SCALE-MODEL EVALUATION OF THE EFFECTIVENESS OF NOVEL ABSORBER TREATMENTS FOR INDUSTRIAL NOISE CONTROL

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1. Introduction

Sound fields in industrial buildings are often controlled by the installation of arrays of baffles suspended from the building roof. The performance of baffle arrays covering the complete ceiling area has recently been evaluated using scale-modeling and ray-tracing techniques [1]. It is clear that such baffle arrays can reduce steady-state sound pressure levels and reverberation times (RT) significantly. Unfortunately, the treatments are also often expensive, since large areas of ceiling are covered. Furthermore, the effectiveness may be reduced by the fact that the ceiling baffles are located a long way from sources and receivers on the floor. This report summarizes the results of further scale-model tests aimed at evaluating novel local-absorber treatments, which are less extensive and expensive and, thus, potentially more cost-effective than traditional treatments.

2. Scale model

The 1:8 scale model of an idealized typical industrial workroom was built. It had a length of 30 mFS (FS = full-scale equivalent value), a width of 15 mFS and variable height (5 or 10 mFS). The floor of the model was made of painted concrete. Its walls were made of varnished 12 mm plywood. Its flat roof was of varnished 3 mm plywood. The average absorption coefficient of these surfaces was about 0.06 at all test frequencies, values typical of real factories at all but the lowest frequencies. The model was fitted with 12, 2mFS-cube varnished wooden boxes located randomly over the floor area.

3. Measurements made

Measurements were made of sound decay / RT and of sound propagation (SP - the variation with distance of the difference between the sound pressure level and the source sound power level) in third-octave bands from 800-20000 Hz (100-2500 HzFS). The sound source was a 75-mm-diameter tweeter loudspeaker. A rigid cone narrowing from 75 mm to 3 mm was attached to the tweeter. This resulted in a compact source which was omnidirectional even at the highest test frequencies. Its constant output sound power was measured in an anechoic chamber. A B+K 4135 1/4" microphone was used as the receiver. In each test, sound decays were measured at 4 source/receiver positions and the results averaged. For SP testing the source was located 5 mFS from one end wall, at half width and at a height of 1 mFS. The receiver was at half width and at a height of 1.5 mFS; sound pressure levels were measured at source/receiver distances of 1, 2, 5, 10, 15, 20, 25 mFS. Octave-band SP levels were derived from the third-octave results. Measurements were made using a Nortronics 830 real-time analyser. Air absorption was not scaled and was, therefore, excessive at higher frequencies.

4. Treatment test configurations

Test absorbent treatments were made from 6-mm-thick glass fibre. The diffuse-field absorption coefficient of a large sample of the material located against a hard backing was measured to vary from 0.27-0.78 over the test frequency range. The following configurations were tested:

a. Variable-height baffles - roof heights of 5 / 10 mFS; full-coverage baffle array suspended from the roof at various heights. The aim was to see if full-coverage baffle arrays are more effective if suspended closer to sources and receivers on the floor;

b. Ceiling baffles vs wall absorption - roof heights of 5 / 10 mFS; no absorption / full-height, full-coverage baffle array (168 mFS^2 of absorbent material) / absorbent material fully-covering the side walls (300 and 600 mFS^2 of absorbent material) / both ceiling baffles and wall absorption. The aim was to see if wall or ceiling absorption is most effective;

c. Full vs partial wall coverage - 10 mFS roof height; with / without full-coverage ceiling baffles; with full- / partial- (50% - in a checkerboard pattern) coverage wall absorption. The aim was to see if absorbent patches are particularly cost-effective;

d. Partial-coverage ceiling baffles - 10 mFS roof height; full-height ceiling baffles extending full width but covering only 50 / 75 / 100% of the ceiling, starting at the source end. The aim was to see if, in the case of sources located at one end of a workroom, not applying ceiling treatments at the other end is cost effective;

e. Flat local suspended absorbers - 10 mFS roof height; as shown in Figure 1, flat, square absorbers, with / without rigid backing, with dimension 2 / 3 / 4 mFS and heights of 2 / 3 / 4 mFS located directly above the source. In some tests 1-mFS-high sound-reflecting barriers were located around and 1-mFS away from the source in an attempt to reflect sound into the absorbent material, making it more effective;

f. Novel local suspended absorbers - 10 mFS roof height; a number of configurations of novel local suspended absorbers, located directly above the source with bottoms at 2 mFS. As shown in Figure 1, these consisted of partial boxes — with / without internal absorbent dividers — and pyramids, and inverted cones and pyramids, made of absorbent material. In some tests 1-mFS-high sound-reflecting barriers were introduced, as above.

5. Results and conclusions

In general results were different for SP and for RT. SP results depended on source/receiver distance. Trends were difficult to discern at short distances, and at lower frequencies - presumably due to wave effects.

a. Variable-height baffles - the height of a full-coverage baffle array had negligable effect on both SP and RT;

b. Ceiling baffles vs wall absorption - Combined ceiling and wall absorption gave lower SP levels than did ceiling baffles, which gave lower levels than (5 mFS height), or similar levels to (10 mFS height), wall absorption. Given the relative treatment areas, the ceiling treatment was generally most cost-effective. In both cases, the RT decreased in proportion to the amount of absorbent material introduced;

c. Full vs partial wall coverage - SP levels were lower with ceiling baffles and full wall absorption. Again, the RT decreased in proportion to the amount of absorbent material introduced. Applying absorbent material in patches is not particularly cost effective;

d. Partial-coverage ceiling baffles - SP levels at all distances decreased significantly with introduction of 50% coverage, then further decreased slightly with increased coverage. Again, RTs decreased in proportion to the amount of absorbent material introduced. Smaller coverages are more cost-effective at reducing SP levels, but not RTs;

e. Flat local suspended absorbers - Decreased height, increased lateral extent and the presence of reflecting barriers reduced SP levels slightly. The presence of a rigid backing increased levels near the source. Generally the treatments were ineffective at reducing RT;

f. Novel local suspended absorbers - These absorbers were generally more effective than flat absorbers. Partial boxes with absorbent dividers were most effective at reducing SP levels. Generally the treatments were only marginally effective at reducing RT.

Figure 2a compares 1000-Hz SPs measured in the model workroom with no absorption / local flat absorber / full-height, full-coverage ceiling baffles / local divided box. At short distances, the local absorbers were more effective than ceiling baffles - the divided-box configuration was much more effective than the flat one. At large distances the divided-box and the full ceiling baffles were most effective.

Figure 2b compares RTs measured in the model workroom with no absorption / full-height, full-coverage ceiling baffles / flat local absorber and reflecting barriers / open pyramid with reflecting barriers. At all frequencies full baffles were more effective than local absorbers. The open pyramid was more effective than the flat absorber.

References

[1] M. R. Hodgson, M. V. Eldada and L.- P. Simard, "Evaluation of the performance of suspended baffle arrays in typical industrial sound fields - Part I: Scale-model experiment. Part II: Prediction", *J. Acoust. Soc. Am.* **97** (1), 339-354 (1995).

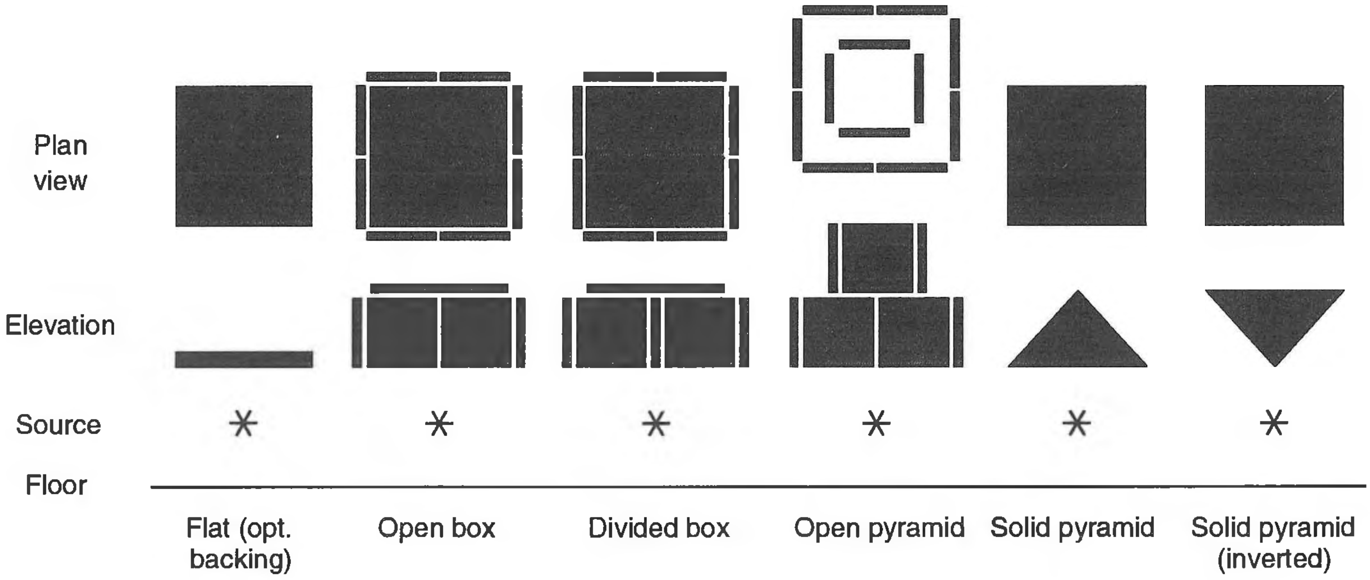

Figure 1. Illustration of the flat and novel local absorbers.

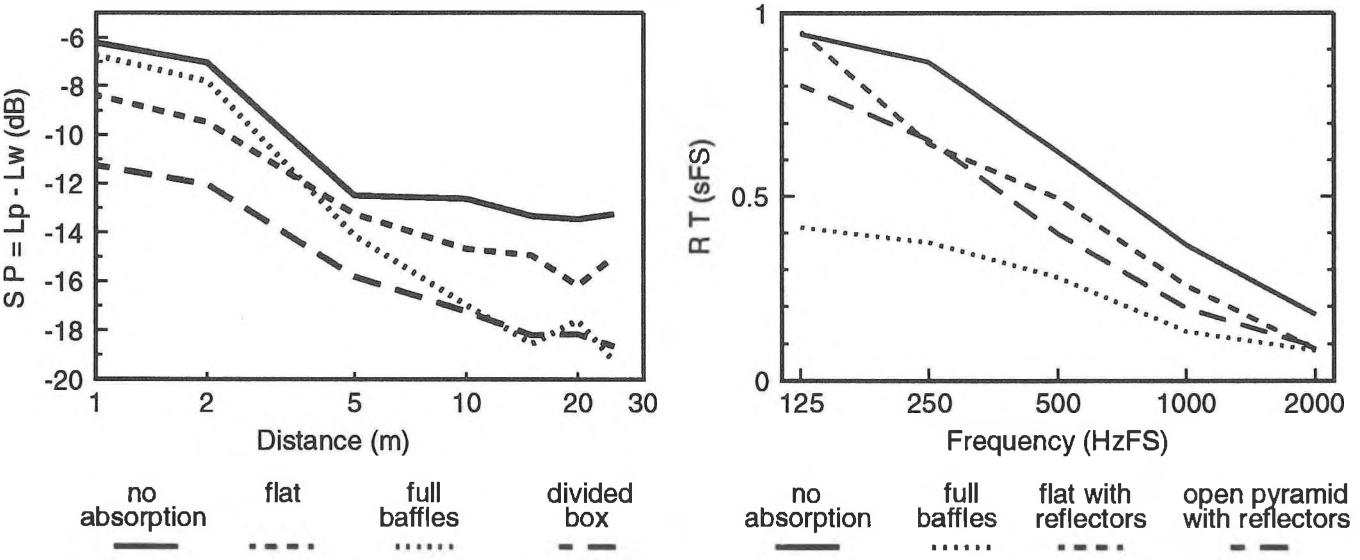

Figure 2. Results of measurements in the fitted 10-mFS-high scale-model workroom without and with absorbent treatments as shown above: a) 1000-HzFS SP; (b) third-octave-band RT.

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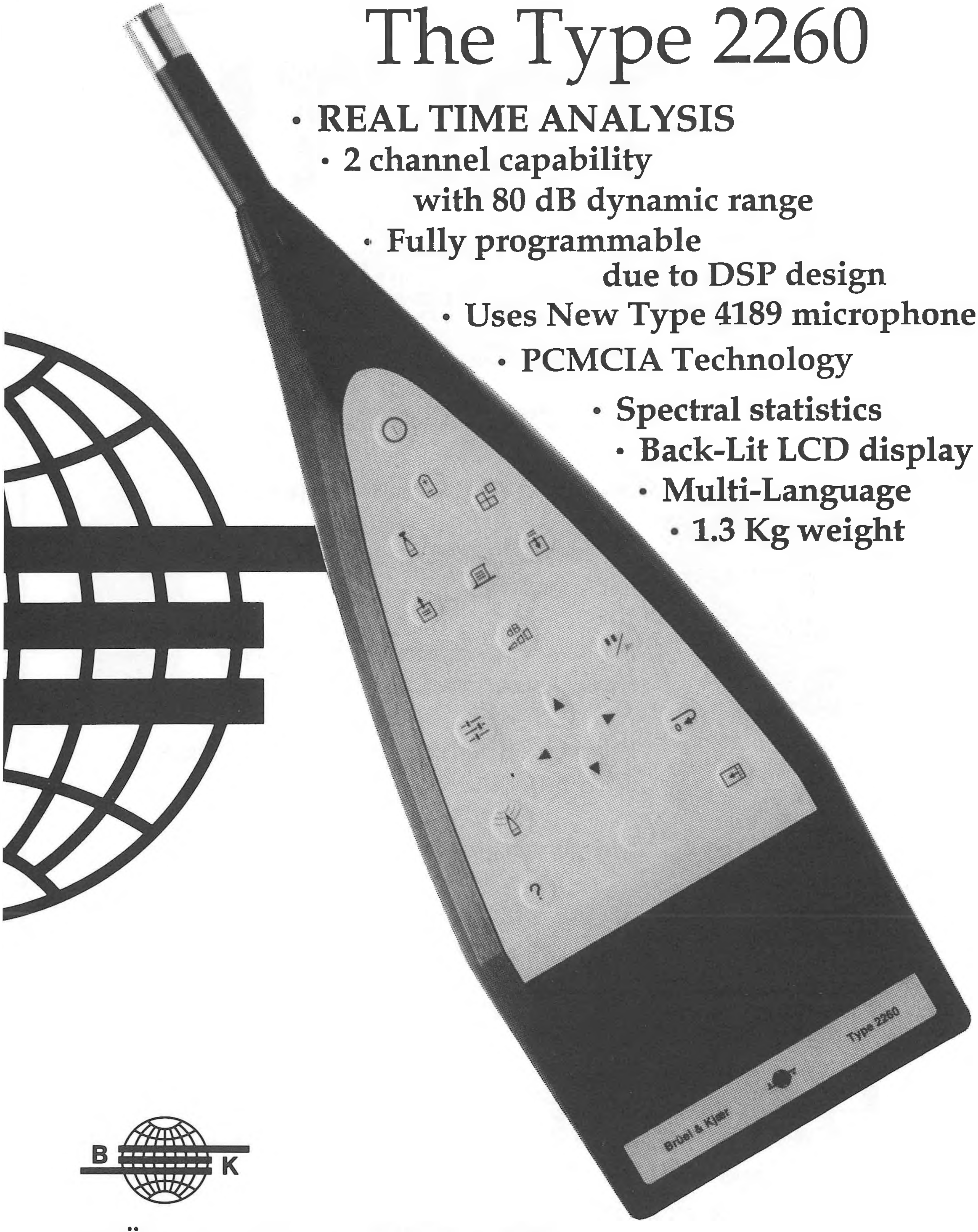
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