VIRGIL C. SUMMER NUCLEAR STATION

ACTIVE FIELD EXPERIMENTS REPORT

SOUTH CAROLINA ELECTRIC & GAS COMPANY

NOVEMBER - 1981

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INTRODUCTION

An active field experiment using shallow explosions was developed for the Virgil C. Summer Nuclear Station in order to provide additional data relative to the large, high frequency peak accelerations produced by the reservoir induced microearthquakes. This experiment was initiated on October 15, 1981, with the field work being completed on October 29, 1981. Results of this experiment are presented herein.

PURPOSE OF THE EXPERIMENT

The purpose of the experiment was to acquire data for a comparative study of ground motion at the two sites currently occupied by USGS accelerographs (USGS SMA-1 #603 and #267) and at additional sites in the free field and in building foundations. Of principal interest were ground motion comparisons of (1) the site of USGS SMA-1 #603 on the dam abutment relative to sites elsewhere in the free field, and (2) the nuclear power plant foundation relative to free field sites. Our aim was to test the hypothesis that earthquake ground motion recorded by USGS SMA-1 #603 may have been systematically larger than that experienced at other

sites at comparable epicentral distances, for shallow RIS events. In particular, we were interested in comparing ground motion on the dam abutment and other free-field sites with each other and with that on the nuclear plant foundation. Experience and theory both indicate that motion on the plant foundation, resting on hard rock, could be significantly less than at free-field sites underlain by a thick layer of stiff soil, such as the saprolite that occurs over much of the study area (including the site of USGS SMA-1 #603). However, it was realized that shallow explosions would not necessarily replicate the earthquake motions in terms of body wave angles of incidence, relative amplitudes of waves of various propagation modes, and duration. In addition, it was anticipated that motions produced by the two explosions would also differ in these respects.

FIELD PROCEDURE

Description - Shot Point 1

The first experiment was developed to provide a distant source of ground motion relative to the locations of the nuclear station and the deployed test instrumentation. Shot point 1 was located on the east side of Monticello Reservoir as shown in Figure 1 with coordinate locations identified in Table 1. This test consisted of four (4) holes, 6" in diameter, drilled to a depth of 125'. The four holes were spaced approximately 30' - 35' apart on a northwest alignment. Bedrock was encountered in each of

the holes at a depth of 70' - 85'. Six inch diameter steel casing was installed in each hole and seated into the bedrock. Explosives of 250 lbs. were installed in the bottom of each hole and were wired for simultaneous explosion. Each hole was subsequently stemmed with a gravel and sand mixture. The explosives were detonated at 8:00 P.M. on October 28, 1981.

Description - Shot Point 2

The second experiment was developed to provide a near source of ground motion relative to the locations of various strong motion accelerometers and seismometers. Shot point 2 was located south of the Fairfield Hydro Plant (approximately 1 mile northwest of the nuclear station) as shown in Figures 1 and 2 with coordinate locations identified in Table 1. This test consisted of one (1) hole, 8" in diameter, drilled to a depth of 492'. Bedrock was encountered at a depth of approximately 55'. An 8" diameter steel casing was installed in this hole and seated into the bedrock. A total explosive charge of 500 lbs. was installed in this hole, however, due to an undefined obstruction within the hole, 1/3 of the explosives (approximately 170 lbs.) was placed at the bottom of the hole, while the remaining 2/3 of the explosives (approximately 330 lbs.) were positioned at the point of obstruction at approximately 180' - 200' depth. All of the explosives were wired for simultaneous detonation. The hole was subsequently stemmed with alternating layers of clean gravel and gravel-sand mixture. A large mound of the gravel-sand mixture was placed over the hole. The explosives were detonated at 4:30 P.M. on October 29, 1981.

Description - Instrumentation and Locations

Instrumentation used in the experiment consisted of Kinemetrics SMA-1 strong motion accelerographs, Kinemetric Triaxial Time-History Accelerographs, Sprengnether DR-100 digital recording seismographs, and URS/Blume seismographs. All instruments were three-component systems, recording one vertical and two horizontal components of motion; horizontal components are oriented north-south and east-west. Locations of the instruments are shown on Figure 2 and identified in Table 1. Instrument sites are described briefly, below. Frequency response characteristics of seismographs are given in Appendix A.

(1) Dam Abutment between Dams B and C - This location was chosen as the existing location of the USGS SMA-1 (#603). The USGS instrument is located on a concrete pad (4' x 4' x 1') on a natural hillock between Monticello Reservoir Dams B and C. As previously reported this location is underlain by 56' of saprolite and residual soils over bedrock. An additional SMA-1 was installed on the same concrete pad. Both a DR-100 and a Blume recorder were installed at this location.

(2) Tail race at Fairfield Hydro Plant - This location was chosen as the existing location of the USGS SMA-1 (#267). The USGS instrument is located on a concrete pad (4' x 4' x 1') on a constructed fill area adjacent to the hydro tailrace. This location is underlain by a sand and stone fill material

over saprolite and residual soils. An additional SMA-1 was installed on the same concrete pad. Both a DR-100 and a Blume recorder were installed at this location.

(3) Near Shot Point 2 - A concrete pad (5' x 7' x 1') was constructed approximately 26' south of the Shot Point 2 location. This location is underlain by a sand and stone fill material over saprolite and residual soils. An SMA-1 was installed on the concrete pad.

(4) Fairfield Hydro Plant Basement - An SMA-1 was installed on the basement elevation of this structure. The hydro plant is a massive reinforced concrete structure which rests directly on bedrock.

(5) Near Meteorological Tower - This location was selected to represent the free-field conditions of the nuclear station, while being remote from construction activities. A concrete pad (5' x 7' x 1') was constructed near the meteorological tower on a natural hillock. This location is underlain by saprolite and residual soils over bedrock. An SMA-1 was installed on the concrete pad, along with a DR-100 near the pad.

(6) Auxiliary Building Basement - Due to construction and start-up testing activities, this location was selected to provide a quiet setting in a large structure with a massive foundation. The auxiliary building foundation rests directly on bedrock. A DR-100 was placed at this location.

(7) Reactor Building - Two (2) permanent Triaxial Time-History Accelerographs (Kinemetrics DSA type) were used in the experiment to record any strong motions within the nuclear station. One instrument is located on the foundation mat of the reactor building on the periphery outside the containment shell. The other instrument is located on the ring girder at the top of the containment. The reactor building foundation rests directly on bedrock.

Conduct of Test

Due to the small point sources of the experiment, it was necessary to manually trigger all of the instrumentation prior to the test. All locations were manned prior to each test, and by means of concurrent radio, telephone and loudspeaker communications, each instrument was manually triggered 60 seconds prior to the detonation, and manually stopped 60 seconds after the detonation. This approach ensured a complete record of the motions at each location. This method was extremely important for the accelerographs due to the small accelerations anticipated.

DATA

Seismograms

The two Blume seismographs functioned very well: three components of motion were recorded at both the dam abutment and tailrace sites, for both shots. These seismograms are shown in Figures 3

through 6. The Blume instruments were accurately calibrated before deployment, and particle velocities (ordinates in Figures 3 through 6) are known to within about 1 percent.

The Sprengnether DR-100 digital seismographs functioned fairly well, except that both horizontal components failed to record at the dam abutment, as did the N-S component at the meteorological tower. Complete, end-to-end calibration (seismometer through A/D converter and multiplexer in recorder) of DR-100 units was performed in the field 10 days following the shots. The preliminary report on this work used partial calibrations, and, therefore, scale factors were in error by as much as a factor of two. These have now been corrected, and are accurate to better than 10 percent. Seismograms as originally plotted are shown with corrected scale bars in Figures 7 through 14. Direct comparison of seismograms for both shots shows some striking differences in peak particle velocities and frequency content among the four seismograph sites. However, we much prefer to make quantitative comparison of ground motions in the frequency domain, as described below.

Accelerograms

Raw accelerograms and peak accelerations read from them are given in Appendix B. Motions for shot 1 were too small to be recorded on any of the accelerographs, and those for shot 2 produced very small records, affording rather marginal resolution.

Therefore, these data are not considered very significant to the present study: the seismographs provided much more useful information.

SPECTRAL ANALYSIS

Methods

Fourier spectral magnitudes of particle-velocity time histories were obtained using a Norland 3001 Digital Signal Analyzer. The sample rate was 200 per second and the number of samples in each discrete Fourier transform (DFT) was 1,024, yielding a record length of 5.12 seconds; sampled frequency separation, therefore, was 0.195 hz. For shot 1, this record length was sufficient to include all P- and S- wave motion, as well as about 3 seconds of coda; for shot 2, practically all observable coda motion is included in the 5-sec window. All spectra were smoothed with a 7-point running average. Timing marks (at 2-sec intervals) present in the Sprengnether DR-100 records were removed before taking DFTs.

All spectra are plotted from 0 to 70 hz. However, values for frequencies less than 1 hz (DR-100) or 2 hz (URS/Blume seismograph) are not correct due to roll-off of seismometer response.

Comparison of ground motions (particle velocities) among stations is based upon ratios of Fourier spectral magnitudes; these are obtained by point-by-point division of the two spectra being compared. Also, ratios of the integral of power spectral density

were used to compare shot-1 motion at the dam abutment with that in the auxiliary building. Further details are given later. All comparisons discussed below are limited to stations recording either shot at nearly equal distances, so that attenuation of motion with distance, which is not known precisely, is not an issue in our analysis.

Results

Fourier magnitudes for shot 1 as recorded at the four seismograph sites are shown in Figures 15 - 18. Figure 19 shows spectra of background noise for 5 seconds immediately preceding the shot, for the horizontal components at the dam abutment, tailrace, and auxiliary building. Most signal energy is in the band 2 - 20 hz, and background noise is nearly white, with peaks at 20 hz and 60 hz (electrical noise). Comparing signal with noise spectra, it can be seen that signal-to-noise ratios at free-field stations generally exceed 50 in the passband 2 - 20 hz, and usually exceed 10 at 20 - 50 hz. In the auxiliary building, noise levels are relatively high, with a strong peak at 30 hz, the frequency of rotation of electric-motor driven equipment in the building. Signal-to-noise ratios there are roughly about 5 to 10 in the passband 2 - 40 hz.

Figures 20 and 21 show spectral ratios for the dam abutment/ tailrace stations, for shots 1 and 2 respectively. There is wide variation across the entire frequency range, for both shots. For shot 1, the ratio is generally between 1 and 2 for

frequencies from 5 hz to 40 hz, on the two horizontal components; on the vertical component, the ratio is usually less than 1 in the same frequency band. The situation is reversed for frequencies less than 5 hz. For shot 2, the ratios are generally less than 1 in the band 10 - 40 hz, for all three components; at lower frequencies, ratios vary markedly, but are greater than 1 in the band 6 - 8 hz. Figure 22 compares vertical components on the dam abutment and the meteorological tower for shot 1, and it may be seen that motion is generally smaller at the former, except in the band 2 - 8 hz.

Based upon the data presented above, it appears that significant amplification of ground motion does not occur on the dam abutment relative to other free field sites at frequencies about 10 hz. At lower frequencies, between about 5 and 10 hz, some minor amplification (factor of 1 to 3, but averaging about 1.5) seems to occur.

Figures 23 - 25 present spectral ratios for the auxiliary building relative to the three free-field sites. These show a major reduction of motion in the auxiliary building at nearly all frequencies between 2 and 40 hz, for horizontal components. Vertical components are not shown because calibration data indicate that the vertical component at the auxiliary building had a response characteristic quite different from the other stations. The most important comparison to be made is between the auxiliary building and the dam abutment, where large, high-frequency accelerations from RIS events have been recorded by

an SMA-1 accelerograph. This comparison (for shot 1) is given in Figure 25, and shows ratios from 0.06 to 0.60, averaging about 0.2, in the band 4 to 30 hz.

In order to summarize the motion in the auxiliary building, relative to that on the dam abutment, we computed integrals of power spectral density in several passbands using an average of N-S and E-W components. . The ratios of these values for the two sites were computed for each passband; the square roots of these ratios were also computed, and represent the ratio of root mean square (RMS) particle velocity in each passband. These data are summarized in Table 3. The data of Table 3 show that RMS velocities in the auxiliary building are from 10 percent to 30 percent of those recorded on the dam abutment, and show a systematic increase with frequency. In the passband 20 to 33 hz, the ratio is 0.305, showing greater than 3-to-1 reduction of RMS velocities in the auxiliary building.

SUMMARY AND CONCLUSIONS

Seismograms from two explosion tests (or shots), recorded at four different sites, have been subjected to spectral analysis in order to assess possible significant differences in site response as a function of frequency. Of primary concern were the response of the dam abutment relative to other free-field sites (tailrace and meteorological tower), and the response of the auxiliary

building foundation relative to the three free-field sites.

Based upon seismograms for both shots, the dam abutment does not appear to manifest substantially greater ground motion than other free-field sites at frequencies of about 10 hz. Therefore, we conclude that modal resonance and amplification, that could occur due to topography (the hill forming the dam abutment), does not appear to be a substantial phenomenon for the two explosion tests.
Comparison of Fourier spectra and integrals of power spectral density for the auxiliary building with those for the dam abutment do show a very substantial reduction of vibrational energy flux and RMS particle velocity in the auxiliary building with respect to the dam abutment. In the frequency band 10 to 33 hz, RMS particle velocities recorded on the auxiliary building foundation were about 20 percent of that recorded on the dam abutment. Table 3 summarizes these relationships in several frequency bands.

The major reduction of vibrational amplitudes and energy on the auxiliary building foundation with respect to that recorded on the dam abutment is ascribed to two effects. One is amplification of ground motion in the stiff soil layer (saprolite) that underlies most of the land surface in the region, including the dam abutment; the auxiliary building is founded directly on crystalline rock, and, therefore, does not experience this effect. Another effect that is probably important is scattering of elastic waves

incident at the foundation of the auxiliary building. The relative importance and frequency dependence of these effects is not precisely known at this time.

APPENDIX A

SUMMARY DESCRIPTION OF SEISMOGRAPH INSTRUMENTS

URS/Blume Systems

Two 3-component (vertical, north-south, and east-west) URS/Blume systems, located at the dam abutment and tailrace, recorded both shots. These systems use Mark Products model L22 geophones (natural period of 2 hz) and portable FM tape recorders (TEAC model R-61). Frequency response is flat to particle velocity from 4 to 100 hz. For shot 1, the geophone outputs were amplified by 200 x, using AC-coupled amplifiers; for shot 2, the geophone output was fed directly into the TEAC recorder. These recorders were also used for playback of the data.

Sprengnether Systems

Four 3-component Sprengnether event-recorder systems were positioned at the following locations: tailrace, dam abutment, meteorological tower, and basement of the auxiliary building in the V.C. Summer plant. Exact locations are given in Table 1. These instruments recorded both shots. Each system uses Mark Products L4C seismometers (natural period of 1 hz), Sprengnether AS110 amplifiers (without preamps and with all filters switched "out"), and DR-100 digital tape recorders. These systems have response which is flat to particle velocity from 2 to 50 hz. Playback of tapes was accomplished with a Sprengnether model DP 100 playback unit.

Kinemetrics - Strong Motion Accelerographs

Five 3-component Kinemetrics strong motion accelerographs were positioned at the following locations: Shot Point 2, tailrace, hydro plant basement, dam abutment, and meteorological tower. These instruments recorded only Shot 2. Each instrument is a self-contained unit, Kinemetrics model SMA-1. These systems have a natural frequency of approximately 25 hz and a sensitivity range of ± 1.0 g. Data is recorded on 70 mm photographic film.

Kinemetrics - Triaxial Time-History Accelerographs

Two Kinemetrics triaxial time-history accelerographs are permanent instrumentation within the nuclear plant. Time-history accelerographs are capable of measuring and permanently recording acceleration versus time. Instrumentation consists of two electrically operated triaxial accelerograph sensor units, one triaxial sensor trigger, a control/recorder unit, and a playback unit in the control building relay room. One triaxial sensor unit is located outside the containment shell on the reactor building foundation mat, and the other unit is located outside the containment shell on top of the ring girder. The measurement range for the units are 0.01 to 1.0 g, with a frequency response range (flat) of 0.1 to 40 hz.

APPENDIX B

DAMES & MOORE

MEMORANDUM

TO: MR. JOE B. KNOTTS, ESQ. DEBEVOIS & LIBERMAN DATE: November 11, 1981

FROM: NEVILLE DONOVAN - SF JOB NO: 5182-068-09 SCEG Virgil Summer Nuclear Power Plant

As part of an experiment designed to determine seismic behavior of the site area near the pumped storage area, Dames & Moore installed several strong motion instruments. This report presents our preliminary results. The experiment was designed by URS/Blume who will report their results separately.

For the experiment, Dames & Moore installed 5 strong motion accelerometers. The locations and the peak acceleration values from the readings of the Dames & Moore instruments and those of the USGS are listed in Table I.

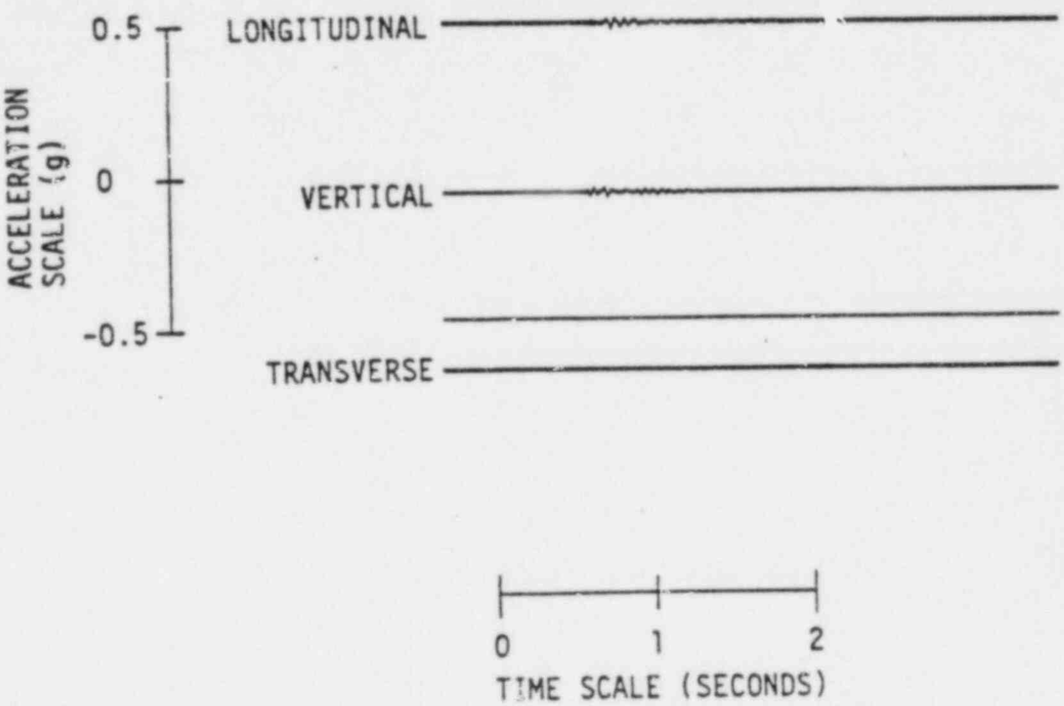
TABLE I
PEAK ACCELERATION VALUES

Record Serial Number	Instrument Location	Acceleration (% g) L	V	T
4724	Abutment, D&M	2.4	2.4	-
603	Abutment, USGS	2.7	2.1	3.1
267	Tail Race, USGS	3.1	4.4	6.1
4722	Ground Zero (500 pound blast)	45	98	34
4679	Meteorological Tower	No visible amplitude		
4673	Hydroplant	Excessive Noise		

Traces for the first 4 records in Table I have been digitized. This digitization has been done with a process compatible only to special programs and equipment operated by the USGS. The USGS has agreed to cooperate with the data processing. The USGS computer system in Menlo Park is being physically moved, and access has not been possible. Response spectra and Fourier Spectra of the records will be computed as soon as possible.

Some preliminary observations can be made from the actual traces. The peak acceleration of 98 percent at ground zero was more than twice as large as the horizontal motion. This would be expected for an explosive event. The two instruments located on the dam abutment gave very comparable peak acceleration values. There is a sinusoidal section apparent on the record from the tail race location. It is possible that this may be a ground response reaction of this filled site to the low level of excitation. The record obtained within the hydroelectric plant has only a low amplitude which is only slightly larger than harmonic equipment motion. Although a copy of the record is attached, it has not been included in the digitization program.

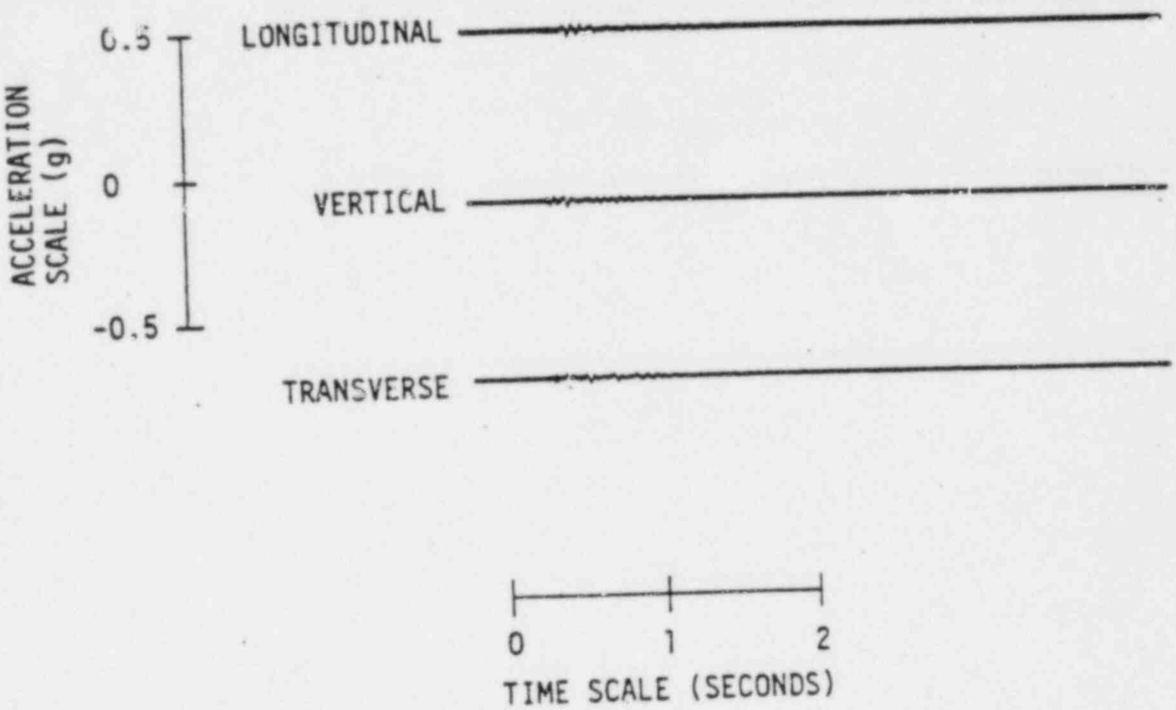
Attachments:
Enlarged copies of 5 instrument records



DAM ABUTMENT

DAMES & MOORE SMA (SERIAL NUMBER 4724)

DAMES & MOORE

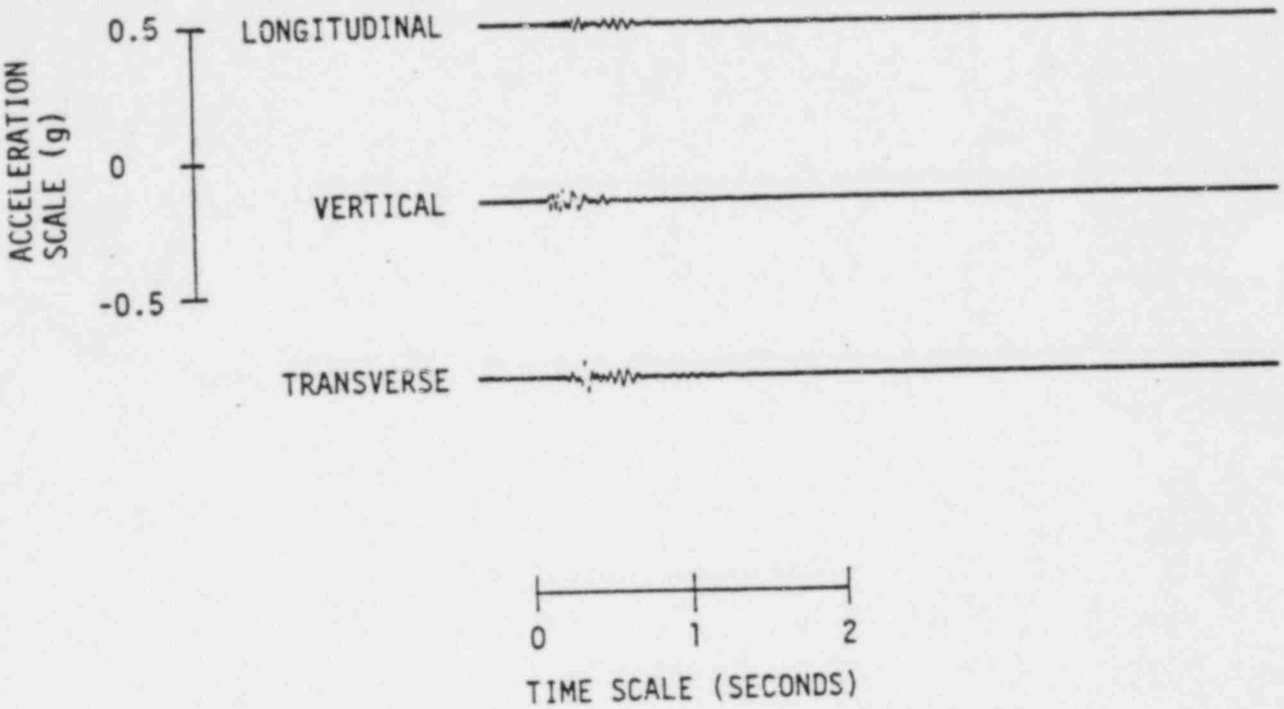


DAM ABUTMENT

USGS SMA (SERIAL NUMBER 603)

DAMES & MOORE

PLATE B-2

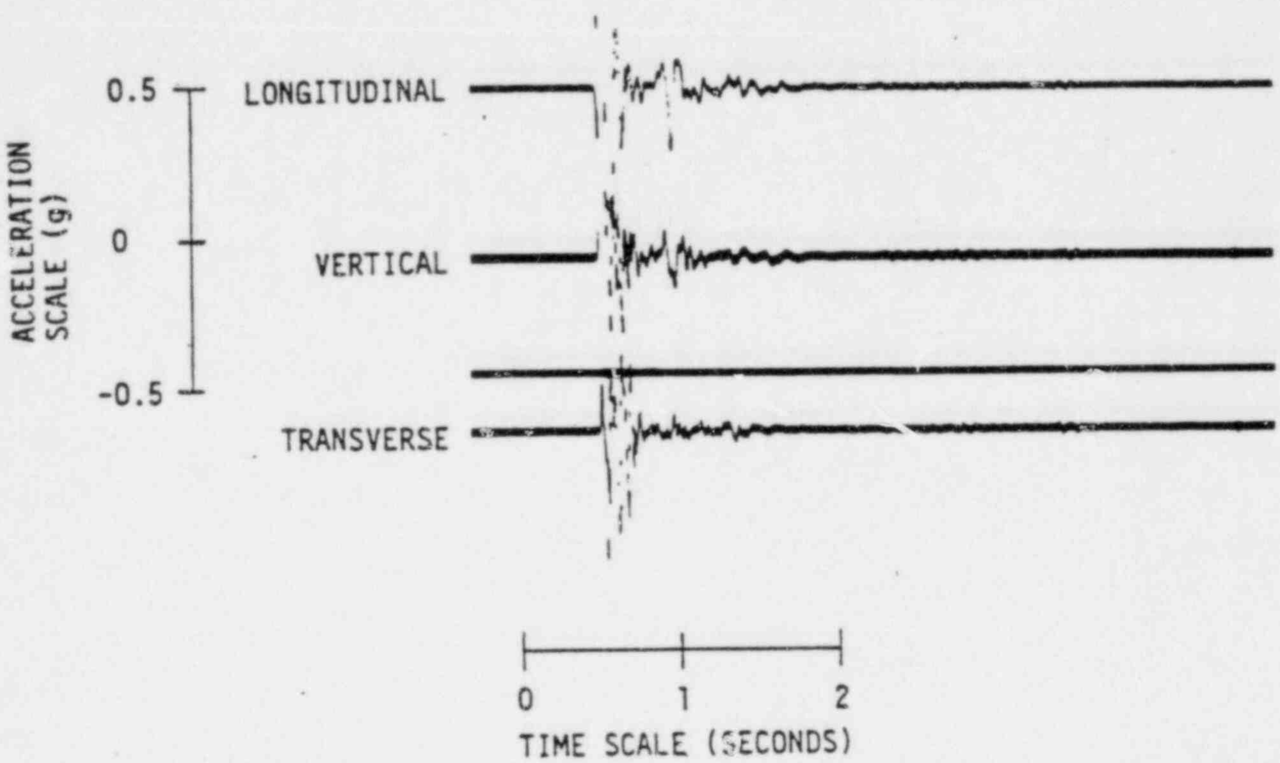


TAIL RACE

USGS SMA (SERIAL NUMBER 267)

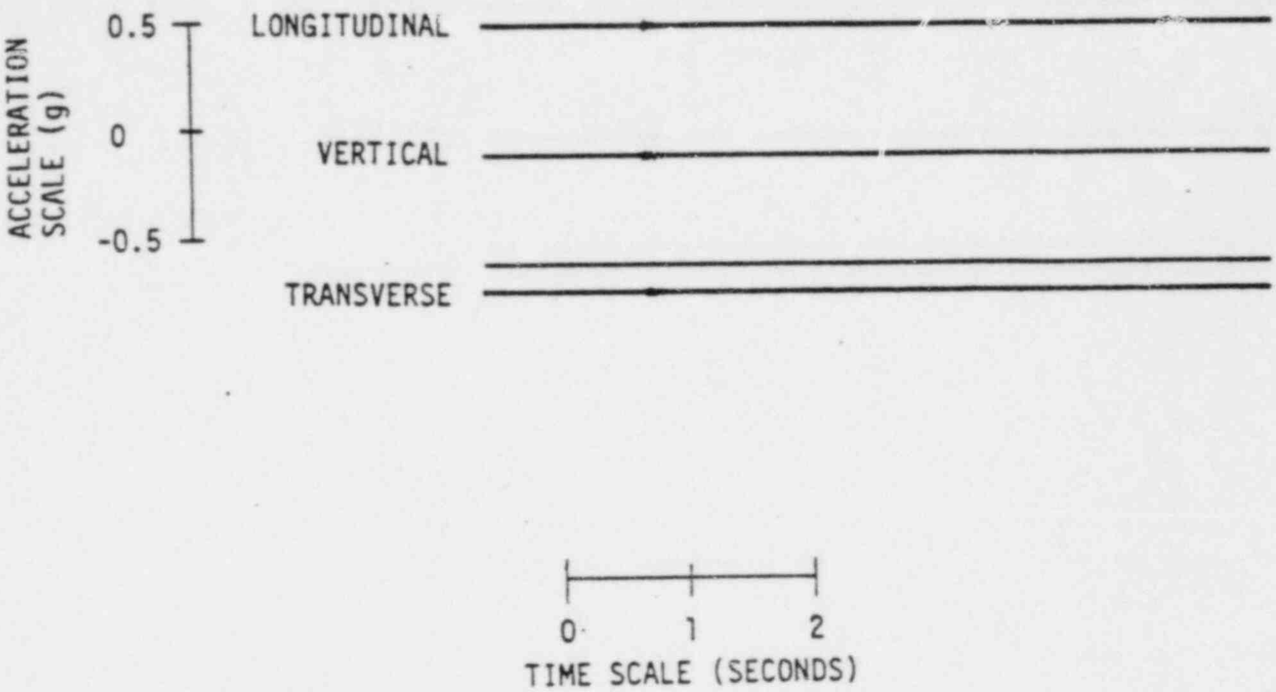
DAMES & MOORE

PLATE 8-3



GROUND ZERO

DAMES & MOORE SMA (SERIAL NUMBER 4722)



HYDRO PLANT

DAMES & MOORE SMA (SERIAL NUMBER 4673)

DAMES & MOORE

PLATE B-5

TABLE 1

V.C. SUMMER ACTIVE FIELD EXPERIMENTS
INSTRUMENT AND SHOT LOCATIONS

Site Description	Coordinates (South Carolina Grid System)	Elevation (Ground Surface) (FT)	Instrumentation
Shot Point 1: (Eastern Shore of Monticello Reservoir)	N484,940 E1,911,300	440	-
Shot Point 2: (South of Fairfield Hydro Plant)	N474,432.9* E1,899,612.8	284.8*	-
Dam Abutment between Dams B and C (USGS Station #2532)	N474,815.8* E1,900,703.2	429.0*	USGS SMA-1 #603 SCE&G SMA-1 Sprengnether DR-100 Blume Recorder
Adjacent to Hydro tailrace (USGS Station #2532)	N475,327.9* E1,899,115.1	274.6*	USGS SMA-1 #267 SCE&G SMA-1 Sprengnether DR-100 Blume Recorder
Near Shot Point 2	N474,406.9* E1,899,612.8	284.8*	SCE&G SMA-1
Fairfield Hydroplant Basement	N476,535 E1,899,790	208.0	SCE&G SMA-1
Near Meteorological Tower	N472,977.0* E1,903,223.2	434.3*	SCE&G SMA-1 Sprengnether DR-100
Auxiliary Building Basement	N472,550 E1,904,750	374.0	Sprengnether DR-100
Reactor Building Foundation Mat	N472,555 E1,904,780	408.5	Triaxial Time-History Accelerograph
Reactor Building Ring Girder	-	577.6	Triaxial Time-History Accelerograph

* Surveyed locations. All other coordinates either located within structures (± 10 feet) or scaled (± 50 feet)

TABLE 2

DISTANCES FROM EXPLOSIONS (SHOTS)

1 AND 2 TO SEISMOGRAPHS AND

ACCELEROGRAPHS LISTED IN TABLE 1.

Recording Site (1)	Distance (feet) from: (2) Shot 1	Shot 2
Dam Abutment	14,800	1,200
Hydro tailrace	15,700	1,100
Hydro plant basement	14,400	1,600
Meteorological tower	14,600	3,800
Auxiliary building	14,000	5,200
Reactor building	14,000	5,300
Shot point 2	15,900	20

(1) Exact locations of shot points and recording sites are given in Table 1.

(2) Precision is about ± 200 feet.

TABLE 3

RATIOS OF ENERGY FLUX AND ROOT MEAN SQUARE PARTICLE VELOCITY FOR AUXILIARY BUILDING/DAM ABUTMENT (1)

Frequency Band (hz)	Ratio: Energy	Ratio: RMS Velocity
2.93 - 9.96	0.0109	0.104
9.96 - 19.92	0.0241	0.155
19.92 - 33.00	0.0930	0.305
5.08 - 33.00	0.0283	0.168
9.96 - 33.00	0.0396	0.199

(1) Computed from integrals of power spectral density (PSD) of average horizontal motion for the two pairs of seismograms (N-S and E-W components).

FIGURES

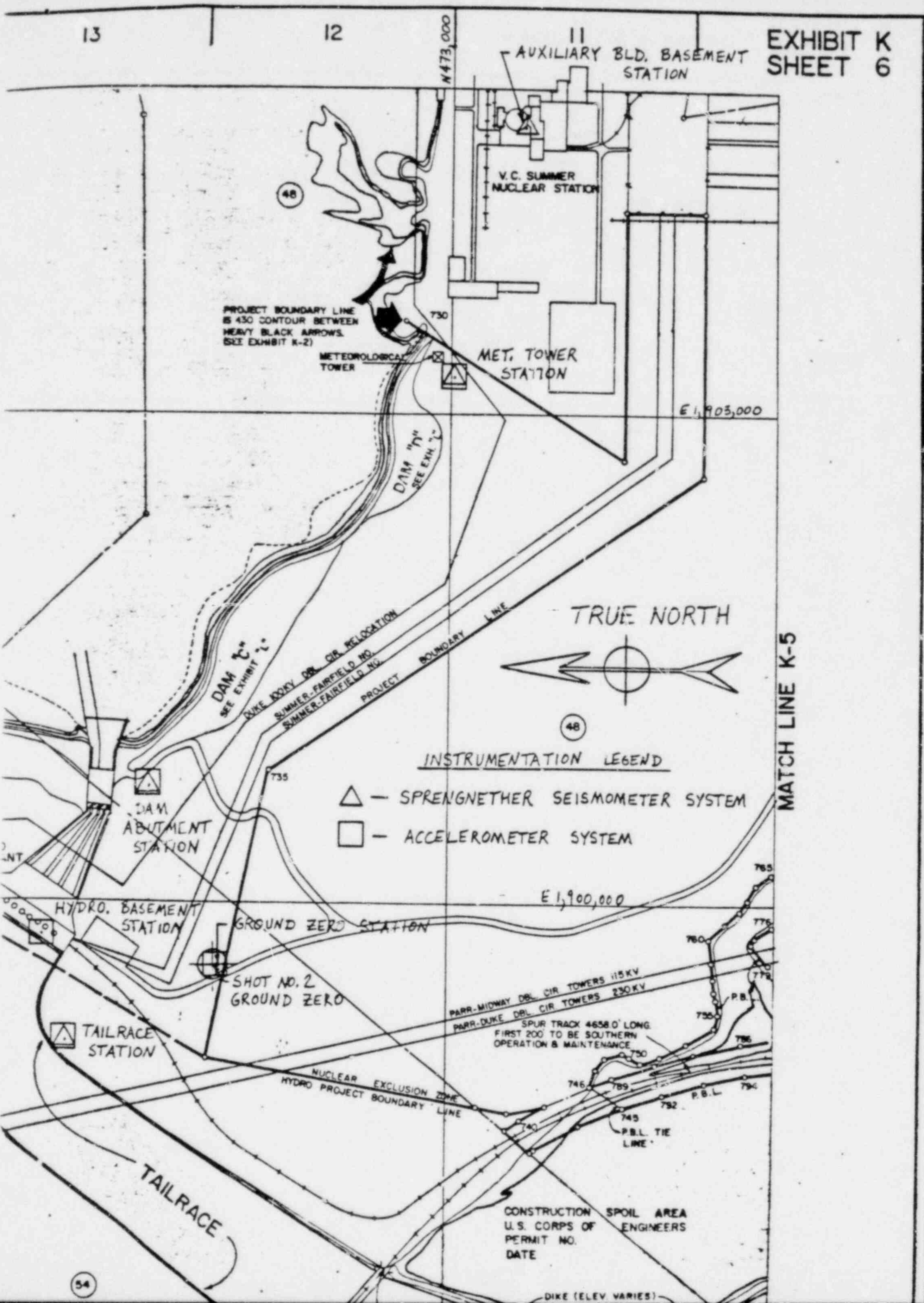
23. Fourier spectral ratios, shot 1, auxiliary building/meteorological tower.

24. Fourier spectral ratios, shot 1, auxiliary building/tailrace.

25. Fourier spectral ratios, shot 1, auxiliary building/dam abutment.


FIGURE 1
JENKINSVILLE QUADRANGLE
SOUTH CAROLINA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
UTM GRID AND 1969 MAGNETIC
DECLINATION AT CENTER OF
SHOT NO. 1
GROUND ZERO
MONTICELLO
RESERVOIR
TOP OF DAM
ELEV. 434
Creek
N480,000
SPOIL AREA
EL 300
FAIRFIELD
POWERHOUSE
NUCLEAR
EXCLUSION
ZONE
V. C. SUMMER
NUCLEAR STA.
N34°17'-56"
W81°18'-50"
SHOT NO. 2
GROUND ZERO
EL 436
EL. 438
DISCHARGE CHANNEL
BOTTOM ELEV 404
Substation
BORR
AREA
"E"
BORROW
AREA
"F"
SPOIL
AREA
EL 260

FIGURE 2


13
12
11
N473,000
EXHIBIT K
SHEET 6
AUXILIARY BLD. BASEMENT
STATION
V.C. SUMMER
NUCLEAR STATION
48
PROJECT BOUNDARY LINE
IS 430 CONTOUR BETWEEN
HEAVY BLACK ARROWS.
(SEE EXHIBIT K-2)
730
METEOROLOGICAL
TOWER
MET. TOWER
STATION
E 1,903,000
DAM "D"
SEE EXH. "L"
TRUE NORTH
DAM "C"
SEE EXHIBIT "L"
DUKE 100KV DBL. CIR. RELOCATION
SUMMER-FAIRFIELD NO.
SUMMER-FAIRFIELD NO.
PROJECT BOUNDARY LINE
48
INSTRUMENTATION LEGEND
735
△ – SPRENGNETHER SEISMOMETER SYSTEM
☐ – ACCELEROMETER SYSTEM
DAM
ABUTMENT
STATION
MATCH LINE K-5
E 1,900,000
HYDRO. BASEMENT
STATION
GROUND ZERO STATION
SHOT NO. 2
GROUND ZERO
PARR-MIDWAY DBL. CIR. TOWERS 115KV
PARR-DUKE DBL. CIR. TOWERS 230KV
SPUR TRACK 4658.0' LONG.
FIRST 200' TO BE SOUTHERN
OPERATION & MAINTENANCE
TAILRACE
STATION
NUCLEAR EXCLUSION ZONE
HYDRO PROJECT BOUNDARY LINE
P.B.L.
P.B.L. TIE
LINE
TAILRACE
CONSTRUCTION SPOIL AREA
U.S. CORPS OF ENGINEERS
PERMIT NO.
DATE
54
DIKE (ELEV. VARIES)

JOB No. 8153   2 Nov 81

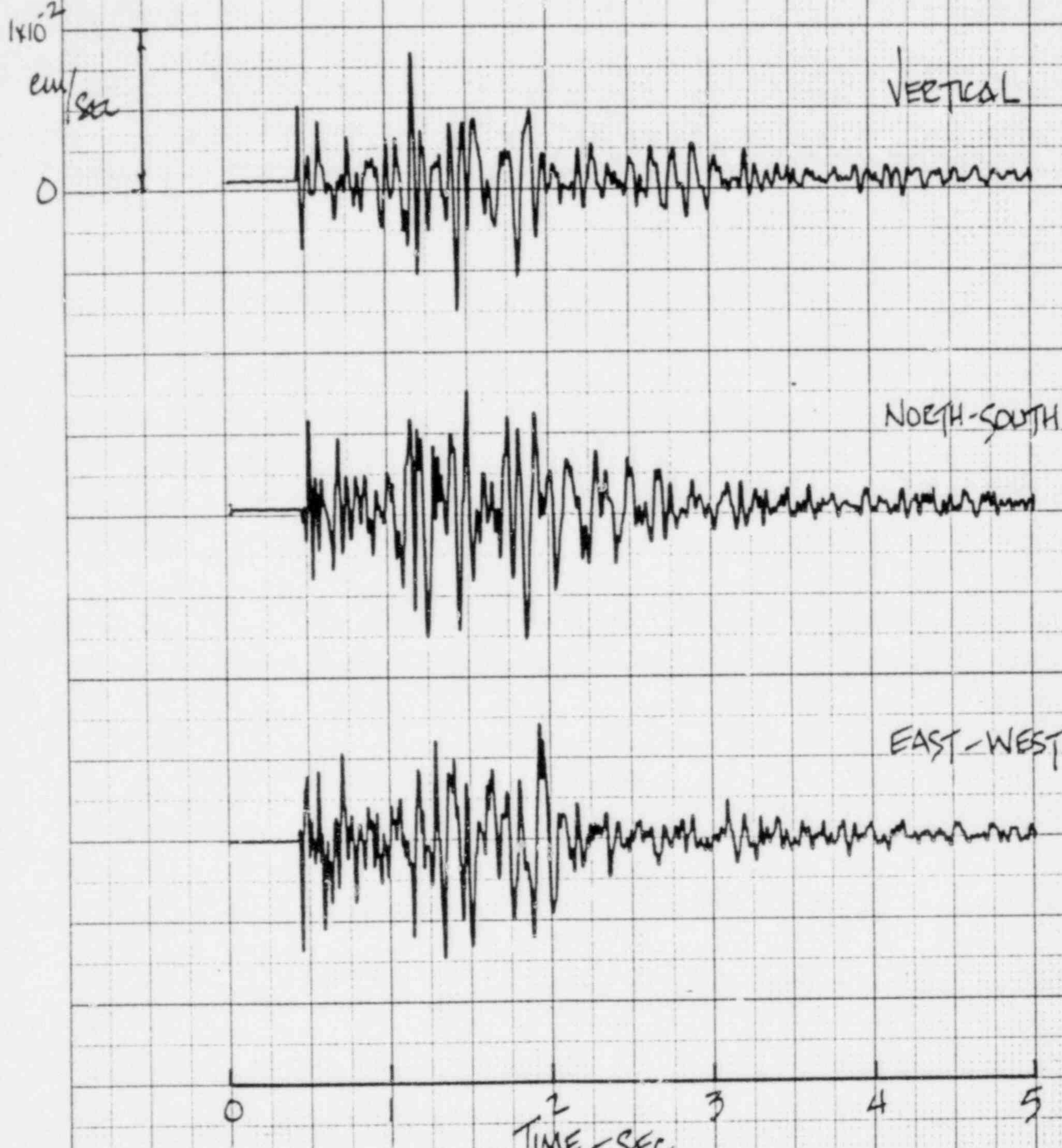


FIG. No. 3

EXPLOSION TEST No. 1
URS/BLUME SEISMOGRAPH
DAM, V.C. SUMMER NUCLEAR PLANT

OB No. 8153 2 Nov 81

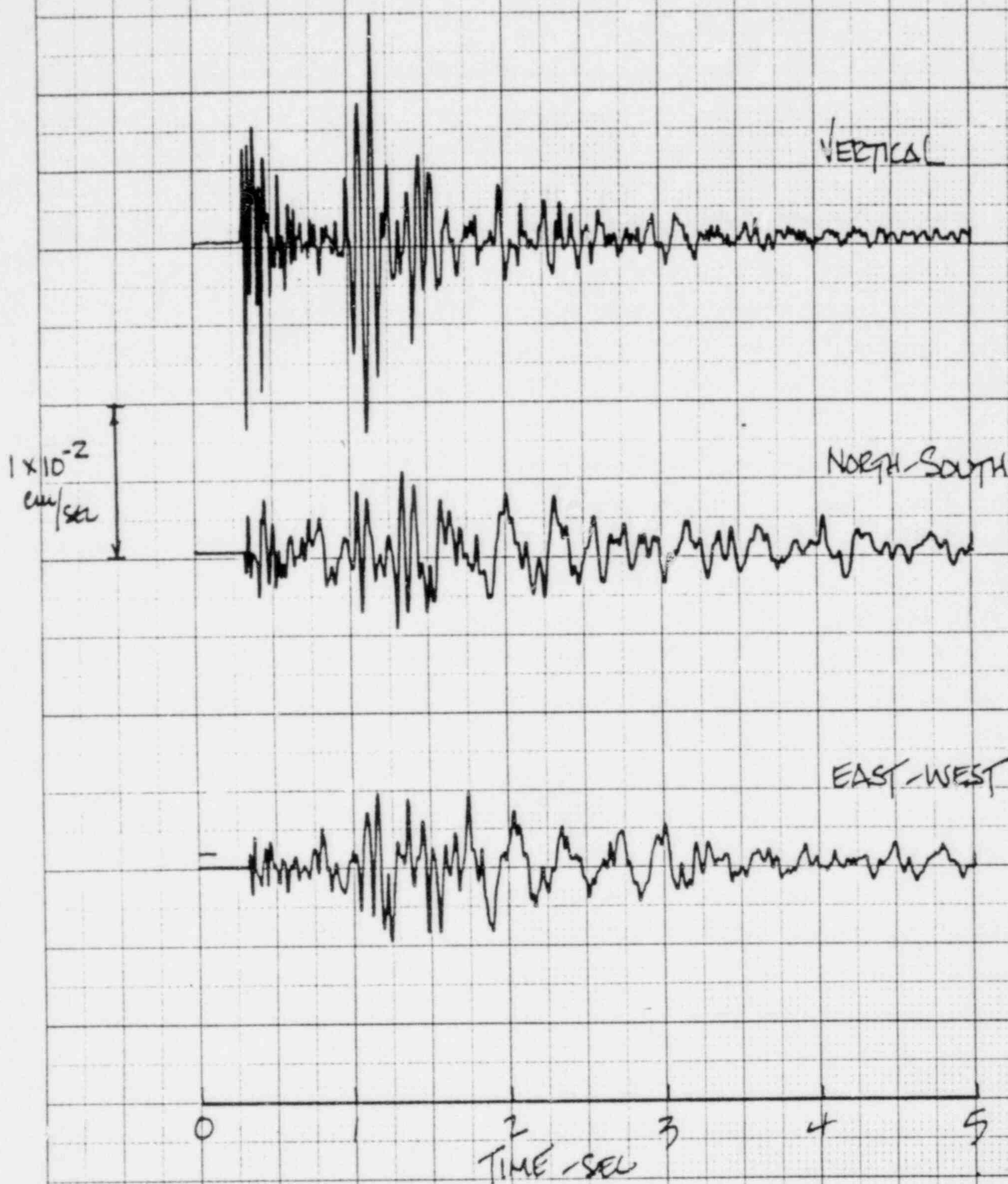


FIG. No. 4

EXPLOSION TEST No. 1
URS/BLUME SEISMOGRAPH
TAILRACE V.C. SUMMER NUCLEAR PLANT

JOB N° 8153

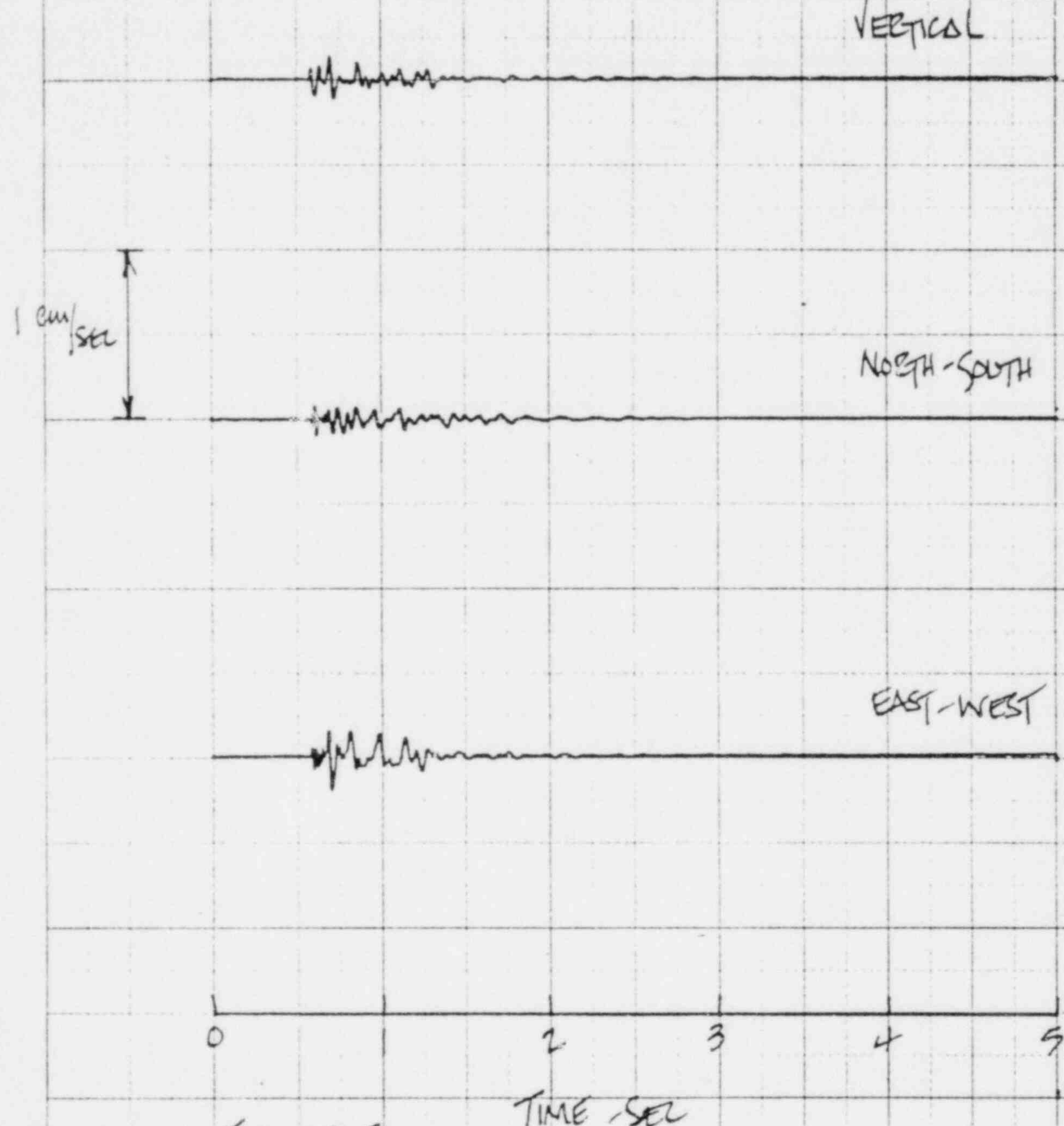


FIG. N° 5

EXPLOSION TEST N° 2
URS/BLUME SEISMOGRAPH
DAM, V.C. SUMMER NUCLEAR PLANT

JOB No 8153 2 NOV 81

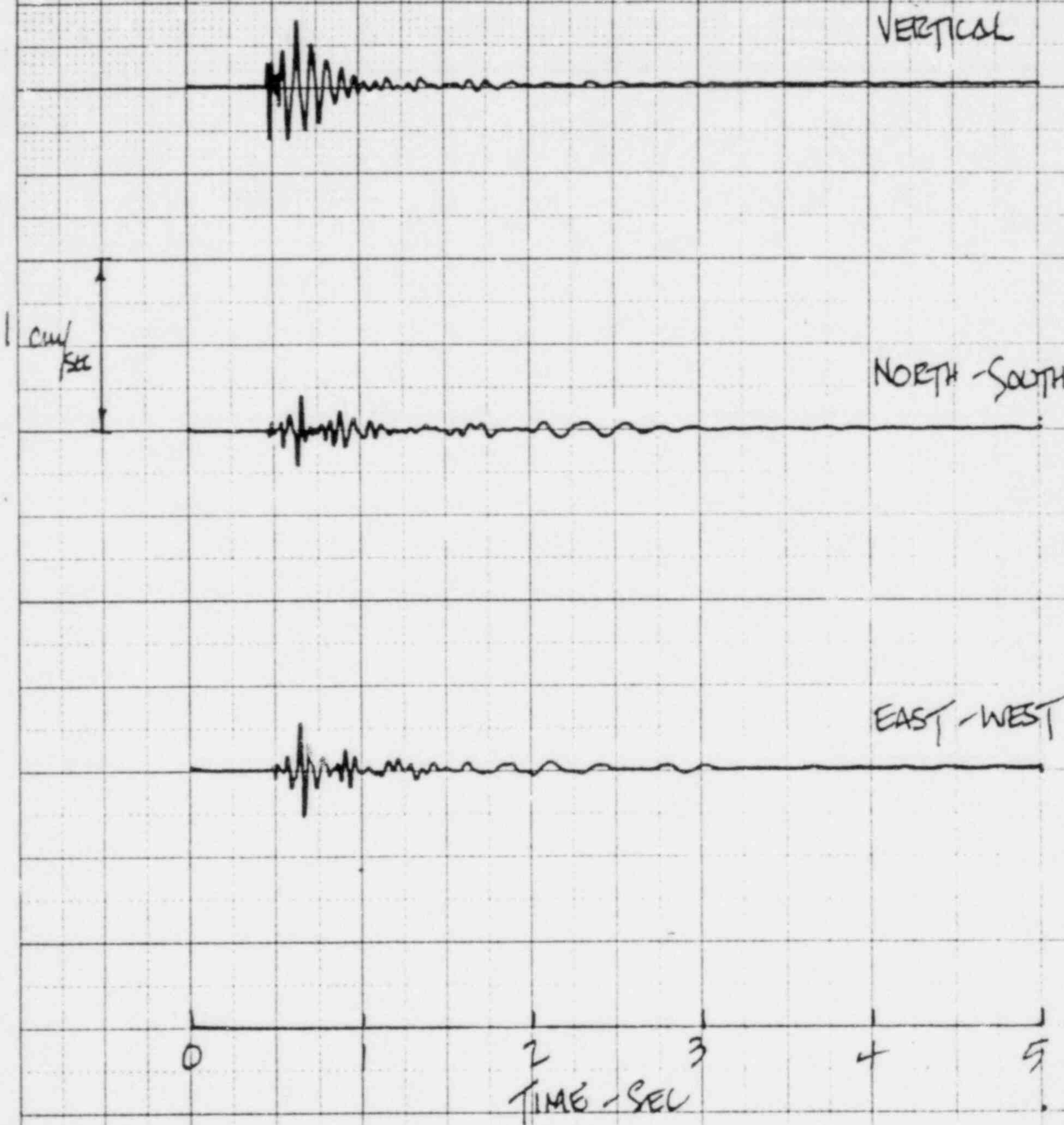
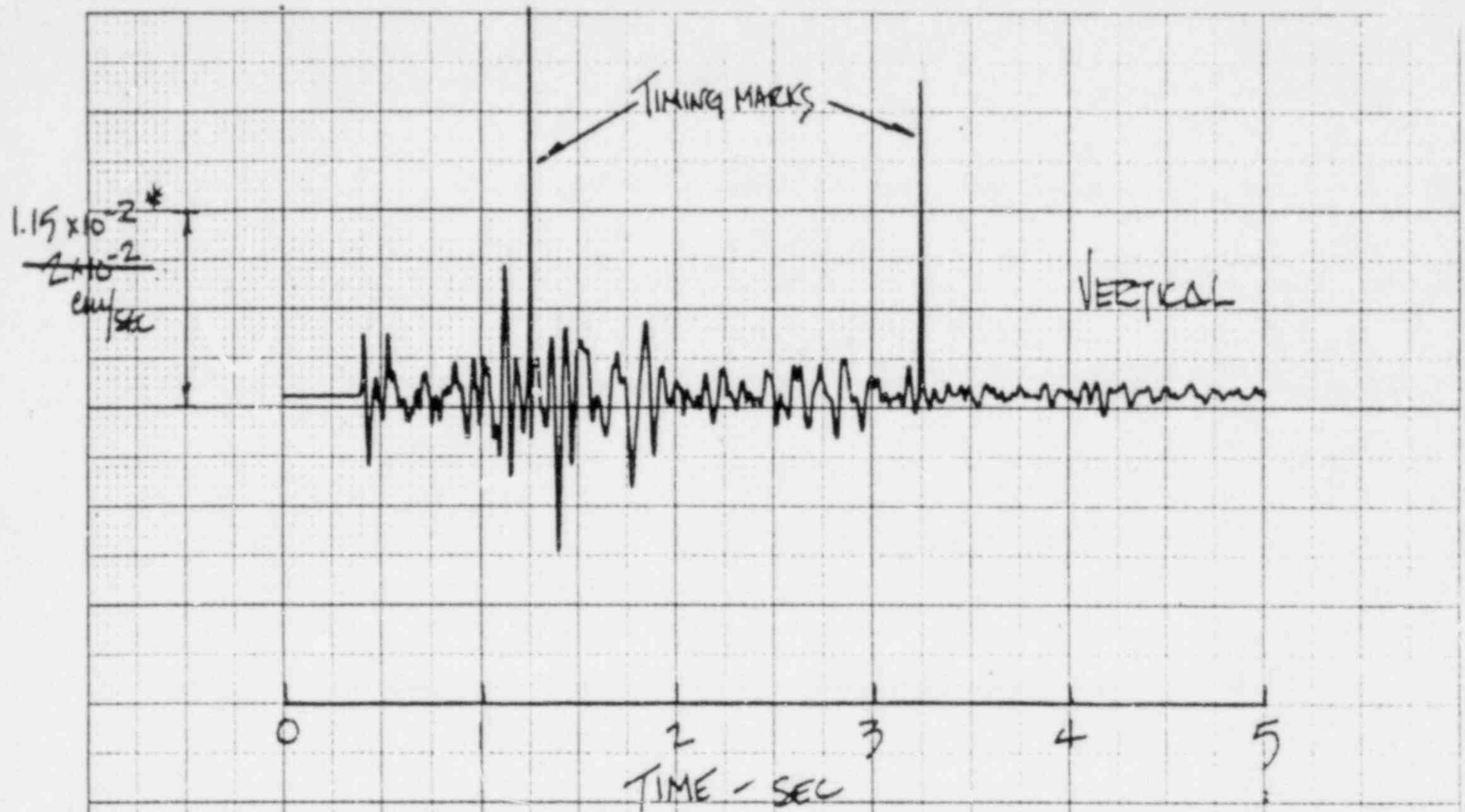


FIG. No 6

EXPLOSION TEST No 2
URS/BLUME SEISMOGRAPH
TAILRACE, V.C. SUMMER NUCLEAR PLANT

JOB NO. 8453. 3NOV81



* SCALE CHANGED AFTER CALIBRATION 16 NOV '81

FIG. No 7

EXPLOSION TEST No 1
SPRENGNETHER SEISMOGRAPH
DAM ABUTMENT

JOB No 8153 3 NOV 81

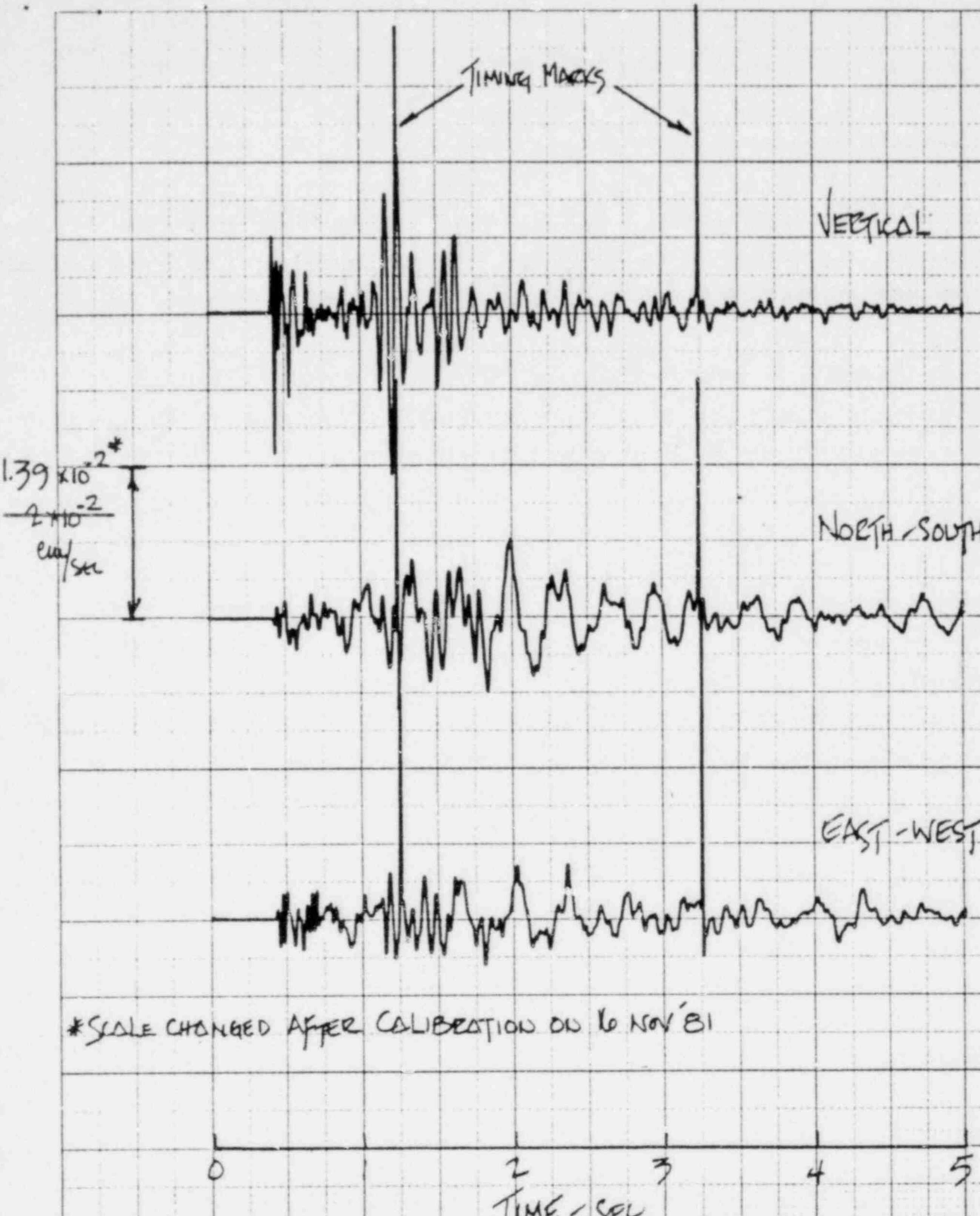


FIG. No 8

EXPLOSION TEST No 1
SPRENGNETHER SEISMOGRAPH
TAILRACE

JOB Nº 8153 17 NOV 81

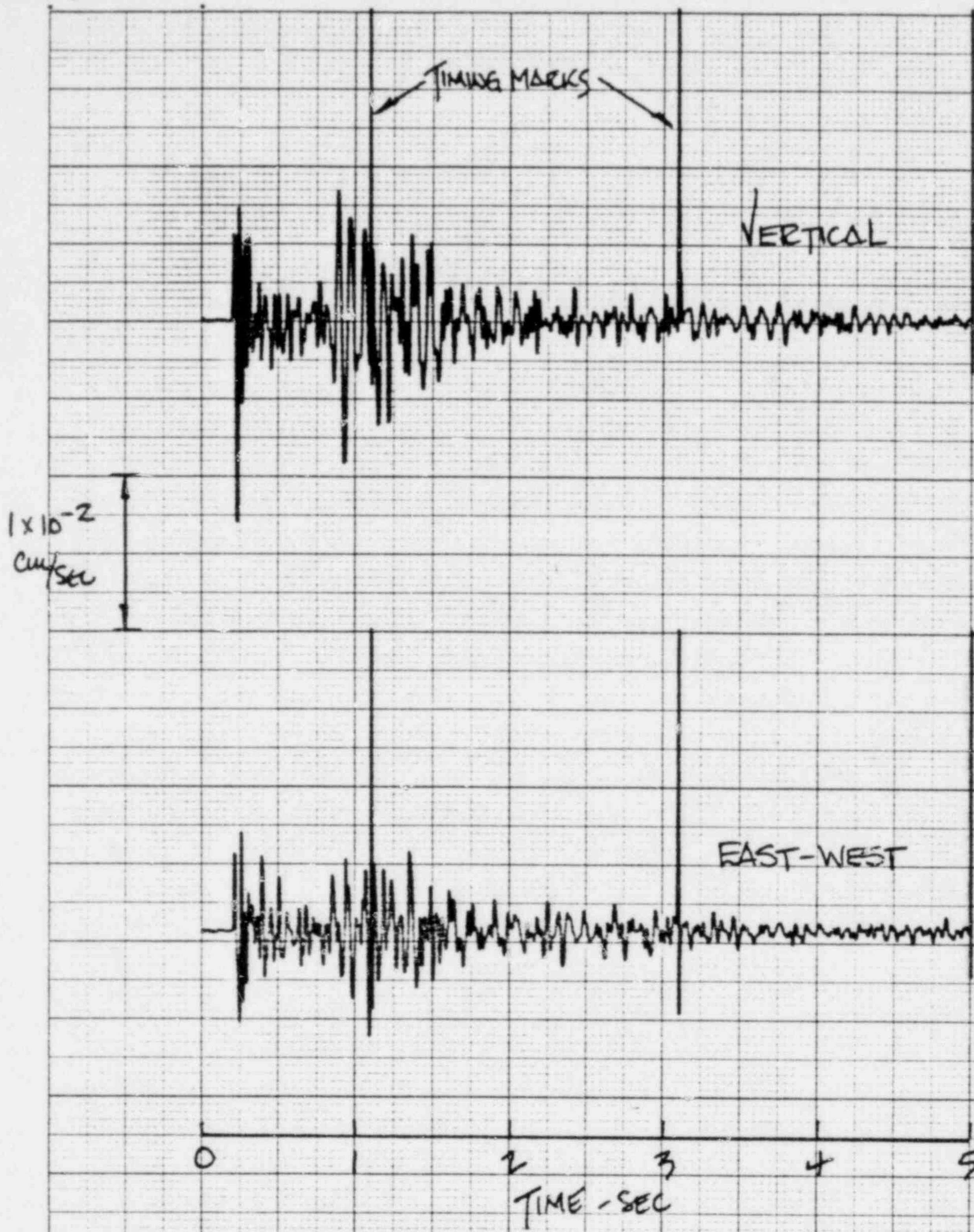


FIG. Nº 9

EXPLOSION TEST Nº 1

SPRENGNETHER SEISMOGRAPH

METEOROLOGICAL TOWER

CALIBRATED RE-PLOT

Job. no. 8193 3 Nov 81

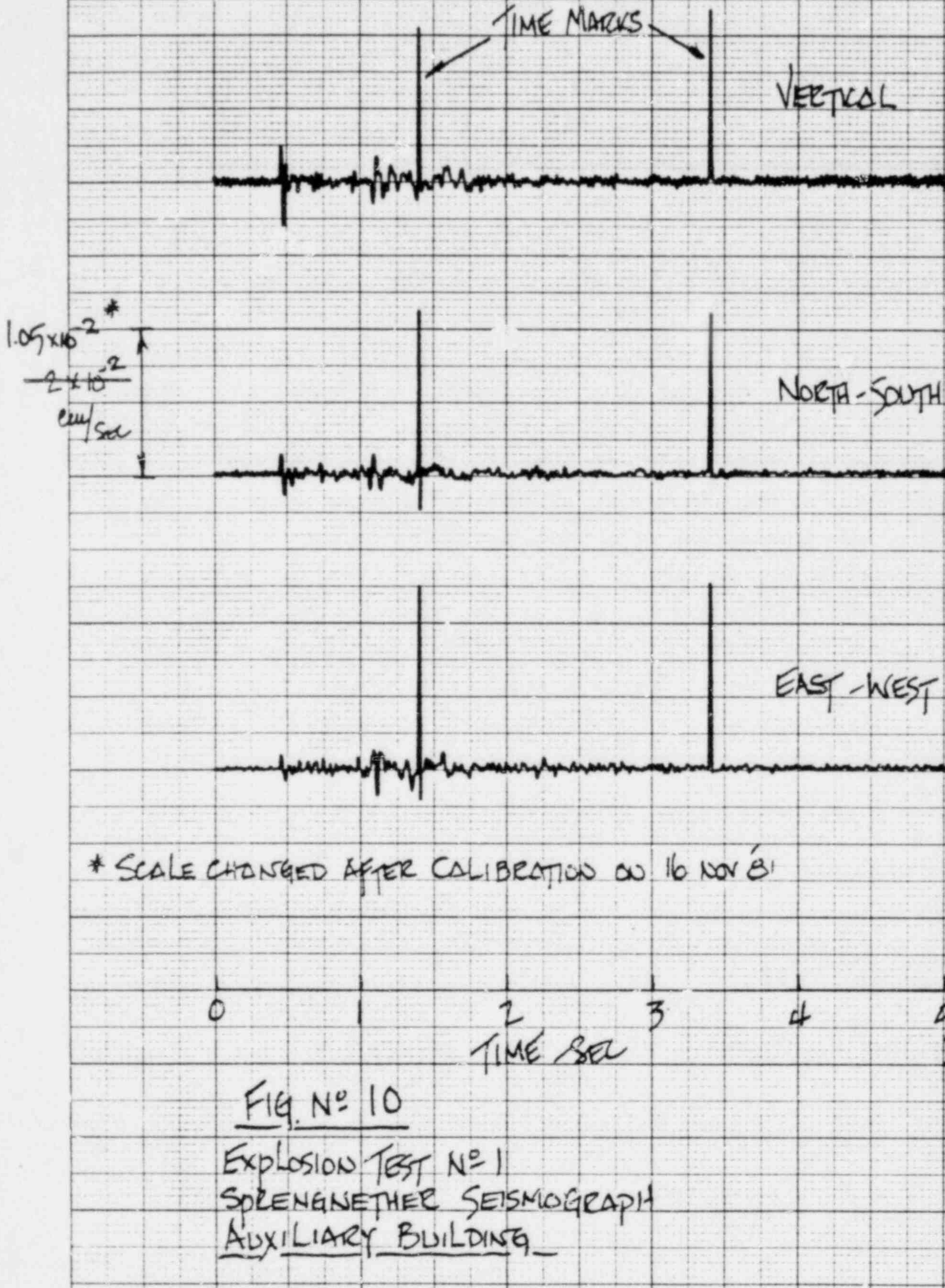
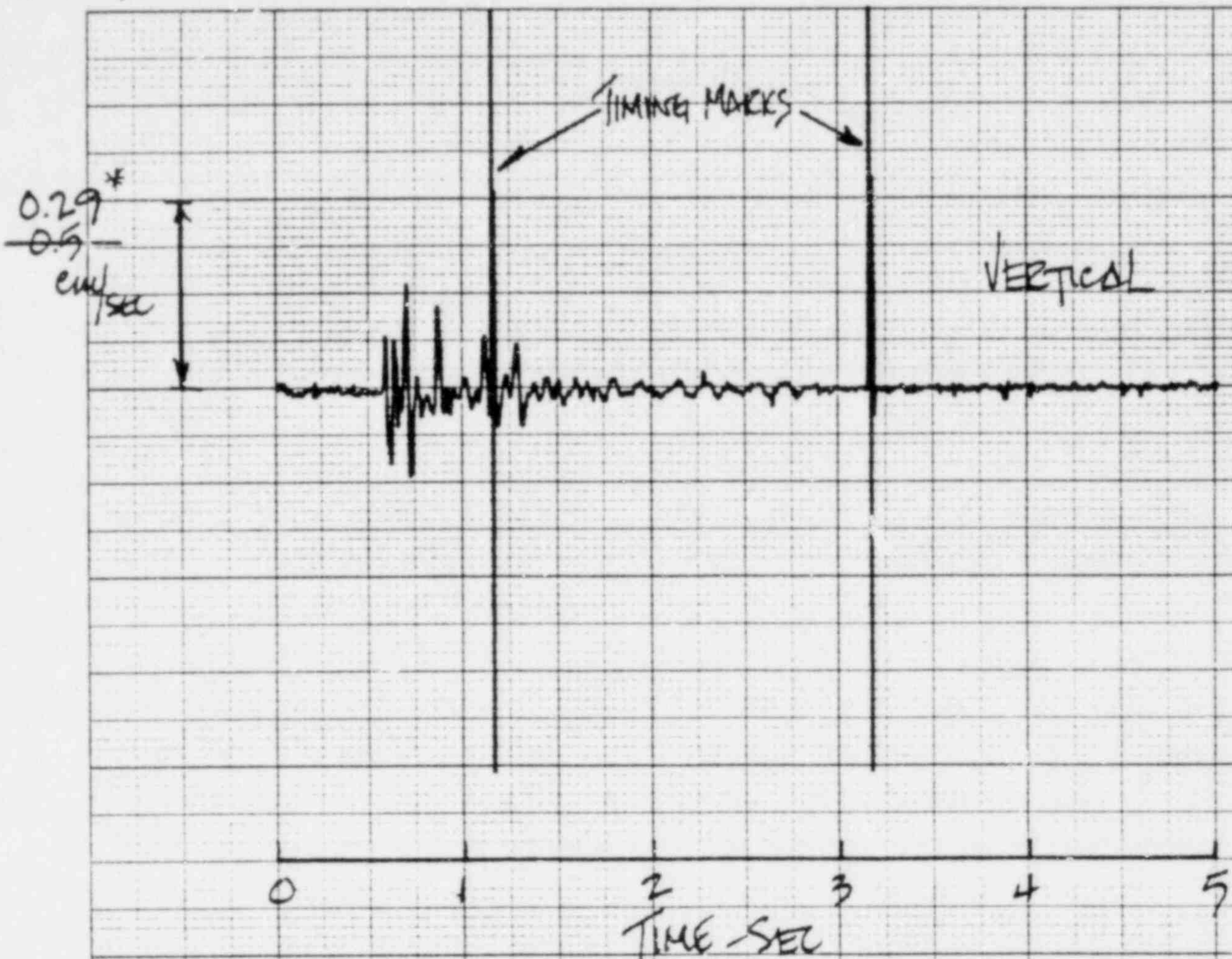


FIG. No 10

EXPLOSION TEST No 1
SPRENGNETHER SEISMOGRAPH
AUXILIARY BUILDING

JOB Nº 8153 3 NOV 81

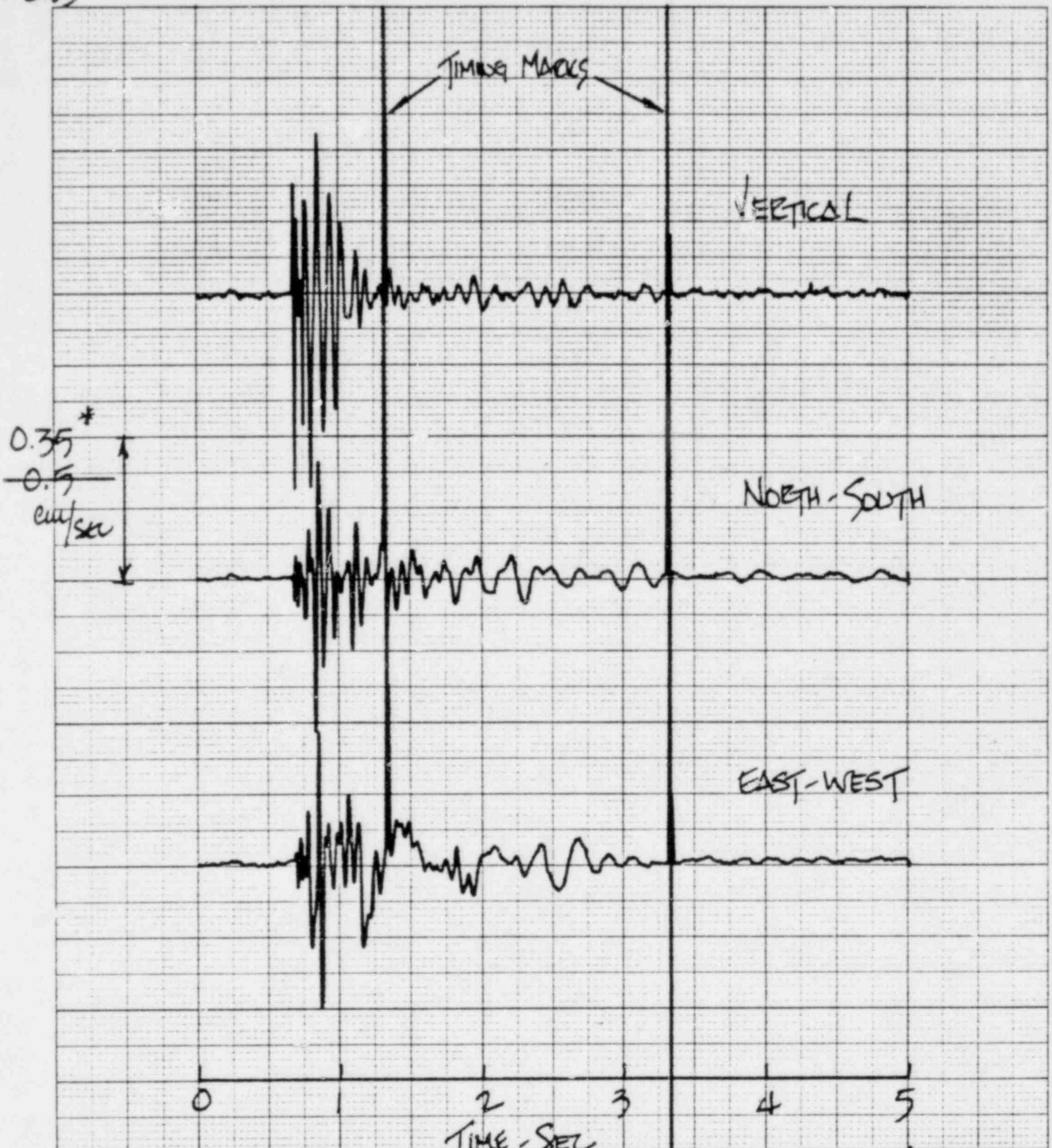


* SCALE CHANGED AFTER CALIBRATION ON 16 NOV 81

FIG. Nº 11

EXPLOSION TEST Nº 2
SPRENGNETHER SEISMOGRAPH
DAM ABUTMENT

Job no. 8153 3 Nov 81



* Scale changed after calibration on 16 Nov '81

Fig № 12

Explosion Test № 2

Sprengnether Seismograph

Tailrace

46 1240

K+E 20 X 20 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO.

Job no. 8153 3 Nov 81

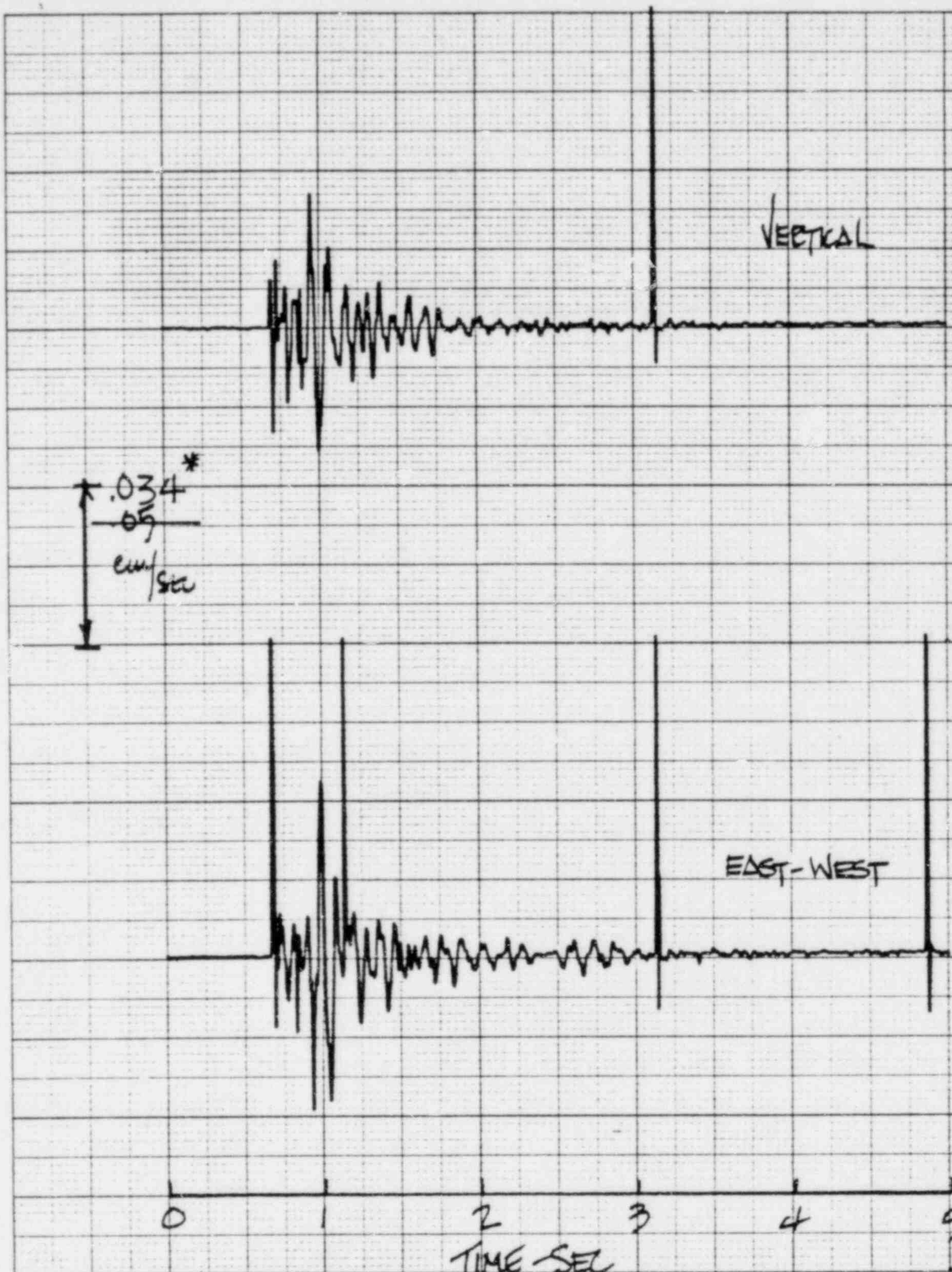


FIG. No 13
EXPLOSION TEST No 2
SPRENGNETHER SEISMOGRAPH
METEOROLOGICAL TOWER

* SCALE CHANGED AFTER CALIBRATION ON 16 NOV 81

Job no. 8153 3 Nov 81

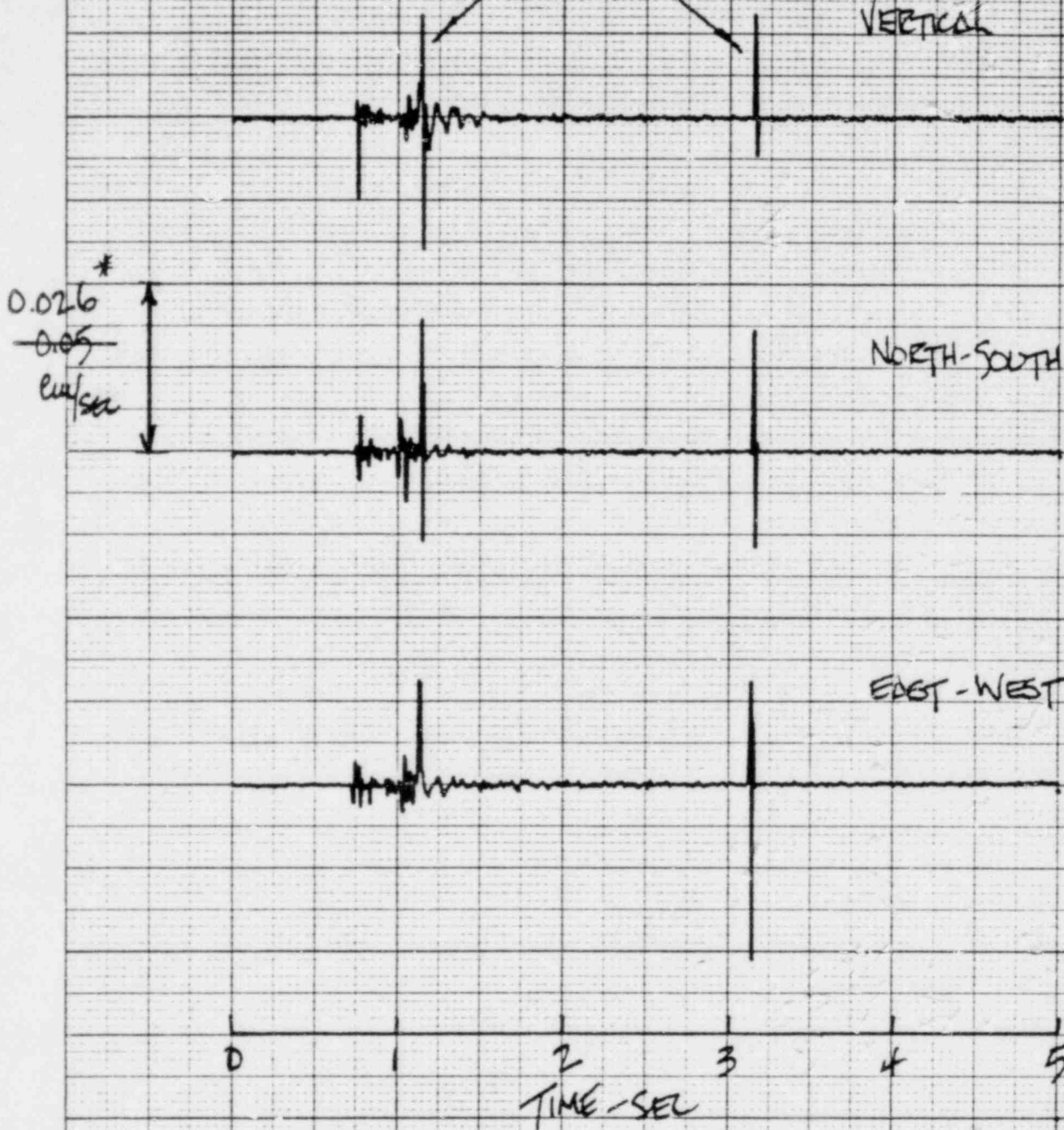


Fig. № 14

Explosion Test № 2
Sprengnether Seismograph
Auxiliary Building

* Scale changed after calibration on 16 Nov '81

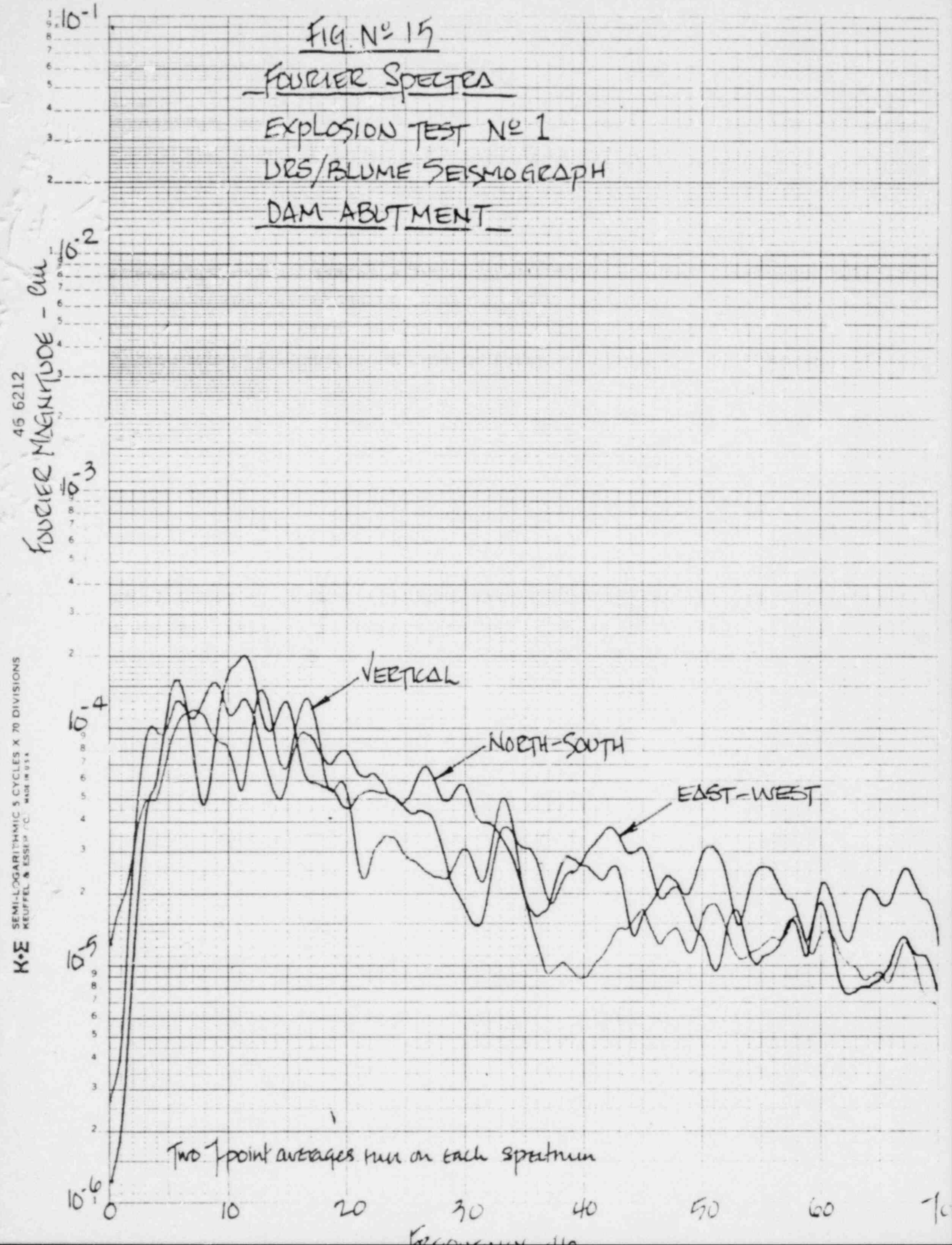


FIG. Nº 15
FOURIER SPECTRA
EXPLOSION TEST Nº 1
URS/BLUME SEISMOGRAPH
DAM ABUTMENT
VERTICAL
NORTH-SOUTH
EAST-WEST
Two 7 point averages run on each spectrum
FOURIER MAGNITUDE - cm
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
10
20
30
40
50
60
70
K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6212

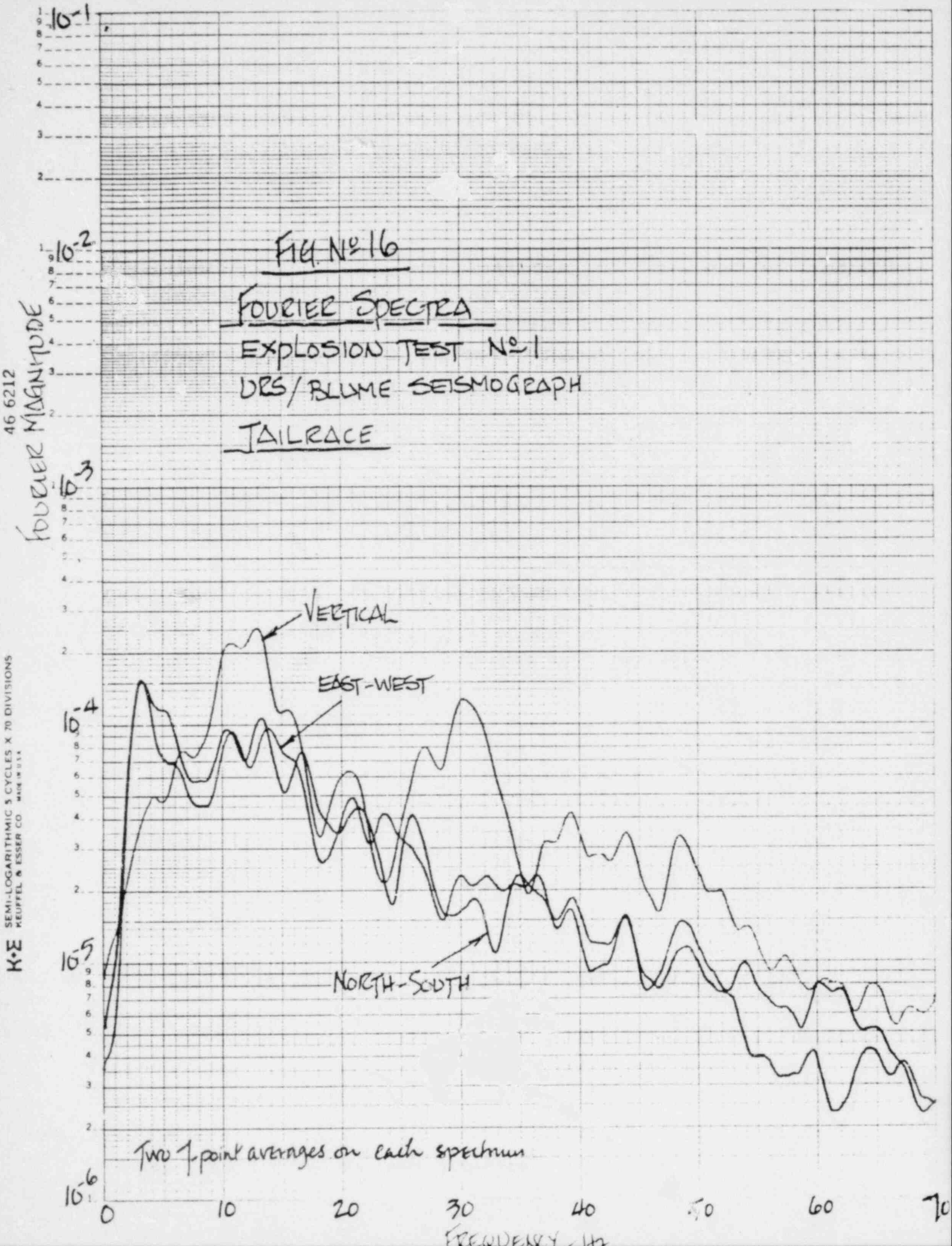


FIG. No 16
FOURIER SPECTRA
EXPLOSION TEST No 1
URS/BLUME SEISMOGRAPH
TAILRACE
VERTICAL
EAST-WEST
NORTH-SOUTH
Two 7-point averages on each spectrum
FOURIER MAGNITUDE
FREQUENCY - Hz
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
10
20
30
40
50
60
70
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6212

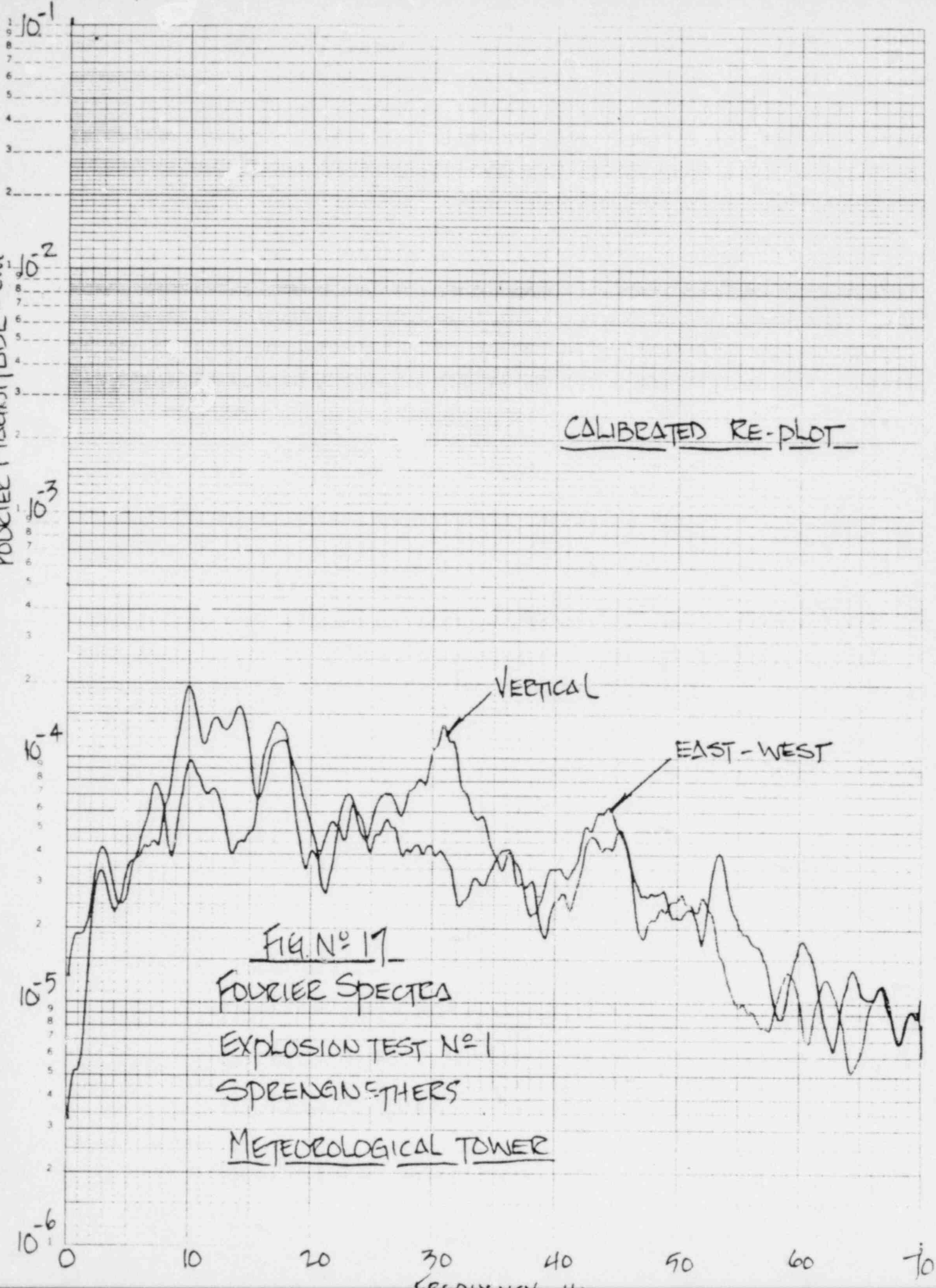


FIG. No 17
FOURIER SPECTRA
EXPLOSION TEST No 1
SPRENGNETHERS
METEOROLOGICAL TOWER

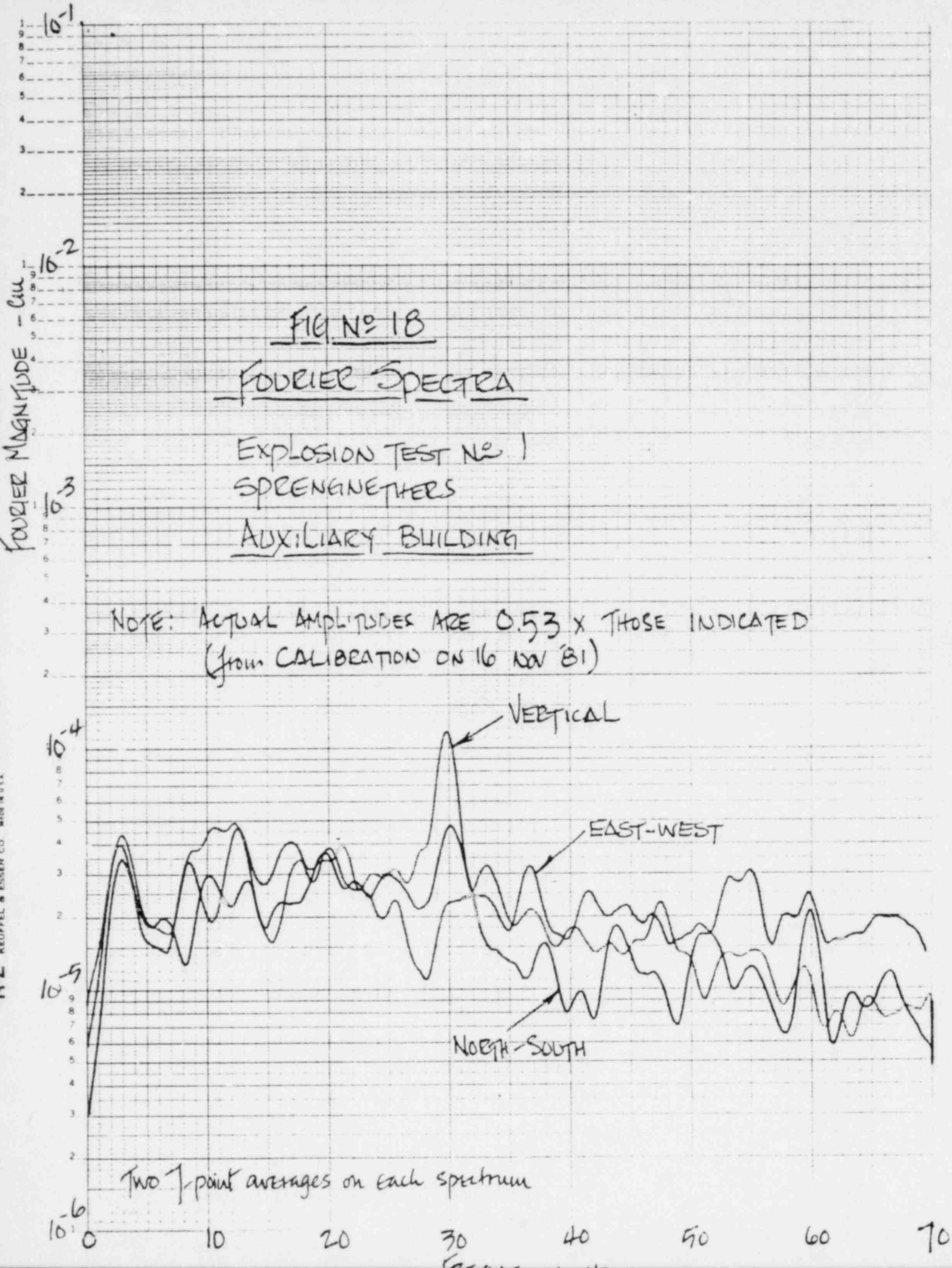


FIG. Nº 18
FOURIER SPECTRA
EXPLOSION TEST Nº 1
SPRENGNETHERS
AUXILIARY BUILDING
NOTE: ACTUAL AMPLITUDES ARE 0.53 x THOSE INDICATED
(from CALIBRATION ON 16 NOV '81)
VERTICAL
EAST-WEST
NORTH-SOUTH
Two 7-point averages on each spectrum
FOURIER MAGNITUDE - cm
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
10
20
30
40
50
60
70
46 6212
K·E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

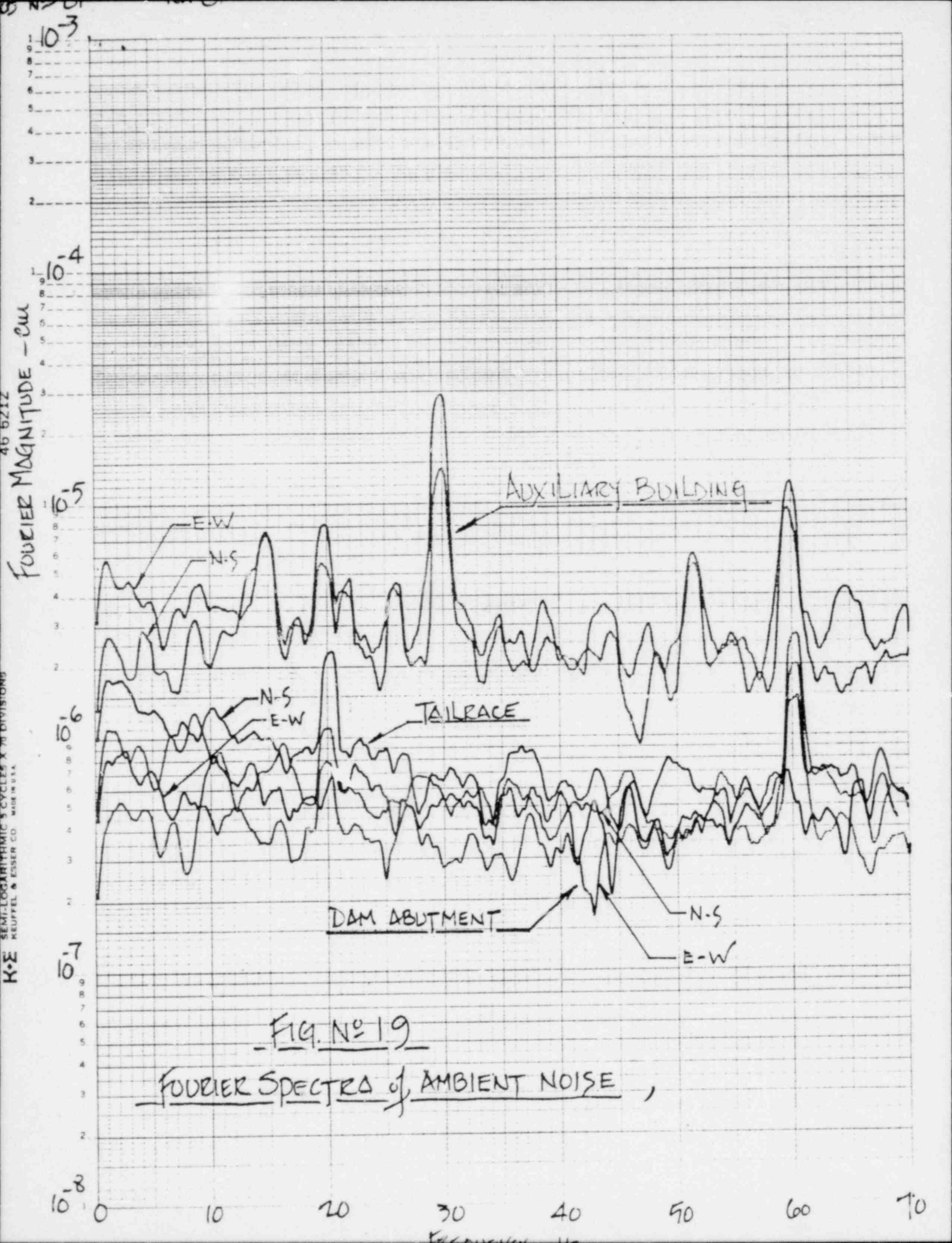


FIG. No 19

FOURIER SPECTRA of AMBIENT NOISE

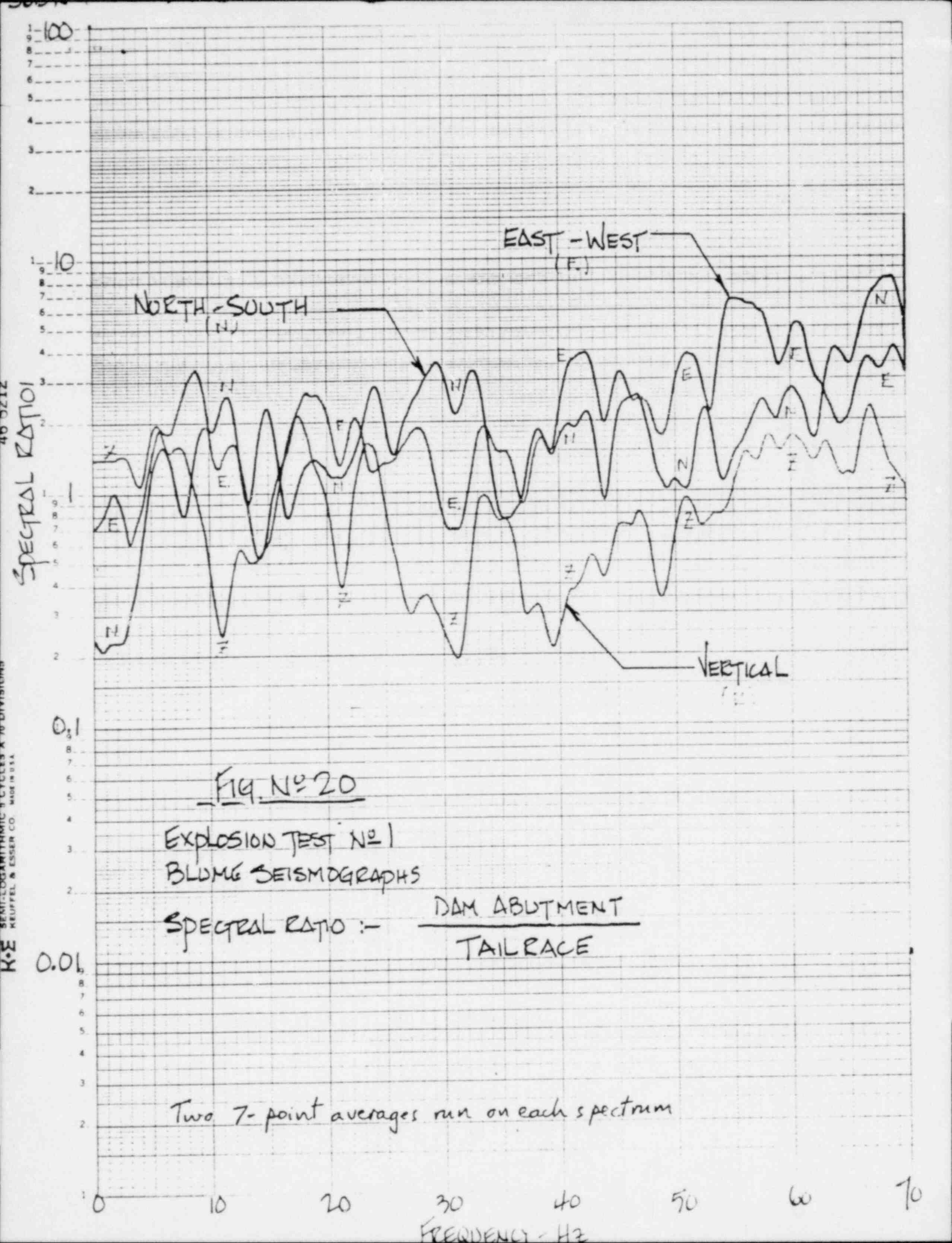


FIG. Nº 20

EXPLOSION TEST Nº 1

BLUME SEISMOGRAPHS

SPECTRAL RATIO :- DAM ABUTMENT / TAILRACE

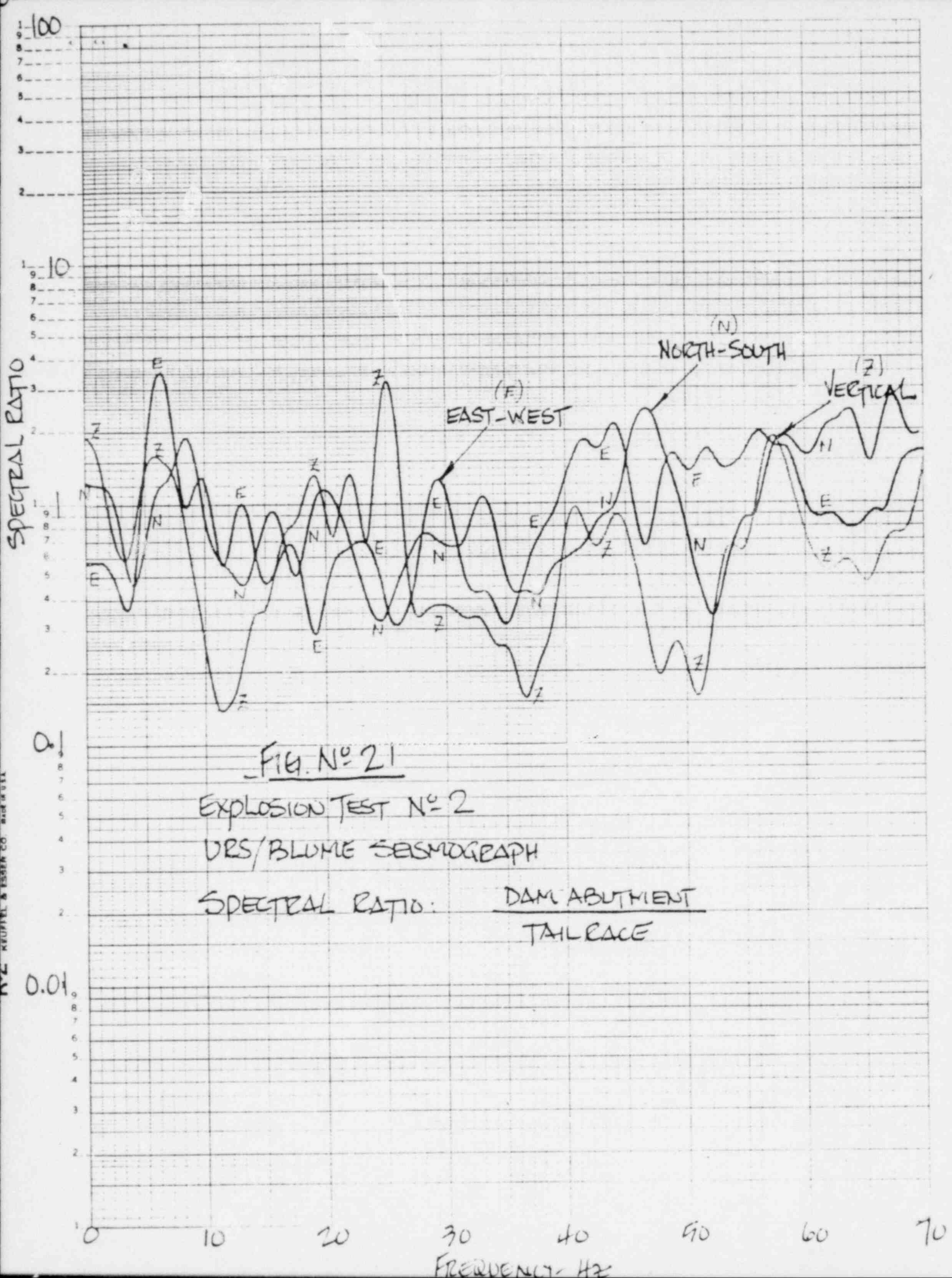
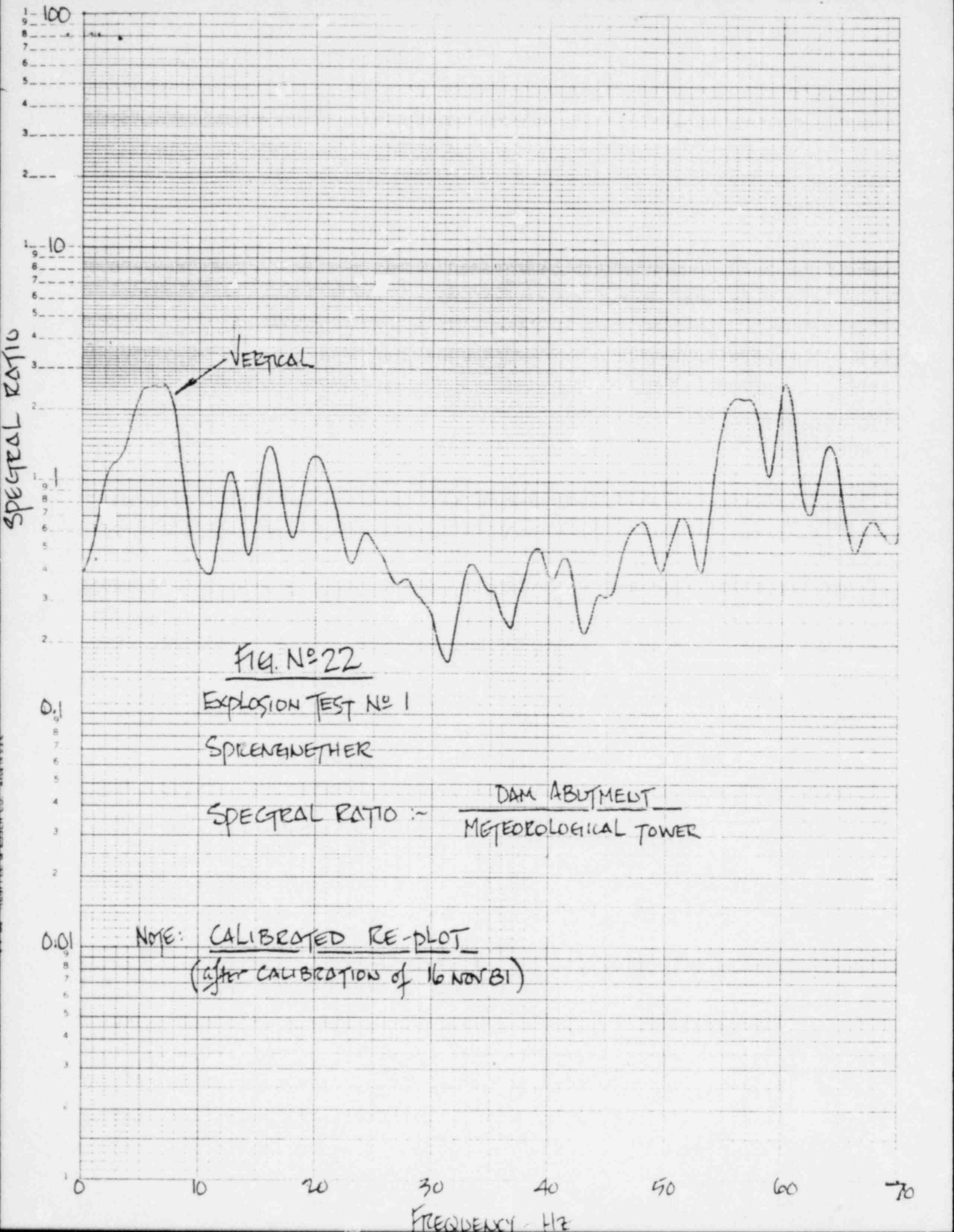


FIG. No 21

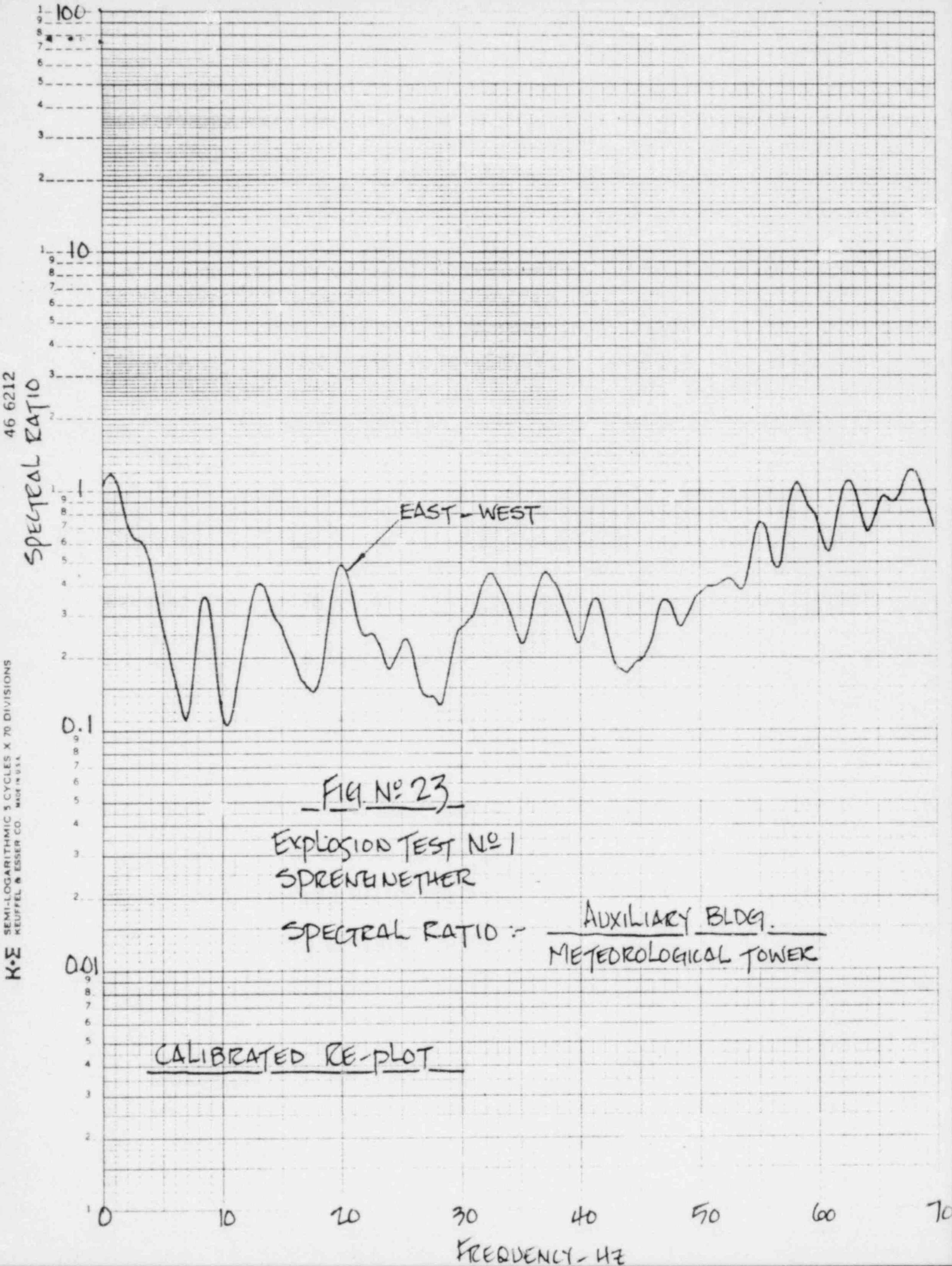
EXPLOSION TEST No 2

URS/BLUME SEISMOGRAPH

SPECTRAL RATIO: DAM ABUTMENT / TAILRACE



SPECTRAL RATIO
100
10
1
0.1
0.01
VERTICAL
FIG. No 22
EXPLOSION TEST No 1
SPRENGNETHER
SPECTRAL RATIO :~ DAM ABUTMENT / METEOROLOGICAL TOWER
NOTE: CALIBRATED RE-PLOT
(after CALIBRATION of 16 NOV 81)
0
10
20
30
40
50
60
70
FREQUENCY - Hz



SPECTRAL RATIO
46 6212
K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
100
10
1
0.1
0.01
EAST-WEST
FIG. Nº 23
EXPLOSION TEST Nº 1
SPRENGNETHER
SPECTRAL RATIO :- AUXILIARY BLDG. / METEOROLOGICAL TOWER
CALIBRATED RE-PLOT
0
10
20
30
40
50
60
70
FREQUENCY - HZ

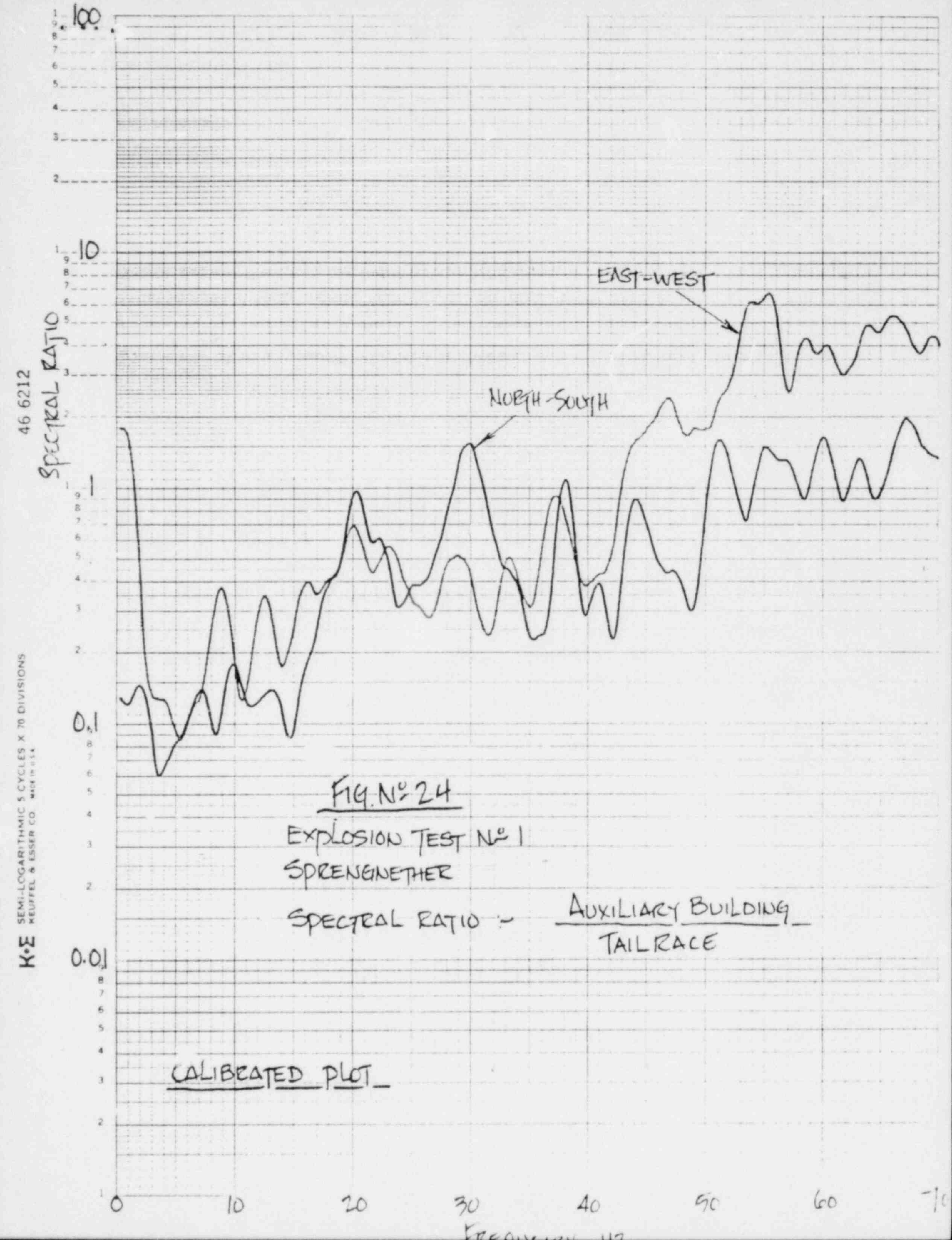


FIG. N° 24
EXPLOSION TEST N° 1
SPRENGNETHER
SPECTRAL RATIO ~ AUXILIARY BUILDING / TAILRACE

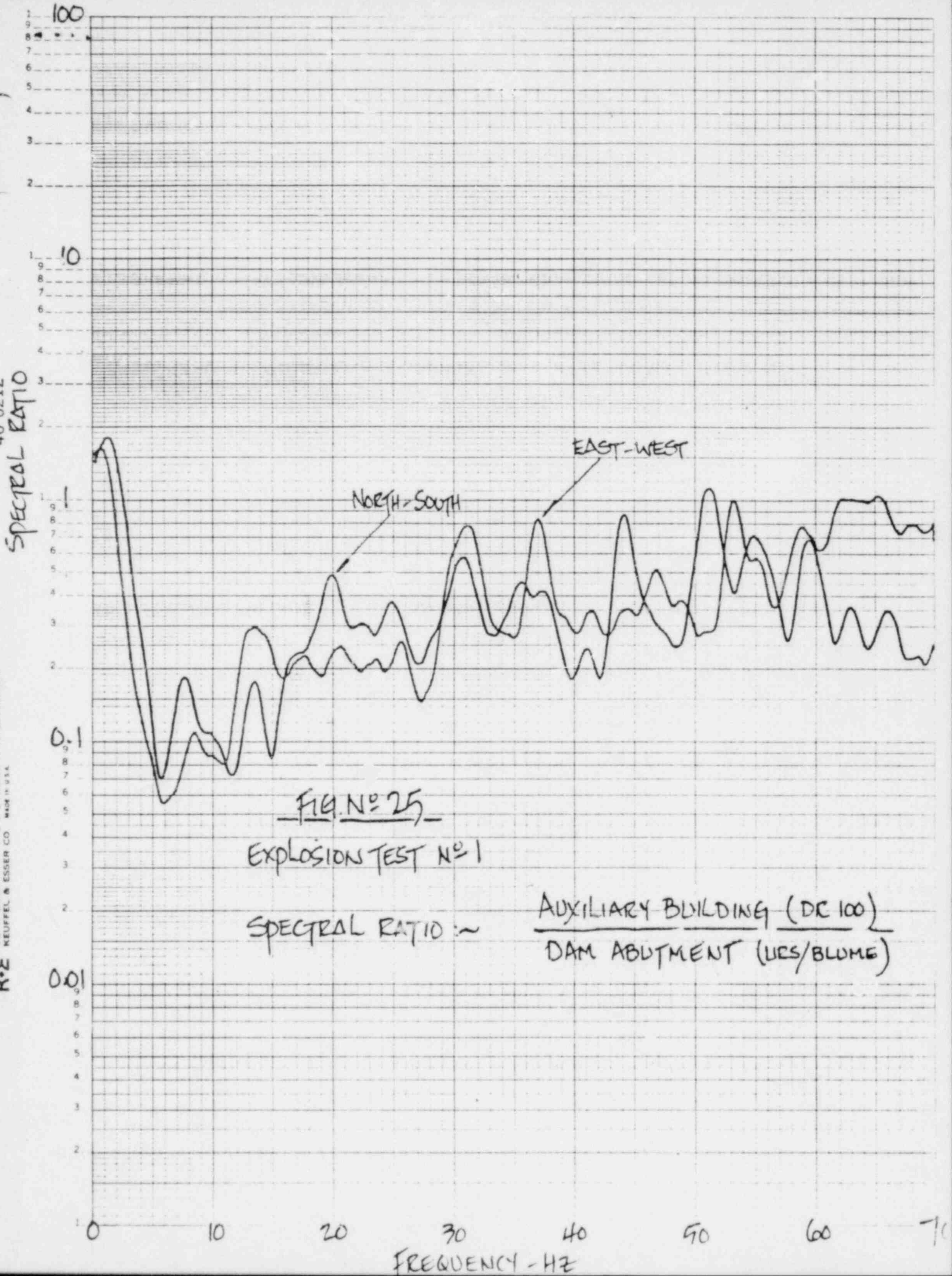


FIG. No 25

EXPLOSION TEST No 1

SPECTRAL RATIO :~ AUXILIARY BUILDING (DC 100) / DAM ABUTMENT (UCS/BLUME)