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SANDIA SYSTEMATIC DECLASSIFICATION REVIEW

Ilda Selph 1-30-97	W. C. Layne
Carmela M. Gallegos 5/5/97	97SN355
	DATED 1-28-97

SCTM-115-55-51

METHODS OF PRODUCING PRECURSORS IN THE LABORATORY

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW

1st Review Date: 7-15-81	Determination (Circle Numbers):
Authority: ☐ ADC ☒ ADD CCRP-RR	1 Classification Retained
Name:	2 Classification Changed to U
	3 Contains No DOE Classified Information
2nd Review Date: 1-28-97	4 Coordinate With:
Authority: ADD	5 Contains UCAI
Name: W Layne	6 Comments: Unclassified

J. Todd

ABSTRACT

Six methods of producing precursor-type shock waves in the laboratory are discussed. Two of these methods have been successfully applied at Sandia to spherical shocks. The attainment of precursor-type waves from spherical shocks is considered as evidence substantiating the thermal layer shock theory.

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Case No. 407.02

June 15, 1955

INVENTORIED
DATE 3-8-69

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METHODS OF PRODUCING THE PRECURSOR IN THE LABORATORY

Introduction

Weapons effects tests in Nevada have indicated that for certain combinations of height of burst and yield a precursor (a wave travelling ahead of the expected main shock) is formed. Speculation guided by early German reports and an experiment on shock waves impinging on a boundary layer of carbon tetrachloride and water led to the theory that the precursor is caused by a layer of hot air along the ground. Evidence for this theory is found in the good agreement between the predictions by the theory of occurrence of the precursor with occurrence in the field.* Additional evidence would be production of a three-dimensional precursor in the laboratory by forming a layer of hot air along a surface. Walker Bleakney, and subsequently Cassen, produced one-dimensional precursors in shock tubes, but there still remained the problem of producing precursors from spherical shocks on a laboratory scale.** Several attempts on this scale were made at Sandia to induce precursors from spherical shock waves, two of which were successful. Sandia's experiments and the work of other investigators in this field are reviewed here.

Proposed Methods of Producing Precursors

One method of producing the precursor is by creating layers of gas with differing sound speeds due primarily to changes in the nature of the gas. At Princeton, Walker Bleakney has produced a layer of helium by permitting diffusion through a porous plate, but no experiments have been made with spherical shock waves on such a gas layer.

The second method, that of producing a sharply defined boundary between layers of hot and cold air, can be achieved in several ways:

Actual Popcorning of Sand -- Thermal equipment needed to produce a popcorning of sand over a sizable area is not often found in the laboratory, but if a sufficient area could be irradiated it would offer several advantages:

1. It would be another method of producing the phenomenon;

2. It would correspond more nearly than any of the other methods to the proposed Nevada model; and

3. It would offer the possibility of studying the precursor in dust-laden air.

* Shelton, F. H., The Precursor, Its Formation, Prediction, and Effects, Sandia Corporation Report SC-2850(TR) July 27, 1953

** Griffith, Wayland C., and Bleakney, Walker, Diffusion Analogy to Interaction of a Shock Wave with a Thermal Boundary Layer, PU-TR-11-17, Jan. 3, 1955 and Cassen, (unpublished).

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Separating Hot and Cold Layers by Thin Films (eg, Collodion or Soap Bubble) — Both collodion and soap bubble are used in shock tubes successfully. Attempts at using film separation for spherical shocks at Sandia Corporation have not been successful because of the thicker films necessary.

Combustion of a Layer of Gasoline — This method has been tried with 1/2-ounce charges of Comp B, but the system sets up so much turbulence that results are meaningless. Larger scale tests (250 lbs of TNT) were partially successful in that the shock wave was found to be distorted. The photographic instrumentation was not adequate to give complete details about the phenomenon. The gamma of the hot layer is undoubtedly modified by the inclusion of products of combustion (CO_2, CO, etc).

Grazing Incidence of Streams of Hot and Cold Air -- Although it is not yet possible to remove turbulence completely, this method, which utilizes a spark for a shock source, has yielded promising results, Fig. 1. Unfortunately, the cold air side was cooled by passing it over dry ice. The CO_2 included in the gas stream changed the gamma of the cold air. A liquid nitrogen heat exchanger is being built to remove this objection. In the Sandia Corporation version of this method the hot layer is heated by passing air over nichrome ribbon heaters while the cold air is cooled by passing it over a heat exchanger. In addition, the possibility of using boiling liquid nitrogen as a source for the cold air becomes evident when the index refraction of sound between hot and cold layers is considered:

$$N = \frac{c_1}{c_2} = \left(\frac{T_1}{T_2}\right)^{1/2} = \left(\frac{300 + (\Delta T)_1}{300 - (\Delta T)_2}\right)^{1/2} .$$

Much more is gained by reducing the cold air temperature by 100°C than by heating the warm air by 100°C. However, strong heating will be necessary to reach the same index of refraction encountered in the field.

Hot Plate Techniques — Successful use of the hot plate technique in the shock tube was first accomplished by Bleakney at Princeton, and subsequent studies have been made at UCLA. Robert Hess at Langley Field has developed theoretical considerations to classify, and in some cases to qualitatively describe, the flow.* Hot plates have been used with approximations to spherical shock waves by Sandia Corporation and NOL. At Sandia Corporation, shock waves were generated by 5-gram charges of Comp C initiated by No. 6 caps. The shock produced by this system is not entirely spherical but it gives a good approximation in the region of interest. The NOL data are from a spark gap in a well, a method which will also produce a distorted spherical shock wave.

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*Hess, R. V., Interaction of a Shock Wave with a Thermal Boundary Layer, to be published.

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Shadowgraphs of Sandia Corporation experiments are shown in Figs. 2a-b. The temperature of the hot plate was about 200°C and the ambient air about 20°C. The surface of the hot plate is about 1/2-inch inside the demarcation line between the hot and cold layers.

One limitation of this and the grazing incidence technique is that there is no radial dependence of temperature. This means that in the laboratory the thermal layer is much broader in extent than it is in the field so that the precursor wave does not die out in the same manner.

General Limitation

Unfortunately, only the optical methods of shadowgraph, schlieren, and interferometry are available for experimental measurements. To measure adequately the shock parameters for such brief transients, a long and laborious instrumentation program which would develop equipment with sufficient time resolution and temperature compensation would have to be undertaken.

Conclusions

1. Corroboratory evidence for the thermal layer theory of precursor formation is found in production of precursors from spherical shock waves.

2. Two methods of producing definite layers of hot and cold air capable of producing precursors are available.

3. Realization of the full potential from these techniques is dependent upon a successful instrumentation program.

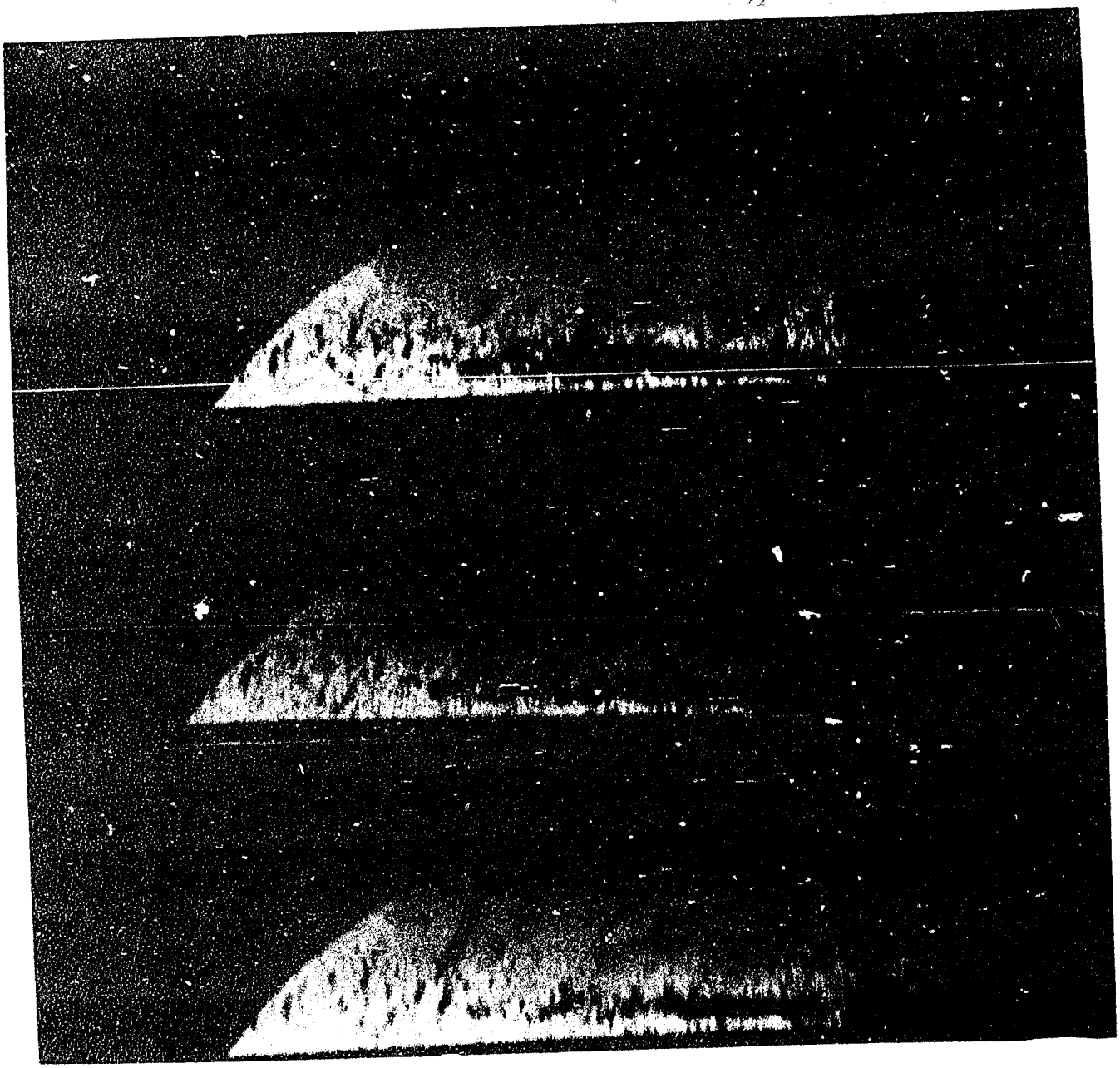

Fig. 1 Precursor-type wave generated by grazing incidence flow technique.
Note: Time increases downward; travel is from right to left.

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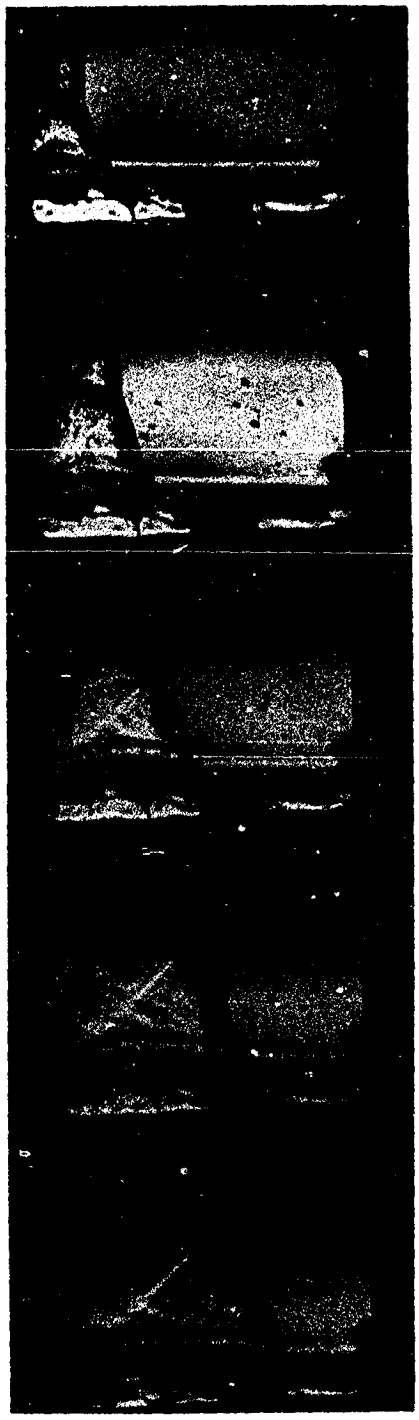

Fig. 2a Successive shadowgraphs of a shock wave from a 5-gram charge as it passes over a hot plate. The surface of the hot plate is below the visible boundary which is caused by the hot layer. The hot plate was about an inch thick. Note: time increases downward.

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Fig. 2b Successive shadowgraphs of a shock wave from a 5-gram charge as it passes over a hot plate. Note the double shock wave just above the heated layer. The surface of the hot plate is below the visible boundary which is caused by the hot layer. The hot plate was about an inch thick. Time increases downward.

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