

The Noise Perception Index (NPI) for Assessing Noise Impact From Major Industrial Facilities and Power Plants in the U.S.

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Abstract

There is no standardized federal, state or local methodology for assessing noise impact from major industrial facilities and power plants in the U.S. The U.S. EPA "Levels" document guideline of DNL = 55 dBA is sometimes used as a de facto standard, but is misapplied more often than not. Thirteen states promulgate noise emission standards for industrial sources. Of these, eight issue "maximum-emission" levels and five publish "ambient-based" standards. Levels deemed "acceptable" for permitting purposes for an identical project in the thirteen states can vary by 17 dBA or more, and the rest of the states consider noise a local issue. This paper reviews and critiques in-use assessment methods and develops a method called the Noise Perception Index (NPI) that is based on core thresholds and methods used for decades in the states using ambient-based assessment procedures. The intent is to develop a uniform and relatively simple method to predict true community perception over the long range course of the installation. Spectral imbalance and tonal character are accounted for as are adverse cumulative effects inherent in ambient-based methods. It is believed that the developed NPI assessment method is fair and reasonable for both the community and the project owner since the core method has been validated from years of application throughout the U.S.

Summary of Current Practice for Assessing Industrial and Power Plant Noise

There is no uniform method for assessing power plant or general industry noise in the U.S. In fact, assessment requirements and permitted noise emissions at potentially sensitive receptors vary dramatically from state to state and county to county and all cannot possibly be correct. The following brief summary of guideline methods are frequently consulted for guidance in areas not formally regulated.

World Standards

The World Health Organization (WHO) publishes the following current guidelines for community noise in residential environments.

- 55 dBA Leq Daytime Levels: "Serious Annoyance, daytime and evening"
- 50 dBA Leq Daytime Levels: "Moderate Annoyance, daytime and evening"
- 45 dBA Exterior/30 dBA Interior Leq Nighttime Levels: To avoid sleep disturbance issues.

U.S. Federal Standards

The U.S. federal government issues

no standards for industrial noise, but does promulgate noise regulations for major transportation systems. These regulations by the Federal Aviation Authority (FAA) and the Federal Highway Administration (FHWA) are predicated on the fundamental basis that some noise annoyance is justified or offset by the public good provided by the systems. Generally, acceptable regulatory levels in the 60 to 65 DNL (day night sound level) range have been shown to "highly annoy" approximately 10% of affected residential receptors. Hence, these standards are not useful for comparing to operational plant noise emissions since the public good of a new power plant or industrial facility is not obvious, and conscientious owners would want no annoyed neighbors.

The U.S. EPA Office of Noise Abatement was disbanded in the late seventies but did issue a landmark report suggesting guidelines for environmental noise in residential communities from all environmental sources. The report is often called the "Levels" document for short. The document has become a defacto standard for such organizations as the World Bank and others. Unfortunately the report is often misused and the cited recommended level of DNL = 55 dB for residential land use is commonly use an acceptable or criterion level for emission sources in any type residential environment. The

EPA intent was to provide a guideline or country goal for total environmental noise (ambient noise plus any other industrial and/or transportation sources). The report acknowledges there was no cost-benefit analysis performed. In addition, the report clearly demonstrates the level of DNL = 55 dB is applicable to an urban residential background and must be normalized to any other specific environment under consideration to obtain just an acceptable level of correlation between DNL and community response. Otherwise, correlation is very poor based on the analysis presented in the levels document and others.

The EPA did conclude in the document that an outside noise level of 45 dBA at nighttime (10 p.m. to 7 a.m.) is adequate to preclude sleep-interference issues. This was based on a noise reduction of 10 dBA with open windows that results in interior bedroom levels of 35 dBA. The much later work summarized above by WHO also recommends an exterior background level of 45 dBA to avoid sleep interference, but implies a 15 dBA open-window noise reduction resulting in an interior level of 30 dBA.

We could conclude from these studies that a maximum steady total sound level of 45 dB during nighttime hours should be considered a maximum for any facility noise limit design goal. It should be noted however that millions

STATE	NOISE LIMIT AT RESIDENTIAL RECEPTORS *A* WTD. EMISSIONS LEVEL	COMMENTS
MARYLAND	55	EMISSION LIMIT, ANY AMBIENT
DISTRICT OF COLUMBIA	55	EMISSION LIMIT, ANY AMBIENT
DELAWARE	55	EMISSION LIMIT, ANY AMBIENT
ILLINOIS	51	EMISSION LIMIT, ANY AMBIENT-EQUIVALENT A-WTD LEVEL FROM SPECIFIED OCTAVE BANDS
CONNECTICUT	51	EMISSION LIMIT, ANY AMBIENT
MINNESOTA	51	EMISSION LIMIT, ANY AMBIENT
NEW JERSEY	50	EMISSION LIMIT, ANY AMBIENT
OREGON	50	L50 IN ANY ONE HOUR IN "QUIET" ENVIRONMENTS
COLORADO	50	EMISSION LIMIT, ANY AMBIENT
MAINE	45	50 dBA WHEN AMBIENT LEQ>35 dBA, 45 dBA BELOW (USE Leq=33 dBA)
MASSACHUSETTS	40	MAXIMUM OF 5 TO 10 dBA ABOVE LOWEST L90 AMBIENT (USE MIN L90=33 + 7 dBA)
WASHINGTON	39	EMISSION LIMIT DEPENDING ON RURAL (39) OR RESIDENTIAL (42) ZONING
CALIFORNIA	38	MAXIMUM OF 5 dBA ABOVE L90 AMBIENT (FOUR QUIETEST CONSECUTIVE HOURS, USE MIN L90=33 dBA)
NEW YORK	38	MAXIMUM OF 5 dBA ABOVE UNDEFINED AMBIENT (USE MIN L90 OR Leq =33 dBA)
MEAN STATE NIGHTTIME LIMIT:	50	
AVERAGE STATE NIGHTTIME LIMIT	47.7	

Table 1: Tabulation for State Noise Regulations and Standards

of residences have exterior noise levels exceeding 45 dBA, and the sound of airflow in HVAC residential ducting systems often exceed interior levels of 30 or 35 dBA in bedrooms.

State Standards

Just over a dozen states have codified regulations or zoning guidance or siting standards that have the same result as regulations for industrial noise. Most allow a higher limit for daytime hours. The night-time limits for industrial noise sources are tabulated above for thirteen states, assuming a residual or equivalent ambient level of 33 dBA for the last states using an ambient based standard.

Clearly there is a large variance of “acceptable” levels for nighttime noise emissions at sensitive receptors from state to state amounting to a huge range of 17 dBA for the case above. Not all can possibly be appropriate.

Eight states issue ‘maximum emission limits’ that differ during daytime and nighttime hours and are applicable at residential receptor areas regardless of the acoustic environment in those areas. While simple to codify and enforce, it is illogical that the same level

could be satisfactory for any residential environment ranging from loud urban to remote quiet rural residential locations. The state of Maryland acknowledges this and has found that fully 50% of excessive noise complaints comply with the State’s regulations.

Maine and Washington acknowledge the differing ambient environments by including a clause that reduces the allowable emission limit for “quiet” areas in Maine and “rural” areas in Washington. The states of New York, Massachusetts and California use ambient-based emission levels, i.e. the allowable emission level is calculated based on some prescribed relatively small increase to existing ambient or background sound levels. An ambient-based method is based on the perception of the new sound in the specific residential community. A perception-based method is clearly a better approach than a single emissions level limit, and in fact many years of experience have shown this approach is working successfully in these three states.

The difficulty of just selecting one of these state methods for general use is in

the definitions and implementation of the standards, i.e. in the details and methods. For examples, the states of CA and NY set the threshold for potential adverse response at a level of 5 to 6 dBA above the background while MA uses an increase of 10 dBA except for major power plants over 100 MW where the burden is placed on the applicant to demonstrate that the plant cannot be made quieter for technical or economic reasons.

In addition the three states define the baseline background differently. MA defines the background as the quietest hourly LA90 measured while CA has evolved into using the minimum hourly LA90 for the quietest consecutive four hour period. NY does not specifically define the ambient metric to use so various units and measurement times are used by different applicants that can result in quite different permit levels. These differences are complicated by the fact the ambient can be measured in as little as one day. It will be shown later that the day to day variance in the quietest hour sound level can easily vary by 5 to 10 dBA.

Despite the detail variances in the three states, experience over many years has shown the standards to be effective in avoiding adverse impact from facility noise emissions. This experience plus safeguards for tonal and excessive low frequency noise can be crafted into a proven objective and fair ambient-based method for assessing noise impact for major facilities.

Local Standards

Finally, it should be said that countless counties and local municipalities have enacted noise laws and codes. These vary even more than state standards, and are very often ill defined and outdated.



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Noise Perception Methodology for Developing Operational Noise Design Goals

As discussed above a design goal for noise should be based on the perception of the new source by the affected potentially sensitive receptors. Noise perception is complex and depends on at least the following basic factors:

- Existing background or ambient masking noise levels
- Operational time of day and night
- Calendar operational time
- Noise level magnitude of the emissions from the planned new source
- Character of the noise emissions from the planned new source
- Pre-exposure and cumulative effects of an ambient-based method

Basis for Audibility and Perception

It is well known that a change in sound from an identical source is just perceptible or audible if the volume

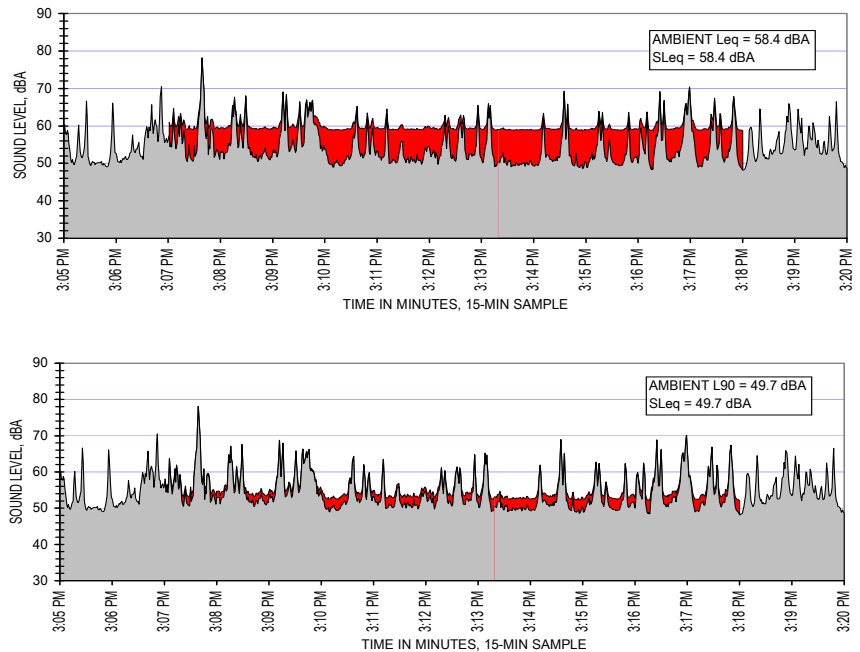


Figure 1: Ambient Sound Levels in Urban Environment

Figure 1 above plots the instantaneous measured ambient sound level (in gray) over a 15-minute interval in an urban residential environment with heavy passing traffic shown by the individual vehicle passes. The measured sound levels for this 15-minute interval were LAeq = 58.4 dBA and LA90 = 49.7 dBA. The LAeq metric (energy or true pressure average) includes the contributions of all noise sources, i.e. the passing traffic. Conversely, the residual LA90 essentially quantifies the noise level during lulls between identifiable sporadic traffic passes.

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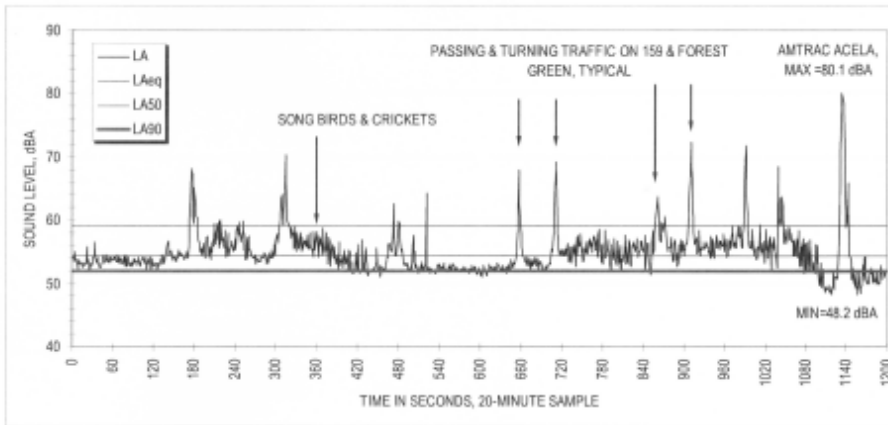


Figure 2: Ambient Time Trace for a Suburban Daytime Sample

is raised or lowered by 2 to 3 dBA. At 5 dBA, the change in sound is easily perceptible and level changes above 5 dBA become noticeable. A 10 dBA change to an identical source is perceived as a doubling or halving of that source. These well known relationships are often used or misused in environmental permitting documents for power plants and other facilities. The permitting scenario is quite different in most cases in that we are evaluating a different character sound that is superimposed upon the ambient or background sound. To compound this problem, the ambient is constantly changing from second to second and day to day. Plus, the measured ambient level is different depending on the measurement metric used (generally LAeq or LA90) for measuring sound for any given measurement length.

We can mathematically superimpose a new steady sound level source, SLeq that could be set equal to the ambient LAeq or LA90 value. The new total level (ambient plus source) caused by these new sources are shown in red in figure 1 (previous page). The upper plot is for SLeq set equal to the measured LAeq of the ambient and the lower plot is set equal to LA90. The intent is to cause a 3 dBA increase to the “ambient”.

Notice on the upper graphic that the new source will certainly be perceptible (change => 3 dBA) for a large percentage of the time, and actually would only be imperceptible during very brief and loud traffic passes. To example, the source would be clearly audible for a full minute just after 3:13 p.m. When the source level SLeq is lowered from LAeq to LA90, the increase to ambient never exceeds 3 dBA. This does not mean the

new source is totally imperceptible or inaudible because the new industrial or power plant source probably will have some distinguishable character such as a faint tone, whistle, hum or pronounced high or low frequency spectrum unbalance that would make the source both identifiable and perceptible, certainly when careful listening is used by the observer. If the new source was a truly broadband source at a level of 49.7 dBA, it could possibly be judged imperceptible.

In our opinion, this discussion shows why using the measurement metric LA90 (the residual ambient) should be used for noise assessment purposes as opposed to LAeq. The increase to the “ambient” is the same in both cases, but actual perception of a listener is totally different. This applies to both loud urban and quiet remote residential environments.

It must be said that using LA90 as the “ambient” is still somewhat conservative in that the ambient is higher 90% of the sampling time. A very good case could be made for using LA50, the mean level for defining the ambient. In quiet areas, LA50 is the mean of the slowly varying level caused by natural sources such as rustling trees and grasses, but the metric excludes loud sporadic events such as passing traffic. Refer to Figure 2 where one can observe that LA50 better quantifies the slowly changing quasi-steady ambient level, exclusive of the loud identifiable sources. At loud constant-source sites, LA50 approaches LAeq. Nevertheless, there is a lot of precedence for using LA90, and the inherent conservatism will be shown later to offset other factors that could enhance perception of the new source.

Character Perception

A source without pronounced tones is called a broadband source because there are no narrow frequency bands of peak noise over the audible frequency range between 20 and 20,000 Hz. Residual background sound usually from far-off unidentifiable traffic sources is a broadband source. Residual background sound containing cricket or insect sound or far-off diesel truck engine tones is a broadband source with superimposed tones.

Power plant noise close to, or in the plant is a highly tonal source with many distinct equipment tones, but tends to become a broadband source as one moves away from the plant where the tonal character sources reduce to levels comparable to ambient sound. This blending of sources creates the very low level “hum” often perceived far from a plant. Power plant or other industrial noise may also contain high levels of low or high frequency sound resulting in a frequency spectrum very different than the residual ambient sound in a community.

Because of the sound character of a power plant, or any industrial facility for that matter, the noise emissions may be just audible and perceptible at levels comparable to the ambient community sound. Thus, a plant emission introduced to an ambient level of the same level as the ambient would cause an increase to the ambient of 3 dBA, but may still be identifiable and perceptible due to tonal or other characteristics of the sound.

The above discussions show that it is virtually impossible to design a large facility or power plant to be inaudible or imperceptible in a community at any time of day or night during calm and still winds unless there is a very large buffer distance between the plant and community, or the plant emissions can be practically and technically designed below the lowest possible ambient levels. What is required is a permitting methodology that fairly evaluates perception and balances the needs of adjacent receptors and the plant owner.

Develop a Noise Perception Index for Assessment Purposes

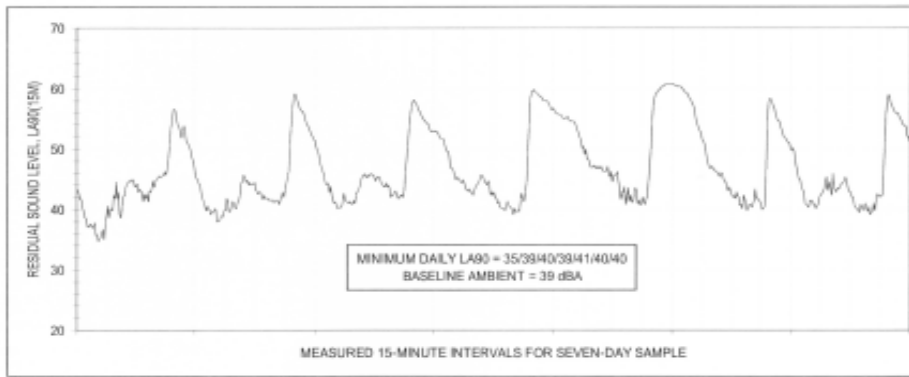


Figure 3: A seven day ambient survey showing insect noise patterns

On the surface, the discussed perception or audibility basis above would seem to conflict with the successful experience in the states of MA, NY and CA where a 5 to 10 dBA increase to the ambient is judged as the threshold of potential adverse response or essentially judged to be acceptable noise increases to the ambient. It is reasoned that this results because the nominal increase to the ambient of 5 to 10 dBA is based on the minimum ambient measured over a 24 hour day. Therefore the increase is actually less than 5 or 10 dBA at most other times of the day. Based on this we propose a method of calculating the actual time-varying increase to the ambient over a representative length of operation of the new facility, a seven day week. The method will be called the Noise Perception Index (NPI) that should correlate with actual observed community response.

Each input parameter or detail will be evaluated to develop the NPI methodology:

Ambient Measurement Metric

As previously discussed for perception considerations, LA90 is the conventional and preferred measurement metric. LAeq is an excellent metric for what it is currently used for – to measure and evaluate major transportation noise sources in the environment. However, the metric falls short in quantifying levels in residential environments for practical reasons. For example, DNL using LAeq as the measurement metric is woefully misleading all summer as long as there is insect activity at night that can skew the measurement by 10 to 15 dBA because of nighttime weighting. It is also misleading as illustrated above to evaluate perception due to incremental

changes to an ‘average’ LAeq level.

Ambient Measurement Duration

It is convenient to define the “ambient” as a single value to use as a baseline for assessing impact, even though the ambient is changing both in the short term – second to second and over the longer term from hour to hour and day to day. Examples will be given later showing that the minimum hourly LA90 residual ambient can easily vary by 5 to 10 dBA over a week’s measurement period. It has been customary in the three states with ambient-based assessment guidelines to determine the minimum measured level for any hour in a 24 or 25-hour measurement day, which is then called the ambient for all time. Two of the states specifically dictate the use of LA90 while the third does not specifically define the metric and various applicants use LA90 or LAeq.

Based on years of experience, we recommend a measurement of the minimum hourly LA90 over a minimum of a seven day week. The single value for a baseline is then defined as the arithmetic average of the seven or more minimum daily hourly LA90 measurements. Again, it could be argued that using the minimum LA90 metric is unduly conservative since perception is then based on an hour that may occur only once a day at 3 a.m. and the instantaneous level is actually higher 90% of that hour as well as all other daily hours. Conversely, the quietest hour is often midday in rural and quiet residential environments. We believe the conservatism using the minimum LA90 may be the single most important reason that increases to the ambient on the order of 5 to 10 dBA caused by a new source with recognizable character

has been found over many years to result in successful noise-compatible installations in the three states.

The final argument for using the minimum LA90 in a given day is for residential environments with insect activity. As is well known, high frequency insect sound skews the A-weighted sound level metric to the point it negates using LAeq for an environmental measure for summertime. While insect activity is a natural source of environmental sound such sound offers little masking of typical power plant noise below 1 kHz since all the energy is well above 1 kHz. Figure 3 below plots a seven day survey in a residential neighborhood during summer. Insect activity starts each evening just after 6 p.m., peaks and then gradually diminishes. There is still a minimum daily LA90 that may occur in the early morning hours or later in the day.

Frequency Measurements

An earlier detailed community response scheme³ employed frequency analysis in octave bands to detect tonal qualities and spectrum imbalance. It is even easier today to measure and analyze in frequency bands, no doubt a superior technical approach. However, the recommended A-weighted overall sound level, the universal world wide metric, leads to a simpler approach and importantly, a more understandable method for both concerned citizens and responsible regulators. For this reason, the simpler approach is much preferred but must be designed to preclude adverse noise character issues.

Noise Emission Character Limitations-Low Frequency Noise

It is now better known that excessive low frequency noise (LFN) can cause real adverse community distress^{4 5 6} and may not be detected with an A-weighted community noise rating scheme. Potential excessive frequency spectra imbalance can be detected by the simple quantity; C-weighted minus A-weighted level or dBC – dBA => X, where X is usually 20 dB but as low as 15 dB in some country standards. The quantity X serves as a marker or threshold that there may be a LFN issue if X is exceeded and the spectrum should be investigated. The NPI assessment

method can easily incorporate the marker by adding a precautionary LFN note for the calculated C-weighted level 20 dB above the developed A-weighted source level, SLeq.

Noise Emission Character Limitations-Tonal Noise

The EPA defined a pure tone limit in a 1/3 octave band spectrum as any tone that exceeds the prominence quantities as follows:

Any sound that can be distinctly heard as a single pitch or a set of single pitches. For the purposes of this (Model) ordinance, a pure tone shall exist if the one-third octave band sound pressure level in the band with the tone exceeds the arithmetic average of the sound pressure levels of the two contiguous one-third octave bands by 5 dB for center frequencies of 500 Hz and above and 8 dB for center frequencies between 160 and 400 Hz and by 15 dB for center frequencies less than or equal to 125 Hz.

Experience in practice with this easily measured limit, which is also found in numerous codes and standards, indicates a tone is indeed prominent (and annoying) if equal or exceeding the definition. Tones under the prominence

values are generally still audible but are perceived as low-level or faint or just detectable depending on the level. Again, we believe the conservatism built into using the minimum hourly LA90 as the ambient base effectively reduces the actual audibility or time of perception for the perceived tonal noise. Nevertheless, for purposes of an assessment the definition serves as a very useful upper limit for excessive tonal noise and must be incorporated into any A-weighting based response prediction method. The simplicity of measurement far outweighs the more technically precise ANSI standard definition⁸ for tones.

Cumulative Effects of an Ambient Based Method

The discussion so far accounts for the six bulleted items above in the previous section except for the last 'preexposure and cumulative effects'. Large facilities and power plants may contribute or even dominate the "ambient" sound level at the closest adjoining residences. However, just as probable, the site could be a completely green field. Some noise response prediction schemes add a 3 to 5 dBA correction for "prior

exposure", i.e. the correction implies a higher sound level is needed to provoke adverse response because receptors are acclimated to the noise. The presence of audible plant or facility noise may be tolerated, or not, for various reasons with some not technical, but this does not justify continually increasing noise emissions by 5 dBA. It also seems logical that a facility or an area of differently owned facilities cannot keep expanding on the basis that a 5 dBA increase would be acceptable or the threshold for invoking adverse response. The developed NPI assessment method can take this into account by lowering the allowed increase above ambient. For example, if the measured ambient level at a site under investigation already has distinctly audible or dominant facility noise or very high noise levels for that matter, the increase could be kept to 3 dBA or even less depending on the severity of the site. In this way, the new source is generally not going to be perceptible or discernable except under possibly ideal sound propagation conditions when receptors may or may not be outdoors to perceive the source. In effect, judgment can be easily applied to account for unique site conditions.



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Noise Perception Index (NPI) Assessment Method

In summary, the following parameters and definitions are recommended for use to define a comprehensive ambient-based noise assessment analysis called the Noise Perception Index (NPI) method. The NPI index is defined as the true pressure average of the hourly increases above ambient caused by a new source during typical operation over a seven day minimum period.

- An emissions source level, SL_{eq} , approximately 5 dBA above the baseline ambient shall be considered as the threshold of adverse response for a green field site.
- An emissions source level, SL_{eq} , equal or less than 3 dBA above a baseline ambient shall be considered the threshold for adverse response for cumulative site situations or high-ambient sites.
- The hourly LA_{90} is defined as the ambient measurement metric for computation of NPI.
- A minimum seven day survey is required to measure the temporal trends of hourly LA_{90}
- The baseline ambient is defined as the arithmetic average of seven or more daily minimum hourly LA_{90} values.
- The nominal increase to ambient is defined by $SL_{eq} - \text{baseline ambient}$.
- LA_{eq} and LC_{eq} metrics are used for emissions measurements to avoid low frequency noise imbalance.
- The EPA definition for a pure tone in 1/3 octave bands shall be used as the upper tonal limit to avoid prominent tone issues.

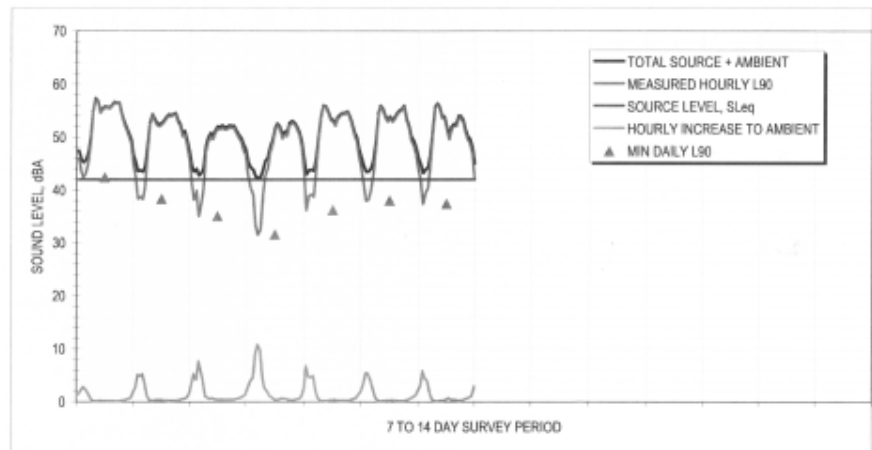
The Noise Perception Index (NPI) method is believed to be an accurate and reliable predictor of community response to industrial and power plant noise. The core principles of the method have now been used successfully for decades in three states and can be considered as proven experience. Please note the definitions that prescribe the detail methodology for determining NPI in Table 2. This methodology more carefully defines the details and adds character limitations, but is essentially a

NPI INDEX	PERCEPTION	PREDICTED COMMUNITY RESPONSE
≤ 3 dBA	GENERALLY IMPERCEPTIBLE	NO RESPONSE
3 TO 5 dBA	BARELY PERCEPTIBLE TO PERCEPTIBLE	NO RESPONSE TO POTENTIALLY ADVERSE RESPONSE
5 TO 10 dBA	PERCEPTIBLE TO NOTICEABLE	POTENTIALLY ADVERSE TO ADVERSE RESPONSE
> 10 dBA	READILY NOTICEABLE	ADVERSE RESPONSE

DEFINITIONS AND CONDITIONS FOR ABOVE TO BE APPLICABLE:

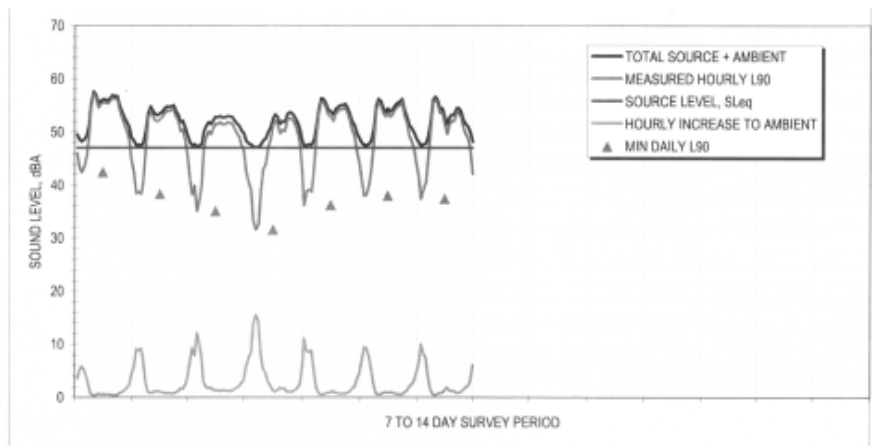
NPI INDEX	The Noise Perception Index (NPI) is the true pressure average increase calculated for each hour over a seven-day (or more) operation of the new source
AMBIENT	The measured hourly LA_{90} residual level over a minimum seven-day (168 hour) period.
MINIMUM DAILY AMBIENT	The minimum measured hourly LA_{90} in any hour over each of seven days (or more) ambient survey period
BASELINE AMBIENT	The arithmetic average of the seven minimum daily ambient LA_{90} measurements
SOURCE LEVEL	The source level, LA_{eq} or LC_{eq} is the equivalent sound level of the source under evaluation
PURE TONE	No pure or prominent tone is permitted at any potentially sensitive receptor location. A pure tone is defined in EPA Report 550/9-76-003
LOW FREQUENCY NOISE (LFN)	Potential adverse impact from LFN must be evaluated if $LC_{eq} - LA_{eq} \Rightarrow 20$ at any receptor
NOMINAL INCREASE TO AMBIENT	The difference between SL_{eq} and the baseline ambient at any receptor

Table 2: Noise Perception Index (NPI) Community Noise Assessment Method



ANALYSIS RESULTS:

5	NOMINAL INCREASE TO BASELINE AMBIENT
37	BASELINE AMBIENT
42	SOURCE LEVEL, SL_{eq}
2.1	NPI INDEX
x	24/7 OPERATION



ANALYSIS RESULTS:

10	NOMINAL INCREASE TO BASELINE AMBIENT
37	BASELINE AMBIENT
47	SOURCE LEVEL, SL_{eq}
4.8	NPI INDEX
x	24/7 OPERATION

Figures 4 and 5: Examples of NPI index Applications in a traffic-noise dominated residential area, upper plot with 5 dBA increase, and lower plot with 10 dBA increase

compilation of the successful permitting requirements for the states of MA, NY and CA.

Test Examples of NPI Index Method

Only two inputs are required to compute NPI, seven days of hourly LA90 ambient noise measurements at each potentially sensitive receptor, and the predicted or set new noise emission level at the same locations. The source level, SLeq could be set as a design goal or generated by a sound propagation noise model for a defined facility. A spreadsheet to illustrate the hourly temporal plot of the measured ambient along with the computed NPI index is recommended. The examples below illustrated in Figures 4 and 5 are for a minimum length survey in an urban environment where the nominal increase to the ambient is set at 5 and 10 dBA to verify that the predicted response corresponds to the experience for the three states now using this technique.

The measured residual LA90 ambient level in green has a repeating temporal road-traffic pattern because the receptor location is fairly close to a major commuting route. The level drops at night and reaches a minimum in the early morning hours. Note the daily measured minimum hourly LA90 varies by 10 dBA over the course of the week. This occurs because weather and natural sound sources control the minimum level in the near absence of traffic sources during late night and early morning hours. The single number ambient arithmetic average or baseline ambient is 37 dBA for this example. The source level, SLeq, is nominally set to 5 dBA above the baseline ambient of 37 dBA, or 42 dBA in the upper graphic, the steady red line for 24/7 operation. The increase to the ambient or NPI is calculated for each hour and plotted on the bottom of the graph.

$$NPI = \frac{\sum((10 \log(10^{(SLeq/10)} + 10^{(LA90/10)}) - LA90))}{n} \quad (1)$$

where LA90 is the measured hourly ambient for each operational hour and n = number of operational hours in the seven day minimum ambient measurement.

Note the major hourly increases occur late night and early morning. NPI is

the single-number true pressure average of the resulting increase over the 168 hour survey period, or 2.1 dBA. Looking above to Table 2, the expected perception and response is “generally imperceptible and no adverse response”. When SLeq is nominally set to 10 dBA above the baseline ambient in the lower graphic, the NPI index increases to 4.8 dBA, essentially at the threshold for adverse response. Note the distinction between NPI and the single number nominal increase to ambient. These results correspond very well with the state’s experience. It is noteworthy that in the state of Massachusetts, the prescribed 10 dBA increase is actually

negotiated downward for major power plants (over 100 MW) with the burden placed on the applicant to demonstrate that the power plant cannot be made quieter on economic or technical grounds. So, the nominal increase approaches 5 dBA, corresponding to the other two states. If the planned operation is not 24/7 as in the above examples, the source level SLeq could be limited to the planned schedule and input into the calculation and the NPI index recalculated on this basis. For example, the NPI index would reduce from 2.1 and 4.8 dBA shown above in Figures 4 and 5 to 1.5 and 3.7 dBA for the 5 and 10 dBA increase scenarios,

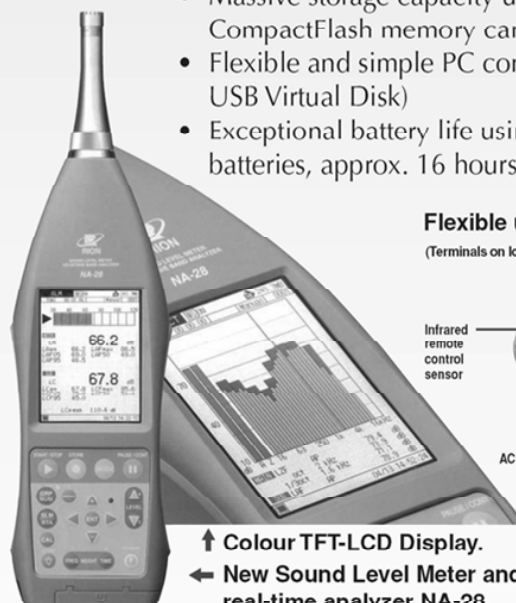
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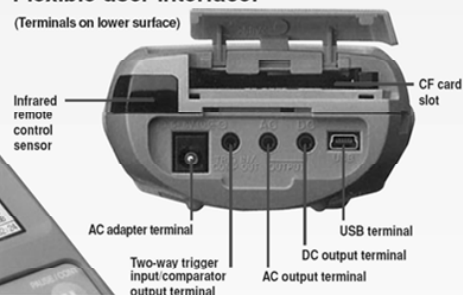
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- One keystroke to switch between sound level meter and analyzer display.
 - Massive storage capacity using text files stored to CompactFlash memory cards (CF card).
 - Flexible and simple PC connectivity (CF card and USB Virtual Disk)
 - Exceptional battery life using standard alkaline batteries, approx. 16 hours.



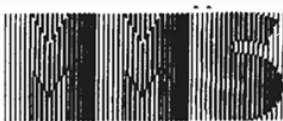
Flexible user interface.

(Terminals on lower surface)



↑ Colour TFT-LCD Display.

← New Sound Level Meter and 1/3 octave band real-time analyzer NA-28.



Machinery Monitoring Systems

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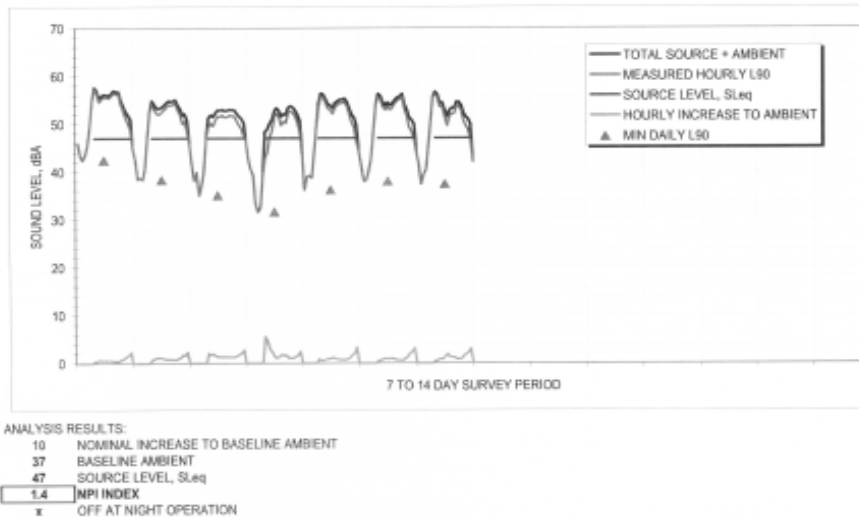
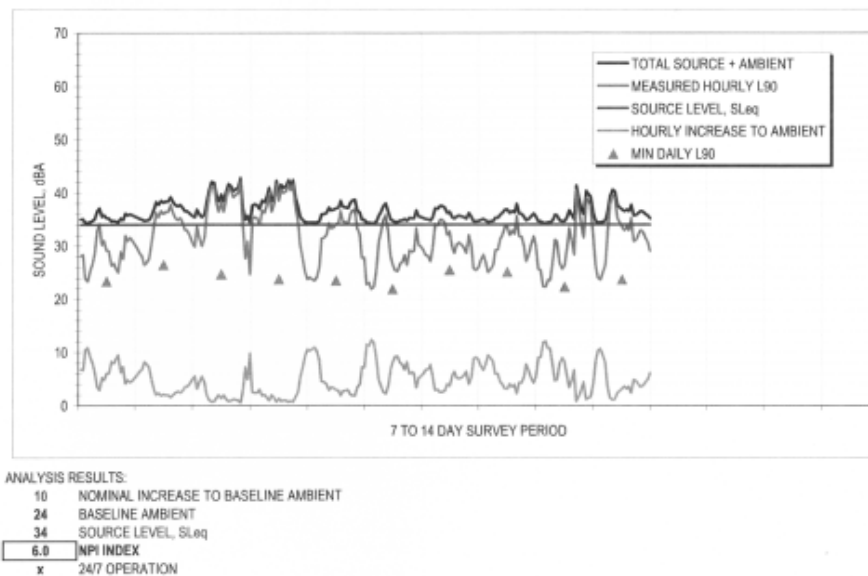
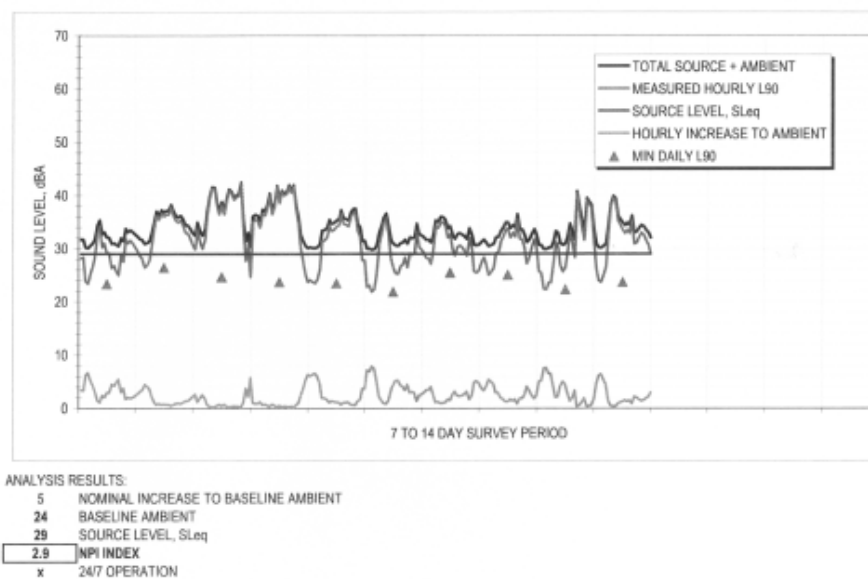


Figure 6: NPI summary plot for the same environment as Figures 4 and 5 but with reduced night-time operating time for SLeq



Figures 7 and 8: Examples of NPI index applications in a very quiet residential area. Upper plot with 5 dBA increase and lower plot with 10 dBA increase

respectively, if the source level did not operate on weekends.

Similarly, the index would drop significantly, i.e. perception would be lessened if the source did not operate during nighttime hours, especially in an environment dominated by traffic. The single-number ambient is still to be averaged over the entire sampling period. The example in Figure 6 shows the source level, SLeq nominally set to 10 dBA above the baseline LA90 ambient for an industrial source operating two shifts a day from 7 a.m. to 11 p.m., or a utility peaking generator that operates 16 hours per day, off at night.

The resulting NPI index is 1.4 dBA or imperceptible compared to 4.8 dBA computed above for 24/7 operation. This result is intuitive since the intruding noise is reduced or eliminated during the quiet period of the night. The NPI method provides a way of quantifying the improvement and predicting true community response for the actual planned operation. It remains to check the nominal 5 and 10 dBA impact points against a very quiet environment not exposed to traffic.

Figures 7 and 8 show a summary plot for each over an eight day sample. Note again that the minimum daily hourly LA90 varied by 4 dBA from 22 to 26 dBA over the eight day wintertime sample at this quiet site.

The computed NPI index is 2.9 and 6.0 dBA for the 5 and 10 dBA nominal increase inputs that corresponds acceptably in Table 2 for the community perception and response experienced in the three states.

Conclusions

A simple but thorough noise assessment methodology termed “Noise Perception Index” has been developed based on decades of experience in 3 states that use the principles and perception thresholds of the developed method.

We believe the defined index approach offers a fair and comprehensive assessment for assessing industrial and power plant noise, and an accurate predictor of long range community response to the planned source.

For references see page 36

