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Prediction of Industrial Noise – an Advanced Methodology based on ISO 9613-2

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ABSTRACT

ISO 9613-2 is a widely used method to predict the noise from industrial and many other sources. There is a lot of experience with its application in cases where the distances are not extremely large and meteorological conditions are not the dominant influence. A lot of software strategies have been developed to support and improve this method. Examples are expert systems, that determine the source data like the frequency dependent sound power level from technical parameters for technical sources like motors, gears, fans or cooling towers. These and other modifications like the determination of result uncertainties are presented and discussed.

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1 INTRODUCTION

The basic element of a noise prediction for any facility is the calculation of the noise level produced by a point source in a given position relative to the receiver point. These calculations are carried out by using algorithms that are laid down in standards and guidelines. The rules how to calculate the noise caused by point sources and extended line- or area sources are laid down in national and international standards and implemented in software packages for noise prediction /1/.

For noise prediction of industrial sources the International Standard ISO 9613-2 is applied in most cases. It is based on the propagation calculation in octave bands, but can also be used with A-weighted levels if no spectral data are available. The method is simple but nevertheless detailed enough to allow the prediction for quite complex sources like power plants or extended factories.

A general problem is to decide about the emission values like sound power levels of all these sources because these are input data for the calculation of sound pressure levels at receiver positions. In some cases these emission data are declared by the manufacturers, but in many cases they must be taken from technical literature or even be estimated using experience from similar cases. The software tool SET /2/ is an expert system that provides information about the sound emission of about 150 technical sources. It is a summary of the technical knowledge about noise generation in dependence of technical parameters and shortens the development of such virtual models of industrial facilities.

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2 EMISSION OF INDUSTRIAL SOURCES FROM TECHNICAL PARAMETERS

The calculation of the noise produced by industrial facilities is one of the most important applications of noise prediction software. If a 3D-model of a production plant has been developed, it is easy to take into account environmental aspects in all further modifications or extensions in the planning phase. The 3D noise model makes it an easy job to decide how the noise impact in a neighbouring flat will change if a new cooling tower or any other device will be installed.

With the special additional option SET (Sound Emission and Transmission) for the noise prediction program CadnaA it is possible to determine the sound power spectra of technical devices from the technical parameters.

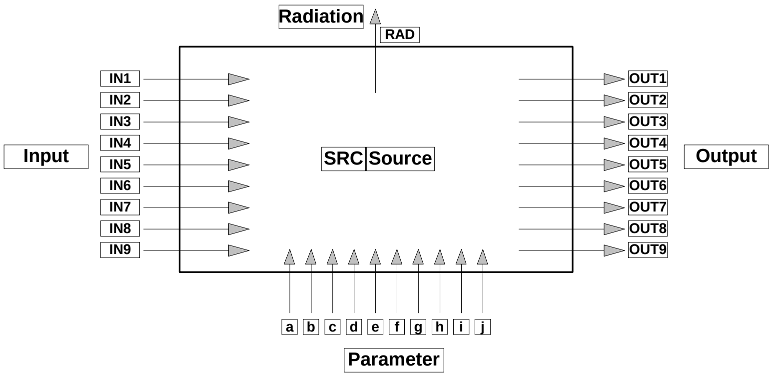

Figure 2: The software module SET

Figure 2 shows the principle of the software module SET. Based on this module about 150 technical sources have been implemented and the user is able to use this structure to create his own models of complex technical sources. The module has 9 ports to import and to export spectra, 10 ports to import parameter values and one port to connect it with a source in the 3D-model – this is the spectrum radiated from the source. Inputs and outputs can be connected to other modules. The source is a program that calculates the spectrum from the parameters.

This structure allows to simulate any complex system, where the sound power is generated, partly radiated and partly transmitted to other parts of the facility. An example is the cooling tower, where noise is generated by the fan, motor and gear driving it and by the falling water drops.

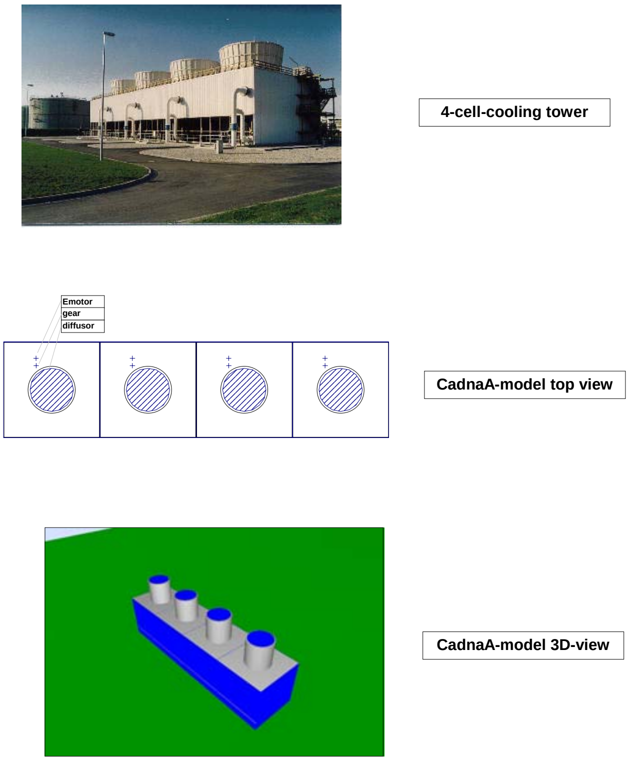

Figure 3: Modelling a cooling tower with the different radiating parts

Another example is the hose filter that is used in exhaust gas cleaning systems (figure 4)

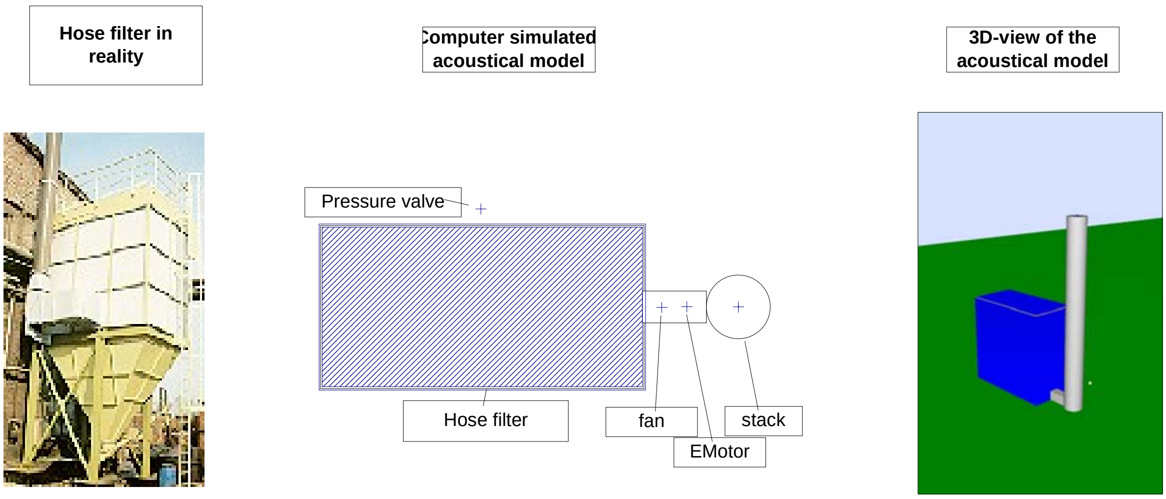

Figure 4: Detailed modelling of an exhaust gas cleaning with a hose filter

The emission of fan, motor, stack and even the filter casing are automatically calculated from the relevant parameters like electrical power or flow volume per minute.

3 SPECIAL OBJECTS TO MODEL INDUSTRIAL FACILITIES

ISO 9613-2 describes how to calculate reflected and diffracted sound generally, but gives nearly no support to include more complex elements like cylindrical chimneys or partially reflecting and transmitting objects.

A cylinder can act as a reflector, but ISO 9613-2 gives no procedure that allows the calculation of reflected sound at cylinders for all possible positions of source and receiver. As it is shown in figures 5 and 6, a sound ray is reflected according to the well known optical mirror image principle, but even parallel incident rays will show an angle after reflection depending on the curvature of the cylinder.

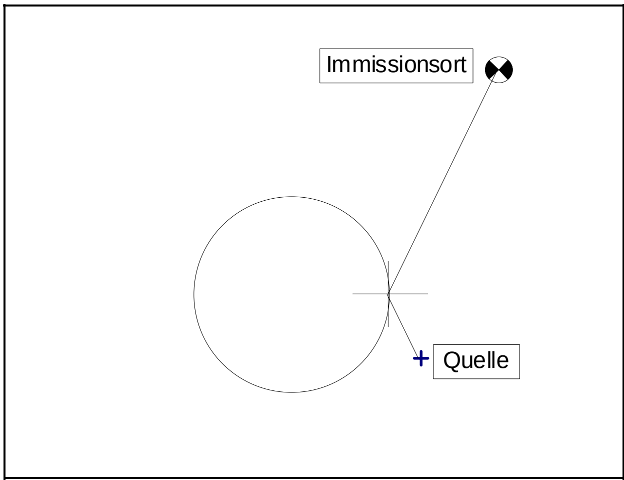

Figure 5: Reflection with equal angles for incident and reflected ray.

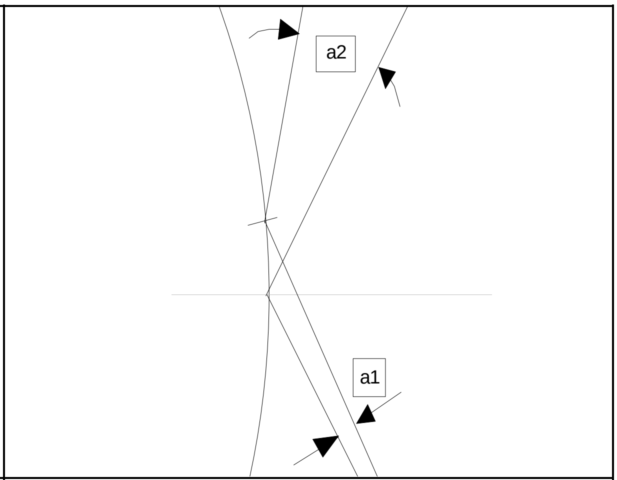

Figure 6: Additional attenuation by widening of the reflected ray.

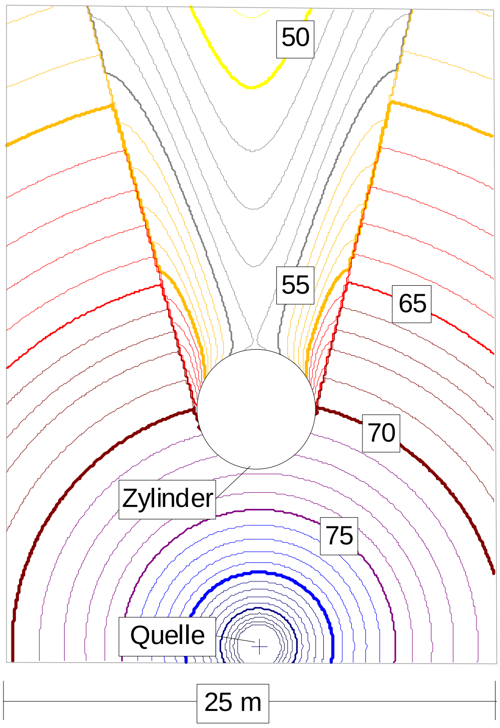

Figure 7: Screening without reflection.

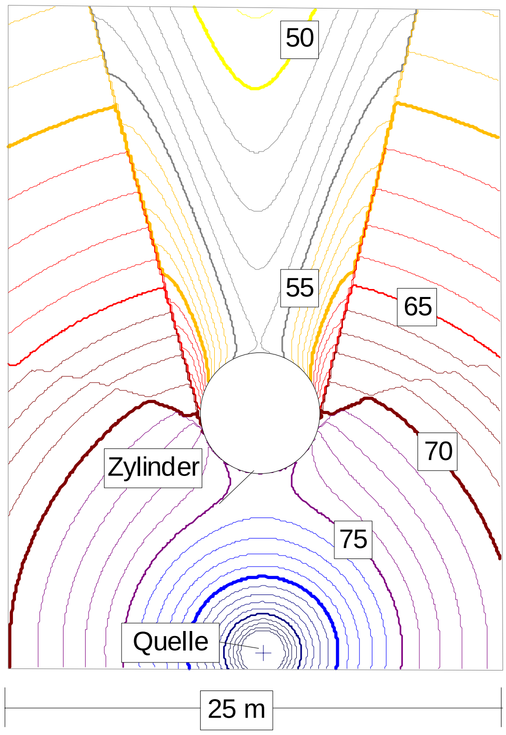

Figure 8: Screening and reflection

Algorithms have been developed to calculate the reflection at the source side of the cylinder by taking into account the additional attenuation caused by its curvature. At the backside attenuation by diffraction is included. This allows to include such a cylinder in models of any complexity even if noise maps are calculated.

In many industrial environments technical facilities like pipes, tanks or ovens form blocks like buildings that are partially reflecting, partially transmitting noise. Such an example is the arrangement of cylindrical tanks shown in figure 9.

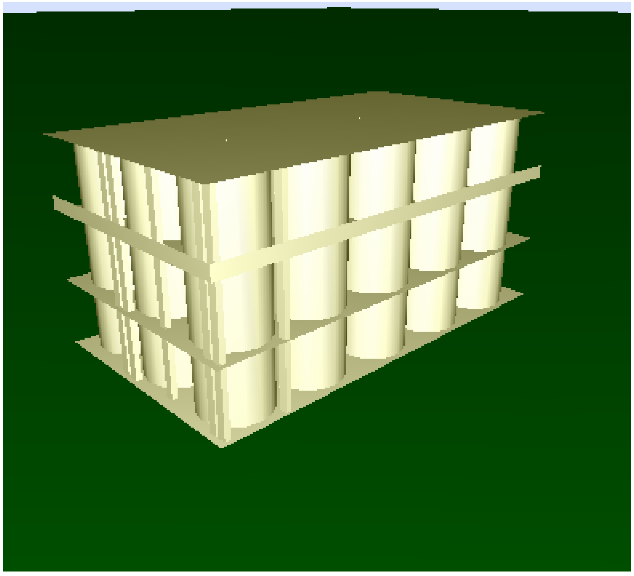

Figure 9: Layout of tanks where gaps allow transmission of sound

Such objects can be simulated by the object type "building" if the property "transmission" is used to define the portion of transmitted sound energy. Only the sound energy that is not transmitted directly is included in the screening calculation.

4 DETERMINATION OF UNCERTAINTIES

The emission values of sources are measured or taken from technical literature. The uncertainty of the emission value of the source n shall be characterized by a standard deviation σ_n . If L_n is the sound pressure level caused by this source at the receiver position the uncertainty of the level caused by all sources together is

$$\sigma = \frac{\sqrt{\sum \left(\sigma_n \cdot 10^{0.1 \cdot L_n}\right)^2}}{\sum 10^{0.1 \cdot L_n}}$$

This methodology published in /3/ has been implemented in the noise prediction software CadnaA. The sources are not only characterized by a sound power level L_W, but also by an uncertainty σ . Therefore not only the noise level L_i is calculated at a receiver i, but also the uncertainty of this value σ_i .

This enables the calculation of a level with a wanted confidence. A simple example with two sources in a distance of 100 m is shown in figures 10. Source 1 radiates with a sound power level 110 dB, that is characterized by an uncertainty σ of 4 dB. Source 2 radiates with 100 dB and the uncertainty of this value is 3 dB.

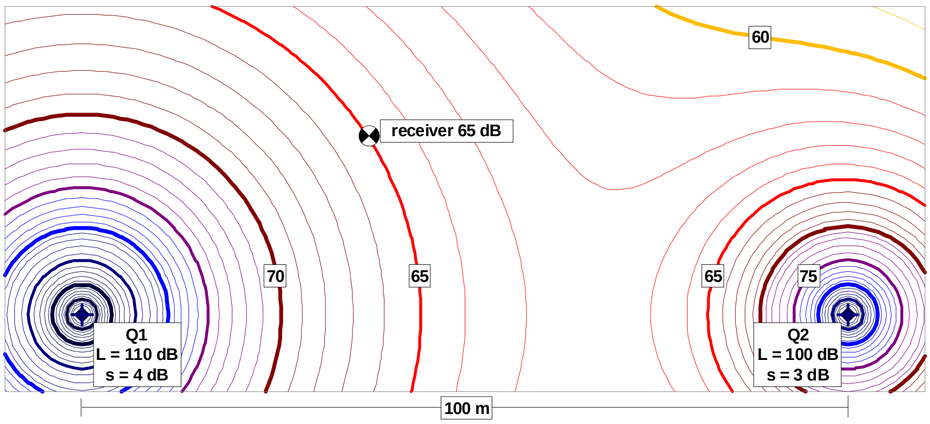

Figure 10: Noise map calculated with ISO 9613-2

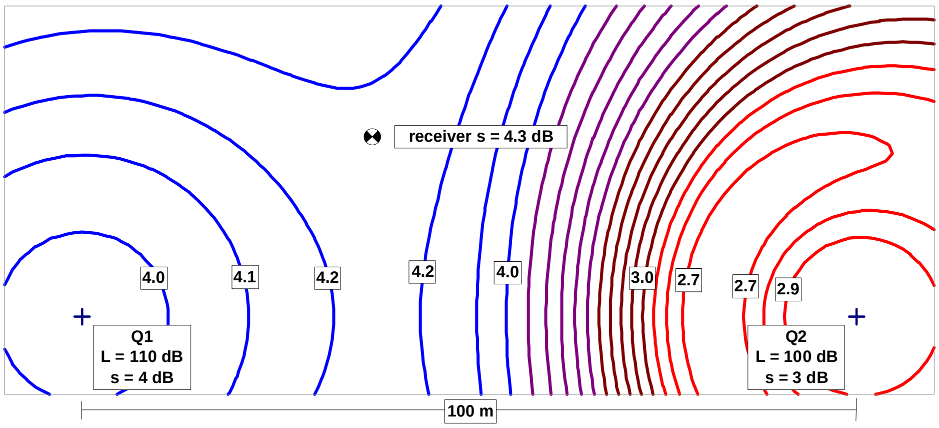

Figure 11: Total uncertainty of the predicted receiver level and it's spatial distribution

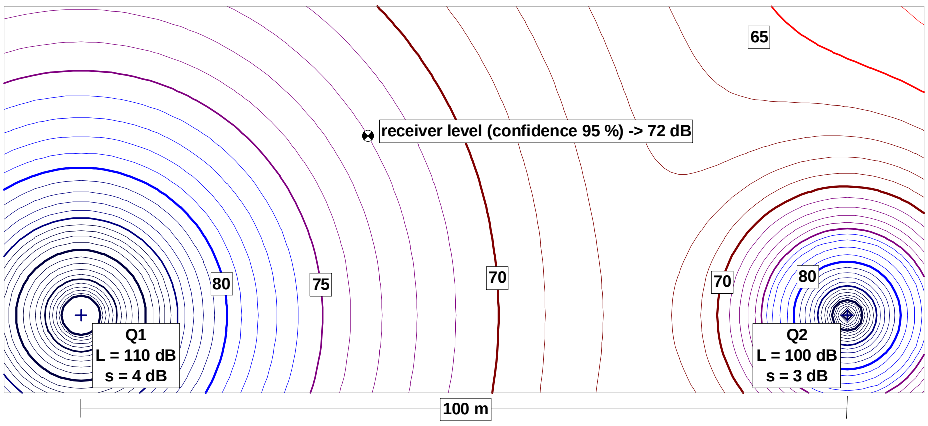

Figure 12: Map of noise levels not to be exceeded with confidence 95 %

Figure 10 shows the distribution of sound presented as noise map with lines of 1 dB spacing. Based on the abovementioned methodology /3/ for each grid point the uncertainty of the calculated level was determined and presented as "uncertainty map" figure 11. If the values of the map figure 11 are multiplied by 1,65 and added to the values of the map figure 10, the resulting noise map figure 12 shows the distribution of levels with a confidence of 95 %. Especially with industry noise where emission values must be derived from single measurements or even be estimated such considerations are extremely helpful in critical situations, where limiting values may be exceeded.

5 REFERENCES

1. DataKustik GmbH, ‘‘CadnaA – Software for Environmental Noise,’’ brochure published by DataKustik GmbH, www.datakustik.de
2. DataKustik GmbH, ‘‘SET – Sound Emission and Transmission’’ brochure published by DataKustik GmbH, www.datakustik.de
3. Probst, Wolfgang, ‘‘Uncertainties in the prediction of environmental noise’’, *Proceedings of the INCE Europe Symposium “Managing Uncertainty in Noise Measurement and Prediction”*, Le Mans (France), June 2005