SHOCK WAVES IN SOLIDS[1]

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INTRODUCTION

Shock waves have been important in military and industrial technology at least since the invention of blasting powder. Theorizing about them dates as far back as Rankine's classical memoir of 1870.[2] Yet only now, with improved techniques and instrumentation, are the interactions between shock waves and matter beginning to play a serious research role. The reasons for such long delay in exploiting a potent research avenue are not difficult to understand.

Requirements on instrumentation for shock-wave research are rigorous indeed; and carrying out work with high explosives calls for both isolation and considerable expense (Fig. 1). But probably the most serious barrier has been the paralysis that overtakes the inexperienced mind when it is faced with an explosion. This prevents the novice from recognizing an explosion as the orderly process it is. Like any orderly process, an explosive shock can be investigated, its effects recorded (Fig. 2), understood, and used. The rapidity and violence of an explosion do not vitiate Newton's laws, nor those of thermodynamics, chemistry, or quantum mechanics. They do, however, force matter into new states quite different from those we customarily study. These provide stringent tests for some of our favorite assumptions about matter's bulk properties.

BROAD ACCOMPLISHMENTS AND APPLICATIONS

Although the laboratories devoted to shock-wave work are very few, their research accomplishments in the last dozen years already are impressive, and the range of applications opened to further development is very broad. Transient pressures as high as 9 million atmospheres have been achieved; this is three times greater than the pressure at the earth's core, and about 18 times higher than the pressure that can be reached in static pressure-generating equipment (Tilsen, 1962). Shock pressures of such magnitude drastically change electronic energy levels in solids, rearrange atoms in lattices, and alter the equilibrium partition of energy in substances.

Thus, such pressures—applied almost instantaneously, and under controlled conditions—have yielded fundamental thermodynamic data (known as equation-of-state data) essential to every science for over two hundred materials at pressures where data could not be obtained by any other means. Changes in crystal structure (such as the familiar graphite-diamond transition)—permanent in some materials, transient in others—have been induced by shock.

Shocks change electrical conductivity too, almost magically making conductors out of such insulators as sulfur and paraffin. Shocks also release electrical charges from piezoelectrics, ferroelectrics, and many insulator materials, producing measurable currents in an external circuit; this effect is already the basis of new developments in transducer materials and applications.

Shocks harden metals and create and alter

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[1] *Editor's note:* This article, which provides an excellent introduction to shock waves, is a revision of an article published in *International Science and Technology* for April, 1963 (no. 16, p. 45–52), when the author was affiliated with Poulter Laboratories of the Stanford Research Institute. We are deeply grateful to Conover-Mast Publications, Inc., and to Robert Colborn, Editor of *International Science and Technology,* for permission to republish the article in this volume. Thanks are also due to Professor Duvall for undertaking, on short notice, an extensive revision and updating of the original article for publication here.

[2] Some general references are cited at the end of the article.

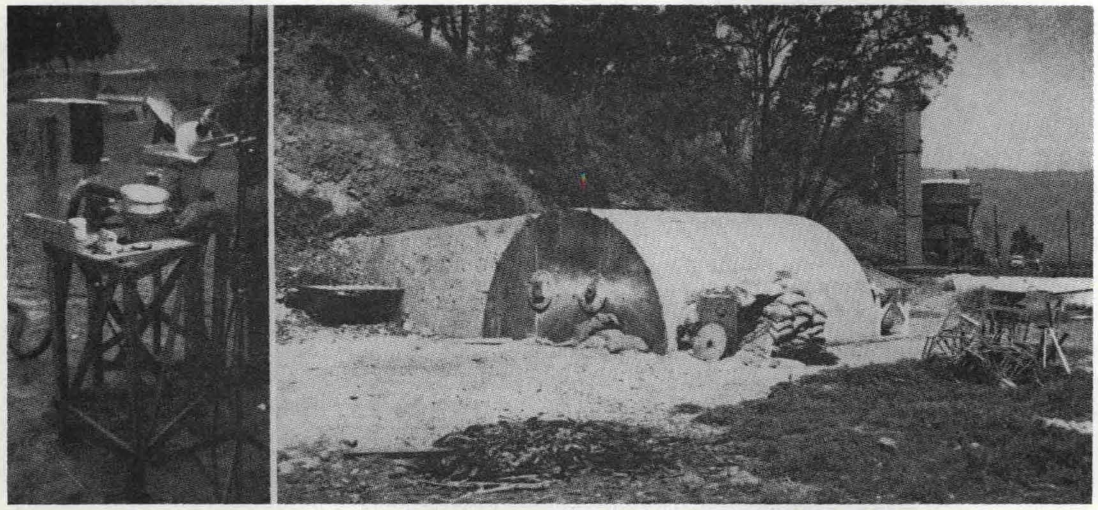

Fig. 1. Typical shock experiment uses firing mount at left, placed in front of armor-plated instrument bunker at right. Streak camera inside bunker views mirror at top of mount through glass ports. Light source for camera is in rectangular box next to mirror. Just below it is specimen assembly, in cylinder with hose attached to vacuum line; below this is second cylinder with explosive and plane-wave generator. The shot reduces entire firing mount to rubble.

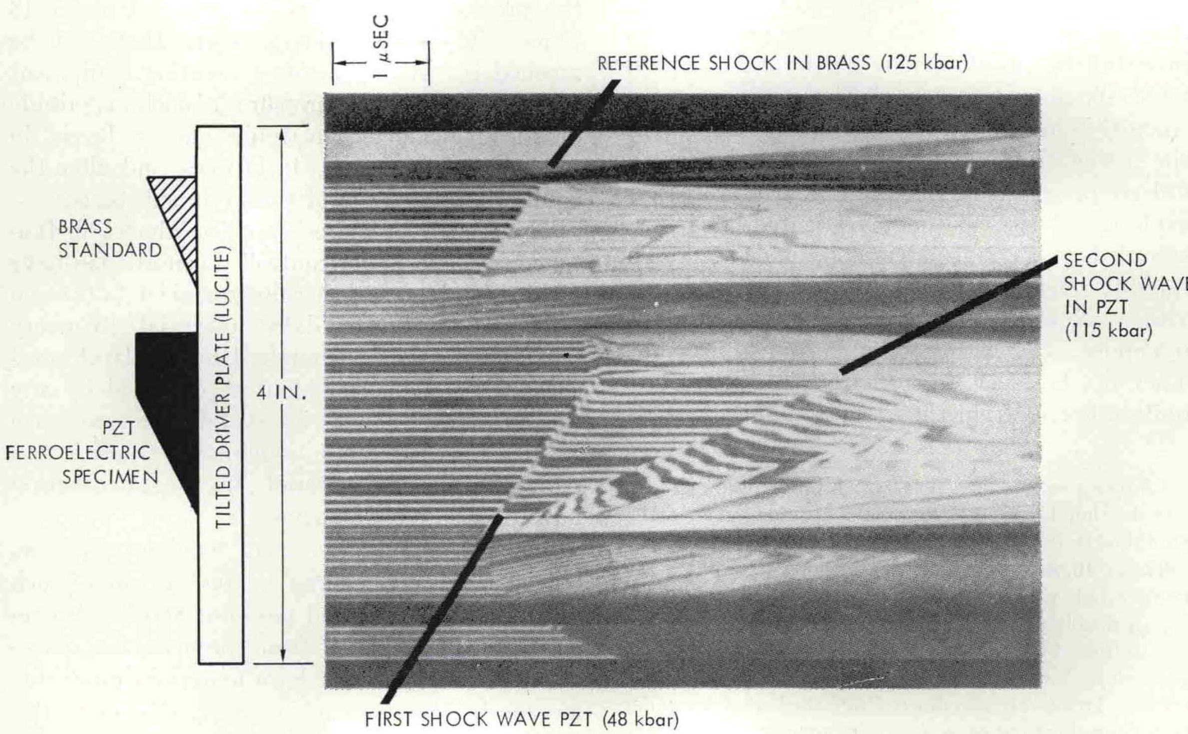

Fig. 2. Streak camera record shows shock arrival preceded by an elastic wave. Reference shock in brass gives needed data on state in the driver plate. Record of this kind yields either shock velocity or the velocity of free surface on specimen. Either one can be used to determine the material's (here PZT) equation-of-state.