Welcome to
Vibrationdata.com

Acoustics • Shock • Vibration • Signal Processing

December 2002 Newsletter

Pax Vobiscum

May peace be with you throughout the coming new year.

The August 2001 newsletter featured an article on sunquakes, as caused by solar flares collapsing into the Sun's surface. The resulting sunquakes consist of transient waves.

To explore helioseismology further, this month's newsletter presents an article on standing waves that are generated by turbulence in the Sun's convection zone.

The second article discusses the overpressure effects from nuclear weapons blast. The image on the right is taken from the film Dr. Strangelove, which is arguably the greatest black comedy ever made. One of the early scenes in this film showed a sign at a fictional air force base. The sign displayed the real-life motto of the Strategic Air Command, "Peace is our Profession."

Sincerely,

Tom Irvine

Tom Irvine
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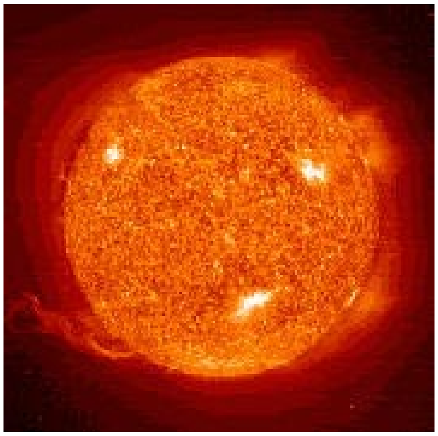
Feature Articles



Welcome to Vibrationdata Consulting Services

Vibrationdata specializes in acoustics, shock, vibration, signal processing, and modal testing. The following services are offered within these specialties:

1. Dynamic data acquisition
2. Data analysis and report writing
3. Custom software development and training
4. Test planning and support

Vibrationdata also performs finite element analysis.

Vibrationdata's Customers

Allied-Signal Fluid Systems and Turbine Engine Divisions

Boshart Automotive

Delphi Automotive

Dynacs Engineering

Dynamic Labs

ECS Composites

Itron

Motorola Flat Panel Display

Motorola Government Electronics Group

Orbital Sciences Corporation

Prolink

SpeedFam

Sumitomo Sitix

Three-Five Systems

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Helioseismology By Tom Irvine

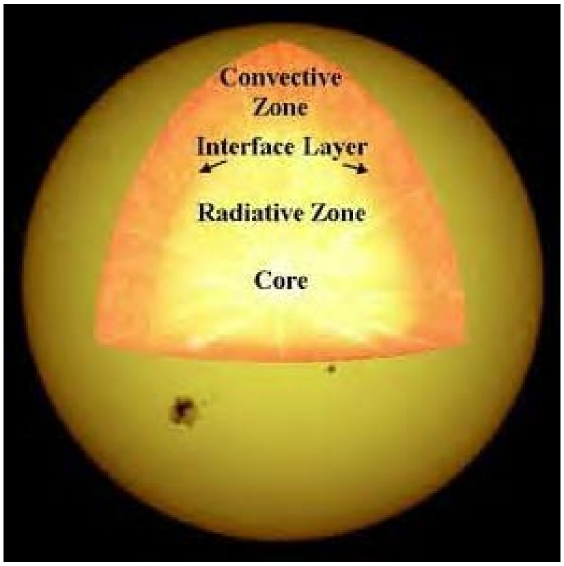

Figure 1-1. The Sun's Layers

Introduction

The Sun is a spherical resonator, or resonant cavity, with millions of oscillation modes. These modes are excited by turbulence in the Sun's convection zone, where the gas flows are driven by temperature gradients. A diagram of the convection zone is shown in Figure 1-1. The predominant oscillation has a period of nearly five minutes.

Measurement

The oscillation modes are measured using the Doppler shifting of light emitted at the Sun's surface. Measurements are taken at the following solar observatories:

- Big Bear
- Learmonth
- Udaipur
- Del Teide
- Cerra Tololo
- Mauna Loa

Additional measurements are taken by the Michelson Doppler Imager (MDI) on the Solar and Heliospheric Observatory (SOHO) spacecraft.

Wave Types

The oscillation modes consist of standing waves that propagate throughout the Sun. There are three types of waves: acoustic, gravity, and surface gravity waves.

Helioseismologists use the properties of these waves to determine the temperature, density, composition, and motion of the interior of the Sun.

Acoustic Waves

Pressure is the restoring force for acoustics waves.

Acoustic waves generate p-modes, which are the source of the 5-minute oscillation mentioned previously. The corresponding frequency is approximately $3400\,\mu\mathrm{Hz}$, as shown in Figure 1-2.

The acoustic waves tend to originate at the Sun's surface. The waves then travel radially inward. The temperature increases as the depth increases. Note that the speed of sound increases with the square root of temperature. This condition causes the acoustic waves to bend back toward the surface, as shown in Figure 1-3. This bending is a form of refraction.

Gravity Waves

Buoyancy is the restoring force for gravity waves.

Gravity waves generate g-modes, with frequencies around 100 $\mu\mathrm{Hz}$ and below. These modes are created by the turbulent motions at the base of the convection zone.

The g-modes are predominant at the Sun's core.

Surface Gravity Waves

The surface gravity waves generate f-modes, or fundamental modes.

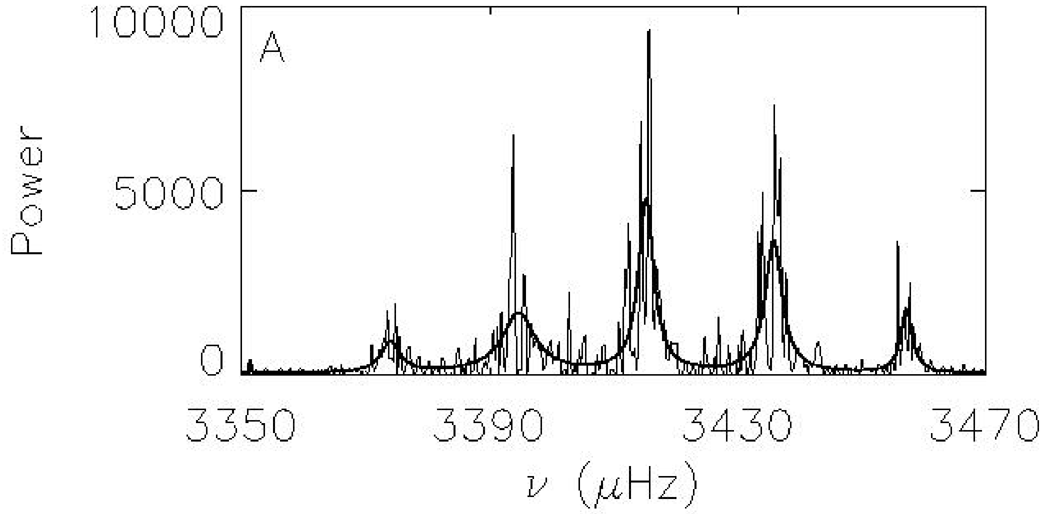

Figure 1-2. Power Spectrum of the Sun's Oscillation Modes

Data courtesy of P.B. Stark, University of California Berkeley.

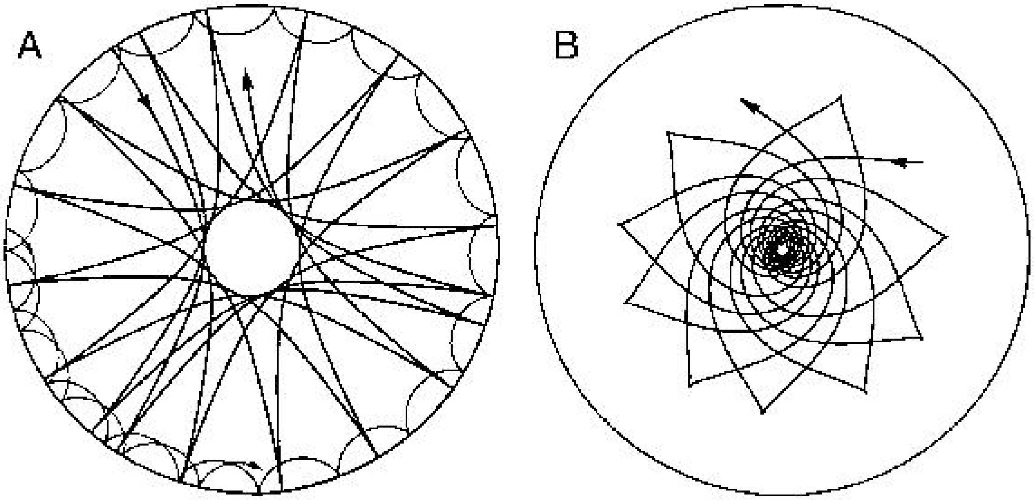

Figure 1-3. Ray Paths

The diagrams are taken from the Global Oscillation Network Group (GONG) website. See Gough, Leibacher, Scherrer, and Toomre, *Science*, *272*, 1281-1283. The left figure shows ray paths associated with two p- modes. The right shows the ray path associated with a g-mode.

Nuclear Weapons Blast Overpressure

By Tom Irvine

Introduction

A nuclear bomb explosion generates a high-pressure wave, which moves radially outward.

The front of the wave is called the shock front. The shock front is a wall of highly compressed air that travels at a supersonic speed. Hurricane-like wind follows the shock front. Both the shock front and the following winds may damage or destroy structures.

Nuclear blast waves differ from those produced by conventional chemical explosives due to their long duration and large overpressures.

Static Overpressure

Static overpressure is the pressure in excess of the ambient atmospheric pressure. The overpressure may be either positive or negative with respect to this reference. The static overpressure travels with the blast wave at supersonic speeds.

Dynamic Pressure

Dynamic pressure is the pressure due to the wind generated by the blast. It depends on the wind velocity and the air density behind the shock front. Dynamic pressure is always positive. Furthermore, the wind creates drag forces on structures.

The wind velocity can range from a few miles per hour to hundreds of miles per hour. The velocity depends on the yield of the weapon, height of the burst, and distance from the point of detonation.

Structural Damage

A diagram showing the blast pressure effects on a structure is shown in Figure 2-1. Time history plots for each pressure mechanism are shown in Figure 2-2, as measured at a fixed location.

Damage potential as a function of pressure amplitude is shown in Table 2-1.

Blast Wave Propagation

The following example is taken from Fundamentals of Aerospace Weapon Systems, published by the Air Force ROTC, Air University.

Consider the airburst of a 1-megaton nuclear bomb. The fireball will attain its maximum expansion of 7200 feet across at about 10 seconds. The shock front initially lags behind the surface of the developing fireball. The shock front, however, will be 3 miles beyond the fireball at 10 seconds. The shock front will reach a distance of 12 miles at 50 seconds, after the fireball is no longer visible.

The final distance reached by the shock front depends on the explosion magnitude and the height of the burst.

The pressure amplitude of the blast wave diminishes at the wave expands. The intensity decreases approximately as the square of the distance, as the wave expands radially.

The speed of propagation also decreases from the initial supersonic velocity to that of sound in the transmitting medium.

Furthermore, some sources claim that the dynamic pressure tends to decrease more rapidly with distance than does the shock overpressure. Other sources report the converse. The answer for a given situation may depend on the explosive yield, airburst height, and other variables.

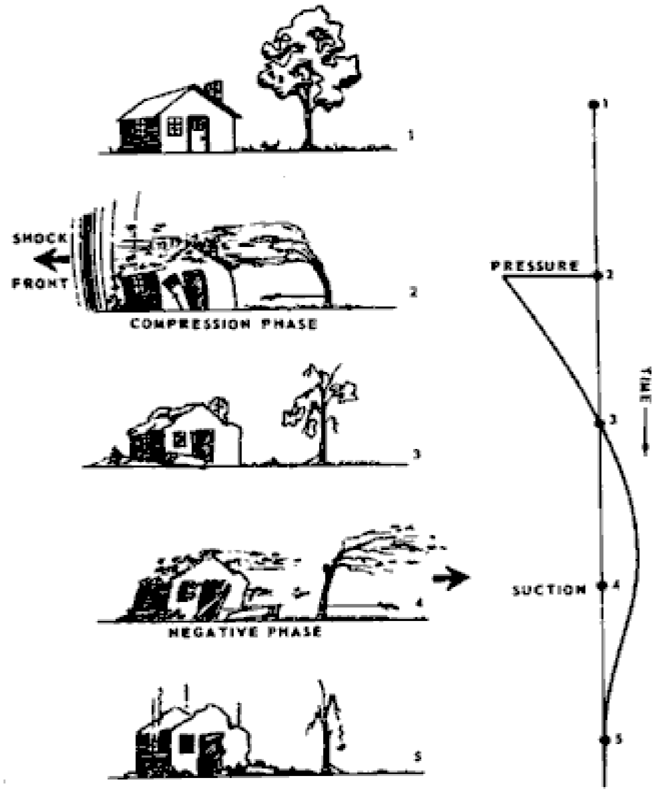
1
SHOCK
FRONT
2
COMPRESSION PHASE
3
4
NEGATIVE PHASE
5
PRESSURE
SUCTION
TIME

Figure 2-1.

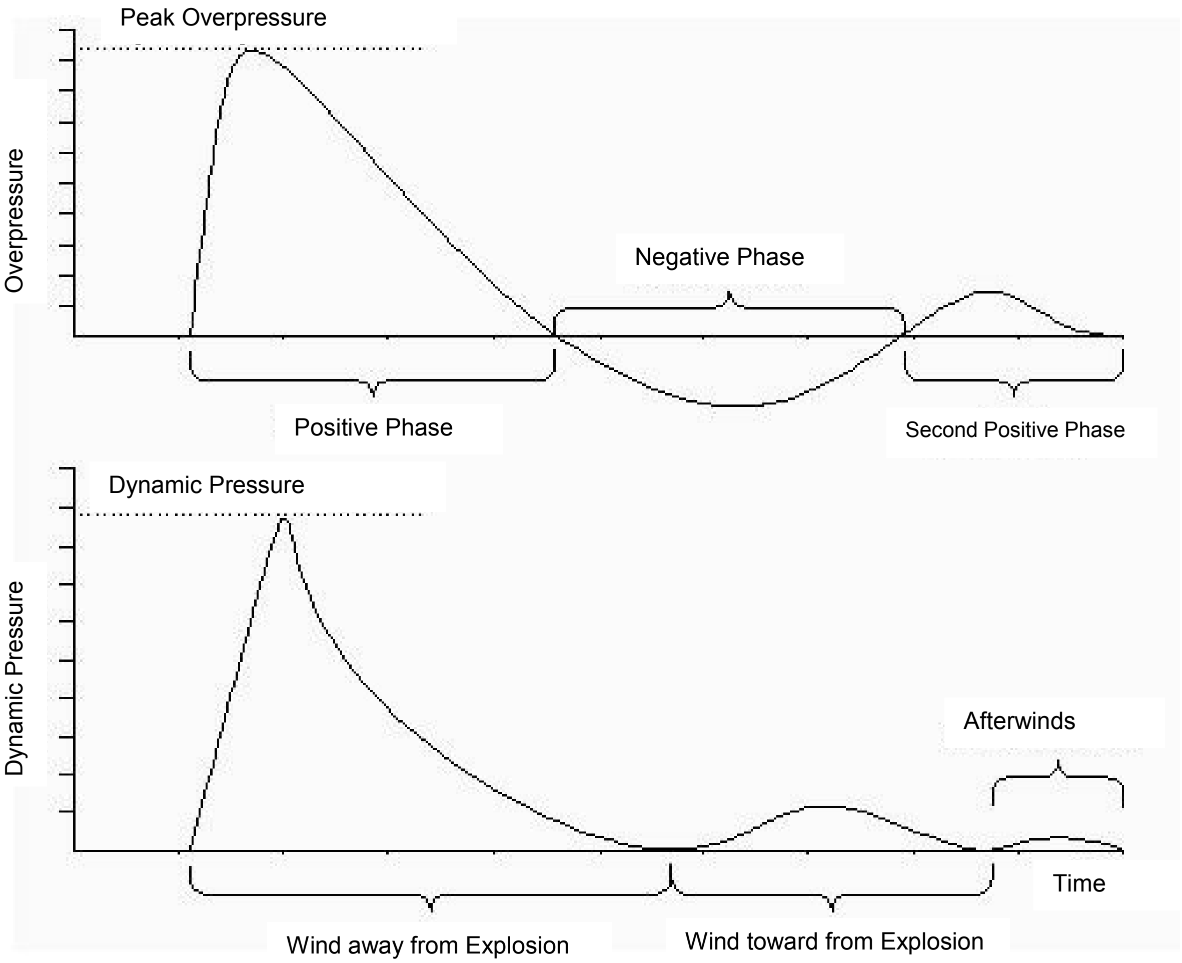
Peak Overpressure
Overpressure
Negative Phase
Positive Phase
Second Positive Phase
Dynamic Pressure
Dynamic Pressure
Afterwinds
Time
Wind away from Explosion
Wind toward from Explosion

Figure 2-2.

Table 2-1. 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 Cinder-block 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

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.

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).

Further threshold data is given in the following references:

http://www.aescalgary.com/QRAChapter5.pdf

http://www.fas.org/nuke/guide/usa/doctrine/dod/fm8-9/1ch3.htm

http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/1-111/app-c.htm

http://ast.faa.gov/lrra/environmental/coop/aitea/AppC1.htm

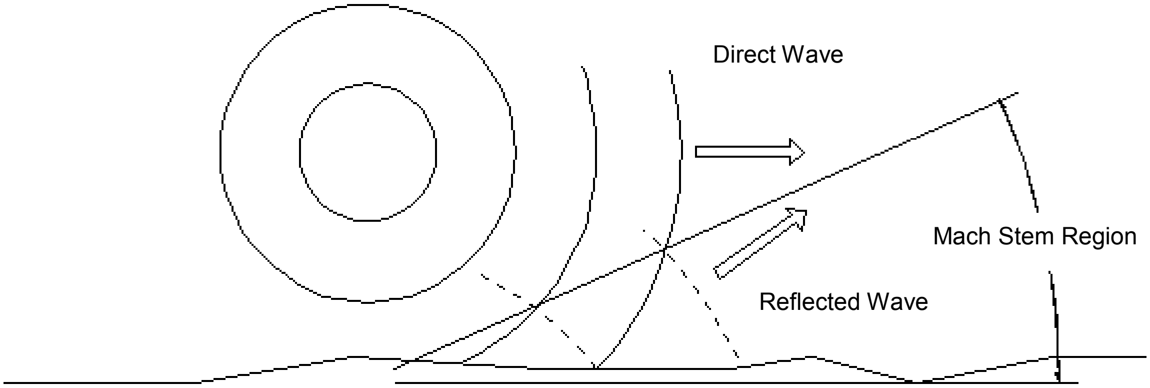

Figure 2-3.

Mach Effect

The expanding blast wave from a nuclear airburst strikes the surface of the earth, generating a reflected wave.

The reflected wave reinforces and intensifies the primary wave, as shown in Figure 2-3.

A single shock wave may thus be formed from the incident and reflected waves. This is called a Mach reflection.