LIGHTHILL'S EIGHTH POWER LAW FOR JET NOISE

By Tom Irvine
Email: tomirvine@aol.com

October 28, 2004

Introduction

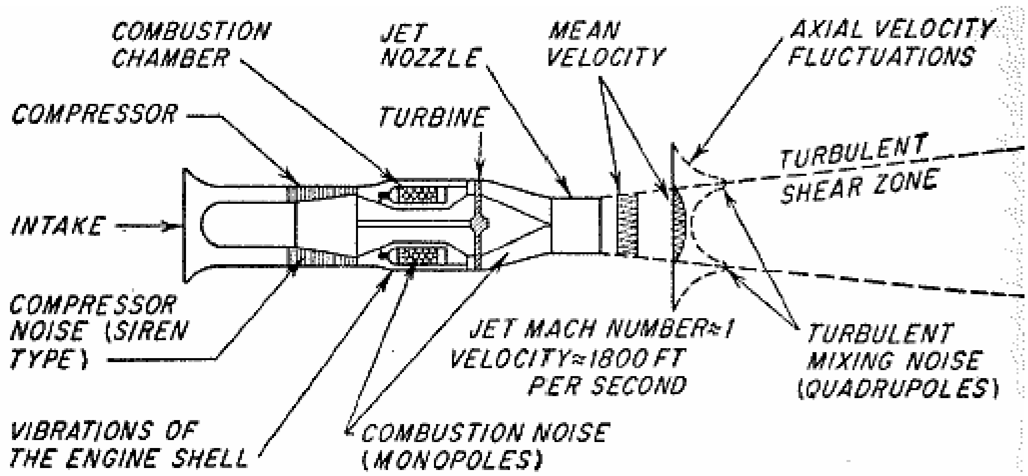

Figure 1. Turbojet Engine from 1950s Era, from Reference 3.

Turbojet engine noise sources include the compressor, turbine, combustor, and the exhaust jet.

The jet noise is significantly reduced in high-bypass-ratio turbofan engines, but the fan noise is an additional noise source.

Furthermore, the airframe itself is a noise source.

Source	Discrete Tones	Broadband Noise
Fan	Tones at various frequencies, whine and whistle	Yes
Compressor	High frequency tones	Yes
Combustor	No	Low frequency noise
Turbine	High frequency tones	High frequency noise
Jet	No	Low frequency noise, rumble and roar

Variables

- P is the acoustic pressure
- I is the intensity
- W is the radiated power
- ρ is the mean density of the gas
- C is the speed of sound in the gas
- U is the flow velocity in the source region
- L is a length scale of flow in the source region
- M is the Mach number
- A is the exhaust nozzle area

Lighthill's Scaling Formulas

Consider a high-speed, subsonic, turbulent air jet.

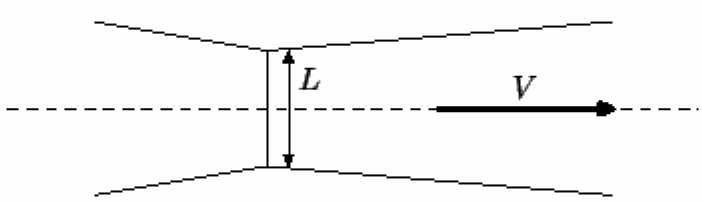

Figure 2. Parameters for Jet Noise

The acoustic pressure P is

$$P \propto \frac{\rho U^4}{c^2}\left(\frac{L}{x}\right) \qquad (1)$$

The intensity I is

$$I \propto \frac{P^2}{\rho c} \qquad (2)$$

$$I \propto \frac{\rho U^8}{c^5}\left(\frac{L}{x}\right)^2 \qquad (3)$$

The radiated power W is the intensity integrated over a spherical surface of radius x. Essentially, this is the same as multiplying the intensity by the surface area of the sphere.

Thus, the radiated sound power W is

$$W \propto \frac{\rho L^2 U^8}{c^5} = \rho L^2 U^3 M^5 \qquad (4)$$

Note that L^2 is proportional to the exhaust nozzle area A.

References

1. L. Beranek and I. Ver, Noise and Vibration Control Engineering Principles, Wiley Intersciences, New York, 1992.

2. http://www.bath.ac.uk/~ensmjc/Notes/MECH0050/html/node34.html

3. C. Harris, editor, Handbook of Noise Control, McGraw-Hill, New York, 1957. See H. von Gierke, Chapter 33, Aircraft Noise Sources.