UNCLASSIFIED

AD NUMBER

AD033616

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Operational and administrative use; 16 Dec 1953. Other requests shall be referred to U.S. Naval Ordnance Lab., White Oak, MD.

AUTHORITY

USNOL ltr, 29 Aug 1974

THIS PAGE IS UNCLASSIFIED

AD 33616

Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO

UNCLASSIFIED

NAVORD REPORT [illegible]

[illegible] [illegible] THE OBSERVATION OF THE IONIZATION PROFILE BEHIND EXPLOSIVE PRODUCED SHOCKS IN AIR

16 DECEMBER 1953

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

63155

NAVORD Report 3589

A METHOD FOR THE OBSERVATION OF THE IONIZATION PROFILE BEHIND EXPLOSIVE PRODUCED SHOCKS IN AIR

By:
Jacob Savitt

Approved by: Russell McGill
Russell McGill, Chief
Explosives Properties Division

ABSTRACT: A method for the observation of the ionization profile behind explosive produced shocks in air is described. Preliminary measurements of a qualitative nature of the shocks produced by the detonation of small quantities of dextrinated lead azide are presented and discussed. It is found that the region of maximum ionization for these shocks is at some distance behind the shock front.

Explosives Research Department
U.S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVORD Report 3589 16 December 1953

The physical properties of the disturbed region immediately behind explosive produced shocks in air have been found to be related to the ability of the disturbance producing explosive to initiate other explosives. It is the purpose of this report to present the results of some preliminary tests which were designed to test the feasibility of observing the ionization profile immediately behind the explosive produced shock fronts. The method described looks promising and may prove to be a useful research tool. The results are preliminary in character and are presented for information only. The author wishes to acknowledge the general advise and encouragement of Mr. R.H. Stresau and the help of Mr. C. Goode with the electronic design and construction. This work was done as part of the program under Task Assignment NOL-B2c-1-1-54, Initiation and Detonation of Explosives, and is a continuation of the work reported in NavOrd Reports 2132 and 2283.

EDWARD L. WOODYARD
Captain, USN
Commander

JEAblard
J. E. ABLARD
By direction

CONTENTS

ILLUSTRATIONS

INTRODUCTION

In many types of explosive experiments, references (a) through (c), the ionization produced by the detonation of primary and high explosives is used to start and stop electrical circuits by shorting ionization probes. In these systems, current flows through the ionized region produced at and behind shock fronts in air. It is, therefore, of interest to obtain more detailed information about the conductivity of the air at the shock front and immediately behind it. Furthermore, it is probable that the pressure and temperature profiles and distributions in time and space of this air, which are directly related to the initiating ability of a detonating explosive, references (d) and (e), are also closely related to the ionization in the region behind the shock. It has been shown, reference (e), that some complicated integral of the ionization behind the air shock produced by the detonation of lead azide correlates well with the ability of the lead azide to initiate confined tetryl across an air gap. A method for the observation of the ionization profile behind explosive produced shocks in air is described in this report and some results which indicate that the method is feasible are presented.

EXPERIMENTAL DETAILS

The Probe:

The type of measurement which we wish to make requires a probing system which will remain fixed in space and undamaged and which will detect electrically the ionization in the compressed air as the air passes the probe. For this purpose the following design, Figure 1, was used. Two brass cylinders 1.000 inch in diameter with axially centered holes 0.150 inch in diameter were placed end to end as shown and insulated from each other with electrical tape 0.010 inch thick. A hole was cut in the tape slightly larger than in the brass and placed in line with the holes in the brass as shown. Brass screws were fixed in the cylinders so that electrical contact to them could be easily made.

The Explosive Charge:

The explosive charge holder used in these experiments is illustrated in Figure 2. Twenty-five milligrams of dextrinated lead azide were pressed into the plug element under a pressure of 4,000 psi. The plug element was then crimped into place in a brass cylinder with the dimensions shown.

The Firing Circuit:

The firing circuit consisted of a 45 volt battery and a 10 microfarad condenser connected in parallel to each other and in series with

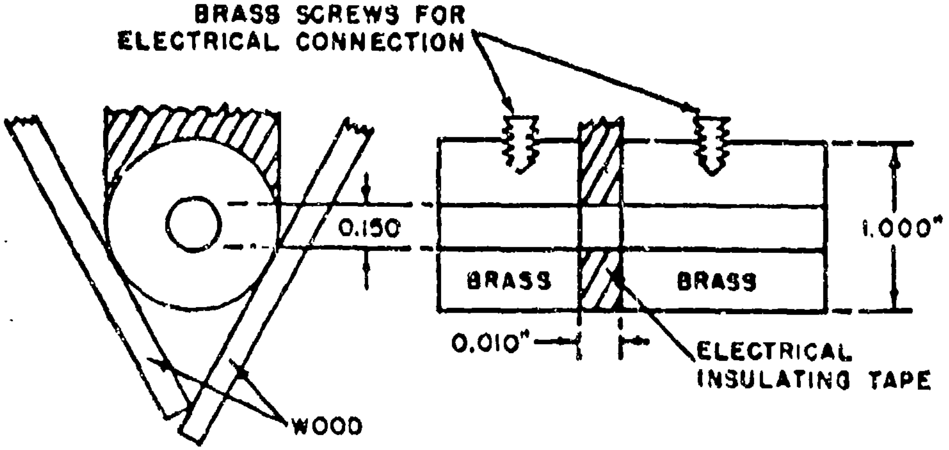


FIG. I DETECTION PROBE

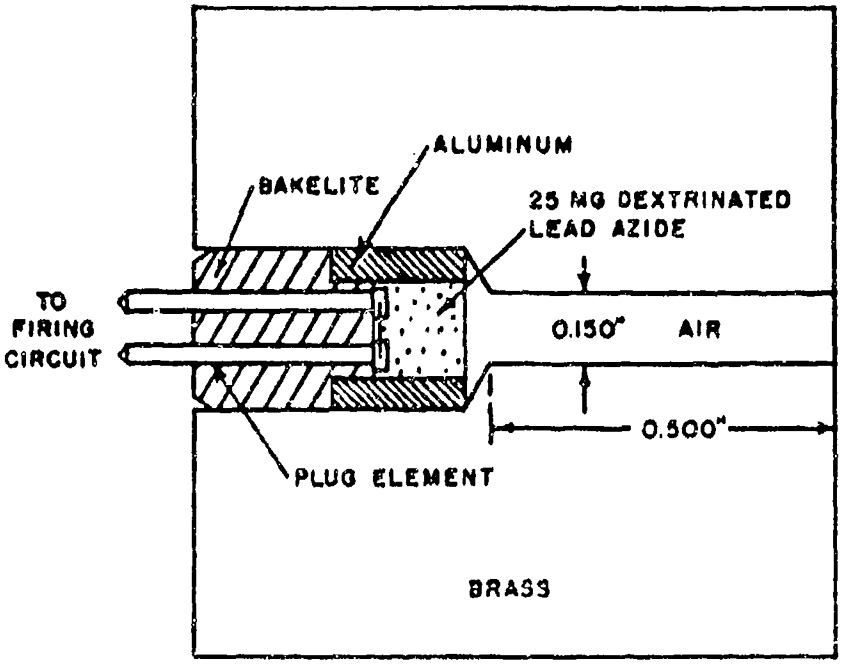


FIG. 2 EXPLOSIVE CHARGE HOLDER

a switch and the heating wire of the plug element.

The Complete System:

The complete system is shown schematically in Figure 3. A simple condenser discharge circuit was arranged so that a resistance, R, and an open gap, G, (our probe) were in series with a condenser, C, charged to a voltage, V. The time RC was large enough so that when the gap G was shorted, RC was very long compared to the time during which we wish to observe the current flow in the circuit. In Figure 4 an oscilloscope trace of the voltage across R during the first 10 microseconds of current flow after shorting the gap G is shown.

Our observation of the conductivity of the compressed air at and behind the shock front was made in the following manner, see Figure 3. The explosive holder was connected to the firing circuit. The probe gap was placed at the distance x from the explosive-air interface by choosing a suitable length for the "A" piece of the probe and placing the probe directly in contact with the explosive holder. The explosive holder and the "B" piece of probe were insulated from each other by electrical tape and wood as shown in Figures 1 and 3. The "A" piece of the probe and one side of the condenser were connected to ground. The "B" piece of the probe was connected to the high side of the condenser through the resistance R as shown in Figure 3. The deflecting plates of a Tektronix oscilloscope No. 517T were connected across the resistance R so that the variation of the voltage across R as a function of time could be observed. The 10 microsecond sweep scale was used and the triggering circuit arranged so that the sweep would be started by the first appearance of a voltage across R so that we would be able to observe the voltage variation across R during the first 10 microseconds of current flow through the probe circuit. The condenser C was then charged to 70 volts and the switch placed in position (2) as shown in Figure 3.

When the firing circuit switch was closed, the heating element of the explosive holder initiated detonation in the lead azide. When the detonation shock reached the explosive-air interface a shock was formed in the cylindrical air tube. This air shock then propagated down the tube toward the probe with a pressure profile like that shown in Figure 5. The pressure and the temperature are a maximum at the shock front and decrease together behind the shock front. At the boundary between the compressed air and the reaction products which act as the piston which is driving the shock, the temperature takes a sudden drop but the pressure continues its gradual decrease. As this decaying shock propagates down our cylindrical tube the pressures and temperatures at and behind the shock front decrease as more and more air is picked up, compressed, and pushed along by the reaction products.

It is reasonable to expect also that the conductivity of the air decreases in somewhat the same manner as the pressure and temperature

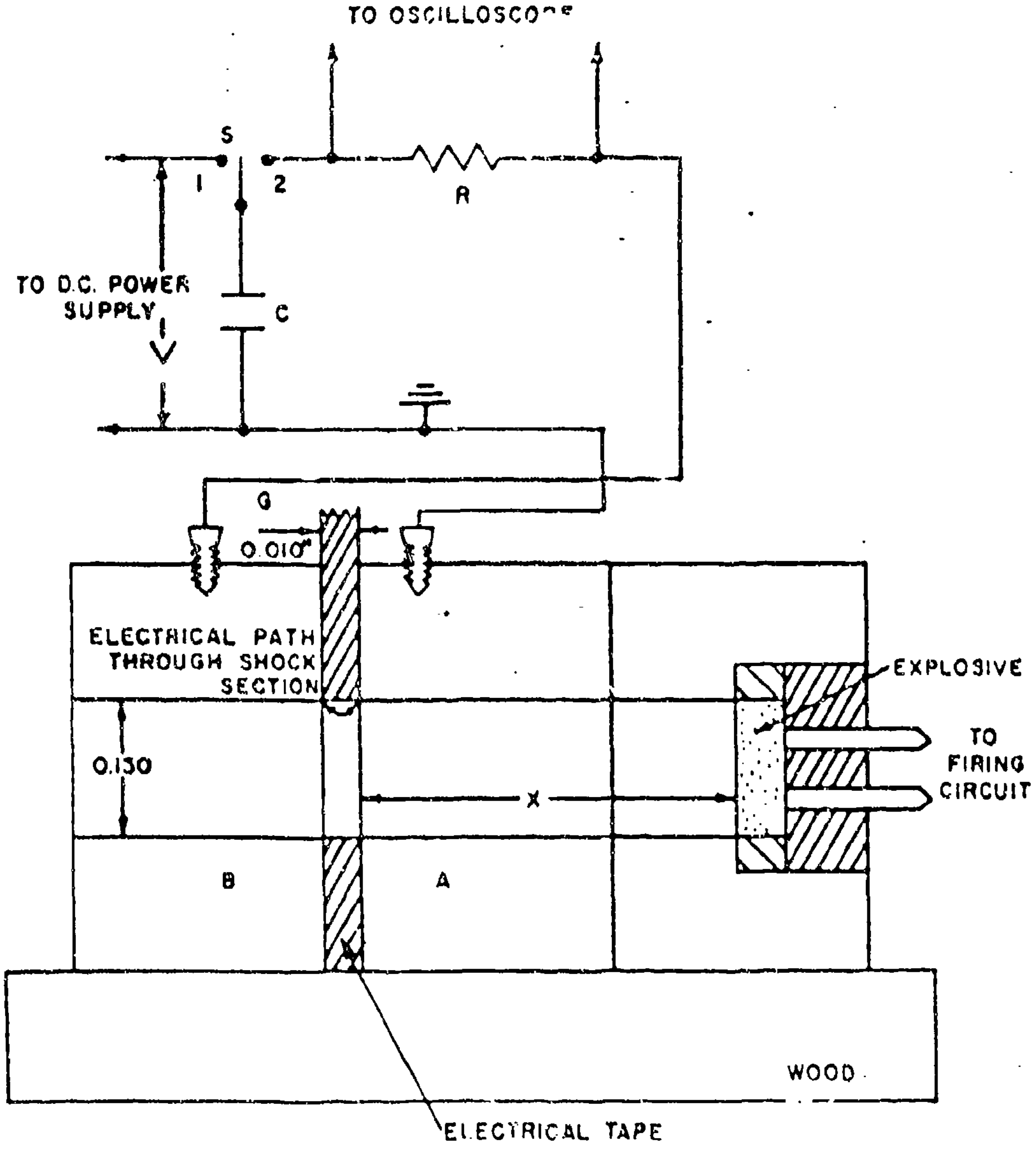


FIG. 3 THE COMPLETE SYSTEM

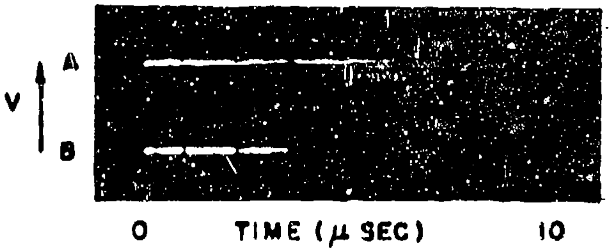


FIG. 4 OSCILLOSCOPE TRACE (A) OF VOLTAGE VARIATION ACROSS R OF FIG. 3 DURING FIRST 10 MICROSECONDS OF CURRENT FLOW AFTER SHORTING GAP G. TRACE (B) IS BASE LINE DUE TO RETRIGGERING

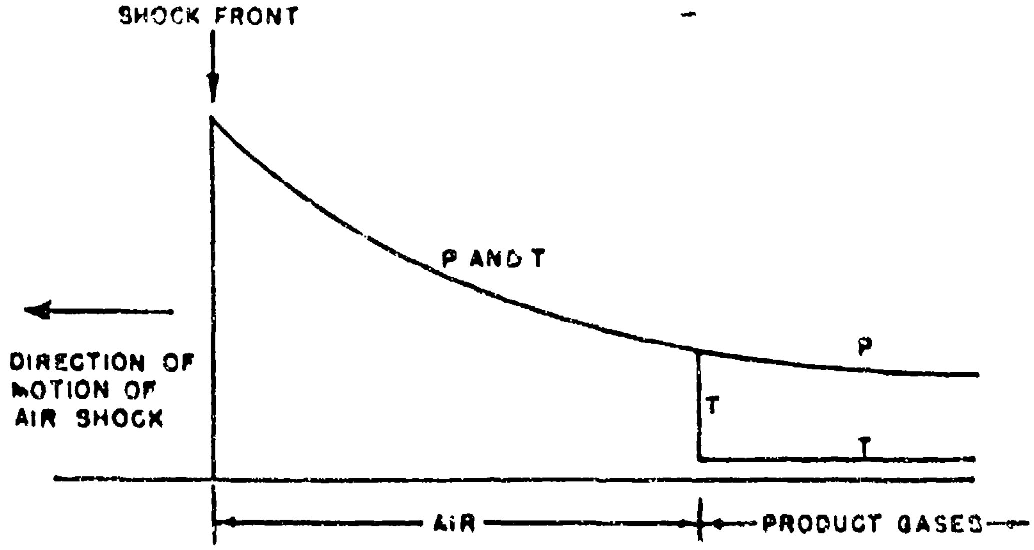
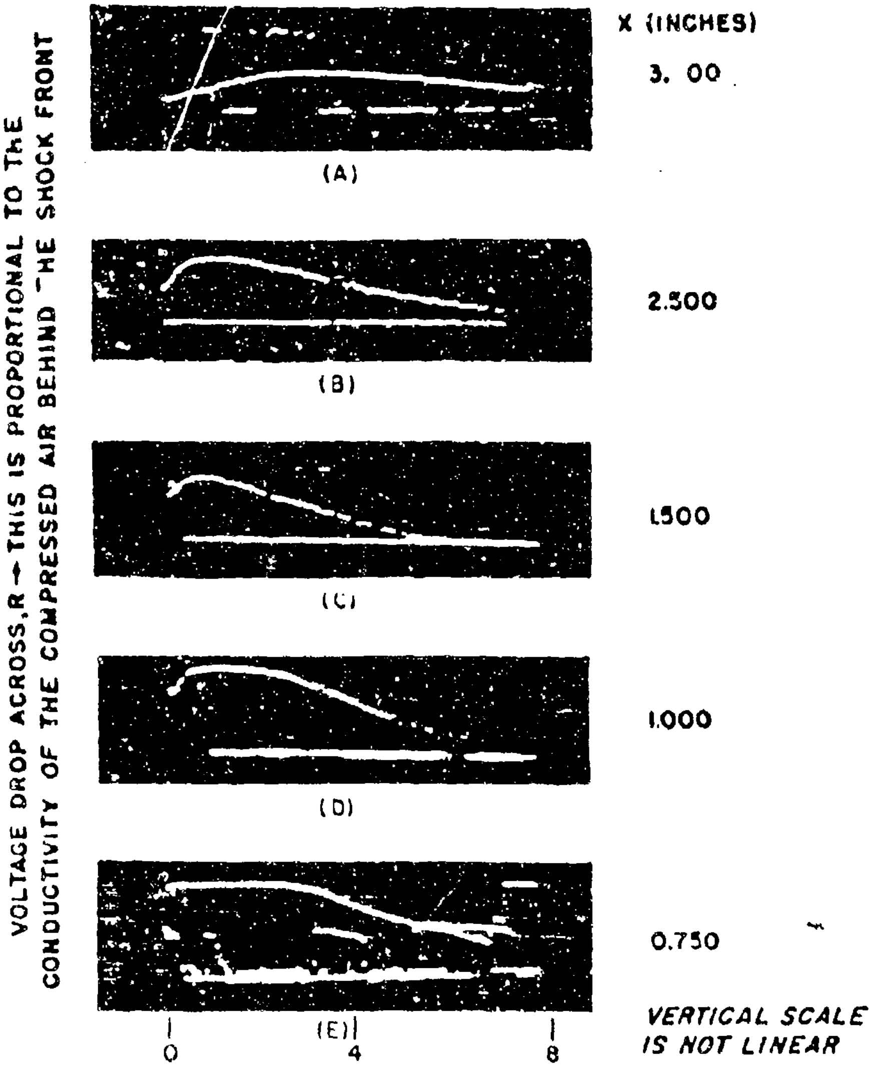


FIG. 5 PRESSURE AND TEMPERATURE PROFILE BEHIND AN EXPLOSIVE PRODUCED AIR SHOCK



TIME AFTER SHOCK ARRIVAL AT PROBE (μ SEC)
THIS IS ROUGHLY PROPORTIONAL
TO DISTANCE BEHIND SHOCK FRONT

FIG. 6

as we move into the compressed gases behind the shock front. We find, however, that this does not appear to be the case.

RESULTS

In Figure 6 the results of measurements of a qualitative nature of the conductivity produced by the detonation of 25 mg of dextrinated lead azide for the system of Figure 3 are shown. These are oscilloscope traces on the 10 microsecond sweep scale of the Tektronix Model 517T. The vertical deflections are proportional to the voltage across the resistance R, of Figure 3 and consequently to the current through R and hence to the conductivity of the electrical path through the ionized gas across the probe.

It is very clear that the maximum conductivity is not at the shock front.

DISCUSSION OF RESULTS

The oscilloscope traces of Figure 6 may be interpreted as qualitative graphical representations of the variation of the conductivity of the compressed air at and immediately behind the shock front. When x = 3.500 inches, that is, when the probe gap is 3.500 inches from the explosive-air interface, the conductivity of the air at the probe takes a sudden small jump upon the arrival of the shock front. Then for about three microseconds the conductivity increases as we look into the compressed gases behind this front. Measurements of the air shock velocity at the probe indicate that it is about 2800 meters/second. According to some unpublished calculations by S. G. Reed*, this time is of the right order of magnitude for the time for the ionization to reach equilibrium when produced by a shock of this velocity. When the distance between the explosive-air interface and the probe is reduced and consequently observations of higher velocity shocks are made, the initial ionization upon the first arrival of the air shock at the probe increases with increasing shock intensity. Furthermore, the time to reach equilibrium was observed to decrease with increasing shock velocity. All of this is consistent with the theoretical speculations of W. Doring, reference (f).

It appears then that the method described can successfully detect the conductivity of the ionized gases at and immediately behind explosive produced air shocks. The effect of the probe geometry upon the system has not yet been determined.

*Naval Ordnance Laboratory, Aeroballistic Research Department, Hyperballistics Division.

REFERENCES

(a) NavOrd Report 2450, Detonation Velocities of Several New Explosives Measured by the Small Scale Technique, L.D. Hampton, 19 May 1952

(b) NavOrd Report 2841, Velocities of Explosive Produced Air Shocks, Jacob Savitt, 8 April 1953

(c) NavOrd Report 2824, Primary Explosives Evaluation Tests, L.D. Hampton, J. Savitt, W.M. Slie, and R.H. Stresau, 19 March 1953

(d) BRL Report No. 865, Induction Time to Sympathetic High Order Detonation in an Explosive Receptor Induced by Explosive Air Shock, M. Sultanoff and R.A. Bails May 1953

(e) NavOrd Report 2283, Investigation of Explosive Phenomena Through Ionization Measurements, Jacob Savitt, 27 December 1951

(f) Speed and Structure of Intense Shock Waves in Gases, Annalen der Physik, 5, 1949, pp. 133-50, W. Doring

DISTRIBUTION

	Copies
Chief, Bureau of Ordnance (Re2c), Wash., D.C.	5
Chief, Bureau of Ordnance (Re2b), Wash., D.C.	2
University of Arkansas, Institute of Science and Technology, Fayetteville, Ark., Attention: Dr. Zaboj V. Harvalik, via InsMat Chicago 11, Ill.	1
Solid Propellant Information Agency, Applied Physics Lab. Johns Hopkins Univ., Silver Spring, Md., via InsOrd Silver Spring, Md.	1
Chief of Naval Research, Navy Department, Wash. 25, D.C. Attention: Code 466	1
Commander, Naval Proving Ground, Dahlgren, Va.	2
Commander, Naval Ordnance Test Station, Inyokern, Calif.	2
Commander, Naval Ordnance Test Station, Inyokern, Calif. Attention: Mr. C.E. Weinland, Dr. R.W. Van Dolah, Mr. B.A. Breslow, Dr. H.J. Gryting	4
Commanding General, Air Material Test Center, Eglin Air Force Base, Fla.	1
Officer in Charge, Naval Ordnance Laboratory Test Facility, P.O. Drawer 6, Ft. Monroe, Va.	1
Commanding General, Aberdeen Proving Ground, Aberdeen, Md.	1
Director, Ballistic Research Laboratories, Aberdeen, Md.	2
Director, Woods Hole Oceanographic Institute, via InsMat Boston 10, Mass.	2
U.S. Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa., Attention: Dr. Bernard Lewis	2
Chief of Ordnance, Department of the Army, Research and Development Div., Wash., D.C., Attention: ORDTQ	2
Office, Chief of Ordnance, Department of Army, Wash., D.C. Attention: ORDTA - Mr. S.S. Podnos, ORDTA, Dr. L.R. Littleton	2
Commanding Officer, Engineer Research & Development Laboratories, Ft. Belvoir, Va.	2
Commanding Officer, Picatinny Arsenal, Dover, N.J.	3
Attention: Amm Dev. Br. A, Fuze Section	1
Attention: Amm Dev. Br. B, Bomb, Mine & Grenade Sec.	1
Attention: Amm Dev. Br. B, Physical Res. Sec.	1
Attention: Amm Dev. Br. B, Pyrotechnic Sec.	1
Attention: Amm Dev. Br. B, Chemical Res. Sec.	1
Attention: Library	1
Director, Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md., via InsOrd Silver Spring, Md.	1

DISTRIBUTION

	Copies
Commanding Officer, Naval Mine Depot, Yorktown, Va.	1
Chief, Bureau of Ships, Wash., D.C., for distribution to Branches	6
Commanding Officer, Naval Powder Factory, Indian Head, Md.	4
Commanding Officer, Norfolk Naval Shipyard, Portsmouth, Va.	1
Atlas Powder Co., Reynolds Experimental Lab., Tamaqua, Pa., via InsMat Phila., Pa.	1
Chief, Bureau of Yards and Docks, Wash., D.C.	2
Chief, Bureau of Aeronautics, Wash., D.C.	2
Chief, Naval Operations, Wash., D.C.	3
A.D. Little Inc., Cambridge 42, Mass., Attention: Dr. W.C. Lothrop, via InsMat Boston 10, Mass.	1
Evans Research and Development Corp., New York, N.Y., Attention Dr. E.J. Hewitt, via InsMat Brooklyn, N.Y.	1
George Washington Univ., Dept. of Chemistry, Wash., D.C., via InsMat Baltimore, Md., Attention: Dr. B.D. Van Evera	1
E.I. DuPont de Nemours & Co., Inc., Eastern Laboratory, Gibbstown, N.J., Attention: Miss Margaret W. Imbrie, via InsMat Newark, N.J.	1
Western Cartridge Co., Div. of Olin Industries, East Alton, Ill., Attention: Mr. R.L. Womer, Associate Director of Research, via InsMat Chicago, Ill.	1
Aerojet Engineering Corp., Azusa, Calif., Attention: Dr. M.H. Gold, via InsMat Los Angeles, Calif.	1
University of Utah, Salt Lake City, Utah, Attention: Dr. Melvin Cook, via ONR Branch Off., 1000 Geary St., InsMat San Francisco, Calif.	1
Bureau of Ordnance (Re3d) Wash., D.C., Attention: Mr. H. Freeman	1
Commander, U.S. Naval Proving Ground, Dahlgren, Va., A&P Laboratories, Attention: Dr. H.E. Romine	1
Atlantic Research Corp., 812 N. Fairfax, Alexandria, Virginia, via InsMat, Baltimore, Md.	1
Attention: Dr. L. L. Weil, Attn: Mr. Keith Rumbel	2
Diamond Ordnance Fuze Laboratories, Conn. Ave. & Van Ness Sts., N.W., Wash. 25, D.C., via InsMat	
Attention: Mr. Milton Lipnick, Section 30.4	1
Attention Mr. Richard Weingrad, Section 30.4	1
Mr. Samuel Kolodny, Section 30.3	1
Mr. George Keehn, Section 30.1	1
Mr. Leo Rubinowitz, Section 20.2	1

DISTRIBUTION

	Copies
Director, New Mexico School of Mines, Research and Development Div., P.O. Box 6000, Station A, Albuquerque, N.M., via InsMat Los Angeles, Calif.	2
Chief, Armed Forces Special Weapons Program, Pentagon, Wash., D.C.	5
Chief, Naval Operations, Wash., D.C.	3
Hercules Powder Co., Wilmington 99, Delaware, Attention: Dr. Julius Roth, via InsMat Phila., Pa.	1
Hercules Powder Co., Port Ewen, N.Y., Attention: Mr. Scharrer, via InsMat Kingston, N.Y.	1
Director, National Bureau of Standards, Wash., D.C., Attention: Mr. Apstein	2
Armour Research Foundation, Research Center, Chicago, Ill.	
Attention: Mr. W.C. Troy, via InsMat Chicago, Ill.	1
Attention: Dr. W.C. McCrone	1
Beckman Instruments Inc., Pasadena, Calif., via InsMat Los Angeles, Calif., Attention Dr. D.C. Taylor, Jr.	1
Commanding General, Ordnance Ammunition Center, U.S. Army, Attention: ORDLY-R, Joliet, Illinois	1
Superintendent of Naval Post Graduate School, Monterey, Calif.	1
University of Maryland, College Park, Md., via InsOrd Silver Spring, Md.	1
Bureau of Ordnance, Ad8, for distribution as follows:	
British Joint Services Mission	5
Defense Research Member Canadian Joint Staff, Wash., D.C.	2
U.S. Naval Attache, London, England	3
Rohm and Haas Co., Redstone Arsenal, Research Division, Huntsville, Ala., via InsMat Atlanta, Ga., Attention: Dr. R. M. Ross	1
Rohm and Haas Co., Phila., Pa., Attention: Dr. Ralph Connor, via InsMat Phila., Pa.	1
U.S. Rubber Co., General Laboratories, Passaic, N.J., Attention: Dr. P. O. Tawney, via InsMat Port Newark, Newark 5, N.J.	1
U.S. Rubber Co., Naugatuck Chemical Co., Naugatuck, Conn., Attention: Mr. F.J. Foster, via InsMat Bridgeport 8, Conn.	1
Los Alamos Scientific Laboratory, Los Alamos, N.M., Attention: Dr. D. P. MacDougall, Attention: Dr. L.C. Smith, via InsMat Los Angeles 15, Calif.	2
National Fireworks Ordnance Corp., West Hanover, Mass., Attention: Mr. S.J. Porter, via InsMat Springfield, Mass.	1
Princeton Univ., Princeton, N.J., Attention: Director, Project Squid, via InsMat Phila., Pa.	1
Harvard Univ., Department of Chemistry, Cambridge, Mass., via InsMat Boston 10, Mass.	1