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The One-Minute L_{eq} Measurement Method

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ABSTRACT

A noise measurement method for energy-average sound level (L_{eq}) that provides more flexibility and information than most methods in use today is discussed. The one-minute L_{eq} measurement method consists of a series of L_{eq} measurements, each one minute in duration. This method requires an integrating sound level meter or portable noise monitor. Limitations of other commonly used methods and advantages of the one-minute method are discussed. An example of the L_{eq} method's use is presented.

A method for the short-term measurement of the energy-average sound level (L_{eq}) of environmental noise is described. This method uses currently available integrating sound level meters (SLMs) or portable noise monitors. It consists of dividing the measurement period into a series of one-minute intervals. [A similar measurement technique has been described in Sirieys and Commins (1).] L_{eq} is measured and recorded each minute and observations of significant noise events are made. The overall measurement period can be of any duration but is usually one hour or less and always consists of contiguous one-minute intervals. Overall L_{eq} is determined by calculation of the energy average of the valid one-minute L_{eq}s.

The advantages of the one-minute L_{eq} measurement method over more commonly used methods, such as the check-off method and continuous-monitoring method, include increased flexibility, complete sampling of the sound level, and diagnostic capabilities for contributions from various noise sources. In the following sections, limitations of these commonly used methods are discussed further and examples are presented.

LIMITATIONS OF COMMONLY USED METHODS

Check-Off Method

The check-off method (2,3) for measuring environmental noise levels has been in use for many years. Originally developed for statistical sampling of noise levels with hand-held SLMs, this method required reading the SLM instantaneously every 10 sec and checking off a box corresponding to the observed level on a data sheet, thereby creating a distribution of check marks. Statistical descriptors, such as L_{10}, L_{50}, and L_{90}, can readily be determined from such a distribution. L_{eq} can also be determined, typically by using a scientific calculator. Statistical tests are then performed to determine the precision with which the descriptor is known. Described in "Fundamentals and Abatement of Highway Traffic Noise" are the procedure and the tests for determining L_{10} in detail (2).

Although the check-mark method is a relatively straightforward procedure, it has some limitations:

- The method is a coarse sampling of the sound level (one sample every 5 or 10 sec), and therefore fairly long measurement periods are often required before L_{10} or L_{eq} can be determined with reasonable confidence. Determining confidence intervals on L_{eq} requires some calculation and the intervals are often quite large.
- The method is subject to reading error.
- Significant loud events can be missed during attenuator switching. This problem is particularly significant when using the method to determine L_{eq}. L_{eq} is critically dependent on maxima and, if one or more high-level samples are missed, L_{eq} could be significantly underestimated.
- The measurement engineer's attention is often strongly focused on the mechanics of performing the method properly and little time is available for note-taking about noise sources, important events, or traffic conditions.
- Two individuals are required if simultaneous traffic counts are to be made even on a roadway having only a moderate level of traffic.

Continuous-Monitoring Method

Over the past several years, portable noise monitoring systems (and, more recently, integrating SLMs) have been used significantly often for making short-term environmental noise measurements. Most noise monitors (or SLMs) sample the sound level essentially continuously; sampling rate and detector time constant are usually set to avoid missing any level variation. At the end of a selected time period, the monitor prints or displays the sound level descriptors for the previous sample period. For short-term measurements, monitoring is commonly performed for sample periods ranging from 10 to 60 min.

Using monitors for making sound level measurements is much less arduous than using the check-off method and frees the engineer to observe significant events. However, using sample periods of 10 to 60 min substantially reduces the flexibility and amount of information that is available when using shorter sample periods or the check-off method, as can be seen in the following two examples.

• Example 1: Many common noise events cannot be conveniently excluded. Significant noise events such as construction operations, barking dogs, voices, or particularly noisy vehicles nearby may be considered atypical of average conditions. Such events may contribute significantly to the measured L_{eq} but, with some monitors, cannot be excluded from the measurement. Although some monitors or SLMs have standby or pause switches that enable the engineer to avoid an unwanted event, many events such as shouts or dog barks are too sudden to exclude. As soon as an unwanted noise event occurs, the validity of the L_{eq} for that sample period becomes questionable. Typically, the engineer will be unaware of the extent to which the period L_{eq} is affected. The engineer restarts the measurement period after such an intrusion, discarding perhaps many minutes of otherwise useful noise data.

• Example 2: Traffic noise on roadways that are under study cannot be separated from total ambient noise. Frequently, traffic noise measurements are compared with predicted noise levels. These comparisons are most appropriate if the measured noise levels are exclusively due to traffic noise. However, with a continuous monitor accumulating data for the entire measurement period, significant events such as aircraft overflights, railroad passbys, and nearby (nonproject) traffic cannot be separated out. If they are excluded through the use of a pause switch, the engineer loses information about total noise levels.

SUMMARY OF THE ONE-MINUTE L_{eq} MEASUREMENT METHOD

The one-minute L_{eq} measurement method requires the use of an integrating SLM or a portable noise monitoring system. The SLM or monitor is set to operate for one-minute intervals, if it is so equipped. If the instrument must be manually reset, this is done once per minute. L_{eq} can be recorded manually or printed, depending on the capabilities of the instrument.

During each one-minute interval, the engineer is free to note events that may influence L_{eq}. For general environmental noise measurement surveys, notes about specific noise events during each minute can prove valuable for later determination of overall controlling noise sources. For traffic noise measurements, vehicle counts are often valuable. Counts of heavy and medium trucks can often be kept and automobile counts can sometimes be made for moderate- or low-volume roadways. (For automobile counts, a hand counter combined with noting the cumulative automobile count each minute is convenient.)

At the end of the measurement period, the L_{eq} for the entire period is calculated by using Equation 1:

$$L_{eq}(P) = 10 \log \quad (1/N) \sum_{i=1}^{N} 10^{\left\{[(L_{eq})i]/10\right\}} \qquad (1)$$

where

$L_{eq}(P)$ = the L_{eq} for the measurement period,
N = the number of minutes or one-minute L_{eq}s to be included in the period L_{eq}, and
$(L_{eq})i$ = the ith one-minute L_{eq}.

An example of a field data sheet used for this method is given in Figure 1.

PROJECT: Littleton By-Pass ENGINEER: CWM
SITE NO: 2 DESCRIP: Center School, 190' From ℄ By-Pass DATE: 5 Aug 83

MINUTE STARTING	MEAS. 1-MIN. LEQ	CUMULATIVE LEQ	AIRCRAFT	By-Pass HEAVY TRUCKS	By-Pass MEDIUM TRUCKS	~~AUTOS~~	NOTES
11:52 am	62.7						
11:53	64.1	63.5			I		
:54	63.2	63.4		II			
:55	74.5	69.4	1 Jet, 2	I	I		Noisy Jet Overflight
:56	66.3	68.5		I	I		Some A/C Noise From 1
:57	61.9	68.3			I		Quiet Minute
:58	65.1	68.0		I	II		
:59	64.6	67.7		I	I		
12:00 N	63.2	67.3			I		
:01	63.5	67.1			II		
:02	70.1	67.5	1 LP	I			Fast Overflight
:03	64.6	67.3		I			
:04	63.2	67.1			II		
:05	62.6	66.9					
:06	62.4	66.7			I		
:07	65.3	66.6		II	I		Noisy Med Tr.
:08	64.5	66.5		I	I		
:09	64.8	66.4			II		
:10	64.0	66.3		I	I		
:11	65.2	66.3		II			
:12	67.9	66.3			I		Delivery Truck Parked Nearby
:13	66.8	66.4					left halfway thru this min
:14	65.6	66.3		II	III		
:15	64.2	66.3		I	I		
:16	63.9	66.2		I	I		
:17	64.7	66.1			II		
:18	64.3	66.1		I	I		
TOTAL LEQ =	66.1	dBA (28 min)					
SUBSET LEQ =	64.1	dBA (23 min)	w/o Aircraft & Delivery Truck				

(ADD SKETCH AND WEATHER CONDITIONS TO REVERSE SIDE)

FIGURE 1 Example of field data sheet used in the one-minute L_{eq} measurement method.

Total Length of Sample Period

The duration of the sample period necessary to fairly represent the one-hour L_{eq} varies according to the nature of the noise sources and the distance of the observer from them. In general, a minimum of 15 to 20 min is recommended. Longer periods are advisable if somewhat intermittent noise sources are present. Also, if the variation among the one-minute L_{eq}s is more than a few decibels, then longer sample periods will improve the representativeness of the measurement.

A programmable scientific calculator can be employed in the field to provide additional information to the measurement engineer. The calculator can be programmed to display the cumulative L_{eq} if each one-minute L_{eq} is entered at the end of each minute. The minute-to-minute change in the cumulative L_{eq} can then be used as a guide to the engineer to indicate when the measurement period might be stopped. When the minute-to-minute cumulative L_{eq} becomes a relatively constant value, the engineer may consider ending the measurement period. This procedure requires time, however, and is difficult to employ if traffic counts are desired.

WHY ONE MINUTE?

The one-minute interval for L_{eq} was arrived at through experimentation with many measurement methods and interval durations as well as many hours of field experience with short-term noise measurements.

One minute is long enough to free the engineer for observation for a reasonable length of time; at the same time, the one-minute period is short enough so that individual interval samples of L_{eq} that contain contributions from unwanted or atypical noise sources can be separated out or eliminated without a significant loss of valuable measurement time. Also, the number of interval L_{eq} values that must be energy averaged to obtain the period L_{eq} is not excessive (for short-term measurement periods).

ADVANTAGES OF THE ONE-MINUTE L_{eq} MEASUREMENT METHOD

The major advantages of the one-minute L_{eq} measurement method are efficiency and information. This method allows the engineer to efficiently obtain useful and complete measurement data.

Because the one-minute L_{eq} measurement method allows the separation or exclusion of individual one-minute L_{eq}s, the engineer can perform measurements at less-than-ideal locations and still obtain useful data. Usually, measurement of traffic-only L_{eq} and total ambient L_{eq} can be obtained at the same time, along with simultaneous traffic counts. The engineer only has to note the one-minute periods during which noise sources other than traffic apparently contributed to L_{eq}. (He can do this by listening and estimating the significance of other sources, or by a combination of listening and observing how the L_{eq} for that minute compares with the foregoing L_{eq}s.) Then, those minutes are included only in the calculation of the period L_{eq} for total noise. L_{eq} for traffic noise is calculated excluding those minutes influenced by nontraffic noise. If simultaneous traffic counts were made, they can be used to compare a prediction method with the measured L_{eq} for traffic only.

Another advantage of the one-minute L_{eq} measurement method is that there are inexpensive integrating SLMs available with which one can use the method (such as Bruel & Kjaer Models 2225 and 2226). Until recently, the only methods available for measuring L_{eq} with inexpensive instrumentation have been relatively tedious hand-sampling methods (3) using standard SLMs. These methods are susceptible to operator error and have relatively complex procedures for determining confidence intervals.

The one-minute L_{eq} measurement method doesn't involve a sampling of the sound level; rather, it is effectively a continuous integration (depending on the circuit design). Therefore, sample bias is limited or nonexistent and no confidence interval calculations based on a sampling need be applied. Although recording L_{eq} and resetting an SLM requires a brief pause, this pause can be kept short with practice. The potential measurement error therefore approaches the error in the instrument itself; this error is usually published with the instrument specifications.

Some portable noise monitoring systems can be set up to operate automatically in the one-minute L_{eq} mode (such as Digital Acoustics 607, BBN 614) and can be used to advantage with the L_{eq} measurement method. Although such monitoring systems are more cumbersome than integrating SLMs, their automatic operation and data recording features free the engineer from the recording and resetting tasks.

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