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Noise Generated by a Flight Weight, Air Flow Control Valve in a Vertical Takeoff and Landing Aircraft Thrust Vectoring System

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NOISE GENERATED BY A FLIGHT WEIGHT, AIR FLOW CONTROL VALVE IN A VERTICAL TAKEOFF AND LANDING AIRCRAFT THRUST VECTORING SYSTEM

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SUMMARY

Tests were conducted in the NASA Lewis Research Center's Powered Lift Facility to experimentally evaluate the noise generated by a flight weight, 12 in. butterfly valve installed in a proposed vertical takeoff and landing thrust vectoring system. Fluctuating pressure measurements were made in the circular duct upstream and downstream of the valve. This data report presents the results of these tests. The maximum overall sound pressure level is generated in the duct downstream of the valve and reached a value of 180 dB at a valve pressure ratio of 2.8. At the higher valve pressure ratios the spectra downstream of the valve is broad banded with its maximum at 1000 Hz.

INTRODUCTION

Noise generated in military aircraft can be a major problem if it interferes with radio communication with the pilot or creates a permanent hearing loss. Fatigue, due to excessive noise can also be a problem during long duration flights. Noise protection offered by acoustically treated helmets appear to be reaching a limit. Vertical takeoff and landing aircraft have high external noise levels during hovering flight. In this mode the thrust is vectored by throttling the flow between vertical and horizontal nozzles. The valves used to throttle the flow generate additional noise inside the aircraft that may be transmitted to the cockpit thus acting as a noise source that directly affects the pilot.

Tests were conducted in the NASA Lewis Research Center's Powered Lift Facility to experimentally evaluate the noise generated by a flight weight, 12 in., butterfly valve installed in a proposed vertical takeoff and landing thrust vectoring system. Fluctuating pressure measurements were made in the circular duct upstream and downstream of the valve. This data report presents the results of these tests.

APPARATUS

An aerial photograph of the Powered Lift Facility (PLF) is shown in figure 1. The test stand has thrust measurement capability that was not used during the valve noise tests. Air is provided by the NASA Lewis Research Center's Central air handling facility through an underground piping system to a point shown at the upper right corner of the schematic shown in figure 2. A

positive shut off gate valve is located just above the ground and is used to isolate the rig from the central supply system when the rig is not in operation. When PLF is operating this gate valve is completely open and is not expected to generate significant noise levels. Following the gate valve, the flow passes through two 90° elbows and then through a venturi used to measure the mass flow rate through the facility. Downstream of the venturi, the flow encounters the first flow control valve. Downstream of this valve, a tee allows the flow to be split between two pipes. The smaller pipe leads to an in line J57 combustor can, used to heat the air supplied to the test hardware. Downstream of the tee, a 90° elbow is installed in the smaller pipe allowing the pipe to be run parallel to the large pipe. Butterfly valves are installed in both the large and small pipes to allow the flow through each of the pipes to be independently controlled. Downstream of the burner, the bypass flow passes through a 90° elbow and rejoins the flow in the larger pipe. The burner was not used for these cold flow tests.

The merged flow passes through two 90° elbows and then to a tee located at the test stand. At the tee, the flow is split as shown in figure 2. Each half passes through two 90° elbows and then through bellows to another tee where the flow enters the floating portion of the test stand through a single pipe. The bellows were installed to isolate the test hardware from the piping leading to the floating portion of the test rig to accommodate the thrust measurement. A flow straightener is installed in the straight pipe downstream of the tee. No acoustic mufflers or noise suppression devices were installed in the piping to suppress the internally generated noise during these tests.

The test hardware is shown pictorially in figure 3. The test hardware is connected to the facility piping immediately downstream of the last facility pipe tee. A schematic of the test hardware is shown in figure 4. The test hardware consist of a pipe leading to a plenum chamber. A perforated pipe is inserted inside the plenum chamber as shown in figure 4 to help distribute the flow in the plenum and to facilitate its entry into the pipe leading to the 12 in. butterfly valve. This valve is used to throttle the flow to the vertical thrust nozzles. For these tests the pipe leading to the horizontal thrust nozzle is blanked off. In the actual flight version another valve would exist in that pipe and would, in conjunction with the test valve, provide the mechanism for splitting the flow between the vertical and horizontal nozzles for thrust vectoring purposes. The pipe wall thickness was one-eighth inch and therefore can be expected to transmit a large part of the pressure disturbances in the pipe to its surroundings.

INSTRUMENTATION

Aerodynamic

Aerodynamics instrumentation provided for measurement of the air mass flow rate using a venturi installed in the main supply pipe upstream of the burner bypass pipe tee. Air total temperature and pressure were measured upstream of the test hardware. Barometric pressure was recorded. All aerodynamic measurements were recorded using a central data processing system.

Acoustic

The acoustic instrumentation consisted of four internal pipe fluctuating pressures pickups. The pressure transducers used to measure the fluctuating wall static pressures in the pipe, were set up to read the differential pressure between the transducer face mounted flush at the inside surface of the pipe and a static pressure tap placed in the pipe near the transducer face. A long length of tubing was connected between the transducer reference side and the static tap thus damping the dynamic pressure component coming from the tap, figure 5.

The transducers were installed in pairs spaced a half pipe diameter apart along the pipe axial direction, figure 4. Pairs of transducers were installed at two axial locations in the pipe, one pair upstream of the valve and the other downstream of the valve. The first transducer in each pair is placed at one pipe diameter from the valve.

The output from the pressure transducer was passed through a signal conditioner and then to a linear amplifier. To eliminate electrical noise in the signal a 10 kHz low pass filter was used at the amplifier. Therefore, all of the transducer data is limited to frequencies at or below 10 kHz. The output from the transducer amplifiers were recorded on FM tape for off line data reduction.

DATA REDUCTION

Aerodynamic

The aerodynamic data was recorded using the central data processing facility located at NASA Lewis for post run computer processing. A computer located at this facility later reduced the data to engineering units and produced the required output. Mass flow rates were calculated as was the valve pressure ratio. Table I list the reading numbers, valve pressure ratios, and upstream total pressure and mass flow rate.

Acoustic

The acoustic data was recorded on FM tape for post run analysis. Spectral analysis was performed on a Rockland third octave analyzer and transmitted to the central data processing facility for computer processing. The third octave and overall sound pressure level data were processed and tabulated using an existing acoustic data reduction program. Plots of all the third octave spectra are shown in the appendix for record purposes. The overall sound pressure level (OASPL) data are tabulated in table II along with the reading numbers and nozzle pressure ratios.

EXPERIMENTAL PROCEDURE

The procedure followed to obtain the valve noise data presented herein was as follows. First the valve was set manually and locked at a predetermined angular position. Then the mass flow rate through the valve was adjusted using the upstream flow control valve so that the ratio of the total pressure upstream

of the 12 in. test valve to the atmospheric pressure downstream of the valve equaled the desired set point pressure ratio. After the flow stabilized the amplifier gains for each of the transducers were adjusted to eliminate signal clipping but insure adequate signal at the tape recorder input. The gains were then recorded manually and a 2 min recording of the signals was made for post run analysis purposes. This procedure was followed for valve angular positions of 30°, 37.5°, 45°, 52.5°, 60°, 75° and 90° with nominal valve pressure ratios covering the range of 1.4, 1.8, 2.0, 2.4, and 2.8. Valve angular positions less than 30° were prohibited due to geometric restriction on the valve adjustment mechanism.

RESULTS AND DISCUSSION

Overall Sound Pressure Level

The overall sound pressure level is shown in figure 6 as a function of valve angular position for each of the valve pressure ratios set during these tests. Figures 6(a) to (d) show the OASPL for transducer numbers 1 to 4 respectively. At the upstream locations, figures 6(a) and (b) the OASPL at 30° starts at a relatively low level and increases to a maximum of 156 dB between the 50° and 60° valve positions and then decreased. Downstream of the valve, figures 6(c) and (d) the OASPL at 30° starts at a relatively high level and peaks 180 dB at angular position less than 60°. The general conclusion is that the overall sound pressure level for this test valve reaches a maximum at a midrange valve angular position and falls off on either side of this maximum.

To compare the upstream to the downstream overall sound pressure levels the OASPL were plotted at these locations as a function of valve angular position, figure 7. The data are shown for nominal valve pressure ratios of 1.4, 1.8, 2.0, 2.4 and 2.8 in figures 7(a) to (e), respectively . The downstream OASPL are always significantly higher than the upstream levels except when the valve is completely open. This is the result of the noise being generated in the region downstream of the butterfly disc where the flow separates creating turbulence and thus generating noise that is similar to that generated by a jet in its shear layer. As the valve is opened the size of the separated region downstream of the valve disc decreases and the noise diminishes. With the valve at the fully open position, 90°, the separated region minimizes and the downstream noise approaches the upstream levels.

For comparison a plot having the same parameters as figure 7 but for a 54 in. butterfly valve used to control the flow from the NASA Lewis Research Center's 8- by 6-Foot Supersonic Wind Tunnel plenum chamber is shown in figure 8. The data were taken from reference 1. Comparison of the downstream OASPL, transducer numbers 1 and 2 to the upstream transducer numbers 3 and 4 show the same trends as the current test data. Transducer numbers 5 and 6 were microphones placed in the plenum chamber upstream of the pipe bellmouth and exhibit the same shape as the internal pipe transducers. The level is lower due to the spherical spreading of the sound waves as they leave the bellmouth.

Figure 7(e) shows that maximum noise levels in the pipe downstream of the valve can reach 180 dB. Steel pipe with wall thickness on the order of a quarter inch are expected to cause a transmission loss of about 20 dB. Since the pipe wall is half this thickness its mass will not produce as much attenuation. Thus, the level in the fuselage from the valve can be expected to be on

the order of 160 dB or greater. If the fuselage is considered to be a reverberant chamber the pilot will be exposed to this level. If the pilot's helmet further reduces the level by 30 dB the pilot would be exposed to 130 dB, the so called threshold of pain. From this scenario it is obvious that acoustic treatment will be required if this valve configuration is employed in flight hardware.

One-Third Octave Spectra

Typical spectra are shown in figure 9 for the upstream and downstream transducers at a valve pressure ratio of 1.4. The downstream spectra have broad-banded maximums between 200 and 1000 Hz. Estimates of peak jet noise frequency, based on a 1 ft diameter and a Strouhal number of 0.2, 160 Hz, (band number 22). If the diameter is assumed to be a half foot the frequency is 320 Hz (band number 25). These frequencies are on the order of those shown in figure 9. Spectral weighting curves used to evaluate the spectra for the response of the human ear decrease the sound pressure levels (SPL) below a frequency of 1000 Hz. This would be a benefit to the "A" weighted sound level. However the spectra are broad banded and have high SPL above 1000 Hz so that the decrease is not expected to be significant.

Upstream of the valve the spectra is less smooth with a peak at 80 Hz (band number 19) and a broad banded maximum just above 1000 Hz (band number 30).

At the higher valve pressure ratios, figure 10, the downstream spectra again have broad banded maximums but peak at about 1000 Hz, a higher frequency then the low pressure condition, figure 9. The "A" weighting of this spectra will have little affect on the OASPL value so that the value of the OASPL may be assumed equal to the "A" weighted sound level.

Upstream of the valve the spectra shows a peak that probably is a tone at a frequency of 630 Hz (band number 28). The spectra are relatively flat but as irregular as the low pressure ratio spectra shown in figure 9.

CONCLUDING REMARKS

During transition from vertical takeoff to normal flight high noise levels can be expected from the thrust vectoring system. With noise levels approaching 180 dB in the ducting system leading to the forward end of the fuselage and thin wall ducts the noise level in the fuselage is expected to reach at least 160 dB. Thus, it is clear that acoustic treatment will be required to lower the level to an acceptable level in the cockpit to avoid interference with pilot communication, pilot fatigue and permanent hearing loss problems.

CONCLUSIONS

Noise levels generated by a flight weight, 12 in. butterfly valve applicable to a vertical take off and landing aircraft thrust vectoring control system were determined experimentally. The measurements were taken in the duct both upstream and downstream of the valve. The following conclusions are drawn:

5

1. The maximum overall sound pressure level is generated in the duct downstream of the valve and reached a value of 180 dB at a nozzle pressure ratio of 2.8.

2. At the higher valve pressure ratios the spectra downstream of the valve is broad banded with its maximum at 1000 Hz.

3. The maximum overall sound pressure level generated upstream of the valve reached 156 dB at a nozzle pressure ratio of 2.8.

4. At the higher valve pressure ratios the upstream spectra are broad banded with an apparent tone being generated at the 630 Hz third octave filter band.

5. The overall sound pressure level for this test valve reaches a maximum at a mid range valve angular position and falls off on either side of this maximum.

REFERENCE

1. Huff, Ronald G.: Noise Generated by Flow Through Large Butterfly Valves. NASA TM-88911, 1987.

TABLE I. – POWERED LIFT FACILITY AERODYNAMIC DATA FOR THE 12-IN. VALVE NOISE TEST

Reading number	Valve angular position, deg	Valve pressure ratio	Valve upstream total pressure, psi	Mass flow rate, lb/s
487	30	2.77	39.27	13.26
488	30	2.38	33.79	11.13
489	30	1.9	26.95	11.13
490	30	1.77	25.15	8.42
491	30	1.37	19.47	5.03
494	37.5	2.77	39.35	19.53
495	37.5	2.41	34.19	16.89
496	37.5	1.99	28.22	13.53
497	37.5	1.78	25.29	11.75
498	37.5	1.36	19.26	7.69
501	45	2.77	39.39	27.15
502	45	2.41	34.18	23.27
503	45	1.97	27.55	18.35
504	45	1.81	25.64	16.41
505	45	1.38	19.61	10.66
508	52.5	2.84	40.33	34.8
509	52.5	2.39	33.88	28.64
510	52.5	1.98	28.15	23
511	52.5	1.81	25.65	20.46
512	52.5	1.4	19.93	13.61
515	60	2.79	39.58	39.13
516	60	2.41	34.19	32.93
517	60	1.99	28.27	26.41
518	60	1.79	25.39	23.03
519	60	1.42	20.16	15.58
522	75	2.79	39.68	43.59
523	75	2.43	34.47	37.29
524	75	2	28.47	29.66
525	75	1.78	25.32	25.42
526	75	1.38	19.66	16.72
529	90	2.82	39.99	45.17
530	90	2.39	33.55	37.62
531	90	1.01	28.53	30.59
532	90	1.81	25.76	26.73
533	90	1.41	20.09	17.91

TABLE II. – OVERALL SOUND PRESSURE LEVEL DATA
12-IN. VALVE NOISE TESTS

Reading number	Trans 1	Trans 2	Trans 3	Trans 4
Overall sound pressure level, dB ref. 20 μN/m^2				
487	145.8	144.9	162.2	175.9
488	144.7	144.2	167.4	175.1
489	142.1	141.7	164.5	173
490	142.2	141.6	164.1	172.2
491	140.6	140.1	165.8	174.3
494	149.3	149.2	173.4	179.7
495	148.1	148.3	171.8	178.2
496	145.9	145.7	168.7	174.7
497	146.1	145.4	167.5	173.4
498	142.6	142	163.4	166.5
501	150.5	150.7	174.9	177.5
502	150	149.7	174.4	176
503	148.6	148.4	172.3	171.9
504	148.6	148.5	171.7	171
505	145.4	144.2	165.9	164
508	155.2	154.4	175.8	173.1
509	154.3	153.7	174.4	171.8
510	151.7	151.3	173.2	169.2
511	150.9	150.1	172.1	167.9
512	147.3	146.4	167.3	161.5
515	155.7	155.8	174.2	167.6
516	154.9	154.4	172.8	165.6
517	152.9	152.3	170.6	164.3
518	150.3	149.8	168.9	163.3
519	147.5	146.9	163.5	156.7
522	154.7	154.2	164.4	162.6
523	153.5	153.1	163.6	161
524	151.8	150.2	161.4	157.7
525	149.4	148.5	159.1	156.3
526	146.2	145.9	153.9	150.4
529	153.8	151.9	149.1	150.7
530	151.7	150.7	145.7	147.2
531	149.7	148.2	144.5	145.8
532	149.4	147.4	144.2	145.2
533	146	144.4	141.1	142.1

8

APPENDIX A

12-IN. VALVE 1/3 OCTAVE SPECTRAL DATA PLOTS

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.4, VALVE AT 30 Degree

Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL dB ret 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

10

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.8, VALVE AT 30 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCTAVE BAND NUMBER

SPL, dB rel 20 mic-N/m**2

11
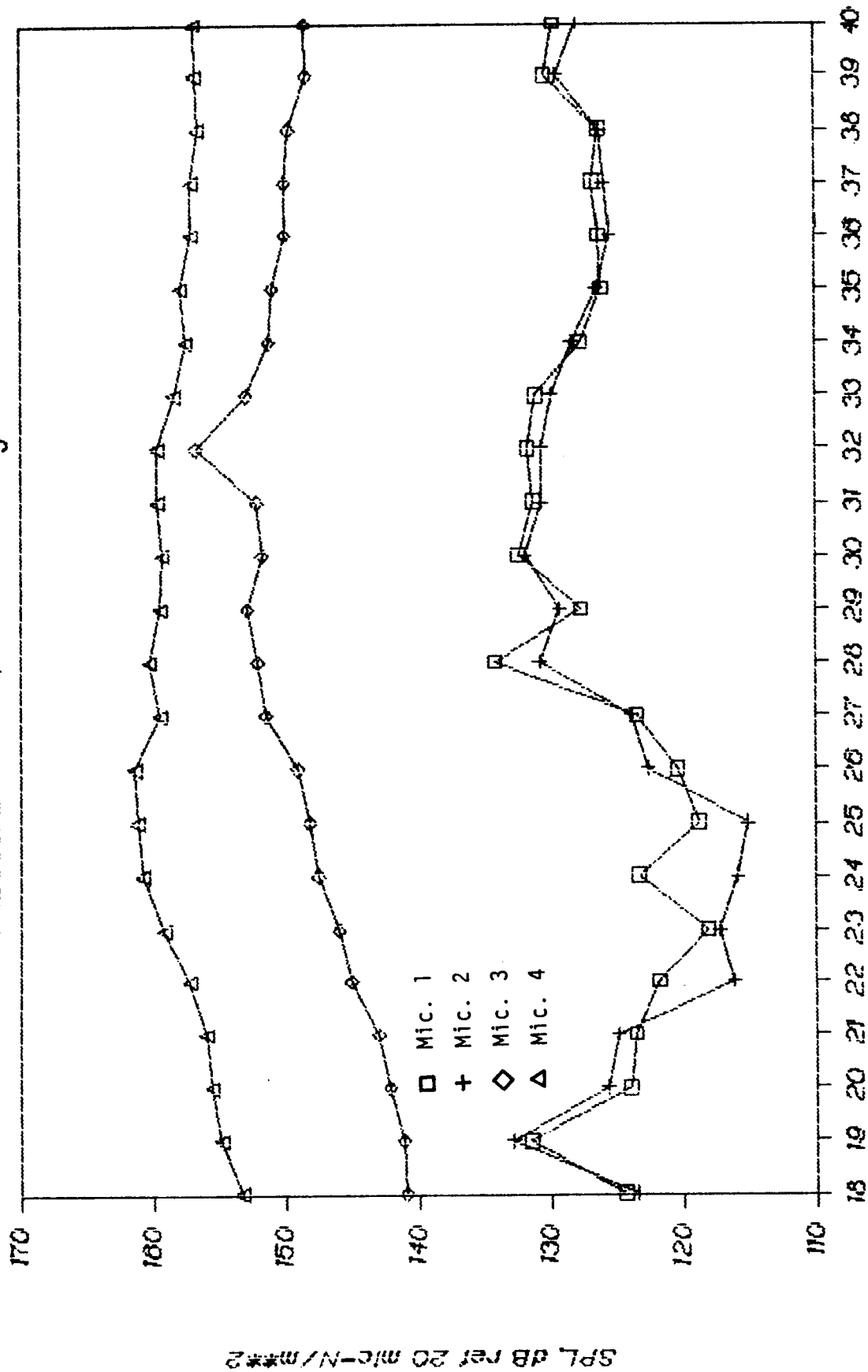
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.0, VALVE AT 30 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

12
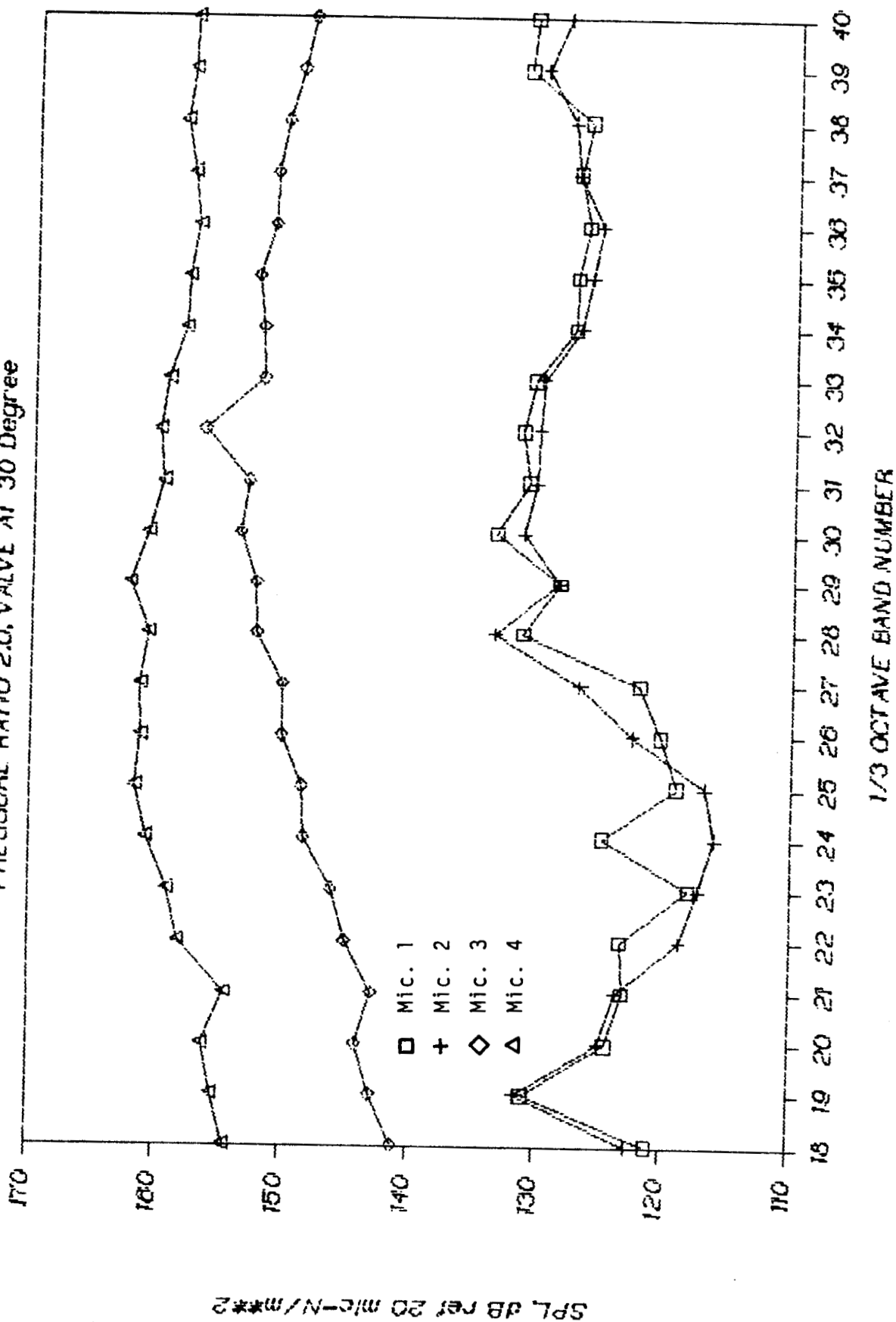
12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.4, VALVE AT 30 Degree

1/3 OCT AVE BAND NUMBER

SPL dB ref 20 mic-N/m**2

Mic. 1
Mic. 2
Mic. 3
Mic. 4

13

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.8, VALVE AT 30 Degree

Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL, dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

14

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.4, VALVE AT 38 Degree
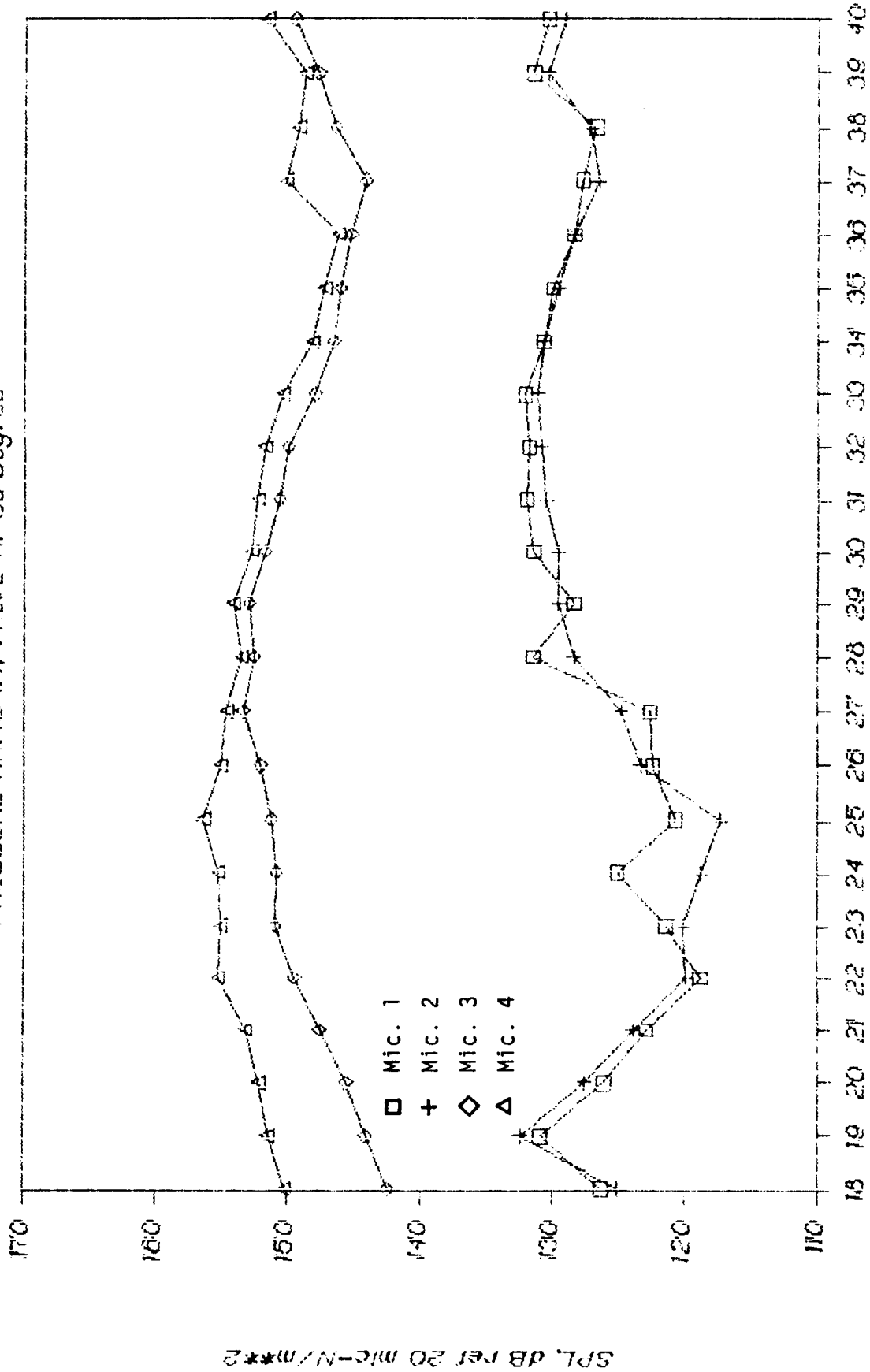
Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

1/3 OCTAVE BAND NUMBER

SPL, dB ref 20 mic-N/m**2

15

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.8, VALVE AT 33 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCTAVE BAND NUMBER
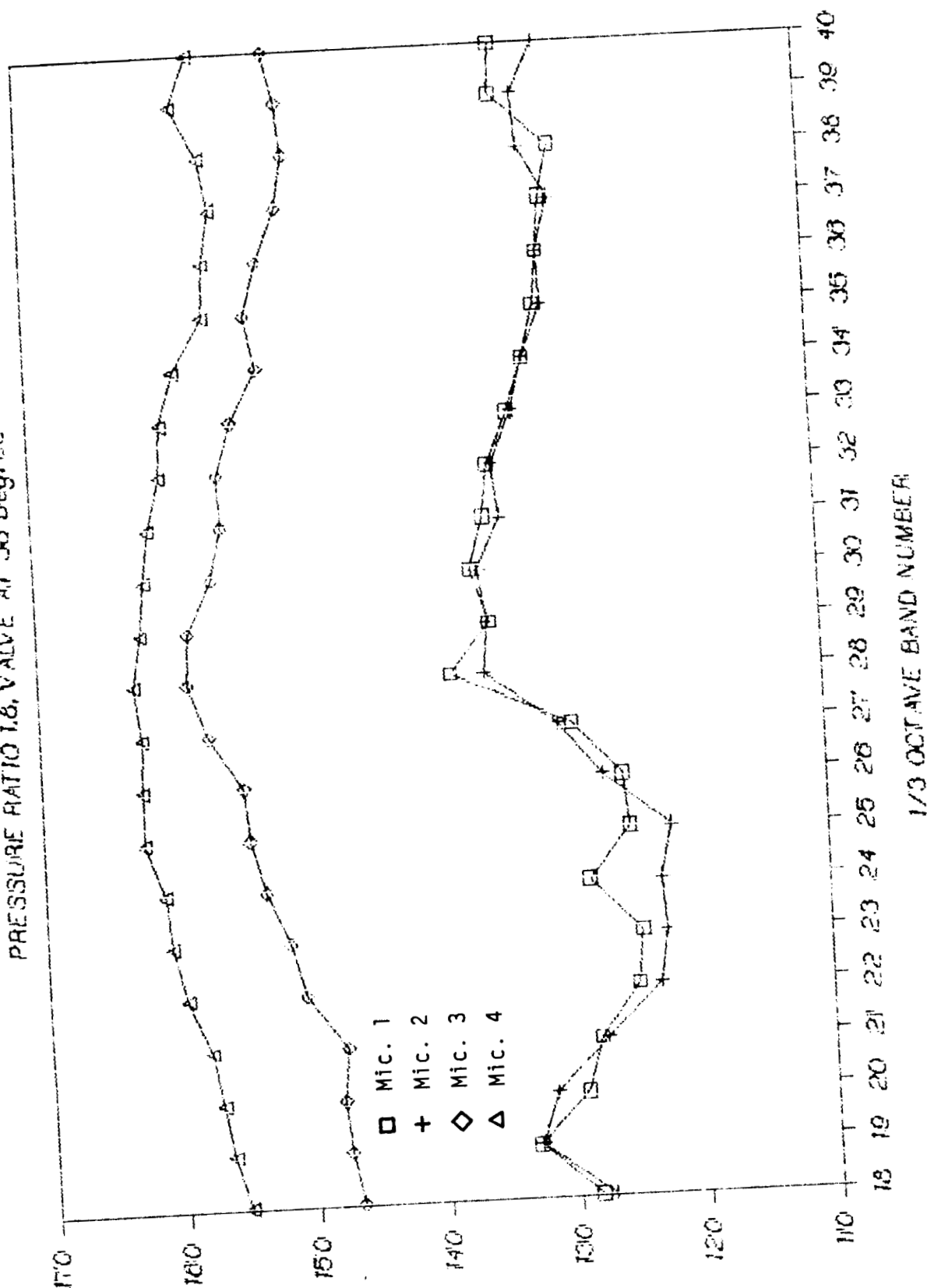
SPL, dB ref 20 mic-N/m**2

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16

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.0, VALVE AT 38 Degree

Mic. 1   □
Mic. 2   +
Mic. 3   ◇
Mic. 4   △

1/3 OCTAVE BAND NUMBER

SPL, dB rel 20 micro-N/m**2

17

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.4, VALVE AT 38 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

18

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.8 VALVE AT 36 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB ret 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

19

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.4, VALVE AT 45 Degree
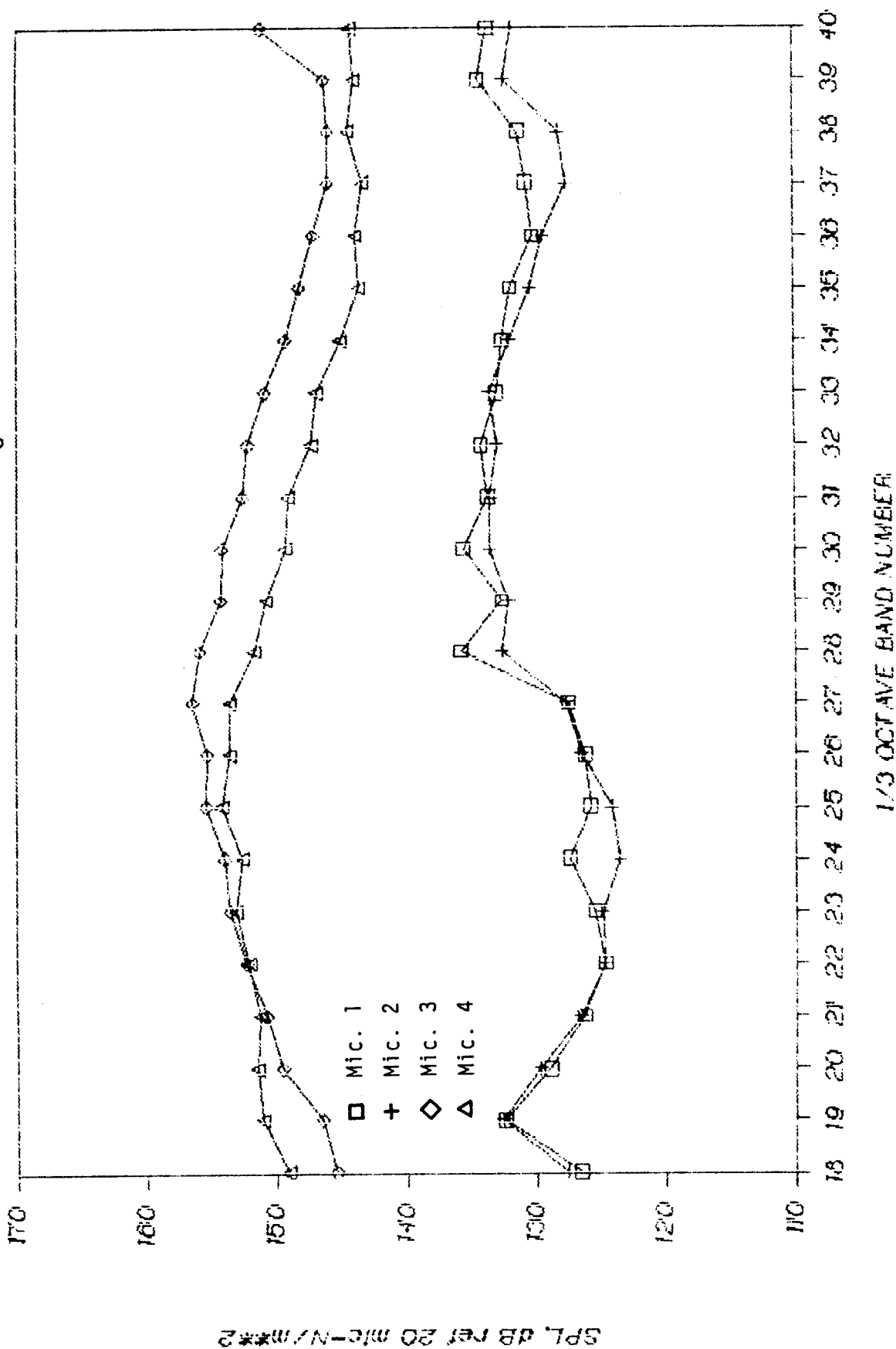
Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL, dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

20

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.8, VALVE AT 45 Degree

Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL, dB rel 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

21
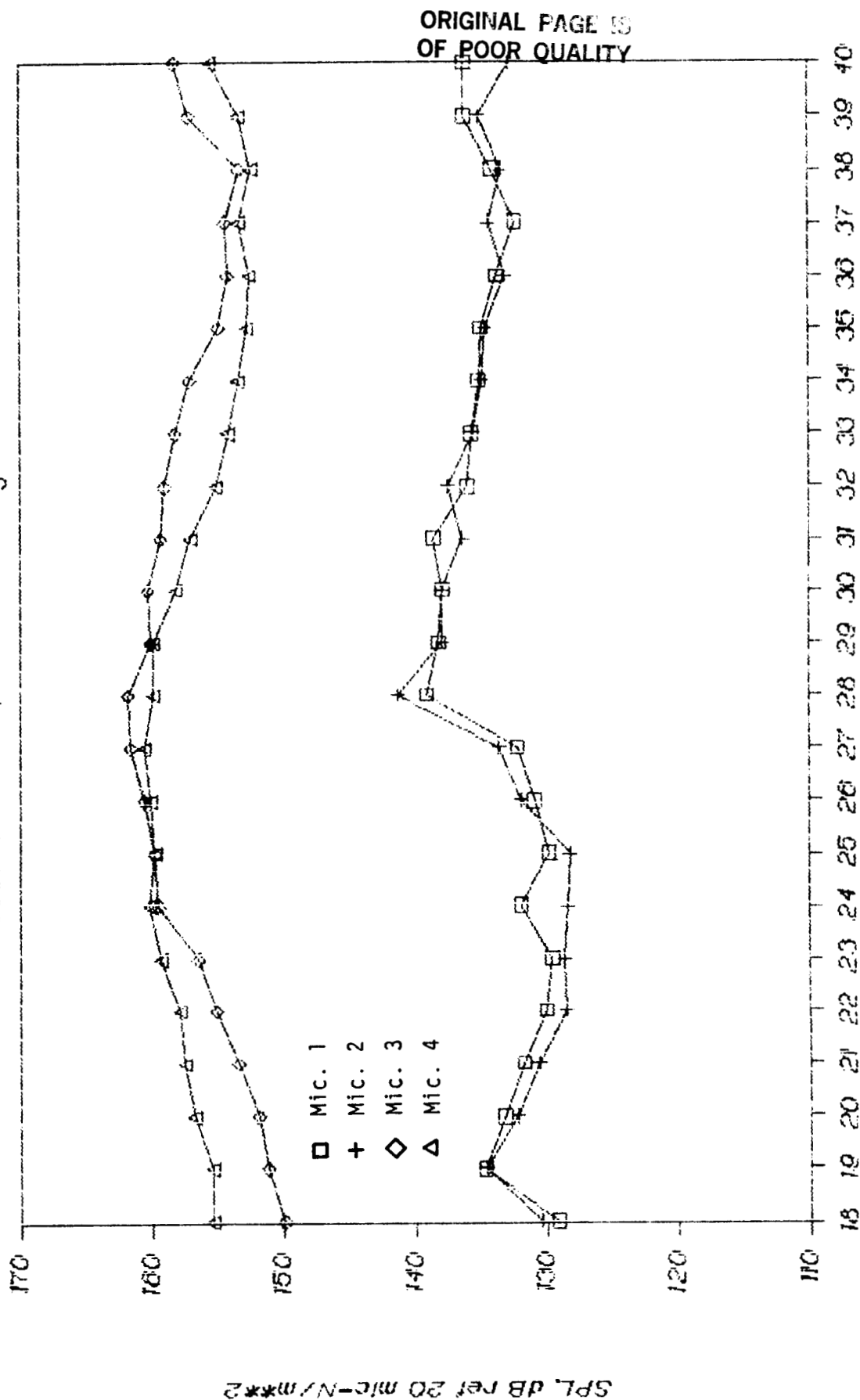
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.0, VALVE AT 45 Degree
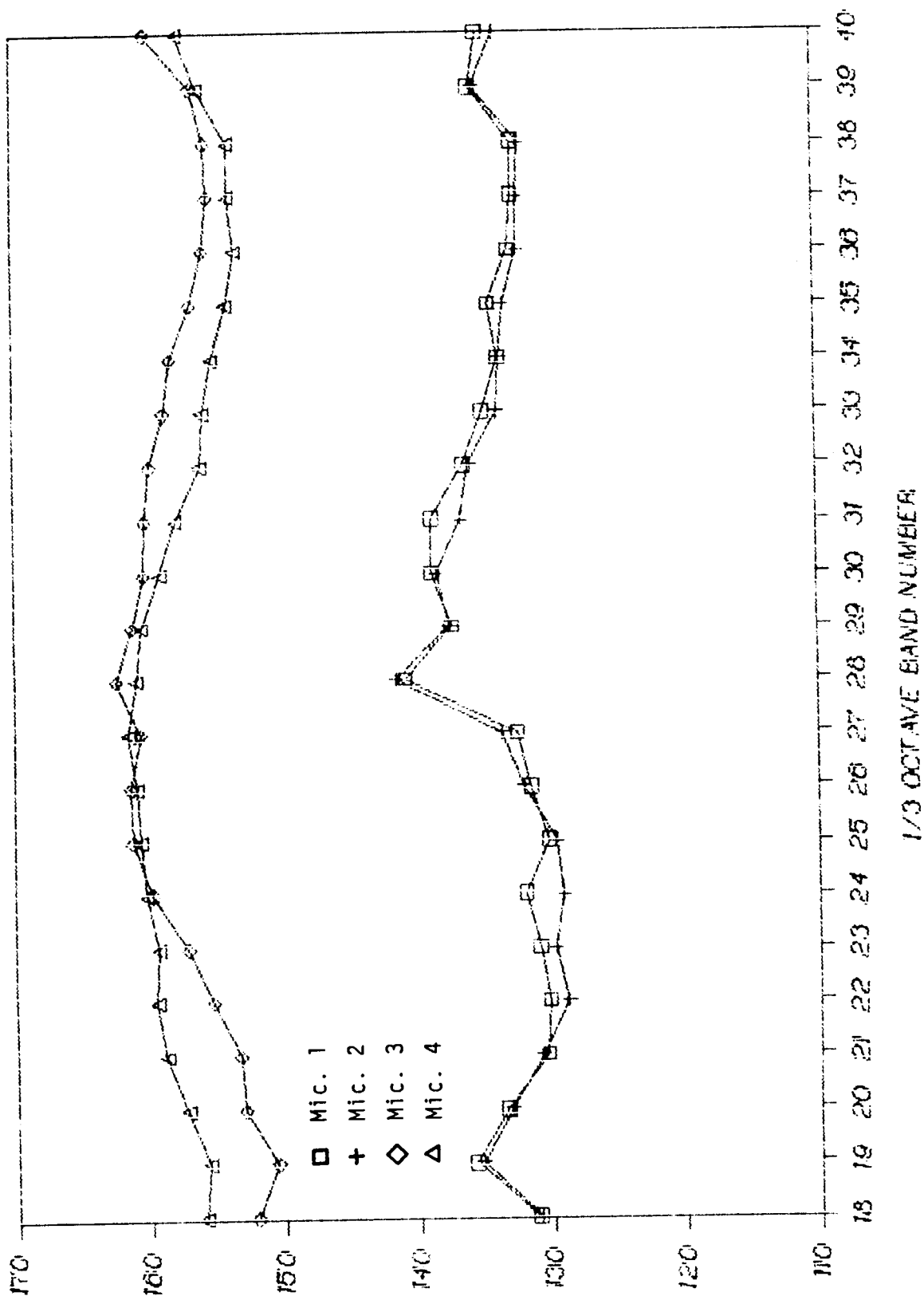
Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCTAVE BAND NUMBER

SPL, dB ret 20 mic-N/m**2

22

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.4, VALVE AT 45 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER
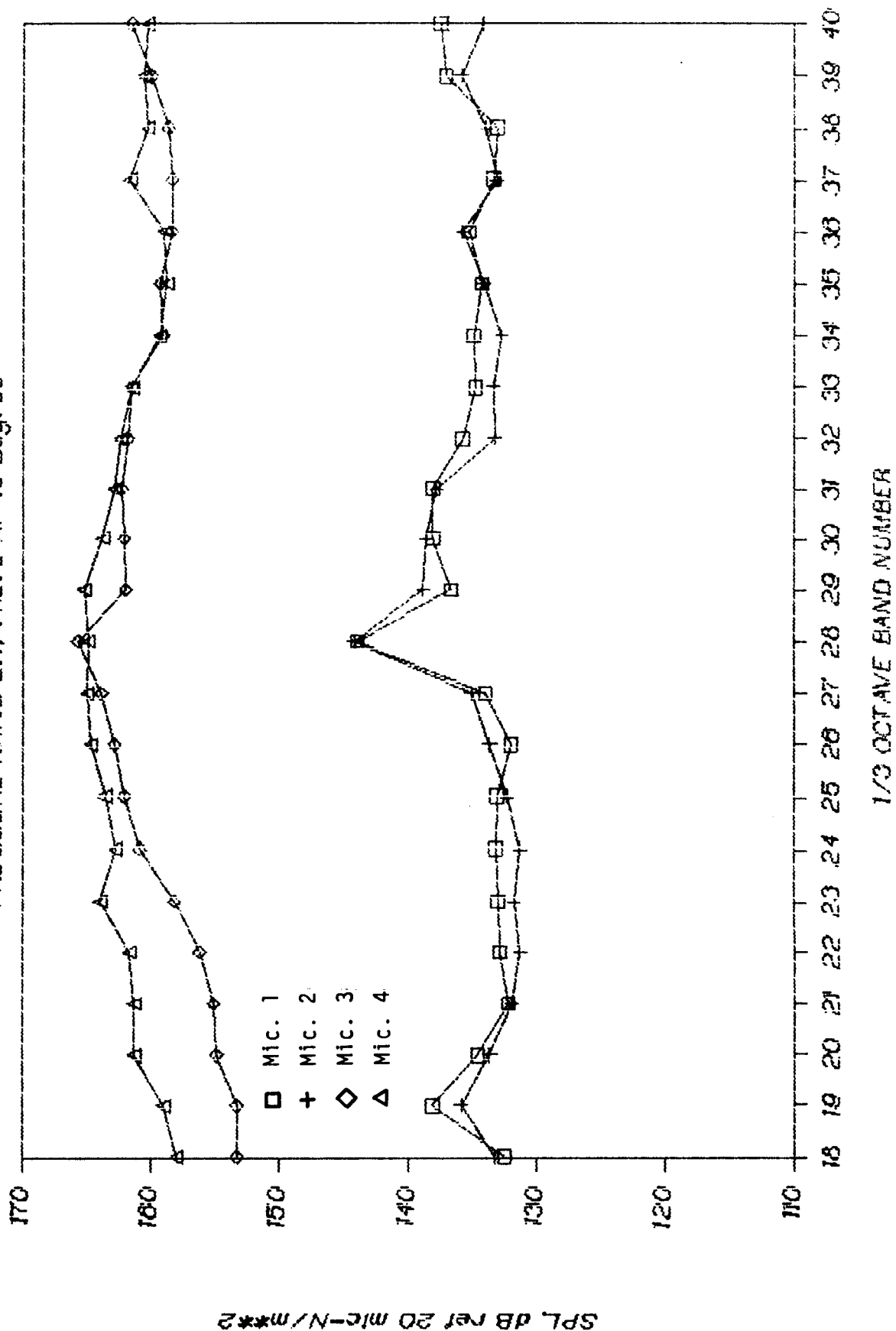
12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.8, VALVE AT 45 Degree
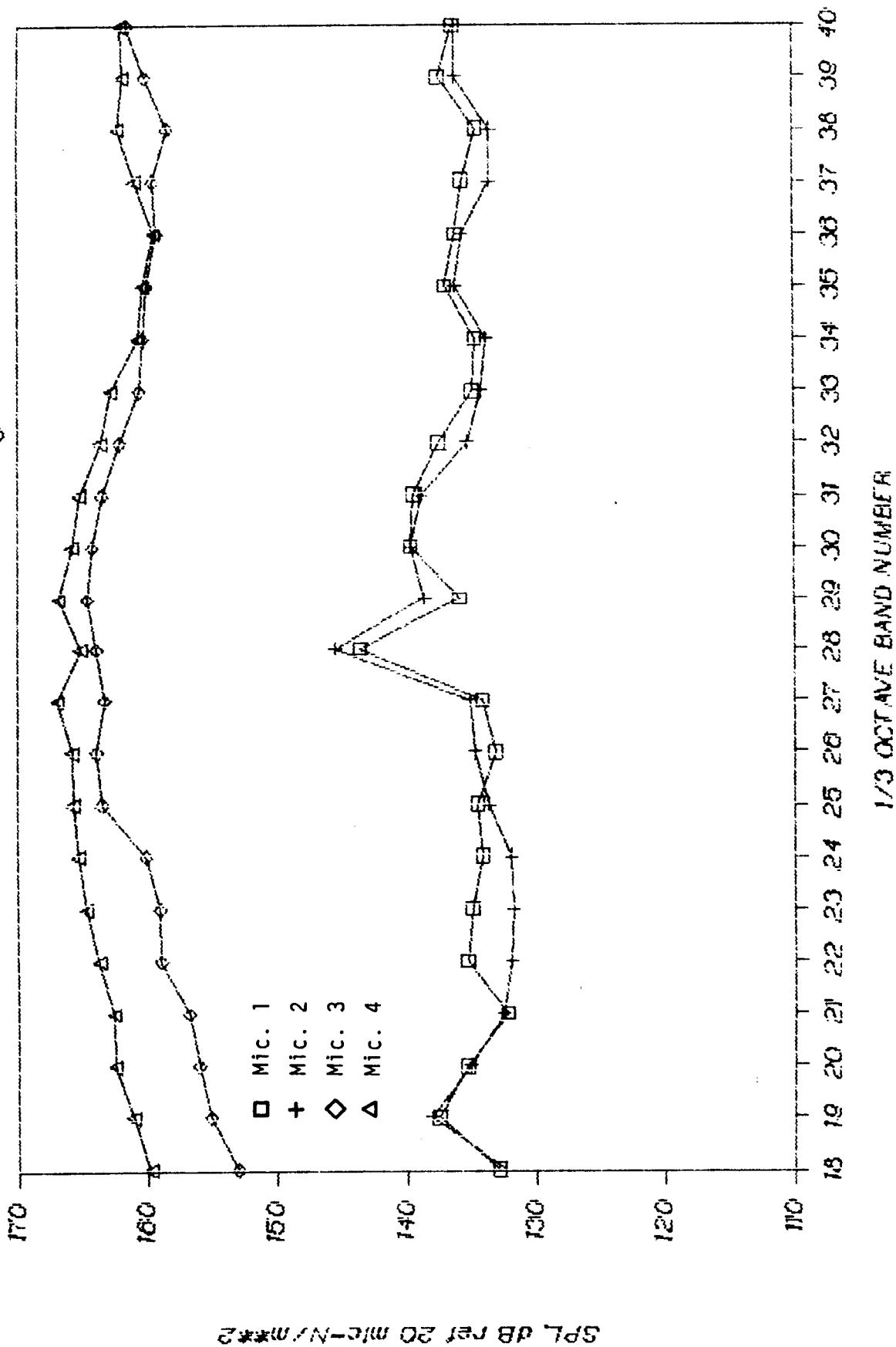
Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

24

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.4, VALVE AT 58 Degree
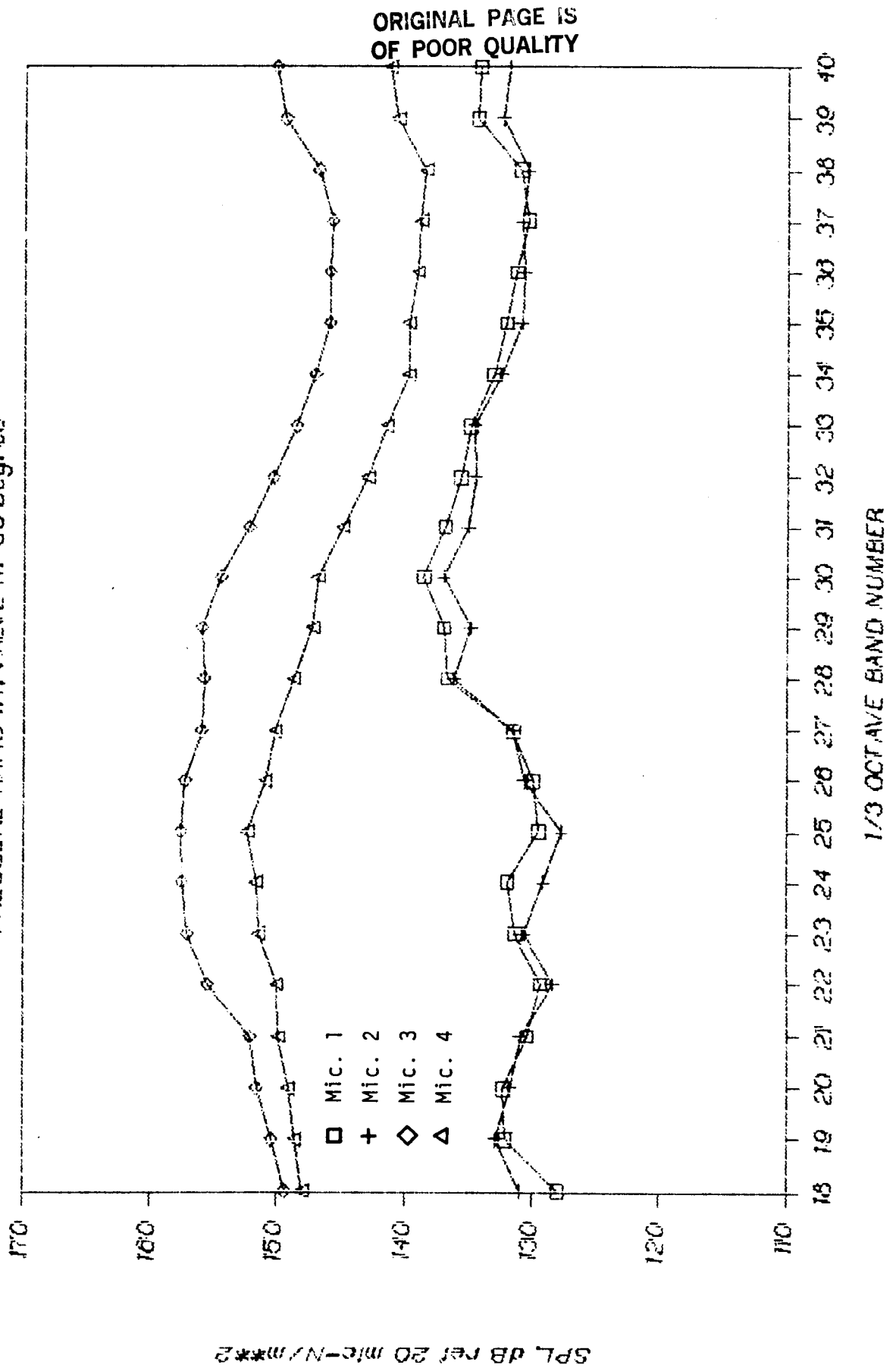
Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

1/3 OCTAVE BAND NUMBER

SPL dB rel 20 mic-N/m**2

25

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.8, VALVE AT 58 Degree

□ Mic. 1
+ Mic. 2
◇ Mic. 3
△ Mic. 4

1/3 OCTAVE BAND NUMBER

SPL, dB ref 20 mic-N/m**2

26
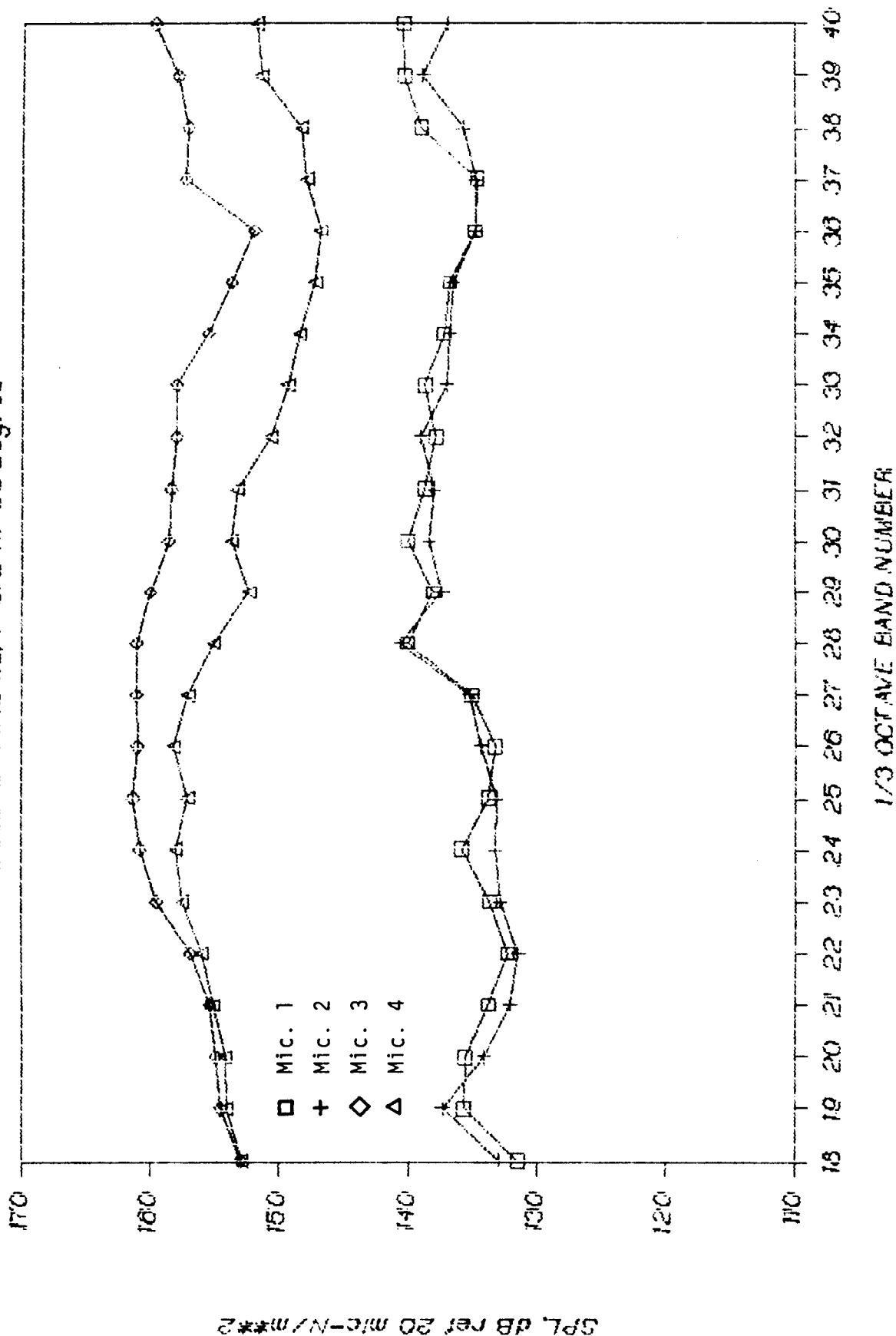
12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.0, VALVE AT 58 Degree

Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL, dB rel 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

27
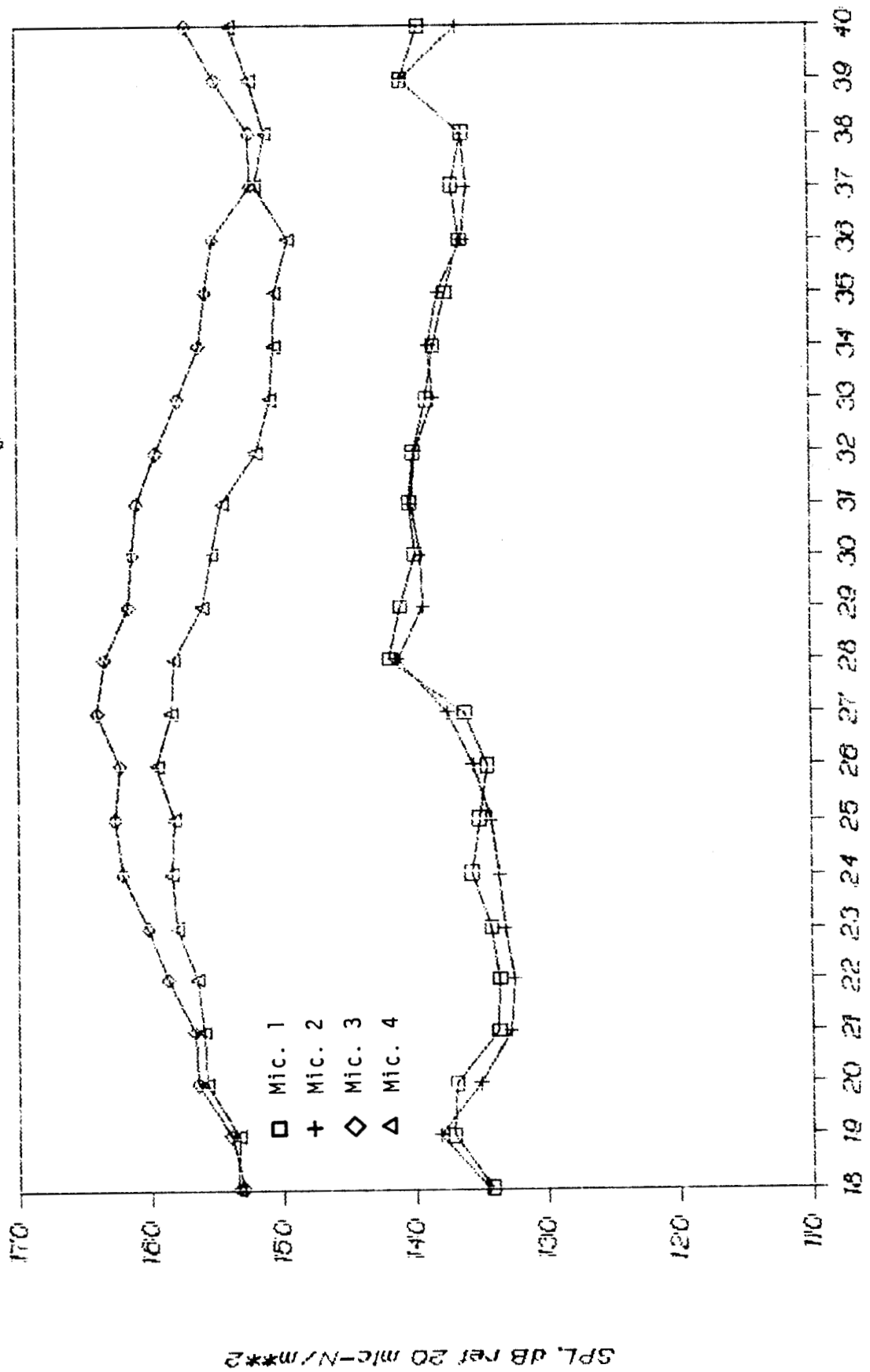
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.4, VALVE AT 58 Degree
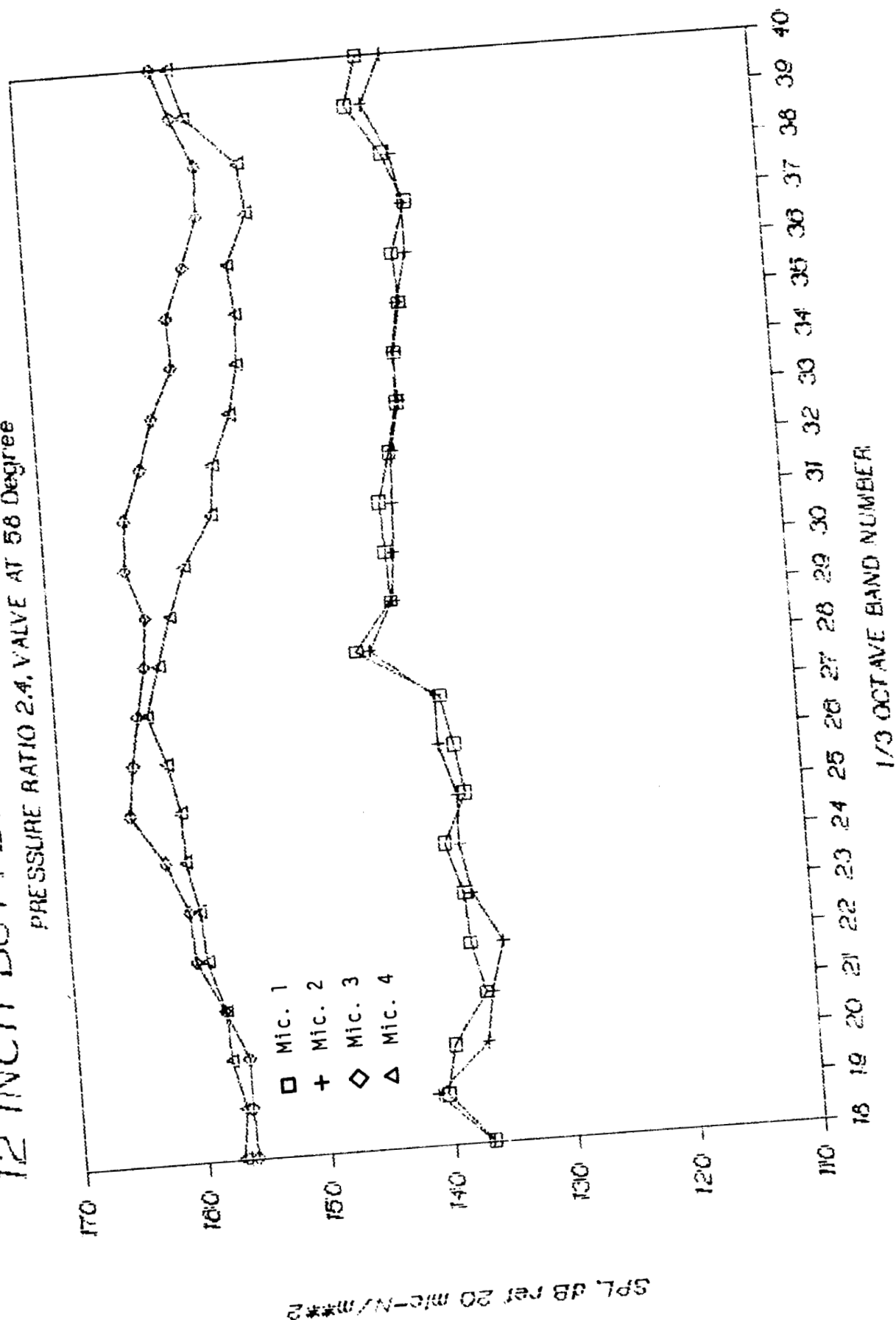
Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

SPL, dB rel 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

28

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.8, VALVE AT 58 Degree

1/3 OCTAVE BAND NUMBER

SPL, dB ref 20 mic-N/m**2

Mic. 1
Mic. 2
Mic. 3
Mic. 4

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.4, VALVE AT 80 Degrees

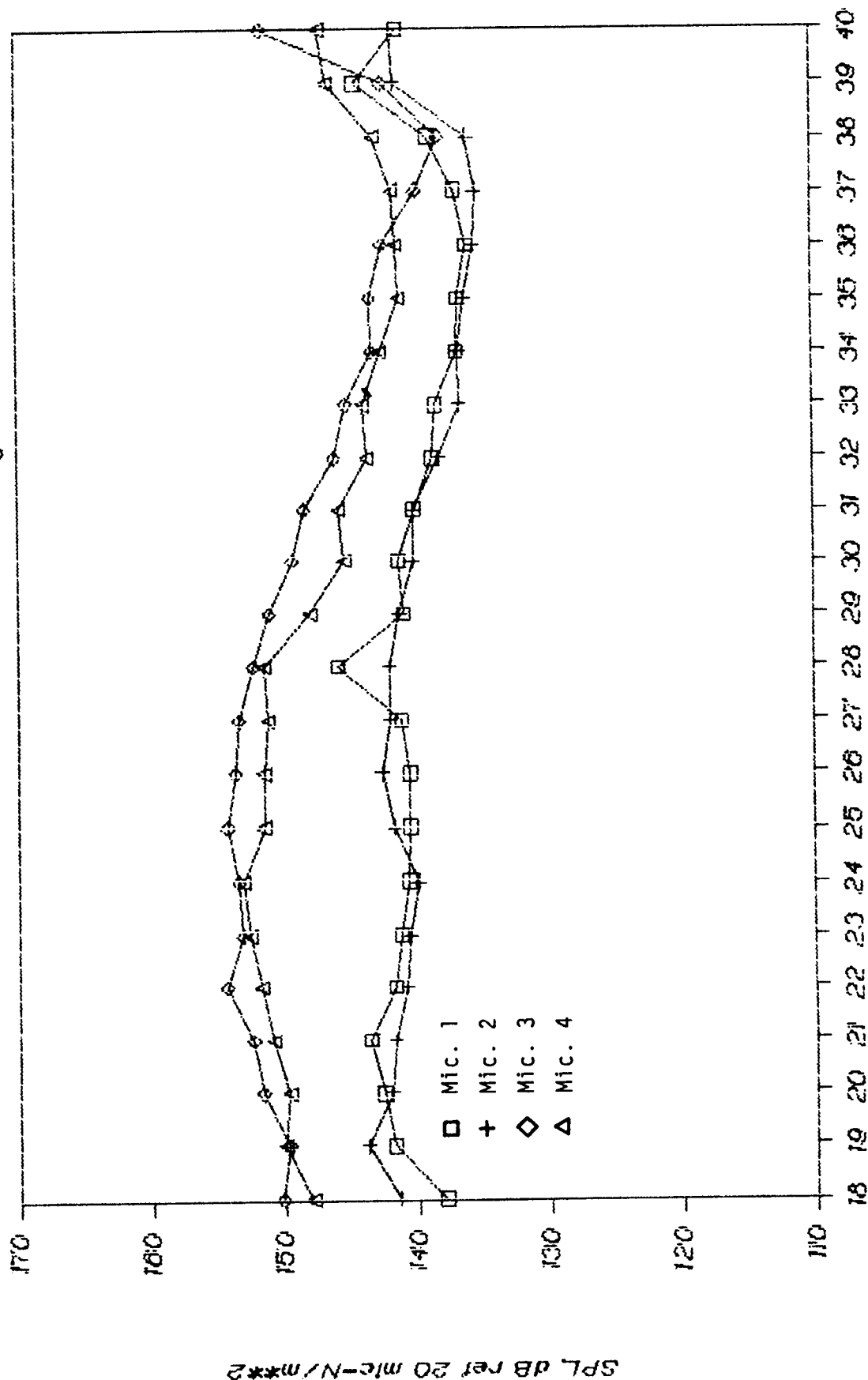Mic. 1 □
Mic. 2 +
Mic. 3 ◇
Mic. 4 △

1/3 OCTAVE BAND NUMBER

SPL dB ref 20 mic-N/m**2

30

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12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.8, VALVE AT 80 Degree
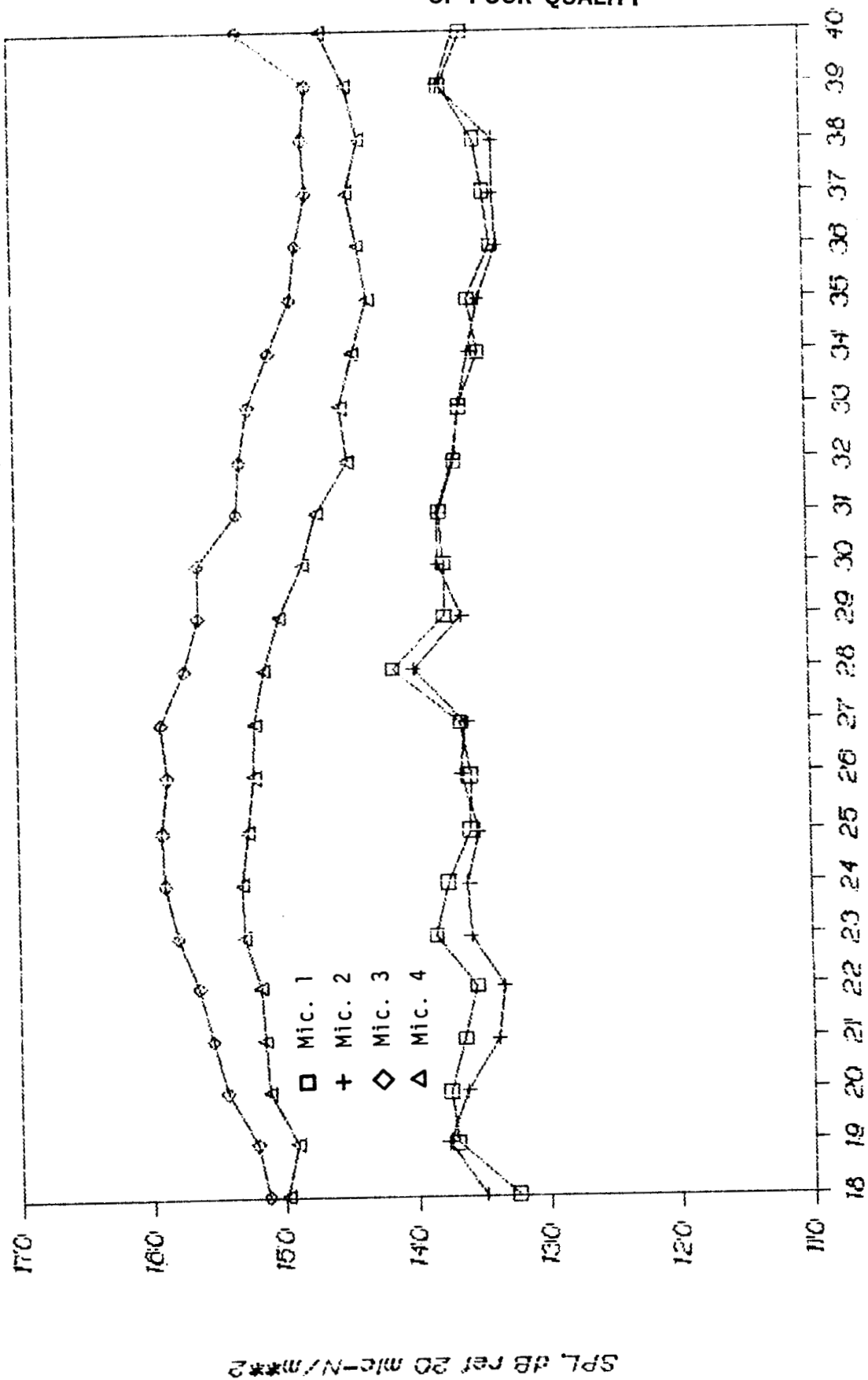
Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL dB rel 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

31

12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.0, VALVE AT 80 Degree

SPL, dB ret 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

Mic. 1
Mic. 2
Mic. 3
Mic. 4

32
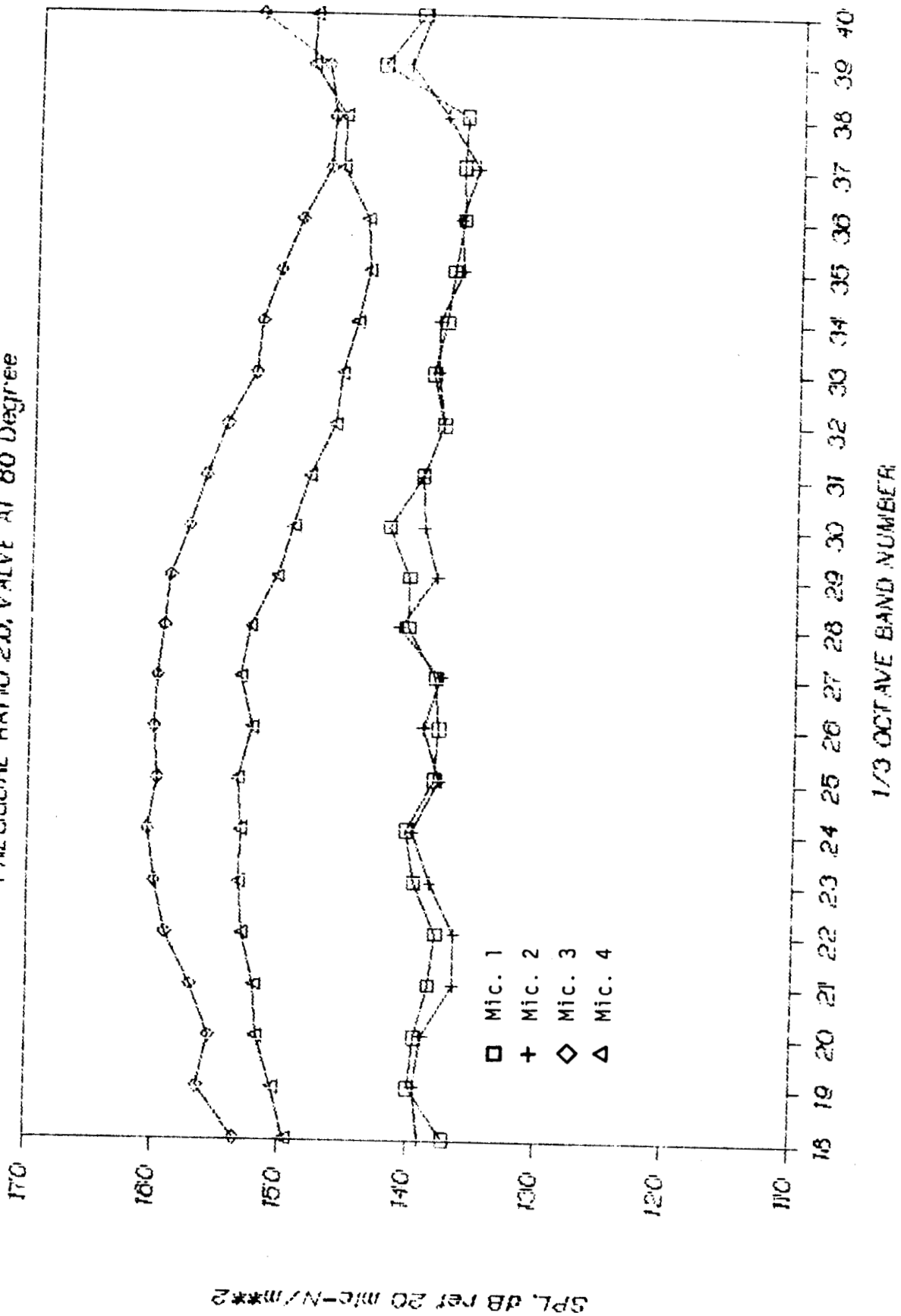
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12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.4, VALVE AT 60 Degree
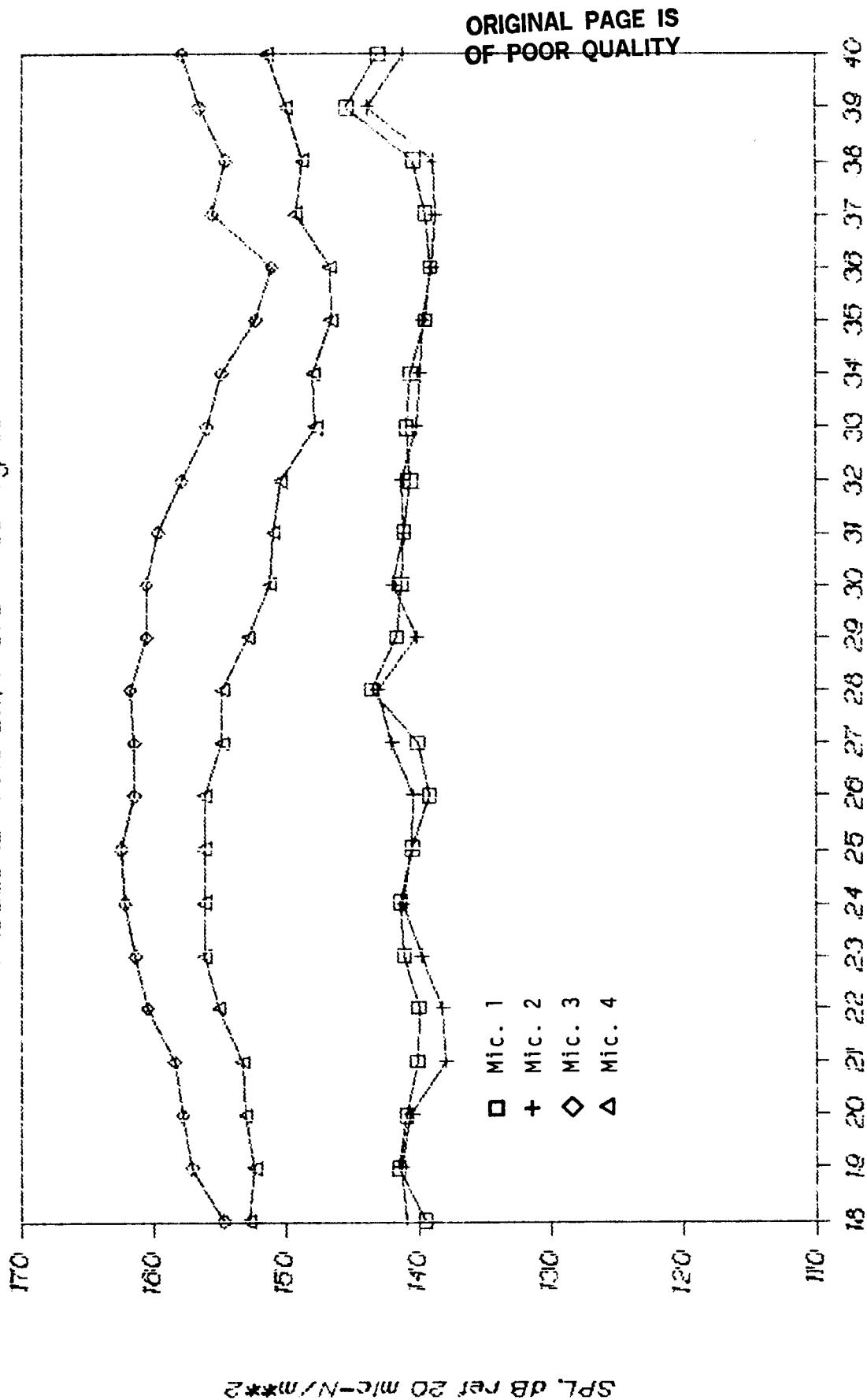
Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL, dB ref 20 mic-N/m**2
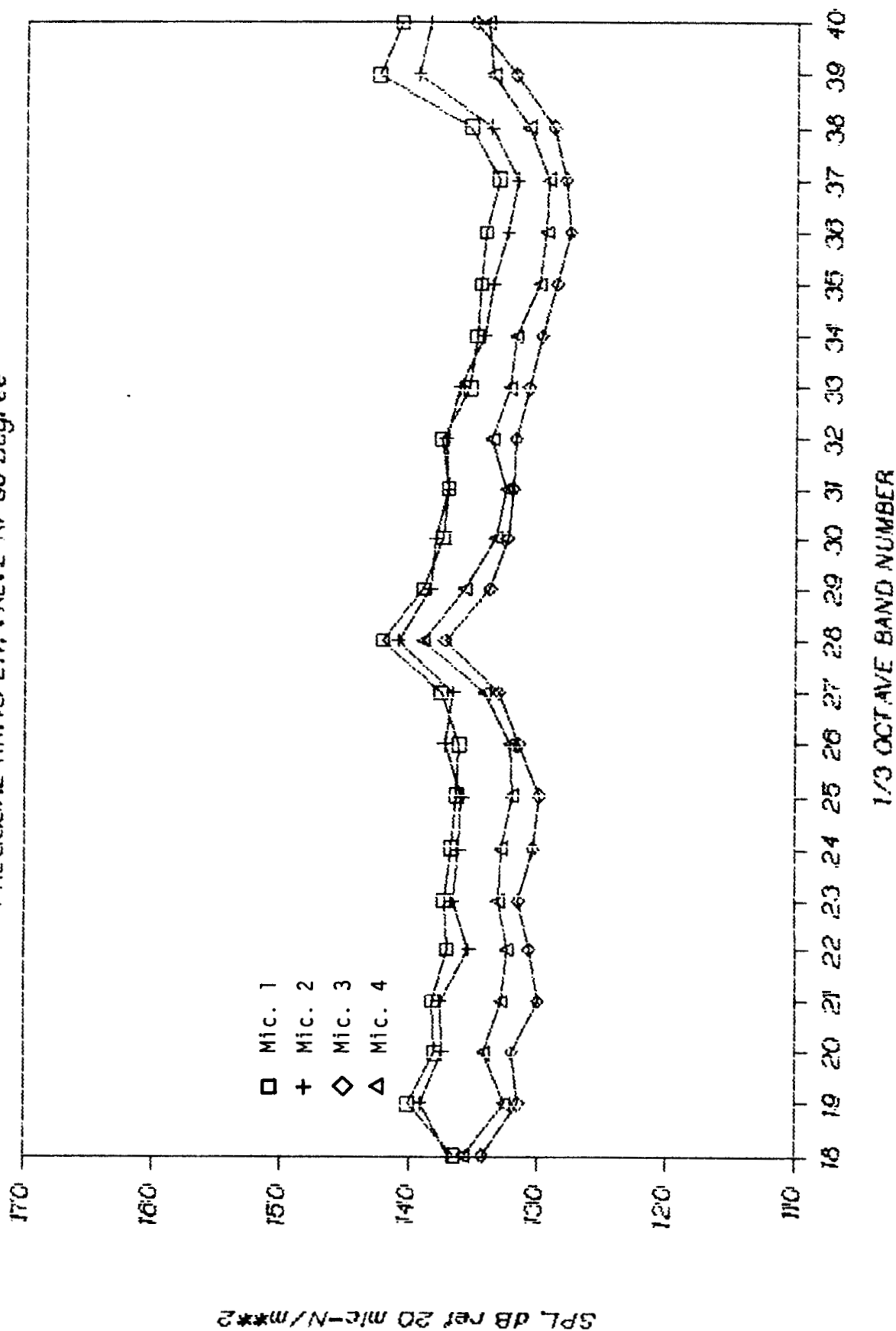
1/3 OCTAVE BAND NUMBER

33

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.8, VALVE AT 80 Degree

SPL dB rel 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

□ Mic. 1
+ Mic. 2
◇ Mic. 3
△ Mic. 4

34
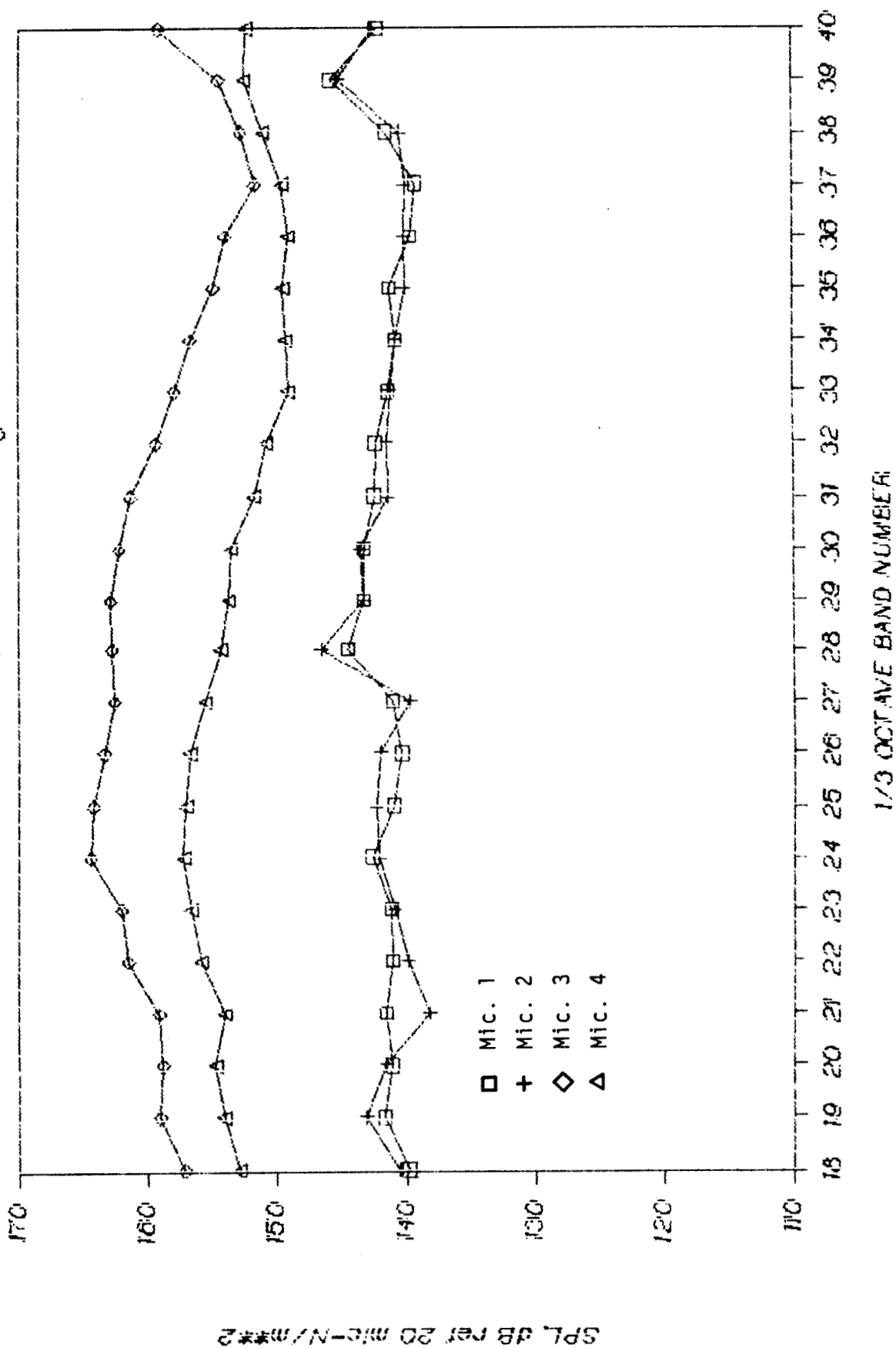
12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.4, VALVE AT 75 Degrees

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCTAVE BAND NUMBER

SPL, dB ref 20 mic-N/m**2

35
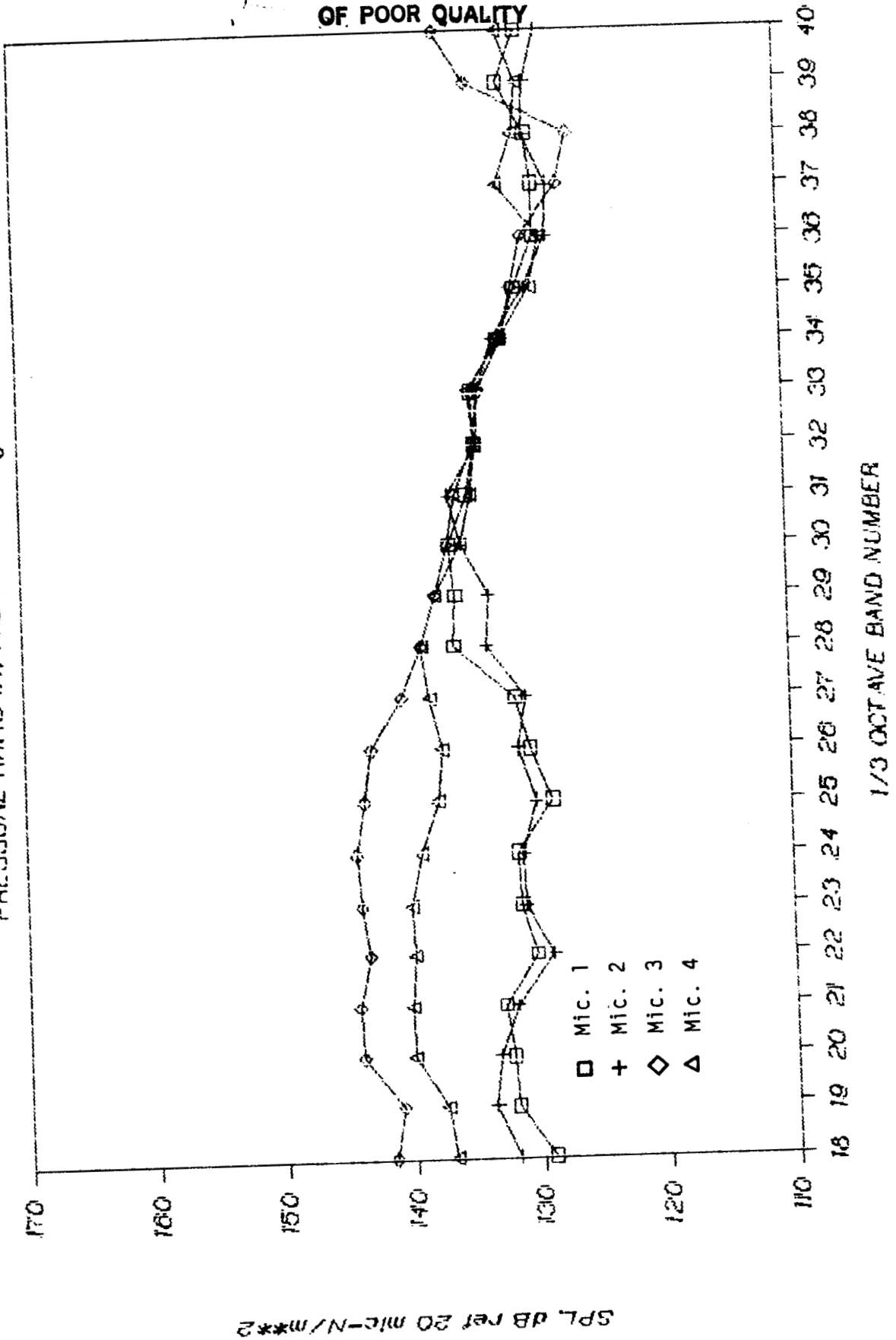
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 1.8, VALVE AT 75 Degree

1/3 OCTAVE BAND NUMBER

SPL dB ret 20 mic-N/m**2

Mic. 1
Mic. 2
Mic. 3
Mic. 4
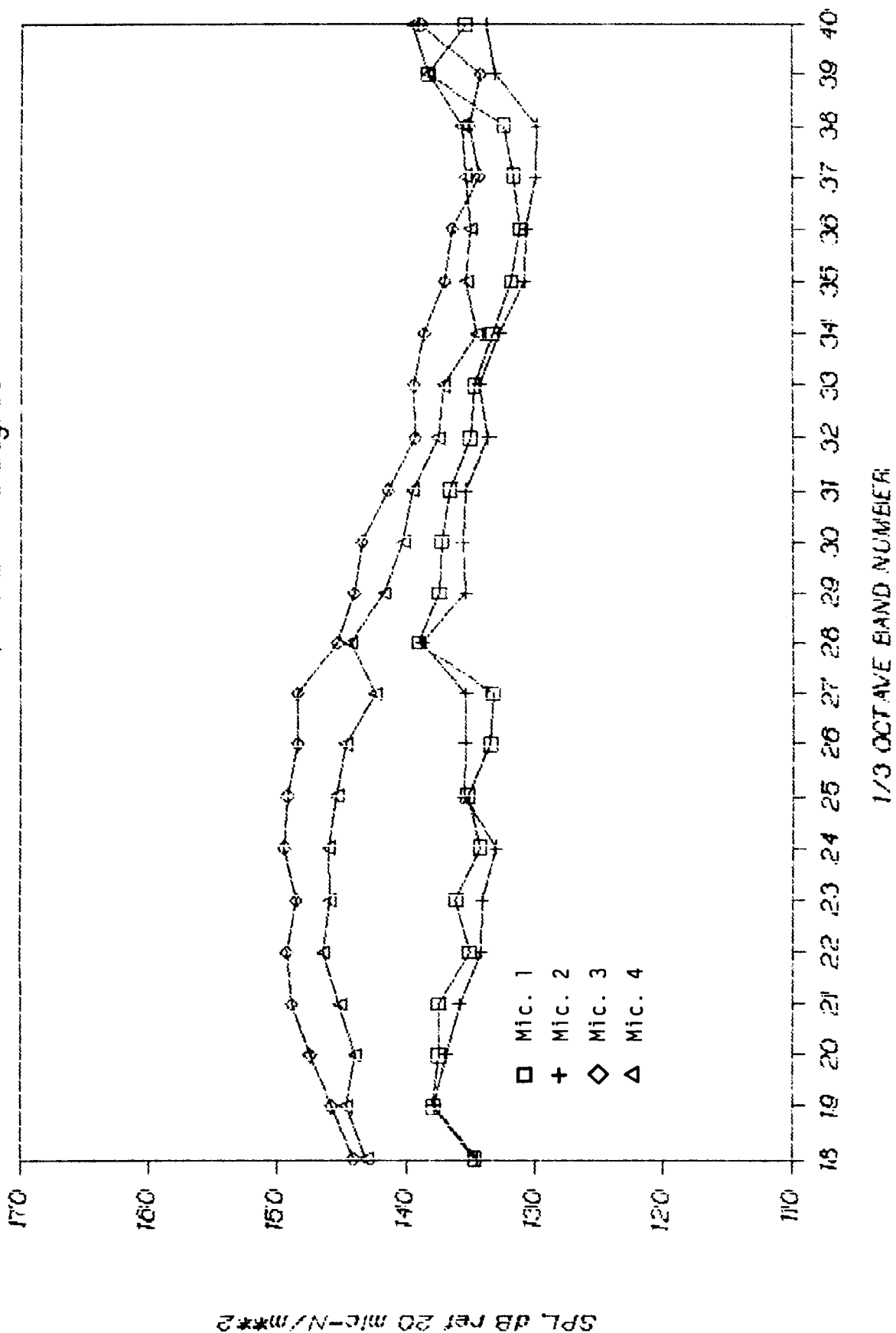
12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.0, VALVE AT 75 Degree

SPL, dB ref 20 micro-N/m**2

1/3 OCTAVE BAND NUMBER

Mic. 1
Mic. 2
Mic. 3
Mic. 4

37
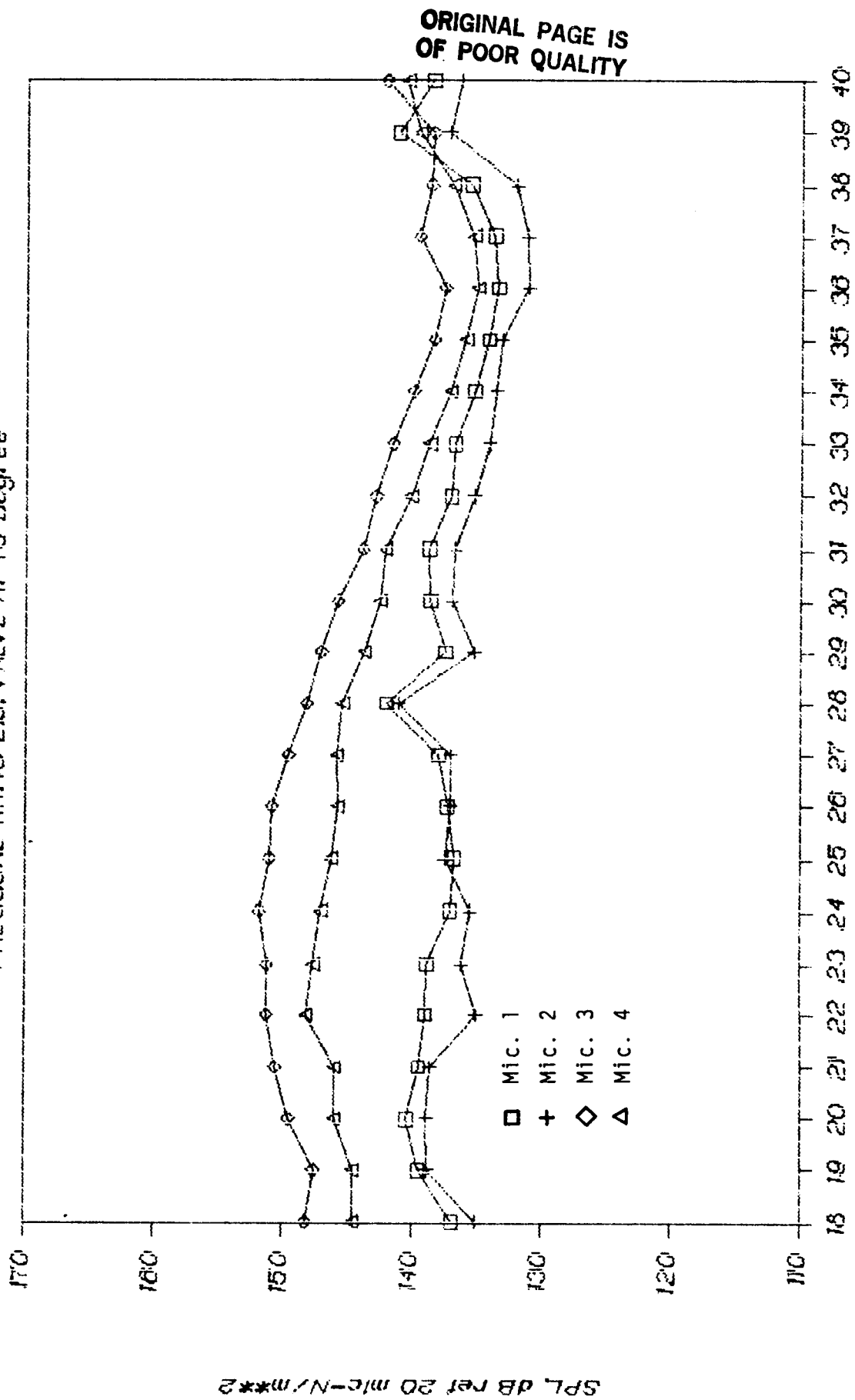
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.4, VALVE AT 75 Degree
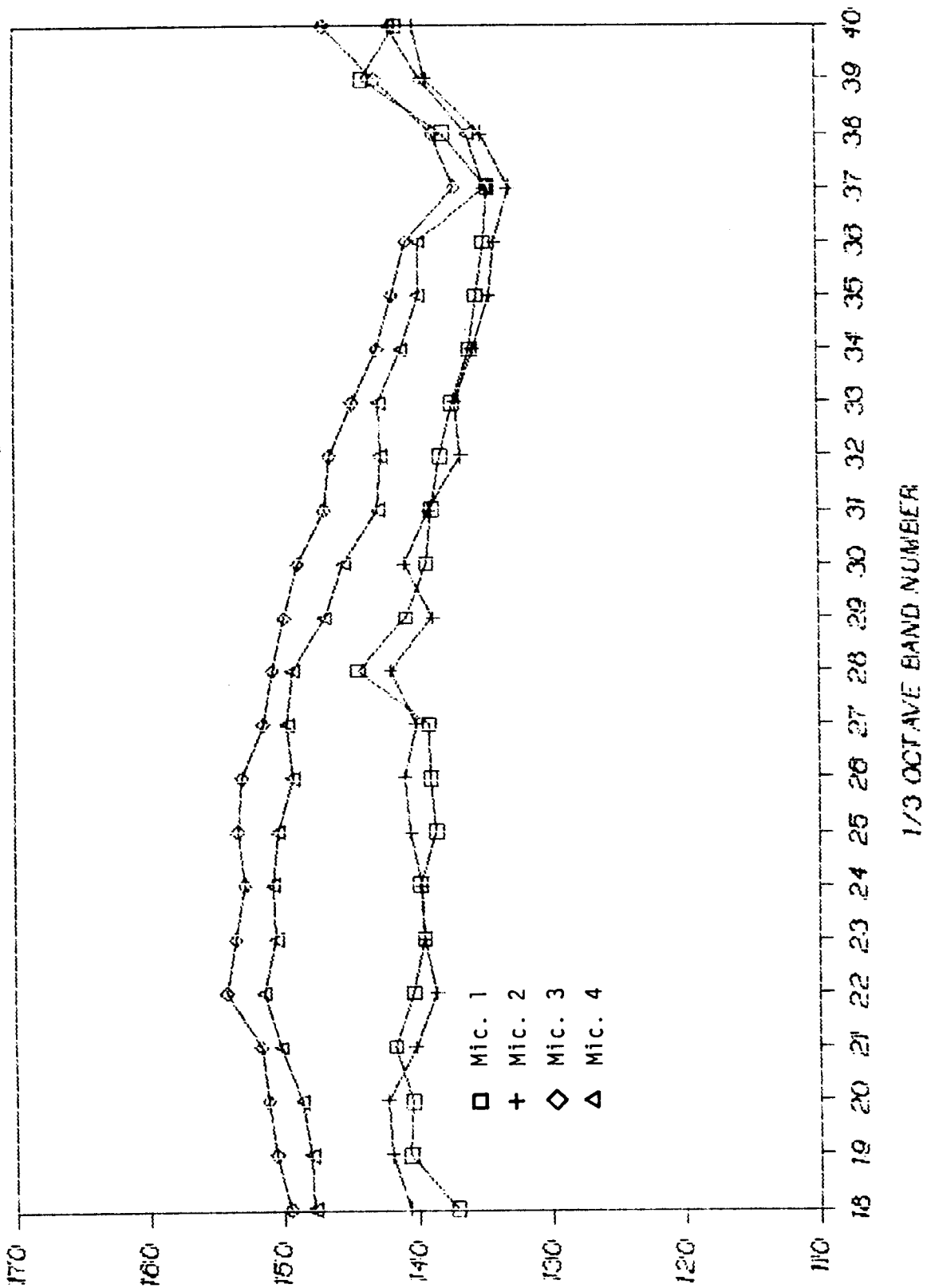
SPL, dB ret 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

Mic. 1
Mic. 2
Mic. 3
Mic. 4

38

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.8, VALVE AT 75 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCT AVE BAND NUMBER

SPL dB ref 20 mic-N/m**2

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.4, VALVE AT 90 Degree

SPL, dB ref 20 mic-N/m**2
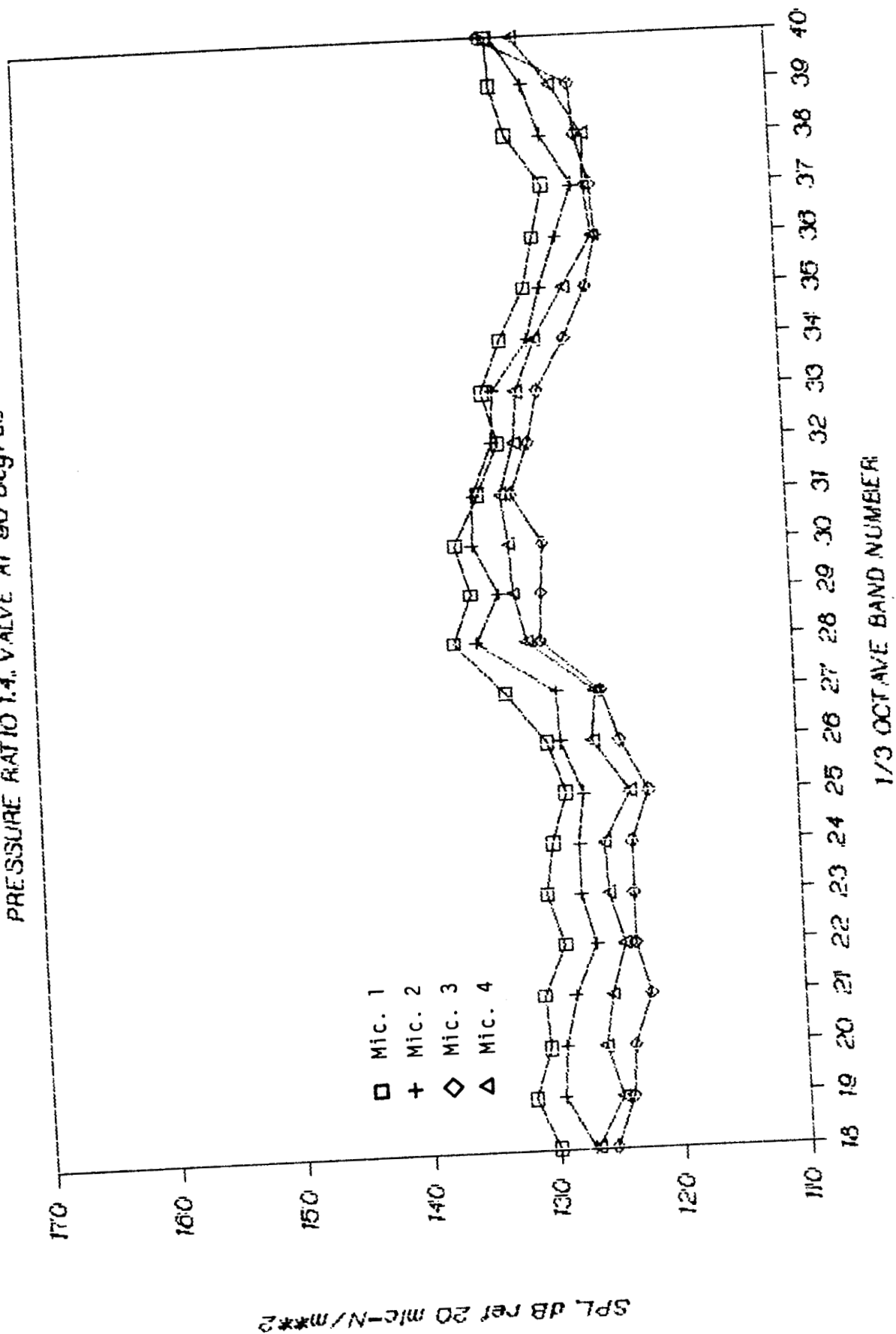
1/3 OCT AVE BAND NUMBER

□ Mic. 1
+ Mic. 2
◇ Mic. 3
△ Mic. 4

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 1.8, VALVE AT 90 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCT AVE BAND NUMBER

SPL dB ref 20 mic-N/m**2

41
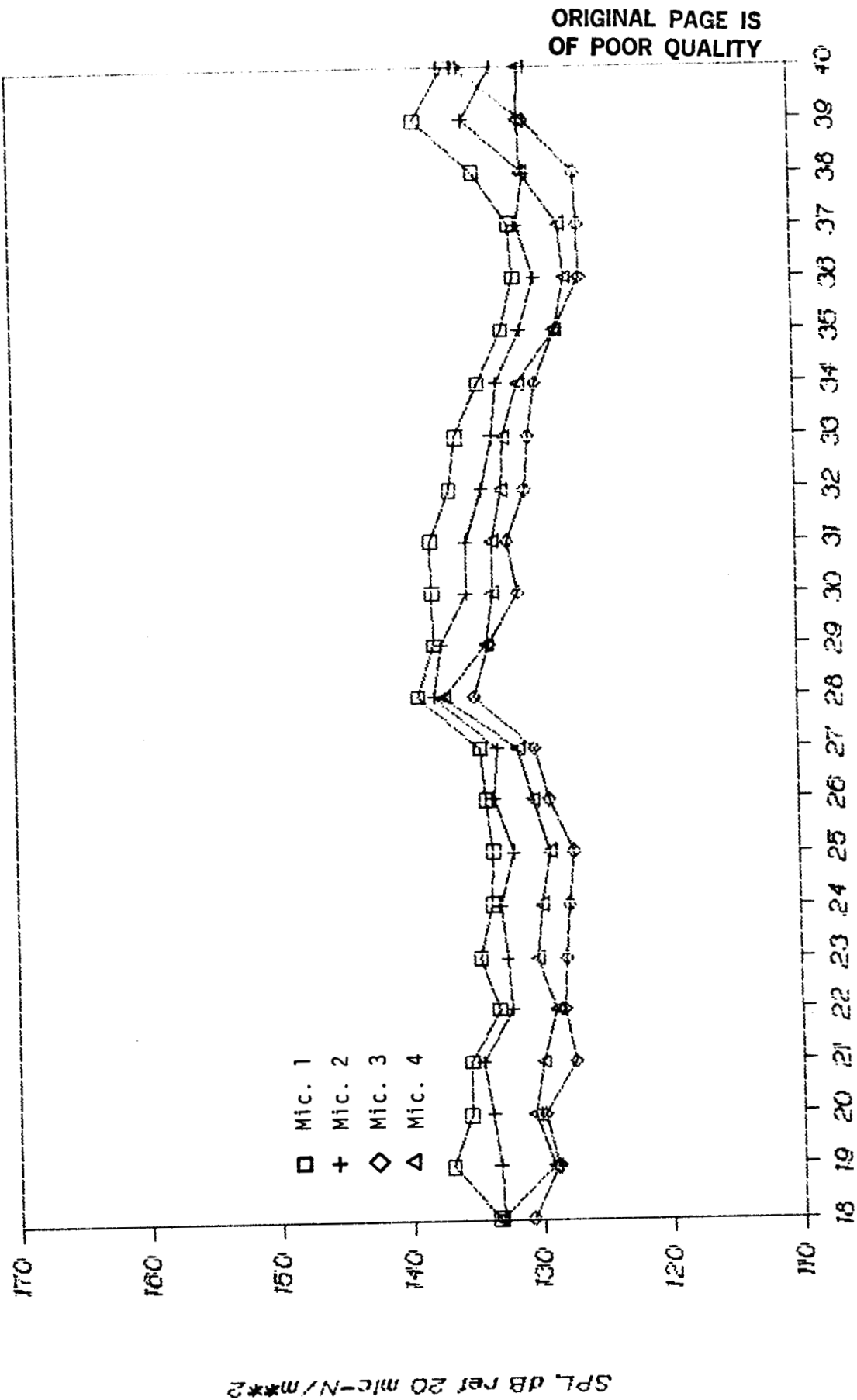
12 INCH BUTTERFLY VALVE THIRD OCTAVE

PRESSURE RATIO 2.0, VALVE AT 90 Degree
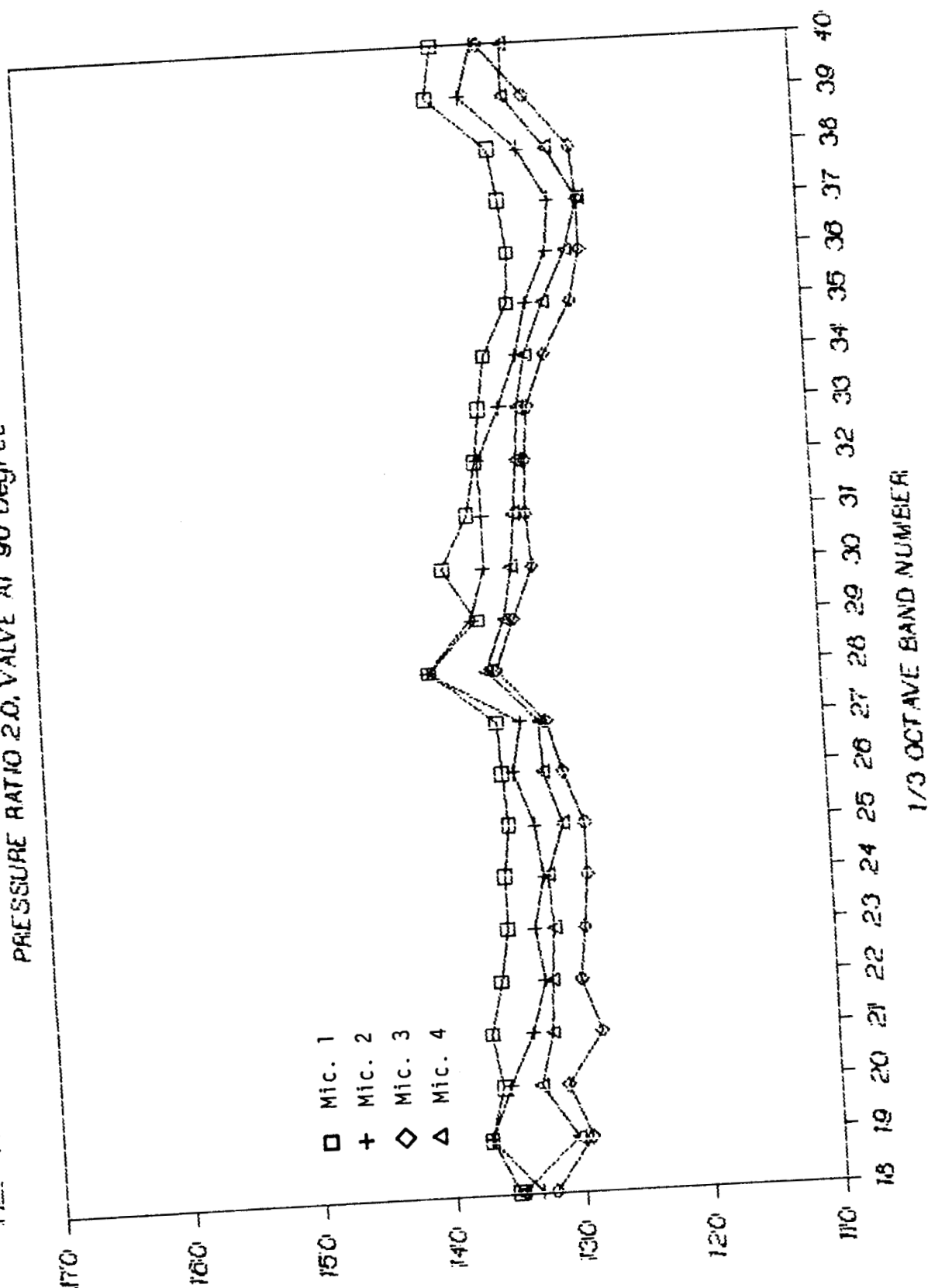
□ Mic. 1
+ Mic. 2
◇ Mic. 3
△ Mic. 4

SPL, dB ref 20 mic-N/m**2

1/3 OCTAVE BAND NUMBER

42

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.4, VALVE AT 90 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

1/3 OCTAVE BAND NUMBER

SPL dB ref 20 mic-N/m**2

43

12 INCH BUTTERFLY VALVE THIRD OCT AVE

PRESSURE RATIO 2.8, VALVE AT 90 Degree

Mic. 1
Mic. 2
Mic. 3
Mic. 4

SPL, dB ref 20 mic-N/m**2

1/3 OCT AVE BAND NUMBER

44
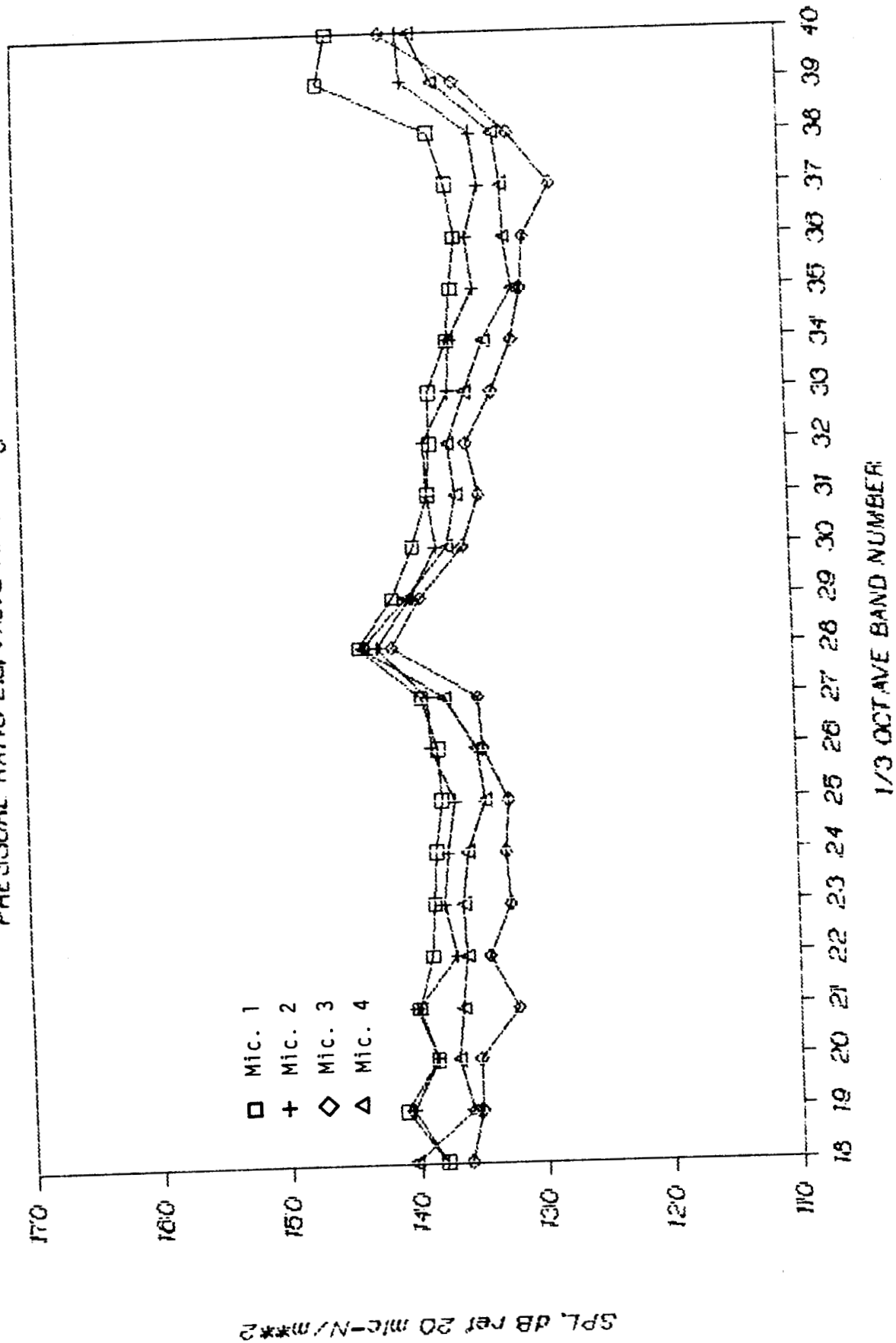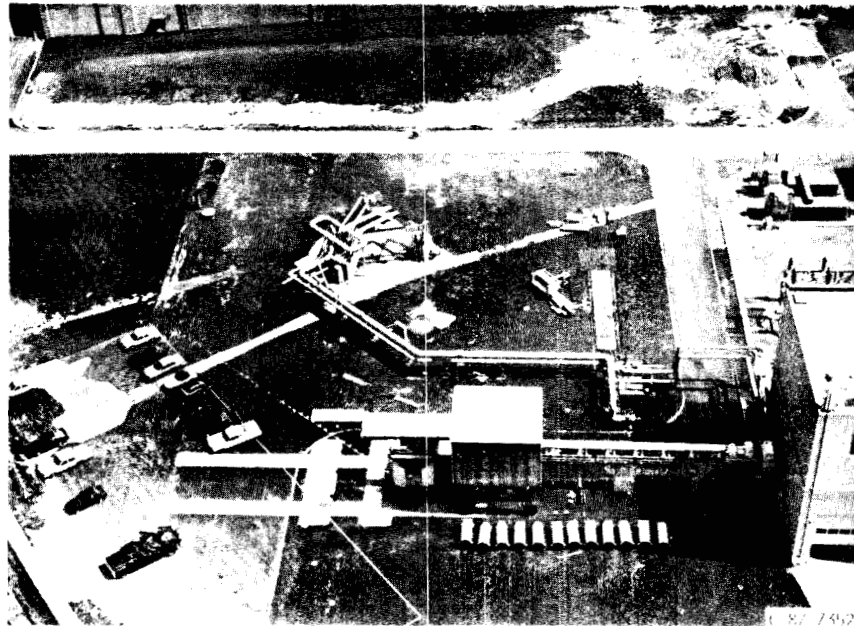
FIGURE 1. - OVERALL AERIAL VIEW OF POWERED LIFT FACILITY.
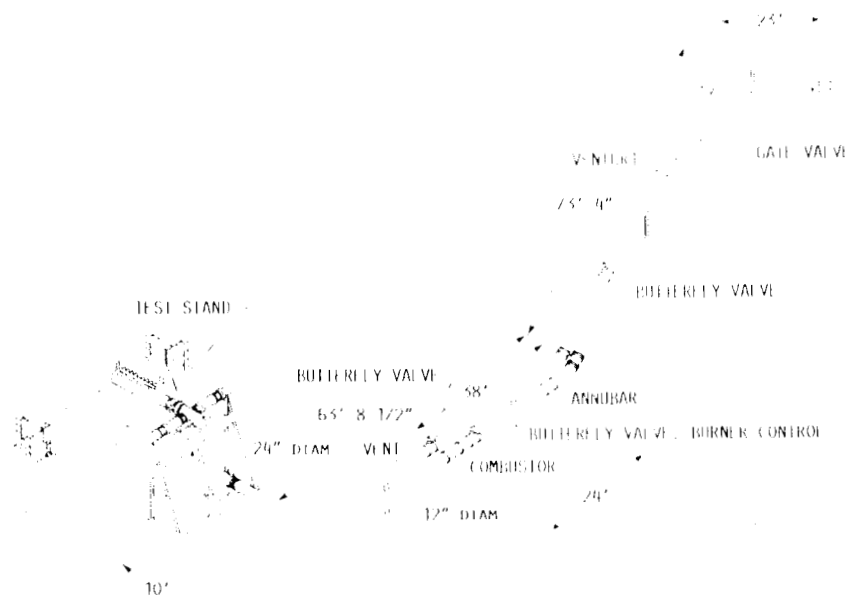
FIGURE 2. - SCHEMATIC OF POWERED LIFT FACILITY.
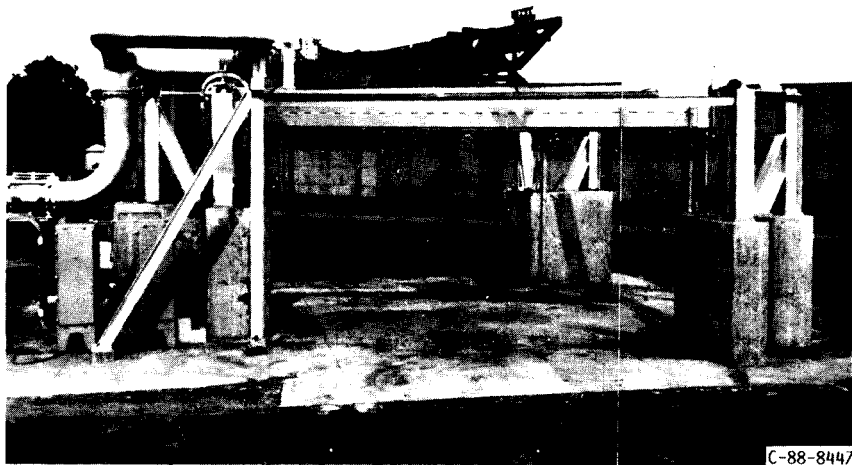
FIGURE 3. - PHOTOGRAPH OF 12 IN. VALVE TEST HARDWARE MOUNTED IN THE POWER LIFT FACILITY.
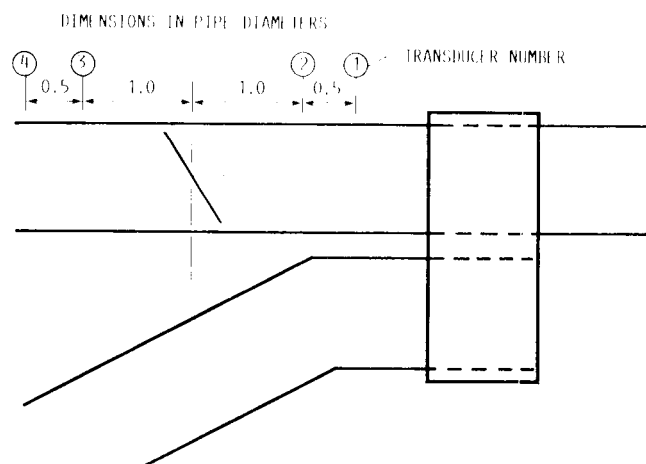
FIGURE 4. - SKETCH OF 12 IN. BUTTERFLY VALVE NOISE TEST LAYOUT AND INSTRUMENTATION LOCATIONS.
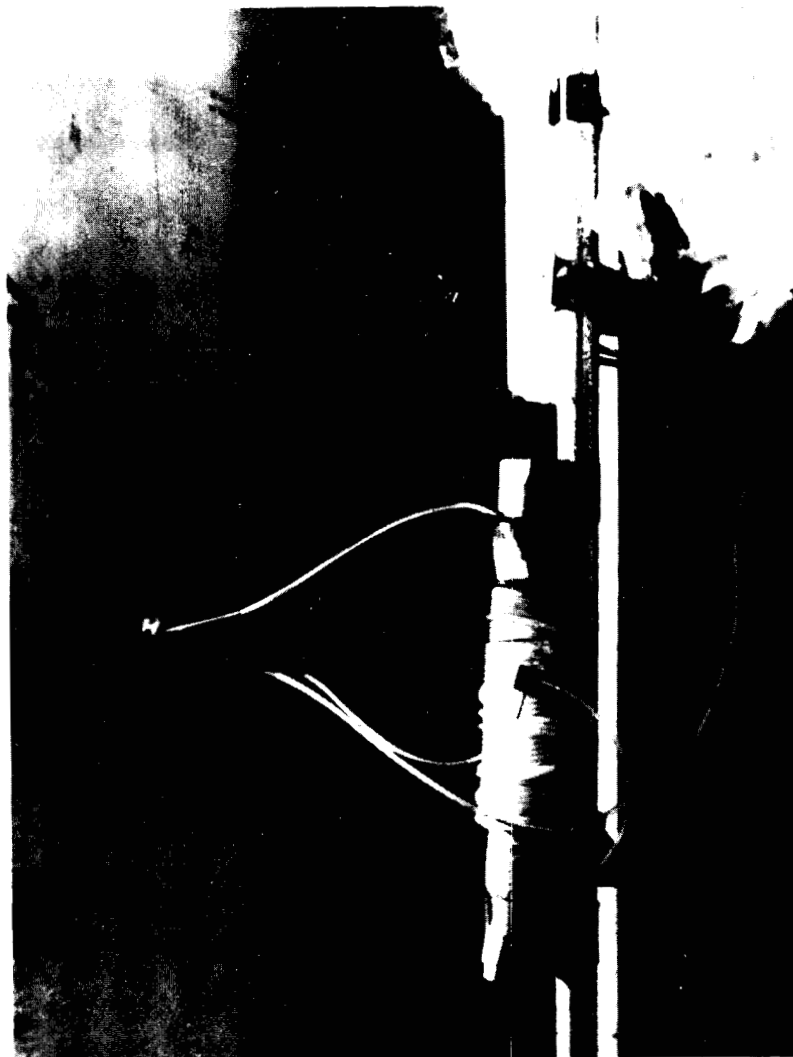
FIGURE 5. - INTERNAL KULITE PRESSURE TRANSDUCER INSTALLATION SHOWING INFINITE TUBE
REFERENCE PRESSURE CONFIGURATION.
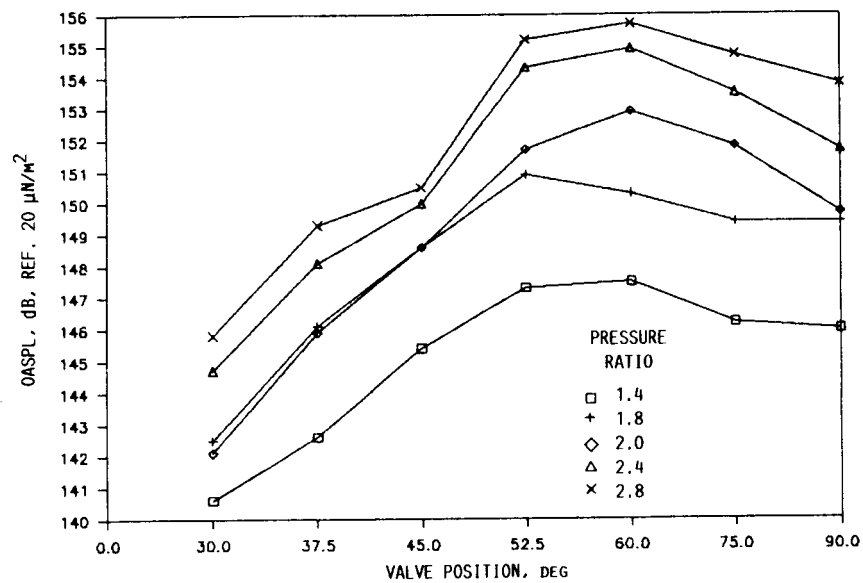
(A) TRANSDUCER NUMBER 1, UPSTREAM.

FIGURE 6. - COMPARISON OF OVERALL SOUND PRESSURE LEVEL AT EACH OF THE TRANS-
DUCER LOCATIONS AS A FUNCTION OF VALVE ANGULAR POSITION AND VALVE PRESSURE
RATIO.
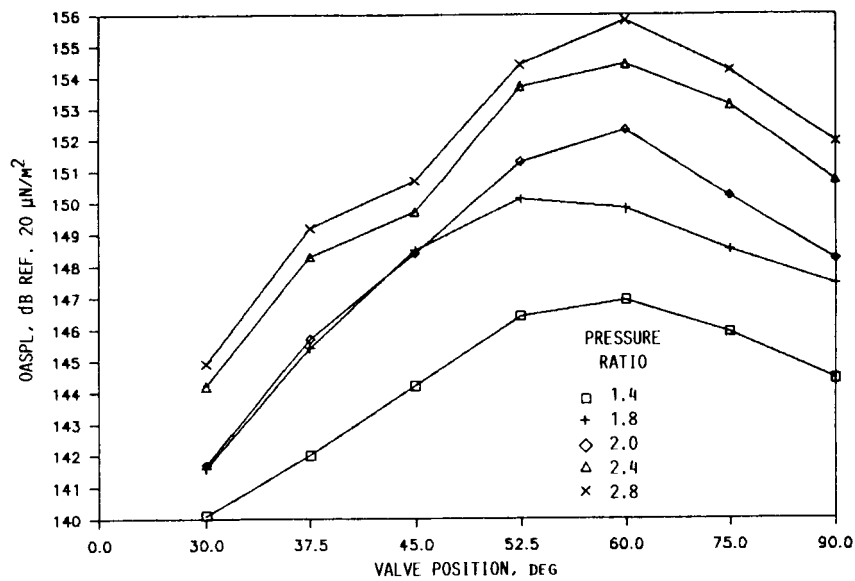
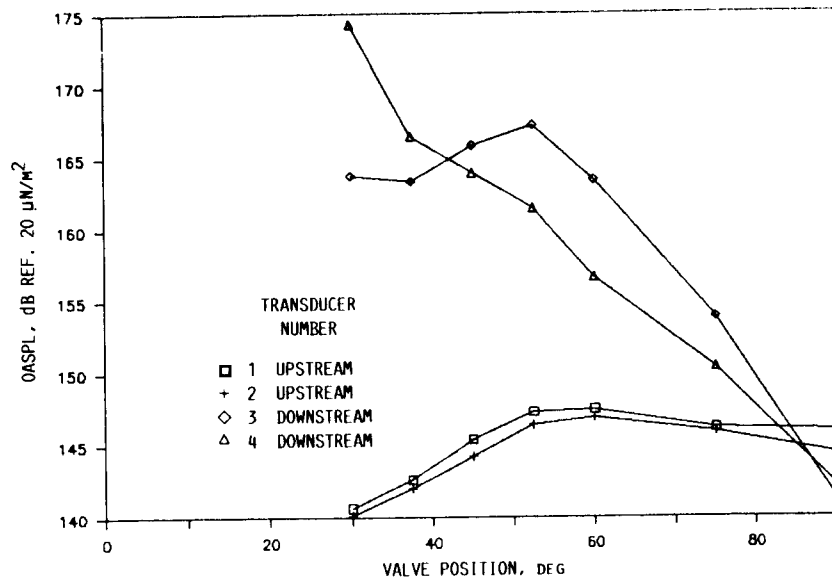(B) TRANSDUCER NUMBER 2, UPSTREAM.

FIGURE 6. - CONTINUED.
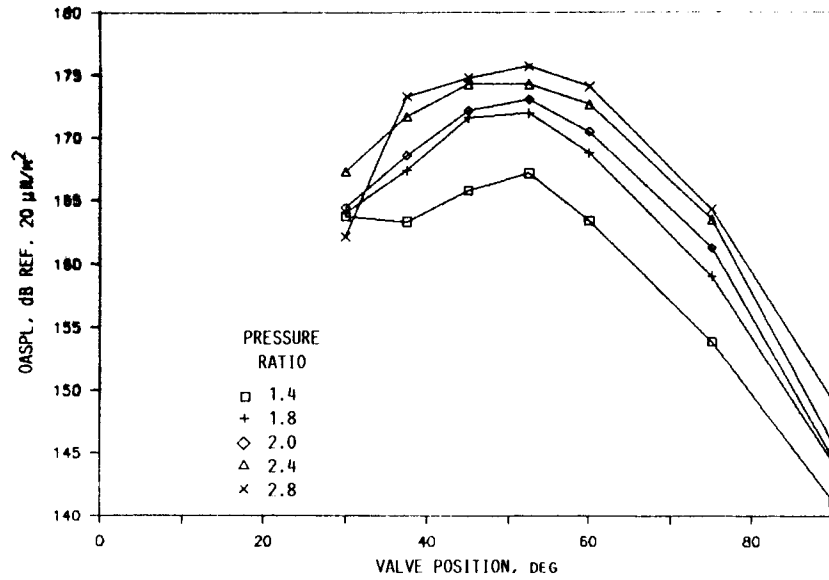
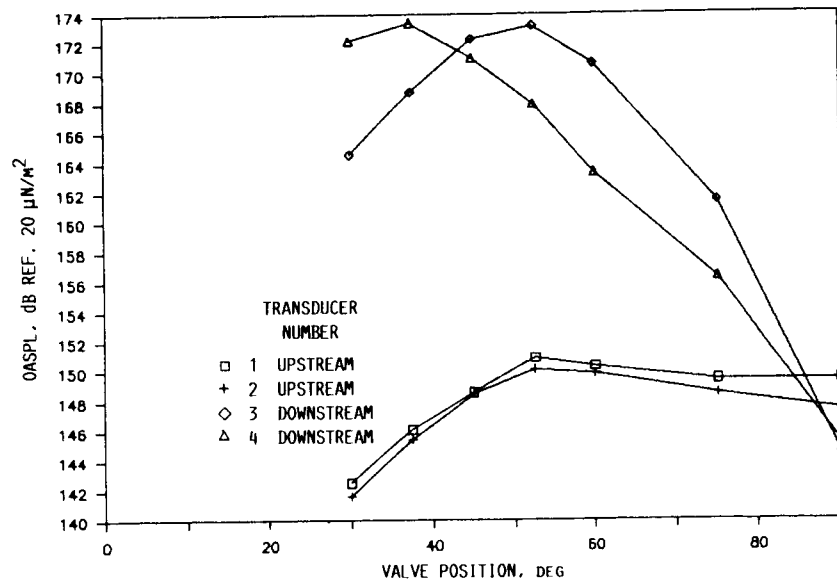(C) TRANSDUCER NUMBER 3, DOWNSTREAM.

FIGURE 6. - CONTINUED.
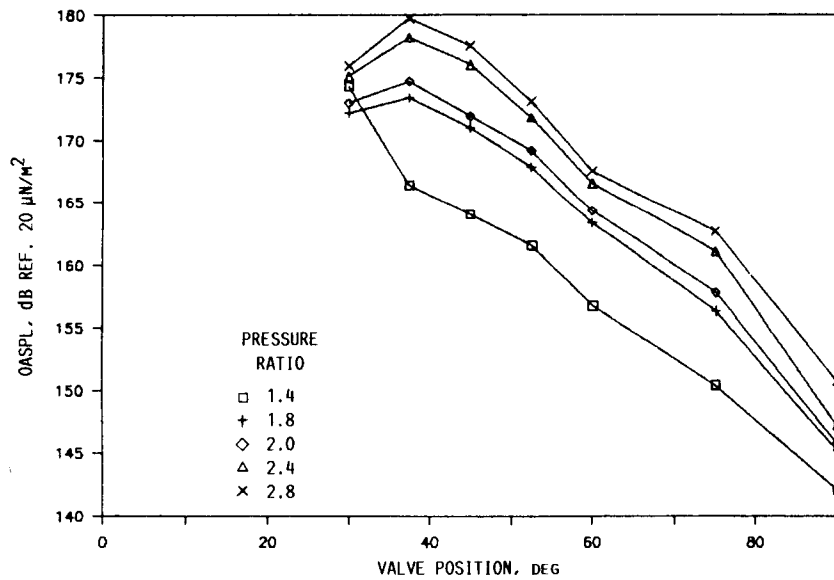
(D) TRANSDUCER NUMBER 4, DOWNSTREAM.

FIGURE 6. - CONCLUDED.
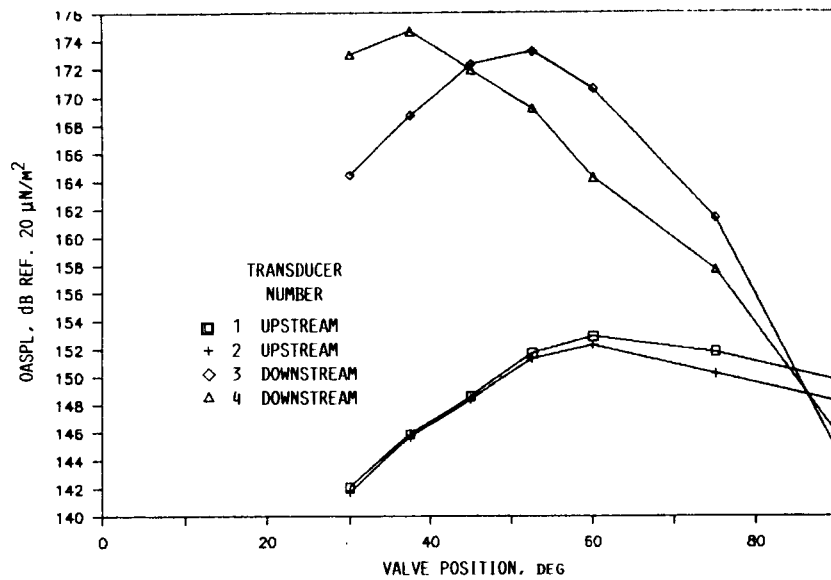
49

(A) VALVE PRESSURE RATIO 1.4.

FIGURE 7. - COMPARISON OF OVERALL SOUND PRESSURE LEVEL UPSTREAM OF THE VALVE TO DOWNSTREAM LEVEL AS A FUNCTION OF VALVE ANGULAR POSITION.
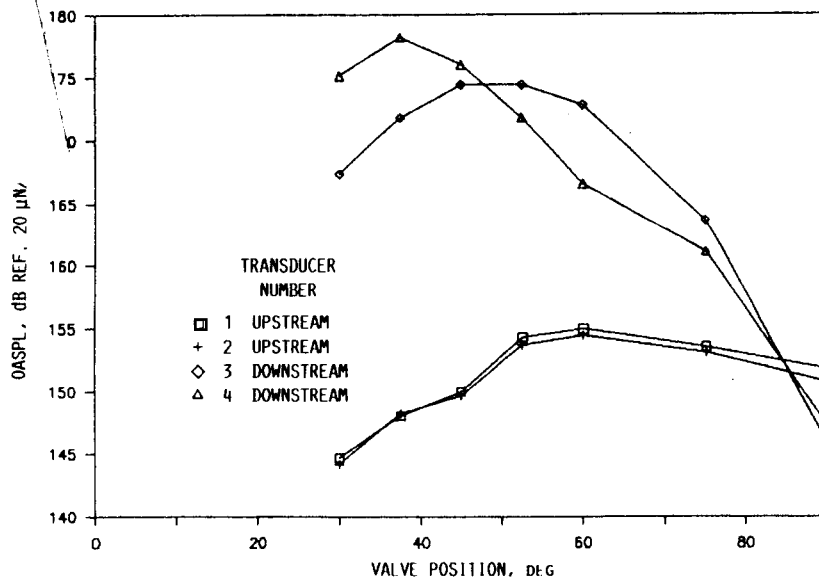

(B) VALVE PRESSURE RATIO 1.8.

FIGURE 7. - CONTINUED.

(C) VALVE PRESSURE RATIO 2.0.

FIGURE 7. - CONTINUED.

(D) VALVE PRESSURE RATIO 2.4.

FIGURE 7. - CONTINUED.
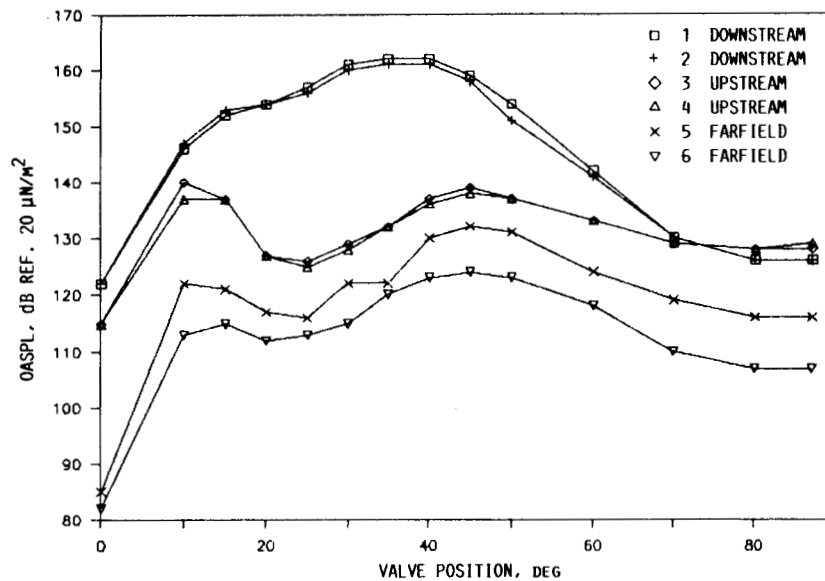
51

(E) VALVE PRESSURE RATIO 2.8.

FIGURE 7. - CONCLUDED.

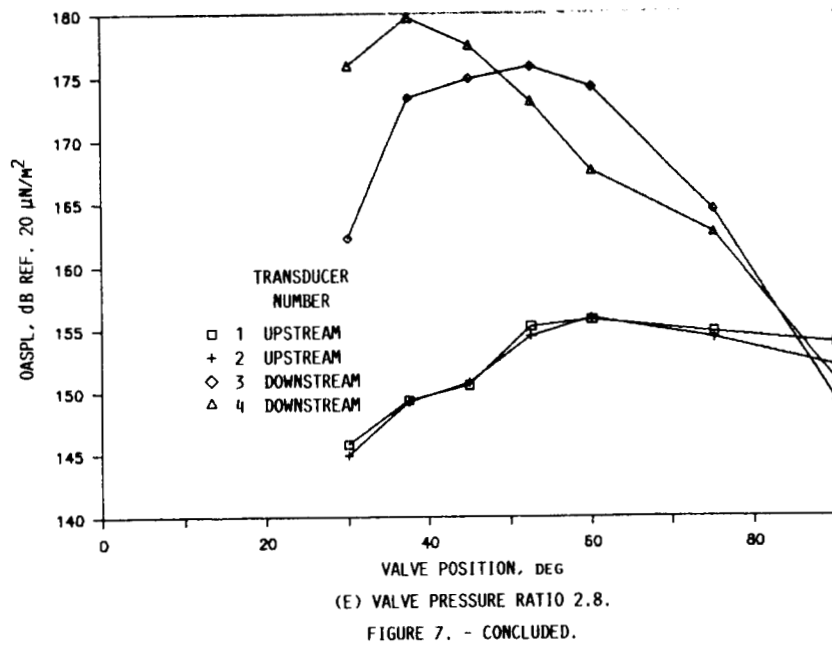

FIGURE 8. - 54 IN. VALVE, OVERALL SOUND PRESSURE LEVEL UPSTREAM AND DOWNSTREAM
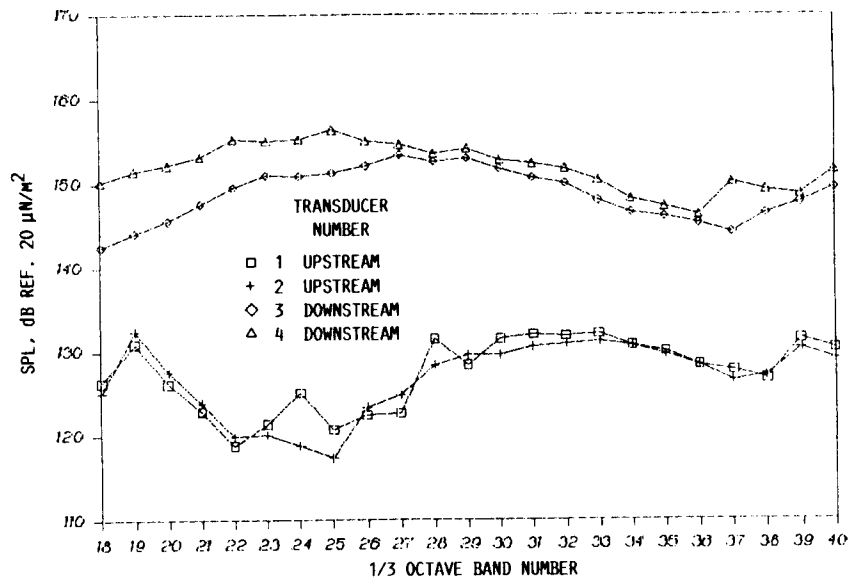OF THE VALVE AS A FUNCTION OF VALVE ANGULAR POSITION.

FIGURE 9. - TYPICAL LOW VALVE PRESSURE RATIO 1/3 OCTAVE SPECTRA, PRESSURE
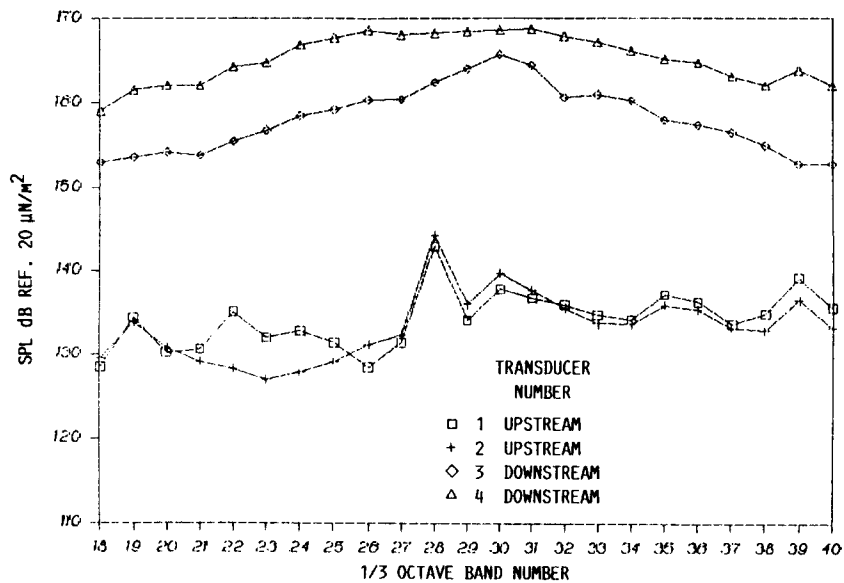RATIO, 1.4; VALVE POSITION 38 DEG.

FIGURE 10. - TYPICAL HIGH VALVE PRESSURE RATIO 1/3 OCTAVE SPECTRA, PRESSURE
RATIO, 2.8; VALVE POSITION 38 DEG.

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Report Documentation Page

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15. Supplementary Notes

16. Abstract

Tests were conducted in the NASA Lewis Research Center's Powered Lift Facility to experimentally evaluate the noise generated by a flight weight, 12 in. butterfly valve installed in a proposed vertical takeoff and landing thrust vectoring system. Fluctuating pressure measurements were made in the circular duct upstream and downstream of the valve. This data report presents the results of these tests. The maximum overall sound pressure level is generated in the duct downstream of the valve and reached a value of 180 dB at a valve pressure ratio of 2.8. At the higher valve pressure ratios the spectra downstream of the valve is broad banded with its maximum at 1000 Hz.

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