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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

THE EFFECT OF BASIC HIGHWAY DESIGNS ON TRAFFIC NOISE ATTENUATION

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DND

MATERIALS & RESEARCH DEPARTMENT
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State of California
Department of Public Works
Division of Highways
Materials and Research Department

September 1961

Laboratory Project
Auth. 100-R-6227

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is a report concerning:

THE EFFECT OF BASIC HIGHWAY DESIGNS

ON TRAFFIC NOISE ATTENUATION

Study made by . . . . . Structural Materials Section
Under general direction of . . . . . J. L. Beaton
Measurements by . . . . . L. Bourget, L. Kubel, and A. Sequeira
Report by . . . . . Louis Bourget

Very truly yours,

F. N. Hveem
Materials and Research Engineer

LB/mw

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INTRODUCTION

As requested on August 30, 1960, an investigation has been carried out for the purpose of determining the relative intensity of vehicular noise emanating from modern highways having different grade line elevation in relation to the surrounding terrain.

The Design Department designated three conditions as desirable for study and comparison. These are described as flat section, elevated section, and depressed section. The Design Department also specified the general geographical areas where tests were desired, and these suggestions were followed as closely as field conditions would permit. Readings were made at seventeen selected locations throughout the State.

Data are shown to represent typical noise levels from loud trucks at 25 feet from the source, at the minimum right of way line, and at various other distances at right angles to the roadway up to 800 feet from the pavement edge. The measurements were made in areas relatively free from buildings and other obstructions as far as local conditions would permit so the instruments would be well exposed to the noise source.

This report is intended to present information on sound reduction in a form convenient and useful for the highway engineer. It is evident that serious public relations problems have developed in many regions as a result of traffic noise emanating from modern highways. Strictly speaking, of course, no highway or any other type of roadway generates noise. The noise is generated by the vehicles that travel on them. Some of the noise originates with the tires, moving parts, bodies, and certain types of cargo, but by far the most important source is from internal combustion engine exhaust stacks.

As outlined in this report, the measurements of noise radiation from vehicles is an objective science. The effect of this noise on a human being, however, is subjective and depends on physical and psychological factors. People vary in tolerance level as well as preference level. Some guides that influence personal opinion are shown on the charts in this report. They are ambient (environmental) noise levels normal to areas frequently encountered near highways. These levels are referred to as semi-commercial, active residential and quiet residential. Full commercial and industrial area noise environments are not shown as they normally will exceed and mask the highway sounds during the hours of occupancy.

Whenever loud truck noises (of highway origin) project significantly above the normal ambient background noise, some public complaint may be anticipated. The higher the projection, the more the complaint.

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It should be noted that some ambient noise levels can change. For example, an area which has a high percentage of local passenger car traffic in the daytime is considered as "active residential". If the local traffic drops to almost zero at night, the noise environment can also drop to levels described as "quiet residential". Under these conditions a noisy truck, which might pass unnoticed during the day, will stand out sharply at night and be disturbing.

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SUMMARY

EXHIBITS

A simplified presentation of the basic test method and the detailed results derived from analysis of the tests are illustrated in the Appendix.

Figure 1 is a simplified diagram of the basic test layout. Details are in the report under the item, Test Methods.

Figure 2 shows the noise distribution of 441 trucks at the #1 microphone position. It establishes the "typical value" of a loud truck noise as 92 dba at 25 feet from the source. This reference level is indicated on all profile charts.

Figures 3, 4, and 5 show the noise range of most trucks and the attenuation of this noise with distance from each type of road cross section. The "typical value" is emphasized.

Figure 6 is the most important chart because it is a composite of all data and permits direct comparison of the noise level emanating from different highway sections based on the "typical value".

FLAT SECTION

As shown on Figure 6, the noise decreases with distance as one moves away from the source. The typical loud truck noise of 92 dba at 25 feet will decrease to about 76.5 dba at 150 feet. The attenuation is 15.5 decibels over this distance. From any point on the line, noise will drop about 6 decibels if the distance from the source is doubled.

ELEVATED SECTION (Fill or structure)

Noise from an elevated section is about 3 decibels less than from a flat section at all significant distances.

DEPRESSED SECTION

Noise from a depressed section is about 9.5 decibels less than from a flat section at all significant distances.

COMPARISONS

The graph readily yields comparative information; e.g., the noise from a depressed section at 100 feet equals that from an elevated section at 210 feet or a flat section at 300 feet.

EFFECT OF PLUS GRADES

Add 1 decibel for each 2 percent of grade but only for lanes related to the "up grade side" of the highway.

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EFFECT OF SHRUBBERY

With either flat or elevated sections, subtract only 1 decibel for high dense planting. The exhaust stacks of trucks are about 12 feet high, and the noise screening effect is slight for trucks in the nearest lane. No correction is needed for the depressed sections chart line. The effect of usual slope planting is already included. Any additional planting at the crest of the cut may improve the appearance or provide erosion control but offers negligible sound reduction.

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DISCUSSION

OBJECTIVE

As directed, this report compares typical peak noise intensity and the attenuation (reduction) that may be expected at various distances from three basic highway designs:

1. FLAT SECTION. Traveled way reasonably level with the adjacent terrain.

2. ELEVATED SECTION. Traveled way approximately 20 feet or higher than surrounding terrain as on a fill or viaduct.

3. DEPRESSED SECTION. Traveled way approximately 20 feet or more below the terrain adjacent to the cut section.

NOISE SOURCES

As a result of this and other studies, it is evident that the various vehicles may be grouped as follows in the order of their contribution to the over-all noise problem:

1. Diesel trucks. The most prominent and disturbing noise source.

2. Gasoline powered trucks. A less frequent and less marked noise source. Occasionally disturbing but many gasoline engine trucks compare favorably with passenger automobiles.

3. Certain sports cars and hot-rods. An occasional noise source.

4. Motorcycles. Relatively rare but a capable noise source.

5. Passenger cars. Generally inoffensive even in large volumes.

BEST NOISE FOR DATA REDUCTION

Preliminary field tests indicated that over 90 percent of the highest and most frequent peak noises would be from diesel trucks. Therefore, the data in this study were derived from carefully indexed peak truck noises which projected significantly above the noise background at the remote measurement location.

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ERROR SOURCES

When analysis was made, some peaks had to be dropped from the series because of interference at the remote location due to local non-highway traffic, airplane noise, or other uncontrollable disturbances. These interfering noises, not originating on the highway, make it impractical to set up microphones to measure the highway noise at distances greater than 150 feet. Perhaps the greatest difficulty in obtaining accurate measurements of vehicle noise is in finding locations with sufficiently quiet surroundings so that the remote noise measurement is not cluttered by an unrelated noise that obscures the true attenuation figure. Recording samples are shown on Figures 9, 10, and 11.

HIGHWAY PLACEMENT

There are three major position factors that affect the noise heard from a highway. They are (1) relative elevation of the traveled way to the listener, (2) horizontal distance of the noise source from the position of the listener, and (3) level of the local noise environment surrounding the listener.

The effect of the first two factors is shown by Figures 3, 4, 5, and 6 as is also, to a lesser degree, the effect of the third factor. A further example of the third factor is the case of an industrial area where the local environmental noises usually completely mask the highway noise during the daytime working hours. Since occupancy of such areas is largely limited to daytime, any change at night in the relative sound levels normally is unnoticed.

APPLICATION OF DATA

It is believed that the technical information contained in the Appendix may be used with confidence in almost all projected situations and particularly in cases where a selection between differing highway profiles is desirable and possible. Figure 6 is probably the most important chart because it is a composite of significant data and permits direct comparison of alternative profiles.

TEST METHODS

1. Microphone Placement

The test method finally adopted was the result of many preliminary trials in the field and is outlined on Figure 1.

The location of the sound level meter nearest to the noise source is identified as "Mic. 1". The location of the sound level meter, remote from the noise source, is identified as "Mic. 2". All distances refer to a vertical line representing the edge of the pavement and are the shortest horizontal distances to that vertical line.

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Mic. 1, at 23 feet from the pavement edge, is actually about 25 feet from the exhaust stacks of trucks in the nearest lane; therefore all measurements at Mic. 1 were regarded as 25 feet from the noise source. All sound data were derived from specific individual vehicles traveling in the nearest lane.

2. Recording

Each sound level meter was coupled to a separate graphic level recorder (paper strip chart recorder) which is especially made to match the sound level meter. A different color of ink was used on each recorder to avoid confusion. Recording samples are shown on Figures 9, 10, and 11.

3. Calibration

Calibration before every test run was accomplished in the field; first with a special transistor oscillator and calibrator (small loudspeaker) designed to fit over the microphone. Fine adjustment was then made on a series of actual peak noises until both meters recorded as close to identity as possible at the same measuring location. During this adjustment one sound level meter was used as a reference standard (always the same meter), and the other meter adjusted for closest possible agreement. The reference sound level meter was always connected to the same recorder after calibration had been completed.

4. Cable Error

The avoidance of errors and correction factors associated with microphone cables was accomplished by not using them. Remote operation of either sound level meter, as a complete unit, was enabled by patching from the output jack of the sound level meter to the recorder input through a reel of RG-62/U coaxial cable. Up to 200 feet of this cable can be used with negligible error.

5. Noise Indexing

Both recorders were operated within a station wagon from a vibrator type power supply that plugged into the cigarette lighter socket. This permitted the two engineers, one at each recorder, to converse and index noisy vehicles in the nearest lane by marking the charts simultaneously. Depressed sections required a different procedure. One engineer had to mark both charts, and the other engineer took a position at the edge of the cut and relayed information by a system of hand signals.

6. Wind Screens

Effective wind and sun screens were developed by the writer especially for this project. They are frames large enough to completely enclose a sound level meter and are covered with two layers of cheesecloth, snugly drawn and glued in place. These

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screens have virtually no measurable effect on sound amplitude or frequency response, yet provide about 15 decibels of wind protection and lessen the danger of sun damage to the microphones. See Figure 8.

7. A-Scale

The differences between A, B, and C scales of a sound level meter are shown on Figure 7. The present opinion of the International Standards Organization is that A-scale is better suited for traffic noise evaluation than either B or C-scale. Human hearing response to traffic noise more nearly resembles the A-scale at all distances beyond 60 feet. Therefore, A-scale was employed for this study. Note: Some prior studies of traffic noise have been made on the C-scale. No attempt should be made to relate these readings by direct comparison of decibel numbers. The local background noise levels provided on the charts in this report minimize the need for any other comparisons.

TEST EQUIPMENT

The equipment normally used at a field location is shown on Figure 8. The list below covers the complete instrumentation used during different phases of this study:

General Radio Sound Level Meter, Type 1551-A.

This meter was relied upon as the reference standard.

General Radio Sound Level Meter, Type 759-B.

General Radio Graphic Level Recorder, Type 1521-A.

Two were required, one for each sound level meter.

Cornell Dubilier, "Powercon", converter Type 12L8.

This unit plugs into the cigarette lighter socket and converts 12 volts D.C. to 110 volts A.C. at 80 watts output (for the two recorders).

General Radio Transistor Oscillator, Type 1307-A.

General Radio Sound Level Calibrator, Type 1552-A.

Two Wind Screens as described under Test Methods, topic 6 (locally made).

Metal Card Tables to support sound level meters.

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200 feet of RG 62/U coaxial cable, mounted on crank operated reel with stand (locally made). Fitted with appropriate plugs to connect sound level meter to recorder. See Test Methods, topic 4.

Two 25 foot lengths of RG 62/U cable with plugs, as above. No reel is needed. Handy for patching from nearest sound level meter to recorder and for calibration. See Test Methods, topic 3.

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Figure 1

TYPICAL TEST METHOD FOR DETERMINATION OF NOISE ATTENUATION WITH DISTANCE

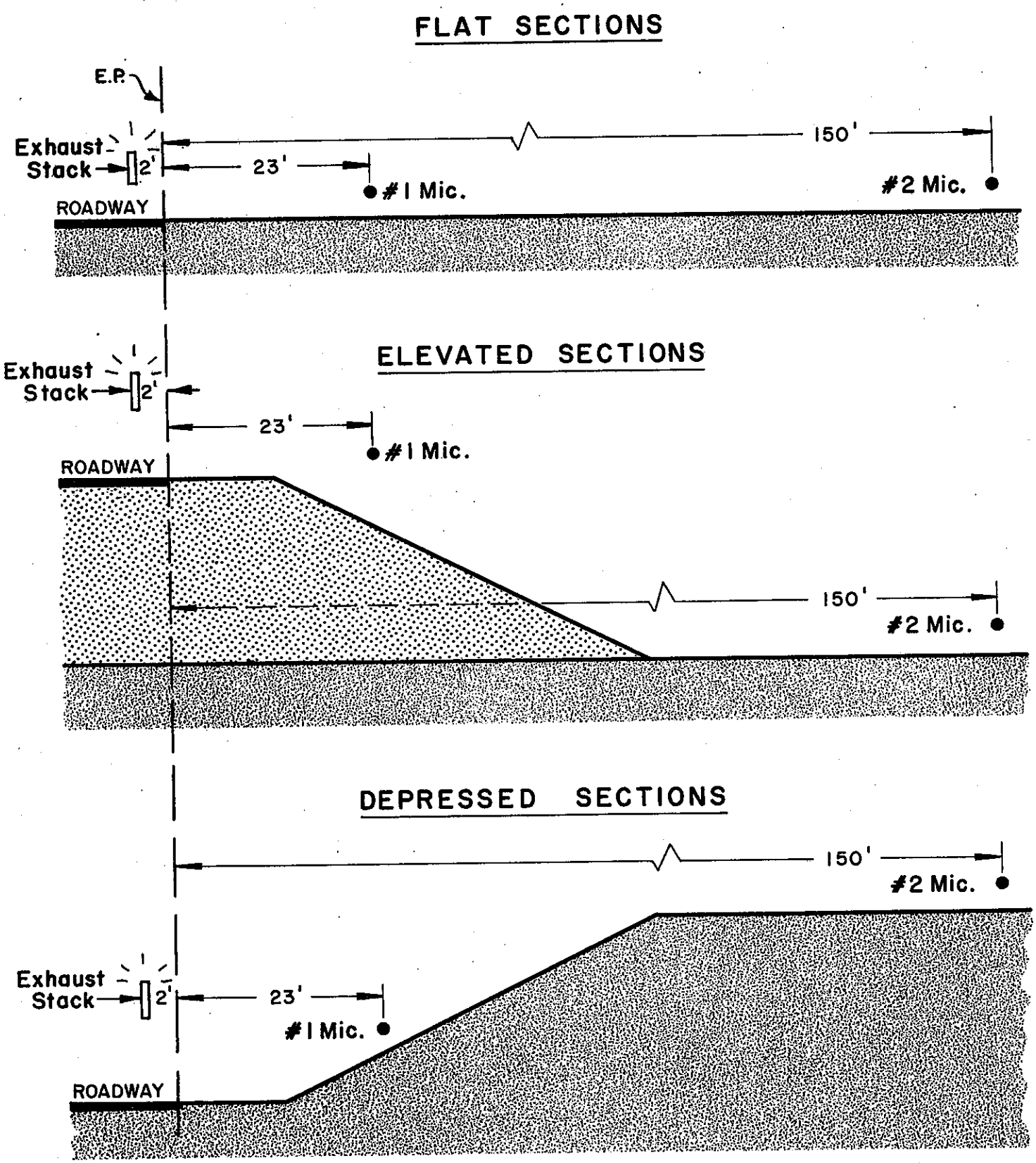

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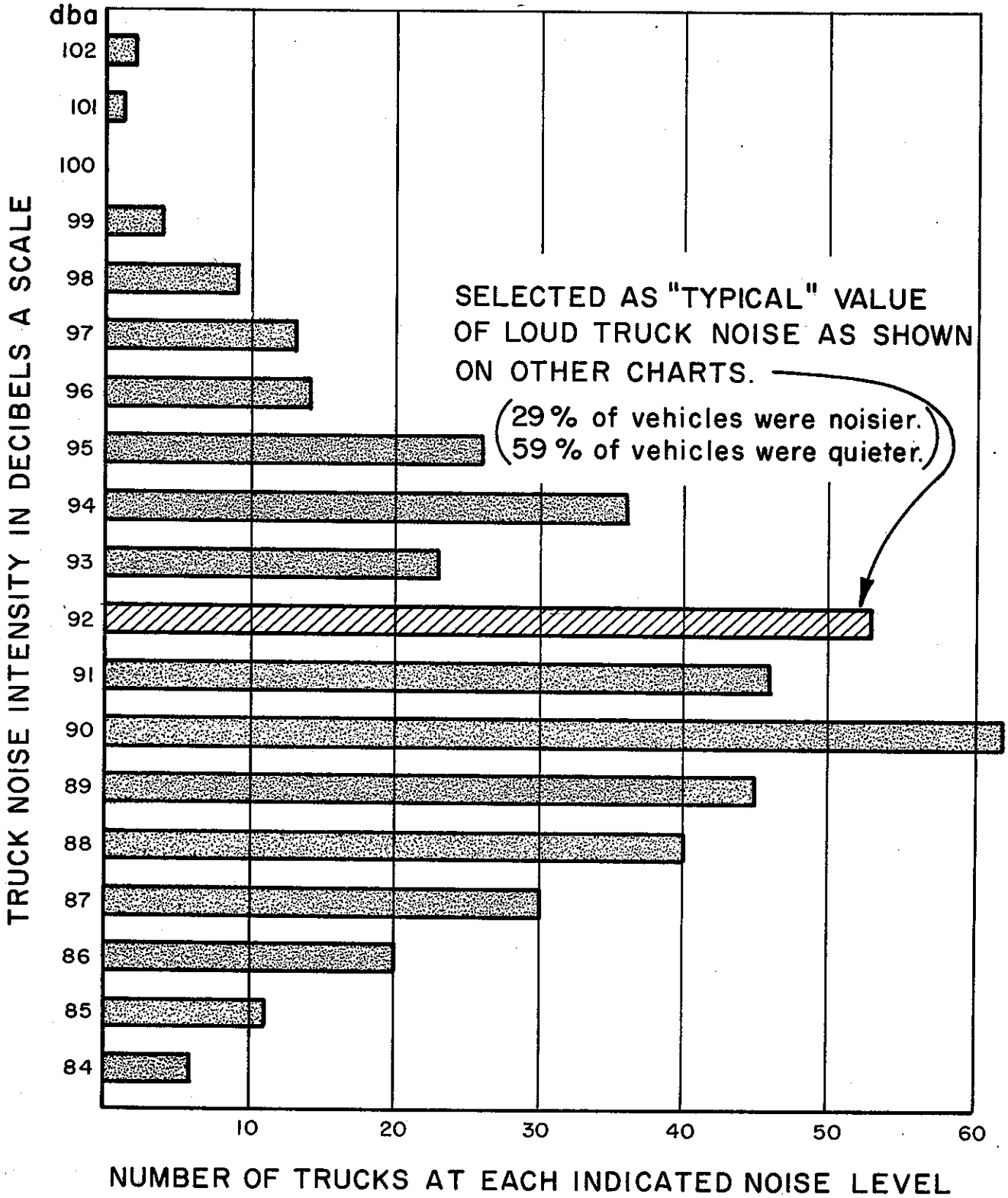
Figure 2

TRUCK NOISE DISTRIBUTION AT 25' FROM THE EXHAUST STACK

A COMPOSITE OF THE 441 VEHICLES INDEXED ON THE NOISE CHART RECORDINGS AT 17 LOCATIONS THROUGHOUT CALIFORNIA



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FLAT SECTION

TRUCK PEAK NOISE RANGE OF MOST FREQUENT OCCURRENCE

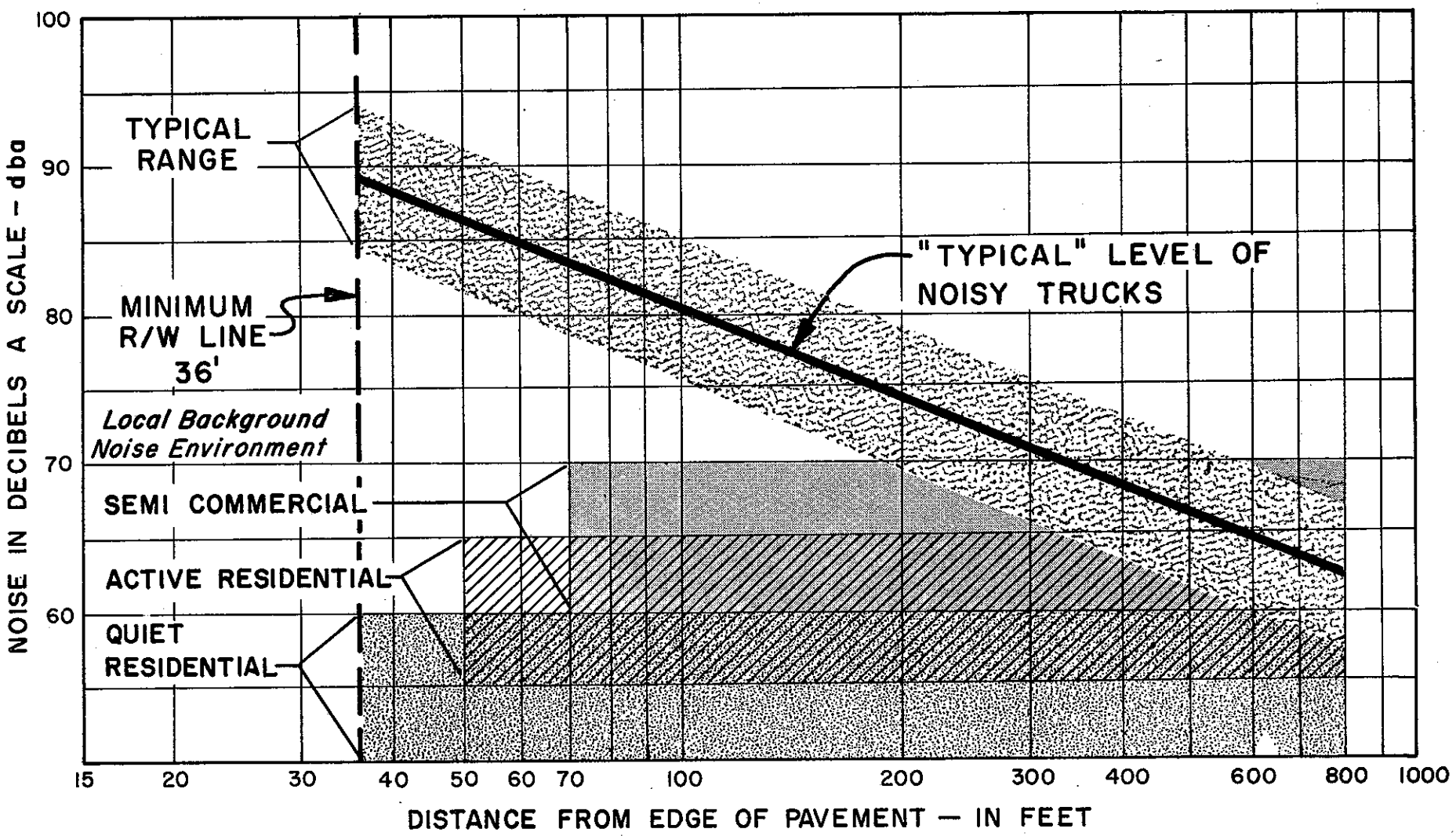

Figure 3

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20' ELEVATED SECTION

TRUCK PEAK NOISE RANGE OF MOST FREQUENT OCCURRENCE

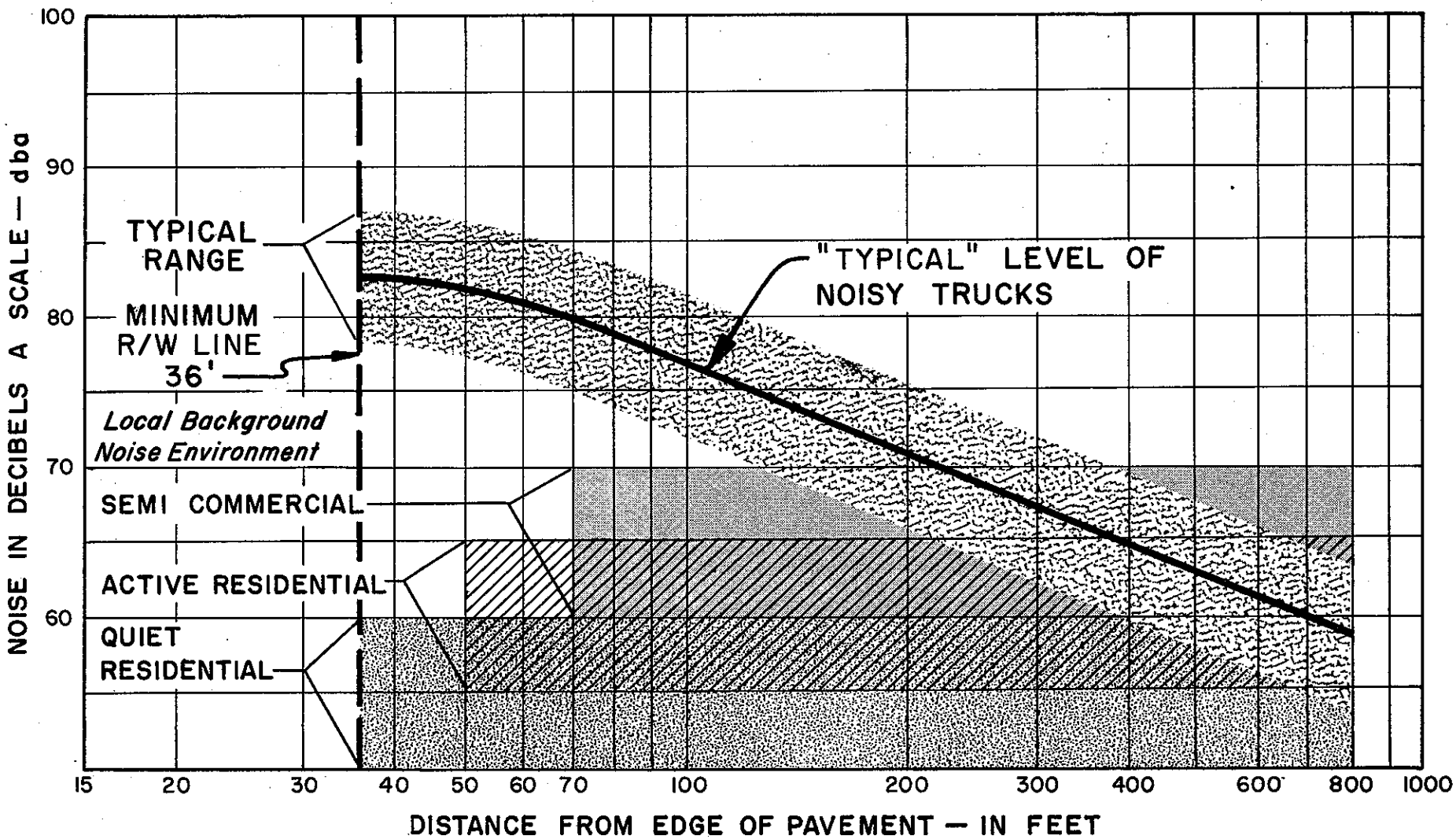

Figure 4

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20' DEPRESSED SECTION

TRUCK PEAK NOISE RANGE OF MOST FREQUENT OCCURRENCE

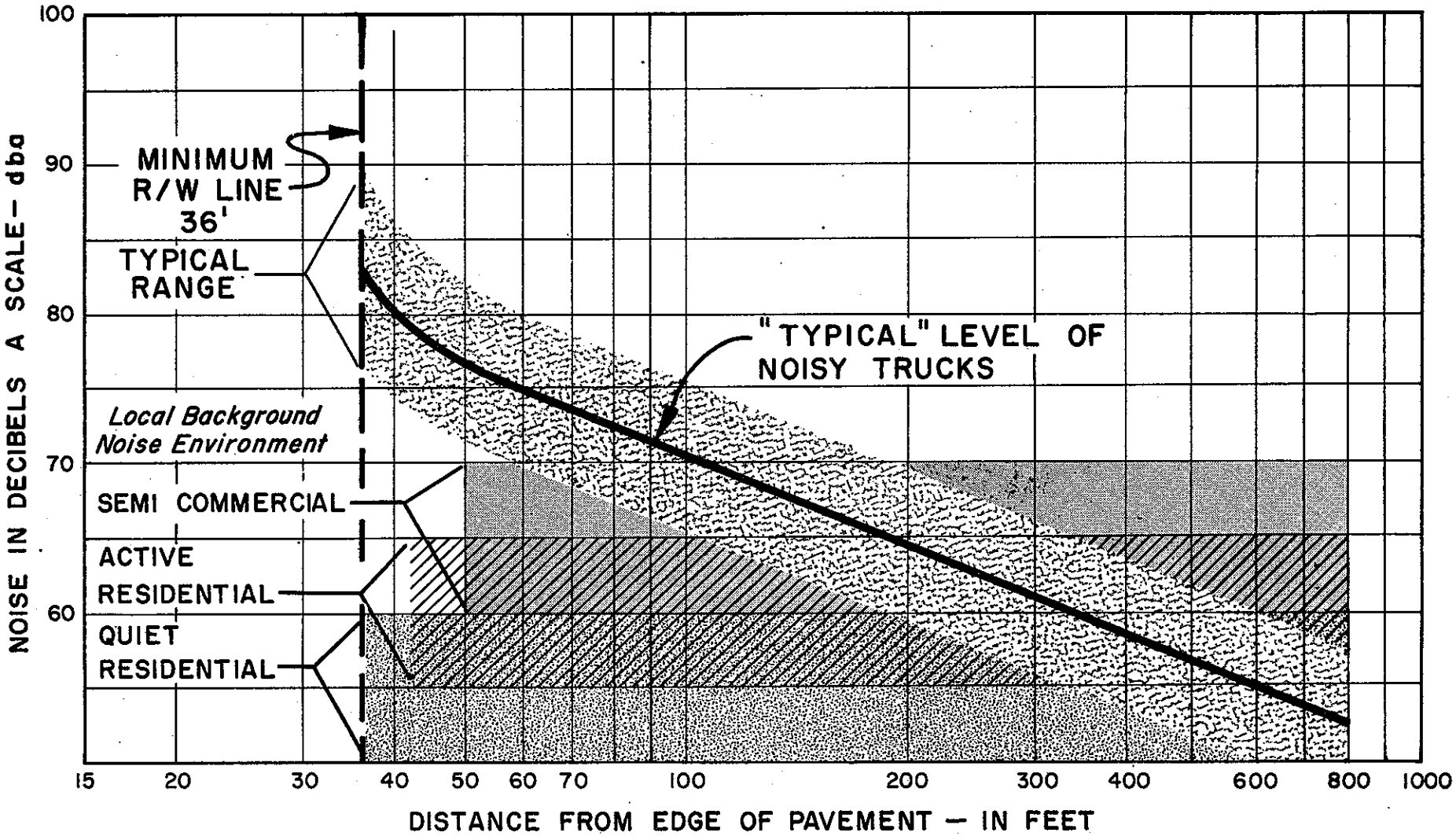

Figure 5

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"TYPICAL" TRUCK NOISE VERSUS DISTANCE FROM 3 BASIC FREEWAY DESIGNS

NOISE = 92 dba AT 25' FROM SOURCE

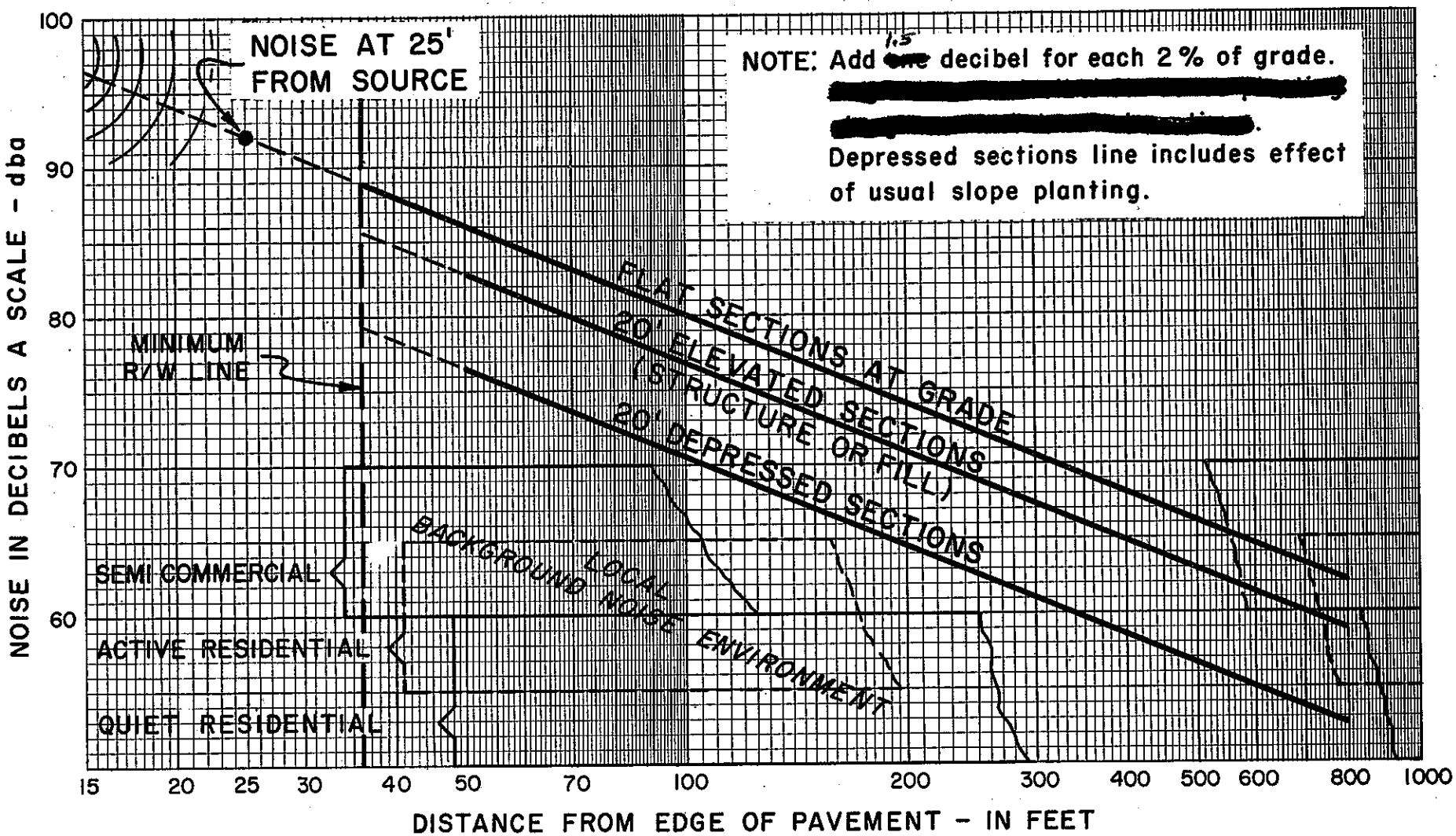

Figure 6

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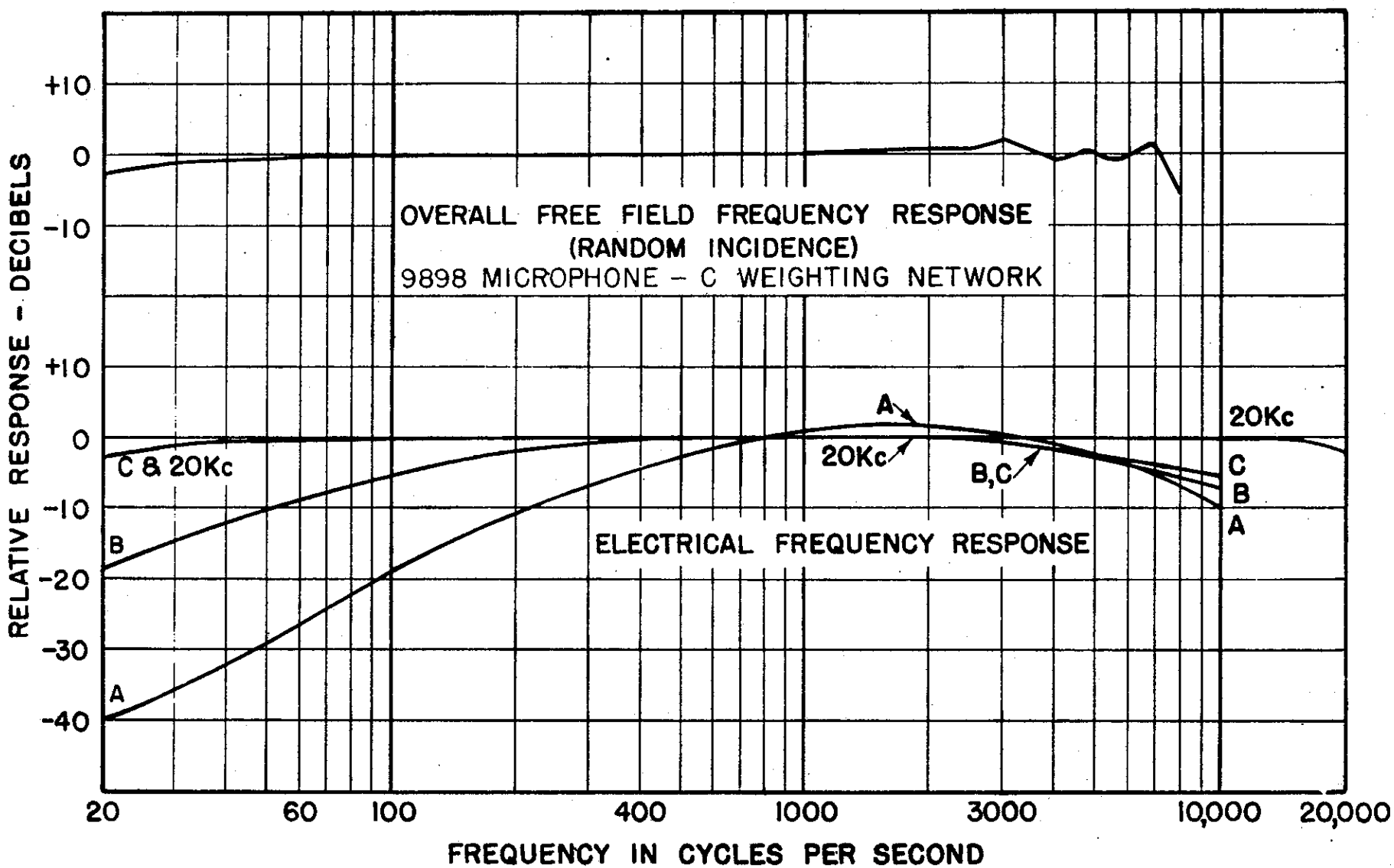

Typical average acoustical and electrical calibration curves for the Type 1551-A Sound-Level Meter.

Figure 7

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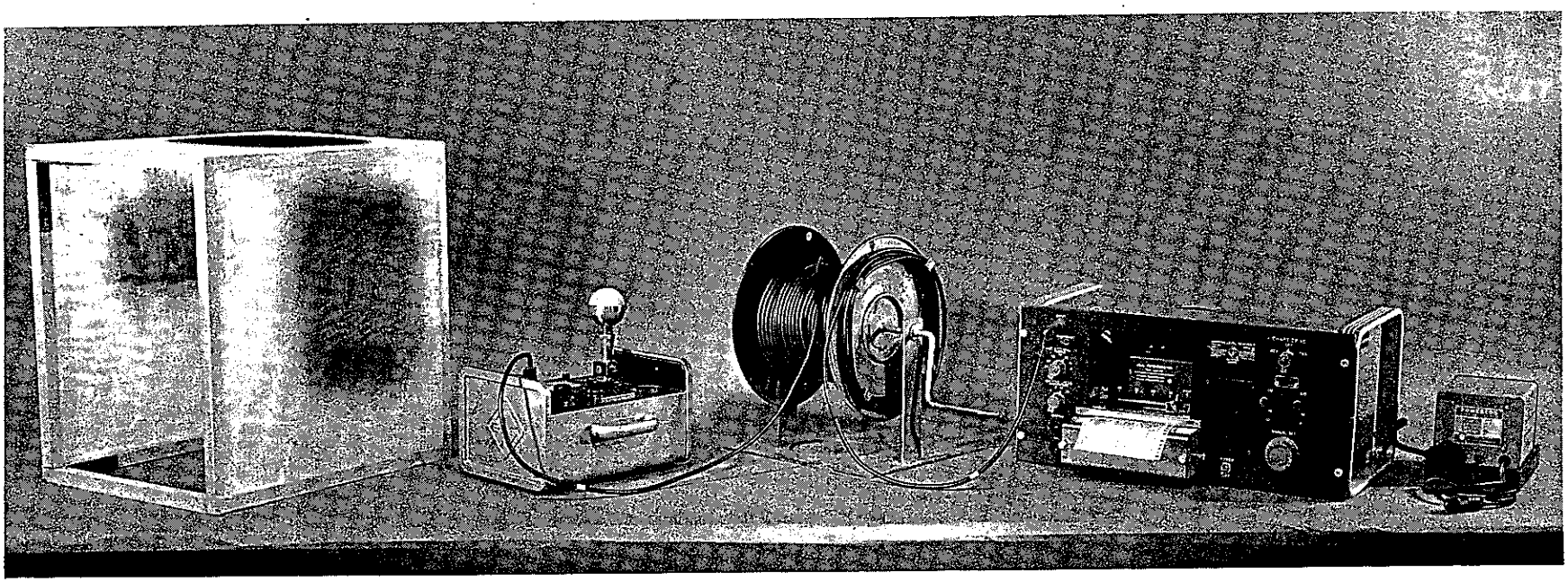
TEST EQUIPMENT FOR REMOTE MEASUREMENTS



SUN / WIND SCREEN (locally made)

SOUND LEVEL METER

RG-62 / U CABLE (reel, locally made)

POWER SUPPLY

RECORDER

Figure 8

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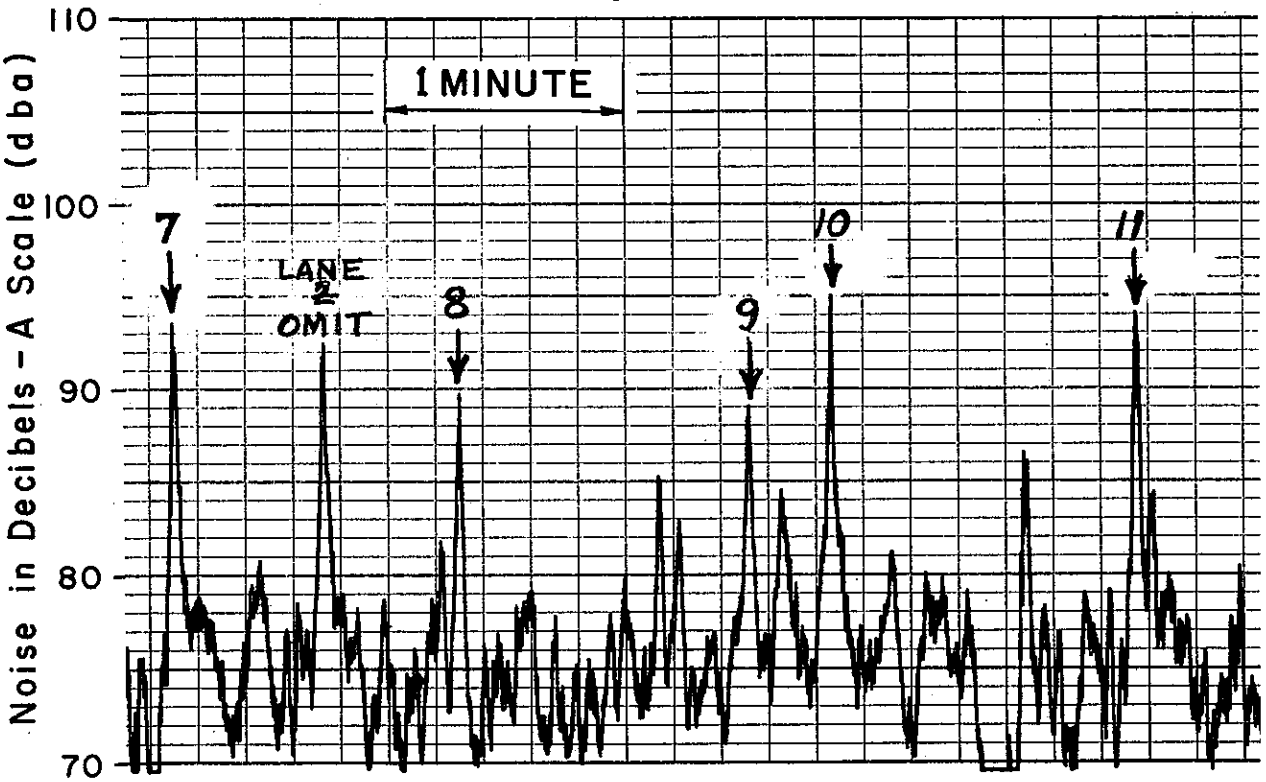
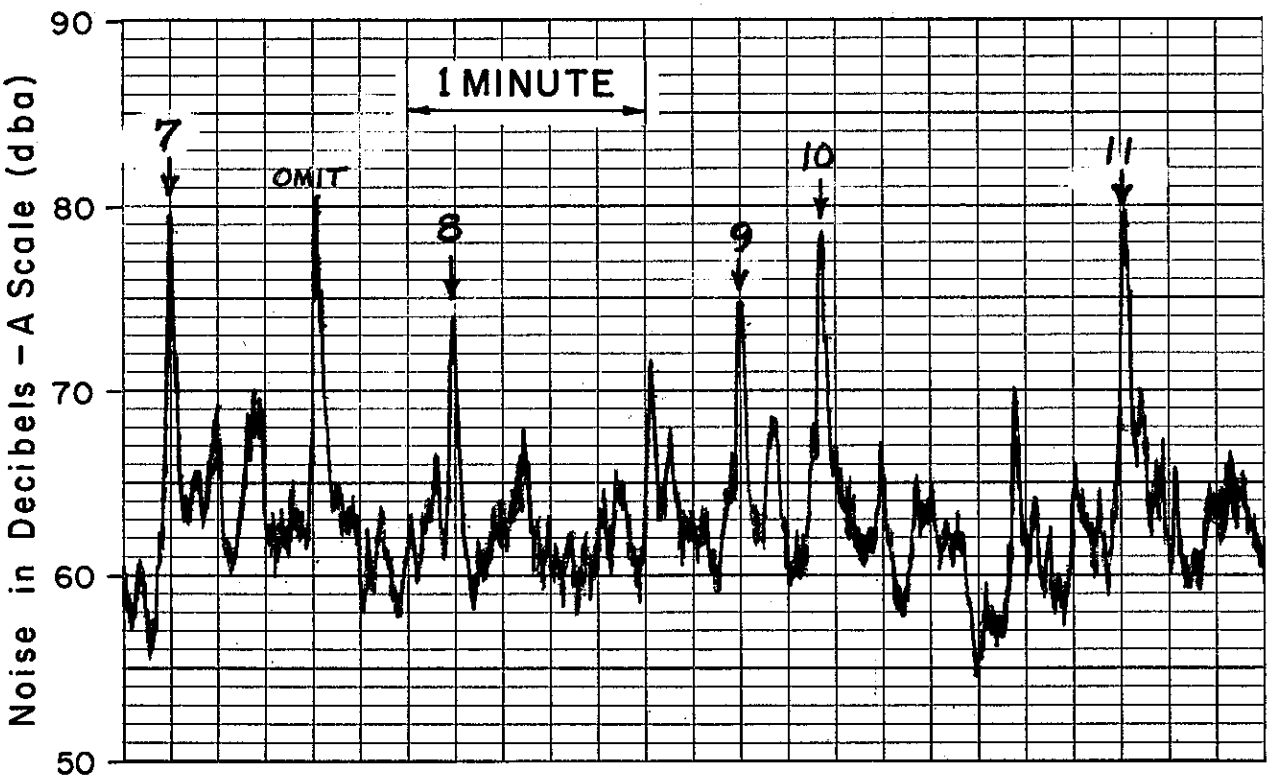
Figure 9

FLAT SECTION

SAMPLE FROM SIMULTANEOUS RECORDINGS
Indexing Marks Trucks in Nearest Lane
LOS ANGELES HWY. 101 AT TOWNSEND AVENUE



AT 25 FEET FROM SOURCE



AT 150 FEET FROM SOURCE

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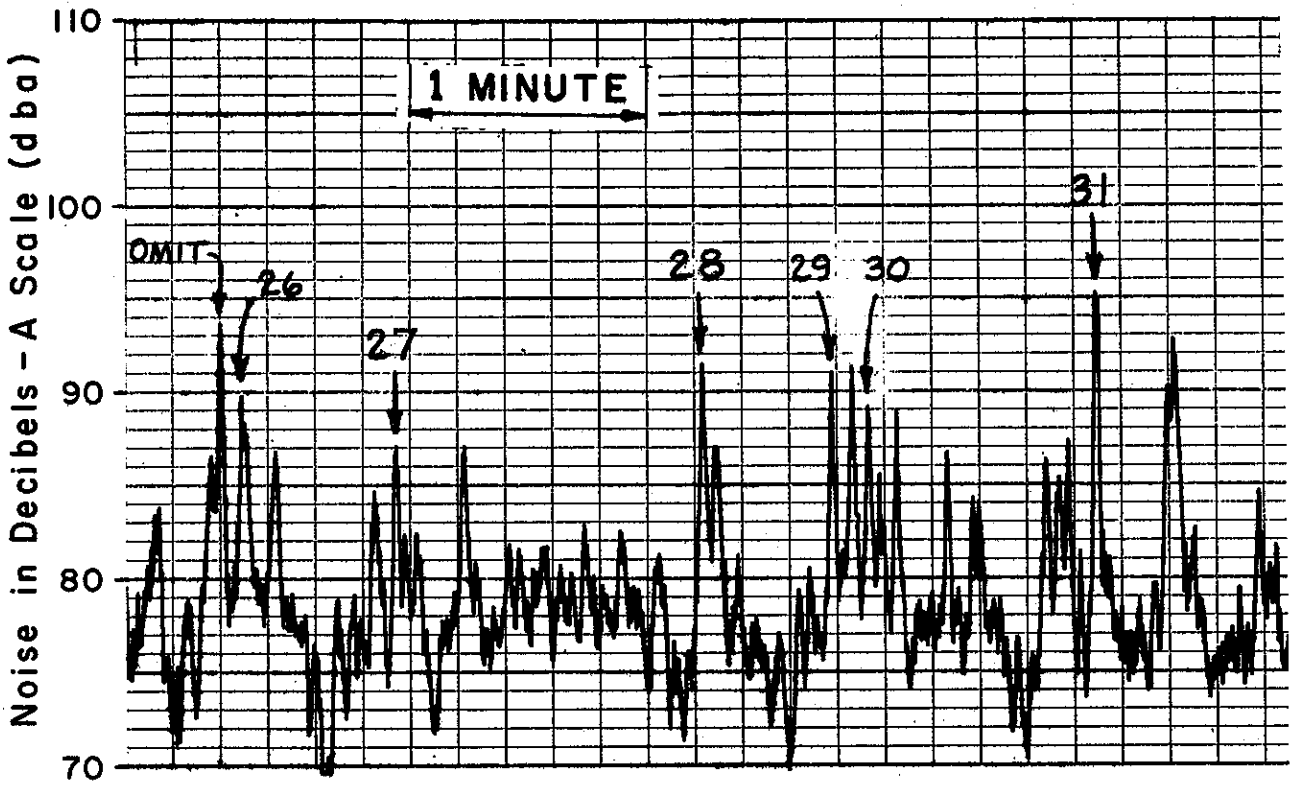
Figure 10

ELEVATED SECTION

SAMPLE FROM SIMULTANEOUS RECORDINGS
Indexing Marks Trucks in Nearest Lane
LOS ANGELES HWY 101 AT INDIANA STREET



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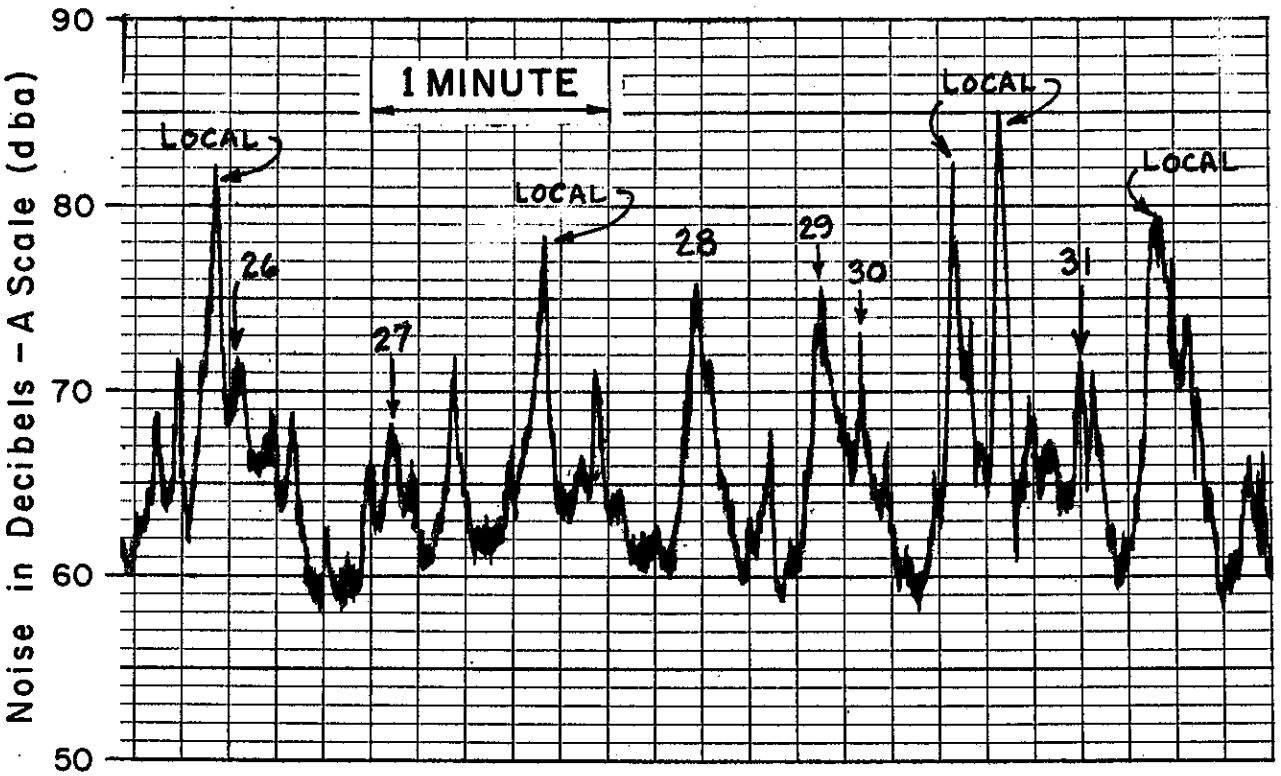

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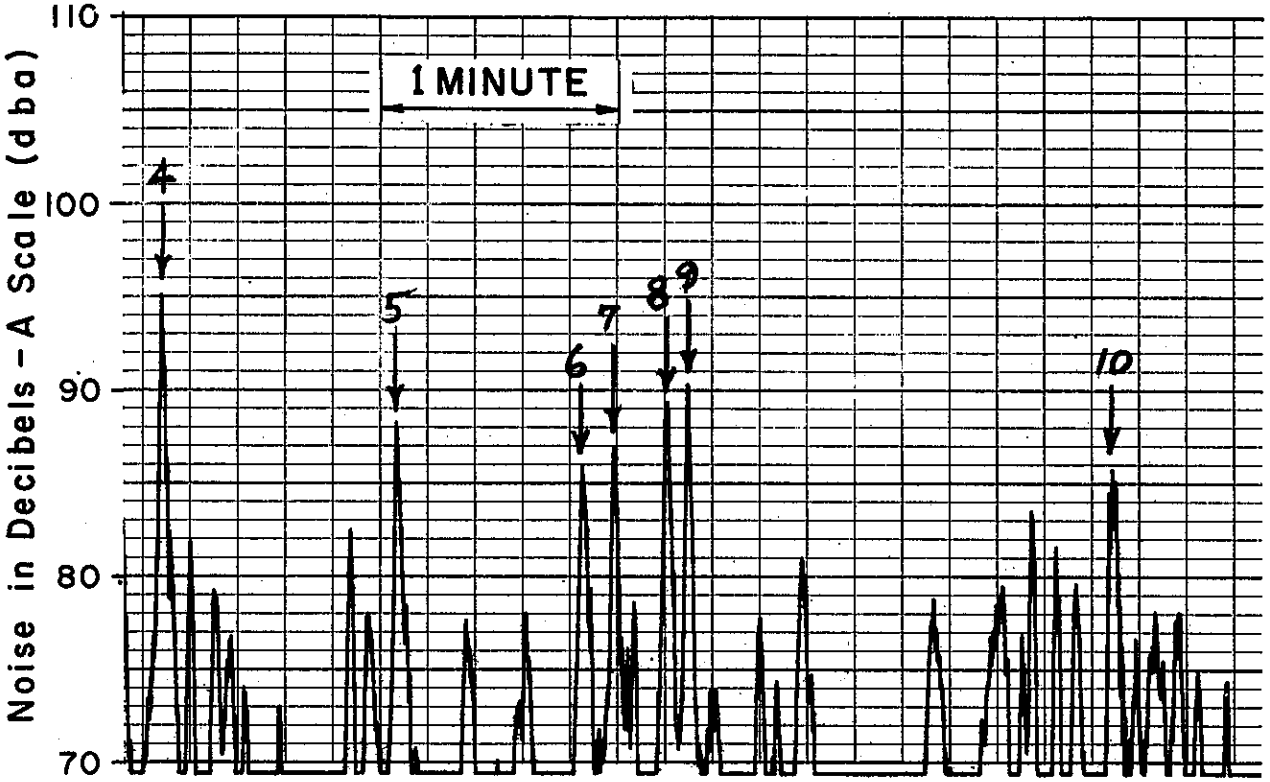
DEPRESSED SECTION

Figure 11

SAMPLE FROM SIMULTANEOUS RECORDINGS
Indexing Marks Trucks in Nearest Lane
FRESNO HWY 99 NEAR BELMONT AVENUE



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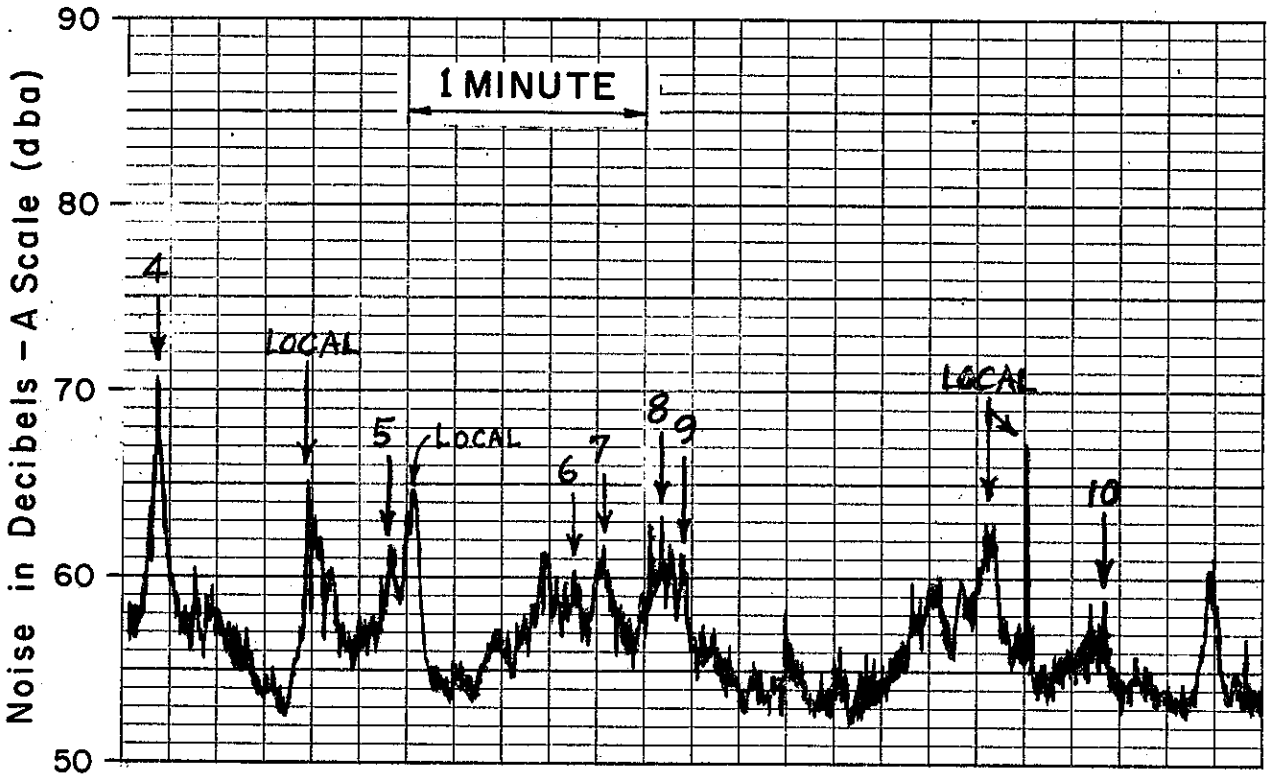

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