GE-MTSD-R-045

# PYROTECHNIC HAZARDS CLASSIFICATION AND EVALUATION PROGRAM

CONTRACT NAS8-23524

FINAL REPORT - PHASE II, SEGMENT 1
RECORDS AND EXPERIENCE ANALYSIS

AUGUST 1970


PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MISSISSIPPI TEST FACILITY



GENERAL ELECTRIC

Management and Technical
Services Department

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# FOREWORD

The studies described in this report comprise Segment 1 of Phase II of Edgewood Arsenal's three-phase Pyrotechnic Hazards Classification and Evaluation Program. The report was prepared by the General Electric Company, Management and Technical Services Department (GE-MTSD), Bay Saint Louis, Mississippi, under National Aeronautics and Space Administration (NASA) Contract NAS8-23524 for the Engineering Test and Evaluation Section, Process Technology Branch, Chemical Process Laboratory, Weapons Development and Engineering Laboratory, Edgewood Arsenal, Edgewood, Maryland.

# ABSTRACT

A comprehensive search review and analysis was made of various technical documents relating to both pyrotechnics and high explosives testing, handling, storage, manufacturing, physical and chemical characteristics and accidents and incidents. Of approximately 5000 technical abstracts reviewed, 300 applicable documents were analyzed in detail. These 300 documents were then converted to a subject matrix so that they may be readily referenced for application to the current Phase II and Phase III programs.

It was generally concluded that information in several important categories was lacking. Two of the more important categories were in pyrotechnics sensitivity testing and TNT equivalency testing. A general recommendation resulting from this study was that this activity continue in future programs and a comprehensive "data bank" be generated that would allow immediate access to a large volume of pertinent information in a relatively short period of time.

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# SECTION 1
# INTRODUCTION

## 1.1 GENERAL

This report contains the findings, recommendations, and conclusions of a search of the various records and technical documents containing significant data and information relative to pyrotechnic hazards classification and evaluation. This effort comprised the first segment of the seven-segment Phase II Pyrotechnic Hazards Classification and Evaluation Program.

Phase I of the overall program has been completed and was reported in Report Number GE-MTSD-R-035, dated May 1970. This phase involved TB 700-2 testing of selected pyrotechnic mixtures and TNT equivalency determinations for the same pyrotechnic compounds. Phase I also included a literature search of technical documents, many of which were also reviewed during this Phase II, Segment 1 document search.

Phase III has recently been started. This phase includes development of new and/or revised criteria, methods, procedures, and instruments for evaluating and classifying pyrotechnics with respect to both DOT and DOD handling, transportation, and storage requirements.

## 1.2 OBJECTIVES

The objectives of this segment were to:

a. Review the Phase I findings relative to the characteristics of pyrotechnics as established by tests and the literature search and also to identify and attempt to resolve any anomalous findings or to determine the course of further studies and/or tests.

b. Contact all available sources for the accumulation of records of accident/incident experiences in pyrotechnic and related industries, and to analyze this data with particular reference to:

- Causes - procedures, human error, training, skills, equipment, or facilities
- Type of initiation stimuli - static, friction, dust, impact, heat, shear, pinching, etc.
- Source of stimuli - machinery, air, or human
- Propagation, communication, and transition reactions
- Type and degree of damage - fire, blast, and fragmentation
- Identification of major damaging factor(s)

- Probability, in gross terms, of various types of accidents
- Correlation of damage data with "quality distance" criteria specified in AMR 385-224

c. Direct particular attention toward little known reactions, incompatibilities, contaminants, evidence of synergism, and effects of geometric configurations during the review, and to analyze pyrotechnic incidents.

d. Use the results of this analysis as the basis for the formulation of the Segment 2 operational survey and to provide the background for design of the Segment 3 test program.

# SECTION 2
# RECORDS AND EXPERIENCE ANALYSIS

## 2.1 GENERAL

Approximately 310 related technical handbooks, reports, manuals, references, and other documents were reviewed for applicability to the immediate Phase II program and also to the Phase III program. An attempt was made to classify the documents in two ways: a qualitative "excellent, good, fair, and general" classification; and a subject classification such as "fragmentation," "sensitivity," etc. Appendix A of this report contains a bibliographical listing of the documents reviewed and classifications for each based on these two criteria.

## 2.2 DOCUMENT SOURCES

The documents researched were obtained from the following primary sources:

- Defense Documentation Center
- General Electric Technical Information Retrieval System
- Bureau of Mines Technical Reports
- Bureau of Explosives Reports
- Chemical Propulsion Information Agency Reports
- Picatinny Arsenal Publications
- Army Materiel Command Safety Office Reports (including Edgewood Arsenal and Pine Bluff Arsenal Reports)
- Ballistics Research Laboratory Reports
- NASA Scientific and Technical Information Facility, College Park, Maryland
- Department of the Army Publications
- Department of the Navy Publications
- Department of Defense Publications

## 2.3 CLASSIFICATION SYSTEM

The following four categories were used to record a meaningful description relative to the general value of the documents:

| CODE | CLASSIFICATION |
|---|---|
| 1 | Excellent Source Document |
| 2 | Good Source Document |
| 3 | Fair Source Document |
| 4 | General Source Document |

An "excellent" source document is a document which contains finite and specific information immediately pertinent and relative to the current Phase II and Phase III programs. It also means that the document contains information, data, etc., which is equal to or slightly above the average for this particular field of endeavor.

A "good" source document is a document which contains some information and data which may be used to support the current program plans, tests, and experiments.

A "fair" source document relates to the subject matter of Phase II and Phase III but is in most cases not pertinent to pyrotechnics and/or the specific tests and experiments being conducted.

A "general" source document is a standard reference, textbook, DOD technical manual, specification, etc. These documents are necessary to form an understanding and sound technical base for the program.

The other part of the two-part classification system contains the subject descriptions listed in the remainder of this section. Each of these descriptions is defined and expanded upon to facilitate a more complete understanding of the matrix and the classifications.

| MATRIX TITLE | EXPLANATION |
|---|---|
| Specification | Military or Federal specifications used for the Phase I program and found pertinent to the overall program. |
| Accidents/Incidents | Documents detailing accidents or incidents caused by high explosives, pyrotechnics, and/or propellants. |
| Fragmentation | Documents reporting the phenomena of fragment velocities, weight, size, and shape. In addition, these documents generally contain the mathematics and formula of fragmentation phenomena. |
| Blast Measurement and TNT Equivalency | Documents containing information and data on all aspects of measurement, recording, and treating of overpressures and impulse from a high explosive blast. In addition, TNT equivalency data is found in a few of these documents. |
| Sensitivity | Documents relative to virtually all types of and methods and procedures for testing explosive and/or hazardous materials, including friction, impact, thermal, external heat, electrostatics, and others. Sensitivity data on a number of materials is also present in these reports. |

| MATRIX TITLE | EXPLANATION |
|---|---|
| Barricading | Documents detailing the problem of protecting lines and property by means of physical barriers. Data is also available on the size, effectiveness, and materials of construction of barricades. |
| Propagation | Documents covering the tendencies of explosives, pyrotechnics, propellants, and other hazardous materials to propagate from an ignition by a given stimuli to a higher order reaction such as deflagration, explosion, or detonation. |
| Total Containment | Reports detailing the effects of totally containing or confining an explosive reaction. |
| Confinement | Documents containing approximately the same information as in the "total containment" documents, but covering varying degrees of confinement and environments. |
| Attenuation and Suppression | Documents containing information on the methods, devices, and effects of attenuation and suppression of fire, deflagration, explosion, and detonation. |
| Facilities | Data and design criteria on facilities for storage and handling of explosives and hazardous materials, including materials of construction, electrical and grounding criteria, etc. |
| Utilities | Documents containing relatively the same information as that in "facilities" documents, including construction and design of electrical and grounding systems, sprinkler systems, and other utility systems related to hazardous operations. |
| Manufacturing | Documents relating to the manufacturing of various pyrotechnics and high explosives. |
| Storage | Documents relating to storage of various pyrotechnics and high explosives. |
| Handling | Documents relating to handling of various pyrotechnics and high explosives. |
| DOD Manuals, TM's/FM's, etc. | Standard DOD manuals, TM's, FM's and similar documents containing information relative to explosives, munitions, pyrotechnics, chemical warfare items, etc. |

| MATRIX TITLE | EXPLANATION |
|---|---|
| Safety | Documents containing explosives and hazardous operations safety procedures and protective measures. |
| Personnel | Documents relating to protection and protective devices, and measures and procedures for personnel engaged in hazardous operations such as handling, storing, and manufacturing of pyrotechnics and explosives. |
| Anomalies | Documents containing information and data on out of the ordinary or unusual phenomena relating to tests, reactions, incidents, etc., involving pyrotechnics, high explosives, and hazardous materials. |

# SECTION 3
# CONCLUSIONS

More than 300 technical reports and other documents were reviewed and analyzed for their application to the overall Pyrotechnic Hazards Classification and Evaluation Program in order to structure the proposed program plan for Phases II and III. Other reports and specifications which were utilized as basic references during Phase I of the program will continue to be utilized during Phases II and III.

The documents searched were selected from sources cited previously and present a very wide spectrum of the field. Much of the literature consists of reports and technical papers on the pyrotechnic and high explosives industries. However, it was found that a large percentage of the literature does not contain sufficient technical detail. The results and conclusions reported in some of the technical literature indicate that the industry may need more exact test methods, test equipment, and instrumentation. In addition, a systems approach to the overall problem of hazards evaluation is lacking. Much of the literature is redundant and is concerned with obsolete methods and procedures.

The value of a literature search such as this is difficult to ascertain in specific terms. The obvious advantage to performing a literature search is that it provides a technical and scientific basis upon which to plan and conduct a program and avoids the costly procedure of "reinventing the wheel."

The "data bank" of literature thus derived through this records and experience analysis will be expanded as the program continues.

# APPENDIX A

# DOCUMENT LISTING

## DOCUMENT RESEARCH & ANALYSIS PERFORMANCE

*Legend* 1 – Excellent Source Document
2 – Good Source Document
3 – Fair Source Document
4 – General Source Document

| NO. | DOCUMENT DESCRIPTION | RATING | SPECIFICATION | ACCIDENTS & INCIDENTS | FRAGMENTATION | BLAST MEASURE & TNT EQUIV | SENSITIVITY | BARRICADING | PROPAGATION | TOTAL CONTAINMENT | CONFINEMENT | ATTENUATION & SUPPRESSION | FACILITIES | UTILITIES | MANUFACTURING | STORAGE | HANDLING | DOD MANUALS TM/FM, etc. | SAFETY | PERSONNEL | ANOMALIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hazard Classification Test Report: Phases I and II. Space Systems Division, United States Air Force Systems Command, Los Angeles 45, California. 26 May 1964. | 2 | | | | 2 | 2 | | 2 | | 2 | | | | | | | 2 | | | 2 |
| 2 | Proceedings of the Fifth Symposium of Elextroexplosive Devices. 5EED-67, The Franklin Institute Research Laboratories, Philadelphia, Pennsylvania 19103. 13-14 June 1967. | 1 | | | | 2 | 2 | | 2 | 2 | 2 | 2 | | | 1 | 1 | 1 | 1 | 2 | | 2 |
| 3 | Pollard, Frank B. and Arnold, Jack H., Jr. Aerospace Ordnance Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966. | 2 | 2 | | | 2 | | | | | | | 2 | 2 | | | | 2 | 2 | 2 | |
| 4 | This item has been deleted. | 4 | | | | | | | | | | | | | | | | 4 | | | |
| 5 | Ellern, Dr. Herbert. Military and Civilian Pyrotechnics. New York: Chemical Publishing Company, 1968. | 4 | 2 | 1 | | 3 | | | | | | | | | | | | | | | |
| 6 | Fundamentals of Protective Desigh. Corps of Engineers, Office of the Chief of Engineers. 1946. | 2 | 3 | | 2 | 2 | 3 | 1 | 3 | 3 | 3 | | 1 | 2 | | | | 3 | 1 | 1 | 3 |
| 7 | Explosives Series Properties of Explosives of Military Interest. AMCP 706-177. March 1967. | 4 | | | | | | | | | | | | | | | | 4 | | | |
| 8 | Theory of Explosives (Russian). Foreign Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. 1963. | 2 | 2 | | | 2 | 1 | | 2 | 3 | 3 | | | | | | | 2 | 3 | 3 | 3 |
| 9 | Shidlovskiy, A. A. Foundations of Pyrotechnics. AD 602 687. Foreign Technology Division, Wright-Patterson Air Force Base, Ohio. 30 April 1964. | 4 | 3 | | | | 3 | 3 | | 3 | 3 | | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 |
| 10 | Demolition Materials. TM 9-1375-200. Department of the Army, January 1964. | 3 | 3 | | 2 | | 3 | | | 3 | | | | | | 3 | 3 | | | 2 | 3 |
| 11 | Military Explosives. TM 9-1300-214 and TO 11A-1-34. Departments of the Army and the Air Force. November 1967. | 2 | 1 | | 3 | | 1 | | | | | | | 3 | 2 | 2 | 2 | 3 | 2 | | |
| 12 | Military Pyrotechnics Series, Part One: Theory and Application. AMCP 706-185. April 1967. | 2 | 2 | | 3 | | | | | | | | | 3 | | | | | | | |

## DOCUMENT RESEARCH & ANALYSIS PERFORMANCE

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| NO. | DOCUMENT DESCRIPTION | RATING | SPECIFICATION | ACCIDENTS & INCIDENTS | FRAGMENTATION | BLAST MEASURE & INT. EQUIV. | SENSITIVITY | BARRICADING | PROPAGATION | TOTAL CONTAINMENT | CONFINEMENT | ATTENUATION & SUPPRESSION | FACILITIES | UTILITIES | MANUFACTURING | STORAGE | HANDLING | DOD MANUALS TMs/FMs, etc. | SAFETY | PERSONNEL | ANOMALIES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Rindner, Richard M., Wachtell, Standly, and Saffian, Leon W. Establishment of Safety Design Criteria for Use in Engineering of Explosive Facilities and Operation. Ammunition Engineering Directorate, Picatinny Arsenal, Dover, New Jersey. June 1967. | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 3 | | | 1 | 1 | | | | 2 | 2 | 2 | | |
| 14 | The Theory of Detonation, the Combustion Mechanism, and the Properties of Explosives. ATD Report 64-88. Aerospace Technology Division, Library of Congress. 11 August 1964. | 3 | | | 3 | 3 | 3 | | | | | | | | | | | | | | |
| 15 | Explosives Accident/Incident Abstracts. AD 660 020. Armed Services Explosives Safety Board. October 1967. | 1 | 2 | 1 | | | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 1 | 1 | |
| 16 | Detection Techniques for Hazardous Vapors of Elemental Propellants. Technical Documentary Report No. ASD-TDR-63-294. AD 414 947. Directorate of Aeromechanics, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. July 1963. | 4 | 3 | | | | 3 | | 3 | 3 | 3 | | 3 | 3 | 2 | | | | 2 | | |
| 17 | Berlad, A. L. and Buley, C. R. Radiatine Effects on Explosive Instability. AFRPL-TR-67-24. AD 807 548. Defense Research Corporation, Air Force Rocket Propulsion Laboratory, Air Force Systems Command, Edwards, California. January 1967. | 3 | 3 | | | | 4 | | | 4 | 4 | | 3 | 3 | 3 | 3 | 3 | | 3 | | 3 |
| 18 | Safety Principles for Laboratory and Pilot Plant Operations with Explosives, Pyrotechnics, and Propellants. AD 446 737. The Naval Ordnance Laboratory, White Oak, Maryland. July 1964. | 2 | 3 | | | 3 | 3 | | | 3 | 3 | | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | |
| 19 | Explosives Safety Manual. AFM No. 32-6. Department of the Air Force. 1 November 1961. | 2 | 3 | | 3 | | | 1 | | 2 | 2 | | 3 | 3 | 3 | 3 | 3 | | 2 | | |
| 20 | This item has been deleted. | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 21 | Altman, F. D. Model Studies of Explosive Storage Cubicles. U. S. Naval Weapons Laboratory, Dahlgren, Virginia. May 1964. | 3 | | | 3 | 2 | 2 | | 3 | 2 | 2 | | 3 | 3 | | | | 3 | 3 | | |
| 22 | Coulter, George A. Dynamic Calibration of Pressure Transducers at the BRL Shock Tube Facility. AD 654 508. Ballistic Research Laboratories, Aberdeen Proving Grounds, Maryland. May 1967. | 2 | | | 4 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 2 | 3 | | | | 1 | | | |

## DOCUMENT RESEARCH & ANALYSIS PERFORMANCE

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3 – Fair Source Document
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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | Military Pyrotechnics Series, Part Two: Safety, Procedures and Glossary. AMCP 706-186. October 1963. | 2 | 3 | | 3 | | 2 | 2 | | 3 | 3 | | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 3 |
| 24 | Cohen, Edward and Dobbs, Narval. Minutes of the Ninth Explosives Safety Seminar, Cost Effectiveness Studies of Facilities for High-Hazard Explosive Material, page 427. Ammann and Whitney, Consulting Engineers, New York, New York. | 2 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | |
| 25 | Roth, Milton. Process Control Methods for Determining Small Amounts of Moisture in Pyrotechnics, I. Electrolyic Hygrometer. Technical Report 3239. AD 463 060 or 1. | 3 | 3 | | | 3 | 2 | | | 3 | 3 | | | 2 | | 3 | 3 | 2 | | | |
| 26 | McLain, Joseph H. and McClure, Michael D. Effect of Phase Change in Solid-Solid Reactions. AD 831 733. Department of the Army, Edgewood Arsenal Research Laboratories, Chemical Research Laboratory, Edgewood Arsenal, Maryland. Prepared by Department of Chemistry, Washington College, Chestertown, Maryland. | 3 | 3 | | | | 3 | | | | 2 | | | | | | | | | | |
| 27 | Kholevo, N. A. New Data on the Sensitivity of Condensed Explosives to Mechanical Shock. AD 834 333. Picatinny Arsenal, Dover, New Jersey. May 1968. | 3 | 3 | | | 3 | 3 | | | 3 | 3 | | 3 | 2 | | | | 3 | 3 | | 3 |
| 28 | Bowden, F. P., et al. Growth of Burning to Detonation in Liquids and Solids. AD 667 216. Cambridge University, Cambridge, England. December 1967. | 2 | 3 | | 3 | 3 | | | 2 | 3 | 3 | | 3 | 3 | | | | 2 | | | |
| 29 | Methodology for Assessing the Hazard of Electromagnetic Radiation to Ordnance: Final Report for the Contract Period 23 July 1965 through 23 October 1966, Research Report SU-238/6. Electromagnetic Hazards Division, U. S. Naval Weapons Laboratory, Dahlgren, Virginia. 23 November 1966. | 3 | | 3 | | | 3 | | | | | | | | | | 3 | | 3 | 3 | |
| 30 | Clear, Arthur J. Standard Laboratory Procedures for Determining Sensitivity, Brisance, and Stability of Explosives. Technical Report 3278. Feltman Research Laboratories, Picatinny Arsenal, Dover, New Jersey. December 1965. (Revision of Technical Report FRL-TR-25 dated January 1961.) | 3 | 3 | | | | 3 | | | 3 | 3 | | 3 | 2 | | | 3 | 3 | 3 | | |
| 31 | Cleaver, Harry E. Instrumentation of a Standard Dropweight Tester for Liquids. AD 649 510. U. S. Naval Ordnance Laboratory, White Oak, Maryland. 2 February 1967. | 3 | 3 | | | 3 | 2 | | | | | | 2 | 2 | | | | 2 | 3 | | 3 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Collection and Destruction Standards for Ammunition and Explosive Material. | 2 | 3 | | | | | | | 3 | 3 | | 3 | 3 | | 2 | 2 | | 2 | 2 | |
| 33 | Mississippi Test Facility Safety Manual. | 2 | | | | | 2 | 2 | | | | | | | | 2 | 2 | | 2 | | |
| 34 | Comparative Test of Propellants by Peak Side on Overpressure and Side on Impulse. Report HS-148. U. S. Army Missile Command. October 1967. | 2 | | | | 3 | | | 3 | | | | | | | | | 3 | | | |
| 35 | Napodensky, H. S. Sensitivity of Solid Propellants to Impact. Technical Report AFRPL-TR-67-145. AD 816 625. Air Force Rocket Propulsion Laboratory, Edwards, California 93523. April 1967. | 2 | | | | 2 | | | | | | | | | | 2 | 2 | 2 | | | |
| 36 | Ammunition Series: Section 4, Design for Projection. AMCP 706-247. July 1964. | 2 | 2 | | | 3 | | | | | | | | 2 | | | | | | | |
| 37 | Elwell, R. B., Irwin, O. R., and Vail, R. W., Jr. Project SOPHY - Solid Propellant Hazards Program. AD 819 299. Aerojet Corporation. August 1967. | 3 | | 4 | | 2 | 2 | | 2 | | | | | | | 2 | 2 | 2 | | 2 | |
| 38 | Engineering Design Handbook, Explosive Series, Explosive Trains. Headquarters, U. S. Army Material Command. AMCP 706-179. March 1965. | 1 | 2 | | 3 | | 3 | | | 2 | | 4 | | 2 | 3 | 3 | 3 | | | | |
| 39 | Laing, Edward B. Design of Ammunition Maintenance Facility for Conventional and Advanced Weapons. Ammann and Whitney, Consulting Engineers, New York, New York. (Originally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 2 | | | | | 2 | 2 | 3 | | | 2 | | | 2 | 2 | | 3 | | | |
| 40 | Goff, Charles R. Processing of Initiating Explosives. Day and Zimmermann, Inc., Lone Star Army Ammunition Plant, Texarkana, Texas. 1 November 1967. | 2 | 2 | | | 2 | 2 | 2 | | | 3 | 3 | | 3 | 3 | 3 | | 3 | 3 | 4 | |
| 41 | Kaplan, Kenneth. The Meaning of Simultaneity of Detonation with Respect to the Application of Quantity-Distance Regulations. URS Corporation, Burlingam, California. (Orginally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 2 | 2 | | 2 | | 3 | 2 | | | | 3 | | | 2 | | 3 | 3 | | | |
| 42 | Rindner, R. M. Supporting Studies to Establish Safety Design Criteria for Storage and Processing of Explosive Materials. AD 828 638. Ammunition Engineering Directorate, Ammunition Production and Maintenance Engineering Division, Picatinny Arsenal, Dover, New Jersey. 1 October 1967 - 31 December 1967. Quarterly Report No. 21 | 4 | | | 4 | | 4 | 4 | 4 | | | 4 | | | 4 | 4 | 4 | 4 | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | Same as above-dated 1 October 1966 - 31 December 1966. | 4 | | | | 4 | | 4 | 4 | 4 | | | 4 | | | 4 | 4 | 4 | 4 | | |
| 44 | Woolfolk, R. W. and Amster, A. B. Low Velocity Detonations. AD 827 748. Stanford Research Institute, Menlo Park, California. (Orginally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 3 | 1 | | | 1 | | 1 | 2 | | | | | | 2 | | | 2 | | | |
| 45 | Buschman, E. H. Recent Developments in Flooring for Hazardous Areas. AD 827 756. Naval Ordnance Station, Indian Head, Maryland. (Originally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 1 | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | | |
| 46 | Biron, J. E. Explosive Accident/Incident Information Report Systems Briefing. AD 827 742. Naval Weapons Laboratory, Dahlgreen, Virginia. (Originally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 3 | | 4 | | | | | | | | | | | | | | 3 | 3 | | |
| 47 | Liddiard, T. P., Jr. Low Amplitude Shock Initiation of Burning in High Explosives. AD 827 739. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland. 1 November 1967. | 3 | | | 3 | 3 | | 3 | | | | | | | | 3 | | 3 | | | |
| 48 | Mason, Charles M., Van Dolak, Robert W., and Weiss, Milton L. Dropweight Testing of Explosive Liquids. 6799. United States Department of the Interior, Bureau of Mines. 1966. | 3 | | | 3 | 3 | | 3 | | | | | | | | 3 | | 3 | | 3 | |
| 49 | Singer, Irwing A. and Smith, Maynard E. Atmospheric Dispersion at Brookhaven National Laboratory. AD 414 401. Brookhaven National Laboratory, Upton, Long Island, New York. (Air and Water Pollution Int. J. Pergamon, President.) 1966. | 3 | | | | 3 | | 3 | | | | | | | | | | | | | |
| 50 | McCay, W. C. Safety in Pyrotechnic Manufacture. AD 827 758. Longhorn Army Ammunition Plant, Marshall, Texas. (Originally published in the Minutes of the Ninth Explosives Safety Seminar, Naval Training Center, San Diego, California, 15-17 August 1967, 1 November 1967 (AD 824 044).) | 3 | | | | | | | | | | 3 | | 3 | | 3 | | 3 | 3 | | |
| 51 | Environmental Criteria for Pyrotechnic Storage and Handling. MIL-STD-5272C or MIL-STD-81D. AD 815 967. | 1 | | | | | | | | | | 2 | | 2 | 1 | 1 | | 1 | | | |

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