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by Richard N. Tedrick and Robert C. Polly
George C. Marshall Space Flight Center
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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MEASURED ACOUSTIC PROPAGATION PARAMETERS
IN THE MISSISSIPPI TEST OPERATIONS AREA

SUMMARY

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To investigate the propagation of sound in the Mississippi Test Operations (MTO) area, MSFC initiated a year-long study using a large exponential horn, a U. S. Weather Bureau radiosonde station, and several portable acoustic monitoring systems. Approximately 100,000 acoustic and 1000 atmospheric measurements were made during calendar year 1963. These were summarized with the aid of a large-scale digital computer to present information on the propagation, refraction, and attenuation of low frequency sound in the area.

Curves are presented showing the effects of variations in acoustic velocity gradient, humidity and wind at 40, 80, 120, and 160 Hertz (cycles per second). The persistence and repeatability of these propagation conditions were also investigated and are presented.

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SECTION I. INTRODUCTION

In the past few years, a new phenomenon in the field of acoustics has appeared; namely, the rocket engine as a major noise source. While it always has been obvious that such devices create noise, their relatively low powers excited little interest among either the public or the acoustics profession. However, since the development of large scale rockets capable of space exploration and satellite placement, the noise from such tests has become an increasing part of the planning of many areas.

During the static testing of rocket engines, the noise is quite often of several minutes duration. If then, as has occurred occasionally, the prevailing meteorological conditions are suitable for the long-range propagation of sound, it is possible to cause vibration in structures and buildings in the area. The low frequency nature of the sound has contributed to the problem through the lower atmospheric attenuation with distance. Thus, the tests generating the lower frequencies result in higher observed sound pressure levels at long ranges. Business and residential areas surrounding such static test sites have been periodically alarmed or annoyed by these tests. Therefore, in the planning of the National Aeronautics and Space Administration's new static test facility in southern Mississippi, it was decided early that the effects of such sound should be thoroughly investigated. It was hoped to make the most efficient use of the surrounding buffer areas

and of the prevailing winds and other climatological conditions so that sound generated during the static testing of very large boosters (possibly up to 30 million pounds of thrust) would not have deleterious effects upon either other missile test stands or the surrounding communities which would certainly grow up around this new facility.

Many researchers [1 through 5] have examined the attenuation of sound in air. This is, for free-field acoustics, almost the basic experiment. However, there has been a wide range of values reported [6]. The attenuation rate has been found mainly to be dependent upon frequency, terrain, ground cover, and prevailing meteorological conditions. It has also been found to be different for ground-to-ground transmission and air-to-ground transmission. With the exception of the latter, none of these parameters is variable within the control of the acoustician for a given rocket test. For this reason it has always been difficult to separate and identify the effects of each of them. However, it was necessary to accurately estimate the acoustical effects of static firing in the Mississippi Test Operations (MTO) area. For this reason, a large-scale program was initiated to measure sound pressure levels and to correlate them with variations in the basic parameters.

SECTION II. BACKGROUND

The terrain in the MTO area is exceedingly flat, being in the Mississippi River delta area. It approaches the idealized infinite flat plane more than almost any other land area within the continental United States. The ground is rather spongy and at present is densely covered with trees and undergrowth.

To simulate the spacing of the booster above the ground plane, an artificial noise source was mounted atop a 60-foot tower. The source and tower chosen had been previously built and tested at the Marshall Space Flight Center in Huntsville, Alabama (Fig. 1). In the fall of 1962, this installation was dismantled and shipped to the Mississippi Test Operations site.

The noise source consisted basically of four electro-pneumatic transducers which were paralleled into an exponential horn for coupling of the acoustic energy to the atmosphere. Because of the physical limitations inherent in the construction and operation of such a horn, the designed lower frequency cutoff was 30 cycles per second. This fixed the dimensions of the horn at 12.5 feet in diameter at the mouth and 25 feet in length. The power output of the horn and transducer combination was found to be between five and seven kilowatts of acoustic power. This noise source was regularly heard for about nine kilometers and, under some meteorological conditions, as far as 35 kilometers.

It was necessary to look at the data statistically because of the large volume collected. Well over 100,000 acoustical and 1000 atmospheric measurements were made during the period from January 1 through December 31, 1963. For the attenuation portion

of this report, the acoustical data used were restricted to those taken within the first three kilometers. The reason for imposing this restriction was that beyond the three kilometer point only data taken under favorable meteorological conditions were sufficiently above the ambient background noise level. This condition tended to weight any averages or mean values which were calculated using that data. Within the three-kilometer range there were somewhat over 29,000 measurements sufficiently (10 decibels or greater) above the background noise to warrant their usage.

Since the sound from the static test of large rocket vehicles has a rather broad spectrum peaking below 200 cycles per second [7], the horn and transducer combination was operated below that limit. As mentioned previously, the physical dimensions of the horn provided a lower limit of 30 cycles per second. However, severe vibrations were encountered in the horn and tower structure as that limit was approached. Therefore, it was decided to use four discrete frequency tones: 40, 80, 120, and 160 Hertz (cycles per second).

Unlike many previous attempts at measurements of such phenomena, it was decided early in the planning of this program to obtain the services of a team of meteorologically-trained personnel so that complete atmospheric data could be taken. Balloon-borne radiosonde measurements were made during each test sequence and these data were used to calculate acoustic velocity gradients as functions of attitude above the surface. The meteorological data taken were temperature, relative humidity, wind speed, and wind direction from the surface to above four kilometers.

For this report, the acoustical data were analyzed as possible functions of the mean velocity gradient, of the mean relative humidity, and of the mean wind speed. This was accomplished with the use of a high-speed computer, the General Electric Company 225. Figure 2 shows the statistical distribution of the acoustic velocity gradients at the Mississippi Test Operations during the calendar year 1963. Also shown in this figure is the idealized Gaussian distribution which one might expect to have occurred. As can be seen, the distribution appears to be weighted somewhat around the zero gradient. This is to say that the extremes of such gradient conditions occurred more rarely. This figure is included to demonstrate the slight variation from the statistical ideal which the Mississippi data sampling represented. In fact, the mean velocity gradient for the year's data was found to be -0.004 foot/sec/foot. This indicates that the temperature distribution with altitude generally follows the adiabatic lapse rate. The data were taken during all types of weather; and, as a result, this study represents as nearly as possible the whole range of conditions under which static testing might occur.

SECTION III. ACOUSTIC PROPAGATION DATA

The velocity of sound gradient was calculated for only the first 300 meters of altitude for purposes of this one portion of the study. The sound was monitored manually with commercial sound level meters at 183 meters range and beyond. The 183-meter reading was used to normalize the horn output. The deviations from the classical inverse square law at the further ranges (366, 732, 1542, and 3048 meters) were noted. The next sixteen figures (Figs. 3 through 18) show the measured atmospheric response for different frequencies for these ranges. "Response" means the variation above or below the calculated inverse square law sound pressure level value. Thus a negative response is the same as attenuation. In each figure, a calculated mean is shown, and above and below is shown the statistical standard deviation of the measured acoustic data.

Upon examination of these 16 figures, it is seen most readily that the positive portion of the mean response curve is constant. However, the negative portion of the mean atmospheric response curve has a decided slope. The implications of this are (1) that when the static test is made under the condition of a positive velocity of sound gradient, the deviation at a particular point from the inverse square law value is constant for a given frequency, and (2) for negative gradients the attenuation is also a function of the velocity of sound gradient. These effects were apparent to earlier investigations [8 and 9]. However, it is the purpose of this report to more clearly delineate the actual numerical relationships which exist.

The study also pointed out the effect of varying frequency. In Figure 23, the variation in negative response (attenuation greater than inverse square law) with range is shown. Quite obviously, for zero or positive gradients the effect of range is linear for a given frequency. The lower frequencies approach inverse square law propagation due to the lower attenuation of the acoustic energy.

In Figure 24, the negative portions of the atmospheric response curves are represented. This figure demonstrates that as the lower frequencies approach the inverse square law propagation, the slope of the response curve changes. It shows that increasing frequency and increasing range each have the effect of increasing the deviation from the inverse square law. With the data in this form, it is possible to estimate the atmospheric response curves for other frequencies and ranges within a single-layered, homogeneous atmosphere.

The velocity of sound gradient with altitude was not the only atmospheric parameter against which it was possible to correlate the measured sound pressure levels or the excess attenuation. Without attempting a detailed analysis such as Dr. Cyril Harris [8] and others have performed, it was possible to examine the gross effects of relative humidity upon the measured sound pressure levels. This effect is shown in Figure 25.

The correction which could be made to a predicted sound pressure level (predicted from the above presentations and discussion) upon the basis of a particular gradient and its meteorological causes is illustrated.

In Figure 26, the acoustical data are shown as functions of mean wind speed, again broken into only very large categories. The data very definitely show trends which are important in the calculation of the sound pressure levels which might be expected to result from a static test. One of these is the increase in observed sound pressure level with increasing wind speed. This is the result of diffusion of the acoustic wave fronts by gusts in the higher speed winds as shown by Pridmore-Brown and Ingard nearly a decade ago. The effect of the wind (at least in the low frequencies used in this program) was insensitive to change in frequency.

The corrections which are shown for mean wind speed really result from variations in the amount of attenuation which this phenomena contributes to the total. The positive corrections should not be assumed to mean or to infer that there is an amplification or magnification at some value of wind velocity. They simply have reference to the mean response curves shown in earlier figures. The resultant mean attenuation as a function of frequency for the particular test area and time is not at all unreasonable when compared to those others published for similar circumstances of climate and propagation path [5 and 10]. The values are higher than those found using this same equipment in an identical installation in Huntsville, Alabama, in 1962 [5]. However, it is also considerably lower than some attenuation reported for areas with dense vegetative cover [11]. In view of the large amount of vegetation in the MTO area in southwestern Mississippi, this appears to be a reasonable set of values.

SECTION IV. REFRACTIVE EFFECTS

To complete the investigation of the measured acoustic propagation parameters in the Mississippi Test Operations area, it was necessary to investigate the total velocity gradient distribution with time [12]. This was necessary because the sound pressure levels which would be experienced by civilian communities and military and governmental installations at ranges beyond three kilometers would be dependent upon the amount and type of atmospheric refraction which the sound energy experiences [5]. This refraction, in turn, is dependent completely upon the velocity of sound distribution with altitude. This distribution, or profile, is calculated similarly to the velocity distribution used in the first section of this report. However, because of the longer ranges involved in this portion of the investigation, it was necessary to calculate the velocity of sound profile to altitudes beyond four kilometers. Because the wind is a vector quantity, the velocity of sound profile varies with azimuth. The azimuths chosen for investigation in this report were those through the three major population centers around MTO (Bay St. Louis, Slidell, and Picayune). These azimuths were 103, 135, and 342 degrees, respectively.

For convenience sake, it was necessary to divide the acoustic velocity profiles into six categories (Fig. 28). The first of these is the 0 or no characteristics profile type. This profile, while relatively rare in nature, is that which is most often assumed in the theoretical calculation of the effects of large noise sources. Thus while neither the wind nor temperature may be individually single-layered or homogeneous, their vector sum occasionally may be. Category 1 profile causes the sound to be refracted up and away from the earth's surface. Types 2, 3, and 4 give generally similar increases in overall sound pressure level adjacent to or near the test site. Type 5, with its negative gradient near the surface with a strong positive gradient above that, results in a shadow zone near the test area and a focal zone at some distance, usually in the 2 to 12 kilometer range. It may be seen that there would be no intensification or focusing of acoustic energy with profile types 0 or 1. However, categories 2, 3, 4, and 5 return rays to the earth's surface. In Table I, the average intensification in the focal zone for each profile type is presented in decibels. This intensification is defined as the quantity or amount of sound in excess of that which was found to occur during the 0 condition. By defining intensification in this manner, it is possible to separate the effects of refraction from other atmospheric variables.

As seen in Table I, the category 2 velocity profile type tends to increase the sound pressure level by 6 to 7 decibels out to a range of approximately 12 kilometers. The few measurements made beyond that range show a decline in the intensification resulting from this profile type. In general, it might be said that there is an indication that the stronger intensification from profile 2 takes place near the source and a gradual decline in effect results from increasing range. Profile type 3 shows that a maximum sound pressure level occurs in the range from 12 through 18 kilometers. This is probably due to the characteristic meteorological conditions which cause the category 3 profile type to occur in the area around the Mississippi Test Operation. Type 4 profiles show a marked increase with range in the measured sound pressure level as does the category 5 profile type. Since category 5 is prevalent quite often during the year, this is of major importance in site planning in the Mississippi area.

Table II shows the number of times that intensification of acoustical energy is within specified intervals of range and sound pressure level for each profile type (2, 3, 4, and 5). Table IIA shows these data for the condition 2 profile. There were 2500 separate acoustic measurements taken under condition 2 profiles. The number taken at each of the range points and the associated measured increase in sound pressure level over the 0 category measurements are shown. Tables IIB, IIC, and IID present similar data for the 3, 4, and 5 profile conditions.

Until now it has not been necessary to consider the effects of variation in either time of day or season in the observed acoustic propagation characteristics. However, an understanding of the effects which might be experienced from the static firing at MTO of a high-thrust booster must include both diurnal and seasonal variations in the relative probabilities of the aforementioned conditions. In other words, for a given azimuth and for a given time of day the likelihood of a particular profile type occurring varies from

month to month. Similarly, with a given test configuration of booster stand and stand orientation (which itself determines the azimuth of prime consideration), there would arise the question of the optimum time of day for firing during that month. Such information is given in Table III. The occurrence of each of the six profile types is given in percentage of frequency of occurrence for morning, mid-day, and afternoon balloon measurements.

In the actual firing situation, the tables and graphs in this report allow the practicing acoustician to fairly judge the acoustical effects which might be anticipated from such a test. Certainly, however, the author does not intend to infer that under a given set of conditions for time and azimuth that it is not feasible to attempt certain classes of test firings. On many days during even the worst period of the winter there are short time spans during which a test of nearly any magnitude might be safely attempted. One measure of this is what is known as persistence. This is the probability that the condition, whatever it may be, is likely to continue through a given later time span. Tables IV and V present the complex acoustic persistence which was measured in the Mississippi Test Operations area. The acoustic profile category which was measured at 9 o'clock was again tested at the 12 o'clock balloon measurement. The percentage of those 12 o'clock measurements which repeated the 9 o'clock profile type is shown in Table IV. In the afternoon, another balloon run was made and these data were again tested to see if it still agreed with the 9 and 12 o'clock profile categorization. This percentage is shown in Table V. Quite obviously if the profile type in the afternoon was not the same as both the earlier runs it was not counted toward the afternoon persistence percentage. As can be seen from these tables, the complex acoustic persistence in the Mississippi Test Operations area was quite high over the three-hour period. However, it fell to approximately 50 percent in most cases for the six-hour test. This, then, demonstrates what was found to be true for the MSFC-Huntsville area, namely, that acoustic propagation characteristics are relatively short-lived. The prevalent meteorological conditions may generally appear to remain constant over longer periods, but the complex nature of the acoustic velocity profile makes it quite susceptible to minor variations in its atmospheric components.

There is a modification of the persistence technique which is occasionally used in the preparation of rough atmospheric forecasts. This technique judges the repeatability of atmospheric conditions from day to day at the same time of day. In other words, taking the conditions at a given time on Monday (for example) and predicting those identical conditions for the similar time in succeeding days. In many tropical and oceanic areas this technique is used with a fairly high degree of reliability. While southern Mississippi is not in the tropics, it does appear to have a very definite pattern of repeatability. This is shown in Table VI. In this tabulation, the percentage of consecutive days which have the same profile types at a given time of day is shown. These data are presented both by month and by azimuth. Thus, while in a random process the repeatability of any one of the six velocity profile types might be considered to be approximately 20 percent, in nearly every instance the measured repeatability was found to be from

about 45 percent to 100 percent. The yearly averages are also given in Table VI. These range from a low of 53 percent to a high to 70 percent.

Both the acoustic persistence and acoustic repeatability, which are referred to in this report, are more complex than those similar terms used in the field of meteorology and climatology. Since the acoustic velocity profile is a quantity derived from meteorological or atmospheric parameters, it is, however, related in all probability to the persistence of some one or more quantities. However, the author has not attempted for this report to separately evaluate those atmospheric quantities or their persistence.

SECTION V. CONCLUSIONS

The data which were taken during this program show the dependence upon the meteorological conditions of the propagation of low frequency sound. Specific values have been assigned by this program to the attenuation which can be expected in the Mississippi Test Operations area under meteorological conditions ranging from the very worst to some of the very best. The effects upon attenuation rates of changes in the acoustic velocity gradient and the mean wind speed have been noted and have been established numerically. The effects of changes in these parameters have been documented at four low frequencies in the free atmosphere.

Great care should be exercised in attempting to use these numerical values for other climates, ground cover areas, and source height. The effects of the vegetative covering and of the topography have only been intimated and considerable additional information will be required over the next few years to ascertain these effects quantitatively. The Mississippi Test Operations lends itself quite well for this further investigation of the effects of vegetative cover since it will be systematically denuded as new facilities and residential areas are built. Where this was by nature a deciduous rain forest, it shall be rapidly converted into an industrialized and urbanized region. As this is done, it may be expected that the attenuation rate and propagation characteristics will change somewhat. It is hoped that the documentation of this year's program in this report will lay the foundation for further investigation.

The first statistical investigation into the relative occurrence of focusing conditions in the Mississippi Test Operations area has now been made. As in most areas which have been similarly investigated, it was found that a high percentage of the days during any month might be expected to contain some period of focusing or intensification of sound. This condition in the MTO area was found to be especially severe during the winter months; however, it was shown that the persistence of such conditions was not of long duration. The day to day repeatability of profile types at a given time was found to average greater than 60 percent.

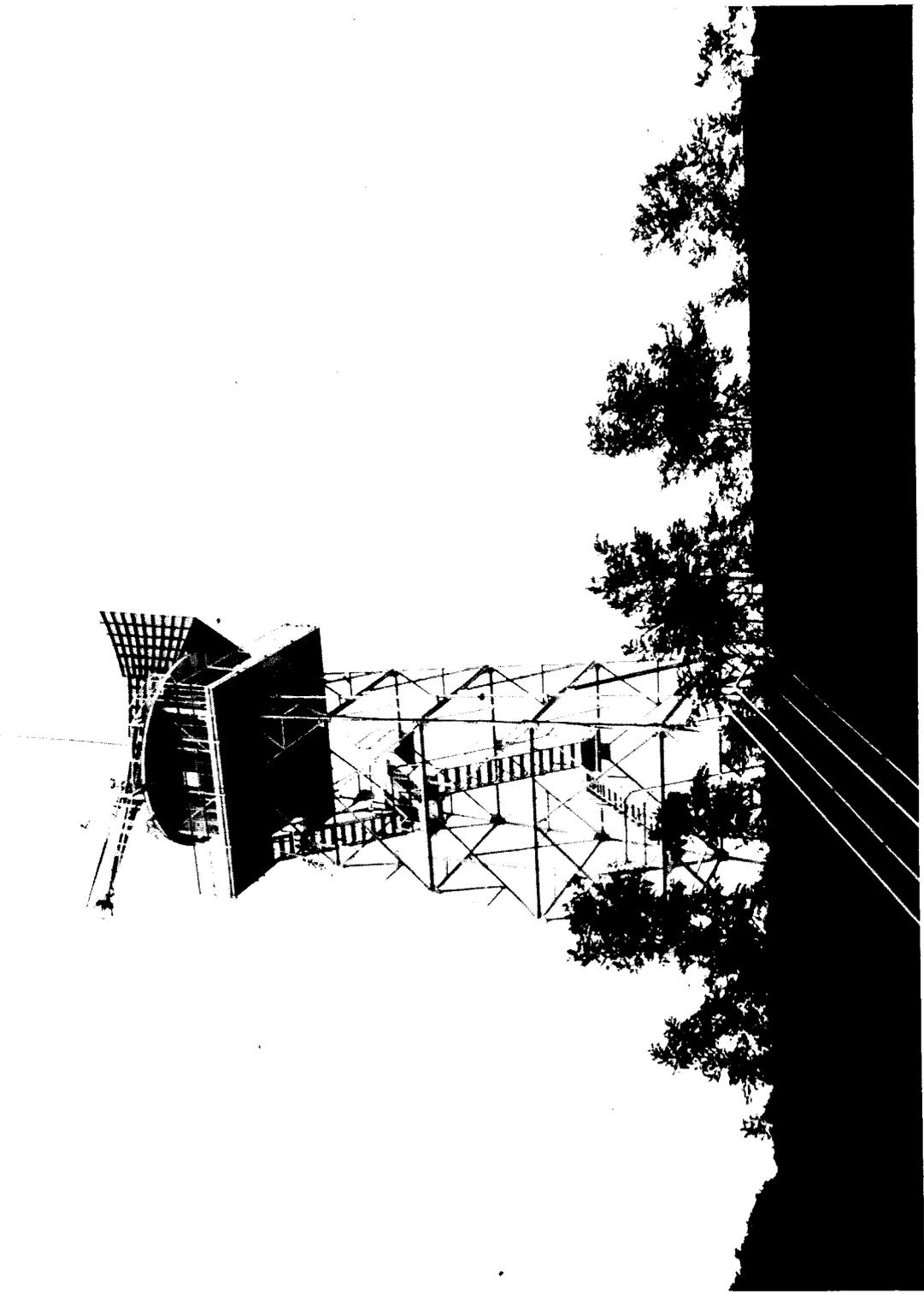


FIGURE 1. ARTIFICIAL SOUND SOURCE MOUNTED ATOP A 60-FOOT TOWER

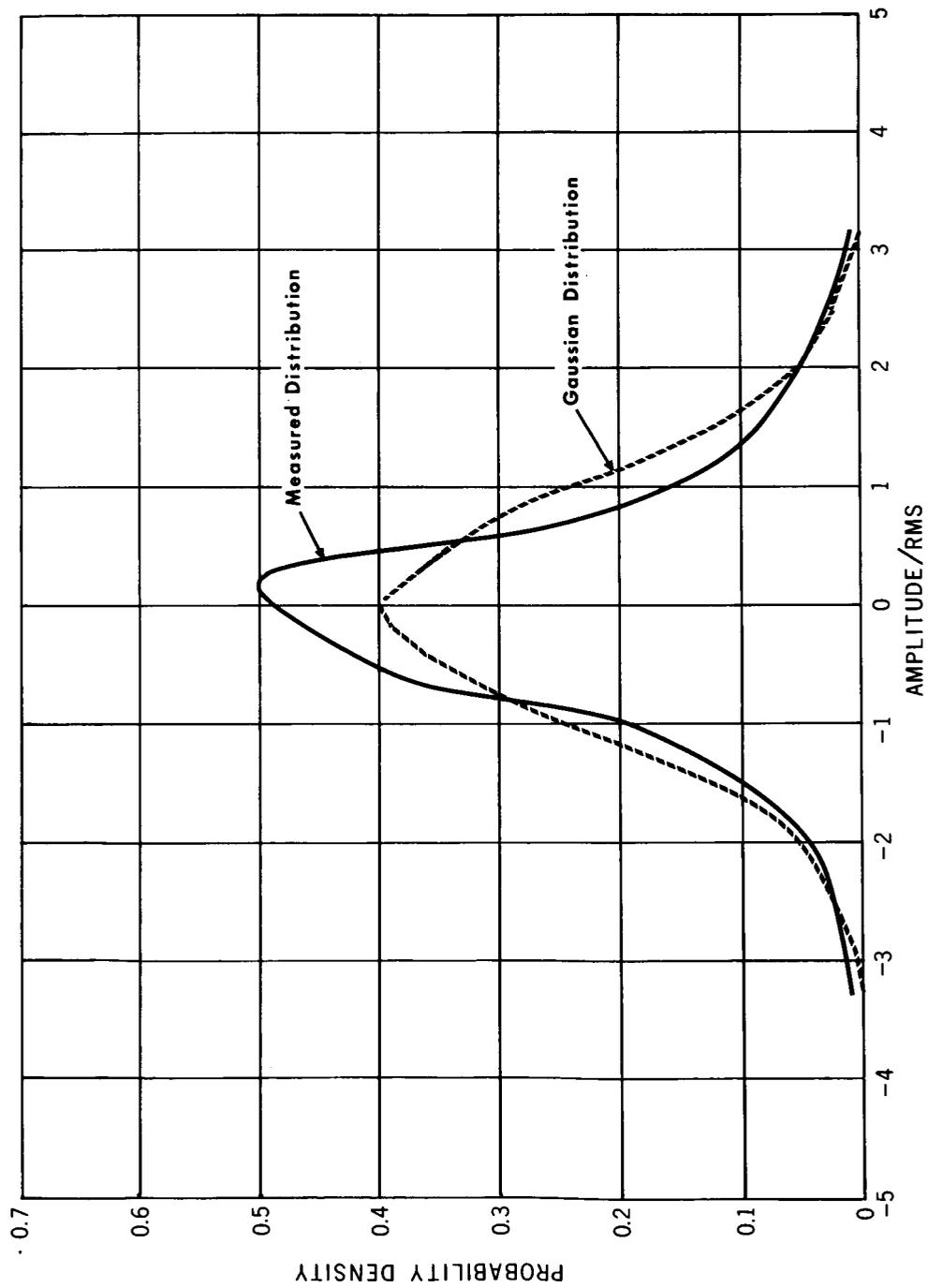


FIGURE 2. STATISTICAL DISTRIBUTION OF ACOUSTIC GRADIENTS AT MTO DURING 1963

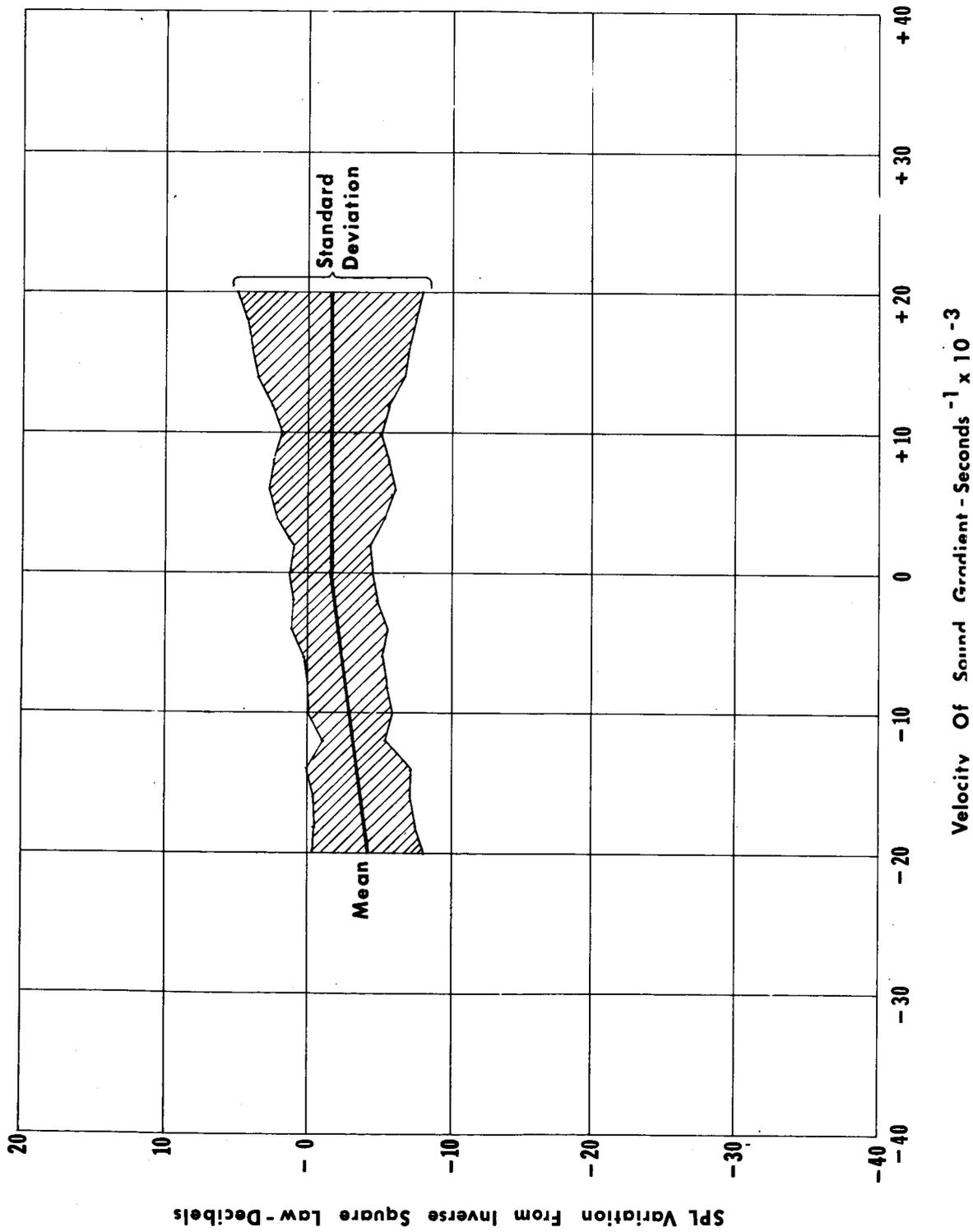


FIGURE 3. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 40 HERTZ AT 366 METERS RANGE

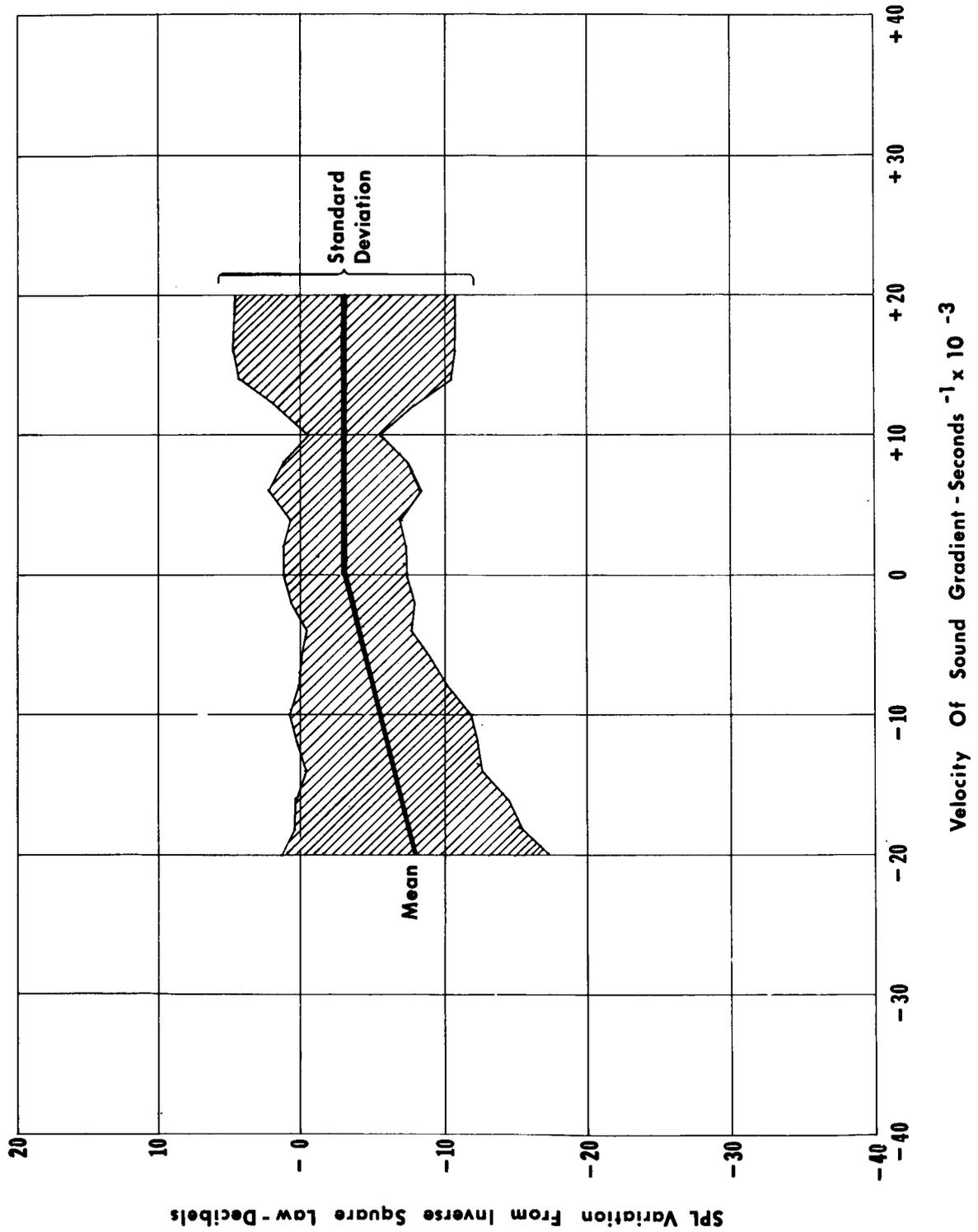


FIGURE 4. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 40 HERTZ AT 732 METERS RANGE

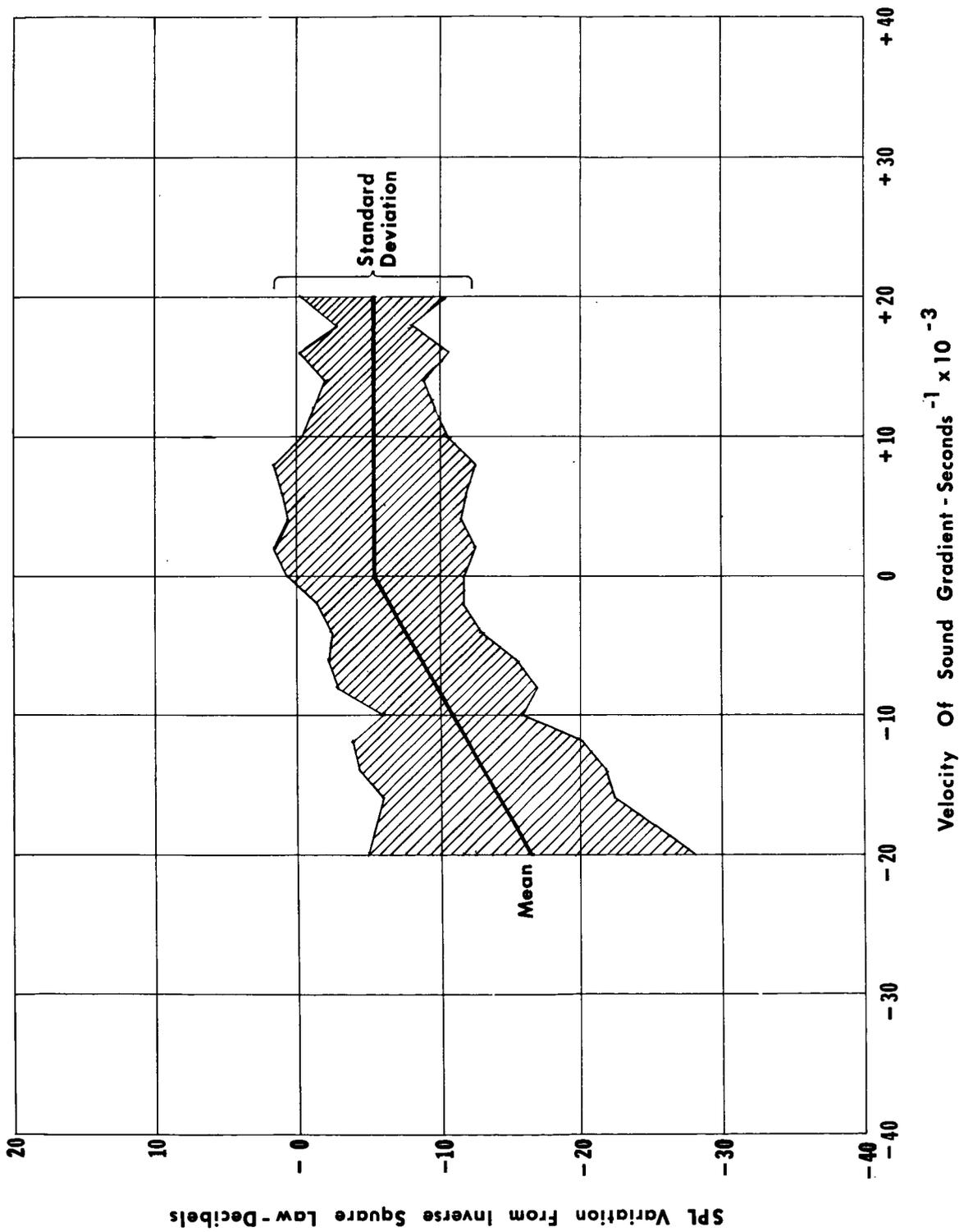


FIGURE 5. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 40 HERTZ AT 1524 METERS RANGE

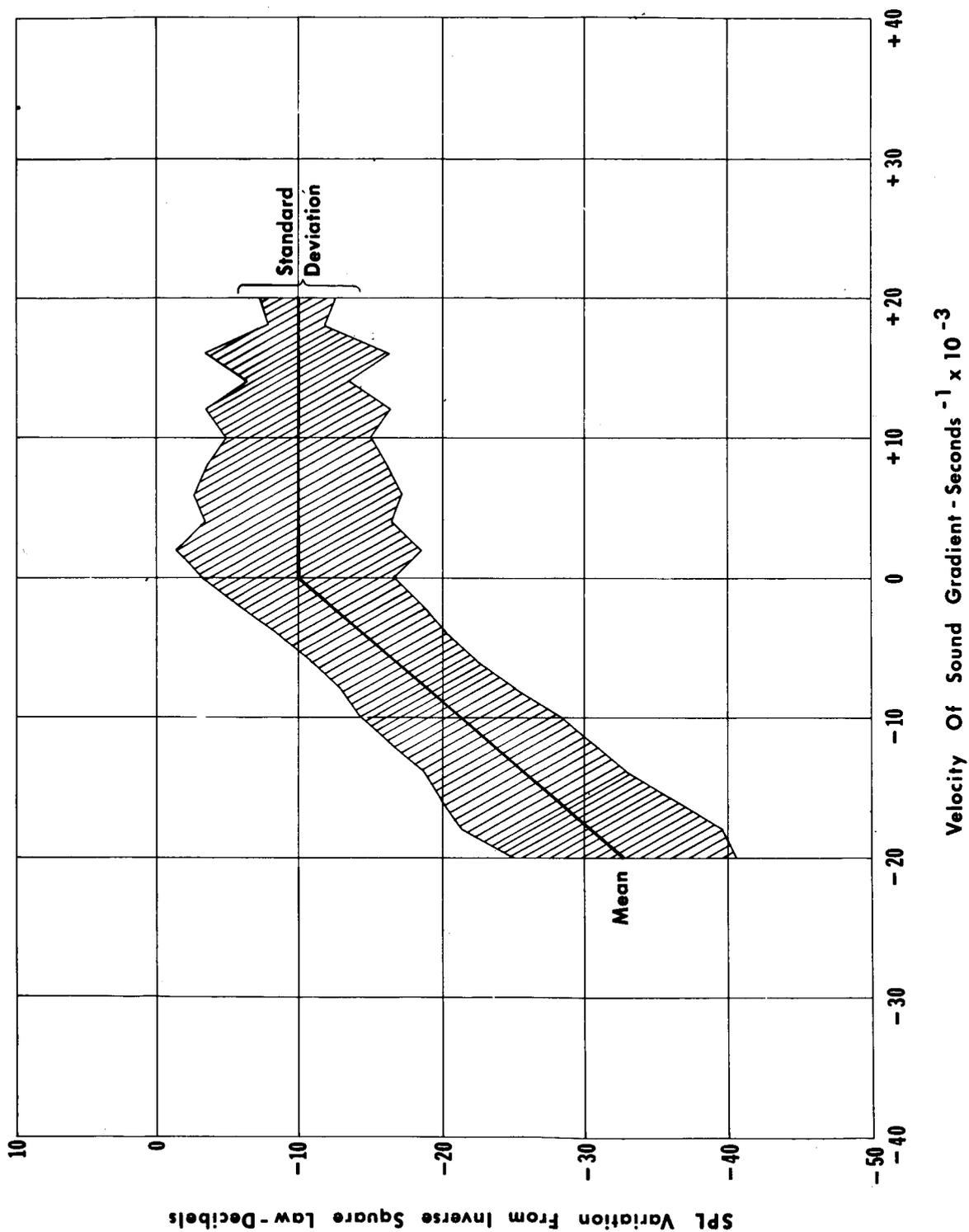


FIGURE 6. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 40 HERTZ AT 3048 METERS RANGE

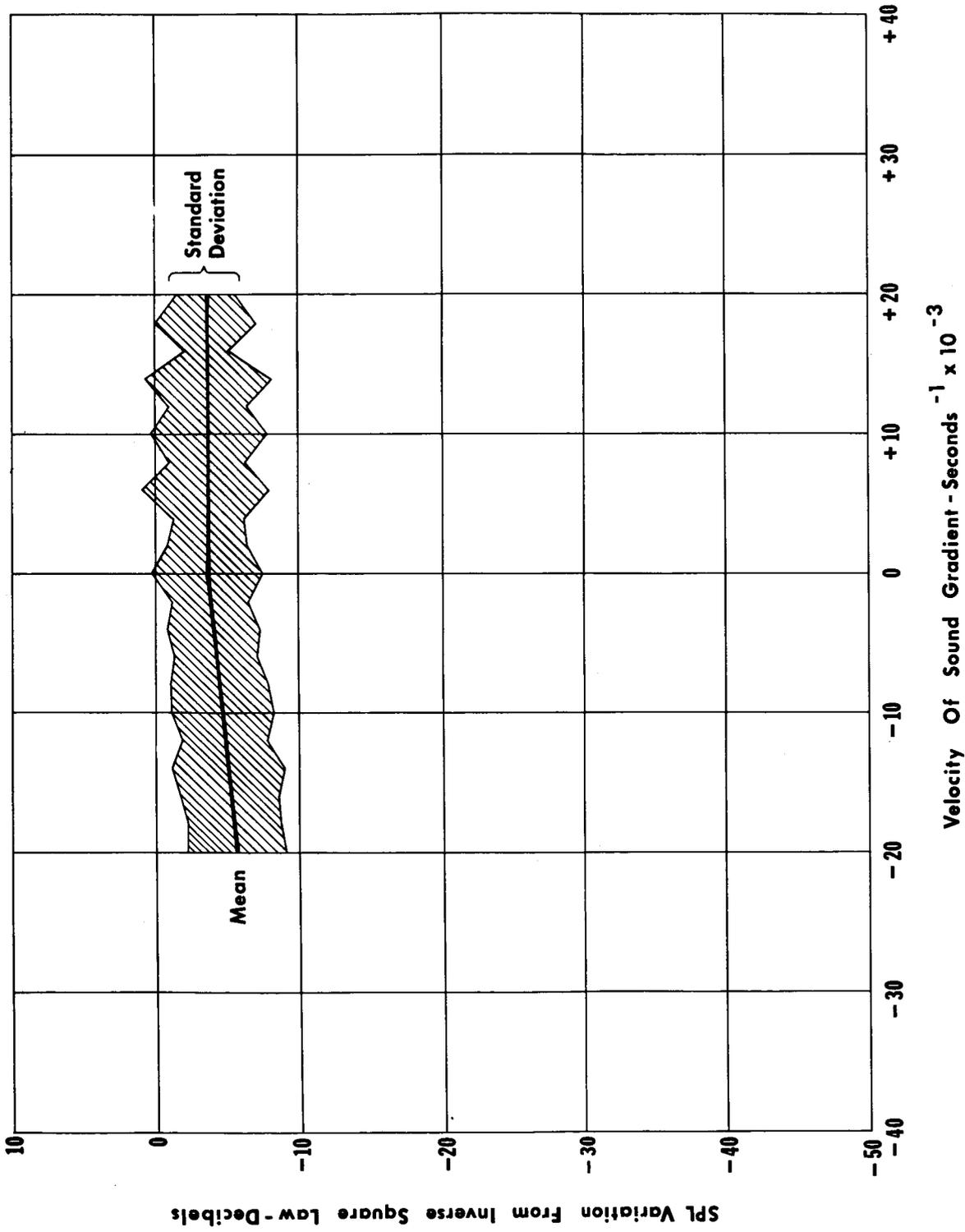


FIGURE 7. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 80 HERTZ AT 366 METERS RANGE

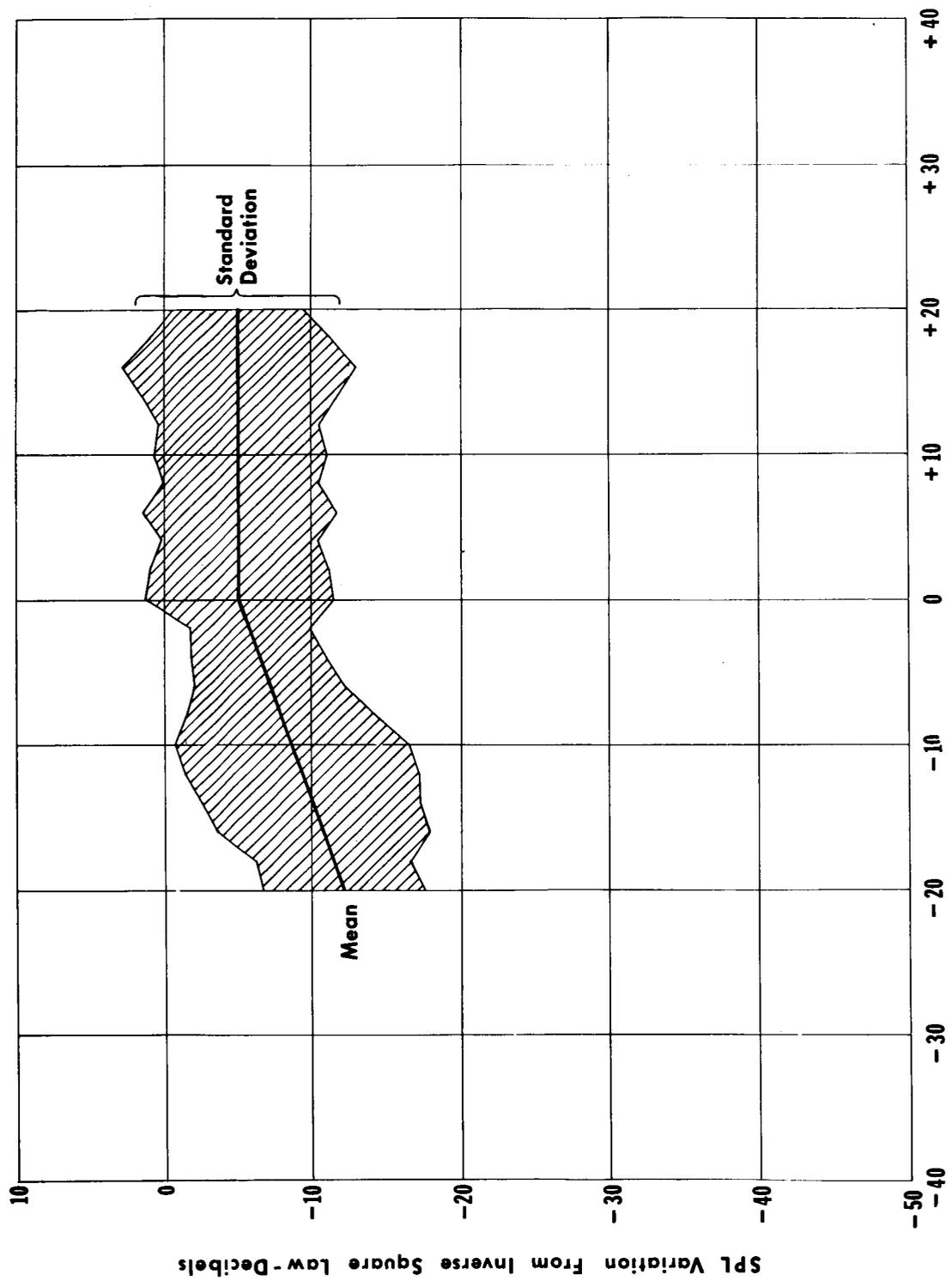


FIGURE 8. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 80 HERTZ AT 732 METERS RANGE

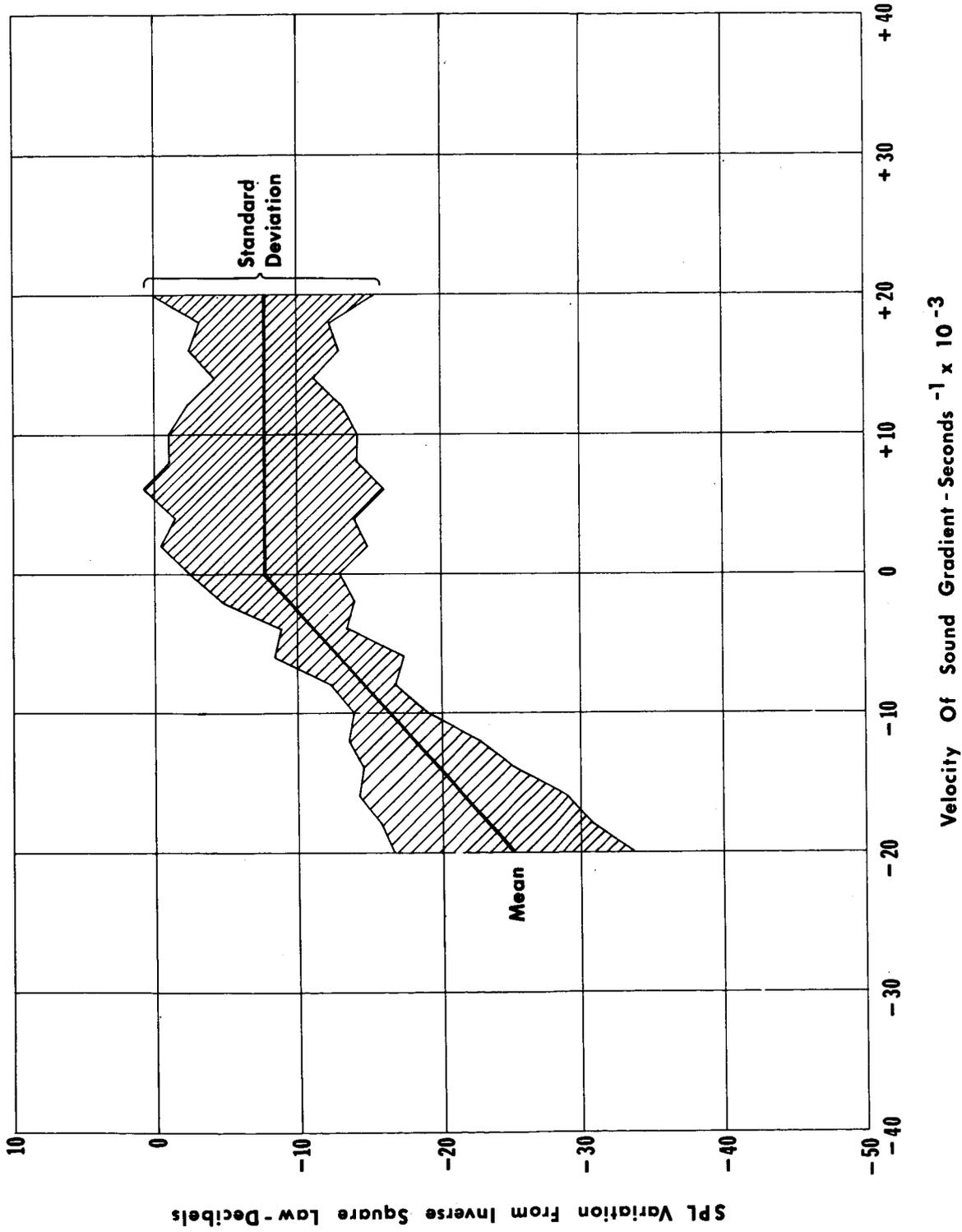


FIGURE 9. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 80 HERTZ AT 1524 METERS RANGE

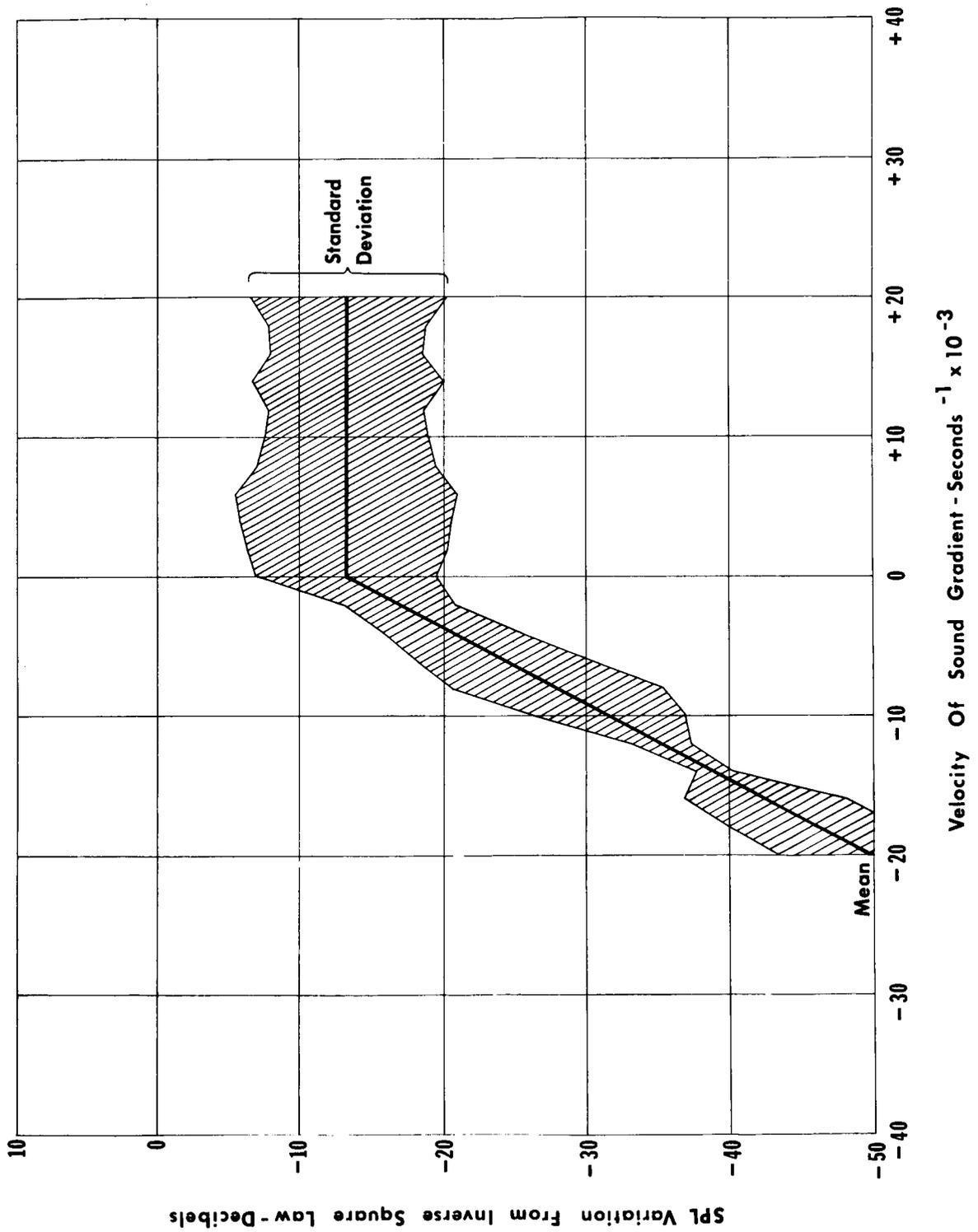


FIGURE 10. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 80 HERTZ AT 3048 METERS RANGE

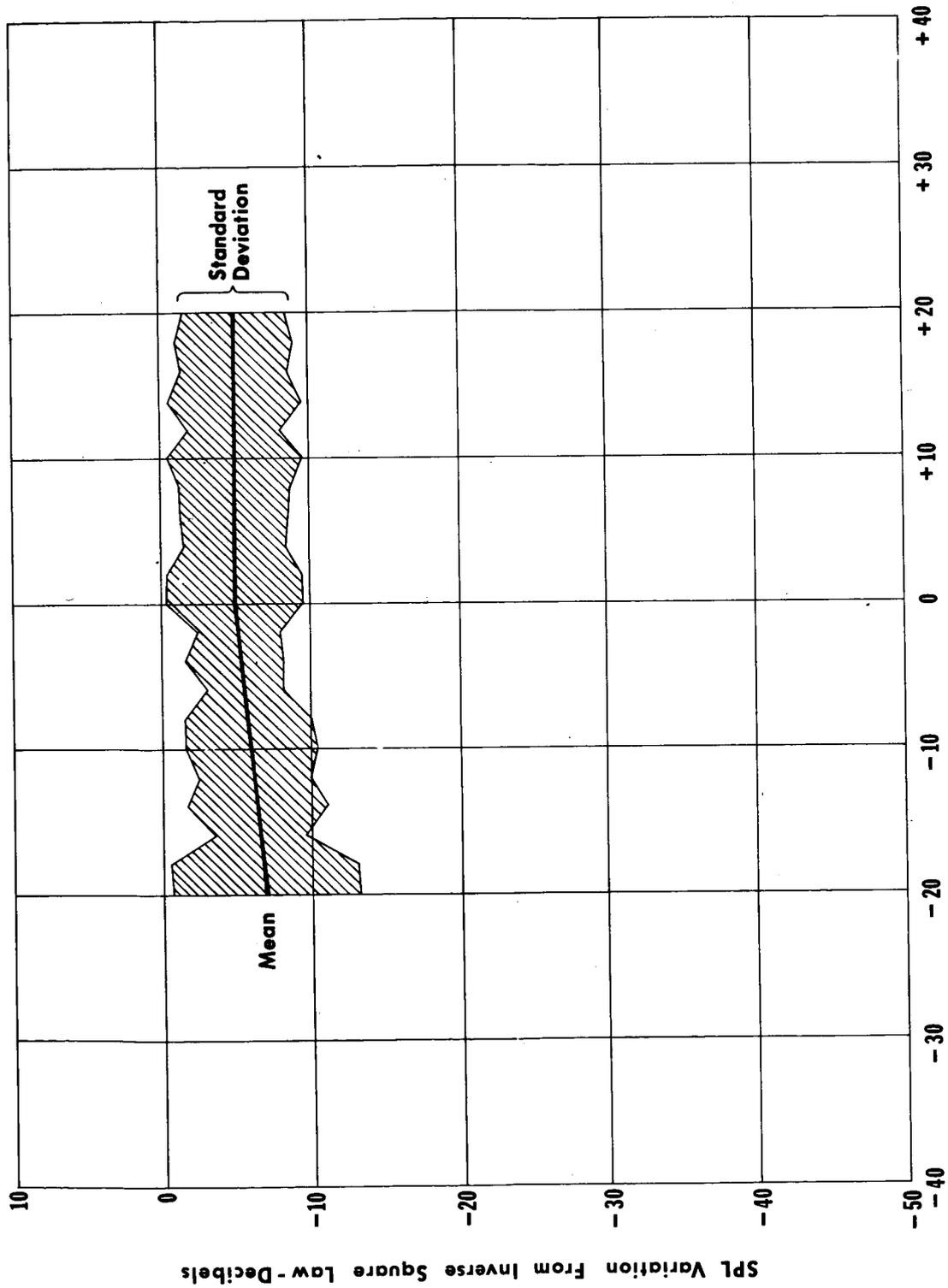


FIGURE 11. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 120 HERTZ AT 366 METERS RANGE

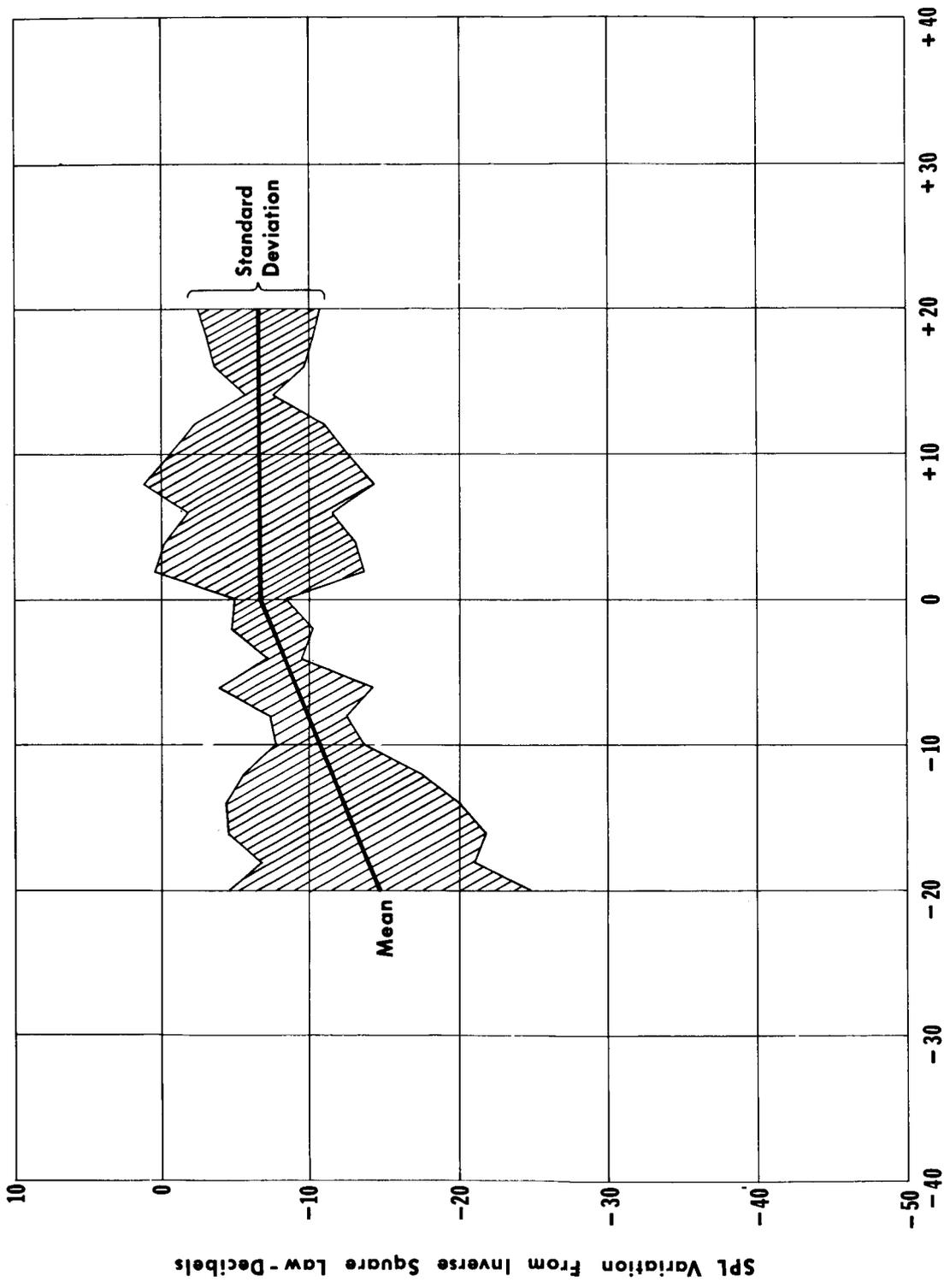


FIGURE 12. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 120 HERTZ AT 732 METERS RANGE

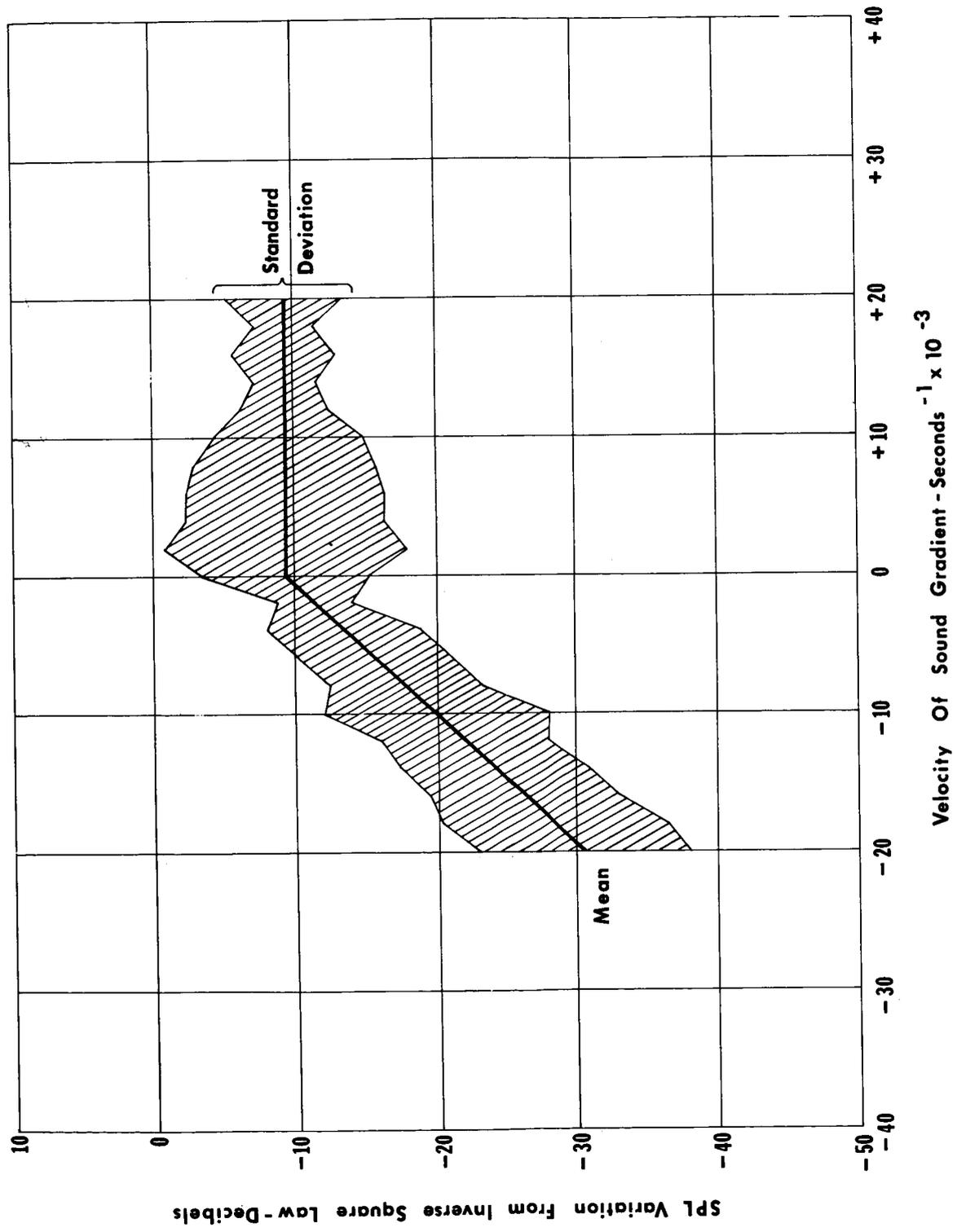


FIGURE 13. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 120 HERTZ AT 1524 METERS RANGE

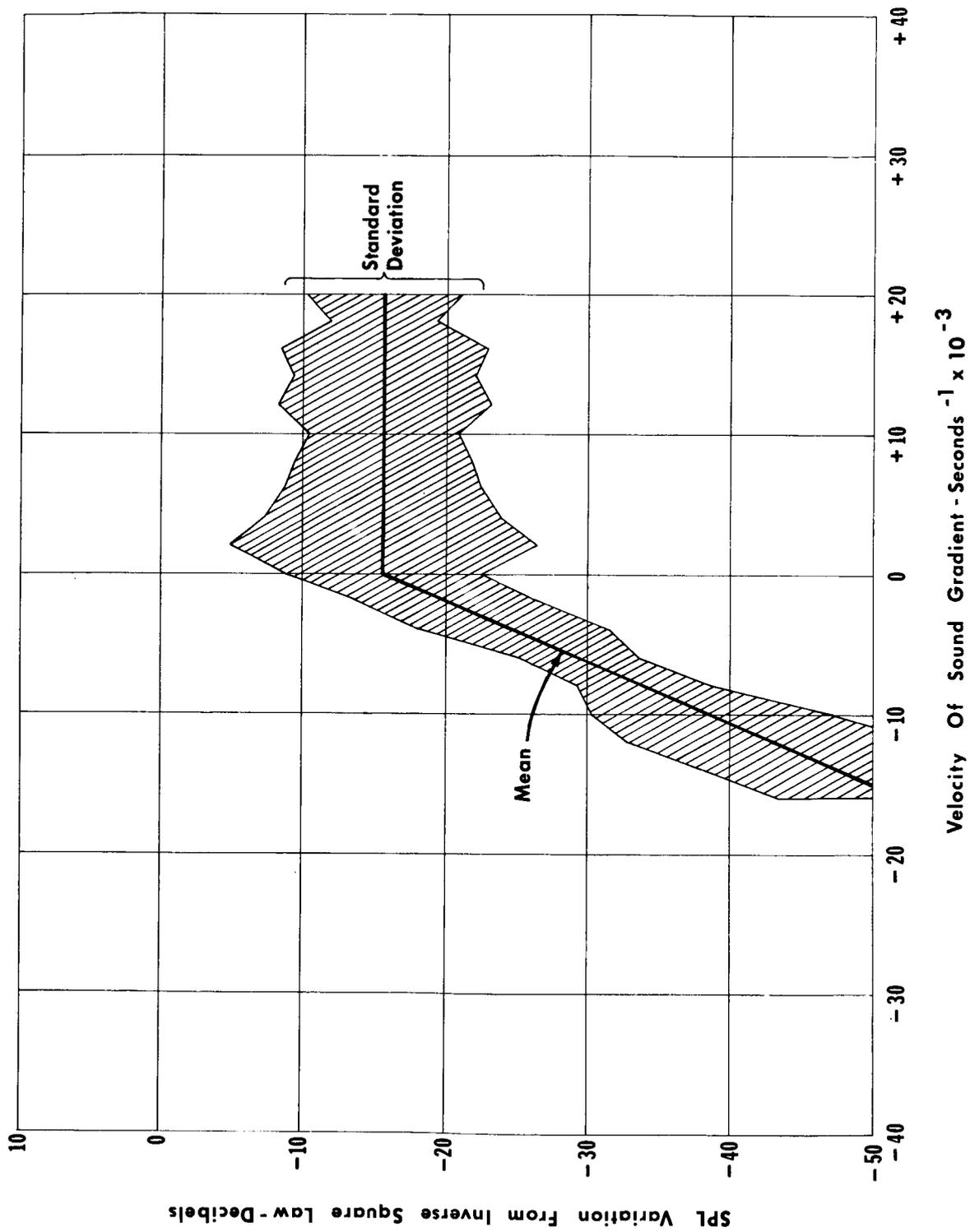


FIGURE 14. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 120 HERTZ AT 3048 METERS RANGE

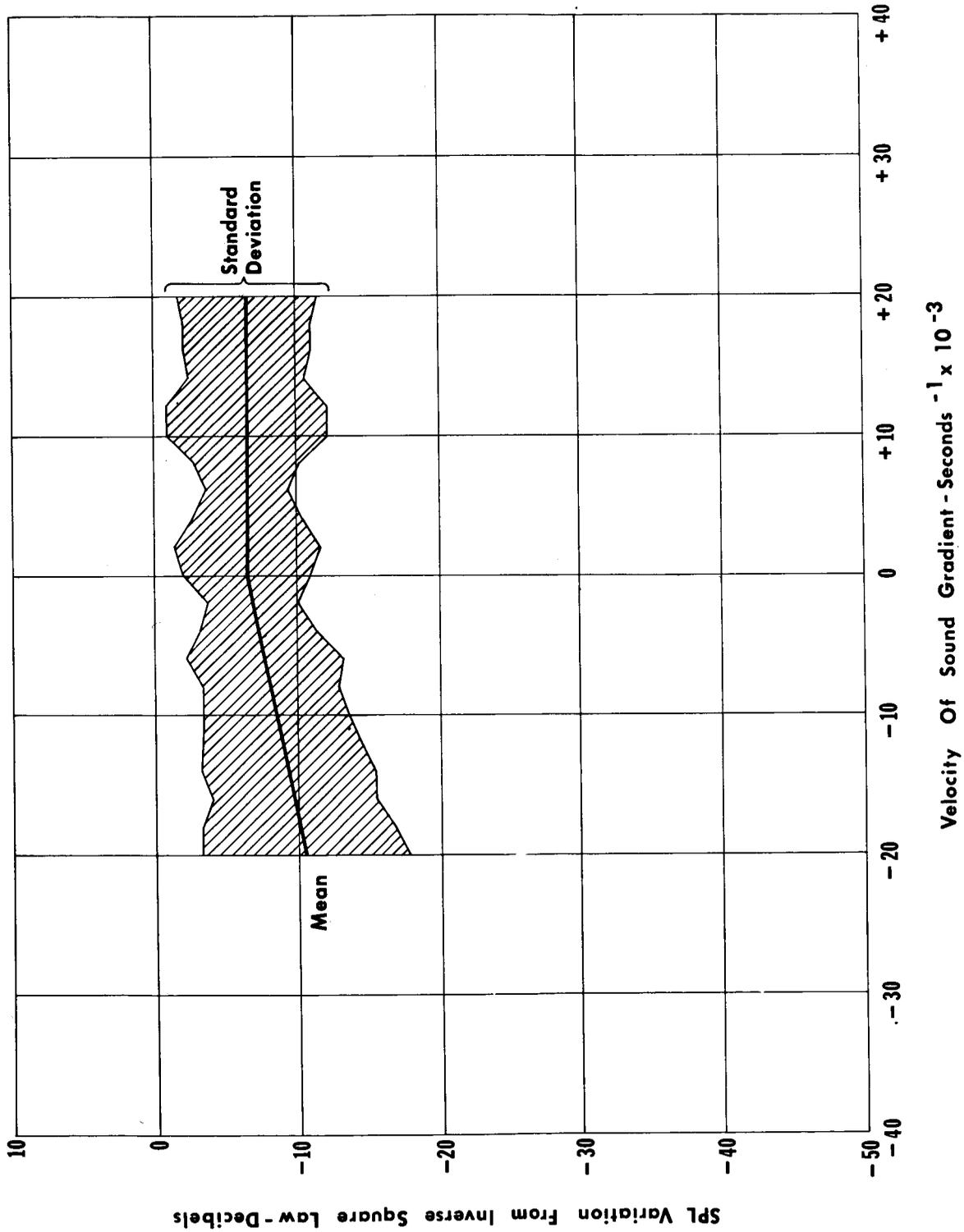


FIGURE 15. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 160 HERTZ AT 366 METERS RANGE

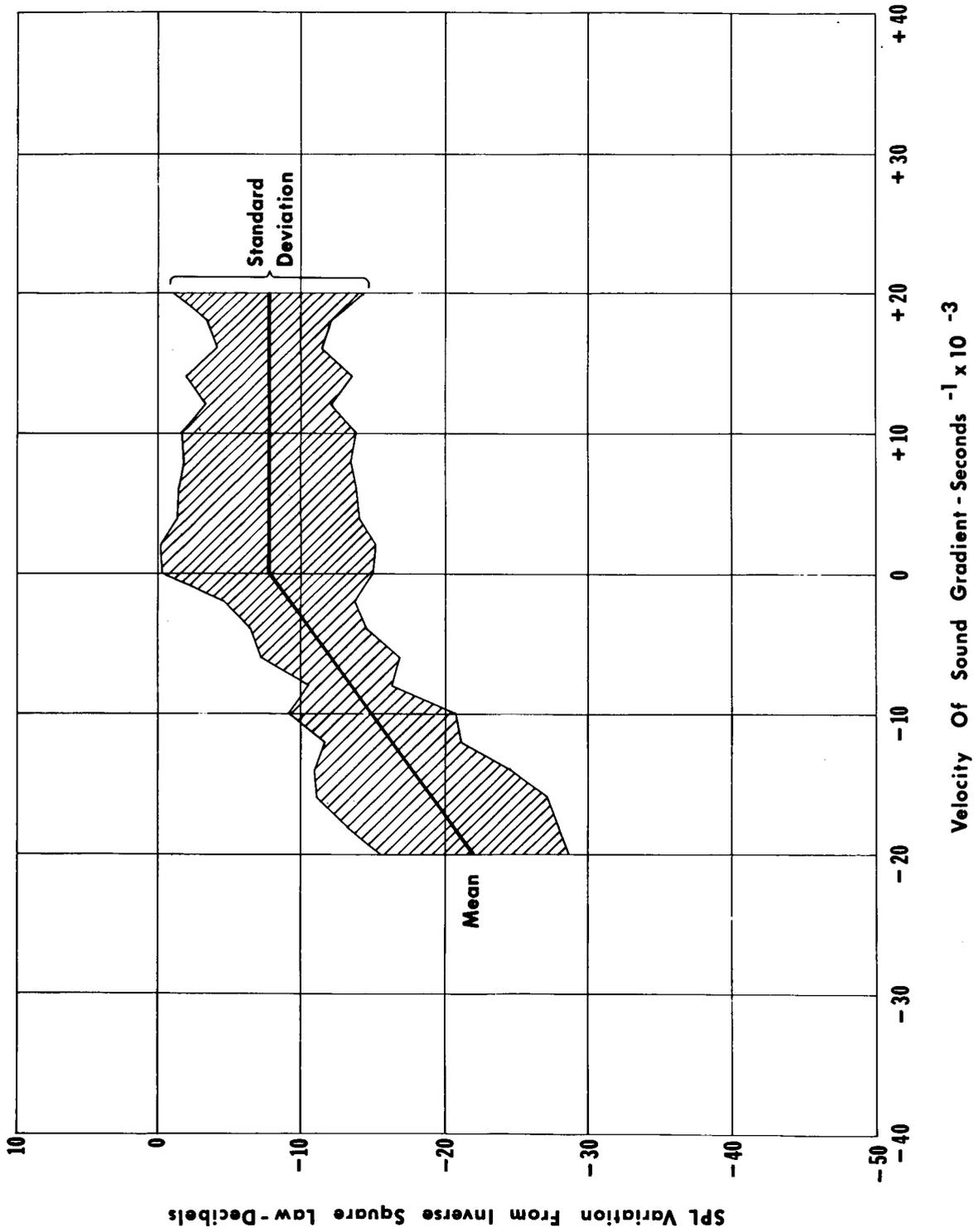


FIGURE 16. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 160 HERTZ AT 732 METERS RANGE

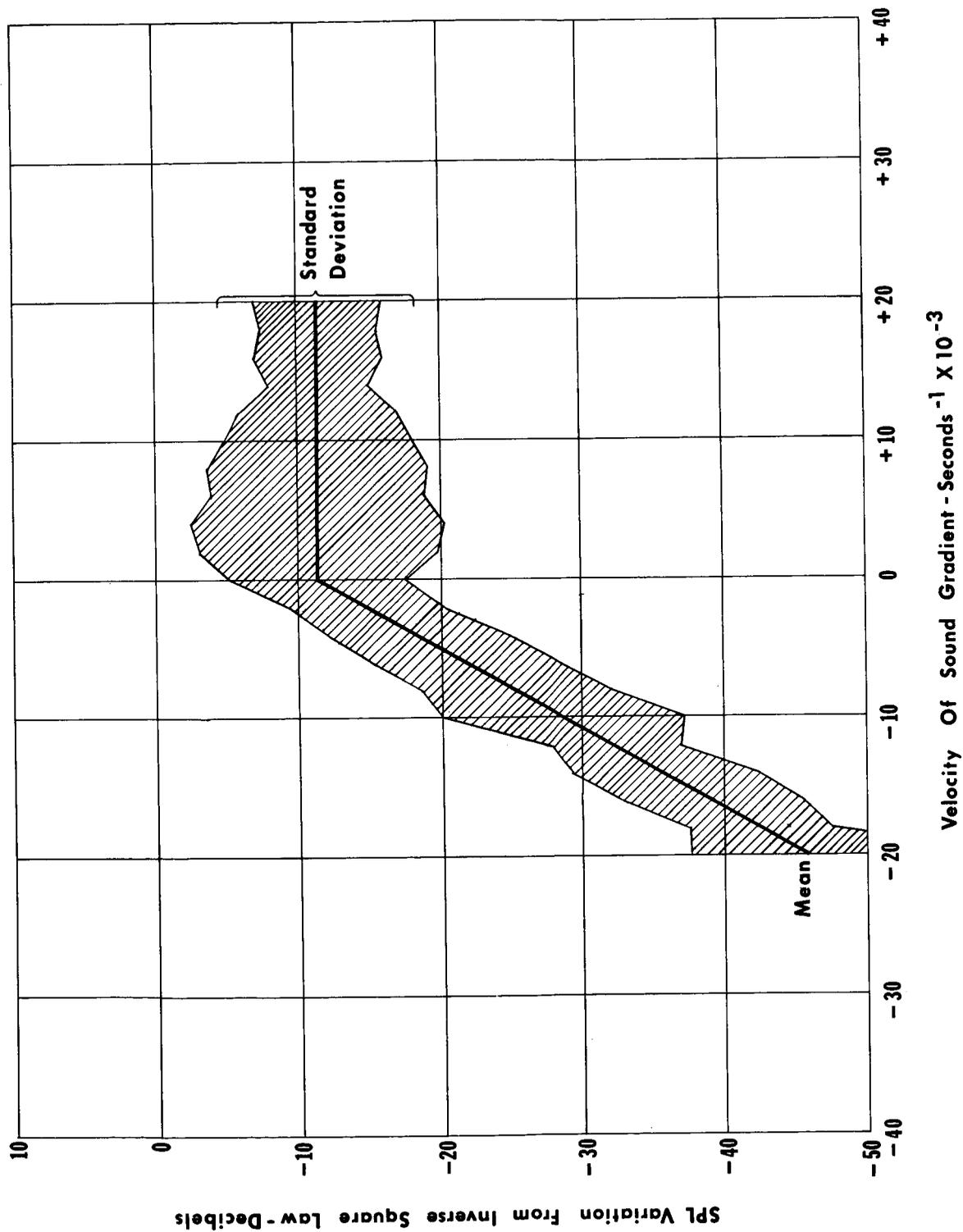


FIGURE 17. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 160 HERTZ AT 1524 METERS RANGE

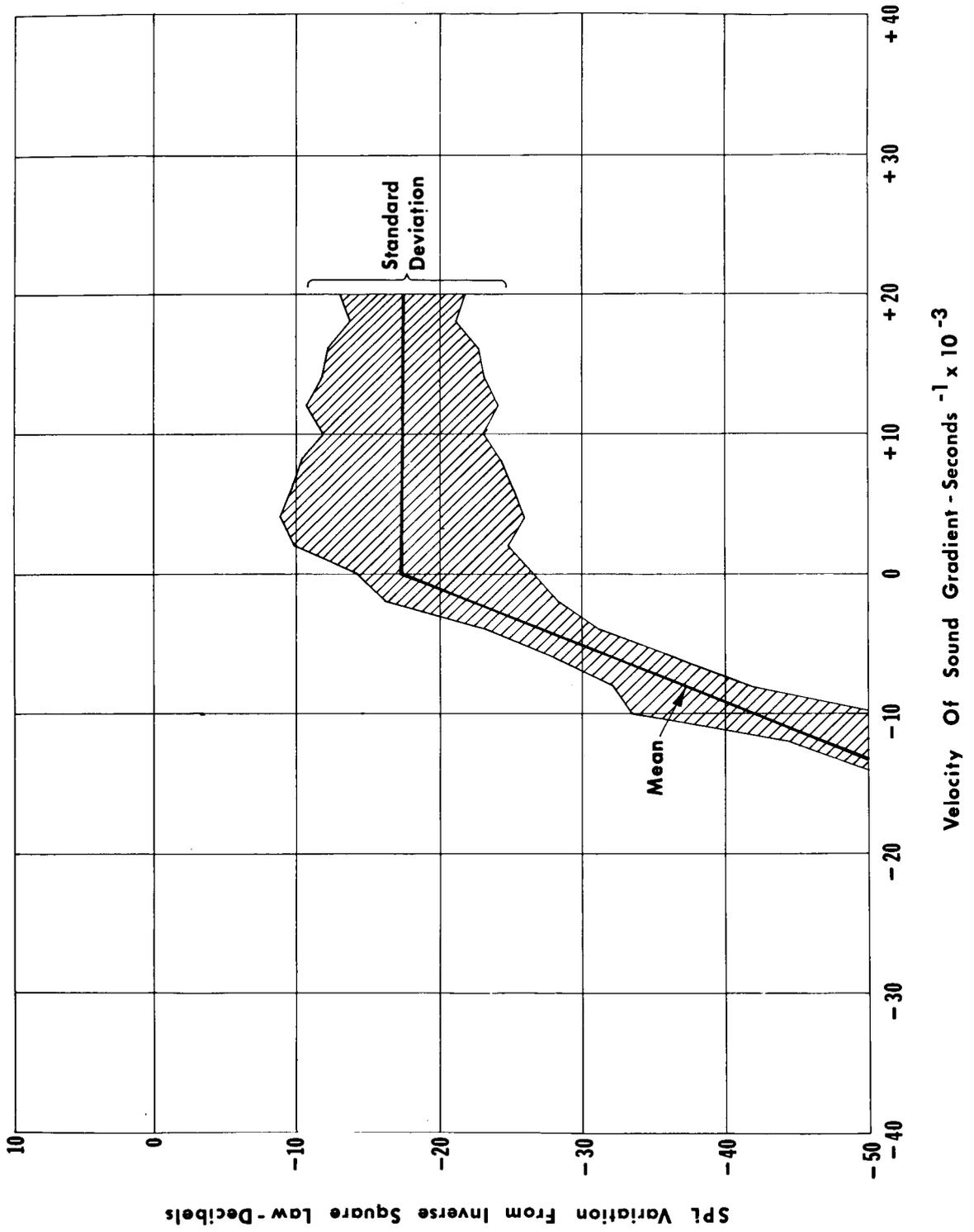


FIGURE 18. MEASURED ATMOSPHERIC RESPONSE CURVE FOR 160 HERTZ AT 3048 METERS RANGE

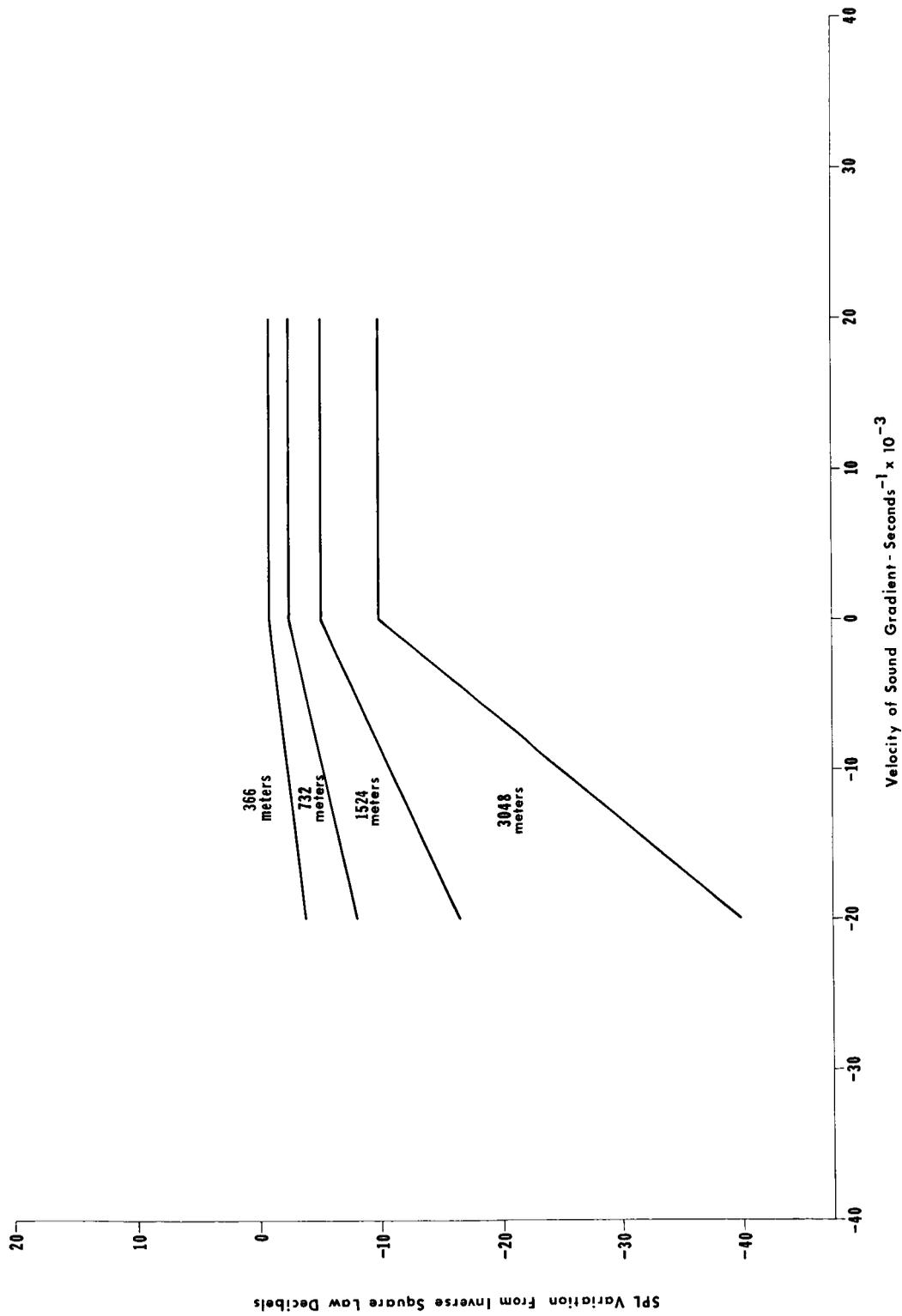


FIGURE 19. MEAN MEASURED ATMOSPHERIC RESPONSE CURVE FOR 40 HERTZ (CPS)

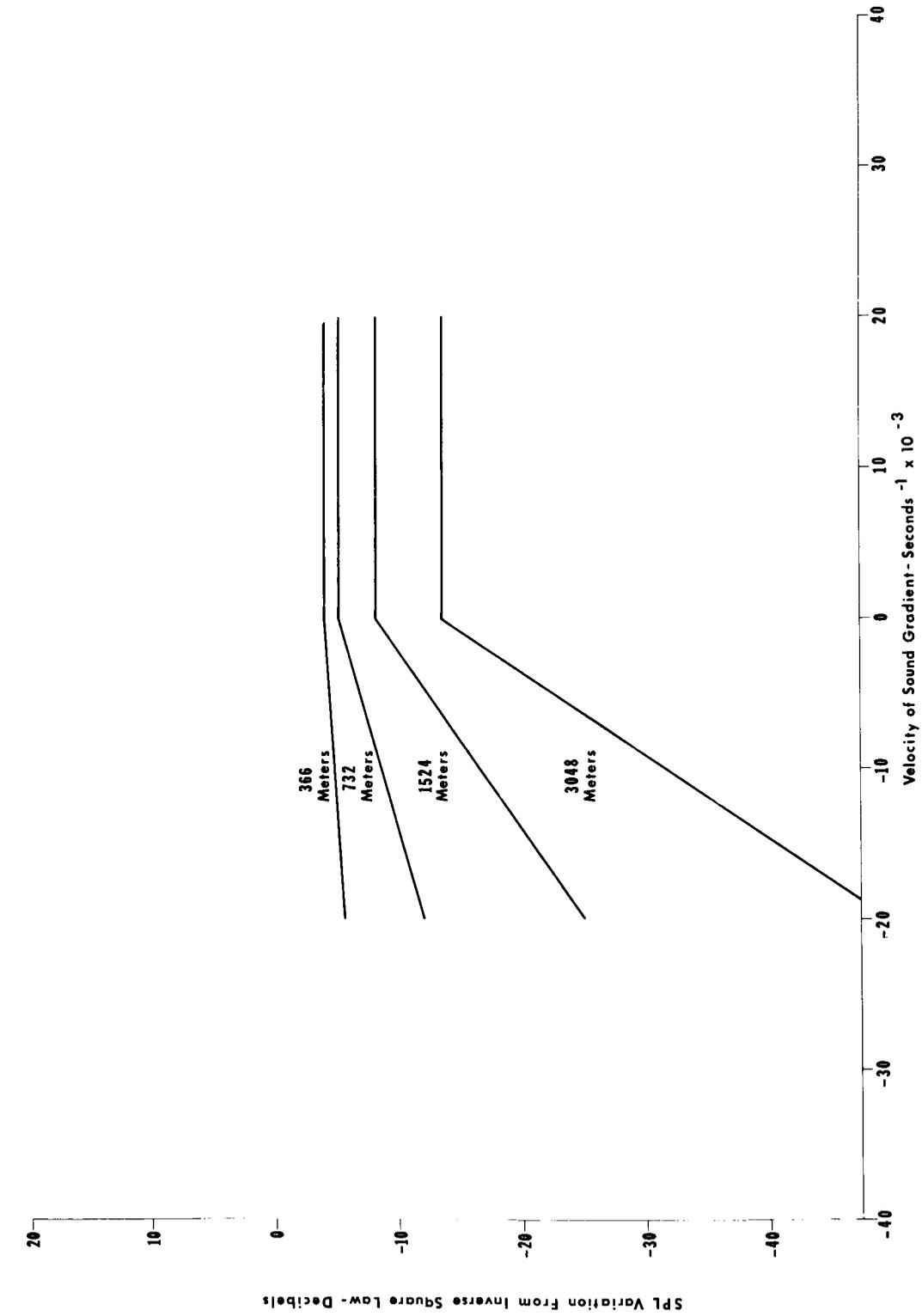


FIGURE 20. MEAN MEASURED ATMOSPHERIC RESPONSE CURVES FOR 80 HERTZ (CPS)

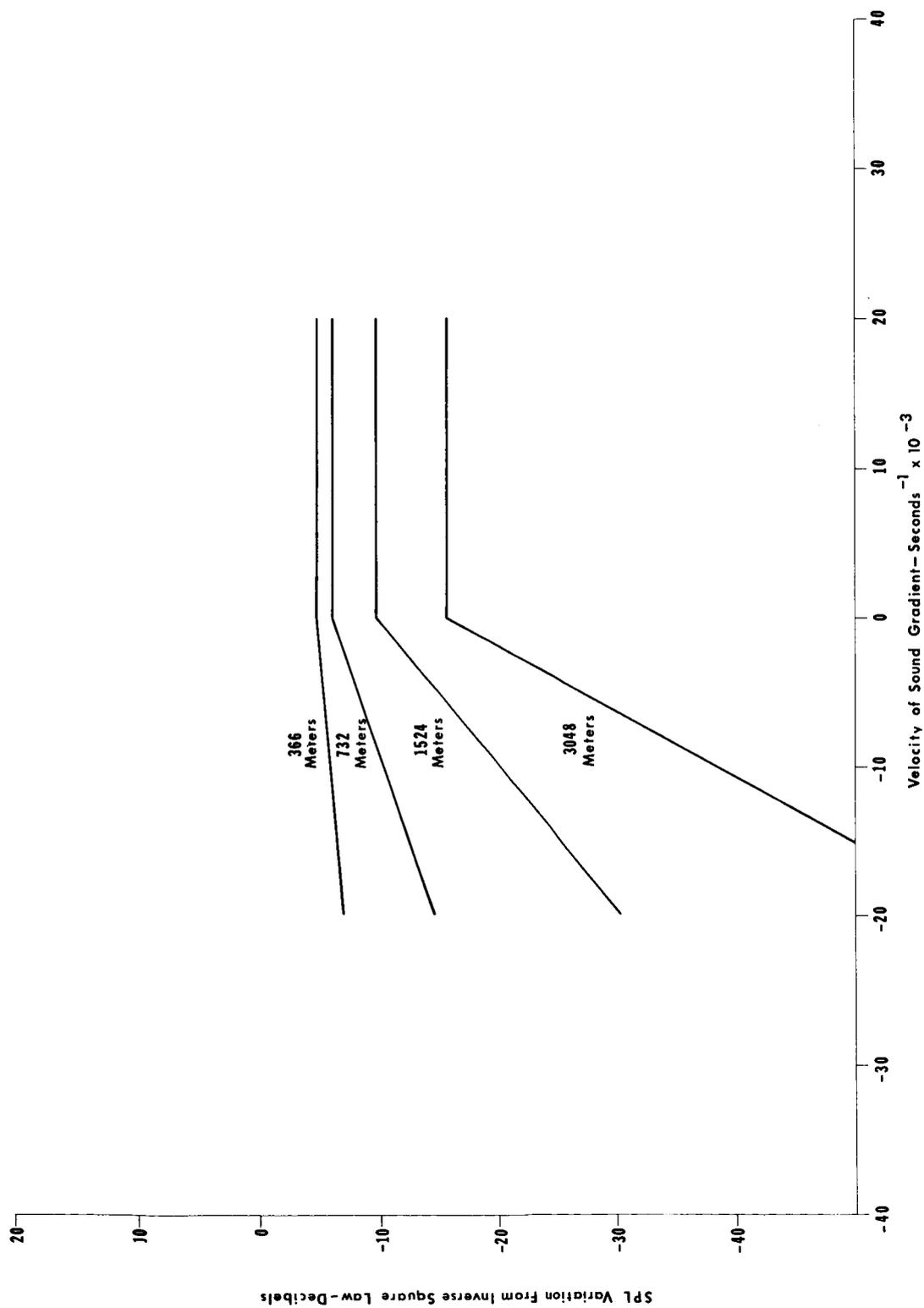


FIGURE 21. MEAN MEASURED ATMOSPHERIC RESPONSE CURVES FOR 120 HERTZ (CPS)

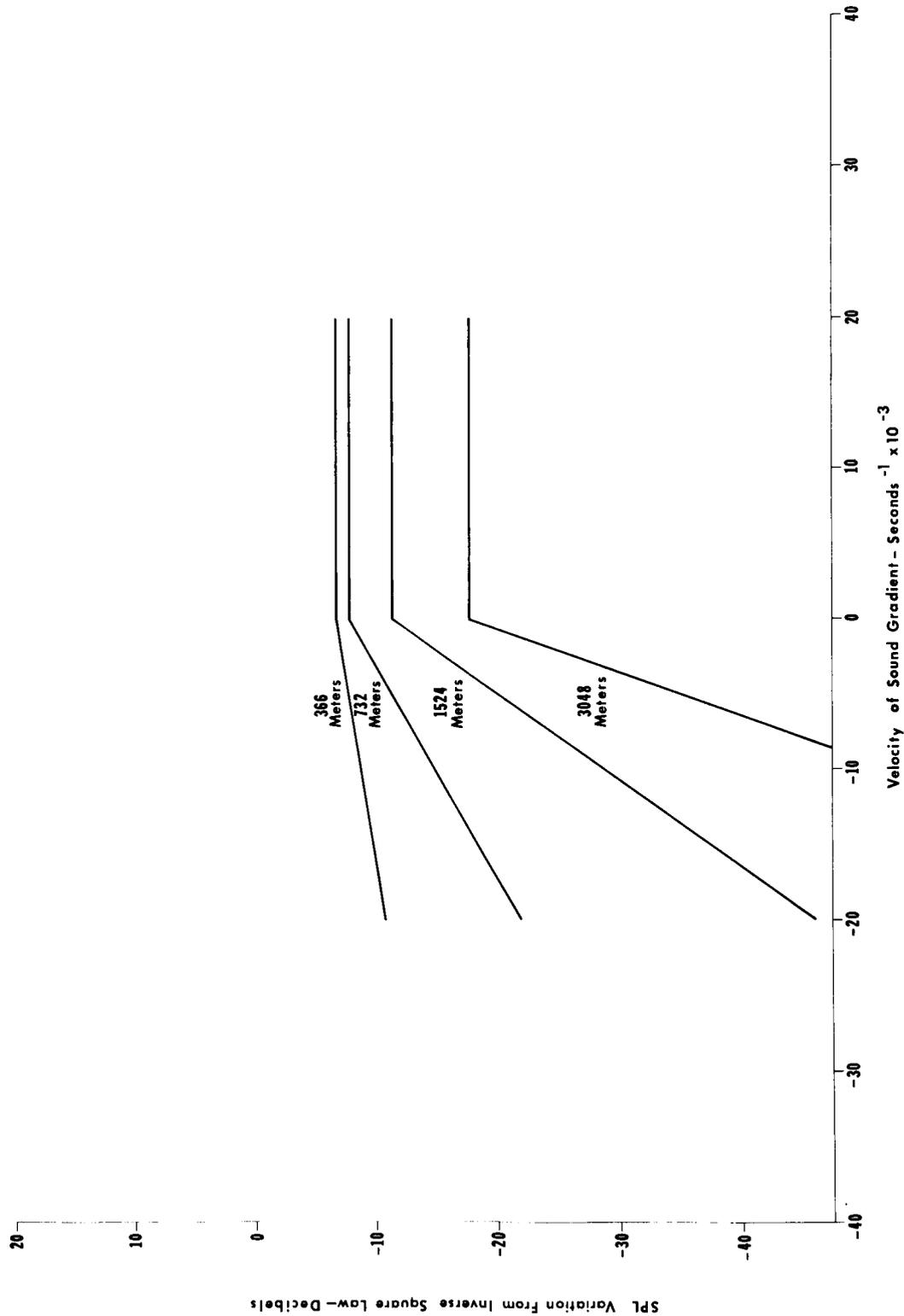
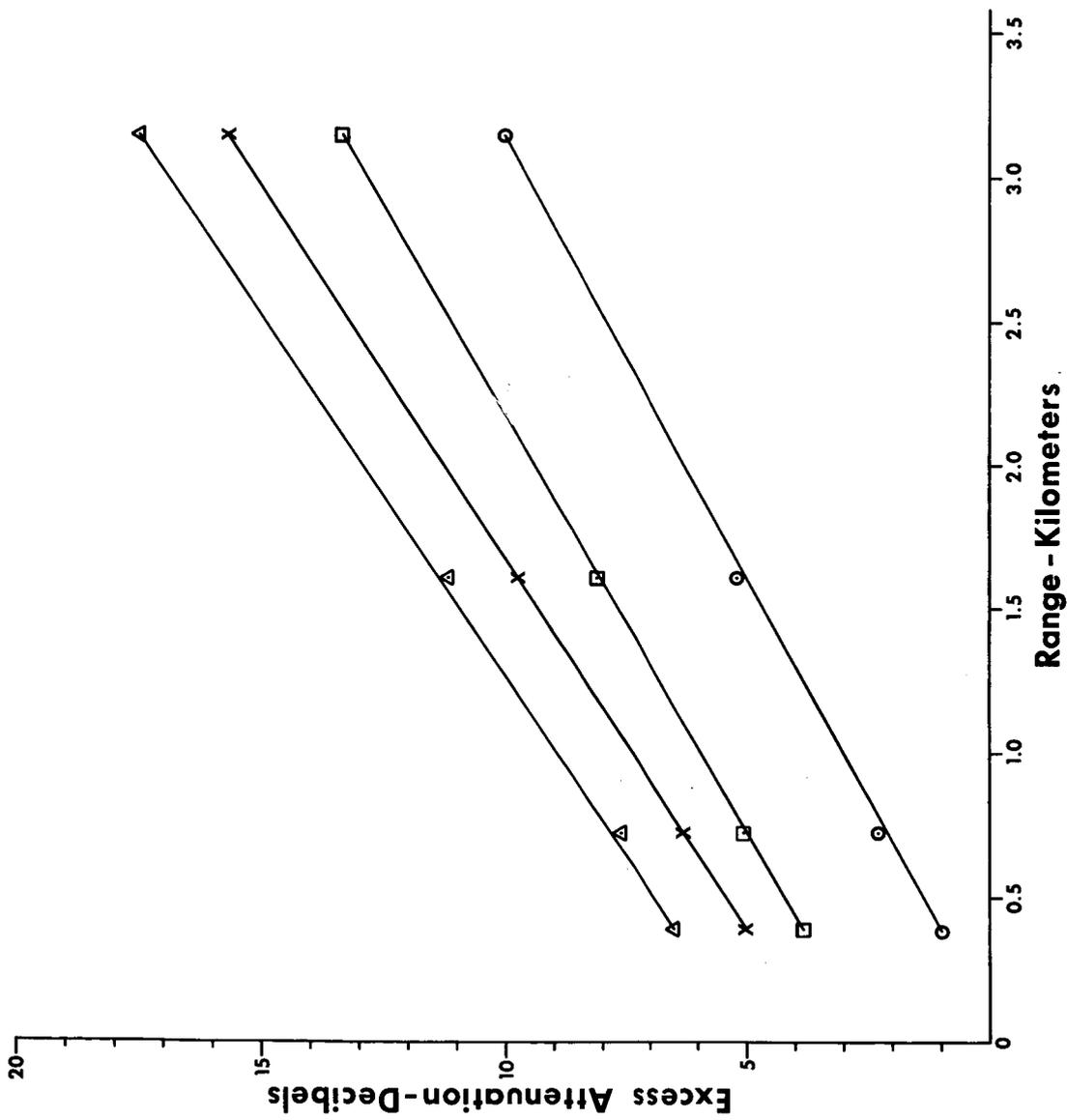


FIGURE 22. MEAN MEASURED ATMOSPHERIC RESPONSE CURVES FOR 160 HERTZ (CPS)



○ 40 Hertz
 □ 80 " "
 X 120 " "
 △ 160 " "

FIGURE 23. VARIATION IN EXCESS ATTENUATION FOR VARIOUS FREQUENCIES AS FUNCTIONS OF RANGE FROM SOURCES IN A SINGLE LAYERED HOMOGENEOUS ATMOSPHERE

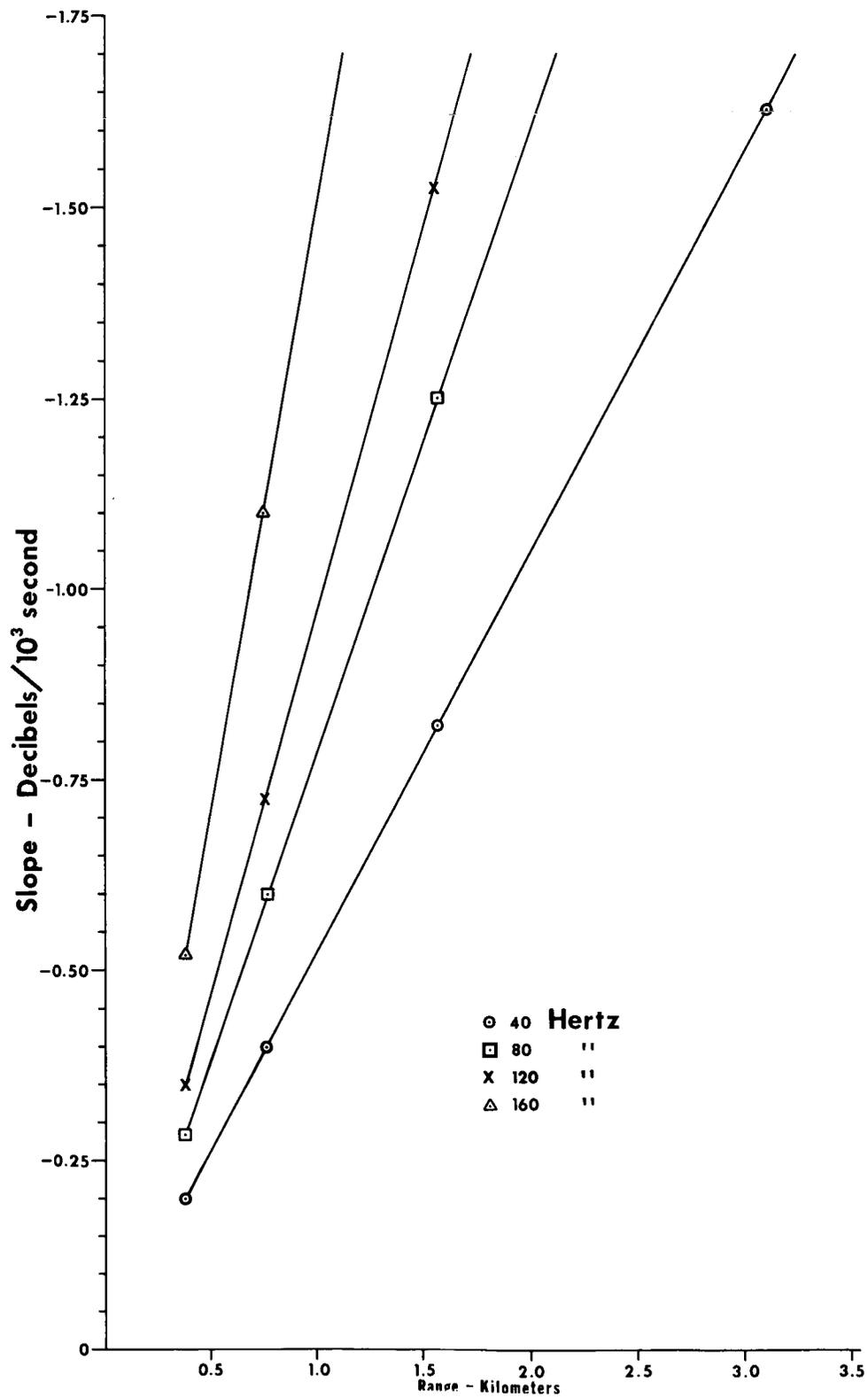


FIGURE 24. SLOPES OF NEGATIVE PORTIONS OF ATMOSPHERIC RESPONSE CURVES AS FUNCTIONS OF RANGE FROM SOURCE

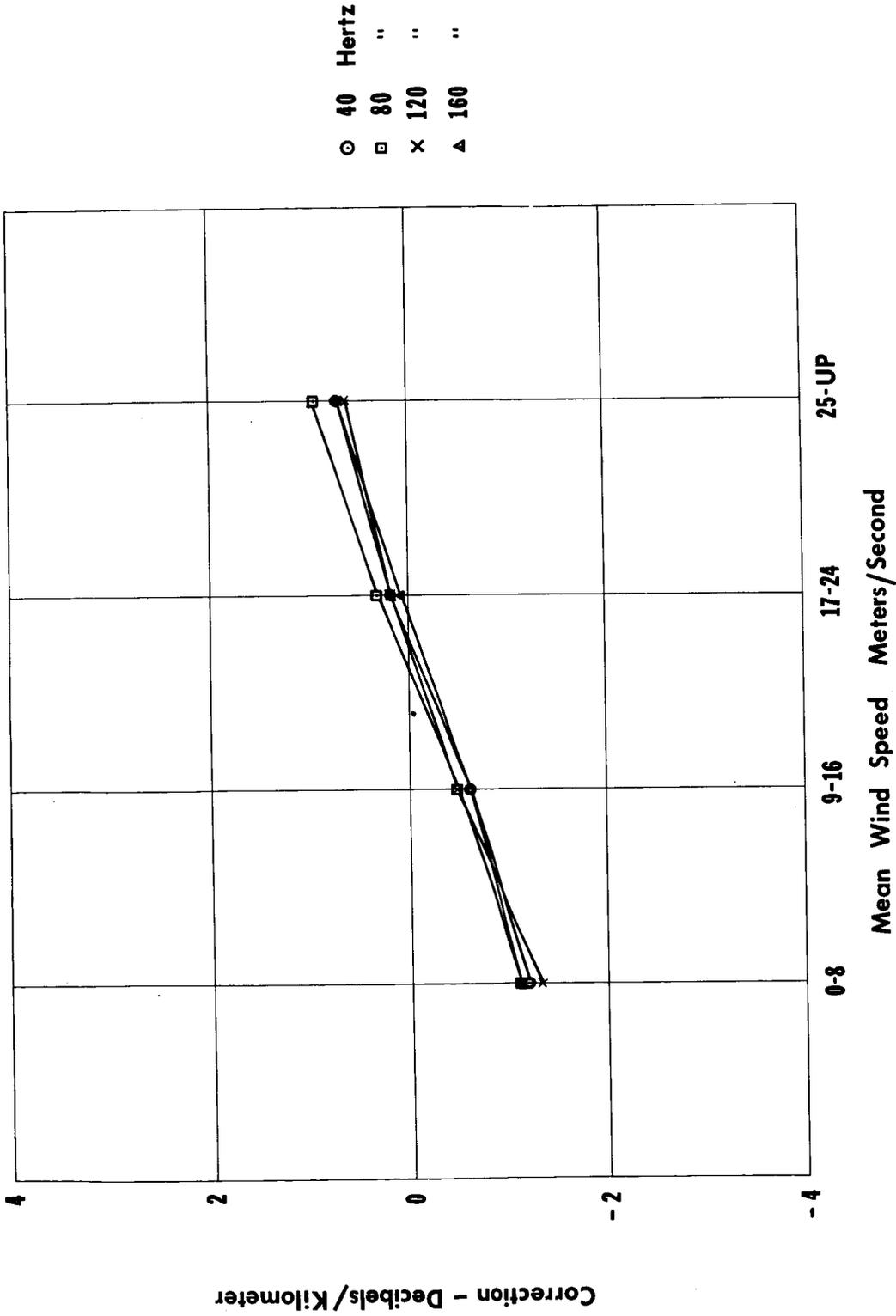


FIGURE 25. MEASURED CORRECTION FOR SPL VERSUS RANGE DUE TO WIND

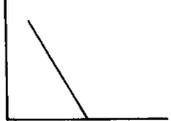
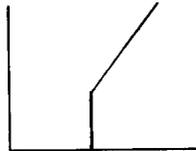
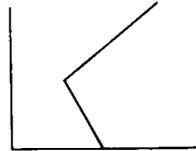
CATEGORY	DESCRIPTION	TYPICAL GRAPHS
0	NO VELOCITY GRADIENT	
1	SINGLE NEGATIVE GRADIENT	
2	SINGLE POSITIVE GRADIENT	
3	ZERO GRADIENT NEAR SURFACE WITH POSITIVE GRADIENT ABOVE	
4	WEAK POSITIVE GRADIENT NEAR SURFACE WITH STRONG POSITIVE GRADIENT ABOVE	
5	NEGATIVE GRADIENT NEAR SURFACE WITH STRONG POSITIVE GRADIENT ABOVE	

FIGURE 26. ACOUSTIC VELOCITY PROFILE CATEGORIES

Table I

Average Intensification in Decibels in the Focal Zone for Each Profile Type.
(2, 3, 4, and 5).

Type	Range (meters)					
	1524	3048	6096	12192	18288	24384
2	7.1	6.5	7.0	6.8	6.2	3.3
3	6.1	5.8	6.9	8.7	15.8	9.7
4	7.3	6.5	8.9	8.9	10.4	11.0
5	6.2	6.0	7.8	7.9	9.5	10.1

Table II

Number of Times That Intensification of Acoustical Energy is Within Specified
Interval for Each Profile Type. (2, 3, 4, and 5)

A. Category 2

Increase (db)	Range (meters)					
	1524	3048	6096	12192	18288	24384
0-5	233	177	165	63	21	4
5-10	197	149	112	50	9	2
10-15	103	85	84	32	3	0
15-20	49	22	28	8	3	0
20-25	11	6	10	5	0	0
25-30	1	0	2	0	0	0
30-35	0	0	0	0	0	0
35-40	0	0	1	0	0	0
40-45	0	0	0	0	0	0
45-50	0	0	0	0	0	0
Total Observations	788	717	619	303	68	15

Table II (Continued)

B. Category 3

Increase (db)	Range (meters)					
	1524	3048	6096	12192	18288	24384
0-5	68	66	38	19	1	3
5-10	70	38	43	30	6	7
10-15	23	29	22	21	14	6
15-20	8	6	4	11	9	2
20-25	1	1	2	1	2	1
25-30	0	0	2	0	2	0
30-35	0	0	0	0	2	0
35-40	0	0	0	0	1	0
40-45	0	0	0	0	1	0
45-50	0	0	0	0	0	0
Total Observations	235	211	163	94	44	19

Table II (Continued)

C. Category 4

Increase (db)	Range (meters)					
	1524	3048	6096	12194	18288	24384
0-5	124	136	86	60	23	6
5-10	155	146	112	61	22	3
10-15	90	70	77	41	19	10
15-20	32	21	40	18	13	6
20-25	4	2	18	14	8	1
25-30	0	0	2	4	1	0
30-35	0	0	1	1	0	0
35-40	0	0	0	0	1	0
40-45	0	0	0	0	1	0
45-50	0	0	0	0	0	0
Total Observations	157	498	428	264	105	38

Table II (Continued)

D. Category 5

Increase (db)	Range (meters)					
	1524	3049	6096	12192	18288	24384
0-5	147	93	77	64	38	19
5-10	121	87	73	65	53	22
10-15	59	45	54	45	28	12
15-20	19	6	22	20	20	10
20-25	2	2	7	8	12	3
25-30	0	0	3	0	3	4
30-35	0	0	1	0	2	2
35-40	0	0	0	0	0	0
40-45	0	0	0	0	0	0
45-50	0	0	0	0	0	0
Total Observations	691	605	495	285	199	96

Table III A

Percentage Distribution of Profile Types by Time and Month for 103° Azimuth

Month	Time (cst)	0	1	2	3	4	5	No. Obs.
January	0900	0.0	0.0	7.7	11.5	3.9	76.9	26
	1200	0.0	8.3	0.0	0.0	0.0	91.7	12
	1500	0.0	7.1	10.7	7.1	3.7	71.4	28
February	0900	0.0	7.4	7.4	3.7	11.1	70.4	27
	1200	3.9	15.4	7.7	7.7	0.0	65.3	26
	1500	0.0	17.9	0.0	7.1	3.5	71.5	28
March	0900	0.0	23.3	10.0	0.0	13.3	53.4	30
	1200	3.3	46.7	3.3	3.3	6.7	36.7	30
	1500	3.2	38.7	9.7	6.4	0.0	42.0	31
April	0900	0.0	46.7	10.0	3.3	6.7	33.3	30
	1200	3.7	63.0	0.0	11.1	0.0	22.2	27
	1500	6.7	56.7	6.7	3.3	3.3	23.3	20
May	0900	3.2	87.2	6.4	0.0	3.2	0.0	31
	1200	8.7	78.4	4.3	0.0	4.3	4.3	23
	1500	6.4	80.7	3.2	0.0	0.0	9.7	31
June	0900	3.3	53.4	26.7	3.3	10.0	3.3	30
	1200	13.3	53.4	6.7	0.0	13.3	13.3	15
	1500	13.3	53.4	19.9	0.0	6.7	6.7	30
July	0900	0.0	58.1	22.6	3.2	6.4	9.7	31
	1200	9.5	76.2	14.3	0.0	0.0	0.0	21
	1500	9.7	45.2	35.5	0.0	3.2	6.4	31
August	0900	3.2	80.7	9.7	0.0	3.2	3.2	31
	1200	5.9	70.5	11.8	0.0	11.8	0.0	22
	1500	0.0	51.6	19.4	12.9	6.4	9.7	31
September	0900	0.0	79.3	6.9	0.0	10.4	3.4	30
	1200	0.0	86.4	0.0	0.0	0.0	13.6	21
	1500	0.0	71.5	7.1	0.0	21.4	0.0	28
October	0900	0.0	73.3	6.7	0.0	3.3	16.7	30
	1200	0.0	100.0	0.0	0.0	0.0	0.0	20
	1500	0.0	87.2	3.2	0.0	6.4	3.2	31

Table III A (Continued)

Month	Time (<i>est</i>)	0	1	2	3	4	5	No. Obs.
November	0900	0.0	31.0	6.9	0.0	20.7	41.4	29
	1200	0.0	65.2	0.0	0.0	17.4	17.4	23
	1500	0.0	46.7	0.0	3.3	13.3	36.7	30
December	0900	0.0	3.3	10.0	3.3	23.3	60.1	30
	1200	0.0	19.2	3.8	3.8	7.7	65.5	26
	1500	0.0	10.7	10.7	7.1	14.3	57.2	28

Table IIIB

Percentage Distribution of Profile Types by Time and Month for 235° Azimuth

Month	Time (cst)	0	1	2	3	4	5	No. Obs.
January	0900	0.0	38.5	11.5	11.5	3.9	34.6	26
	1200	8.3	66.8	8.3	8.3	8.3	0.0	12
	1500	14.3	64.3	17.8	0.0	0.0	3.6	28
February	0900	3.7	63.0	3.7	11.1	14.8	3.7	27
	1200	3.9	76.7	3.9	3.9	3.9	7.7	26
	1500	3.5	75.1	14.3	0.0	7.1	0.0	28
March	0900	3.3	70.1	13.3	0.0	10.0	3.3	30
	1200	0.0	83.4	10.0	0.0	0.0	6.6	30
	1500	3.2	84.0	6.4	0.0	0.0	6.4	31
April	0900	3.3	80.1	3.3	3.3	0.0	10.0	30
	1200	0.0	92.6	3.7	3.7	0.0	0.0	27
	1500	0.0	86.6	6.7	6.7	0.0	0.0	30
May	0900	0.0	93.6	3.2	0.0	3.2	0.0	31
	1200	0.0	91.4	4.3	0.0	0.0	4.3	23
	1500	0.0	87.1	12.9	0.0	0.0	0.0	31
June	0900	0.0	100.0	0.0	0.0	0.0	0.0	30
	1200	6.7	93.3	0.0	0.0	0.0	0.0	15
	1500	0.0	86.7	10.0	0.0	0.0	3.3	30
July	0900	3.2	93.6	0.0	3.2	0.0	0.0	31
	1200	0.0	95.2	0.0	0.0	0.0	4.8	21
	1500	3.2	87.2	6.4	0.0	0.0	3.2	31
August	0900	0.0	90.4	3.2	0.0	0.0	6.4	31
	1200	0.0	100.0	0.0	0.0	0.0	0.0	22
	1500	0.0	84.0	3.2	3.2	6.4	3.2	31
September	0900	0.0	48.3	6.9	0.0	24.1	20.7	30
	1200	0.0	68.2	4.5	0.0	18.2	9.1	21
	1500	0.0	50.1	14.3	0.0	17.8	17.8	28
October	0900	0.0	10.0	0.0	0.0	33.3	57.7	30
	1200	0.0	72.5	10.3	0.0	3.4	13.8	29
	1500	0.0	71.0	6.4	0.0	3.2	19.4	31

Table IIIB (Continued)

Month	Time (cst)	0	1	2	3	4	5	No. Obs.
November	0900	3.4	27.7	20.7	6.9	24.1	17.2	29
	1200	0.0	69.7	0.0	4.3	13.1	13.0	23
	1500	6.7	63.3	0.0	3.3	16.7	10.0	30
December	0900	0.0	23.3	13.3	10.0	33.3	20.1	30
	1200	7.7	61.6	0.0	3.8	15.4	11.5	26
	1500	0.0	46.5	7.1	7.1	21.4	17.9	28

Table IIIC

Percentage Distribution of Profile Types by Time and Month for 342° Azimuth

Month	Time (cst)	0	1	2	3	4	5	No. Obs.
January	0900	3.9	23.1	19.2	11.5	11.5	30.8	26
	1200	0.0	33.6	16.6	16.6	16.6	16.6	12
	1500	0.0	35.7	14.4	7.6	7.6	35.7	28
February	0900	0.0	63.0	11.1	3.7	7.4	14.8	27
	1200	0.0	73.1	11.5	3.9	0.0	11.5	26
	1500	3.5	71.7	7.1	3.5	7.1	7.1	28
March	0900	0.0	36.6	46.7	6.7	3.3	6.7	30
	1200	3.3	60.0	26.7	0.0	3.3	6.7	30
	1500	0.0	51.7	32.2	6.4	3.2	6.4	31
April	0900	3.3	56.7	13.3	3.3	16.7	6.7	30
	1200	0.0	81.5	14.8	0.0	3.7	0.0	27
	1500	3.3	56.7	36.7	0.0	3.3	0.0	30
May	0900	0.0	77.5	6.4	0.0	3.2	12.9	31
	1200	0.0	95.7	4.3	0.0	0.0	0.0	23
	1500	3.2	74.3	19.3	0.0	3.2	0.0	31
June	0900	0.0	83.4	10.0	0.0	6.7	0.0	30
	1200	0.0	86.6	6.7	6.7	0.0	0.0	15
	1500	3.3	66.8	23.3	3.3	0.0	3.3	30
July	0900	0.0	87.1	9.7	3.2	0.0	0.0	31
	1200	0.0	85.7	14.3	0.0	0.0	0.0	21
	1500	0.0	61.4	29.0	3.2	3.2	3.2	31
August	0900	0.0	100.0	0.0	0.0	0.0	0.0	31
	1200	0.0	82.3	5.9	0.0	5.9	5.9	22
	1500	0.0	71.0	9.7	6.4	3.2	9.7	31
September	0900	0.0	65.5	0.0	0.0	0.0	34.5	30
	1200	0.0	68.3	4.5	0.0	4.5	22.7	21
	1500	0.0	57.2	10.7	0.0	17.9	15.2	28
October	0900	0.0	63.3	0.0	0.0	6.7	30.0	30
	1200	0.0	96.6	0.0	0.0	0.0	3.4	29
	1500	0.0	93.6	0.0	0.0	0.0	6.4	31

Table IIIC (Continued)

Month	Time (cst)	0	1	2	3	4	5	No. Obs.
November	0900	3.4	27.7	10.2	10.3	20.7	27.7	29
	1200	0.0	43.5	0.0	4.3	17.4	34.8	23
	1500	3.3	43.4	10.0	6.7	13.3	23.3	30
December	0900	0.0	26.7	26.6	6.7	6.7	33.3	30
	1200	0.0	16.3	11.5	3.8	3.8	34.6	26
	1500	0.0	51.1	3.6	0.0	17.9	21.4	28

Table IV

Measured Complex Acoustic Persistence from 0900 CST to 1200 CST
in the Mississippi Test Operations area

Month	103° Azimuth (%)	235° Azimuth (%)	342° Azimuth (%)
January	80	50	80
February	80	68	72
March	53	66	46
April	48	81	62
May	69	86	78
June	68	93	81
July	61	90	80
August	68	81	86
September	80	65	80
October	78	21	67
November	52	52	80
December	66	37	74

Table V

Measured Complex Acoustic Persistence from 0900 CST to 1500 CST
in the Mississippi Test Operations Area

Month	103° Azimuth (%)	235° Azimuth (%)	342° Azimuth (%)
January	70	50	70
February	52	56	64
March	33	40	36
April	29	74	48
May	60	82	69
June	43	87	62
July	45	80	55
August	40	63	68
September	73	36	42
October	71	17	60
November	42	33	66
December	52	20	52

Table VI

A. Repeatability of Acoustical Velocity Profile Type from 0900 CST
One Day to 0900 CST the Next Day

Month	103° Azimuth (%)	235° Azimuth (%)	342° Azimuth (%)
January	64	36	40
February	46	53	46
March	50	60	50
April	44	65	58
May	80	96	53
June	58	100	86
July	50	93	70
August	80	76	100
September	59	48	88
October	71	42	57
November	51	40	62
December	60	43	43
Yearly Average	59	63	63

Table VI

B. Repeatability of Acoustical Velocity Profile Type from 1200 CST
One Day to 1200 CST the Next Day

Month	103° Azimuth (%)	235° Azimuth (%)	342° Azimuth (%)
January	80	20	40
February	52	60	56
March	67	64	53
April	66	83	66
May	61	94	94
June	81	90	72
July	86	93	66
August	52	94	76
September	81	68	62
October	100	48	92
November	46	60	60
December	58	70	33
Yearly Average	69	70	64

Table VI

C. Repeatability of Acoustical Velocity Profile Type from 1500 CST
One Day to 1500 CST the Next Day

Month	103° Azimuth (%)	235° Azimuth (%)	342° Azimuth (%)
January	66	33	50
February	48	51	48
March	56	56	40
April	48	75	41
May	73	83	66
June	68	82	58
July	50	82	50
August	36	63	43
September	73	23	57
October	80	63	90
November	41	58	37
December	46	38	61
Yearly Average	57	59	53

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