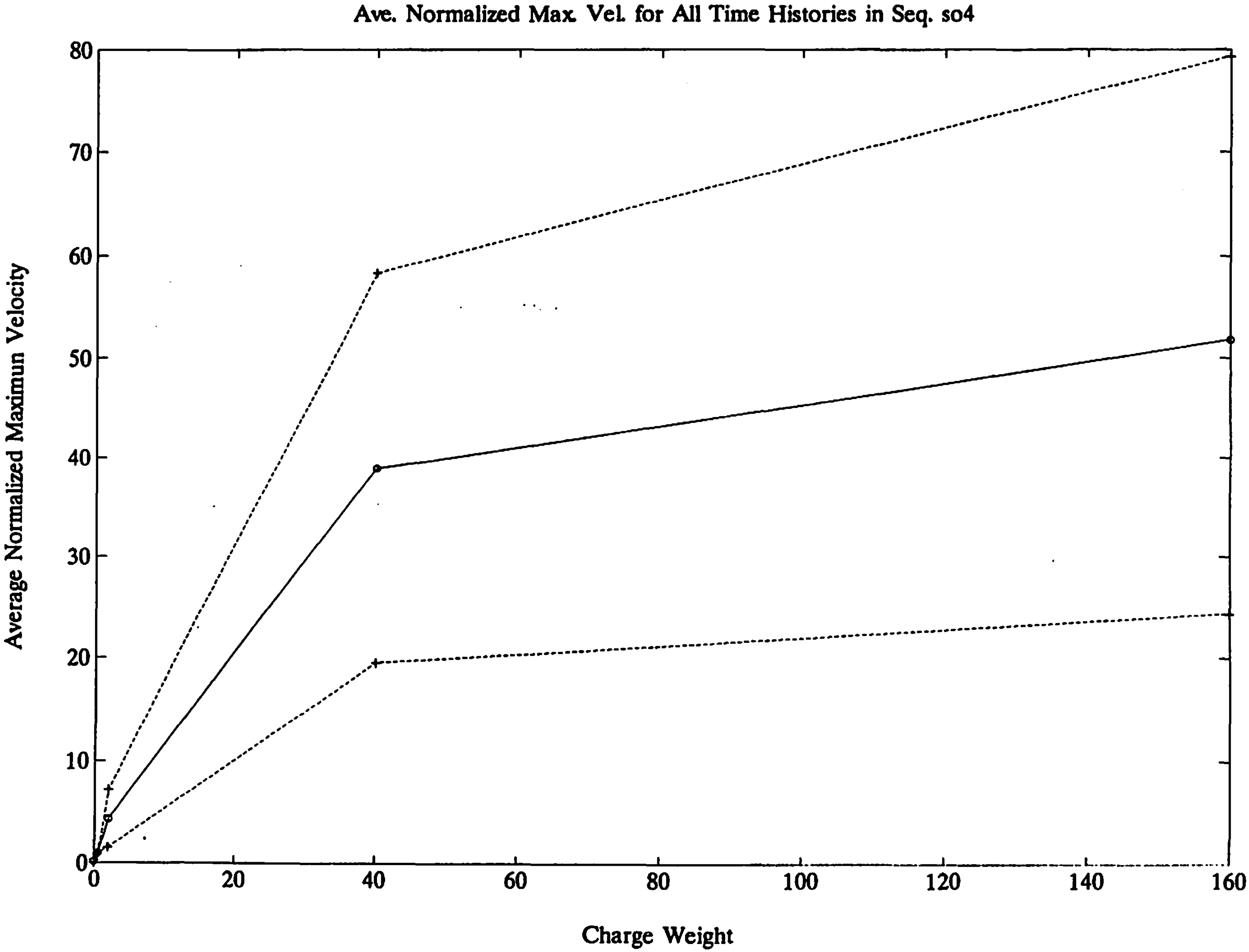
ch	sensor location	channel mode	peak particle velocity
8	(21,25, 0)	vertical	absolute ppv: 1.36806
9	(21,25, 0)	longitudinal	absolute ppv: 1.84132
10	(21,25, 0)	transverse	absolute ppv: 1.52979
11	(16,25, 0)	vertical	absolute ppv: 1.8518
12	(16,25, 0)	longitudinal	absolute ppv: 3.15066
13	(16,25, 0)	transverse	absolute ppv: 2.73681
14	(16,30, 0)	vertical	absolute ppv: 3.39169
15	(16,30, 0)	longitudinal	absolute ppv: 3.87735
16	(16,30, 0)	transverse	absolute ppv: 6.0167
17	(21,25, 0)	vertical	absolute ppv: 3.76436
18	(21,25, 0)	longitudinal	absolute ppv: 5.99932
19	(21,25, 0)	transverse	absolute ppv: 4.15721
20	(16,30,-10)	vertical	absolute ppv: 0.59268
21	(16,30,-10)	longitudinal	absolute ppv: 0.59276
22	(16,30,-10)	transverse	absolute ppv: 0.28373
23	(17,25, -5)	vertical	absolute ppv: 1.11283
24	(17,25, -5)	longitudinal	absolute ppv: 0.3892
25	(17,25, -5)	transverse	absolute ppv: 1.34752
26	(16,30,-20)	vertical	absolute ppv: 1.05369
27	(16,30,-20)	longitudinal	absolute ppv: 0.39953
28	(16,30,-20)	transverse	absolute ppv: 0.3326
29	(21,25, -5)	vertical	absolute ppv: 0.71075
30	(21,25, -5)	longitudinal	absolute ppv: 0.40596
31	(21,25, -5)	transverse	absolute ppv: 0.867
32	(16,25, -4)	vertical	absolute ppv: 0.39551
33	(16,25, -4)	longitudinal	absolute ppv: 0.28904
34	(25,25, -5)	vertical	absolute ppv: 0.54329
35	(25,25, -5)	longitudinal	absolute ppv: 0.40915
36	(25,25, -5)	transverse	absolute ppv: 0.97688
37	(26,25, -4)	vertical	absolute ppv: 0.39996
38	(26,25, -4)	longitudinal	absolute ppv: 0.12987
39	(26,25, -4)	transverse	absolute ppv: 0.15784

SECTION E-5

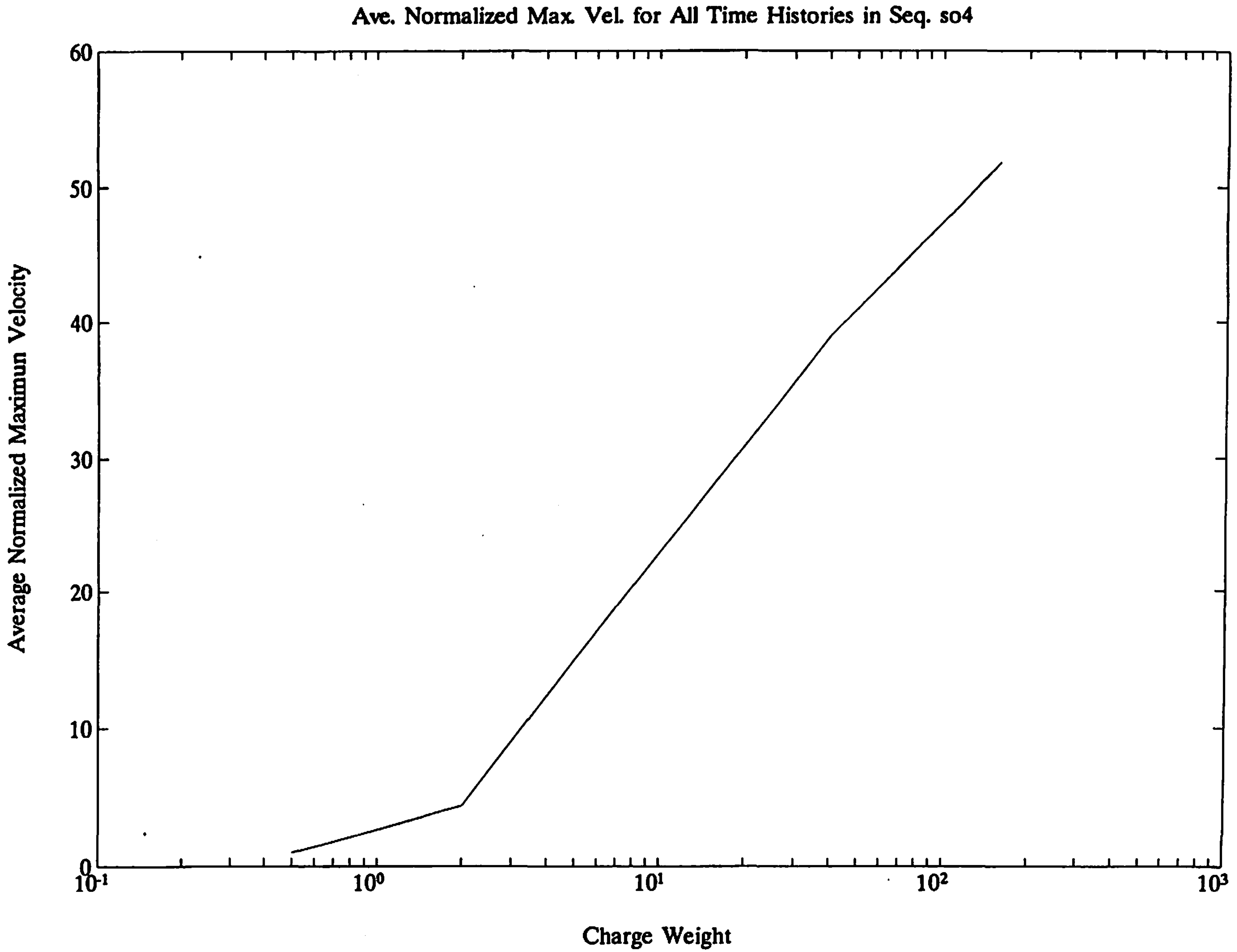
NORMALIZED MAXIMUM VELOCITIES VERSUS TOTAL CHARGE WEIGHT

FOR

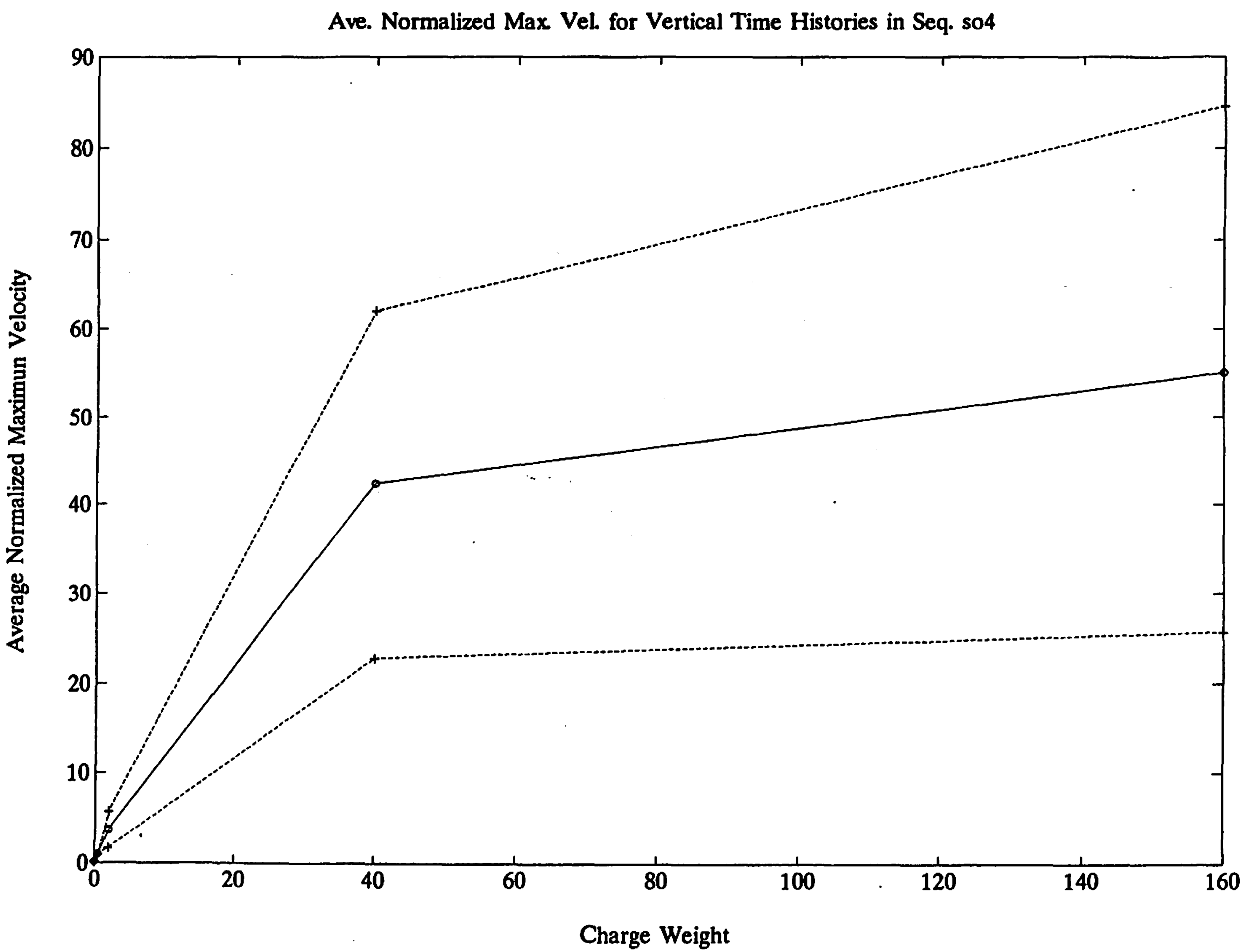
TIME HISTORIES IN SEQUENCE S04

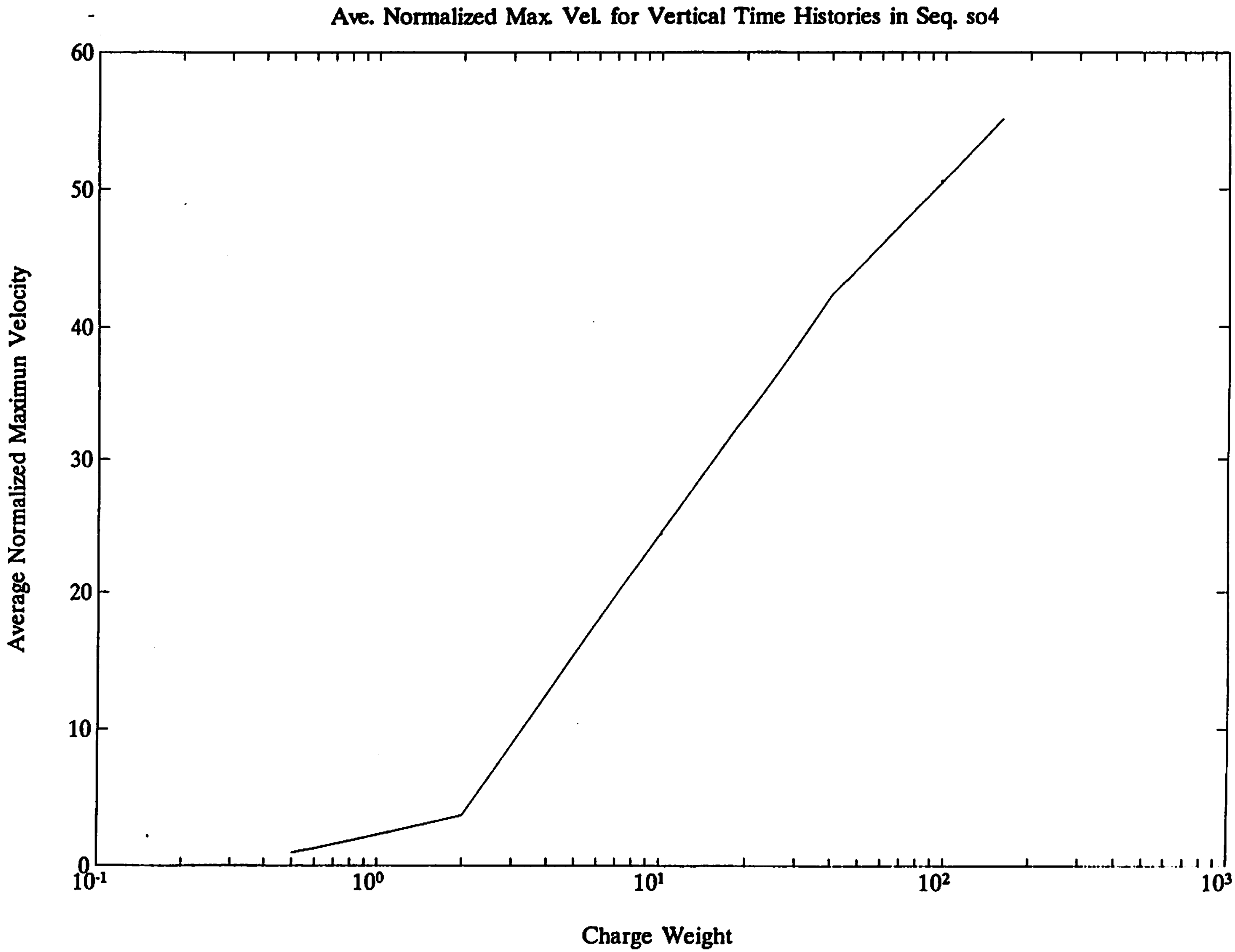


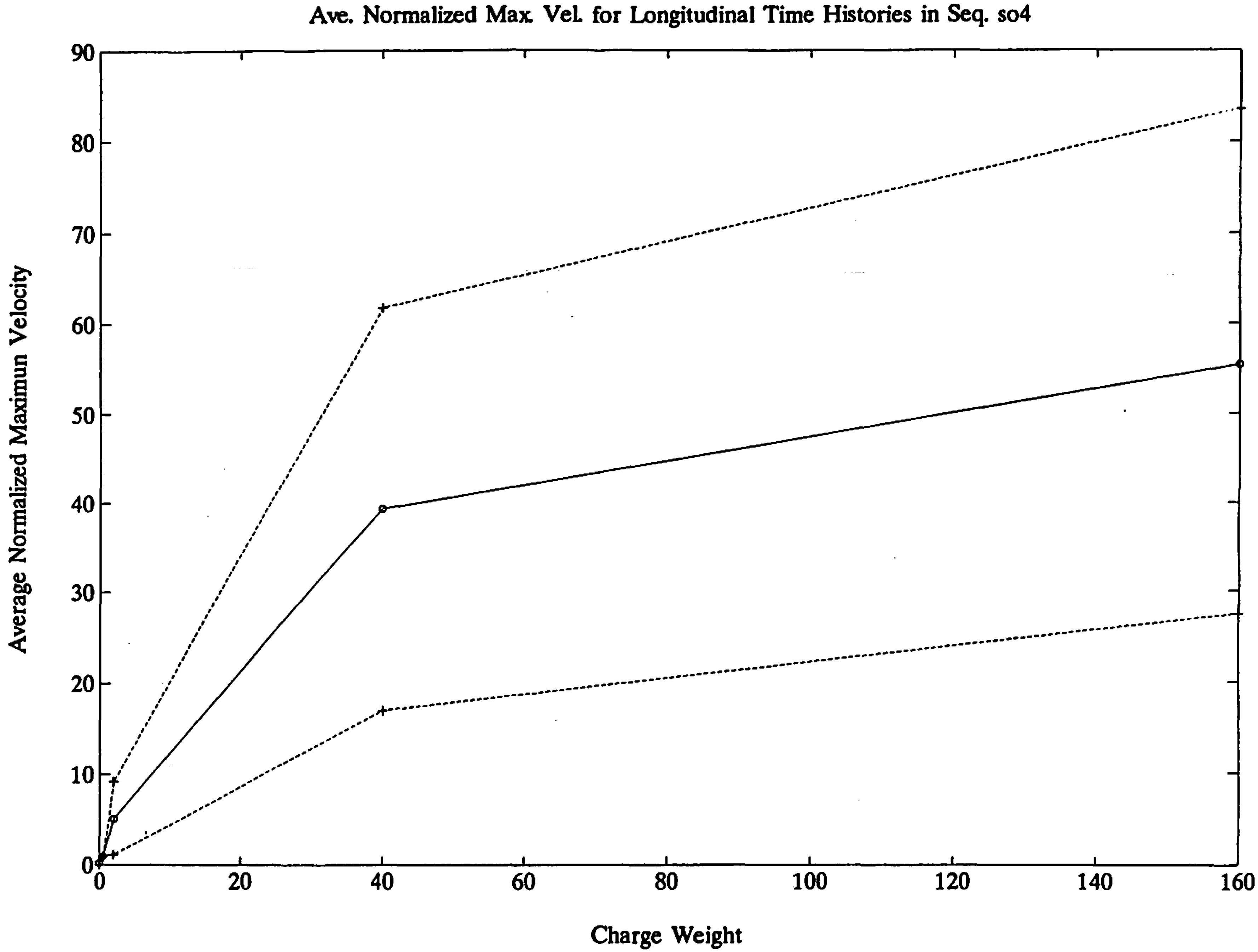
Ave. Normalized Max. Vel. for All Time Histories in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160

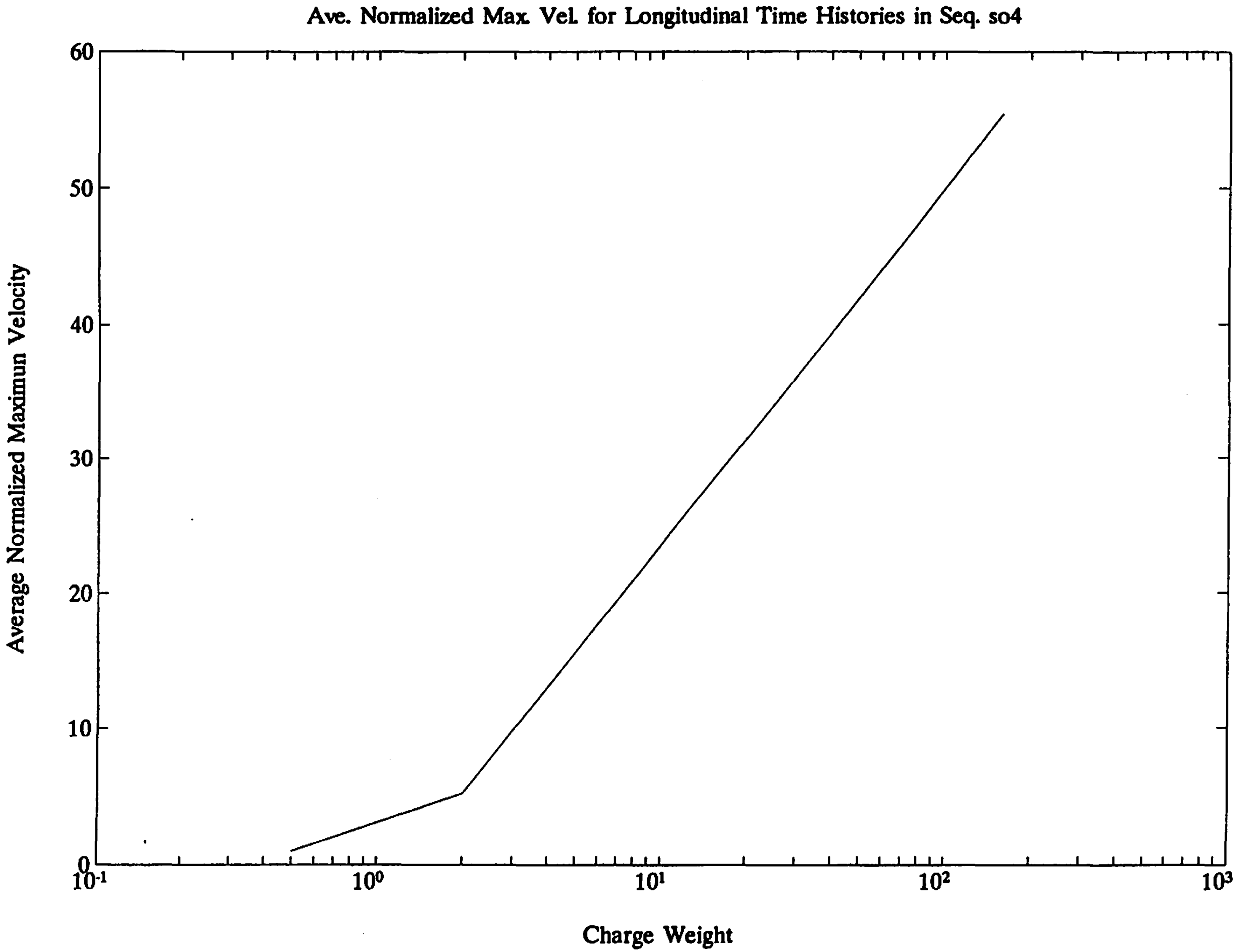


Ave. Normalized Max. Vel. for All Time Histories in Seq. so4
Average Normalized Maximun Velocity
60
50
40
30
20
10
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Charge Weight

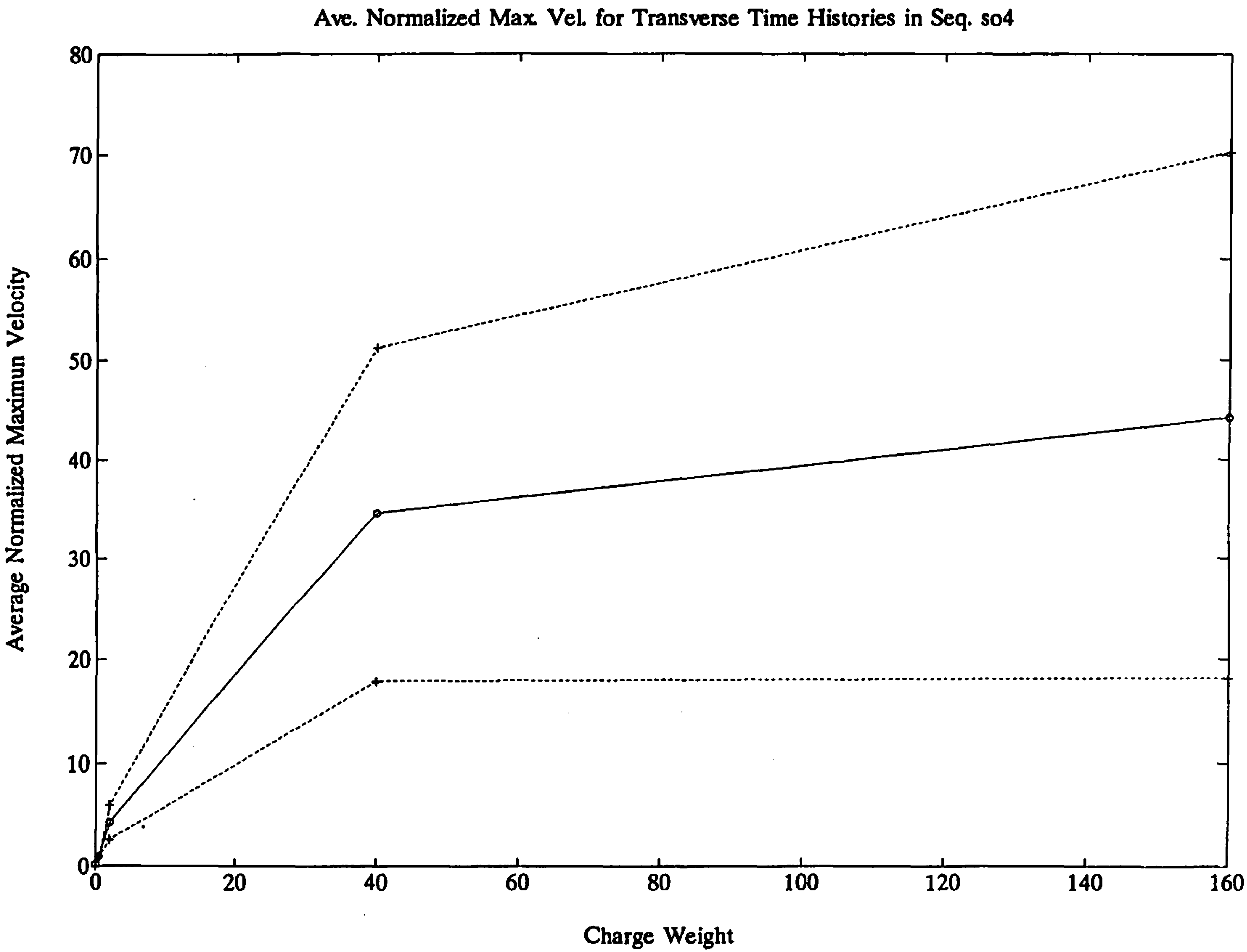

Ave. Normalized Max. Vel. for Vertical Time Histories in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160


Ave. Normalized Max. Vel. for Vertical Time Histories in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
60
50
40
30
20
10
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

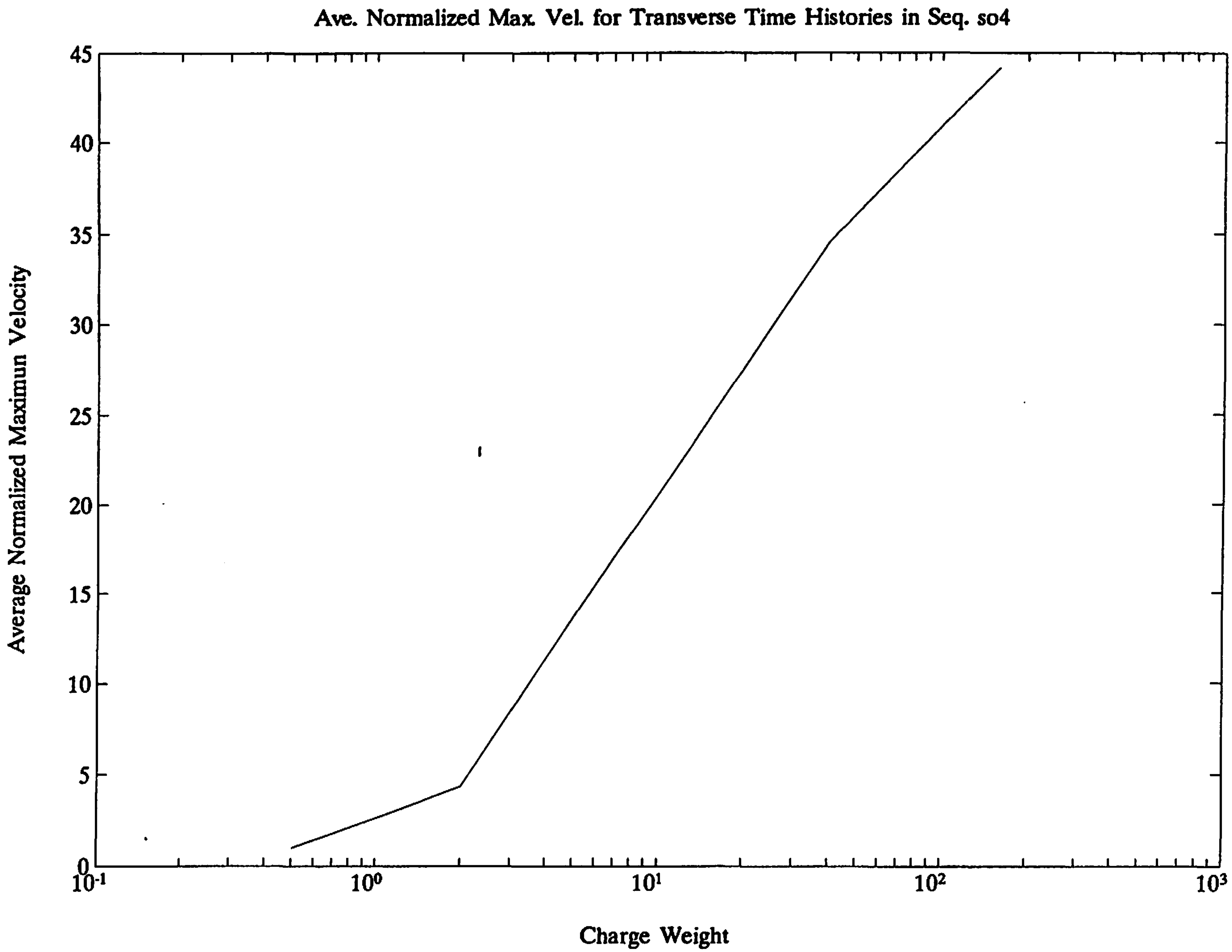

Ave. Normalized Max. Vel. for Longitudinal Time Histories in Seq. so4
Average Normalized Maximun Velocity
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
Charge Weight



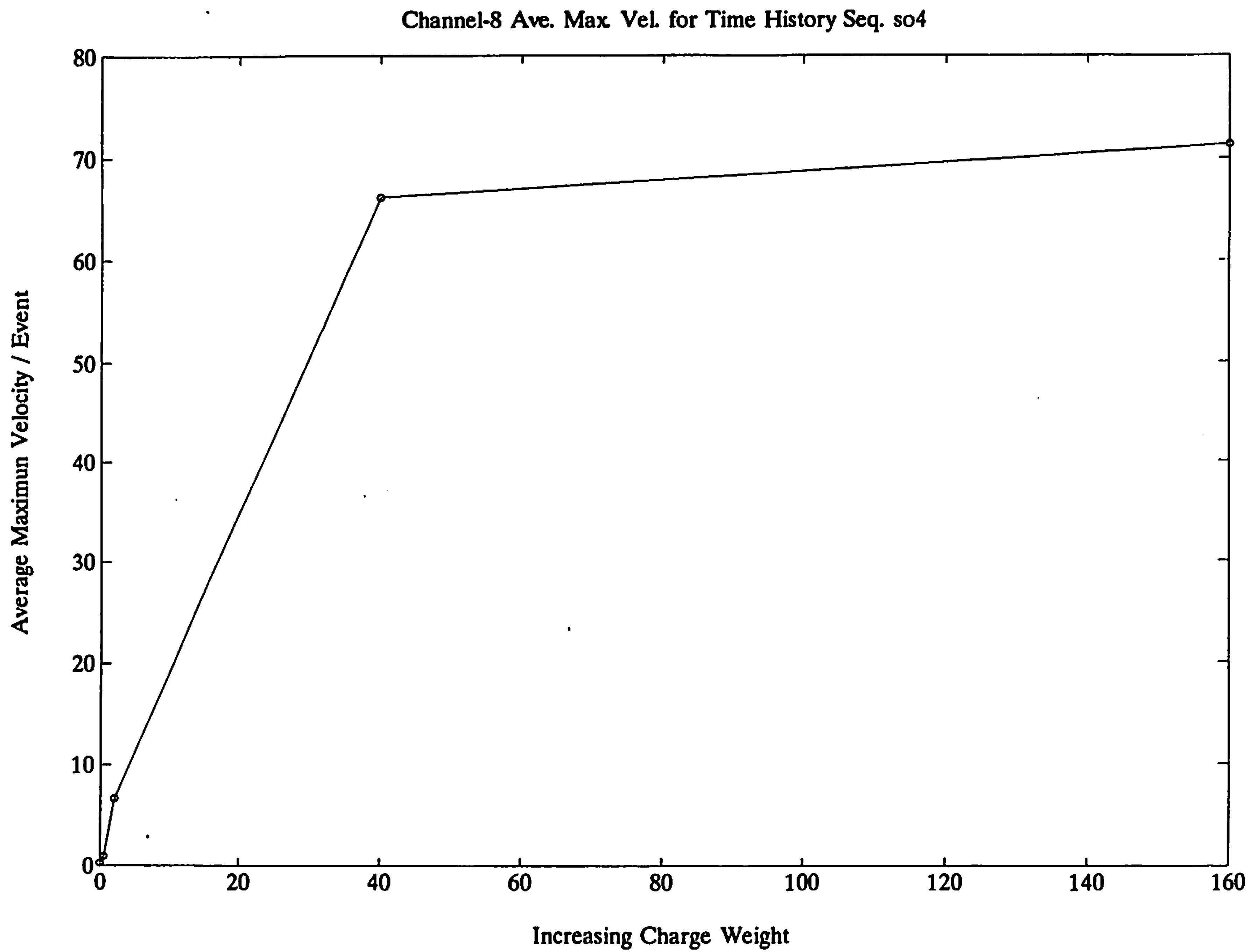
Ave. Normalized Max. Vel. for Longitudinal Time Histories in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
10
20
30
40
50
60
10-1
100
101
102
103

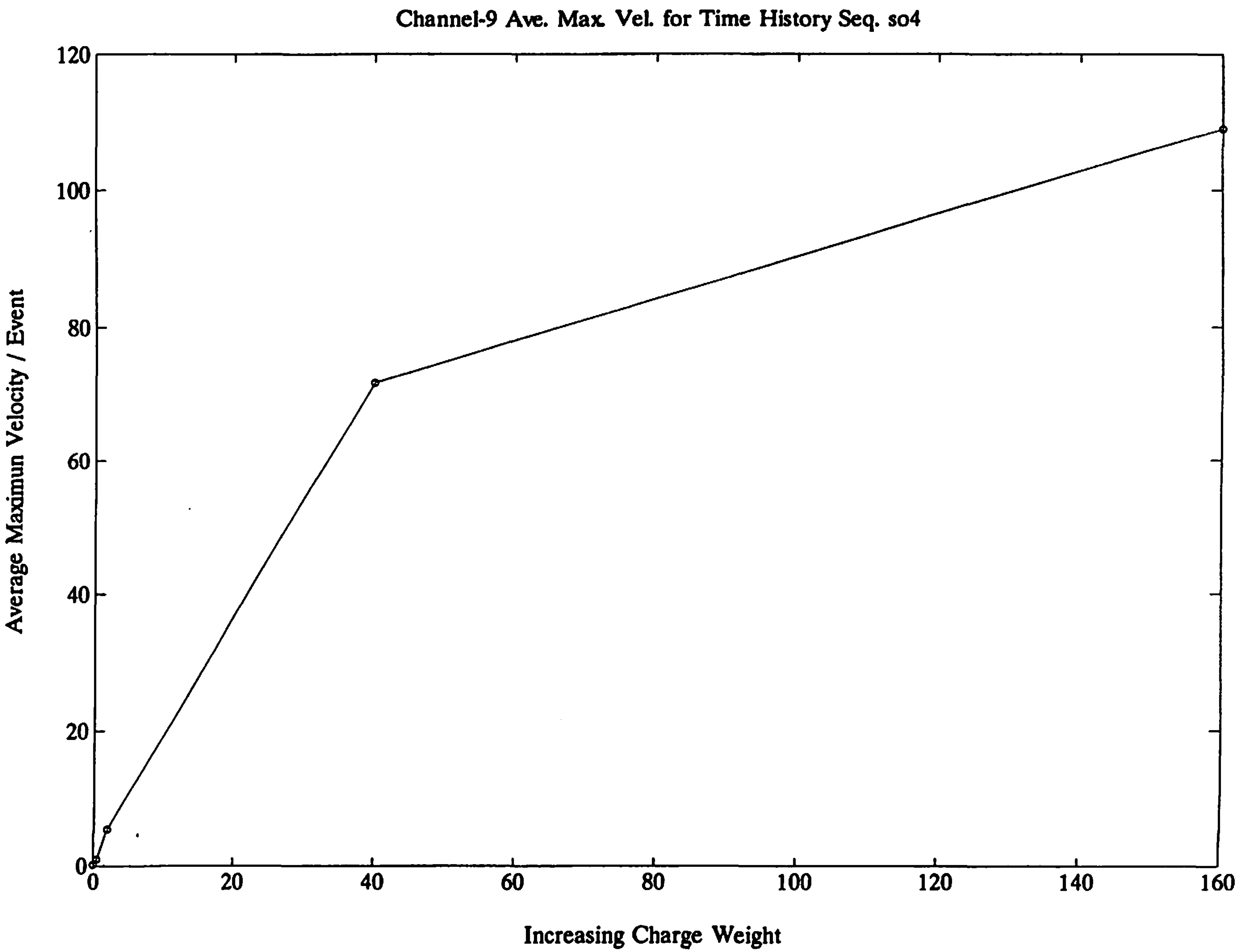


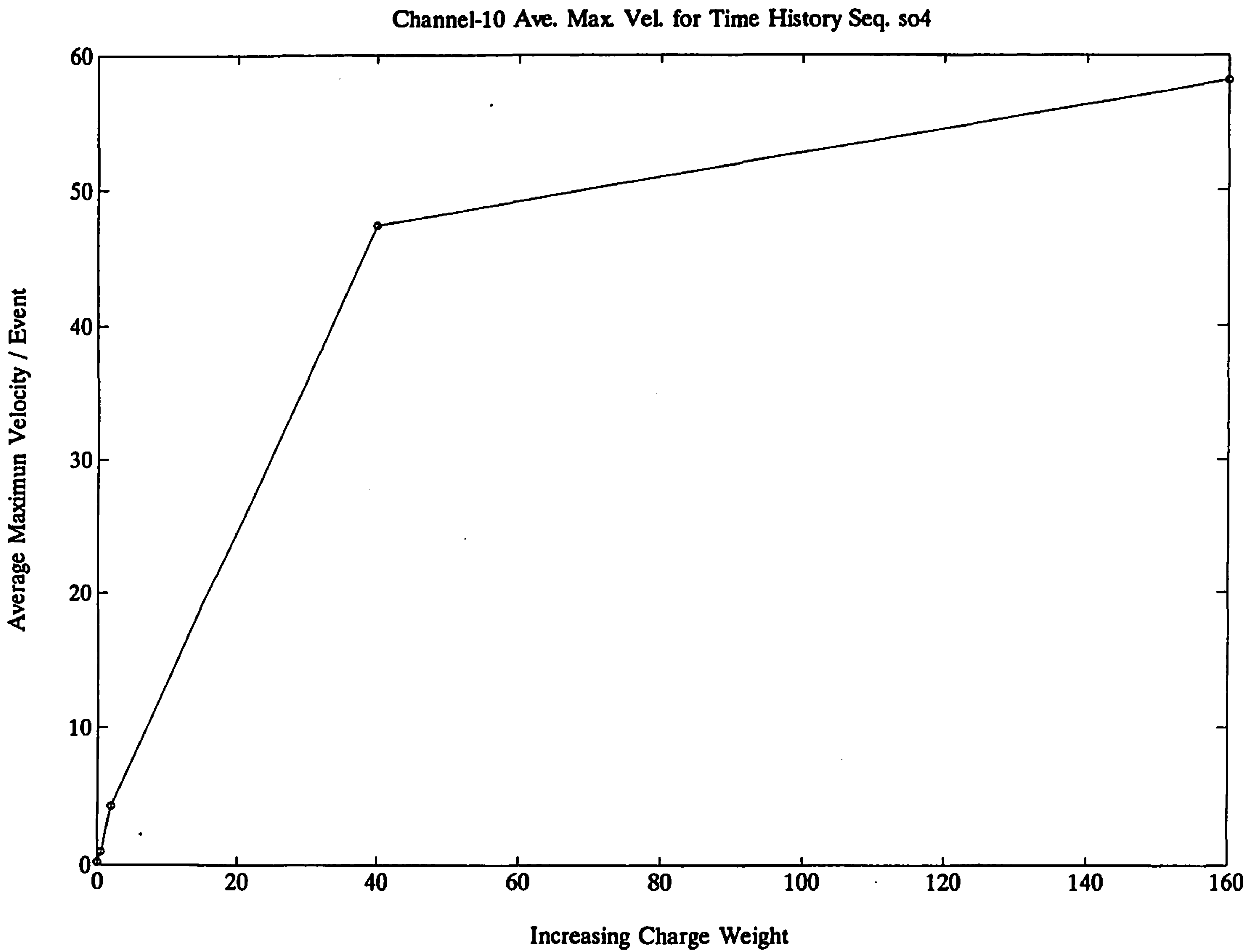
Ave. Normalized Max. Vel. for Transverse Time Histories in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160

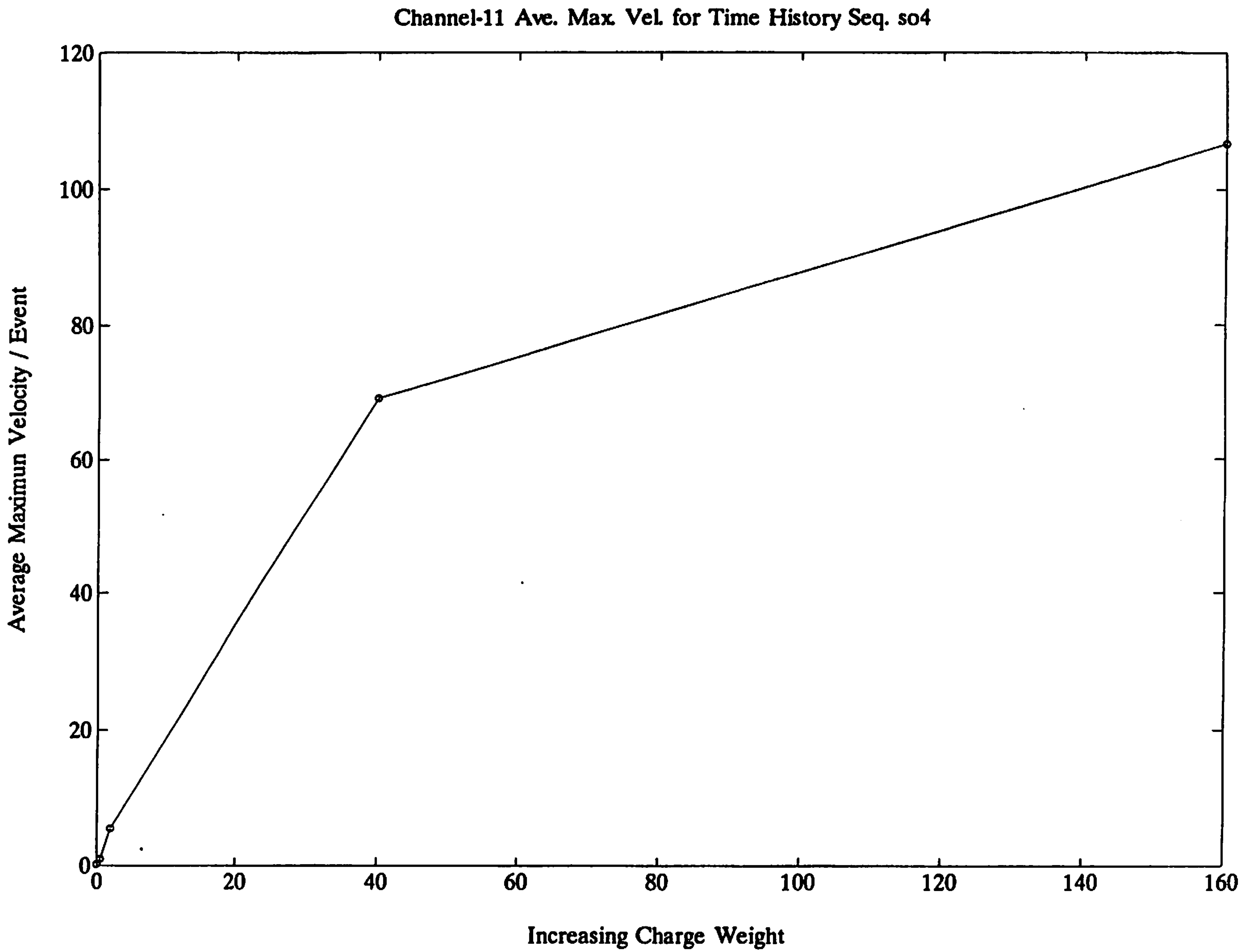


Ave. Normalized Max. Vel. for Transverse Time Histories in Seq. so4
Average Normalized Maximun Velocity
45
40
35
30
25
20
15
10
5
0
10-1
100
101
102
103
Charge Weight

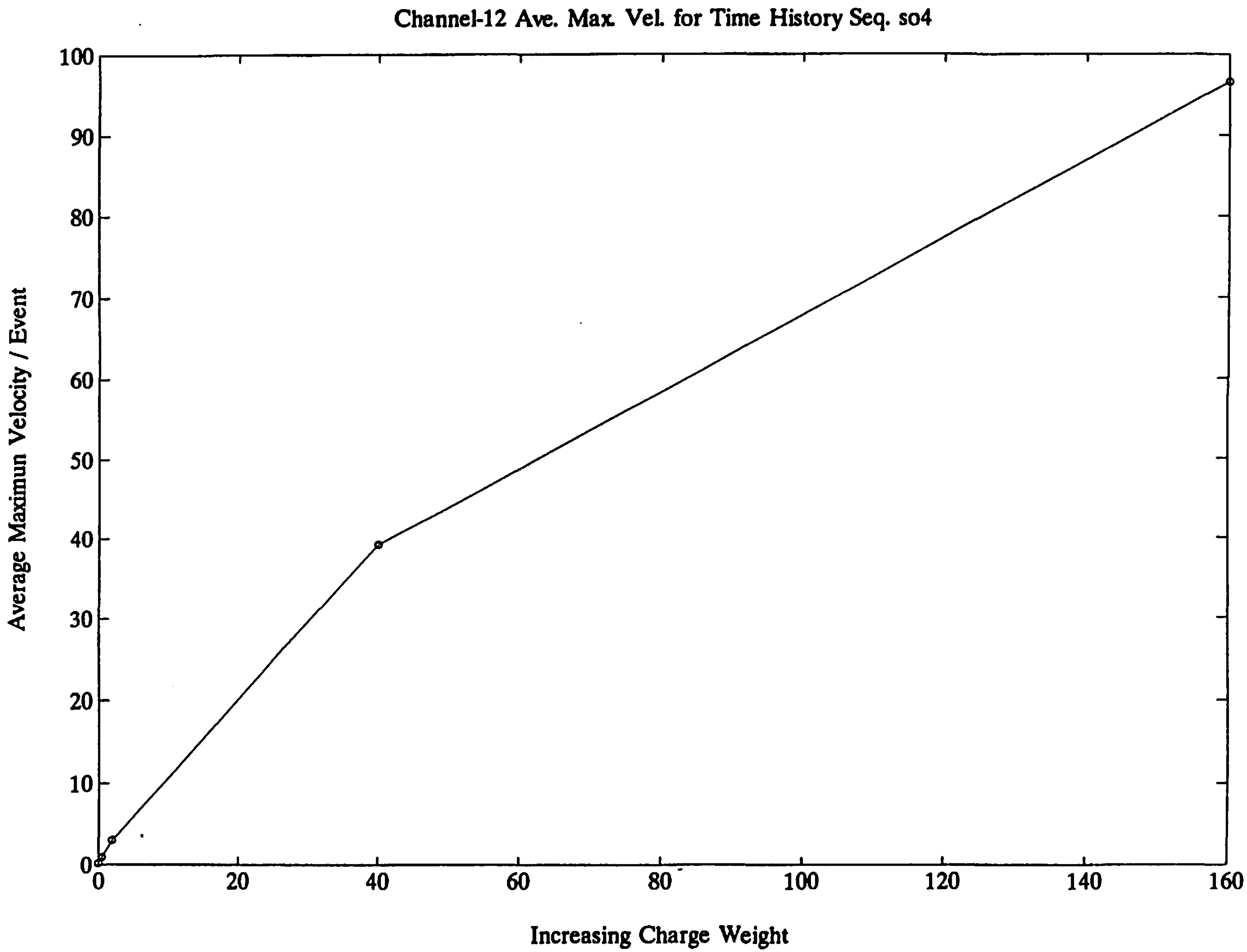

Channel-8 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160

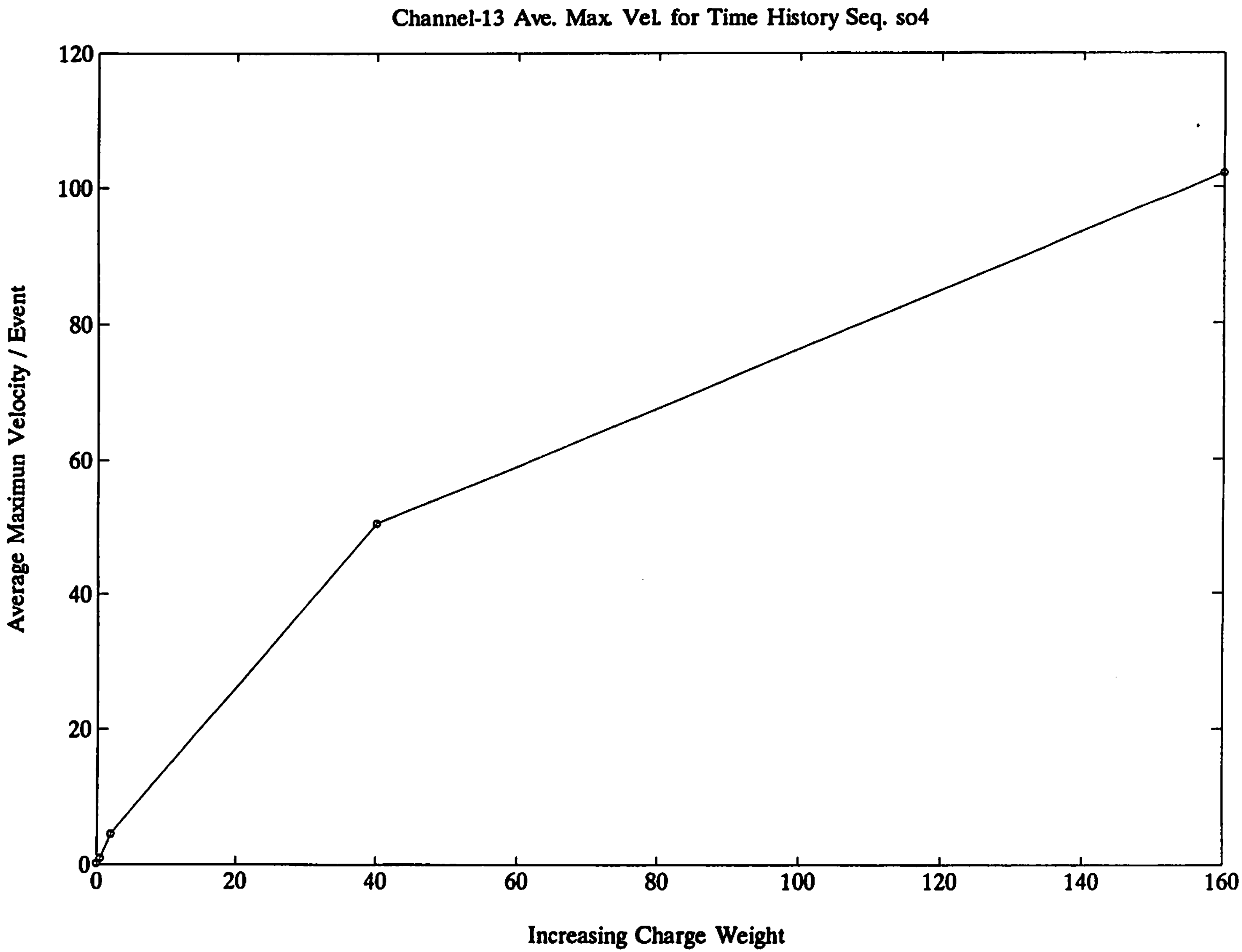

Channel-9 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

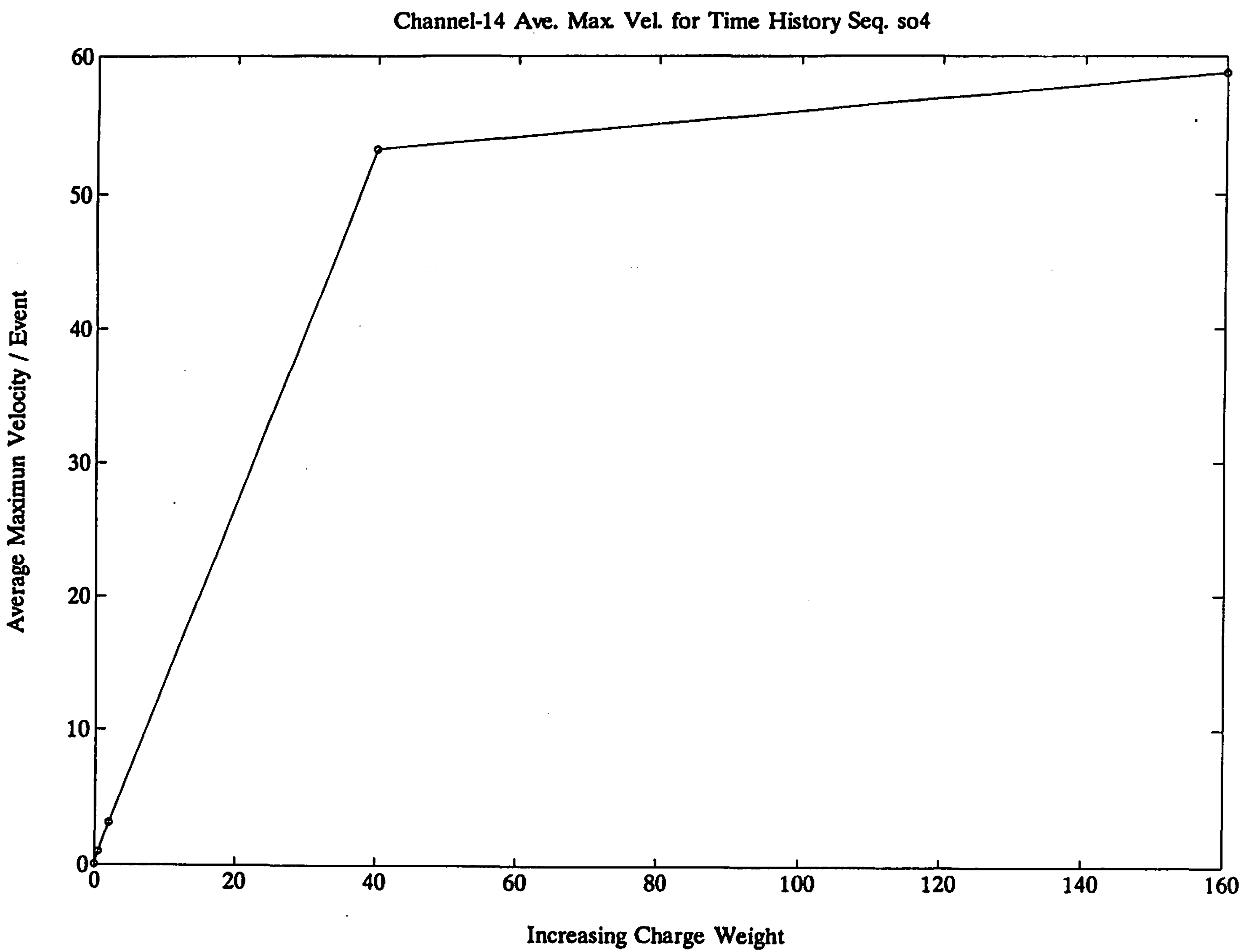

Channel-10 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160
Increasing Charge Weight



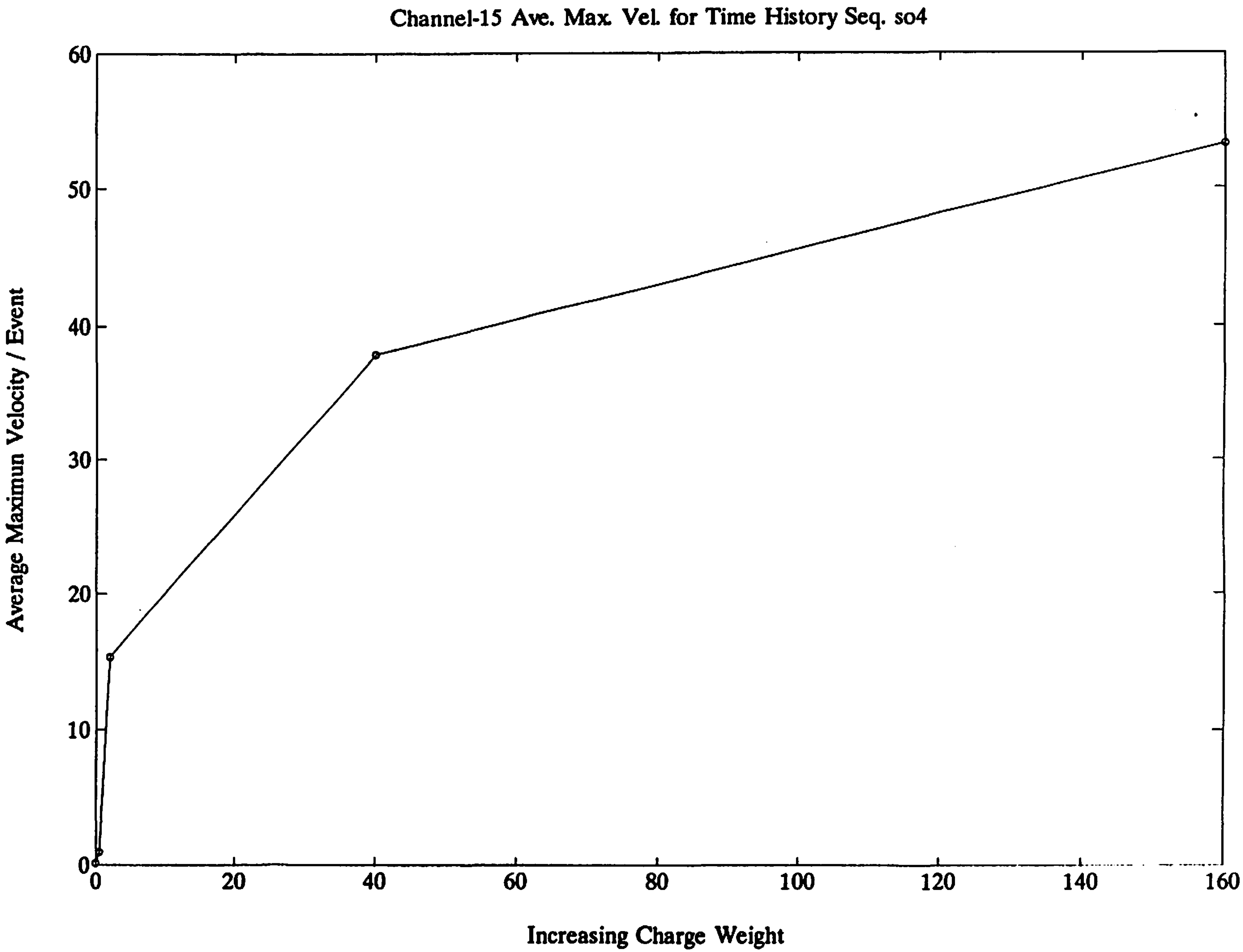
Channel-11 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160


Channel-12 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

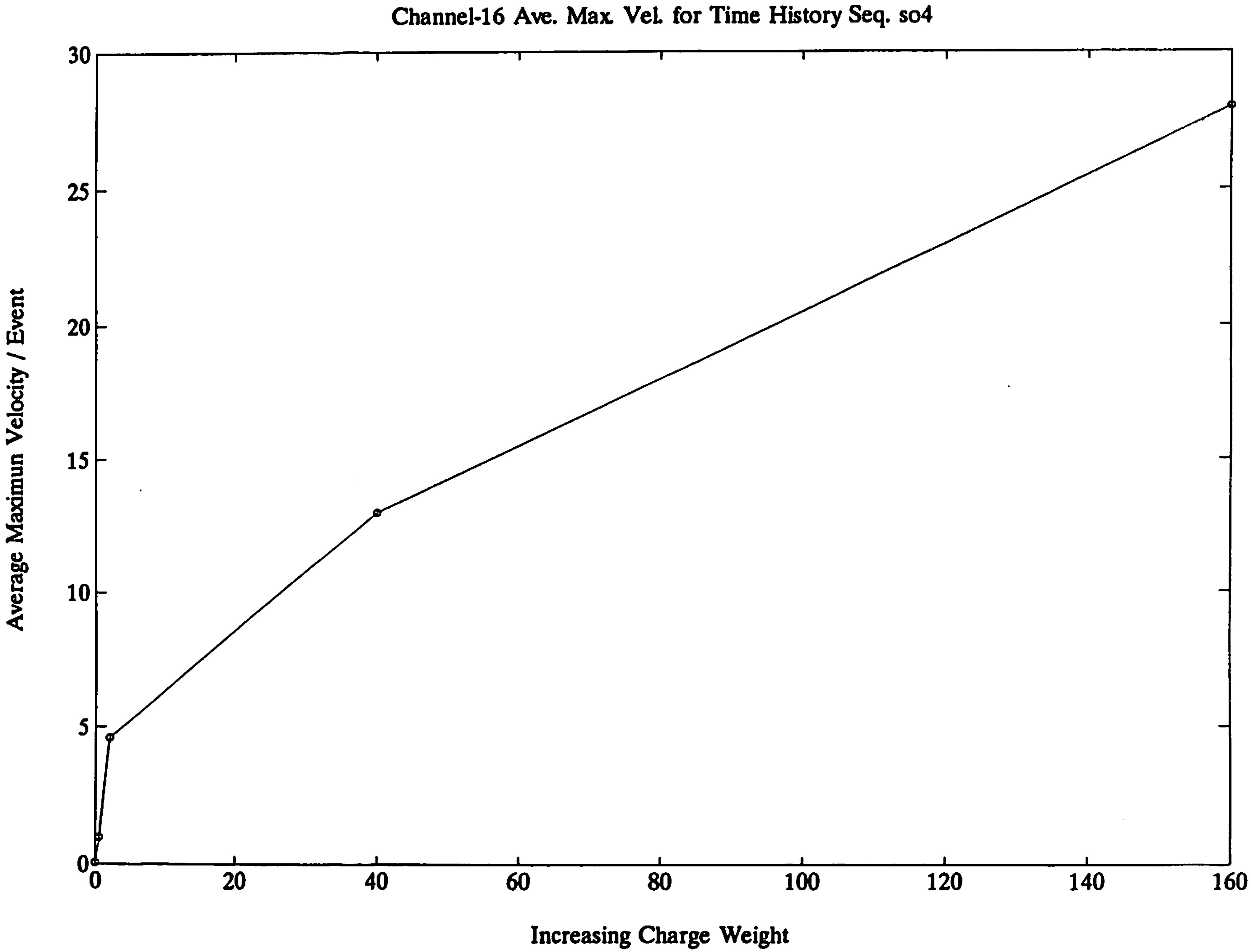

Channel-13 Ave. Max. Vel. for Time History Seq. so4
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
Average Maximun Velocity / Event
Increasing Charge Weight

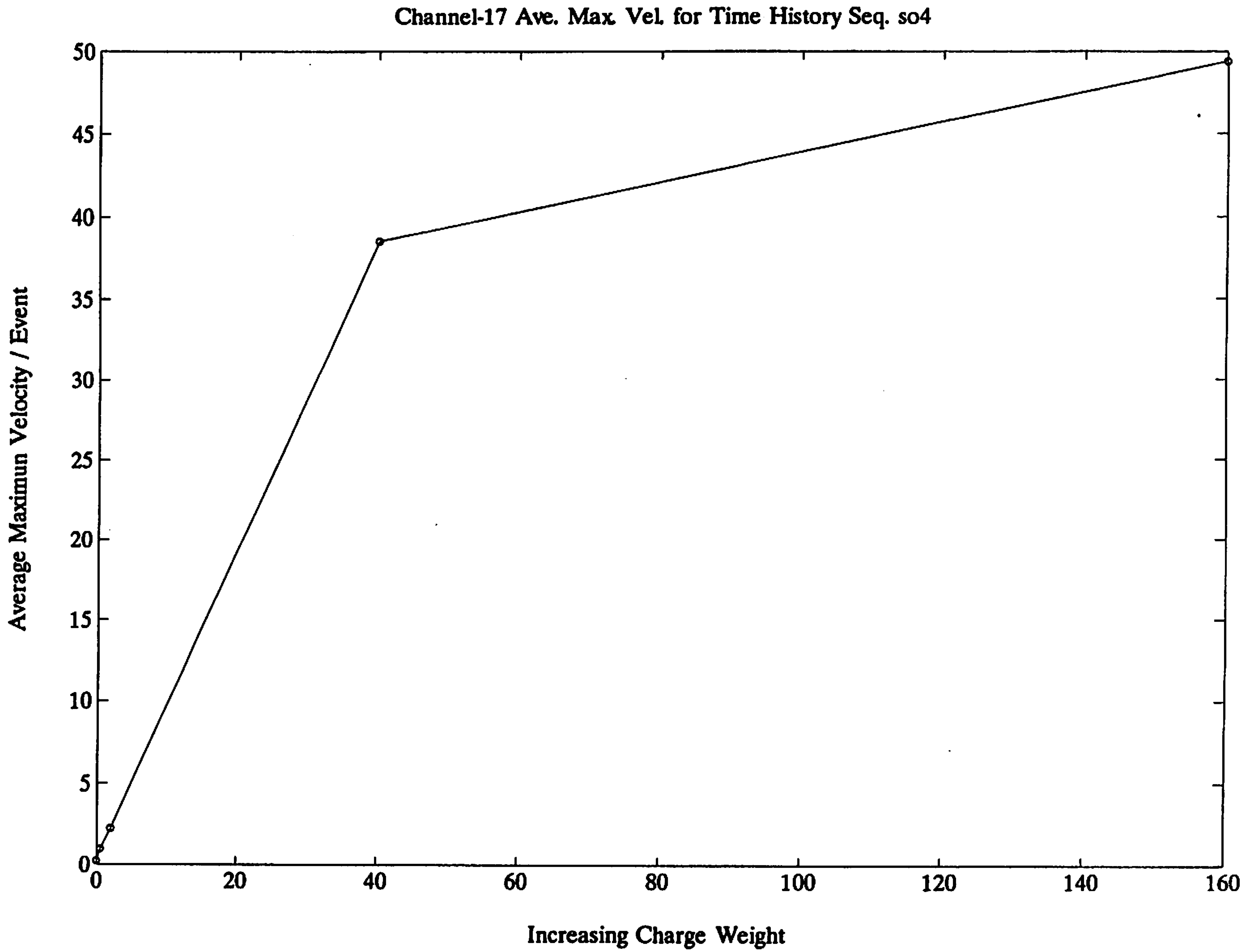


Channel-14 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

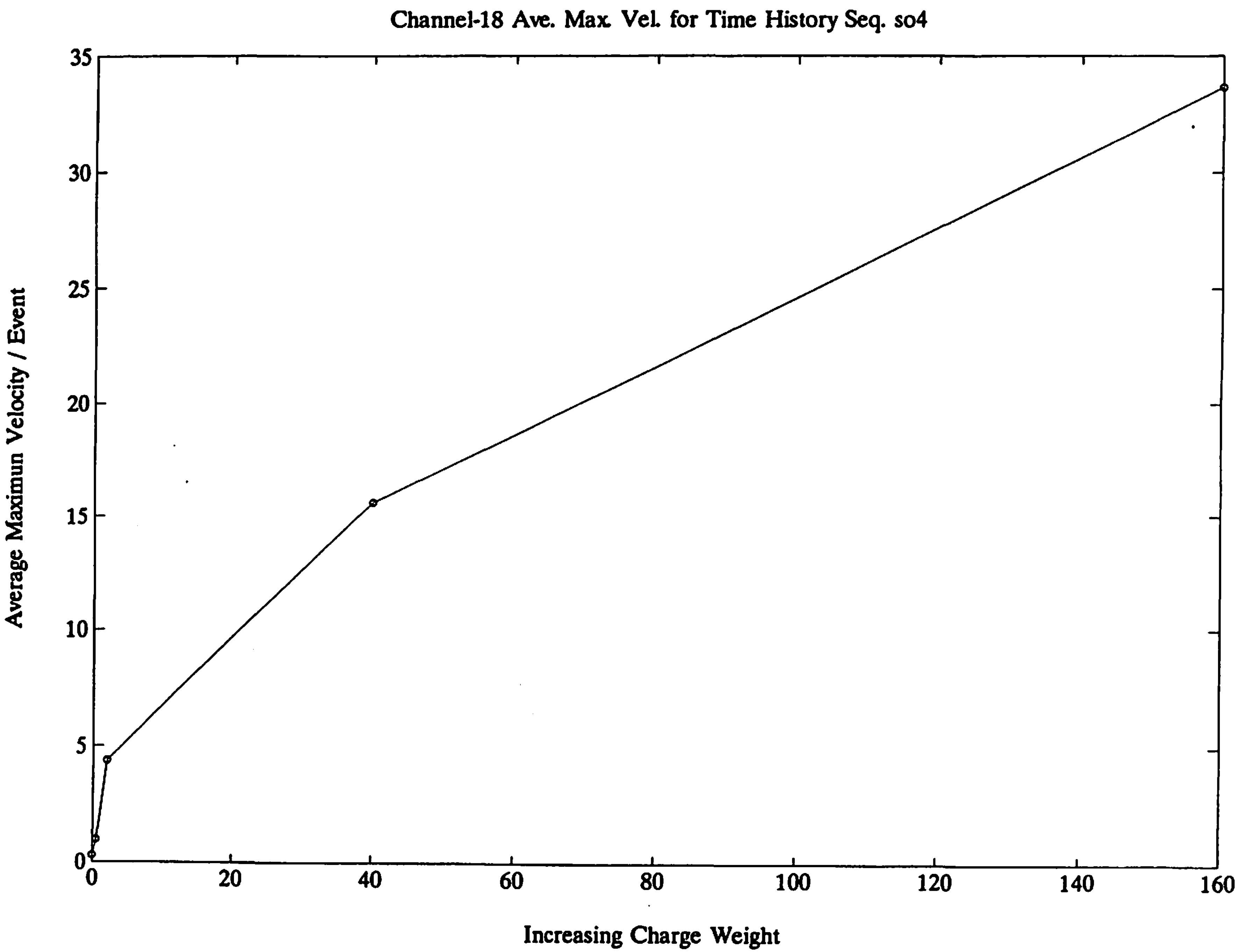


Channel-15 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

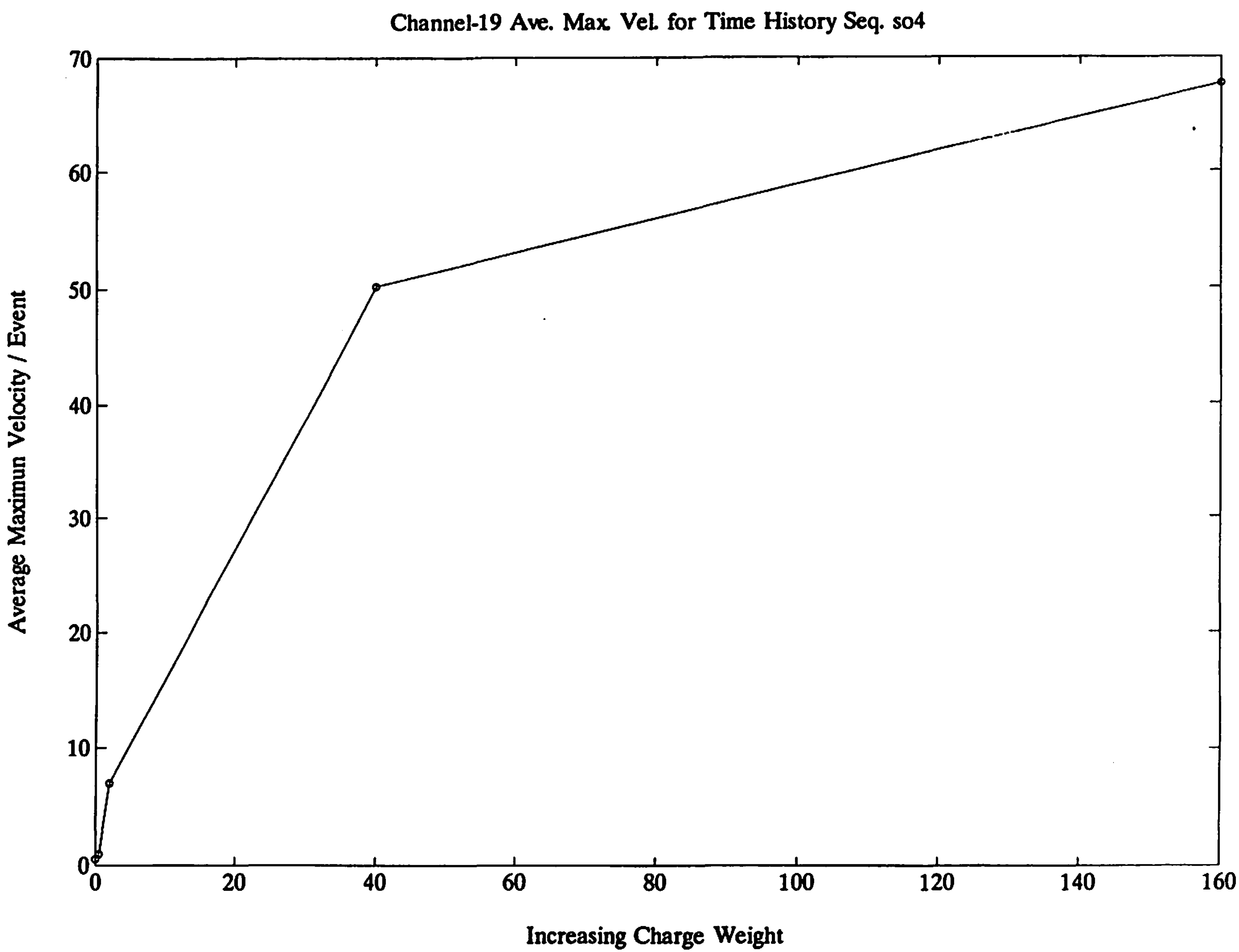

Channel-16 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160



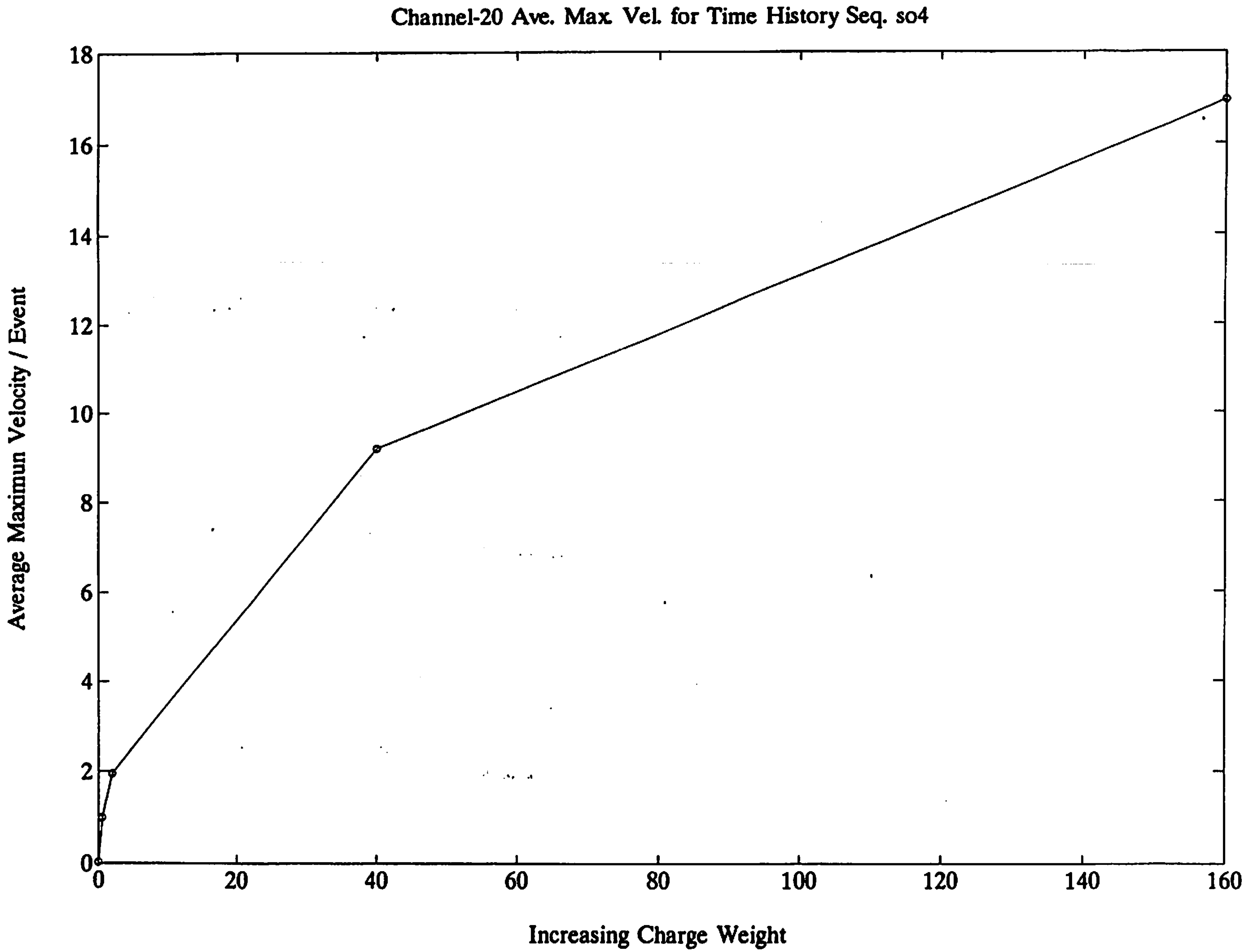
Channel-17 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160



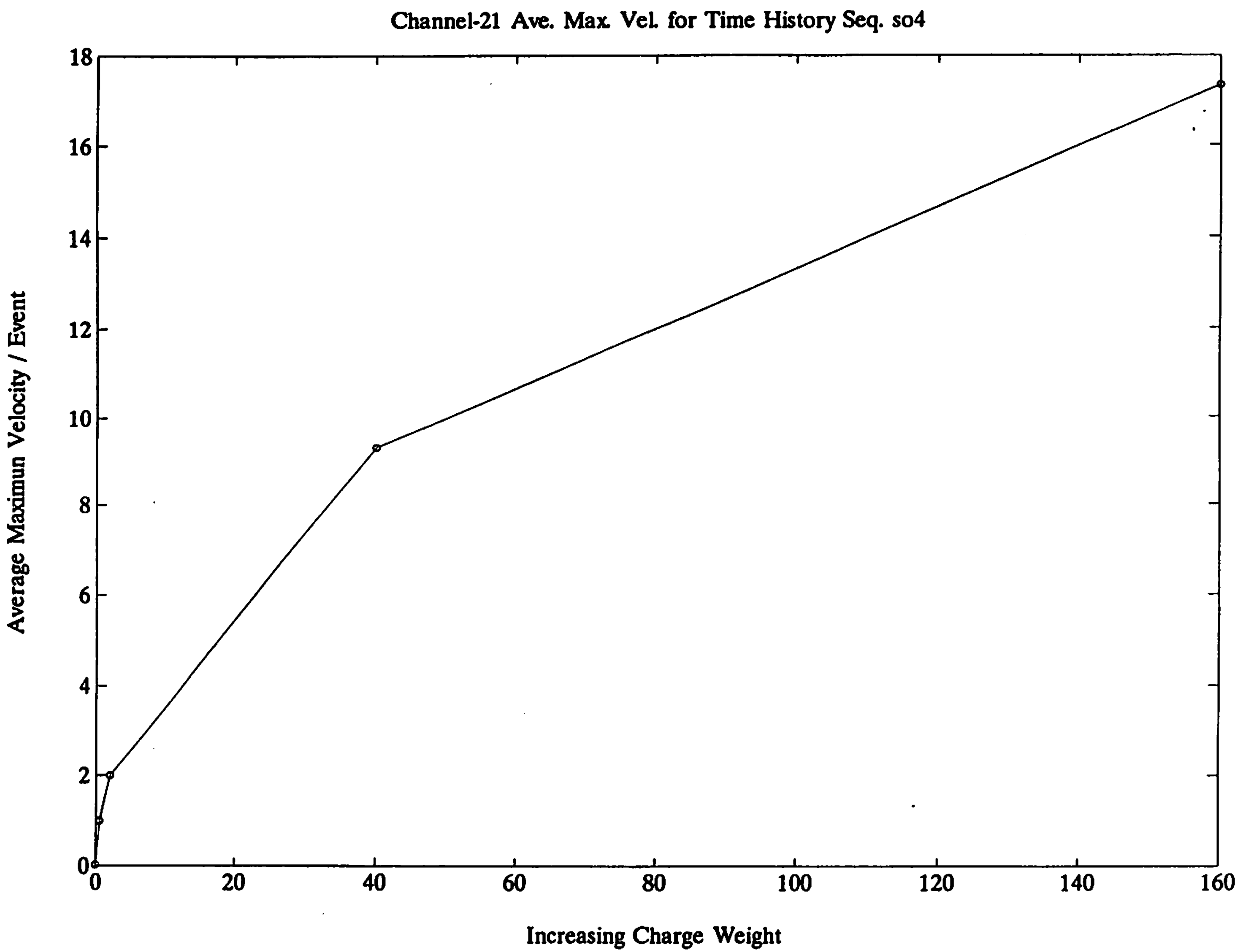
Channel-18 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160



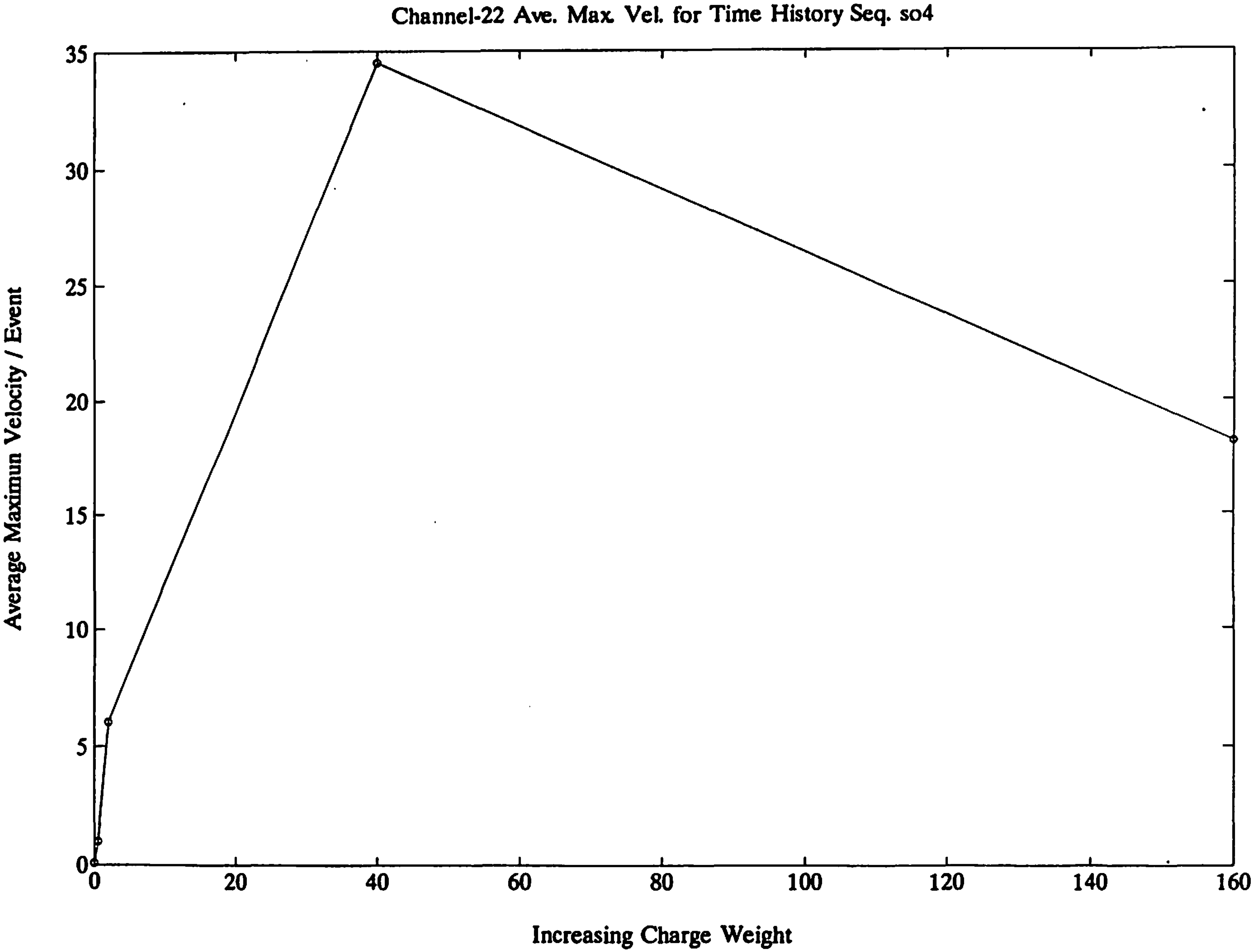
Channel-19 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160



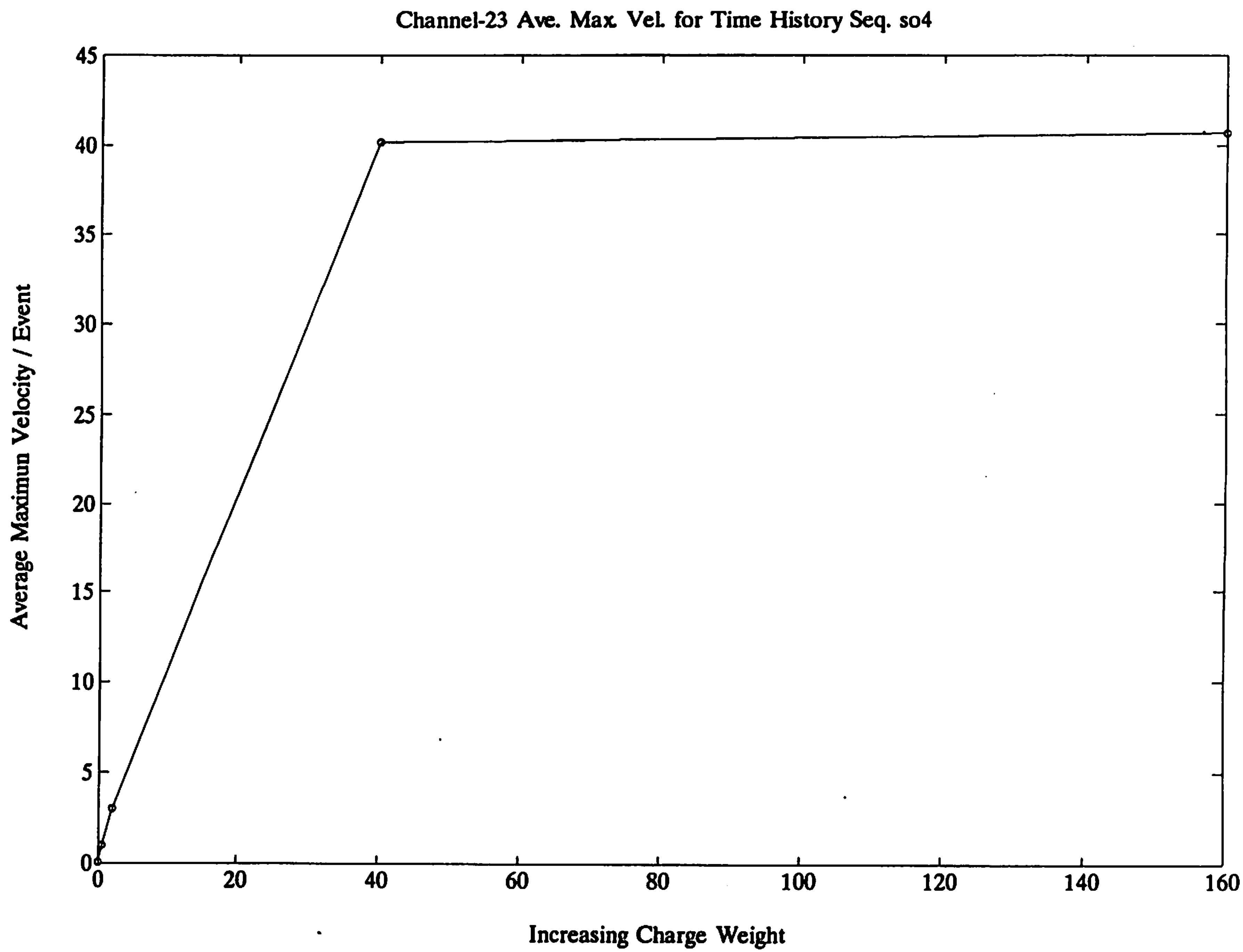
Channel-20 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
120
140
160



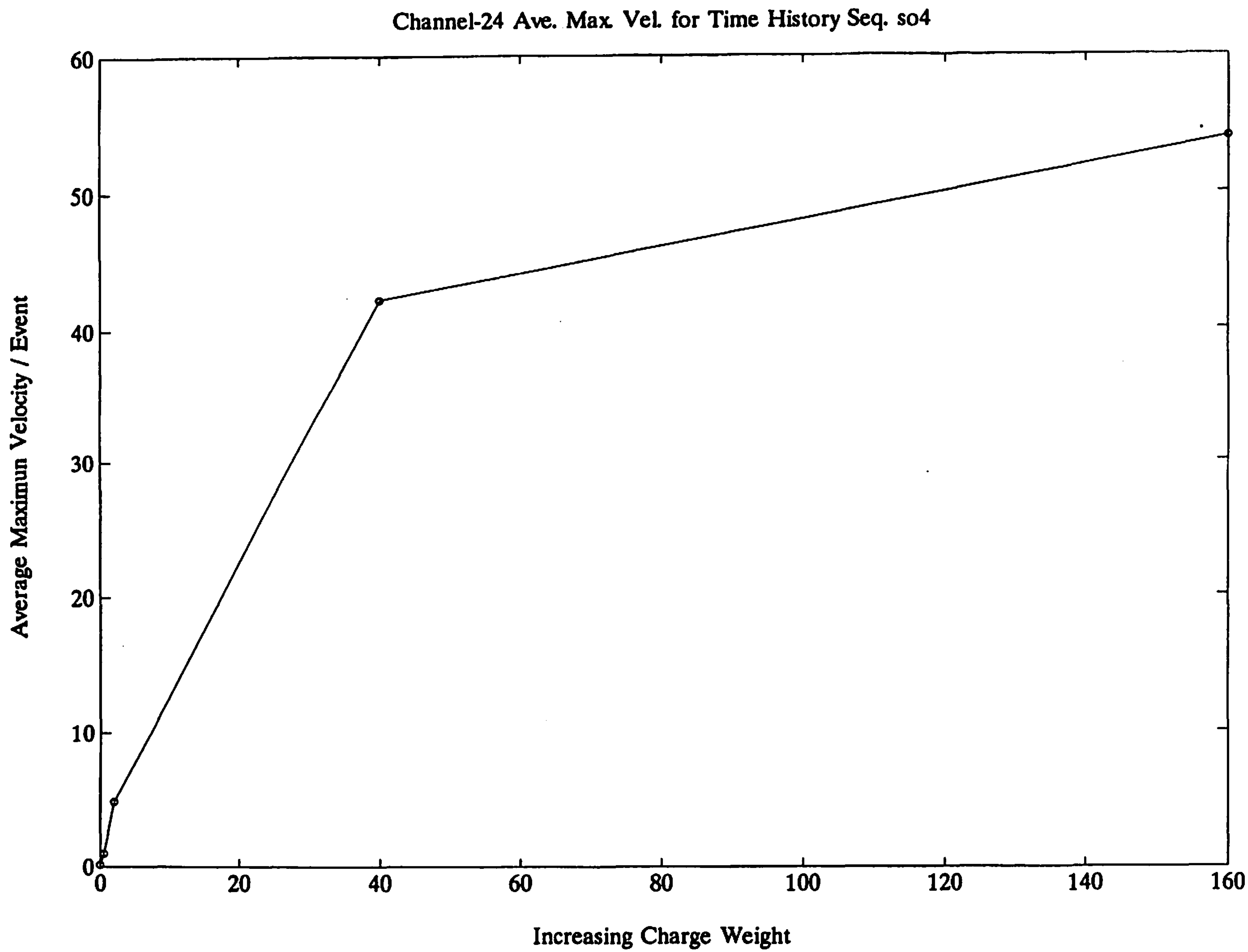
Channel-21 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
120
140
160



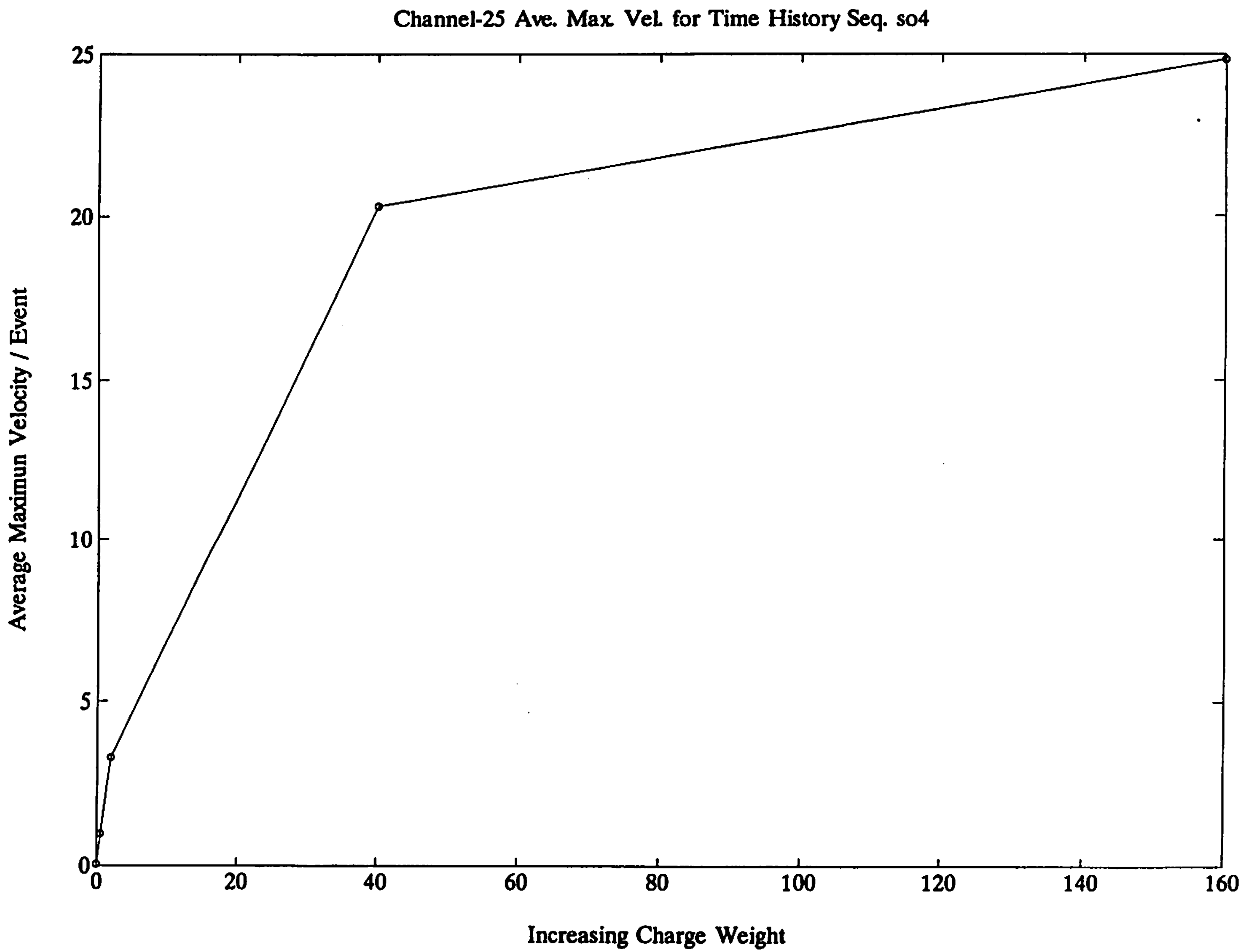
Channel-22 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160

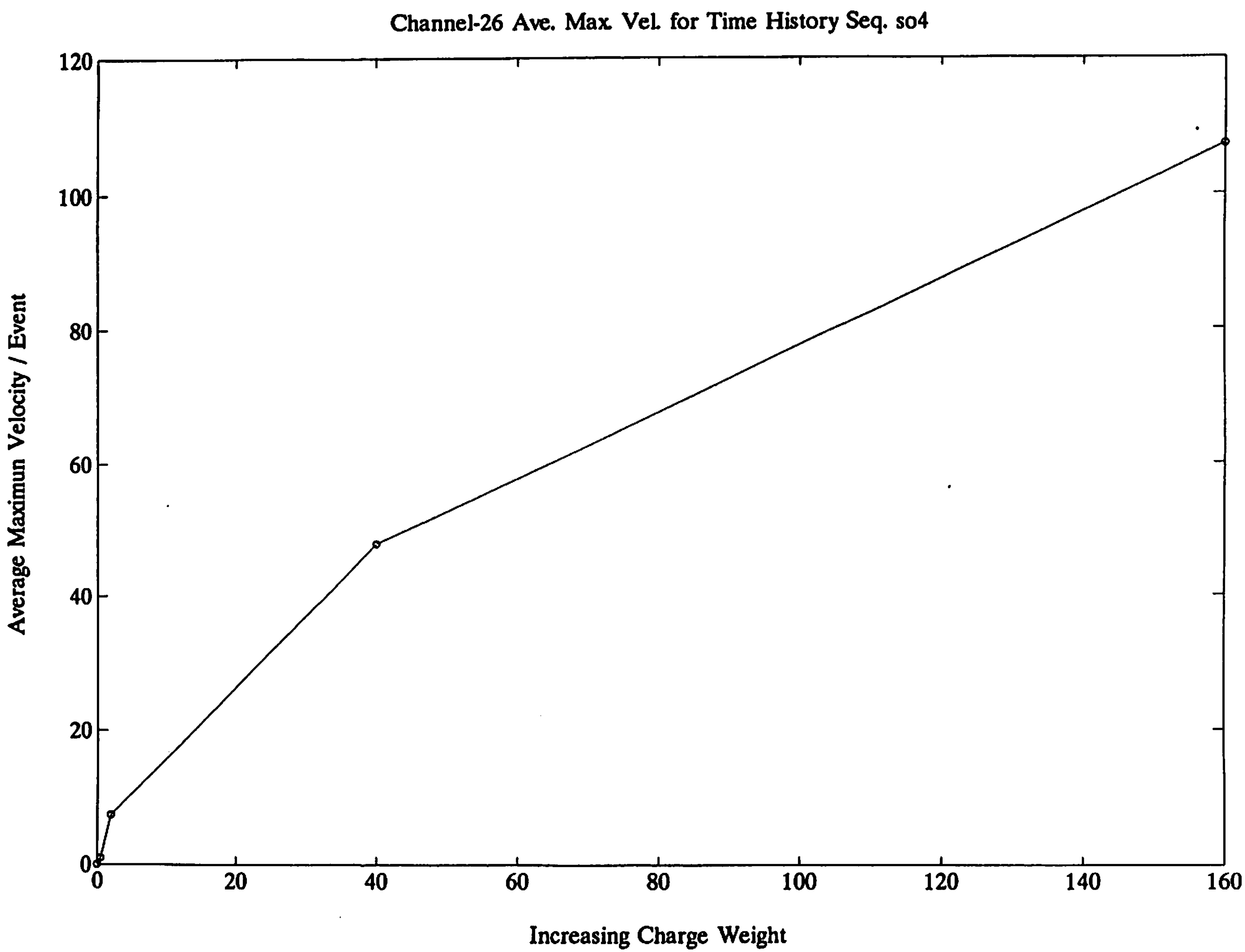


Channel-23 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160

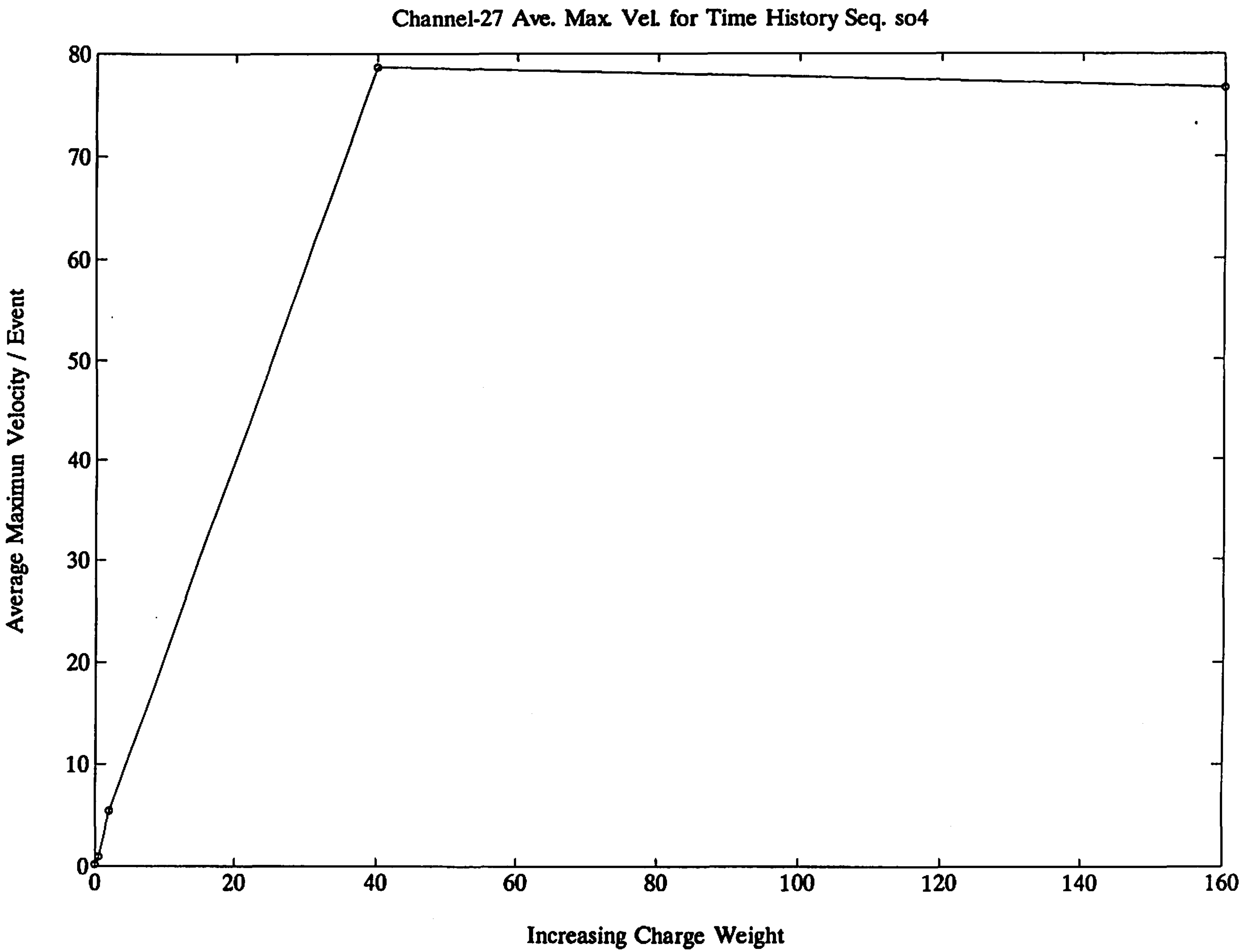


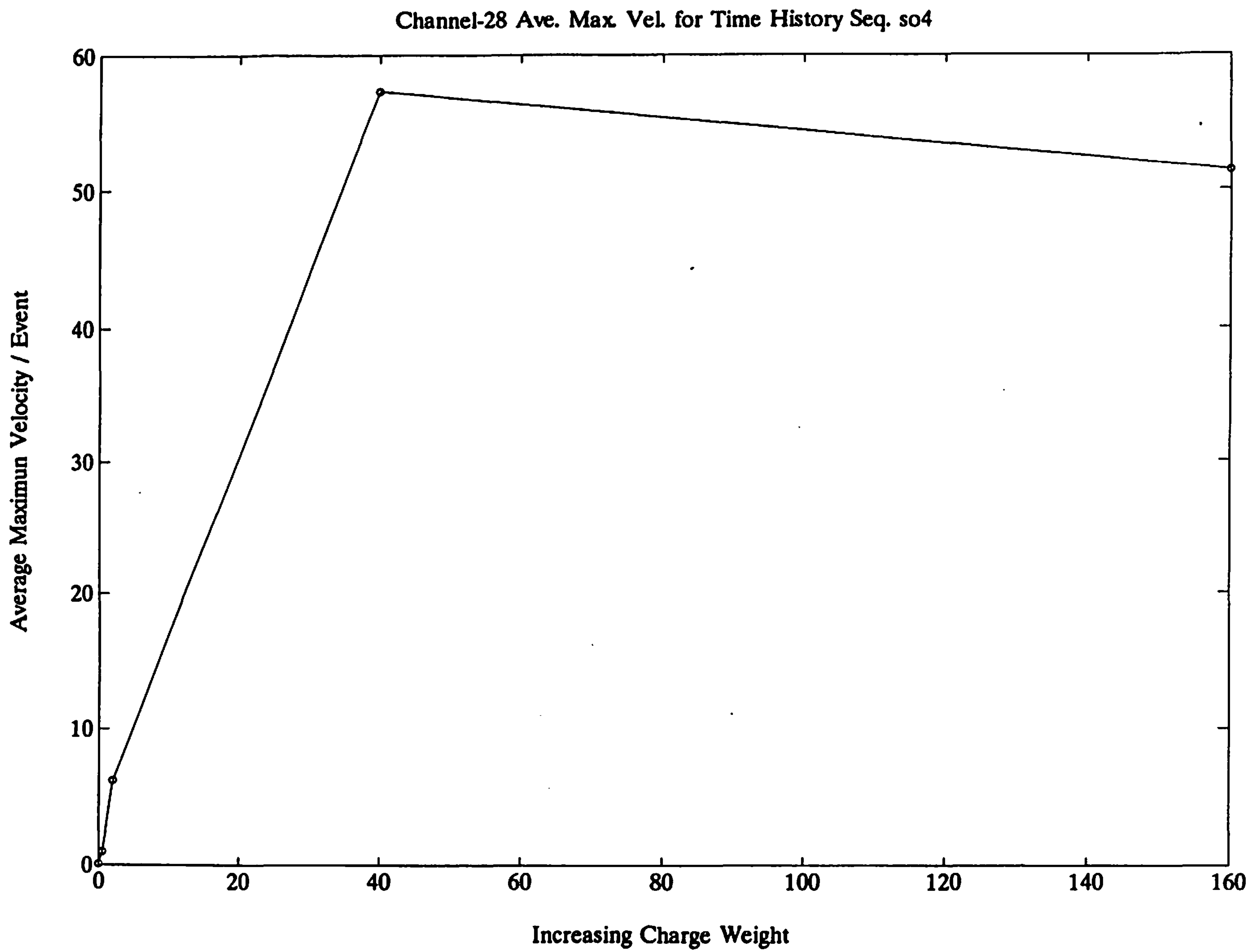
Channel-24 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160


Channel-25 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160

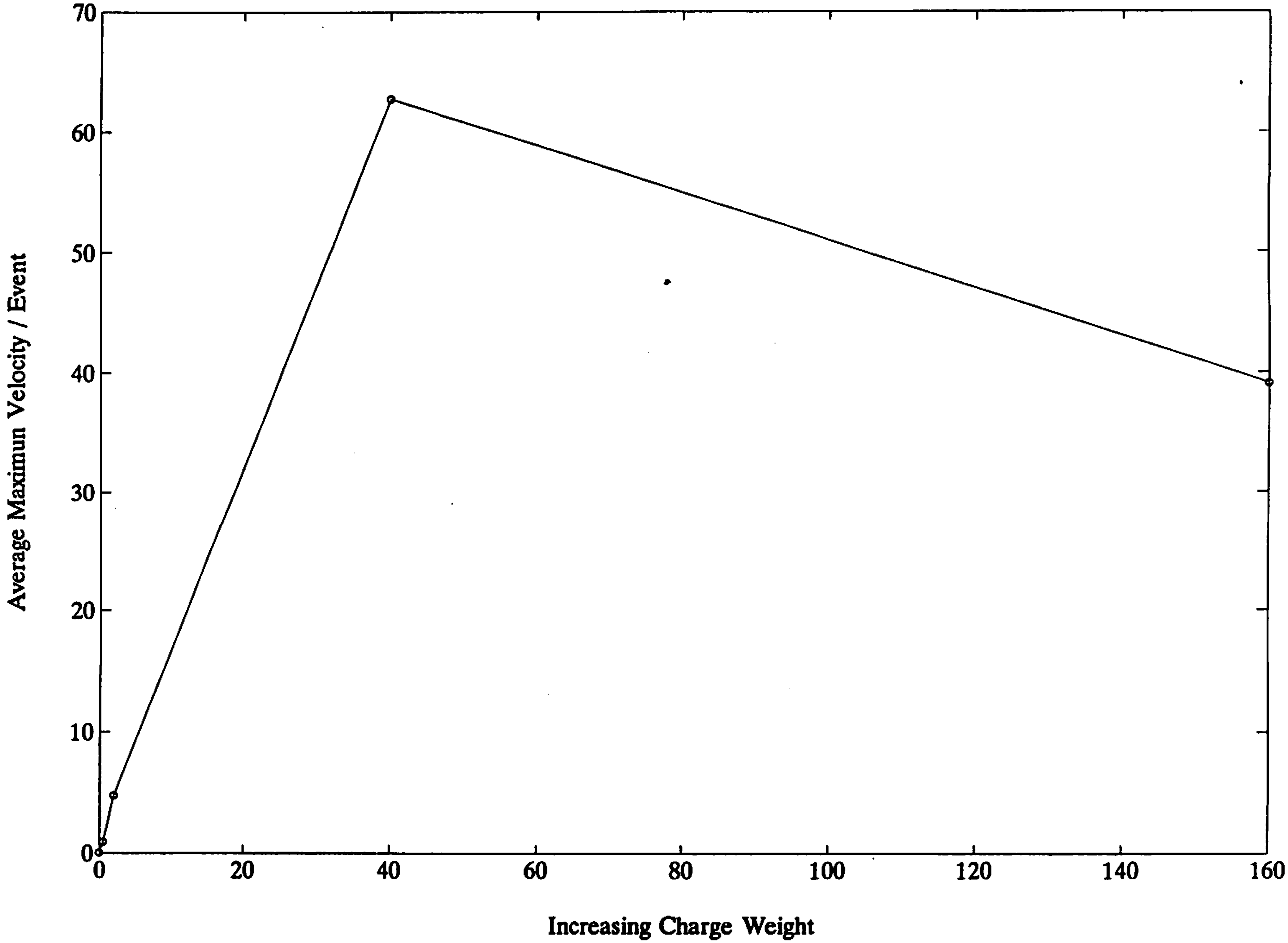


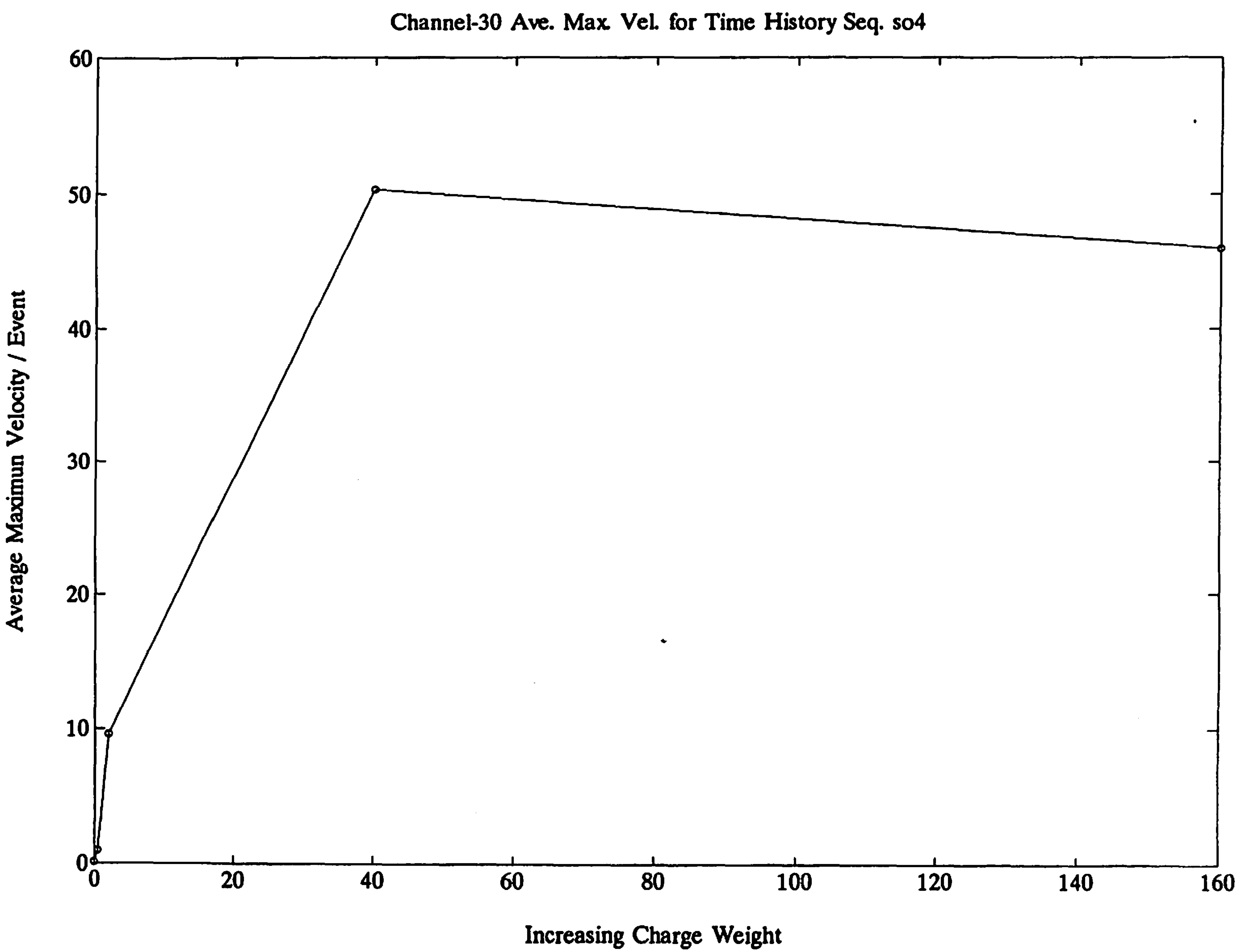
Channel-26 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

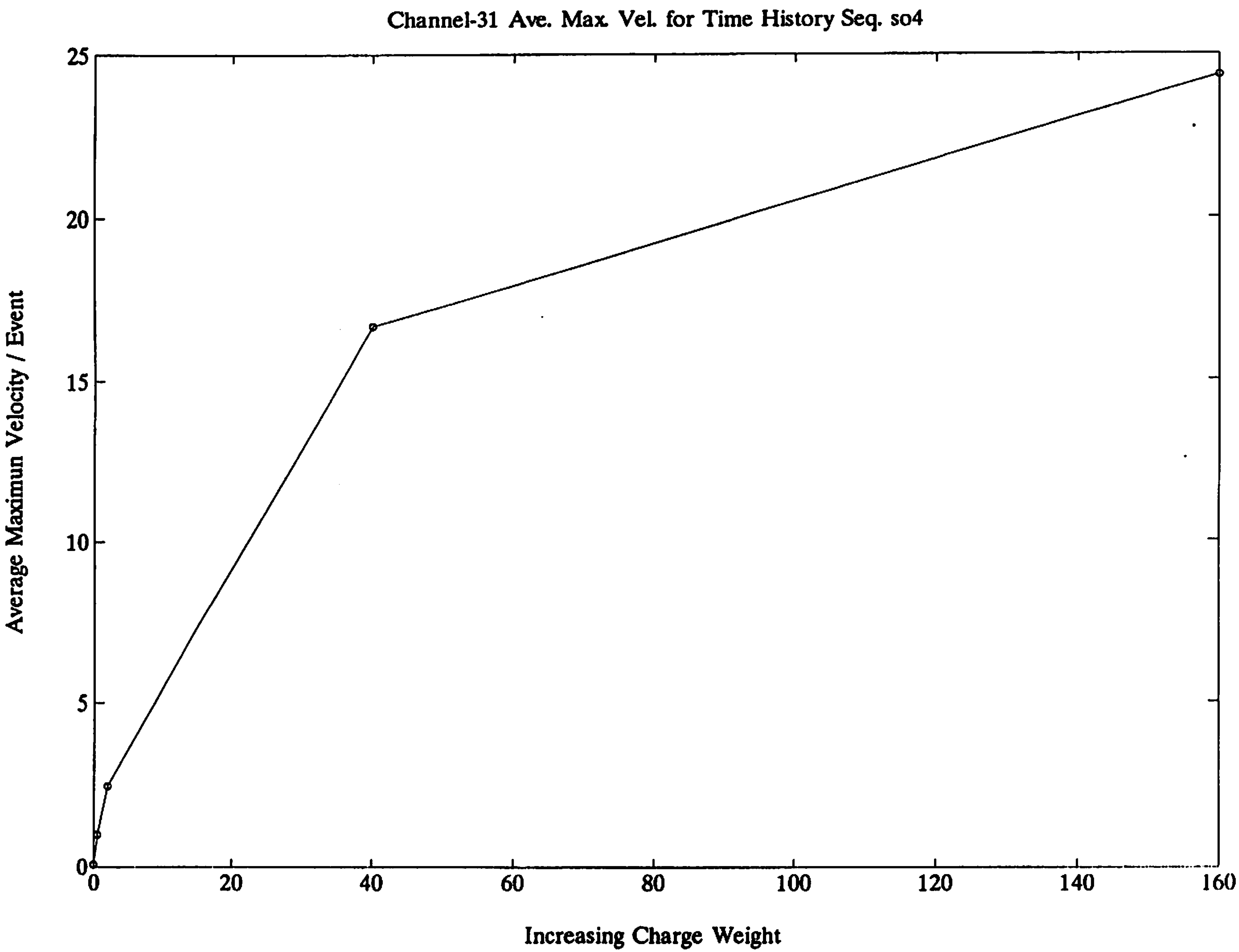

Channel-27 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160

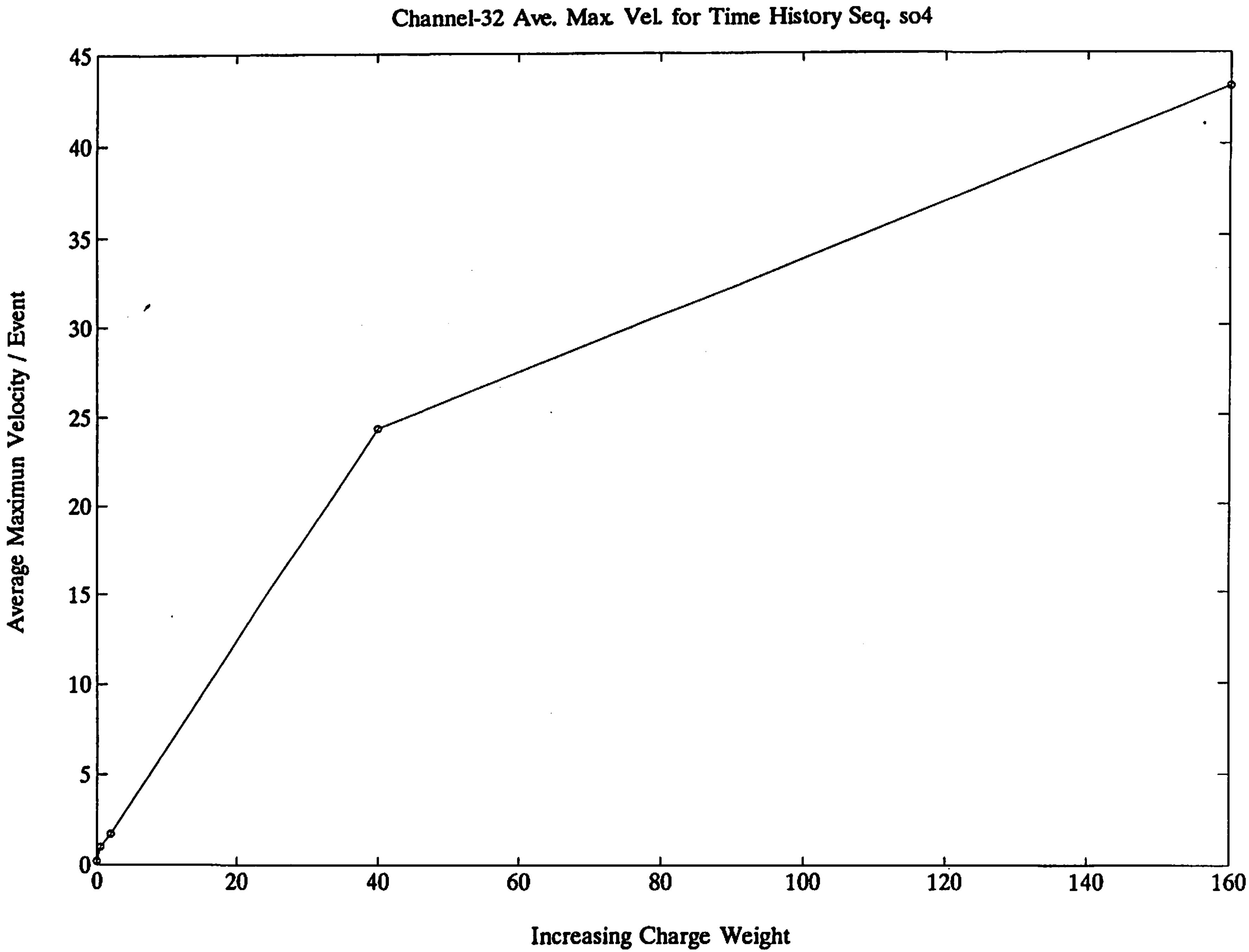

Channel-28 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

Channel-29 Ave. Max. Vel. for Time History Seq. so4

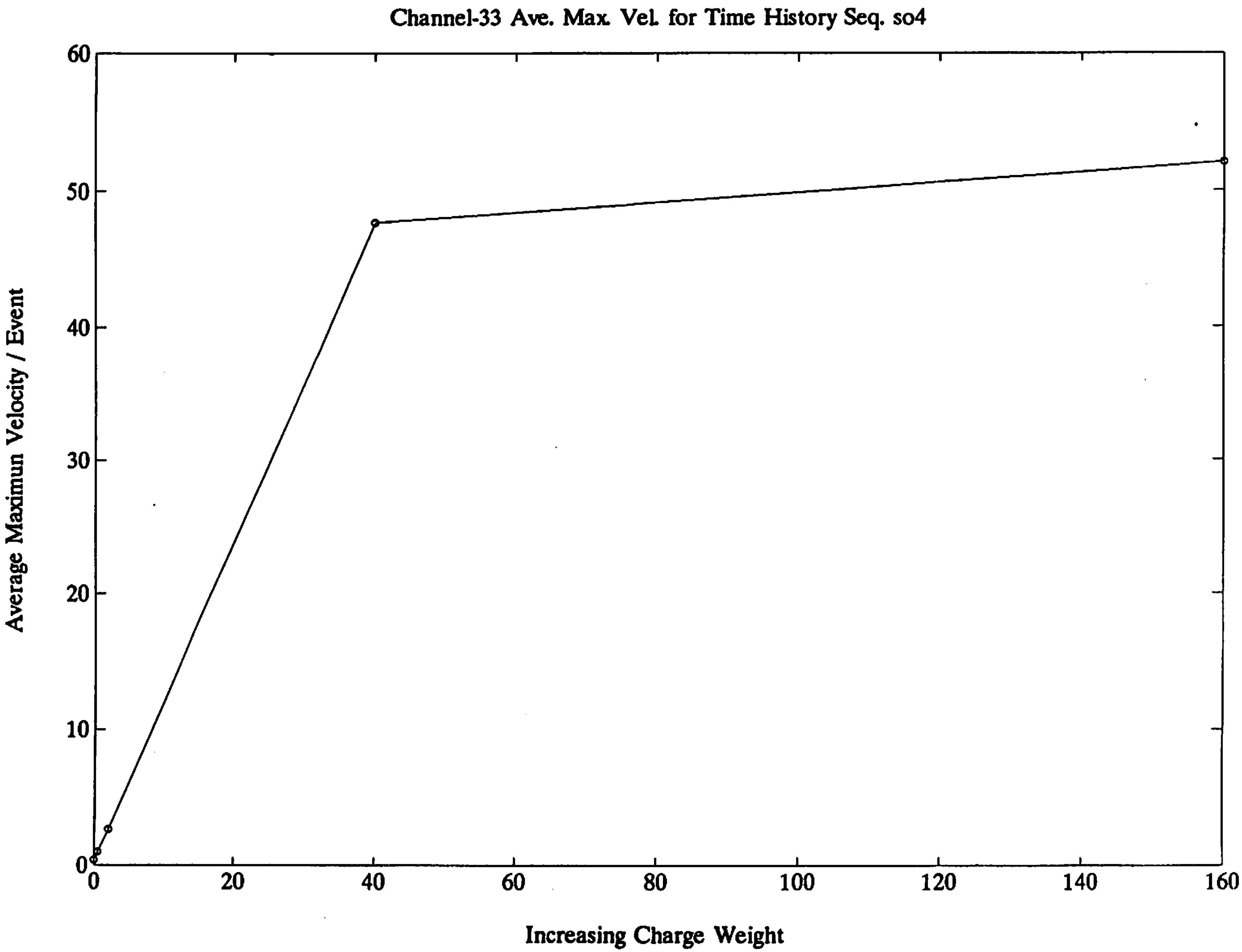


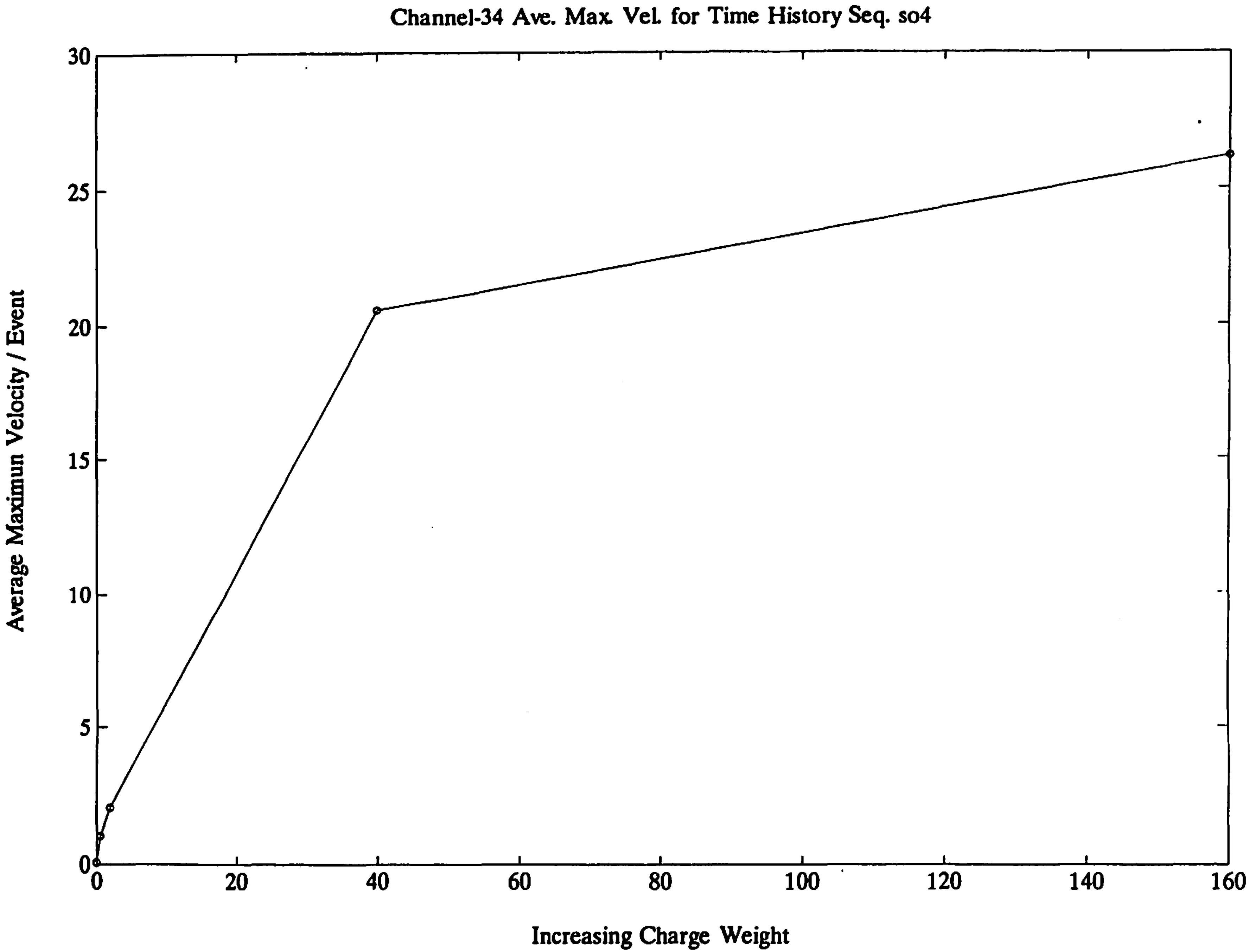

Channel-30 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

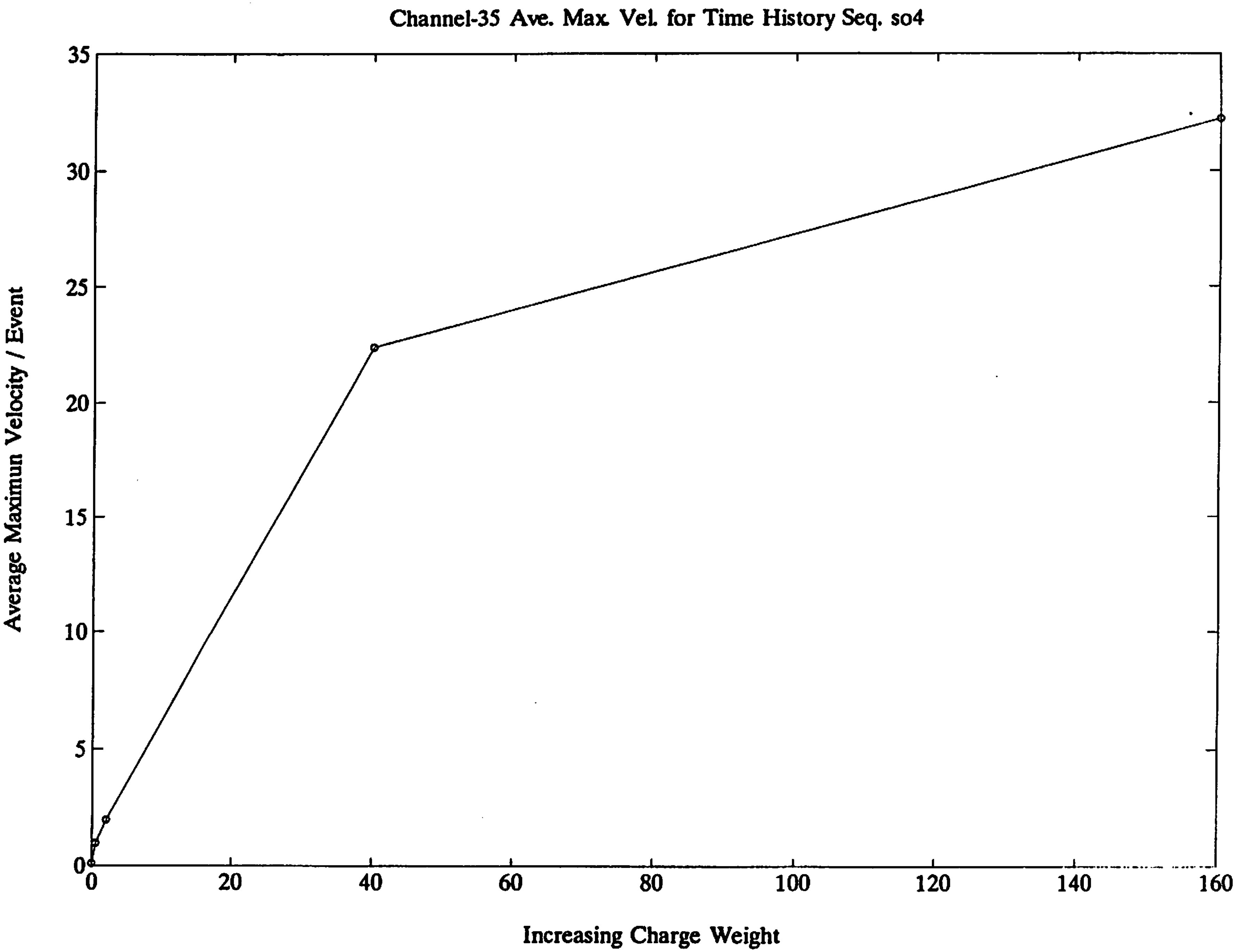

Channel-31 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160

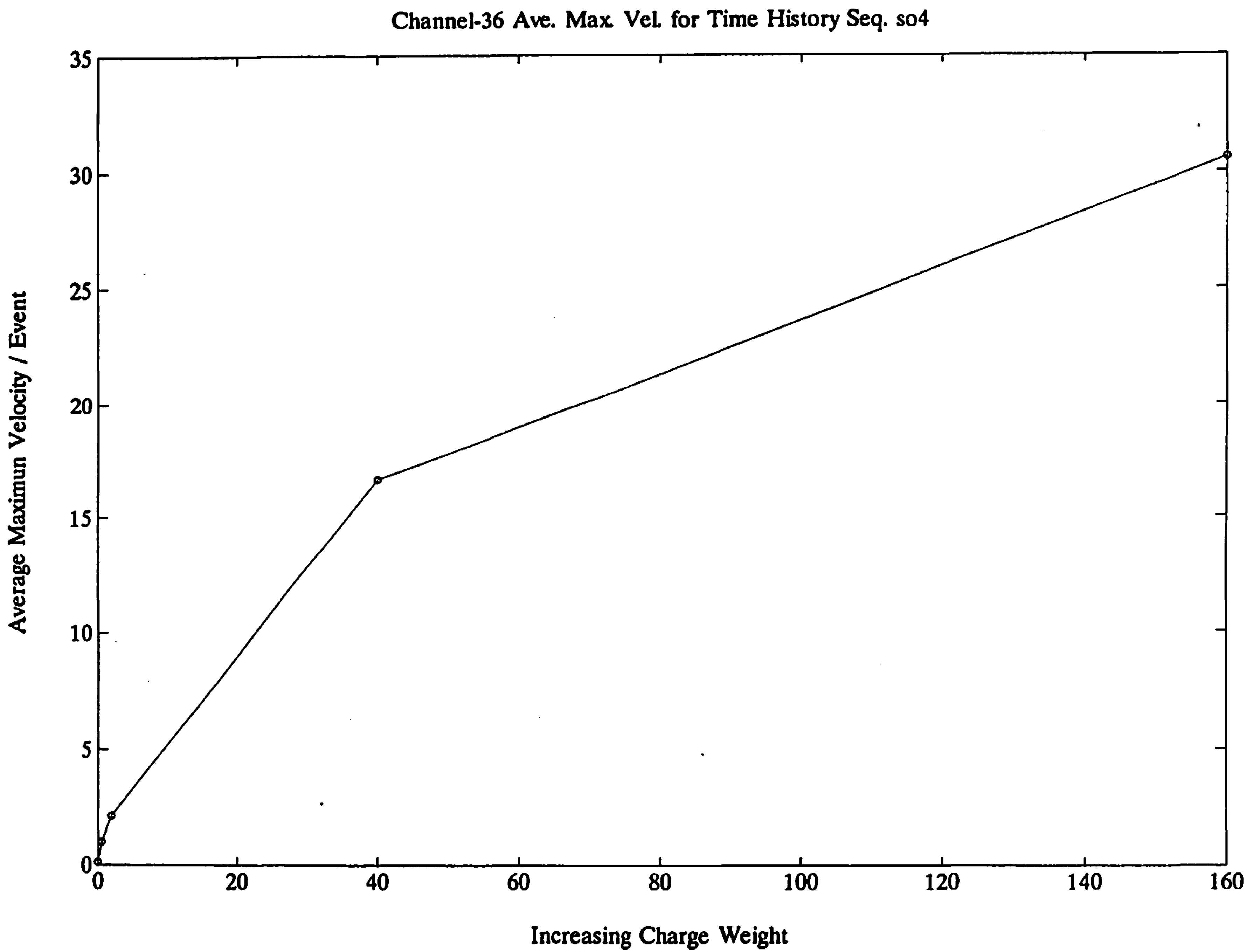


Channel-32 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160
Increasing Charge Weight

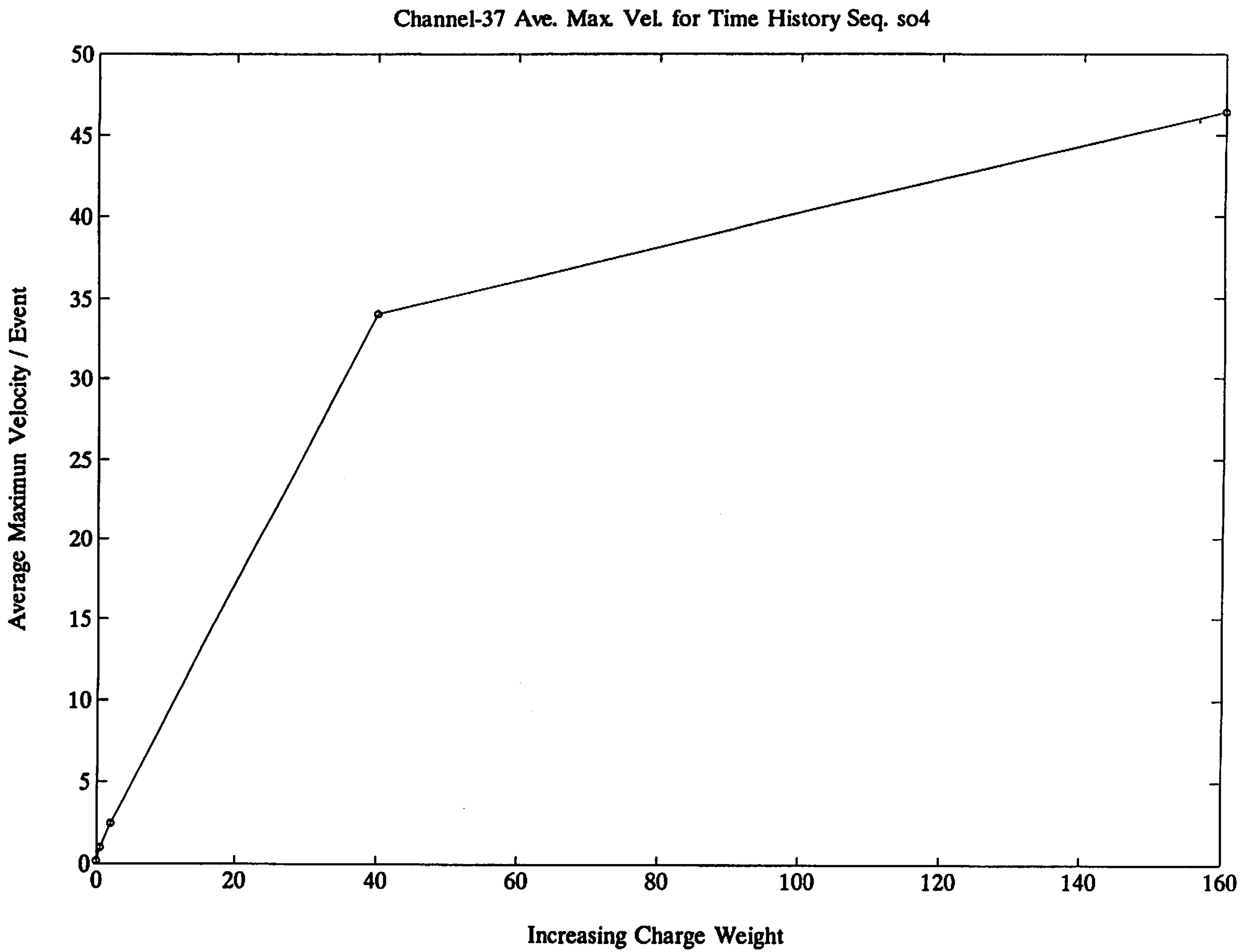

Channel-33 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

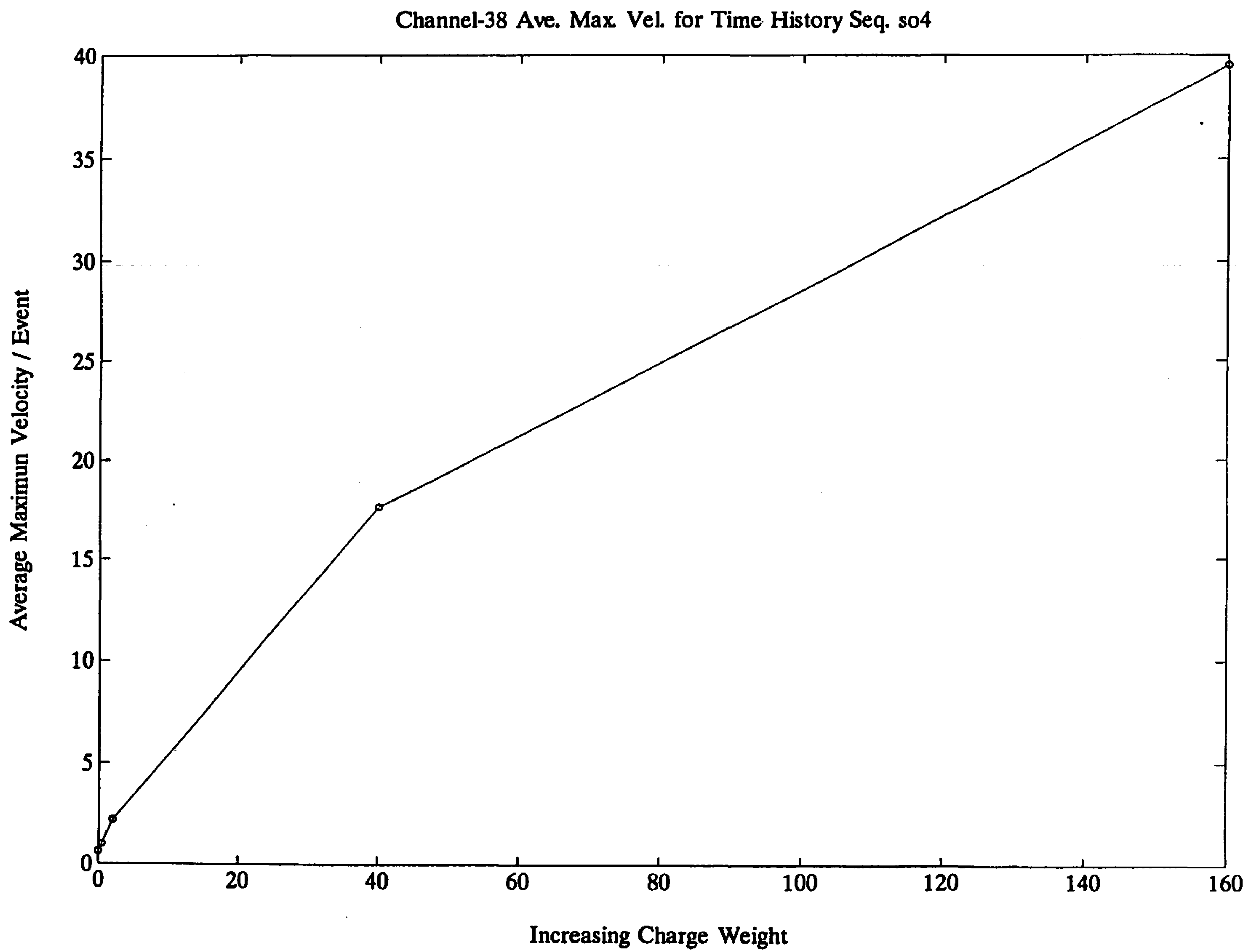

Channel-34 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160

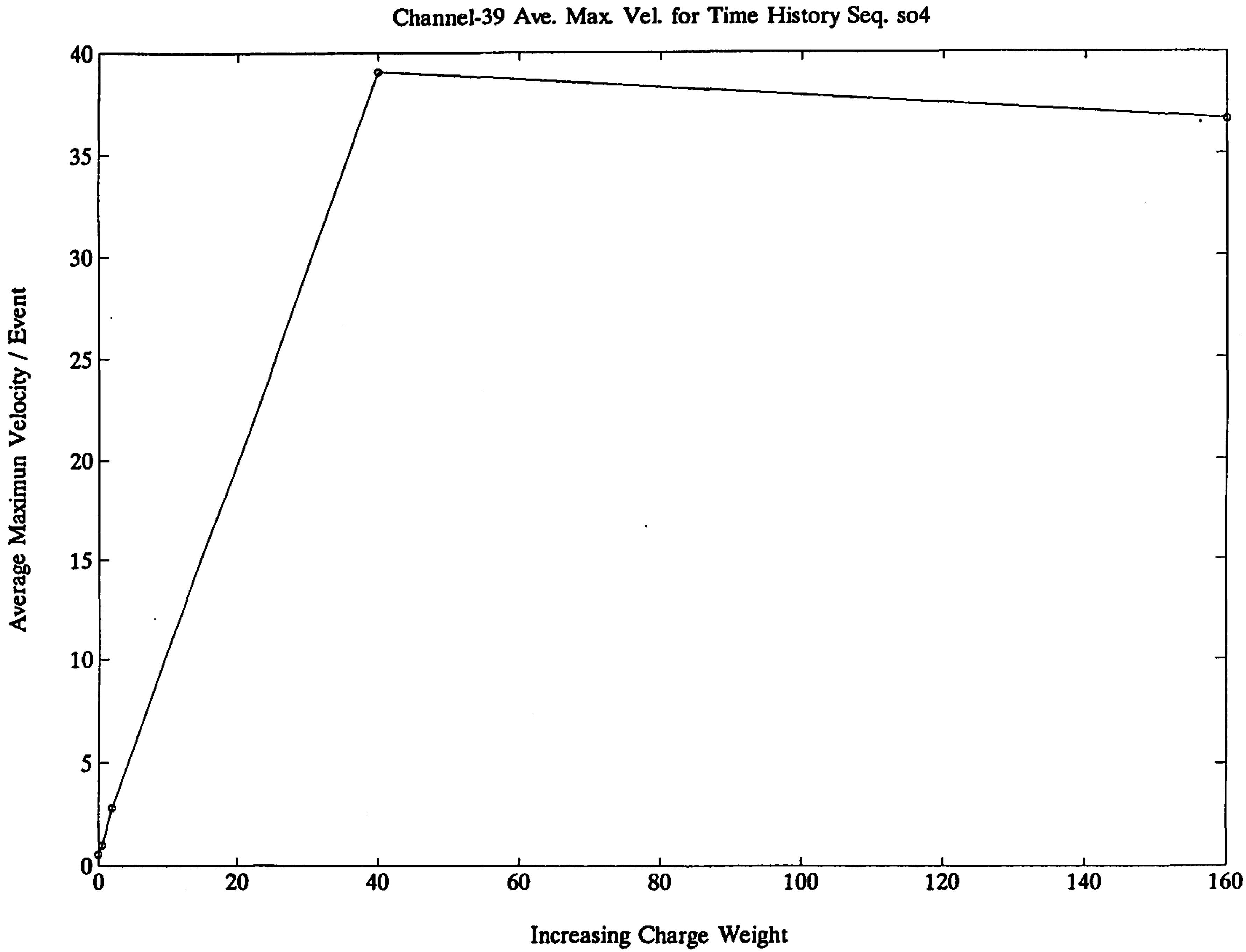

Channel-35 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160



Channel-36 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160
Increasing Charge Weight


Channel-37 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
Increasing Charge Weight


Channel-38 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120
140
160

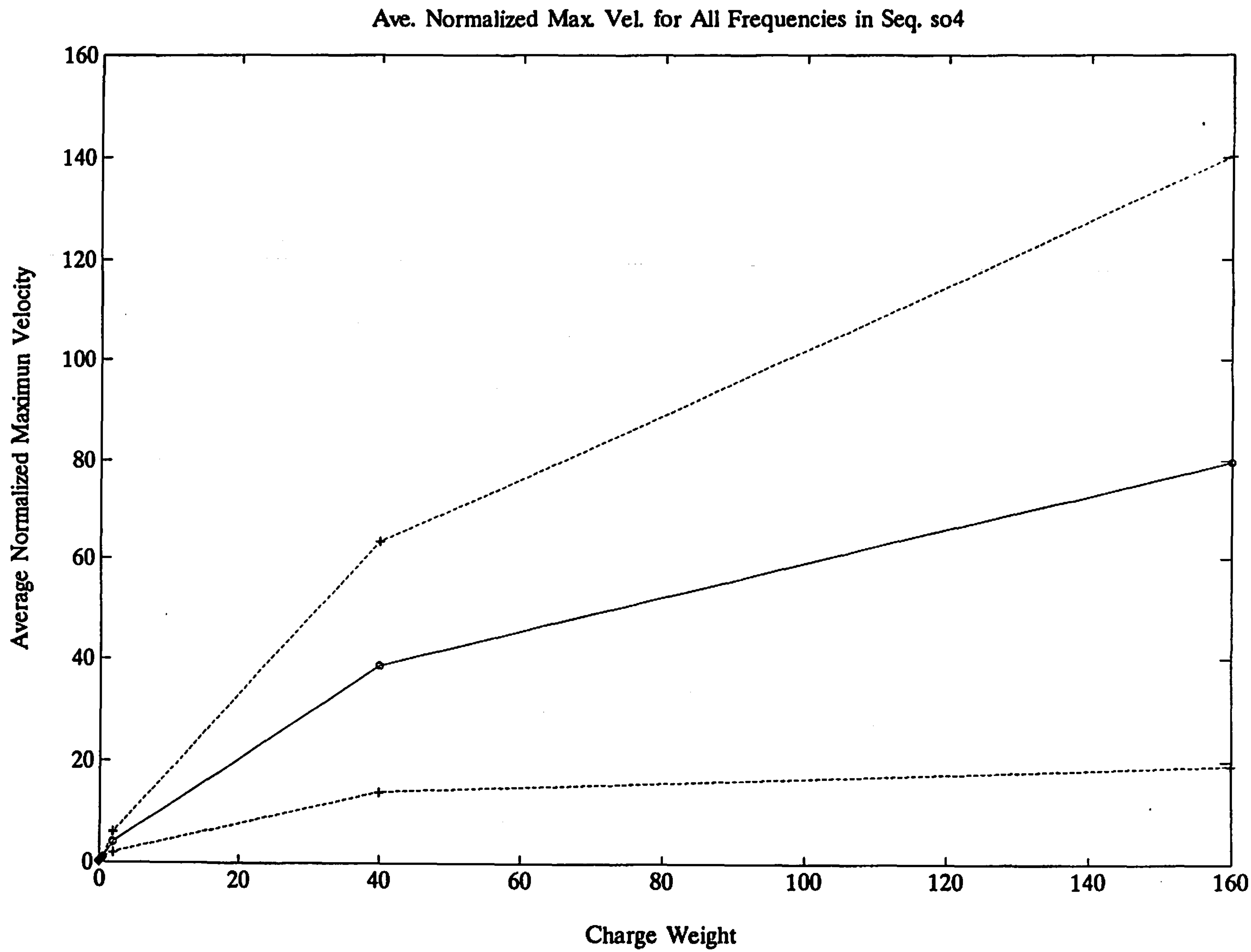

Channel-39 Ave. Max. Vel. for Time History Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120
140
160

SECTION E-6

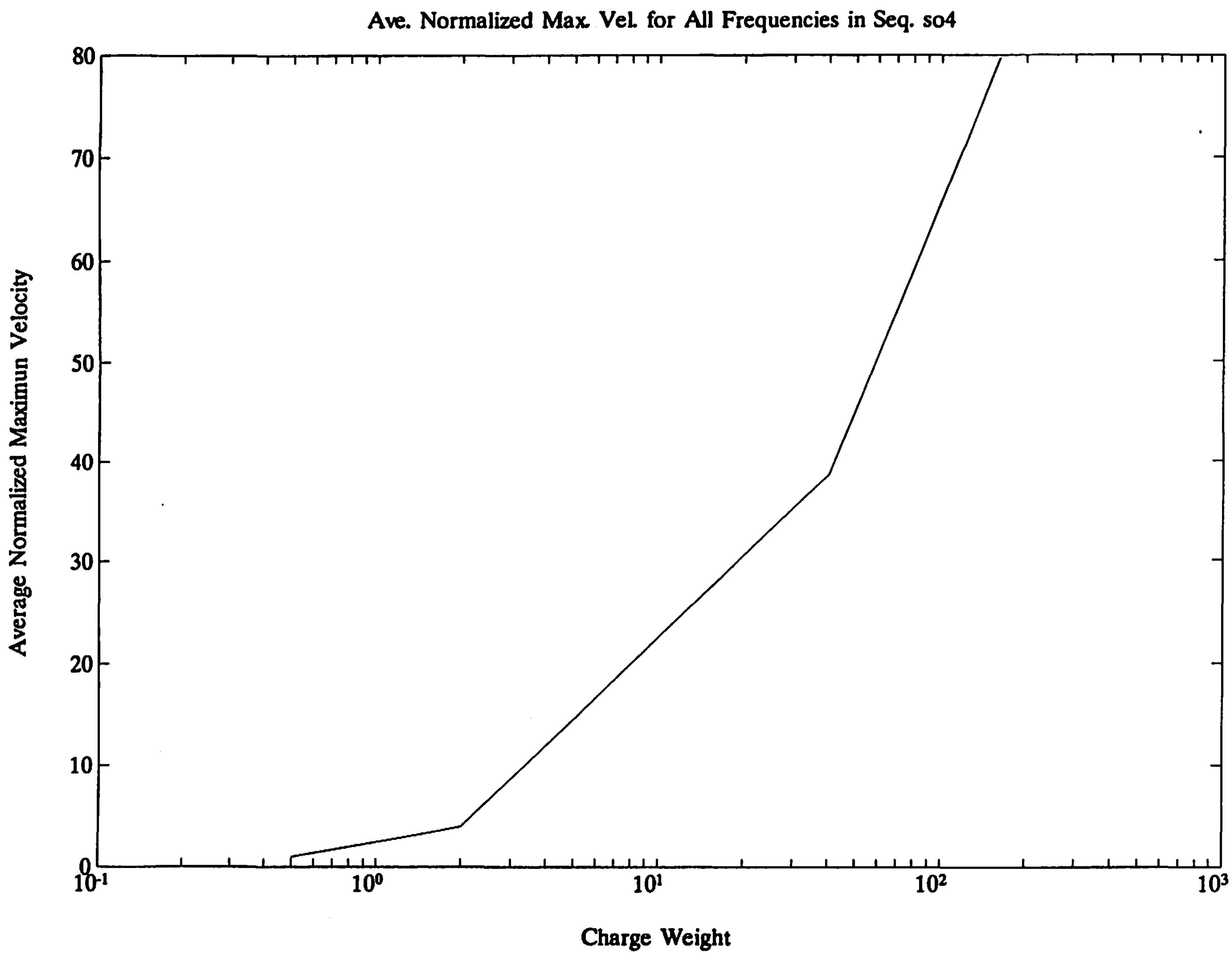
NORMALIZED MAXIMUM VELOCITIES VERSUS TOTAL CHARGE WEIGHT

FOR

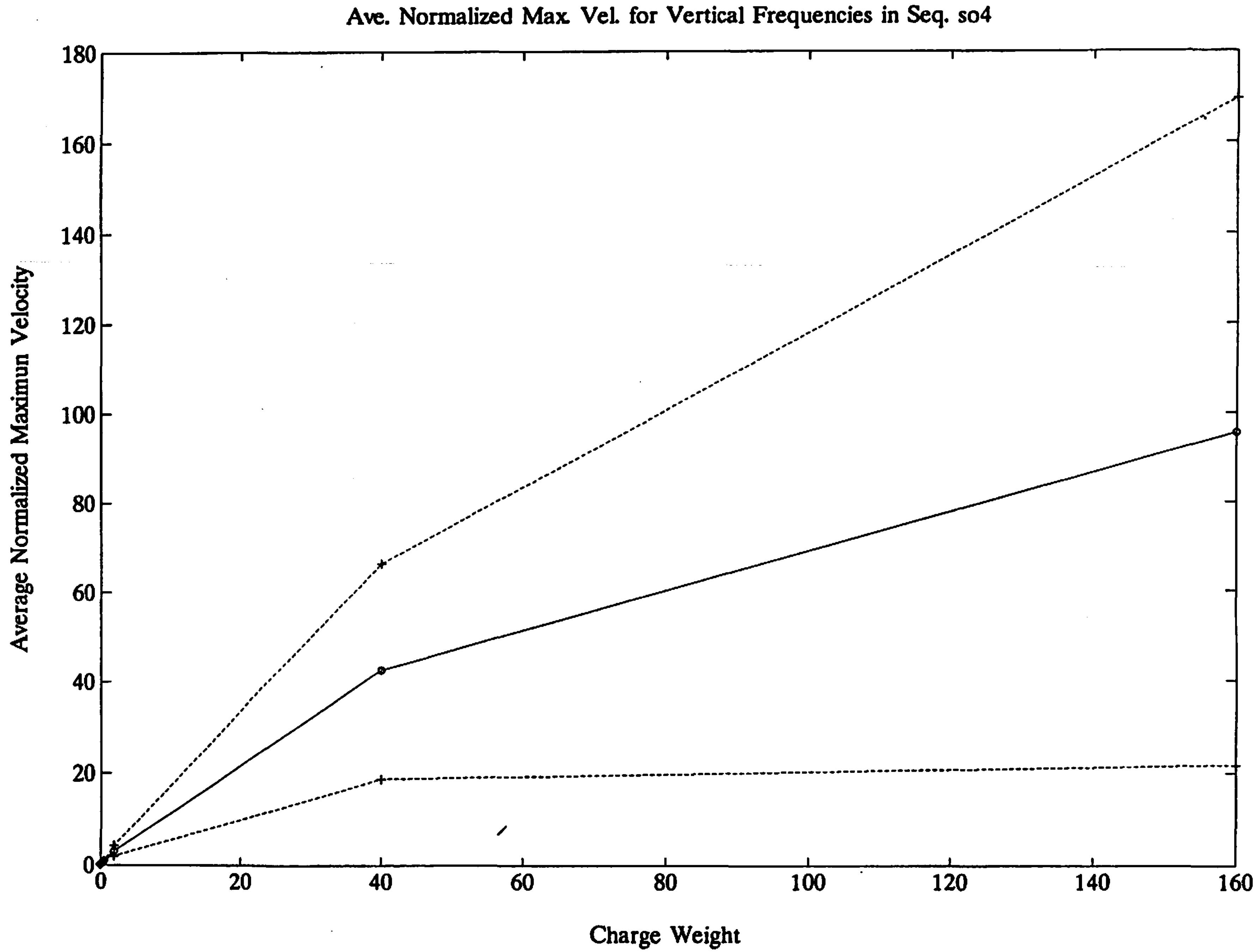
FOURIER TRANSFORMS OF TIME HISTORIES IN SEQUENCE S04

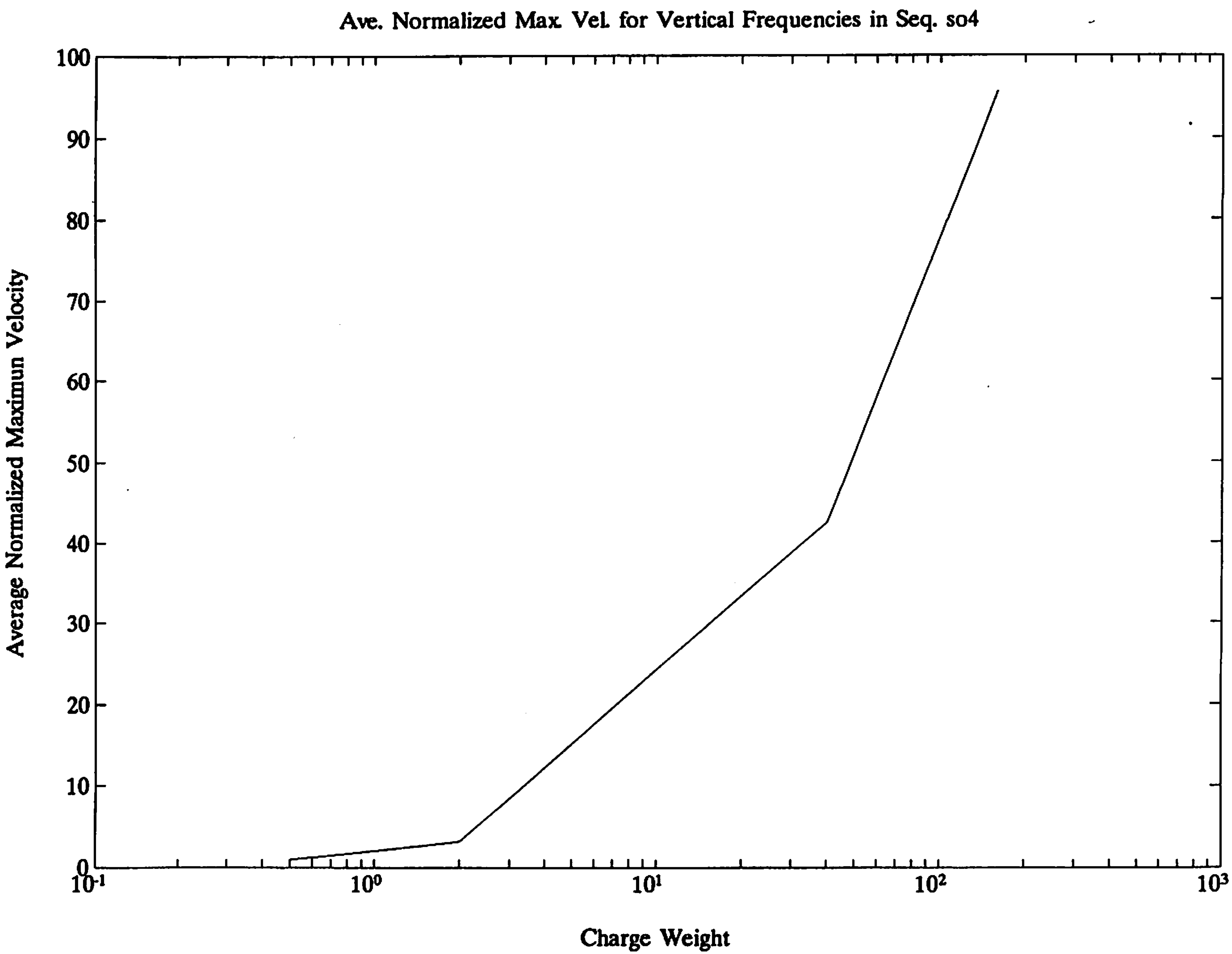


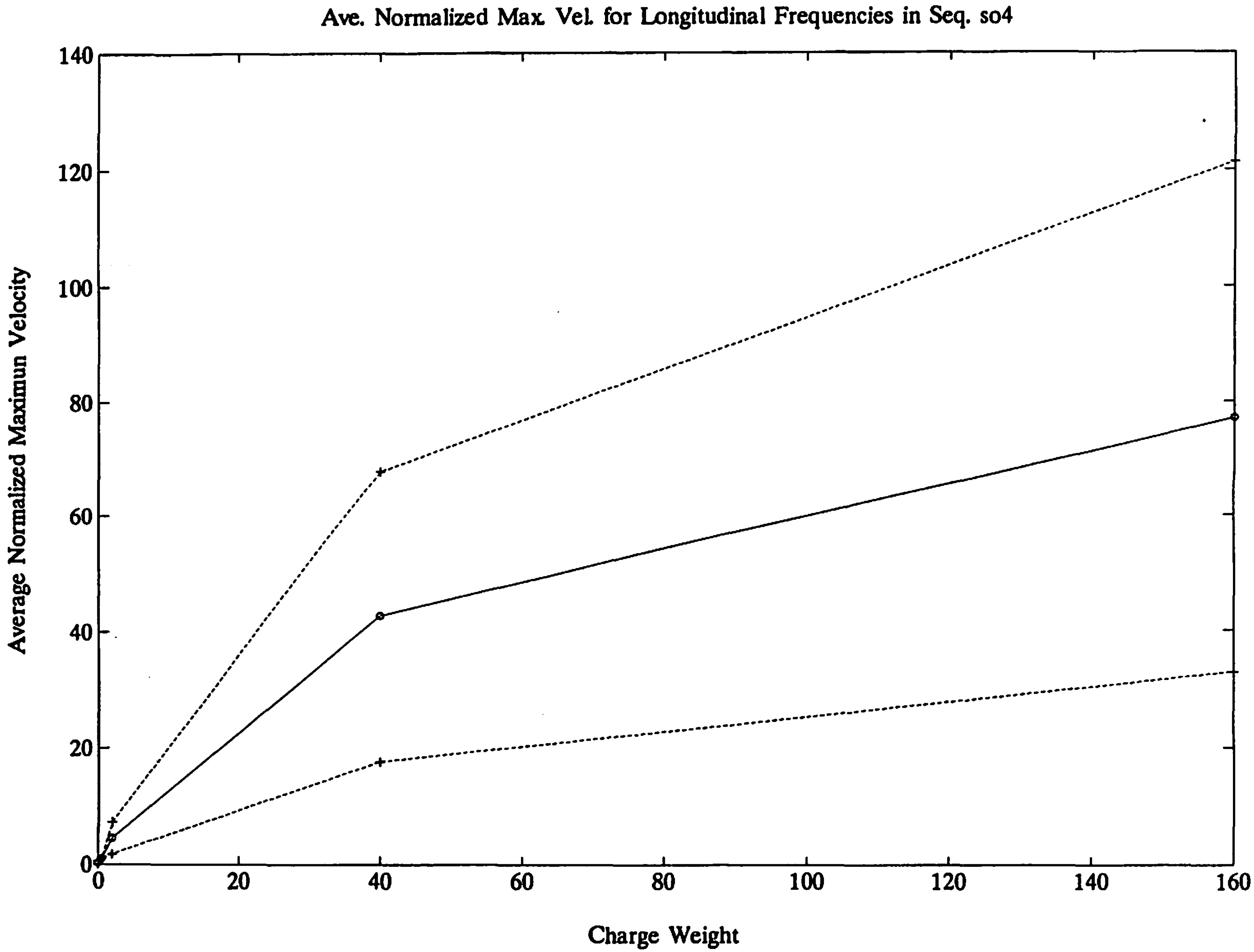
Ave. Normalized Max. Vel. for All Frequencies in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
20
40
60
80
100
120
140
160

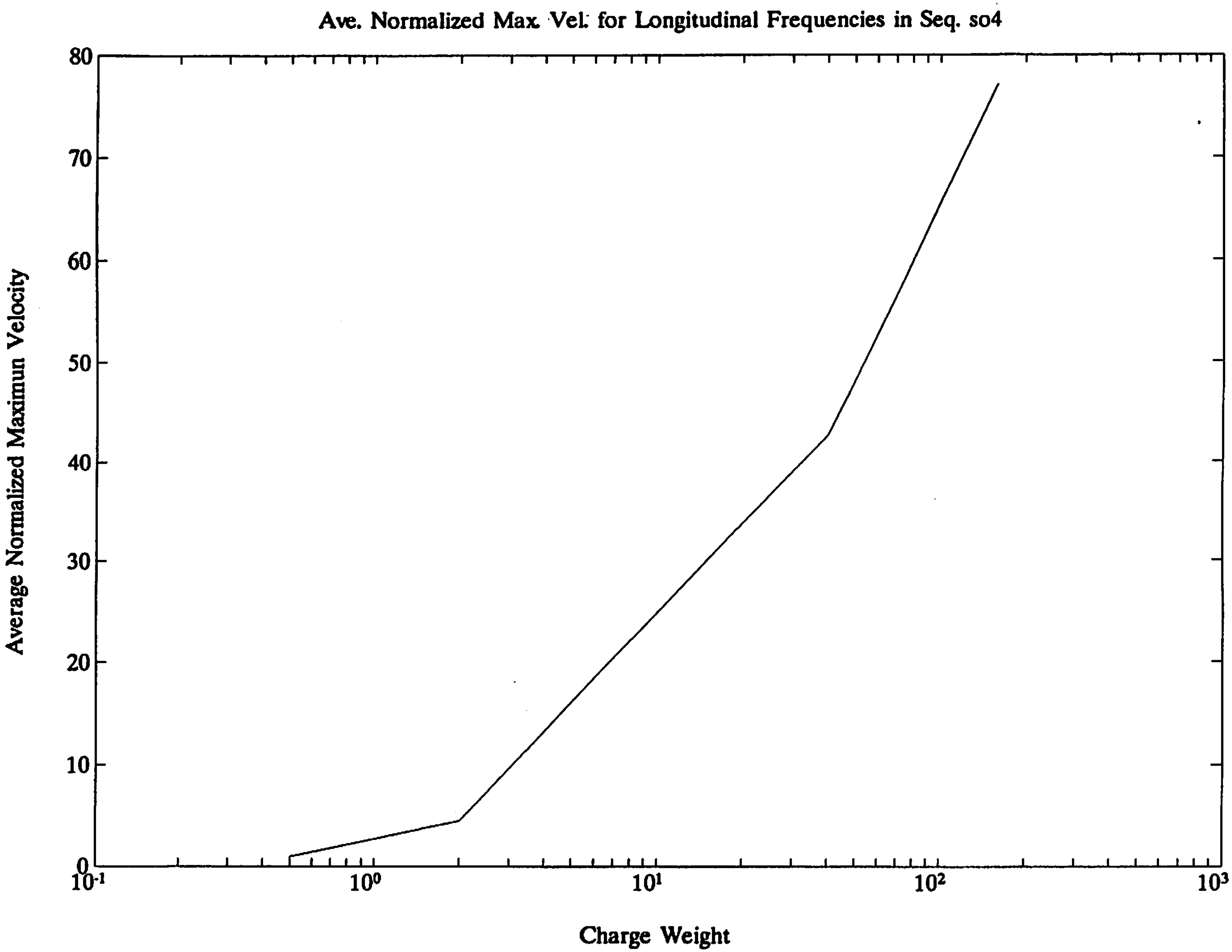


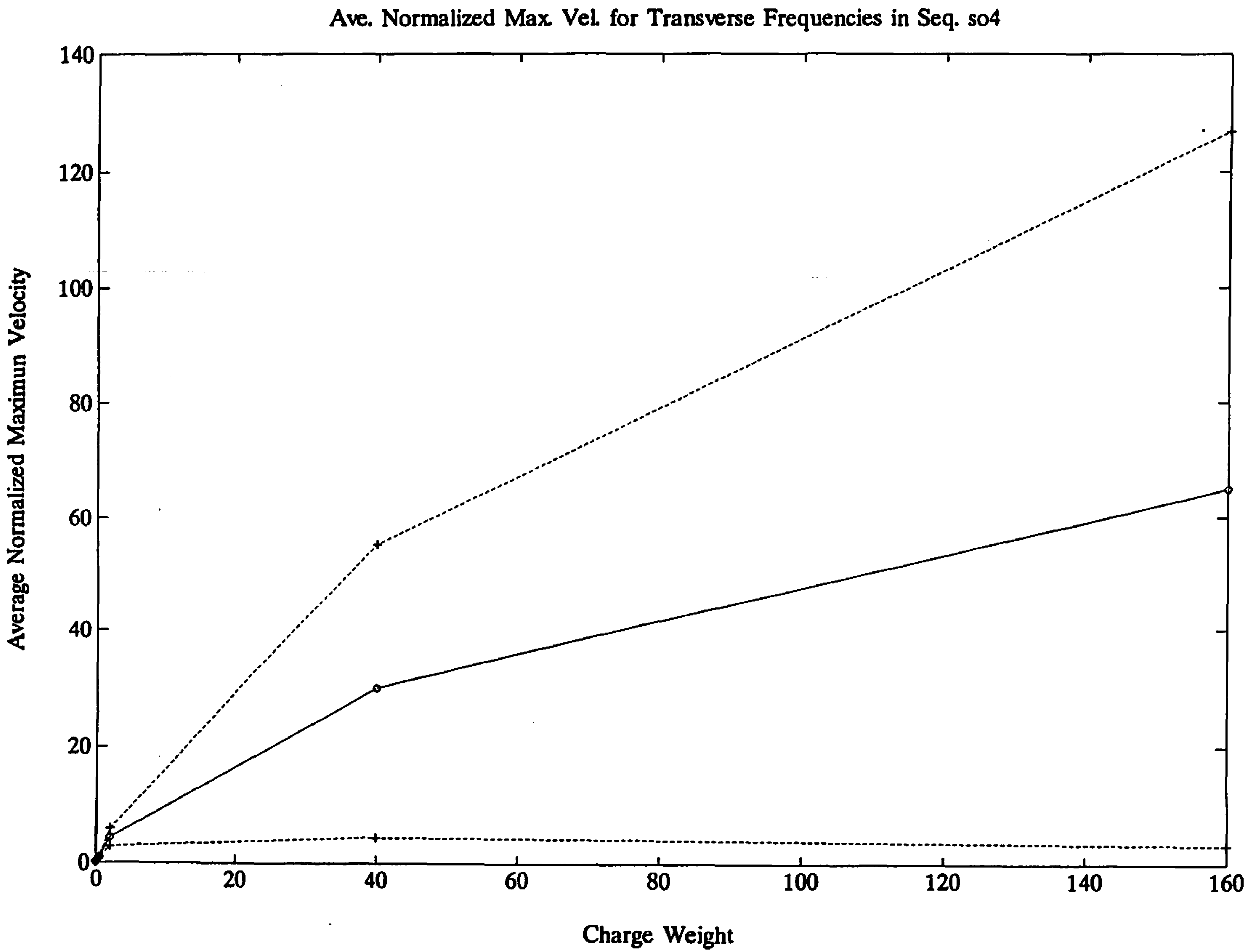
Ave. Normalized Max. Vel. for All Frequencies in Seq. so4
Average Normalized Maximun Velocity
80
70
60
50
40
30
20
10
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Charge Weight

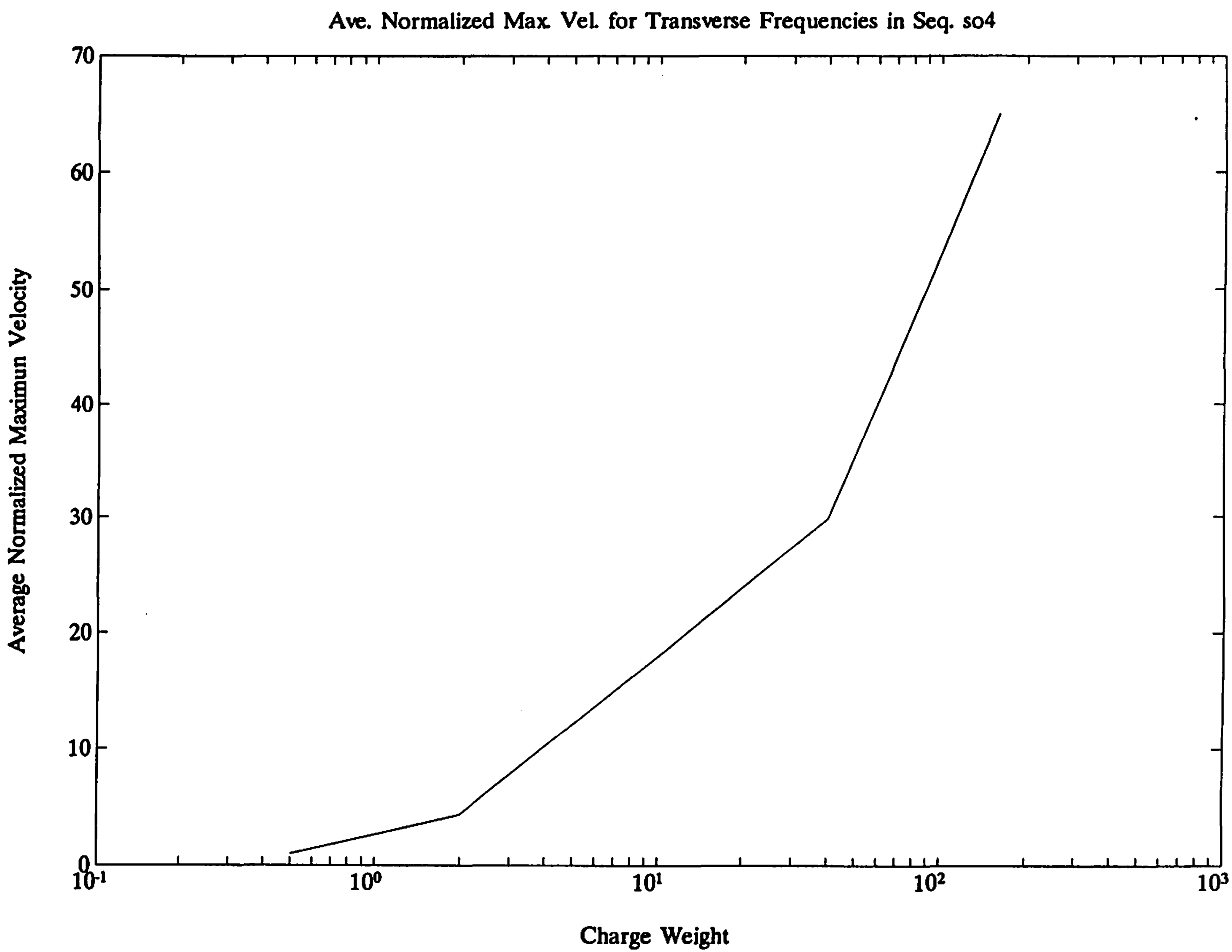

Ave. Normalized Max. Vel. for Vertical Frequencies in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
20
40
60
80
100
120
140
160
180


Ave. Normalized Max. Vel. for Vertical Frequencies in Seq. so4
Average Normalized Maximun Velocity
100
90
80
70
60
50
40
30
20
10
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Charge Weight

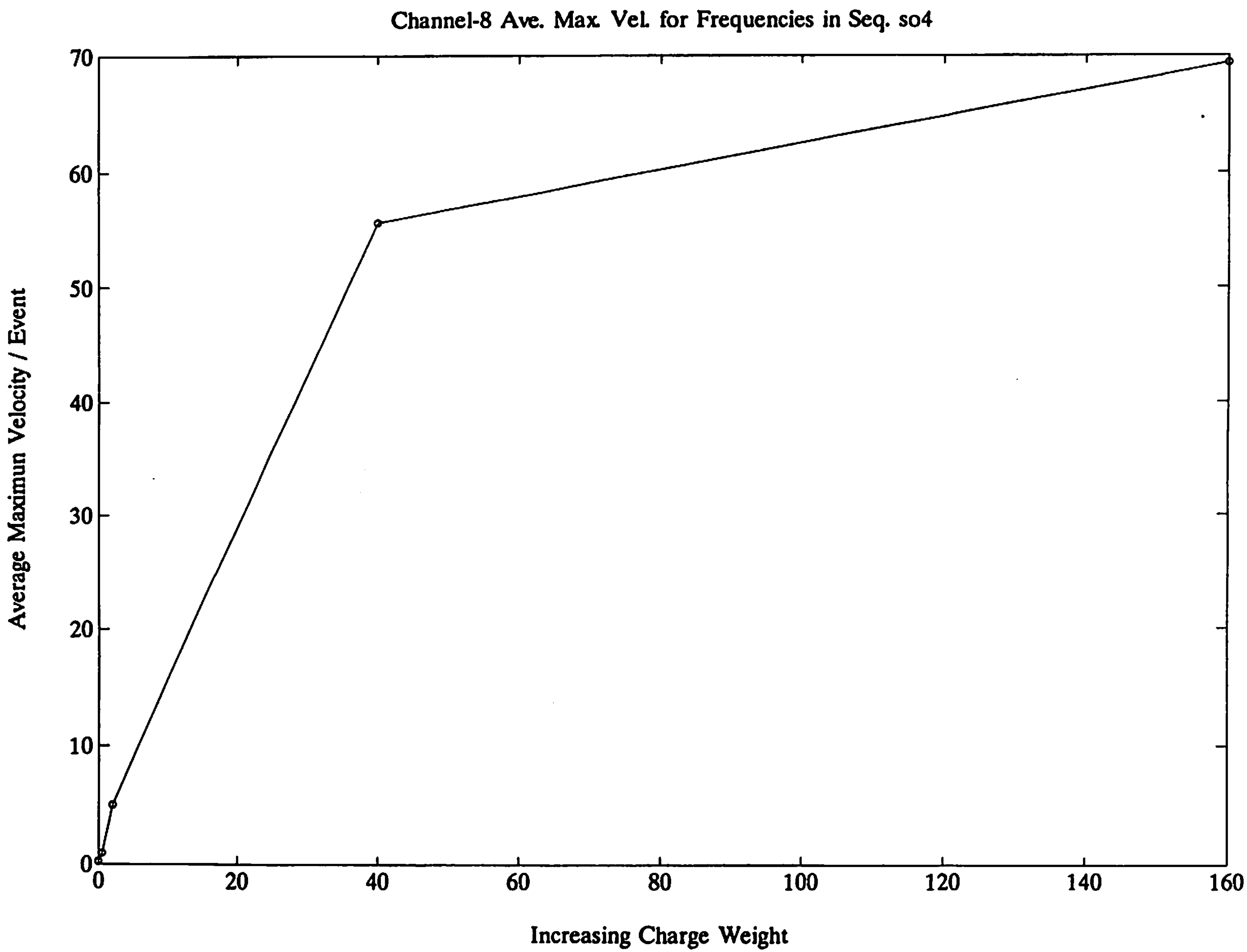

Ave. Normalized Max. Vel. for Longitudinal Frequencies in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
20
40
60
80
100
120
140
160

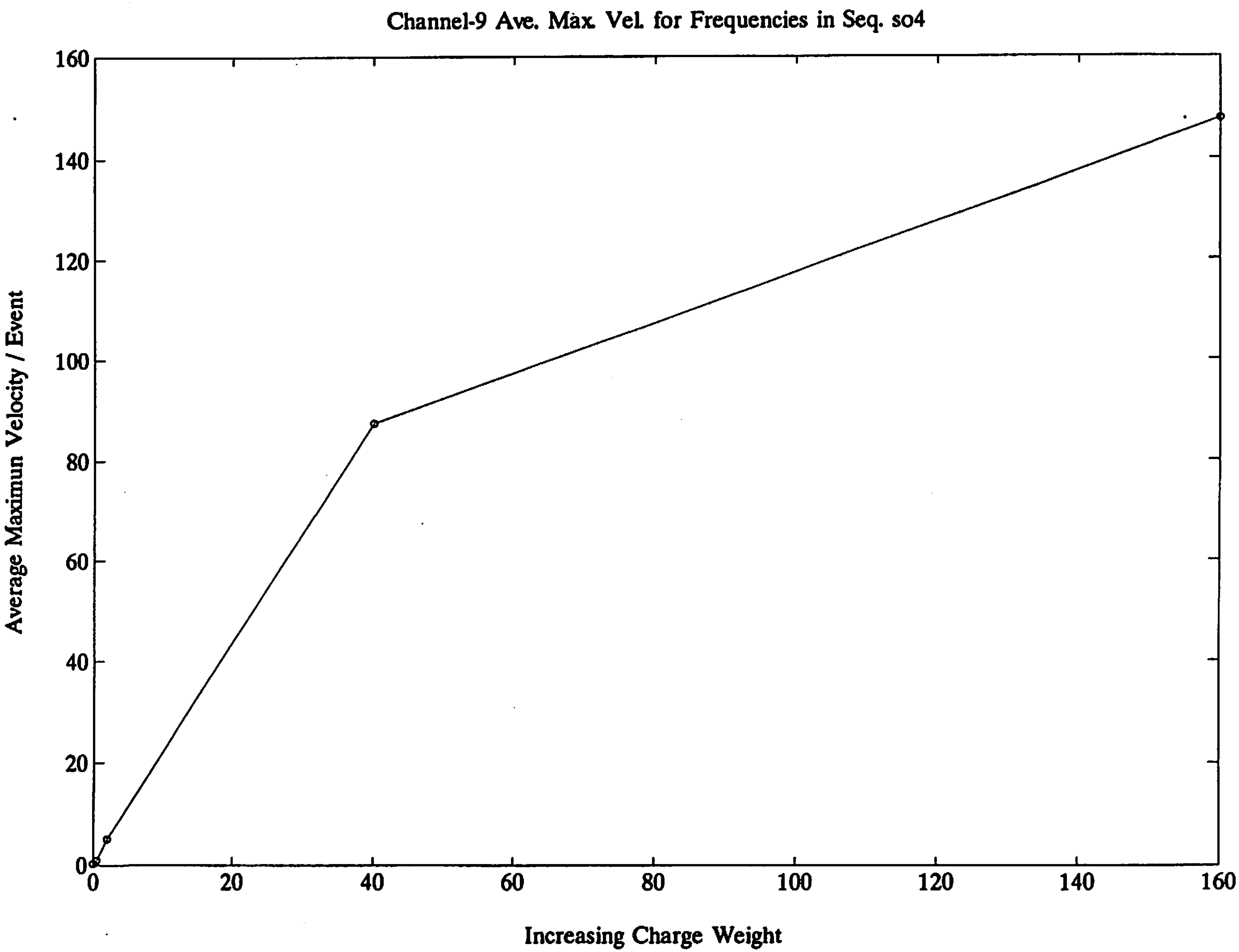

Ave. Normalized Max. Vel. for Longitudinal Frequencies in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
10
20
30
40
50
60
70
80
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

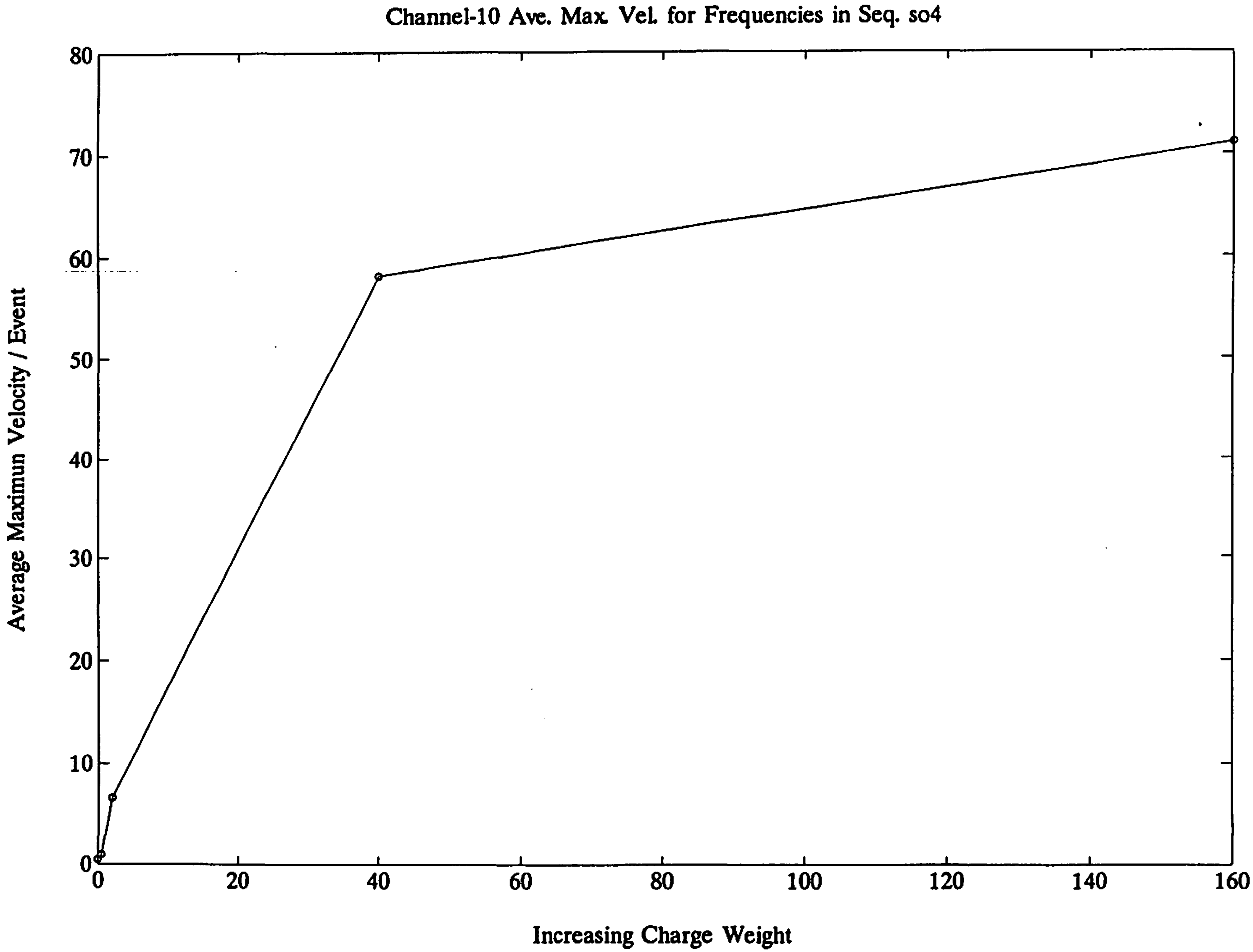

Ave. Normalized Max. Vel. for Transverse Frequencies in Seq. so4
Average Normalized Maximun Velocity
Charge Weight
0
20
40
60
80
100
120
140
160

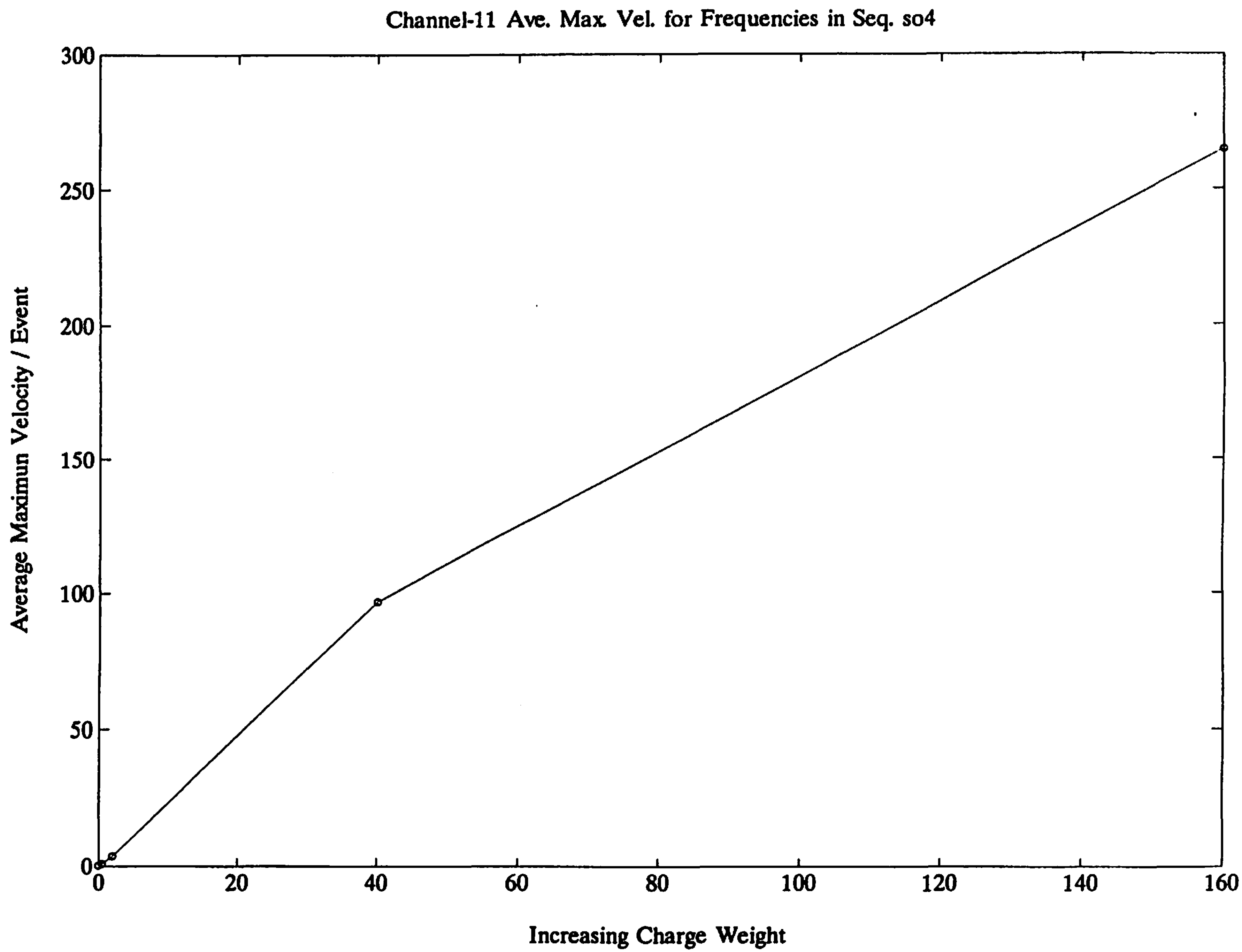


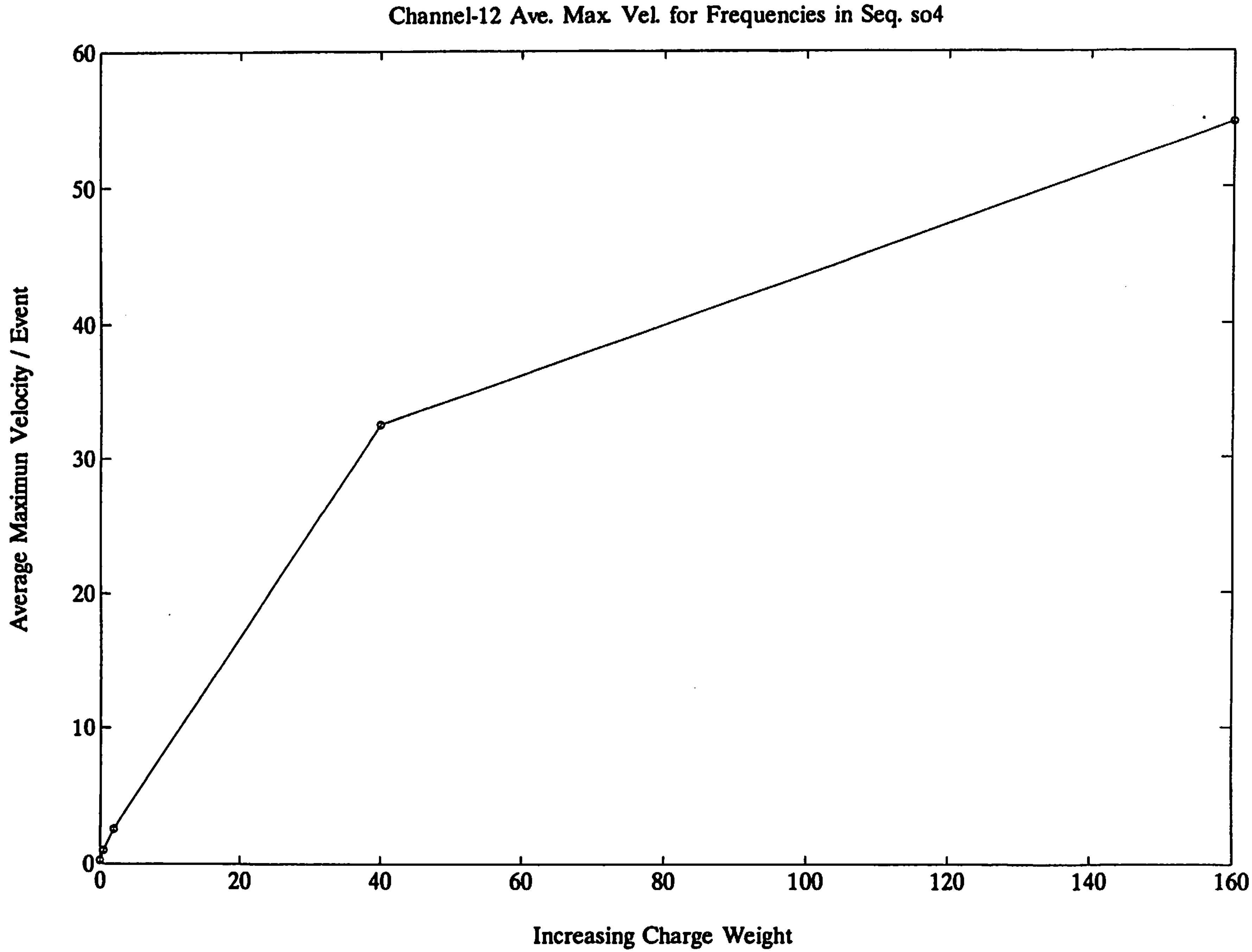
Ave. Normalized Max. Vel. for Transverse Frequencies in Seq. so4
Average Normalized Maximun Velocity
0
10
20
30
40
50
60
70
10-1
100
101
102
103
Charge Weight

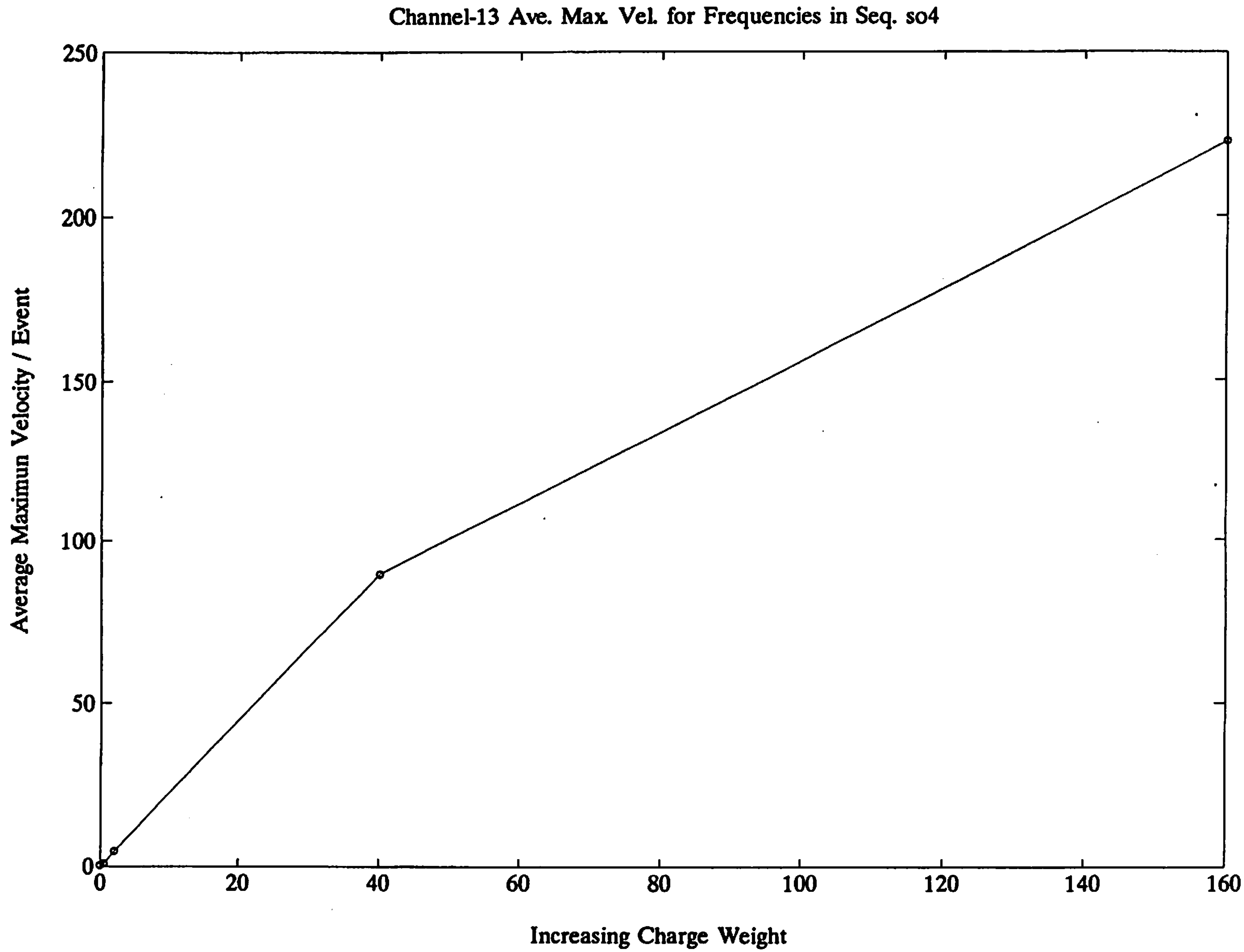

Channel-8 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160

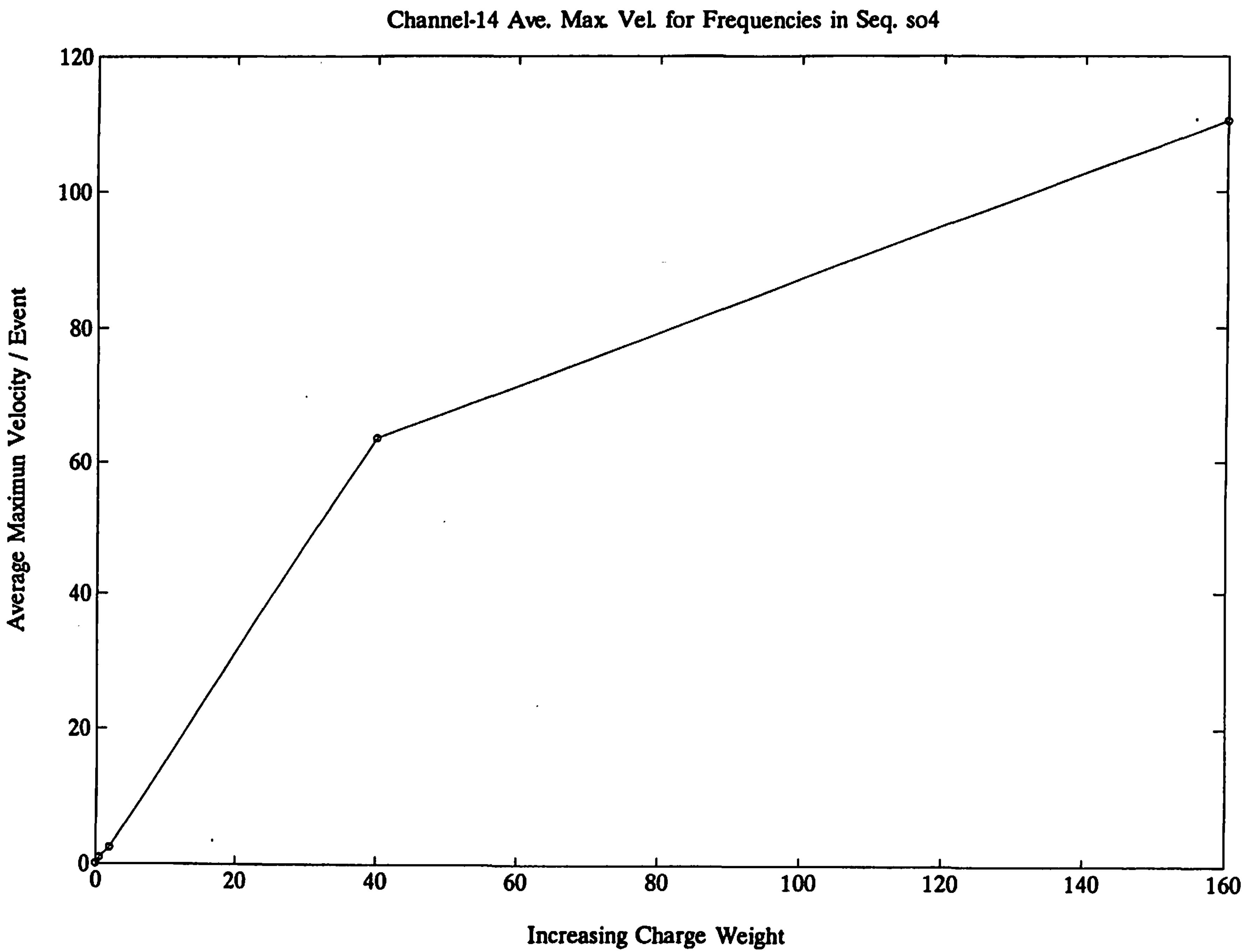

Channel-9 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

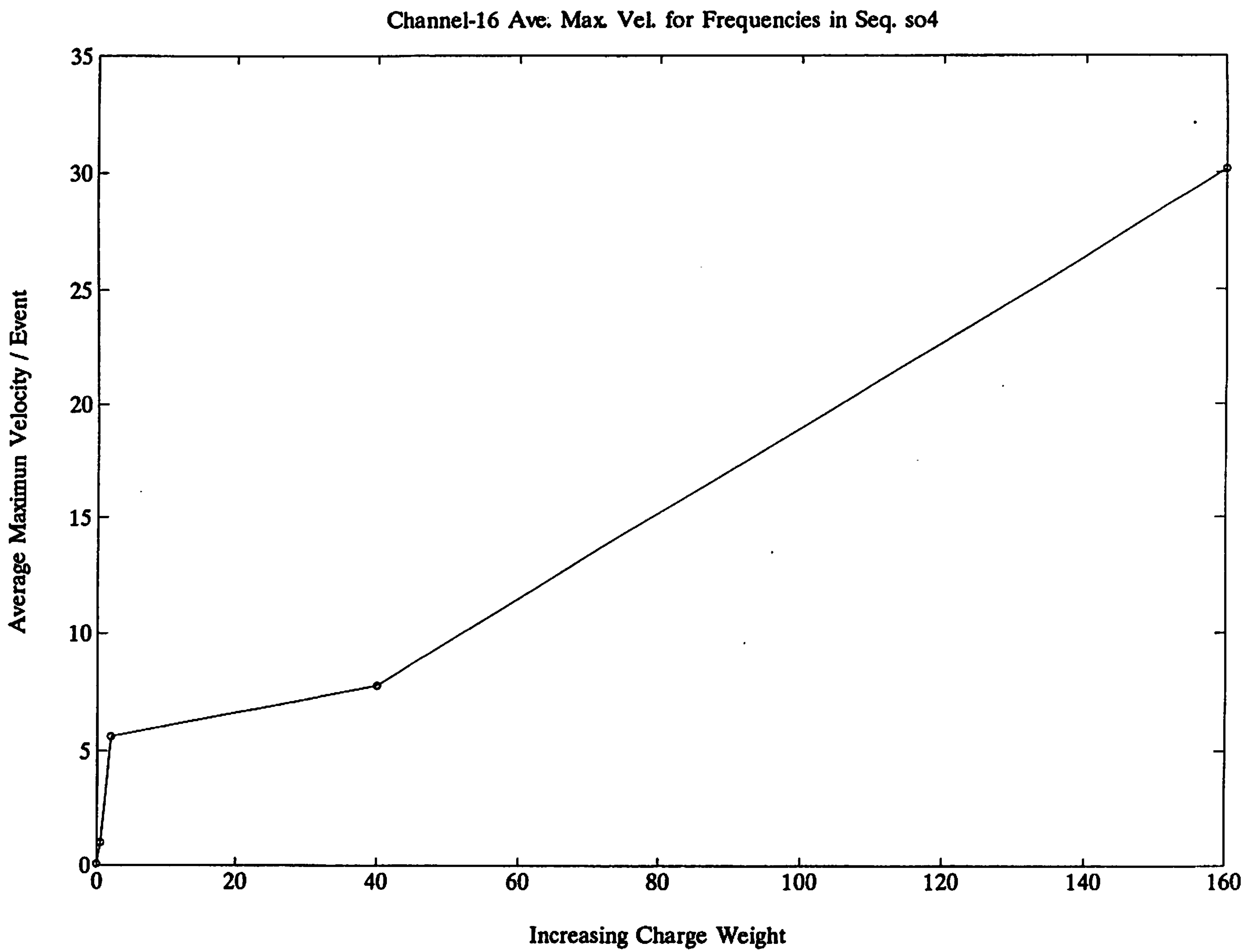

Channel-10 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160


Channel-11 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140
160

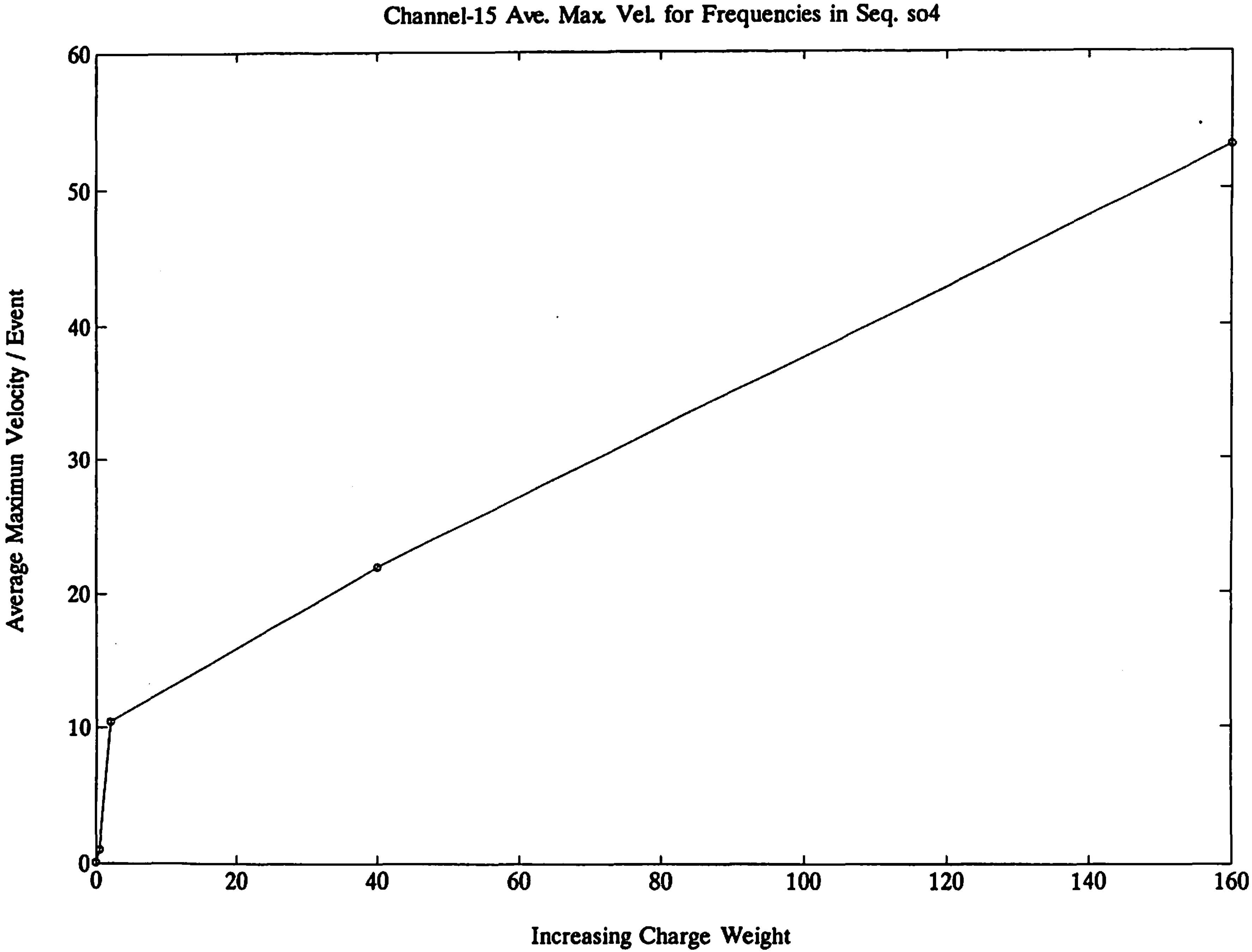

Channel-12 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160


Channel-13 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

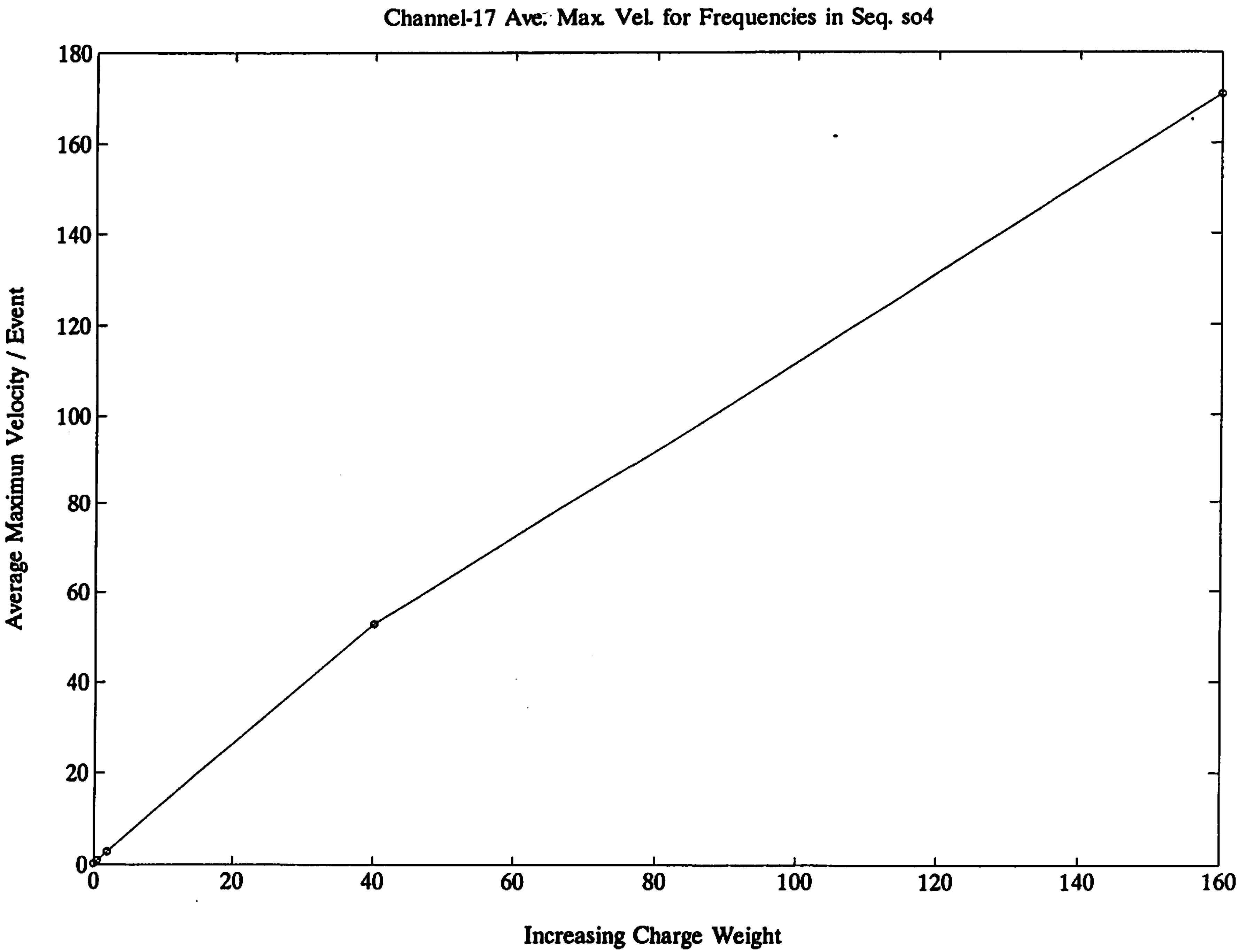

Channel-14 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

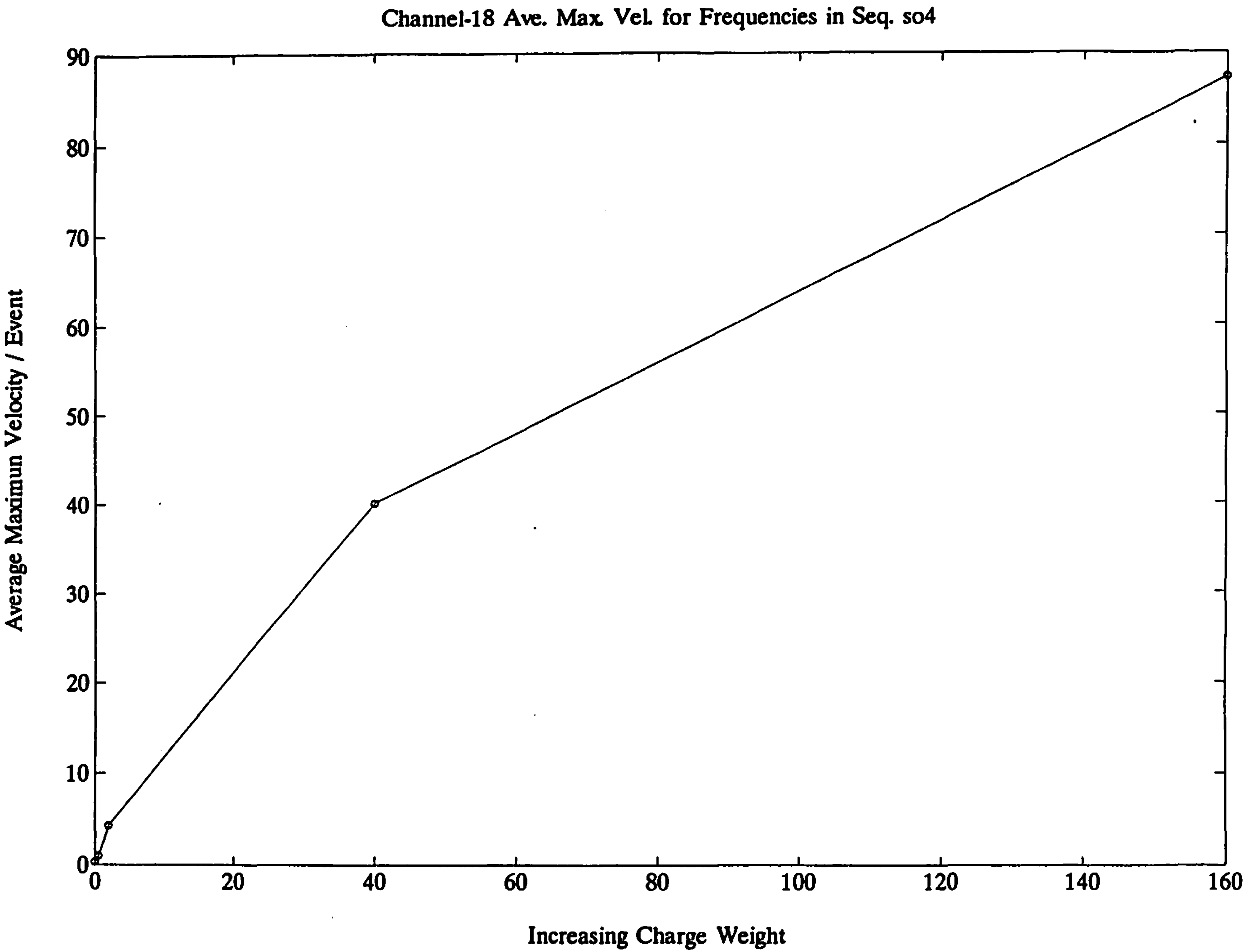


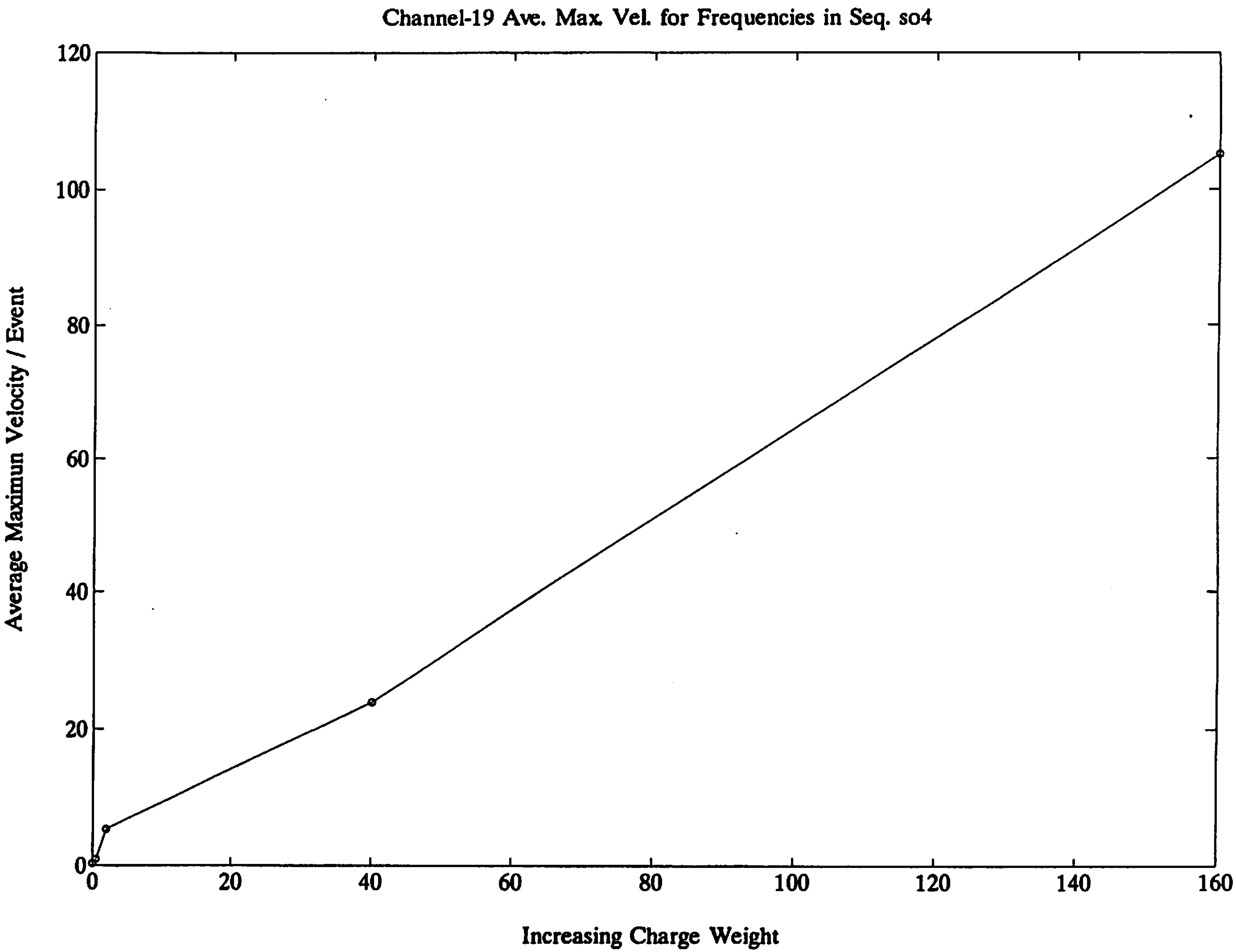
Channel-16 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160

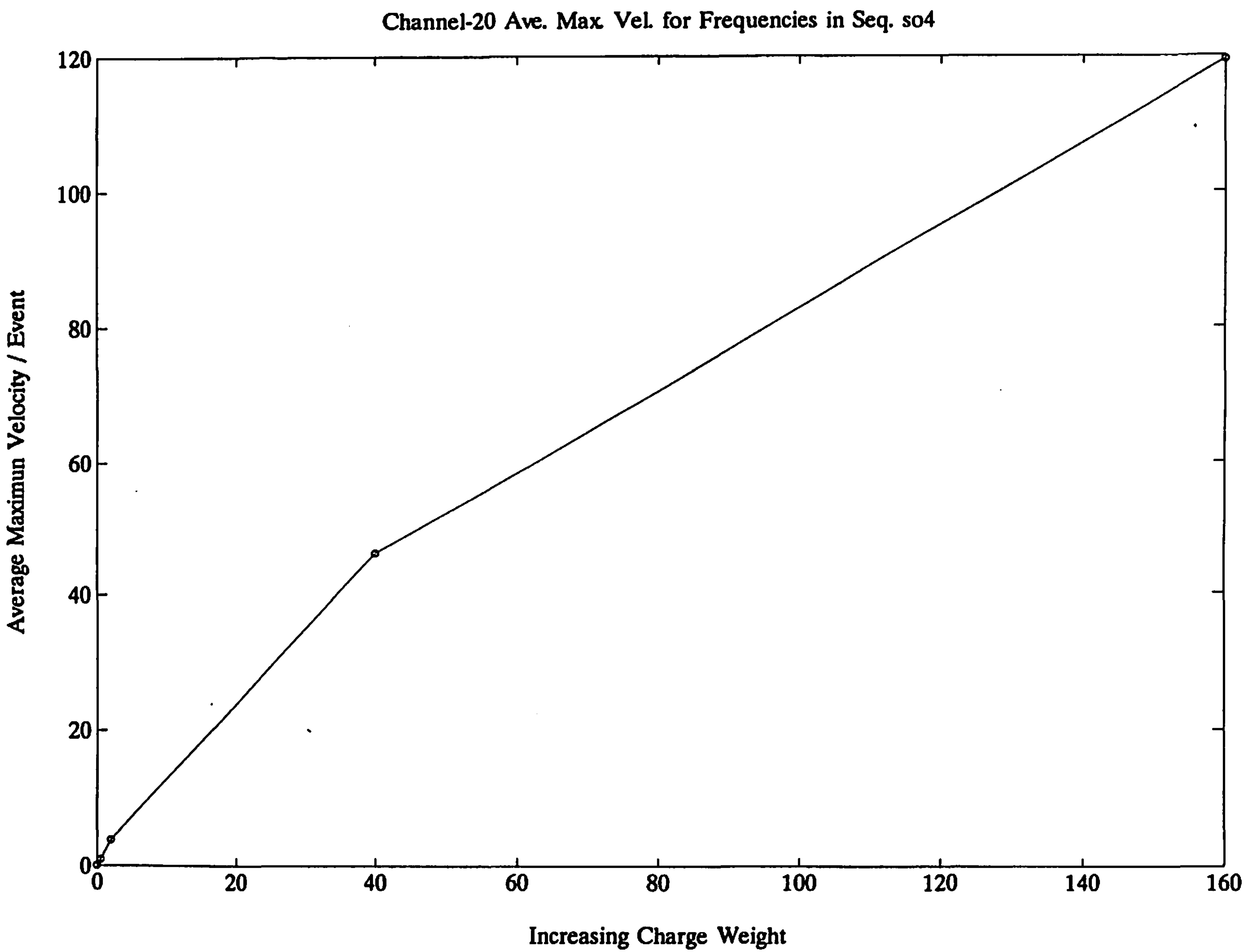


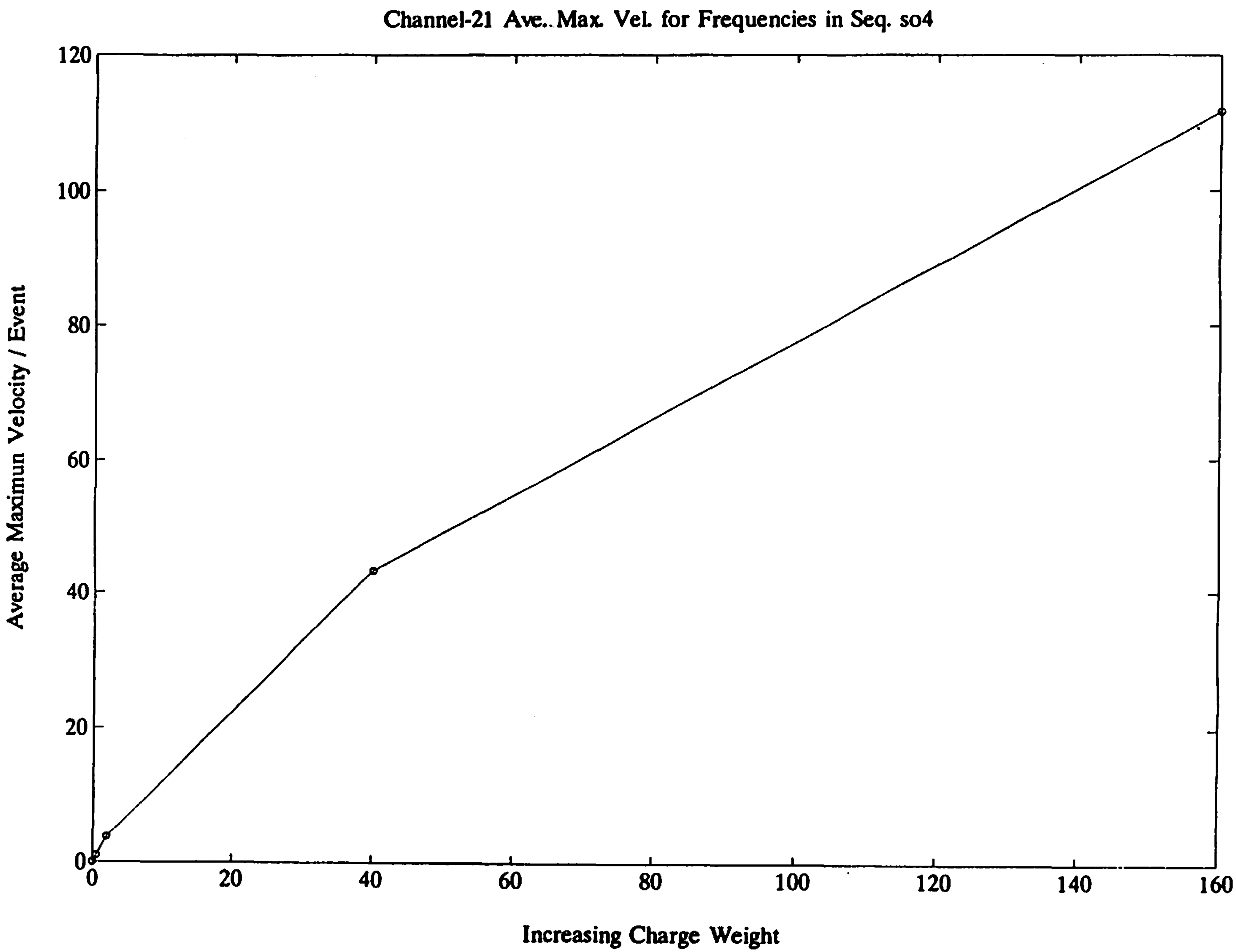
Channel-15 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160

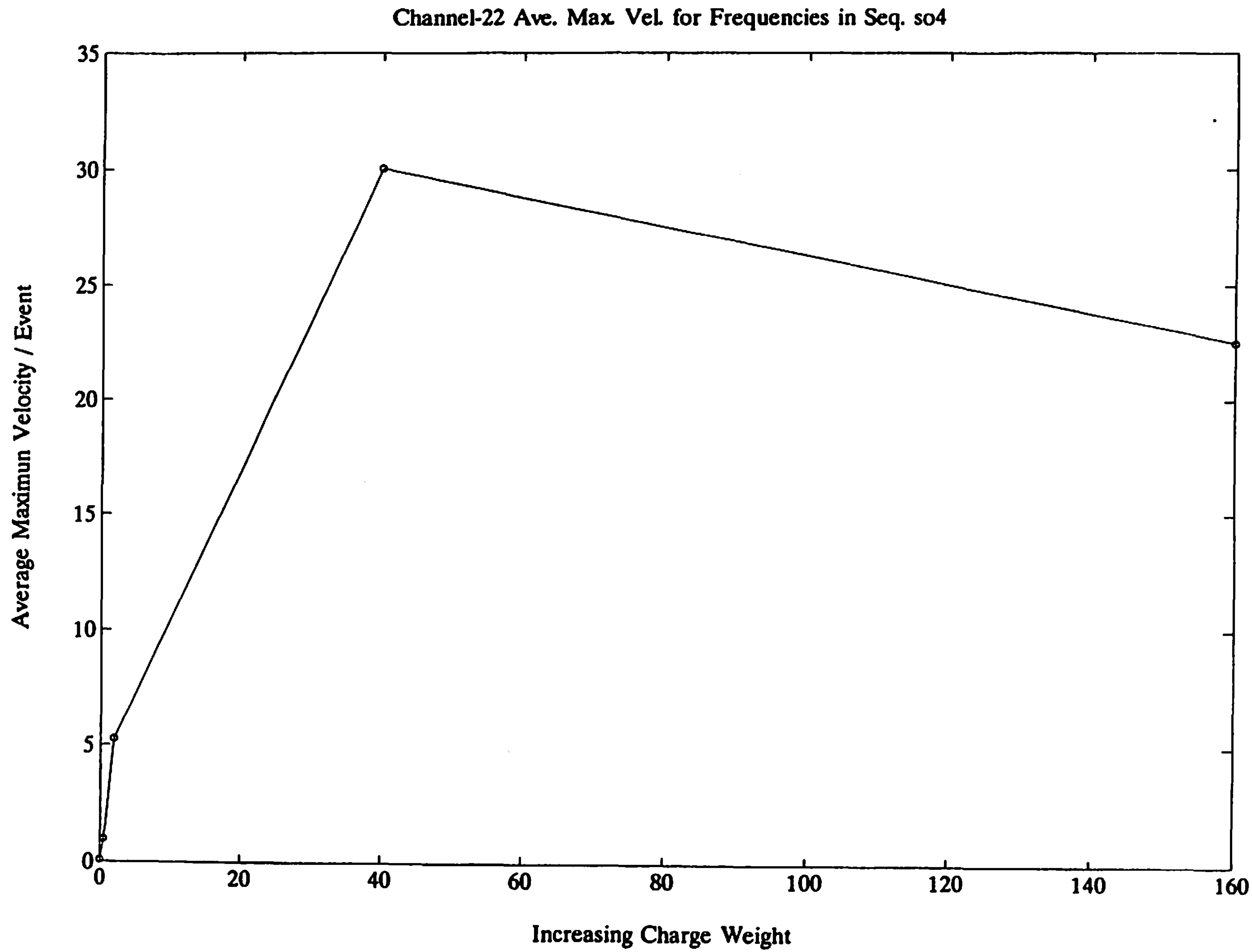

Channel-17 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
Increasing Charge Weight


Channel-18 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160

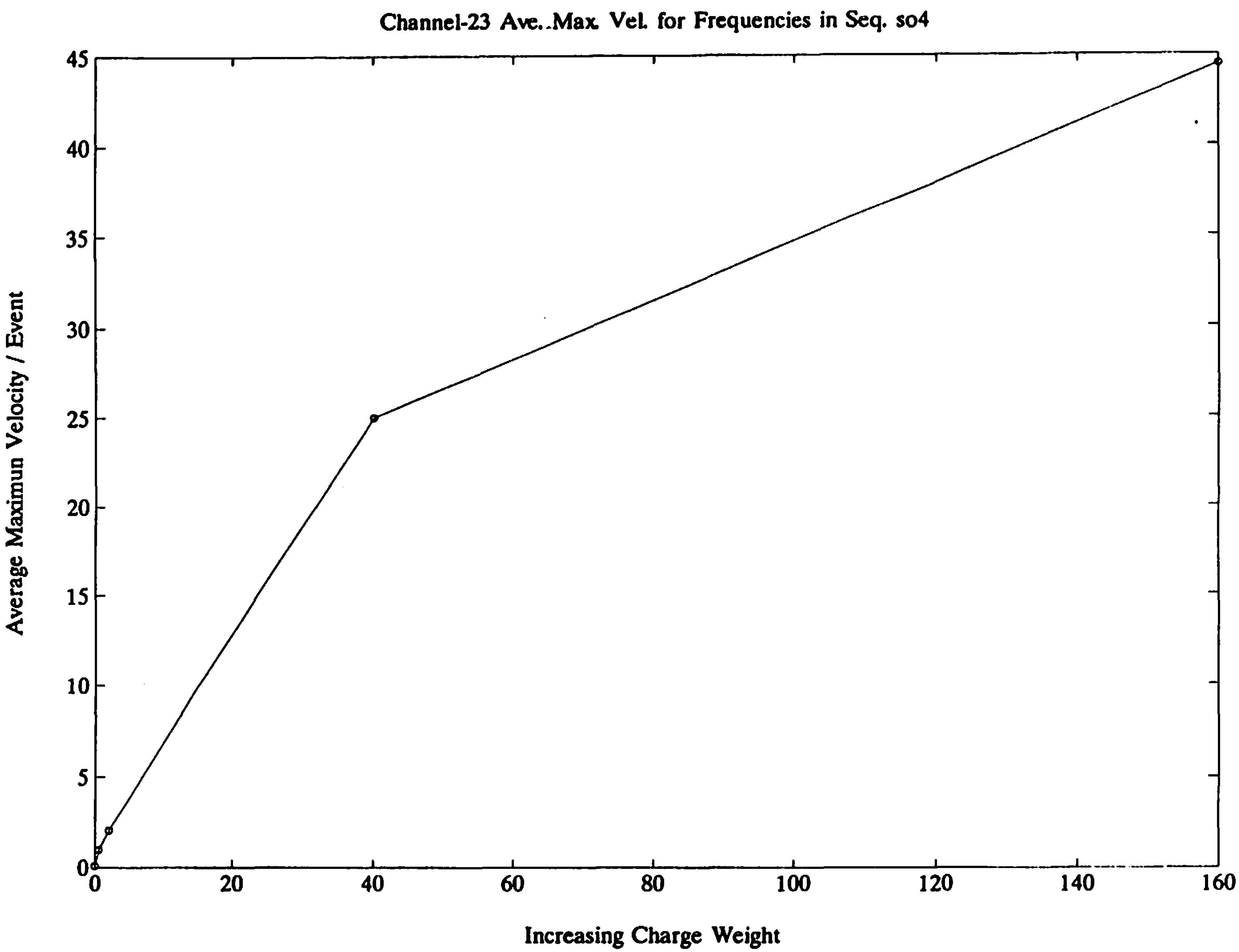

Channel-19 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

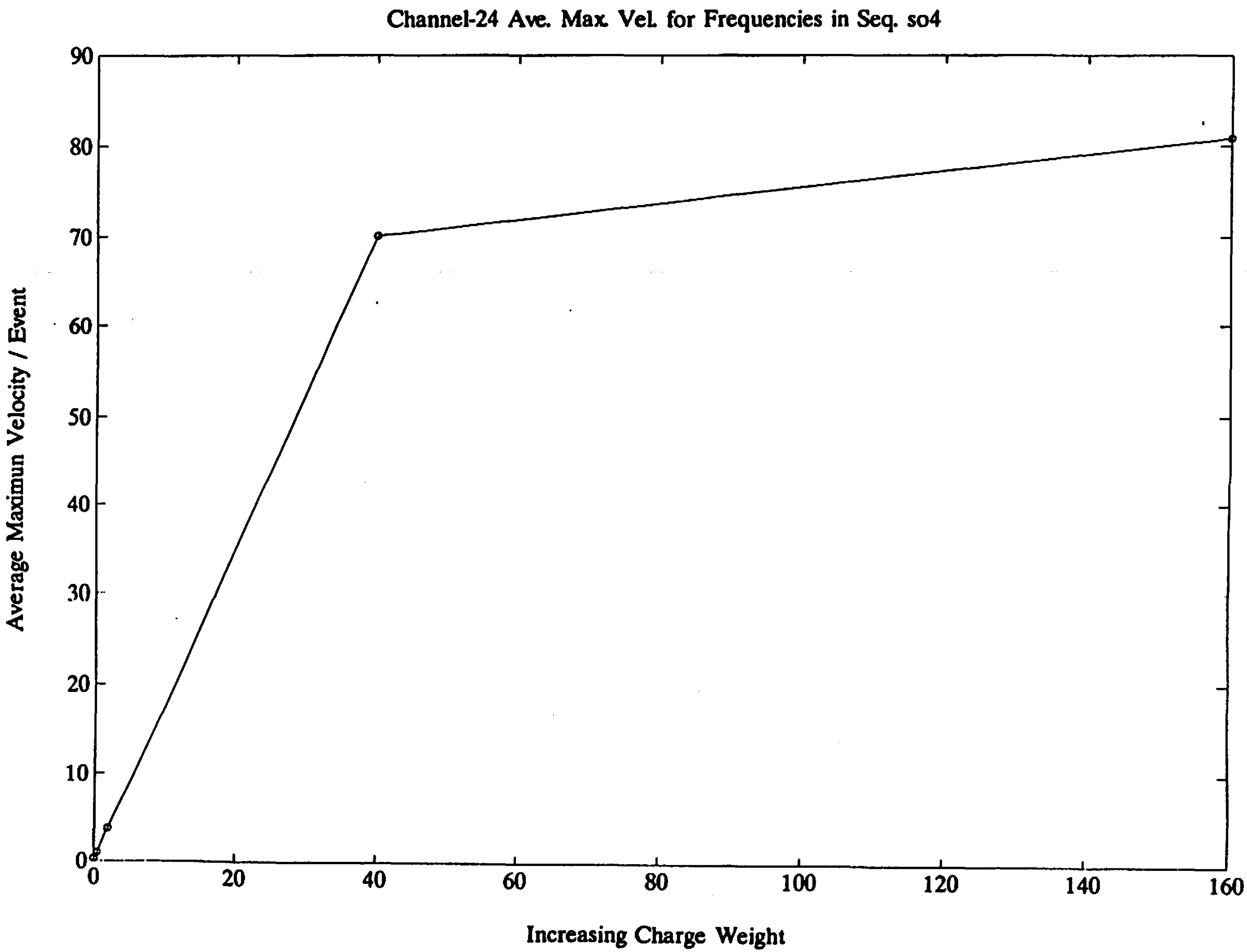

Channel-20 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160
0
20
40
60
80
100
120


Channel-21 Ave..Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
0
20
40
60
80
100
120
140
160

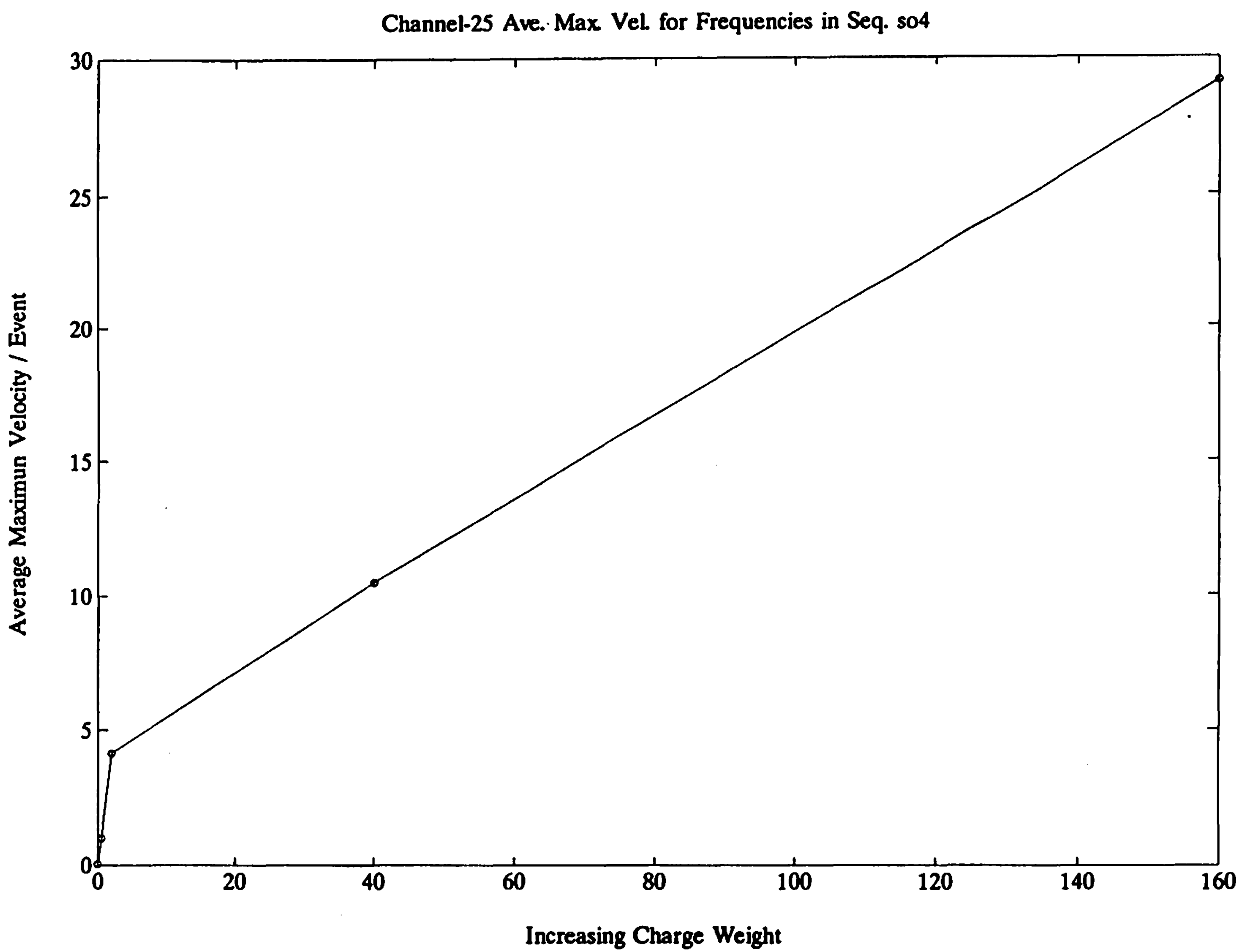


Channel-22 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160

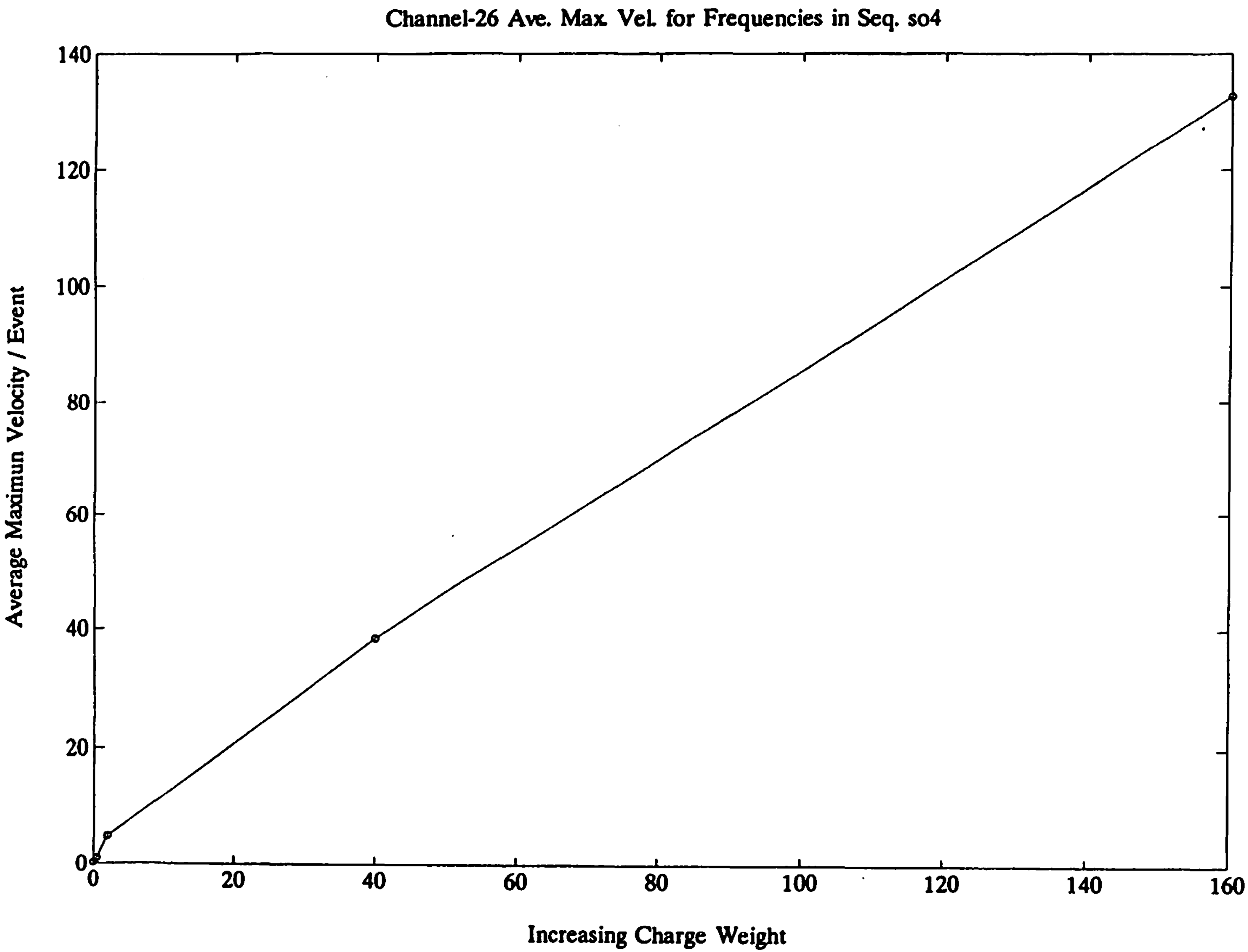

Channel-23 Ave..Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160

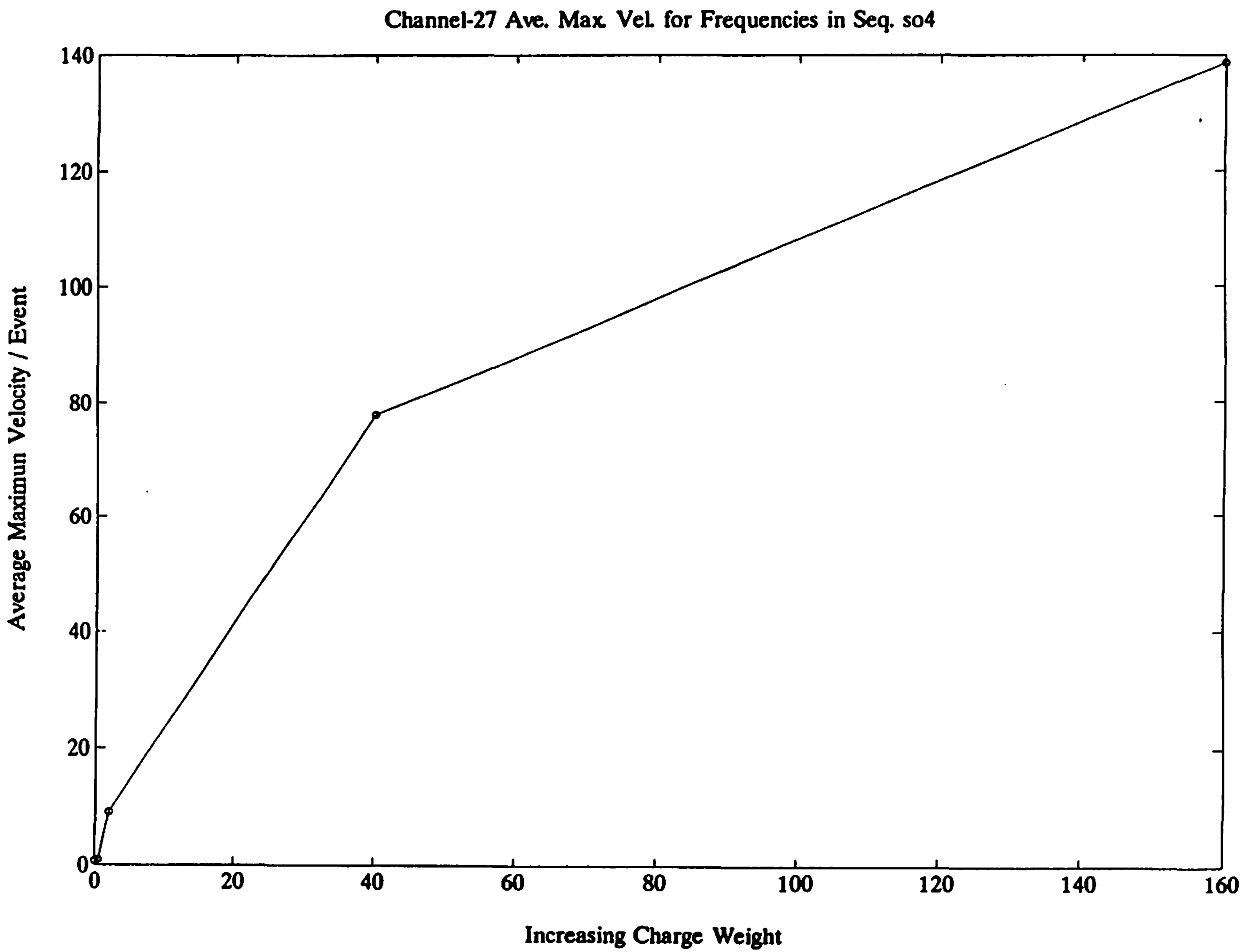


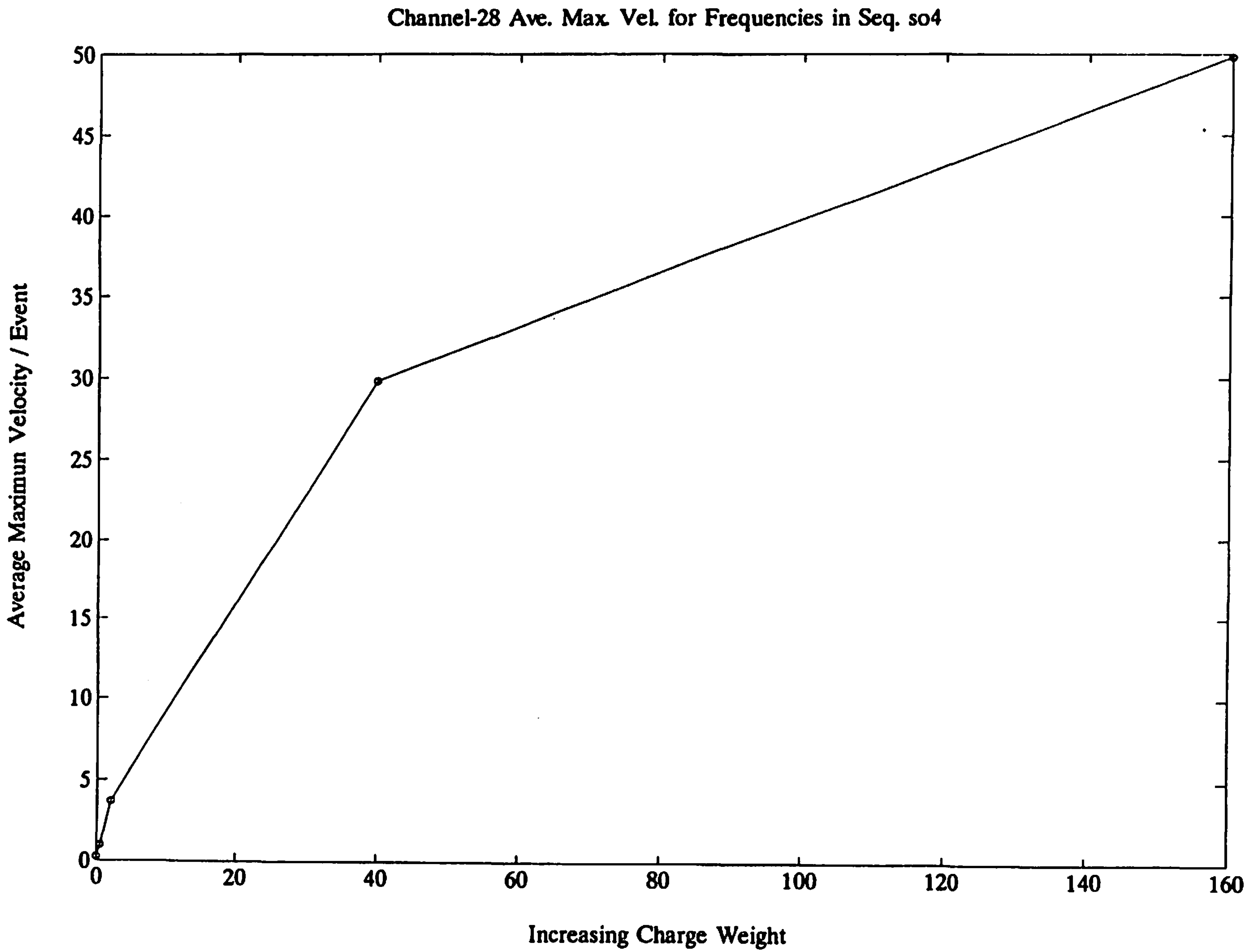
Channel-24 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160



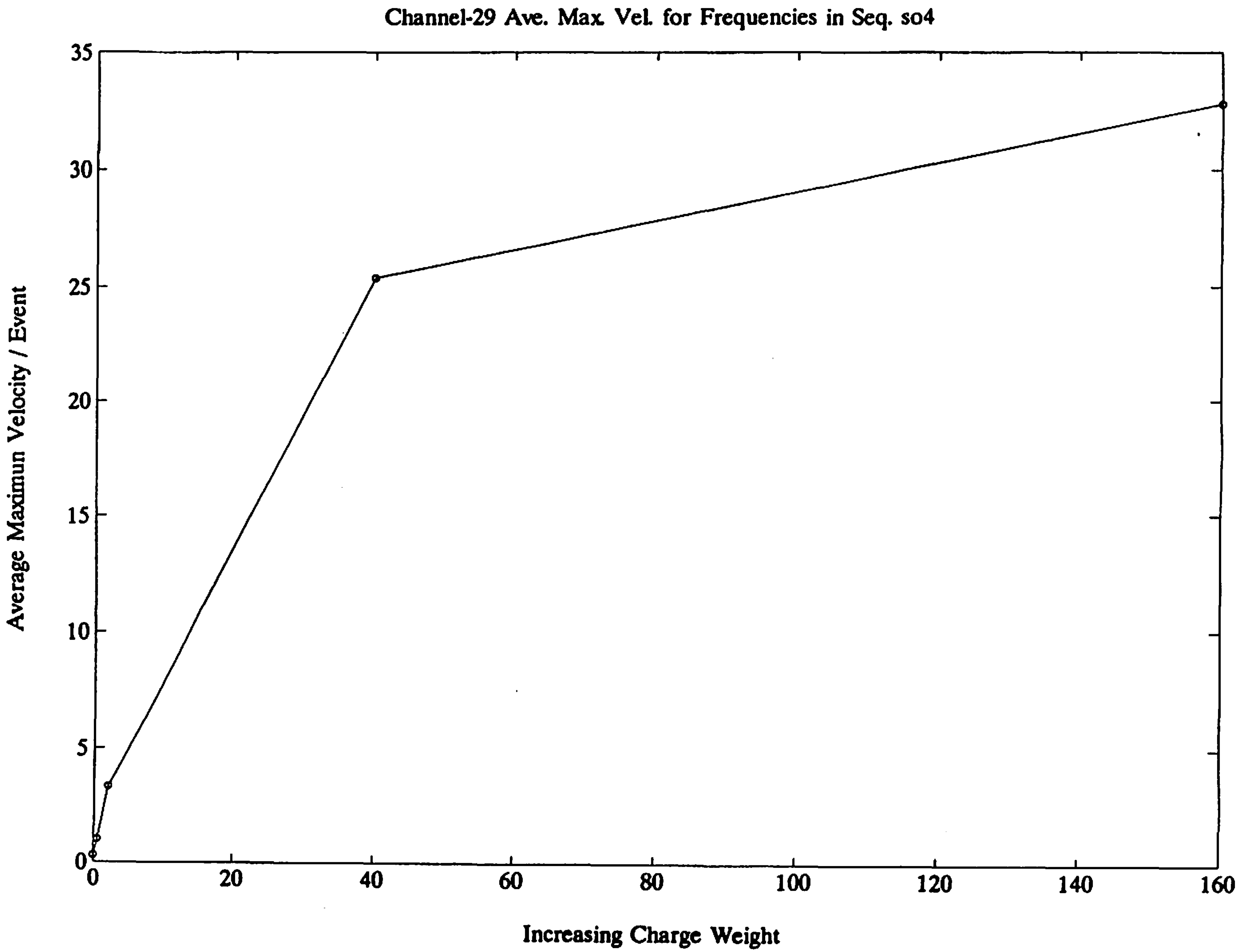
Channel-25 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
Increasing Charge Weight

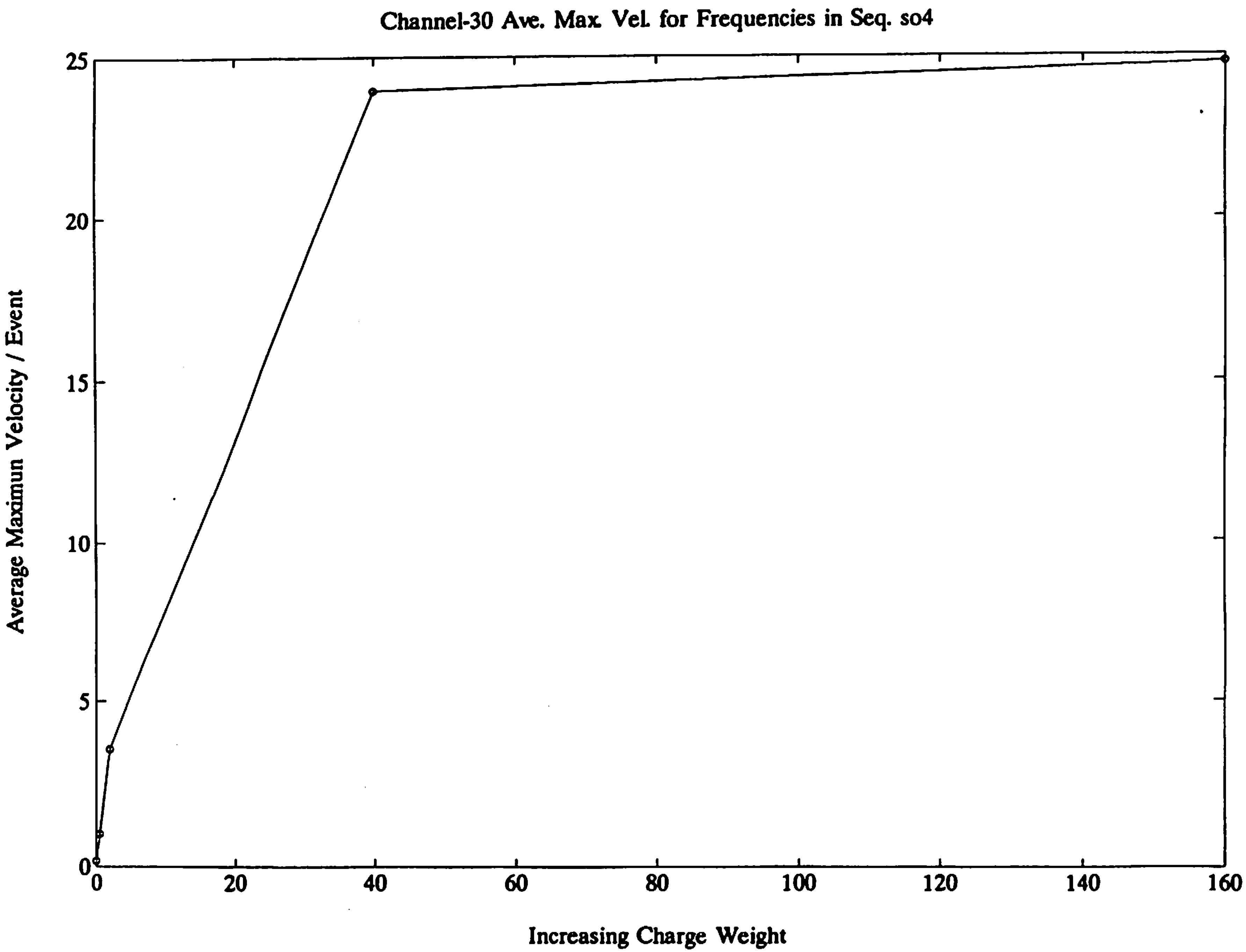

Channel-26 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

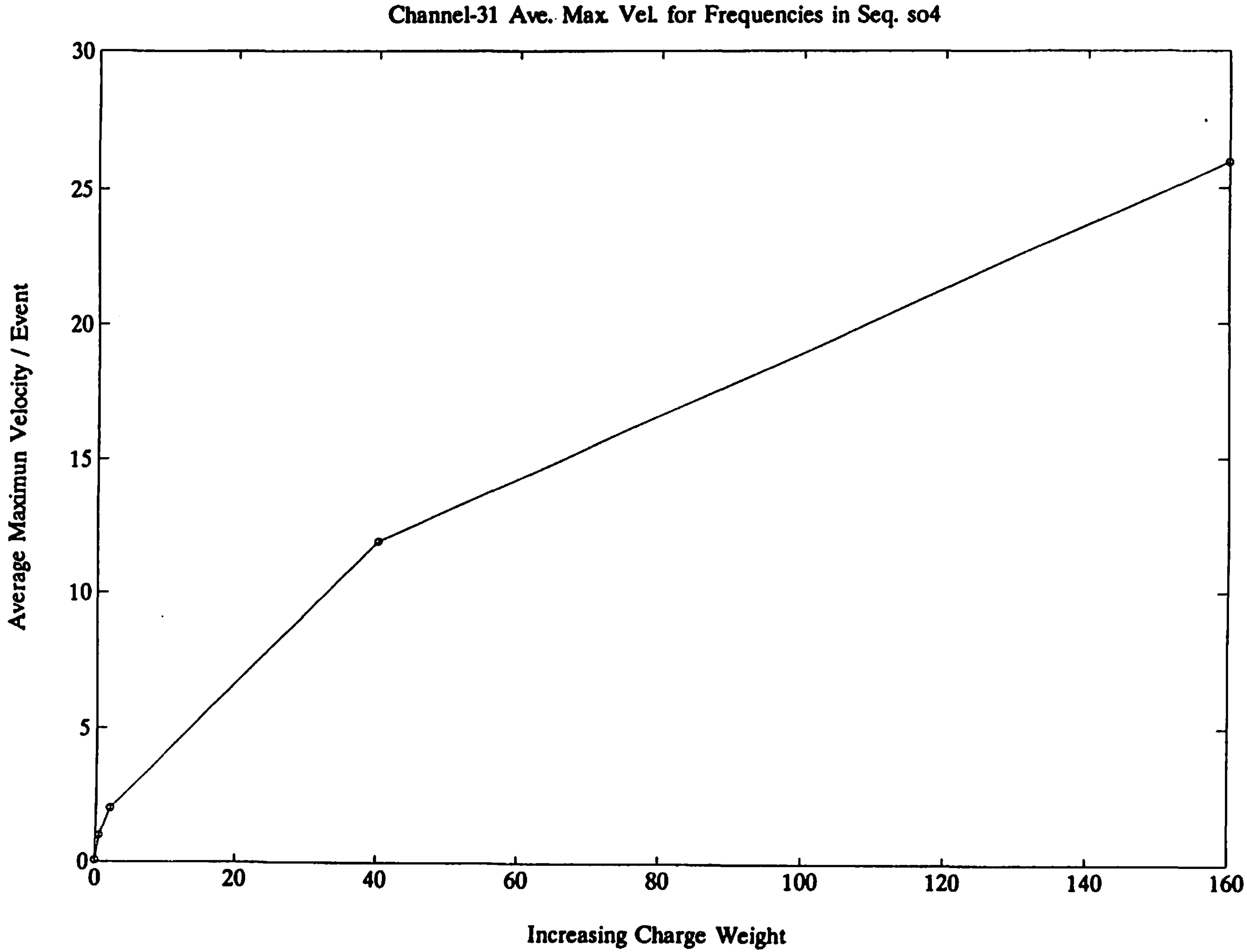

Channel-27 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
20
40
60
80
100
120
140
160

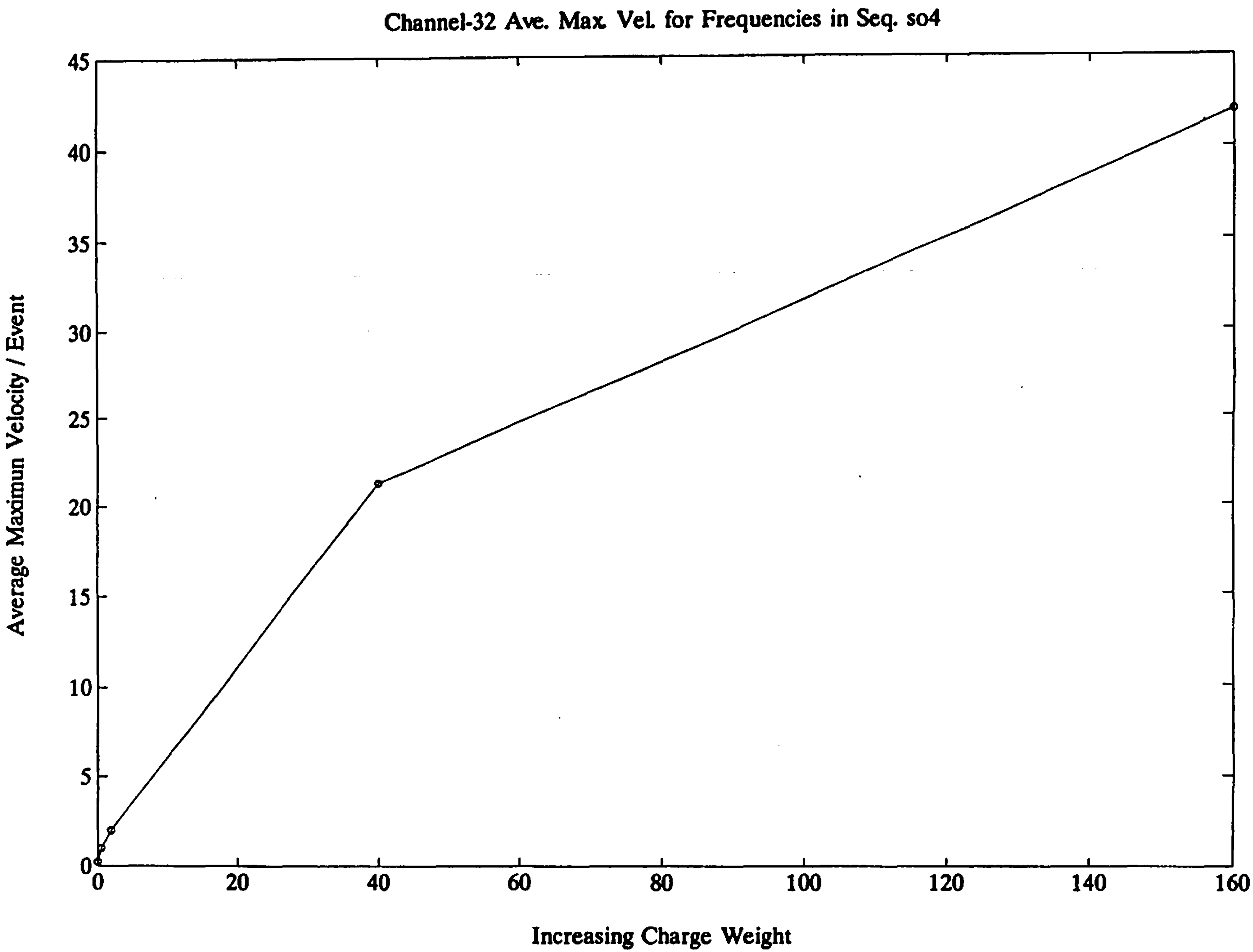


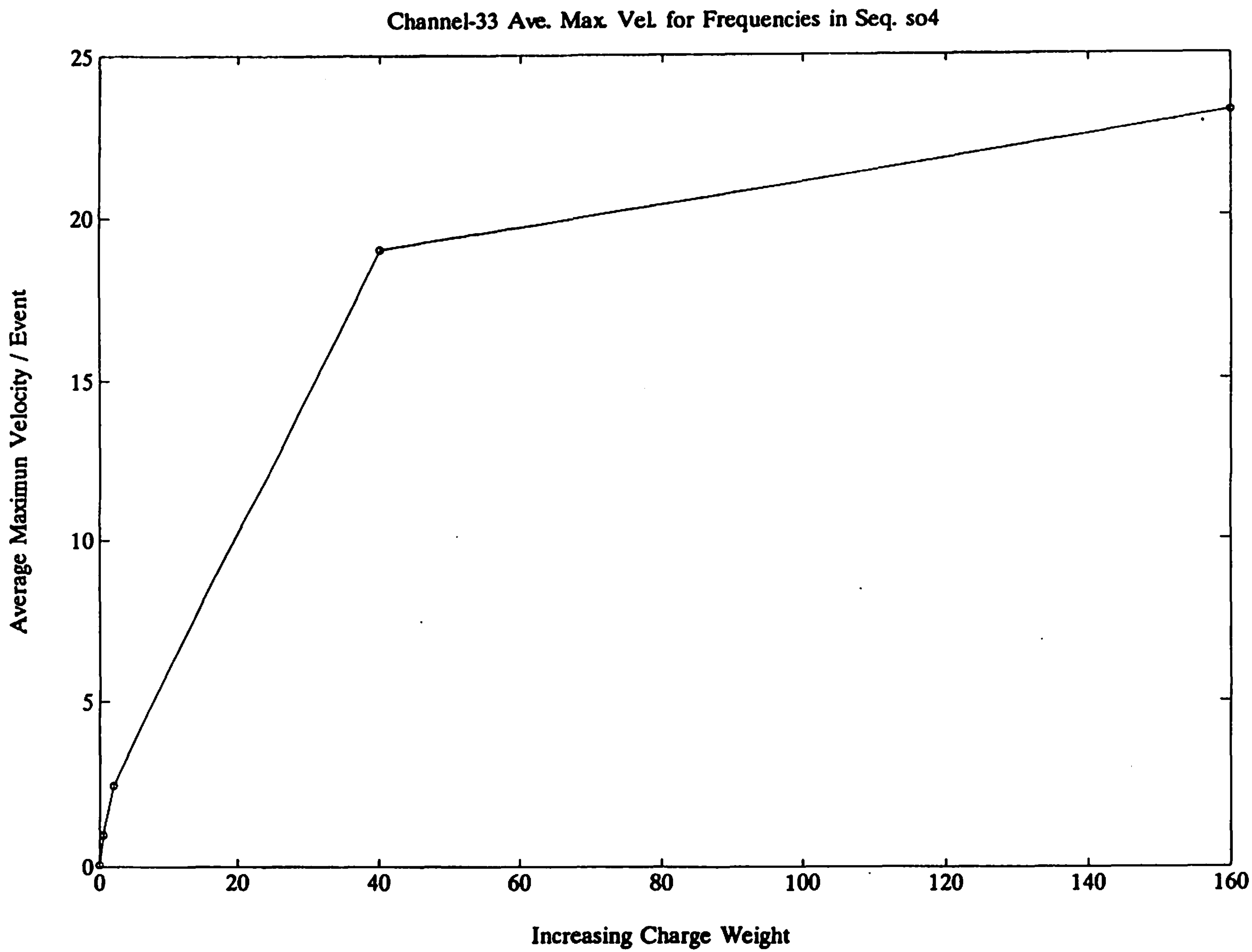
Channel-28 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160

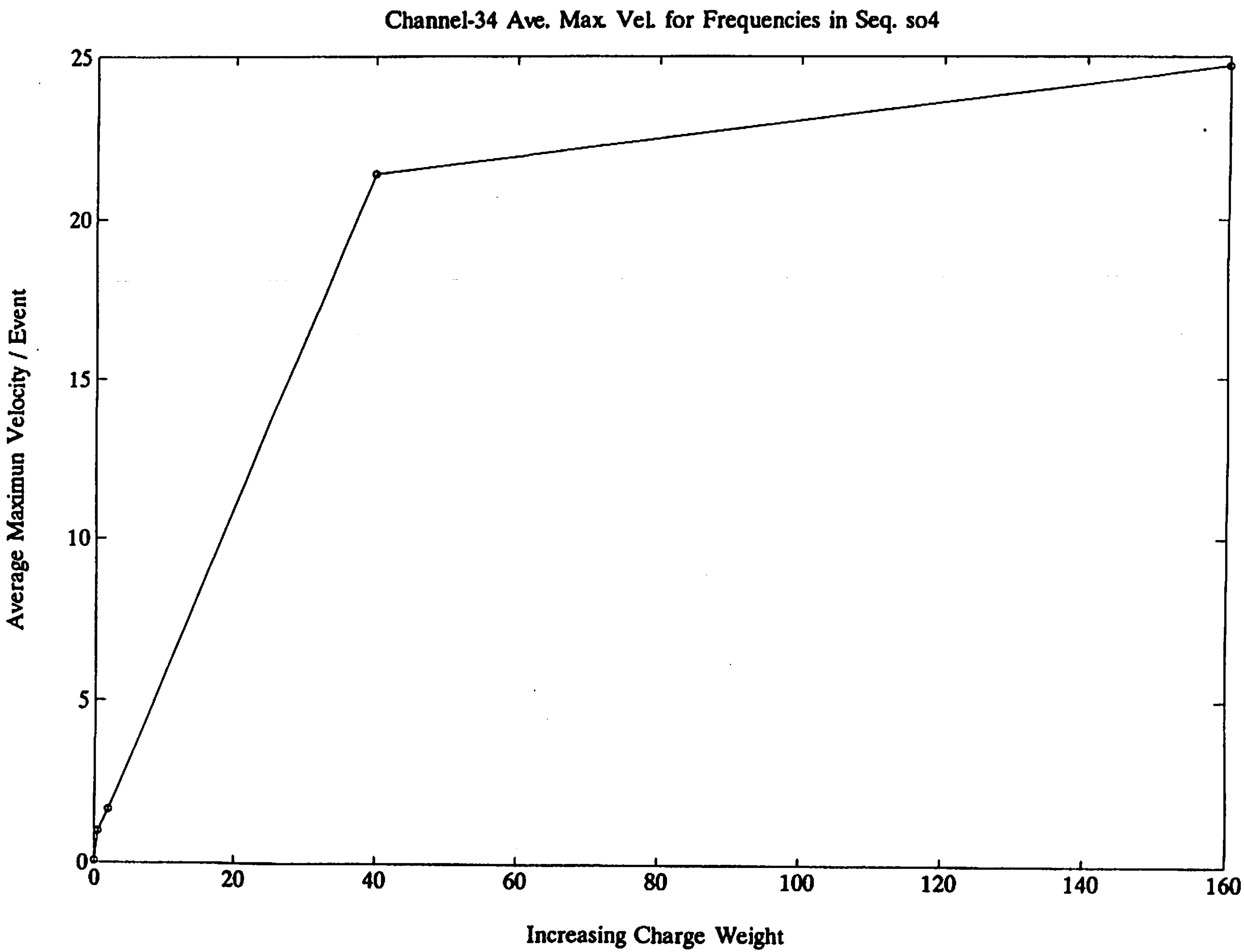

Channel-29 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160


Channel-30 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160

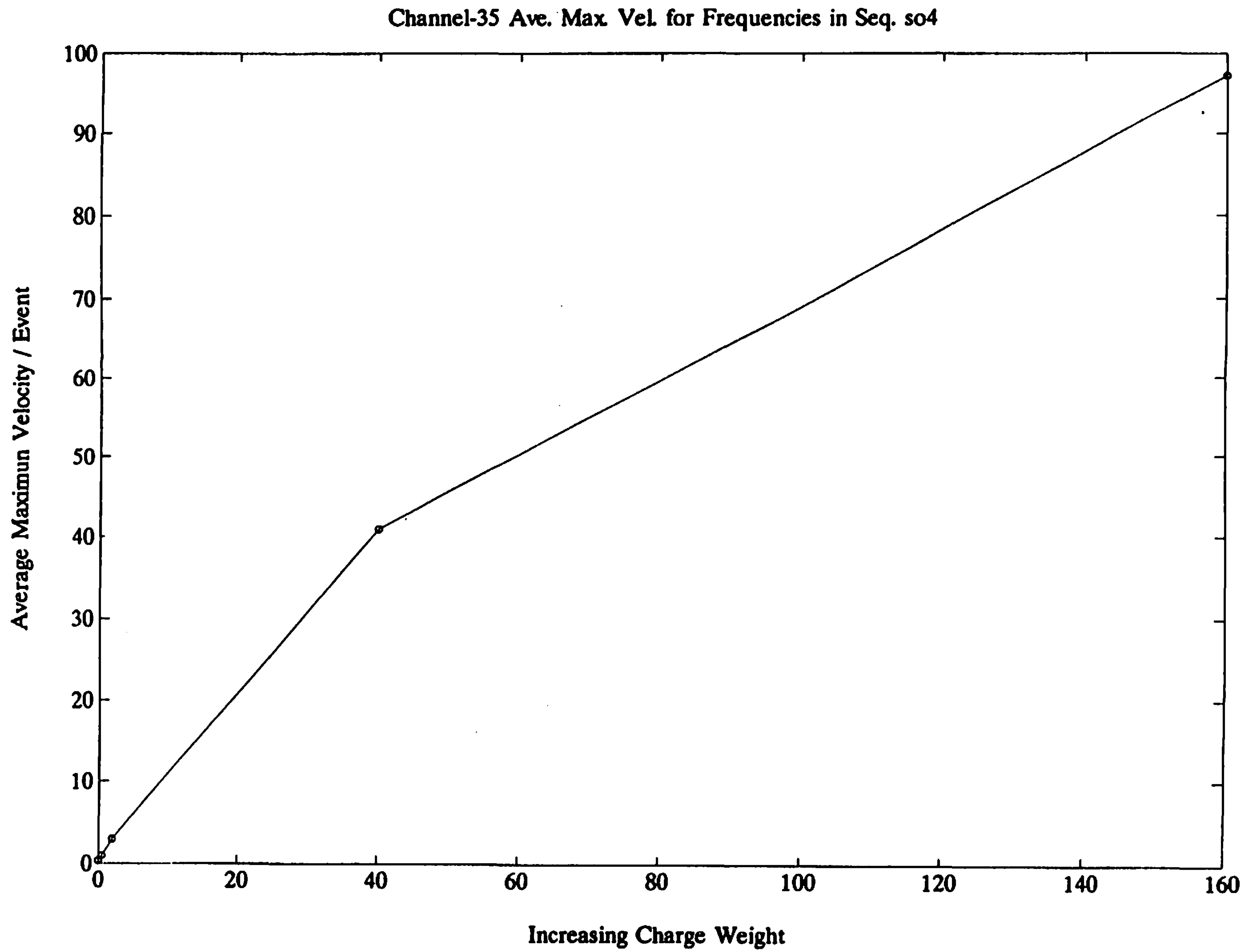

Channel-31 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160

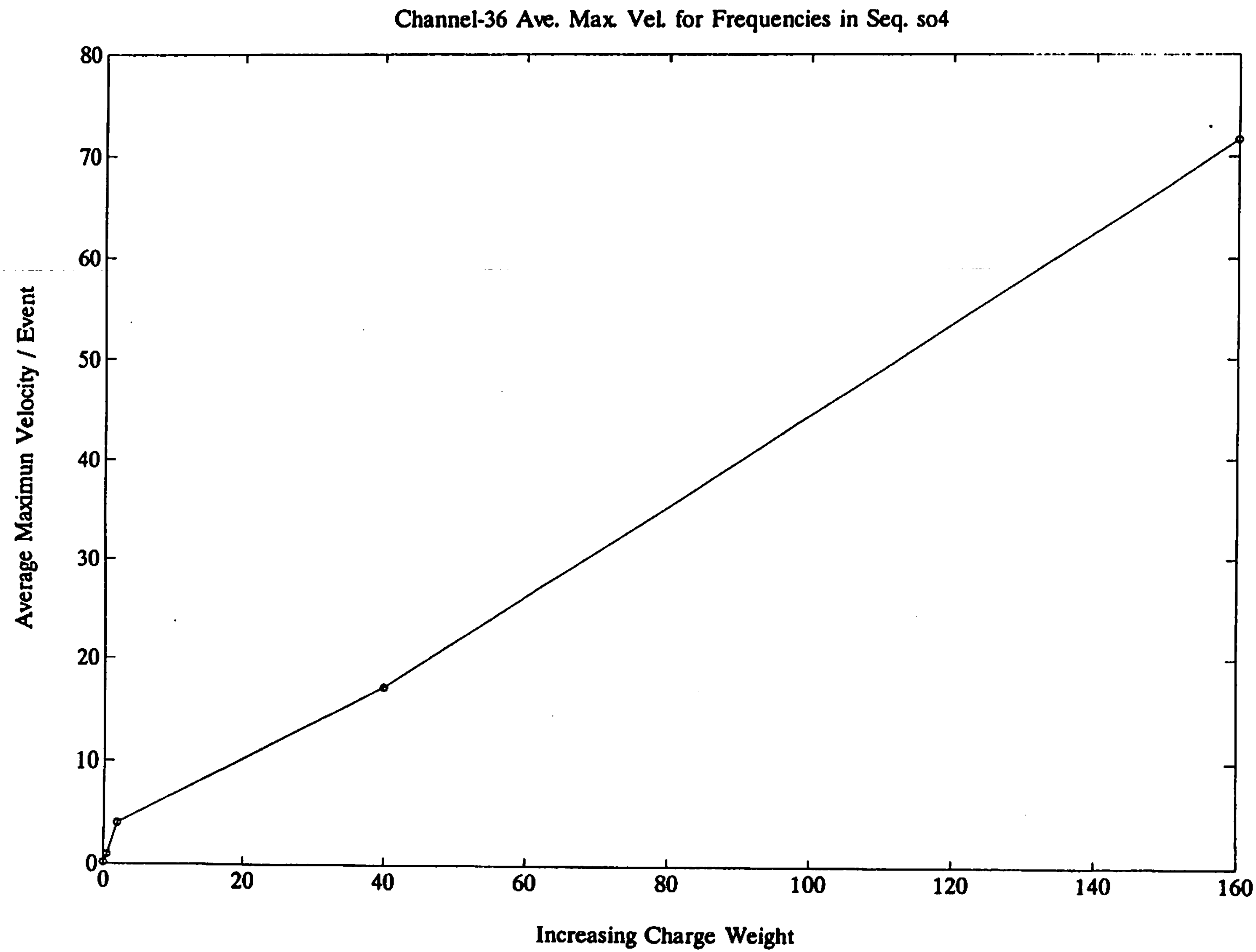

Channel-32 Ave. Max. Vel. for Frequencies in Seq. so4
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160
Average Maximun Velocity / Event
Increasing Charge Weight

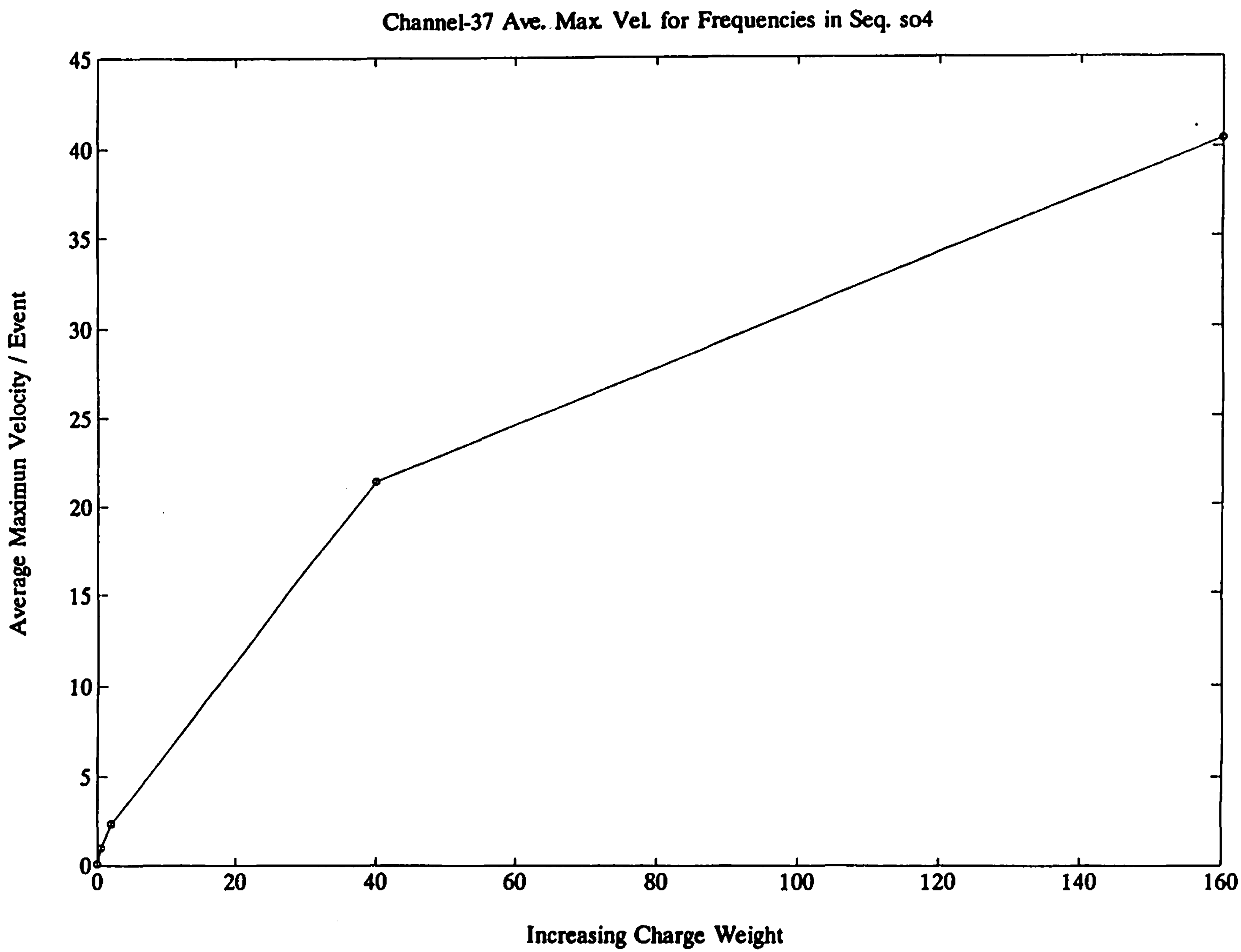

Channel-33 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160

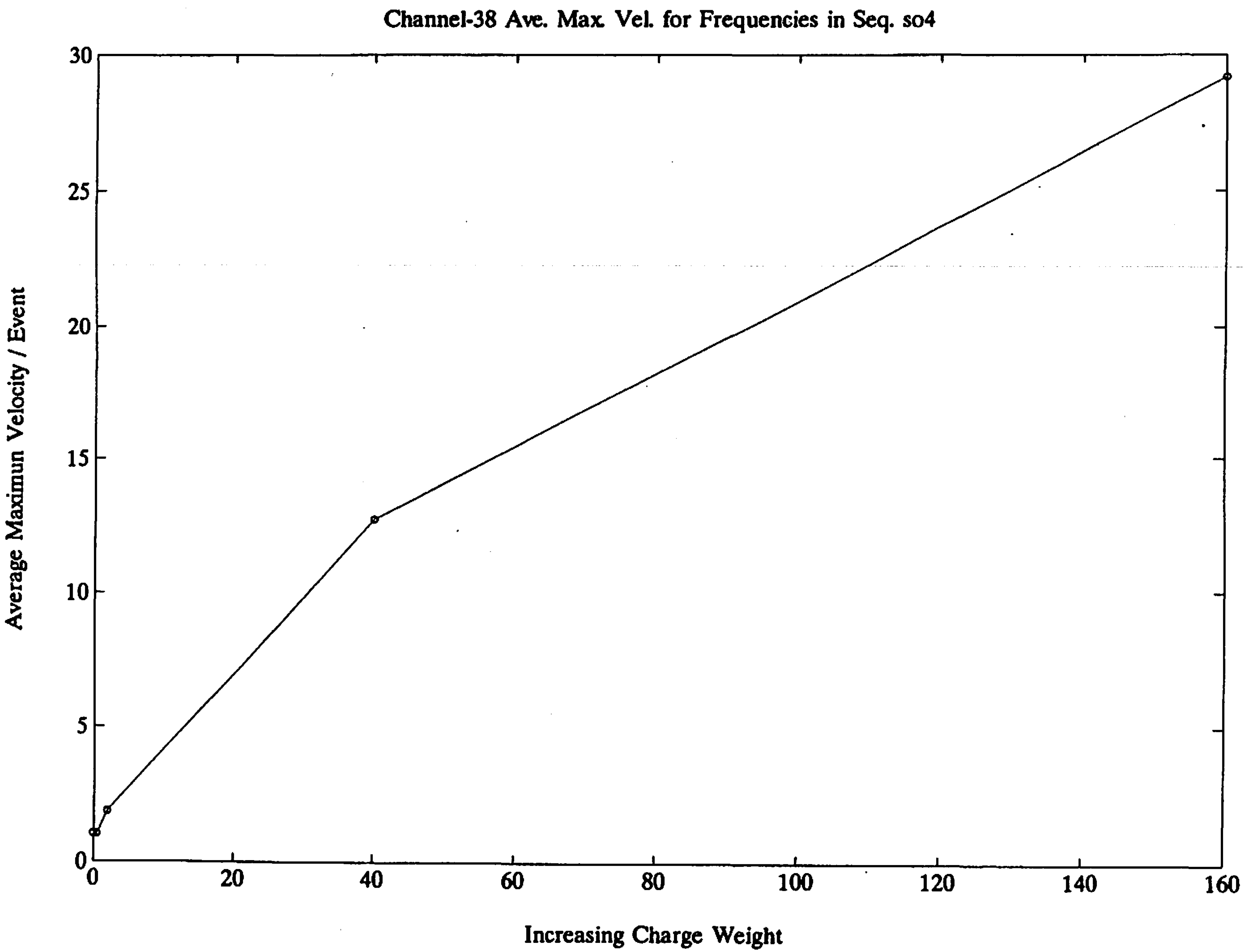


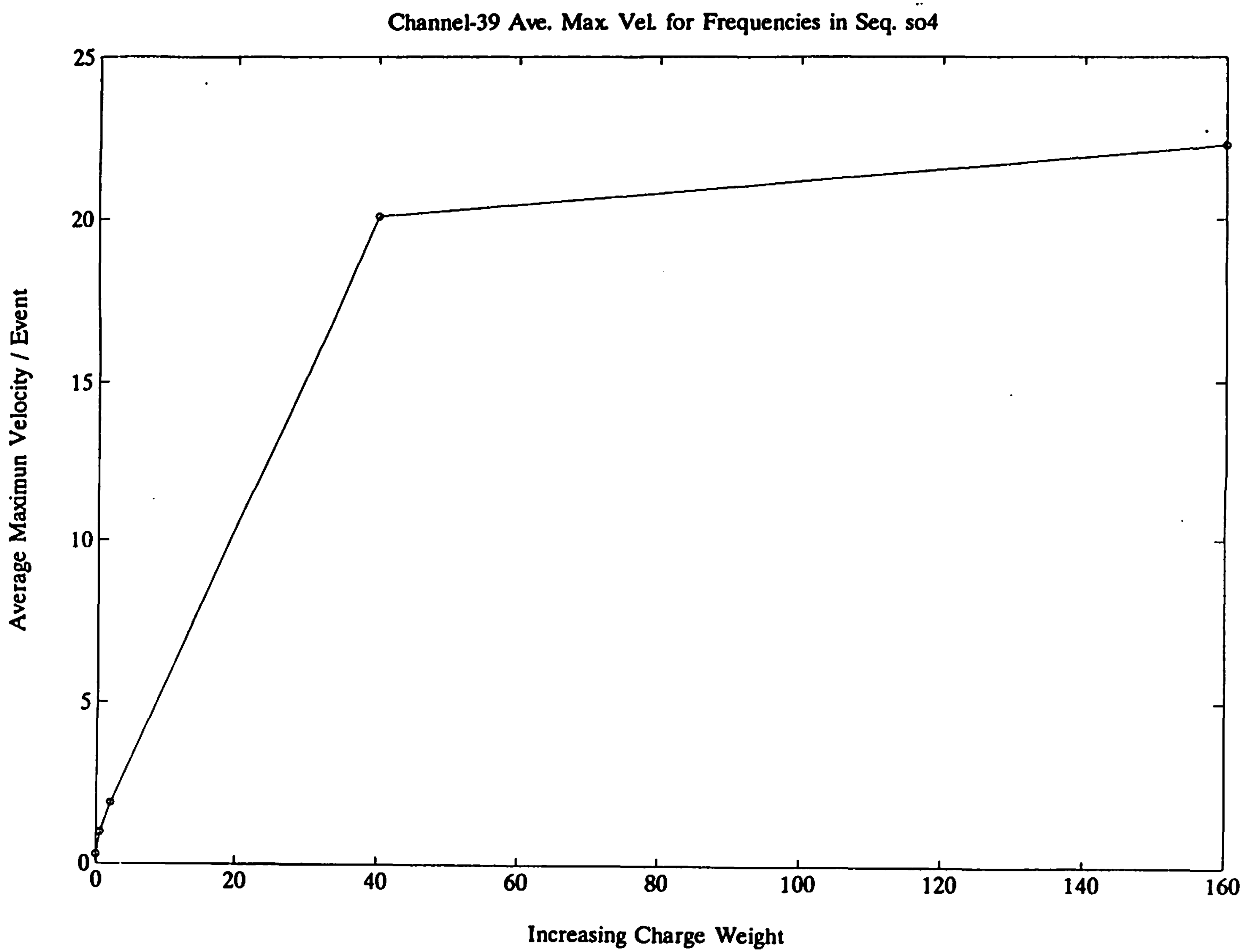
Channel-34 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160


Channel-35 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160


Channel-36 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
10
20
30
40
50
60
70
80
100
120
140
160


Channel-37 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160


Channel-38 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160


Channel-39 Ave. Max. Vel. for Frequencies in Seq. so4
Average Maximun Velocity / Event
Increasing Charge Weight
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160

SECTION E-7

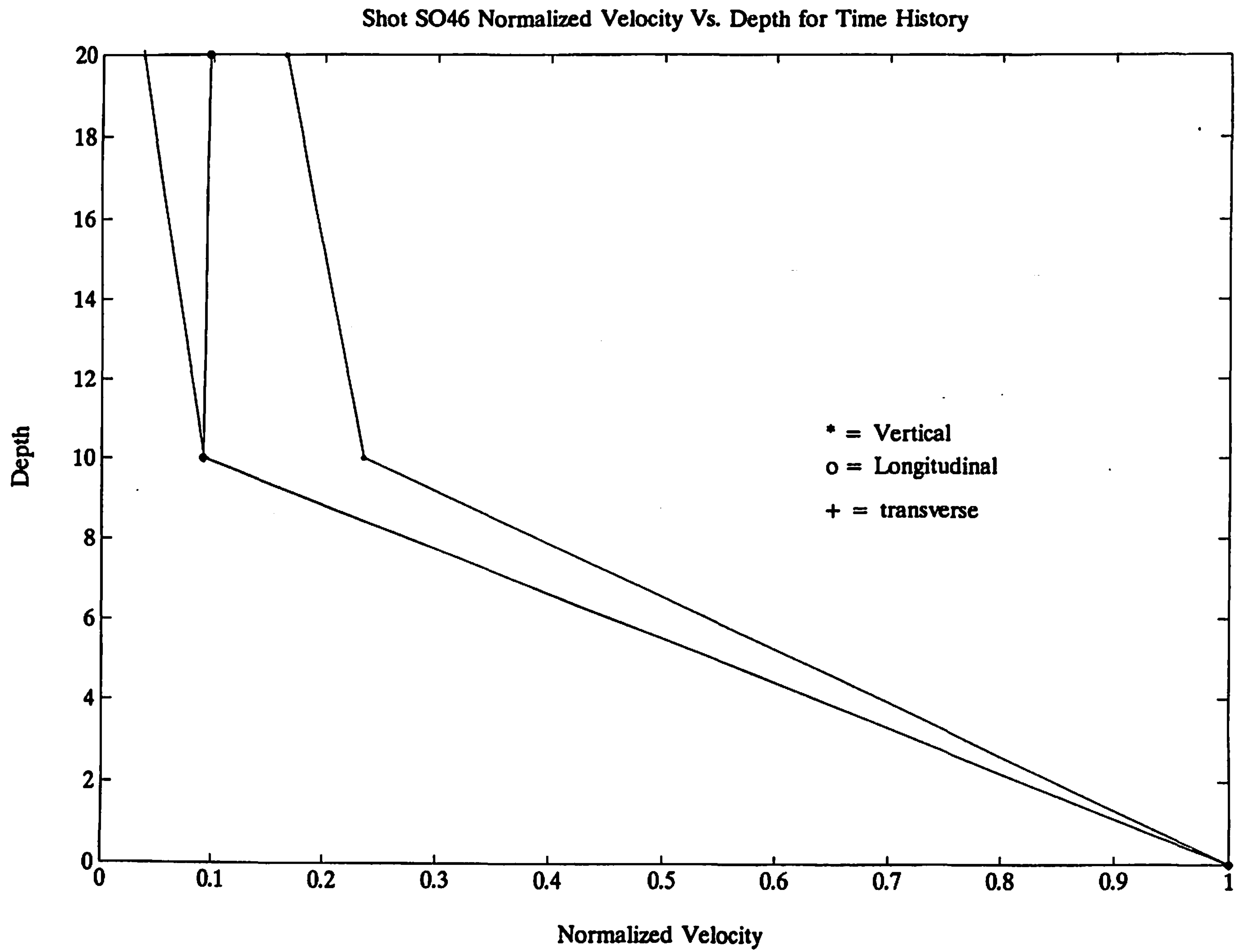
NORMALIZED MAXIMUM VELOCITIES VERSUS DEPTH

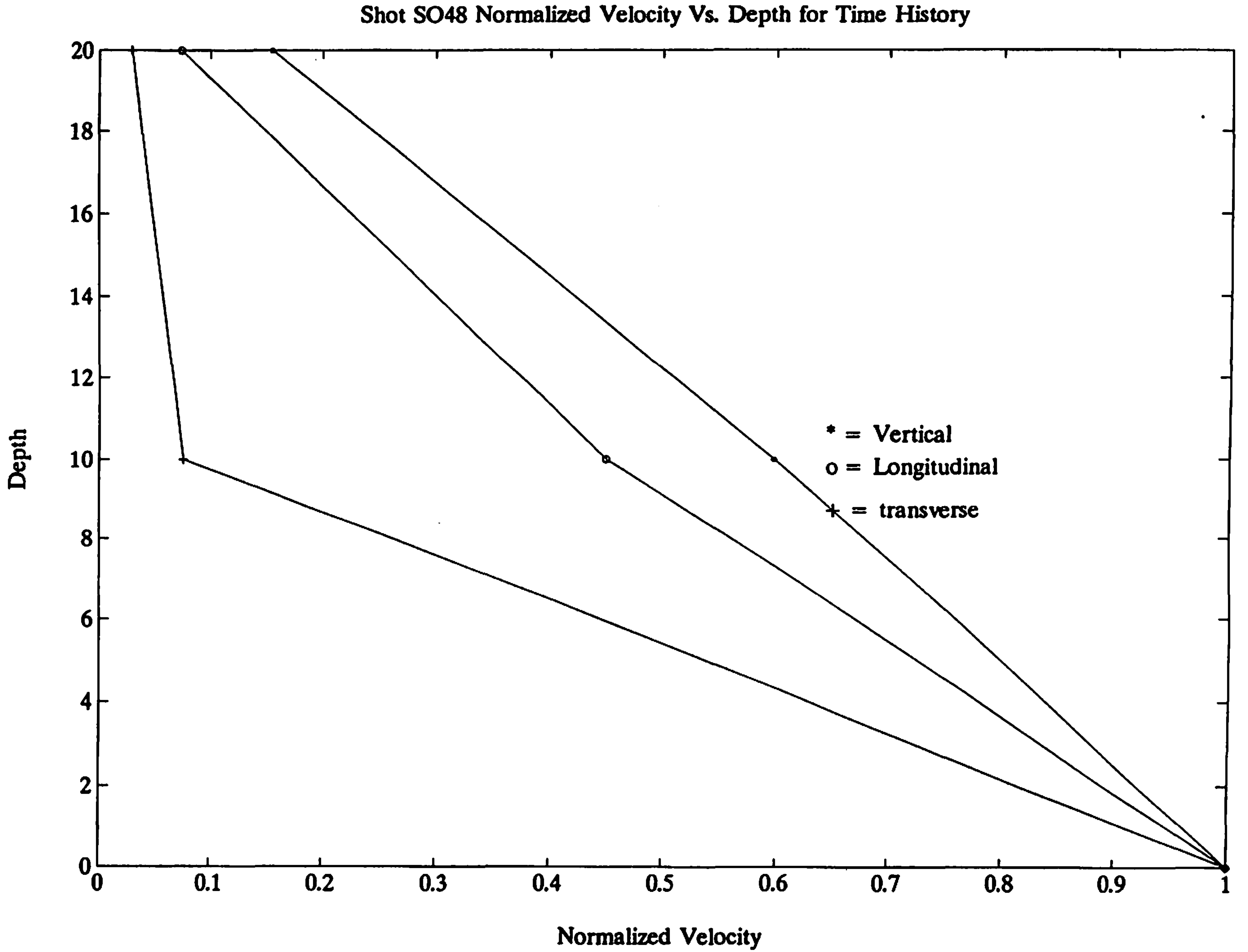
IN

BOREHOLE B-9

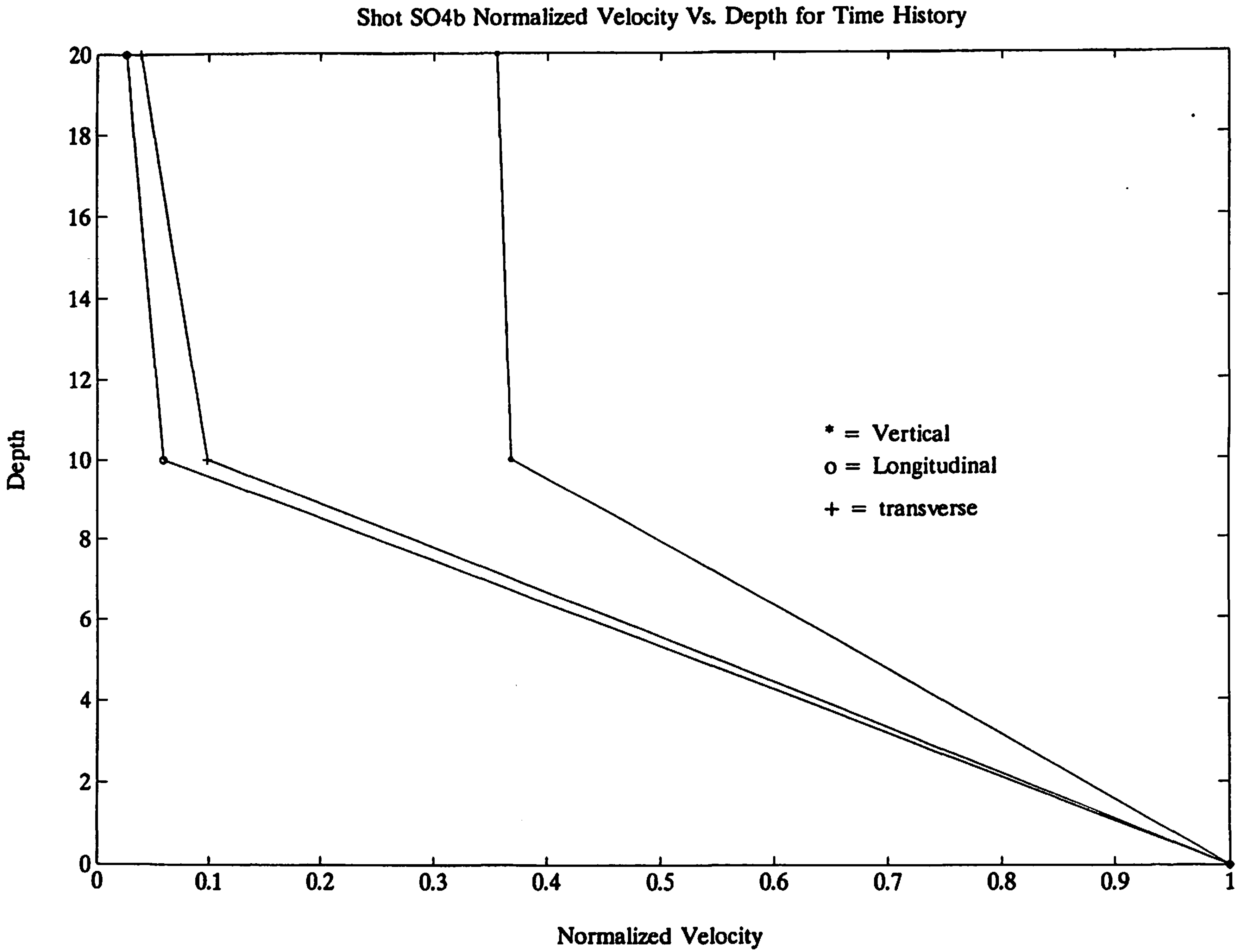
FOR

TIME HISTORIES IN SEQUENCE S04

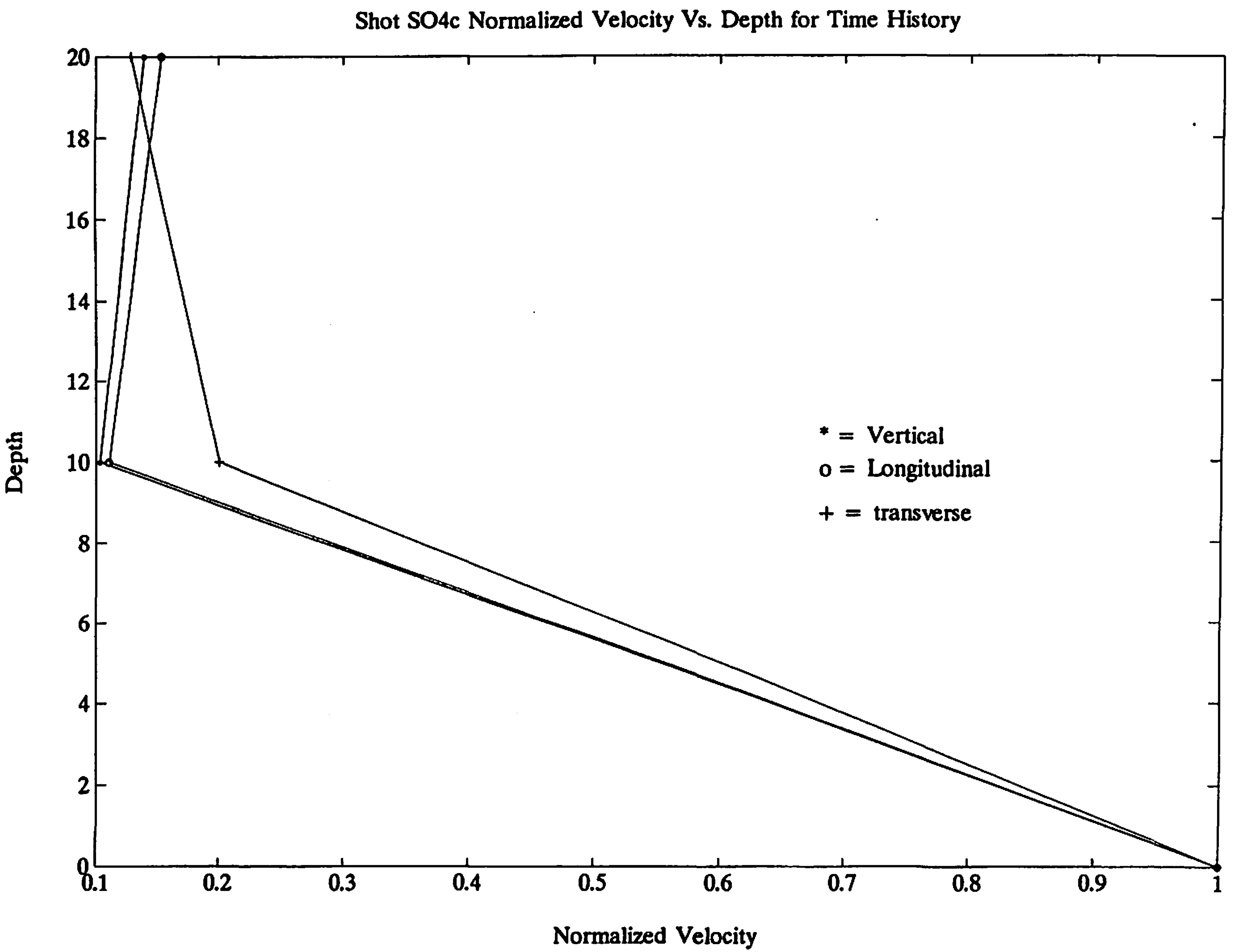

Shot SO46 Normalized Velocity Vs. Depth for Time History
Depth
20
18
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse



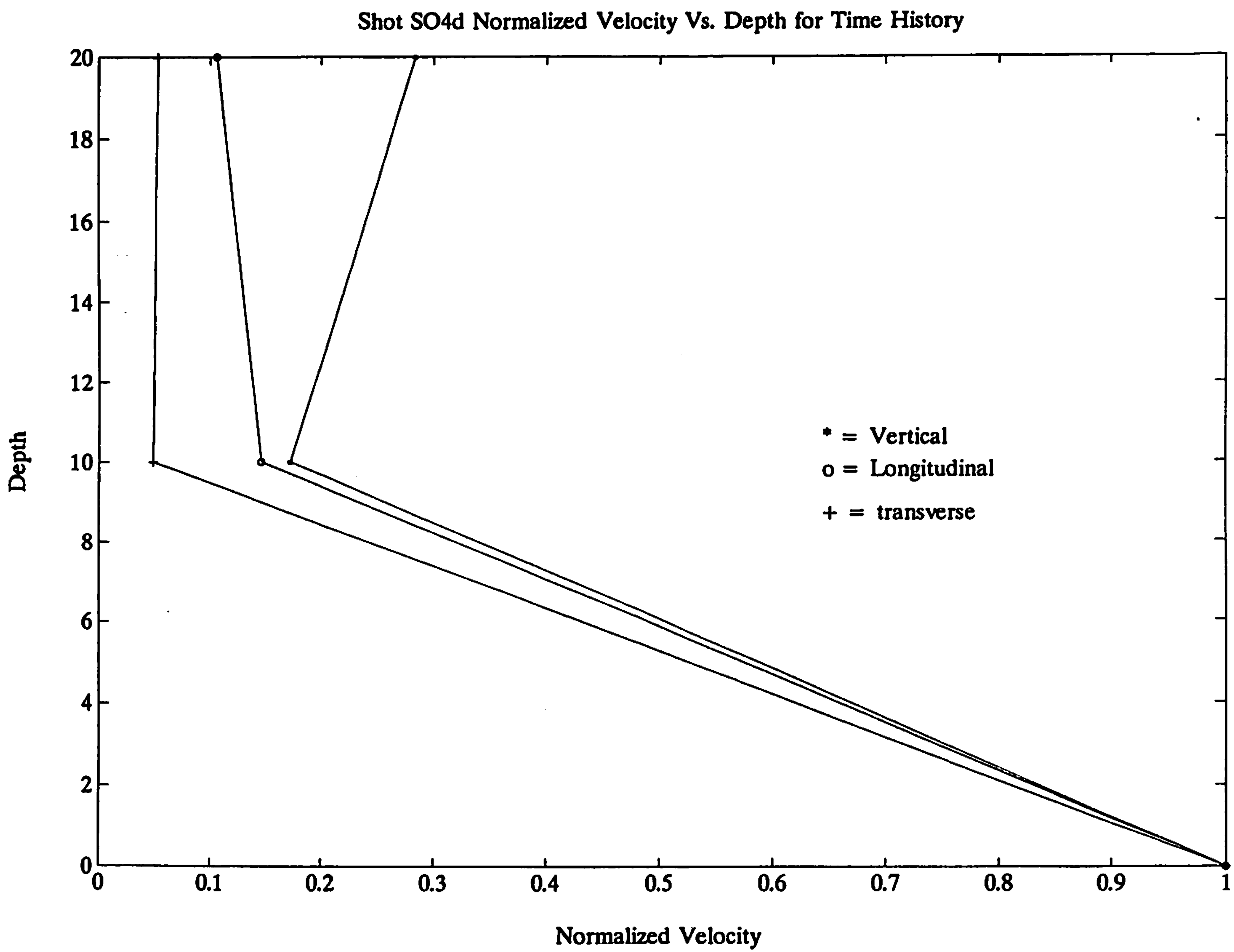
Shot SO48 Normalized Velocity Vs. Depth for Time History
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
2
4
6
8
10
12
14
16
18
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



Shot SO4b Normalized Velocity Vs. Depth for Time History
Depth
Normalized Velocity
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse



Shot SO4c Normalized Velocity Vs. Depth for Time History
Depth
20
18
16
14
12
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse
Normalized Velocity


Shot SO4d Normalized Velocity Vs. Depth for Time History
Depth
20
18
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse

SECTION E-8

NORMALIZED MAXIMUM VELOCITIES VERSUS DEPTH

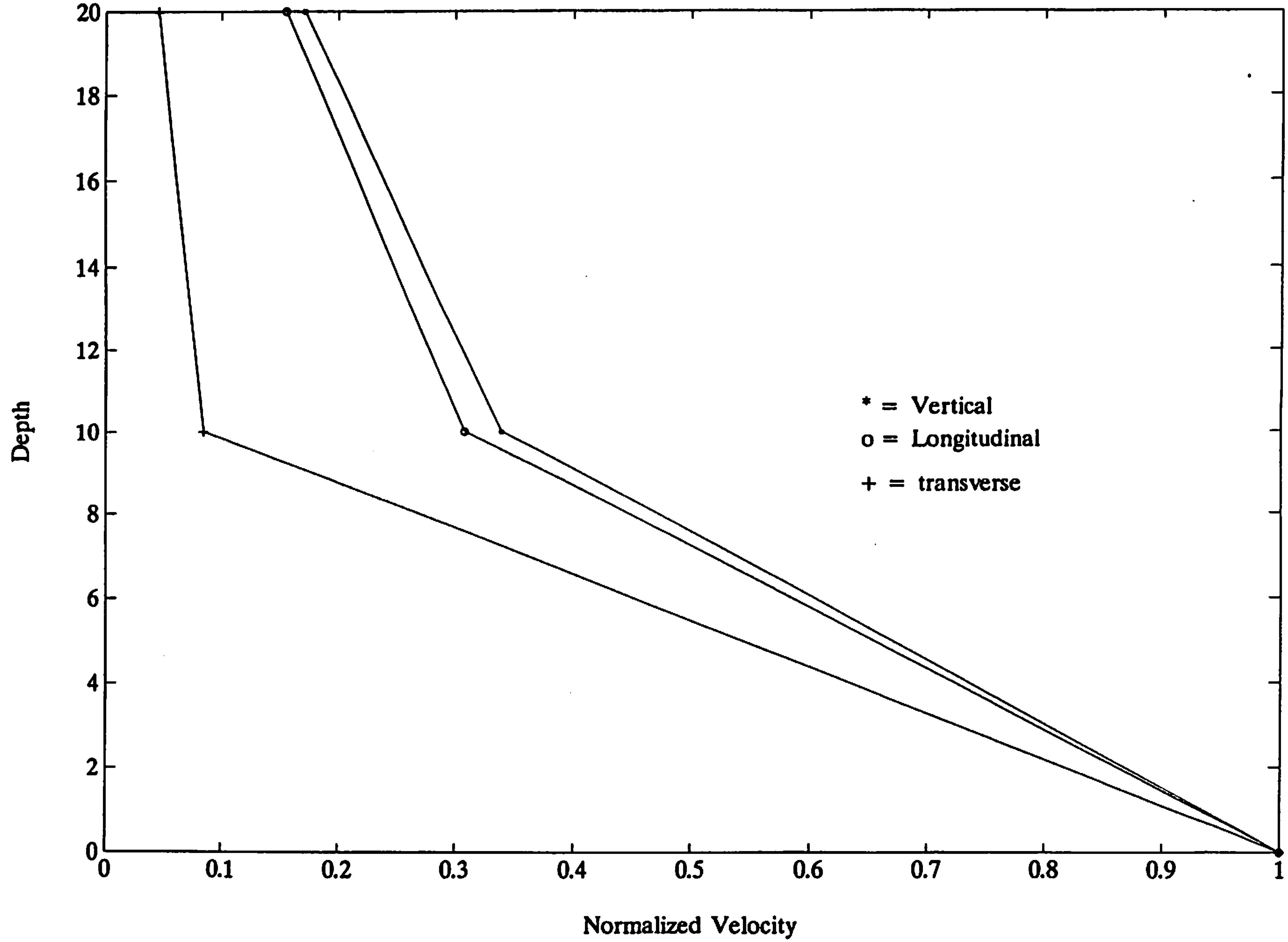
IN

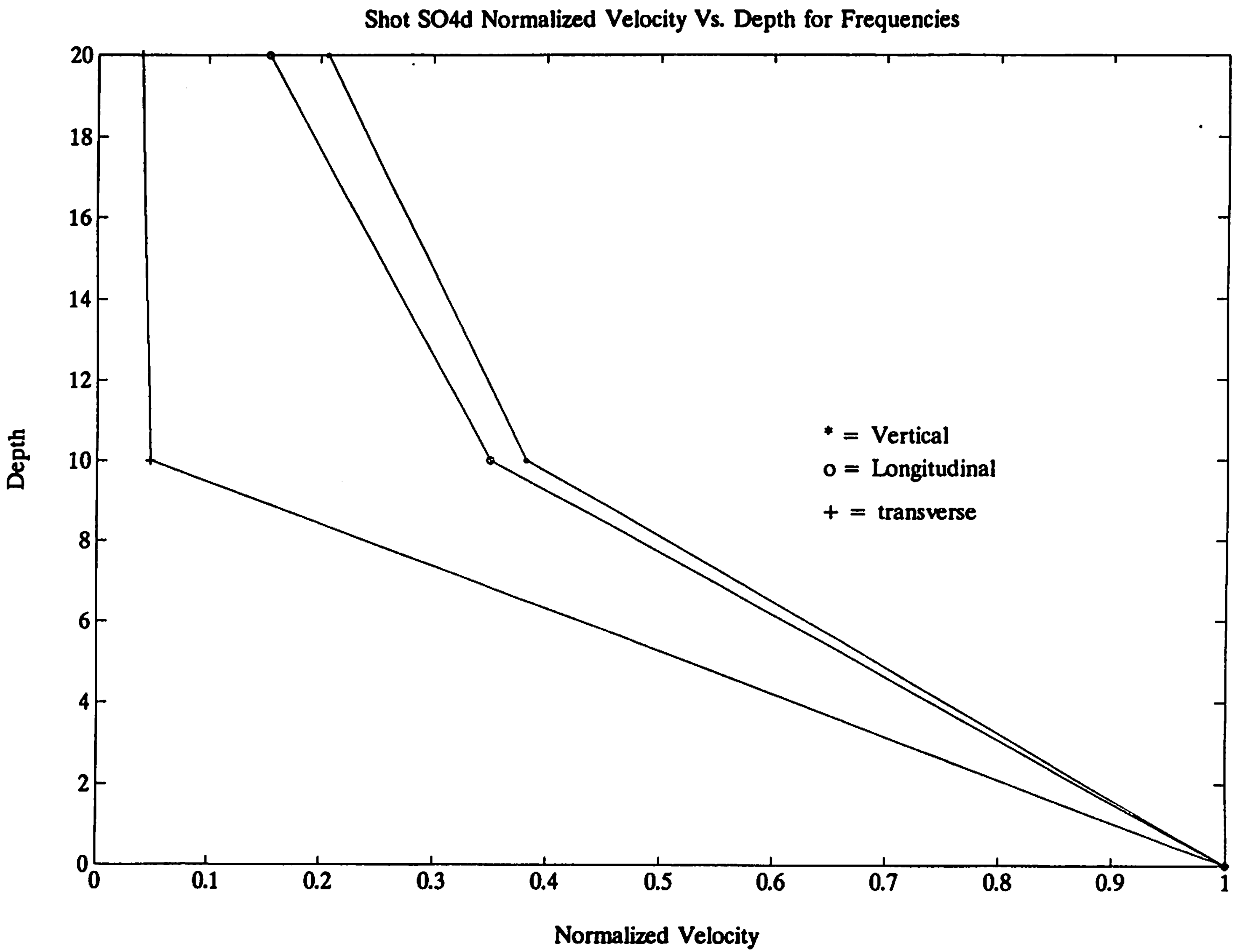
BOREHOLE B-9

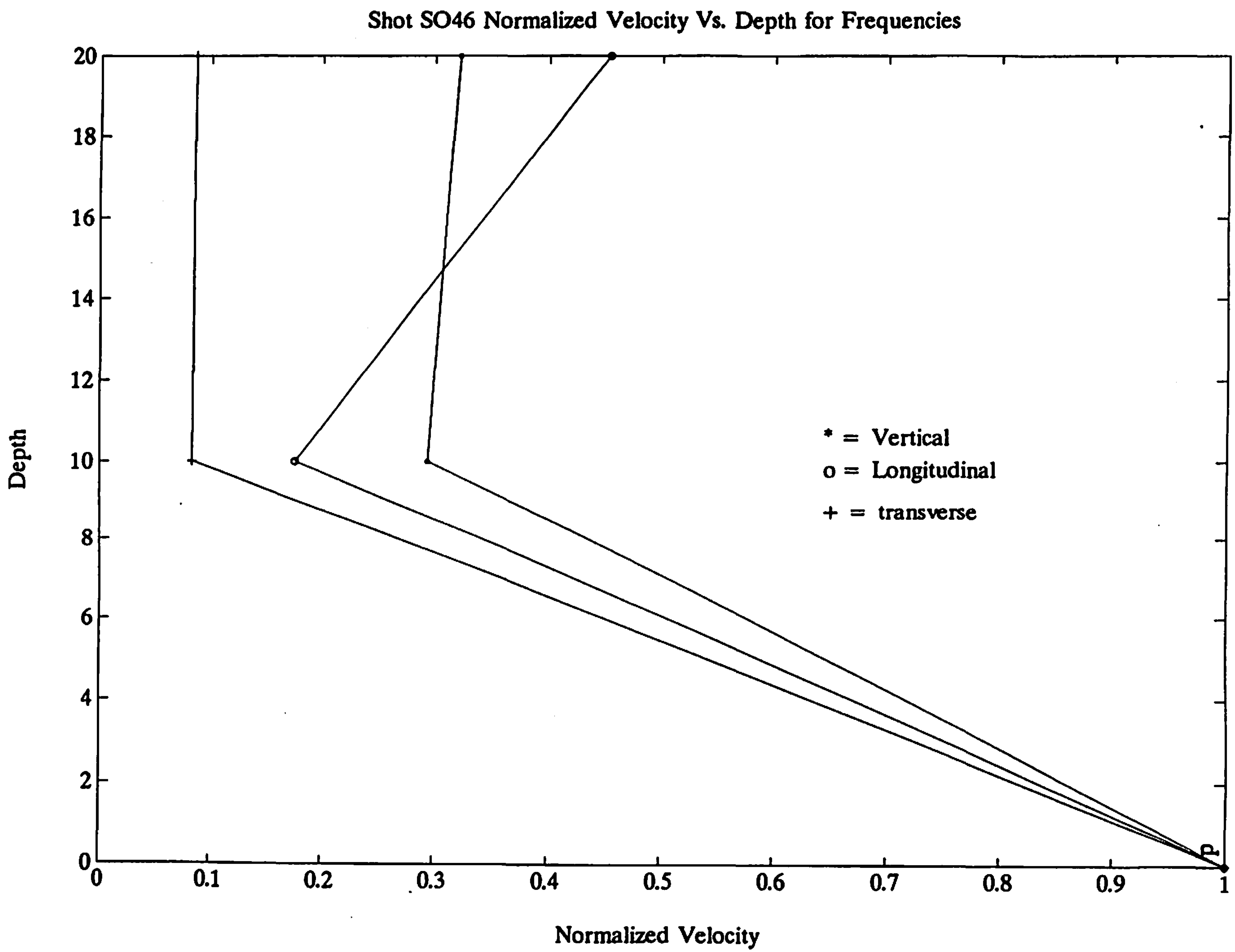
FOR

FOURIER TRANSFORMS OF TIME HISTORIES IN SEQUENCE S04

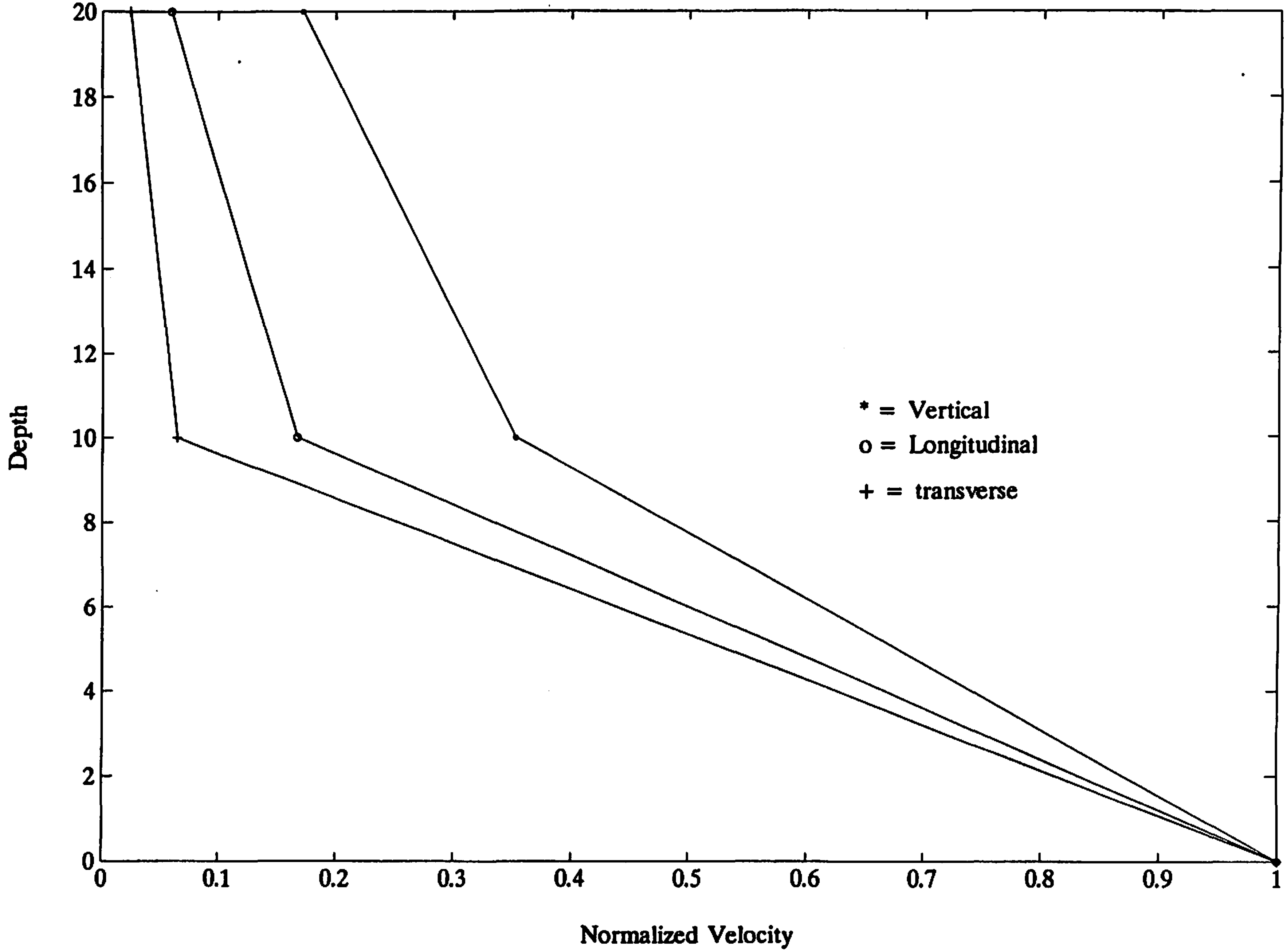
Averaged Normalized Velocity Vs. Depth for Frequencies for SO4

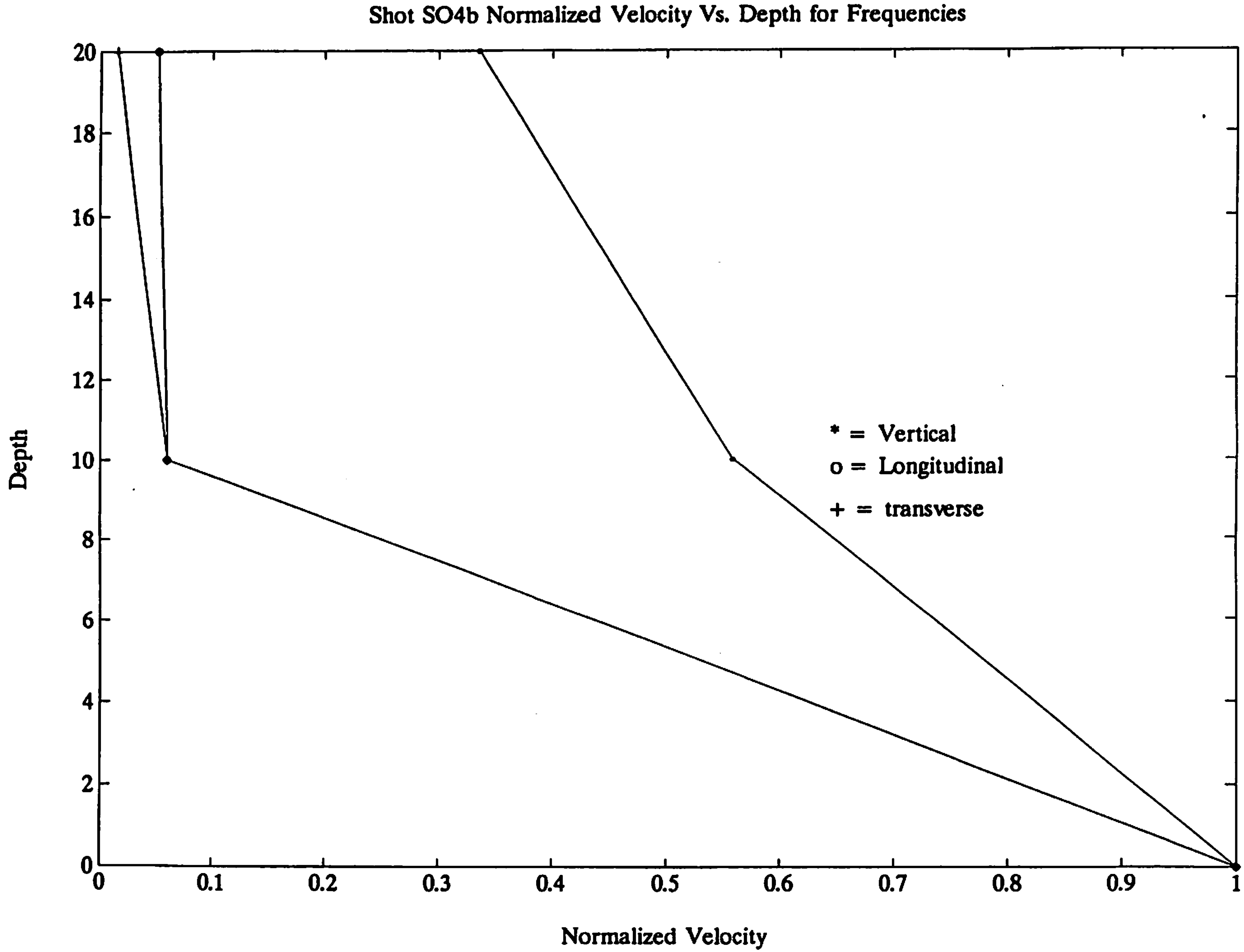


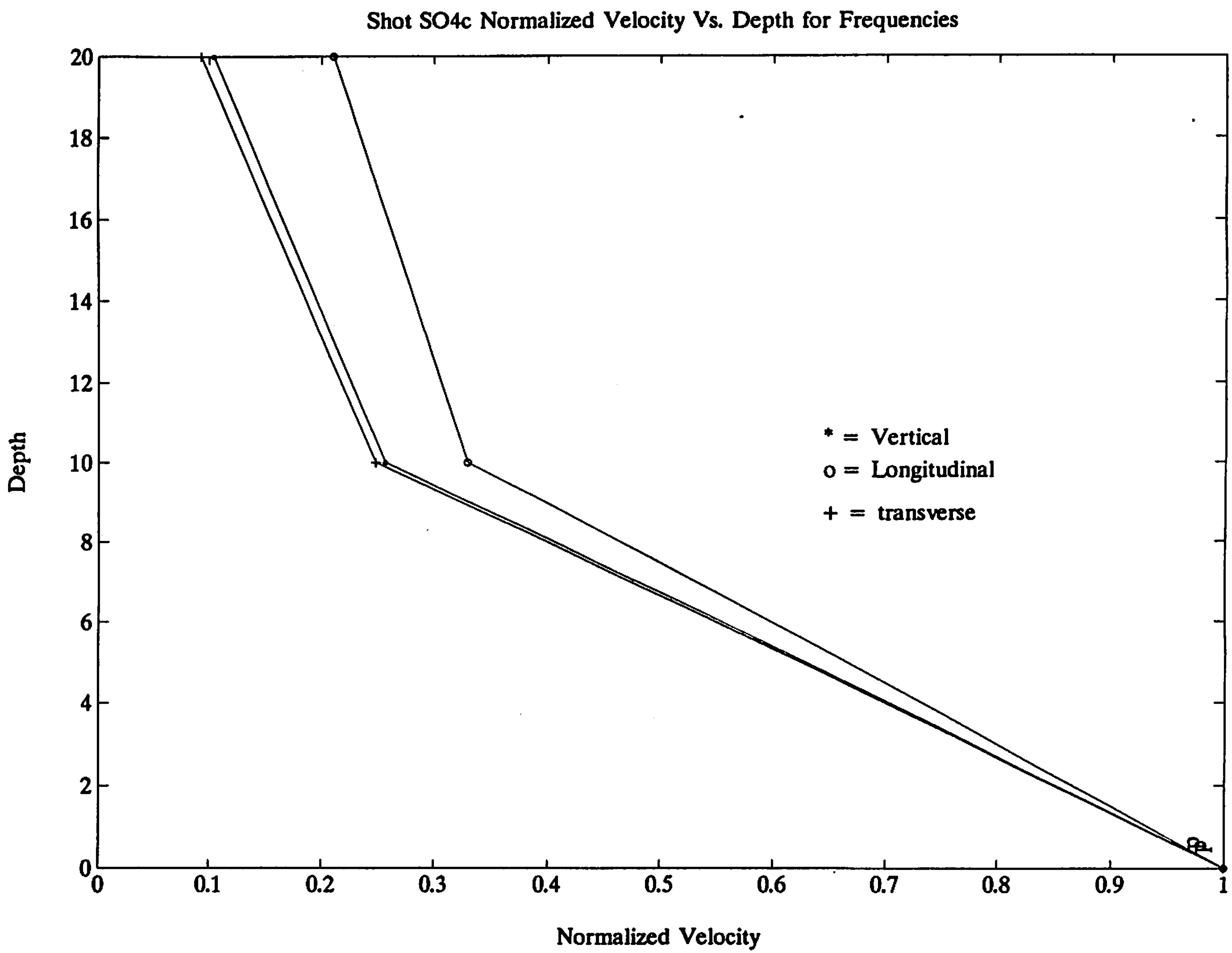

Shot SO4d Normalized Velocity Vs. Depth for Frequencies
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
2
4
6
8
10
12
14
16
18
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Shot SO46 Normalized Velocity Vs. Depth for Frequencies
Depth
20
18
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse

Shot SO48 Normalized Velocity Vs. Depth for Frequencies




Shot SO4b Normalized Velocity Vs. Depth for Frequencies
Depth
20
18
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse


Shot SO4c Normalized Velocity Vs. Depth for Frequencies
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

SECTION E-9

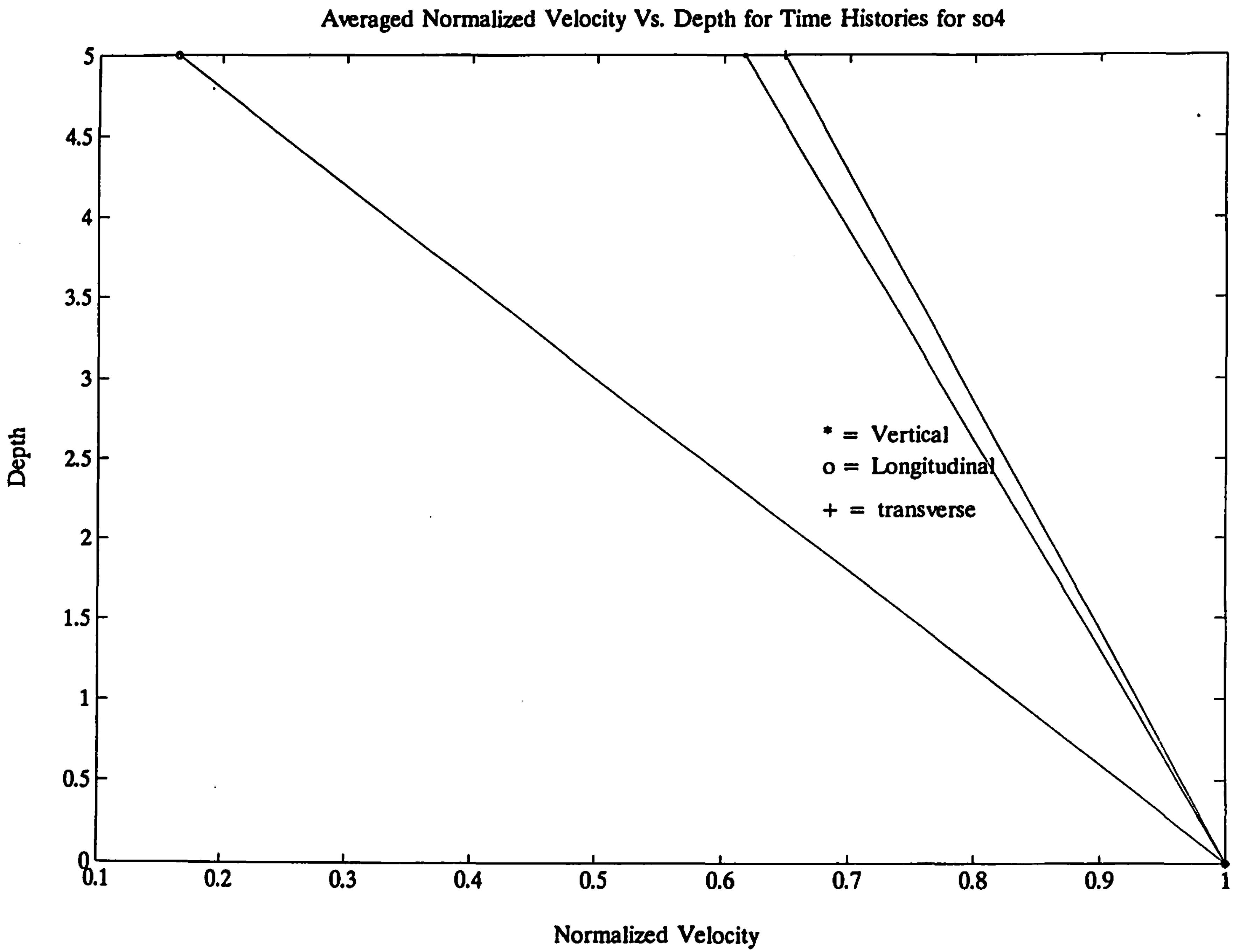
NORMALIZED MAXIMUM VELOCITIES VERSUS DEPTH

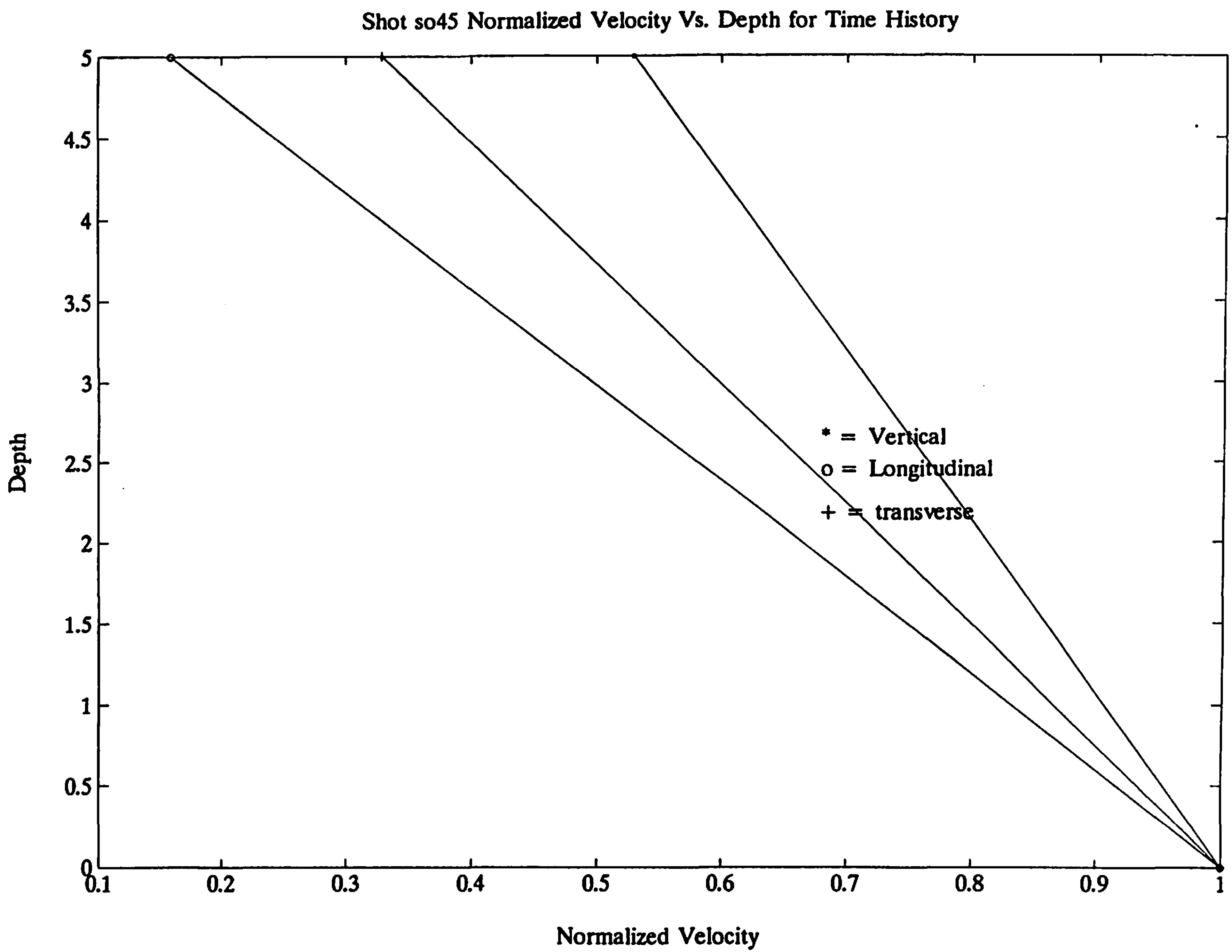
IN

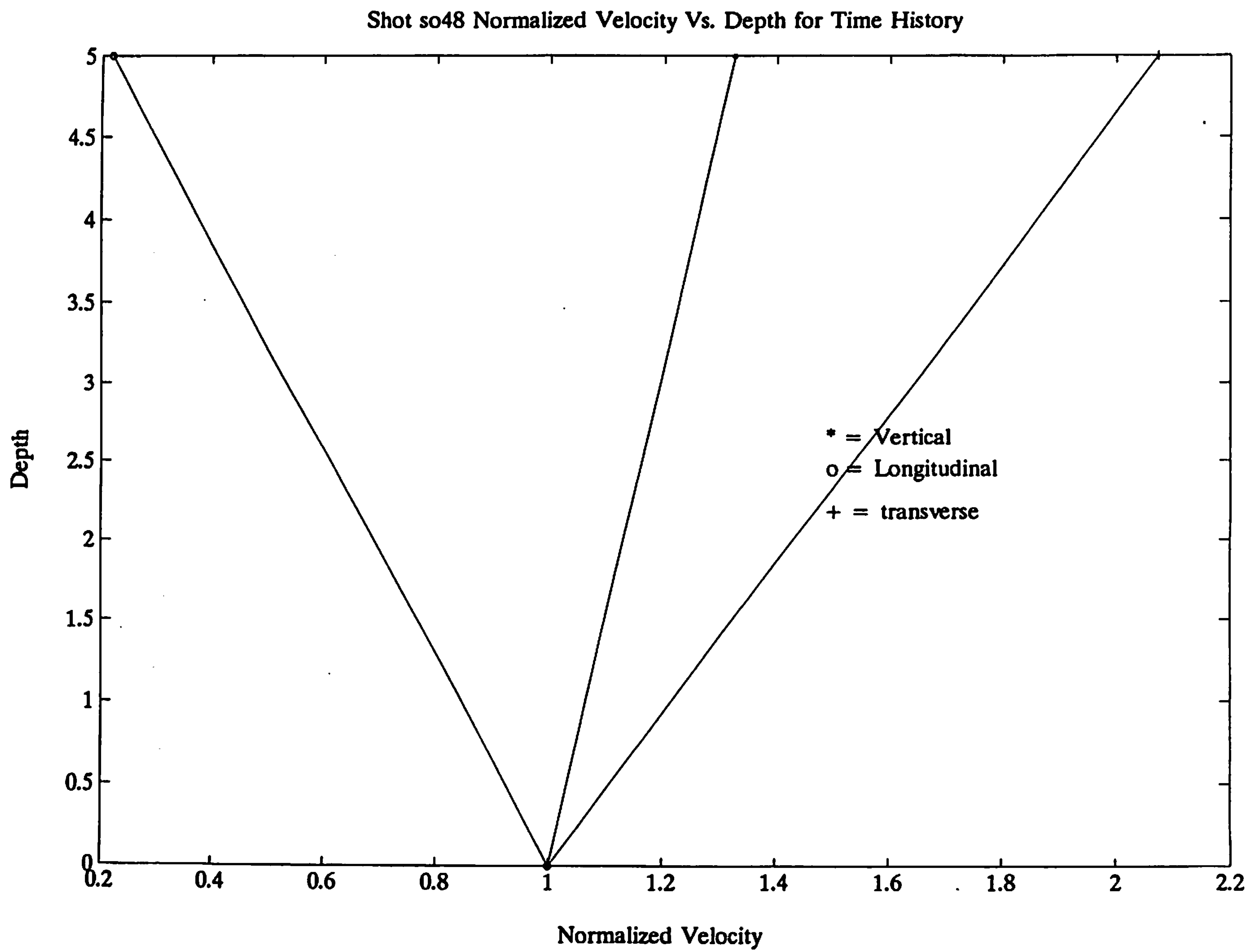
MANHOLE AT STATION 2+00

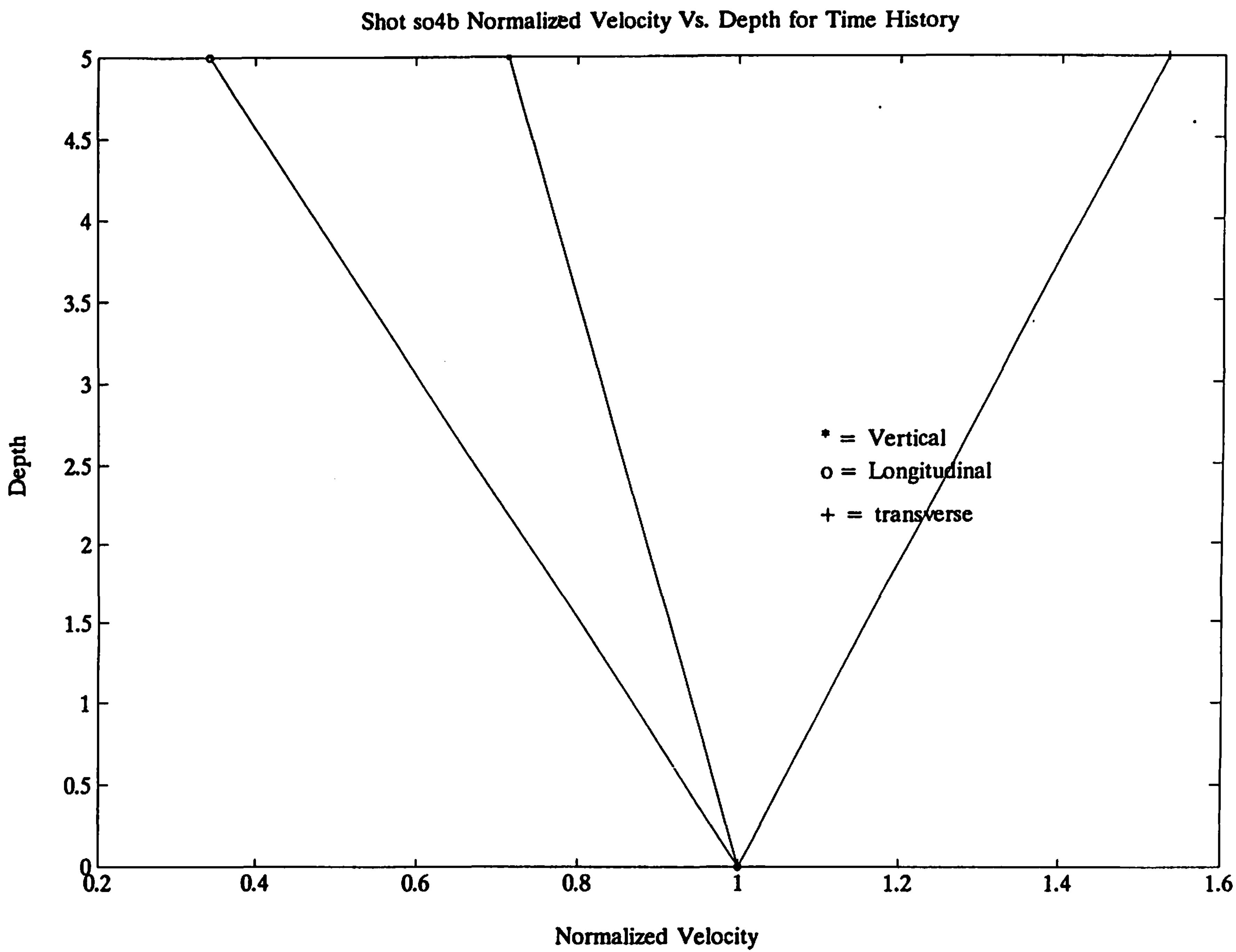
FOR

TIME HISTORIES IN SEQUENCE S04

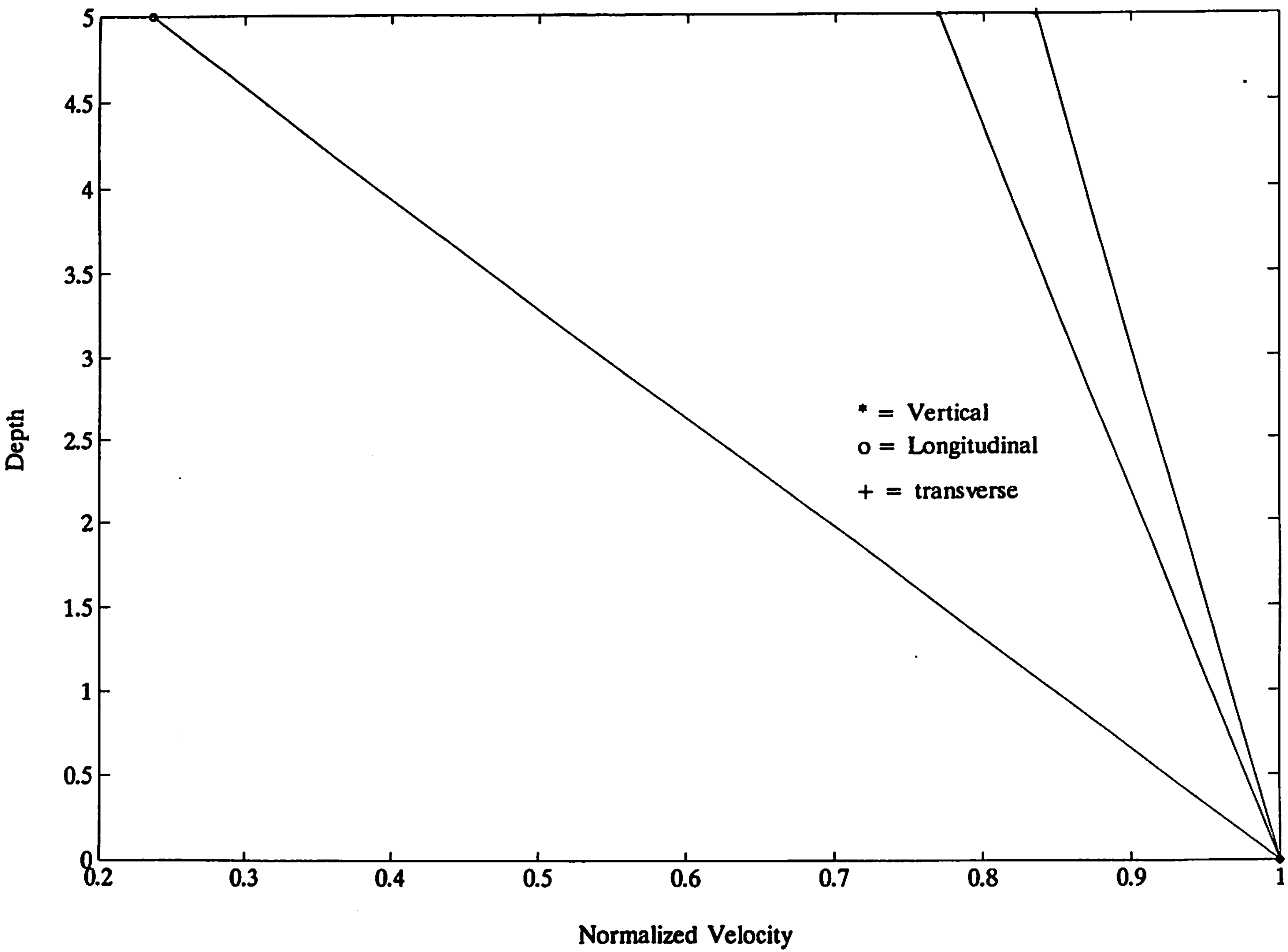

Averaged Normalized Velocity Vs. Depth for Time Histories for so4
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse
Normalized Velocity

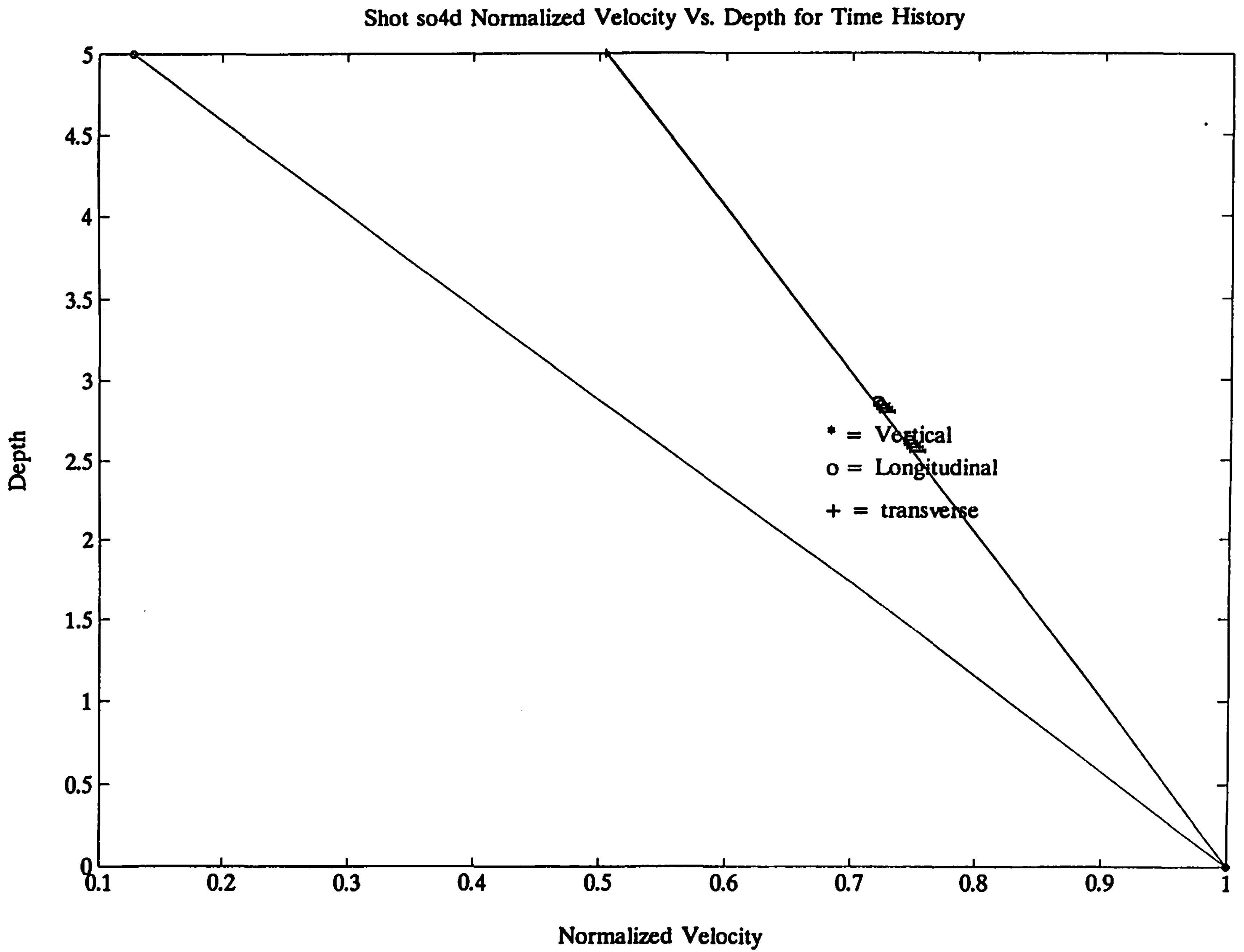

Shot so45 Normalized Velocity Vs. Depth for Time History
Depth
Normalized Velocity
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse


Shot so48 Normalized Velocity Vs. Depth for Time History
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse


Shot so4b Normalized Velocity Vs. Depth for Time History
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

Shot so4c Normalized Velocity Vs. Depth for Time History





Shot so4d Normalized Velocity Vs. Depth for Time History
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

SECTION E-10

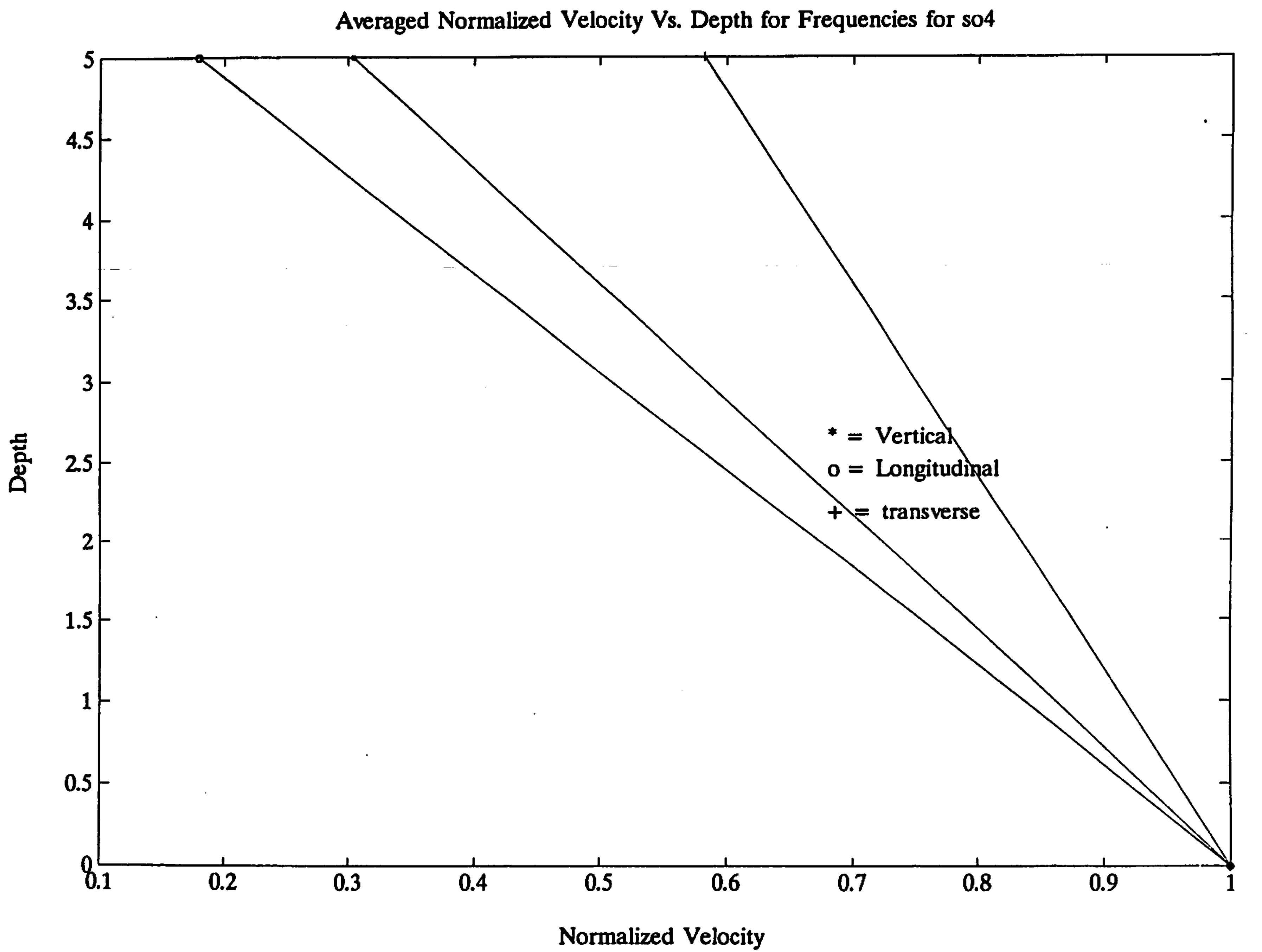
NORMALIZED MAXIMUM VELOCITIES VERSUS DEPTH

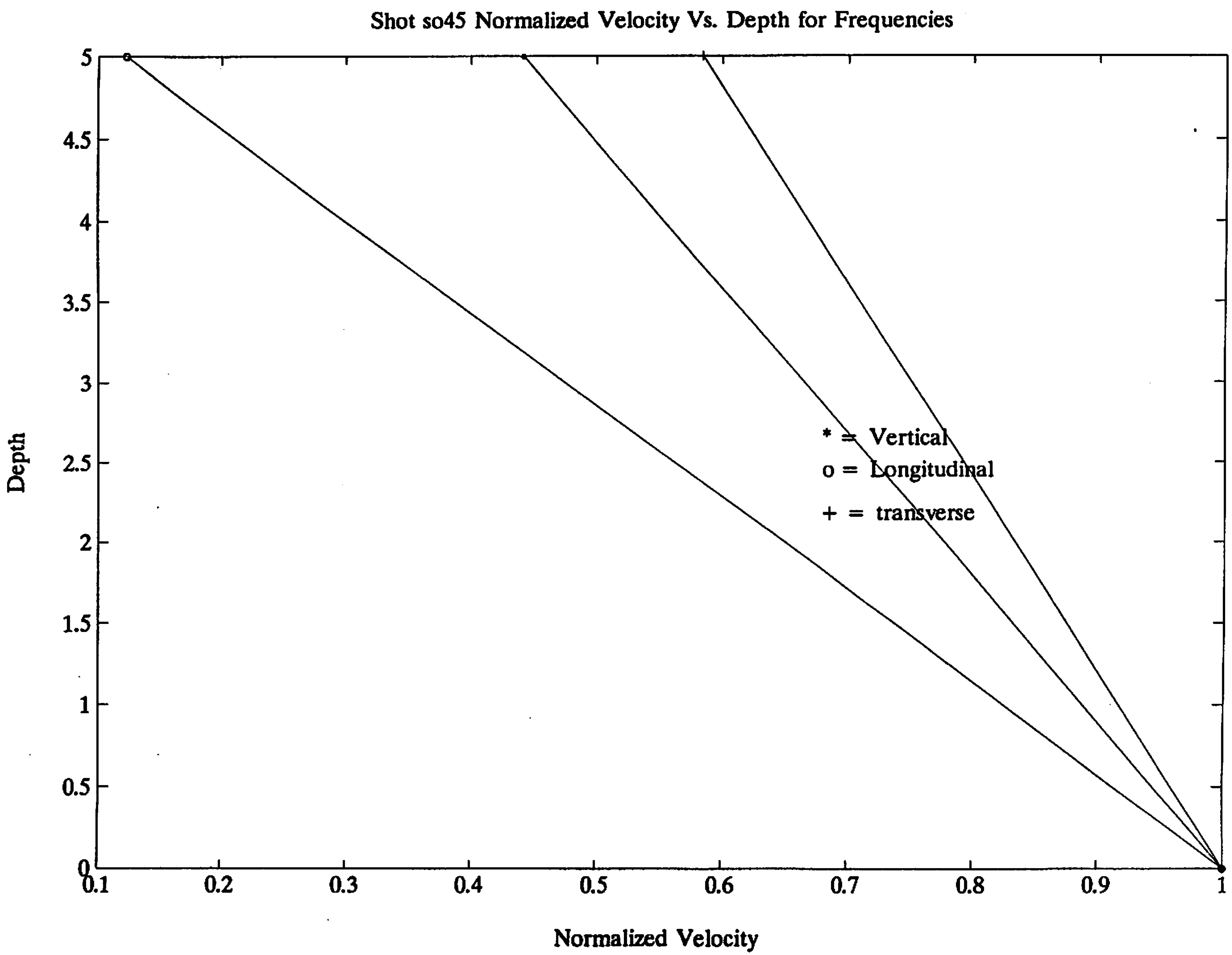
IN

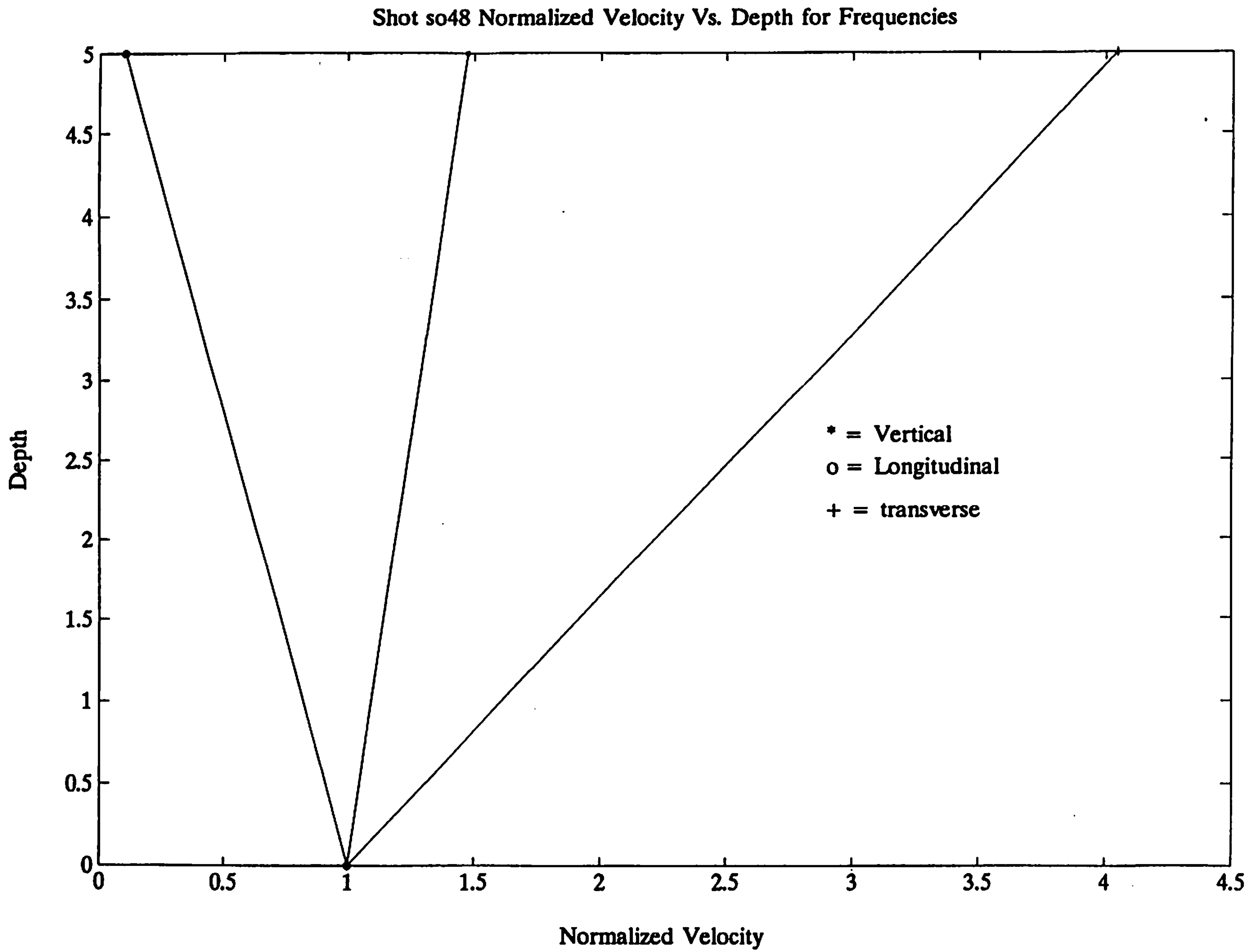
MANHOLE AT STATION 2+00

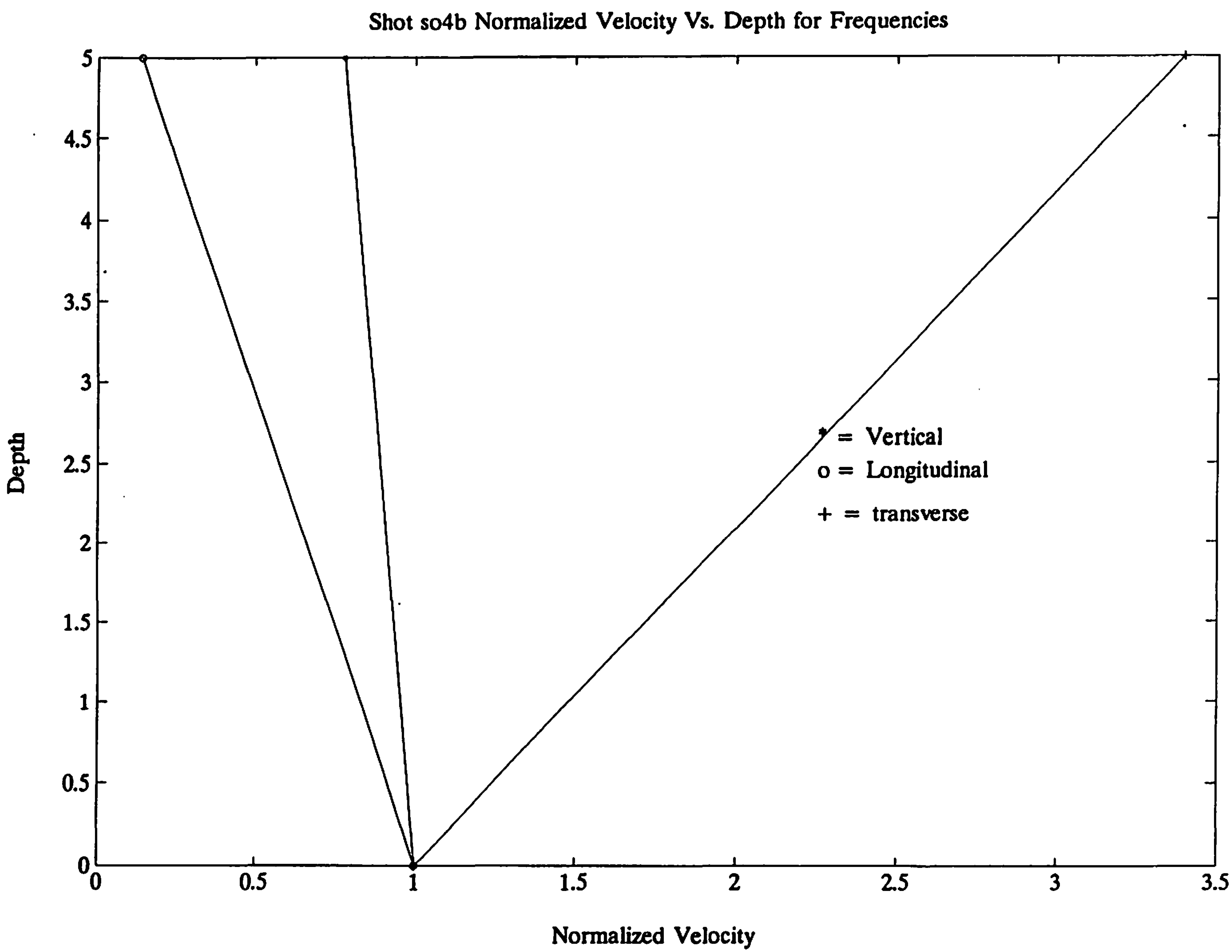
FOR

FOURIER TRANSFORMS OF TIME HISTORIES IN SEQUENCE S04

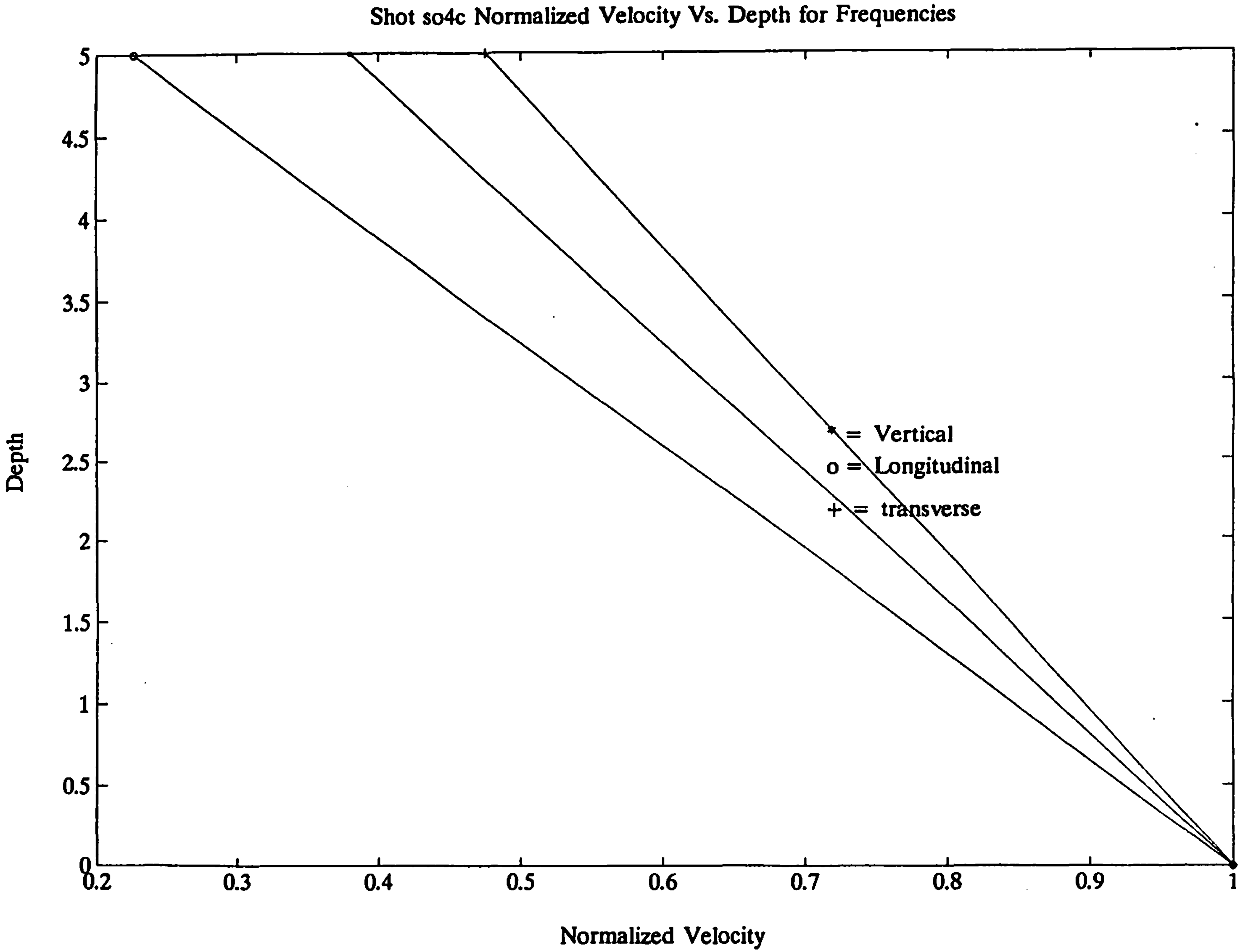

Averaged Normalized Velocity Vs. Depth for Frequencies for so4
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse
Normalized Velocity

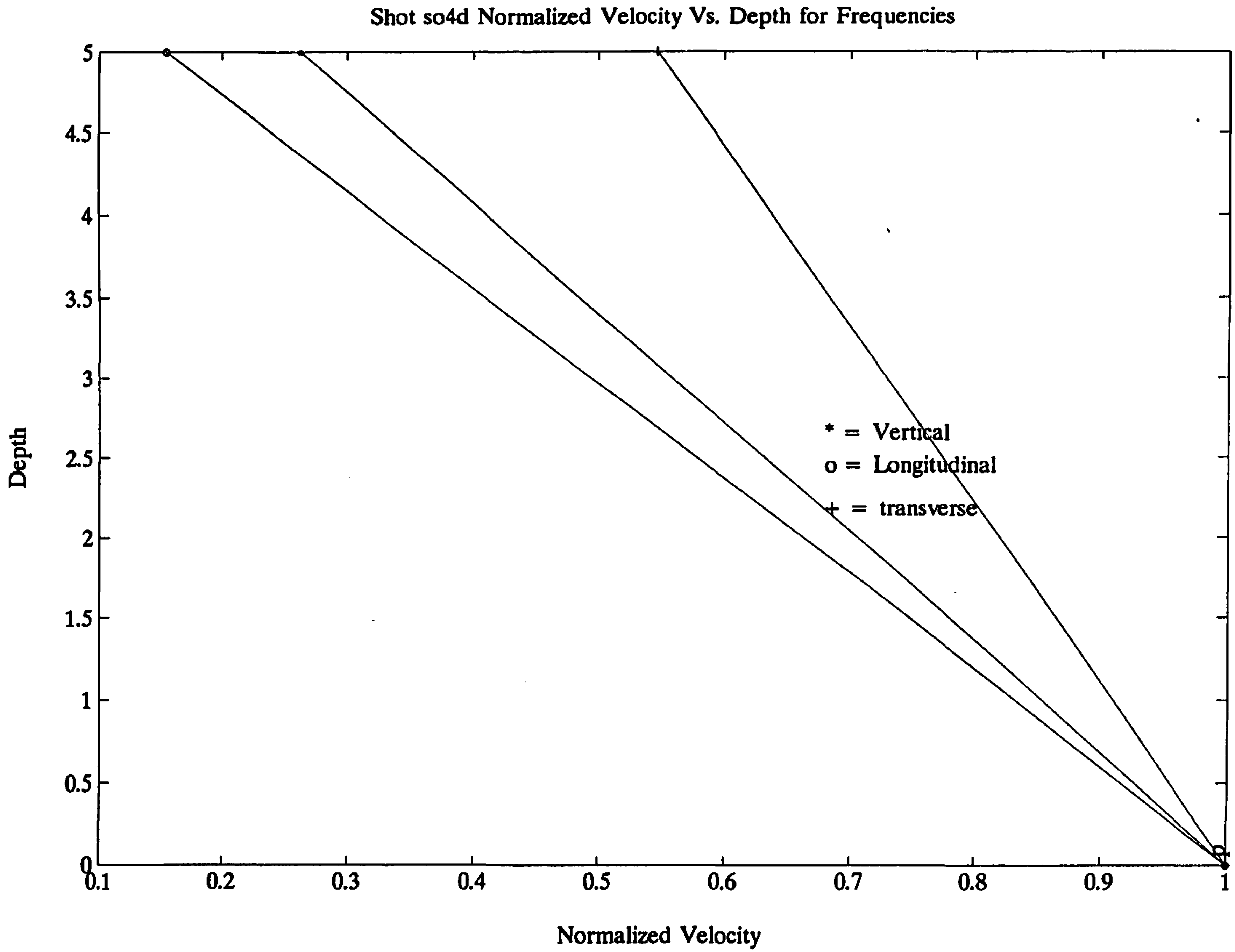

Shot so45 Normalized Velocity Vs. Depth for Frequencies
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse


Shot so48 Normalized Velocity Vs. Depth for Frequencies
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Shot so4b Normalized Velocity Vs. Depth for Frequencies
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.5
1
1.5
2
2.5
3
3.5
* = Vertical
o = Longitudinal
+ = transverse
Normalized Velocity


Shot so4c Normalized Velocity Vs. Depth for Frequencies
Depth
Normalized Velocity
* = Vertical
o = Longitudinal
+ = transverse
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Shot so4d Normalized Velocity Vs. Depth for Frequencies
Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
* = Vertical
o = Longitudinal
+ = transverse
Normalized Velocity

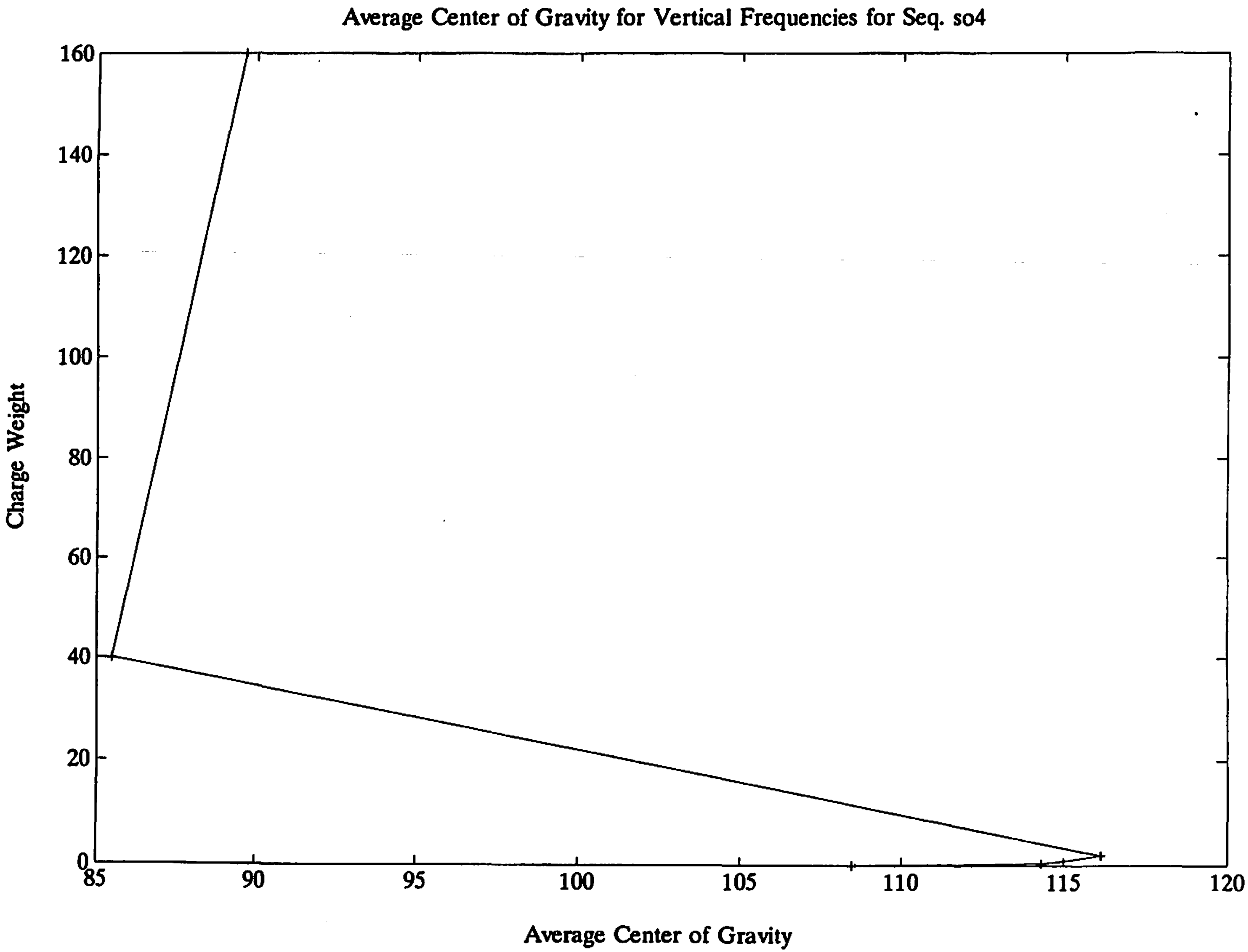
SECTION E-11

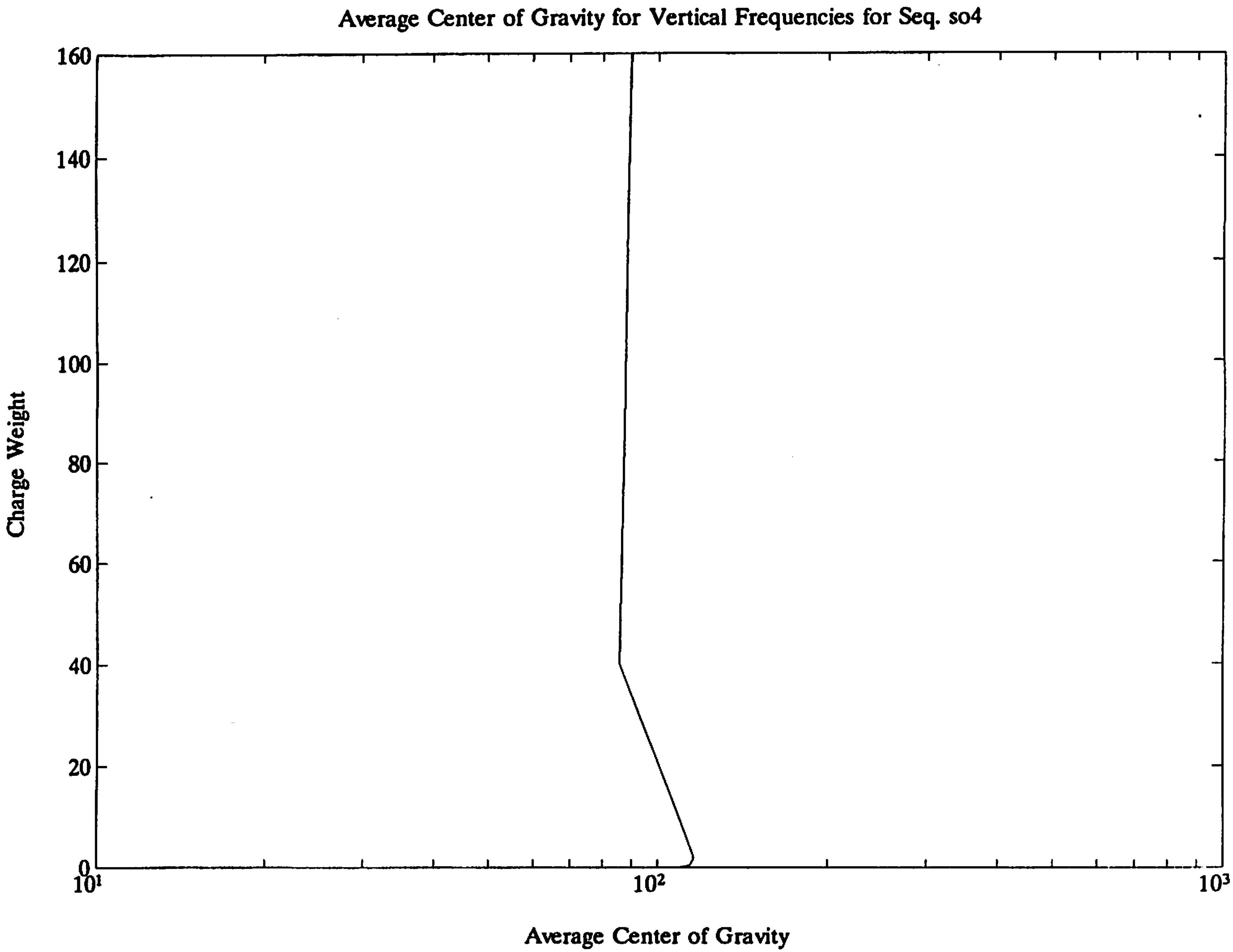
CENTER OF GRAVITY OF FOURIER TRANSFORM PLOT

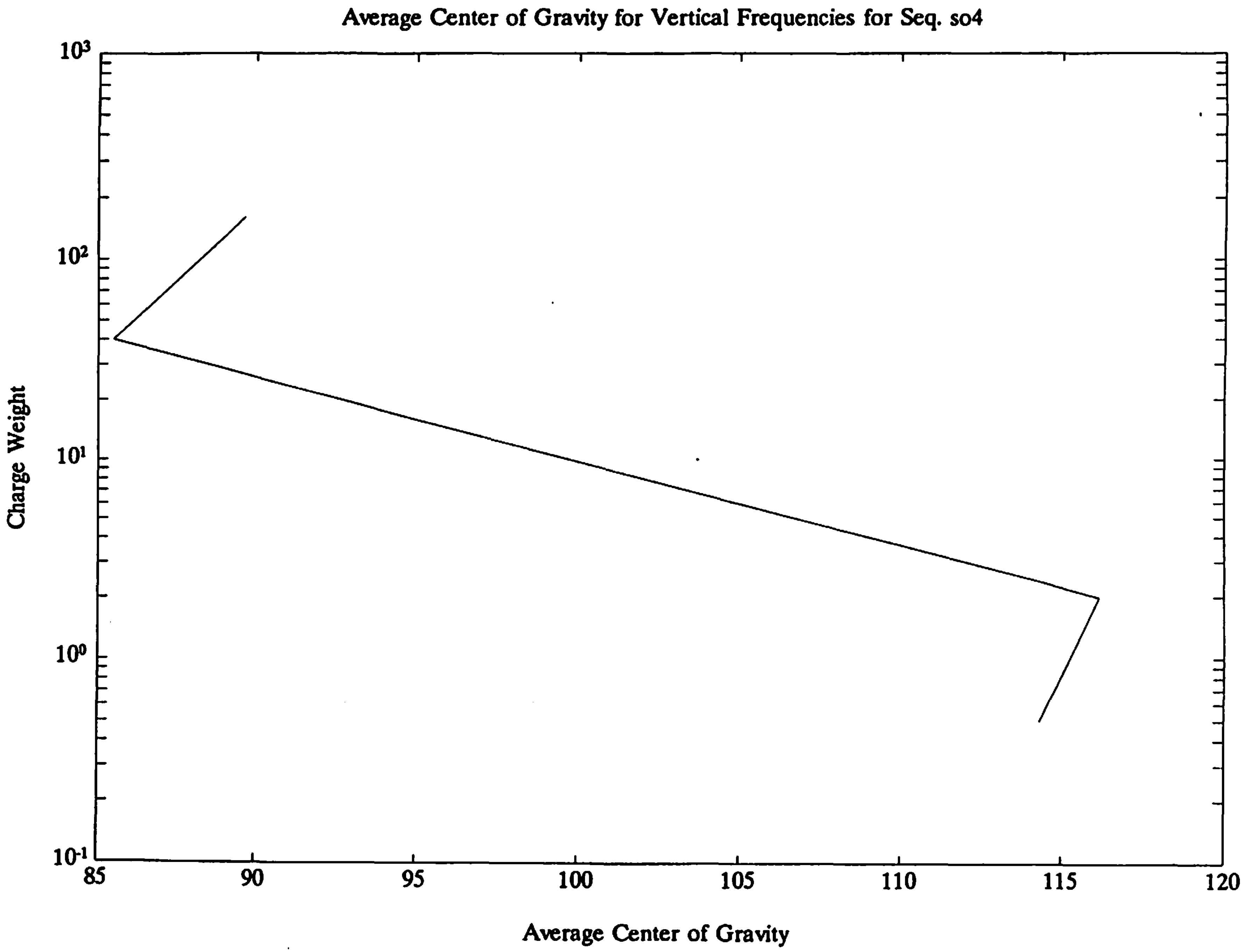
VERSUS CHARGE WEIGHT

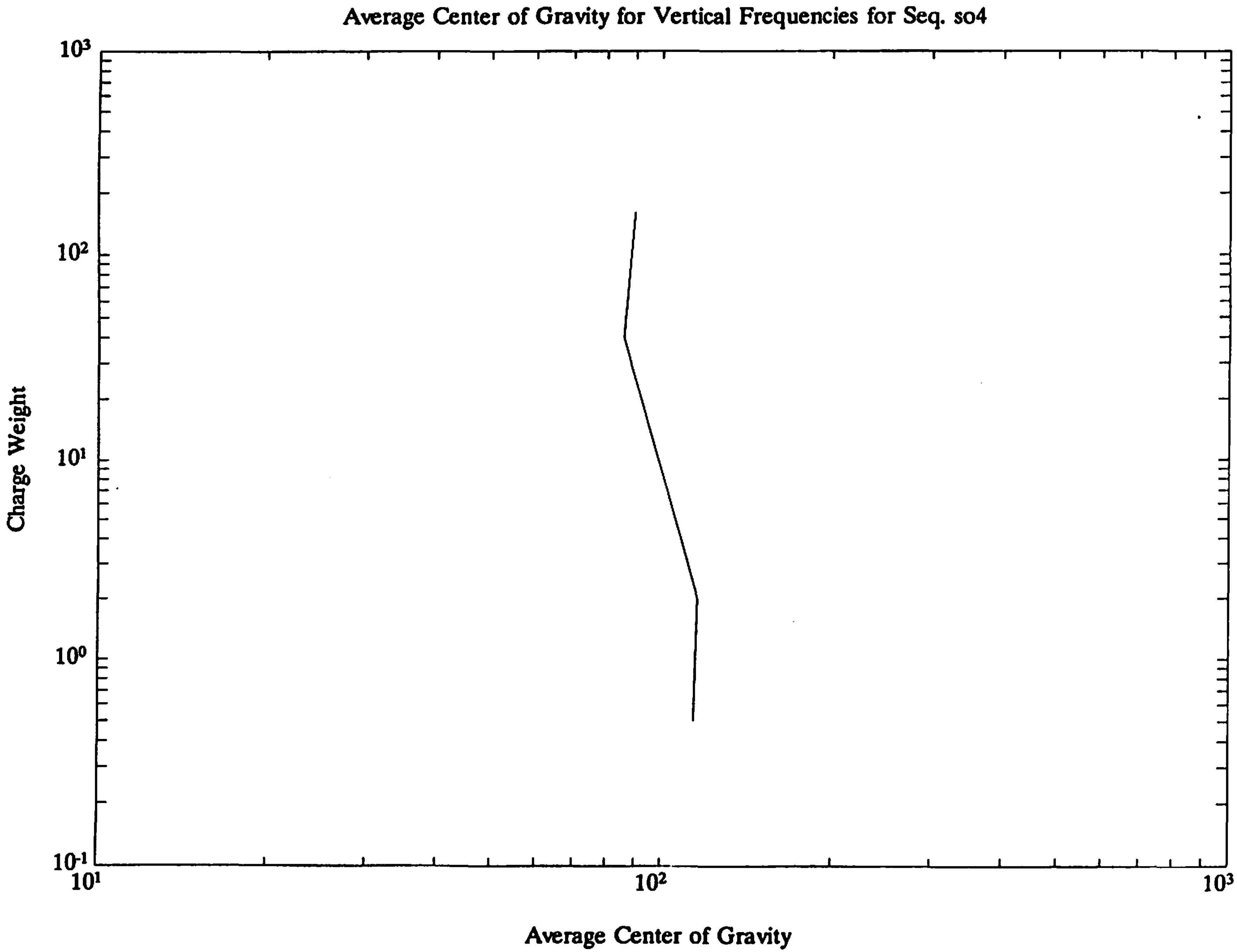
FOR

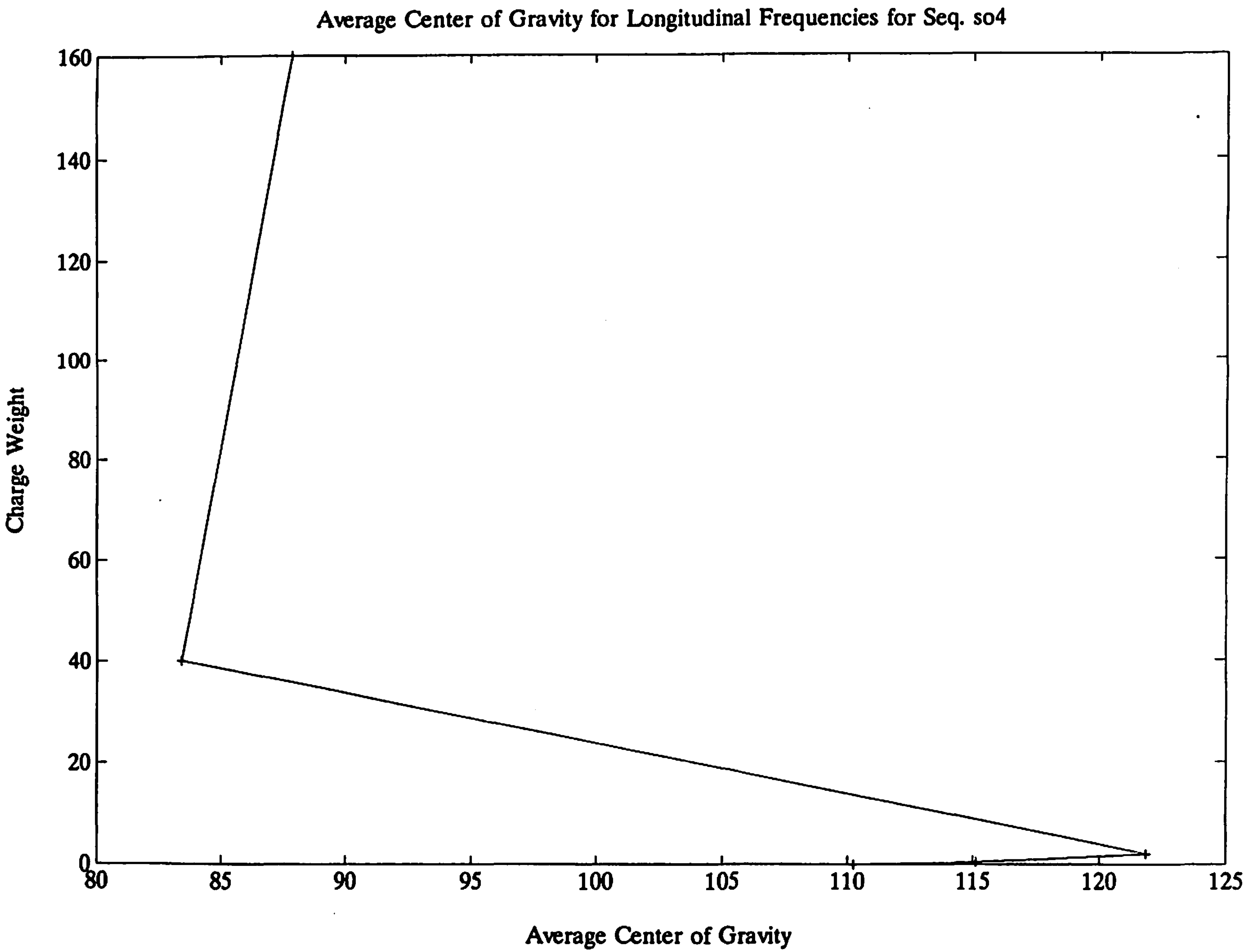
FOURIER TRANSFORMS OF TIME HISTORIES IN SEQUENCE S04

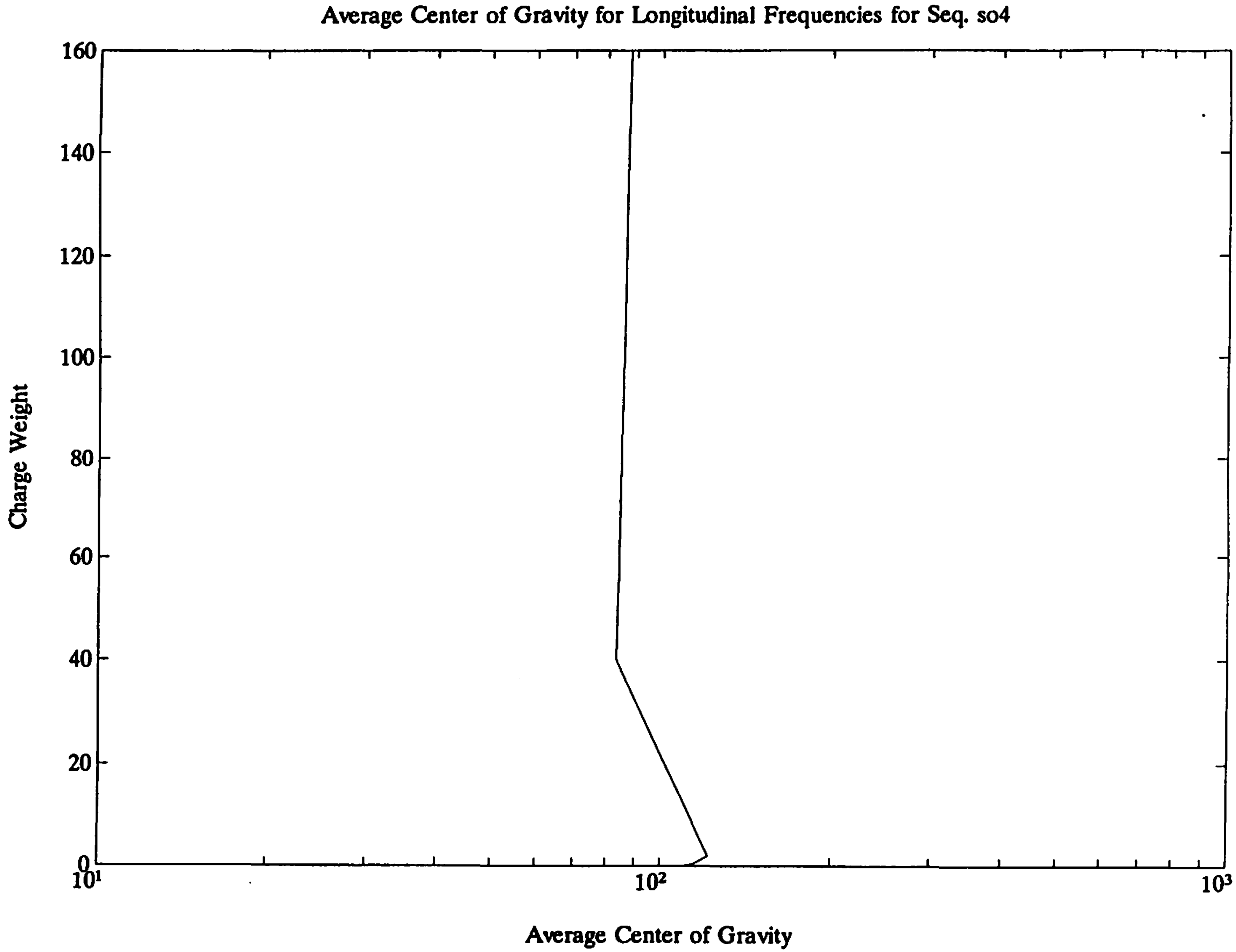

Average Center of Gravity for Vertical Frequencies for Seq. so4
Charge Weight
160
140
120
100
80
60
40
20
0
85
90
95
100
105
110
115
120
Average Center of Gravity

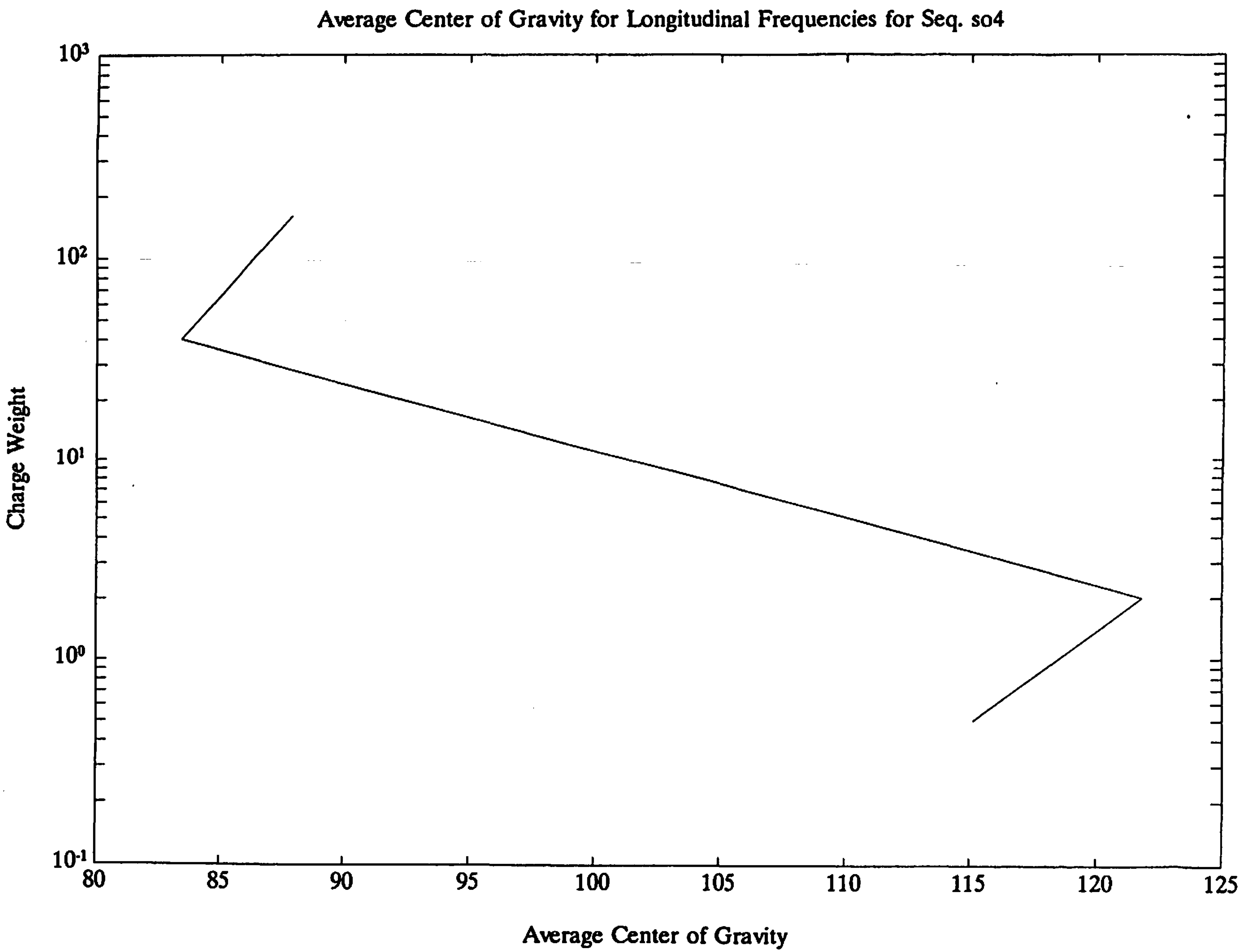

Average Center of Gravity for Vertical Frequencies for Seq. so4
Charge Weight
160
140
120
100
80
60
40
20
0
10¹
10²
10³
Average Center of Gravity

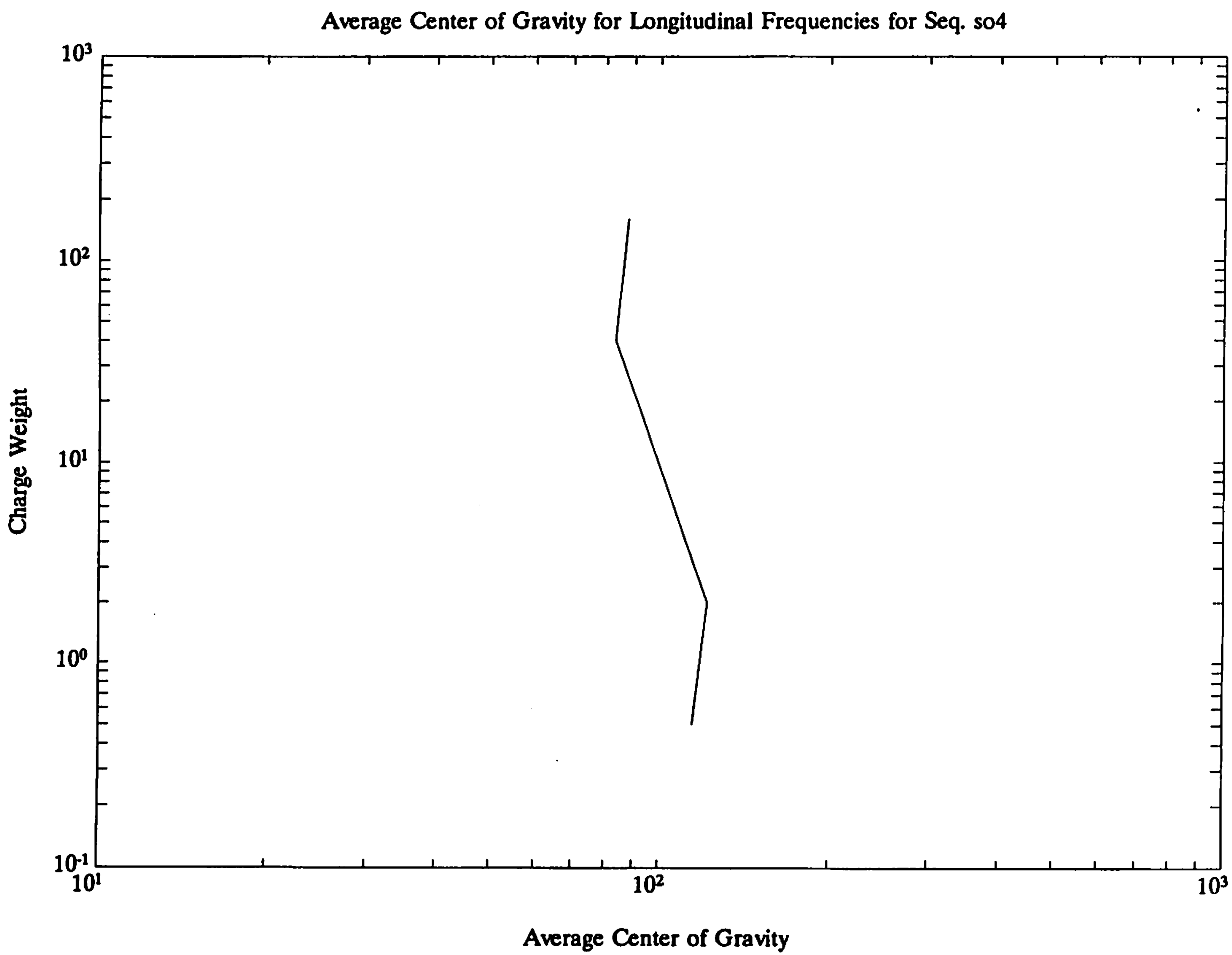

Average Center of Gravity for Vertical Frequencies for Seq. so4
10^3
10^2
10^1
10^0
10^{-1}
Charge Weight
85
90
95
100
105
110
115
120
Average Center of Gravity


Average Center of Gravity for Vertical Frequencies for Seq. so4
Charge Weight
10^3
10^2
10^1
10^0
10^-1
10^1
10^2
10^3
Average Center of Gravity

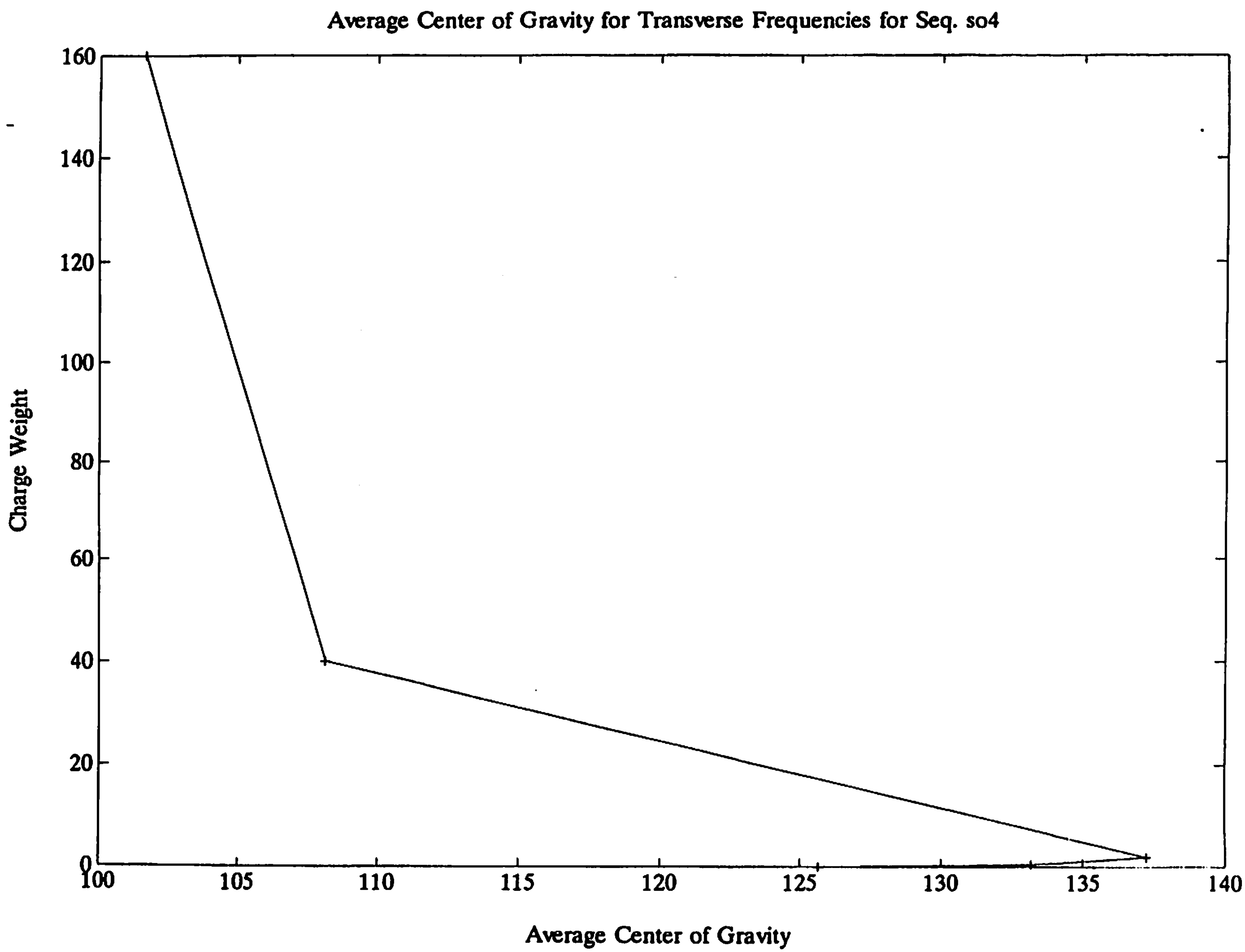

Average Center of Gravity for Longitudinal Frequencies for Seq. so4
Charge Weight
0
20
40
60
80
100
120
140
160
80
85
90
95
100
105
110
115
120
125
Average Center of Gravity

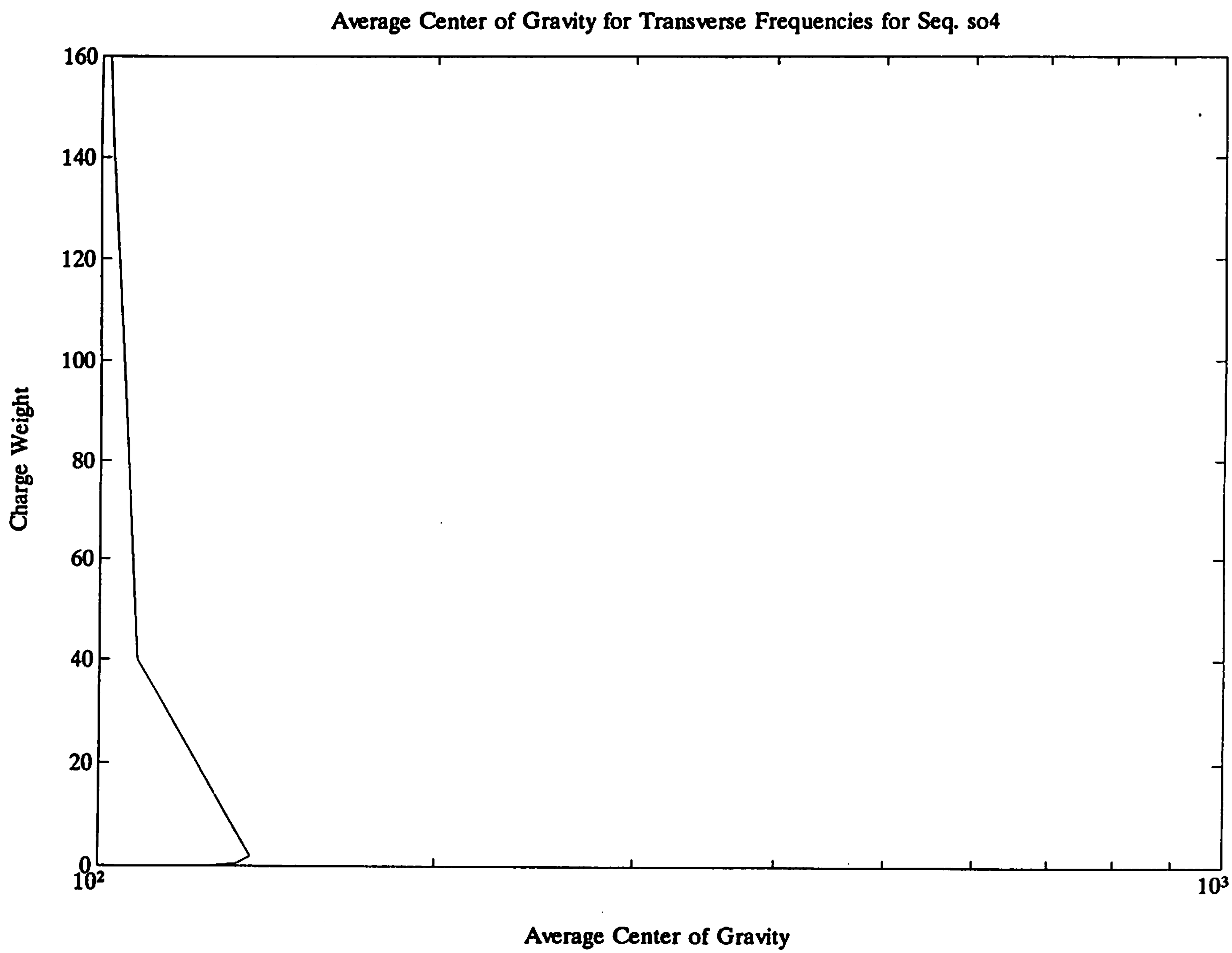

Average Center of Gravity for Longitudinal Frequencies for Seq. so4
Charge Weight
160
140
120
100
80
60
40
20
0
10^1
10^2
10^3
Average Center of Gravity


Average Center of Gravity for Longitudinal Frequencies for Seq. so4
Charge Weight
10^3
10^2
10^1
10^0
10^{-1}
80
85
90
95
100
105
110
115
120
125
Average Center of Gravity

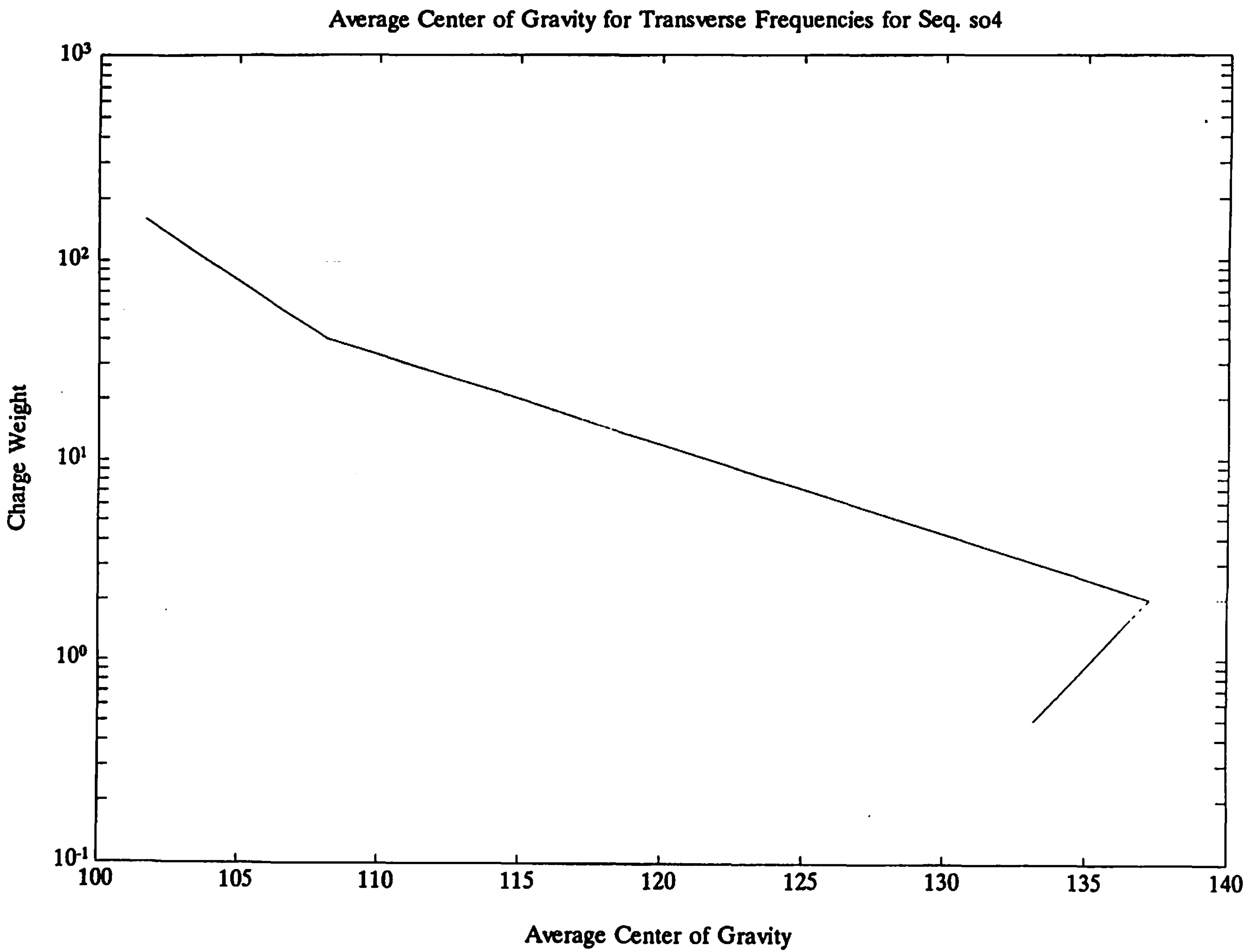


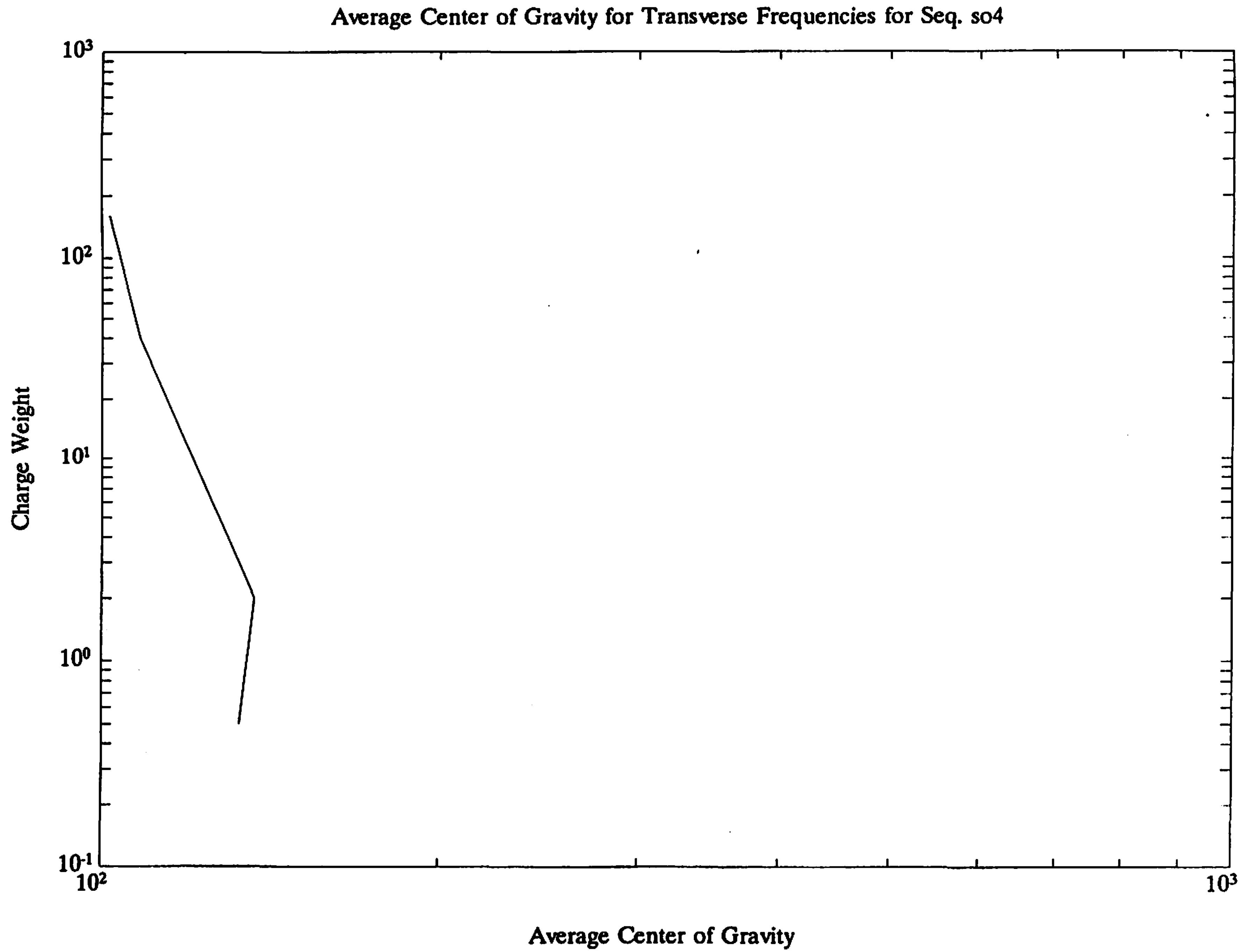
Average Center of Gravity for Longitudinal Frequencies for Seq. so4
Charge Weight
10³
10²
10¹
10⁰
10⁻¹
10¹
10²
10³
Average Center of Gravity

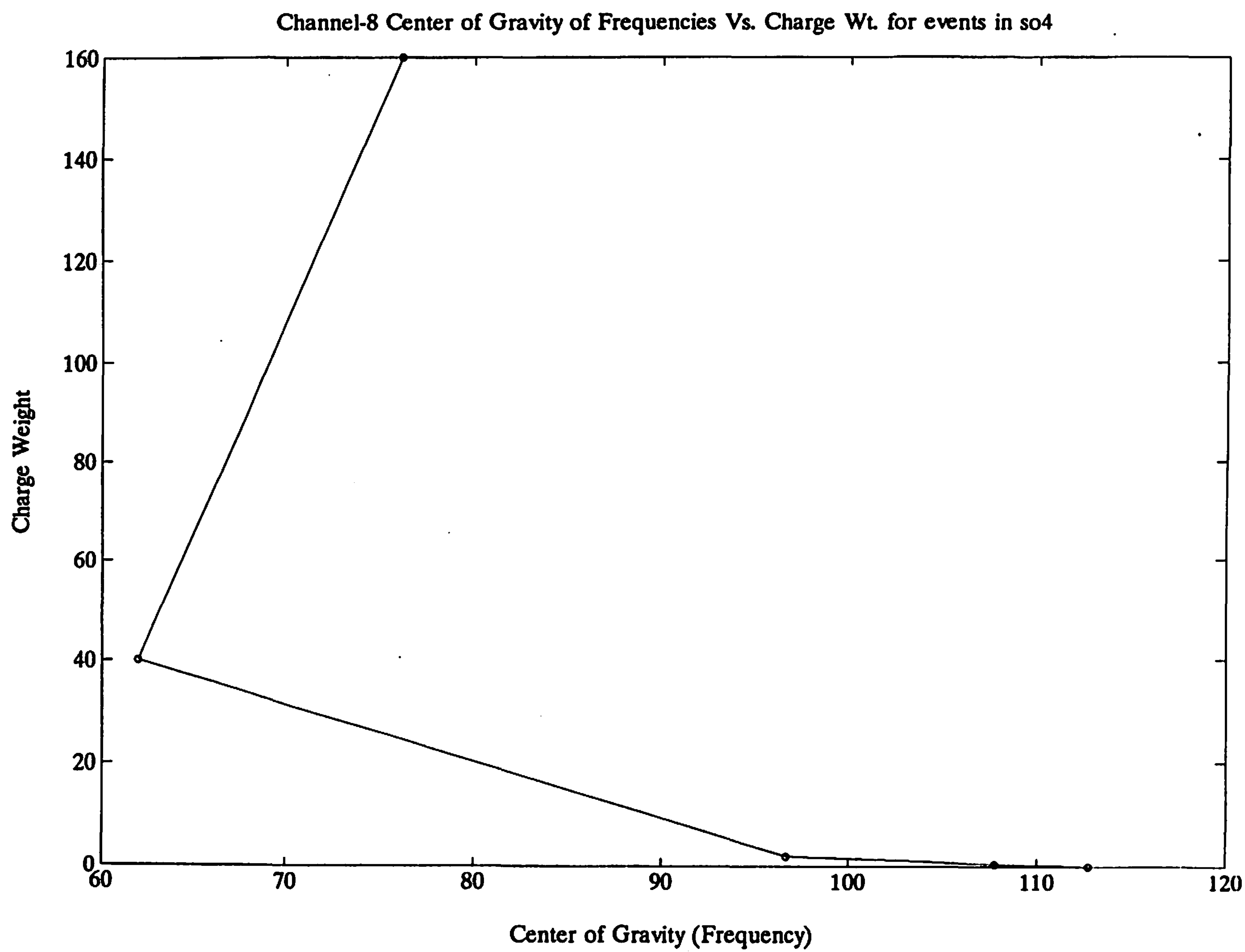

Average Center of Gravity for Transverse Frequencies for Seq. so4
Charge Weight
160
140
120
100
80
60
40
20
0
100
105
110
115
120
125
130
135
140
Average Center of Gravity

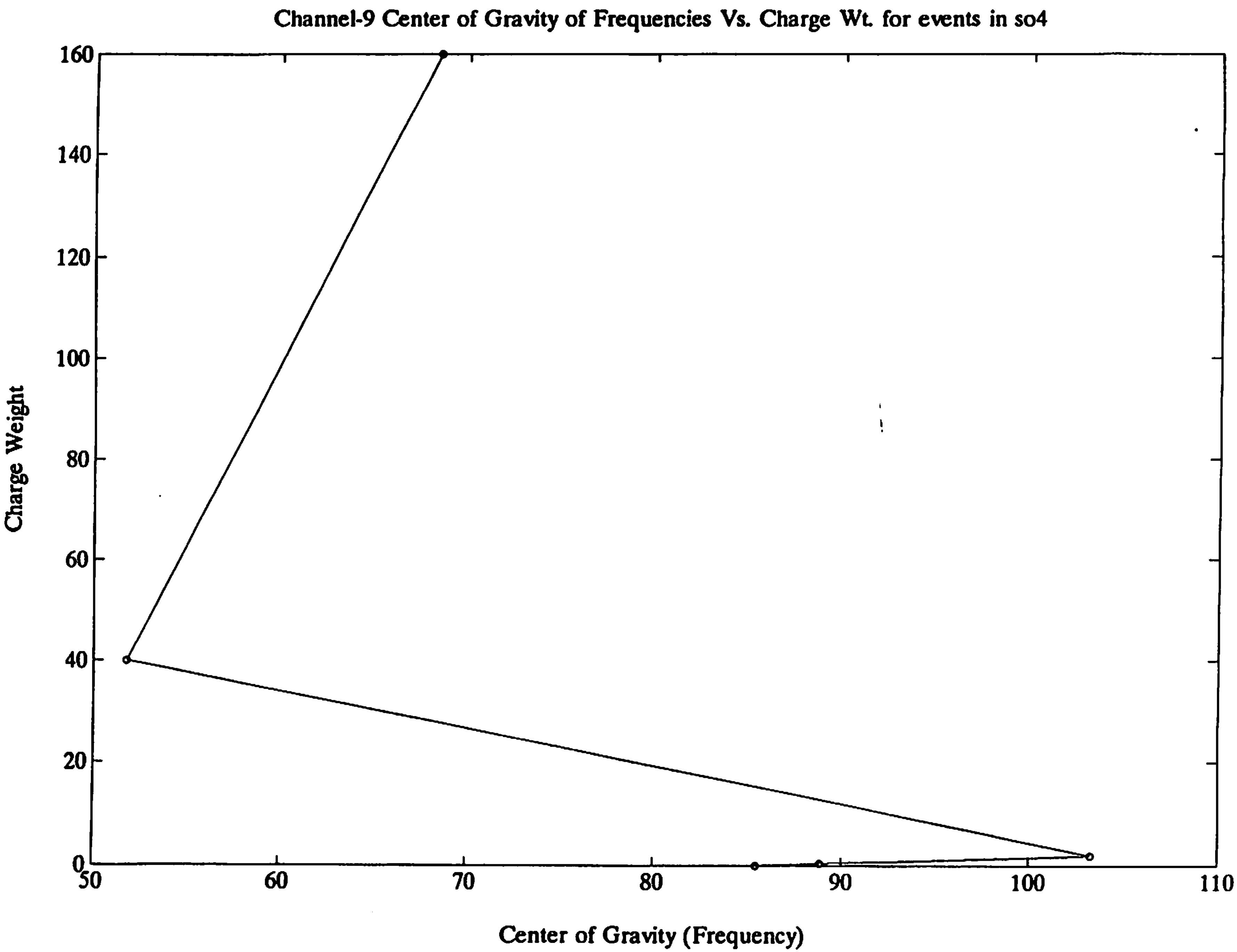


Average Center of Gravity for Transverse Frequencies for Seq. so4
Charge Weight
160
140
120
100
80
60
40
20
0
10^2
10^3
Average Center of Gravity

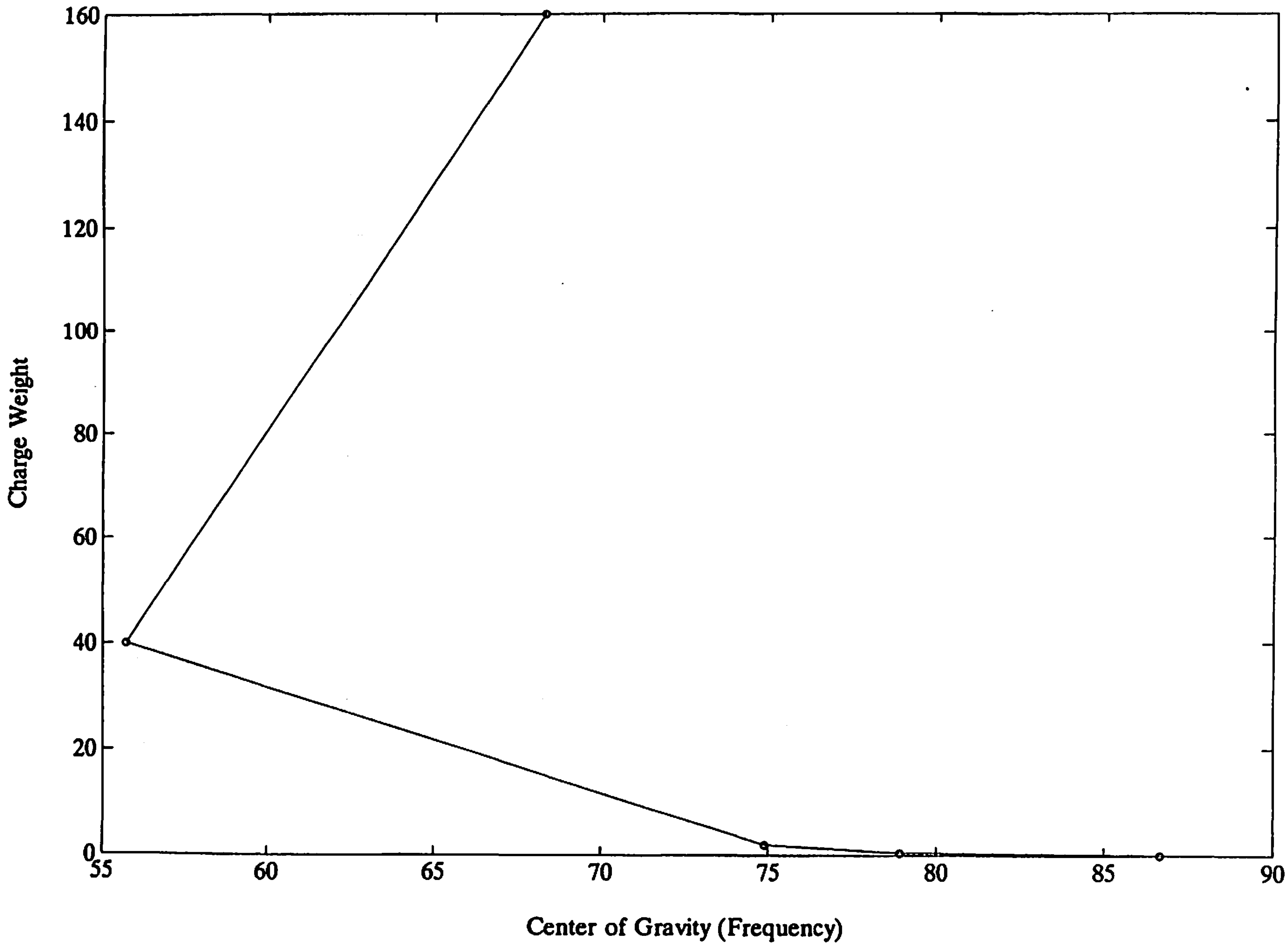

Average Center of Gravity for Transverse Frequencies for Seq. so4
Charge Weight
10^3
10^2
10^1
10^0
10^-1
100
105
110
115
120
125
130
135
140
Average Center of Gravity

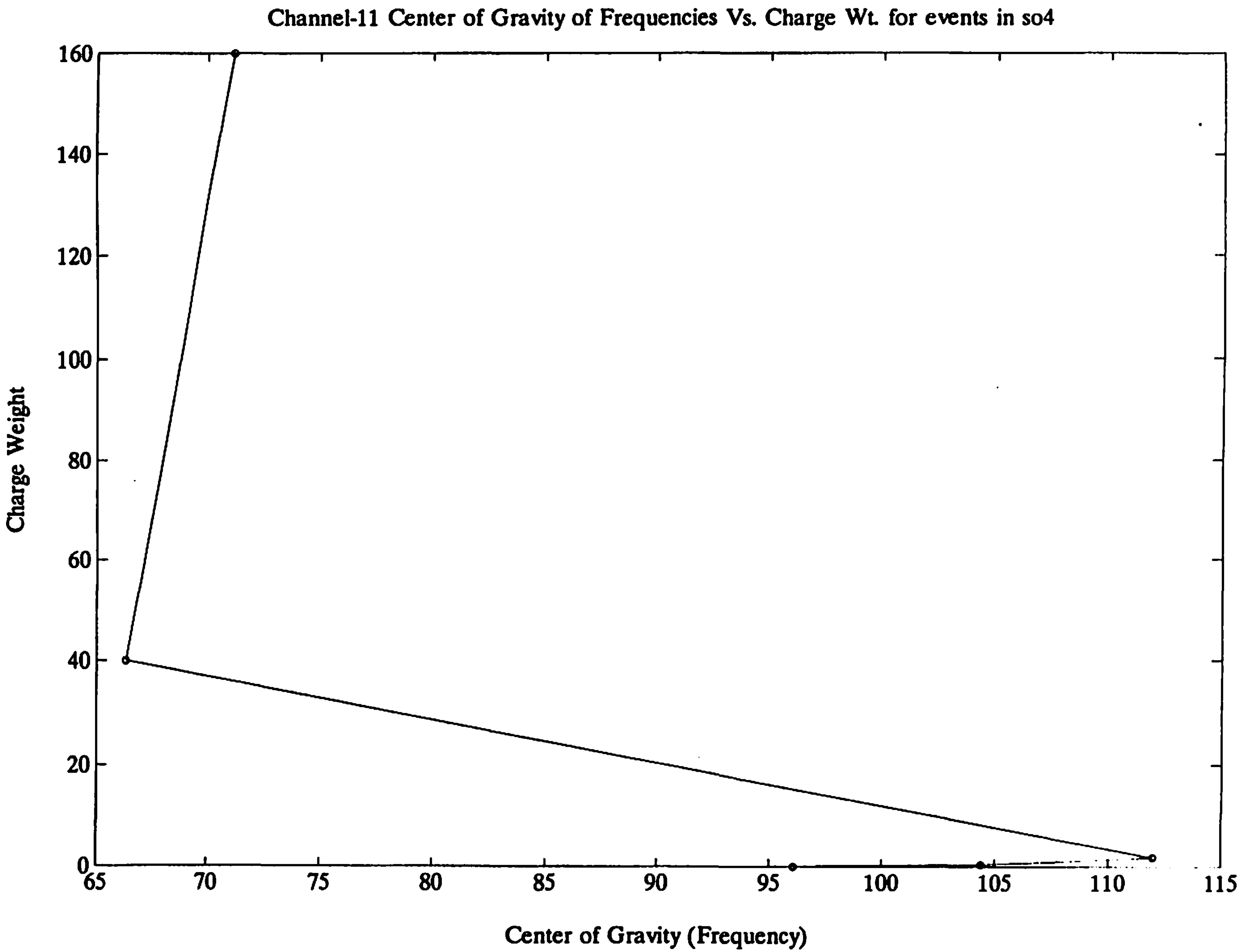

Average Center of Gravity for Transverse Frequencies for Seq. so4
Charge Weight
10^3
10^2
10^1
10^0
10^{-1}
10^2
10^3
Average Center of Gravity


Channel-8 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
60
70
80
90
100
110
120
Center of Gravity (Frequency)

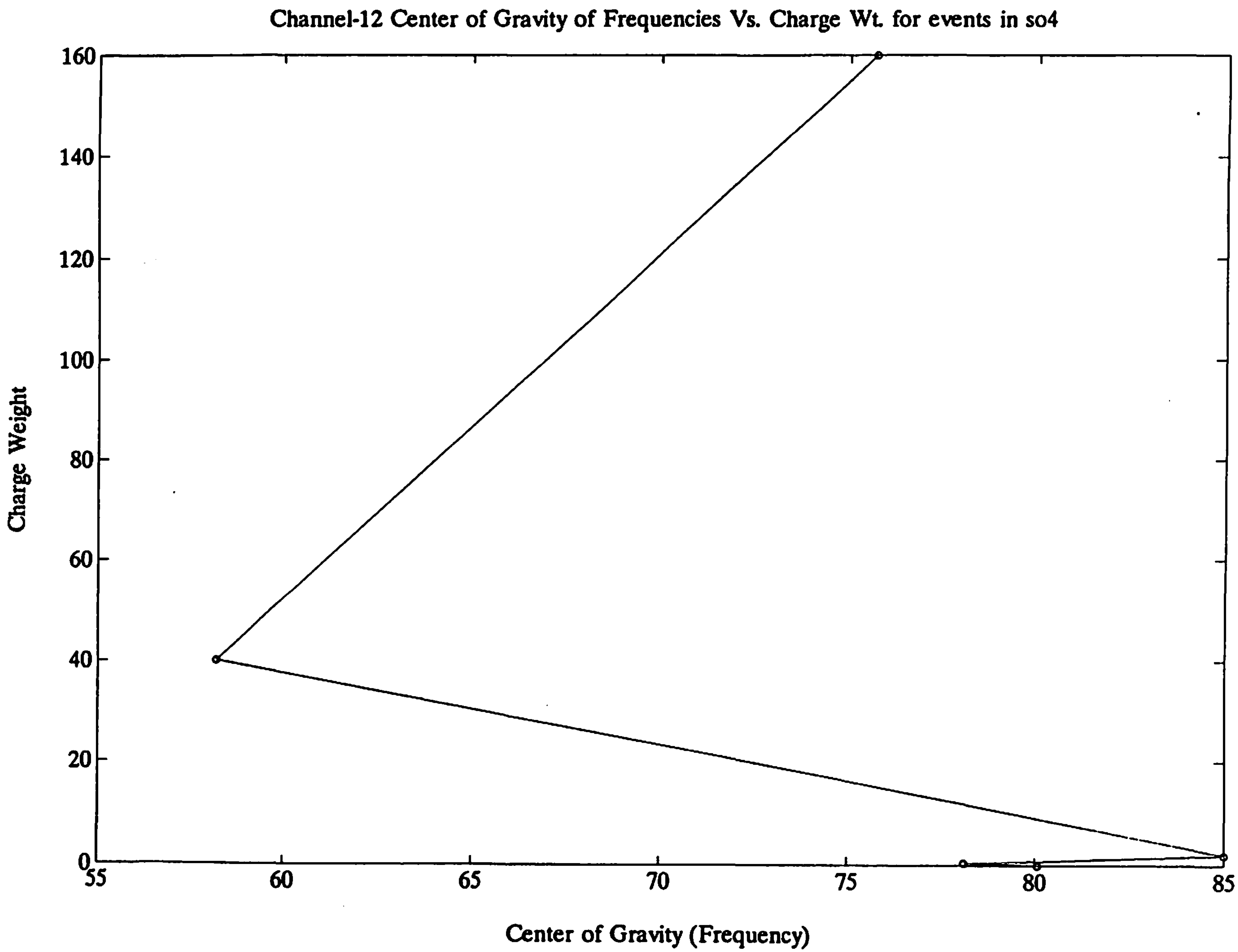

Channel-9 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
50
60
70
80
90
100
110
Center of Gravity (Frequency)

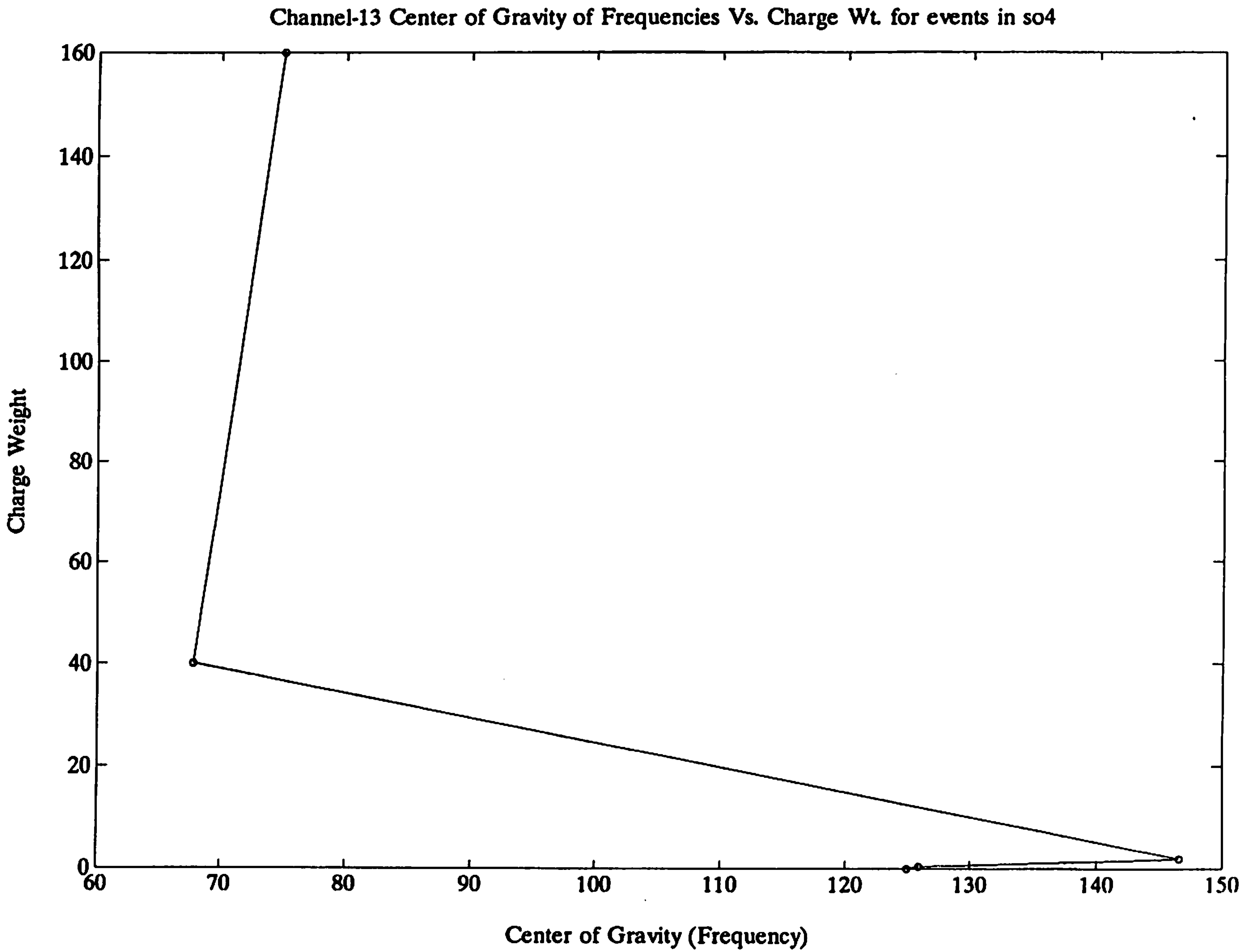
Channel-10 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4

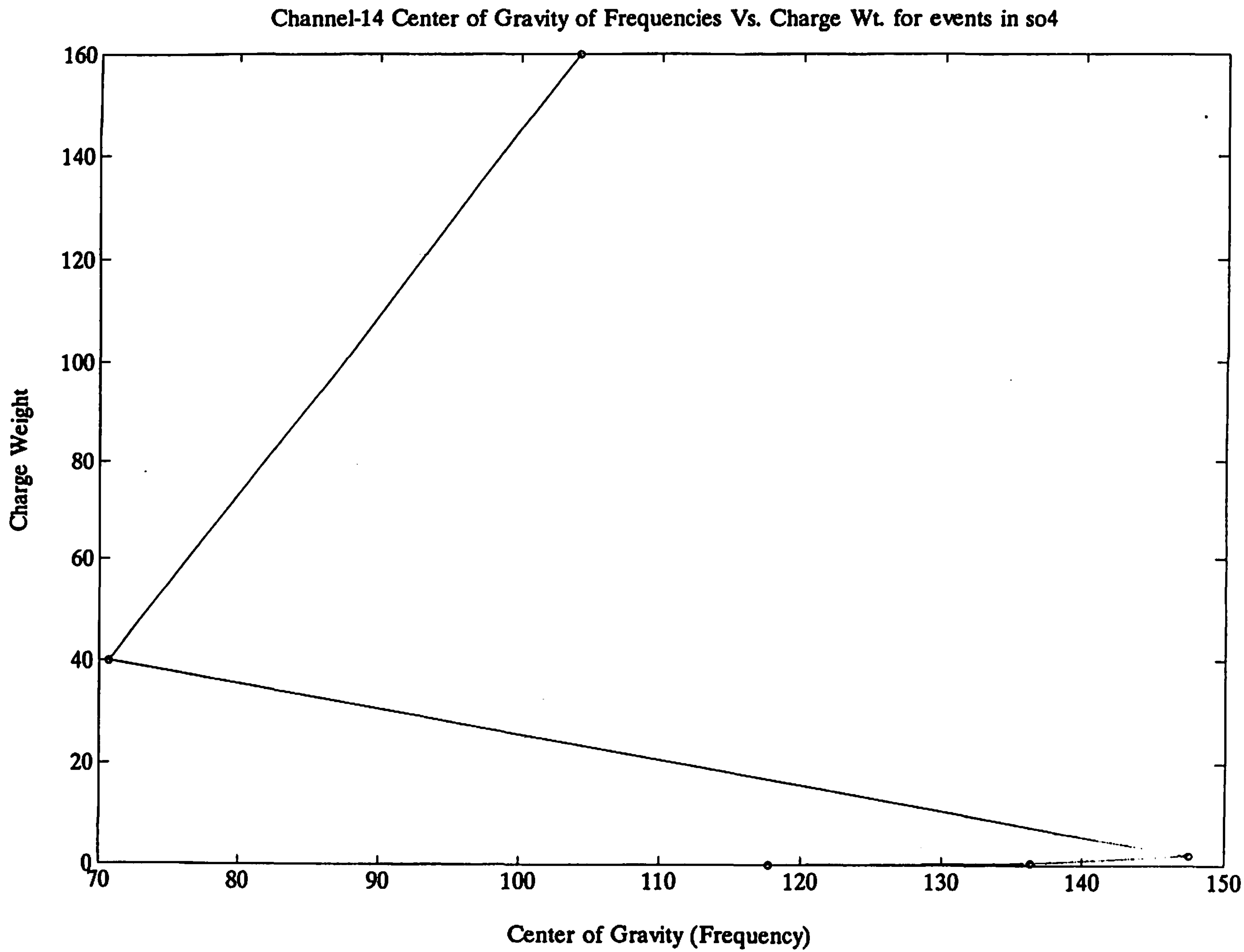


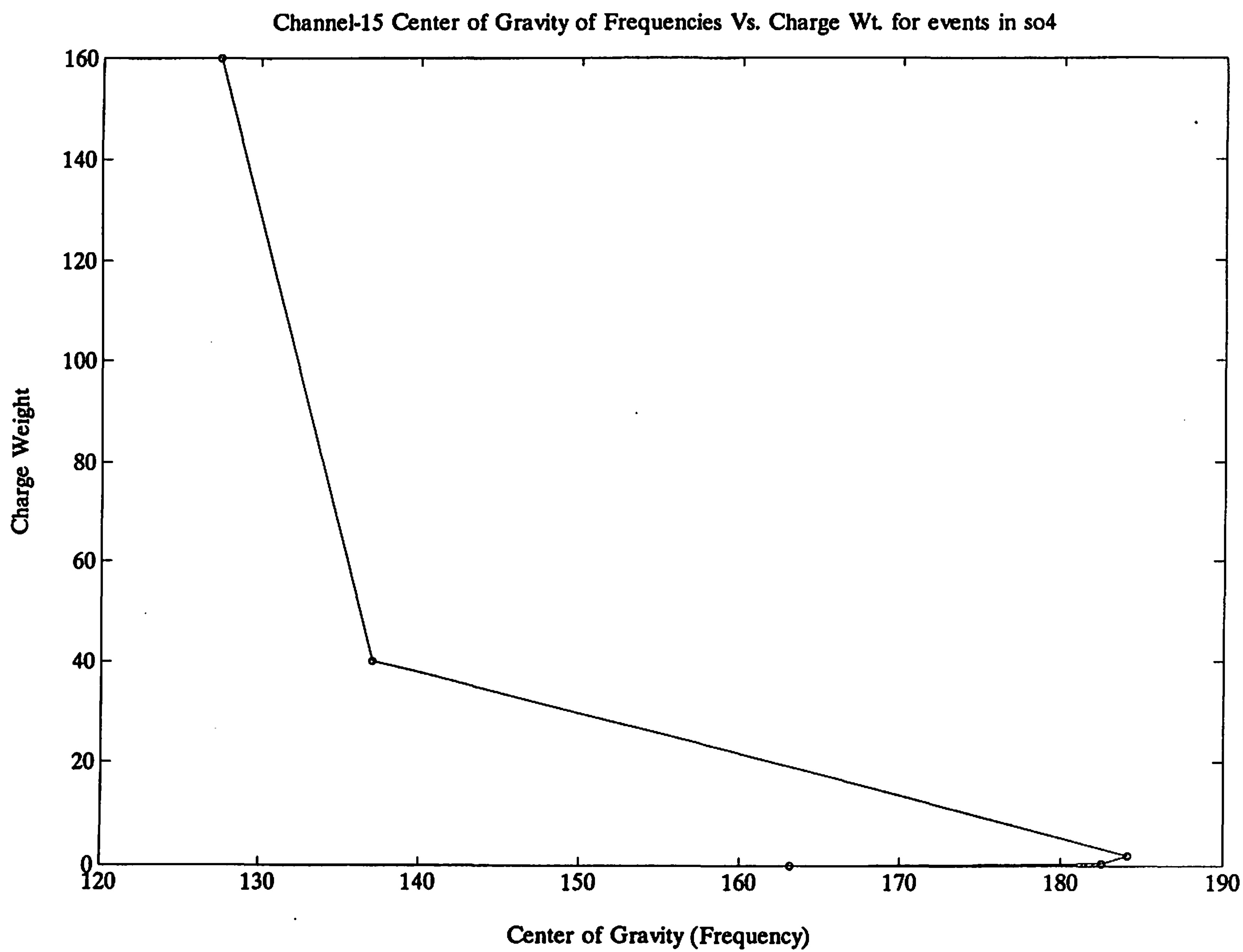


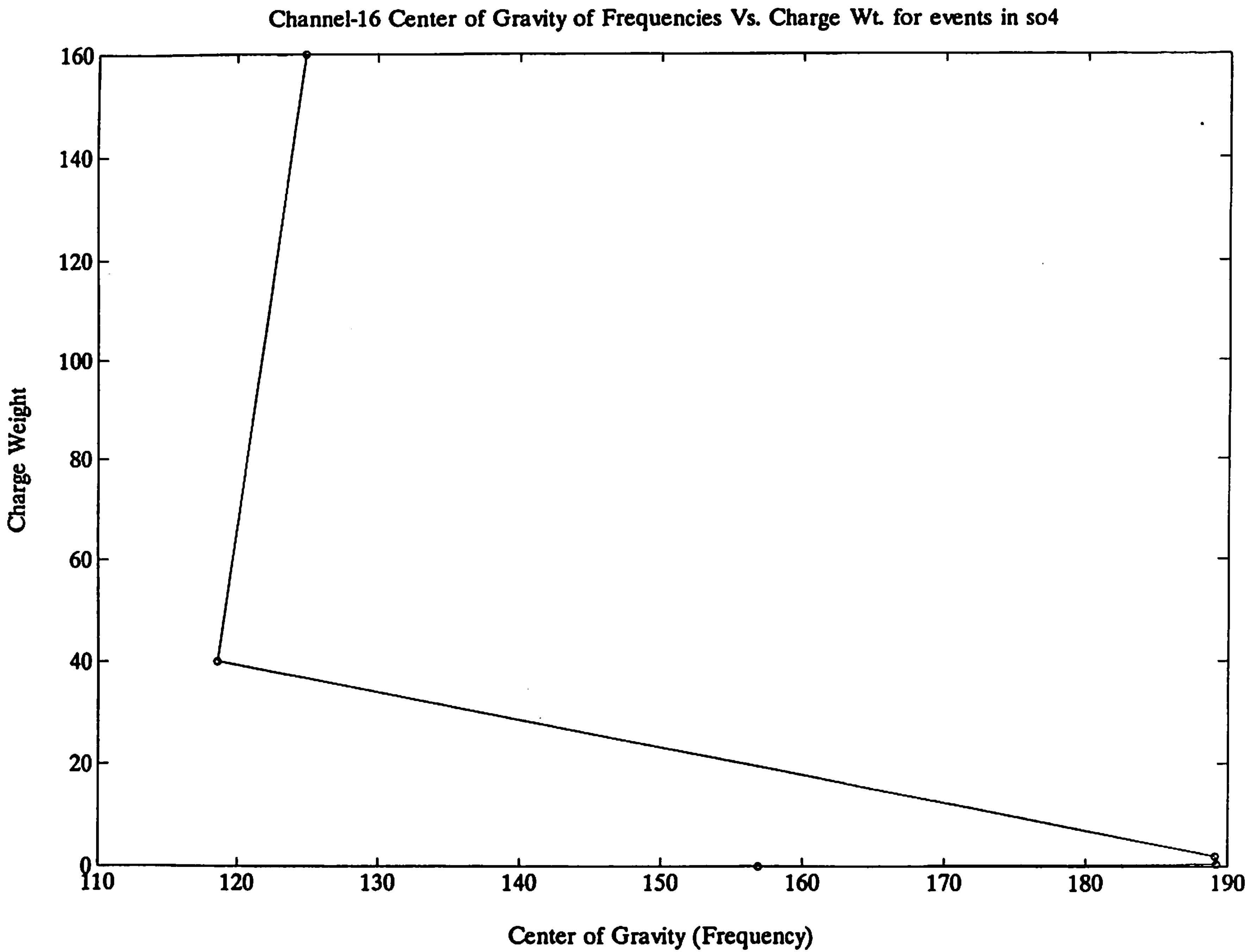
Channel-11 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
65
70
75
80
85
90
95
100
105
110
115
Center of Gravity (Frequency)

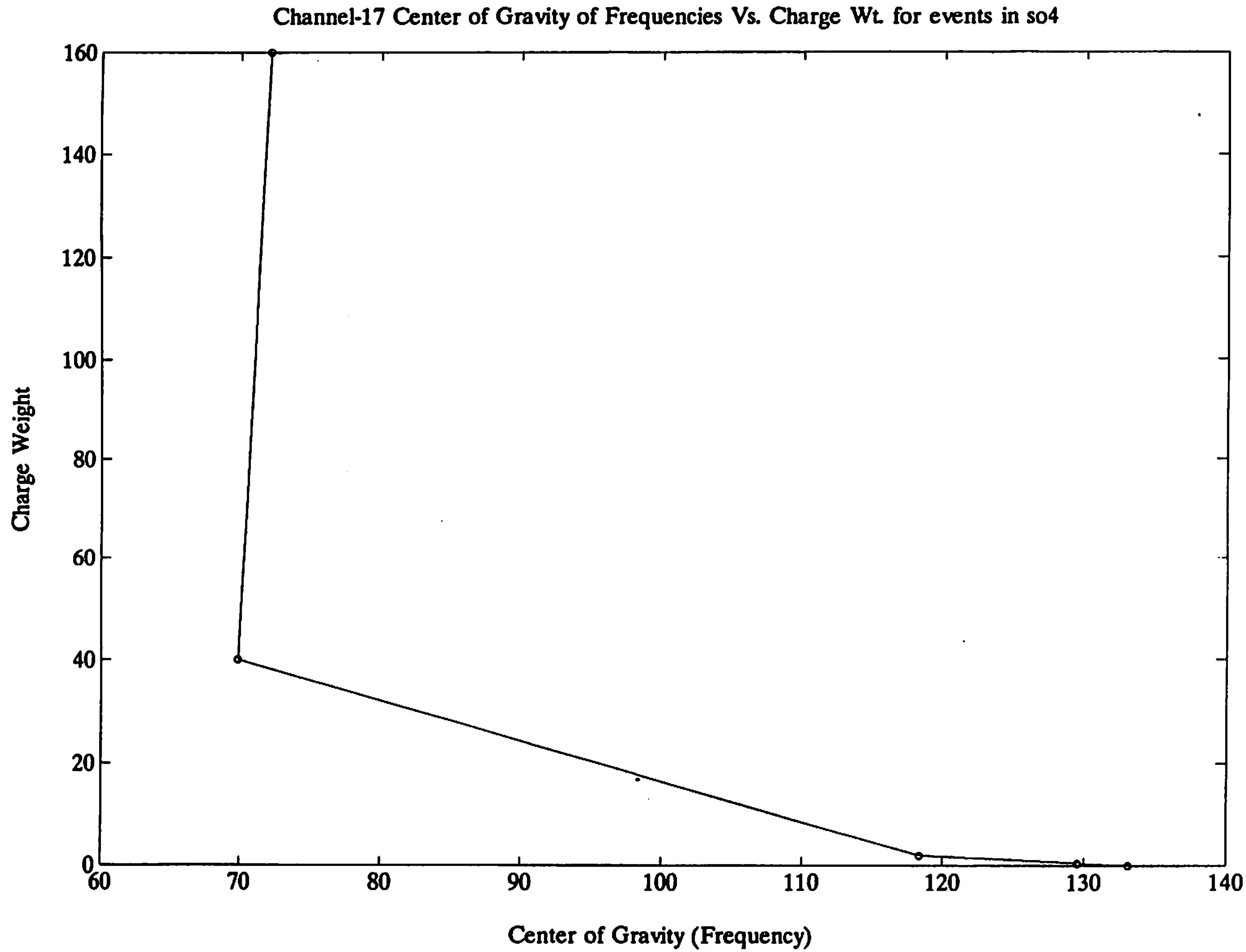

Channel-12 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
55
60
65
70
75
80
85

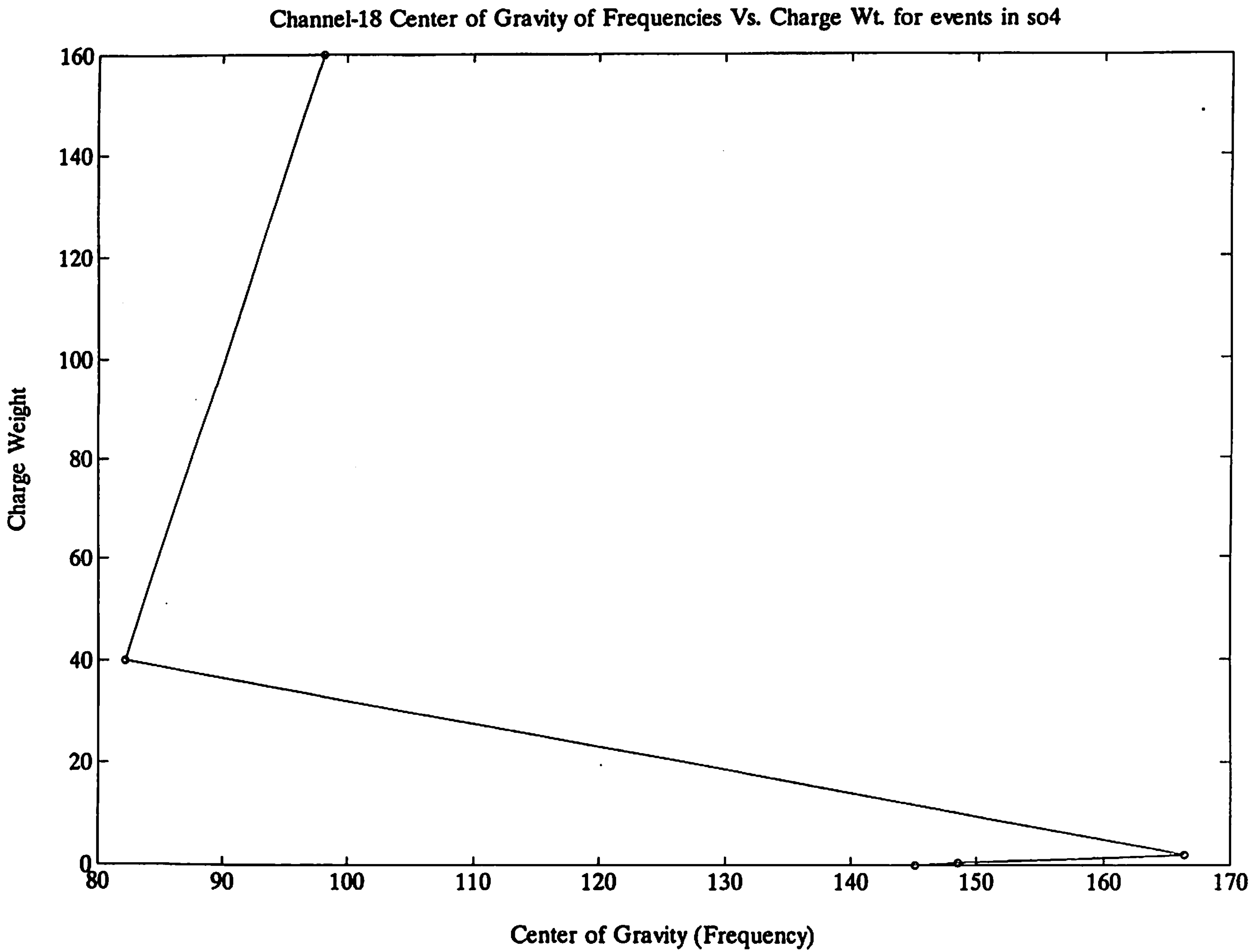

Channel-13 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
160
140
120
100
80
60
40
20
0
60
70
80
90
100
110
120
130
140
150


Channel-14 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
70
80
90
100
110
120
130
140
150
Center of Gravity (Frequency)

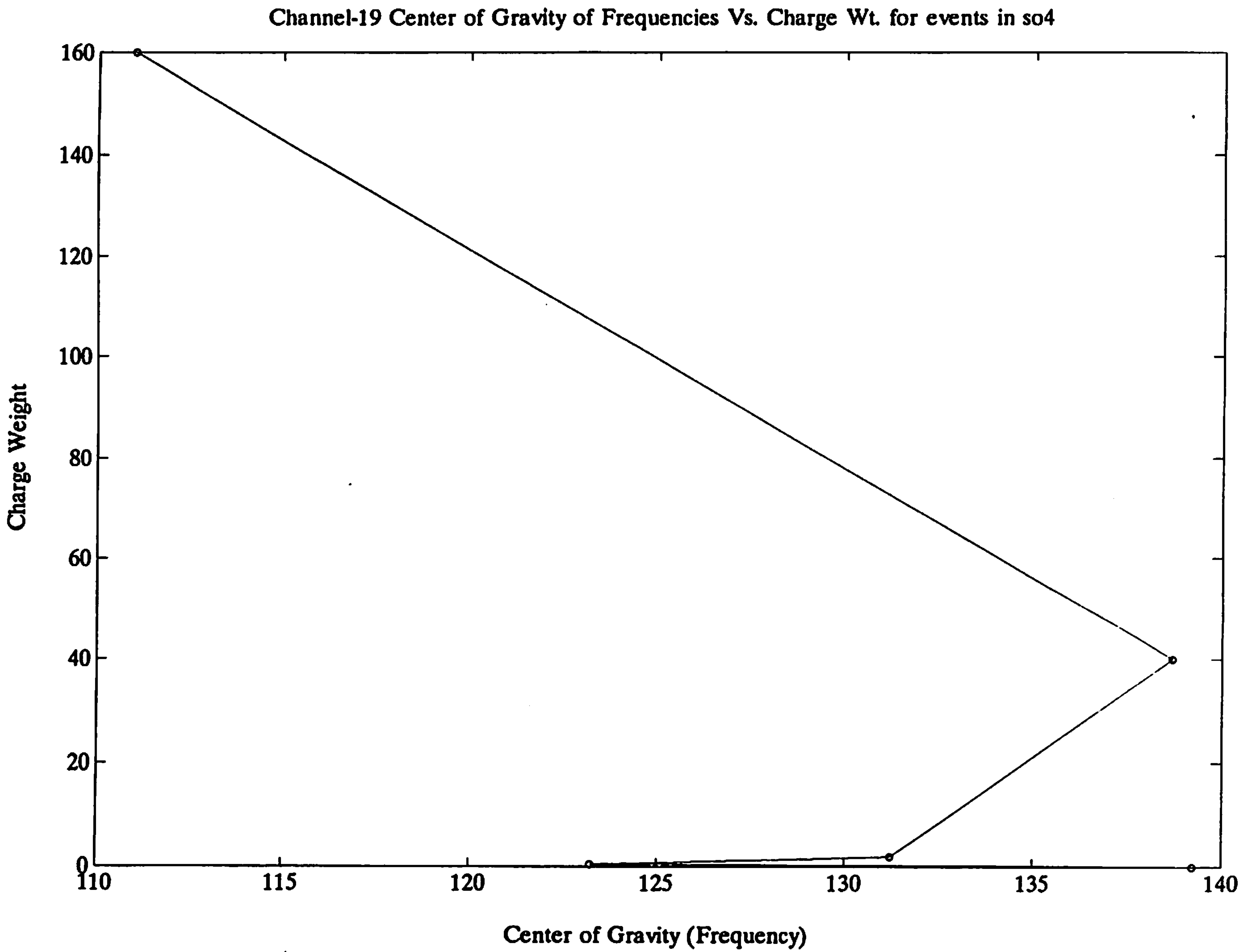

Channel-15 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
120
130
140
150
160
170
180
190

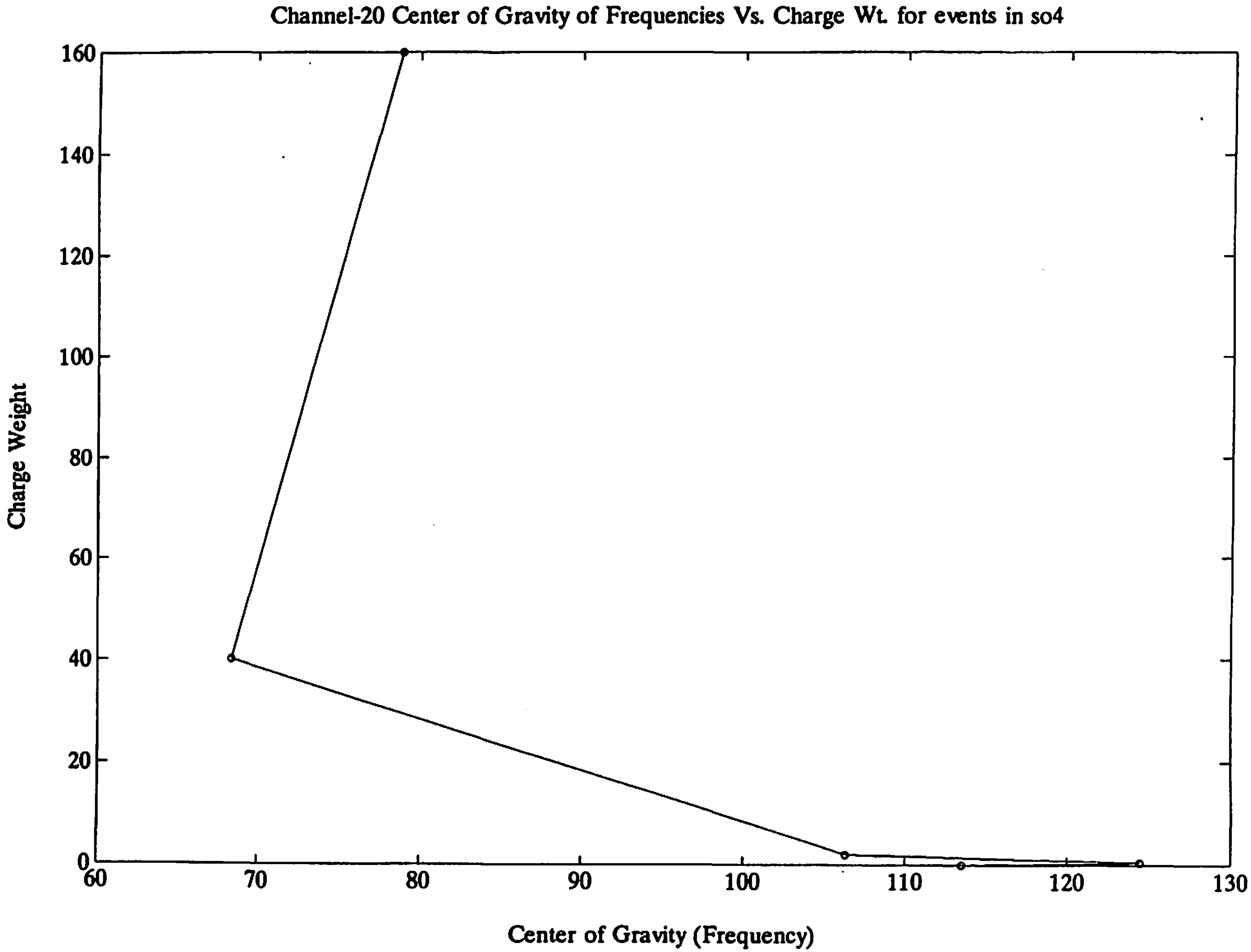

Channel-16 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
110
120
130
140
150
160
170
180
190


Channel-17 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
160
140
120
100
80
60
40
20
0
60
70
80
90
100
110
120
130
140

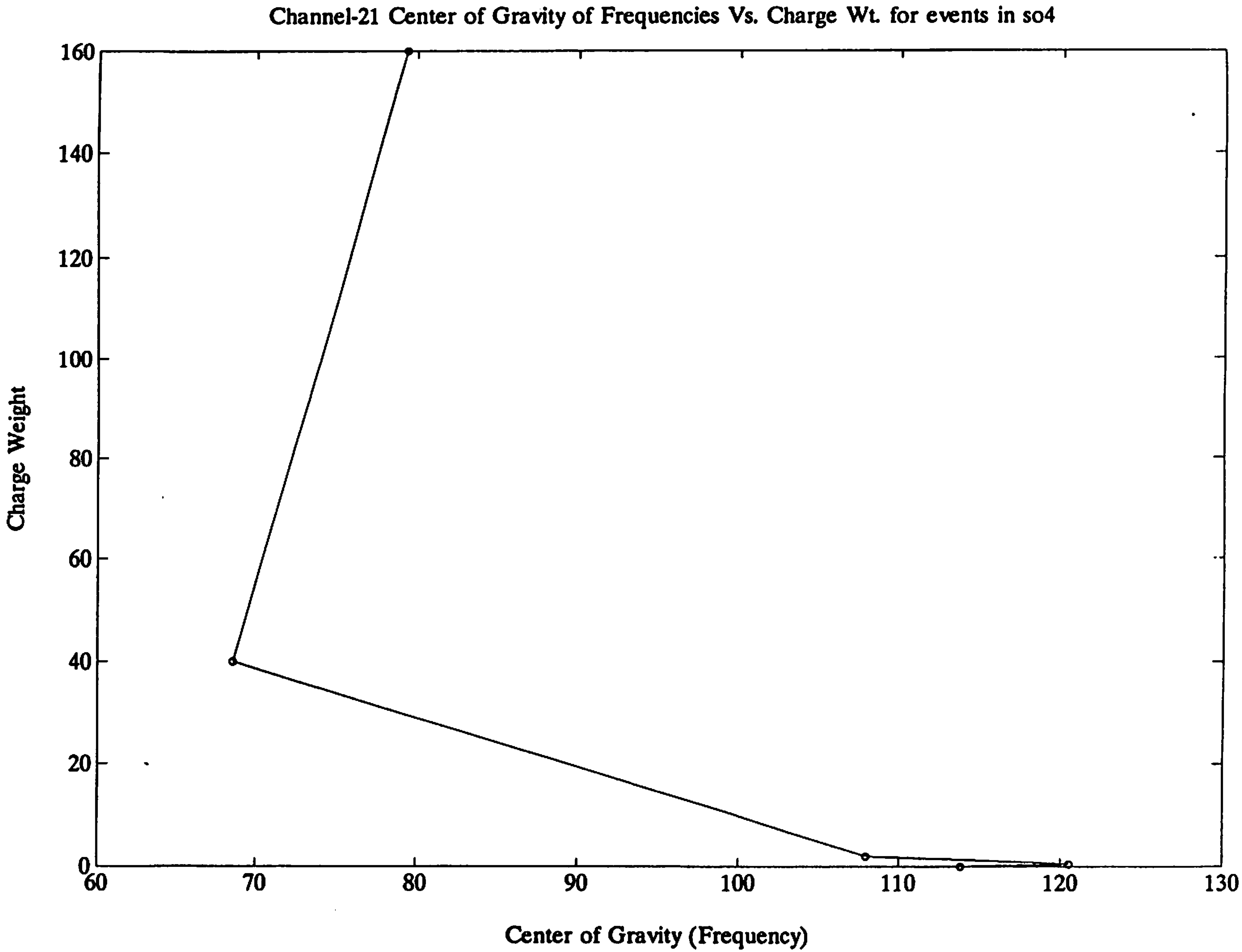


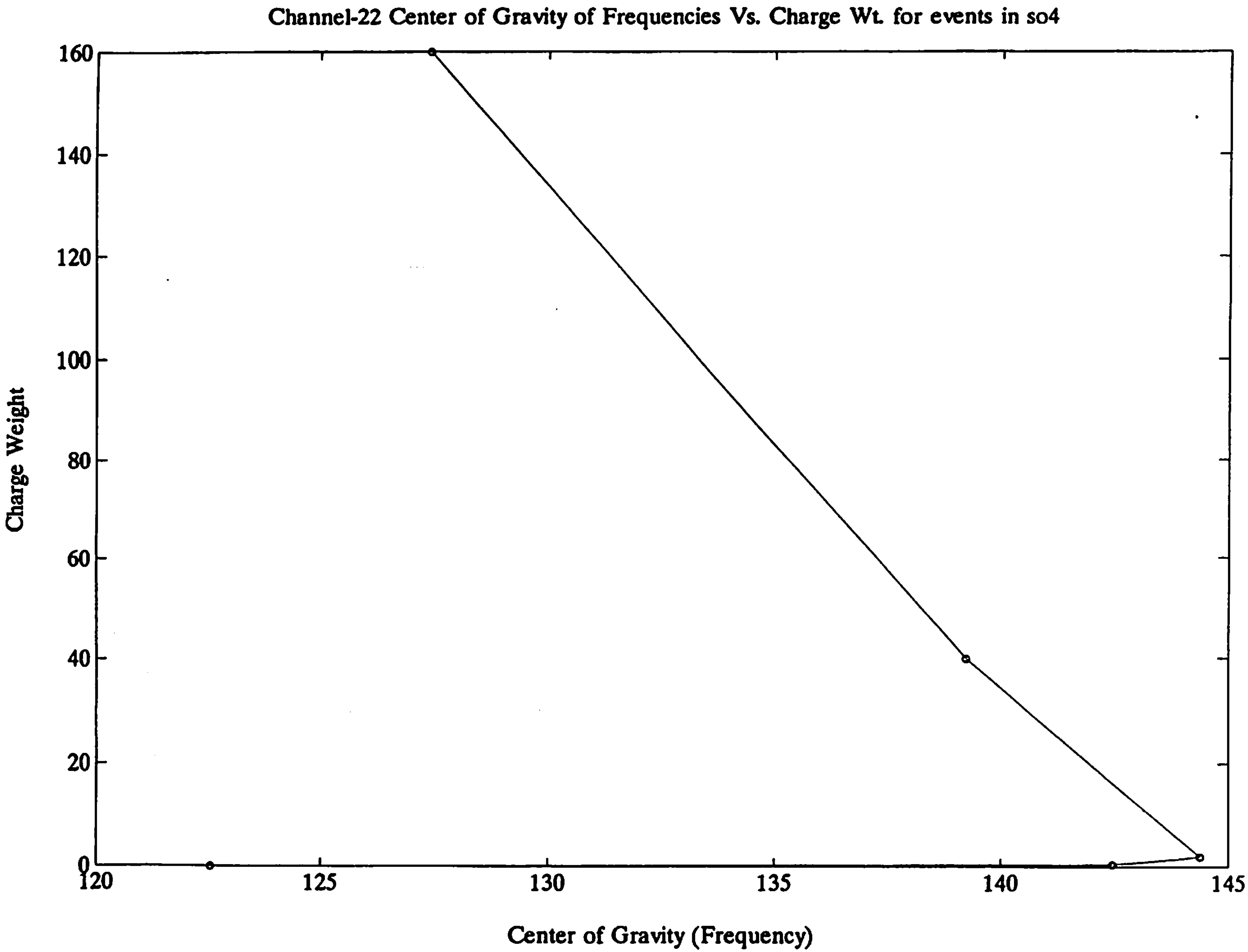
Channel-18 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
80
90
100
110
120
130
140
150
160
170

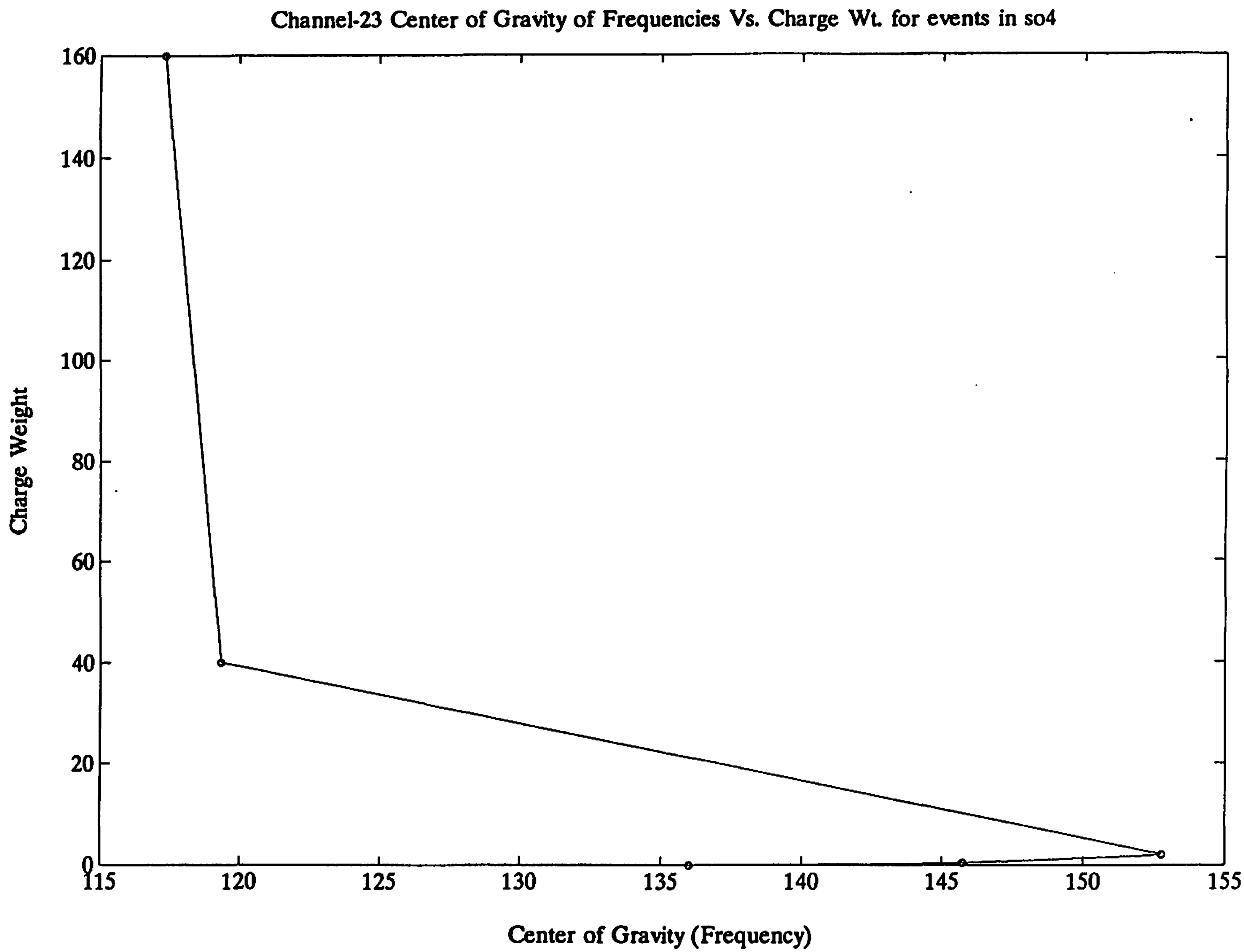

Channel-19 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
160
140
120
100
80
60
40
20
0
110
115
120
125
130
135
140



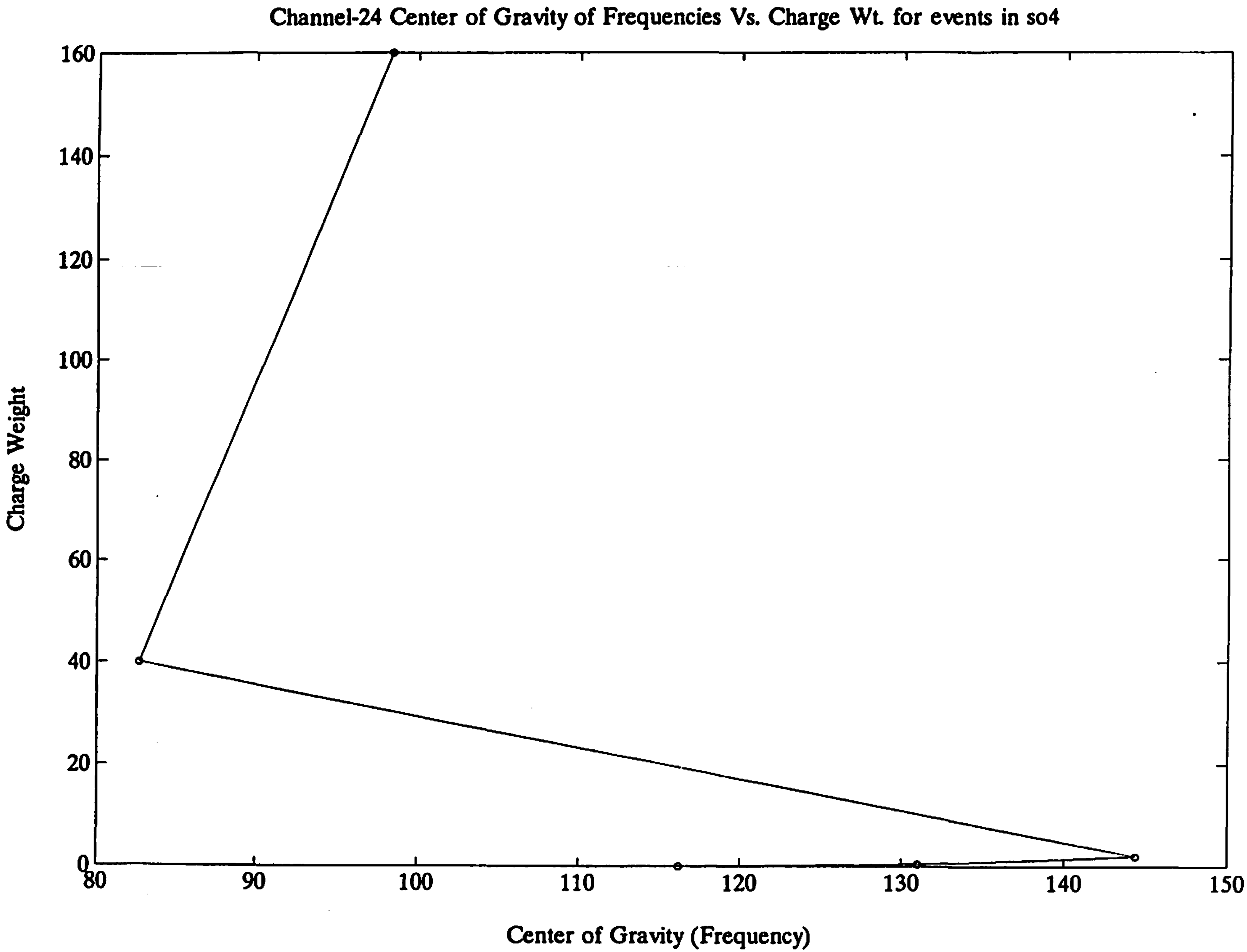
Channel-20 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
60
70
80
90
100
110
120
130
Center of Gravity (Frequency)

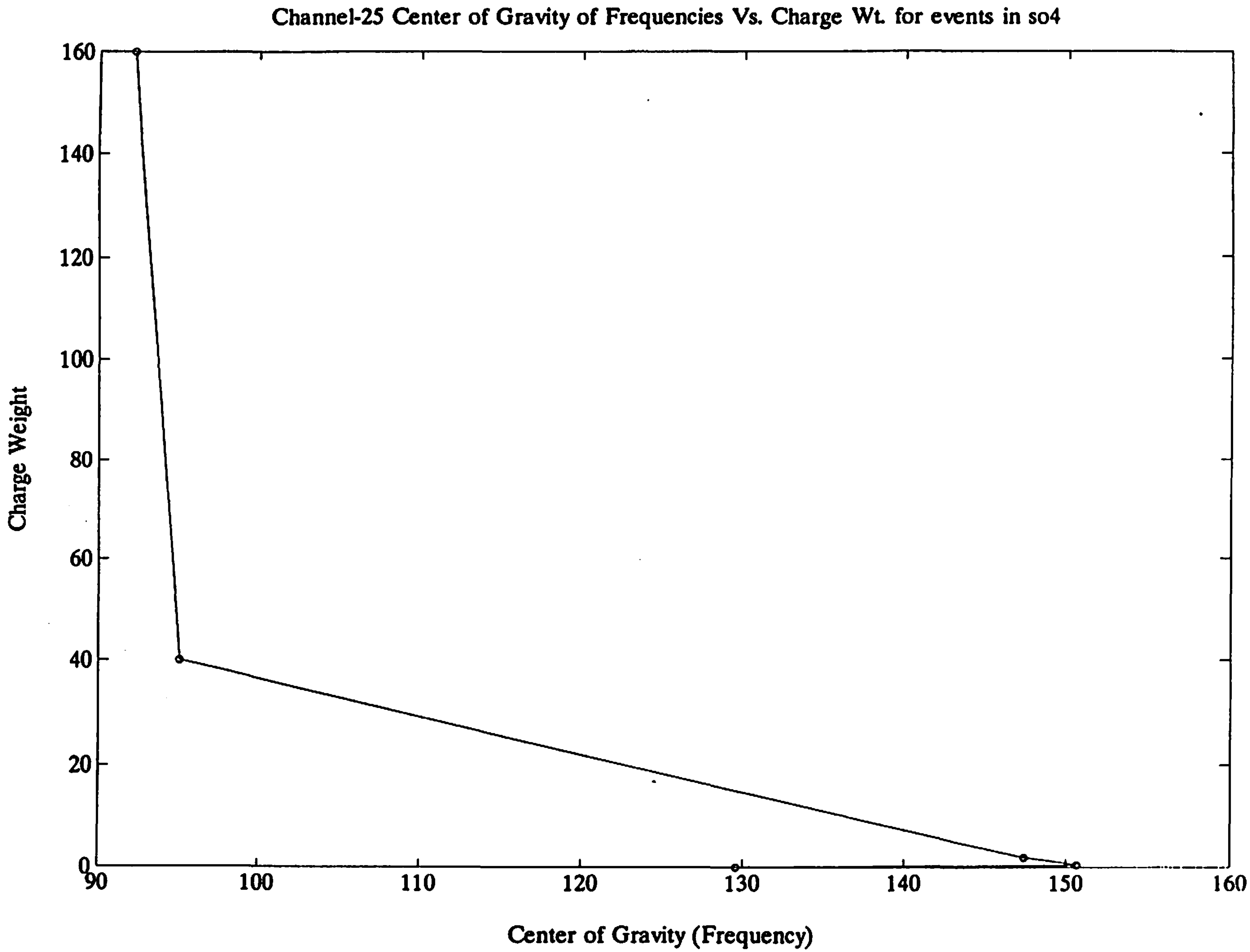

Channel-21 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
160
140
120
100
80
60
40
20
0
Charge Weight
60
70
80
90
100
110
120
130
Center of Gravity (Frequency)


Channel-22 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
120
125
130
135
140
145
Center of Gravity (Frequency)



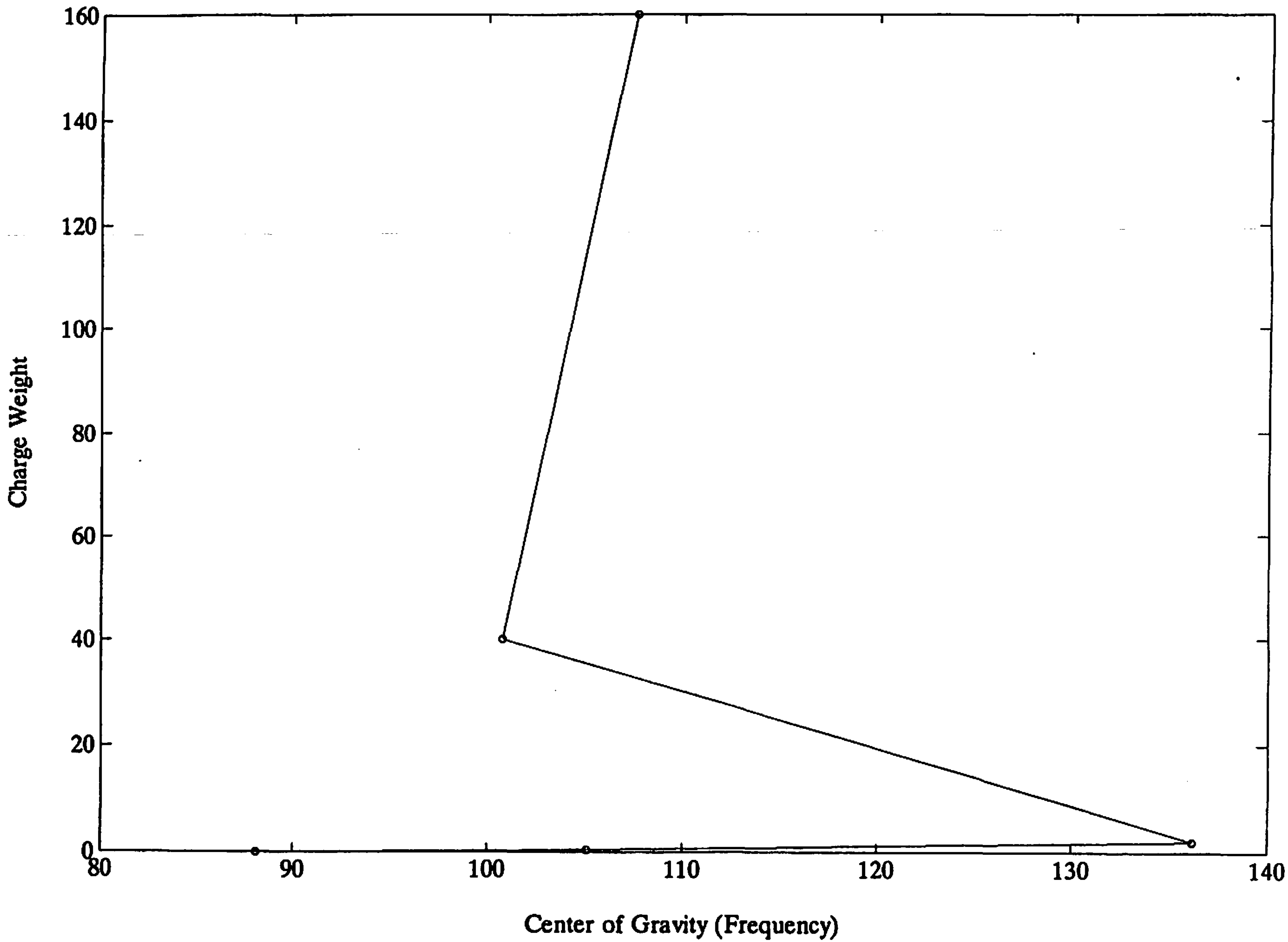
Channel-23 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
115
120
125
130
135
140
145
150
155

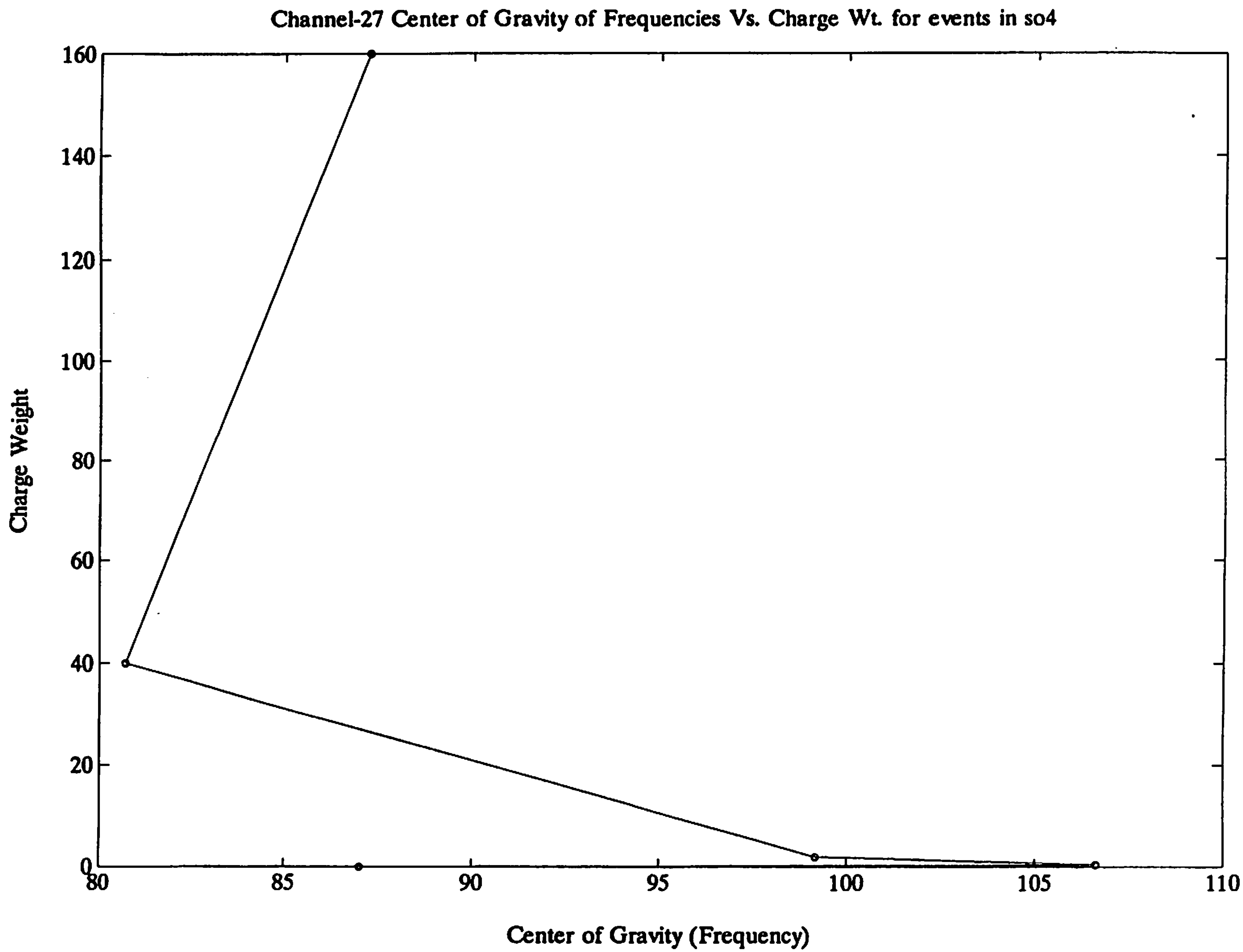

Channel-24 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
80
90
100
110
120
130
140
150
Center of Gravity (Frequency)

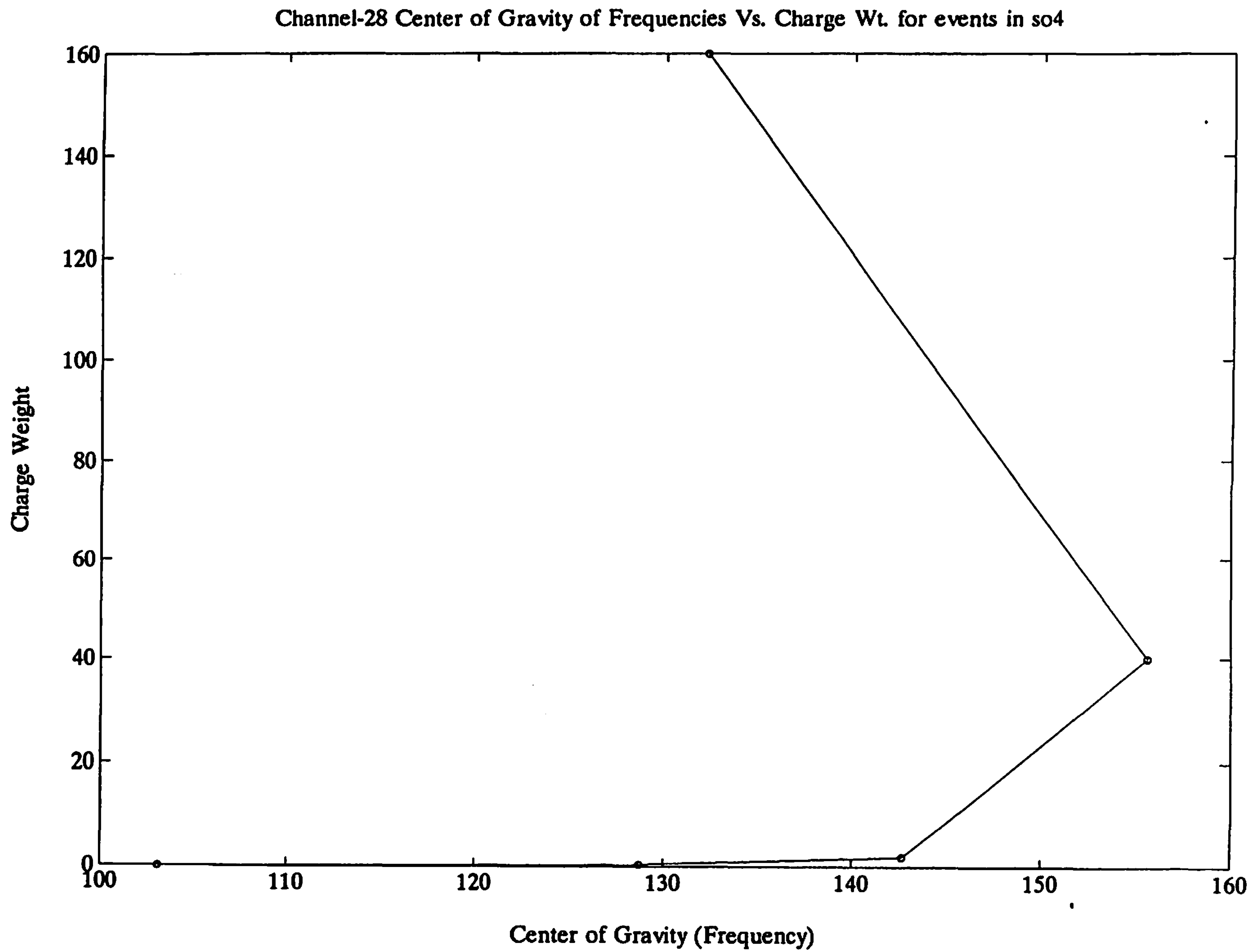


Channel-25 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
0
20
40
60
80
100
120
140
160
90
100
110
120
130
140
150
160
Center of Gravity (Frequency)

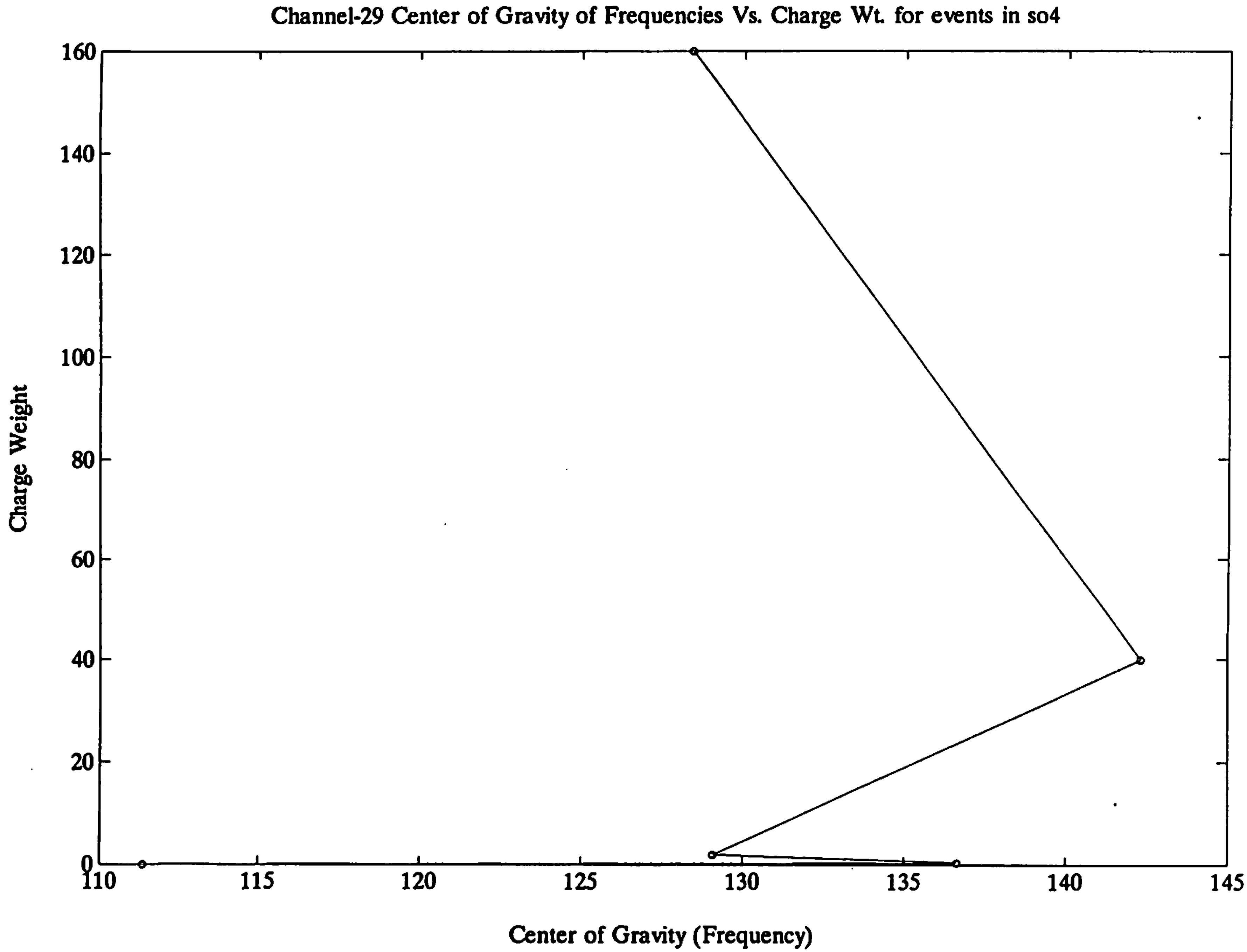
Channel-26 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4

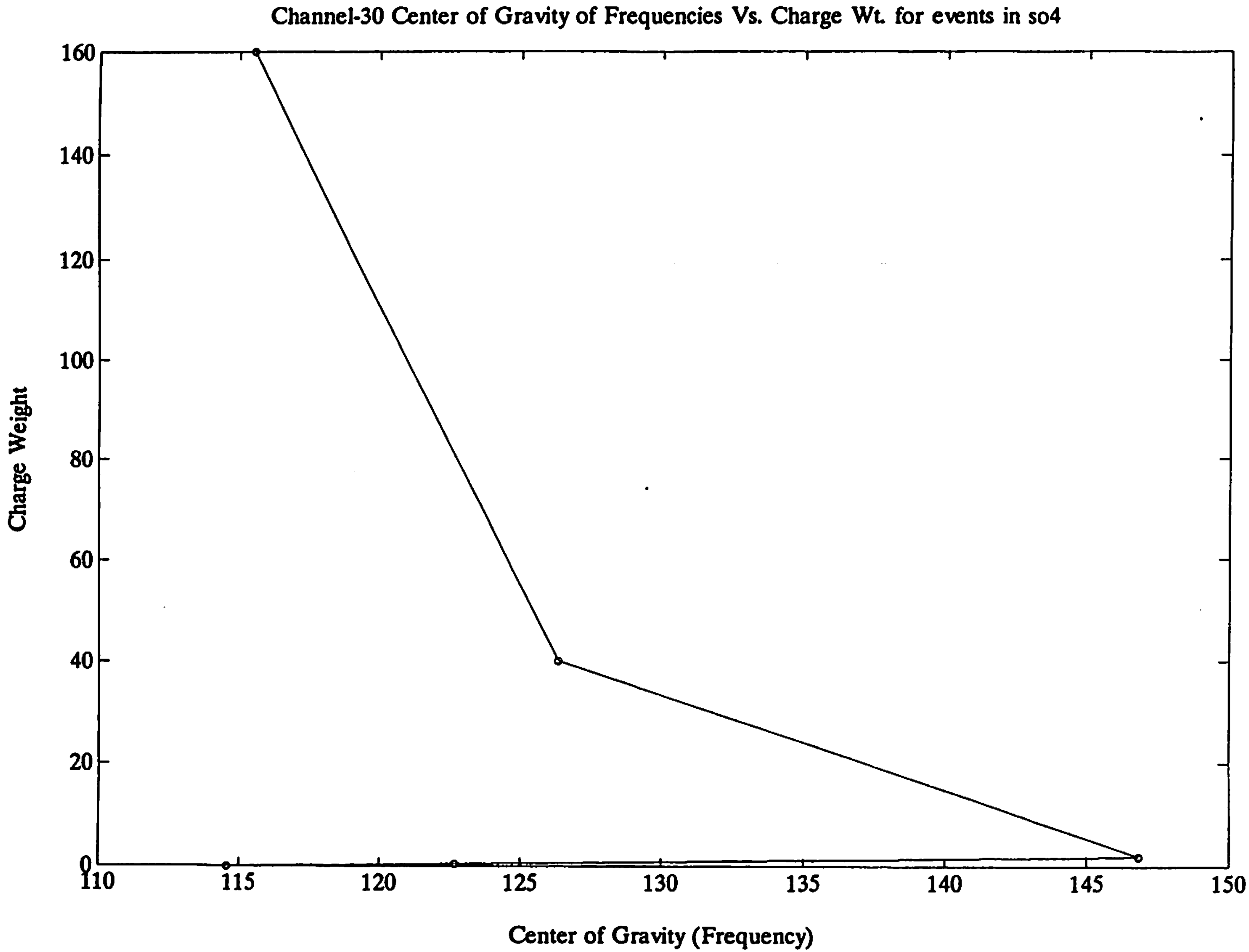



Channel-27 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
80
85
90
95
100
105
110

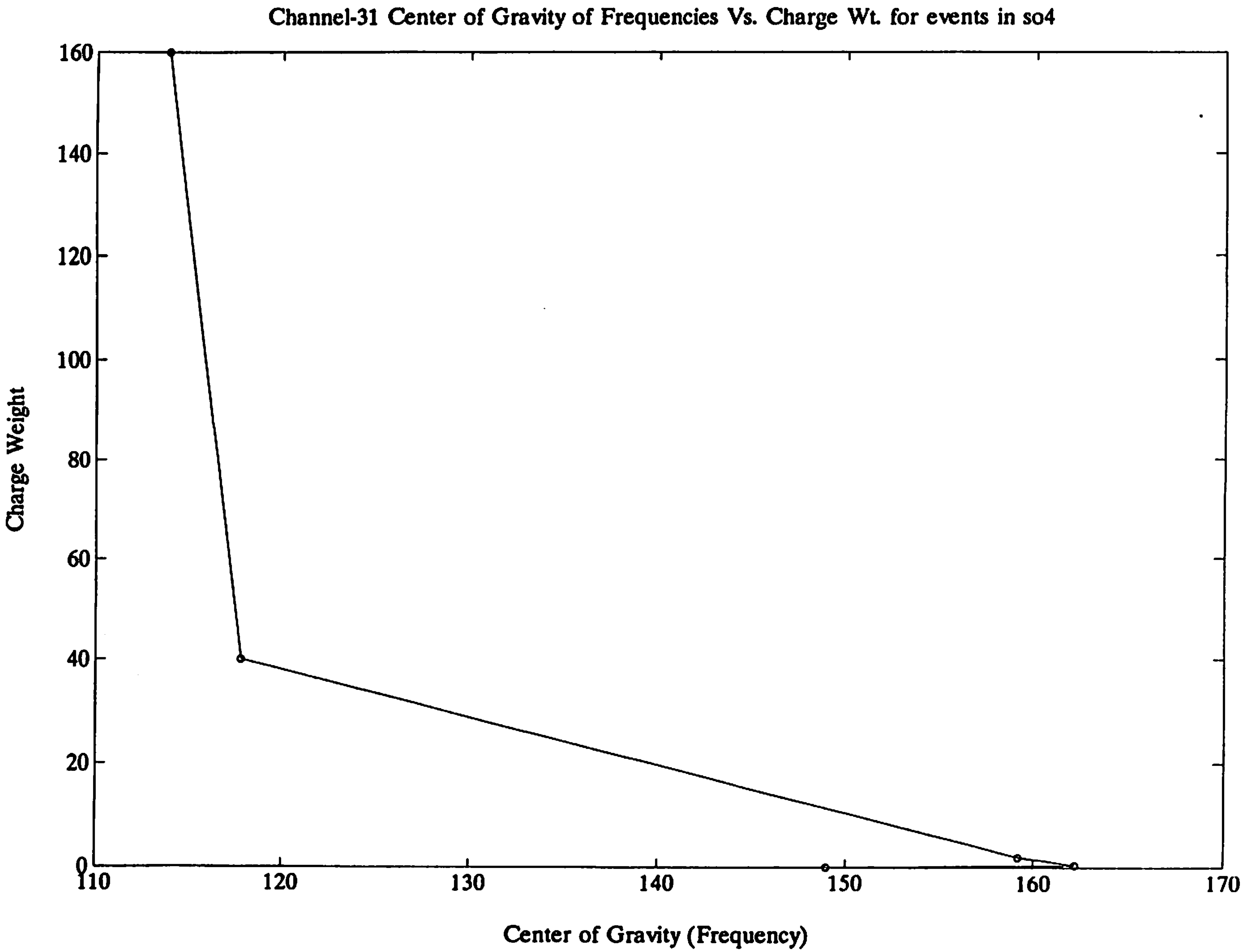


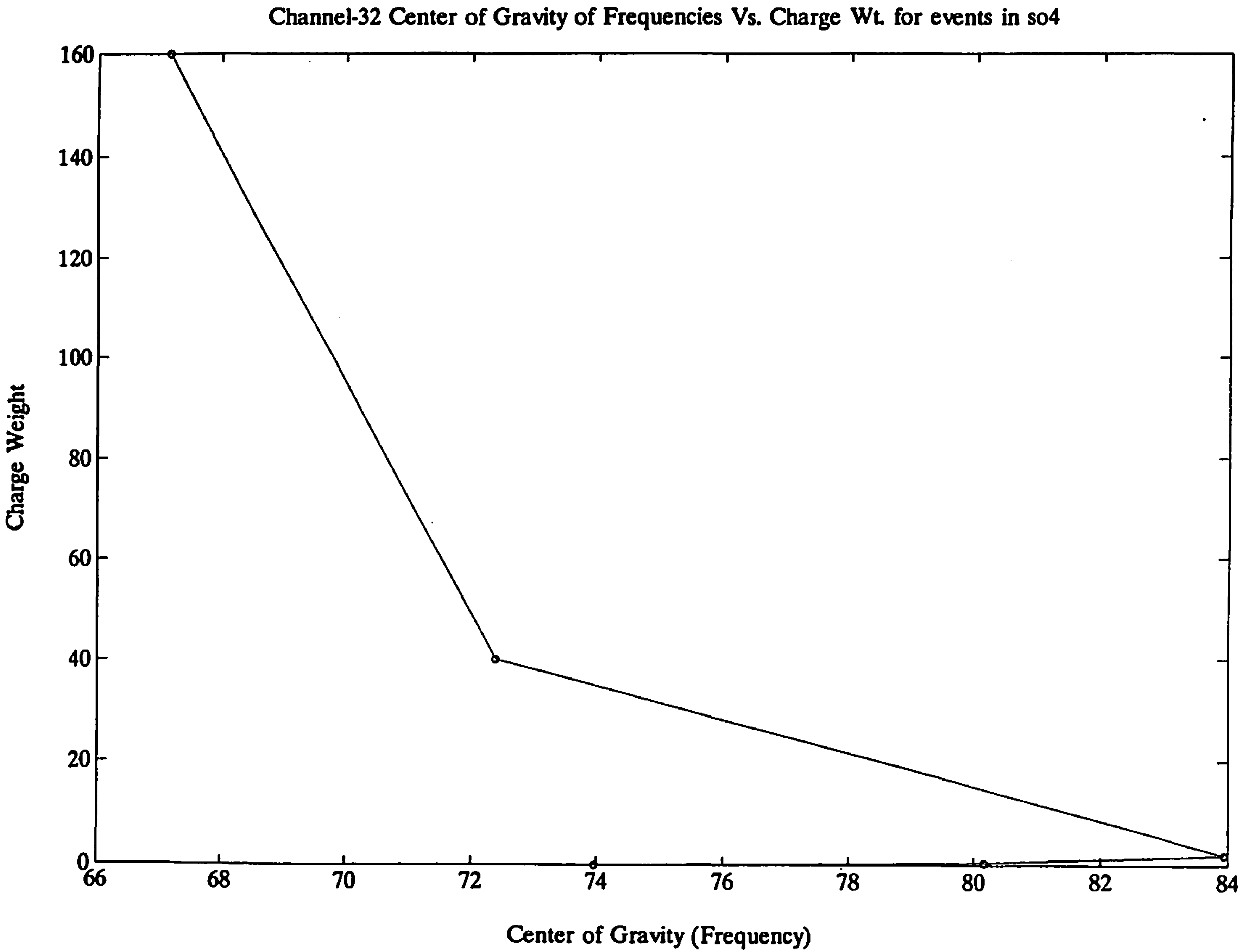
Channel-28 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
100
110
120
130
140
150
160
Center of Gravity (Frequency)

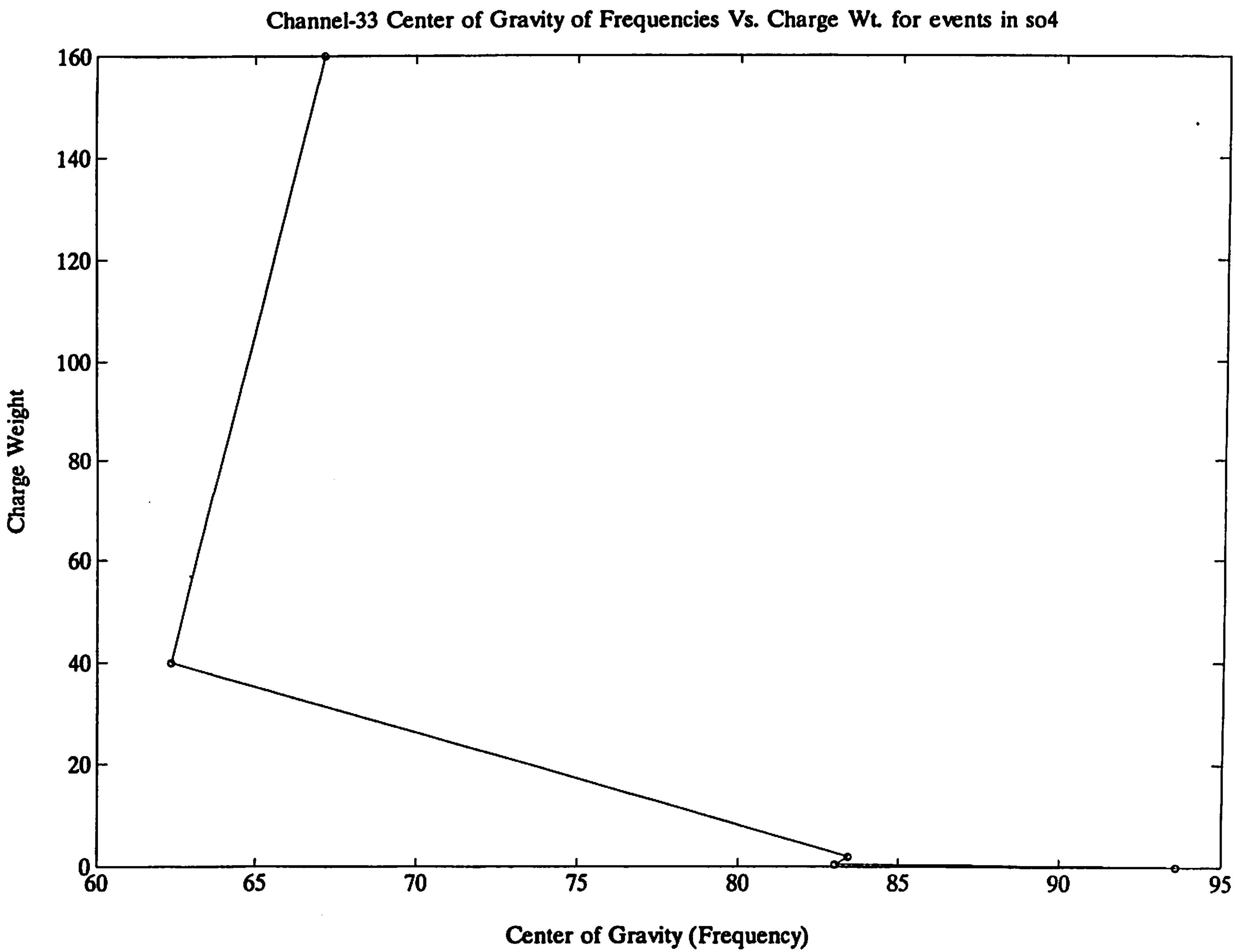

Channel-29 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
110
115
120
125
130
135
140
145

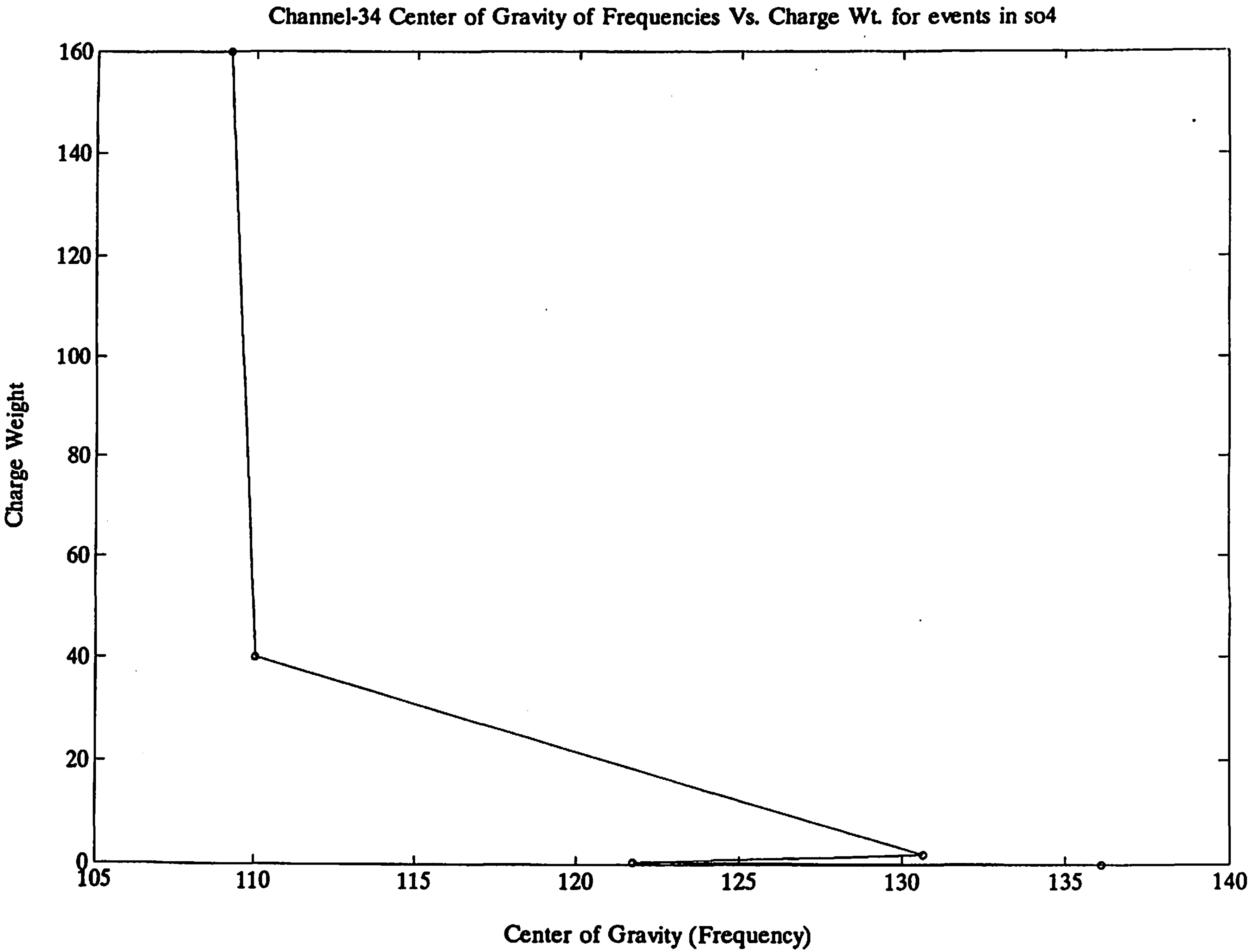


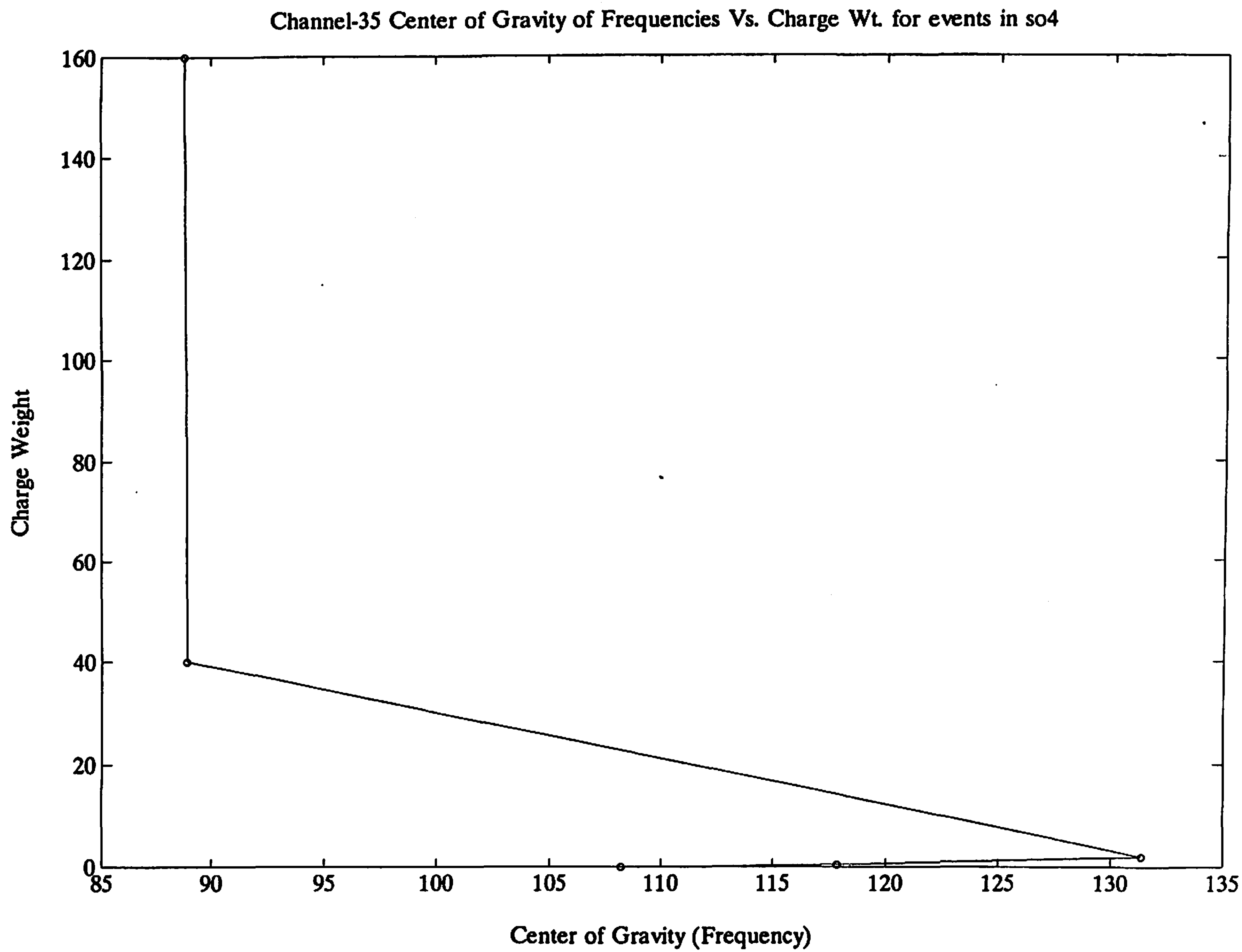
Channel-30 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
Center of Gravity (Frequency)
0
20
40
60
80
100
120
140
160
110
115
120
125
130
135
140
145
150

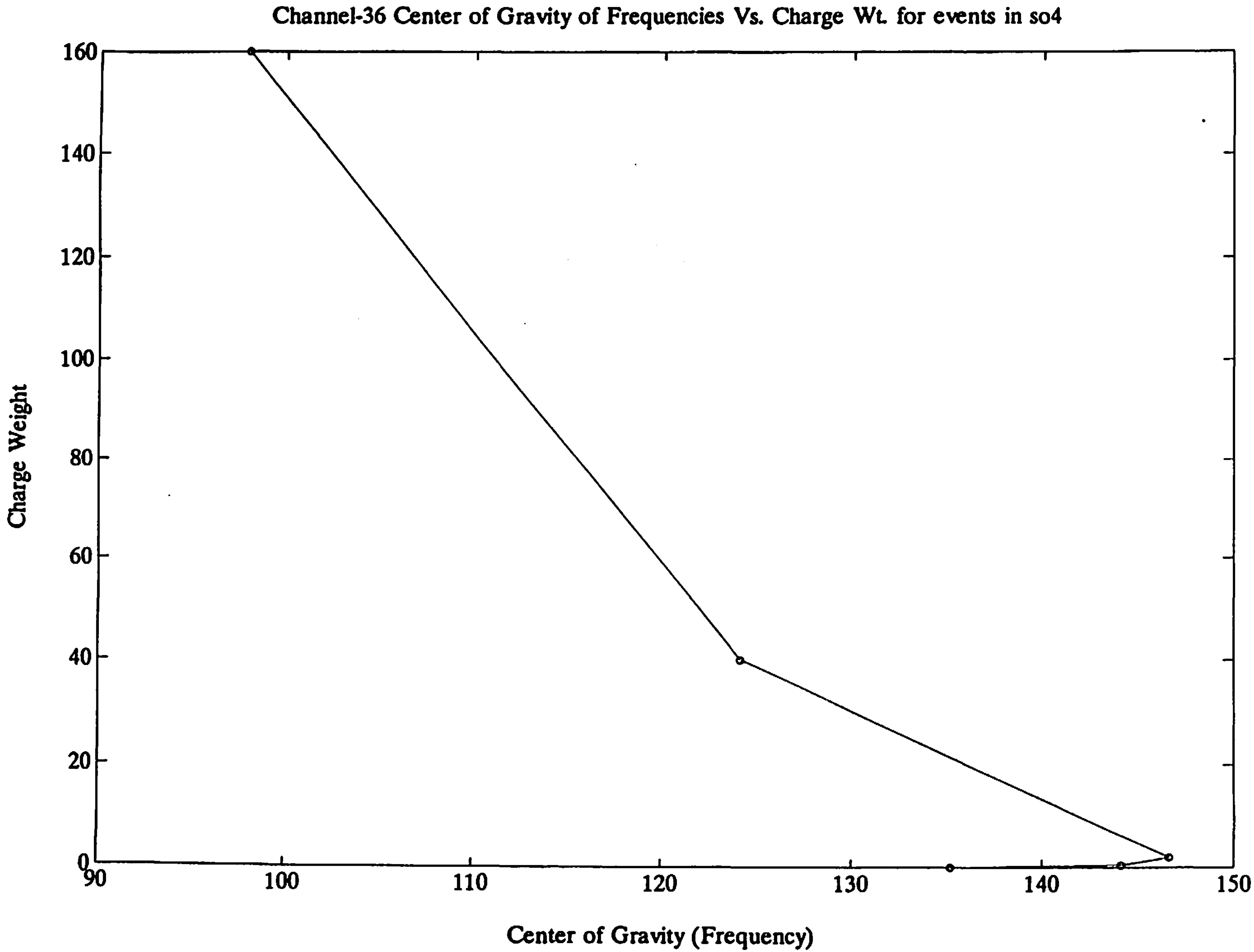

Channel-31 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
0
20
40
60
80
100
120
140
160
110
120
130
140
150
160
170
Center of Gravity (Frequency)

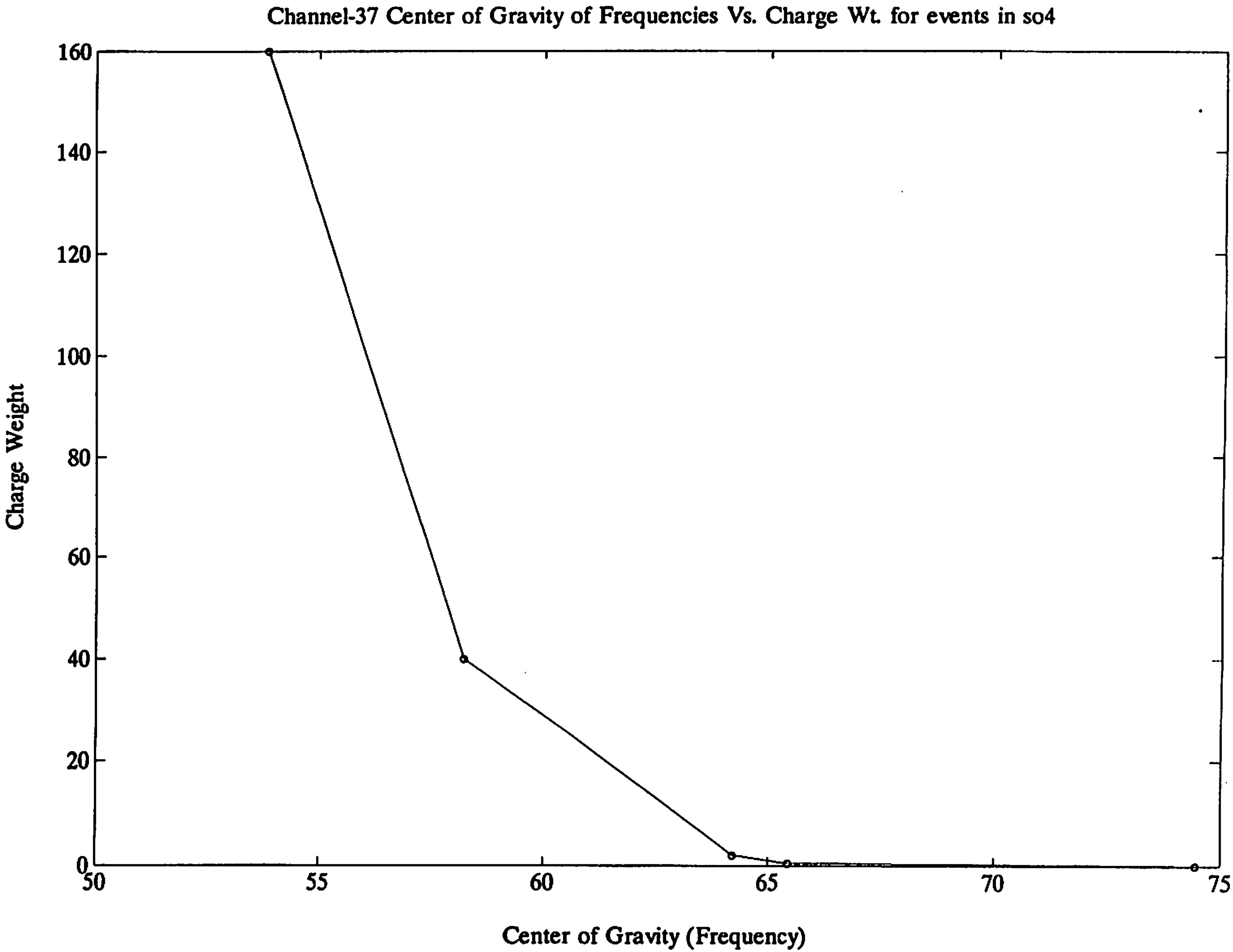

Channel-32 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
66
68
70
72
74
76
78
80
82
84
Center of Gravity (Frequency)


Channel-33 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
160
140
120
100
80
60
40
20
0
60
65
70
75
80
85
90
95
Charge Weight
Center of Gravity (Frequency)

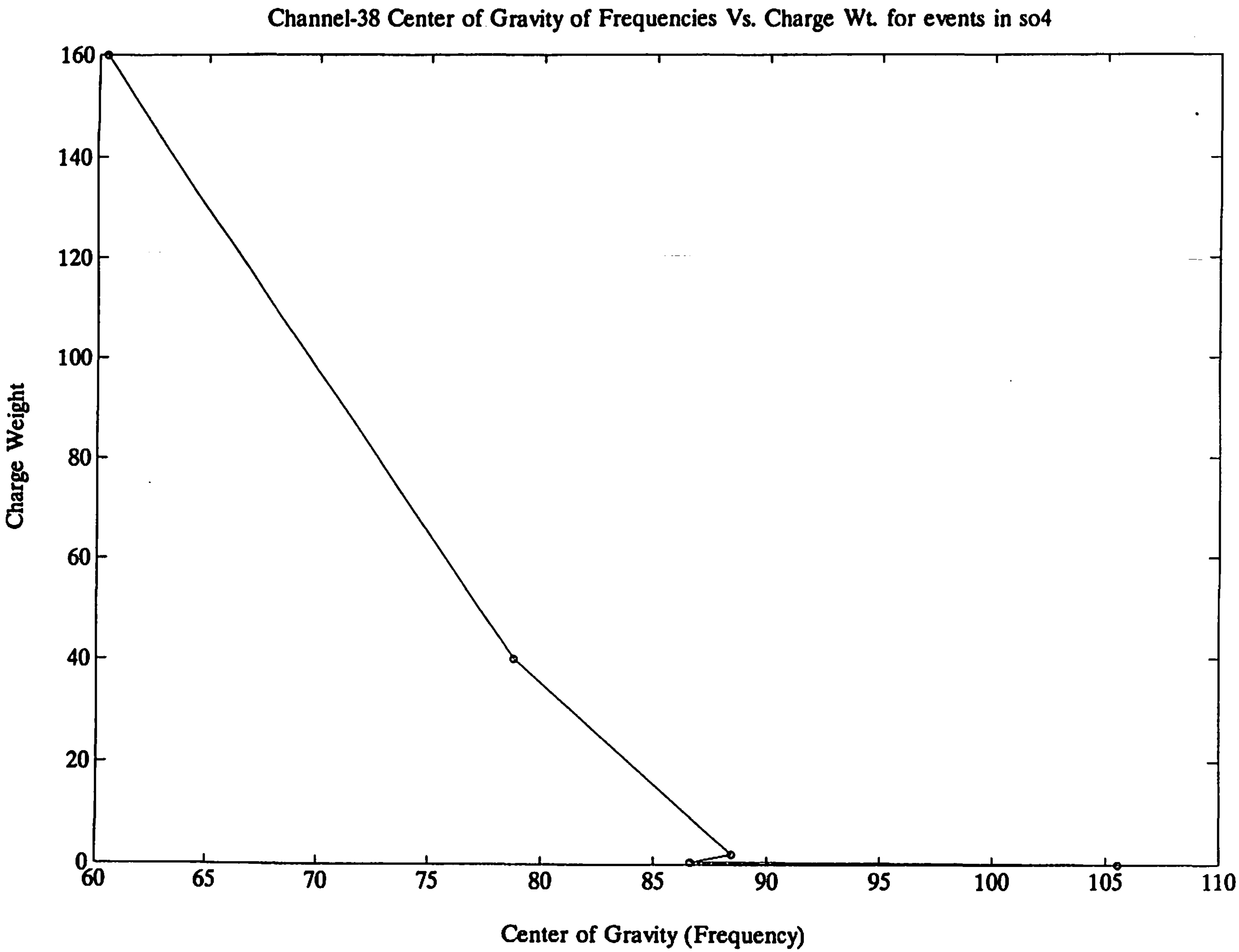

Channel-34 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
105
110
115
120
125
130
135
140
Center of Gravity (Frequency)


Channel-35 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
85
90
95
100
105
110
115
120
125
130
135
Center of Gravity (Frequency)

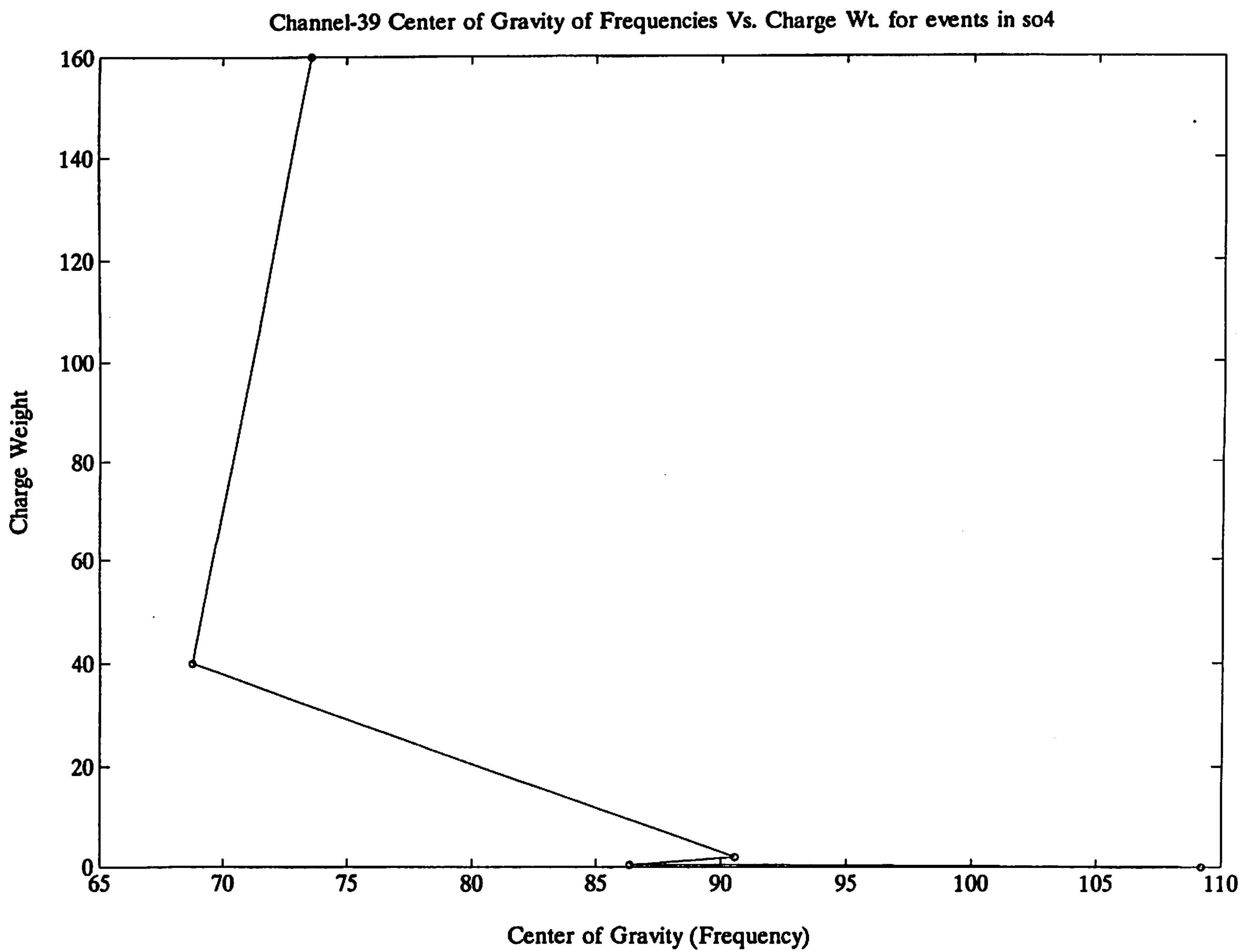

Channel-36 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
90
100
110
120
130
140
150
Center of Gravity (Frequency)



Channel-37 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
50
55
60
65
70
75
Center of Gravity (Frequency)



Channel-38 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
0
20
40
60
80
100
120
140
160
60
65
70
75
80
85
90
95
100
105
110
Center of Gravity (Frequency)


Channel-39 Center of Gravity of Frequencies Vs. Charge Wt. for events in so4
Charge Weight
160
140
120
100
80
60
40
20
0
65
70
75
80
85
90
95
100
105
110
Center of Gravity (Frequency)

APPENDIX F

EFFECTS OF DELAY ON RESPONSE CURVES

Effects of Delay on Response Curves

Conventional plots of peak particle velocity versus charge weight (eg. Figure 4.8, reference 2) use the weight of charge per blast delay as a measure of the magnitude of the energy source. The relationship is fairly linear on a log scale, however the scatter in the data reflects some inconsistencies between one blast and another. In particular, vibrations from one delay may reinforce or cancel the vibrations from previous or following delays. The magnitude and nature of these effects depends upon the predominant natural frequencies of the rock, the velocity of transmission of the vibrations in the rock, the pattern of the blast holes, and the spacial and time sequence of detonation. No one simple charge weight parameter can include all of the above effects.

An alternate representation of the blast energy, which was followed in this report, is based on the total charge weight per blast, without regard for delays (Figure F.1). The result of this representation is a significant reduction in the slope of the amplitude/charge weight curve with increasing charge weight for blasts with multiple delays. This slope reduction reflects two phenomenae. First, since the holes are not detonated simultaneously, the energy from individual holes is not addative, and a significant amount of energy cancellation may occur. Second, the capability of the rock to transmit energy locally in the vecinity of the blast is bounded by its failure strenth. Once the rock mass fails and the continuity between discrete blocks is interupted, a significant amount of energy is lost to inter-block friction and gas compression.

Dispite the difficulties in determining the energy output of individual delays within a muiltiple-delay shot, the importance of this information in the blast response prediction process requires that a basic understanding of the magnitude of the interactions between delays be developed. Analysis of the data in Figure F.1 provides insight into how that may be done. The charge weight per delay for the 160 lb. production blasts was 40 lbs., which equals the total charge weight for the largest of the single-delay test blasts. Thus the point (1) with coordinates (40 lbs., 44) in Figure F.2 represents the true normalized response for an isolated 40 lb. delay. Extending the curve past point (1) at the same slope as the curve below this point to a normalized velocity equal to that of the 160 lb. blast (point (2)), we can determine an equivalent charge weight per delay for the production blast (4) of approximately 52 lbs, and increase of 24% with respect to the isolated 40 lb blast. This weight actually could be larger if the charge weight per delay curve slope decreased at W greater than 40 lbs. The greater equivalent charge weight per delay for the production blast reflects the effects of positive reinforcement between individual delays of the production blast.

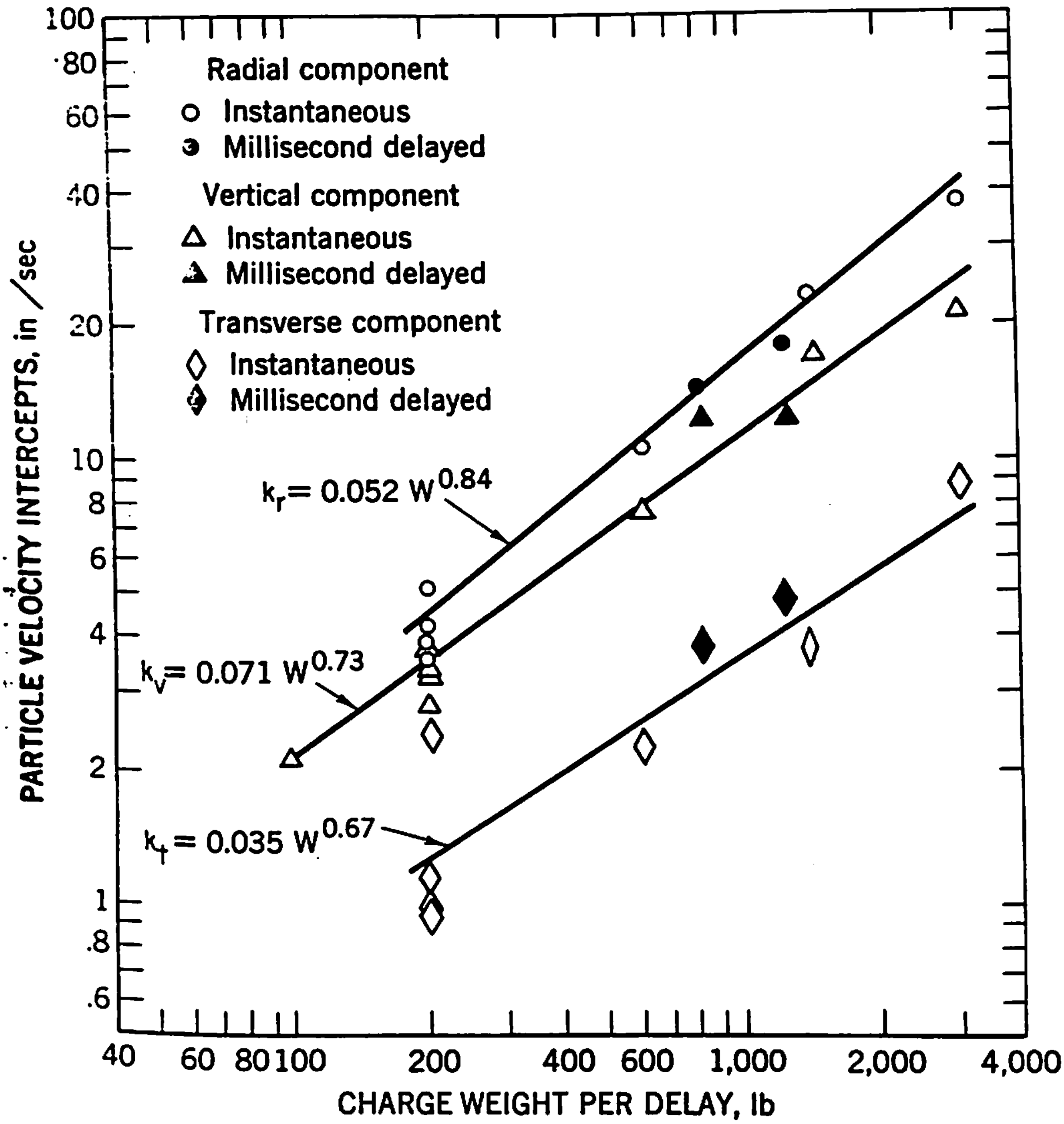


Figure 4.8.–Comparison of effect of charge weight on level of vibration from instantaneous and millisecond-delayed blasts.

(From Reference 2. The particle velocity intercept is the value of the measured velocity/distance relationship at a distance of 100 ft. from the blast.)

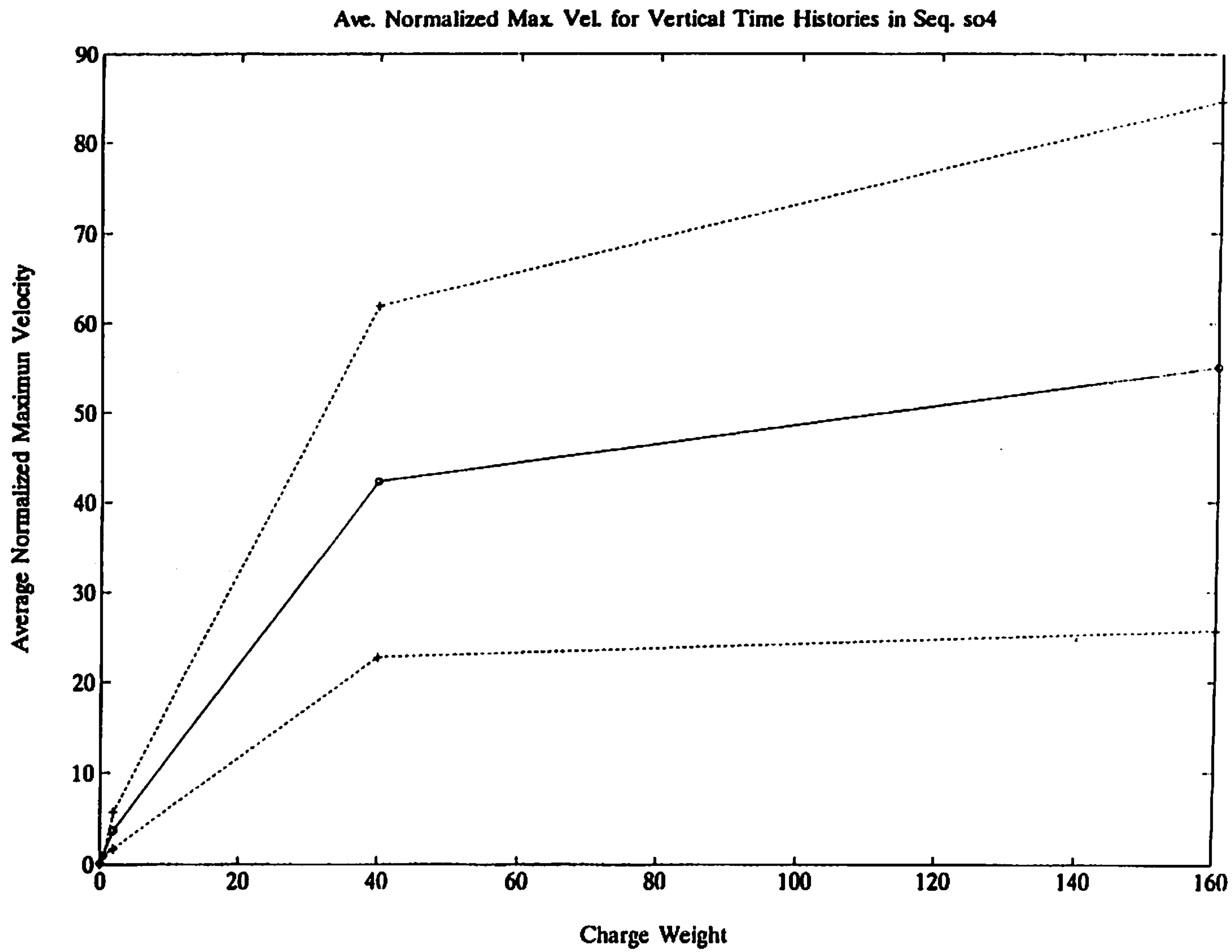


Figure F.1 - Velocity Response Ratio Versus Charge Weight

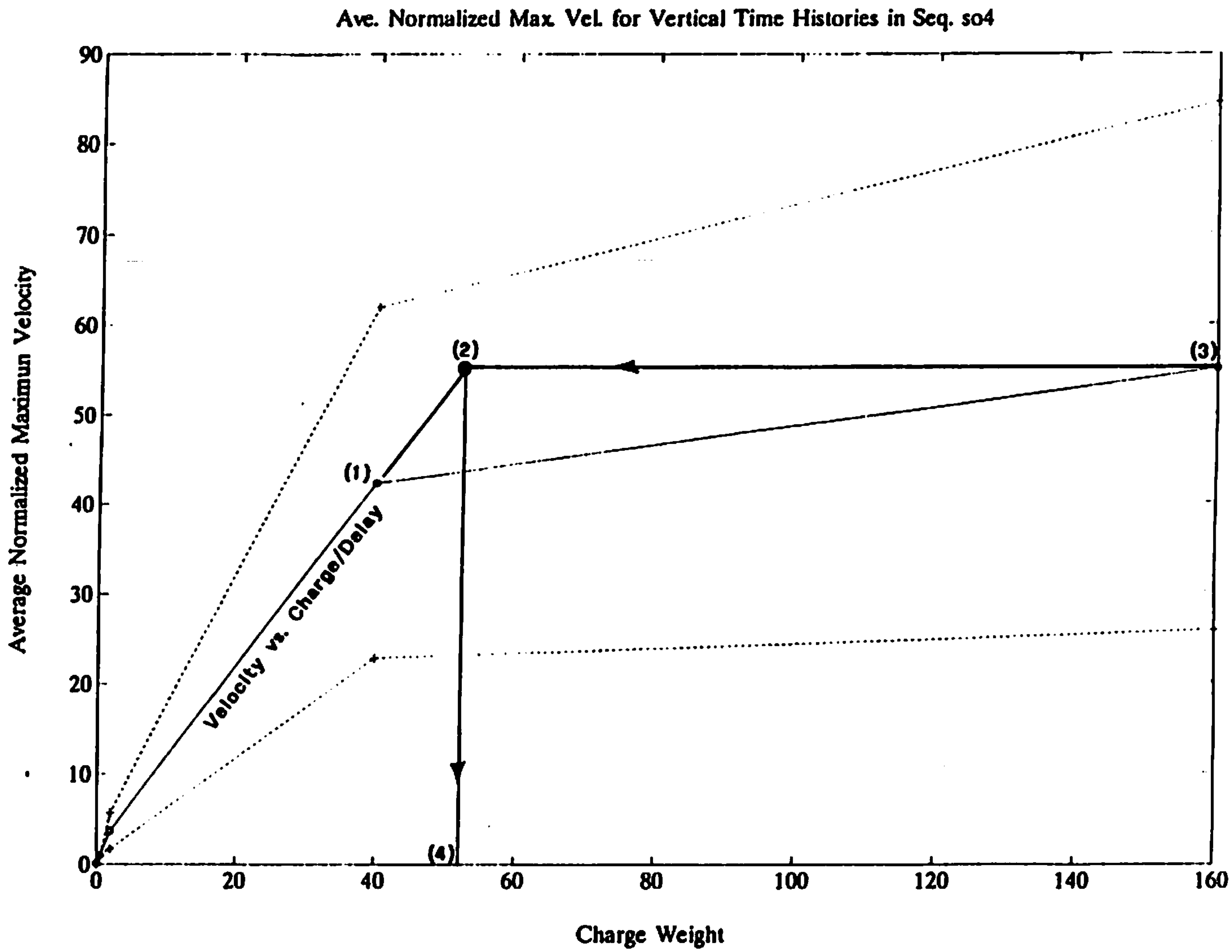


Figure F.2 - Determination Of Effective Charge Weight Per Delay
For a Multi-Delay Blast

APPENDIX G

MEASURED DAMAGE LEVELS

Damage Criteria

G.1 Accepted Criteria

A review of the literature indicates that criteria for damage to light structures have been well established from analysis of experimental data. The following general principles have been developed;

(1) "Particle velocity is more closely associated with damage to structures than either displacement or acceleration." (Reference 1, p. 22)

(2) "A reasonable separation between the safe and damage zones appears to be a particle velocity of 2.0 inches/sec." (Reference 1, p.23 and Figure 3.7)

Detailed analysis of blast damage data has yielded a more sophisticated criterion, based on the relationship between peak particle displacement, peak particle velocity and frequency (Reference 2, Appendix B; Table 13). The basic principle underlying this criterion is the ability of the structure to withstand relatively high peak particle velocities and displacements at frequencies well above the natural frequency of the structure. At relatively low frequencies (eg. between 1 and 10 Hz), the ground motion is amplified by resonant vibrations in the structure (Figures 38 and 39), and the allowable peak vibration amplitudes are much lower. Both peak displacement (Figure 52) and peak velocity (Figure 54) can be related to damage potential through analysis of damage statistics. Combining the two in a single frequency-dependent relationship (Figure B-1) provides more flexibility at high frequencies while providing more protection at the low end of the frequency spectrum where structural effects are more pronounced.

G.2 Analysis of Field Test Data

Analysis of data from the present project for large blasts close to the pipes and tanks and wells has yielded consistent relationships between peak vibration amplitudes and structural damage. In general, the pipe connections showed some sensitivity to vibration levels, while the tanks and well were relatively insensitive.

G.3 Pipe Response

Peak velocity amplitudes at instrument stations on the ground surface and in the pipe midway between manholes 2 and 3 were on the order of 0.1 inches/sec for the 160 lb. production blast array A-4 (Figure 5.9, Table G.1). The edge of the blast array was located 42 feet from the pipe center line. The measured amplitudes for this blast array are an order of magnitude below the commonly-accepted blast damage criterion, and were not associated with noticeable damage to the structures.

Velocity peaks for array A-5, located 10 feet from the pipeline, were much higher. The 40 lb. test blast located at the southeast corner of the array was only 10 feet from the pipe and 20 feet from manhole 2. Peak velocities at the pipe were on the order of 2 inches/sec, while peaks at the manhole were approximately 3 inches/sec (Table G.2). The array A-5 production blast was 10 feet from the pipe and centered between manholes 2 and 3. Peak velocities at the pipe exceeded 7 inches/sec, while maximum amplitudes at the manhole/pipe interface were on the order of 2 inches/sec (Table G.3). Cracking of the mortar seal between the precast manhole and pvc pipe was noted after both blasts, indicating that the peak velocities of 2 inches/sec were sufficient to cause minor structural damage. Air pressure tests conducted after the blasts confirmed that the rubber boot seals between the pipes and manholes had remained intact.

G.4 Tank Response

The steel tank was subjected to vibrations from a 160 lb. production o7 3 blast, the edge of which was 23 feet from the center line of the tank. Peak velocity response amplitudes increased from approximately 1 inch/sec at the top of the tank to almost 3 inches/sec at the bottom of the tank (Table G.4). The most efficient energy transfer was through the bedrock and up through the compacted fill to the base of the tank. No structural damage was observed.

G.5 Well Response

The amplitude of velocity response of a 4-inch-diameter steel well casing penetrating the Buda formation was also a function of depth below the ground surface. Peak amplitudes ranged from 8 inch/sec at the ground surface to 12 inch/sec at depths greater than 5 feet (Table G.5). The blast vibrations were transmitted directly from the 13.5-foot-deep blast holes through competent rock to the well casing. No structural damage to the casing was recorded, although some permanent ground displacement was observed at the surface.

G.6 Summary

At peak velocity amplitudes below 2 inches/sec, mortar joints in buried pipes were not damaged. Amplitudes above 2 inches/sec induced relative motion between pvc pipes and precast manholes, which cracked mortar joints at the connections. Rubber boot seals were not, however, damaged by vibrations with amplitudes of up to 7 inches/sec.

The steel tank was not damaged by vibrations with amplitudes of up to 3 inches/sec, while the steel well casing was not visibly damaged by amplitudes of up to 12 inches/sec. The greater resistance of the continuous steel structures is consistent with the greater strength and ductility of steel compared with the weak and brittle cement-based mortar.

Table 13.—Safe levels of blasting vibrations for residential type structures

Type of structure	Ground vibration—peak particle velocity, in/sec	
	At low frequency[1] (<40 Hz)	At high frequency (≥40 Hz)
Modern homes. Drywall interiors	0.75	2.0
Older homes, plaster on wood lath construction for interior walls	.50	2.0

[1] All spectral peaks within 6 dB (50 pct) amplitude of the predominant frequency must be analyzed.

(From Reference 2, Nicholls Et Al)

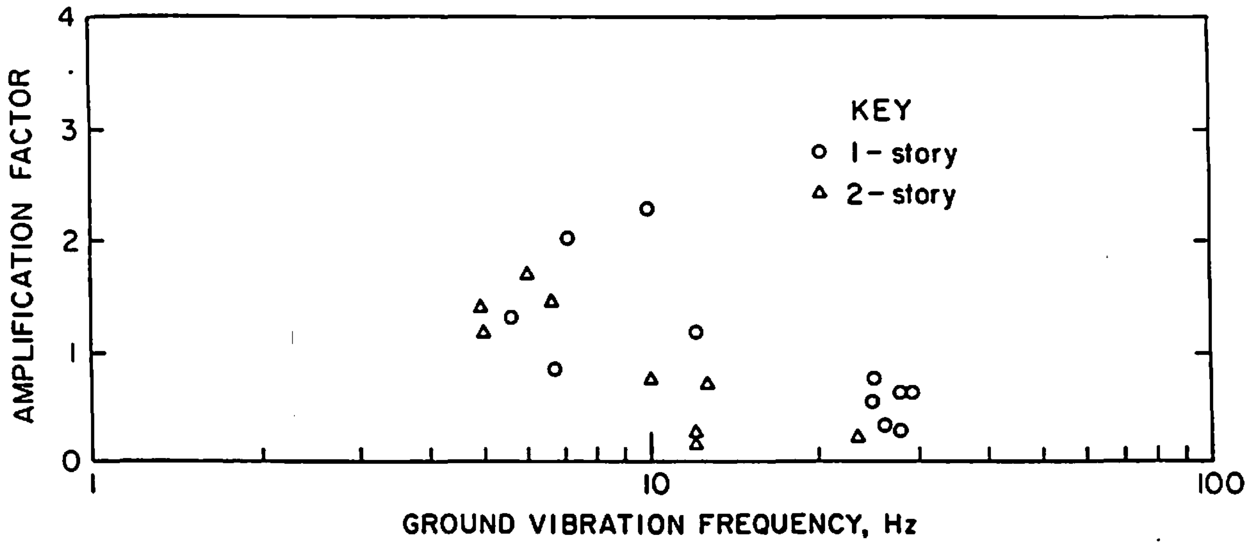


Figure 38.—Amplification factors for blast-produced structure vibration (corners) of a single 1-story and a single 2-story house.

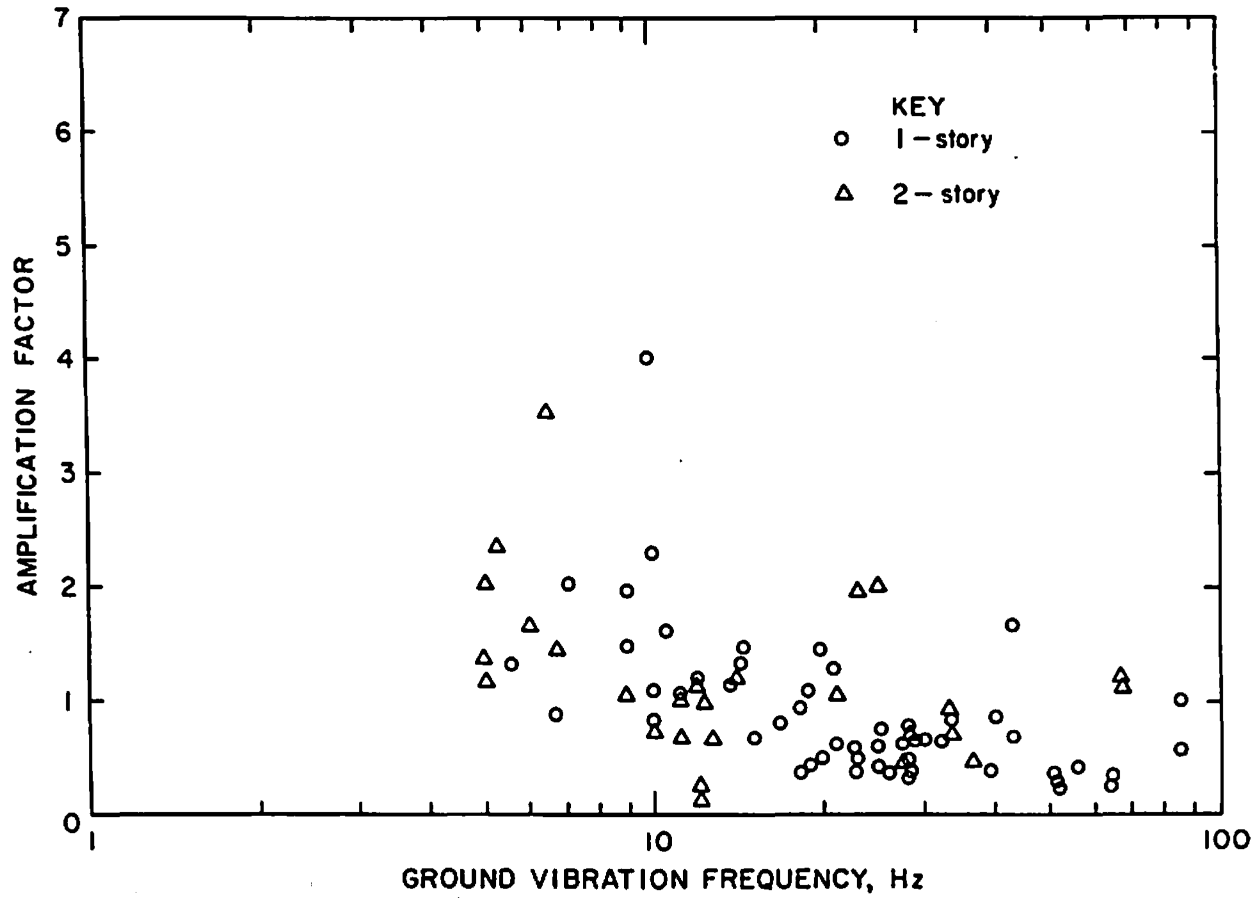


Figure 39.—Amplification factors for blast-produced structure vibration (corners), all homes.

(From Reference 2, Nicholls Et Al)

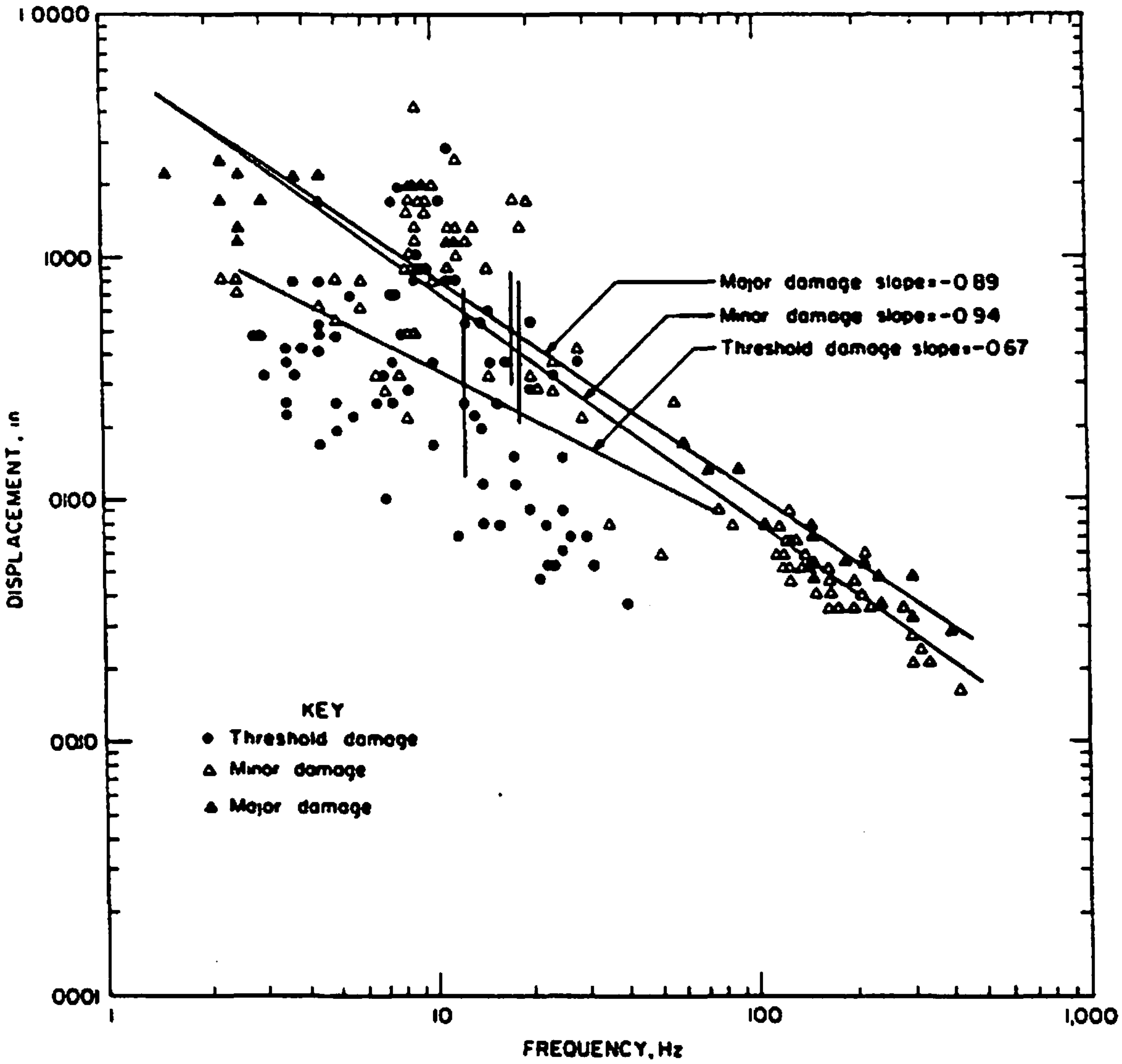


Figure 52.—Displacement versus frequency summary, set 7 mean and variance analysis.

(From Reference 2, Nicholls Et Al)

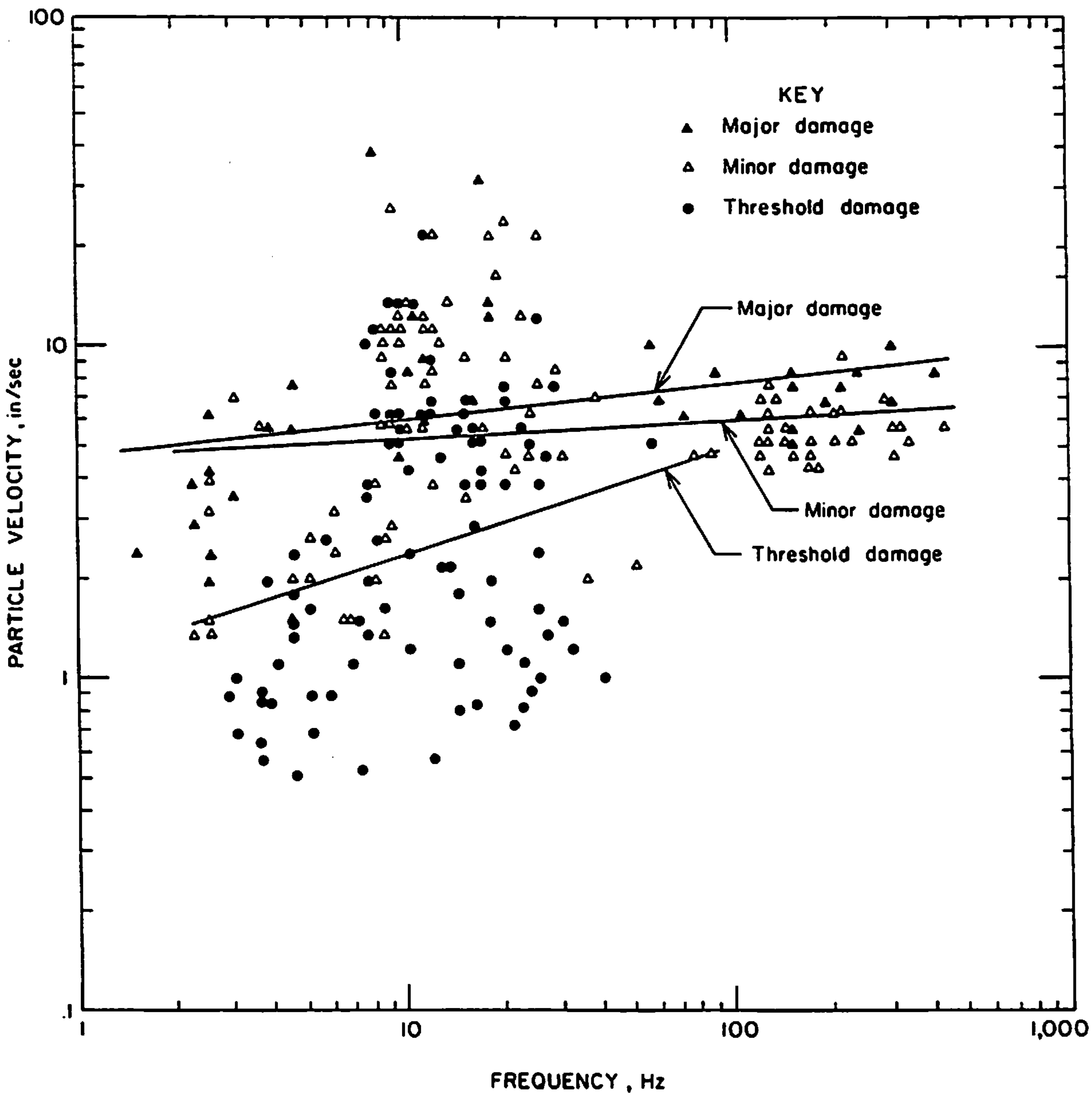


Figure 54.—Velocity versus frequency summary, set 7 mean and variance analysis.

(From Reference 2, Nicholls Et Al)

APPENDIX B.—ALTERNATIVE BLASTING LEVEL CRITERIA

Safe blasting vibration criteria were developed for residential structures, having two frequency ranges and a sharp discontinuity at 40 Hz (table 13). There are blasts that represent an intermediate frequency case, being higher than the structure resonances (4 to 12 Hz) and lower than 40 Hz. The criteria of table 13 apply equally to a 35-Hz and a 10-Hz ground vibration, although the responses and damage potentials are very much different.

Using both the measured structure amplifications (fig. 39) and damage summaries (figs. 52 and 54), a smoother set of criteria was developed. These criteria have more severe measuring requirements, involving both displacement and velocity (fig. B–1).

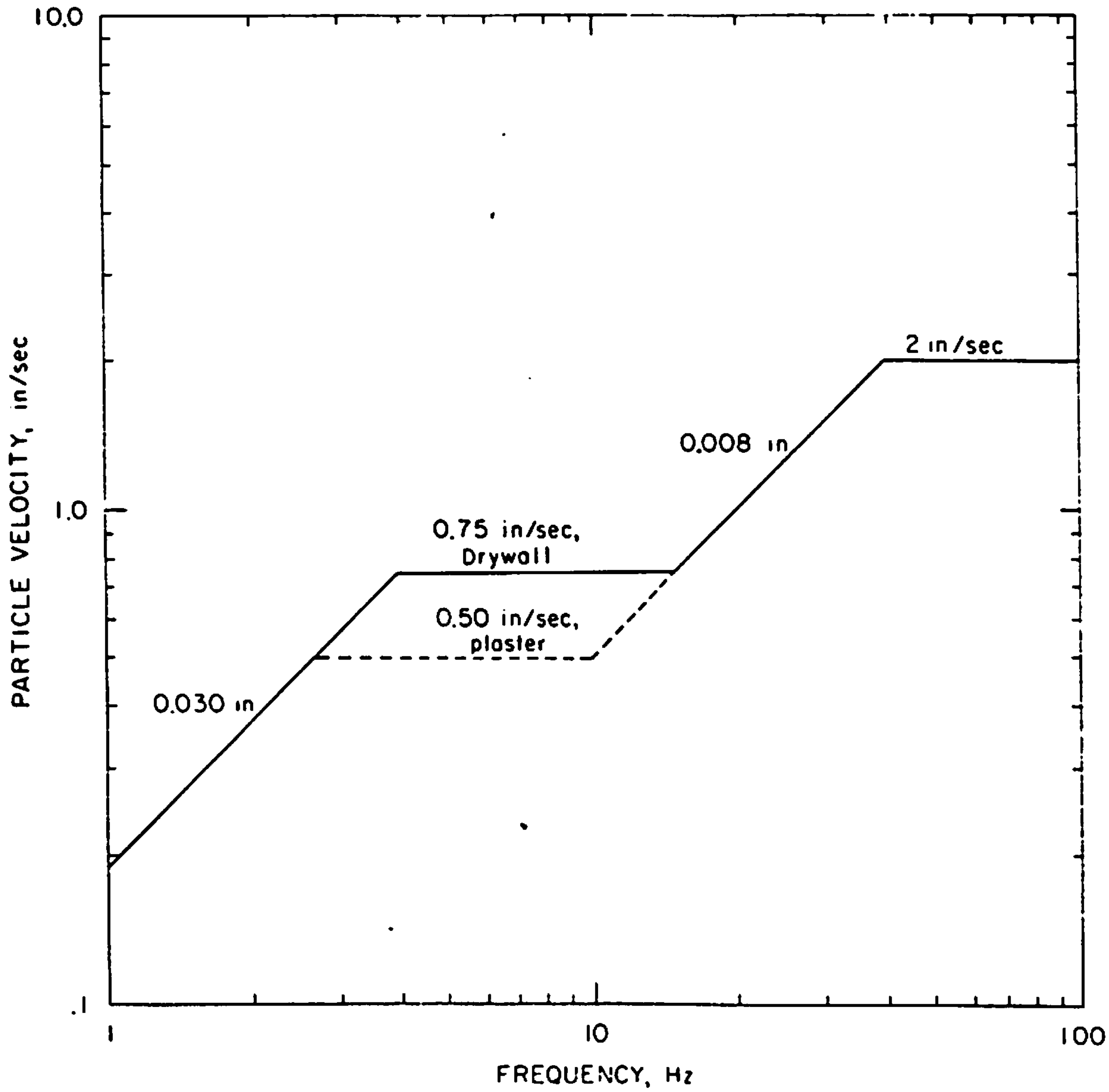


Figure B–1.—Safe levels of blasting vibration for houses using a combination of velocity and displacement.

(From Reference 2, Nicholls Et Al)

Table G.1 - Peak Velocity Amplitudes for 160# Production Pipeline Blast, Array A-4, 4-18-91

Instrument Package	Channel	Peak Velocity (Inches/Sec)	Predominant Frequency (Hertz)
S-1	8	0.13 (clipped)	40, 60
(Station 2+50,	9	0.10 (clipped)	40, 60
at surface)	10	0.10 (clipped)	40, 60
IP4	29	0.10 (clipped)	30
(Station 2+50,	30	0.10 (clipped)	30
in pipe)	31	0.10 (clipped)	30

Table G.2 - Peak Velocity Amplitudes for 40# Test Pipeline Blast, Array A-5, 4-22-91

Instrument Package	Channel	Peak Velocity (Inches/Sec)	Predominant Frequency (Hertz)
S-2	11	2.1	10
(Station 2+50,	12	2.5 (clipped)	10
at surface)	13	2.5 (clipped)	10
IP4	29	-1.8	12
(Station 2+50,	30	1.4	10
at Pipe)	31	1.2	12
S-3	14	2.8	10
(Station 2+00,	15	2.5 (clipped)	11
at Surface)	16	3.1 (clipped)	10
IP2	23	2.8	15
(Station 2+10,	24	2.8	22
at Pipe)	25	-2.5	10
IP5	32	0.7	10
(Manhole)	33	0.55	10

Table G.3 - Peak Velocity Amplitudes for 160# Production Pipeline Blast, Array A-5, 4-22-91

Instrument Package	Channel	Peak Velocity (Inches/Sec)	Predominant Frequency (Hertz)
S-2	11	7.5	15, 45
(Station 2+50,	12	6.0	5, 20
at Surface)	13	6.2	15
IP4	29	7. (clipped)	45
(Station 2+50,	30	2.8	14
at Pipe)	31	3.8	10
S-3	14	-1.2	38
(Station 2+00,	15	1.5	25, 45
at Surface)	16	0.95	35
IP2	23	-1.3	100
(Station 2+10,	24	0.44	40
at Pipe)	25	-1.8	100, 140
S-1	8	3.2	12
(Station 3+00,	9	2.8	10
at Surface)	10	5.7	12
IP6	34	1.7	17
(Station 3+00,	35	1.4	10
at Pipe)	36	2.3	10
IP7	37	-1.2	12
(Station 3+00,	38	-0.27	12
at Manhole)	39	0.7	10

Table G.4 - Peak Velocity Amplitudes for 160# Production Steel Tank Blast, Array CCC-3, 7-2-91

Instrument Package	Channel	Peak Velocity (Inches/Sec)	Predominant Frequency (Hertz)
S-3	14	-1.4	12
(Surface @	15	-0.9	12
Ctr. Tank)	16	0.3	10
IP5	31	0.55	14
(Top Tank	32	0.6	15
@ Ctr.)	33	0.5	14
IP2	23	-2.8	14
(Bottom Tank	24	-2.0	14
@ Ctr.)	25	-0.4	12

Table G.5 - Peak Velocity Amplitudes for Production Blast 16 at Judson Road and Loop 1604

Instrument Package	Channel	Peak Velocity (Inches/Sec)	Predominant Frequency (Hertz)
7	14	-6.0	20
(Ground Surface	26	8.0	20, 40
at Well)	38	-5.8	20
8	15	8.0	11
(In Well	27	11.0 (clipped)	24
at 5 FT)	39	12.0 (clipped)	20
9	16	11.0	11
(In Well	28	11.0	27
at 27 FT)			

NOTES:

(1) Closest Hole to well was 15 ft east of the well. A total of 46 holes with 675 # of mix were detonated (14.67#/Hole). Each hole was 13.5 ft deep, with 6 ft stem.

(2) Analysis of time sequence of detonation of each hole would be required to determine charge weight per delay.