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THE HIGH INTENSITY ACOUSTICS LABORATORY AT RADBROKE HALL, KNUTSFORD

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1. Introduction

The acoustics laboratory described in this paper was built specifically for the development of components for the company's Advanced Gas-cooled nuclear reactors (AGRs). It was brought into operation in 1971, and is situated on a rural site at Radbroke Hall near Knutsford.

Experience with the earlier generation of Magnox Gas-cooled reactors had demonstrated that the acoustic response of structures in a nuclear reactor is significantly affected by the properties of the surrounding gas. It was therefore necessary to carry out at least some testing in a pressurised acoustic chamber.

The laboratory was therefore planned around three facilities - a conventional high intensity reverberation chamber, a progressive wave tube in which rather higher sound pressure levels could be achieved, and the pressurised high intensity facility. Figure 1 shows the general arrangement of the laboratory in which the three main test facilities are grouped, together with all the noisy plant, in a high transmission-loss cell. The workshop, office, and control room are conveniently situated in low noise areas, and the building design successfully avoids neighbourhood noise problems. With both chambers operating at sound pressure levels of 155 dB,* the noise level outside the laboratory is 52 dBA, and most of this originates from a roof mounted water cooling tower.

2. The Pressurised High Intensity Facility

The pressurised facility consists of a steel pressure vessel 2.4 metres in diameter and 4 metres long, fabricated from plate 5 to 15 centimetres thick. One end is near hemispherical in shape while the other has a conical reduction leading to a penetration 1.4 metres in diameter. The vessel weighs some 25 tonnes and is designed to operate at up to 40 bars with internal sound pressure levels of up to 170 dB. Since the pressure vessel design codes did not cover such conditions, calculations and model tests were carried out to ensure that the dynamic stresses induced in the vessel would not result in fatigue failures. Extreme care was also taken during manufacture to ensure that unacceptable flaws did not arise, and visual, ultrasonic, magnetic, and radiographic inspection was employed.

Originally, noise was generated inside the vessel using an electro-magnetically modulated pneumatic valve. Gas from the pressure vessel was pumped by a high pressure gas circulator through the noise generator in a closed loop. The modulating valve varied the flow in a manner related

(*dB re2 x 10^{-5}N/m^2 throughout)

to the applied electrical signal which could be controlled to give the desired noise characteristics. The noise source was connected to the chamber by means of an exponential horn within the vessel. Broad band noise levels of up to 160 dB were produced in this way.

Some development did not require the available acoustic power and it was found convenient to develop a high intensity dynamic speaker, which can produce 148 dB when driven by a 300 v-a amplifier. The success of this unit and the simplification of the operating procedures has lead to a larger model being designed and built. This version will produce the full 160 dB when driven by a 3 kv-a amplifier.

3. The Atmospheric Reverberation Chamber

This chamber is a rectangular enclosure constructed from brick steel, and concrete, and has internal dimensions of approximately 5 metres x 4 metres x 3 metres high, and an access doorway 1.5 metres x 2 metres high. Again, at the design stage, a number of models were constructed, and contrary to the popular opinion at the time, the rectangular shape was chosen. One of the reasons for this choice was that if unusual characteristics were encountered, they would be more amenable to analysis.

Three electro-pneumatic noise generators are used. They are coupled to 50 Hz cut-off exponential horns and are supplied with compressed air at a gauge pressure of 2.5 bars. To optimise the acoustic coupling between the source and the enclosure, the exponential horn enters the lower half of one of the vertical edges of the room. Broad band noise with a sound pressure level of over 155 dB can be obtained in the chamber while up to 160 dB may be obtained with discrete tones.

For early development tests and comparative testing, this facility is more convenient and economical to operate.

4. The Progressive Wave Tube

This facility is a brick and concrete duct having a section about 0.3 metres x 1 metre high. Flat specimens up to 2 metres x 1 metre high may be mounted in an aperture in one side of the duct. The tube uses the same noise generator assembly as the reverberation chamber and was designed to give a sound pressure level of over 160 dB over the specimen surface.

5. Instrumentation

All the test facilities are remotely controlled from the control room to avoid exposure of operators to high noise levels.

Comprehensive instrumentation is available to generate narrow or broadband noise and discrete frequencies, and channels to monitor 90 strain gauges and 24 accelerometers or microphones are permanently connected to each of the rigs. These arrangements ensure that the times for installation of a specimen and for testing are both reduced to an absolute minimum. Equipment is available for narrow band, one-third octave and octave band frequency analysis, the output from which can be displayed on a level recorder.

6. Acoustic Response Testing

Most of the components that have to be tested are associated with the thermal insulation that protects the prestressed-concrete reactor vessel from high temperature gas. A fuller description of the prediction of the environmental conditions and the estimation of vibration responses is given in Reference 1.

The acoustic performance of a structure is assessed by carrying out a structural response test with the specimen suspended from fixed points in the chamber using nylon chords that give a low natural frequency and avoid direct excitation by the chamber walls. Stress and vibration amplitudes on all components are determined as a function of frequency at an applied noise spectrum, which is sampled by several microphones in the vicinity of the structure under test. In general, the mean noise spectrum is controlled using a one-third octave band spectrum shaper to be as near as possible to that predicted for the arrangement in the reactor. A typical specimen has 70 strain gauges and 15 accelerometers, while the sound field is sampled using up to 10 microphones. These transducers are analysed in one-third octave bands, and corrections made for any differences between the test and reactor spectra.

Tests in the pressurised facility are normally carried out using high pressure nitrogen at room temperature, as this most nearly simulates the acoustic properties of the reactor coolant, carbon dioxide, at reactor pressure and high temperatures. Figure 2 shows the importance of testing at high pressure, by demonstrating a significant reduction in the response of a particular structure. Reference 2 gives further details of this effect.

If the reactor gas circulator has a strong blade-passing tone, large amplitude structural resonances can be excited, especially with a variable speed machine. Orginally, this effect was studied using a slow sine-wave sweep test, but this proved very time consuming. The method now employed is to use broad band excitation but narrow band analysis of the response and the sound field. Structural response peaks can be clearly seen from the resulting transfer function, and additional testing is carried out in just those frequency bands to confirm the maximum stress predictions.

Long term endurance tests have been carried out to highlight any inherent deficiencies such as fretting and wear. Subsequent reactor testing and power generation has confirmed the satisfactory operation of the structures developed.

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7. Future Development

So far the work in the laboratory has been mainly geared to confirming the designs of the first generation of AGRs, now in operation and under construction. In the next few years development will take place on designs for the new generation of AGRs planned for Heysham II and Torness.

Consideration is being given to the possibility of improving the low frequency characteristics of the pressurised facility by using it as a progressive wave tube. Sound would be generated at one end of the vessel using a speaker array, while another array at the opposite end would be driven with a suitably delayed signal to act as an active absorber.

8. Acknowledgements

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9. References

1. E.A.C. JONES, W. HARTLEY and I.H.G. HOPKINS Paper H5/6, Second International Conference on Structural Mechanics in Reactor Technology, Berlin (September 1973):

   "Response of fibrous prestressed concrete pressure vessel insulation to typical noise spectra."

2. E.A.C. JONES Paper 216 International Symposium on Vibration Problems in Industry, Keswick (April 1973):

   "Acoustically induced vibration in thermal insulation containment structures for Advanced Gas-cooled Reactors."

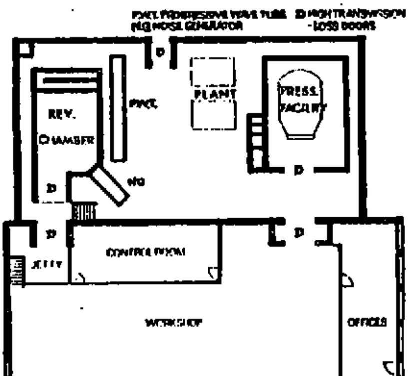

Fig 1 Layout of Laboratory

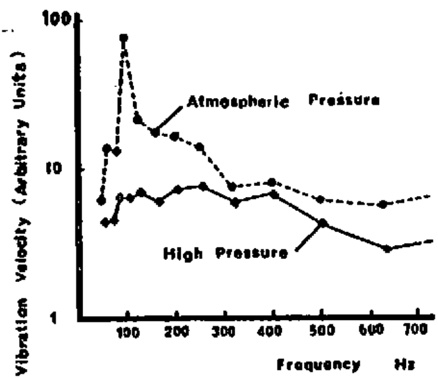

Fig 2 Effect of Pressure on Response

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