Noise Allocation for Industrial Plant Acoustic Design

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Abstract: - Due to industrial plant customer’s awareness and legislator’s attention about aspects connected with environmental noise, engineering companies developing new settlements are often required to accurately design sound reduction measures from the time when the project development begins, or even before, during its proposal. The outdated method to deal with industrial plant noise control during the equipment procurement or, worst, during construction, by means of retrofitting, is going to be left as it leads to poor acoustic performance and high costs. Besides, especially for plant engineering purposes from the authorization point of view, the environmental noise limitations to be respected is also set in terms of maximum allowed sound power level. This vision represents the state of art approach to industrial plants design; it requires the plant constructor to supply low noise equipment and noise reduction systems at source in order to comply with the goal. Presently noise predictions using sound pressure levels are more prevalent in industry than those provided by means of the more flexible to use sound power levels, due to lack of manufacturers data and because plant customers and equipment suppliers usually deal with pressure levels, easier to measure.

Key-Words: - Industrial, equipment, piping, valve noise; noise control design; noise allocation, open plant sound power level

1 Introduction
Noise allocation and assessment have become important design parameters for new industrial plants. Studies, mainly carried out by oil companies since at least three decades, have demonstrated that noise control in the design stage is more effective and less costly than postponing till a contingent problem or a complaint arises and then retrofitting noise control measures [1] [3]. Therefore engineering companies are now more and more frequently request that the acoustical project relevant is to industrial plants, to be developed at earlier stages, starting from the allowable maximum sound power level related to the whole plant. The use of suitable noise modelling procedures [8] is fundamental to accomplish the industrial plant acoustic design task. To predict environmental acoustical impact, here is highlighted in which way, starting from the plant sound power level, it is possible to verify the noise limits values established by the Authorities, generally expressed in terms of sound pressure levels. Vice versa, starting from single receiving point or contour averaged sound pressure levels, it is possible to go back at the total sound power level due to all sources generating the sound field [11].

2 Setting Noise Limits
In order to plan a noise reduction program for new industrial plants, it is necessary to establish noise limits to comply with. There are as many noise limits, according to as many criteria, distinct on application areas, exposed or interested subjects, type of noise source besides the enforcing subject, mainly the authority and the customer.

Used noise limits to design industrial plants are generally expressed as sound pressure level and apply to the followings:
- equipment, to limit workers exposure or identify restricted areas, where noise reduction is not reasonably practicable and ear protection must be worn;
- emergency devices, such as alarms or safety discharges;
- background noise inside occupied buildings, in terms of Noise Rating (NR) or Noise Criteria (NC) curves, to ensure no interference with work, communication and concentration;
- property fence, surrounding area and receiving points, to respect environment and community.

Based on the above-mentioned noise limits and following a preliminary noise impact study, which
takes into account their superimposed effect, further noise limits in terms of sound power level can be defined for the whole plant, for its production areas or for single systems, units, or equipment, according to specific needs and criticality.

Fig.1 – Noise Limits application fields.

The estimation of the “target” values includes the evaluation of adequate tolerances, according to previous experience and by considering dedicated studies carried out by other [2] [13] [15]. The allowed maximum sound power levels are then evaluated through noise simulation models; for example, suitable formulas for preliminary noise estimations are the ones given in International Standards ISO 8297 [18] and ISO 9613-2 [19].

The standard ISO 8297 allows the definition of the sound power level for complex industrial noise sources for many different purposes, including the check of the compliance with environmental noise requirements [16]. The basic formula, formerly proposed by Stüber and below shown, is particularly helpful when noise limits to be respected are applied at property fence or, in general, along a boundary enclosing the considered sound sources and not so far from them:

\[ L_W = L_p + 10 \log (2S_m + hl) + 0.5 \alpha \sqrt{S_m} \]  

(1)

where:
- \( L_p \) is the average sound pressure level along a given iso-level or enveloping contour,
- \( S_m \) is the delimited area,
- \( h \) is the receiver height above the ground,
- \( l \) is the contour perimeter,
- \( \alpha \) is the air absorption coefficient.

Fig. 2 – Conversion of sound pressure level limit into sound power level limit by means the application of ISO 8297 formulas.

The formulas included in the standard ISO 9613-2, on the other hand, allows carrying out more detailed acoustic study, for industrial design purposes [12], with single or grouped sound sources, provided that the receiving point is located in the far field. It is possible, then, to further detail, or aggregate, the calculation, according to the specific exigencies, obtaining more accurate results. The basic equations to be used are:

\[ L_pA = L_wA + D - A \]  

(2)

where:
- \( L_pA \): sound pressure level (in dB(A)), at receiving point P from noise source,
- \( L_wA \): sound power level (in dB(A)), relevant to noise source,
- \( D \): noise source Directivity Index (in dB),
- \( A \): excess attenuation (in dB), during sound propagation from source \( W \) to receiver point \( P \).
Fig. 3 – Conversion of sound pressure level limit into sound power level limit by means the application of ISO 9613-2 formulas.

The excess attenuation term $A$ is generally expressed by the following formula:

$$ A = A_{\text{div}} + A_{\text{atm}} + A_{\text{gr}} + A_{\text{bar}} + A_{\text{misc}} $$

where:
- $A_{\text{div}}$: wave divergence attenuation,
- $A_{\text{atm}}$: atmospheric absorption,
- $A_{\text{gr}}$: ground attenuation,
- $A_{\text{bar}}$: screen attenuation,
- $A_{\text{misc}}$: other effects (described in ISO 9613-2 standard annex).

The overall A-weighted sound level in every receiving point is obtained by summing up all acoustic contributions relevant to all sound sources, according to the following equation:

$$ L_{P}(A) = 10 \log \left( \sum_{i=1}^{n} 10^{0.1(L_p-i)} \right) $$

where:
- $L_{P}(A)$: overall A-weighted sound level
- $i, n$: noise sources index and number

As already stated, by means the above described calculation methods, it is possible to derive the sound power level to be allocated for each single equivalent point source (machine, equipment, package, working area, even the whole plant), depending on the ambient in-plant or environmental noise limits, on sound sources geometrical distribution, on directivity effects and on excess acoustic attenuation other than the wave divergence. For the subsequent acoustic detailed industrial plant design purposes, sound power levels are handier than sound pressure levels, due to their invariability with surrounding space. The established sound power level limits and the noise allocation allow checking acoustic plant conformity and carrying intervention adjustments during each design stages.

3 Noise Allocation

To develop the noise allocation, it is required the design documentation including plant layouts, equipment list, installed electric power list, equipment manufacturers noise information, along with detailed data on the surrounding environment, extended up to the points where the noise limits apply. Working on these data, the assessment study and the acoustic planning can be worked out through three steps, evaluation, design and check. The first preliminary acoustic analysis is essentially meant to define whether the project is feasible or not from acoustic point of view and which are the related impacts and the risks to be considered, if any.

Fig. 4 – Typical Polyethylene plant layout.

The following noise allocation study is used to set the acoustic requirements for both the equipment suppliers and the construction company; meanwhile,
the noise control design progress and effectiveness are monitored, by updating the information during the engineering development.

3.1 In-plant and environmental noise assessment without mitigation systems

The core for carrying out the acoustic study is represented by the sound sources acoustic data relevant to equipment, piping, building and other. Generally sound power level spectra are not always available, even if vendors are requested to provide them by means of measurement [4] [5], calculation or similar. For this reason the initial evaluation is made using equipment noise data taken from historical database, international standards and directives, or by applying theoretic or practice formulas to the available working parameters [7].

The plant acoustic situation without noise reduction systems, that is assuming standard construction equipment only, is then assessed considering the sources grouped by productive sections, so that the critical areas are evident at once, both in terms of location and of noise limits exceeding. The analysis results are represented in noise maps and summarised in a table (see Table 1.).

<table>
<thead>
<tr>
<th>Plant Area</th>
<th>Sound Proofing System*</th>
<th>L_w before dB(A)</th>
<th>L_w after dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop reactors</td>
<td>LN, NH, EB</td>
<td>105</td>
<td>103</td>
</tr>
<tr>
<td>Gas phase reactors</td>
<td>NH</td>
<td>115</td>
<td>107</td>
</tr>
<tr>
<td>Recoveries</td>
<td>NH</td>
<td>110</td>
<td>103</td>
</tr>
<tr>
<td>Purification</td>
<td>NH</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>Ethylene compressors</td>
<td>EB</td>
<td>112</td>
<td>106</td>
</tr>
<tr>
<td>Utility</td>
<td>LN</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pelletising</td>
<td>WAI, DS</td>
<td>109</td>
<td>100</td>
</tr>
<tr>
<td>Powder bins</td>
<td>PAI, DS</td>
<td>122</td>
<td>113</td>
</tr>
<tr>
<td>Blending</td>
<td>PAI, DS</td>
<td>119</td>
<td>110</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>125</td>
<td>117</td>
</tr>
</tbody>
</table>

* LN = equipment Low Noise type, NH = equipment with Noise Hood, EB = equipment Enclosing in Building, WAI = building Walls Acoustic Improvement, PAI = Piping Acoustic Insulation, DS = Duct Silencers for blowers and HVAC

3.2 Noise abatement design

Sound proofing interventions on significant noise sources are foreseen in order not to exceed the overall plant sound power level [17] [21]), accordingly to layout, process, operability, maintenance and safety need. The preferred solution is to reduce noise emissions at source, by means the following intervention:
- for rotating equipment, by supplying low noise type items (eventually designed after ISO guide lines [20]), by noise hooding (to be avoided for machinery handling flammable substances) or, lastly, by enclosing in buildings;
- for valves, by providing them with low noise devices and by installing proper in-line silencers at downstream flange;
- for static equipment and piping, by coating them with sound deadening materials and by inserting at inlet and outlet flanges rubber joint for pumps or duct silencers for fans, compressors and blowers;
- for vents, by installing adequate atmospheric silencers;
- for buildings containing noisy equipment, by improving sound insulation of walls, external doors, windows, air intakes and exhaust; taking into account ventilation, safety, maintenance and cleaning requirements;
- for Heating, Ventilation, Air Conditioning systems (HVAC), by providing low noise type fans and by duct silencing.

To be effective, all mentioned soundproofing systems has to be adopted provided that structure borne noise transmission is avoided or reduced, by means of rotating machines proper balancing, equipment supports, frames, skids and basements stiffening or damping, anti-vibrating joints and washers installation and similar shrewdness or devices.

Where not possible to act on the noise sources, suitable acoustic screens can be installed near them, after proper analysis and evaluation of the safety aspects.

Besides technical aspects, the economic impact of noise reduction plan on plant cost should be considered. As result, one obtains the noise allocation with sound proofing systems (as shown in Table 1.).

4 Conclusion

According to the proposed paper, the compliance with sound pressure levels fixed by the Authorities can be obtained, with best and adequate accuracy, by transforming them in sound power level values. Moreover, sound power levels are influenced neither by other noise sources nor by environmental conditions therefore, starting from the sound power emitted from the whole plant, one is in a position to know the sound pressure distribution throughout.
This work has tentatively looked up trace out a guideline to face the subject matter.

References: