AN ANNOTATED BIBLIOGRAPHY USEFUL IN
THE FORENSIC EXAMINATION OF EXPLOSIVES

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Because of our involvement in the forensic examination of explosives, the National Laboratory Center, Bureau of Alcohol, Tobacco and Firearms often receives requests for reprints and/or technical references in the explosives/explosive residue area. The following is a bibliography of works found useful in our laboratory.

This annotated bibliography is divided into the following three groups: I. Reference Books; II. Military Manuals; and III. Scientific Articles.

Section I deals with works covering many aspects of explosives and related information. It includes scientific reference works, textbooks and clandestine or underground type publications. Section II contains those military manuals which have been found useful by the ATF Laboratory. Technical articles which we have found to be particularly valuable in the examination of various types of evidence for the identification of explosives and/or explosive residues are listed in Section III.

This bibliography is not comprehensive and makes no attempt to cover every publication on explosives. Is designed only to list some of those which may be useful to laboratory and investigative personnel who are building a library relating to the investigation and analysis of explosives, or as suggestions for those wishing to add to an existing collection.

I. Reference Books

This section presents works covering many aspects of explosives and related information. Included are reference works, textbooks and clandestine or underground type publications.

The clandestine articles are particularly important as they give the examiner a starting point for the identification of homemade and/or clandestine explosives. Many of the procedures given in these books are actually used or attempted by various groups.

A great deal of time in the forensic laboratory is spent in identifying not only the explosive used, but also the container. This can be facilitated by the ability of the examiner to recognize the item. On the surface this appears simple but many times the item to be identified, after being fragmented by the explosion, bears little resemblance to its original form. These references can, therefore, assist the examiner.

1. Anonymous, "Blasters' Handbook", Montreal, Quebec: Canadian Industries Limited, sixth edition, 1968. (Reprinted December, 1978).

Provides the examiner with the Canadian Trade Marks for explosives, blasting agents, and blasting accessories and supplies. Gives tips on blasting with safety fuse, electrically or with detonating cord.

2. Anonymous, "Blasters' Handbook," Wilmington, Delaware: E.I. DuPont de Nemours and Company (Inc.), 1969.

A manual describing explosives and practical methods of use. The purpose of this handbook is to furnish a convenient source of information on commercial explosives and their most frequent applications. While information is given on a number of specific uses, it has not been possible to treat them all in detail. It should be pointed out that some practices recommended in this edition are at variance with those described in one or more previous editions. These are a result of broader knowledge and experience plus radical changes in the explosives industry which have altered many practices in recent years. Some of the information included in this edition is omitted in later versions.

3. Anonymous, "Blasters' Handbook", Wilmington, Delaware: E.I. DuPont de Nemours and Company (Inc.), 175th anniversary edition, 1978.

Intended as a guide to knowledgeable users of explosives. This work is divided into five sections and eight appendices. A very good chronology is provided for black powder, dynamites, ammonium nitrate and "Tovex" water gel as well as initiating devices. Describes the various types of explosives, methods and techniques, applications, and the equipment, accessories and pratices utilized by the explosives industry. This covers material that the previous edition omitted and vice versa.

4. Anonymous, "Fireworks Manual," Ottawa: Explosive Division; Department of Energy, Mines and Resources.

Excellent description of fireworks including the following: compositions, sensitivity, cases, government quality assurance and quickmatch. High-level fireworks, low-level fireworks and ground-level fireworks are photographically illustrated, which is helpful in the identification of those materials after they have either burned or exploded. This reference also gives basic safety rules for a fireworks display, disposal of duds after the display, storage and transportation, and firecrackers found in Canada.

5. Anonymous, "Manual for the Preparation of Field Expedient Incendiaries."

This reference is divided into four sections: I. Introduction, II. Incendiaries, III. Igniters, and IV. Delays. This manual describes useful incendiaries, igniters, and delays which can be easily improvised. Describes what an incendiary, igniter, and delay consists of. Charts present a

description of the materials required for the making of various incendiaries. Tells what the material is to be used against, how it can be ignited, advantages, disadvantages, materials needed, equipment needed, preparation, alternate procedures, application, and quantities required. Gives illustrations of several of the items described in the text.

6. Brauer, K.O., "Handbook of Pyrotechnics," New York: Chemical Publishing Company, Inc., 1974.

This handbook provides considerable data and information on the theory and practical application of pyrotechnics and is designed for the use of engineers, designers, technicians and students. The numerous charts, graphs and illustrations make the book particularly helpful. Theory, data, and practical applications are explained in detail. Valuable information is presented on the effects of extreme environmental conditions on pyrotechnic materials and devices; qualification testing; the design and application of pyrotechnic systems, and the uses of explosive methods in manufacturing processes.

7. Brucker, E.W., "Blasting Cap Recognition and Identification Manual," Gaithersburg, Maryland: International Association of Chiefs of Police, Inc. 1973.

Contains a collection of background information, and specific investigative data on blasting caps. Provides good illustrations of the various components of blasting caps thru 1972, however, little information is provided after this date. Covers the history of non-electric, electric and improvised blasting caps. This is a very useful reference.

8. Conkling, J.A., "The Chemistry of Pyrotechnics and Explosives: Basic Principles and Theory," New York: Marcel Dekker, Inc., 1985.

Describes basic chemical principles, ingredients, pyrotechnic principles, ignition and propagation, heat and delays, color and light, smoke and sound as they apply to the fireworks industry. Shows how thermal analysis can be utilized to predict how and why certain chemical mixtures react as they do. A readable and understandable reference. Gives many basic principles necessary in this field of explosives.

9. Crockett, T.S., "Police Chemical Agents Manual," Gaithersburg, Maryland: International Association of Chiefs of Police Inc.

The purpose of this manual is to provide law enforcement personnel with the information needed to make sound decisions relating to the use of chemical agents in the achievement of police objectives. Covers modern riot control agents including CN, DM and CS. Describes the history of each agent. Helpful descriptions of the various containers and dispensers used by law enforcement for the dissemination of chemical agents. Describes and identifies the various component parts of grenades used by police officers.

10. Crockett, T.S., and Newhouser, C.R., "Recognition of Explosive and Incendiary Devices. Part I. Hand and Rifle Grenades," Gaithersburg, Maryland: International Association of Chiefs of Police, Inc.

Contains formulae which are used in both common fireworks and military smoke mixtures. Provides illustrations of hand and rifle grenades commercially available for law enforcement and military use. Several types of improvised fragmentation and incendiary grenades are described.

11. Crockett, T.S., and Newhouser, C.R., "Recognition of Explosive and Incendiary Devices. Part II. Land Mines, Artillery, Mortars, and Rocket Projectiles," Gaithersburg, Maryland: International Association of Chiefs of Police, Inc.

Covers those classes of military and improvised ordnance items that are most likely to be encountered by public safety personnel. The approach throughout has been to provide recognition data. However, it should be noted that some ordnance items will not possess the common or general identification features normally associated with their particular classification. This publicati is the second of a two-part series.

12. Davis, T.L., "The Chemistry of Powder and Explosives," California: Angriff Press, (Reprint of 1943 edition).

Volume I, first published in May, 1941, and volume II published in March, 1943, have been republished in one volume. The book is primarily for chemists. The purpose of the book is to supply chemists with information concerning the modes of behavior of explosive substances and the phenomena, both chemical and physical, which they exhibit. The book brings together much material which had never before been collected in one volume, and it sets down some of the facts in what are probably new relationships to one another, but it contains nothing which is not already known to those who are skilled either in chemistry or in the manufacture and use of explosives. This is considered one of the classical books on the subject.

13. Ellern, H., "Modern Pyrotechnics," New York: Chemical Publishing Co., Inc., 1961.

This reference was designed for the practical worker in the field. It attempts to give a broader view of exothermic dry reaction chemistry and physics than would be achieved by describing devices, their manufacture, and other strictly technological or tactical aspects of pyrotechnics. A great many people contributed to the book indirectly. Also covered in this work are the following subjects: Primary flame and glow producers, light production, smoke production, gas production, sound production, heat production per se, chemical production, the materials of pyrotechnics as functional groups, specific materials, and formulas.

14. Ellern, H., "Military and Civilian Pyrotechnics," New York: Chemical

Publishing Company, Inc., 1968.

Written for manufacturers, laboratory pyrotechnicians, and lay students, the book is a comprehensive treatise on pyrotechnics and contains an enormous amount of invaluable data on the properties and production of pyrotechnic materials, on heat and light production, on aerosols, energy and noise. Includes a manufacturing formulary, an extensive glossary, a list of government specifications, and a very complete reference section. Its wealth of information and highly readable style makes it an important addition to the rather sparse pyrotechnics literature.

15. Fedoroff, B.T., and Sheffield, O.E., "Encyclopedia of Explosives and Related Items," PATR 2700, Picatinny Arsenal, Dover, New Jersey, Volumes 1-10.

The history, production, formulation and analysis of commercial, military and experimental explosives is presented in this set of encyclopedias. Presents an excellent cross reference of items having more than one designation. The following topics are covered as follows: Volume 1, A to Azoxy; Volume 2, B (Explosif) to chloric acid; Volume 3, Chlorides to detonating relays; Volume 4, Detonation to detonators; Volume 5, detoniruyushcii shnur to esters, nitric (of polyhydroxydicarboxylic acids); Volume 6, etagenguss to gyroscopic movement of projectiles; Volume 7, H_2 to lysol; Volume 8, ml thickener to pyruvonitrolic acid; Volume 9, ODX to type explosives; and Volume 10 is expected to finish the series. One of the most comprehensive series written on explosives. A considerable insight to explosives is presented, a vast undertaking.

16. Feigl, F., "Spot Tests in Inorganic Analysis," New York: Elsevier Publishing Company. 1972.

Presents preliminary and orientational tests whereby general chemical information about samples can be obtained before actual analysis. All tests have been arranged according to the element of interest. The tests cited are sufficient to establish the presence or absence of a given element or ion. Another innovation is the inclusion of tests for non-ionic compounds of some elements as well as tests for organometallic ions and tests to detect elements in organic compounds. A reference list is provided for each subsection, followed in some cases by a bibliography of the appropriate quantitative methods.

17. Feigl, F., "Spot Tests in Organic Analysis," New York: Elsevier Publishing Company. 1966.

The text has been divided into seven chapters followed by a comprehensive appendix of individual compounds and products examined, giving the limits of identification obtainable by the procedures. A complete author index is included as well as a subject index. It should be pointed out that for most of the studies included in the present edition there are now several tests available that differ in sensitivity and selectivity, a fortunate state of affairs that makes for greater reliability in the findings. The book has purposely been limited to description of spot tests and their chemical foundations.

18. Fordham, S., "High Explosives and Propellants.", 2nd edition, Oxford: Pergamon Press, 1980.

This book gives a factual account of explosives and accessories and their uses. It is concerned with the UK Commercial Explosives Industry, but reference is made to important practices elsewhere where relevant. After a review of the industry as a whole, the theory of detonation and of shock waves is discussed, followed by consideration of the more important commercial and military high explosives. Detonators and fuses are considered separately and all the major products described. The final part deals with propellants and includes applications for both ammunition and rockets. This second edition has been thoroughly revised and includes new sections on slurry explosives and other recent developments.

19. Hermann, S.L., "Explosives Data Guide," Scottsdale, Arizona: Explosives Research Institute, 1977.

Provides general information on dynamite, water gels or slurries and blasting agents. Covers the major uses of various common explosives. Describes binary (two-component) explosives, explaining what the solid and liquid components consist of. Briefly illustrates cast boosters, military explosives, blasting caps, safety fuse, igniter cord and connectors, detonating cord, linear shaped charges and electric squibs. A good, brief outlined reference.

20. Imwinkelried, E.J., Editor, "Scientific and Expert Evidence," 2nd edition, Chapter 19: Explosives, New York: Practising Law Institute, 1981.

A good glossary of terms used in the examination of explosives is presented. Identifies possible causes of instrument malfunction. Stresses extrinsic causes in the early, evidence collection phase of an explosives investigation. Describes the types of explosives manufactured, development of evidence, packaging of evidence, and the laboratory examination in an explosive investigation. This last section is divided into two parts: A. The identification of the explosive and B. The identification of other components of the destructive device. Presents 40 additional references.

21. Lancaster, R., Shimizu, T., Butler, R.E.A., and Hall, R.G., "Fireworks - Principles and Practice," New York: Chemical Publishing Co., Inc., 1972.

A book on general firework practice with contributions from several international experts. Extremely accurate and detailed, this work will be quite useful to the professional firework manufacturer and colleagues. Helpful in the identification of various containers used by the fireworks industry.

22. McLain, J.H., "Pyrotechnics", Philadelphia, Pennsylvania: The Franklin Institute, 1980.

Presents a classification system for pyrotechnic material. The author uses an empirical approach. Shows how the mere changing of the percentages of certain ingredients alters the reaction of a given pyrotechnic mixture. Describes how the various solid state reaction equations can be utilized to either predict or explain how a certain chemical mixture will react.

23. Menke, J.L., "Spot Tests for Explosive/Incendiary Components and Residues," General Information Bulletin 74-8, National Bomb Data Center, 1974.

Provides information about the use of spot tests which can be conducted at the scene of an explosion to identify explosive and/or incendiary components or their residue prior to subsequent confirmatory analysis in the laboratory. Although the data will be helpful to lab technicians and investigators, it should be utilized only by trained laboratory personnel engaged in the examination of explosives and/or explosive residues.

24. Meyer, R., "Explosives," New York : Verlag Chemie, 1977.

"Explosives" is a concise handbook covering the entire field of explosives. The book contains approximately 500 entries arranged in alphabetical order. Included are formulas and descriptions of explosive chemicals, additives, fuels, and oxidizing agents, as well as a good subject index. The object of this work is to provide fundamental information on the subject of explosives not only to experts but also to the general public. The properties, manufacturing methods, and applications of each substance are briefly described.

25. Miller, P., "Boom," Rockford, Illinois: Pyrochem, 1976.

A clandestine publication. The author states it is intended for peaceful people like himself who enjoy pyrotechnics in a powerful but non-destructive context. Divided into four parts as follows: Part I - Chemicals. Describes what some chemicals are used for. Part II - Low explosives. Tells how to make low explosives. Part III - High explosives. Gives properties of some oxidizers and explosives used in both military and civilian applications. and Part IV - Miscellaneous. This section describes casings, CHOKNO, detonators, drying, flares, flash powder, fuze, gases, electric ignition, nerve gas, pyrotechnic cement, recrystallization, smoke bombs, spontaneous conbustion, stink bombs, thermite, vacuum distillation, washing and sources of supplies. Does not go into depth on any subject covered. Do not try to follow any of the procedures given as they are not totally correct.

26. Powell, W., "The Anarchist Cookbook," New York: Lyle Stuart, Inc., 1971.

This work deals with subjects other than explosives. Describes how to make various explosives, however do not try any of these experiments yourself as many of them leave out the most important steps and therefore could be quite hazardous to your health. Illustrates various improvised detonators, and boobytraps. Describes camouflaged explosive devices. This is a rather amusing book to read.

27. Saferstein, R. (Editor), "Criminalistics: An Introduction to Forensic Science", Englewood Cliffs, N.J.: Prentice-Hall Inc., 1981.

Chapter 11 of this reference covers the Forensic Aspects of Arson and Explosive Investigations. This book is used in many undergraduate forensic science programs. Covers the Chemistry of fire, ignition temperature of some common

fuels, searching the fire scene, collection and preservation of arson evidence, the analysis of flammable residues, various types of explosives, collection and analysis of explosives, and a number of review questions. The sections on low-order and high-order explosives should be labeled low and high explosives respectively. Basically a good general text on the various forensic science disciplines.

28. Saferstein, R. (Editor), "Forensic Science Handbook", Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1982.

Chapter 6 of this reference deals with Arson and Explosive Investigation. The chapter is presented in two parts: 1. The Arson Investigation and 2. Explosives. The arson section covers collecting arson evidence, identification of flammable liquids, identification of solid chemical incendiaries, and reconstruction of incendiary devices. The explosives section covers high and low explosives, evidence at the bomb scene, the vapor trace analyzer, recovery techniques, infrared spectroscopy, thin layer chromatography, other analytical techniques, black and smokeless powder identification, dynamite identification, identifying other explosives, and reconstructing the destructive device. Presents 179 additional references. In addition to the specifics on the examinations resulting from arson and explosive investigations, this handbook presents pertinent information on the following topics: legal aspects of forensic science, forensic applications of high performance liquid chromatography, forensic applications of mass spectrometry, forensic glass comparisons, the forensic identification and association of human hair, identification and grouping of bloodstains, biochemical markers of individuality, foundations of forensic microscopy, forensic paint examination, detection of gunshot residue, the determination of alcohol in blood and breath, forensic examination of soil, and questioned document examination. A good general forensic reference.

29. Saxon, K., "The Poor Man's James Bond," California: Atlan Formularies, (no date).

Divided into two parts, the first deals with explosives, and the second is arson by electronics. Describes how to order your chemicals without drawing undue attention to yourself. Tells where to order chemicals. Describes the worth and where to order books on explosives. Describes how to make tear gas, stinkum, and the hazards and danger of making your own explosives. Explains how to make explosives and bombs. The information given in this reference is quite useful to the forensic scientist and explosive technician because the militants follow many of the instructions given verbatum. It therefore makes it easier to identify the fragments after the substance explodes.

30. Sisco, D., "The Militants Formulary," 1972.

Describes equipment used, manufacture of various explosives, how to obtain certain oxidizers, gunpowder, igniters, chemical delay igniters, firecrackers, incendiaries and prussic acid. Explanations of how to make various bombs used by militant groups are given. These include the following: match head bomb, pipe bomb, flower pot shape charge, go-fer-gas bomb, gas tank bombs, soft drink can bomb, fire bombs, impact ignition fire bombs, and shotgun shell bombs. It is wise to pay special attention to the first part of this reference,

because it describes what happened to the hand of the author while attempting to make one of the explosive mixtures described in this work.

31. Swearengen, T.F., "Tear Gas Munitions," Springfield, Illinois: Charles C. Thomas, 1966.

An analysis of Commercial Riot Gas Guns, tear gas projectiles, grenades, small arms ammunition, and related tear gas devices. Describes the various parts of several containers used for tear gas, along with excellent photographs of the items in question.

32. "Proceedings: New Concepts Symposium and Workshop on Detection and Identification of Explosives," Reston, VA., The U.S. Departments of Treasury, Energy, Justice, and Transportation, 1978.

A collection of papers presented on various topics including vapor detection, bulk detection, tagging and untagged identification. Contains a very extensive bibliography.

33. Urbanski, T., "Chemistry and Technology of Explosives," Volume 1, New York: The Macmillan Company. 1964. (Reprinted by Pergamon Press with revisions, 1983).

The chemical, physical and physico-chemical properties of explosives are dealt with, and processes of manufacture are described whenever the substance in question is of practical importance. Included in this book are details of a number of original processes used in the German and Japanese explosives industries during World War II. Presents a classification system for explosives as well as the various types of nitration processes utilized in the manufacture of several explosives.

34. Urbanski, T., "Chemistry and Technology of Explosives," Volumes 2 and 3, New York: Pergamon Press. 1965 and 1967. (Reprinted by Pergamon Press with revisions, 1983).

Volume 2 presents physical properties, reactions of chemical stability information on nitric esters. Nitroglycerine, cellulose and nitrocellulose, other glycerine esters, glycol esters, monohydroxylic alcohol esters, polyhydroxylic alcohol esters, sugar nitrates, and salts of nitric acid are described and discussed in detail. Volume 3 presents information on nitramines, aliphatic nitramines, aromatic nitramines, heterocyclic nitramines in part 1. Part 2 deals with primary explosives including fulminic acid and its salts, hyrazoic acid and its salts, and other initiating explosives. Part 3 describes general information on composite explosives, high explosives, liquid explosives, black powder, composite propellants and rockets, mining explosives, the manufacture of mining explosives, smokeless powder, and the manufacturing of smokeless powder.

35. Urbanski, T., "Chemistry and Technology of Explosives", Volume 4, New York: Pergamon Press, 1984.

An extension of the three established volumes in the series. This publication covers recent work on new reactions leading to the formation of new explosives, describing their chemical and physical properties. Modern manufacturing

methods are dealt with, and problems of safety discussed. This is the most up to date work of its kind by a world authority on the subject. Also contains 133 illustrations and 2328 literature references.

36. Weingart, G.W., "Pyrotechnics," New York: Chemical Publishing Company, Inc., 1947.

A handbook on the art of making fireworks. Gives formulas and detailed instructions for all the favorites, exhibition and display pieces, chinese firecrackers.

37. Yinon, J., and Zitrin, S., "The Analysis of Explosives," New York: Pergamon Press. 1981.

This is the first book to review in detail the major analytical techniques for the analysis of explosives. Presenting an overview of various methods and techniques, it describes the principles of different analytical methods, how these methods are used for the analysis of explosives and reviews the major analytical work which has been carried out in this field. Chemical methods, chromatographic techniques, polarography, thermal analysis, ultraviolet and visible spectroscopy, infrared spectroscopy, magnetic resonance methods and mass spectrometry are covered. Also included are recent advances in the field such as novel mass spectrometry methods, HPLC and recently reported methods for the detection of hidden explosives. For readers who do not deal with explosives on a routine basis, a list of explosives and related compounds has been presented.

38. Yallop, H.J., "Explosion Investigation", England and Scotland: The Forensic Science Society and Scottish Academic Press Limited, 1980.

This book is intended as a practical handbook for explosion investigations rather than for instruction in the science of explosives and only briefly describes the fundamentals of explosives. This reference depicts the approach to the scene, observation and assessment of damage, identification of the explosive, causes of initiation, explosions in different types of moving vehicles, injury to persons, examination of suspects, analysis of witnesses' statements, unlikely occurrences, significance and importance of negative evidence, and the drawing of conclusions.

39. DeHaan, J.D., "Kirk's Fire Investigation", 2nd edition, Chapter 12: Explosions and Explosive Combustion, New York: John Wiley and Sons, 1983.

Definitions of the various classes of oxidation reactions are presented. Covers diffuse-phase explosions, dense-phase explosions, and diagnostic signs. Some typical temperature data, common commercial explosives, and structural damage produced by blast are presented in tabular form.

40. "Proceedings: International Symposium on Analysis and Detection of Explosives", Quantico, VA., Forensic Science Research and Training Center, FBI Academy, 1983.

Fifty seven invited papers were presented at a symposium on state-of-the-art explosive detection and identification. The program was divided into the following categories: 1. high pressure liquid chromatography methods (12),

2. general analysis (6), 3. instrumental methods (17), 4. explosive detection (15), and 5. mass spectrometry methods (7). The symposium provides a cross-section of current work by many of the leading researchers in the field.

41. Lurie, I.S., and Wittwer, Jr., J.D. (editors), "High-Performance Liquid Chromatography in Forensic Chemistry", New York, New York: Marcel Dekker, Inc., 1983

Chapter 7 of this reference, written by Ira S. Krull, covers HPLC Analysis of explosives and related materials. The chapter is presented in seven parts: 1. introduction and background, 2. HPLC - ultraviolet analysis and applications, 3. HPLC - mass spectrometry analysis and applications, 4. HPLC - thermal energy analysis and applications, 5. HPLC - electro chemical analysis and applications, 6. HPLC - electron-capture detection analysis and applications, and 7. conclusions. For additional information on the subject one only has to consult the voluminous bibliography (101 citations) included in this work.

II. Military Publications

Presented in these manuals is a listing of various binders and inert components used in propellants. Flares, tracers, heat charges and smoke production are described in detail. Contains an in-depth list of materials found in standard and improvised pyrotechnic mixtures, and their relative sensitivities to other materials with which they may inadvertently be mixed or contact. If the analyst has a particular interest or needs information regarding a device to a greater depth than provided previously they can obtain that information from these references.

A photograph, schematic diagram of operating principle and a brief description of common commercial dynamites, military explosives (and devices) and a small number of specialized weapons (mostly semi- and full-automatic small-calibre shoulder fired military weapons) are provided. The color-codings of many of the grenades in use are presented in tabular form, which might help in recognition and reconstruction of the device. The nomenclature and appearances of the majority of ground, aerial and marine flares, signals (smoke and illumination) and simulators are given.

Provides insight into the nearly limitless realm of fabrications when the analyst or investigator is attempting to reconstruct a device from fragments recovered from a blast site or from precursors from a suspect clandestine laboratory.

1. AMCP 706-175. Engineering Design Handbook, Explosive Series, "Solid Propellants Part One," 1964.

This handbook details the desired ballistic parameters, physical property requirements, standard formulations and manufacturing processes for black powders, single-, double- and triple-base smokeless powders and a limited number of crystalline monopropellants (RDX, HMX, nitroguanidine and ammonium nitrate). A listing of the various binders and inert components of these propellants is presented as well.

2. AMCP 706-177. Engineering Design Handbook, Explosive Series, "Properties of Explosives of Military Interest," 1971.

Contained in this reference, in tabular form, are 38 properties (physical properties, explosive behaviours and results of tests using standard methods) of 110 explosive compounds or mixtures used in military applications.

3. AMCP 706-179. Engineering Design Handbook, Explosive Series, "Explosive Trains," 1974.

This pamphlet provides an extensive discussion of general linked explosive reactions including initiation, propagation and resultant effects. The functions and designs of primers, detonators, delay elements, leads, boosters and main charges are related, and a number of evaluation methods are presented.

4. AMCP 706-180. Engineering Design Handbook, Explosive Series, "Principles of Explosive Behavior," 1972.

As the title implies, this is the reference to consult for an in-depth mathematical dissertation of the theoretical background for the observed effects of explosive detonations. The effects which are discussed include thermal decomposition of explosives, detonation properties and shock wave propagation, and some approaches for calculation of important detonation properties from measured compositional considerations are offered.

5. AMCP 706-185. Engineering Design Handbook, Military Pyrotechnics Series, "Part One - Theory and Application," 1967.

Flares, tracers, heat charges and smoke production are all included in this pamphlet. The theoretical bases, composition and application considerations for each of these topics are discussed in depth.

6. AMCP 706-186. Engineering Design Handbook, Military Pyrotechnics Series, "Part Two - Safety, Procedures and Glossary," 1963.

This short pamphlet is useful because it contains an in-depth list of materials found in standard and improvised pyrotechnic mixtures, and their relative sensitivities to other materials with which they may inadvertently be mixed or contacted. There is a glossary of the terms routinely used when discussing these mixtures, as well as presentation of the normal (required) particle sizes of common pyrotechnic constituents.

7. AMCP 706-187. Engineering Design Handbook, Military Pyrotechnic Series, "Part Three - Properties of Materials Used in Pyrotechnic Compositions," 1963.

A list of thirty physical properties (including "fire and explosion hazard" and "health hazard" statuses) for 128 component materials of pyrotechnic usefulness is presented, along with pertinent literature references in order that a more in-depth study of a particular component or compositon, if necessary, may be facilitated.

8. AMCP 706-188. Engineering Design Handbook, Military Pyrotechnic Series, "Part Four - Design of Ammunition for Pyrotechnic Effects," 1974.

The purpose of this handbook is to provide a reference of fundamental design information for protechnic ammunition with emphasis on the terminal effects of light, sound, heat and ballistic considerations. The forensic analyst will find it most useful when attempting to either identify recovered devices from fragments or to hypothesize regarding the identity of the probable residuals to be found in a post-blast scene when the device fragments are identifiable.

9. AMCP 706-189. Engineering Design Handbook, Military Pyrotechnic Series, "Part Five - Bibliography," 1966.

The bibliography is composed of selected references to source materials of particular value in the field of military pyrotechnics. There are two main sections: "open literature citations" and "reports and memoranda issued by public and private organizations". If the analyst has a particular interest or needs information regarding a device to a greater depth than that provided by the preceding four pamphlets, this may be a useful manual to consult.

10. AMCP 706-210. Engineering Design Handbook, Ammunition Series, "Fuzes," 1969.

Beside providing an information source to be used in identifying recovered military munitions, this pamphlet offers an in-depth discussion of the principles and design of mechanical, electrical, pneumatic, motion-induced and chemical arming devices. This type of information is many times useful when the analyst must attempt to reconstruct an unusual fuzing configuration in an improvised explosive device.

11. ID Manual, "Demolitions, Ammunition, Special Weapons," 1970.

The title of this special-purpose manual is highly accurate: a photograph, schematic diagram of operating principle and brief description of common commercial dynamites, military explosives (and devices) and a small number of specialized weapons (mostly semi- and full-automatic small-calibre shoulder fired military weapons) are provided. It is intended to be used as a reference for quick identification of the most common munitions, hardware and accessories encountered by the forensic explosives analyst.

12. FM 5-25. "Explosives and Demolitions," 1967

Designed to be used as a guide in the use of explosives to destroy military obstacles, this manual contains useful information on the type, characteristics and uses of military explosives and auxiliary equipment, including blasting caps, det cord and fuse igniters.

13. FM 5-31. "Boobytraps," 1965.

Very few people would feel that this source provides dull reading material, but, beyond imposing wonderment at the imagination sometimes employed in the production of improvised demolitions, this pamphlet may help the analyst in reconstructing devices from recovered debris from blast scenes.

14. FM 23-30. "Grenades and Pyrotechnic Signals," 1969.

The forensic scientist will find this source useful when identifying recovered grenades or military pyrotechnic devices, or during reconstruction of an unknown device of this type from recovered fragments. Fragmentation, smoke, illumination and riot control devices are all outlined, as well as a number of rifle grenades and accessories.

15. NAVORD REPORT 6256. "Explosions and Chemistry Research Departments Safety Manual, U.S. Naval Ordnance Laboratory, White Oak, Maryland, 1959.

Detailed instructions on procedures to be used in the laboratory when handling explosives of all types, including precautions regarding fires, static electricity, particulate contamination of air, toxicity of explosive compounds and many more considerations are offered in this manual. Anyone who may contact low and/or high explosives should be familiar with the correct handling procedures for these materials.

16. TM 3-215/AFM 355-7. "Military Chemistry and Chemical Agents," 1963.

Here are listed the physical and chemical properties and physiological effects of four classes of chemical agents which have military usefulness: toxic agents, riot control agents, incendiaries and smokes. The compositional formulations and mechanisms of action are described in depth.

17. TM 9-1300-203. "Artillery Ammunition," 1967.

This is a useful manual for identifying recovered ammunition having suspected military origin. Provided are diagrams and photographs of ammunition for: guns and Howitzer from the 37-mm automatics to the 170-mm cannon, recoilless rifles, and 60-mm to 4.2-in. mortars. External markings, propellant configurations and schematic operating diagrams for the different classes of ammunition are all included.

18. TM 9-1300-206. "Care, Handling, Preservation and Destruction of Ammunition," 1964.

Although this publication has a limited usefulness for the forensic explosives

analyst, it does offer some handy tips for rendering small-calibre ammunition safe and recovering propellant from the shell casings, if this is desired.

19. TM 9-1300-214/TO 11A-1-34. "Military Explosives," 1967.

This manual should be required reading for any forensic scientist who will encounter explosives of <u>any</u> type during the analysis of evidence. The chemistry and physics of explosives and propellants are provided, to a useful depth, and this information serves to lay a groundwork for understanding both the effects of explosives on materials of varying compositions and the complex fracturing of explosive containment vessels. A large number of foreign and domestic propellants and explosives are described, and the testing procedures used during the measurements of the explosive properties of these materials are discussed.

20. TM 9-1330-200/NAVORD OP 3833. "Grenades, Hand and Rifle," 1966.

If identification of an unknown grenade cannot be made using the information found in reference 14 (above), then this manual may be helpful. The color-codings of all of the grenades in use at the date of publication are presented in tabular form, and may aid the analyst in recognition and reconstruction of the device.

21. TM 9-1370-200/TO 11A10-1-1. "Military Pyrotechnics," 1958.

This manual provides the analyst with the nomenclature and appearances of the majority of ground, aerial and marine flares, signals (smoke and illumination) and simulators.

22. TM 31-201-1. "Incendiaries," 1966.

Unconventional incendiary devices and techniques are discussed here, with exact device production directions and methods for the procurement of necessary ingredients from common, non-regulated donor sources. Beyond piquing the curioisity of the reader, this manual offers insight into the nearly limitless realm of fabrications which the analyst may have to contend with when attempting to reconstruct a device from fragments recovered from the blast site or from precursors recovered from a suspect clandestine laboratory.

23. Brittain, A.H., "A Summary of Vapour Pressure Data of Selected Explosives," Royal Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, U.K., 1978.

In many cases, published values for the vapor pressures of explosives exhibit wide scatter. This report is designed to draw together all the available data from many journals (both native and foreign to the U.K.) and arrive at a "best value" for the vapor pressure of thirteen common explosives at room temperature. A rigorous mathematical approach is used in comparing the values from the different sources and arriving at this useful tabulation of the "standard values".

III. Scientific Articles

A systematic approach to the examination of explosives and explosive residues are presented as follows: 1. basic techniques, 2. trace vapor analysis, 3. commercial dynamite, 4. military explosives, 5. black powders, 6. flash powders, and 7. blasting cap leg wire. Simplified techniques for examining various explosives are also presented. IR and UV spectra of various tear gases, explosives and related compounds are included in the articles. TLC methods for the separation of many explosive compounds as well as the separation of other aromatic nitro derivatives are related in these publications.

Some of the earlier works are included to give the examiner a historical background of the procedures utilized over the years for the detection and identification of explosives and/or explosive residues. Even though some of these articles might appear out of date, they are still helpful to the forensic chemist. This section is concluded with a series of articles describing newer instrumental techniques for examining and identifying explosives and/or explosive residues.

1. Washington, W.D. and Midkiff, Jr., C.R., "Systematic Approach to the Detection of Explosive Residues. I. Basic Techniques," Journal of the AOAC, Vol. 55, No. 4, 1972, pp. 811-822.

This paper describes the recovery of unconsumed explosive material in post-blast debris, using either microscopic surveying or solvent extraction. The morphology of the residuals to be recovered and the materials needed to effect recovery are discussed. Eighteen B&W photographs of explosive exemplars and actual residues are included to aid the reader.

2. Washington, W.D. and Midkiff, Jr., C.R., "Systematic Approach to the Detection of Explosive Residues. II. Trace Vapor Analysis," Journal of the AOAC, Vol. 56, No. 5, 1973, pp. 1239-1245.

Here the authors discuss the use of the Vapor Trace Analyzer (VTA) for screening bomb debris for traces of explosives. The VTA is a special purpose gas chromatograph which detects vapor from explosives (most notably EGDN in commercial dynamites) in air samples. Procedures for use and possible interferences are noted.

3. Midkiff, Jr., C.R. and Washington, W.D., "Systematic Approach to the Detection of Explosive Residues. III. Commercial Dynamite," Journal of the AOAC, Vol. 57, No. 5, 1974, pp. 1092-1097.

A brief discussion of the basic categories and compositions of commercial dynamite formulations is followed by an in-depth outline of the procedure used to analyze debris for traces of these explosives. Analysis by IR spectrophotometry, TLC and spot tests are described for the determination of NG and EGDN, as well as ionic residues and filler materials. IR spectra and information regarding the TLC solvent systems used are also included.

4. Midkiff, Jr., C.R. and Washington, W.D., "Systematic Approach to the Detection of Explosive Residues. IV. Military Explosives," Journal of the AOAC, Vol. 59, No. 6, 1976, pp. 1357-1374.

The military explosives TNT, RDX, HMX and PETN are detected in post-blast debris using a straightforward approach including the analytical techniques of microscopy, IR spectrophotometry, TLC, X-Ray Diffraction and spot tests. IR spectra, TLC solvent choices and an in-depth discussion of problems encountered in these types of analyses are all included.

5. Washington, W.D., Kopec, R.J. and Midkiff, Jr., C.R., "Systematic Approach to the Detection of Explosive Residues. V. Black Powders," Journal of the AOAC, Vol. 60, No. 6, 1977, pp. 1331-1340.

After a thorough discussion of various formulations of black powders which are encountered in the forensic analysis of post-blast debris, the authors relate the tests used to characterize these residues; these tests include microscopy, ignition tests, spot tests, IR spectrophotometry, TLC, X-Ray Diffraction and the use of a Scanning Electron Microscope with an Energy Dispersive X-Ray Analyzer (EDAX) attachment. IR spectra, photomicrographs of some of the black powders and the EDAX results are included in the report.

6. Meyers, R.E., "A Systematic Approach to the Forensic Examination of Flash Powders," Journal of Forensic Sciences, Vol. 23, No. 1, 1978, pp. 66-73.

A technique is described in which flash powders, or suspected flash powder residues, are analyzed for trace inorganic components, including: aluminum, charcoal, sulfur, $KClO_4$, $KClO_3$, $NaNO_3$ and antimony. The method involves solvent extraction followed by spot tests and IR analysis. The report includes a flow scheme for the analysis, IR spectra and photomicrographs of the results of the crystal tests.

7. Washington, W.D. and Midkiff, Jr., C.R., "Forensic Applications of Diamond Cell-Infrared Spectroscopy. Identification of Blasting Cap Leg Wire Manufacturers," Journal of Forensic Sciences, Vol. 21, No. 4, 1976, pp. 862-867.

This paper surveys materials used in the manufacture of blasting-cap leg wire insulation, and outlines a procedure for analyzing unknown samples using the diamond cell holder. The main advantages of this type of sample holder are the small sample size necessary for each analysis and the ease of sample preparation. IR spectra are included.

8. Washington, W.D., Midkiff, Jr., C.R. and Snow, K.B., "Dynamite Contamination of Blasting Cap Leg Wire Insulation," Journal of Forensic Sciences, Vol. 22, No. 2, 1977, pp. 329-331.

The authors report the possibility of recovering traces of NG and EGDN from PVC leg wire insulation material. These volatile explosives may be adsorbed due to contact between the blasting cap assembly and commercial dynamite during improper storage or handling.

9. Kopec, R.J., Washington, W.D. and Midkiff, Jr., C.R., "Forensic Applications of Sapphire Cell-Infrared Spectroscopy: Companion to the Diamond Cell in Explosive and Leg Wire Identification," Journal of Forensic Sciences, Vol. 23, No. 1, 1978, pp. 57-65.

Sapphire cells for IR analysis offer most of the advantages of the diamond cell, such as small sample size requirements and reduced sample handling, yet cost considerably less than diamond cells. This paper discusses the use of the sapphire cells for the IR analysis of blasting cap leg wire insulation materials and the explosives TNT, PETN, RDX, and HMX. IR spectra are included.

10. Hoffman, C.M. and Byall, E.B., "Identification of Explosive Residues in Bomb Scene Investigations," Journal of Forensic Sciences, Vol. 19, No. 1, 1974, pp. 54-63.

This is the precursor to the five-part series by Midkiff and Washington, et. al. (1-5 above) from the BATF laboratory facility. Some proccdures for evidence collection from the scene and from suspects are offered, and the authors provide the reader with a capsule approach to the handling of bomb debris evidence, including tests used for the detection of most of the major components to be discovered during forensic analysis.

11. Parker, R.G., Stephenson, M.O., McOwen, J.M. and Cherolis, J.A., "Analysis of Explosives and Explosive Residues. Part 1. Chemical tests," Journal of Forensic Sciences, Vol. 20, No. 1, 1975, pp. 133-140.

This publication is a detailed summary of the results of eleven spot tests for seventeen different organic and inorganic species normally encountered in post-blast residue samples. The tabulated form of the reported results is easy to use; when used in conjunction with papers (1-5) above, the findings in spot tests become easy to interpret and therefore more useful.

12. Parker, R.G., McOwen, J.M. and Cherolis, J.A., "Analysis of Explosives and Explosive Residues. Part 2: Thin-Layer Chromatography," Journal of Forensic Sciences, Vol. 20, No. 2, 1975, pp. 254-256.

The TLC solvent systems to be used for ten common explosive compounds, in combination in most cases, are listed in. Satisfactory separations for most of the compounds are related, as well as some of the problems inherent in these TLC analysis.

13. Parker, R.G., "Analysis of Explosives and Explosive Residues. Part 3: Monomethylamine Nitrate," Journal of Forensic Sciences, Vol. 20, No. 2, 1975, pp. 257-260.

This publication briefly describes the physical nature and properties of MMAN, as well as the spot tests and TLC solvent and visualization systems used in the detection of this compound in post-blast debris. An IR spectrum and a Differential Thermal Analysis (DTA) thermogram of MMAN are also included.

14. Chrostowski, J.E., Holmes, R.N. and Rehn, B.W., "The Collection and Determination of Ethylene Glycol Dinitrate, Nitroglycerine and Trinitrotoluene Explosive Vapors," Journal of Forensic Sciences, Vol. 21, No. 3, 1976, pp. 611-615.

The technique described involves the adsorption of EGDN, NG and TNT, from the vapor drawn from heated post-blast debris onto porous polymer beads (GC packing material). After this preconcentration, the explosives are eluted from the packing material and analyzed using TLC. Similar adsorption-elution techniques are frequently used today when post-blast debris is suspected to contain traces of commercial dynamite.

15. Holmes, R.N., "The Identification of Silver Fulminate in the Analysis of 'Fun Snaps'," Crime Laboratory Digest, Issue 79-7, December 1979, pp. 4-6.

This short paper outlines a fast method for extracting the explosive component of these noise-makers for subsequent IR analysis. Characteristic absorbances are delineated and the IR spectrum is attached.

16. Meyers, R.E., "A Simplified Method for the Detection of Sulfur in the Presence of Aluminum Metal," Arson Analysis Newsletter, Vol. 4, No.1, 1980, pp. 1-3.

A rapid test for the presence of sulfur in flash powders is described in this brief paper.

17. Twibell, J.D., Home, J.M., Smalldon, K.W., Higgs, D.G., and Hayes, T.S., "Assessment of Solvents for the Recovery of Nitroglycerine from Hands Using Cotton Swabs ", Journal of Forensic Sciences, Vol. 27, No. 4, Oct. 1982, pp. 792 - 800.

A number of swabbing techniques, materials and solvents are examined in this reference. The authors conclude that by using cotton wool swabs wetted with ethanol, NG can be removed with high efficiency from the hands of a suspect. The "normal" procedures of swabbing, using ether or acetone, are not as sensitive as that using ethanol because they also extract a number of contaminants from the donor's hands, inhibiting the subsequent trace detection of NG.

18. Twibell, J.D., Home, J.M., Smalldon, K.W., and Higgs, D.G., " Transfer of Nitroglycerine to Hands During Contact with Commercial Explosives ", Journal of Forensic Sciences, Vol. 27, No. 4, Oct. 1982, pp. 783 - 791.

The reported study was designed to inform the investigator of the levels of NG which might be expected on the hands of those who contact explosives in various situations. GC-ECD was used to detect the NG removed by acetone swabbing. The results point out that the degree of transfer is extremely variable, depending on a number of synergistic factors.

19. Sreenivasan, V.R. and Boese, R.A., "Identification of Lachrymators," Journal of Forensic Sciences, Vol. 15, No. 3, 1970, pp. 433-442.

In this reference the three primary chemicals used in the manufacture of commercial tear gases ("CN", "CS" and oleoresin capsicum) are detailed. Physical properties and the IR and UV spectra of these three compounds are included in the report.

20. Forestier, H., "Characterisation of Explosives' Traces After an Explosion," International Criminal Police Review, Number 277, April 1974, pp. 99-106.

The bulk of the material found in this reference is a restatement of the material one could obtain from a number of other publications which outline analysis schemes for the detection of explosives in post-blast residues. However, the authors have also categorized possible post-blast materials (matrices) on which the residues may be found, and have related exact handling procedures for each of these different matrices; herein lies the usefulness of this publication for the inexperienced analyst.

21. Elie-Calmet, M.J. and Forestier, H., "Characterisation of Explosives' Traces After an Explosion," International Criminal Police Review, Number 325, February 1979, pp. 38-47.

TLC methods for the separation of fourteen explosive compounds, and an additional method for the separation of twelve other aromatic nitro derivatives, are related in this work.

22. Helie-Calmet, M.J. and Forestier, H., "Characterisation of Explosives' Traces After an Explosion," International Criminal Police Review, Number 326, March 1979, pp. 62-74.

The separations of NG and PETN from their respective hydrolysis products are described, and two-dimensional TLC is used effectively to separate several major explosives.

23. DeHaan, J.D., "Quantitative Differential Thermal Analysis of Nitrocellulose Propellants," Journal of Forensic Sciences, Vol. 20, No. 2, 1975, pp. 243-253.

Although DTA is not a method of choice in the analysis of unknown smokeless powders, this reference contains good background theory on the composition of these propellants. While identification of suspected powders should not be based solely on thermograms, this information may be useful when comparing a known and suspected sample.

24. Beveridge, A.D., Payton, S.F., Audette, R.J., Lambertus, A.J. and Shaddick, R.C., "Systematic Analysis of Explosive Residues," Journal of Forensic Sciences, Vol. 20, No. 3, 1975, pp. 431-454.

In this paper, the authors include a discussion of the properties of many explosives, a detailed extraction/analysis diagram, a glossary of terms common to these types of analyses and a list of reagent formulations. A number of test explosions are related in the report so that the reader may follow the analysis scheme through real-world applications and see the problems which may arise. IR spectrophotometry, X-Ray Diffraction, Emission spectroscopy, microscopy, TLC and spot tests are all employed.

25. Christos, T. and Spinetti, L., "Determining Explosive Oil in Dynamites Using High-Pressure Liquid Chromatography," Report of Investigations 7795, U.S. Bureau of Mines, Pittsburgh Mining and Safety Research Center, 1973.

This report presents one early attempt to determine NG and EGDN chromatographically with UV detection.

26. Robinson, R.V., "Water Gel Explosives - Three Generations," C.I.M. Transactions, Vol. LXXII, 1969, pp. 348-356.

The author presents an exhaustive study of the evolution of water gel explosives from 1943 to 1969. Composition, explosive properties and usefulness of all of the most common formulations are discussed and each is related to the other performance-determining considerations. The theoretical bases behind the important physical effects of these water gels are discussed as well.

27. Dick, R.A., "Factors in Selecting and Applying Commercial Explosives and Blasting Agents," Information Circular 8405, Bureau of Mines, 1968.

This reference is useful to the novice explosive analyst in that it succinctly defines the various types of explosives and explosive compositions which are commercially available, and delineates the parameters on which the

nomenclature of these materials are based. The author attempts to insure that the reader is not confused by trade names and industrial conventions. The discussion covers dynamites, gelatins, blasting agents, military explosives (briefly), blasting accessories and black powders.

28. Miller, F.A. and Wilkins, C.H., "Infrared Spectra and Characteristic Frequencies of Inorganic Ions," Analytical Chemistry, Vol. 24, No. 8, August 1952, pp. 1253-1294.

The IR spectra of 159 pure inorganic compounds, most of which are salts containing polyatomic ions, are presented. When used in combination with emission spectroscopy and X-Ray diffraction the information obtained from IR analysis of the inorganic species may lead the investigator to the identity of an unknown crystalline substance.

29. Zack, P.J. and House, Jr., J.E., "Propellant Identification by Particle Size Measurement," Journal of Forensic Sciences, Vol. 23, No. 1, 1978, pp. 74-77.

The differentiation of nineteen brands of smokeless powder is achieved based on the morphology of each type. Measurements of the powders are made using a Gaertner comparator. This paper helps point out that, due to manufacturing processes and standards, the morphology of smokeless powders may be important to the analyst in determining the identity of an unknown sample.

30. Hardy, D.R. and Chera, J.J., "Differentiation Between Single-Base and Double-Base Gunpowders," Journal of Forensic Sciences, Vol. 24, No. 3, 1979, pp. 618-622.

Using a technique of sampling which the authors term "headspace analysis", a CI-MS analysis of a single flake of eighteen different smokeless powders is performed, and a determination of the single- or double-base nature of the propellant is made.

31. Peak, S.A., "A Thin-Layer Chromatographic Procedure for Confirming the presence and Identity of Smokeless Powder Flakes," Journal of Forensic Sciences, Vol. 25, No. 3, 1980, pp. 679-681.

This technical note outlines a rapid TLC technique for the identification of smokeless powders in debris, as differentiated from non-propellent substances which contain nitrocellulose (e.g. varnishes, lacquers, inks, etc.). Sequential development of the TLC plate is used for the separation fo NG and NC.

32. Krull, I.S. and Camp, M.J., "Analysis of Explosives by HPLC," American Laboratory, Vol. 12, No. 5, 1980, pp. 63-76.

HPLC promises to become a standard tool within the explosive analyst's domain. The authors discuss HPLC with Ultra-violet (UV), Electrochemical (EC), Mass Spectrophotometric (MS), Thermal Energy Analyzer (TEA) and Electron Capture (ECD) detection for the trace determination of explosives. The reader may easily find information regarding any of these techniques, merely by consulting

the papers relating to the particular detector listed in the bibliography (68 citations) included in this work.

33. Peimer, R.E., Washington, W.D. and Snow, K.B., "On the Examination of the Military Explosive, C-4," Journal of Forensic Sciences, Vol. 25, No. 2, April 1980, pp. 398-400.

A technique is described for the analysis of the plastic explosive, C-4. The method involves a chloroform extraction of the sample and an infrared examination of the extract. Problems that may be encountered in attempting to identify C-4 are discussed and solutions to these problems are proposed.

34. Pristera, F., Halik, M., Castelli, A., and Fredericks, W., "Analysis of Explosives Using Infrared Spectroscopy", Analytical Chemistry, Vol. 32, No. 4, April 1960, pp. 495-508.

A compilation of 68 infrared spectrograms covering many common high-explosive compounds and several possible explosive ingredients, additives, and related compounds is given. An examination of the spectrograms made possible the empirical deduction of several new assignments, which should facilitate the infrared structural investigation of unknown ingredients, such as newly synthesized compounds. Extensive descriptions are presented for the preparation and qualitative use of infrared spectrograms of explosive ingredients. There is considerable information regarding qualitative and quantitative analysis of mixtures of explosive ingredients by infrared and/or other methods.

35. Huggins, D., and Drinkard, W.C., "Quantitative Analysis for Ethylenediamine in the Presence of Hydroxyalkylamines", Analytical Chemistry, Vol. 34, No. 13, December 1962, pp. 1756-1757.

A quantitative gravimetric procedure is presented for the determination of ethylenediamine in the presence of large amounts of hydroxyalkylamines. Ethylenediamine is precipitated as a Schiff's base with salicylaldehyde from an aqueous solution of pH 9.

36. Chasan, D.E., and Norwitz, G., "Qualitative Analysis of Primers, Tracers, Igniters, Incendiaries, Boosters, and Delay Compositions on a Microscale by Use of Infrared Spectroscopy", Microchemical Journal, Vol. 17, 1972, pp. 31-60.

The application of infrared spectroscopy to the detection of the constituents of primers, tracers, igniters, incendiaries, boosters, and delay compositions on a microscale was investigated. These constituents can be identified quickly and with certainty, using an infrared pellet technique for organic and inorganic compounds and emission spectroscopy to identify metals. The grinding and pressing operation was found to be safe even with the most sensitive explosives. The infrared spectra of 43 common ingredients of primers, tracers, igniters, incendiaries, boosters, and delay compositions are given over the range 2.5 to 5u. The qualitative analysis of 7 typical compositions is demonstrated.

37. Yinon, J., "Identification of Explosives by Chemical Ionization Mass Spectrometry using Water as Reagent", Biomedical Mass Spectrometry, Vol. 1, No. 6, December 1974, pp. 393-396.

Chemical ionization mass spectra of four explosive compounds have been obtained using water as reagent gas. The compounds are 1, 3, 5, 7 - tetranitro - 1, 3, 5, 7 - tetrazacyclooctane, 1, 3, 5 - trinitro - 1, 3, 5 - triazacyclohexane, pentaerythritol tetranitrate, and an explosive which has been used in letter bombs, containing the two latter compounds and a plasticizer. Unlike in chemical ionization using methane or isobutane, chemical ionization H_2O spectrum of these compounds provides a method for obtaining quasimolecular peaks. Adduct ion peaks like $[M + H_3O]^+$, $[M + H_3O_2]^+$, $[M + NO]^+$ and $[M + NO_2]^+$ are also observed in the chemical ionization H_2O mass spectra of these compounds. Chemical ionization H_2O mass spectra thus provide a better means of explosive identification.

38. Saferstein, R., Chao, J-M., and Manura, J.J., "Isobutane Chemical Ionization Mass Spectrographic Examination of Explosives", Journal of the AOAC, Vol. 58, No. 4, 1975, pp. 734-742.

The detection of explosive residues in debris is difficult because of the thermal instabilitly of many explosives along with the high sensitivity requirements of the analyses. The isobutane chemical ionization (CI) mass spectra of common civilian and military explosives were obtained under different instrumental parameters. The intent of the study was to determine the feasibility of applying CI to residue examinations. The CI Spectra of the explosives 1, 3, 5 - trinitro - 1, 3, 5 - triazocyclohexane, 1, 3, 5, 7 - tetraazocyclooctane, and pentaerythritol tetranitrate were shown to be particularly sensitive to the conditions of source temperature and reagent gas pressure. These parameters were adjusted to yield the least complex CI Spectra for the explosives studied. The simplicity of the CI Spectra obtained makes it a feasible technique for detecting explosive residues in the presence of extraneous materials found in the acetone extracts of debris material. Direct introduction of the extract into the probe of the CI mass spectrometer eliminates the need for prior chromatographic treatment of the extract and optimizes the high sensitivity of the CI technique.

39. Kaplan, M.A., and Zitrin, S., "Identification of Post-Explosion Residues", Journal of the AOAC, Vol. 60, No. 3, 1977, pp. 619-624.

A scheme for the identification of explosive residues from post-explosion scenes is described. The first step consists of organic and inorganic extractions rather than microscopic examination. Methods of identification include thin-layer and gas-liquid chromatography, infrared and ultraviolet spectroscopy and chemical tests. The system deals efficiently with standard military explosives as well as home-made, improvised mixtures.

40. Vouras, P., Peterson, B.A., Colwell, L., and Karger, B.L., "Analysis of Explosives by High Performance Liquid Chromatography and Chemical Ionization Mass Spectrometry", Analytical Chemistry, Vol. 49, No. 7, June 1977, pp. 1039-1044.

High performance liquid chromatography and chemical ionization mass spectrometry have been applied to the isolation and identification of explosives. Ammonia, as a reagent gas for chemical ionization, has been evaluated and the advantages over methane, water, hydrogen and isobutane discussed on the basis of data from common explosives. The off-line LC-MS approach has been applied to the analysis of simple residues from test explosives under controlled conditions to simulate actual bombings.

41. Yinon, J., and Zitrin, S., "Processing and Interpreting Mass Spectral Data in Forensic Identification of Drugs and Explosives", Journal of Forensic Sciences, Vol. 22, No. 4, October 1977, pp. 742-747.

The value of CI-MS in combination with EI-MS has been demonstrated as an analytical method for the identification of forensic compounds. Data acquisition consists of converting the recorded mass spectra into plotted and tabulated normalized mass spectra using a central computer. Chemical ionization mass spectral library comparison and identification are done manually.

42. Pate, C.T., and Mach, M.H., "Analysis of Explosives Using Chemical Ionization Mass Spectroscopy", International Journal of Mass Spectrometry and Ion Physics, Vol. 26, 1978, pp. 267-277.

Methane chemical ionization (Me CI) mass spectra of several explosives, including nitrate esters, nitramines, nitroaromatics, and stabilizers, are presented. The predominance of the pseudomolecular ion $(M + H)^+$ greatly facilitates identification of these temperature - sensitive compounds. Structural effects and mechanistic pathways rationalizing formation of the major ions are included. Gas chromatographic (GC) separation of selected explosive formulations is shown. GC chemical ionization mass spectra response factors for ethylene glycol dinitrate, nitroglycerin, 2, 4 - dinitrotoluene, and 2, 4, 6 - trinitrotoluene show nanogram sensitivity with this technique.

43. Yinon, J., "Analysis of Explosives by Negative Ion Chemical Ionization Mass Spectrometry", Journal of Forensic Sciences, Vol. 25, No. 2, April 1980, pp. 401-407.

Negative ion chemical ionization (NCI) mass spectrometry using isobutane as a reagent has been applied to the analysis of explosives. The method is evaluated as complementary to positive ion CI, as both methods can be applied to the same sample. A magnetic-sector-type mass spectrometer is used without changing the electron multiplier voltage. Under these conditions NCI mass spectra of explosives have been obtained at a sensitivity similar to that of positive ion CI mass spectra.

44. Buechele, R.C., and Reutter, D.J., "Determination of Ethylenediamine in Aqueous Solutions by Ion Chromatography", Analytical Chemistry, Vol. 54, No. 12, October 1982, pp. 2113-2114.

By using $ZnCl_2$ and HCl in the eluent, the authors were able to successfully chromatograph ethylenediamine and demonstrate a linear response with conductometric detection. A veterinary iodine supplement containing

ethylenediamine dihydroiodide and sucrose was dissolved in deionized water for examination. The results were confirmed by mass spectral analysis.

45. Peterson, G.F., Dietz, W.R., and Stewart, L.E., "Identification of Explosives Containing Alkylammonium Nitrates by Thin-Layer Chromatography," Journal of Forensic Sciences, Vol. 28, No. 3, July 1983, pp. 638-643.

This paper describes thin-layer chromatography (TLC) systems for currently used alkylammonium nitrate sensitizers, MMAN and MEAN. These TLC methods also identify the presence of other explosive ingredients and contaminants commonly found in debris from bombings.

46. Reutter, D.J., Buechele, R.C., and Rudolph, T.L., "Ion Chromatography in Bombing Investigations", Analytical Chemistry, Vol. 55, No. 14, December 1983, pp. 1468A - 1472A.

Describes the need for developing a method for using ion chromatography in the analysis of bombing debris. Simulated bombing tests were performed and the remains sent to the laboratory for analysis. In every test IC gave more information than XRD. Some of the differences are due to the superior sensitivity and selectivity of IC for those types of samples. It was found that the chemical nature of the samples was altered while the extracts were dried for XRD analysis.

END