LAMINAR BLADE DAMPER

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ABSTRACT

This device consists of multiple layers of graphite-epoxy sheets separated from each other by a film of silicone grease. The sheets are interleaved and fastened to a structure in such a way as to permit sliding motion between alternate sheets as the structure bends. Damping results as this sliding motion is resisted by the viscosity of the silicone grease.

1. Introduction

A discrete flexible vibration damping unit to co-extend with a vibratile product for sensing and damping vibrations of said product, the unit including, a framework portion means and means including, a laminar group of flexible strip members of the framework having opposed side faces directly confronting one another interiorly of the group, with there being a flexible first strip member in the group, and the laminar group and framework portion means having portions of the framework interconnected in the framework through the flexible first strip member in the group and the framework portions to be secured to the vibratile product with the unit co-extending with the product side facially of the framework toward the product, for the flexible strip members in the group to be flexed from side to side and longitudinally relatively move with reference to one another having said all other of the flexible strip members in the group remain connected with the flexible first strip member and longitudinally movably free-ended, when the group is flexed between the framework portions, and a tacky visco-elastic substance longitudinally reaching between the opposed side faces all of the flexible strip members in the group about as far as the opposed side faces of one and next of the flexible strip members in the group longitudinally co-extend directly opposing one another, and the tacky visco-elastic substance directly visco-elastically interengaging the opposed side faces with one another in the group, for the unit to have the flexible strip members in the group, flex from side to side and be retarded in the relative longitudinal movements thereof by the tacky viscoelastic substance when the flexible unit is on the vibratile product co-extending with the product side facially of the framework portions secured to the product and the unit is responding to vibrations of the product by flexing between the framework portions, with all other of the flexible strip members in the group remaining connected with the flexible first strip member in the group and longitudinally movably free-ended.

Flat-wise, edge-wise and end-to-end damping is achieved with three dimensional vibration absorbing system, adding little stiffness and small frequency change to the product.

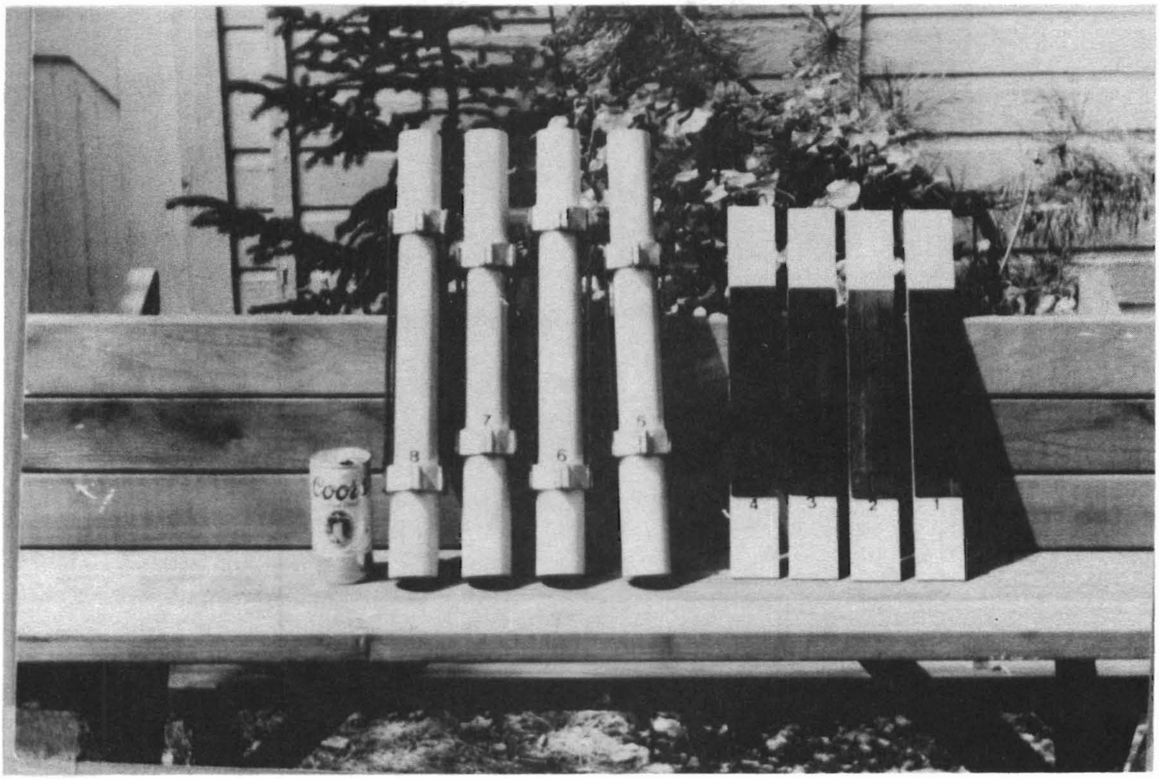


Figure 1. Two damper units fixed to segment clamps, secured to tubular specimens.

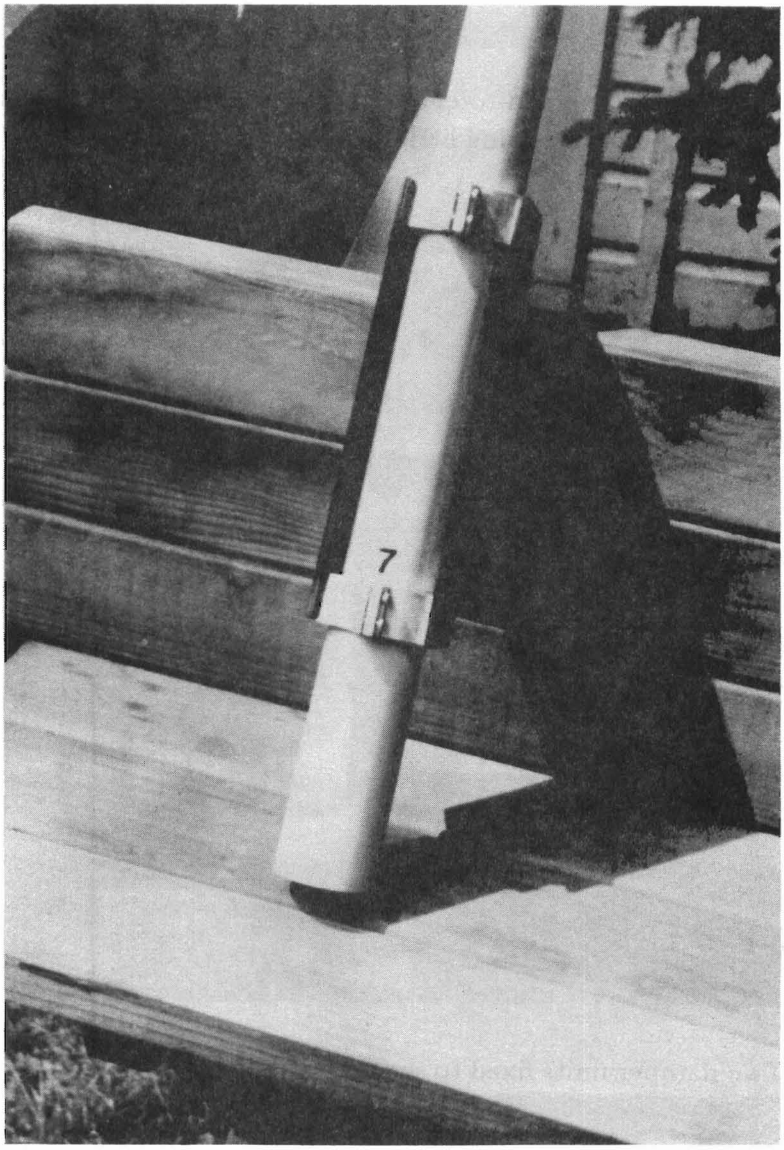


Figure 2. Two damper strips bonded to segment clamps, fixed to tubular specimen.

2. First Analytic Summary

The following seven pages indicate a damping factor of eight times.

The damper unit is 1/8 inch thick
2 inches wide
11 inches long
weight 1 and 1/2 ounce

The damper unit is bonded to "E" glass specimen 1/4 inch thick
2 inches wide
16 inches long

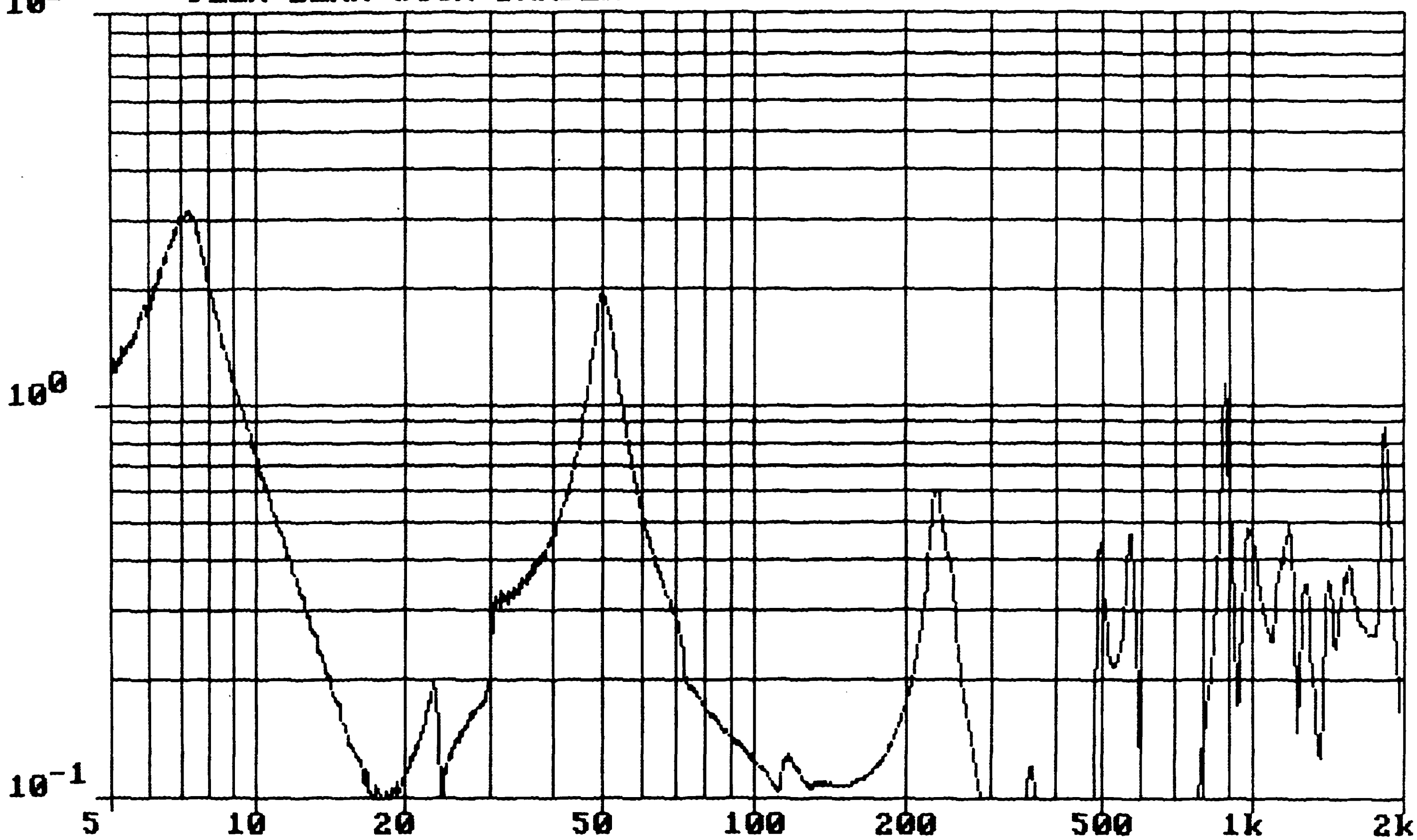
The specimen is clamped to a shaker table, the opposite end is weighted for these tests.

The next five pages are with damper, the two following are without damper.

#1

TEST SETUP-ID: FLEX   TEST RUN NAME: RUN2   autosave 01/10/90 10:22:46

FLEX BEAM WITH DAMPER



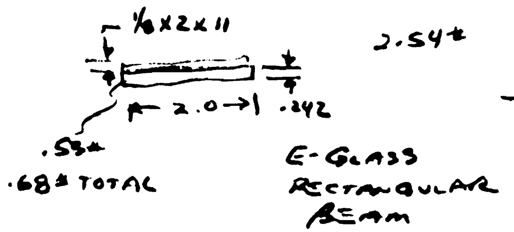
DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
1998.3
CH2/CON=
0.148

REF LEV=
20.72 g
CONSTANT
ACC
LOG SWP#
1 up
of 1

Hz

10 mv/g   AUTO : 00:02:52   STATUS: Finished

MAX SERV SPD 1k TOTAL: 00:03:00   SWEEP TIME: 2.9 Min   CHAN 1

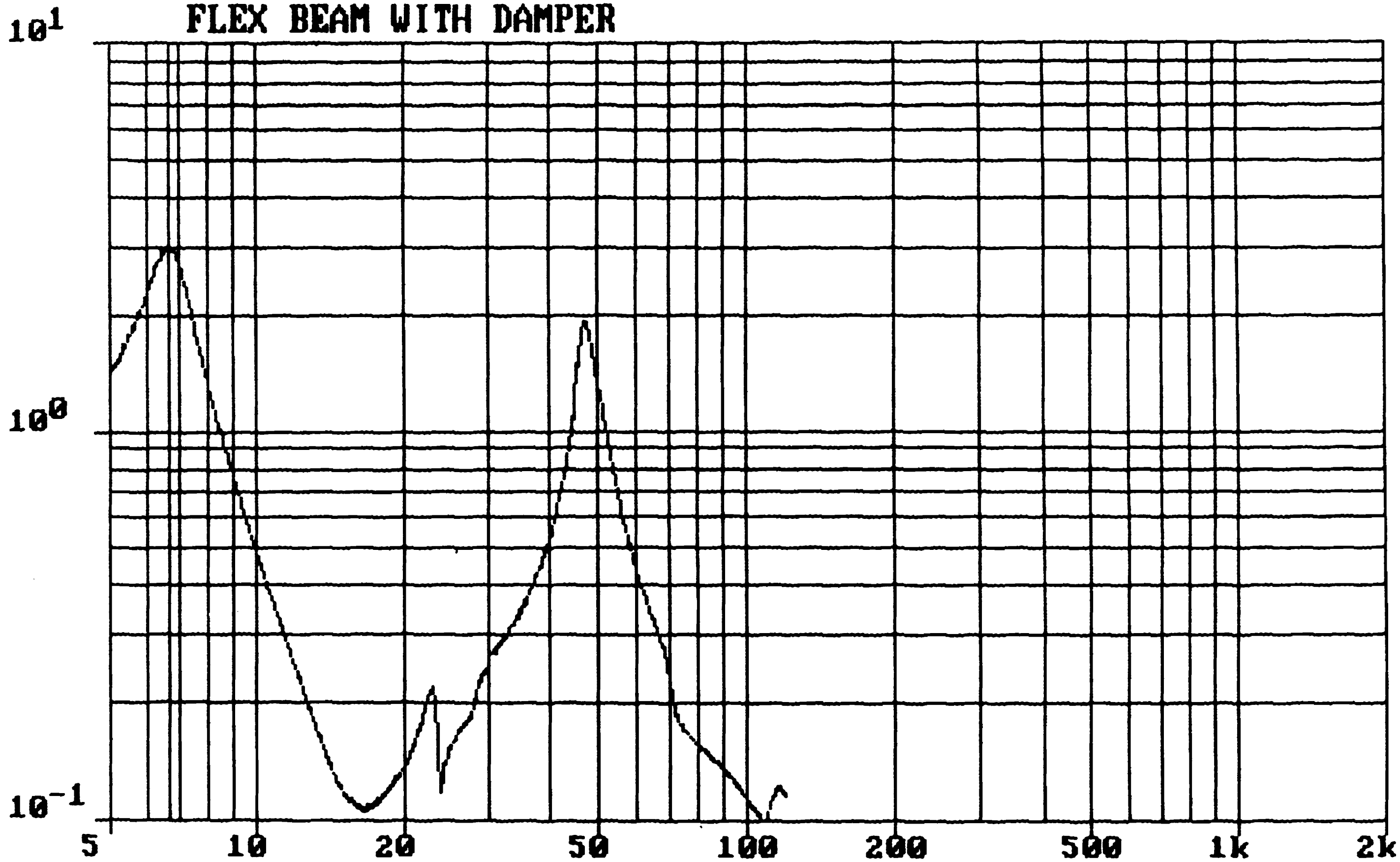


.02" 5-140 Hz
20g 140-2000 Hz
2 oct/min

EDG-6

TEST SETUP-ID: FLEX TEST RUN NAME: RUN3 autosave 01/10/90
10:28:17

FLEX BEAM WITH DAMPER



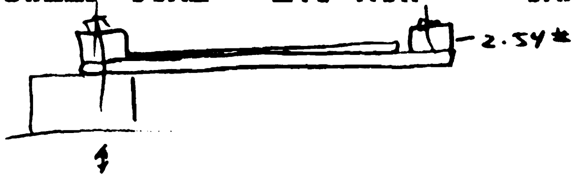
DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
6.7
CH2/CON=
2.988

REF LEV=
100 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

EDG-7

10 mv/g AUTO : 00:01:31 STATUS: Abort - F1 pressed
MAX SERV SPD 1k TOTAL: 00:01:41 SWEEP TIME: 2.9 Min CHAN 1

.10 DA 5-63 HZ
20G 63 -

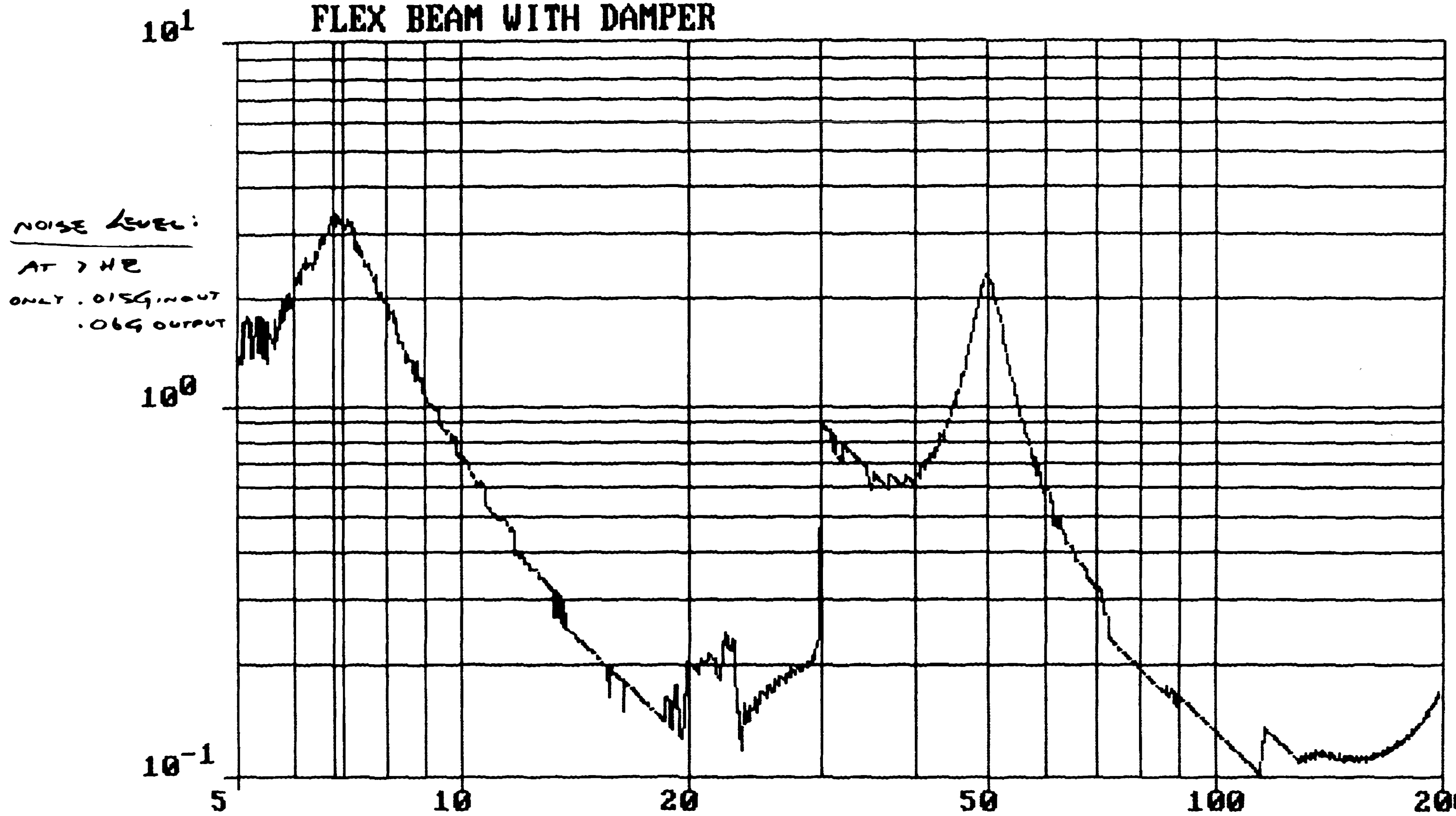


3 oct/min

3

TEST SETUP-ID: FLEX   TEST RUN NAME: RUN3   autosave 01/10/90 10:34:55

FLEX BEAM WITH DAMPER



DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
6.8
CH2/CON=
3.333

REF LEV=
6.00 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

10 mv/g   AUTO : 00:02:52   STATUS: Finished

MAX SERV SPD 1k TOTAL: 00:02:54   SWEEP TIME: 2.9 Min   CHAN 1

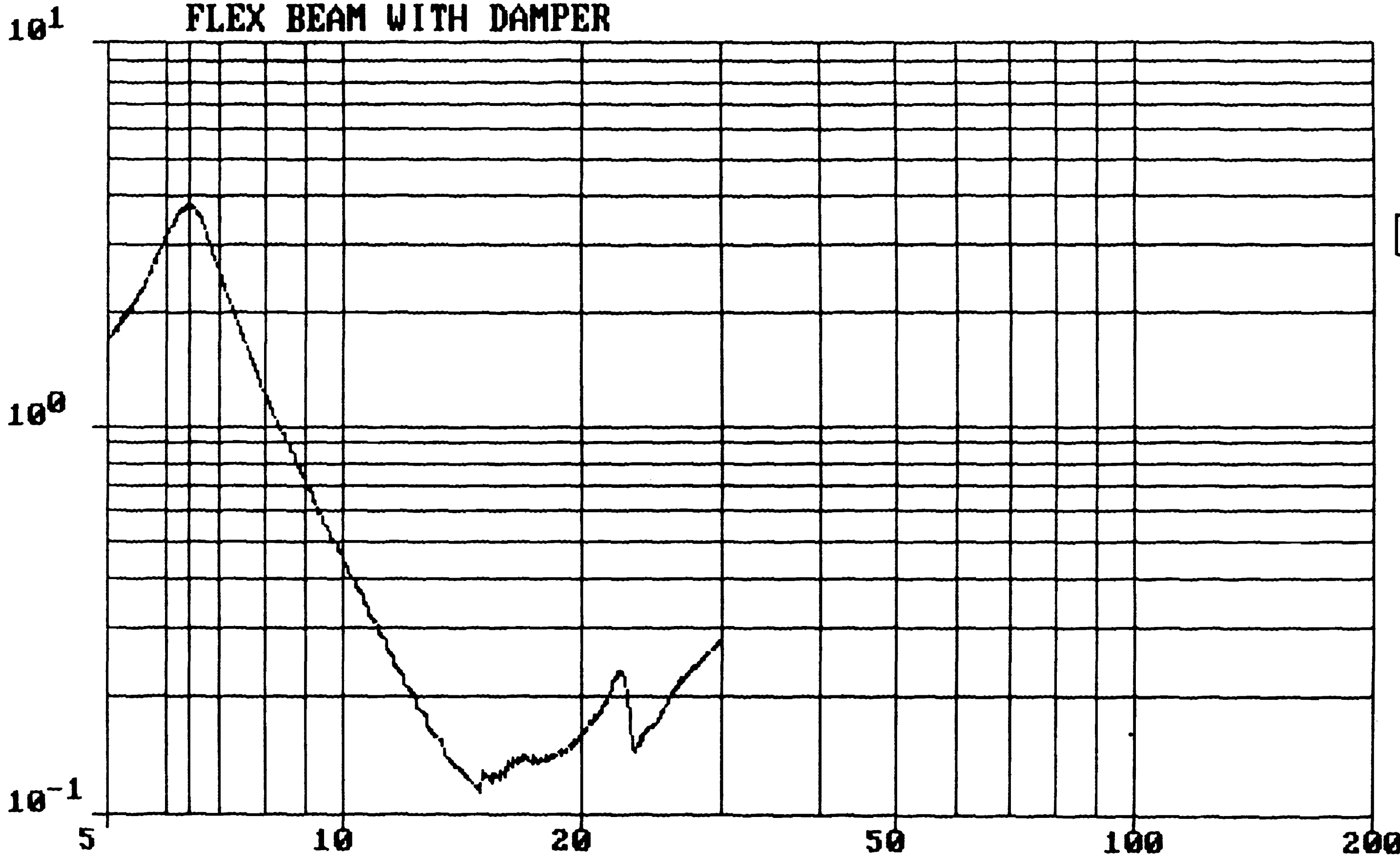
.006 DA – 5 – 250 HZ   3 OCT/MIN

20G –

#4

TEST SETUP-ID: FLEX TEST RUN NAME: RUN4 autosave 01/10/90

FLEX BEAM WITH DAMPER

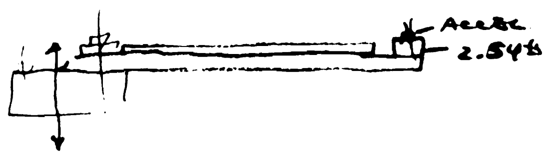


10:41:27
DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
6.4
CH2/CON=
3.770

REF LEV=
300 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

10 mv/g AUTO : 00:01:24 STATUS: Abort 177.8 mil
MAX SERV SPD 1k TOTAL: 00:01:36 SWEEP TIME: 2.9 Min CHAN 1

.3" DA 5 - 36
20G 36 -



1.8 OCT/min

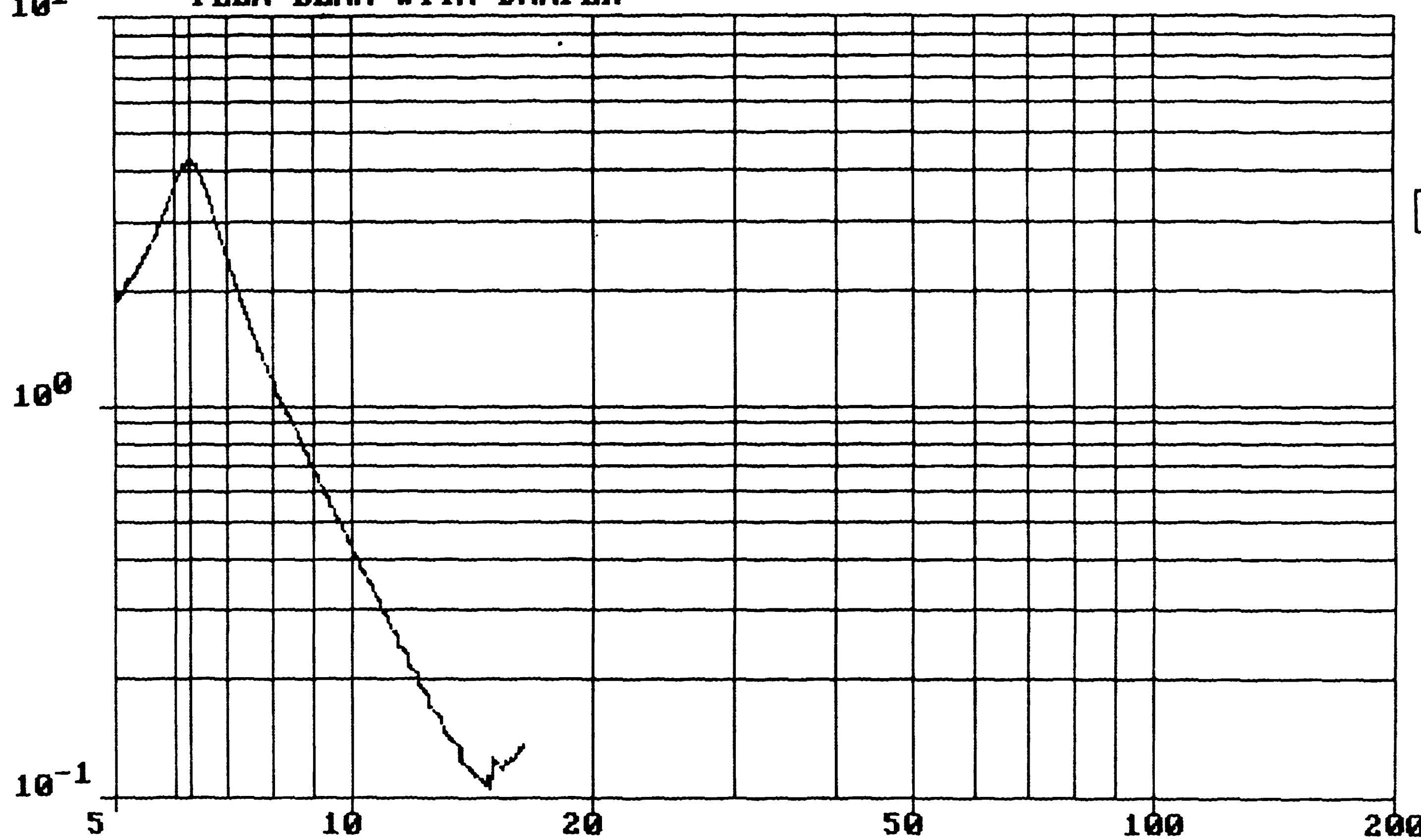
EDG-9

#5

EDG-10

TEST SETUP-ID: FLEX   TEST RUN NAME: RUN5   autosave 01/10/90

FLEX BEAM WITH DAMPER



10:48:53
DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
6.2
CH2/CON=
4.225

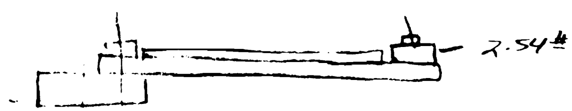
REF LEV=
300 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

10 mv/g   AUTO : 00:03:27   STATUS: Abort - F1 pressed

MAX SERV SPD 1k TOTAL: 00:03:39   SWEEP TIME: 10.6 Min   CHAN 1

.30" DA   5-36 HZ

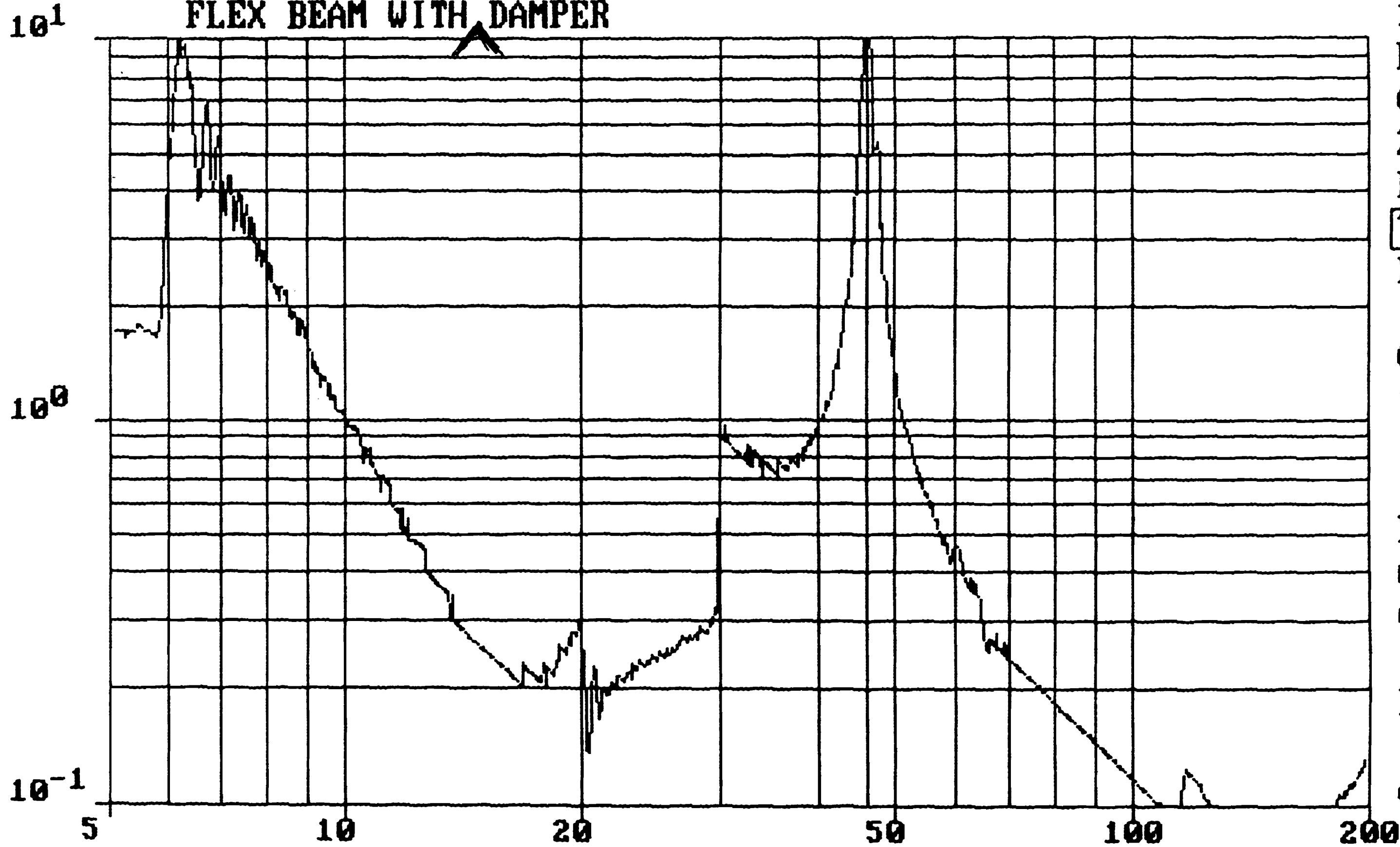
.5 OCT/MIN.



#6

TEST SETUP-ID: FLEX TEST RUN NAME: RUN5 autosave 01/10/90

FLEX BEAM WITH ^out DAMPER 11:01:36



DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
46.3
CH2/CON=
12.857

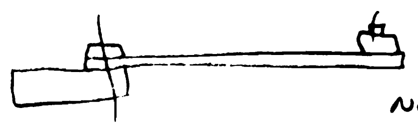
REF LEV=
6.00 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

10 mv/g AUTO : 00:01:46 STATUS: Finished

MAX SERV SPD 1k TOTAL: 00:01:48 SWEEP TIME: 1.8 Min CHAN 1

first Peak 6.2 Hz 0.006" DA 5-250 Hz 3 oct/min

TR 10



NO DAMPER

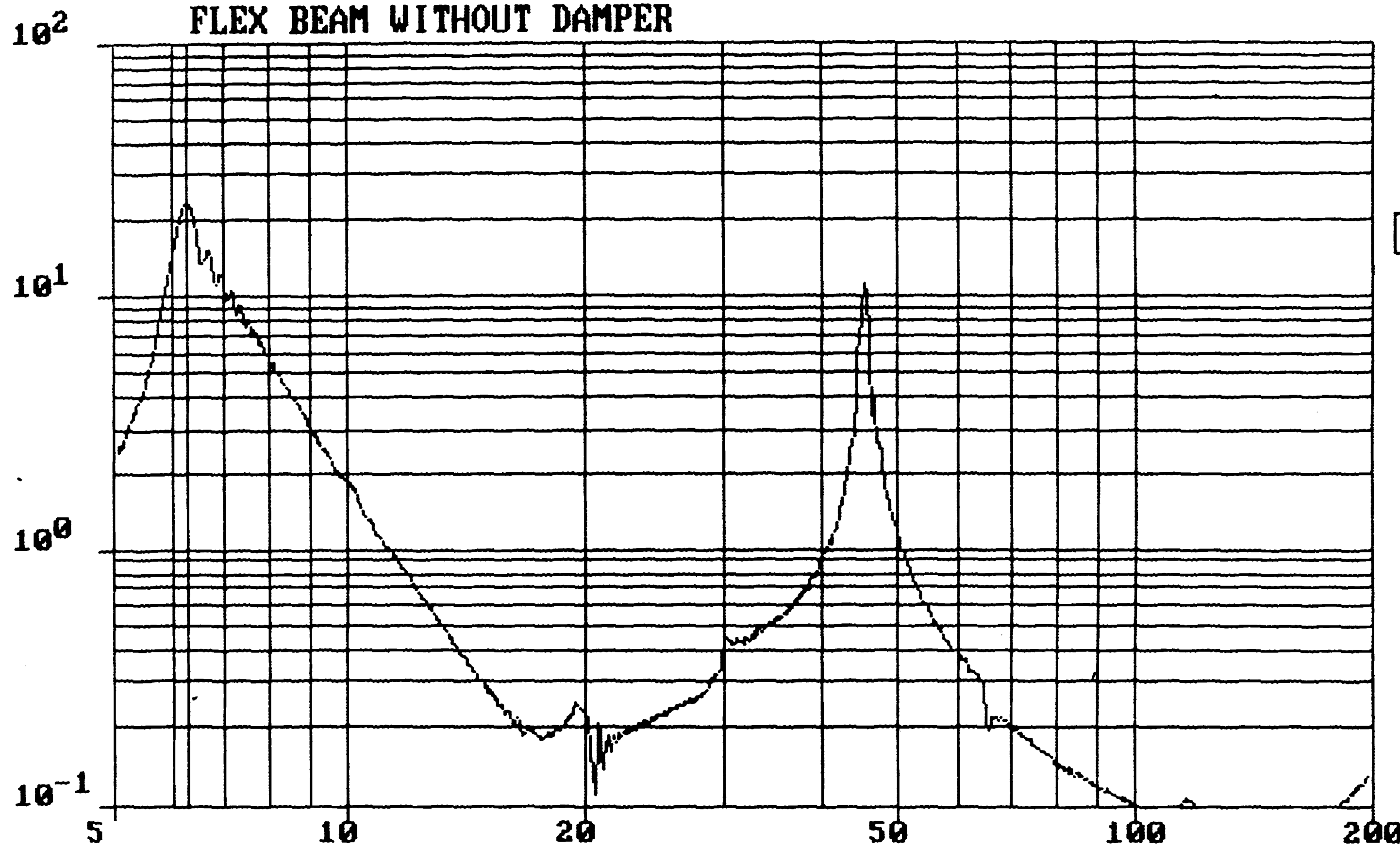
EDG-11

#7

TEST SETUP-ID: FLEX TEST RUN NAME: RUN6 autosave 01/10/90

FLEX BEAM WITHOUT DAMPER

11:08:14



DISPLAY
C-CTRL
2-CH2
D-DRIVE
^2-2/CT
FREQ=
6.2
CH2/CON=
23.501

REF LEV=
20.0 mil
CONSTANT
DISP
LOG SWP#
1 up
of 1

10 mv/g AUTO : 00:01:46 STATUS: Finished

MAX SERV SPD 1k TOTAL: 00:01:54 SWEEP TIME: 1.8 Min CHAN 1

.020" DA 5-140 HZ

20G - 140-200HZ

No Damping

EDG-12

3. Second Analytic Summary

The following five pages relate to temperature and twisting of laminar damper in a flat-wise and edge-wise mode.

Single damper bonded on each side of specimen in these tests.

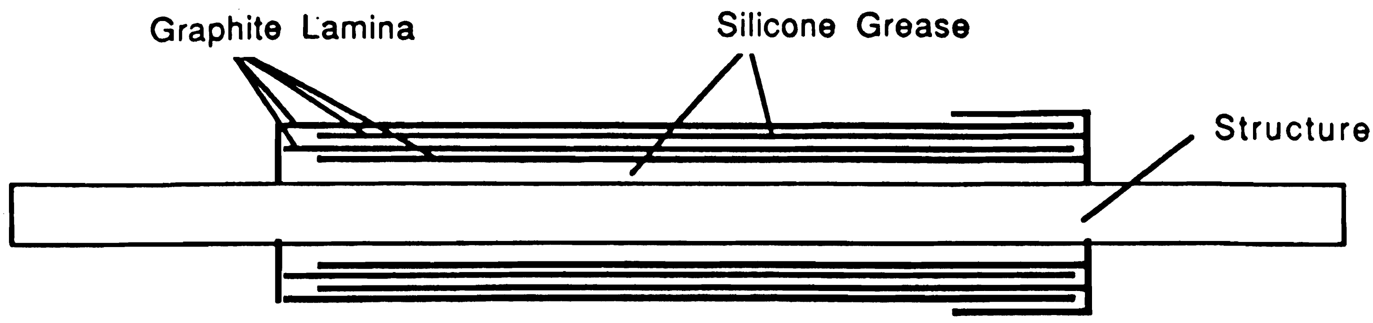


Figure 1. Cross-section of Laminar Damper

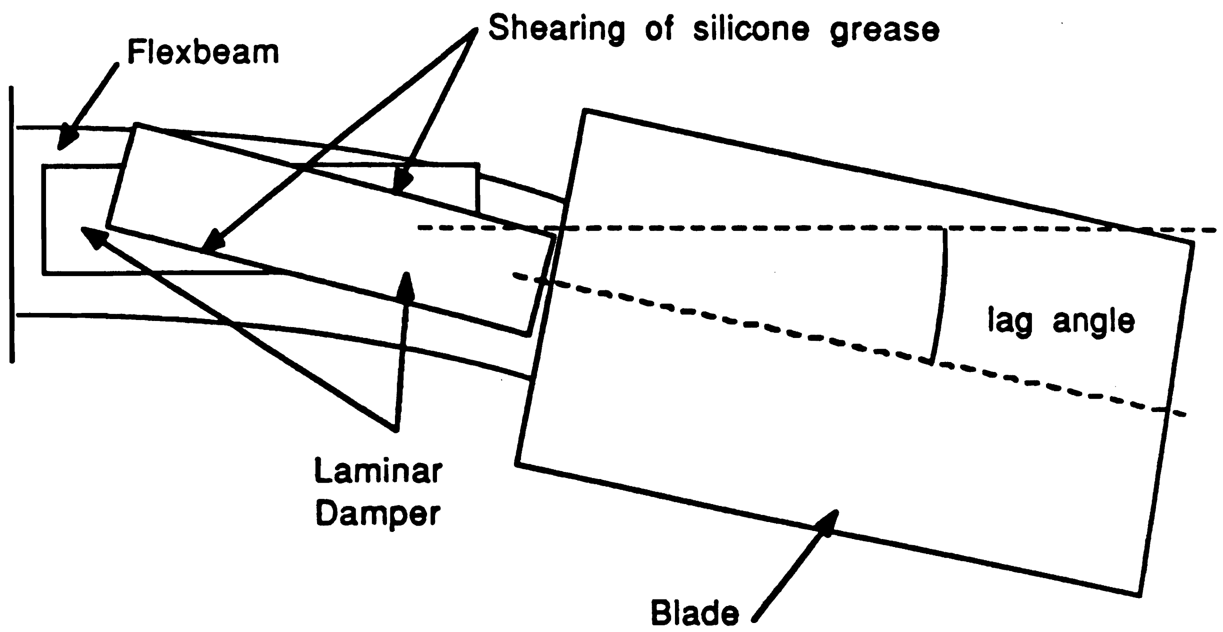


Figure 2. Action of Laminar Damper During Lead-Lag of Blade

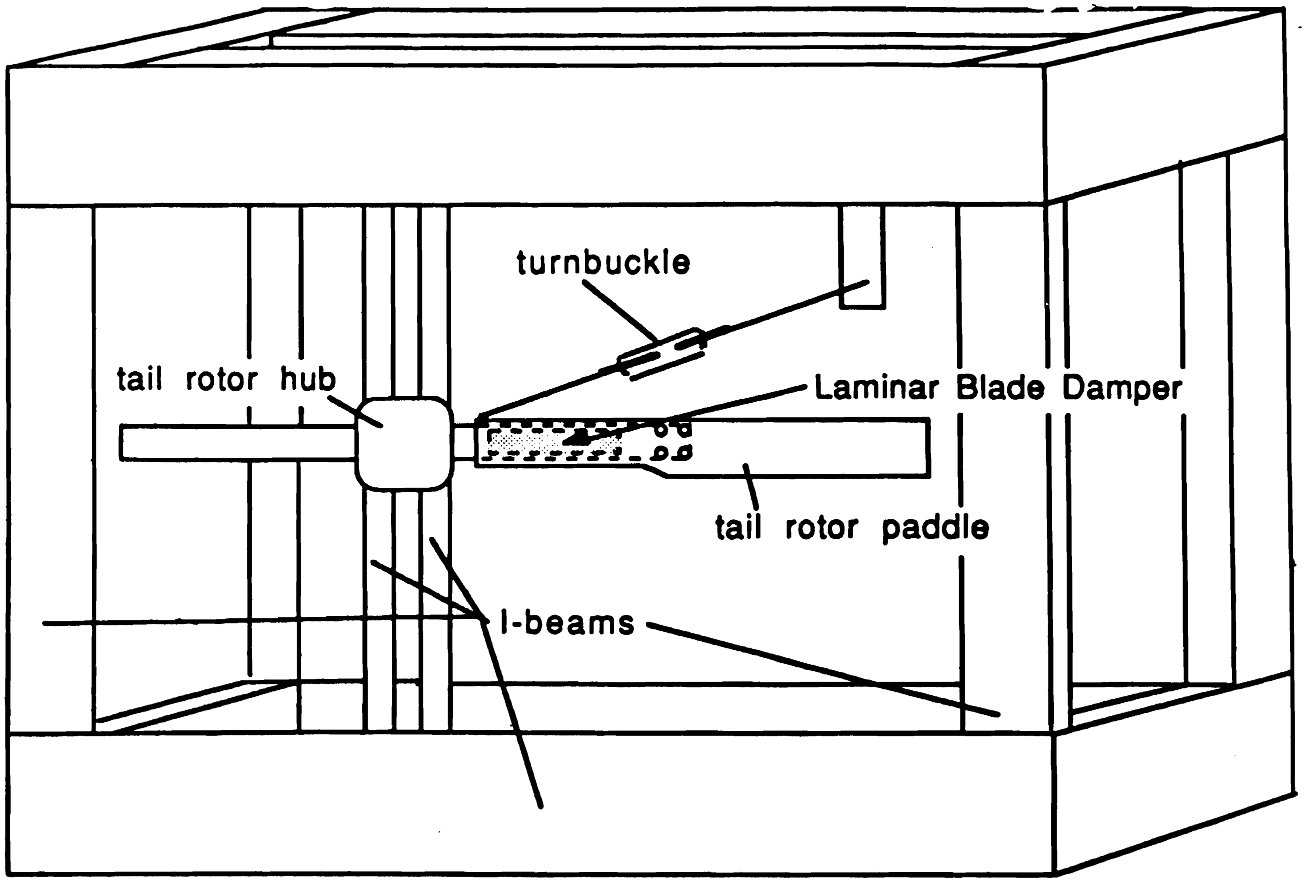


Figure 3.
Test Set-up for Determining Effect of Twist on Laminar Blade Damper Effectiveness

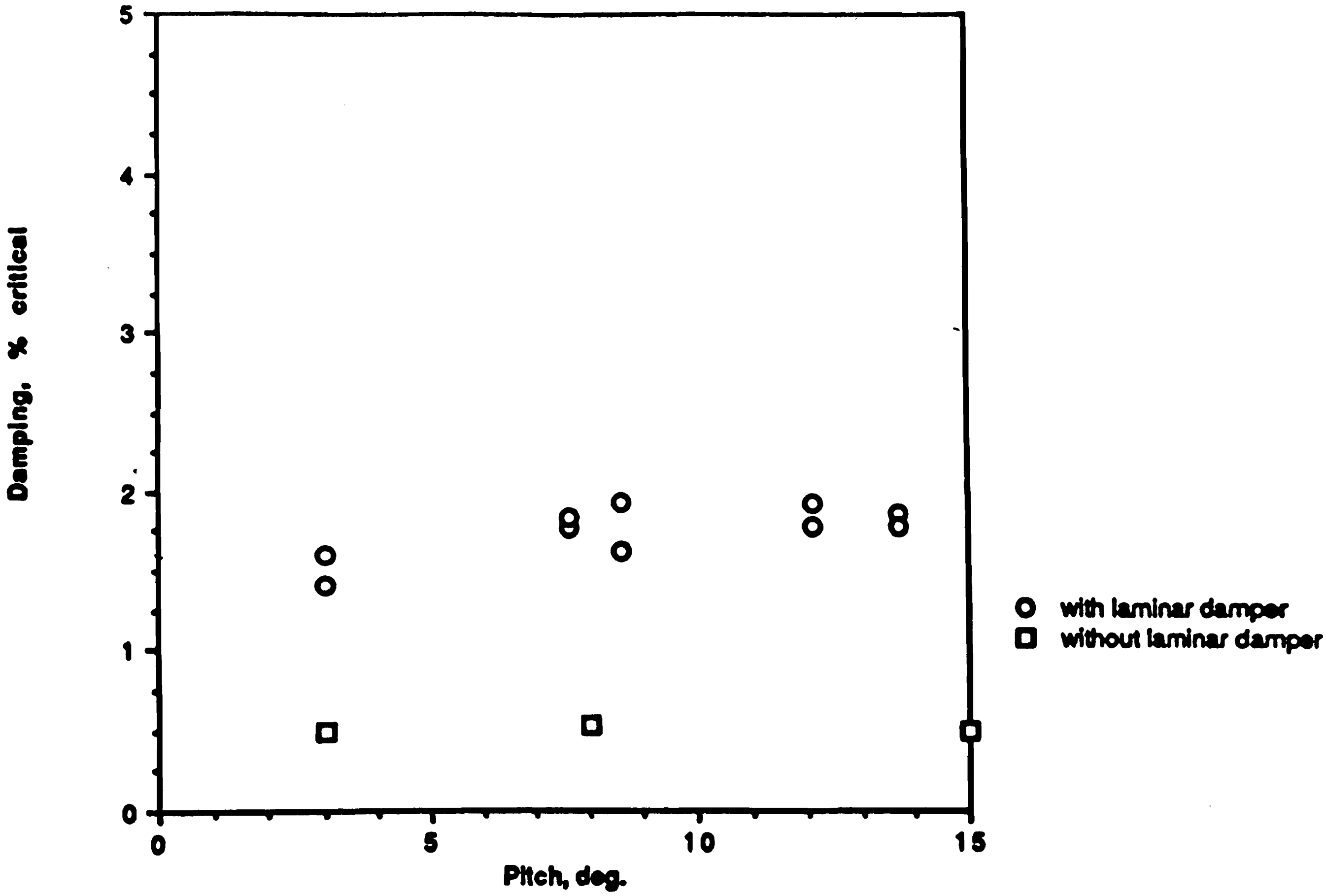


Figure 4.
Laminar Damper Damping vs Impressed Pitch
Non-Rotating Rap Test of S-76 Tail Rotor Spar

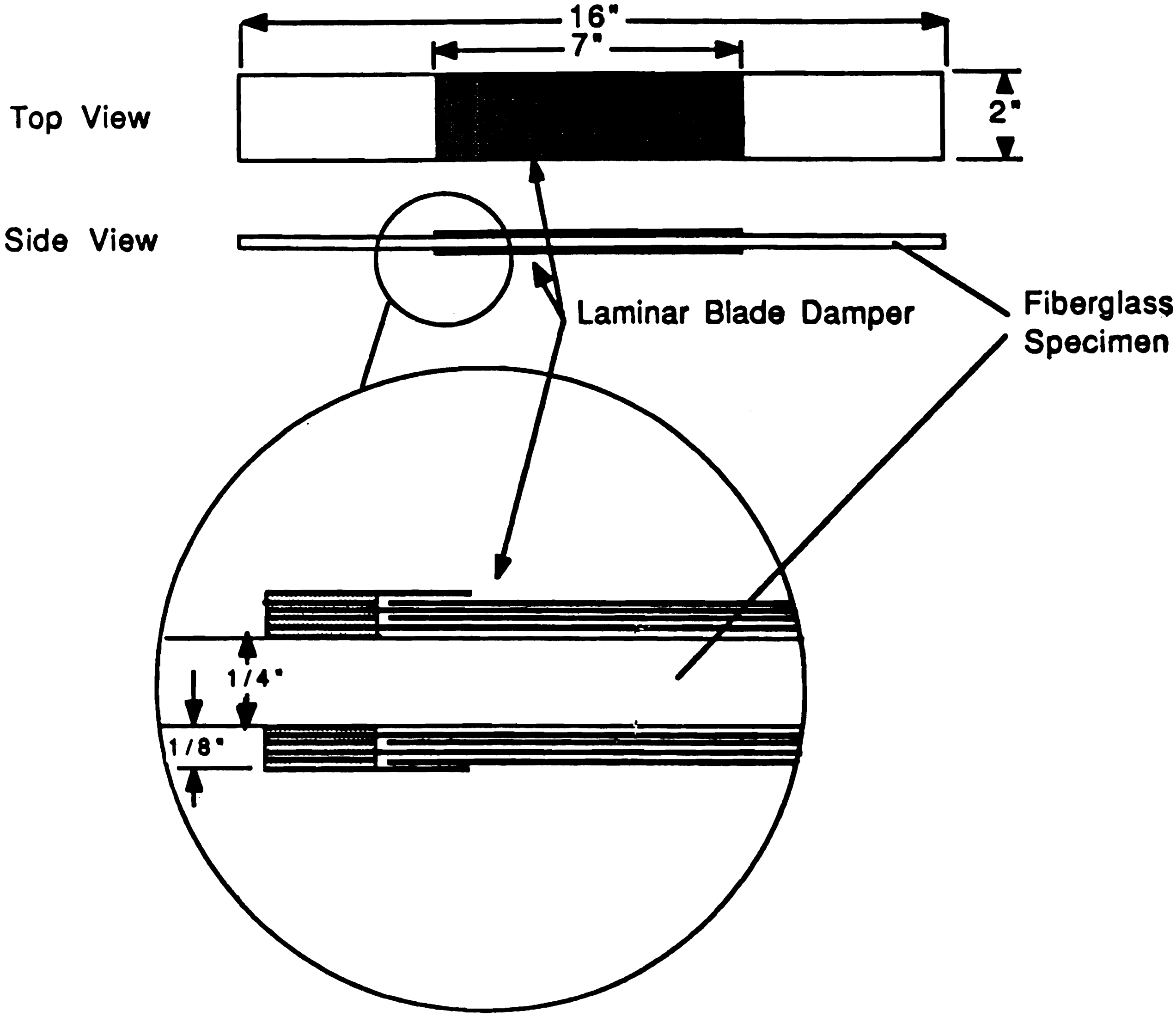


Figure 5. Second Prototype Laminar Blade Damper Mounted on Fiberglass Sample

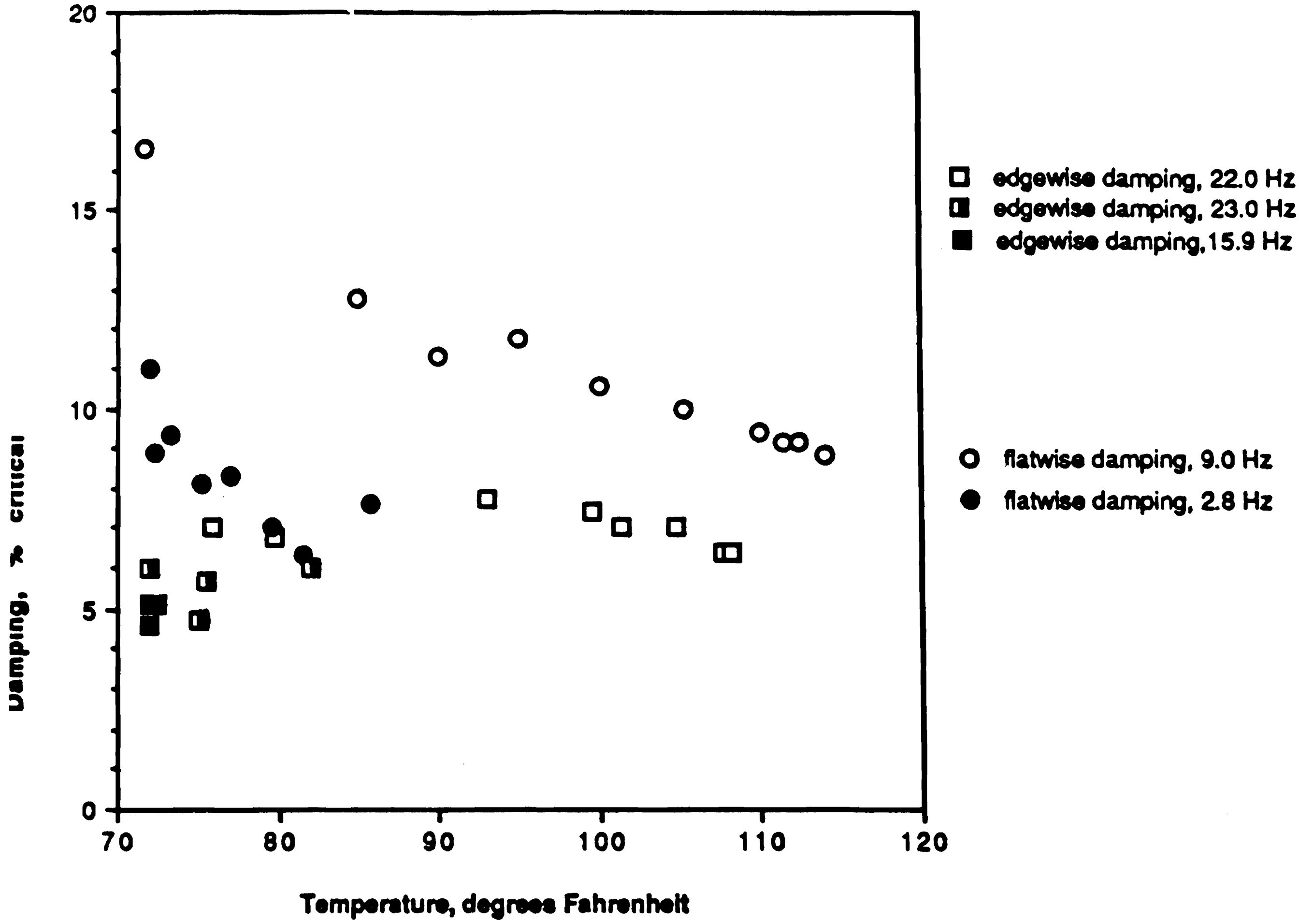


Figure 6.
Damping Variation with Laminar Blade Damper Temperature

4. Third Analytic Summary

4.1 Bang Test Results on a Tail Rotor Flexbeam

Two graphite tail rotor flexbeams and two tail rotor blades. One of these flexbeams has two dampers attached. The dampers each consist of four sheets 2-1/2 in wide and 8-1/2 in long, and were mounted on opposite sides of the flexbeam. To perform the test, the flexbeams were firmly clamped to a solid base with one end hanging down vertically. An accelerometer was then used to record the time history of the flexbeam motion in response to an impulse. A moving-block analysis was employed to calculate the damping ratio.

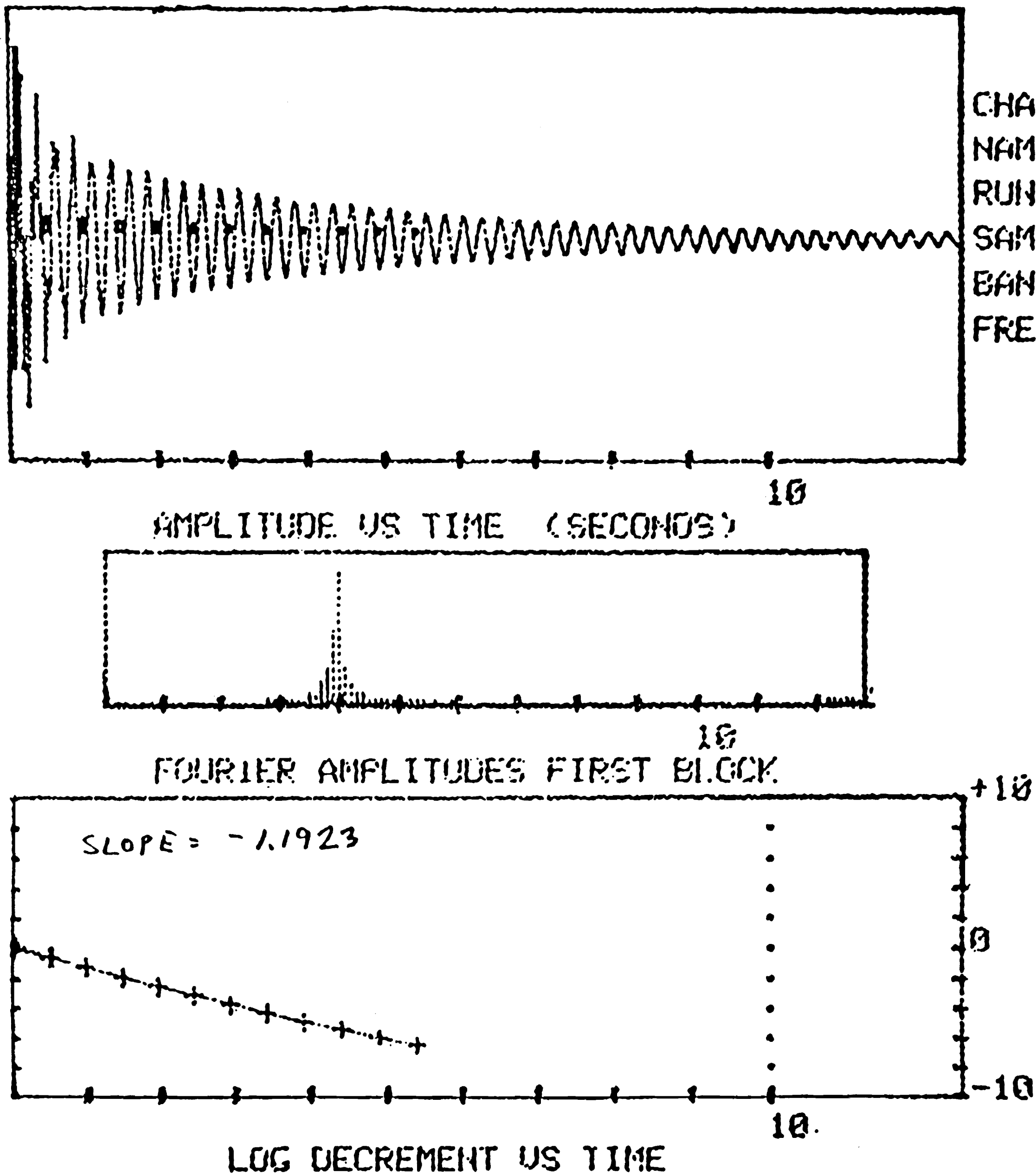
Bang tests were performed both with and without dampers, and with and without tail rotor blades attached for both flapwise and chordwise excitation. The damping ratio results are summarized in Table 1. The actual moving-block data is attached as Appendix B.

			Damping (% Critical)	
Figure	Description	Natural Frequency (HZ)	Without Damper	With Damper
B-1	Flapwise Excitation Blade Attached	4.0	1.19	-
B-2		4.1	-	3.23
B-3	Chordwise Excitation Blade Attached	35.6	0.77	-
B-4		33.6	-	8.43
B-5	Flapwise Excitation 1-lb Weight Attached	5.7	0.21	-
B-6		6.4	-	11.68

Table 1. Summary of Results

THE MOVING-BLOCK METHOD

On-line damping ratio data reduction was accomplished using a digital computer program based on the Fast Fourier Transform (FFT). This method, called a moving-block analysis, was applied to the time history of the transient response of the unfiltered accelerometer signal. The frequency of the mode being analyzed was identified from the frequency spectrum. Having identified the frequency, a moving-block size (time period) was selected based on the frequency accuracy required, the length of the time history, and the frequency of interest. Starting at the beginning of the transient, the FFT was performed on the block of data, and the amplitude of the frequency of interest was determined and saved. The block was then moved forward an increment in time and the process was repeated. This scheme of moving the block and FFT analysis was continued over a prescribed time period. After this process, the computer compiled a history of the transient behavior of the mode's free vibration decay. Then the logarithm of the amplitude changes was plotted against the time. A damping ratio was obtained by measuring the slope of this curve.



BVWT

MOVING BLOCK ANALYSIS

CHANNEL NO. 2

NAME ACCEL

RUN 1 TEST POINT 3

SAMPLE RATE: 1918 SMPL/SEC

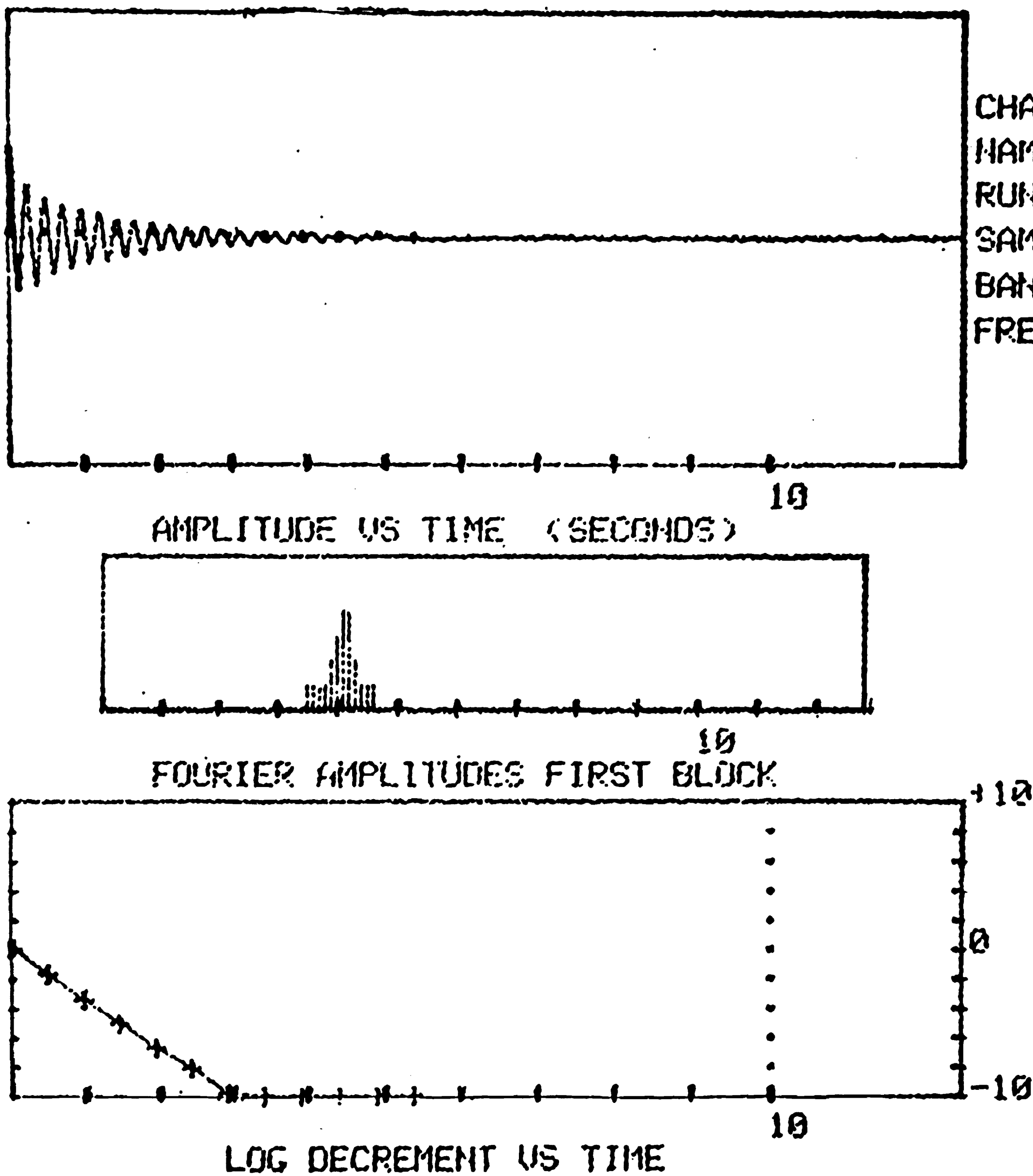
BANDWIDTH: 25.7 HZ

FREQUENCY ANALYZED: 4.0 HZ

DECREMENT RATIOS

1 +0.0
2 -0.6
3 -1.2
4 -1.9
5 -2.5
6 -3.1
7 -3.7
8 -4.3
9 -4.9
10 -5.4
11 -6.0
12 -6.5

Figure B-1



BVWT

MOVING BLOCK ANALYSIS

CHANNEL NO. 2

NAME ACCEL

RUN 8 TEST POINT 1

SAMPLE RATE: 1918 SMPL/SEC

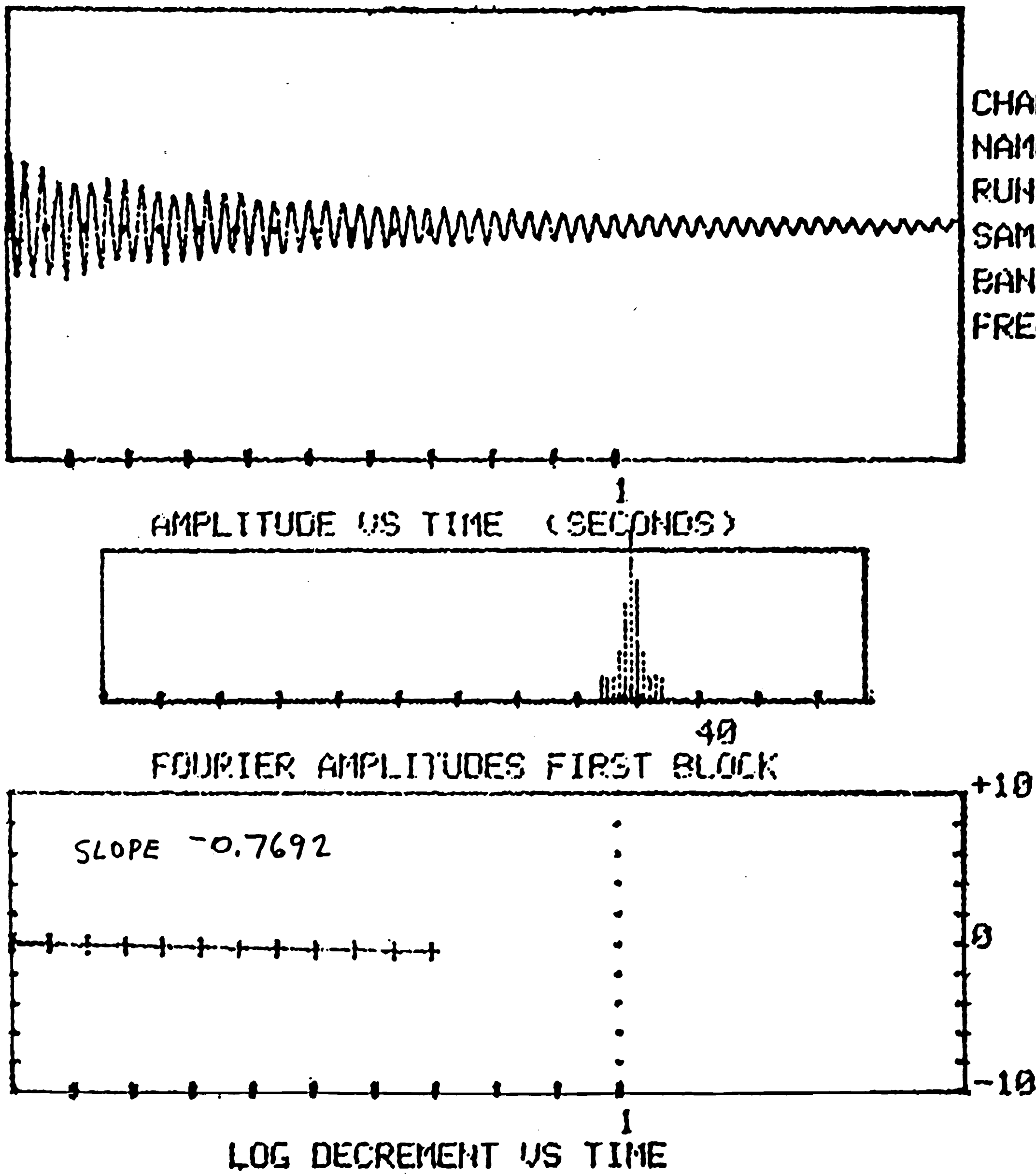
BANDWIDTH: 25.7 HZ

FREQUENCY ANALYZED: 4.1 HZ

DECREMENT RATIOS

1 +0.0
2 -1.7
3 -3.4
4 -5.0
5 -6.7
6 -8.1
7 -9.8
8 -11 2
9 -13.0
10 -15.0
11 -17.5
12 -16.6

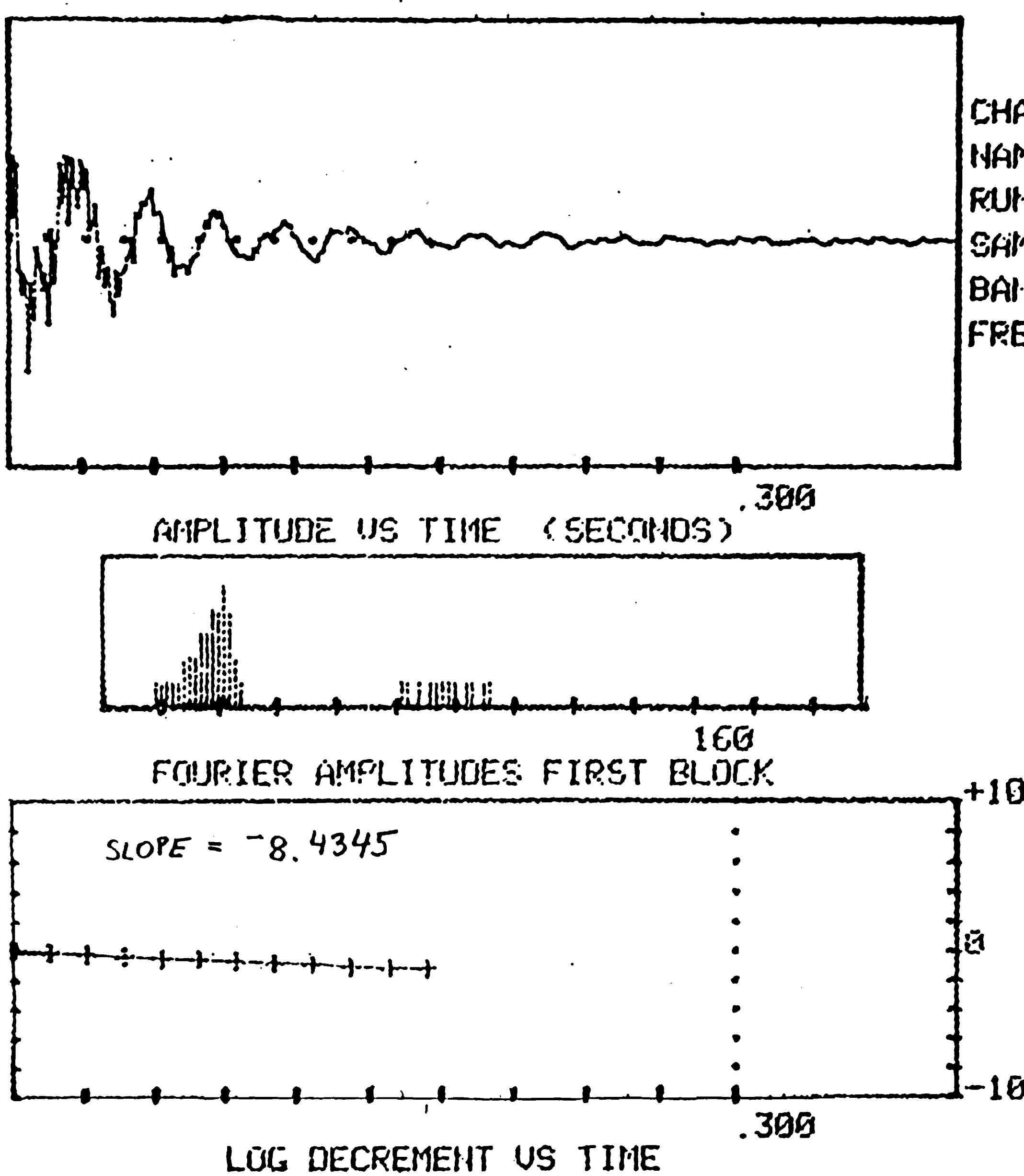
Figure B-2



BVWT
MOVING BLOCK ANALYSIS
CHANNEL NO. 2
NAME ACCEL
RUN 2 TEST POINT 4
SAMPLE RATE: 200 SMPL/SEC
BANDWIDTH: 26.0 HZ
FREQUENCY ANALYZED: 35.6HZ

DECREMENT RATIOS
1 +0.0
2 +0.0
3 -0.1
4 -0.1
5 -0.2
6 -0.2
7 -0.3
8 -0.3
9 -0.4
10 -0.4
11 -0.5
12 -0.5

Figure B-3

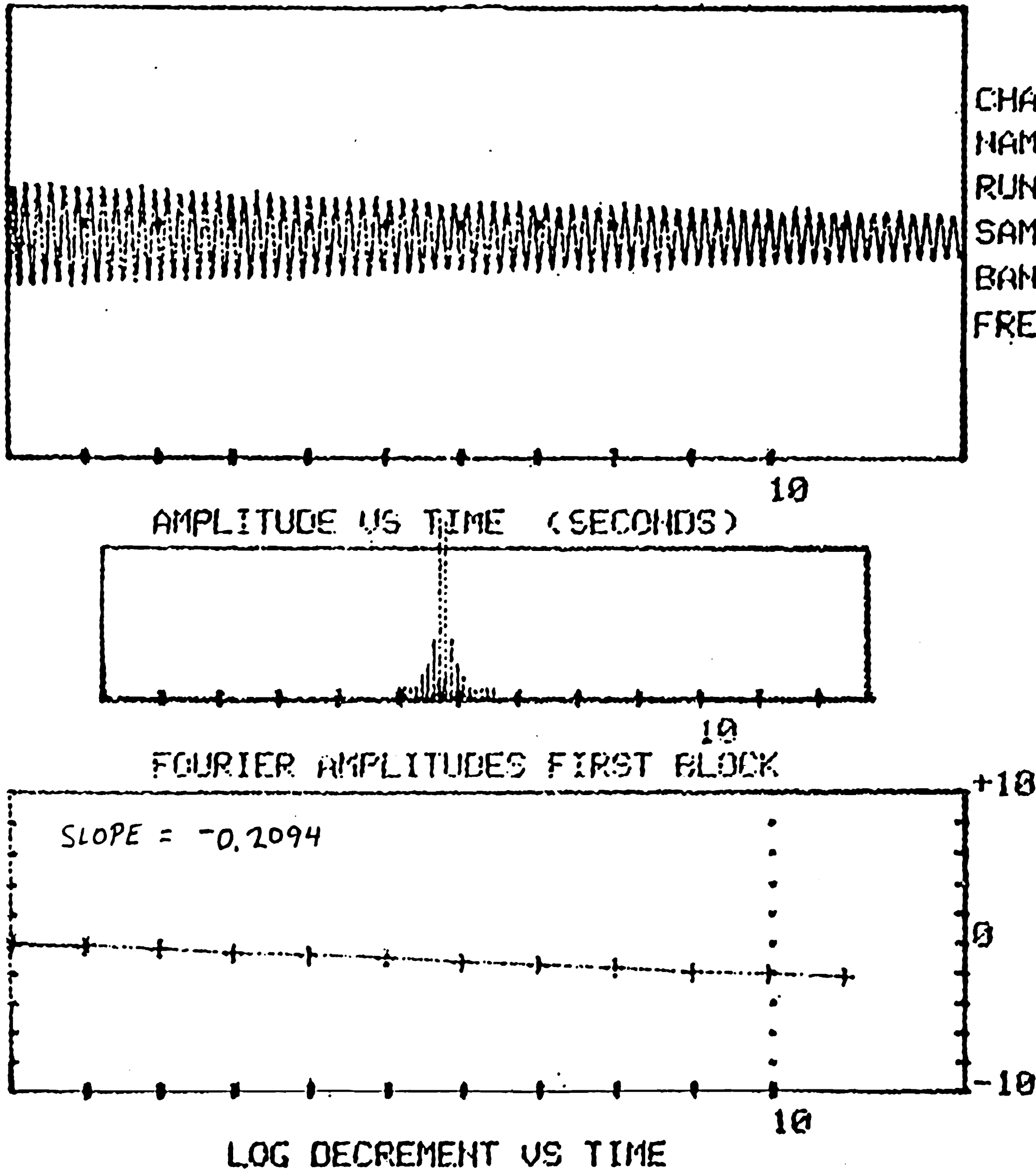


BVWT
MOVING BLOCK ANALYSIS
CHANNEL NO. 2
NAME ACCEL
RUN 9 TEST POINT 2
SAMPLE RATE: 26 SMPL/SEC
BANDWIDTH: 27.2 HZ
FREQUENCY ANALYZED: 33.6HZ

DECREMENT RATIOS
1 +0.0
2 -0.1
3 -0.2
4 -0.4
5 -0.5
6 -0.6
7 -0.7
8 -0.8
9 -0.9
10 -1.1
11 -1.2
12 -1.2

Figure B-4

BVWT
MOVING BLOCK ANALYSIS
CHANNEL NO. 2
NAME ACCEL
RUN 6 TEST POINT 2
SAMPLE RATE: 1918 SMPL/SEC
BANDWIDTH: 25.7 HZ
FREQUENCY ANALYZED: 5.7 HZ



DECREMENT RATIOS

1	+0.0
2	-0.1
3	-0.3
4	-0.6
5	-0.7
6	-0.9
7	-1.2
8	-1.4
9	-1.6
10	-1.9
11	-2.0
12	-2.2

Figure B-5

BVWT

MOVING BLOCK ANALYSIS

CHANNEL NO 2

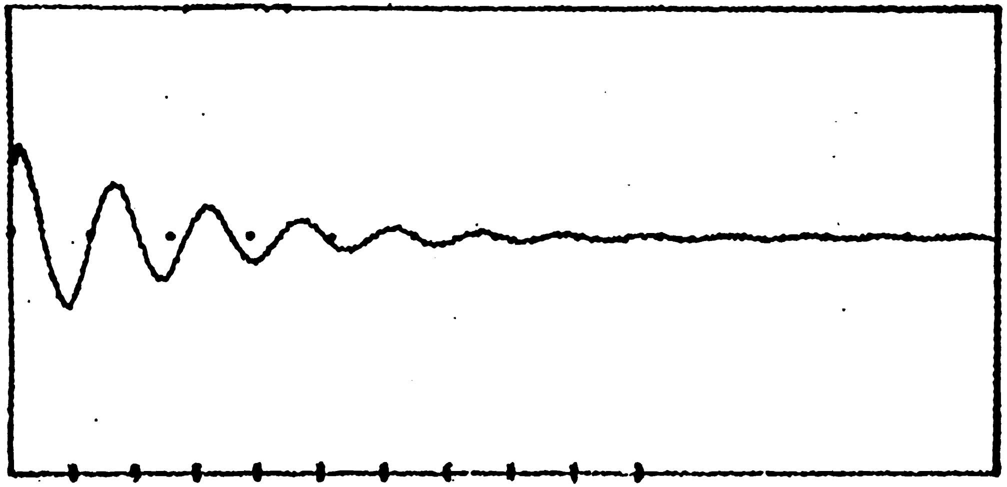
NAME ACCEL

RUN 10 TEST POINT 1

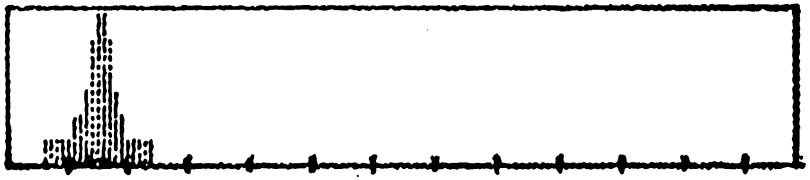
SAMPLE RATE: 209 SMPL/SEC

BANDWIDTH: 26.0 HZ

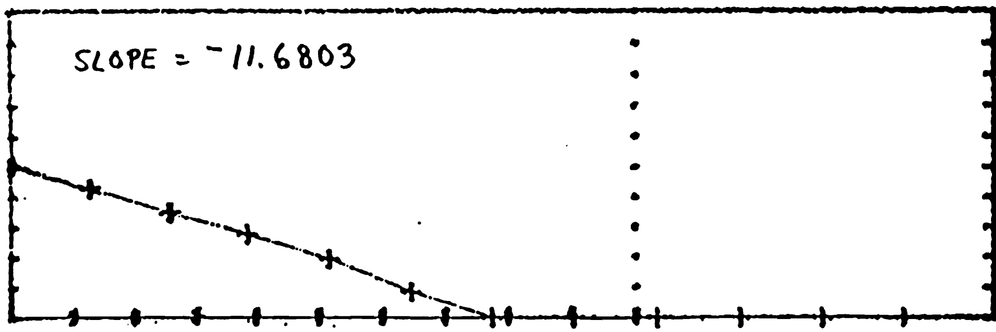
FREQUENCY ANALYZED: 6.4 HZ



AMPLITUDE VS TIME (SECONDS)



FOURIER AMPLITUDES FIRST BLOCK



LOG DECREMENT VS TIME

DECREMENT RATIOS

1	+0.0
2	-1.4
3	-3.0
4	-4.4
5	-6.1
6	-8.3
7	-10.4
8	-11.7
9	-12.2
10	-14.4
11	-16.1
12	-14.5

Figure B-6

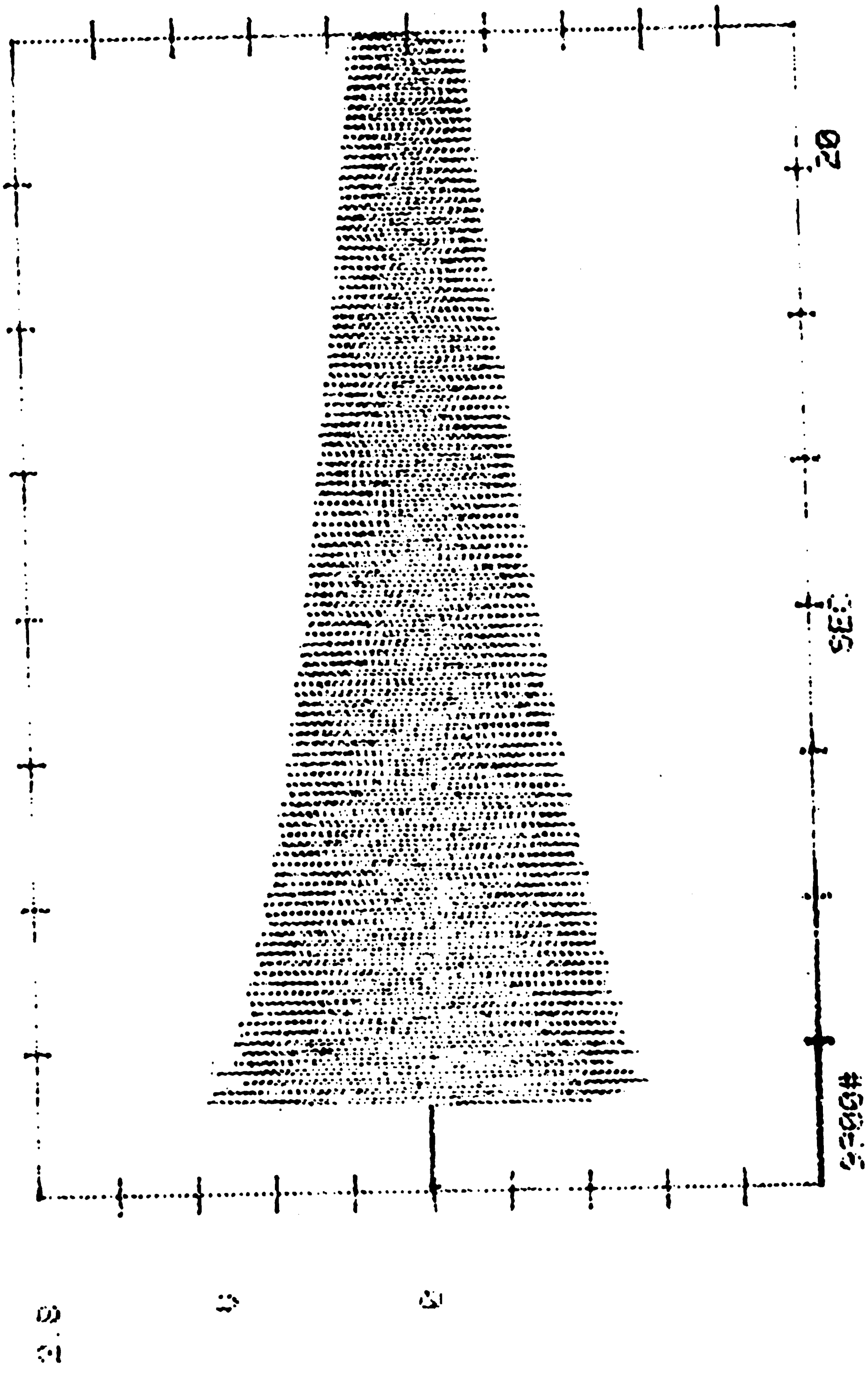


Figure B-5

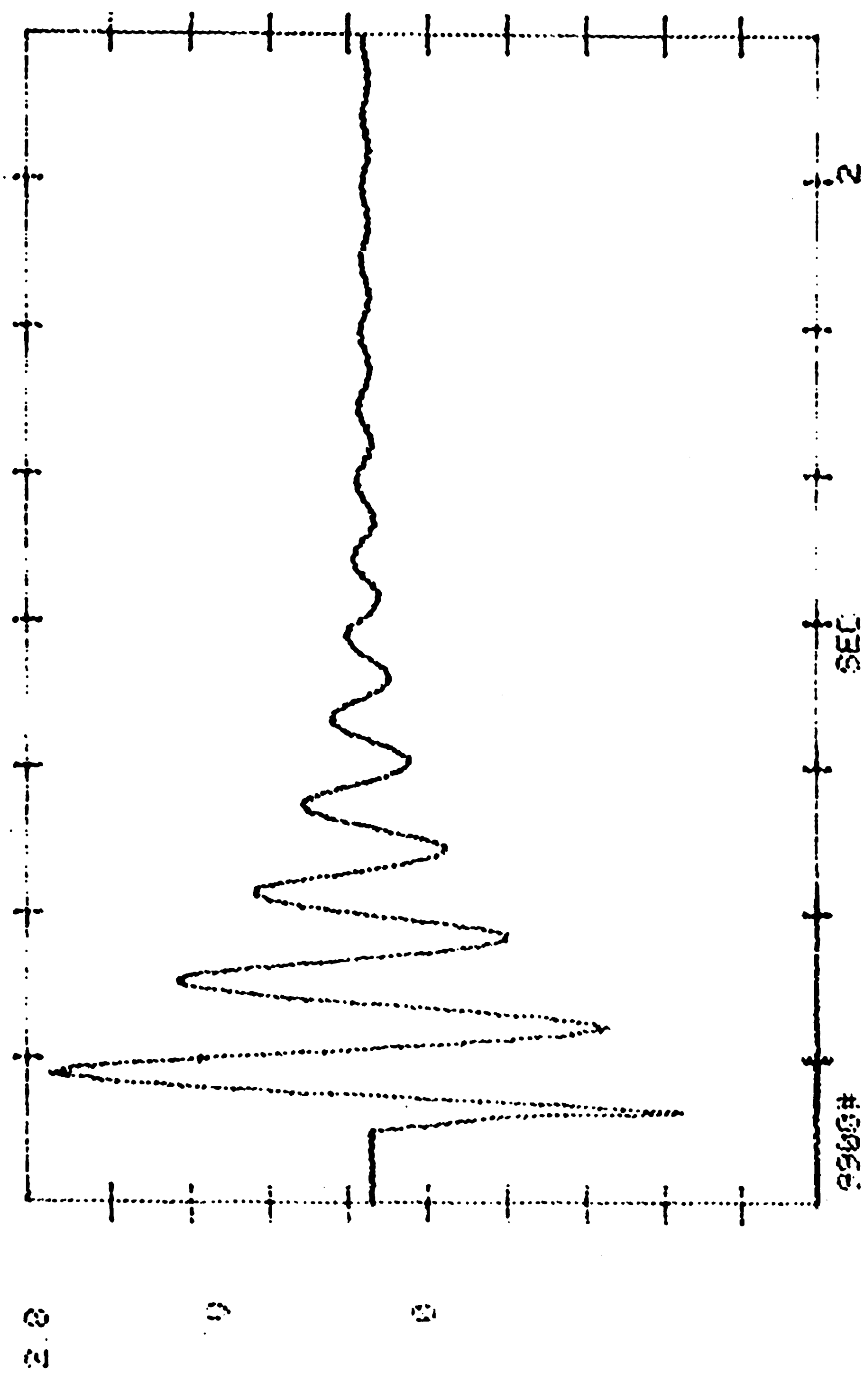


Figure B-6

5. References

Michael Koleda, United States Patent
France
Switzerland
West Germany
Austria