DYNAMIC PRESSURE MEASUREMENT WITH FLUSH MOUNTED TRANSDUCERS

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Introduction

Initial tests of sample Gaeltec transducers seemed to show them to be well suited, by virtue of their small size and cost, to multiple flush mounting on wind tunnel models to explore instantaneous pressure patterns. When mounted in a simple cylindrical model, it was noted that their outputs varied by as much as 15% under identical conditions of fluctuating pressure.

The dynamic test rig described was developed to deal with this problem over the frequency range 0 to 1 kHz. The individual transducers of the 20 channel system can be compared with each other and with other types, as available. Bell and Howell, Tyco, Kistler and Bruel & Kjaer transducers were tested. Eventually the B & K system was adopted as a sub-standard.

The Dynamic Calibrator

Essentially this consists of a loud-speaker diaphragm D driven by an oscillator O with variable power and frequency. The loud-speaker casing forms one end of a long cylinder, the other end being an adjustable plane plunger with O-ring seal to the cylinder wall (Figure 1). The cavity length between loud-speaker and plunger can thus be tuned to resonate at various frequencies.

Transducers are mounted in the plunger with their sensors facing the loud-speaker and their static lines vented to the atmosphere. There are two connections to the cylinder, A and B; A is for a vacuum supply to control the mean pressure in the rig and B for a micro-manometer to measure this mean pressure.

With the components used in these tests, fluctuating pressures of ± 50 mm water (r.m.s.) could be maintained up to 200 Hz, ± 25 mm water up to 750 Hz and smaller values up to 1 kHz. Under resonant conditions the wave form was a good sine curve on the monitor oscilloscope. 50 Hz is the lowest resonant frequency with the existing cylinder and this was adequate for these tests. Lower frequencies could be investigated by moving the plunger close to the loud-speaker but this resulted in a very weak signal, of course.

Static calibration, too, may be undertaken in the rig by varying the vacuum supply pressure.

Test Procedure

The cavity length was tuned to give the best signal, the oscillator adjusted to give a convenient value on the reference transducer and the output from the test transducers recorded. Frequent checks for zero drift and static calibration were made.

The results are generally presented as curves of r vs f where r is the r.m.s. pressure ratio between the test transducer and the reference transducer and f is the signal frequency. The reference transducer was either the Bell and Howell flush transducer or the Bruel & Kjaer microphone.

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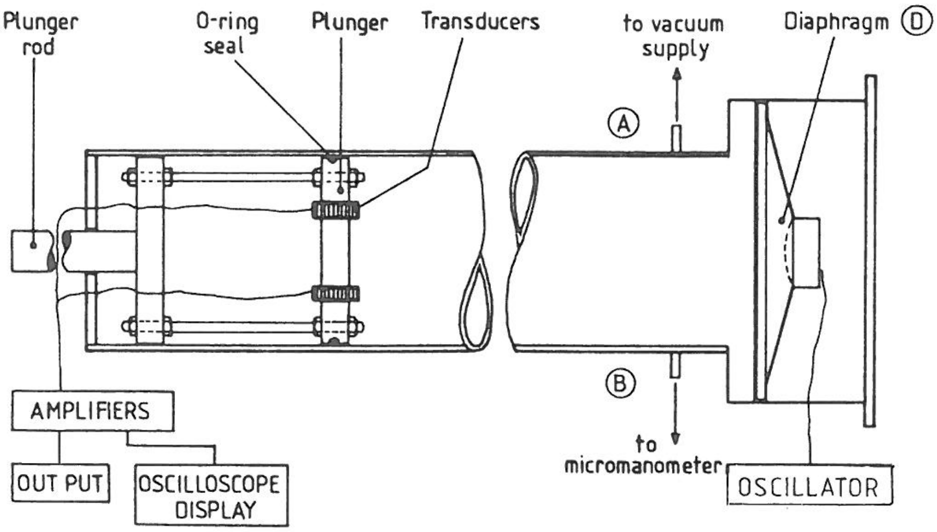

FIGURE 1

Dynamic calibration rig

Test Results

(i) Gaeltec transducers

21 transducers were tested over the range 0 - 800 Kz and each one compared with the overall mean. Results varied from -15% to +9%.

(ii) Use of Bell and Howell 4-366 as reference

These transducers are very robust but their pressure range is 10 times higher than the Gaeltec's so that a large amplifier gain is necessary. The instrument noise is still low but the zero shift is rather troublesome.

The protective inlet passages upstream of the diaphragm seem more suited to static than to dynamic pressures and since two of these transducers were available it was decided to convert one to a flush diaphragm transducer by machining off the inlet. A comparative test was then made, in the test rig, of the modified and original transducers and the results, shown in Figure 2, indicate that the standard inlet geometry is unacceptable. The flush mounted version was therefore used as a reference.

(iii) Gaeltec referred to Bell and Howell

Test 1 was repeated to compare the mean Gaeltec performance with the Bell and Howell and the results are shown in Figure 3.

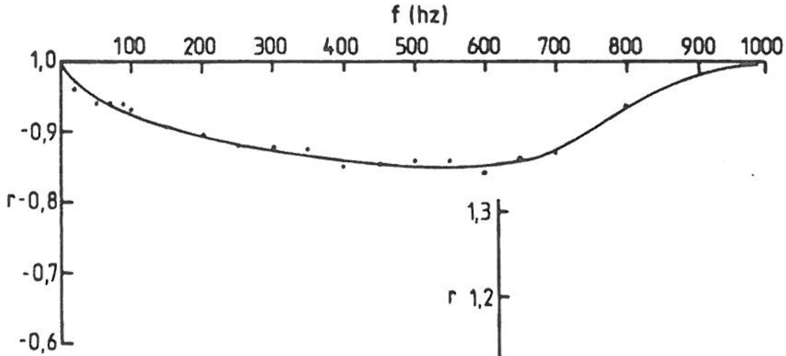

FIGURE 2 (below)

B&H transducers effect of inlet passages

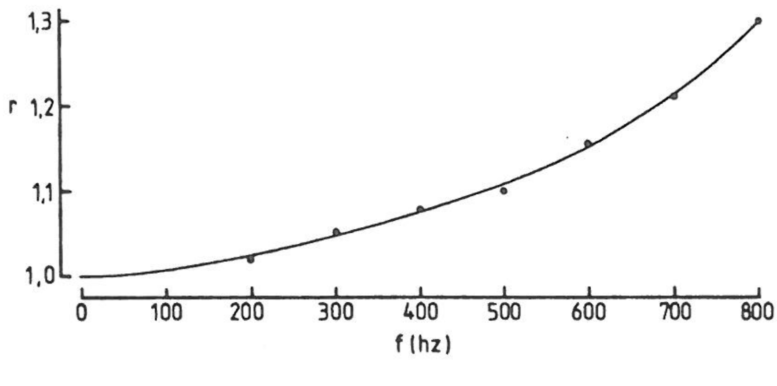

Figure 3(above)

Mean Gaeltec compared with Bell and Howell

(iv) Tyco flush diaphragm transducer

This test was of general interest only, the transducer being similar to the Bell and Howell type but intended for higher pressures and static measurement and therefore rather less suitable. It agrees surprisingly well with the Bell and Howell as far as 500 Hz.

(v) The Kistler type 7261

This is a low pressure quartz transducer and may be mounted as a flush diaphragm sensor or with a protective cover. In these two forms it has specified resonant frequencies of 13 and 2.5 kHz respectively. The diaphragm is of large diameter (35 mm) and a charge amplifier is required to convert the electrostatic charge signal of the transducer into a proportional output voltage, with amplification. Unfortunately, it is not possible to calibrate the system statically but it is very stable, relying on the piezo-electric effect, and the manufacturer supplies calibration formulae for various conditions. A quasi-static calibration can be achieved by applying a step change of pressure which is retained for some 2/3 seconds and this was found to agree with the manufacturer's figure.

The transducer was used with the protective cover removed and it had been hoped to establish it as a sub-standard. Any comparison was unsatisfactory involving large random errors which must be blamed on the Kistler transducer in view of the consistency of previous tests.

However, it was established that the "r factor" was independent of signal strength and varied 20% with frequency in the range 0 - 1000 Hz but it also varied with the distance between transducer and signal source. It is suggested that the Kistler transducer is susceptible to mechanical vibration in addition to the pressure signals, as installed in this test rig, and it is therefore unsatisfactory. Figure 4 shows the widely scattered results obtained.

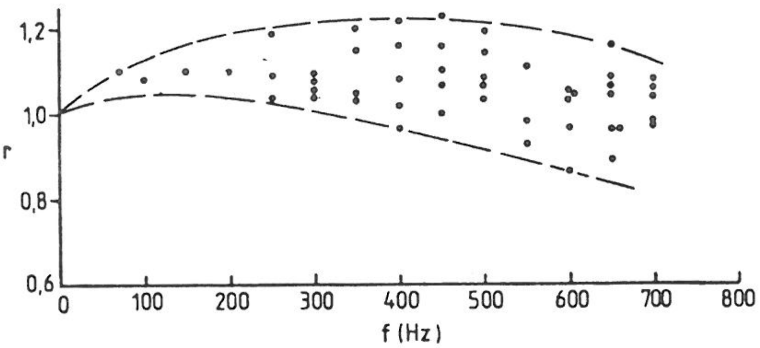

FIGURE 4

Kistler compared with Bell & Howell microphone

(iv) The Bruel & Kjaer condenser microphone system.

This is manufactured to comply with U.S. specification for laboratory standards ANSI SI.12-1967. Each cartridge has its own calibration and frequency reponse characteristic with a stability of 1 db over a very long time period. The frequency response curves are absolutely flat over the range involved in these tests.

The system tested was a 1/2" cartridge type 4134 with pre-amplifier type 2615 supplied by Mechanical Engineering Department Laboratory. The manufacturers calibration was 12.25 mm water/volt. (120.17 Pa/volt). The instrument was not new and had been used extensively. Figure 5a shows the comparison between this transducer and the best 10 Gaeltecs. There is some doubt about the quoted microphone calibration since r must be 1 at f = 0 and Figure 5b shows a more likely result which agrees closely with that for the Bell & Howell transducer.

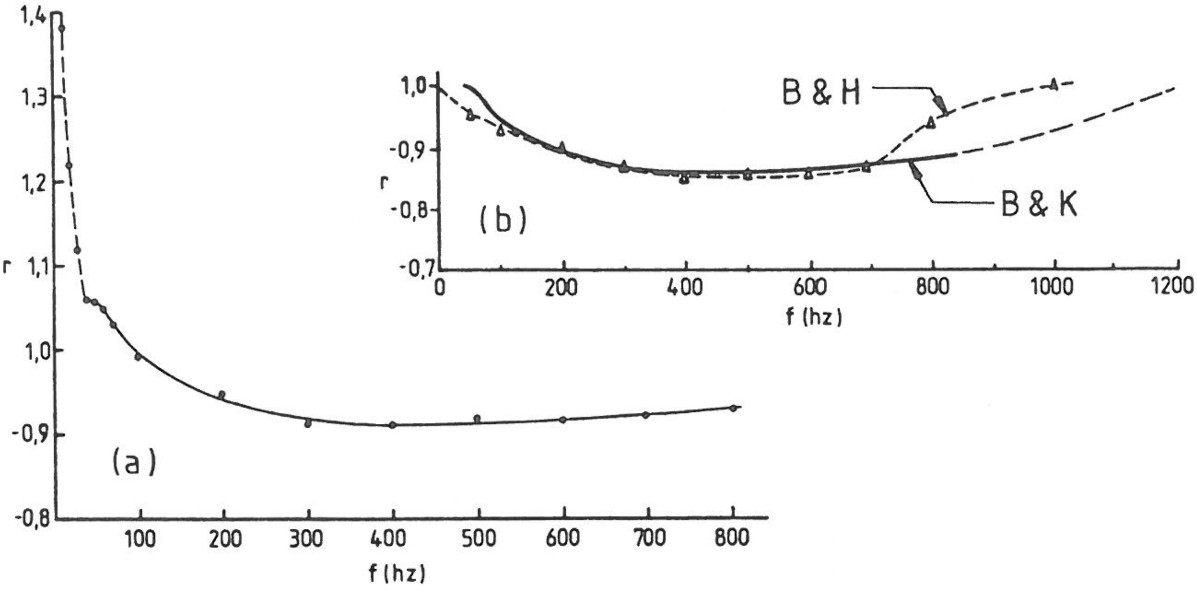

FIGURE 5 Gaeltec compared with B&K microphone
(a) maker's calibration
(b) revised calibration (and B&H comparison)

Since these tests a new 1/4" Bruel and Kjaer system has been bought and dedicated to the test rig as its standard. Its calibration is checked periodically against the Pistonphone and shows no change yet.

Conclusion

(i) The B & K microphone is the best laboratory sub-standard for transducers but the calibration constants require periodic checks.

(ii) The Bell and Howell transducer, with the inlet passage machined away, is very satisfactory up to 700 Hz.

(iii) The Kistler 7261 transducer is unsuitable in this application by virtue of its response to mechanical vibration.

(iv) For Gaeltec transducers individual dynamics calibration is necessary.

Flush Mounted Transducers

The dynamic test rig has been modified so that complete wind tunnel models, carrying the transducers, can be accommodated. A mounting block replaces the plunger used previously and adjustment of the length of the resonator is achieved by making it from two telescoping tubes. The microphone fits through the mounting block so that its sensor is adjacent to the pressure hole tested. A range of mounting blocks is required for different models.

Significant modifications to the 'open' calibrations above are detected and calibrations are performed whenever any physical change to the model is implemented. Intermediate checks have been carried out during long test runs and have shown that the dynamic calibration of a particular geometry does not vary with time.