SINGLE SOURCE SOUND POWER LEVELS DETERMINATION FROM COMPLEX NOISE SOURCE MEASURED DATA

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ABSTRACT

This paper describes the determination of the sound power level of a multi sources object from a set of field measurements around it. The object under analysis, an auxiliary boiler package, includes different noisy components: equipment, machinery, piping, and valves, which are physically distinguished, but, from industrial point of view, are considered as a single independent assembly. For this reason, manufacturers supply complete packages of this type and are quite common in industrial plants. The applied methodology has been possible thanks to a commercial noise modelling software which includes such a tool. The results of the study will be used for future modelling activities, due to the standard size of the investigated industrial component.

Keywords: *Sound Source Modelling, Sound Source Measurements, Auxiliary Boiler Noise*

1. INTRODUCTION

Sound source characterization is always a fundamental activity for several application in acoustics, for example to design mitigation measures as well as to model the expected sound levels, both outdoors and indoors, at receiver points without limited measurements. These are only two of the various possibility offered by a sound source software representation, i.e., a non-physical copy of an existing sound source.

As a matter of fact, acousticians build sound source models from measured data to carry out works or develop studies, by applying recognised standards, guidelines or procedures resulting from know-how and experience.

Generally, when modelling an acoustic scenario, for best calculation fitting purposes in the relatively near field[1], the tendency is to represent as much as possible separate sound sources, with directivity features if any, and significant propagation obstacles, without exceeding in unnecessary physical details to improve the sound field definition. Therefore, the creation of individual digital sound sources is fundamental for this scope. For single industrial sources installed outdoors, like for example an equipment, a valve or a pipe, the determination of acoustic emission parameters is rather simple and standard methods may be applied, provided that the measurement environment is not much affected by background noise [1].

On the other hand, when the acoustic scenario to be modelled is extended far from the whole set of industrial sound sources, an equivalent "combined" sound source, either concentrated in a single point or distributed over the horizontal enveloping area, may be used, according to item 4 of ISO 9613-2 [2]. In this case, it is possible to describe such an equivalent sound source with emission parameters obtained from a set of experimental data measured at a specified distance around the area containing the group of the industrial sources. Details on this methodology are given in ISO 8297 [3].

Another possible approach to estimate the emission of

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[1] By near field here we mean the acoustic field not influenced by sound sources other than those under examination, nor by sound shielding or reflections from relevant equipment casing nearby.

individual sound sources from a measurement dataset collected in the vicinity of a group of them may be the application of Least Squares method. This procedure, applicable when the number of measurement points is equal or higher than the number of unknown sound sources, has been implemented in commercial software SoundPLAN®, since version 7.4 issued in 2015 [4]. The purpose of present paper is to investigate the possibility to determine the acoustic emission of single sources, part of an industrial auxiliary boiler packaged supply, from measured data around it, by means of such SoundPLAN® tool.

2. BACKGROUND

Least Squares method is a standard approach to approximately solve equations systems in which there are more equations than unknowns by minimizing the sum of the squared residuals in the results of each equation.
This method is widely used for data fitting problems allowing to apply regression analysis to balance as much as possible the data sets; an example is the Chemical Mass Balance (CMB) air quality model developed initially by Friedlander [5], then further upgraded, and freely available with US Environmental Protection Agency (EPA) website.
The determination of the sound power level of M unknown sources from the sound pressure level measured in N receiver points, all connected by N*M attenuations related to propagation paths, is one of the cases that can be solved by Least Squares methods. Referred examples are the technique described by Lu and Hong [6], then applied by Chandha in workshops [7], both directed to investigate workplaces where many noise sources are operating.
For completeness, application of inverse methods to obtain the acoustic power of noise sources in factories are the works published by Luzzato and Lecointre [8], Guasch et al. [9] and Cirac et al. [10].
Once implemented, SoundPLAN® tool to calculate the sound power level of unknown sources from measured data has been first tested by software developers and distributors on individual running equipment, subsequently endorsed by software's users, as no issues have been recorded yet.

3. METHODOLOGY

During a recent noise survey, measurements around an industrial auxiliary boiler package supply have been carried out to assess its total sound power level by applying the ISO 8297 methodology.
The auxiliary boiler has a capacity of 100 t/h steam and the envelope dimensions are approximately 14 m by 18 m, and 8 m height, with a 25 m height stack on west side of the package footprint, as shown in Figure 1 3D views.

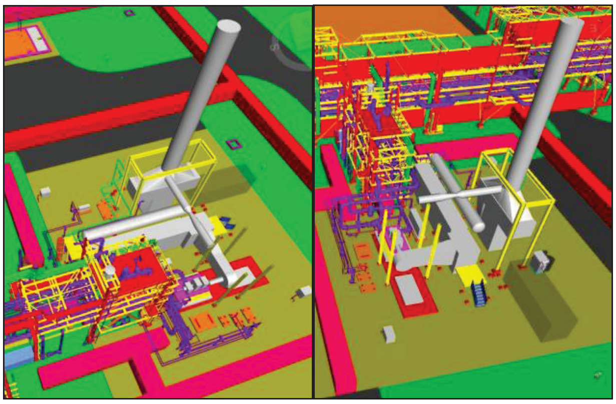

Figure 1. 3D model views of the aux boiler package.

3.1 Measured sound pressure levels

To apply standard ISO 8297, measurements along a contour path enclosing the group of sound sources of the auxiliary boiler package as shown in Figure 2 was carried out. The collected overall sound pressure levels are reported in Table 4 under para 3.3.

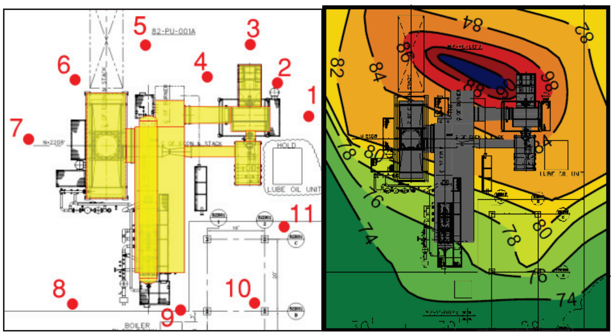

Figure 2. Auxiliary boiler package with casings, measurement points and contoured noise map.

3.2 Auxiliary boiler sound power level (ISO 8297)

The standard ISO 8297 allows the calculation of the sound power level for complex industrial noise sources for many different purposes, including the check of the compliance with environmental noise requirements [11]. The formula, formerly proposed by Stüber, is shown in equation (1):

$$L_W = L_p + 10Log(2S_m + hl) + Log\left(\frac{\bar{d}}{4\sqrt{(S_p)}}\right) + 0.5\alpha\sqrt{(S_m)} \quad (1)$$

where:

L_w is the total sound power level of enclosed noise sources,
L_p is the logarithmic (energetic) average sound pressure level along the measurement contour,
S_m is the area delimited by measurement points,
h is the receiver height above the ground,
l is the contour perimeter,
$\bar{d}$ is the average measurement distance from sources,
S_p is the multisource plant area,
α is the air absorption coefficient.

The application of formula (1) is shown in below Table 1, where overall (OVR (A)) and octave band averaged L_p and calculated L_W are reported, for $S_m = 410$ m^2, h = 1.5 m, l = 78 m, $\bar{d} = 3.9$ m and $S_p = 144$ m^2. The contribution for air absorption is negligible, due the short distances.

Table 1. Auxiliary boiler package sound power level calculated with ISO 8297 formula.

	OVR (A)	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz
L_p	87	89	82	84	77	73	78	84	76
L_W	115	116	109	111	104	100	106	112	103

3.3 Determination of single source sound power levels

The main noise sources of this multisource item are a forced draft fan of 670 kW, 1780 RPM, its outdoor air inlet, a natural draft burner with annexed combustion chamber, a superheater, an economizer and a steam drum, as listed in Table 2. The body and the outlet of flue gas stack are not considered as noise sources since the sound waves have already lost their energy through previous equipment, further they are located at higher elevation than the measurements and the calculation points. The acoustic modelling of above package components has been carried out by means of point sources for relatively small items, line sources for long items, area sources for large items and vertical barriers to model the screening effect by large equipment casings, to avoid unrealistic sound contribution on calculation points. The selection of noise sources to be modelled was based on experiences from present and previous field investigations and further adjustments have been applied for best fitting of results. For the application of SoundPLAN® tool, the noise measured values have been inputted as known data at receiver points of Figure 2, then the calculation of source emission from measurement points function was activated and the results are reported in Table 2. The total sound power level of the complete auxiliary boiler package is the obtained by summing up the noise emission of noise sources listed in Table 2 and is reported in Table 3.

Table 2. Auxiliary boiler package noise sources.

Name	Description	Type	L_W(A)
B101A	Boiler Radiant Section	Area	99
B101A-B	Boiler natural draft burner	Point	111
D101A	Boiler steam drum	Line	99
E101A	Boiler economizer	Area	98
E104A	Forced draft fan air inlet	Point	105
K101A	Forced draft fan	Point	103
KM101A	Forced draft fan motor	Point	95

Table 3. Auxiliary boiler sound power level from the sound sources obtained with SoundPLAN® tool.

	OVR (A)	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz
L_W	113	118	115	110	104	96	106	109	102

From the noise source set of Table 2, a further noise map, here reported in Figure 3, and the sound pressure levels at measurement points, shown in Table 4, have been calculated.

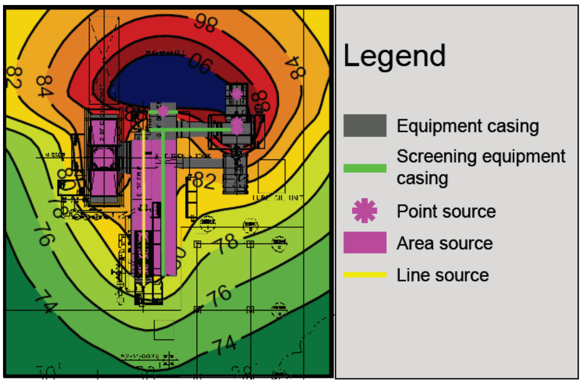

Figure 3. Boiler package noise map calculated with sound sources derived from SoundPLAN® tool.

Table 4. Boiler sound levels Lp(A) measured (M) and calculated (C) from the sound sources obtained with SoundPLAN® tool at measurement points.

point	1	2	3	4	5	6	7	8	9	10	11
M	83.6	86.8	86.5	93.8	91.4	84.2	82.0	73.8	75.9	78.9	81.9
C	82.6	87.8	87.7	93.8	91.3	86.9	77.2	75.2	77.1	75.3	77.8

4. DISCUSSION

Looking at Table 1 and Table **3**, the sound power level of the boiler package calculated with ISO 8297 formula is 2 dB higher than the resulting one from the sum of single components obtained with the SoundPLAN® tool, even though the difference between the relevant logarithmic average sound pressure levels is less than 0.5 dB. The reason of such difference is not clear but, at a glance, it appears to be related to the definition of the "measurement surface" to be used in the formula. A comprehensive investigation on this point and the combination with other factors shall be analysed separately in future research developments.

The comparison between the measured sound pressure levels and those modelled both at measuring points (Table 4) and as noise contour lines (Figure 2-Figure **3**) shows that the software tool is working better for small sources with limited screening or reflecting surfaces nearby, since the least gaps are close to noisiest sources, i.e. points 1 to 5, influenced by the burner and the forced fan with its air inlet.

Nevertheless, this inverse method looks to be more viable than the use of ISO 3744 or intensimetry, for the complex configuration of such multi source boiler package: indeed, both above techniques cannot be applied for sound sources shaped with protrusions and recesses.

Perhaps, a more detailed acoustic model with volume[2] sources would improve the accuracy of the results obtained by applying the SoundPLAN® tool, but this surely increase the number of required measurement points.

The experience here described has demonstrate that to apply the software tool it is fundamental a proper planning of measurement points in function of the multisource to be studied. Actually, the points here utilized was formerly chosen for the determination of the total boiler package sound power level by means of ISO 8297, not for the application of the software tool. There had been additional measurement points inside the package envelope, the single sources sound power level would have been more accurate.

Finally, two options are available for the acoustic modelling of multisource items to apply the software tool: the use of volume sources, or by means point and other basic sources and screens, this latter may require less measurements.

5. CONCLUSION

Inverse methods are more practical than ISO 3744 or intensimetry for multi component sound sources, shaped with protrusions and recesses. Integrated software tool for calculating sound power levels from measured data is useful for complex multisource noise characterization, provided the data set is consistent. Future investigations on the accuracy and precision of attainable results will follow, to define applicability conditions and limits.

[2] A volume source is a box with area sources on side and upper surfaces and cannot by crossed by sound rays.

6. ACKNOWLEDGMENTS

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