STUDY NOTES ON OVERPRESSURE & SONIC BOOMS

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Why does the Space Shuttle Orbiter make a double sonic boom when it lands?

As a simple example, consider an aircraft flying at supersonic speeds. The aircraft typically creates two shock waves: a bow wave and a tail wave. These waves continue with the aircraft the entire time it flies at supersonic speeds.

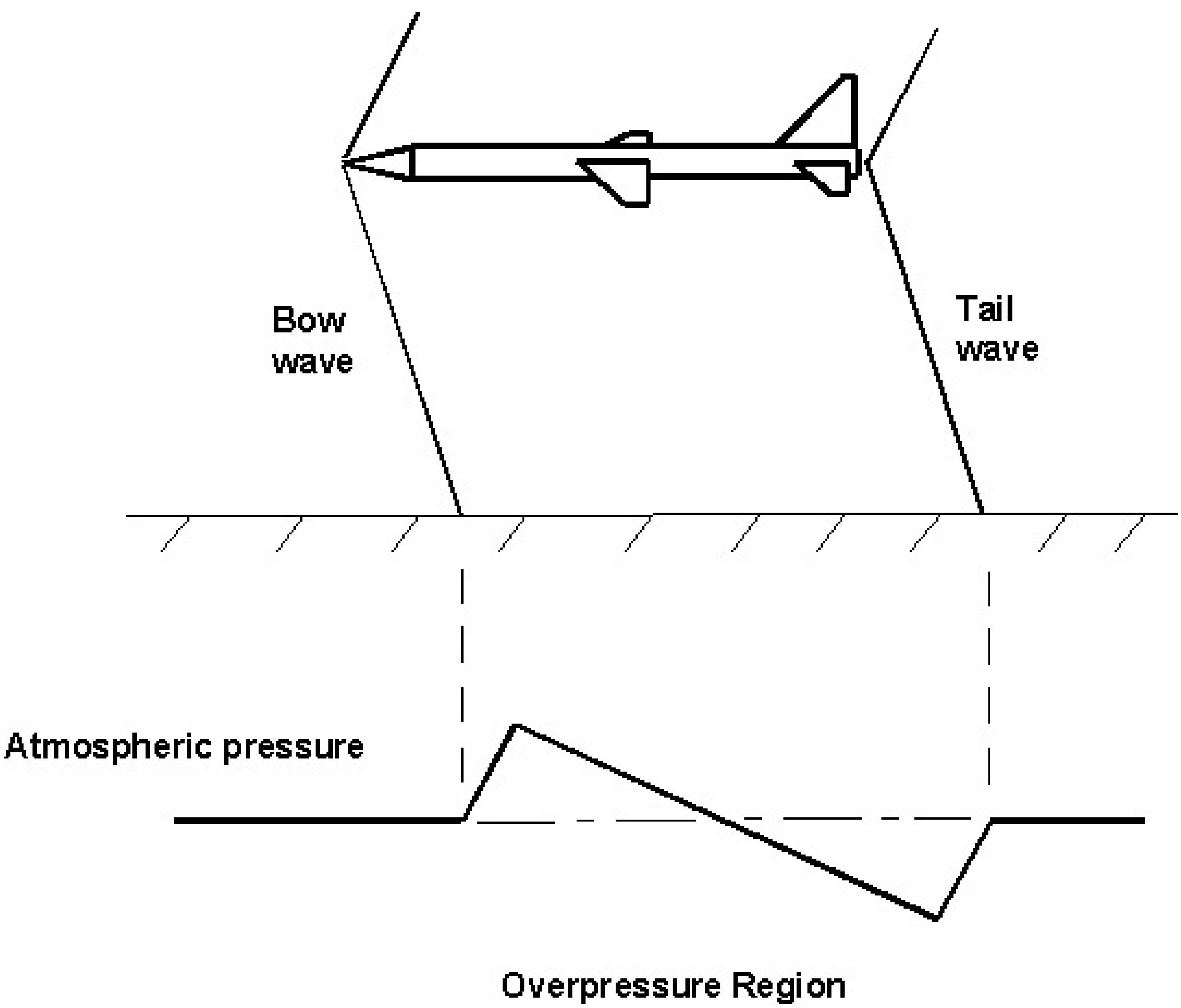


Figure 1.

Each of the two waves actually generates a cone. The two cones intersect the ground. A region of overpressure exists between the cones.

Imagine that you are standing on the ground. The air pressure is the normal atmospheric value. Suddenly, the bow wave from a supersonic aircraft comes past you. The air pressure level rises instantaneously. You hear a sonic boom as a result.

You are now between the bow wave and the tail wave. The pressure gradually decreases and even dips below the normal atmospheric value. Suddenly, the tail wave comes past you. The air pressure jumps to the normal atmospheric value. You hear a second sonic boom as a result.

Of course, all of this may happen in a fraction of a second depending on the aircraft size, aircraft speed, wind conditions, and other variables.

The aerodynamics of a landing shuttle are more complicated, but the basic principle is the same.

The space shuttle orbits the Earth at about 17,500 miles per hour, which is about Mach 25. It is traveling at this speed as it re-enters the atmosphere. It is moving at about 224 miles per hour as it touches down. The duration from touchdown to complete stop is about 70 seconds.

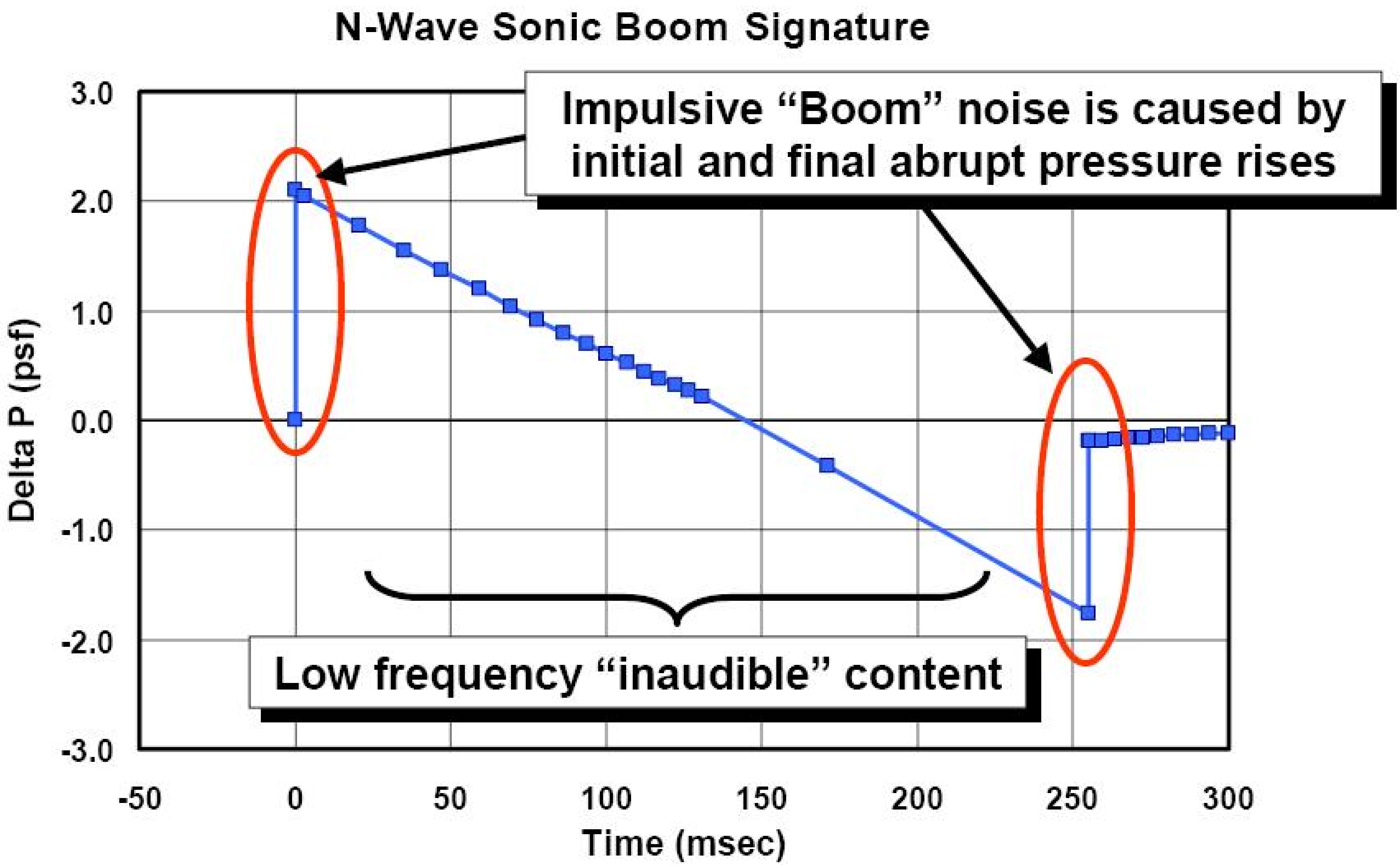


Figure 2. Sonic Boom Noise Source (Courtesy of Gulfstream)

## APPENDIX A

Overpressure

| Table A-1. Overpressure Measured at the Ground | |
|---|---|
| Overpressure (psf) | Source |
| 0.8 | F-104 at Mach 1.93 and 48,000 feet |
| 0.9 | SR-71 at Mach 3 and 80,000 feet |
| 1.25 | Space Shuttle at Mach 1.5 and 60,000 feet during landing approach |
| 1.94 | Concorde SST at Mach 2 and 52,000 feet |
| 2.0 | SR-71 at Mach 1.3 and 31,000 feet |
| 10.5 | Bolide over Williamsport, Pennsylvania, July 23, 2001 |

Table A-1 is taken from the Vibrationdata, December 2002 Newsletter.

| Table A-2. Estimated Overpressure at a Blast Wall for a Launch Vehicle with a Peacekeeper SR-118 Motor | | |
|---|---|---|
| Overpressure (psi) | Overpressure (psf) | Blast Wall Distance (feet) |
| 5.3 | 760 | 150 |
| 1.1 | 160 | 300 |

| Table A-3. Structural Failure Approximate Thresholds | | | | |
|---|---|---|---|---|
| Structural Element | Failure Mode | Peak Overpressure (side-on) | | |
| | | (psi) | (psf) | (kPa) |
| Glass Window | Shattering | 0.07 – 0.30 | 10 – 43 | 0.48 – 2.1 |
| Plexiglass or Safety Glass | Shattering | 0.5 | 72 | 3.4 |
| Corrugated Metal Siding or Paneling | Connection Failure and Buckling | 1.0 | 144 | 6.9 |
| Wood Siding Panels | Connection Failure, Panel Blown in | 1.0 | 144 | 6.9 |
| Concrete or Cinderblock Wall Panels | Shattering of the Wall | 1.5 | 220 | 10.4 |
| Brick Wall Panel, not reinforced | Shearing and Flexure Failures | 3.0 | 433 | 20.7 |

Table A-3 is taken from the Vibrationdata, December 2002 Newsletter.

The values in this table are rough approximations. The actual values depend on the structural dimensions and the quality of the materials, workmanship, and design.

APPENDIX B

Human Body

The human body is remarkably resilient to overpressure. The most sensitive part of the human body is the eardrum. The eardrum burst threshold is 2.9 psi (20 kPa). In addition, severe lung damage may occur at a higher threshold, approximately 10 psi (69 kPa). The lethal overpressure level is variable.

Overpressures as low as 28 psi (193 kPa) have been estimated to be lethal, but survival is possible with overpressures as high as 38 psi (262 kPa).