WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

SURVEY OF ACOUSTICAL WAVES GENERATED BY VEHICULAR TRAFFIC

1.0 OBJECTIVE

1.1 To determine the acoustical noise level of a particular area or project by actual field measurements and statistical evaluation of the data using a real time analyzer and associated equipment.

2.0 SCOPE

2.1 This acoustical study will be accomplished for any particular area or new project within the State. The study encompasses not only statistically evaluated decibel levels, but also contour maps of decibel levels for the area involved.

3.0 EQUIPMENT

3.1 A precision sound level meter with a linear frequency response from 5 Hertz (H_z) to 100 Kilohertz (KH_z). The sound level meter measures sound levels in true Root Mean Square (RMS) values. In addition to a visual meter reading, the meter also supplies Alternating Current (AC) output signals to drive a cassette tape recorder. The meter is equipped with a 12.7 mm flat random incidence response Electret Condenser Microphone.

3.1.2 A two channel, two track magnetic cassette tape recorder which records the desired signal on one channel, while on the other channel it records the setting of the sound level meter range control. Voice notes can also be recorded by interrupting the range code. The recorder provides an AC output signal which can be used to drive an analyzer or other similar equipment.

3.1.3 An inverter is used to convert Direct Current (DC) voltage from 12V automobile batteries to a 120V, AC 60 cycle output to operate the equipment. The inverter has a 275 watt continuous output potential. Frequency stability is within ±2 cycles.

3.1.4 A portable DC power supply is also used since part of the field equipment operates on DC power. The DC power supply operates off of 120V AC and the output is variable from 0-24V DC.

3.2 Analyzing Equipment

3.2.1 A Real Time Analyzer (RTA) capable of 1/3 octave band analysis of acoustic information. The analyzer has a 60 dB dynamic range making it ideal for the range of signals normally found in acoustic work. The input signal from a cassette recorder is applied to a set of analog filters (from 25 H_z) - 16 KH_z) giving 29 frequency bands and an overall A-weighted band. The outputs from the filters are converted to a digital binary form from which RMS levels are computed. The levels are then averaged by a method of true (linear) integration with a choice of nine integration times ranging from 1/8 second to 32 seconds. The computed levels are stored in digital memory to be retrieved at a rate determined by the output recording device. The analyzer has outputs to operate a magnetic tape unit a DC strip chart recorder and a display scope.

3.2.2 A desk top magnetic tape unit is used to record the output data from the RTA.

3.2.3 A DC strip chart recorder is available to graphically depict histograms of the decibel levels across the audible region of the frequency spectrum.

3.2.4 A display scope is also available to demonstrate a visual display of the sound levels if desired.

3.2.5 A multifilter can be used in conjunction with the RTA. The multifilter contains attenuation devices from 0 to ± 20 dB for each of the 29 frequency ranges associated with the RTA.

3.2.6 A computer is used to summarize the data available on the magnetic tape and to compute average levels, 95 percent confidence limits, standard deviations L_{10} and Le_q values.

4.0 TEST PROCEDURE

4.1 Selection of acoustical measuring sites.

4.1.1 A site is defined as the actual location of the measuring device during acoustical measurements.

4.1.2 While selecting sites where sound measurements are to be taken consideration is given to schools, churches, libraries, or other sensitive areas. One or more sites are usually placed near these areas.

4.1.3 The second major consideration in selecting sites involves the maps which are to be utilized in contouring the dB levels for the area. Sites are selected at points along the map in a manner such that the contouring may be performed most accurately.

4.2 Procedure used in obtaining readings.

4.2.1 At each of the selected sites, readings are taken for 5 two hour time intervals during a 24 hour period. The time intervals used are (1) 0700-0900, (2) 1000-1200, (3) 1600-1800, (4) 2300-0100, and (5) 0200-0400. These time intervals were chosen from experimentally acquired and statistically evaluated data which indicated that these were the time frames yielding the most pronounced points of inflection in acoustical levels during a 24 hour period. Figure 2 illustrates the curve from which these time frames were selected.

4.2.2 Normally one to two sites are covered during a two hour interval. For each site, five observations are taken during each two hour period. These five readings are measured at randomly selected times for a duration of three minutes each.

4.2.3 Before beginning the readings at a particular site, the microphone is placed on a tripod outside the vehicle at the preselected point. The AC power supply is then connected and the voltages necessary to operate the sound level meter and recorder are adjusted accordingly. Several minutes of visual observation are made with the sound level meter to determine the approximate maximum scale needed.

4.2.4 A blank cassette is then inserted into the cassette recorder and a calibration procedure performed. This calibration procedure involves placing a small sound level calibrator over the microphone. The calibrator produces a 1 KH_z tone at a sound level of 114 dB. If the reading on the sound level meter is 114 dB ± 1 dB, the tone is recorded on the cassette for approximately 30 seconds. This tone is recorded at the beginning of each new tape for purposes of calibrating the particular tape with the real time analyzer. If the sound level meter does not read 114 dB ± 1 dB, a calibrate adjustment is made.

4.2.5 A random time is then chosen for the first three minute observation. The recorder is started and an oral announcement is put on the tape consisting of the site number, time of observation, and the maximum dB level being used. A stop watch is then immediately started and the recorder allowed to continue for three minutes. After the three minute period, the recorder is stopped. This process is repeated for four additional random times during each time interval.

4.2.6 Upon completion of a cassette tape, the tape is rewound and a few minutes of the tape are monitored using an earphone to assure the proper operation of the equipment.

4.2.7 Any pertinent extraneous non-vehicular noises encountered such as trains, industrial plants, etc. are recorded in a log book along with the time of the occurrence. These comments are later incorporated into the final report.

4.2.8 Adverse effects such as rain and wind are sometimes causes for postponing of readings. This decision is left up to the discretion of the operator.

5.0 ANALYSIS OF DATA

5.1 Processing the data using the RTA and associated equipment.

5.1.1 The prerecorded data tapes are played back using a cassette recorder. The output from the recorder is cabled into the RTA's filter network where the analysis process begins. In order to calibrate the analyzer with respect to the prerecorded tape, the recorded calibration tone is first played into the analyzer and the analyzer adjusted for a display of 114 dB ± 1 dB.

5.1.2 An integration time of four seconds is selected on the RTA. A series of eight identifiers located on the coupling device between the analyzer and the magnetic tape unit are then set manually corresponding to the site number and time of the observation. These identifiers are punched at the beginning of each set of data on the magnetic tape format followed by the decibel levels for the 29 frequency bands and the overall A-weighted band. (See Figure 3).

5.1.3 To begin analysis of the data, the recorder is started and immediately the start button on the RTA is depressed. The RTA will then integrate the received data for four seconds. Following the integration period, the analyzer will simultaneously flash out the 30 band levels and send the data to the coupling device where it is converted to the proper format to be recorded on the magnetic tape. The process will then repeat. Forty 4 second integrations are allowed to be processed for each three minute reading on the cassette tape. Immediately following the print-out of the fortieth integration, the RTA is stopped and the cassette tape paused. The process is then repeated for the next three minute observation.

5.2 Final analysis performed by a computer.

5.2.1 The magnetic tape from the previous step is finally processed by computer to obtain the desired information. The computer summarizes the 200 four second integrations for each hour and prints out average values for each of the 30 bands. For example of computer print-out format, see Figure 3. In addition, the print-out includes values of standard deviation, 95 percent confidence limits, L_{10}, and Le_q values.

5.2.2 From the information obtained by the analysis, it is possible to conduct a frequency analysis of the noise of a particular site. Figure 3 illustrates how the actual sound level for each frequency band is recorded. From this information, one can determine the frequencies of the highest levels obtained. This type of frequency analysis could be an invaluable tool in designing attenuation devices.

5.3 Additional analytical procedures available through further utilization of the RTA.

5.3.1 In addition to using the output from the RTA to punch magnetic tape, the output can also be used to operate a DC strip chart recorder. The DC recorder is capable of producing histograms of sound levels over the entire audio range of the RTA. Figures 4 and 5 demonstrate the permanent type record that can be obtained with the DC strip chart recorder. Again, it can be noted that an individual frequency band analysis is available from the trace. The DC recorder would be most useful in instances where investigation of an unusual noise level is apparent for a short period of time.

5.3.1 A third output device available with the RTA is the display scope. This is merely a specially designed oscilloscope. The scope is capable of displaying histograms of sound levels somewhat like those produced by the DC strip chart recorder. The main advantage of the scope over the strip chart recorder is that the scope is capable of storage of a trace. Therefore, any number of successive integrations may be displayed on the scope without erasing pervious traces. This allows analysis of long intervals of data. Using this method of analysis, one can see a definite pattern develop on the scope for overall noise created by vehicular traffic. A typical bi-modal type of distribution of the frequency spectrum is obtained under somewhat ideal conditions in the absence of non-vehicular noise sources.

This first mode is found within the range 50 H_z - 200 H_z and the second commonly found from 500 H_z - 2 KH_z. The first mode can be attributed to exhaust and engine noise while the latter to transmission noise and interaction of tires and pavement surface.

5.3.2.1 Another valuable analytical technique combines the use of the display scope, and the RTA multifilter. Using the multifilter, various frequencies can be attenuated up to 20 dB. Therefore, using the multifilter in conjunction with the scope an undesirable background noise can be eliminated from a trace. The background is merely displayed on the scope then the filters adjusted to eliminate the background leaving only the desired frequency spectrum being studied.

6.0 COMPILATION OF DATA AND FINAL REPORT

6.1 Recording the data on the various forms

6.1.1 Recorded sound levels are taken directly from the computer print sheet. A form containing the L_{10} values, average sound levels, and Le_q values for each particular site and time is completed and included with the final report.

6.1.2 A form is also completed giving a brief description of the sites. This form is likewise included with the final report.

6.1.3 A T-7 and T-702 is completed for each site listing the L_{10} and Le_q values. These are then sent to teletype for further processing.

6.2 Procedure for contouring Le_q values

6.2.1 Selection of the proper maps for contouring is based on the surrounding area involved in a project. If the area is an urban area with large interchanges and residential areas a map with a scale of 25 mm = 15.2 m - 30.4 m is desirable. If the area involved is a rural area with scattered residences, a larger scale such as 25 mm = 61 m - 122 m or larger is sufficient.

6.2.2 Five copies of each map are needed and the maps should be either mylars or sepias in order that copies can be made for use in the actual contouring. The contour lines are originally drawn on blue line maps and then transferred to sepias or mylars.

6.2.3 The various sites and their respective Le_q values for the time slot being contoured are placed on the map. The contour lines are drawn taking into consideration the surrounding area. The surrounding topography is a major consideration as well as localized noise sources such as trains, industrial complexes, construction sites, etc. The contour lines are generally drawn for even decibel levels and at 2 dB intervals.

6.3 Preparation of final report

6.3.1 The final report is written as a Materials Inspection Report and includes the previously mentioned data tabulation sheets as well as the contour maps. A brief conclusion is written which includes explanations for any abnormal readings or occurrences.

Gary L. Robson, Director
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GLR:c

Attachment

DEFINITION OF TERMS

dB - The decibel is a relative scale of sound pressure, defined as ten times the logarithm to the base ten of the ratio between two quantities of power.

A - Weighted sound level - The value of sound pressure in decibels that most closely resembles that level heard by the human ear.

L_{10} - That noise level which can be exceeded ten percent of the time, based on statistical calculations of the raw data.

H_z - A unit of frequency equal to one cycle per second.

KH_z - A unit of frequency to 1000 cycles per second.

Octave - Band - A band of frequencies the limits of which have the ratio two to one.

Real Time Analyzer - An analyzer capable of processing the input signal continuously.

Standard Deviation - The measure of dispersion of all results around the mean or point of central tendency.

Confidence Limits - Those bounds within which the true mean of the entire universe of the measured characteristic would be expected to fall at the stated level of significance.

Linear Frequency Response - An essentially straight response across the entire frequency range concerned without attenuating a portion of any frequency.

RMS (Room Mean Square) - The square root of the average of the square of the values of a periodic quantity taken throughout one complete period.

Audio Range - That portion of the electromagnetic spectrum which is within the range of human hearing. Approximately 15 H_z - 20 KH_z.

Le_q - The equivalent steady state sound level which in a stated period of time would contain the same acoustic energy as the time-varying sound level during the same time period or in mathematical terms:

$$Le_q = 10 \log_{10} \frac{1}{N} \sum_{i=1}^{N} 10^{\frac{Li}{10}}$$

Where Li is the sound level (in decibels) of the sample numbered "i".