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AERONAUTICAL NOISE: SESSION A: JET NOISE

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BASIC ACOUSTIC CONSIDERATIONS FOR MODEL NOISE EXPERIMENTS IN WIND-TUNNELS

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1 NEED FOR WIND-TUNNEL MODEL EXPERIMENTS ON AIRCRAFT NOISE

Important problems now face the aircraft designer in predicting, assessing and guaranteeing the noise field from future aircraft projects to a much greater accuracy than hitherto. These problems are aggravated by the continuing demand for even lower noise levels and improved airfield performance capabilities, together with the incorporation of novel airframe/engine arrangements to attain such goals. The noise estimation process for flight conditions is much more complex than for static, not merely because of Doppler shift and flight path considerations, but also because of the effects of the relative mainstream flow past the aircraft on the characteristics and propagation of the source noise from the engine-aircraft combination. For the early clarification of such mainstream effects, and for guidance towards the formulation of reliable theoretical frameworks and prediction methods, experimental research and development studies are essential at model scale in suitable anechoic wind-tunnels, as well as ultimately at full-scale under static and forward-flight conditions for aircraft development and proving.

Acoustic considerations for noise experiments at model-scale in subsonic wind-tunnels do raise of course new tunnel-technique problems, as discussed in detail by Holbeche and Williams in RAE TR 72155. It seems appropriate here at least to draw attention to the basic difficulties and their implications on tunnel design and utilisation.

2 SPECIAL PROBLEMS OF TUNNEL EXPERIMENTS ON NOISE

The available experience on noise testing of powered models in wind-tunnels and on associated techniques is still very limited, comprising quite small efforts over the past few years, as compared with extensive continuous aerodynamic testing over several decades. However, it is now possible to identify most of the major problem areas arising in such wind-tunnel testing, with a view to their individual clarification and treatment.

Firstly, for adequate simulation at model-scale, significant geometrical and constructional features have to be selected for representation in relation to aerodynamic, elastic and inertial aspects affecting noise generation, with overall consideration of size scaling-factor implications. Also, some non-dimensional similarity parameters have to be reasonably satisfied or interpreted (eg Mach number, Reynolds number, Advance ratio), while others (eg acoustic/dynamic frequency parameters

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and sound-level parameters) have to be validated as applicable to full-scale practical prediction for the particular aircraft type. As yet, it is difficult to assess properly the degree of practical aerodynamic representation necessary to cover aircraft noise aspects and the extent to which any powered noise source itself will need to be represented. This special difficulty of simulating the propulsion-unit noise source and radiation characteristics, other than perhaps from pure jet-efflux or simple rotor-blades, represents an area in which much progress is needed soon.

Unacceptable parasitic noise fields can be produced naturally by the tunnel testing environment (Fig 1), unless special precautions are taken. In particular, the following origins may be identified:- Intrinsic noise of the tunnel in operation, associated with the tunnel drive, circuit and mainstream flow. Spurious noise associated with flow over the measuring microphones and over the model supporting rig (eg vortex shedding tones). Reverberation or standing waves caused by reflection of the model noise by the test-section boundaries and around the tunnel circuit. Modification of the quality and characteristics of the mainstream flow around the tunnel circuit and into the test-section (and hence spurious noise generation) with variation of powered model conditions.

To facilitate analysis of model noise measurements and extrapolation to full-scale far-field conditions, reliable noise-measurement should be achievable in the 'free-field' portion of the model-source far-field, where the sound pressure level varies almost inversely as the square of the distance, apart from atmospheric attenuation. This 'free-field' region is bounded internally by the 'near-field' region of the noise source and externally by the 'reverberation-field' of the test-section enclosure, thus restricting the maximum permissible size of the model and the minimum acceptable size of the test-section from acoustic as well as aerodynamic considerations. Also, a minimum acceptable size of the model can be determined by the practical difficulties with associated high frequency noise measurements as well as with model constructional problems.

Such tunnel-testing difficulties while significant can be overcome or alleviated by careful model design and provision of improved tunnel facilities. More generally, as regards the investigation of relative mainstream effects on model noise, some correlation of the observed noise changes with probable variations in aerodynamic conditions should invariably be sought, if meaningful interpretation of the noise measurement for reliable application towards practical developments and improvements is to be ensured.

3 SPECIAL FACTORS IN TUNNEL DESIGN AND APPLICATION FOR NOISE EXPERIMENTS

Although there do exist a few small-scale 'near-anechoic' wind-tunnels with test-section diameters up to 2.5m, the existing larger tunnels were designed with little concern about the special requirements for acoustic investigations as distinct from aerodynamic model testing (including unsteady pressure measurements). These latter tunnels, if left acoustically untreated, may allow some quantitative measurements of discrete frequency (rotation) noise, by careful application of narrow-band analysis, correlation and averaging techniques to overcome the effects of reverberation or reflected sound fields. However, as regards broadband noise investigations, such untreated tunnels can at best be used only as an expedient for qualitative measurements; possibly with application of some gross first-order noise corrections to the model test results wind-on, based on control measurements under free-field ambient conditions outdoors and in the tunnel wind-off.

Basic tunnel design considerations can be influenced significantly by model noise testing needs. A typical fan-driven tunnel of the 'closed-return' type is illustrated in Fig 2, with the addition of various background noise suppression schemes which may be worth application in individual circumstances. The following particular features of tunnel design will be discussed more fully in the spoken lecture, taking account of our recent experience from background noise analysis (eg Fig 3) for the RAE 24' open-jet tunnel.

i) Tunnel Circuit Type, especially the choice needed between 'straight-through' and 'closed-return' arrangements from noise aspects. The attraction of the former with an open-circuit return to atmosphere, in precluding circulation of noise and disturbed airflow around the tunnel circuit, can be counterbalanced by the spurious noise and aerodynamic effects arising from poor airflow conditions at the tunnel intake and from providing direct entry for transmission of external ambient noise and wind effects to the tunnel test-section.

ii) Tunnel Drive-Fan, which can contribute a significant component to the background noise level in the test-section. The fan design and position in the duct represent particularly critical features for any noise-testing tunnel, warranting careful selection, and early proving.

iii) Test-Section Type, especially the choice needed between free and walled boundaries from noise aspects. The open test-section inside a large acoustically-treated chamber is often preferred to the closed test-section with acoustically treated walls (Fig 2), partly because of ease of access for rigging, but mainly because noise measurements may then be attempted outside the open-jet test-section boundary, with the measurement microphones and their supports in nominally still air. However, some falsification of the source-noise propagation characteristics may then arise from refraction/scattering through the free-boundary jet-mixing region, and possibly from the transmission through two distinct airflow regimes inside and outside the boundary. Furthermore, excessive background noise or significant variation of background noise (with model condition) must not be generated from the jet-boundary, the nozzle exit, and the flow collector.

iv) Test-Section Size, particularly with respect to the achievement of far-field conditions for measurements of model noise, at locations adequately distant from the test-section boundaries to avoid significant acoustic/aerodynamic interference. The acceptable ratio of tunnel to model size thus depends not only on aerodynamic flow-field constraints, but also on the relative spatial extent and the characteristics of the model noise sources, together with the minimum values of acoustic frequency parameters of practical interest for full-scale noise prediction.

4 CONCLUDING REMARKS

Broadly speaking, acoustic requirements tend to increase the relative size of wind-tunnel demanded, as compared with aerodynamic requirements. However, a large subsonic tunnel provided primarily for aerodynamic testing of powered models could certainly permit reliable tests of forward-speed effects on broadband noise as well as discrete-frequency noise; provided the tunnel incorporates a quiet drive, some acoustic treatment of the tunnel circuit and test-section, and a steady low turbulence airstream at entry to the test-section even with models in operation.

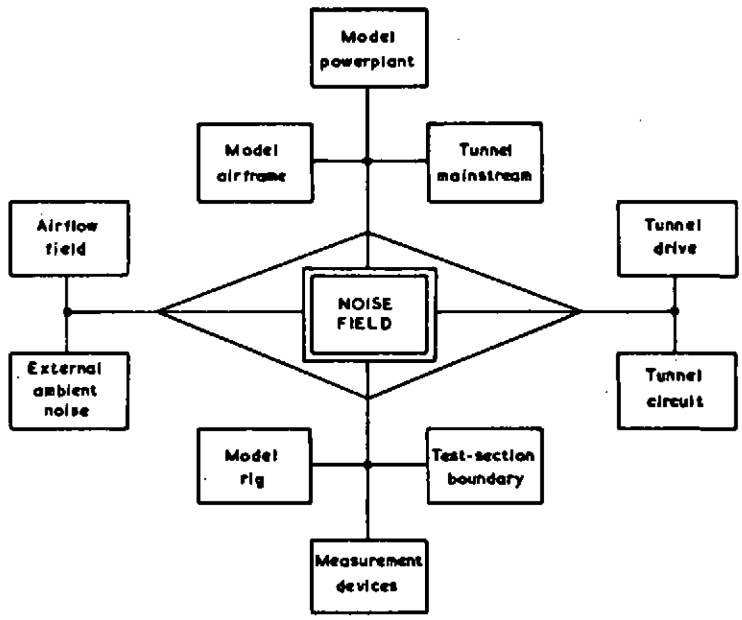

Fig.1 Simplified interaction element diagram

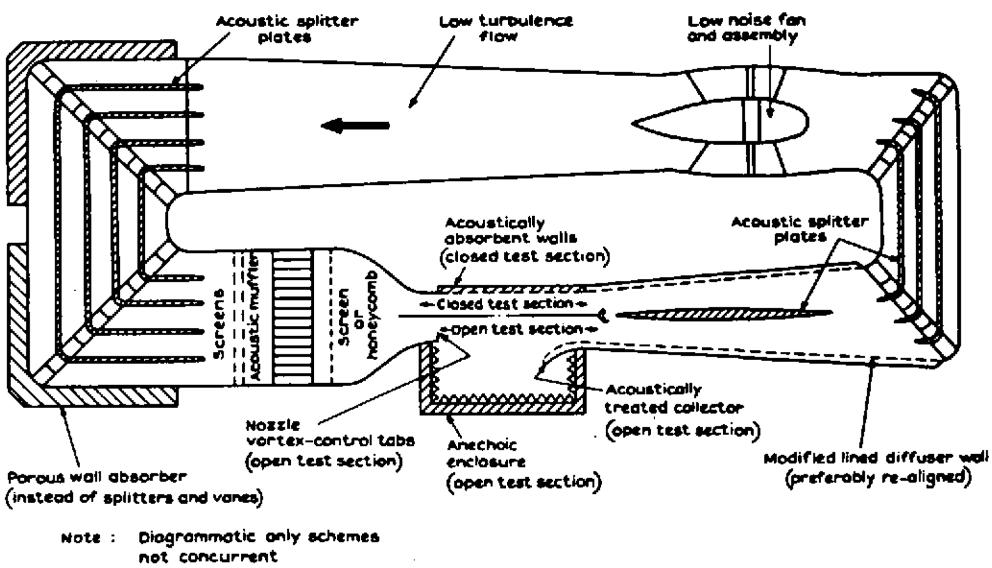

Fig.2 Typical subsonic wind-tunnel circuit with possible noise-suppression schemes

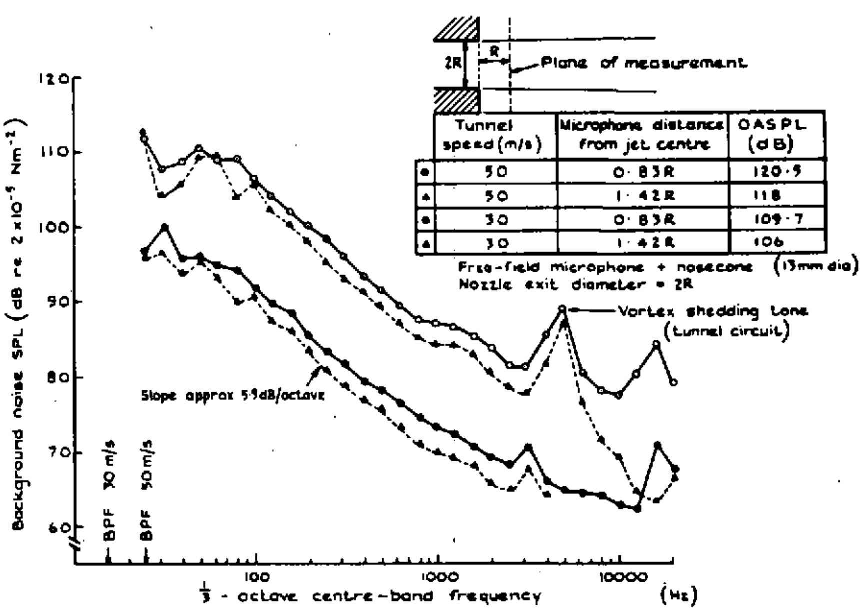

Fig.3 RAE 24-foot open-jet wind tunnel, background noise v frequency