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Prediction of single-stream jet noise in flight from static circular-nozzle data

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the following Jet Noise Working Party on behalf of the Aircraft Noise Committee:

Mr W.D.Bryce	— Royal Aircraft Establishment, Pyestock
Mr L.W.Illston	— British Aerospace plc, Military Aircraft Division, Weybridge
Dr P.Pack	— Rolls-Royce plc, Derby
Mr R.A.Pinker	— Royal Aircraft Establishment, Pyestock
Dr P.J.R.Strange	— Rolls-Royce plc, Derby
Mr R.J.Woodrow	— British Aerospace plc, Civil Aircraft Division, Hatfield

The Aircraft Noise Committee, first met in 1971 and now has the following membership:

Chairman	
Mr R. Pinker	— Independent
Members	
Mr S. Arrowsmith*	— European Aviation Safety Agency (EASA), Germany
Mr W.D. Bryce	— Bryce Research (Member Emeritus)
Ms C.L. Burley*	— NASA, Langley Research Center, USA
Mr P.J. Hopkins	— Rolls-Royce plc, Derby
Dr I. Imamura*	— Japan Aerospace Exploration Agency, Japan
Dr P. Joseph	— Institute of Sound and Vibration Research, Southampton
M. P. Lempereur	— Airbus France, Toulouse, France
Mr C.J. Mead	— QinetiQ, Farnborough
Mr D. Patience	— BAE SYSTEMS, Farnborough
Mr W.J. Readman*	— European Aviation Safety Agency (EASA), Germany
Dr D. Rhodes	— Civil Aviation Authority, Environmental Research & Consultancy Department (ERCD), London
Mr D.C. Riordan	— Bombardier Aerospace Short Brothers plc, Northern Ireland

* Corresponding Member

The construction and subsequent development of the Data Item were undertaken by

Dr C.B.Chinoy	— Head of Aircraft Noise and Structural Dynamics Group
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PREDICTION OF SINGLE-STREAM JET NOISE IN FLIGHT FROM STATIC CIRCULAR-NOZZLE DATA

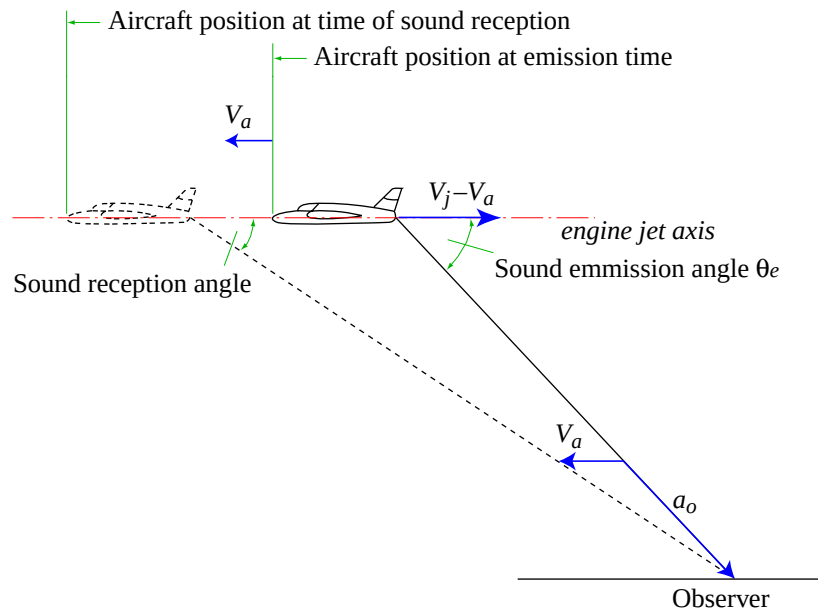
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PREDICTION OF SINGLE-STREAM JET NOISE IN FLIGHT FROM STATIC CIRCULAR-NOZZLE DATA

1. NOTATION

		<i>SI Units</i>	<i>British Units</i>
a_0	ambient speed of sound	m/s	ft/s
f_f	frequency of sound, as heard by a stationary observer, emanating from a jet in flight	Hz	Hz
f_s	frequency of sound emanating from a stationary jet	Hz	Hz
m	velocity exponent in Equation (4.1)		
M	flight Mach number = V_a / a_0		
$OASPL$	overall sound pressure level	dB	dB
r	radial distance from centre of nozzle exit to observer	m	ft
SPL	one-third octave band sound pressure level	dB	dB
ΔSPL	noise level reduction from static to flight conditions	dB	dB
T_0	ambient temperature	K	K
T_{js}	static temperature of jet flow	K	K
V_a	flight speed	m/s	ft/s
V_j	fully expanded jet velocity relative to nozzle	m/s	ft/s
V_{rel}	relative jet velocity = $V_j - V_a$	m/s	ft/s
θ_e	sound emission angle between jet exhaust axis and observer for a jet in flight (see Sketch 1.1)	deg	deg
θ_j	sound emission angle between jet exhaust axis and observer for a stationary jet	deg	deg
τ	temperature function defined in Equation (4.3)		



Sketch 1.1

2. INTRODUCTION

This Item provides a computerized method for predicting pure jet flyover noise spectra from noise spectra measured from, or predicted for, a stationary jet. The changes in noise levels from static to flight conditions are often referred to as static-to-flight effects. The computational procedure is almost identical to the method described in Derivation 1 and is applicable to single-stream jets with circular nozzles.

There are three basic changes in noise spectra when going from static conditions to flight conditions. The first is the spectral shape change which arises from changes in jet refraction due to flight. The second and third changes are the shifts in amplitude and frequency arising from the effects of motion on the source. The approach used in this Item considers the change in jet refraction by an angle transposition and uses empirical correlations of experimental data to predict amplitude and frequency changes.

3. SPECTRAL SHAPE CHANGES

It is assumed that the changes in spectral shape in going from static to flight conditions may be attributed solely to changes in jet refraction. This leads to a simple angle transposition such that a static jet noise spectrum at an emission angle, θ_j , will have the same spectral shape as a flight spectrum at another emission angle, θ_e .

The flight emission angle θ_e , corresponding to a given static angle can be obtained explicitly from the relationship in Derivation 1.

$$\cos \theta_e = \frac{\cos \theta_j}{1 - 0.65 M \cos \theta_j} \quad (3.1)$$

There are of course, no refraction effects at 90 degrees.

As the minimum value of θ_e is 0 degrees, it is evident from Equation (3.1) that for values of θ_j below $\cos^{-1}[1/(1 + 0.65 M_a)]$, there is no equivalent flight angle. Also, by substituting $\theta_j = 180$ degrees in Equation (3.1), the maximum value of θ_e is given by $\cos^{-1}[1/(1 + 0.65 M)]$.

4. AMPLITUDE AND FREQUENCY EFFECTS

The sound pressure levels of a static spectrum are reduced in flight by an amount given by

$$\Delta SPL = 10 \log_{10} (V_j/V_{rel})^m. \quad (4.1)$$

The velocity exponent, m is given by the relationship

$$\begin{aligned} m = & 5.4 - \tau + 4.2[1 - 0.5(V_a/V_j)] (V_j/a_0) \cos \theta_e \\ & + (V_j/a_0)^{1.3} (0.5 \cos \theta_e - 1) \sin 2\theta_e \\ & + \tau(V_j/a_0) [1 - 2(V_a/V_j) \cos^2 \theta_e] \cos \theta_e, \end{aligned} \quad (4.2)$$

where the temperature function, τ (Derivation 2) is given by

$$\tau = \frac{1.2[T_{js}/T_0 - 1]^2}{[(T_{js}/T_0) - 1]^2 + 0.05[(T_{js}/T_0) + 0.7] [V_j/a_0]^2}. \quad (4.3)$$

This latter expression from Derivation 2 is a modified version of that given in Derivation 1. The difference between the two derivations is only apparent at temperature ratios between 1.0 and 1.5, where the above equation is more consistent with jet noise theory.

The other effect of going from static to flight conditions in jet spectra is a frequency shift. The ratio of the flight to static frequencies is given by

$$\frac{f_f}{f_s} = [1 - (V_a/V_j)] [1 + 1.2\tau(V_a/V_j) \sin \theta_e] [1 + 0.2 \sin^2 2\theta_e \cos^2 \theta_e - 0.08\tau]. \quad (4.4)$$

5. CALCULATION METHOD

The method allows the prediction of flight spectra at various emission angles and propagation distances, from a database containing static jet noise spectra from a single-stream jet. The database must include jet noise spectra, at a range of sound emission angles, for the same jet operating conditions as the flight case of interest. The required database may be obtained by measurement or may be predicted using ESDU 98019 (Reference 6).

The method normalizes the static jet database to unit distance so that extrapolation to any required distance using the inverse square law can be readily performed.