TRENDS IN AERO-ACOUSTIC WIND TUNNEL TESTING

Gary M. Elfstrom
Aiolos Engineering Corp, 2150 Islington Ave., Suite 100, ON, Canada, M9P 3V4 gme@aiolos.com

1. INTRODUCTION

Wind tunnels are an important tool in the aero-acoustic development of ground and air vehicles: for investigation of noise sources and characterization of interior and exterior noise environment associated with external flow aerodynamics. Recent trends in new aero-acoustic wind tunnels, upgraded aerodynamic wind tunnels, and climatic wind tunnels are presented in terms of innovation to serve as aero-acoustic tools for the vehicle designer.

2. THE NEED

Prototype ground vehicles, especially automobiles, require large wind tunnels for the development of quiet vehicles, and for comparative testing against competitor's models. High speed vehicles such as trains and aircraft are tested in smaller wind tunnels using scale models, primarily due to capital and operating costs of large high speed wind tunnels.

Hucho (1998) mentions three basic wind noise source types: leak noise (high frequency, about 4kHz), cavity noise (low frequency, about 40Hz), and wind rush noise (mid frequency, greater than 500Hz). Car designers are steadily pushing towards lower aerodynamically driven noise and so tools are needed to systematically identify and deal with all noise sources in a controlled environment.

3. THE TOOLS – WIND TUNNELS

The normal goal for good simulation in a wind tunnel is to have a "signal to noise" ratio of about 10dB between vehicle noise and background noise, across the full frequency spectrum of interest for a given vehicle. Lesser ratios, e.g. 5dB have been routinely used in cases where it is not feasible to achieve any better but care should be taken when comparing results from different wind tunnels.

The other important aspect of wind tunnel test capability is the cut-off frequency, f_c, of the test section. This should be as low as possible to capture the frequencies of interest. In this regard, scale model aircraft testing require much higher frequencies than full scale automotive vehicles.

3.1 Aero-Acoustic Wind Tunnels

The most recent publication on aero-acoustic wind tunnel *capabilities* is given by Duell (2002). The present paper can be considered an extension of that report in that it presents new aero-acoustic and related wind tunnel developments. Three new facilities are discussed here, each with its own unique requirements and challenges.

Agency for Defence Development (ADD) 3mx2.25m low speed aero-acoustic aircraft wind tunnel in Korea – Elfstrom (2007) – see Figure 1. This test section is a closed/open-jet, f_c = 200Hz using wedges; circuit acoustic treatment on turning vanes and some of the airline walls.

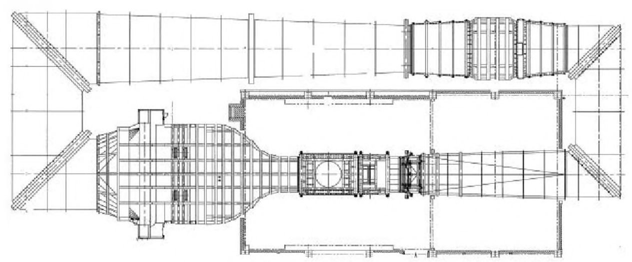

Figure 1. ADD wind tunnel

GIE S2A 24m^2 automotive aero-acoustic wind tunnel in France – Waudby-Smith et al (2004) – see Figure 2. The test section is a semi-open, f_c = 80Hz using flat panels; circuit acoustic treatment on turning vanes and some walls.

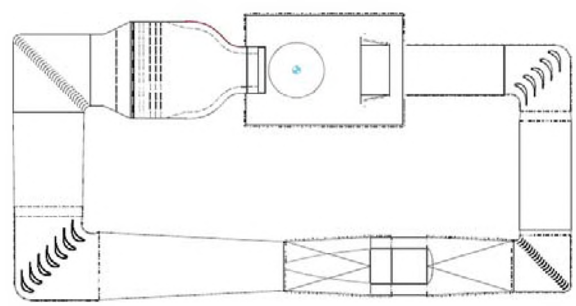

Figure 2. GIE wind tunnel

General Motors Aerodynamic Lab (GMAL) 56.2m^2 in USA – Yeh et all (2008) – see Figure 3. The test section is a closed-wall, f_c = 50Hz using foam; circuit acoustic treatment on turning vanes. This facility is unique, not just because it is an upgrade of an aerodynamic wind tunnel.

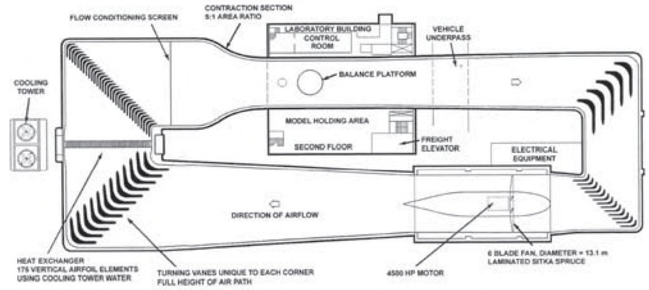

Figure 3. GMAL wind tunnel

Figures 4 and 5 show the in-flow and out-of-flow noise measured in the ADD, GIE, and GMAL facilities lie within the envelope of contemporary wind tunnels given by Duell et al (2002).

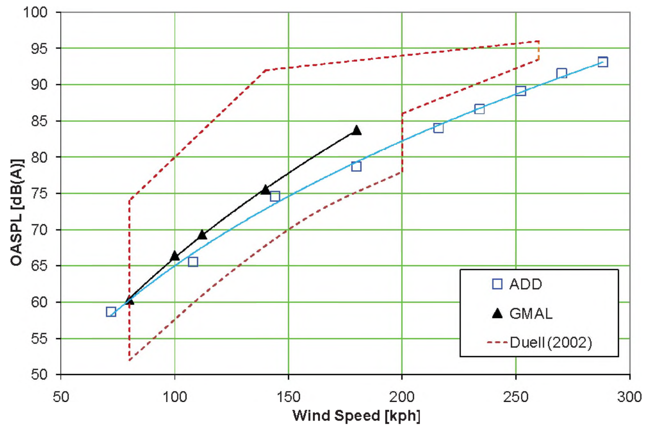

Figure 4. In-flow noise data

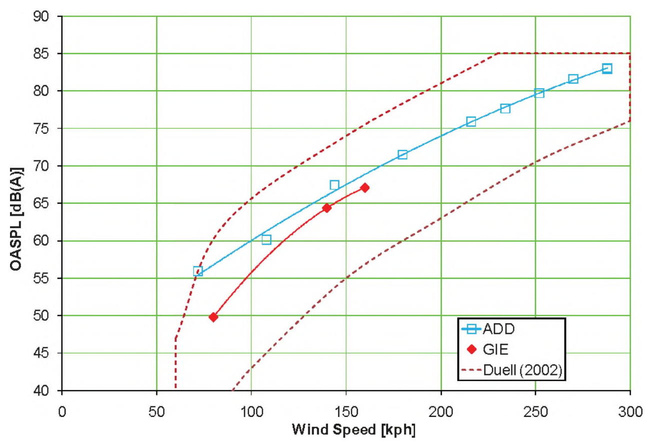

Figure 5. Out-of-flow noise data

The lower limit to the Duell (2002) envelope in Figure 5 is defined by a railroad wind tunnel, RTRI (1997). Being so low in OASPL, this at first seems out of character with its contemporaries. However, when examined in the context of circuit efficiency – see Figure 6 – it becomes clear that low noise may come with a penalty of high installed fan power.

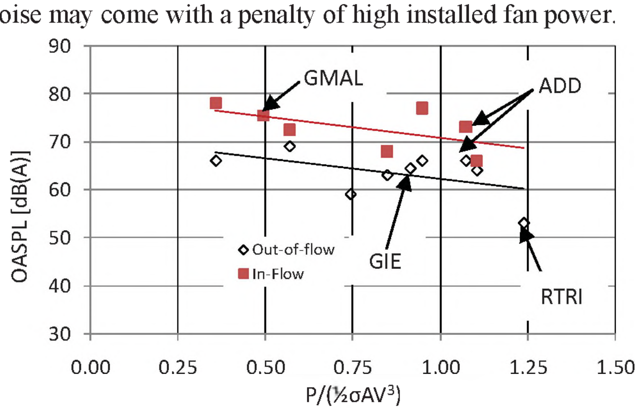

Figure 6. OASPL at 140kph vs non-dimensional fan power

The RTRI circuit is the least efficient of all due to high loss baffle sets included in each cross leg. In this context, the GMAL case deserves special mention because even with the additional losses incurred in the upgrade, it is still an extremely efficient circuit.

3.2 Climatic Wind Tunnels (CWT)

Noise sources other than external airflows, such as drive-train and exhaust system, do not require ultra low background noise levels and so recently there has been a trend towards outfitting CWT's with a modest amount of acoustic treatment. Figure 7 shows data from the Ford UK Engineering Test Laboratory CWT No.1.

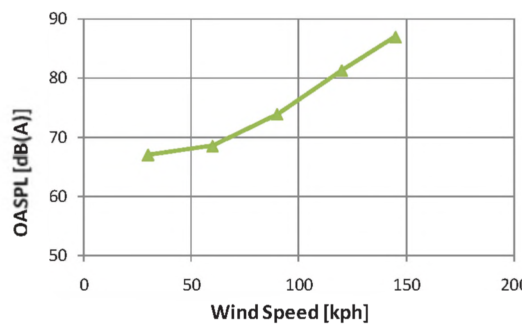

Figure 7. Climatic Wind Tunnel out-of-flow noise data

Figure 7 shows the background noise level is low enough that an experienced test engineer will be able detect any misfires, combustion instability, etc. and then to advise whether further driveability testing should be conducted.

REFERENCES

Duell, E., Walter, J., Arnette, S., and Yen, J. (2002) Recent Advances in Large Scale Aeroacoustic Wind Tunnels, AIAA Paper 2002-2503.

Elfstrom, G., (2007) History of Test Facility Design Expertise at Aiolos Engineering Corporation, AIAA Paper 2007-0149.

Hucho, W-H, *Aerodynamics of Road Vehicles (4th Edition)*, SAE, 1998, pp 343-355.

Künstner, R., Potthoff, J., and Essers, U. (1995) The Aero-Acoustic Wind Tunnel of Stuttgart University, SAE Paper 950625.

RTRI (1997) RTRI's Large Scale Low Noise Wind Tunnel, Informational Brochure, Railway Technical Research Institute.

Waudby-Smith, P., Bender, T., Vigneron, R. (2004) The GIE S2A Full Scale Aero-acoustic Wind Tunnel, SAE Paper 2004-01-8080.

Yeh, Y. P., Schenkel, F., Meinert, F., and Niemiec, J. (2008). Calculation of Wind Tunnel Circuit Losses and Speed With Acoustic Foams, SAE Paper 2008-01-1203.

ACKNOWLEDGEMENTS

The author wishes to thank Aiolos colleagues David Van Every and Peter Waudby-Smith for assistance in preparing data for this paper; also to Jim Zunich of General Motors and Ken Huntington of Ford for useful comments and permission to publish the preliminary data on the aero-acoustic upgrade of GMAL and CWT data, respectively.