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THE SOUND ENVIRONMENT IN LOCOMOTIVE CABS

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16. Abstract

Measurements of the sound environment in locomotive cabs including audible warnings perceived by crew members are described. Data was collected during two different test runs under diverse conditions, one on the Long Island R.R. and the other on the St. Louis-San Francisco Railway. The crew's working environment was found to approach the exposure limits set in the Walsh-Healey Public Contract Service Act. Tape recordings from each run indicate the following elements as significant: engine noise, horn sounds and air brake application noise. Data indicate sound level readings taken under various operating conditions in the cab. This study does not include a definition of legal exposure in the cabs, but the noise survey forms presented are useful to compute approximate exposure from observed data.

The study suggests that because measurements of noise level in a typical locomotive cab approach the limits allowed in the Walsh-Healey Act, a more detailed survey would be desirable to determine whether exposures do exceed legal limits, and if so under what conditions.

Forms of frequency analysis used in the study are also explained.

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INTRODUCTION

This is the report on measurements of the sound environment in locomotive cabs, made as a preliminary assessment of the sounds, including audible warnings, perceived by crew members. Through the courtesy of the Long Island Rail Road and the St. Louis-San Francisco Railway, an observer with battery-powered tape recorder and calibrated microphone made recordings and measurements on regularly-scheduled trains inside the locomotive cab.

The primary sound in the locomotive cab (when horn warnings are not sounding or brakes are not being applied) is engine noise, with wheel noise being less obtrusive. Sound-level meter readings were approximately 90 dB on the "A" scale. Approximately 135 blasts of the horn were sounded per hour during these runs. A typical blast on the horn of the Frisco locomotive produced a 98 dB reading. The Long Island locomotive had the horn mounted 15 feet from the cab on the long hood; the sound level meter indicated 93 dB during a typical blast. Another significant sound was the air blast from the brake valve during application; 105 dB was measured during one such blast.

The crew's working environment was found to approach the exposure limits set in the Walsh-Healey Public Contracts Act; further investigation is recommended to determine whether these limits are actually being exceeded, and to devise better sound conditioning for locomotive cabs.

Third-octave analyses and amplitude vs. frequency plots are contained in the appendix.

DATA COLLECTION

Sounds inside the cabs of locomotives were recorded, using a battery-powered magnetic tape recorder and a calibrated microphone. Each recording was' made aboard a locomotive operating in regular service, and each was of at least four hours duration. Two different test runs were made under diverse conditions.

Long Island Rail Road - The first recording was made on the 106-mile route from Jamaica to Montauk on Long Island, New York. A 2000-HP ALCo locomotive (Model AGP-20-MSC) was used, for a train consisting of a baggage car and two coaches. This is the Long Island's longest route, with a running time of about three hours each way (17 stops) and a layover of about one and three-quarters hours at Montauk. Eastbound to Montauk it was Train 4, and returning it was Train 9.

The route is relatively straight and flat, in an area that shades from urban to rural in the 44 miles from Jamaica (within the New York City limits) eastward to Patchogue (the end of the commuting zone). From Patchogue to Montauk, speed limits are in the 45 MPH range since the light traffic does not justify maintenance of a high-speed line.

The locomotive had a 3-chime Nathan Model "M" horn mounted on the hood about 15 feet forward of the cab. Operating practice is to run with the hood in front where possible (the locomotive is turned on a wye track at Montauk and has the same orientation on the return trip), and the horn is on the right (engineer's) side. Two sheet-metal baffles are located on the hood halfway between the cab and the horn, apparently intended to deflect the sound upwards and away from the cab. Two chimes face away from the cab, and one faces toward it. A double-stem valve is provided, so that reduced sound output can be obtained by the engineer as desired.

St. Louis - San Francisco Railway - This run was selected to provide operating conditions considerably different from those encountered on the Long Island route. The route was one-way from St. Louis to Springfield, Missouri, 232 miles. The train was a freight of 57 loads and 15 empties, with 27 long cars for an equivalent length of 99, 50-foot lengths and a weight of 4065 tons. Two, 3600-HP General Motors locomotive units (Model SD-45) were used.

The route is basically rural, with some towns interspersed along it. There are more curves on it than on the Long Island route of the first run, and the western half is through the foothills of the Ozark Mountains. The line is a main route for through freights, mostly single track with frequent turnouts. The train, number 39, had only one stop scheduled, at Newburg, for a quick crew change. Maximum speed was about 60 MPH, and the entire trip took about 7 hours.

The Frisco normally uses SD-45's in pairs, coupled back-to-back with the cabs at the ends and the hoods in the middle. A five-chime Leslie S-5T Supertyfon horn is used, mounted to the cab roof with all chimes facing in the normal direction of travel.

MEASUREMENT/ANALYSIS

Sounds - The tape recordings from each run were played back and reviewed to determine the significant elements of the acoustic environment in each locomotive cab. Since each run produced a recording at least four hours in length, a good range of operating conditions was obtained. The following elements were identified as being significant:

1. Engine Noise. This sound is continuous but somewhat varying in character and intensity according to load conditions.

2. Horn Sounds.

3. Air Brake Application Noise.

It is interesting to note that wheel noise was generally not obtrusive, and that one could usually not estimate the speed of the train from listening to the tapes.

Engine Noise - Sounds produced by the engines of the locomotives contained predominately low frequency components, with the largest component at approximately 100 Hz. Analysis was made on the cab sound environment at sampling points covering the following operating conditions:

1. SD-45 locomotive heavily loaded. It was accelerating a 4065-ton freight train leaving the yard area at low speed and entering the main line.

2. SD-45 locomotive, lightly loaded. The train was drifting into a curve at medium speed, with little or no effort from the locomotive.

3. ACP-20 locomotive, medium loading. The train was underway at operating speed (about 45 MPH). Two samples were analyzed under these conditions.

Horn Sounds - The grade crossing warning signal consists of four blasts of the horn. In four hours of running, the Long Island Rail Road engineer sounded this signal 159 times. The Frisco engineer sounded the signal 112 times in an equal period.

The Long Island locomotive, as noted prviously, was equipped with a double-stem valve which allowed for a loud or a soft blast of the horn; the engineer used the soft tone more frequently than the loud tone. The horn on the Long Island locomotive was located 15 feet away from the cab on the side of the hood, and the engineer sounded very short blasts. The result was that the observer in the cab did not find the horn sounds to be very loud.

The two enginemen differed considerably in horn-blowing technique, with the Frisco engineer sounding longer blasts than the Long Island engineer. This, combined with the mounting of the 5-chime horn directly on the cab roof, made horn sounds considerably more obtrusive in the cab of the Frisco locomotive. The horn was not used at crossings within the St. Louis city limits.

Analysis was made on the cab sound environment at sampling points covering the following operating conditions with horn sounding:

1. SD-45 locomotive, lightly loaded. The train was drifting into a curve at medium speed, with little or no effort from the locomotive.

2. AGP-20 locomotive, medium loading. The train was underway at operating speed (about 45 MPH).

Air Brake Application- Air escaping from brake lines through the brake valve into the cab during application of the brakes creates a sound that is rich in high-frequency components, and that can be quite loud. This observer found the sound quite annoying (at times almost painful), but the engineers considered it to be a useful indication of brake performance.

Sound Levels - Table I tabulates sound-level meter readings for operating conditions listed above. It should be recognized that two readings taken under similar conditons will not agree perfectly. The sound level in the cab is constantly changing, and the reported reading is an average selected by eye. Accuracy is estimated to be ± 3 decibels. The "C" reading is a measure of total sound energy, and the "A" reading is similar except that the meter is made less sensitive to low frequencies than to high ones. The "A" reading is used as a crude approximation of the human response to noise, since a low-pitched noise is generally less annoying than a mid-frequency noise of the same energy content (amplitude).

Note that the "A" reading is higher on the SD-45 locomotive lightly loaded

TABLE I. SOUNDS IN LOCOMOTIVE CABS

"A" READING

Locomotive	Loading	Speed	Sound Source	Sound Level
AGP-20	Medium	Medium	Brake Appl	105 dB
SD-45	Light	Medium	Horn	98
AGP-20	Medium	Medium	Horn	93
SD-45	Light	Medium	No Horn	92
*AGP-20	Medium	Medium	No Horn	90
SD-45	Heavy	Low	No Horn	88

"C" READING

Locomotive	Loading	Speed	Sound Source	Sound Level
AGP-20	Medium	Medium	Brake Appl	105 dB
SD-45	Light	Medium	Horn	104
SD-45	Heavy	Low	No Horn	103
*AGP-20	Medium	Medium	No Horn	102
AGP-20	Medium	Medium	Horn	101
SD-45	Light	Medium	No Horn	98

*Average of two measurements made at different times under similar operating conditions.

Note that the "A" reading emphasizes high-frequency sounds such as horn and wheel noise, and discriminates against low-frequency sounds such as engine noise. The "A" reading is commonly used for evaluating industrial noise exposure.

than for the same locomotive under heavy load. The "A" meter characteristic discriminates against low frequencies such as engine sounds, and favors higher frequencies such as wheel noise. The lightly loaded reading was taken at higher speed, which would produce greater wheel noise (this result raises the possibility that an hour in the cab of a locomotive pulling a heavy train upgrade at 15 MPH might represent less acoustic exposure than the same time spent highballing the same train on the level).

Sound level readings taken under operating conditions in the cab as the horn is sounded include sound energy from all sources; the engine and wheels as well as the horn. Readings were taken with the horn sounding and immediately afterwards with the horn silent, in order to obtain the increase in level attributable to the horn. Table II summarizes the result of this comparison. Sound levels shown for the operation of the horn on the Long Island Rail Road AGP-20 locomotive are for use of the loud tone. The soft tone of this horn produced no measurable change in the sound level reading.

A typical air brake application on the AGP-20 locomotive produced a reading of 105 dB on both the "A" and the "C" scales.

TABLE II

EFFECT OF HORN OPERATION ON SOUNDS IN CAB

"A" Reading

Locomotive	Loading	Speed	Sound Level	Sound Level Horn Silent
SD-45	Light	Medium	98 dB	92 dB
AGP-20	Medium	Medium	93	87

"C" Reading

Locomotive	Loading	Speed	Sound Level With Horn	Sound Level Horn Silent
SD-45	Light	Medium	104 dB	98
AGP-20	Medium	Medium	101	100

CONCLUSIONS

A criterion for excessively noisy industrial environments is contained in the Walsh-Healey Public Contracts Act Safety and Health Standards, 1969. The Act states that, in working environments where sound levels exceed 90 dB as measured on the "A" scale of a sound-level meter, either the time of exposure should be limited or the workers should wear personal protective equipment. The Act sets times of exposure, in steps, for sound levels above 90 dB.

Table III illustrates sound levels typical of familiar types of noises. Table IV is a noise survey form, used as a worksheet for computing whether a working environment exceeds the sound exposure specified in the Act. Table IV also shows the allowable exposure for each range of sound levels. Note that a 92 dB environment is permissible for six hours per day. 98 dB, the highest reading in Table I for horn operation, is permissible for two hours per day. 105 dB, the level during brake applications in the AGP-20 locomotive, is permissible for one hour per day.

While the study and the analysis contained in it were not made for defining legal exposure in the cabs, it is illustrative to use the survey form to compute approximate exposure from the observed data. The SD-45 locomotive cab, under light loading and medium speed was measured at 92 dB. This was a 'spot' measurement, and the level varies somewhat with changes in conditions, etc.; this level is, however, reasonably typical of those encountered during the run.

Assume, for the analysis, that a four-hour run is made with a sound level of 92 dB from engine and wheel noise. Assume that the horn is used for 135, 2-second blasts each hour (270 seconds or 4-1/2 minutes.....for simplicity, round this to 1/10 hour) at 98 dB. For this analysis, ignore brake application noise. Thus the exposure is 3.6 hours at 92 dB and .4 hours at 98 dB. Table V illustrates the calculation, which gives the exposure factor as .73, a permissible value. The assumed conditions would not, however, be permissible for eight hours.

Since the measurements obtained for this report indicate that the noise level in a typical locomotive cab approaches the limits allowed in the Act, it is recommended that a more detailed survey be made to determine whether exposures do exceed legal limits, and if so under what conditions. The findings also suggest that that it is worthwhile to investigate locomotive cab design, with an eye toward:

1. General sound conditioning, to reduce engine and wheel noise.
2. Mechanical isolation of the horn assembly from the cab roof.
3. Reducing the amplitude of air brake application noise, while retaining the audible indication of brake performance.

TABLE III.

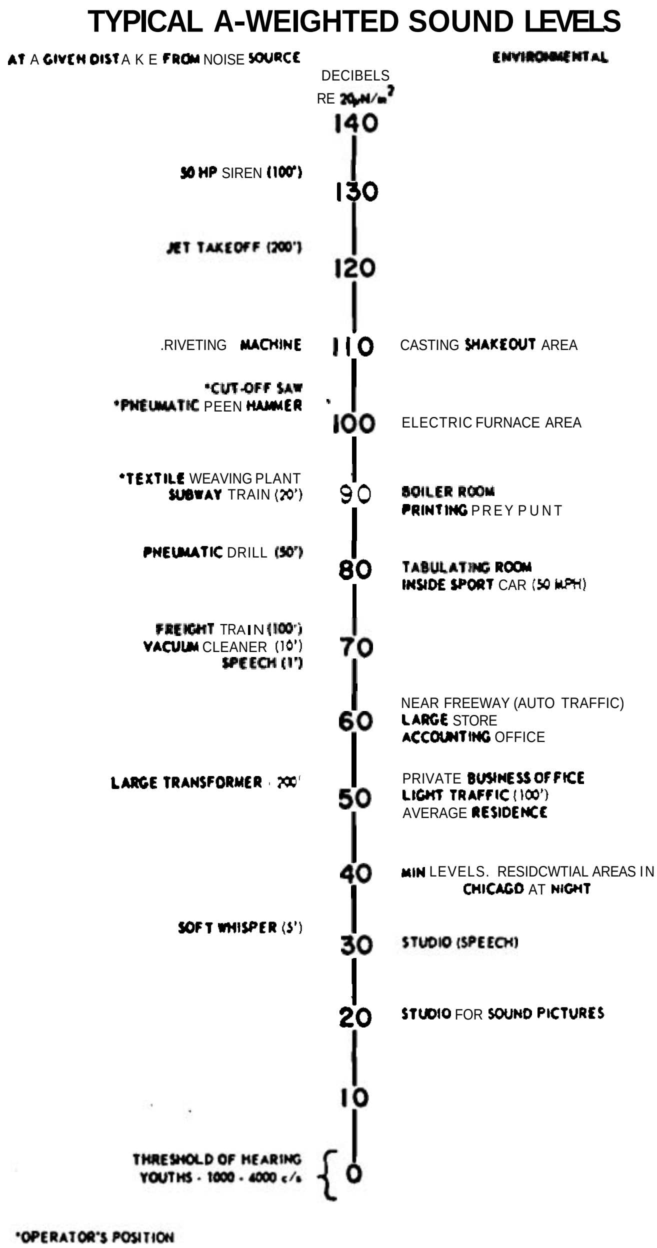


Figure 2-1. Typical A-weighted sound levels measured with a sound-level meter. These values are taken from the literature. Sound-level measurements give only part of the information usually necessary to handle noise problems, and are often supplemented by analysis of the noise spectra.

Reproduced from the <u>Handbook of Noise Measurement</u>, by Arnold P. G. Peterson and Ervin E. Gross, Jr, General Radio Company, West Concord, Mass, 1967.

TABLE IV

Plant-Noise Survey Form

DATE:
METER # :

LOCATION: ....

....

NUMBER OF PERSONNEL EXPOSED: ....

WEARING EAR PROTECTION7 ☐ yes ☐ no

OPERATOR: ....

SIGNED: ....

DIAGRAM:
(Show measuring location with an X.)

1565-A PROCEDURE CHECK LIST

1. REMOVE WHITE CAP.
2. TURN MODE SWITCH TO "A_S" (OR "C_F" FOR IMPACT NOISE).
3. TURN ATTENUATOR KNOB TO GET SCALE READING (OR TO 130 FOR IMPACT NOISE).
4. ADD READING TO KNOB SETTING TO GET TOTAL dB.

NOTES: ....

....

....

....

....

MAXIMUM LEVELS AS MEASURED ON THE "A_S" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	dB(A) MAX LEVEL	EXPOSURE TIME If necessary, note time of day	D TOTAL DURATION IN HOURS PER DAY	P PERMISSIBLE HOURS PER DAY	D/P
	OVER 115			NONE	
	115			¼	
	110			½	
	105			1	
	102			1½	
	100			2	
	97			3	
	95			4	
	92			6	
	90			8	
	UNDER 90			ANY	0

IMPACT CHECK (MUST BE UNDER 140 dB(C) ON "C_F"):

TOTAL
To comply with regulations, total cannot be more than 1.

RECOMMENDATIONS; ....

....

TABLE V

Plant-Noise Survey Form

DATE:
METER # :

LOCATION: SD-45 LOCOMOTIVE CAB

NUMBER OF PERSONNEL EXPOSED: ....

WEARING EAR PROTECTION? ☐ yes ☐ no

OPERATOR: ....

SIGNED: ....

DIAGRAM:
(Show **measuring location with an X.**)

1565-A PROCEDURE CHECK LIST

1. REMOVE WHITE CAP.
2. TURN MODE SWITCH TO "AS" (OR "C_F" FOR IMPACT NOISE).
3. TURN ATTENUATOR KNOB TO GET SCALE READING (OR TO 130 FOR IMPACT NOISEI.
4. ADD READING TO KNOB SETTING TO GET TOTAL dB.

NOTES: ....

	dB(A) MAX LEVEL	EXPOSURE TIME If necessary, note time of day	D TOTAL DURATION IN HOURS PER DAY	P PERMISSIBLE HOURS PER DAY	D/P
MAXIMUM LEVELS AS MEASURED ON THE "AS" SCALE OF THE SOUND-LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	OVER 115			NONE	
	115			¼	
	110			½	
	105			1	
	102			1½	
	100			2	
	97	HORN OPERATION	.4	3	.13
	95			4	
	92	IN MOTION AT MEDIUM SPEED	3.6	6	.60
	90			8	
	UNDER 90			ANY	0

IMPACT CHECK (MUST BE UNDER 140 dB(C) ON "C_F"):

TOTAL .73

To comply **with regulations, total cannot be** more then 1.

RECOMMENDATIONS: ....

APPENDIX

FREQUENCY ANALYSIS

FREQUENCY ANALYSIS

Two forms of frequency analysis were used. In both types of analysis, the sound is passed through a filter which allows one selected frequency component to reach an amplitude measuring device, and rejects all others. For third-octave analysis, the filter is tuned to selected frequencies, and the amplitude is measured and recorded on the graph for each frequency. The standard frequencies at which measurements are made are one-third of an octave apart, and the filter bandwidth is also one-third of an octave. For amplitude vs. frequency plots, a graphic level recorder is used to measure the amplitude of the filtered sound and automatically move a pen across the paper. The paper is moved under the pen by a motor which simultaneously tunes the filter. The result is a continuous plot of amplitude vs. frequency. The filter bandwidth was set at 1/10 octave.

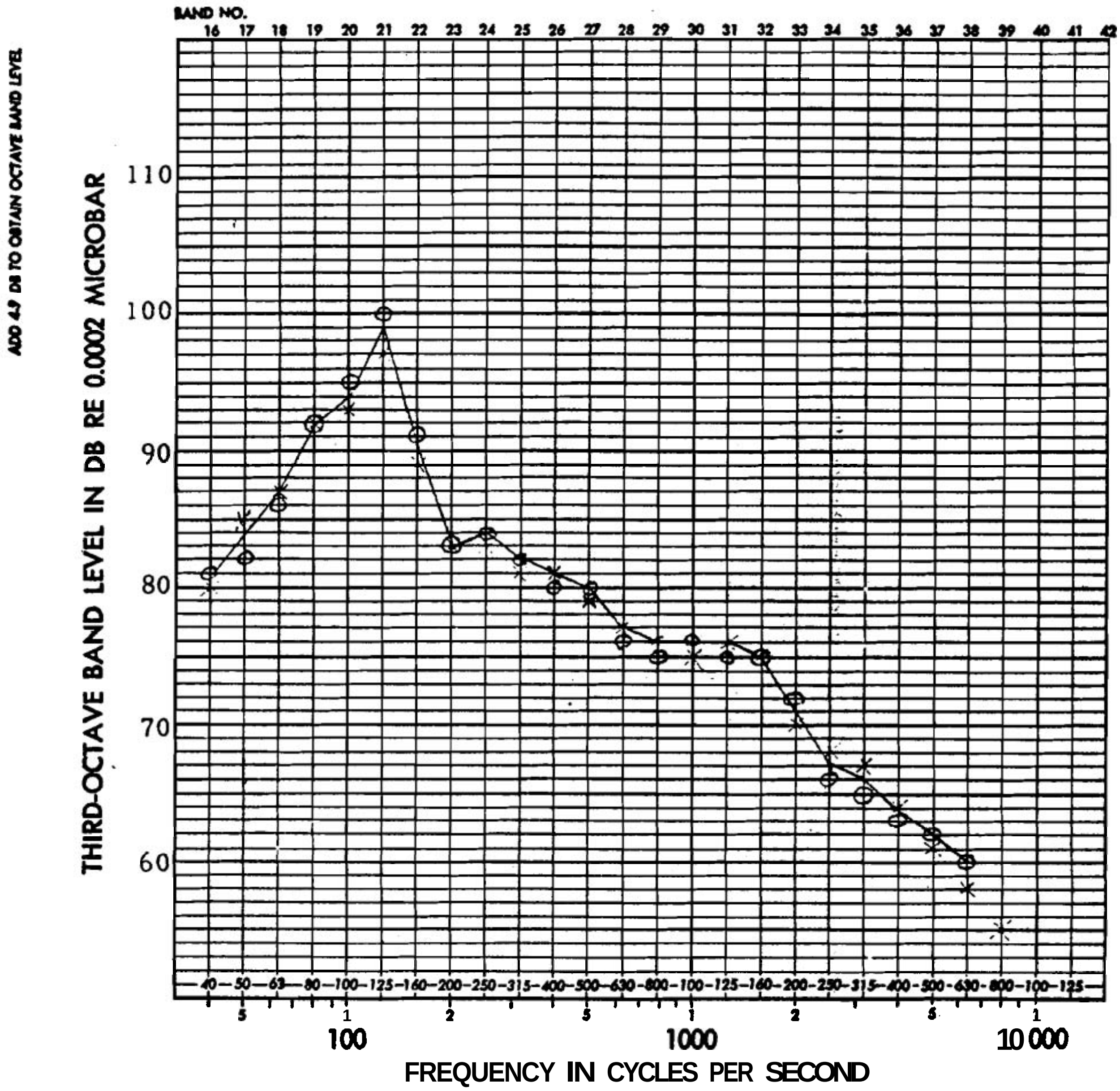
Figure 1 is a third-octave analysis of the SD-45 locomotive under heavy load at low speed.

Figure 2 is a third-octave analysis, and Figure 7 is an amplitude vs. frequency plot, of the AGP-20 locomotive under medium load at medium speed.

Figure 3 is a third-octave analysis showing the SD-45 locomotive under light load at medium speed. Operation with and without use of the horn is compared. Figures 5 (without horn) and 6 (horn in use) give the same information in amplitude vs. frequency form.

Figure 4 is a third-octave analysis showing the **AGP-20** locomotive under medium load at medium speed. Operation with and without use of the horn is compared. Note that the overall sound levels given for operation without the horn differ from those shown in Figure 2, although operating conditions are similar. Figure 8 is an amplitude vs. frequency plot of the same information for horn in use.

Figure 9 is an amplitude vs. frequency plot of the AGP-20 locomotive cab sound with air brakes being applied. Note that the tenth-octave band amplitude remains constant at about 85 dB throughout the spectrum out to the highest frequency the tape recorder could reproduce. In all other sound analyses in the locomotive cabs, the amplitude falls off at high frequencies and is generally not significant above 2.5 KHz.

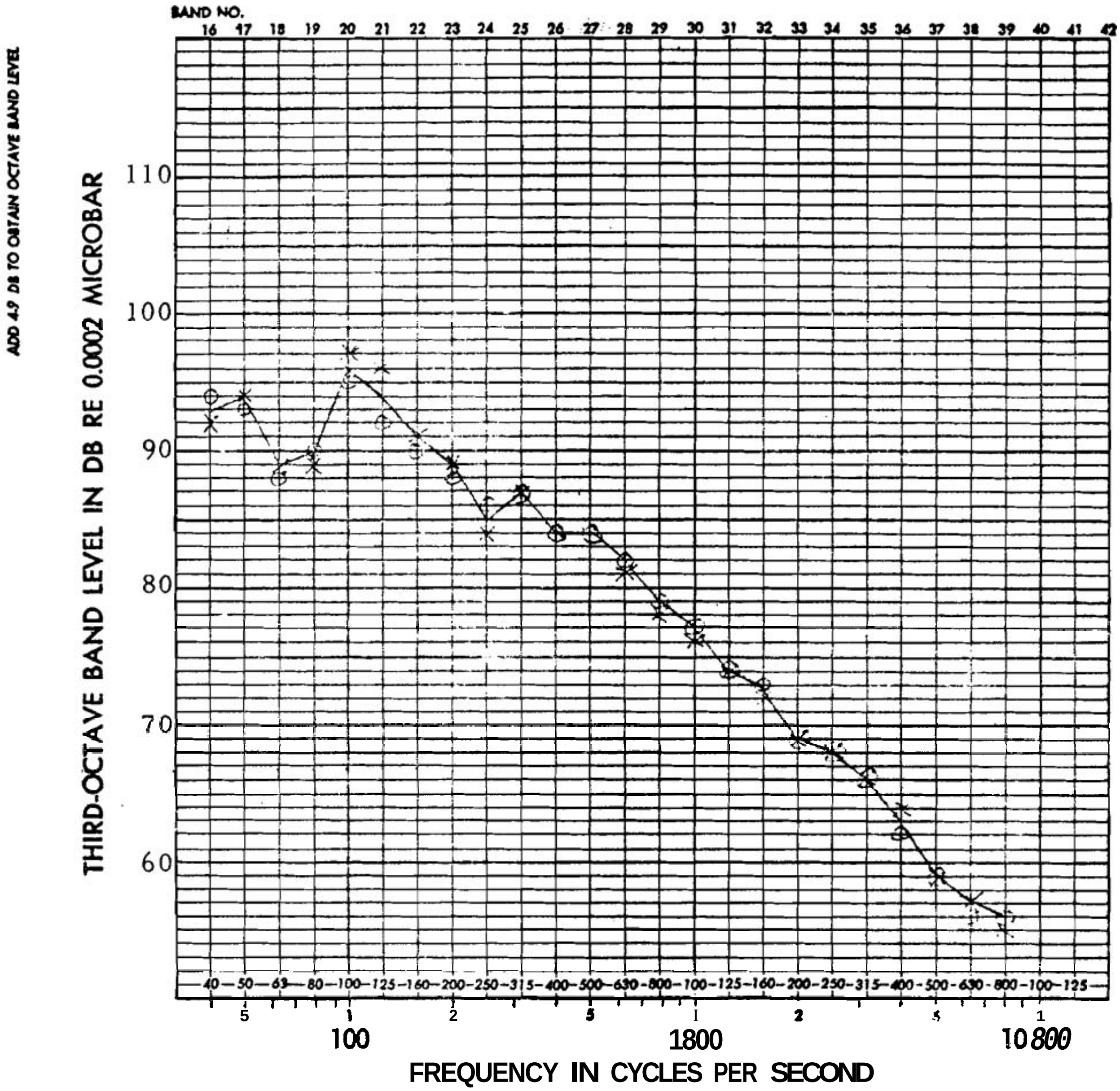


Third-Octave Sound Analysis: Sound in Locomotive Cab. General Motors Model SD-45 (Frisco #942) Under Heavy Loading, Low Speed.

The curve is an average of two analyszs, made under equal operating conditions.

Sound-level meter readings are 103 dB "C", and 88 dB "A", for these sounds.

Figure 1.

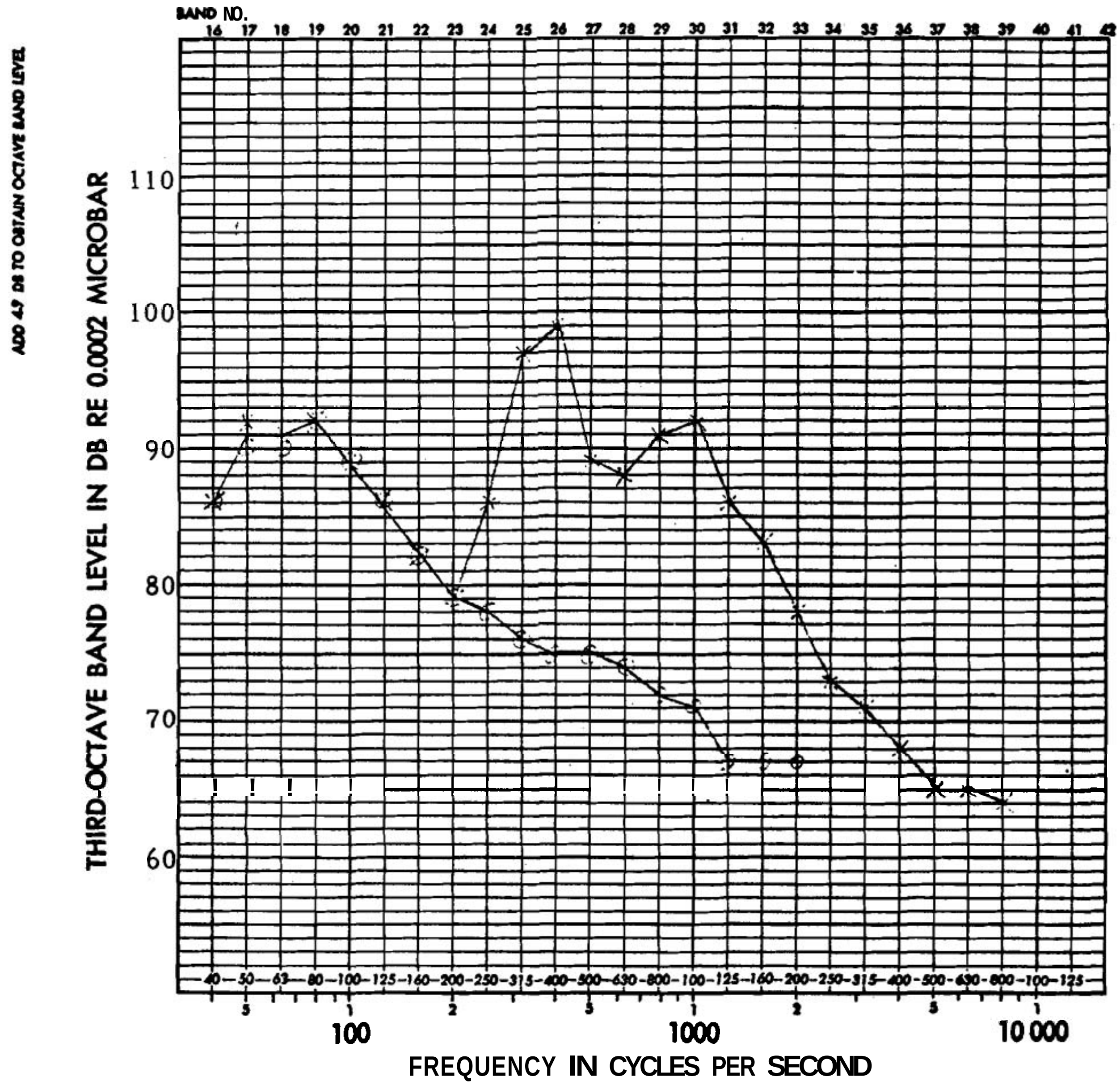


Third-Octave Sound Analysis: Sound in Locomotive Cab. ALCo Model AGP-20-MSC (LIRR #212), Under Medium Loading, Medium Speed.

The curve is an average of two analyses, made under equal operating conditions.

Sound-level meter readings were 104 dB "C", and 92 dB "A", for this sound

Figure 2.

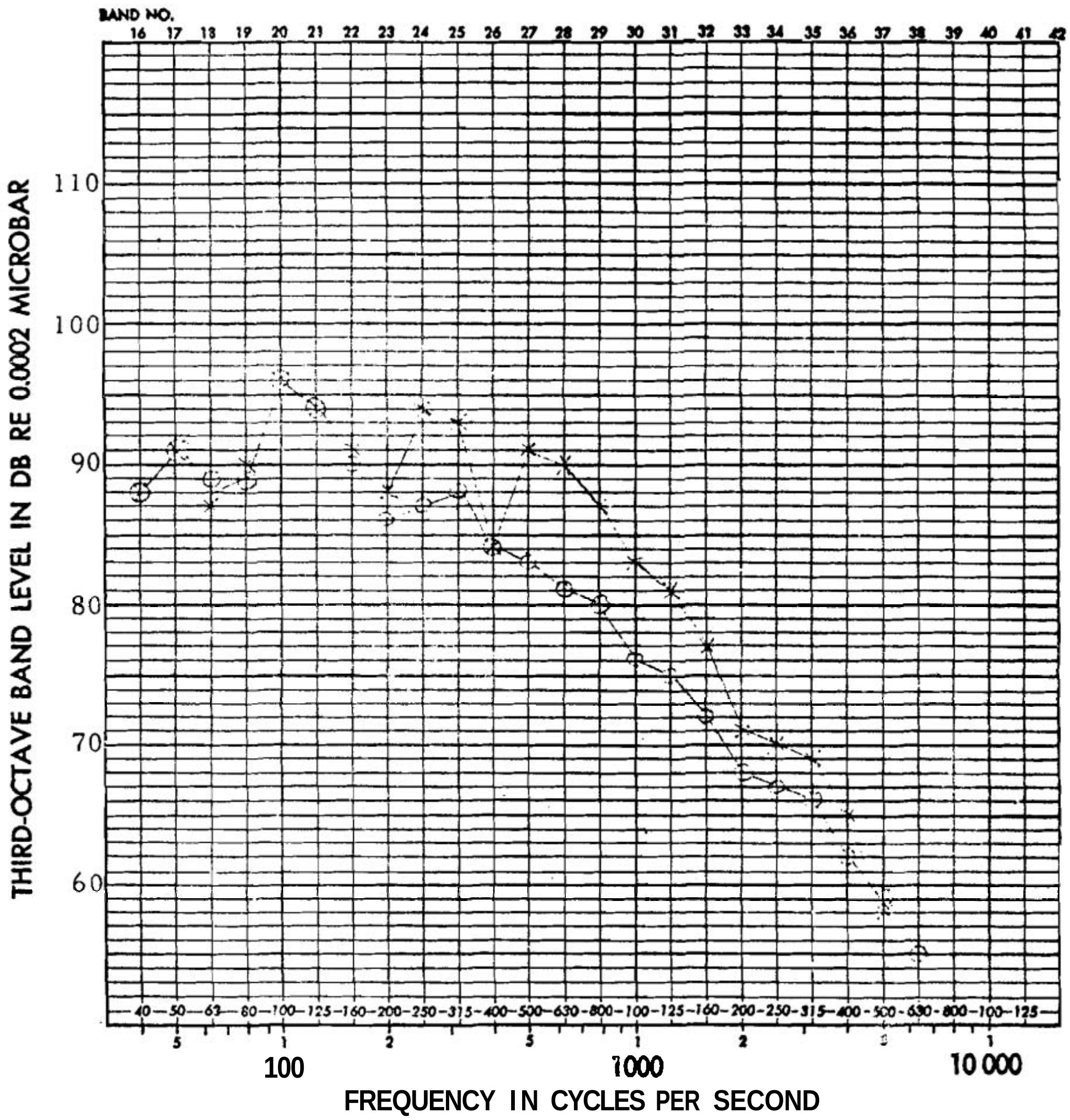


Third-Octave Sound Analysis: Sounds in Locomotive Cab, Horn vs. **Background.** G. M. SD-45 (Frisco #942) Light Loading, Medium Speed.

x = Horn in Use
o = Horn Not in Use (background)

Sound - level meter readings are 104 dB "C", and 98 dB "A", with horn in use; 98 dB "C", and 92 dB "A", for background sounds.

Figure 3.

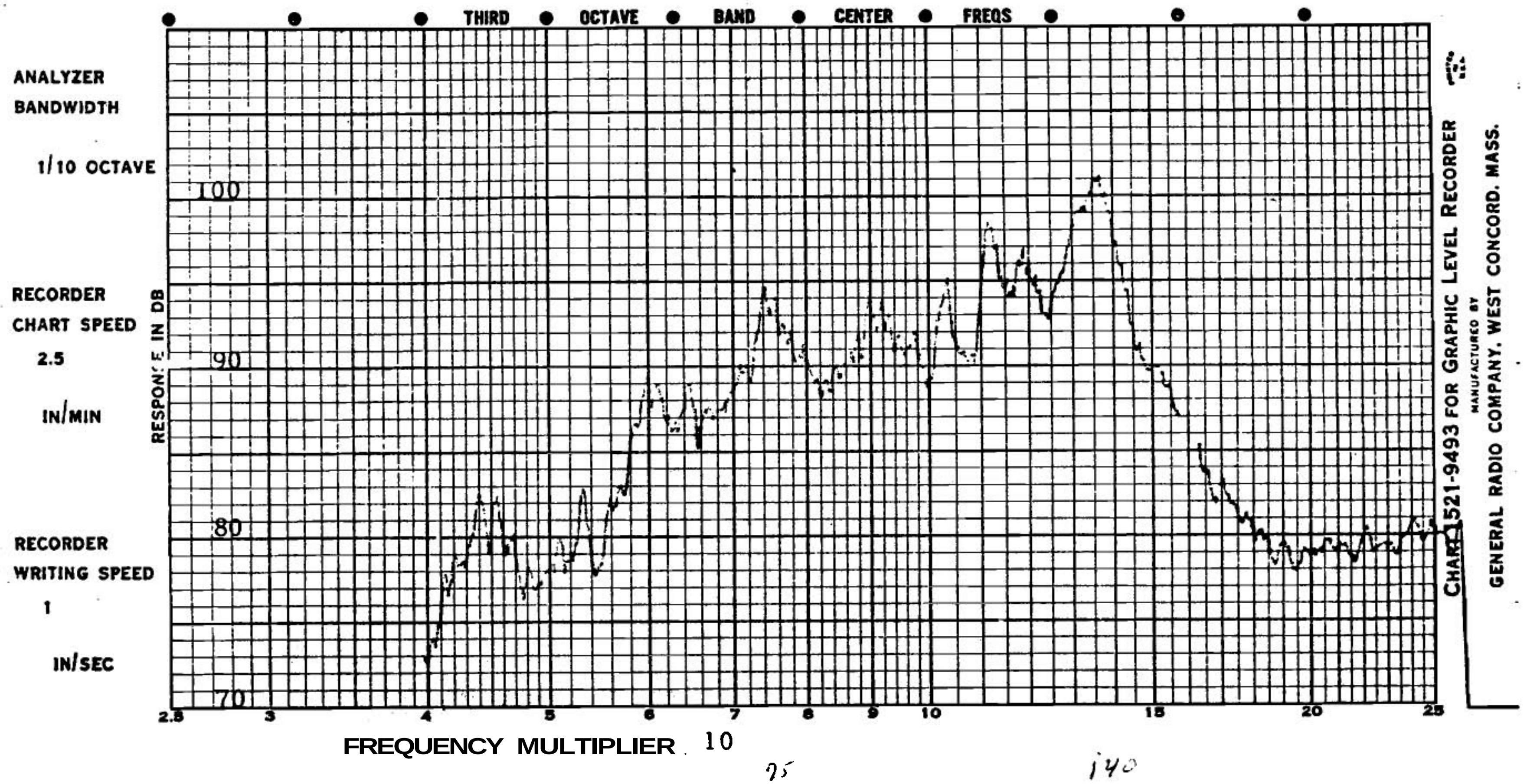


Third-Octave Sound Analysis: Sounds in Locomotive Cab, Horn vs. Background. ALCo AGP-20-MSC (LIRR #212), Medium Load, Medium Speed.

x = Horn in Use
o = Horn Not in Use (background)

Sound-level meter readings are 101 dB "C", and 93 dB "A", with horn in use; 100 dB "C", and 87 dB "A", for background sounds.

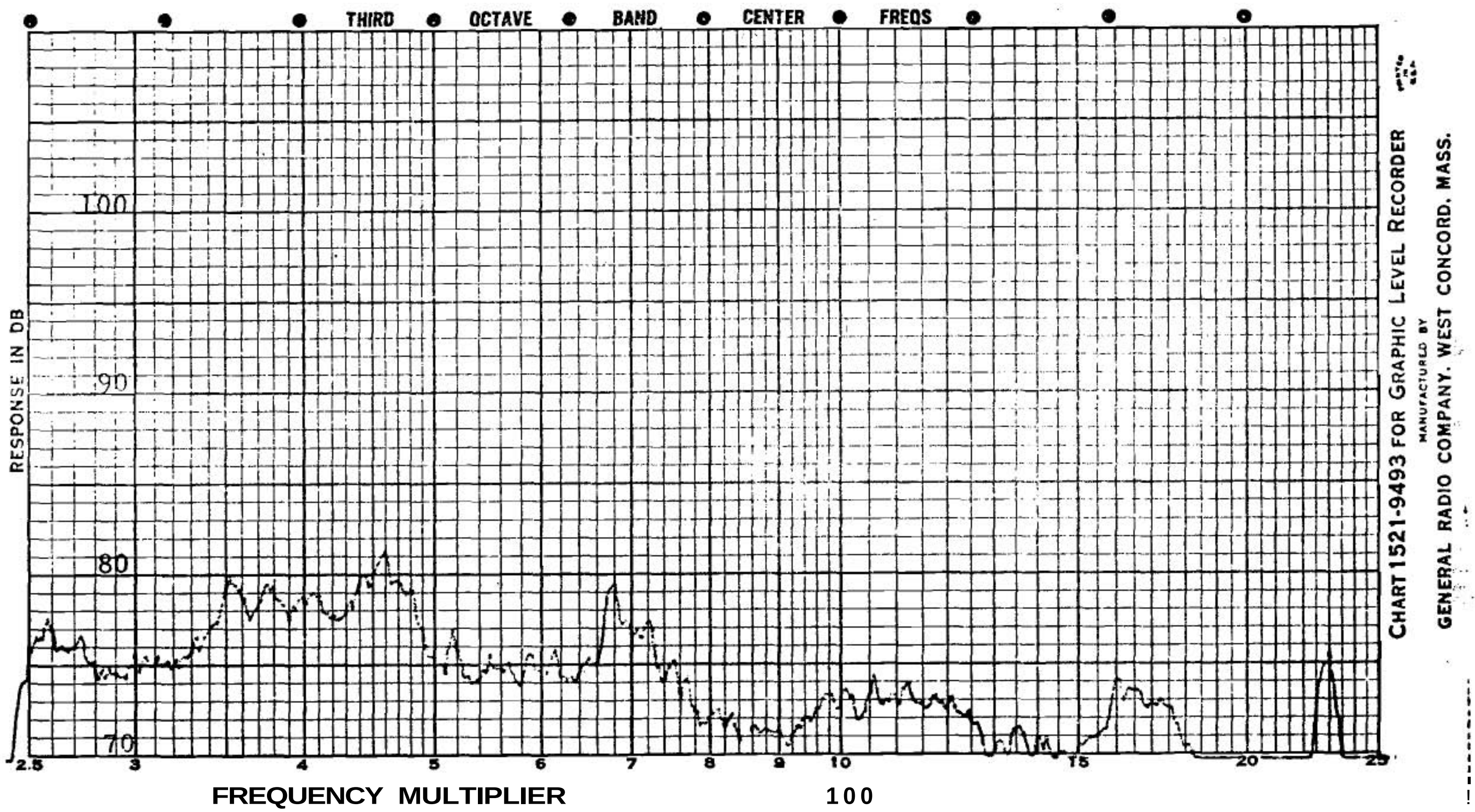
Figure 4.



40-250 Hz

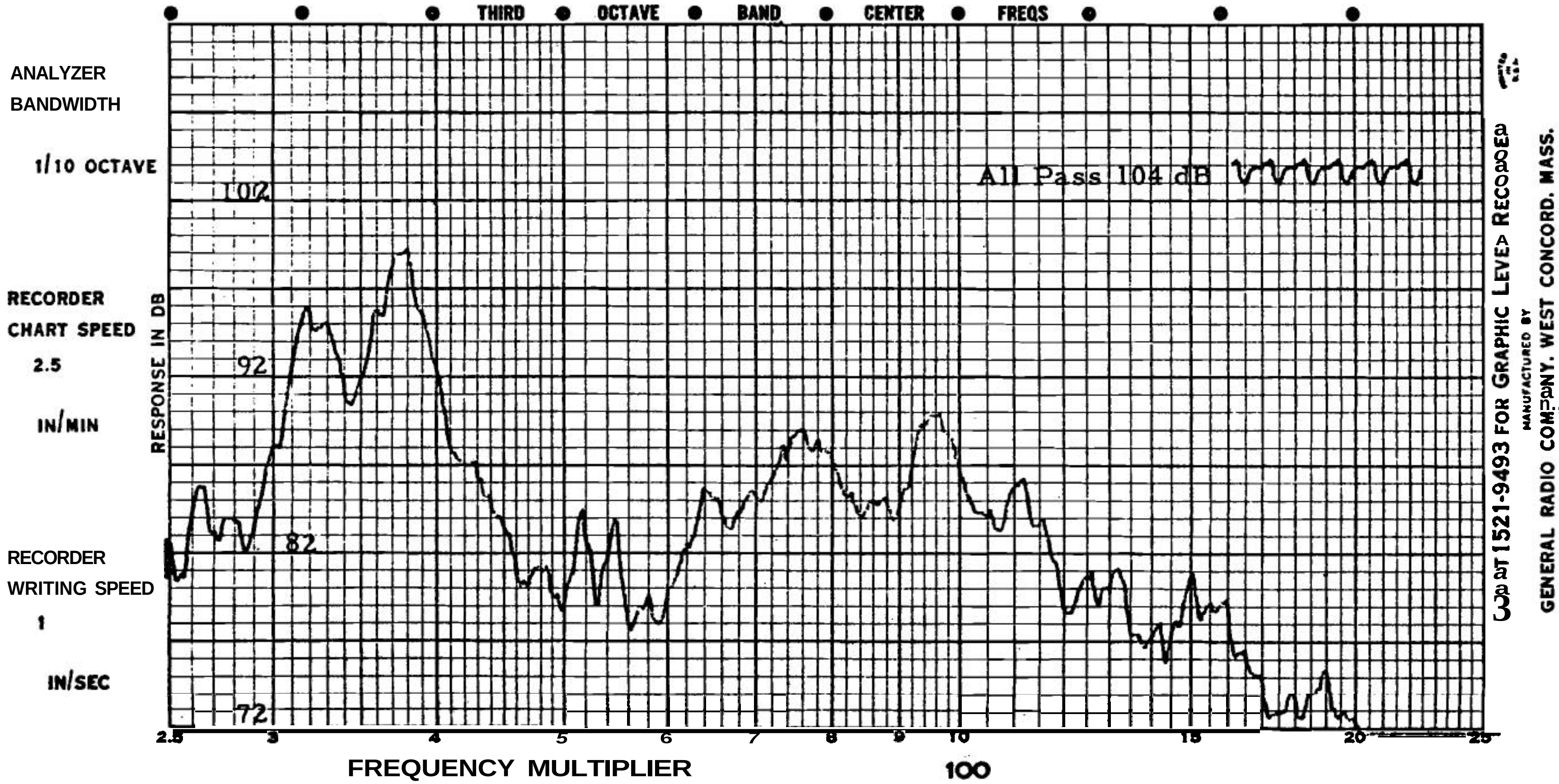
Amplitude vs. Frequency Plot: Sounds in Locomotive Cab. G. M. SD-45 (Frisco #942), Light Loading, Medium Speed.

Figure 5.



250 - 2500 Hz

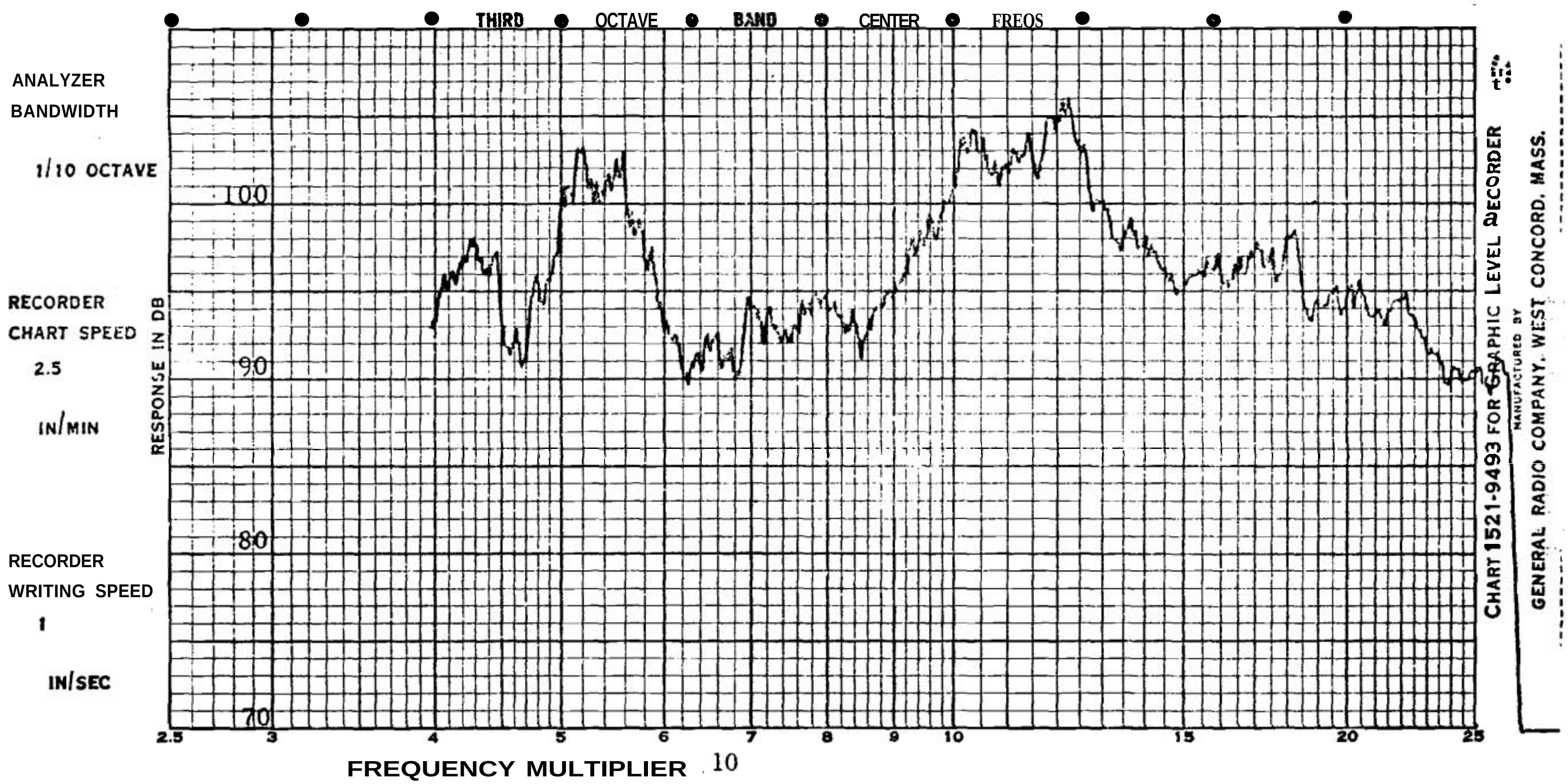
Figure 5 (continued)



250-2500 Hz. (For frequency content in the range 40-250 Hz, see Page 1 of Figure 5).

Amplitude vs. Frequency Plot: Sounds in Locomotive Cab. Horn operating on G. M. SD-45 (Frisco #942), Light Loading, Medium Speed.

Figure 6.

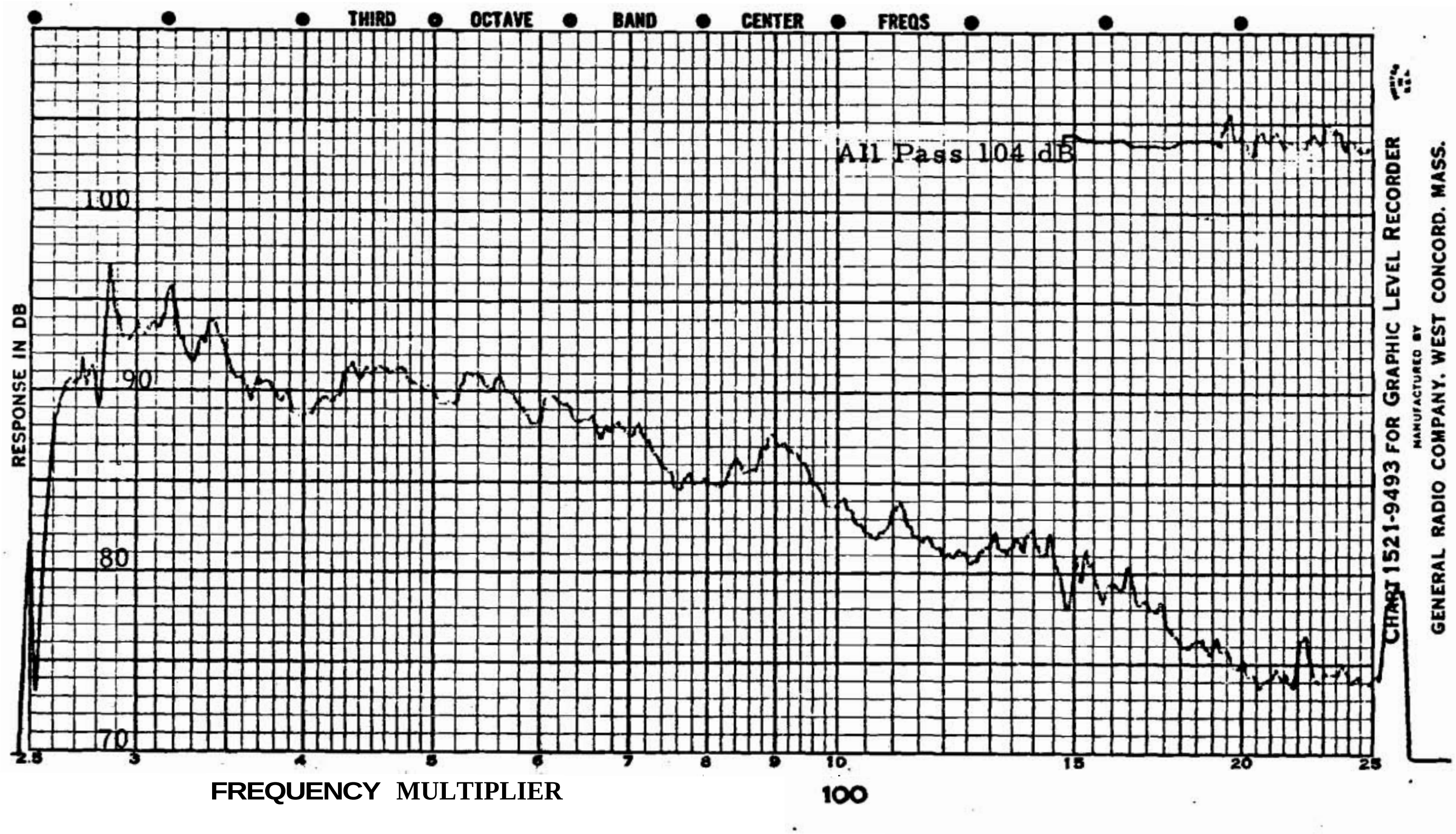


25

40-250 Hz

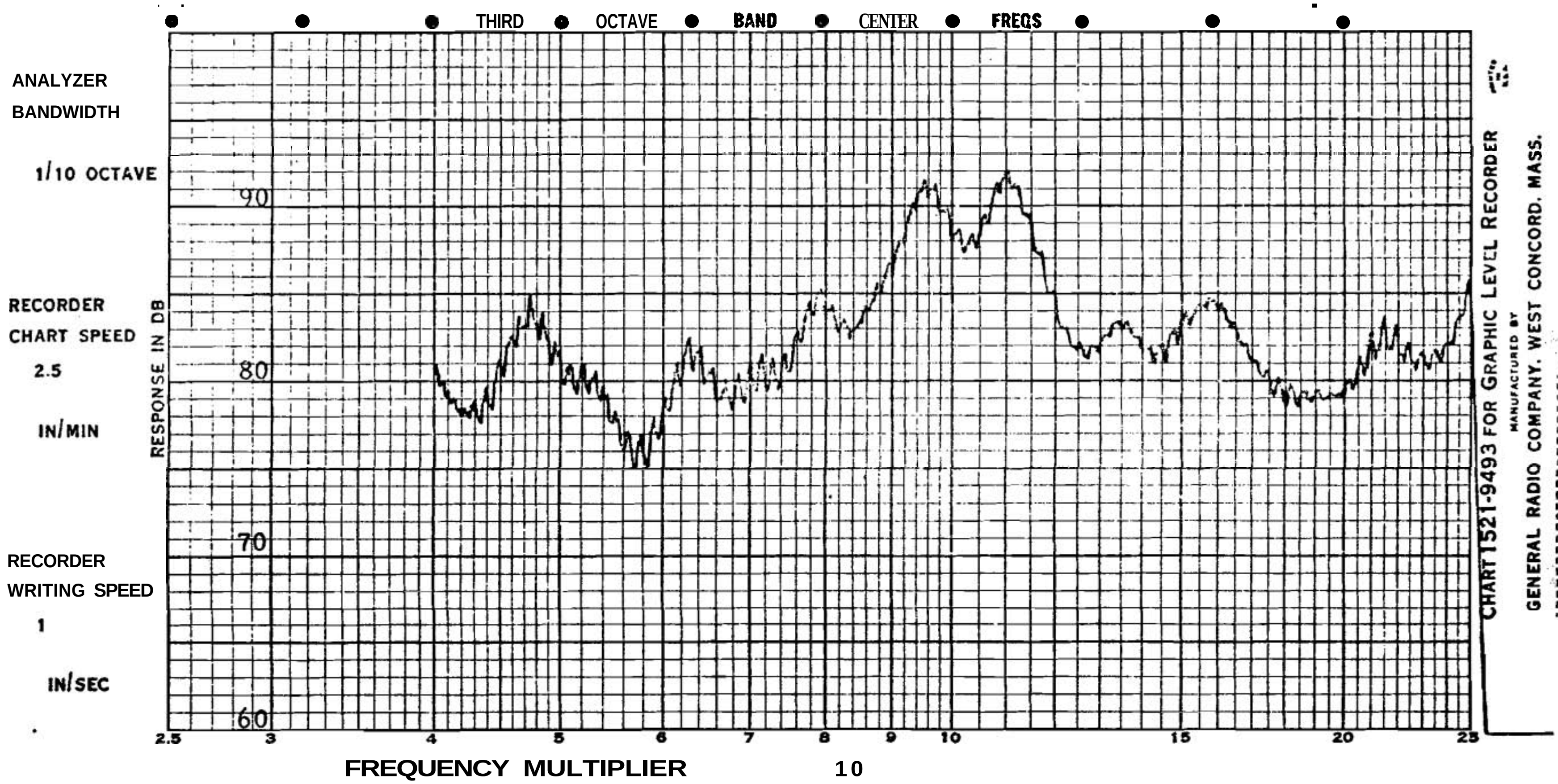
Amplitude vs. Frequency Plot: Sounds in Locomotive Cab. ALCo AGP-20-MSC (LIRR #212)
Medium Loading, Medium Speed.

Figure 7.



250 - 2500 Hz

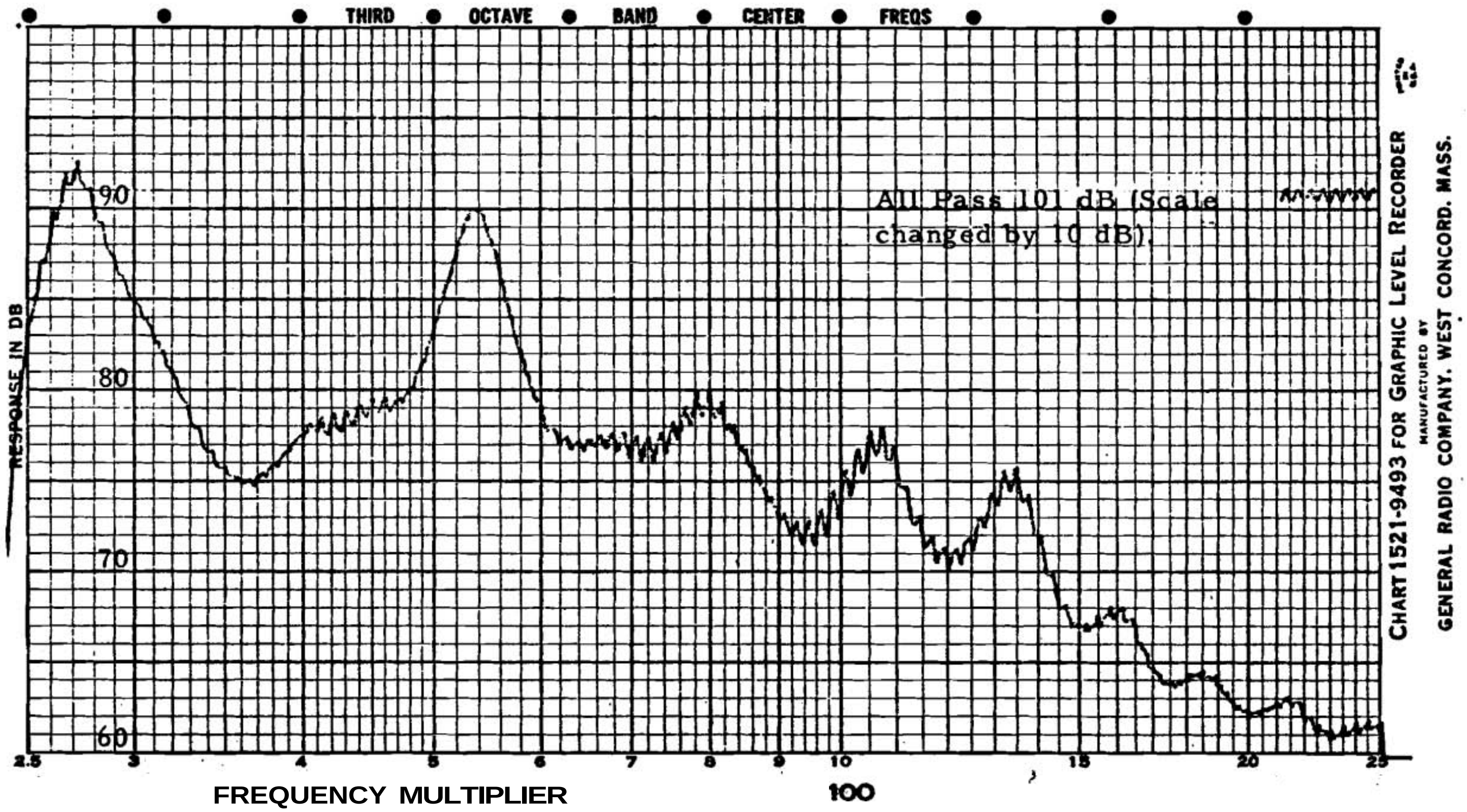
Figure 7 (continued).



40 - 250 Hz

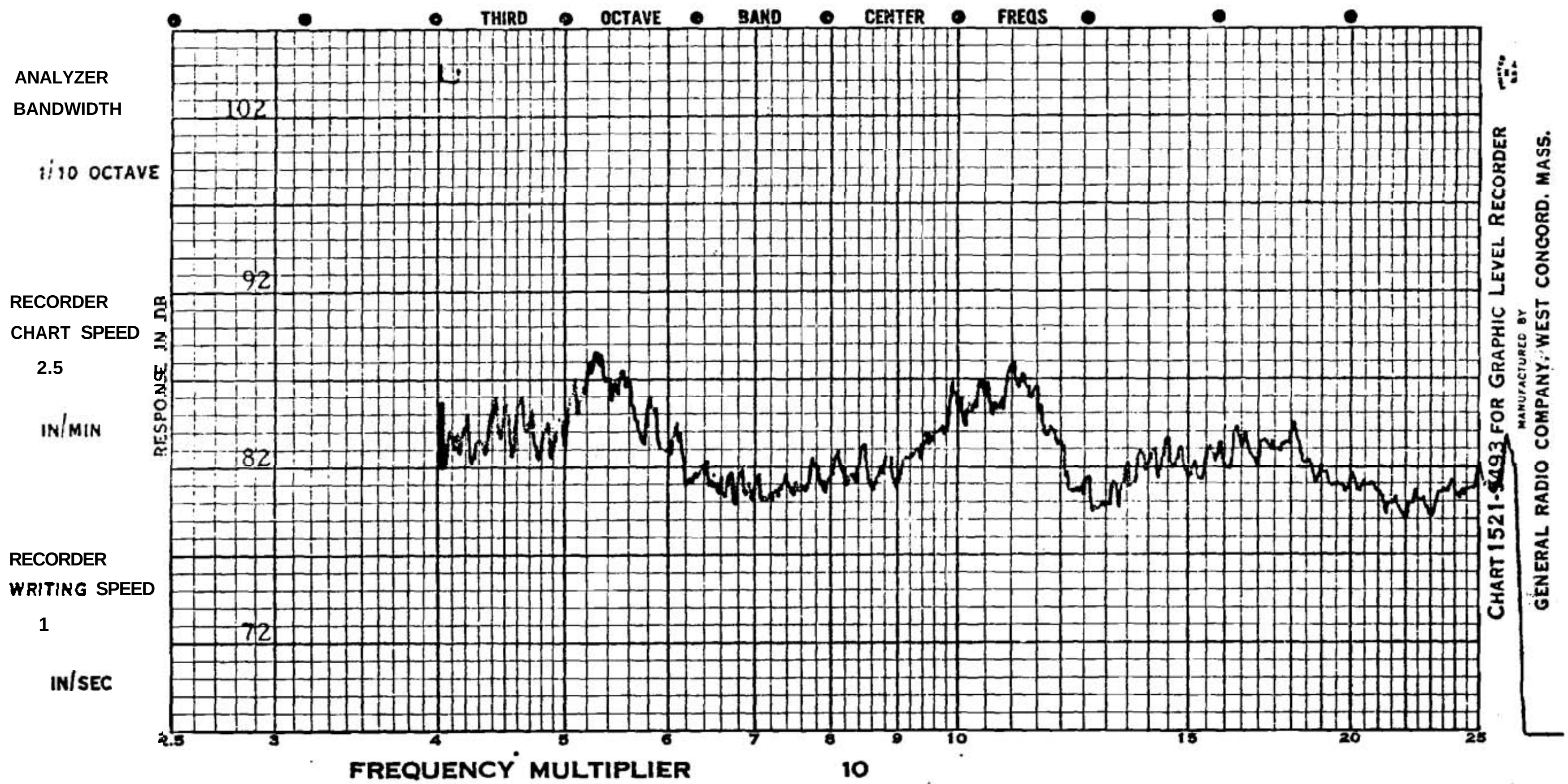
Amplitude vs. Frequency Plot: Sounds in Locomotive Cab. Horn operating on ALCo AGP-20-MSC (LIRR #212) Medium Loading, Medium Speed.

Figure 8.



250 - 2500 Hz

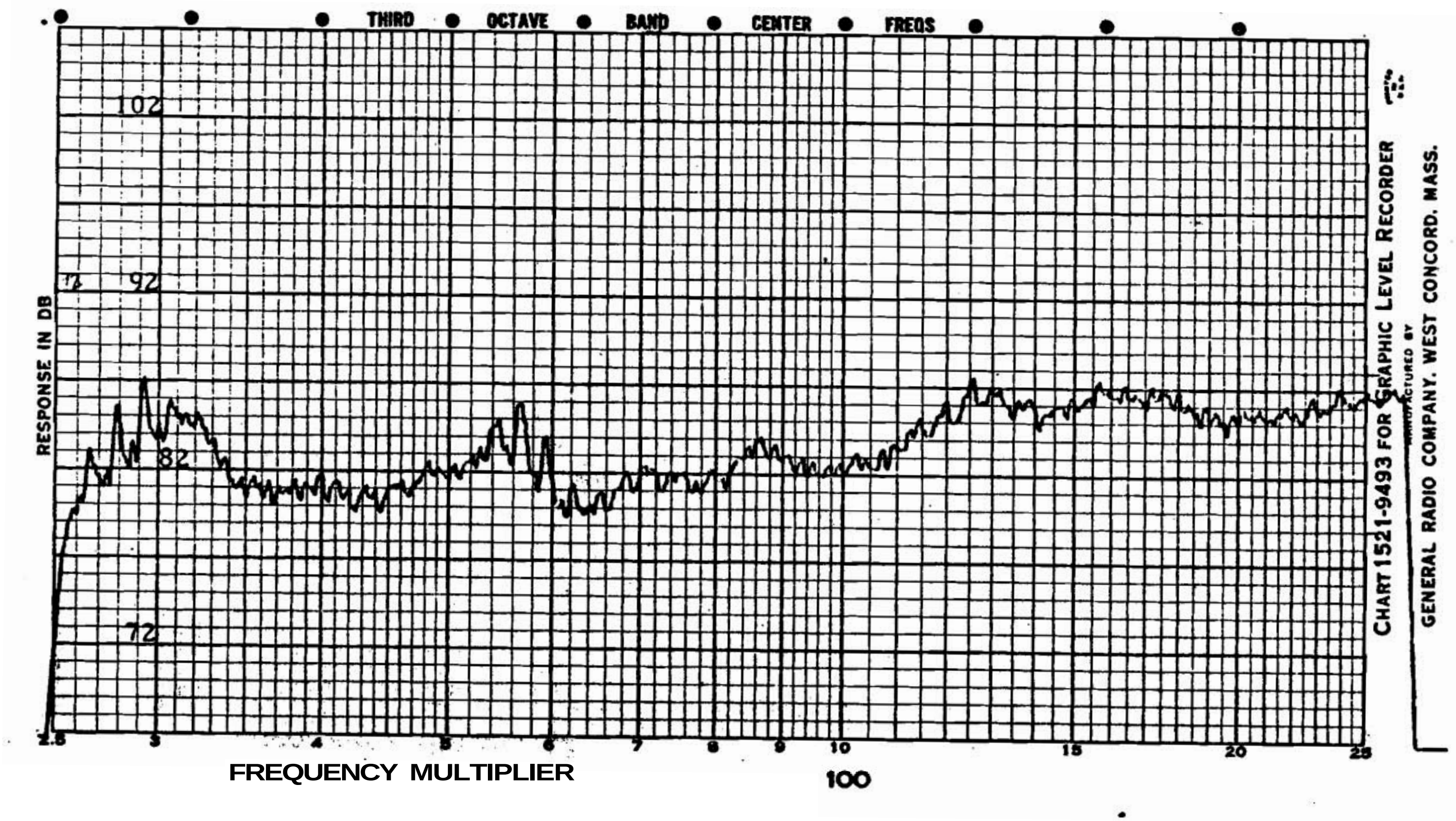
Figure 8 (continued)



40 - 250 Hz

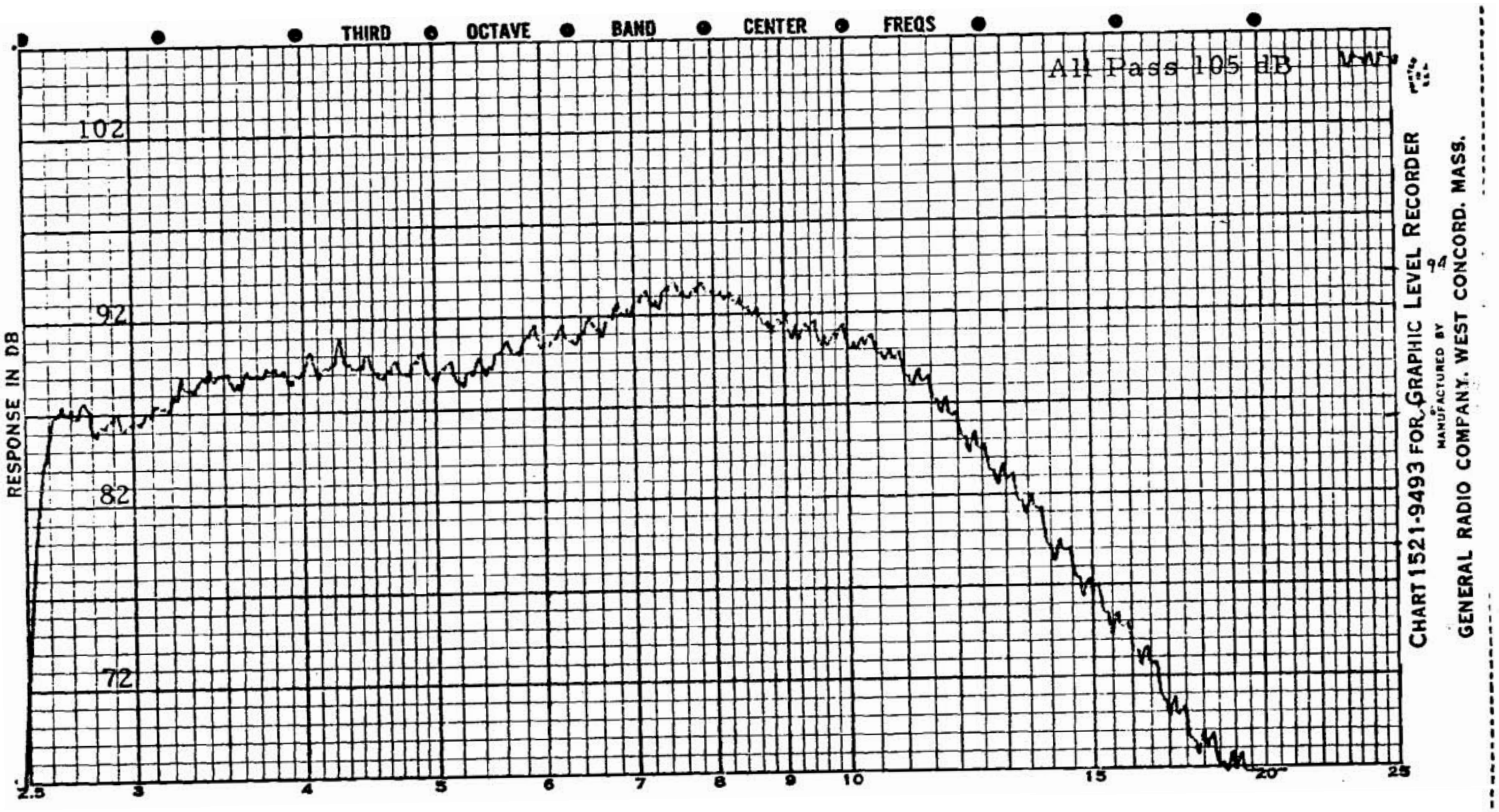
Amplitude vs. Frequency Plot: Sound in Locomotive Cab. Air Brake Application on ALCO AGP-20-MSC (LIRR #212), Medium Loading, Medium Speed.

Figure 9.



250-2500 Hz

Figure 9 (continued)



FREQUENCY MULTIPLIER 1000

2500 - 10 000 Hz

Figure 9 '(continued)