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CHARACTERISATION OF THE ACOUSTIC POWER LEVEL OF A RANGE OF RECTANGULAR DIFFUSERS USING A REDUCED NUMBER OF TESTS

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ABSTRACT
Since the sound level requirements are increasingly strict, the characterisation of the acoustic performances of complete product ranges has become essential for the manufacturers. This is particularly true for ranges of air diffusion terminal units composed of a large number of different types and sizes and for which it would be prohibitively expensive to carry out exhaustive laboratory tests. CETIAT has studied the possibility of carrying out a reduced number of test in order to characterise a complete range of rectangular diffusers. The acoustic power level was measured on a grille model available in 7 different sizes, from 200x200 mm to 600x300 mm (4 flow rates for each one). Then, the regression relation was determined between the global dB(A) level and the air flow and the area of the grill. This relation gave an average error of 1 dB(A) with 82% of the deviations lower than 1.5 dB(A). The next step was to determine how many initial tests were necessary to determine the acoustic performances of the rest of the range with an acceptable error. The regression coefficients were calculated for all the possible combinations of 3 grilles (respectively 4), then the error committed on the other 4 grilles (respectively 3) was calculated. These results show that 3 different sizes are sufficient to establish the regression coefficients for a given type of grille. In addition, if the 3 grilles used in the test are chosen intelligently so as to cover the different sizes and shapes (section and ratio of dimensions), the deviations observed over the rest of the range were among the smallest.

1 - INTRODUCTION
As the sound-level regulatory requirements are evermore severe, it has become essential for the manufacturers to publish the acoustic performances for complete product ranges. The case of ranges of air diffusion terminal units is rather special because they include many sizes and different types, and exhaustive laboratory tests are prohibitively expensive to carry out. CETIAT has studied the possibility of carrying out a reduced number of tests so as to characterise an entire range of rectangular diffusers, with an acceptable accuracy [1].

2 - TEST CONFIGURATIONS
The test series concerned 7 rectangular diffusers with adjustable blades and whose sizes ranged from 200×200 to 600×300 mm. The blades (cf. Figure 1) were maintained in a horizontal position.
The tests were performed in accordance with ISO 5135 [2] by using a double reverberation room. The diffuser was installed in the dividing wall with the upstream room acting as a plenum (Figure 2). The volume of 200 m^3 ensured that the dynamic pressure is negligible relative to the static pressure. In conformity with ISO 5219 [3], a small straightener was positioned upstream of each diffuser ensuring a good air supply.
The acoustic tests were carried out at 4 air flows for each diffuser.
The commercial dimensions of the diffusers were (in mm):

- 200×200
- 300×300

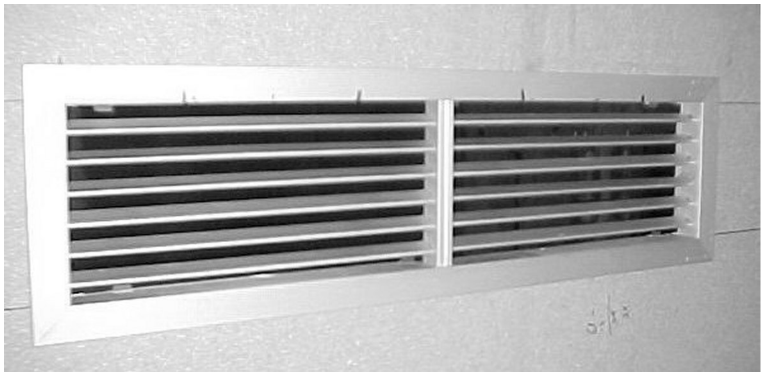

Figure 1: Photo of a diffuser (600×150 mm).

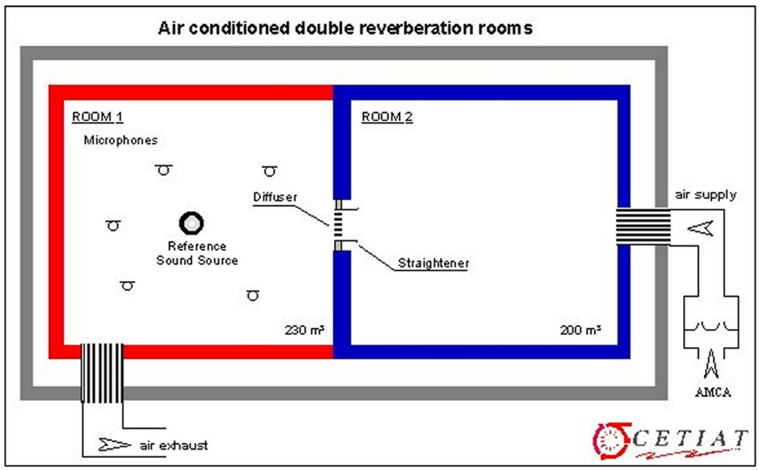

Figure 2: Diagram of the test assembly.

- 400×150
- 400×300
- 600×150
- 600×250
- 600×300

Only the 600 mm-long diffusers had a central upright.

3 - TEST RESULTS

The overall sound power level for each diffuser, expressed in dB(A) as a function of the air flow (m^3/h), are given in Figure 3. Classically, each curve behaves linearly as a function of the air flow logarithm. The curves are parallel, the variable parameter being the free area.

It can also be seen that for some diffusers, the measurement points are not perfectly aligned on straight lines. The first explanation comes from the electronic background noise generated by the acquisition system which perturbs the low level measurements in the high frequency range: the overall level is therefore slightly overestimated. The second explanation is the quite unusual spectrum generated by these diffusers, where the well defined peaks can be observed to move with the flow rate, as in the case of Strouhal frequency behaviour.

4 - REGRESSION FORMULA

It is known that there is a relationship between the sound level and the free area S. This value is estimated by measuring the open section, without taking into account the surface area of the blades. On the other hand, when there is a central uptight, its surface area is deducted from the section of the diffuser.

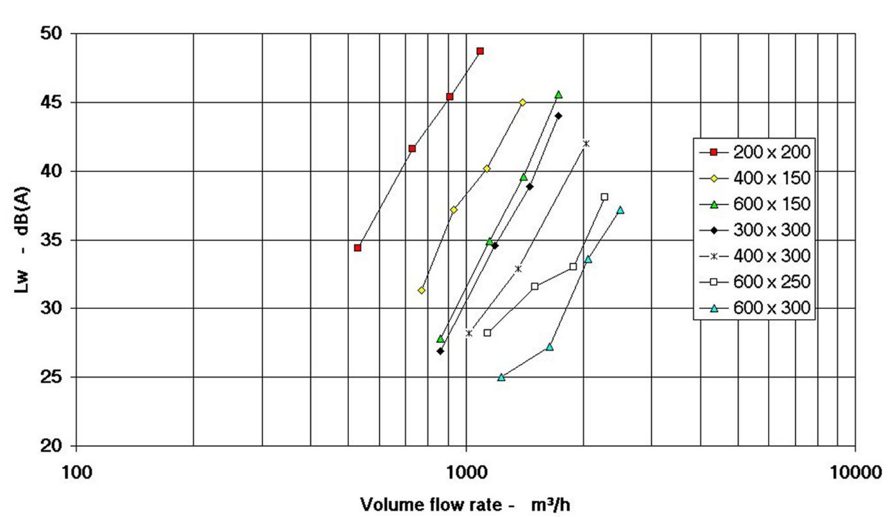

Figure 3: Sound power levels of the diffusers as a function of air flow rate.

The relationship connecting the sound power and the geometrical design of the diffuser at an air flow rate of Qv, for a given range of diffusers is:

$$L_w = aLogQ_v + bLogS + c \tag{1}$$

The coefficients *a*, *b* and *c* were determined from the test results, by minimising the error over all the measurement points. In the case studied, the following relationship was obtained:

$$L_w = 59.1LogQ_v - 49.6LogS - 204.6 \tag{2}$$

As would be expected, the sound level increases with the flow rate and decreases with the flow area. Note that the absolute value of the two weighted coefficients *a* and *b* is of the same order, which implies that the relevant parameter could be the velocity of the air passing through the diffuser. Unfortunately, this parameter is more difficult to measure.
The regression relationship (2) enables the measured values to be found with an absolute average error of 1.1 dB and a maximum error of 3.1 dB, which is reasonable taking into account the measurement difficulties described above.

5 - HOW MANY INITIAL TESTS?

The purpose of the study was also to estimate the minimum number of initial test which need to be carried out on a diffuser model in order to obtain an acceptable regression relationship. Based on the assumption that two tests would not be enough to determine the regression coefficients correctly we examined whether 3 or 4 tests would be sufficient.
The regression coefficients from equation (1) were calculated from the 35 possible combinations of 3 diffusers selected from the 7, and we observed the absolute maximum and average errors when the regression relationship was applied to the experimental results of the 4 remaining diffusers. In the case of the 3 diffusers, the absolute average of the average of the errors was 1.67 dB with a minimum error of 1.2 dB and a maximum error of 5.8 dB.
In the case where 4 diffusers were used as a base to calculate the regression coefficients, the absolute average of the average error was 1.62 dB with a minimum error of 0.9 dB and a maximum error of 5.3 dB.
It was observed that when more diffusers were used as the calculation base for the regression coefficients, the result was slightly better, but the pertinence of the result is weighted by the small population which was tested. Nevertheless, the average error incurred with only 3 diffusers can be considered as very acceptable.

6 - WHICH DIFFUSERS SHOULD BE CHOSEN?

Exhaustive calculations were performed considering all the combinations. In a real case, it would be logical to carefully select the geometrical design of the diffusers to be tested so that the range to be

characterised is represented as best as possible, by selecting extreme sizes and aspect ratios; for instance, the smallest and largest diffusers and the one with the largest length/height ratio.
In this study, the set of the three 200 ×200, 600 ×300 and 600 ×150 mm diffusers met these conditions. The error incurred by this particular combination is 1.4 dB with a maximum deviation of 3.30 dB, which is lower than the average mean values given above.
In the case of 4 diffusers, one possible choice would be the 200 ×200, 600 ×300, 600 ×150 and 400 ×300 mm diffusers. The error incurred by this particular combination is 1.54 dB with a maximum deviation of 3.11 dB, which is also lower than the average mean values given above.

7 - CONCLUSION

CETIAT has carried out a study which enabled the sound power level generated by the passage of air through a diffuser to be characterised for a complete product range, based on a reduced number of tests. The tests performed on 7 diffusers showed a relationship between the sound power level and the air flow-rate logarithm and the free area logarithm. For a given product range of the same nature, the test results can be used to determine a regression relationship between these three parameters.
Calculations have shown that 3 diffusers are sufficient to establish a regression relationship which can be applied to the entire range requiring characterisation. The improvement gained by using 4 diffusers does not really justify carrying out an extra test.
Choosing diffusers from among the extreme geometric designs, in section and sectional area ratio, gave better than average results.

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