Experiments on the reduction of noise radiated by subway-car rails

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No. 109

TECHNICAL NOTE

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SUBJECT: Experiments on the Reduction of Noise Radiated by Subway-car Rails

This note is an addendum to Technical Note No. 102: "Noise Control in Rapid Transit System, Toronto Transportation Commission". The following few sentences, summarizing the previous note, will serve as an introduction to the work reported here:

Although the cars specified for the Toronto subway are of the improved PCC design, which is relatively quiet, they may be expected to produce an uncomfortably loud noise in the confined reverberant space of a subway tunnel. In fact, this has been observed in a Chicago subway which uses the PCC cars. At the request of Deleuw, Cather and Co., consultants to the T.T.C., a series of measurements were made by Armour Research Foundation on the Chicago subway. At a meeting in Chicago, in which I participated, a sound-absorption treatment was prescribed for the walls, which, it was calculated, would reduce the noise to a tolerable level.

The previous Note deals with one way of achieving a reduction in noise. The noise level in an enclosure is determined mainly by the intensity of the noise source and by the sound absorption at the boundaries. Hence the noise may be reduced by applying absorbent material to the walls. Bare concrete walls are highly reflective acoustically, and consequently an untreated subway absorbs the noise very slowly. In these circumstances the introduction of a little absorbent material has a striking effect. The proposed treatment covers only four square feet per foot of the subway tunnel, yet it reduces the noise level by about half the reduction which was observed when the Chicago trains move from the underground to elevated sections of the line.

An alternative method of reducing noise is to reduce the intensity of the noise source. The present note describes some preliminary experiments along this line.

While in Chicago I had the opportunity of listening to the Chicago subway, and reached some conclusions about the nature of the noise source. The noise has a definite frequency range, independent of speed, which appears to be associated with a wheel or rail resonance. It seemed just possible that if the noise were radiated by the rails it could be reduced significantly by some treatment of the rails. This idea was proposed earlier by Mr. Tryhorn, of the T.T.C., and in fact he set up a demonstration showing that the "ringing" of a freely-suspended rail could be reduced by coating it with automobile undercoating.

In the following remarks, a more quantitative version of Mr. Tryhorn's experiment is described. An effort was made to produce in a rail the sort of noise produced by the new PCC subway-trains, and measurements were made of the reduction in noise radiation obtained with various procedures.

2. Experimental Arrangement

Three "I" beams, 6" high by $3\frac{1}{4}$" wide were borrowed from the Plant Engineering Section of the N.R.C. and a discarded cast-iron pulley, 12" in diameter with a 4" rim, was found. The beams were assorted lengths, 7 ft., 9 ft., and 20 ft. Noise reduction experiments were carried out on the two longer beams; the short one was left untreated, since there was some doubt initially about the repeatability of the noise-producing mechanism.

The pulley was found to have no prominent resonance, even when freely suspended, and this was considered a suitable approximation to the wheel of a modern PCC car, in which the rim is bonded to the hub by a layer of rubber. The pulley was mounted on a wooden handle, so that it could be rolled back and forth by hand along the beam.

The site of the experiments was the N.R.C. reverberation chamber, a large bare room which constitutes a good acoustical simulation of a subway tunnel, and which is equipped for making noise analyses.

The beams were laid on the concrete floor of the chamber, with various mounting pads between the beams and the floor. The following mountings were used, spaced at 4- to 5-ft. centres:

Mounting (1): An "acoustic tile", made of wood fibre, 12" x 12" x 3/4" thick. (Hereafter labelled "12 inch pad").

Mounting (2): A 3" strip of acoustic tile was placed between mounting (1) and the beam. (Labelled "3 inch pad")

Mounting (3): A piece of 1" steel strap was placed between the 12" tile and the beam. (Labelled "1 inch steel cleat")

3. Procedure

The pulley was rolled by hand back and forth over about six feet in the middle of the rail. It was found, judging by a number of runs on the control beam, that this procedure was reproducible enough from day to day to give adequate accuracy for the present experiments. The operator settled into a very stable rhythm, which he could maintain within very close limits from day to day (Fig. 2)

The two longer rails, on various mounting pads, were tested before and after a thick layer of automobile undercoating had been applied. The coating was applied to the web and to the non-bearing surfaces of the top and bottom flanges of the rails.

4. Observations

Some preliminary experiments were made with the three mountings and with the effect of coating the inside of the pulley with plastic automobile undercoating. The chief effect of the latter was to increase the wheel load - a process which accentuated the low-frequency rumble slightly. Each rail and each mounting sounded slightly different, owing to rail resonances associated with length. Qualitatively, the 3" and 12" pads sounded like a better simulation of subway-train noise than the 1" steel cleat. The 3" pad sounded best for the 9' beam, the 12" pad for the 20' beam.

Results of four tests are summarized in Fig. 1. These data were obtained by measuring the sound level in each of five octaves covering the important range of sound frequencies and converting to loudness units (Sones). Thus the results may be compared with those reported by Armour Research Foundation for the Chicago subway.

Figure 1 can be interpreted by recalling the basis of the sound absorption treatment which was designed for the Toronto subway (Tech. Note 102). Armour Research Foundation furnished noise measurements made on underground and elevated sections of the same Chicago line, and it was assumed that the difference in noise between these two locations represented the maximum reduction which could be obtained by absorption treatment. An absorption treatment was prescribed which will accomplish approximately half this reduction. The data at the bottom of Fig. 1 show the two noise levels for the Chicago line and the predicted level in Toronto with the prescribed treatment. (Actually, the Chicago measurements were made over a slightly wider frequency range, and a small adjustment has been made here to make them comparable with the rail-noise experiments.)

In the first experiment a significant reduction in loudness was obtained by the rail treatment - a reduction of the same order as will be achieved by the proposed wall absorption treatment. The other three experiments show a much more drastic reduction - greater than the difference between Subway and Elevated noise in Chicago. It is probable that the observations of experiment No. 1 differ from the other three because of an unfortunate combination of the fairly large extraneous factors in these experiments. If this is so, the effectiveness of the rail treatment would best be represented by the average of the four experiments (also shown in Fig. 1).

There seemed no point in refining the present experiment, since the process studied may be far from the real process of a PCC car moving on a properly mounted rail.

The complete set of results is given in Table I, and various details of the observations are illustrated in the subsequent figures. Figure 2 shows the degree of repeatability maintained, in the series of runs on the control beam. This should be compared with Fig. 3, which shows a typical "before" and "after" experiment. Figure 4 shows the noise spectra obtained with the 9-ft. beam on each of the three mountings, and this may be compared with Fig. 5, which shows subway noise spectra.

5. Conclusions

An attempt has been made to simulate the noise produced by a PCC car rolling on rails which are mounted on resilient pads. In the experiments it was found that loading the web and other available portions of the rails with automobile undercoating effected a great reduction in radiated noise. The reduction appeared at least as effective as the proposed wall absorption treatment.

The results indicate that a more precise experiment is warranted. Similar tests might be carried out with a PCC surface car travelling over open rails. Ideally the test should be made on rails which are mounted precisely as is proposed for the subway. However, the effectiveness of the rail treatment would probably be demonstrated as long as the rails are not actually imbedded in concrete or stone ballast. Ordinary railroad construction, of wood ties on rock ballast, would probably provide an adequate test.

So far only the one coating material has been considered. If the street-car tests suggested above confirm the good results of the preliminary work then the next stage might be a laboratory study of coating materials, effect of various thicknesses, etc.

TABLE I

DATA: RAIL NOISE EXPERIMENTS

		Frequency Band 150-300	300-600	600-1200	1200-2400	2400-4800	Total (Sones)
TEST #1							
20' Beam on 12" pads (spaced at 5' c.c.)	Untreated	28	43	75	33	19	198
	Treated	33	45	55	16	10	159
TEST #2							
20' Beam on 3" pads (spaced at 5' c.c.)	Untreated	33	63	90	60	20	266
	Treated	28	48	40	12	8	136
TEST #3							
9' Beam on 3" pads (Spaced at 4' c.c.)	Untreated	30	58	85	57	22	252
	Treated	18	34	43	12	7	114
TEST #4							
9' Beam on 1" steel cleats (spaced at 4' c.c.)	Untreated	38	60	75	87	53	313
	Treated	19	37	46	12	8	122
Untreated 9' Beam on 12" pads (for comparison with #3 and #4 above)		23	38	53	32	13	159
7' Beam on 12" pads (Control runs)	Run #4	42	49	59	27	--	177
	8	40	52	62	57	--	211
	14	34	48	58	37	13	177
	22	38	50	58	35	15	181
Subway Section of Chicago Line		45	70	70	40	15	240
Elevated Section of Chicago Line		32	52	42	22	8	156
Toronto Subway with Wall Absorption (Calculated)		38	59	49	27	10	183

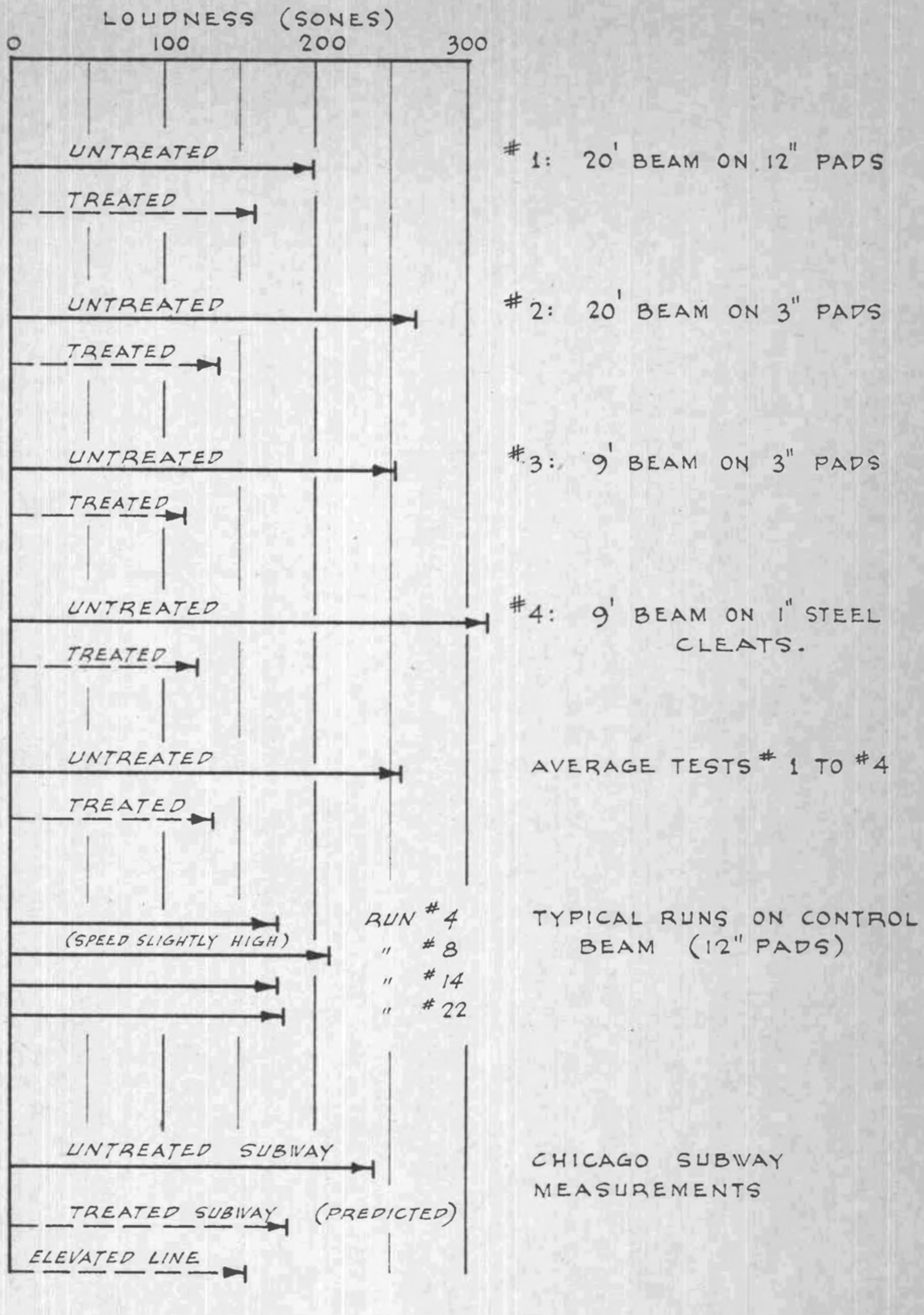


FIG. 1 OVERALL LOUDNESS DATA: TREATED & UNTREATED BEAMS.

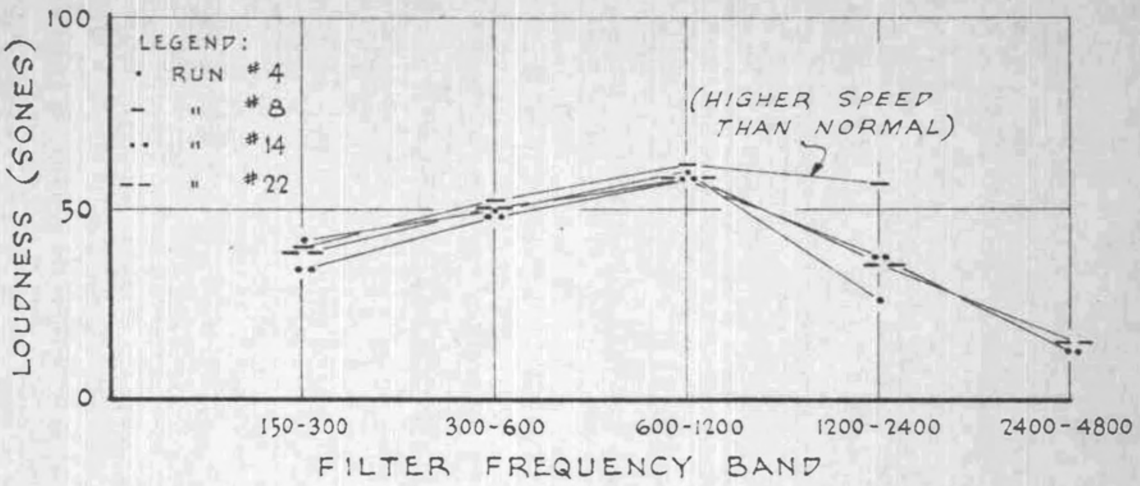


FIG. 2 NOISE SPECTRA of 7' BEAM ON 12" PADS (CONTROL RUNS)

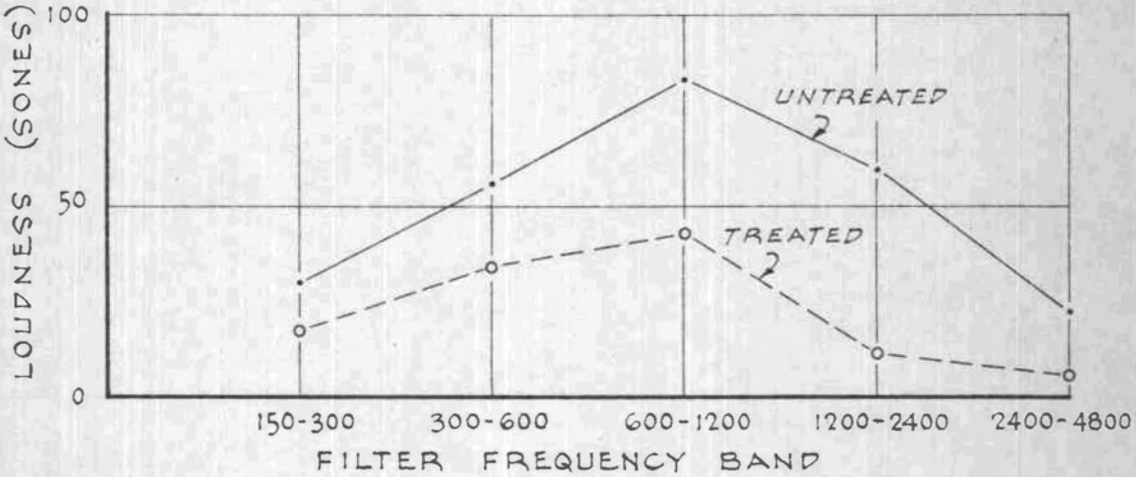


FIG. 3 NOISE SPECTRA of UNTREATED & TREATED BEAM (9' BEAM ON 3" PADS)

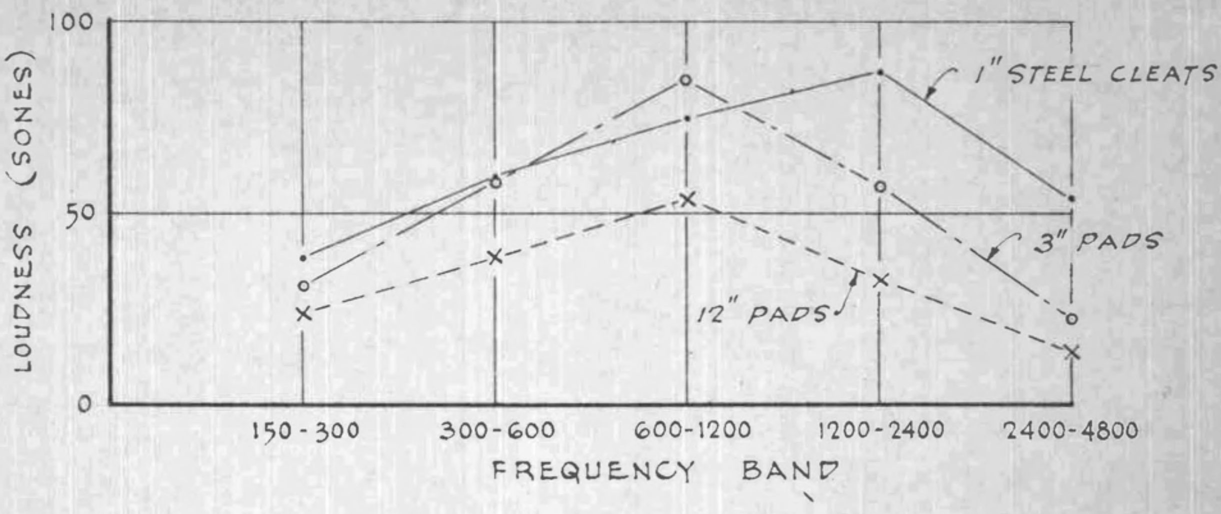


FIG. 4 NOISE SPECTRA FOR 9' BEAM ON THREE MOUNTINGS

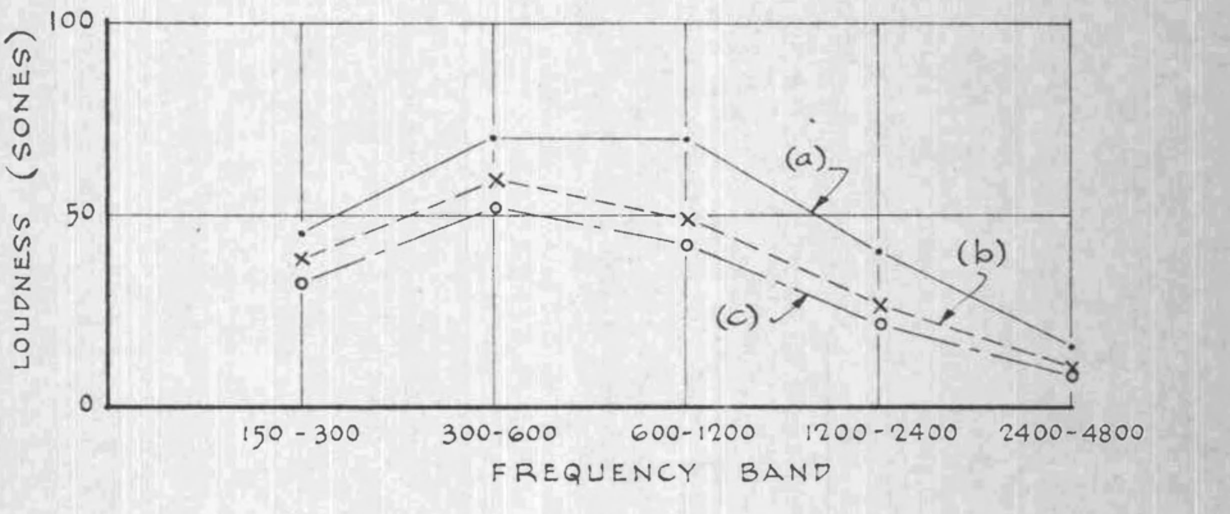
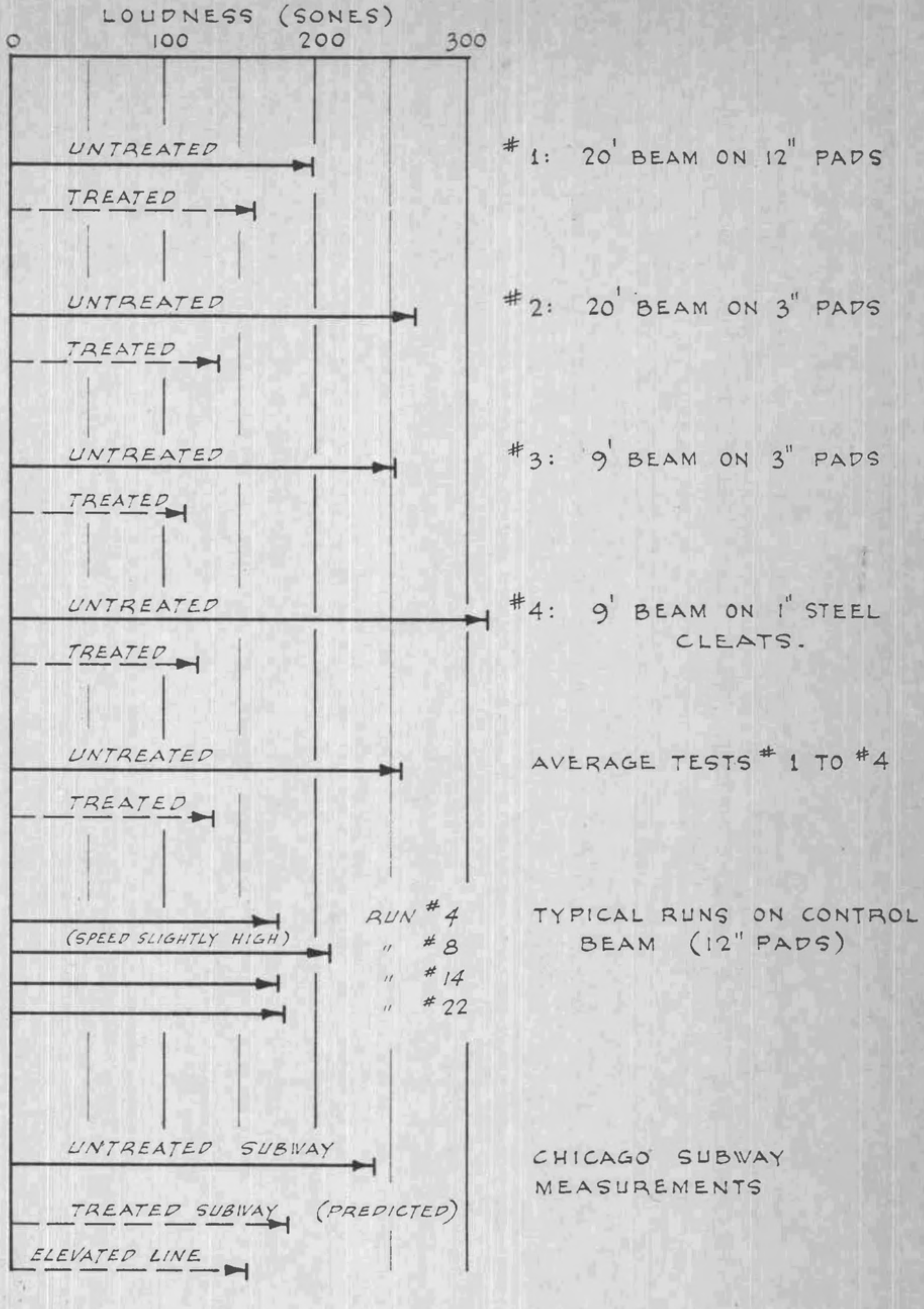


FIG. 5 NOISE SPECTRA of

(a) CHICAGO SUBWAY (UNTREATED)

(b) TORONTO SUBWAY WITH WALL ABSORPTION (CALCULATED)

(c) ELEVATED SECTION of CHICAGO LINE.



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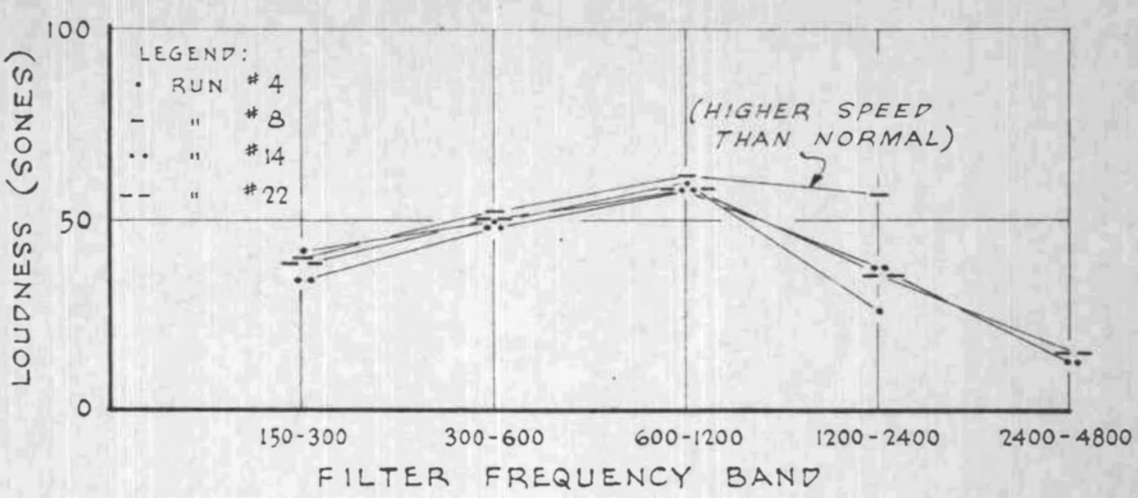

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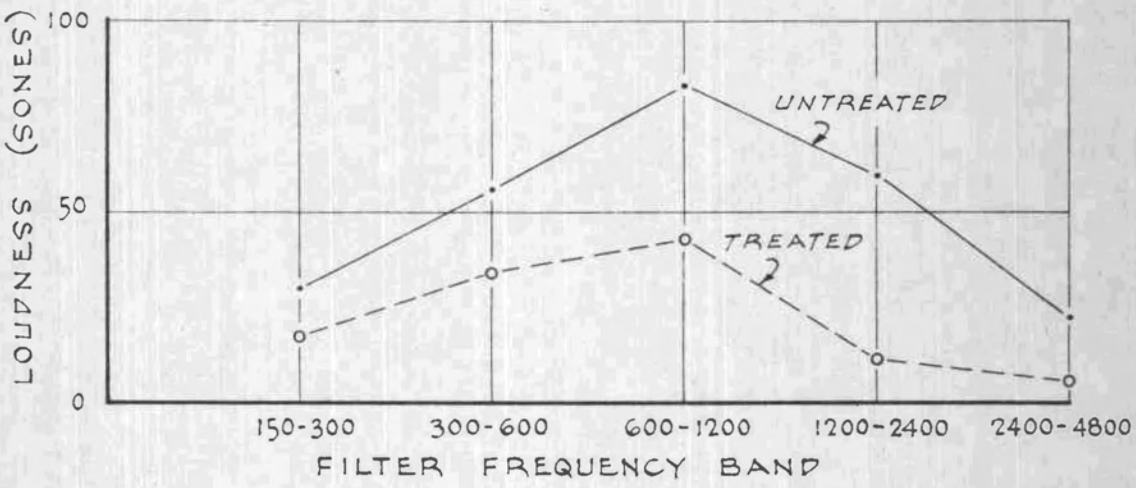

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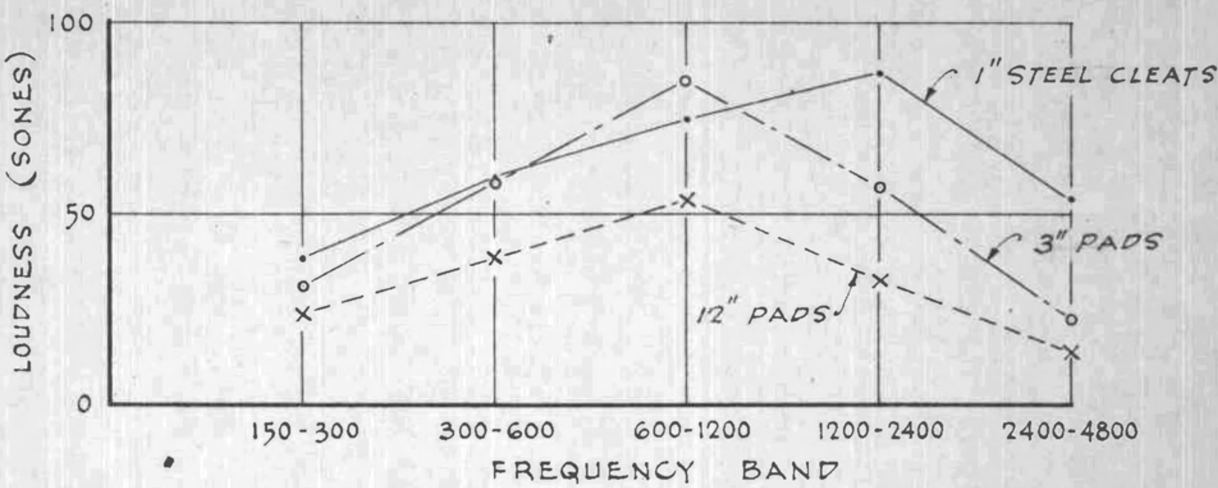

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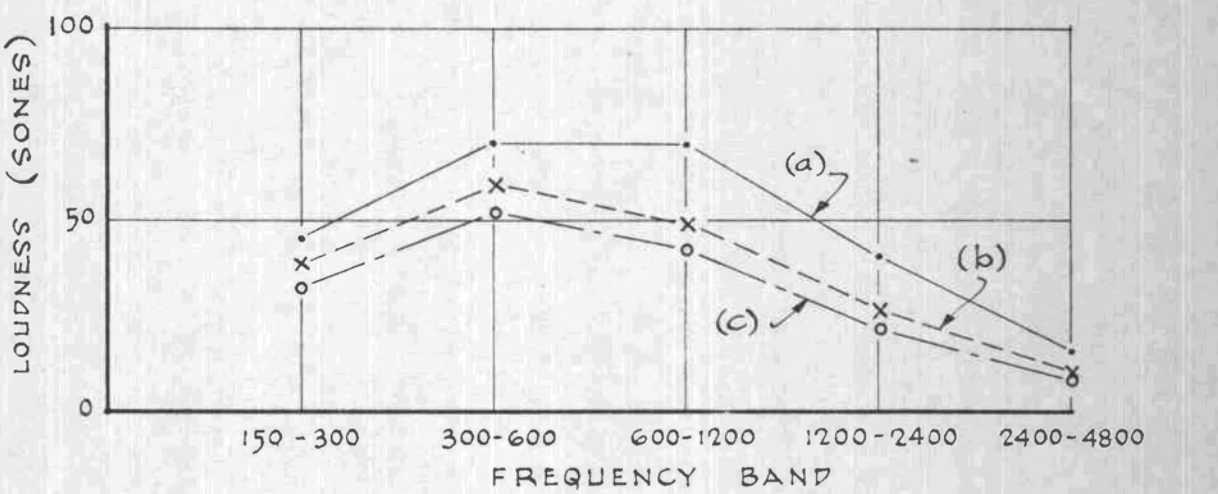

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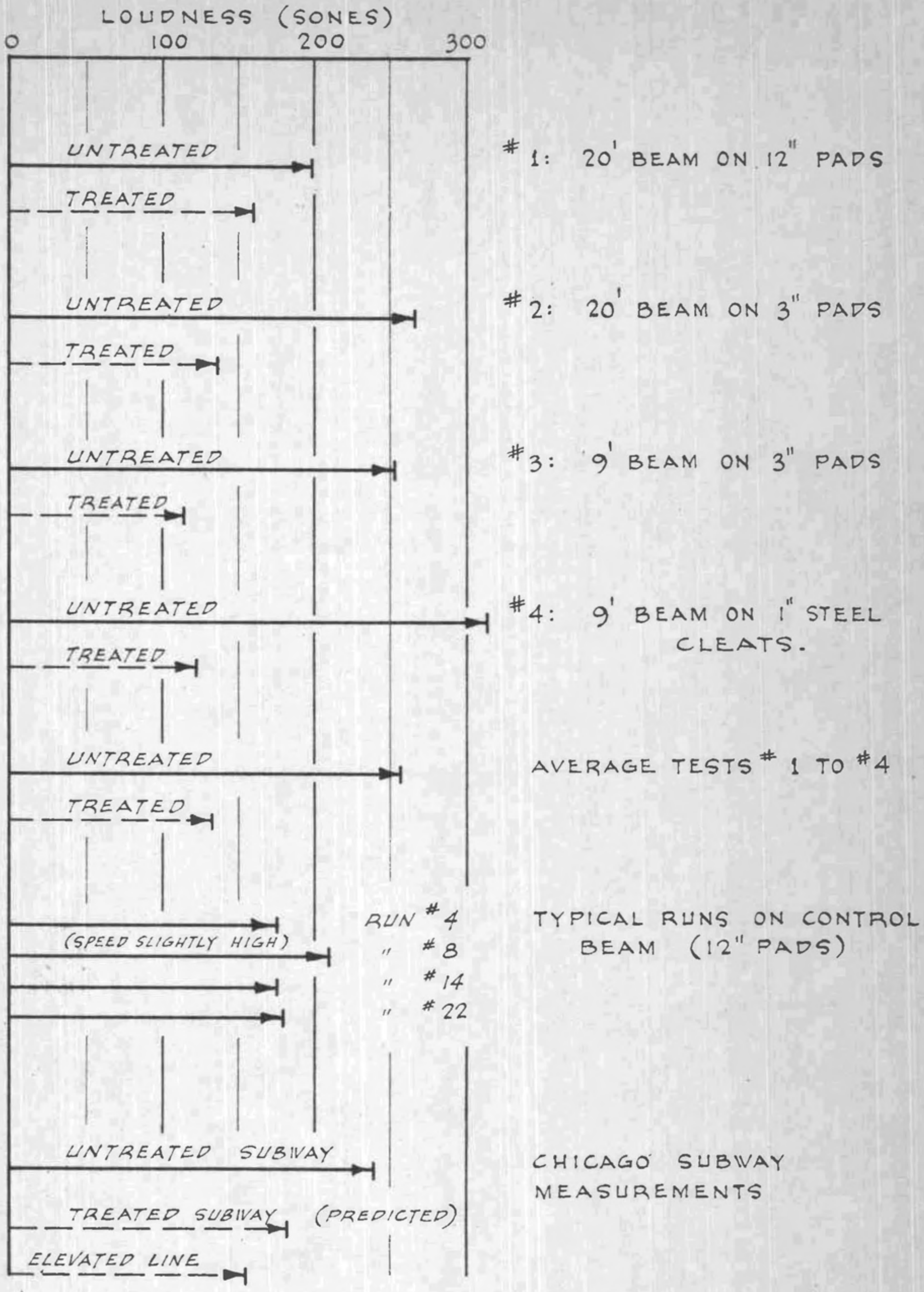

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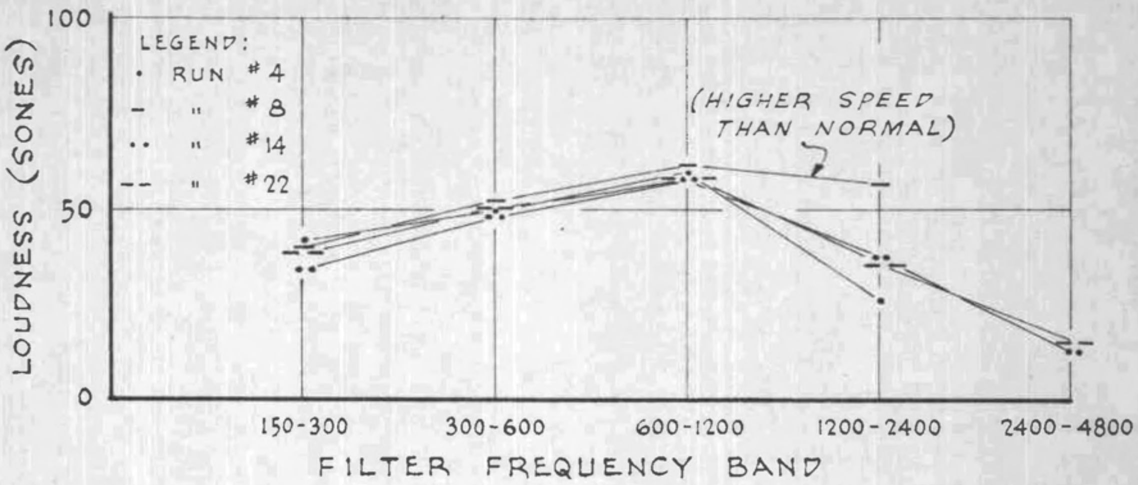

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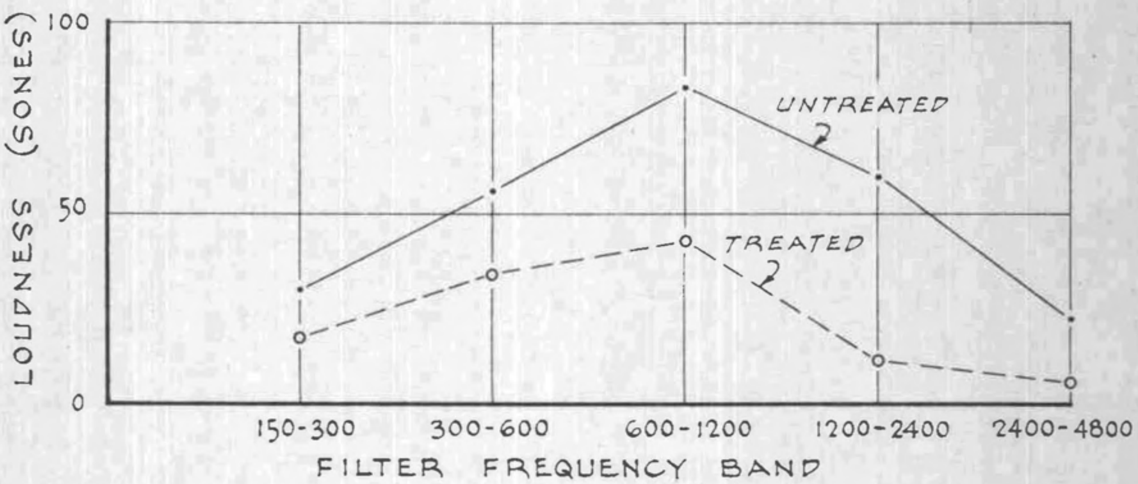

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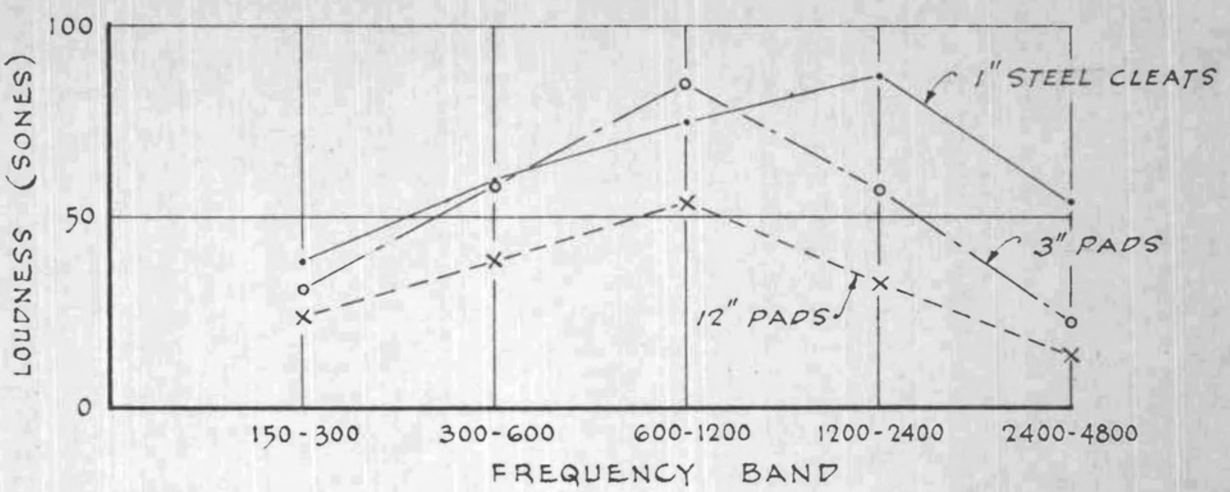

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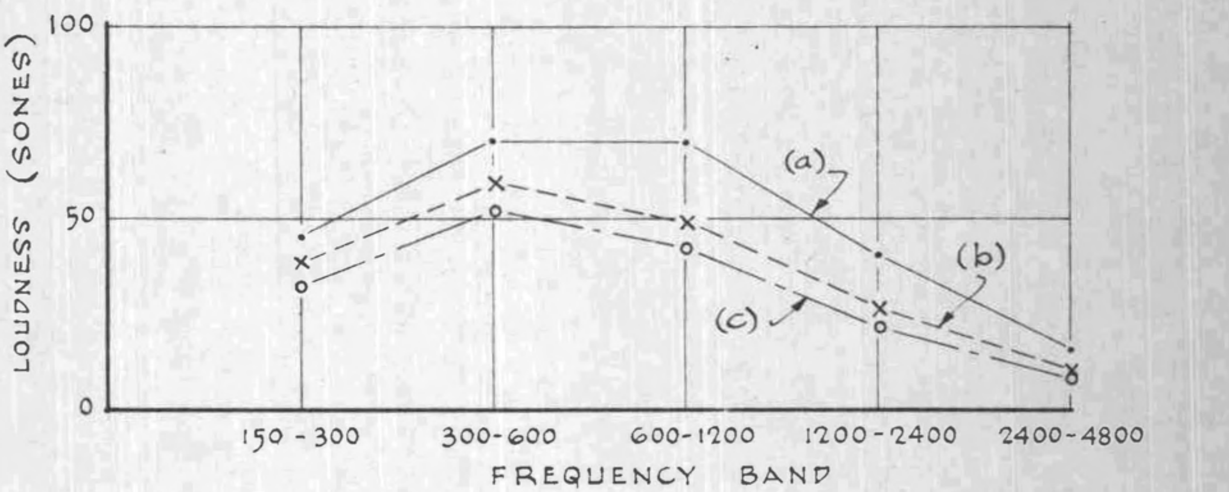

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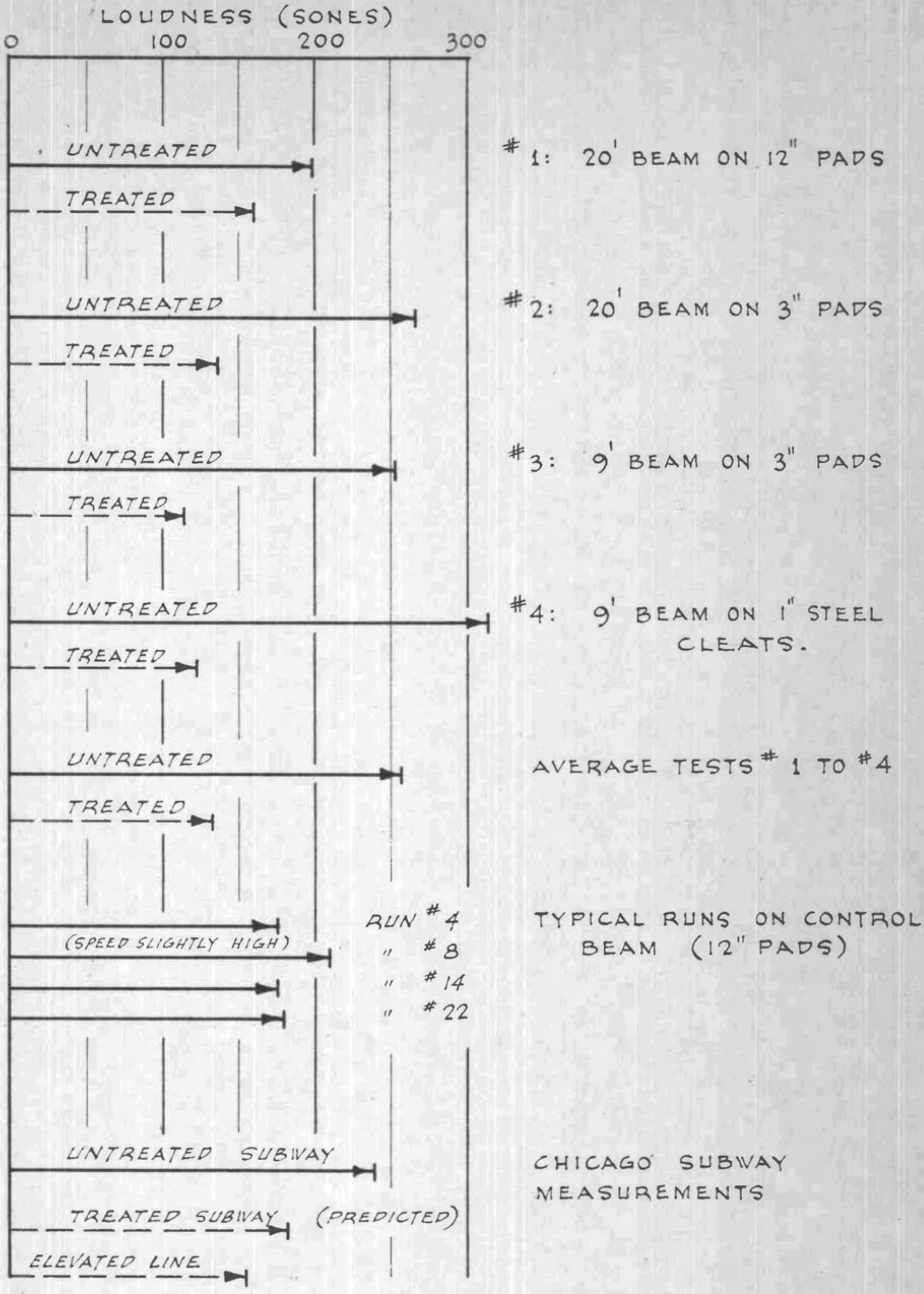

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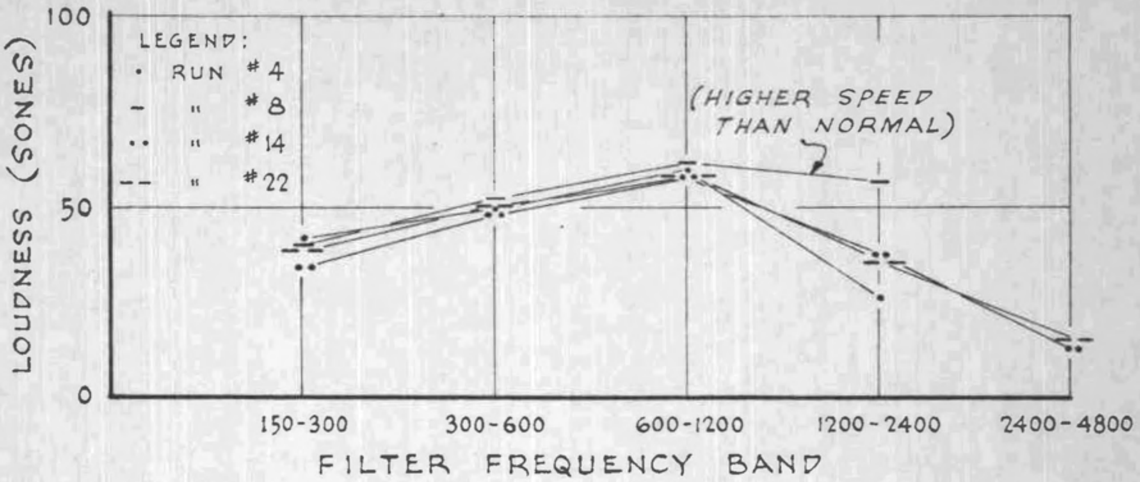

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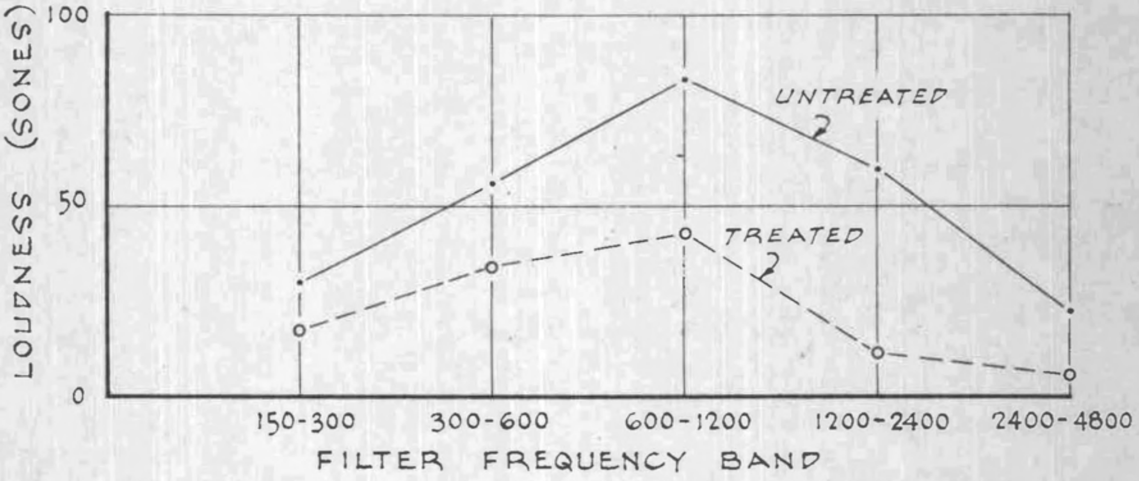

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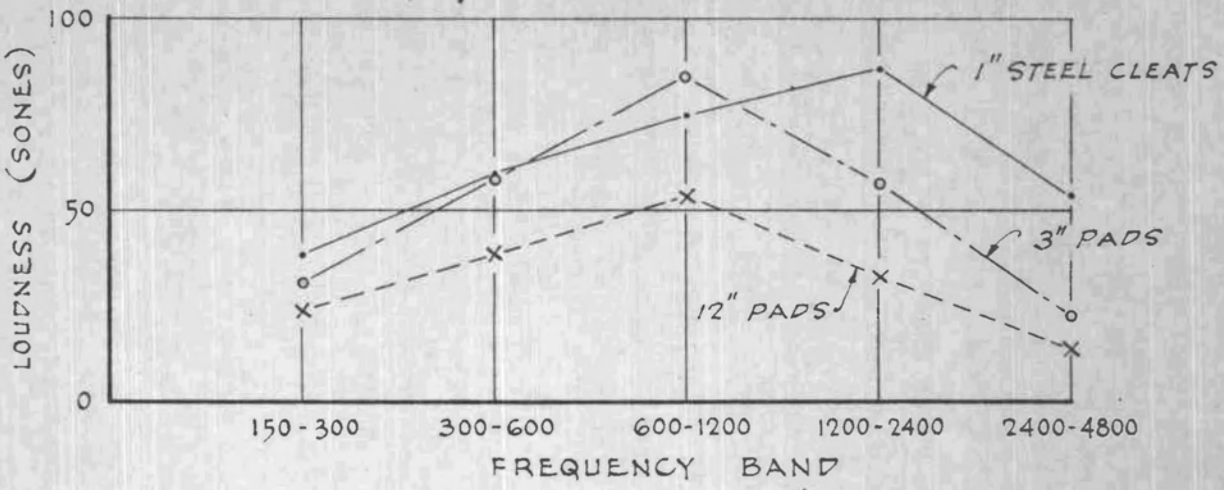

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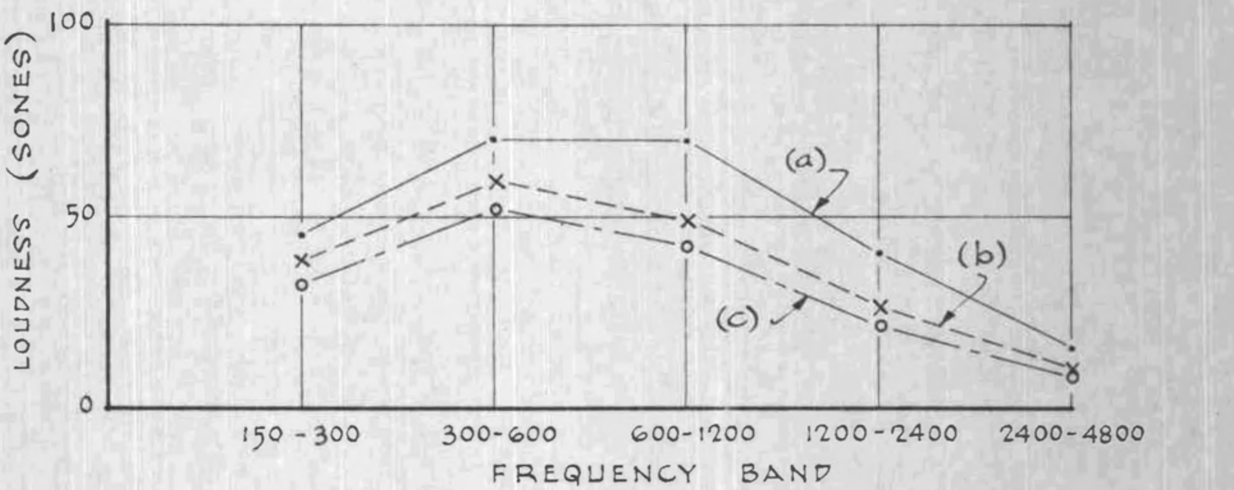

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