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Number 5

GROWTH OF BURNING TO DETONATION IN LIQUIDS AND SOLIDS

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(a) Summary of Work

A detailed investigation is being made of deflagration and growth to detonation in liquids and solids with special reference to the role of small discontinuities in promoting sensitivity, and the Deflagration, Detonation Transition. The various aspects of the work are discussed separately.

(1) Liquid Explosives

As mentioned in Scientific Report Number 5, we are studying the growth of burning to explosion in a homogeneous thin film of nitroglycerine (about 0.1mm thick and 3 cm in diameter) which is confined between two solid discs and initiated at its centre by an electric spark. Reaction grows from the initiation site first as an accelerating burning, which advances into a region of bubble-free liquid that is under high pressure generated by the central burning. This homogeneous region of liquid is surrounded by a region in which the liquid is in tension and contains bubbles. These bubbles are produced by the action of precursor waves which are generated in the confining solids by the developing burning and travel ahead of the flame. The reaction continues to grow as a burning so long as it is surrounded by homogeneous bubble-free liquid. As soon as the flame is able to penetrate into the zone of bubbles, the burning, which has reached only a few hundreds of metres per second, transforms rapidly into a much faster and more powerful explosion. The explosion is able to propagate readily through the zone of bubbles at well over 1,000 m/sec. Discontinuities in the liquid therefore play an important part both in the transition from burning to explosion and in the propagation of the explosion.

(2) Explosive Crystals

Standard shocks have been applied to single crystals of P.E.T.N., R.D.X., H.M.X., and silver azide by explosive detonators separated by thin baffles from the crystals under study. The processes leading to fragmentation, deflagration and detonation have been followed at microsecond framing rates using a Beckman and Whitley high-speed camera. The shock strengths are found either by using piezocrystals or by measuring separately shock velocities in water or lucite.

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The study so far has shown the importance of habit imperfections in determining the sites at which deflagration starts. The imperfections, which may be either crystallographic notches or steps, are to some extent controllable. The crystals are always examined by optical microscopy before use. In this way information is being assembled about the size of defect required to promote sensitivity for a given shock strength.

(3) The Fracture of Inert Solids

As explained in earlier reports it has been observed that with single crystals of explosives intense fragmentation often occurs before deflagration starts. To help in the understanding of this stage research on the fracture of inert crystals is in progress. Fracture is followed both by high-speed photography, and an ultrasonic technique. This latter technique has been described in some detail in earlier reports. It consists essentially of passing a high frequency (say 5×10^6 c.p.s beam of ultrasonics through the materials at the same time as the fracture is developing. If the ultrasonics beam is of sufficient power a faint ripple is put onto the fracture surface; the spacing of the ripples gives a measure of the velocity of fracture since the frequency of the ultrasonics waves is accurately known.

An initial form of the apparatus gave encouraging results, but it was clear that a more powerful power unit to drive the crystal would help. A 500 watt unit has been designed and assembled, and is now being used.

The present fracture work is with magnesium oxide and lithium fluoride. (Earlier work has been with glasses, hard polymers, sapphire and diamond.) The maximum velocities of cleavage in all these materials have been recorded; this is of theoretical interest. The appearance of a fracture surface varies markedly along its course. Factors which affect the surface markings include the dislocation density of the material, the velocity of fracture and stress waves.

(4) Theoretical

The theoretical work is still concerned with studies of the explosion process from the viewpoint of thermal explosion theory. It covers initiation by hot spots of various geometries corresponding to initiation by light, hot wires, plates and spheres and the arrival of a shock wave at an impedance discontinuity. In addition an exhaustive literature survey of thermal explosion theory is in progress.

(b) Difficulties Encountered

No major difficulty is being encountered at present, though synchronisation of events in the camera work can cause occasional headaches. Also in the ultrasonic work, although the ideas behind it are essentially simple, it does involve work at high prequencies (5×10^6 c.p.s.), which creates several problems. The main problem is getting the full power from the power unit onto the crystal. This involves very careful matching of impedance and tuning of frequencies.

(c) Research Plans

1. Liquid Explosives

A continuation of the present work using sparks as low energy ignition sources. Also an investigation of the effects of different degrees of confinement using various solid materials as confining plates.

2. Solid Explosives

(i) Thin films of powder and single crystals of solid explosives and propellants to be studied using the methods described above for liquids.

(ii) Continuation of present work on initiation of deflagration and growth to detonation in single crystals of primary and secondary explosives, with special attention to importance of habit perfection and fracture (see above).

(iii) It is hoped to extend the work shortly to a study of the initiation of solid explosives by intense, short duration flashes or electro-magnetic radiation (U.V., visible, infra-red) using various light sources including lasers. This work could yield valuable information on the high temperature reaction kinetics of explosives. The effects of dopes, dyes and other additives will be investigated.

(iv) A continutation of the theoretical work outlined in section (a).

3. Inert Crystals

(i) The future programme of fracture work involves finding out more about the stresses which exist at the tip of propagating cracks.

(ii) A continuation of the studies of fracture initiation by using stress pulses of very short duration.

(d) Inventions

No inventions have been made during the period of the grant.

(e) Personnel, Conferences and Travel

No personnel changes.

Dr. M. P. McOnie and Dr. T. Boddington to attend the A.F.O.S.R. combined Contractors Meeting on Combustion Dynamics Research, Patrick Air Force Base, Florida, 1-4 June 1965. Dr. M. P. McOnie to present a paper.

31st May, 1965