SHOCK WAVES AND EXPLOSIVES GLOSSARY

Activation Energy: The minimum amount of energy which must be supplied to a chemical system to initiate a chemical reaction.

Acoustic impedance: The shock impedance in the limit of an infinitesimal disturbance. Independent of pressure.

Adiabatic: A process for which there is no heat transfer between a system and its surroundings. An adiabatic process that is reversible is isentropic. Contact discontinuity: A spatial discontinuity in one of the dependent variables other than normal stress (or pressure) and particle velocity. Examples such as density, specific internal energy, or temperature are possible. The contact discontinuity may arise because material on either side of it has experienced a different loading history. It does not give rise to further wave motion.

Adiabatic Flame Temperature ($T_0$ for a gun propellant): The maximum temperature ideally achievable during combustion under adiabatic conditions.

Arrhenius Equation: An important equation in physical chemistry which expresses the way in which the rate constant of a chemical reaction is influenced by temperature.

Binder: A wax, resin or polymer used to aid consolidation of a powdered explosive composition. Mostly used in pyrotechnics.

Booster: Any component of an explosive train which is interposed between the initiator and the main charge.

Bose-Einstein Statistics: A counting method used in quantum statistical mechanics that allows an unlimited number of particles (bosons) to occupy a single state. This applies to phonons and particles with zero and integer-valued spins.

Brisance: The shattering property exhibited by a detonating explosive.

Burning: The propagation of combustion by a surface process.

Cap: A small metal container filled with a flame-producing explosive composition.

Case-bonding: The gas-tight adhesion of a rocket propellant grain to the walls of the combustion chamber of the motor.

CJ (Chapman-Jouguet) Model: The simplest model of planar steady detonation, in which the exothermic chemical reaction is assumed to be instantaneous.
**Combustion**: An exothermic oxidation reaction producing flame, sparks or smoke. The oxidant may be part of the material as in a propellant, or oxygen from the atmosphere or other source.

**Conservation equations**: Expressions that equate the mass, momentum, and energy across a steady wave or shock discontinuity. Also known as the jump conditions or the Rankine-Hugoniot relations.

**Constitutive relation**: An equation that relates the initial state to the final state of a material undergoing shock compression. This equation is a property of the material and distinguishes one material from another. In general it can be rate-dependent. It is combined with the jump conditions to yield the Hugoniot curve which is also material-dependent. The equation of state of a material is a constitutive equation for which the initial and final states are in thermodynamic equilibrium, and there are no rate dependent variables.

**Cook-off**: The initiation of an enclosed explosive by the conduction of heat through its container. Applicable to, for example, munitions exposed to conflagrations, or to live cartridges left loaded in hot guns.

**Coolant**: A substance added to propellants to reduce the flame temperature and hence the rate of burning.

**Corresponding States**: The scaling of thermodynamic variables of liquids by taking the ratio of their values in the liquid to those at their critical point.

**Covolume**: A correction applied to the equation of state to take account of the fact that at very high pressures (e.g. in a gun) the molecules of a gas occupy a finite volume. Each propellant has a slightly different covolume figure, measured in volume per unit mass.

**DDT (Deflagration-to-Detonation Transition)**: The mechanical compaction and reaction build-up processes that an explosive goes through to make the transition from deflagration (burning) to detonation.

**Deflagration**: A rapid burning in which convection often plays an important role.

**Delay**: A device incorporated into an initiation system so as to time the explosive event. Usually a pyrotechnic composition.

**Density**: The mass per unit volume of a material. The reciprocal of specific volume.

**Detonation**: An extremely fast explosive decomposition, in which an exothermic reaction wave follows and also maintains a shock front in the explosive.

**Detonation Pressure**: The dynamic pressure in the shock front of a detonation wave.
**Detonator**: An explosive device for starting detonation. It is small in size and may be designed for initiation by one of several methods, e.g. stabbing.

**Diameter-Effect Curve**: The relation between steady 2D detonation velocity and the lateral charge size.

**Diamond-Anvil Cell (DAC)**: A technique that employs a set of opposing diamonds to obtain measurements of the EOS and optical properties of materials at high pressure.

**Electron-Band Theory**: A generic term for the collection of methods used in solving the quantum-mechanical (Schroedinger) equations for electrons in a lattice.

**Equation of state**: An equation that describes the properties of a given material, and distinguishes one material from another. It defines a surface in thermodynamic variable space on which all equilibrium states lie. In shock-wave applications, the initial and final states are frequently assumed to lie on the equation of state surface, and this equation can be combined with the jump conditions to define the Hugoniot curve which is material specific.

**Eulerian co-ordinates**: The co-ordinate system in which the spatial position (X) and time (t) are the independent variables. The dependent variables are expressed as functions of x as material moves through space. Also known as laboratory co-ordinates when the reference frame is that of an observer.

**Eutectic**: A mixture of two or more materials in the proportions which give the lowest melting point.

**Exothermic**: Giving out heat energy.

**Explosion**: A violent expansion of gas.

**Explosiveness**: The rate at which a particular explosive, when exposed to a given stimulus, gives up its energy, and/or the degree to which it does so.

**Explosive Power**: The work capacity of an explosive, usually referring to high explosives. It is not the rate of doing work, although in practice the rate may affect the experimental measurement of values. Explosive power can be calculated as a percentage of the work done by a standard explosive (commonly picric acid or blasting gelatine) on the basis of the amount of heat and gas generated.

**Explosive Train**: An arrangement used to lead explosive reactions from one place to another. The distance may be minimal, e.g. the assembly of fuze detonator, magazine, exploder and main charge in a shell or bomb. Alternatively it may be
spread over a distance, e.g. by using detonating fuze in a demolition. Regardless of its dimensions, an explosive train may be one of two kinds - igniferous or disruptive.

**Failure Radius:** The radius of a cylindrical explosive charge below which it is impossible to propagate a steady detonation.

**Fermi-Dirac Statistics:** A counting method used in quantum statistical mechanics that allows no more than one particle (fermion) to occupy a single state. This applies to electrons and particles with half-odd integer-valued spins.

**Force, or Force Constant:** The work capacity of an explosive, usually applied to gun propellants. It can be calculated for high explosives or propellants and in the case of the latter it can be determined experimentally by the use of the Closed Vessel.

**Form Function:** The mathematical function describing how the surface area of a propellant grain of particular shape changes in the course of combustion.

**Fragmentation:** The shattering effect of an explosive upon its container, e.g. fragmentation of a shell case by its explosive filling.

**Friction Test:** A test to assess the susceptibility of the explosive to initiation by friction.

**Fuze:** (a) Cord or tube for the transmission of detonation or flame. (b) A compact, engineered assembly of explosive components, including safe-arm devices, as a means of initiating a munition.

Note: The spelling FUZE has been standardised in British service literature for items under both definitions. Most other literature uses FUSE for items under a and b.

**Gruneisen Constant:** Ratio of the logarithmic derivative of the Debye temperature to that of the volume. Used to calculate the thermal properties of a solid.

**Heat Capacity:** The amount of heat absorbed by a substance when its temperature is raised by 1K. The unit of substance may be one of mass, giving a 'specific heat capacity'.

**Heat of Explosion:** The amount of energy released when one mole or unit mass of explosive burns or detonates under adiabatic conditions.

**Heterogeneous Explosive:** A material in which the release of chemical heat is controlled by local high-temperature and -pressure regions at flow irregularities ("hot spots").

**High Explosive:** An explosive which is capable of detonation under the normal conditions of use.
**HMX**: A nitramine secondary high explosive similar to RDX but with a higher performance. Also called Octogen or tetramethylene tetranitramine.

**HNS**: Hexanitrostilbene. A secondary high explosive used in special applications.

**Homogeneous Explosive**: A material in which the release of chemical heat is controlled by the bulk temperature and pressure.

**Hot Spots**: Localised regions in a shocked explosive where energy is concentrated by fluid-flow irregularities in the vicinity of physical imperfections. This is relevant to mechanisms of initiation.

**Hugoniot curve**: A curve representing all possible final states that can be attained by a single shock wave passing into a given initial state. It may be expressed in terms of any two of the five variables: shock velocity, particle velocity, density (or specific volume), normal stress (or pressure), and specific internal energy. This curve is not the loading path in thermodynamic space.

**Impact Test**: A test to assess the susceptibility of the explosive to initiation by impact.

**Incendiary**: A pyrotechnic composition designed to give a large steady heat output to cause fire or damage structural materials.

**Initiator**: A device for detonating explosives or pyrotechnics, commonly a detonator.

**Insensitiveness, Figure of (F of I)**: A figure relating to a particular explosive which indicates its comparative insensitiveness to mechanical impact as determined in the Rotter Test. The higher the figure, the less sensitive is the explosive to this form of initiation.

**Intermediary**: An explosive of which the sensitiveness to initiation by impact or shock wave is intermediate between that of primary explosives and secondary explosives.

**Isentropic**: A reversible adiabatic process, in which there is no change in the entropy of the system.

**Jump conditions**: Expressions for conservation of mass, momentum, and energy across a steady wave or shock discontinuity ((2.1)-(2.3)). Also known as the conservation equations or the Rankine-Hugoniot relations.

**Kistiakowsky - Wilson Rules (K-W Rules)**: A set of empirical rules for calculating approximately the composition of the gaseous products of a high explosive.
Lagrangian co-ordinates: The co-ordinate system in which the material position (h) and time (t) are the independent variables. The dependent variables are described as functions of a particle position within the material which had co-ordinate \( x = h \) at time \( t = 0 \). Also known as material co-ordinates.

Lattice Dynamics: Refers to the vibrations of atoms in a solid about their equilibrium positions and the effect of these vibrations on the properties of the solid.

Local-Density Approximation: The simplification made in atomic and molecular physics for replacing the complicated electron exchange and correlation energies by simple free-electron-gas expressions.

LVD (Low-Velocity Detonation): A low-level reactive wave in an explosive that is dependent on the existence of non-reactive precursor waves. LVD is not a true detonation.

Mie-Gruneisen Equation: An equation of state of the solid that employs the Gruneisen constant to calculate the thermal contribution to the pressure.

Molar (or Universal) Gas Constant: A constant which appears in the equation of state for a perfect gas, viz. \( PV=RT \). Its value is the same for all gases.

Molecular Dynamics: Computer simulation of molecular properties using numerical integration methods to solve Newton's equations for \( N \) interacting particles.

Monte Carlo Method: Computer simulation of molecular properties using stochastic methods.

Munroe Effect (or Neumann Effect): A local concentration of shock wave energy which occurs when the wave emerges from a detonating charge via a re-entrant shape in the charge surface.

Oxygen Balance: For an explosive containing the usual elements carbon, hydrogen, nitrogen and oxygen, it is the percentage by weight of oxygen, positive or negative, remaining after combustion, assuming that all the carbon and hydrogen is converted into carbon dioxide and water.

Particle velocity: The velocity associated with a point attached to the material as it flows through space.

PETN: Pentaerythritol Tetranitrate, a secondary high explosive used as the filling for detonating cords and as a booster in detonating explosive trains.

Phase Diagram: A convenient method of representing the stability regions of solid, liquid, gas, and plasma under the various conditions of temperature and pressure.
**Pressure of Combustion (or of Explosion)**: The maximum static pressure produced when a given weight of high explosive or propellant is burned, without detonating, in a closed vessel of given volume.

**Primary Explosive**: An explosive which is readily ignited or detonated by a small mechanical or electrical stimulus.

**Propellant**: An explosive used to propel a projectile or missile, or to do other work by the expansion of high pressure gas produced by burning, e.g. for starting engines.

**Pyrotechnic**: A material capable of combustion when correctly initiated to provide a special effect. They are usually mixtures of fuel and oxidiser.

**Quickness**: A measure of both the pressure generated in a confined space by a propellant of given composition and grain shape, and the speed with which the pressure is produced. Effectively the product of force constant and vivacity.

**Rate of Burning**: (a) The rate of regression of the burning surface of an explosive, usually a propellant grain, in length per unit time, under given conditions of pressure and grain temperature. Designated \( r \) and sometimes referred to as the 'linear rate of burning'.
(b) The rate of consumption of a burning explosive, usually a propellant, in terms of mass per unit time.

**Rayleigh line**: A chord that connects the initial state of a material on its Hugoniot curve to the final state on the curve. Most frequently drawn in the P-V plane.

**RDX**: A secondary high explosive also called Cyclonite or trimethylenetetranitramine. Much used in high explosive formulations, for example: RDX/TNT or RDX/wax.

**Riemann Invariant**: A constant which is independent of position on a rarefaction wave that propagates into a uniform state.

**Rarefaction wave**: A wave that reduces the normal stress (or pressure) inside a material as it propagates; the mechanism by which a material returns to ambient pressure after being shocked (the state behind the wave is at lower stress than the state in front of it). Also known as unloading, expansion, release, relief, or decompression waves.

**SDT (Shock-to-Detonation Transition)**: The reaction build-up process that an explosive goes through to make the transition from a shock input to detonation.

**Secondary Explosive**: An explosive which can be made to detonate when initiated by a detonation wave or other shock front but which does not normally detonate when heated or ignited.
Sensitiveness: A measure of the relative ease with which an explosive may be ignited or initiated by a particular stimulus.

Shaped Charge: This term usually implies some application of the Munroe effect in the geometry of a HE charge.

Shock Impedance: Defined as $Z = p U$. Describes the ability of material to generate pressure under given loading conditions. Generally a function of pressure.

Shock velocity: The velocity of the shock wave as it passes through the material. In the limit of an infinitesimally small shock wave it is equal to the bulk sound speed of the material.

Steradian: Unit solid angle; there are $4\pi$ steradians in a sphere.

Stoichiometric Mix: A mixture of chemical reactants in which the quantities of each component are such that they are balanced and all material reacts.

Stoichiometry: The relative quantities of components in a reacting system.

Strand Burner: A device for measuring experimentally the rate of regression of the burning surface of a length of propellant, burning endwise at a fixed pressure.

Superdetonation: A detonation that occurs in an explosive precompressed by an initial shock.

Taylor Wave: The pressure-relief wave (rarefaction) following a planar steady detonation.

Temperature of Ignition: The temperature at which an explosive ignites under specified conditions, e.g. the rate of heating.

Tetryl: A secondary high explosive used as a booster in detonating explosive trains.

Thermal Explosion: Explosion resulting from exothermic reaction in an explosive charge in a region where heat is liberated more rapidly than it can be transferred.

Thermite: A generic term for pyrotechnic compositions used to fill incendiary bombs.

Thermite Composition: A mixture of metal powder and a metal oxide providing heat in a gas-less reaction.

Thermitic Reaction: Usually the reaction between a metal powder and metal oxide in a pyrotechnic composition.
TNT : Trinitrotoluene, an insensitive secondary high explosive used in combination with RDX.

van der Waals Equation: The first quantitatively successful equation of state that described the liquid-vapour branches of the phase diagram.

van der Waals Forces: Weak long-range interactions between neutral molecules.

Velocity of Detonation: This is the speed at which a detonation wave progresses through an explosive. When, in a given system, it attains such a value that it will continue without change, it is called the Stable Velocity of Detonation for that system.

Vivacity: The way in which a gun propellant charge of given composition and grain dimensions behaves in respect of its mass burning rate during combustion under adiabatic conditions. Experimental determination is necessary and employs the Closed Vessel.

von Neumann Spike: The leading (high-pressure) point in the ZND model of planar steady detonations (sometimes referred to as the chemical peak).

ZND (Zel'dovich, Von Neumann, Doering) Model: The simplest model of planar steady detonation with a resolved chemical-reaction zone.